THE CULTURE AND TECHNOLOGY OF GLASS

IN RENAISSANCE VENICE

by

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SIGNED: W. Patrick McCray

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"Send lawyers, guns, and money"
- Warren Zevon

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ABSTRACT

Venetian glass, especially that of the Renaissance, has been admired for centuries due to its quality workmanship and overall visual appeal. In addition, a certain mystique surrounds the glassmakers of Venice and their products. This dissertation research undertakes a comprehensive view of the culture and technology of Renaissance Venetian glass and glassmaking. Particular attention is paid to luxury vessel glass, especially those made of the "colorless" material typically referred to as *cristallo*. This segment of the industry is seen as the primary locus of substantial technological change. The primary question examined in this work is the nature of this technological change, specifically that observed in the Renaissance Venetian glass industry circa 1450-1550.

After providing an appropriate social and economic context. a discussion of Venice's glass industry in the pre-Renaissance is given. Industry and guild trends and conditions which would be influential in later centuries are identified. In addition, the sudden expansion of Venice's glass production in the mid-15th century is described as a self-catalyzed phenomenon in response to prevailing cultural and economic conditions. Demand is identified as a necessary precursor to the production of luxury glass.

Building on this concept, activities and behaviors relevant to demand, production, and distribution of Venetian glass are examined in depth. The interaction between the Renaissance consumer and producer is treated along with the position of Venice's glass industry in the overall culture and economy of the city.

It is concluded that the technological changes observed in Venice's Renaissance luxury glass industry arose primarily out of perceived consumer demand. Social and economic circumstances particular to Renaissance Italy created an environment in which a technological development such as *cristallo* glass could take place. The success of the industry in the 15th and 16th centuries can be found in the fruitful interplay between consumers and producers, the manner in which the

industry was organized, coupled with the skill of the Venetian glassmakers to make and work new glass compositions into a variety of desired objects.

CHAPTER 1

INTRODUCTION AND STATEMENT OF PROBLEM

> *Like harmony in music; there is a dark inscrutable workmanship that reconciles discordant elements and makes them cling together in one society.*
>
> William Wordsworth

Venetian glass, particularly that of the Renaissance, has long been admired for its quality workmanship, diversity in forms, and overall visual appearance. Even today, a visitor in Venice will notice the colorful vases and beads in shop windows, the elegance of luxury glass pieces displayed in prominent boutiques in Piazza di San Marco, and the steady stream of tourist boats headed for Murano, where the glass industry has been concentrated since the 13th century, and its glass furnaces.

The glass pieces that have survived intact to the present are typically regarded as masterpieces and encountered in the context of museums. Our experiences with Venetian glass are quite removed from the object's original context. Museum environments rarely bring objects closer to the viewers. Rather they separate them from both their time of creation, their original use, as well as our own life experiences. Glass pieces are often placed on a pedestal as timeless examples of art, lacking context, and losing an opportunity to tell the story of their origin and significance. The object of this dissertation is not to discredit the value attributed to Venetian glass in this connoisseur-oriented perspective, but to instead expand upon it and consider glass in its broader context of use, exchange, demand, and production activities.

In lieu of a more traditional introduction, I have chosen instead to give the reader a more narrative account of my initial involvement with the topic of Renaissance Venetian glass. In this manner, two purposes will be served. The wrong turns and roadblocks described as I encountered them will offer an indication of the shortcomings I perceived in previous work on the subject. Secondly, my story will hopefully lead up to the larger issue of why Venetian glass is relevant as a topic of research along with the general goals of this dissertation work.

Not surprisingly, I began my work by studying the general history of glass and glassmaking technology. From this work, it was possible to develop a picture of how glass, as a pyrotechnology, changed throughout time. All of the literature I was reading at this time suggested that there were two crucial developments to consider. The first was the invention of glassmaking and the subsequent innovations in its use as a material. This occurred sometime around the middle of the second millennium BC in the Near East, probably in Mesopotamia. The use of glass quickly spread to neighboring Egypt and it is to these two civilizations that we look to see the manufacture of the first glass vessels. The second major development in the history of glassmaking occurred around 50 BC with the introduction of a new manufacturing technique - glassblowing. Initially developed in the Syro-Palestine area, the innovation quickly spread throughout the Roman empire. Relative political and economic stability provided by the Romans allowed for glassblowing's rapid dissemination. Glass could be made much more efficiently than before and became available to a greater portion of Roman society. In both of these cases there was a suitable social, political, and economic climate coupled with an existing market that created the appropriate environment for these innovations to emerge.

There were numerous other developments in glassmaking technology up to the present. Why make Renaissance Venetian glass the focus of my investigation? What was unique about the Venetian industry and its products so as to be seen as the next major occurrence in glassmaking? A large part of this answer lies outside of glassmaking itself and is connected to the larger context of the industry. In Venice, and Renaissance Italy in general, there were significant changes taking place in social and economic life, not the least of which were emerging patterns of capitalism, consumerism, and the greater consumption of luxury goods. Glass and glassmaking were part of these phenomena.

During the latter half of the 15th century the glass industry of Venice, by now already established, would undergo substantial changes with regards to organization, distribution, and production techniques. These changes were in response to emerging and changing forces of demand and consumption. It is these events which are the focus of this dissertation research. As my research will demonstrate, Venice's glass industry was significant in that it represented a transition from an older and more traditional manner of "artisan" manufacture to a mode of production closer to modern factory-style. In a narrower sense, the glass industry of Venice was important as it represented the first time in history that a

European glass industry broke away from Levantine influences and established an independent regional technological tradition. Beginning around the middle of the 15th century, particular artistic styles in glass emerged in Venice. These designs would be widely imitated throughout Europe and were arguably the most important influence on glass fashion until the development of English lead crystal in the late 17th century. Venice was unique among other centers of glassmaking in the Renaissance in that all of the raw materials necessary for glass production, especially fine luxury glass production, had to be imported to the city. Wood, sand, soda ash, clay, coloring and de-coloring agents were all unavailable locally and had to be procured elsewhere. The success of the industry despite this apparent shortcoming is even more remarkable.

Once I began my study, I noticed several qualities in past research on the subject. These became instrumental in shaping the directions my work would take. One of the features which became apparent immediately was the almost overriding presence of what I can best describe as "material culture mythology" surrounding Venetian glass and the glass industry. Perhaps it is the success of the industry and its continuation until the present time that has contributed to this feature of Renaissance Venetian glassmaking - the fog of half-truths that has pervaded and obscured the industry and its makers and products.

It is remarkable that the glass industry of Venice, in existence for over 1000 years, has not been the subject of investigation in the same manner as other regional glass industries typically understood to be of lesser importance (cf. Heikamp, 1986;

Mendera, 1989; articles in Mendera (ed.), 1991). Perrot, in his introduction to the 1958 exhibit of Venetian glass, notices the same uneveness. His comment is that perhaps scholars are adverse to dealing with "...the complexity of living subjects and that the continued strength of the Venetian industry is in fact a deterrent to research" (Perrot, 1958:9).

Many of these half-true stories were first developed in pre-20th century monographs about the Venetian industry where the authors either did not have access to the archival information unearthed by later scholars or else made speculations that later assumed the guise of facts. A reliance on outdated or inaccurate sources coupled with insufficient investigation has helped propagate and reinforce these myths. A recent (1994) visit to a major U.S. museum resulted in my overhearing many of these worn stories about the Venetian industry being told to visitors by staff members. The modern glasshouses of Murano do little to help change this reinforcement of mythology and indeed contribute to it. My first trip to the different shops of Murano (1993) was remarkable in that each of the *bottegas* was " the oldest on the island....the only one that has been in continuous production from old days...and the only one that still makes glass in the original style." The reasons these shops promulgate these stories and quasi-history is made evident in the daily boatloads of tourists to the island. The combined effect of all these mythologies is a general masking of the actual historical circumstances.

Venetian glassmaking is by no means the only ancient craft to have a large amount of hyperbole and mythology associated with it. For example, research into the subject of Greek painted pottery (i.e. "vases" in connoisseur circles) has recently begun to unmask a much more realistic picture of these objects and their makers in ancient Greek society (cf. Vickers and Gill, 1994). The revelation that Greek painted pottery was not particularly valuable in ancient Greece and that its elevation to a somewhat fetished art form is a modern (post-18th century) construction is an instructive if not welcome lesson to collectors and museum curators.

This myth-making also permeates into stories regarding the glassmakers of Murano, especially the Barovier family (Zecchin, 1989:207). The Barovier family has attained a legendary position in the pantheon of Muranese glassmakers, partly due to the dissemination of half-truths and unsubstantiated speculation. Also, part of the interest paid to the glassmakers of Murano, particularly Angelo Barovier (c. 1400-1460) may be due to the inability of later glass historians to cope with the anonymity which surrounds many Renaissance glassmakers. Unlike artisans in other media (painting, sculpture, etc.) few, if any, names can actually be attached to particular pieces of Renaissance Venetian glassware. The tendency of early glass scholars to attribute certain pieces (the famous Barovier Cup in the *Museo Vetrario* is perfect example) might be seen as an attempt to compensate for an almost complete lack of a "cult of personality" in Renaissance glassmaking. Perhaps it is an attempt to elevate glass artisans to the level of identifiable and famous artists in a manner similar to what Vasari did for Renaissance painters, architects, and sculptors (Vasari, 1912). It is a fascinating sidenote to this discussion of Muranese glassmaking mythology, and the Barovier in particular, to note the writing in 1901 of a romance novel about the relationship between Angelo Barovier's daughter, Marietta, and one of his shop assistants (Crawford, 1901)!

A second key feature that emerged from my early research and museum visits was the overall lack of social, cultural, and economic context in which to consider the glass. The archaeology of Venice, as described in Chapter Three, is in an early state of development. At the same time, much of what has been written about Renaissance Venetian glass has been based on pieces in museums or private collections. Such writings, typically from a "masterpiece" perspective, are oriented towards the connoisseur. They are usually geared towards addressing very object-specific issues of provenance (where did it come from?), primacy (where was it made first?), and production (who/how was it made?). Such treatments presuppose that the glass object was wanted in the first place and there is little consideration of "why was it made?". Ettema describes the connoisseur-oriented approach as assuming that knowledge of old things equates to knowledge of history (1982). Without a context in which the artifact and other data meet, the facts in art-oriented publications "remain mere trivia for the cultured" (Marling, 1984:100).

One of the goals of this work was to move beyond these previous approaches and attempt to develop a context in which Renaissance Venetian glass could be placed. In order to do this, it soon became apparent that it would be necessary to draw upon widely different sources of information. These included written material (archival records, diaries, recipe books), pictorial representations that depicted glass, and studies (chemical and physical) of the glass itself. The task then became to integrate this material into a cohesive and comprehensive story of technological change and its context.

At this point in the story it seems appropriate to address a fundamental question typically posed to research of this nature - namely, "Who cares?". I believe that a study of the Venetian glass industry in the manner I have presented it is of interest to two primary audiences:

1. Scholars concerned specifically with the history of glass and glassmaking - As mentioned above, during the Italian Renaissance, the glass industry of Venice developed artistically in a manner that was finally independent of other regional traditions. For the first time in centuries, the glass industries of Europe were creating traditions rather than following them and Venice was arguably the most important city in this development. New glass compositions were developed in Venice as well as new decorative techniques in the years between 1450 and 1550. These recipes and ornamental features would be imitated and expanded upon by other glass industries in Europe. The effects of these new artistic and technological trends which originated in Venice would continue to be felt for the next two or three hundred years in glasshouses throughout Europe. Finally, the study of the Renaissance Venetian industry must be of interest to modern glass scholars because the craft of glassmaking is still practiced today in Venice and forms one of the attractions of that city's tourist-based economy. There is a 1000 year tradition of glassmaking in that region that is still alive and Muranese glass artisans are still at the forefront of artistic glass production.

2. Historians of technology - One of the primary goals of this dissertation is to account for the technological change as noted in the Venetian glass industry. Furthermore, glassmaking was not just an art form in Venice but was also part of the local industrial network. It has been suggested that innovations such as specialized labor roles, the entrepreneur as experimenter, state support, and appeals to current fashions were first developed in the ceramics industries of France and England (McKendrick, 1982; Reber, 1990). I will show that these features of modern capitalistic industrial organization had their roots well before the 18th century in the glass factories of Venice. Indeed, I hope to show that, in some senses, they were "factories". Because the glass industry was not isolated, other than geographically, on Murano but was part of a larger system, the study of glassmaking has implications for other local industries such as soap making, pottery and majolica production, optics, scientific instrument making, and the manufacture of pigments (cf. Piccolpasso, 1577, Ashtor and Cevidalli, 1983; Alexander, 1992). Some of these industries shared the same raw materials as the glasshouses while others such as pigment and optic industries required the products of the Venetian glass furnaces.

In a very broad sense, this work is also a study of material culture. Issues relevant to topics such as demand, consumption, and meaning are considered along with their subsequent influence on production and distribution. The function of glass in different segments of Renaissance society is treated along with, to a lesser extent, how these objects exist in a modern context. The hope is that this need not be an esoteric and dry examination of a subject of interest to only a small sub-culture of the museum community but rather to show how a study such as this can broach traditional and artificial disciplinary boundaries to tell a broader story.

The Renaissance Venetian glass industry was much more diverse than many treatments of the subject might indicate. An incredible variety of products were manufactured at Murano before, during, and after the Renaissance. These include vessel glass, of course, in both "common" and luxury types, beads, mirrors, mosaic glass, lenses, enamels, glazes, and glass for scientific apparatus and pigments. These different segments of the industry all underwent change during the Renaissance. While recognizing this diversity is important to this study, it is not possible to adequately research each of these topics. In order to make this study more manageable, some discretion and limitation had to be employed. As described later, the most notable and significant changes, both in terms of glass technology and material culture, took place in the realm of luxury glass. This is, therefore, where the large majority of my attention lies in this work. Even within the topic of luxury vessel glass, there is a considerable variety of compositions to consider. I intend, therefore, to make the focus of this work primarily one particular type of glass (and its variations) made during the Renaissance - Venetian "colorless" vessel glass, typically called *cristallo*[1] in museum contexts

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I wish to note that the distinction between *cristallo* glass and other glass compositions made in Venice is not so apparent to the casual observer. Different communities studying Venetian glass have treated the topic of identification in distinct ways. *Cristallo* is distinguished by its clarity, colorlessness, and particular chemical composition. Frequently, the museum and art historical communities have used only the first two criteria as a basis for labeling a museum piece as *cristallo*.

Reasons for narrowing the scope of investigations may best be presented in light of the different sources of information that are available. These may be divided into three primary categories. The first is written sources which include everything from travel diaries and recipe books to inventory lists. These typically address all types of Venetian glass although "cristallo-type" luxury glass is the most prevalent. The second source is pictorial representations, i.e. glass as shown in Renaissance-era paintings. Here, vessel ware, usually of clear and transparent glass, is the most common. Finally there are examinations of the glass itself. This includes both chemical analyses and physical examinations, as detailed in the Appendices. The

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Yet *cristallo* has a particular composition resulting from the special production steps followed in its manufacture. As a result, it is chemically distinct from other Venetian compositions (*vitrum blanchum*, for example) which may appear somewhat similar (Verita, 1985). Pieces identified as *cristallo* in museum collections may not actually be this type of glass; only chemical analyses can tell for sure. The fact that one curator told me that she could tell what pieces were *cristallo* merely by virtue of their weight and "feel" illustrates the confusion regarding this point. The distinction between these different glass compositions is not entirely academic as the *cristallo* compositions are much more subject to weathering and corrosion in a museum environment.

For now, the reader should be aware that there were three primary glass compositions used for vessel glass production in the Renaissance. The first was "common" glass used for the production of mainly utilitarian items. It easily distinguished from the other two by its characteristic greenish-blue tint arising from the presence of iron in the glass. *Vitrum blanchum* was a reasonably colorless glass and represents an intermediate level of refinement in the technology of Venetian glassmaking. Frequently, vessel of this glass are labeled *cristallo* in museum catalogues. The third glass is *cristallo* and it represents the high point of Venetian glassmaking in the production of a clear, colorless glass evoking rock crystal. All three of these compositions are identified here as "colorless" although any of them may have tints due to impurities. They are called "colorless" as whatever color they do possess was not produced intentionally during the manufacturing process. The actual causes of these tints (or their absence) will be clarified when glassmaking production is discussed in detail later.

large portion of Renaissance glass objects in museums are clear and colorless glass. In addition, the majority of samples available for analysis were vessel glass, either "common" vessel glass or clear and colorless "luxury" glass. The limitations of my available sources dictated, to some degree, the focus and direction this research would have.

I present the case that, from a historical, technological, and material culture viewpoint, it was the development of *cristallo* glass (c. 1450) in response to consumer demand that created the impetus for the Venetian industry to change. Its historical importance provides another reason for making *cristallo* my research focus. Because all of the major events associated with *cristallo* glass take place from about 1450 to 1550, the very broad time scale of the Renaissance can be handled in a more manageable portion. Finally, it was *cristallo* glass that was historically the most important in the influence that the Venetian glass industry had on glassmaking in other parts of the world.

With these limitations in mind, I feel I am justified in making a cultural and technological study of *cristallo* glass the basis of the following work. Certainly, one could follow the general approach of this work in relation to any of the other products of the Venetian (or other) glass industry such as beads, lenses, or mirrors. But as the most significant technological and material culture changes occurred in the vessel glass industry, especially the luxury market, that is where our attention must therefore lie.

CHAPTER 2

APPROACHES TO THE STUDY OF TECHNOLOGICAL CHANGE

Introduction

Without social context, a study of technological change or material culture becomes little more than archaeometry, a detailing of an object's dimensions, or a description more suited to a museum catalog. The history and ultimate failure of rigid determinist and internalist studies of technology have been well documented in recent years (Ferguson, 1977; Staudenmaier, 1985; Reber and Smith, 1986; Pfaffenberger, 1988; Hughes 1991; Smith and Marx, 1993). The danger of rigorous determinist/internalist thinking is that it cripples the ways in which one examines material culture and technology. By making the artifact or the technology the central feature, possible relations between it and culture are limited. Pfaffenberger points out how the failure to consider context and the adoption of a determinist attitude towards technology results in a "fetishism" of technology when it is seen as a "given" and the underlying human relations are disguised (1988:243).

The same effects can occur in material culture studies if they are dominated by an "artifact oriented" approach with most of the attention paid to the object and little paid to the user or producer of the artifact. Many previous studies of Renaissance Venetian glass, due to their origin via museum catalogs or exhibitions, fall into this category (Tait, 1979; Perrot, 1958 for example). This "fetishism" has been revealed and discussed in the practice of museum-based material culture studies, as well (Gathercole, 1991). As I explained in the Introduction, what I hope to present here is a more integrated and holistic approach to the subject that will incorporate a wide variety of sources rather than dwelling entirely on the artifacts themselves.

Definitional Strategy

Before embarking on an examination of models with which to examine technological change, I wish to very briefly outline the word "technology" as it will be used throughout this work. This becomes especially important as numerous definitions exist in the literature for "technology". More importantly, the way in which one defines technology affects the manner in which it is studied.

Technology has been defined in numerous ways ranging from the commonplace "applied science" to the manner in which man enhances control over nature (Schon, 1967). A definition that I find most useful is: "technology is a corpus of artifacts, behaviors, and knowledge for creating and using products that is transmitted [within a generation]" (Schiffer and Skibo, 1992:44, adapted from Merrill 1965: 576). This definition allows for consideration of both the artifact and the behaviors associated with it including its production, distribution, use, and re-use. It is also basic enough to allow one to make the relations between artifact, producer, and user to be systemic or socially constructed (cf. Hughes, 1983; Bijker, et al., 1987).

Contextual Methodologies for Examining Technological Change

Contextualism refers to the consideration of different cultural factors which affect and are affected by technology (adapted from Reber and Smith, 1986). Such studies consider not only the design of the technology but the ambience in which it develops (Staudenmaier, 1985:205). Contextualism "...affirms as a central insight that the specific designs chosen by individuals and institutions embody specific values" (Staudenmaier, 1985:166). Contextual studies stand in opposition to determinist or internalist oriented approaches to technology. In the first instance, technology is autonomous and societal development is determined by technological developments (Bijker, 1995:238). The second case focuses primarily on the functional design of a particular artifact (Staudenmaier, 1985:205).

Within the realm of contextual studies there exists considerable latitude in examining technological change. Reber and Smith (1986) identify two different schools within the contextual camp. One is the view that technology is expanding knowledge with emphasis placed on technical, managerial, and social factors. Culture and society provide the background against which technological change occurs. As an example, Hughes' work can be seen as part of this school. The use of an advancing military line as a metaphor for technological expansion led Hughes (1983) to develop the concept of a reverse salient or a part of the technological advance that lags behind. These reverse salients are points at which further technological change can occur.

A second contextual school identified by Reber and Smith (1986) concentrates more on the social aspects of technological change. Technology is seen as a social product and social force with emphasis on the attitudes and values behind technology. An example would be Ruth Cowan's work looking at the relation between technology and American women (1983) or those of Langdon Winner which focus on the politics of technological objects (1986). The remainder of this section is devoted to discussing different ways in which the study of technological change can be examined within the contextual, rather than determinist or internalist framework.

The Anthropology of Technology and "Technological Choices"

Anthropologists have been faulted at times for viewing technology as nothing more than material culture and thereby taking it for granted (Pfaffenberger, 1988:236). Along with an absence of explicit interest in technology, the lack of an established definition of technology has also been noted by some anthropologists (Pfaffenberger, 1988; Lemmonier, 1986). This, in turn, affects how the topic of technology is broached. Pfaffenberger reveals two tacit notions present in the way that anthropologists look at technology.

The first, that of technological determinism, has been previously discussed. Whether one views technology as "applied science" or as an internally motivated force striving towards ever-greater efficiency (Ellul, 1964), technology is alienated from its cultural context. The second tacit view is what Winner referred to as "technological somnambulism" (1986). Here, the relation between technology and culture is too obvious and is taken for granted. Technology is seen as morally neutral with no social implications or values. Winner argues that such a view of technology creates a "sleepwalker's" perspective, with societies passively accepting whatever technology is offered. Anthropologists have been slow to recognize the presence of technological determinism or somnambulism, leading to disinterest or passive acceptance of it. By not considering the social relations of technology, it becomes a disconnected entity made of only devices and processes- in short, what Marx referred to as a "fetished form". His insight that the Western view of objects tends to obscure the social relations of technology is seen at the core of determinism and somnambulism (Pfaffenberger, 1988:242). Anthropology's role becomes the revelation of these relations.

Lemmonier also cites the traditionally limited view of technology among anthropologists, particularly ethnologists (1986). Few attempts have been made to relate techniques to the societal context in which they developed. This amounts to anthropologists ignoring the choices a society makes when using material culture and the interrelated changes that take place between society and culture. Lemmonier's work is primarily directed towards studying these "choices".

Technical traits arising from these choices may have some degree of signification, to mark identity for example. (Lemmonier, 1986:176). Lemmonier sees the study of technology as part of anthropology with anthropologists ideally studying and understanding the particular technological alternatives adopted by societies. He insists on the need to study the relation between techniques and societies using the definition of technique proposed by Mauss as being "any effective traditional act" (Lemmonier, 1986:153). The presence of different techniques leads to the formation of a system due to the presence of multiple interactions among its elements. Between techniques there exists relations of interdependence leading to a systemic character. Finally, the way in which the different techniques are culturally represented adds more to this systemic nature. As will be seen, this systemic construction bears some resemblance that of some technology historians, notably Thomas Hughes (cf. 1983, 1990, 1991).

Pfaffenberger also identifies this signifying characteristic by describing technology as a total social phenomenon with material, social, and symbolic elements (1988:249). This bears resemblance to the idea of ascribing techno-, socio-, and ideo-functions to artifacts (Schiffer, 1992). To counter technological determinism or somnambulism, Pfaffenberger advocates viewing technology as humanized nature, a fundamentally social phenomenon. Perhaps this accounts for his claim that anthropology is best suited to study the complexities of technological-cultural interaction (1988:245). I find fault with his continued use of the phrase "to construct (or create) a technology" (1988:249) which implies a uni-linear building process or an evolutionary one. Technologies are not built by society; rather they are part of it and cannot be divorced from it without returning back to the "technology is hardware" beliefs of determinism. I would prefer to view technologies as developing, maturing, and changing through time. In many cases, these changes are expressed in material culture.

In their methodological outlines and examples, both Pfaffenberger and Lemmonier realize the complexity involved when considering technology and its intrinsic relation to culture. Understanding the complexities that exist with this perspective requires a working knowledge of all aspects of a society. However, the anthropological approach to technology, using these principles, appears to be somewhat removed from the actual artifacts. This lack of an explicit "artifact orientation" might introduce problems when examining past societies where all that remains are the artifacts from which behavior must be inferred. The work by Pfaffenberger is interesting in that he mentions the need to consider both failed and successful (or chosen vs. rejected) technologies with the same explanatory principles (1988:249). Staudenmaier also makes this point, showing that articles in *Technology and Culture* are heavily biased in favor of successful technologies (1985:175). The consideration of a technology's mythic dimensions is another aspect to explore. For example, Schiffer exposes the mythic crypto-history that underlies Sony corporation's claims to technological change in the portable radio industry (Schiffer, 1991). The issue of mythology permeating into the telling of a technology's history certainly has implications for the glass industry of Renaissance Venice. Chapter One has already presented evidence that the story of Venetian glassmaking is infused with a variety of tales and half-truths.

The issue of technical choices and its further elucidation is particularly interesting as it encourages one to consider the reasons for which a technological system or technique developed in its particular fashion. For example: why was there a switch in the alkali fluxes used by Venetian glassmakers in the decades following the Renaissance? Why were Venetian glass furnaces designed the way they were? In relation to choices such as these, Lemmonier asks three questions: Are they real choices or merely an anthropologist's interpretation; what logic underlies these choices; to what extent do "arbitrary choices" impinge on technology and society? (1993:9). However, I find the phrase "arbitrary choices" to be problematic. Furthermore, there is little consideration given to either actual artifacts or to the process of technological change and innovation. The methodology outlined by Lemmonier in his various writings would seem best suited to the observation and description of a static technological system rather than one in the midst of change and innovation as the Venetian glass industry was in the mid-15th century.

The Concept of "Technological Style"

Lemmonier's work is more directed at understanding the causes behind what he calls technological choices (1992, 1993). However, once a certain number of these choices are made, with others correspondingly rejected, what has been described as a "technological style" emerges. Any given task can usually be accomplished in a number of ways. The particular approach adopted by a society to resolve a technical problem or accomplish an objective may be one that is the technically feasible as determined by physical laws. On the other hand, the chosen solution may have less to do with physical constraints and be more rooted in ideology and social organization. One of the early advocates of this approach was

Lechtman with her work based primarily on examinations of early Andean metallurgy (1975, 1984).

Her viewpoint is developed from the perspective that culture and technology are not independent of one another (Lechtman, 1979) but rather that "...modern technologies are culture-producing as well as culture-using sociocultural systems." (Merrill, 1965). Such a perspective suggests feedbacks between the two. Lechtman describes technology as a subsystem or institution of culture much like religion or values (1979:136). What is needed then is to understand the nature of technology within a particular cultural system. Her goal, as described in the 1979 article sounds deterministic. Indeed, she questions how much of a technological manifestation is determined by a culture's materials, energies, organization, values, sciences, or mythologies. The issue then is "to isolate the deterministic aspects of technology" if they exist and to try to understand the internal forces that drive them (1979:137). Recognizing this determinist orientation, Lechtman qualifies it by saying that she expects the cultural necessities to outweigh those determinants related to specific materials or energy sources. Moving beyond examining aspects of technology solely related to processes and products, Lechtman asks what particular technologies express (1979:139).

From this question the issue of describing and interpreting what Lechtman refers to as "technological style" arises. This style is described as the "sensible manifestation of pattern" (1975:7). It consists of a series of traits (form, function, elaboration) that are culture-specific (1979:154). This is similar to the description suggested by Cyril Smith where style is hierarchical and exists at all levels with relations existing between the styles of different components (Smith, 1982:358-390). And while not defined the same way, Lechtman's view of styles is ultimately similar to that of archaeologists in which style has been traditionally seen as the cause of variability not explained by any particular artifact function (Schiffer, 1992:15-18). The method of investigation proposed to understand technological style is to extract a technological history from artifacts. This is done using laboratory studies and principles of materials science and experimental archaeology (Lechtman, 1979:140-141). The use of gold gilding via surface enrichment and depletion was identified through the use of laboratory studies and replication. Lechtman's idea would have remained merely conjecture except that she verified the existence of this technology through lab studies and also looked at the possible existence of similar values in other aspects of Andean material culture such as weaving.

As noted, there are definite connections between Lemmonier's work with the idea of individual technological choices and the combination of these choices, selected from a variety of possible alternatives, into an overall technological style. Technology must be practiced within the bounds of physics and chemistry as well as available natural and human resources. Usually, however, there exists some latitude within these constraints for a particular technique to be exercised in a variety of means that best conforms with the values and goals of the society in question (Gordon and Killick, 1993:243). It is possible to identify particular ways and manners in which a technology is practiced that are not explicitly determined by physical laws. For example, both sodium and potassium based alkalis will act as fluxes in conjunction with silica; this is a physical fact. However, it does not explain why the Venetian industry developed along a different technological trajectory for centuries when compared to the glass industries of northern Europe only to switch to a different fluxing material in the 17th century (Moretti, 1982). The differential design and construction of glass furnaces in Venice as compared to other parts of Europe presents another manifestation of technological style.

However, none of the advocates of "technological style" mentioned above discuss what I see as a fundamental flaw with this approach. This is the very usage of the concept of "style" in an artifact or technological practice as diametrically opposed to function. The archaeological literature is full of references to the perceived dichotomy between these two attributes and I do not wish to undertake a review of this material here. Style is generally seen among archaeologists as "different ways for doing the same thing" and is sometimes used to rationalize variability in artifacts that cannot be explained away by a functional analysis; i.e. it is a residual category and is not related to adaptive aspects of a given culture (Dunnell, 1978:200; McGuire, 1981). Without opening a full blown epistemological argument with regards to the opposition of style and function, I think that examples illustrating the idea of "technological style" described above show that style is a function of certain artifacts. For example, Lechtman demonstrated that the Andean people developed their own particular metallurgical practices that would allow them to incorporate the essence of gold and silver into the bulk of the object and then reveal the precious metal by depletion and surface enrichment. The act of performing this technological activity in this particular "style" incorporated technical, social, and ideological aspects of Andean culture. Lechtman acknowledges this in her own work (1984:29-31). Therefore, while the techniques and experimental work done to show how technologies such as Andean metallurgy were practiced are appealing due to the intermingling of several disciplines including materials science, the partitioning of the results into "style" versus "function" is artificial. No clear cut boundary exists between the two.

Technological Change and the Role of the Aesthetic

Contextual studies of technology recognize the influence that cultural factors have on technological development and change. Within this school there are scholars who see aesthetics as a powerful, if not primary, impetus for technological choices, growth and change.

Early work recognizing the interrelation between art and technological development is that of Cyril Smith. He draws attention to the fact that that many of the antecedents for today's technology and science lies in the decorative arts (Smith, 1982:191-241). Smith states that the "invention of a technique, until recently, has been more likely to occur in an aesthetically sensitive environment than a practical one." (1982:197). Examples include many of the earliest developments in pyrotechnologies, such as pottery, glass, and metal-working, most of which occurred in relation to objects that perfomed decorative or aesthetic functions rather than purely utilitarian ones.

Once the technology or innovation in question exists, though, the ends to which it is used are decided by government or society. The driving force for technological development is often aesthetic and intellectual curiosity rather than an explicit need. Furthermore, the relation between art and technology is interdependent, not uni-linear. Proper understanding of technology and technique is essential for creating art (Smith, 1981). Smith is critical of art historians who neglect the technique and the technology that is innately required for the making of art just as he is quick to point out that historians of science and technology have been slow to recognize the role of the aesthetic. However, to imply that this technological development was driven solely by aesthetics is an oversimplification. Clearly, the role of intellectual curiosity and experimentation is an important part of the invention process but successful technological change requires attendant social and economic factors, as well. The discussion of the development of *cristallo* glass in Renaissance Venice in later chapters will prove this point.

Later work by Kingery (1986, 1993) and Kingery and Vandiver (1986) continued in the direction established by Smith by looking at the change and development of ceramic technology. As a large part of the wares examined were luxury goods, the role of the aesthetic can still be seen to operate. However, political, economic, and social factors are also relevant for such technological development, modifying and expanding on Smith's original premise. As Kingery points out, "Within the limitations of available materials, the level of ceramic technology rises to the level for which there is a perceived need." (1984). This concept of perceived demand will be seen throughout this work as a important factor to consider. What qualities of glass did consumers prefer that were communicated to and interpreted by glassmakers as a perceived need?

A past example of how such factors become relevant would be the examination of early European porcelain technology (Kingery, 1986; Kingery and Vandiver, 1986). The desire to imitate the Chinese porcelain being imported to Europe was driven by economic, nationalistic, and aesthetic reasons. Correspondingly, it led to technological changes ranging from a better understanding of clay chemistry and higher furnace temperatures to state sponsored scientific investigation and technological development with mercantile intent. A very similar situation for the development and support of the Renaissance Venetian glass industry was present about 100 years earlier.

The advantages of studies such as those of Smith, Kingery, and Vandiver is that their interdisciplinary approach mixes aspects of experimental archaeology, materials science, material culture, history, and archaeology to create a better understanding of the social and technical context in which a materials technology develops. A limitation might be perceived by some in that the technologies examined are those existing for the upper echelons of society. By examining primarily museum quality luxury and elite materials goods, Smith and Kingery make the distinction between "high technology" and "life sustaining technology". Gordon and Killick note a similar distinction in their examination of African iron working which was seen as a "sustaining" technology rather than one practiced for reasons of power and prestige (1993:244). Questions could certainly be posed as to whether an accurate, overall picture of technology is depicted by focusing preferentially on the "state of the art", as it was known at that time. However, if one is going to examine the question of technological change, one has to examine the material culture where such changes took place. The most notable technological and material culture changes of the Venetian glass industry took place in the luxury industry. The primary technological change that is of interest in this dissertation is the introduction and development of the Venetian *cristallo* glass composition. This path leads not to common wares but to the refined glass products for the upper levels of Renaissance society.

The Social Construction of Technology

A 1984 conference between sociologists and historians resulted in a collection of essays which articulate the various roles social factors play in technological change (Bijker, et al., 1987). Like most of the methodologies for the study of technological change discussed previously, this approach is interdisciplinary. The approach labelled as the "social construction of technology" argued that technologies have the traits and imprints of the social context in which they develop. The development of a technological artifact is described as an alteration of variation and selection. The result is a multi-directional model of development as opposed to a linear and progressive form of change (1987:28) This approach has been applied to technologies of differing scale. Bijker and Pinch, for example, show in their opening essay how different social groups affected the development of the bicycle in the 19th century (1987:17-50). These different groups presented unique problems which bicycle makers attempted to solve. Depending on the social and economic influence a particular group had, the bicycle assumed particular technical traits and social meaning.

The "social construction of technology" approach make use of a concept that is pertinent to my study of Venetian glassmaking: the identification of relevant social groups. This term is used to denote organizations and groups of people which share the same sets of meanings in relation to a particular artifact or technology (Bijker and Pinch, 1987: 30; Bijker and Law,1992). The design of a particular artifact, such as a bicycle, is explained by focusing on the problems and needs that these relevant social groups have with respect to the artifact. To understand what social groups, or "actors" are relevant, one must know whether the artifact had any meaning for the group. The dynamics and relations between the groups must be considered as well. As Bijker and Pinch show, the identification of "actors", their specific concerns and problems, and the inter-group dynamics can be quite involved (1987:37).

For example, the relevant social groups for the production and use of Renaissance Venetian glass include: the glassmakers (the groups here might vary with the types of products made, i.e. beads, common glass, mirrors), the government, the distributors of the finished goods, the suppliers of raw materials, the consumers (tremendous variability would exist here depending on the particular commodity; one must also consider domestic versus foreign markets). This approach will be adopted at times in Chapters 7 and 8; the properties of Venetian glass are examined from the perspective of two key social groups -the users (demand side) and the makers (production side).

This system of interacting social groups can be even more complicated if one takes a diachronic view of the artifact and identifies how the social groups change over time. Consumers of the glass, for example, cease being persons who bought the glass for use in their home and instead become collectors, curators, and museums.

The "social construction of technology" approach is useful in that the context of the technology and the differing social groups associated with it are to be considered. The identification of relevant social groups introduces feedbacks into the design of a particular artifact. The multi-linear view of artifact development is a more realistic approach than the progressive determinist, uni-linear model the social constructivists decry. However, it is still primarily a "product centered" approach organized around understanding design and development of an artifact rather than examining the relevant social groups' initial demand for and subsequent use of the same. Furthermore, as Winner notes, the methodology employed by the social constructivists tends to avoid taking any critical position on a technology's political, social, or environmental dimensions (1993:375).

The Contribution of Archaeology

In many resepcts, archaeology is particularly well-suited to the study of changes in a society's technology. This usefulness stems from two central features of archaeology - the use of artifacts as a primary source of information coupled with the tradition of archaeology to treat large spans of time. Briefly considered below are two archaeological approaches to the study of technology.

Evolutionary archaeology is a systemic approach explaining variability using the tenets laid out by biological evolution (Trigger, 1989:305). An approach such as this might be used to explain how the glass industry developed and changed over time with respect to its organization and use of certain compositions. Evolutionary models of technology highlight the variables generated by the practicioners of that technology and focus on the processes by which these are selected (Bijker, 1995:239). Change is explained by differential persistence of variability and is seen as a selective rather than transformational process. Evolution has three components: empirical variability; transmission of some/all of the variability; and differential representation of transmitted variability (Dunnell, 1980:39). A component of cultural evolution is the use of "stages". To avoid a uni-linear and "progress oriented" perspective, the possibility of multilinear evolution is added (Trigger, 1989:45).

An evolutionary view towards technological change is not unique to archaeology. A similar view from a historian of technology is also offered (Basalla, 1988). Here, harking back to an internalist view, the artifact is the central focus. Basalla recognizes such principles as diversity, novelty, and especially the presence of continuity in the evolution of technology. This last principle is emphasized and he is critical of those studies which suggest that technological change proceeds via discontinuous steps or revolutions. In the end, however, Basalla concedes that the use of evolution to describe technological change is only an analogy or metaphor.

His primary focus on artifacts and removal of the human element in discussing technological change ignores the creative processes that take place as well as decisions made by a society regarding the acceptance of a new technology.

Ultimately, the evolutionary approach to technological change is flawed in that there seems to be no explicit factor held responsible for determining or measuring the fitness of a particular technology. Is it the market? The society in which the technology is part of? What about the perceptions of the users in shaping technology? What are the units and terms of selection and choice? How is fitness measured? It also does not allow for de-evolution such as that seen when the Japanese abandoned the use of firearms and returned to traditional sword warfare. Trigger notes that an evolutionary approach tends to deny that there is a role to be played by conscious action and intentionality in the shaping of human behavior (1989:305). Perhaps these failings stem from the fact that the evolutionary model is one borrowed from other sciences and is modified to suit the archaeological facts involved.

An alternative archaeological approach to the study of technological change is behavioral archaeology, defined as the study of the relation between material culture and people, regardless of time or place (Reid, Schiffer, and Rathje, 1975). One of the special characteristics of behavioral archaeology, compared with evolutionary archaeology, it its inclusion of experimental archaeology as a supplemental source of information. This includes the use of replicative or imitative studies used to test whether or not an archaeological hypothesis is valid. While experimental archaeology can not conclusively prove that a conjecture is true, it does remain as a means for the archaeologist to eliminate flawed reasoning and establish what Kingery refers to as "plausible inferences" (Kingery, 1982). Schiffer and Skibo point out the danger of relying too heavily on informant-supplied information as this person is then elevated to the status of an authority (1992:45). The methodology outlined is one in which informant information supplied by ethnographic fieldwork is a testable hypothesis. By applying modern scientific principles to the technological processes and products, especially the use of new experiments, the validity of these hypotheses can be evaluated and the technoscience of a technology further revealed (Schiffer and Skibo, 1992:48). Understanding the science behind a technology is essential if one is to be able to explain the reasons of technological variability and change with any degree of authority.

Change in a given technology is assumed to be caused by variation in the "functional field", the set of different functions an artifact must fulfill. Cultural and societal change varies the functional field thus acting as an impetus for technological change (Schiffer and Skibo, 1992:49-50). Feedback from the society regarding the function and performance of an artifact will also instigate change. Finally, if there is an expanding market for a technology, the need to innovate creates "producer pressure" and technological change. This last instance introduces a role for consumer demand to exist as a force for innovation and is especially relevant for this work. This consumer/demand pull can be viewed in opposition to more traditional technology studies which dwell primarily on a "technology push" perspective (cf.

Schumpeter, 1980). Therefore, change can arise from both cultural causes and those inherent in the technology. By considering the feedbacks between technology and society, this approach differs from both the determinist view of technology which was centered on the artifact and the evolutionary school which tended to deny human intentionality. However, it does still incorporate some deterministic features, this time from the other direction, as change is primarily driven by cultural and societal factors. An ideal model of technological change takes into account that the stimuli to invention and innovation can emerge from both cultural and technocal contexts. As Pfaffenberger notes, " Assertions of one way causality...are suspect..." (1988:244).

A number of different archaeological studies have been presented which focus on certain functions of an artifact and the ways in which the associated technologies changed to accommodate them. Frequently, they have tended to focus on only a limited number of its components. For example, Bleed primarily studied the design component, examining maintainability versus reliability in hunting weapons (1986). Nelson's study on prehistoric toolkits is also heavily oriented towards the design component in an attempt to understand technological organization (Nelson, 1991). She expands on Bleed's work to include factors such as versatility, transportability and so forth. Here, use is not considered directly nor is the possible role of aesthetics in design. Braun primarily considers the techno-functional aspects of pottery ("pots as tools") technology and makes use of laboratory analyses as well as experimental archaeology (1983). A balance in performance characteristics is seen with variation in pottery technology occurring due to the particular techno-functions that the pottery must fulfill.

Braun's work was expanded and refined by Schiffer and Skibo by introducing the concept of a "performance matrix" (1992:60-72). This is a list of the performance characteristics thought to be relevant to the artifact's activities. A performance characteristic is a behavioral capability that an artifact must possess in order to fulfill its functions in a specific activity (Schiffer and Skibo, 1992:51). For example: a glass batch must be workable, have reasonable physical characteristics, such as thermal expansion and chemical durability, and result in a product that is desired by the consumer which usually entails it having particular aesthetic characteristics. Impetus for technological change can thus be seen to originate from a variety of different sources.

These differing performance characteristics generally have optimal levels or states. One estimates the value of each characteristic with information provided through a variety of sources including experimentation. In this way a model is built in which the performance matrix results from specific technical choices made by technologists (cf. Lemmonier, 1992, 1993). Different and individual choices affect the performance characteristics, often in a manner of tradeoffs. For example, adding more soda ash to a glass batch will make it easier to work but less chemically durable, all other aspects being equal.

Behavioral archaeology can provide a framework with which technological change can be evaluated. In theory it allows for a consideration of an artifact's technical, social, and ideological components. However, in practice, it seems to have been applied mostly to techno-functions. In this, it has a decidely functional stance, implying that all aspects of a technology must serve a purpose. Further use of this framework with my own work on Venetian glass needs to consider not only the "techno" or utilitarian functions of an artifact but also characteristics that are harder to evaluate empirically such as user perception and quality as elements of consumer demand.

Overview of Contextual Studies to Technological Change

It may be seen that a number of different academic disciplines (archaeology, history, anthropology, and sociology, among others) have all proposed contextually-oriented models to account for observed instances of technological change in both the prehistorical and historical periods. Furthermore, rigid and simplistic determinisistic or internalist models for such changes have been shown to be unrealistic and reductionist in nature. A common feature observed in contextual approaches to technology is that they typically incorporate three different elements - the artifact(s) in question, the knowledge systems associated with it, and the activities and social practices related to the technology (for example see Schiffer, 1992:44 or Bijker, 1995:237). The difference between the various methodological approaches often lies to the degree that one element is emphasized at the expense of the other two.

No one specific contextual model discussed here is perceived as having explicit or overwhelming interpretative utility to the research I am presenting. At the same time, several of the approaches described contain features that were essential to carrying out my work and which needed to be integrated in the final product. For example, the focus of this work on the "life-enhancing" technology of luxury glassmaking makes the role of the aesthetic as proposed by Smith, Kingery, et al. significant. The approach labeled as the social construction of technology and the identification of relevant social groups (in my case, the producers and consumers of luxury glass) will emerge as a methodological tool with which different performance characteristics (a concept taken from Schiffer's work) can be evaluated. While not explicitly described previously, the distinction drawn by Schumpeter (1980) between "technology push" and "demand pull" forces also becomes crucial. Chapters Seven and Eight, in particular, describes how inventive and innovative activities in the Venetian glass industry responded to changes in consumer demand.

Rather than try to rigidly employ a single methodological stance, I have taken a more flexible approach. I have chosen instead to try to evenly consider the basic elements of glassmaking technology - artifact, knowledge, and activity. In this manner, glassmaking in Venice can be described as constituting what Bijker refers to as a "sociotechnical ensemble" (1995:242). In this manner, the glass objects and the technology that produced them become flexible in that their interpretation and examination reveal the differential meaning and importance attached to them by both consumers and producers in Renaissance society.

CHAPTER 3

THE ARCHAEOLOGY OF GLASS IN THE VENETO

In this section, a discussion of different archaeological sites in and around the city of Venice, Italy is provided. Even with the relatively few excavations undertaken in this part of Italy, a complete overview of this topic cannot be provided in a reasonable space. Therefore, only those sites which have yielded appreciable or important glass finds are covered. Following this, other archaeological sites relevant to the study of Venetian glass are offered for comparison. Figures 3.1 to 3.4 illustrate the geography of Venice and its environs.

Modern Archaeology in Venice

The practice of archaeology in Venice, on the basis of listening to those who are involved with it, can simply be described as frustrating. Part of this lies in the nature of the area itself. The combined effects of tidal action, floods, and human activity in the Venetian lagoon over the past 1400 years have all introduced formation processes which make interpreting the archaeological record quite difficult. Along with this is the problem that many areas of interest are under water at different times of the month or year creating a quasi-marine archaeology situation. These obstacles are accentuated by the formidable Venetian bureaucracy and the lack of financial backing to support excavations to the desired degree (Canal, personal communication, 1994).

Another difficulty is related to the Venetians' concept of identity and history. According to Ernesto Canal, an archaeologist working in the Veneto, there is an unwillingness among Venetians to acknowledge that others lived in the lagoon before the establishment of the City of Venice (Personal communication, 1994). This ties into the mythology of the city itself which asserts that the region was first inhabited by Roman nobility seeking refuge from invading barbarian peoples. Correspondingly, not as much attention is paid to sites dating earlier than A.D. 400 or 500. This sense of history has adverse effects on the study of Renaissance glass, as well. From the Venetian frame of reference, glass (or other objects) that is 400 or 500 years old is not considered "old" or "ancient" and more attention is sometimes given to artifacts dated before this. As a result of these circumstances, geographic and social, the practice of scientific excavations in Venice is seen as still being in the early stages of development (Verita, 1994; Verita and Canal, personal communication: 1994). Little is known, for example about the early origins of the city or its archaeology (Ammerman, 1992:913). This is in stark contrast to other regions of Italy, such as Rome or Tuscany, where formal excavations have been undertaken for decades, if not longer.

The study of Venetian glass from an archaeological perspective falls within the discipline of medieval archaeology. The term "medieval" encompasses a very broad range of time. The discipline's primary journal, Archeologia Medievale, is dedicated to material and sites that are post-classical but pre-industrial; the result is a very elastic definition of "medieval" (Whitehouse, personal communication:1993). In comparison with Italian classical archaeology, medieval archaeology is still in an early, yet rapidly progressing, state of development. Allotments, both in terms of manpower and money, are typically much less for medieval than for classical archaeology. There is an on-going dialogue within the field about the role medieval archaeology has to play in formulating an understanding of the past. This re-evaluation originates partly from medieval archaeology's relation with history. The question (and challenge) facing medieval archaeology is "why is archaeology needed at all for a temporal period in which everything we need to know is [supposedly] contained in written documents?" (Hodges, 1982:7). Hodges addresses the role of archaeology by calling for the discipline to adopt the principles of the "New Archaeology" and to better formulate method and theory. The options presented to medieval archaeologists are, in many ways, a return to those present in American archaeology in the 1950's and 1960's: to either continue as a "lesser child" of history by collecting, describing, and presenting "facts" or to enter the mainstream of current archaeology. A decade after Hodge's article, a similar call was made for medieval archaeologists to consider and apply the tenants of post-processual archaeology to their discipline (Moreland, 1991). The self-reflection and examination taking place within medieval archaeology certainly has implications for the study and understanding of medieval material culture, and specifically of Venetian glass. The contextualization of Venetian glass, both in the current archaeological and art historical literature, is still wanting. It awaits the fruitful merging of a variety of sources of which archaeology is one. As Mannoni concludes

- archaeology is one of several available sources (oral, written, iconographic) that Italian communities can draw upon to become aware of their history and heritage (Mannoni, 1978).

The mythology of Venice surrounding both the city and its glassmaking activities have, to some degree, hampered a beneficial merging of glass studies and archaeology and therefore a more complete understanding of the industry. The fame and pride of the Muranese industry stems primarily from its luxury glassware which is not typically or plentifully encountered in excavations. Rather, it is most frequently found in museums, art galleries, and private collections. While glass studies in other regions of Italy have looked at common glass production and have begun to establish typologies of pieces, dating sequences, et cetera, the notoriety of the Venetian industry has inhibited this type of work until recently.

There has been an extensive amount of work documenting glass production in Tuscany, Lombardy, Emilia Romagna, and other regions of Italy in close proximity to the Veneto. Mendera's recent anthology (1991) offers a good introduction to current research into pre-industrial glass production and archaeology with Italy as its focus. A similar publication examining glass production in Tuscany provides a modern view of how archaeological information can be incorporated with other sources in order to understand glassmaking in context (Mendera, 1989). The work presented by Mendera, et al. in the 1991 volume and related publications is very different from the archaeological work concerning glass production in Venice. Emphasis is on more elaborate excavations with attention paid not just to luxury glass pieces but to simpler, common wares. With the exception of Verita's work with Venetian glass, researchers examining glass production in other parts of Italy have taken greater advantage of scientific examinations of their finds including chemical analyses of the glass and raw materials. Iconographic and written documents are also frequently used to strengthen points of view (cf. Ciappi, Muzzi, and Guidotti, all in Mendera, 1991). There have also been attempts to place the glass found at the different sites into a broader context of material culture as well as to understand the lives and social relations between the producers and consumers of glass in the Renaissance (Guidotti, 1983). Finally, a preliminary typology of medieval glass objects has only recently been presented (Stiaffini, 1991). This typology ends in the 15th century and only considers objects of Venetian origin in relation to their parallels with glass from other Italian regions. It is surprising that, given the number of art historical publications concerning Venetian glass, no explicit typology of vessel type and date has been established.

Relevant Sites in the Veneto

With the aforementioned caveats in mind, let us turn to an examination of sites in the Veneto relevant to the study of Renaissance glass. Probably the earliest evidence of glassmaking or working near Venice comes to us from the harbor town of Aquileia, some 80 kilometers to the east of Venice and close to the Adriatic coast (see Figure 3.2). The evidence from this area dates to the Roman era and consists of glass fragments and fabrication debris (Calvi, et al., 1963). There is also epigraphic evidence of glass being made here in the form of stamps bearing the inscription

"Sentia Secunda facit Aquileia vitra" and *"Sentia Secunda facit Aquileiae"*. These stamps record the name of one of the local glassmakers. Several of the glass pieces found here are displayed at the local *Museo Civico*. Some are thought to be of local production while others may have been imported from other production sites in the Roman empire (Barovier, 1982:9) The glass is typical of Roman-era glass in both style and composition and has been dated to the 1st and 2nd centuries A.D. with a few belonging to later centuries (Calvi, et al., 1963:308). The chemical composition of the glass from Aquileia shows it to have been made in the Roman tradition using natron as a fluxing agent (Ibid.). Other Roman settlements around the Venetian lagoon have yielded large numbers of Roman fragments including Altino and Adria although is has not been proven whether glass was actually made there (Verita, 1990:169). Roman glass fragments are sometimes also found mixed in with Renaissance-era glass at sites in the lagoon discussed below. These typically can only be identified by chemical analyses of the glass.

Of the sites excavated which have yielded either glass or evidence of glassmaking, Torcello in the Venetian lagoon (about 8 kilometers from the modern-day city of Venice; see Figure 3.4) is the best known. The site was excavated in 1961-62 by a joint Polish-Italian team and the entire project is described in a 1977 monograph (Tabaczynska, 1977). Near the center of the small island, adjacent to the present day Basilica of Santa Maria Assunta, the excavators claim to have uncovered the remains of four early medieval furnaces, along with tools and waste associated with glass production. Gasparetto found it likely that the first furnace was for the preparation of the glass frit, the second and third were for the melting and working of the glass, while the fourth was for annealing (1967:71). The dating of the structures, according to the stratigraphy of the site and its relation to the nearby Basilica (whose construction was begun in A.D. 639) is from the end of the 6th century to the second half of the 7th. The proposed function of the furnaces was to produce glass cubes for the mosaics which decorated the church. Pieces of mosaic glass were found at the site. Scholars interpreted the finds as evidence of the historical continuity of a regional glass industry in the lagoon from Roman times as well as a seed for the subsequent flowering of the medieval Venetian glass industry (Gasparetto, 1967; Tabaczynska, 1968:23). The discovery of coins in the layers above the glass furnaces not only provide evidence for when the furnaces were dismantled but also suggests ties that Torcello had with other parts of the world including the Near East, according to excavators. Torcello was indeed an important regional site before the 10th century, gradually fading in light of competition from the town of Rialto which eventually became Venice.

Not all scholars are convinced of the links between the glass and glassmaking artifacts of Torcello with previous Roman-era glassmaking in the region as well as the later Venetian industry at nearby Murano. There are two centuries of silence between the glass of Aquileia and the production of Torcello which is seen as a sign of inactivity in the practice of glassmaking (Barovier, 1982:9-10). Barovier states quite clearly that the glass of Aquileia should not be seen as connected to medieval Venetian production. In a similar manner, she points out the long period (about 200 years) between the cessation of production at Torcello and the first evidence of glassmaking in Venice in the 10th century. Instead, she points to Byzantine and Near Eastern glassmaking traditions as instrumental in affecting the Venetian practice of glassmaking. This question of origin and influence will be taken up again later. The large size of the primary furnace found at Torcello have led some to question whether glass was even made or worked there due to the great amount of heat that would have to be generated to fuse the raw materials (Verita and Canal, personal communication, 1993)

Chemical analysis of the glass from Torcello shows it to be a soda-lime-silica glass, low in both potassium and magnesium oxides, which is evidence that it was made with natron as a fluxing agent (Tabaczynska, 1977:164). Therefore, the glass is quite similar to that found at Aquileia. This might either be seen to be a continuity of the Roman glassmaking tradition which used natron as a flux or the re-melting of glass made in earlier times. In either case, the glass composition is very different from that traditionally associated with medieval or Renaissance Venetian production. The glassmakers of Murano used a soda-rich vegetable ash for a fluxing agent which yielded a chemically distinct glass with greater amounts of potassium and magnesium. The compositional differences represent distinct glassmaking traditions. It is not known exactly when glassmakers in Northern Italy and the rest of Europe turned away from the use of natron as a fluxing agent or glass previously made with natron. Verita has illustrated an overlapping of the two glassmaking traditions with natron fluxed glass appearing as late as the 13th century and soda fluxed glass, found at Ferrara, appearing possibly as the early 8th century and as late as the 12th century (Verita, 1990). Despite a variety of interpretations, the finds of Torcello represent not only one of the few large scale and systematic excavations undertaken in the Venetian lagoon, but also provide evidence that glass was being made or, at least, re-melted and worked in the immediate surroundings of Venice at an early date.

Other than the finds at Torcello, there are no published excavations of a Venetian glass factory. This is partly due to the nature of the subject. Glassmaking in Venice is concentrated on the island of Murano. Glass is still made there today on the same sites as it was 500 years ago. The opportunities for excavating are not present as they are for other regions of Italy. Our attention must then turn to the products of local workshops. Between 1973 and 1976, work was undertaken to repair and restore the church of SS. Maria and Donato on the lagoon island of Murano. During the course of this work, numerous fragments of glass dating from before the 11th century through the 15th century were found (Gasparetto, 1977). The church itself dates originally to the 7th century with numerous reconstructions and alterations done in the following centuries. The sherds found were mainly vessel glass and represent the earliest glass found on the island of Murano. It is believed that the majority of the glass was made locally, either at Murano or Venice. The sherds were divided into two basic groups based on whether they were dated before or after the 11th century.

- The first group dated before the 11th century consists only of 3 lamp fragments. They are similar in shape to pieces found at the Torcello site as well as other sites in the Near East. Therefore, there is a question of whether they were imported or made locally (Gasparetto, 1977:79).
- The second group consists of both flat and vessel glass; the pieces are dated between the 12th and 15th century. The vessel glass includes sherds of various types including necks, rims, bottoms, and feet of bottles or ampules as well as fragments of drinking glasses. The sherds are primarily common glass with various iron or manganese tints such as blue-green, grey, or amber. Some decoration is present such as blue threads applied to the lip of one of the bottle fragments. A few fragments of drinking glasses, referred to in Renaissance-era documents as *moioli*, had walls imprinted with ribbing in relief (Gasparetto 1977:91).

Examples of the pieces found at SS. Maria and Donato are held at the Museo Vetrario in Murano.

Between 1986 and 1989, a series of excavations was done in Venice at San Pietro in the Castello district. Among the artifacts found were glass sherds dated to between the 11th and 14th centuries. Little information was provided about the glass other than that it included both window and vessel glass, along with bead and mirror fragments (Tuzzato, 1991).

The Palazzo Ducale in the great Piazza of San Marco, Venice sponsored an exhibition in the autumn of 1990 entitled *Il Relitto del Vetro* (The Glass Wreck). The focus of the show was objects recovered from a marine archaeology project carried out in the 1980's. The objects displayed were removed from a ship wreck in Malomoco channel which goes into the Venetian lagoon; the wreck was located about 8 km from the Venetian island of Lido. The date of the ship is given as 16th century and apparently was returning to Venice laden with cargo when it sank. Among the many artifacts recovered were statues, buckets of scrap iron, and carpenter tools. Most importantly, though, was the main cargo - lumps of raw, unworked glass in various dimensions. The total weight of the glass carried by the ship is estimated to be about 2 tons (Free, 1990:339). The revelation that glass cullet was being imported to Venice at this late date, when the Muranese industry was well-established, is surprising. It is possible that the glass was instead used as ballast for the ship rather than cargo. The wreck itself was spread over more than 6300 square meters and under 11 meters of sometimes rough water making salvage and interpretation difficult. A more detailed report from the excavators is supposedly forthcoming. Unfortunately, no chemical studies of the glass have been presented and none was available for this research.

Another ship wreck, this off the coast of the former Yugoslavia, was discovered, investigated, and published in the early 1970's (Gasparetto, Petricioli, and Brill, 1973). Shipping and archival records allowed the ship to identified as the *Gagiana*, wrecked probably in late October or early November of 1583 (Gasparetto, 1973:81). The ship was headed for Constantinople and other eastern markets. Among the commodities found on board the ship was a large cache of glassware, which, by the time of recovery, numbered some 2000 pieces, only a few of which were whole. The find of the ship and its glass cargo is especially important as it one of the few discoveries of Venetian glass with a very specific and well-established date. The glass includes a wide variety of objects including goblets, flasks, window panes, beads and mirrors. The vessel glass is described as thin and transparent with grayish, greenish, or purplish tints. Among the decorative techniques utilized are diamond point engraving, mold blown stems and decoration, and incorporation of white filigree threads into the pieces. Some of the pieces, such as the bottles, are Eastern in shape, suggesting not only a destination for the cargo but a sign that the glassmakers of Murano worked to accommodate their customer's tastes (Petricioli, 1973). Samples of the glass were submitted to the Corning Museum of Glass for analysis with the results being in accord with other similarly dated Venetian pieces (Brill, 1973). The glass is held today at the Museum of Zadar in Croatia.

In 1983, the initial season of excavating at the town of Concordia Sagittaria yielded both ceramic and glass fragments dating from the 14th to the 16th century (Cozza, 1985). The town is located about 35 km northeast of Venice; the excavations were done in the *piazza* opposite the cathedral. The ceramic pieces found were much fewer in number than the glass; they include luxury goods such as majolica that were imported to the town from Faenza and Spain. Numerous glass fragments were recovered including 160 bottle fragments, 292 fragments of drinking glasses, and 46 various fragments. The glass fragments are believed to be from objects made at Venice and imported to the town or else made in local furnaces set up by glassmakers who emigrated from Venice. No chemical analyses were reported for the glass.

The typology of the bottle fragments suggests that the original pieces match forms seen in contemporary paintings and referred to as *"inghistre"*. This form commonly appears in inventory lists of Muranese glass shops and in pictorial sources of the 14th, 15th, and 16th centuries. The drinking glasses were present in the excavation in two forms: a cylindrical body and a body in the shape of a truncated cone. In addition, there are two fragments which are believed to originate from a chalice or footed cup. A variety of colors is seen with the glass including colorless, amber, light green, and violet. Different types of decoration are found on the drinking glasses including the use of ribbing, applied drops of glass, and the use of different colors for the walls and feet. Cozza concludes that the glass represents table and kitchen pieces broken during use and discarded (1985:304).

The most important series of excavations and archaeological work, for the sake of this research, is that conducted in the Venetian lagoon by Ernesto Canal in the 1970's and 1980's. The pieces found by Canal represent the majority of Venetian glass that has been chemically analyzed; the major part of the chemical studies of Venetian glass presented in this research is glass donated by Canal. A description of some of the sites that the glass comes from is provided in an article discussing different ceramic finds (Lazzarini and Canal, 1983:22-25). Unpublished site reports filed by Canal with the Venetian government (Canal, 1994) and personal communications with him provided additional information about the locations from where glass studied in this research came.

There are three primary sites to consider in relation to the glass studied:

- San Leonardo in Fossa Mala: This site is now a submerged island in the Venetian lagoon. It was excavated by Canal in the early 1980's. The church of San Leonardo was erected there around A.D. 1000. In the 11th through the 14th centuries, it was the site of a monastery. Later, in 1348, it was abandoned and later became a burial ground for victims of the Black Death. Numerous glass, as well as ceramic fragments, were found there.
- San Arian: Material found here is from 2 different levels dating to the 6th-12th century A.D. and the 13th to 16th century A.D. The site was first discovered by Canal in 1980 and it lies within the Venetian lagoon. It contains the remnants of the chapel of San Pietro spoken about in medieval texts. Site also contains location of the monastery of San Ariano founded in 1160. The island of San Ariano was also the location of the medieval settlement of Costanziaco. This settlement presumably served as a connection for river traffic as it moved along a branch of the Sile river which flows into the lagoon. Along with glass, finds at this site include manufactured goods, stone foundations, streets, landings for boats, and ceramics.

- Fusina-Marghera: The glass found here by Canal represents the largest assemblage of sherds examined and analyzed in this study. It is also where a great majority of sherds used for chemical analyses by other researchers originated (ex: Verita, 1989; Verita, 1990). Fusina is located near modern day Mestre in the Venetian lagoon. Fusina was an embankment of the Brenta River built with natural clays around 1325. It was constructed to divert the river and prevent the silting of the Lagoon. Between the 15th and 16th centuries the embankment was reinforced with solid waste brought to the site from Venice and Murano. The bulk of this waste was material from local ceramic and glass workshops. The embankment was abandoned in 1610 when the Brenta changed course as a new channel was dug. According to Canal, about 99% of the glass found at Fusina is of Venetian origin; the remainder is usually from the Roman era (Canal, personal communication, 1994). The site where the glass fragments studied in this work was destroyed by construction activity and no longer exists.

The difficulties of dating the glass samples are obvious as most were removed from sites where the stratigraphy is poor due to human and natural formation processes. The glass samples are dated primarily on the context of discovery, stylistic traits or on the basis of chemical analyses which were then compared to other Venetian glass of more secure dating. Whenever possible, dates of occupation, et cetera gleaned from historical records were used to confirm or support the dating.

Other Sites of Importance to Venetian Glass Studies

In comparison with the work done in the Venetian lagoon and its environs, archaeological studies relevant to glass and glassmaking in other regions of Italy are much more extensive and sophisticated. This fact is revealed, for example, in a recent collection of papers incorporating glass studies and archaeology (Mendera, 1991). Rather than dwelling on this circumstance, this section will draw upon certain studies of glass and glassmaking that provide information, either by analogy or example, on the practice of this craft in Venice.

Since 1980, the British School at Rome has been involved with excavations at the monastery site of San Vincenzo al Volturno in Central Italy. One of the major discoveries of this work was the glass workshop dated to the 8th-9th century. While the entire site is discussed in a monograph and attendant publications, the date of the glass shop makes it useful to compare with the glass technology practiced at Torcello (Hodges and Mitchell, 1985; Hodges, 1991). The workshop consists of at least four rooms and several small working furnaces. Numerous crucibles, up to 1.5 meters in diameter, were found as well as glass-working debris such as remnants of glass gathered from blow pipes. Numerous types of glass objects made at San Vincenzo were also found. These include several thousand fragments of window glass, vessel glass, beads, and enamels. Window glass, on the basis of what has been excavated to date, is seen as one of the workshop's primary products and was made using the cylinder process. The presence of finer items such as the vessel glass and gilded metalwork shows that the production output was not solely limited to "common" objects. Chemical analysis of the glass from the site shows it to be a "Roman type" made using natron as a fluxing agent rather than vegetable ash (Bimson and Freestone, 1992). Hodges then concludes that much of the glass used at San Vincenzo was recycled Roman glass brought in cart-loads to the site. Therefore, glass itself may not have been made at San Vincenzo but rather re-melted and worked again. In addition to compositional similarities, Hodges points out the parallels between San Vincenzo and Torcello, both of which are religious structures located in proximity to a glass production site (Hodges, 1991:74). The glass production often served to meet the needs of the religious institution.

Another pre-Renaissance site that has implications for the early stages of glassmaking development in Venice is the glass factory at Corinth. In 1937, the remains of two glassmakers' workshops were discovered and subsequently published in 1940 (Davidson, 1940). One area was represented by crucible fragments and other debris but no furnace structures. The other area had the remains of a square glass furnace (2.38 m^2). As only one furnace structure was found at the factory, it was thought to be more than one story, probably three as seen in medieval manuscripts (Davidson, 1940:302).The workshops were assumed to be in operation at the same time (Davidson-Weinberg, 1975:127). The factories were interpreted to have been in operation in the 11th and 12th centuries and run by Greek-speaking craftsmen from Egypt (Davidson 1940:299; Davidson-Weinberg, 1975:141). This conclusion was reached on the basis of 11th and 12th century coins found in relation with the glass furnace as well as the fact that several glass pieces appeared to be styled in an Egyptian fashion. Weinberg also was able to offer a hypothesis for how glass production at Corinth was halted - in 1147 the Normans conquered the city and their leader, Roger of Sicily, was said to have taken with him the artisans and products of the Corinthians (Davidson 1940:324).

Recently, the interpretation of the Corinth site has been re-assessed in light of additional glass finds and a re-examination of the site stratigraphy (Whitehouse, 1989; Whitehouse, 1993). Whitehouse questions whether the glass shops at Corinth were dated accurately on the recognition of more than a 50 year gap between the glass of Corinth and similar pieces in Italy. The main products of the Corinthian workshops - mold-blown cups, vertically ribbed beakers and prunted beakers- have no close parallels in Egypt. However, they are similar to glass found in 13th and 14th century contexts in Italy. Besides questioning the site stratigraphy, he offers a different view of the sack of Corinth in 1147 noting that the only craftsmen explicitly spoken of in the original texts were Corinthian silkweavers. Whitehouse concludes that the Corinthian workshop dates from the 13th-14th century rather than from the 11th-12th century. Therefore, it was in operation during the Frankish occupation of the city and was not staffed by workers of Egyptian origin. The glass workers would have been of Italian origin. As a result, the widely accepted hypothesis that the origins of medieval glassmaking in Italy and central Europe were influenced by Byzantine glassmaking in Greece must be re-evaluated (Whitehouse, 1989:78). This conclusion has implications regarding the origin and early period of glass production in Venice, as will be discussed later.

As mentioned, there have been no excavations of a Venetian glasshouse other than the work at Torcello. Therefore, for an appreciation of a Renaissance-era glasshouse in Venice, we are directed to analogous discoveries at other locations as well as the use of contemporary paintings and writings.

In 1975, the discovery of a medieval glasshouse at Monte Lecco, located near Genoa was published (Mannoni and Fossati, 1975). The site was dated to the latter 14th and early 15th century and included the remains of a round furnace structure, slightly more than 2 meters in diameter. This was not an urban glasshouse as Venice's were but rather it was located in a forested mountain environment. Presumably, the nature of production activities as well as demand for glass would have been different due its more remote location. Gradually, the forest glasshouses of this region were abandoned and glass production became a more urban-oriented activity in the 16th and 17th centuries (Calegari and Moreno, 1975). Glass production at the site appears to have been of the "common" type made for everyday use: small cups, bottles, vials with some rarer open forms such as bowls. Chemical analyses of glass from the site was done which show it be a mixed alkali composition and different from Venetian compositions of the time (Mannoni and Fossati, 1975:83). The glass has a fairly high amount of CaO and MgO in comparison to Venetian compositions and the ratio of Na_2O to K_2O is lower than what one sees in a typical Venetian glass. The authors conclude that the fluxing agent used was a mixture of two types, one predominantly soda based and one potassium based. The great majority of the glass is noted as being greenish in color, presumably due to appreciable amounts of iron present in the glass. Other than the date of this site, the comparisons that can be made to a Renaissance Venetian furnace are certainly questionable. Glassmaking was an urban activity in Venice and the raw materials and production techniques in use there were different. The products of the Muranese furnaces were also different with some directed at a much different clientele.

Another site of relevance to the study of Renaissance glassmaking in Venice because of its location and dating is the discovery of a 16th century glasshouse in Pisa (Redi, 1991). There are several different structures associated with the site, the functions of which are not all known. The structure thought to be the furnace is circular shaped and about 3 meters in diameter. In addition, there is a triangular shaped building thought to have stored raw materials. There is no discussion of any glass found in conjunction with the site.

Despite the long history of the Venetian glass industry and the attention it has received, a systematic study of it which does not draw primarily upon art historical (i.e. connoisseur oriented, museum catalogues, etc.) references is only now developing. While lesser known, the knowledge of glass production in other Italian regions such as Tuscany has benefitted from more focussed and organized archaeological work. The same has yet to be realized for Venice.

CHAPTER 4

VENETIAN SOCIETY AND THE STRUCTURE OF VENETIAN GOVERNMENT

In order to fully discuss the production and consumption of glass in Renaissance Venice, a brief picture of Venetian society is necessary. As the government of Venice frequently intervened in matters of import to the glassmakers of Murano, one should also have an idea of how the city and its territory were ruled and administered. Many of the points made concerning Venetian society are not unique to Venice and could be made with respect to other Renaissance societies and cities. In this section, a brief overview of Renaissance Venetian society and the structure of its government is provided. The intent is to sketch the backdrop of Venetian society and provide a general contextual ambience within which a detailed study of the glass industry may be given.

The Renaissance in Venice

Defining exactly what is meant by the Venetian Renaissnce is difficult. The traditional view of the Renaissance held by art historians differs from that of economists and other scholars. This is compounded by the fact that the general model of the Renaissance, based on events and circumstances in Florence, does not apply to all parts of Europe or Italy. The Renaissance was an international movement yet it took different forms in different locations (Burke, 1992:6). Therefore, one cannot define the Venetian Renaissance in Florentine terms. It is also difficult to focus solely on the city itself as the area dominated by Venice covered a vast and diverse selection of land and people (MacKenney, 1992:53). These difficulties are considered more in the next chapter as a time for "the" Renaissance in Venice is outlined. A model based on economic expansion and maturation is suggested rather than one based on art.

Renaissance Venetian Society

Renaissance Venice was a crowded city. The Venetian diarist, Marin Sanudo, estimated that the population in 1493 was about 150,000. A figure of about 100,000 would be close to that century's average rising to 170,000 by 1563 (Chambers, 1971:123). By the beginning of the 15th century, Venetian society was clearly stratified with distinct classes who enjoyed certain privileges and responsibilities. Typically, the society of Venice is seen as having three basic groupings - the nobility, the clergy, and the rest of the city (Burke, 1994: 11). Due to the limited amount of living space available in the city proper, the homes of even the wealthiest people were restricted in size. Often the rich had to be content with merely erecting the most pretentious facade on the building's exterior.

At the top of the social hierarchy were the families of the nobility. Between the 14th and 16th century, access to this class was essentially closed. In 1323, the Great Closure, the process of which began in 1297, was enacted. Membership in the *Maggior Consiglio*, the central body from which the Doge and other council members were selected, was now permanent and hereditary (Lane, 1973). In 1315, a list was compiled of Venetian citizens eligible for election which would become the registry of noble marriages and births - the *Libro d'Oro*. Over time, other families and persons would be added to this list, particularly those who by donation or deed, earned their way in. But, essentially, nobility was a closed caste of Venetian society. Its numbers changed only through intermarriage with non-nobility. The number of the nobility varied over the course of the Renaissance but was generally between 1 and 1 1/2 per cent of the city's population (Pullan, 1971:7).

Strictly, speaking, "nobility" in Venice was a purely legal status acquired through heredity. Some members of this class were quite poor. For the sake of illustration, we can look at information from assessments made to control the levying of forced loans which survives only for one year - 1379 (Lane, 1973:151). From this list, out of a population of little more than 60,000, only 2,128 heads of households were rich enough, with known property worth more than 300 ducats, to be counted. Among these wealthy persons, 1,211 were nobility and 917 were not. Examining the richest houses over all in Venice at that time, with wealth between 10,000 and 150,000 ducats, we find 91 nobles and 26 commoners. Wealthy and noble were distinct, yet sometimes overlapping, categories. In proportion, though, it was the nobility who had the greatest share of wealth invested in trade and loans to the government (Chambers, 1971:77). Venice had a relatively closed society in which there was a rigidly defined group of who was eligible to rule (the nobility) but a more loosely assembled inner group of who actually held power (Burke, 1994:25). There were no new mass admissions of persons into the nobility during the Renaissance such as those of 1381. When new territories were taken under

Venetian control, the nobilities of towns such as Verona and Treviso were not given a role in Venetian government (Lane, 1973:251).

Those who were in possession of wealth changed with frequency during the Renaissance. As Goldthwaite points out, fluidity of wealth and the rapid re-distribution of money are features of the urban Renaissance economy (Goldthwaite, 1984; Goldthwaite, 1993). By 1460, there were about 2000 members of the nobility with this increasing to 2622 in 1513 (Chambers, 1971:74). Wealth in the Renaissance Venetian economy was distributed further down the social hierarchy than previously and greater latitude for social and economic improvement existed. This greater spending power in the hands of artisans and shopkeepers would have implications for the demand and consumption of luxury goods such as glass (Goldthwaite, 1993:47). While such persons may not have been able to participate in luxury expenditures such as architecture, the possibility of owning less valuable luxury goods such as majolica and glass existed. Historians have often noted how the patronage of art changed during the Renaissance as persons who previously would not have been clients of artists began to have access to such goods (Burke, 1986).

As a member of the highest legal caste, the nobility of Venice were in charge of the higher offices of Venetian government and administration. Transfer of noble status took place along the male line and marriages between sons of nobility and women of citizen class were not uncommon. Between 125 and 150 different family names were recorded in this book with numerous side branches (Chambers, 1971:75).

The elites of Venice have been described as being "bi-cultural" (Burke, 1994:xx). They had access to aristocratic culture with its classical literature, art forms, and so forth. However, their close living quarters and social arrangements made it necessary for them to be knowledgeable of popular culture. Indeed, many of them would have been unable to communicate with the female members of their own families without this appreciation of popular culture as their own wives and daughters were generally shut out from Renaissance "high culture".

Contemporary Renaissance writers often refer to what they perceived as the modest means in which the Venetian nobility lived. One writer, Casola, wrote in 1494 about the "frugal" manner in which the Venetian nobility lived at home. Montaigne was thrilled with the idea that Venetian senators could be seen doing their own shopping while other observers perceived this behavior as strange and unbecoming. Portraits of Venetian persons generally show somber looking people with very restrained clothing such as the traditional black gown. This behavior extended to other manners of behavior and is in stark contrast to Venice's hedonistic reputation of *Carnevale* and exotic courtesans (Chambers, 1970:122-145). The traditional Venetian style of living was one of modesty and frugality along with an emphasis on taciturnity, self-control, and silence (Burke, 1994:72-73). This modest behavior is contrasted by Burke with the typical Venetian noble's desire for displays of public conspicuous consumption in the form of architecture and other media for the glory of the family or state. The implications that behavioral patterns such as these have for the demand for and consumption of decorative arts such as glass will be addressed later in this work. Gradually, the self-restrained behavior in personal lifestyles changed, most notably by the 17th century under the influence of Spanish and French culture.

Gradually a second class began to emerge from the general populace during the 14th century. This was the middle class, who had acquired the title of "citizens". Typically, this group was financially well-off and held themselves above the practice of manual labor that was purely "mechanical". Citizens were given this status by right or favor but were not all of the same rank (Cox, 1959:47). A higher distinction existed among the *cittadini*, belonging to those who were native-born citizens of Venice (*cittadini originari*) (Lane, 1973:151). These had to be legitimate descendants of two generations of Venetian citizens (Logan, 1972:26). From the ranks of original citizens were drawn the clerks of the Ducal Chamber, notaries, and the higher offices of the armed forces. Over time, the *cittadini* were more of a reinforcement of the Venetian oligarchy rather than a force to overthrow it, primarily because the status of citizen was not easily attained (Norwich, 1989:185).

For immigrants, a somewhat lower form of citizenship existed. If they made their home in Venice and did not engage in "mechanical" labor, they received the right of half citizenship after ten years (*de intus*). After twenty-five years, they received full rights (*de extra*) of citizenship such as being able to engage in shipping merchandise, trading in Venetian markets, and enjoying protection throughout the

Republic (Lane, 1973:152; Norwich, 1989:185). According to Cox, the right to engage in foreign commerce under Venetian law and protection was the greatest benefit of citizen status (Cox, 1959:48). Foreign minorities often came to Venice to work and live and were assimilated into all aspects of Venetian society including quite a few who entered the glass craft.

The remainder of Venetian society was composed of lower class workers or commoners. Compared with the nobility and their activities, much less has been said about these people who were the majority of the city's population. This part of the work force included everyone from guild members, unskilled labor, general clergy members to the poor and the institutionalized. Statistics for the latter part of the 16th century show that the population of the city was just over 148,000 persons. Of these, 41,742 were males over age 18. This group can be further divided into 2,147 nobles and 2,312 *cittadini*. The remaining males fall into the other groups mentioned above numbering some 37,283 *popolani* (Rapp, 1976:24).These statistics and their implications will be taken up again later when the labor force and its guild system of Venice is discussed. Suffice it to say for now, that the Venetian guild system provided a means for it members to show some degree of influence over their own day-to-day affairs (Lane, 1973:104). Yet the guild in Venice was never a political force; it was more an organizational tool through which Venetian state policy could be implemented. This is an important distinction to make in comparison to other Italian cities.

A discussion of Venetian society would be incomplete without at least mentioning briefly the artistic and intellectual climate in which crafts such as glassmaking existed. Indeed, the relationship between paintings by artists such as Carpaccio and subsequent enamelled glass pieces made in Venice has been shown previously (cf. Clarke, 1974). The rise of literature and a humanist oriented philosophy in Venice bears mentioning for two reasons. Firstly, the growing interest of Venetian citizens in humanist and naturalist philosophies during the period in which the luxury glass industry saw its great growth is not entirely incidental. The effects of this interest in antiquity, naturalism, and social virtue will be addressed later in a discussion of demand for certain types of objects. Secondly, the rapid development of a printing industry in Venice and the wider availability of books had implications for the dissemination of technical and scientific knowledge, some of which was directly connected with the glass industry.

The Structure of the Renaissance Venetian Government

One of the contributing factors to the importance and mythology of historical Venice is its reputation for political wisdom and stability (Pullan, 1971:3; Chambers, 1971:73). This is in contrast to other Italian city-states of the time such as Florence, Milan, or Genoa which either were often in a state of political chaos, were subject to outside influence, or were under the dominant rule of one family. The mythology of the Venetian government was bolstered by writers who expressed admiration for its constitution along with uncertainty about how it actually worked. Contemporary observers either saw Venice as an aristocracy or as a city with a mixed government with an elected (from the aristocracy) Great Council and a monarchical (yet elected) Doge (Logan, 1972:6).

The real accomplishment of the Venetian government was its ability to exclude almost everyone from positions of authority. This allowed many subordinates into offices which appeased the appointed but did not disrupt the monopoly of real power held by the nobility (Pullan, 1971:9). In addition, interaction of people within the social framework of Venice such as parishes, communes, and guilds provided outlets for people to participate in the community. MacKenney describes the political and social structure of Venice as "corporatist" where the individual found identity as a member of a group (guild, senate, confraternity) (1992:56). These organizations often cut across class lines. Noble families did not monopolize communities in the way they did with the Venetian government. Other activities such as pageants and festivals helped foster this feeling of participation and involvement. Venetian civic ritual celebrated and advertised wealth (MacKenney, 1992:57). Sumptuary laws applied to both commoners and nobility (Lane, 1973: 253). Foreign visitors to Venice often remarked on the modest appearances of Venetian nobility as they went about town. The train of horses and the entourage associated with the nobility in Northern Europe was out of place, and indeed impractical, in Venice (Chambers, 1971:126; Goldthwaite, 1984). Finally, the Venetian reputation for equitable justice among the poor and rich helped to placate any feelings of resentment or underrepresentation. Patricians were allowed no special treatments due to their position. Generally, the government of Venice was popularly supported. Particular Doges might be reviled but the system itself was not attacked (Lane, 1973:271). There were large concentrations of manual laborers in the city districts, such as near the Arsenal, yet the number and seriousness of any uprisings were very small (Chambers, 1971:101).

The central parts of the Venetian government are best described as a pyramid with the Doge at the apex and the General Assembly, with some 2,000 members in 1500, at the base. In between the one and the many were the Great Council, the Forty, and the Ducal Council. Rather than place trust in individual power, the city favored the use of committees and councils thereby creating a system of checks and balances. This is best seen in the process used to elect a new Doge which required ten or more different selections of groups, typically by lot, to minimize factional tendencies (Pullan, 1971:21-24; Lane, 1973: 98, 428). A link existed between the patrician nobility and the *cittadini* in the form of the "grand chancellor". This office was established in 1268 and the right to this office belonged to the *cittadini* class.

The Relation between Murano and Venice

Outside of Venice proper there were other communities in the Lagoon such as Burano, Chioggia, and Murano. These communities had their own statutes and councils. However, their chief executive, the *podesta*, was chosen by the Venetian government (Lane, 1973:99). This person would hear complaints and petitions and essentially acted as an executive and judicial head. The position was temporary, lasting only a few years and the *podesta* was subject to prosecution at the end of his term (Lane, 1973:97). The island of Murano had its own civil, criminal, and administrative justice whose laws formed the *Statut de Murano* (Karklins, 1990:78). The community of Murano was able to elect, from amongst its own citizens, a chancellor, beginning in the year 1445. Furthermore, the community of Murano was able to have its own coins, called *oselle*, struck each year at the mint of Venice. The size and design of these varied over the years an they bore the inscription *Munus Comuniatatis Muriani* (Karklins, 1990:79).

The Commune of Murano was incorporated into the state of Venice in 1171. In 1275, the community became an independent administrative unit with its own *podesta* (Polak, 1975:56). According to Zanetti, the people of Murano enjoyed numerous privileges. One of these was the granting of *cittadini originari* status to some of the Muranese by the end of the 12th century (Zanetti, 1866:203). These persons were then entitled to take part in the island's council. As a result, they also did not require a decree of favor to be admitted to jobs in the various branches of government as was needed by those who were not born in Venice or were lacking residence status. This privilege allowed for the marriage between the daughters of glassmakers with members of upper classes which is viewed by some as the most important and remarkable concession granted to the inhabitiants of Murano (Karklins, 1990:79). As noble status was passed along paternal lines, children of such unions might still be entered in the Venetian *Libro d'Oro*. This connection of Murano with the nobility of Venice is also manifest in the large number of summer homes established there during the Renaissance. Many of Venice's wealthy would escape the oppressive Venetian summers by visiting Murano (Polak, 1975:56). Murano was an intregral part of Venice's leisure; this interaction between the glass industry and the nobles and wealthy persons of Venice was certainly important for stimulating the demand for luxury glass.

Other rights, more symbolic in nature, were accorded to the Muranese. These included the right to carry swords and to have a prominent place in the procession held annually for the Feast of the Ascension. Also, the police of Venice were not permitted to anchor at Murano without permission.

The Commune of Murano had its own *Libro d'Oro*, as well. Many of the family names inscribed in it were owners of glass shops such as Miotti and Ballarin. The process of formally creating the *Libro d'Oro* for Murano took place over about one hundred years and was finally completed in 1605. In the course of its development, criteria for one to be considered a Muranese citizen were developed. These included residency in Murano for at least five years and ownership of property there (Zecchin, 1987:218).

From the rights and privileges detailed above, one is able to see that the island community of Murano occupied a certain prestigious position in relation to the greater government of Venice. Some glass scholars over the years have interpreted this to mean that Murano was granted these favors because of its glass production and the important place it had in the Venetian economy. Whether this is true remains to be seen. A more realistic view might be provided by examining whether the other satellite communities of Venice such as Chioggia or Burano received similar favors from the Venetian State. However, there is little information currently available which would allow one to begin such a study.

CHAPTER 5

THE RENAISSANCE ECONOMY, VENICE AND LUXURY GOODS

Throughout history, glass production and consumption have been linked to regional economic situations. Examples include the decline of glassmaking in 11th century B.C. Egypt or the rapid increase in glass production and use under the umbrella of the Roman empire. Glassmaking in Renaissance Venice is no exception.

In this chapter, a general picture of the Renaissance economy, with emphasis on Venice, will be offered. New economic relations and forms developed during this time which will be discussed. The place of Venice in this economy will be described along with the unique features of the Venetian economic structure. Economic development and change in Renaissance Venice will be discussed in conjunction with historical events. As outlined in Chapter One, the most significant technological changes in the Venetian glass industry occurred in relation to the production of luxury glass. Therefore, the final part of this chapter considers the relations between the Renaissance economy and the increased use and production of luxury goods.

General Treatment of the Renaissance Economy

The Renaissance "World-economy"

How one defines what is meant by the phrase "the Renaissance" often depends from what field of study the person hails. While an art historian may equate the Renaissance with the 16th century and names such as Titian and da Vinci, an economic perspective can present a different time frame.

A transformation in the European economy took place two or three hundred years before the traditional Renaissance period. A major move occurred from a domestic to a market economy. This is what marked Europe's true Renaissance, according to economic historians such as Braudel and Gino Luzzato. It was commerce more than anything which was responsible for the rise of the medieval Italian economy (Luzzato, 1961: 109; Braudel, 1979:94). Economic life changed after the thirteenth century so that the agrarian aspects of Italian towns were de-emphasized relative to other elements such as trade, commerce, or industry. Several general tendencies can be discerned:

The previous political division of town and country was replaced by one existing along economic lines. In this new scenario, the country was a supplier to the urban areas, offering raw materials, while the towns practiced trade and industry (Luzzato, 1961:92). Within the cities of 13th century Italy, greater class distinctions appeared along with the emergence of a merchant or middle class. As trade and industry developed, certain master craftsmen were able to join the ranks of this middle class. The markets for goods came to be centralized in urban areas; industry also was located there. Luzzato divides industry in medieval Italy into two categories: that which met the local needs and that which produced specialized goods for export and wider consumption (Luzzato, 1961:104). The glass industry of Venice can be placed in both categories depending on the products considered. Certain glass houses at Murano produced primarily utilitarian objects such as glass bottles and tavern glasses. Particular shops would work under a type of government contract to produce these items at seasonal times when the shops normally had their furnaces shut down. Other glasshouses were oriented largely towards what can best be described as luxury glassware, a great deal of which was consumed outside of Venice.

Changes in population distribution naturally took place as the towns became centers of economic life in medieval Italy. Larger territorial units were created. As Italian states controlled more land, the large urban centers attracted more people from the surrounding countryside and small towns. For example, after Venice had conquered the mainland to her east in the 15th century, smaller cities such as Padua and Verona experienced a loss of population (Luzzato, 1961:139). Populations were increasingly concentrated in urban areas as was wealth (Goldthwaite, 1993:41). One result of its urban concentration was wealth becoming "more susceptible to the attractions of the market" (Goldthwaite, 1993:44). Wealth became more fluid facilitating consumption. It also tended to filter farther down the social ladder than before.

Coupled with the expanding population and wealth of urban centers, the extent of Italian commerce was greatly enlarged. By the 14th century, Venetian ships were travelling as far as England, North Africa, Egypt, Syria, Constantinople, Crete, and Cyprus (Chambers, 1971:41). As trade routes expanded, so did the variety and volume of goods being carried. This includes not only items made in Italy for export but also the types of goods with which the trade ships of Venice and other cities returned home. Especially important among these import items, as we shall see, were a greater amount of luxury goods coming from Asia and the Near East.

At this point it is useful to ask a very fundamental question of "why Venice?". What were the circumstances, other than historical, that allowed her to reach the position of 14th century supremacy in the Mediterranean? The fortuitous fact of its geography must be noted. Venice was located at the interface between the East and Western Europe. In addition, the city is located at the estuaries of several rivers - the Po, the Brenta, the Adige. All provide access to interior of Italy and Northern Europe (Cox, 1959:30). Its initial position as an interstitial city between the powers of Europe and the Eastern Roman Empire is also relevant. Until the city had sufficiently developed economically and militarily, Venice successfully charted a diplomatic course between these two entities. The peculiar nature of the city of Venice and its immediate neighboring islands could, in some situations, lead to internal factionalization and conflict. Even today, the people of Murano tend to see themselves as distinct from persons living 3 kilometers away in Venice. One solution to this inter-island rivalry was the economy of the city. Rather than being based on land-based resources, it was instead built upon industry and foreign commerce. This promoted cooperation among different social groups as they worked towards making profits in other locations (Cox, 1959:39). To the reasons offered by Cox, Braudel adds Venice's easy access to the Levant (and, indirectly, to China) and her better trade contacts in Germany and central Europe (1979:119).

Prior to the 16th century, the activities of the Italian economy can be described as having three stages (Goldthwaite, 1993:27). The first was a "commercial revolution" beginning in the 11th century. An international commercial sector was created oriented toward a luxury market, with foreign sources of supply chiefly in the Near East. Secondly, an industrial staple was typically produced for export to markets throughout Europe and the Near East itself. Finally, there was the increased production of goods which incorporated innovations aimed at stimulating and continued demand. The glass industry of Venice, as it developed and matured in the years before and during the Renaissance represents a microcosm of this general pattern. Clearly, the Venetian glass industry had reached the 2nd and 3rd stages of Goldthwaite's model by the mid-15th century. Glass was widely distributed outside of Venice, often in forms and fashions that were oriented to foreign markets. New decorative schemes and novel compositions were developed by Muranese glassmakers to meet perceived demand.

What has been explored thus far is the fact that there was tremendous change in the economy of Venice, and Italy as a whole, in the years pre-dating what is traditionally referred to as "the Renaissance". The birth of a commercial revolution set the stage for later economic developments that would characterize the Renaissance economy such as capitalism, consumerism, and conspicuous consumption.

It is at this point that the concept of a "world-economy" and Venice's position within it can be presented. Two ways in which the economy of Europe can be situated are temporally and spatially. Considering the former will show how Venice may be seen as the center of the European-Near Eastern economy for much of the period we are interested in; the latter will serve to justify the particular definition of "the Renaissance" used in this work.

Braudel makes the distinction between a world economy and a "world-economy" (1979:22). The first term applies to the economy of the whole human race. The second term is what concerns us here. Braudel defines this term as meaning the economy of one portion of the planet, to the degree that it forms a self-contained whole (1977:81). In this sense, Braudel's usage of the term is generalized from a model proposed by Wallerstein in his development of world-systems theory (Wallerstein, 1974; Braudel, 1979:69). Wallerstein described the 15th and 16th centuries as a time when a European world-economy developed. The basic linkages between parts of the system are economic and the system is larger than any defined political unit. The world-economy is different from an "empire" in that the latter is a political unit (Wallerstein, 1974:15).

The area that a world economy occupies is identified by having boundaries which change slowly over time. In Wallerstein's model each world system has a "core". One of the characteristics of this dominant city is its social diversity and stratification. Over time, one city fades in importance and another rises to replace it. For Braudel, the center of the European economy, beginning around 1380, was Venice; this continued until about 1500 when a shift to Antwerp occurred and the influence of Venice gradually waned over the next 100 years (1977:85).

Finally, there is a hierarchy within a world-economy. This hierarchy can take a spatial form such as that suggested by Wallerstein. There is a core region, a moderately developed middle zone, and a periphery (Wallerstein, 1974). Venice, for much of the period considered here was a "core" region. Braudel identifies the same pattern for Venice: capital, provinces, and colonies. Here, the city and its immediate surroundings were the *Dogado*; there were the towns and districts of the *Terraferma*; and there were the colonies known as the *Mar* (Braudel, 1979).

This concept of a hierarchy can be extended beyond spatial considerations. For example, there was social hierarchy within the economy. There was also hierarchy in terms of division of labor with certain labor activities restricted to the core or the periphery. Such may be seen in the glass industry. For example, the Near East, which was the periphery of the Venetian world-economy, supplied the soda ash used as a fluxing agent by the glassmakers. The island of Murano, within the core, was where the actual manufacturing of glass took place. There is a hierarchy of technology in the world-economy with the core region tending to be the most advanced (Braudel, 1979:68). There is also a role for the Venetian state within the hierarchy of the world-economy. The state, in a general sense, is strong and aggressive, admired and feared. The state could assert itself, through violence or political channels, to impose its economic priorities. We shall see that the Venetian government played a role as both stimulant and inhibitor for the glass industry.

Spatially, then, we have established that from the late 14th century into the 16th century there was a European world-economy with Venice as its center of gravity. This version of a world economy had been developing for some time before but it was a set of historical circumstances - specifically, Venice's defeat over Genoa in the 1380 War of Chioggia- that definitively pushed Venice to the forefront. Shortly, we consider the rise and gradual decline of Venice in light of historical events and, in particular, examine the existence of capitalism in this city.

Before doing this, let us examine the other way in which the world-economy can be seen: temporally. More specifically, as we shall see later, the period of critical importance for the Venetian glass industry of Murano lies well within certain temporal borders- from 1450 until about 1550. It is key to note that it was no coincidence that the years of Venice's economic supremacy and the revival of the luxury glass industry coincide.

Around 1350, a shift in the European economy towards the south began to take place, culminating in 1380 with Venice as the center of attraction. This is a very good time to mark the initial temporal boundary on the economic Renaissance of Venice. 1650 was a time which found Venice in a marked state of decline and Amsterdam as the center of the world economy. This delineation and use of turning points is based both on changes in the center of the world-economy and on cyclical changes in prices and wages. In any event, the selection of the years c.1380-c. 1600 as the key period for Venice is justified.

The Question of Capitalism

Before moving to discuss the specific case of Venice, general consideration of one of the specific features of the Renaissance economy is needed. This is the question of "capitalism". Putting aside Braudel and Wallerstein's differing views of when capitalism first developed in Italy, the fact remains that it was in existence by the mid-15th century, the prime period of interest for Venetian glassmaking. The very term "capitalism" is so loaded with political overtones and differing interpretations that I hesitate to use it at all. It needs to be employed precisely and with caution. However, capitalism is the only way to describe the new economic circumstances that emerged in the 13th century. The other possibility is to discuss a market economy which Braudel sees as quite different from a capitalist economy.

It is helpful at this point to address a concept that economists and historians use to distinguish between differing economic systems - the mode of production. This was first introduced by Marx and refers to the way in which society produces. Humans produce consciously, not instinctively and how they do this is a significant characteristic of their culture (Russell, 1980:74). The mode of production is a set of social relations by which labor is utilized to create energy from nature by means of tools, skills, organization, and knowledge (Wolf, 1982:75). In order, therefore, to consider the social context of glass production in Renaissance Venice, understanding the way in which that production was organized and performed is necessary. This information is presented in Chapter 8.

However, understanding production is only part of the picture. Other relevant factors such as consumption and distribution must be examined. I will show in a subsequent part of this chapter that understanding demand and use are essential prerequisites to examining production. I find it best that if one is to take the "mode of production" as a starting point to analyze the nature and organization of an industry such as Renaissance glassmaking, the act of distributing the product must be kept in mind as part of the entire process. This is also especially important for a city such as Venice which had strongly developed its commercial tendencies, facilitating the distribution and consumption of goods made by her industries. I mention these caveats because I think the mode of production is a useful general tool in understanding an industry such as glassmaking in Venice. This usefulness is especially manifest as I will attempt to show in subsequent chapters that the glass industry represented a transitional state from an artisan-oriented to a factory-type organization. Perhaps it is best if the mode of production is viewed, as Roseberry suggests, as an abstract concept that allows one to engage structures which lie behind their appearances (1989:159).

Capitalism is characterized by the private ownership of the means of production; it is a mode of production requiring the existence of free wage labor and a proliteriat class. The creation of wealth is based on a class which sells its labor power as a commodity to those who own the means of production (Russell, 1980:13). The capitalist mode exists when monetary wealth exists as a means to buy this labor power. The tie between producers and the means of production is cut; those who produce the commodities must buy them back from the owners of the means of production (Wolf, 1982: 77). In the same sense, there is a disjuncture between the producers and consumers of goods made via an industrial mode of production. This affects the feedbacks between the producer and consumer, making them more complex and less direct (cf. Schiffer, 1992:50). Capitalism requires division of classes. I have already shown how Renaissance Venice had a defined social hierarchy. The laborers in this mode produce a surplus which then belongs to the owner, the capitalist. The capitalist wishes to increase this surplus *in quantity or quality* (my emphasis). This increase in surplus can be accomplished by lowering wages or improving output. An increase in productivity requires improvements in manufacturing techniques or in the organization of production. (Wolf, 1982:78). It is the change in productivity and the organization of production in the Renaissance Venetian glass house that is of interest here. I will show in Chapter 8 how the Renaissance-era glasshouse resembled a factory-style production setting in several ways including standardization, task specialization, and capital investment.

The Venetian Model of Capitalism

The suggestion has been made that Venice was the earliest model of a capitalist economy (Cox, 1959:15). This factor was at least partly responsible for Venice's rise to supremacy in the 14th century world-economy. This hypothesis has not been met with universal acceptance. There were several cities in northern Italy, such as Pisa, Genoa, and Florence, which displayed traits of early capitalist organization. Braudel explicitly disagrees with Cox's suggestion that Venice was the original model. The primary innovations regarded as essential to capitalist development, at least from a commercial viewpoint, did not originate in Venice. Braudel offers several examples: the first use of double-entry book keeping, the first marine insurance, and earlier development of manufacturing in Florence; the first regular sea links to Flanders established by Genoa in 1277 (Braudel, 1979:127-8). Cox counters by saying that Florence and Genoa were motivated to these innovations by Venice's 10th century successes (1959:122). Braudel suggests that Venice's relatively slow and more conventional embrace of a capitalist economy may have worked to its advantage (1979:118). As other Italian cities took forward positions in capitalist development and moved more audaciously, Venice was able to note which innovations were most suitable for her particular economic and geographic circumstances.

Establishing which city was the first to develop an early working model of capitalism is more of an academic question for economic historians. What is more important here is to recognize the fact that several of the features essential to capitalist development and a capitalist economy were present in Renaissance Venice for the time period that is of primary interest here, i.e. c. 1450-1600.

It is here that several of the characteristics cited by Cox as especially prevalent in the capitalist mode of production in Venice become important. These are discussed below without connecting them in a detailed fashion to the Renaissance glass industry of Venice. In later sections on demand and production, they will referred to again in specific relation to Venice's glass industry.

Several attitudes typically prevalent in a capitalist economy were held by the Venetian government and its citizens. One is the presence of nationalistic feelings; these affect both how one views oneself and how one forms relations with other communities. Residents took pride in being Venetian. The members of the capitalist community tend to have exploitative relations with neighbors (Cox, 1959:55). Another example of this civic pride is found in the attachment of all Venetians, including the nobility, to their own form of dialect (Burke, 1994: xxiv). Rather than use classic Italian or Latin in their legal documents, diaries, and other writings, the Venetians continued the use of their own local dialect well into the 18th century. The difficulties that this creates for someone trying to interpret these documents can not be underestimated. The view toward religion in a capitalist society is noted with Venice acting to limit domestic church authority. Furthermore, the fundamental interests of Venetian society and policy were economically oriented, particularly with respect to foreign commerce. I have already mentioned the restrictions and rules that foreign merchants were subject to while in the city. Even the famous Wedding of the Sea traditionally done in Venice on the Feast of the Ascension had strong economic overtones as the sea, at least in the early stages of Venice's supremacy, was her route to economic power.

Both Cox and Lane point to the commercial, rather than industrial, sector of capitalism as the most notable (Cox, 1959:75; Lane, 1973:312). Lane states that there was little notable development in Renaissance Venice of industrial capitalism. Cox's premise is that all capitalism is essentially commercial. I feel the distinction between commercial and industrial capitalism is necessary to make, especially if one is to develop the idea that the Venetian glass industry was a nascent form of capitalism. In order for the products of this industry to be distributed, a system of dissemination was required. The successes of Venice in developing her commercial capitalism, via the *galere mercato* and so forth, facilitated its industrial development. In this sense, commerce and capitalism might be viewed as part of an "exchange technology" (Kopytoff, 1986:72). I would argue that Venice's commercial and industrial capitalism were distinct and that the former was necessary for the success of the latter. The Venetians developed home industries but ones that were typically geared towards the making of export goods - silk, woolens, lace, glass. In a capitalist fashion, Venetian industries, quite notably the glass industry as we shall see, imported raw materials and exported finished and profitable goods (Cox, 1959:76). In this manner, a proto-factory style of production developed with characteristic features such as extensive division of labor, substantial capital input, relatively large labor units, et cetera all situated with a capitalism-based economy.

Foreign trade is essential to a capitalist oriented economy. Venice's colonies were also important for it to develop a capitalist economy. These provided several resources: raw materials for industry, foreign workers, and markets for manufactured goods. Moreover, this commerce was carefully watched and regulated by the State. The government tended to enact polices that would ensure profits for its citizens. These policies had several common characteristics. There was a tendency for the State to create monopolies in important trading regions and in particular commodities (Cox, 1959:91). In order to ensure this dominant position, the Venetian government often limited and restricted industrial output in its colonies thus forcing them to be peripheral regions. These regulations extended to Venice's treatment of foreign merchants as the State took a capitalist position in assuming control over its domestic commerce including the selling and purchasing of glass. All of these were favorable features that contributed to the success of Venice's industrial capitalism. They helped to spur industrial growth and, as will be discussed, were part of a system of positive returns and feedbacks to the glass industry.

Let us return briefly to Lane's suggestion that industrial capitalism in Venice was slow to develop. There were certainly several features of the Venetian economy, particularly with respect to commerce that were unmistakably capitalist in nature. As he points out, wealth in Venice had long been invested as capital with policies shaped so as to maximize profit. At times, this wealth would be invested in business enterprises such as a partnership for making cloth, soap, or glassware, all of which would require capital investment to get started. Lane uses the example of a nobleman who was fined for incorrectly firing his brickmaking furnace. Yet this kind of direct involvement of nobility in Venetian industry was quite rare (Lane, 1973:312). Involvement of the nobility with trade and industry was generally regarded with disfavor in the 16th century; it could also hinder one's entry into the citizen body (Logan, 1972:35). Unlike the nobility in other Italian cities, the Venetian nobility were not industrial entrepreneurs. Their primary interest was commerce. The act of investing in industry seems to have been left to other members of Venetian society.

Aside from the lack of direct involvement of the Venetian nobility in forming, running, and innovating Venetian industry, there is another feature of the

Venetian economic landscape that prevents us from calling her industry purely capitalist. This, of course, is the role of the different industrial guilds. Oftentimes, these acted in ways that served to limit the development of particular industries for the purpose of ensuring that all guild members were making a living. A certain "rule of averages" might be said have been in operation. Examples include set prices for goods including some glass items. The guilds in northern Italy were enemies of industrial progress, to some degree. Modern-day unions are sometimes viewed in the same fashion. In an attempt to prevent inter-guild competition, innovations in production were often discouraged (Cipolla, 1968:131).The refusal on the part of guilds to allow industry develop to the extent that was possible cannot be viewed as a capitalist feature. Furthermore, the very existence of a guild structure does not fit into an explicitly Marxist framework for capitalism which supposes a free market, minimal regulations, etc.. Guilds are more typically seen in the feudal type of economic system which is the precedent for a capitalist system (Russell, 1980:47).

The Venetian State certainly has complicity, perhaps even more so, in limiting the extent to which Venetian industry was capitalist. Lane points out that government regulations were entirely encouraging towards commercial capitalism yet they often limited the capitalist's freedom of operations in industry (Lane, 1973:312). Again, note the distinction between the two spheres of activity. The glass industry most definitely had a large number of regulations imposed on it by the Venetian government via the guild's governing power. These include regulations regarding the type of wood to be burned, furnace construction, and so forth. These went so far as to restrict the time, places, and manner in which glass goods could be sold. At the same time, the Venetian government acted to limit industrial competitiveness among its glass industry and those of other cities via regulations. This protectionist policy had both positive and negative effects for the industry as we shall see.

From a purely theoretical viewpoint, via examination of the mode of production, the Venetian glass industry must be described as capitalist in nature. There was private ownership of the means of production. The owners of these means purchased labor power, and so forth. Closer examination of the industry in practice, however, reveals some decidedly non-capitalistic traits. I would reconcile these two different sets of facts by characterizing the glass industry of Venice as "proto-capitalist" in nature. The glass industry had many of the features that Reber notes as innovative in 18th century Wedgewood pottery production and French porcelain manufacture (1990). It was similar to industrial scale glass operations of later decades and in other cities with specialized production and tasks and significant capital investment. At the same time, it incorporated non-capitalistic features such as guilds and state support and interference. The nascent form of capitalistic organization in the Venetian glass industries would be developed and refined over time. In this sense, the Venetian glass industry was a capitalist model in transition, displaying several new aspects of production and distribution that had not been seen before in other glassmaking or ceramic enterprises.

Economic and Historical Circumstances of Renaissance Venice

The Rise of Venice and Expansion to the Terraferma

In the decades prior to 1380, the European economy may be described as bi-polar in nature (Braudel, 1979:96). The first European world-economy can be placed within a polygon marked by the cities Bruges-London-Lisbon-Fez-Damascus-Azov-Venice. Other areas have been defined as well, all pointing to a very large European region with a great intensity and volume of trade. Eventually, two regional economies, or poles, emerged. Braudel sees the North as being initially more "industrial" in nature while the South was initially more trade oriented. Economic contact with Islamic and Byzantine cultures, and indirectly with China, helped to speed the development of the South (Braudel, 1979:98). Over time, a single center for the European economy emerged that was located in the Mediterranean.

All along the coasts of Italy, small sea ports began to develop and thrive as trade and shipping were revived in the centuries after the fall of Rome. At this time, in the 8th and 9th centuries when the nascent city of Venice was relatively insignificant, there were several "Venices". All of these seaports lacked nearby resources needed for economic success and were obliged to make contact with other Mediterranean regions richer in resources and wealth in the search for prosperity (Braudel, 1979:108). For example - Venice, a city spread out among a series of islands in a lagoon, had no fresh water or food supply. All resources had to be imported into the city and obtained by trade.

The Mediterranean in the 10th century was divided among the economies and cultures of Islam, Byzantium, and western Christendom. A city such as Venice was forced to occupy an interstitial position between these and to gradually penetrate them. In some ways, Venice's position as the beginning of her ascension to prominence bears resemblence to that of Hong Kong following the Second World War. Venice had to be both innovative and conservative in its economic and political dealings.

The Fourth Crusade was the real turning point for Venice. The Venetians built the ships that were to be used by the Crusaders and the expedition departed in 1202. In the winter of 1202-3, a decision was made for the Crusade to proceed to Constantinople. In April of 1204, with the help of the Venetians, the city of Constantinople fell. In addition to a host of relics and treasures which the Venetians took back to their homeland from the looted city, Venice gained in other ways. Venice received three-eighths of the fallen city as well as a series of trading bases in the Aegean and Mediterranean such as Crete and Negropont (Lane, 1973:42; Zorzi, 1983:246). The result was that, at the end of the Fourth Crusade, Venice emerged with a string of naval bases giving them a firm hold on the eastern Mediterranean.

Around the beginning of the 14th century, a series of technological innovations were made in shipping. The port of Venice, once closed in the winter, was now open almost year round. A the same time, the cog ship, a large broad ship with square sails was introduced. The Venetian state began to develop a pattern of trading missions to destinations like Romania, Cyprus, Syria, Alexandria, and

Flanders. In 1329, the Senate decided to auction the state owned galley ships for private use. They were leased to the highest bidder for a given route and under general rules of cargo and crew handling (Lane, 1973:124-134; Zorzi, 1983:248). The result was that a rhythm of Venetian voyages developed along with a more rapid shipping time allowing for a greater turnover of capital investment (Lane, 1973:134).

The year 1380 provides a convenient place to mark the beginning of Venice's "golden age". Venice's primary opponent around this time was Genoa. Genoa did not have the same stability of government as Venice but it still pushed strongly for shipping supremacy, especially in the Black Sea. Venice and Genoa fought a series of wars culminating with the fourth, the war of Chioggia in 1378-80 with Venice emerging victorious.

Scholars acknowledge that the terms of the peace treaty between Venice and Genoa gave the former no formal advantage (Lane, 1973:196; Braudel, 1979:118; Zorzi, 1983:249). Yet Venice had the advantage of both greater political stability and geography. The Adriatic was still home water to Venice while the sea adjacent to Genoa was too large for it to belong to one city (Braudel, 1979:119). Lane points also to Venice's victory of morale in a war which initially found it besieged and near defeat. Venice emerged with its institutions, spirit, and colonies intact (1973:196). Genoa would never again pose a similar threat to the power of Venice.

At the end of the 14th century, Venice was unquestionably in command of the new world-economy. Chambers identifies two branches of Venetian expansion.

The first was overseas. Venice acquired Corfu at the lower Adriatic in 1386. Negroponte returned to Venetian control in 1383 and Argos and Napoli in 1386. To this were added towns along the Dalmatian coast such as Durazzo, Alessio, and Zara. There were areas of Venetian occupation all along the coasts of the Greek islands (Chambers, 1970). As the Ottoman Turks continued their expansion at about the same time, communities in the Aegean had the choice of Venetian or Turkish rulers. Their choice of a Christian polity had the curious effect of strengthening Venetian power (Lane, 1973:198).

The second thrust of Venetian expansion took place in the late 14th and early 15th century as its attention turned to the *Terraferma*, the land surrounding Venice to the east. This expansion was part of a larger process taking place in northern Italy as bigger states such as Venice and Milan took over smaller cites. Treviso was the first to yield to Venice; later, Belluno, Bassano, Friuli, Verona, Udine, Brescia, Bergamo, Padua, Trieste, and Faenza would all be under Venetian rule for some or all of the period from 1380 to 1580. Two reasons are cited by Lane for the expansion of Venice on the land. The first was to secure adequate access to resources such as food, water, and wood. The second was to ensure passage of goods from Venice through the overland routes to French, Swiss, and German cities. These were all via mountain passes such as the Brenner pass which gave access to Germany. Venice needed to ensure that the routes north and west were open to her (Lane, 1973:225-227). Both thrusts of Venetian expansion in the early

Quattrocento can be seen then to have been motivated, at least in part, by commercial and economic concerns.

Lane, Pullan, and Braudel all agree that the latter decades of the 15th century found Venice at the peak of her prosperity which was based on commerce and some industries. This coincides with the sudden and important changes in the glass industry of Venice. Venice was the clearing house of East-West trade and entrepôt trade was the basis of its 15th century prosperity. Other than shipbuilding, Venice had no heavy industry. A woolen industry was only beginning to emerge. More importantly for this research, Venetian craftsmen were engaged in a variety of luxury-oriented industries including glass production.

There are several sources of information which are available to chart the general level of Venice's economic success in the Quattrocento. One of these is the city's budget, the *Bilanci*. In 1423, the receipts for the city of Venice alone totalled 750,000 ducats. Braudel was able to estimate the annual per capita income to be between 50 and 100 ducats based on the assumption that the budget was between 5 and 10 % of national income. Even the lower income figure is quite high (Braudel, 1979:119). To the income of the *Signoria* (the city alone), the income derived from the *Terraferma* and overseas trade can be added. Altogether, this yields a total figure of one and a half million ducats - greater that all of the wealth than France could muster (Braudel, 1979:120). Another source of information can be found in Doge Tommaso Mocenigo's farewell speech of 1423. Here, he states that foreign trade brings in 10 million ducats annually with 2 million in interest; the mint struck one million gold and 200,000 silver coins each year. He also notes the presence of 19,000 persons involved with the textile industries, 6,000 working at ship making, and so forth (Norwich, 1982:298-99). Note that glass figures nowhere in this speech. He clearly indicates that the true road to power for Venice was not through arms but by trade. Finally, budget figures for the year 1500 show two sources of income that were absent one hundred years earlier. Two of the largest receipts were sales taxes in Venice on consumption and goods in transit and from direct taxes collected in Venice. The total budget was 1,150,000 ducats (Lane, 1973:237).

Was there any place for income derived from the production and sale of luxury goods such as glass in the realm of such gigantic figures? Unfortunately, there is little information available to put the glass industry into the context of a larger economic picture. Chapter 8 attempts to describe the position of the glass industry in the larger Venetian economy using the available resources.

Goldthwaite has addressed the question of the economic importance of ceramic industries in his examination of Renaissance majolica. He concluded that ceramics, except in unusual places like Faenza, made up only a very small part of the Renaissance economy (1989:14). Other factors must be suggested to account for interest shown by the Venetian state in the glass houses of Murano. The question of economics and state interest in the glass industry will also be taken up again in Chapter 8.

It was essential for the Venetian economy at this time that the city not be used simply as a stopping place for international trade. Rather the Venetians instituted policies that forced foreigners to depend on Venetian middlemen (Pullan, 1968:2). Over time, other powers would dispense of this entrepôt role and go directly to the Levant or Near East. Perhaps the best known of these commerce policies was the manner in which the Venetian state treated German merchants who came to the city. They were assigned a compulsory segregated residence, the *Fondaco dei Tedeschi*, near the Rialto bridge. Germans were compelled to deposit their wares here and use the proceeds to buy goods offered by Venetians. Actual long distance trade with the Levant was reserved for Venetian citizens only. The Venetian government did not allow its own merchants to buy and sell directly in Germany; the Germans were obliged to travel to Venice to buy spices, silk, and, of course, glass (Lane, 1973; Braudel, 1979).

Venice's Economic Decline

The case of the *galere da mercato*, the Venetian system of auctioning galley ships to individuals for commerce, shows the expansion of the Venetian economy's "tentacular network" in the late 1400's . The system was operating at peak capacity around 1460. The same example illustrates the gradual contraction of Venice's trade in the 16th century. By the 1520's, only the links with the Levant survived (Braudel, 1979:126-127).

The 16th century was a time of great change for the Venetian economy. Generally, the century saw a period of economic growth. Yet by the beginning of the 17th century, the economy, as well as the power, of Venice was flagging. What happened to Venice in the 16th century to bring her to a state of decline by the early

1600's? The year 1503 may be seen as a turning point in Venetian history. Venice made an unfavorable peace with the Turks, losing claims to cities in Albania and Greece. They turned their attention from their historic sea power to deal with political entanglements in Italy (Lane, 1973:241-2). Venice would hereafter be a second rate sea power. This event was shortly followed in 1509 by a union of major European powers, the League of Cambria, which joined forces against Venice. Venice emerged intact yet was forced to regain territory in Terraferma it had won a century earlier (Lane, 1973:243-5; Norwich, 1982:390-402). Venice was finding itself slowly hemmed in on both the eastern and western fronts.

The economy of Venice was not the only one in Italy that suffered. Cipolla documents the overall economic decline of Italy in the 17th century (Cipolla, 1968:133-45). During the 16th century, the structure of the Italian economy changed so that its success depended on its ability to sell manufactured goods and services abroad. Competition came from English and Dutch industries who offered similar goods of poorer quality and lower cost. Production costs were typically higher in Italian industries due to such factors as higher wages, control by guilds, and preoccupation with making higher quality merchandise (Cipolla, 1968:137-8). The textile industries of Italy are the most frequently cited in demonstrating this. However, the glass industry of Murano will be shown as having symptoms of these problems.

In addition to industrial competition, the Venetian economy also faced crisis and change in its commercial activities. Venice no longer had England and France as customers. Rather, they became competitors (Sella, 1968:90). Commercial shipping declined in the 16th century for Venice as land transportation rose in prominence. Even a larger proportion of trade to and from the city of Venice itself was being handled by foreign ships which were faster and safer.Another source of difficulty came from the loss of Germany, its economy crippled after the Thirty Years' War, as an outlet for exports (Sella, 1968:97-8). The discovery and creation of colonies in the Americas both created some new markets for Venetian goods as well as introducing products that competed with Venetian ones. An example is the introduction of New World cochineal which replaced the red dye derived from Greece and supplied previously by Venice (Lane, 1973:298-9).

Aside from commerce, other changes in the Venetian economy were occurring. One of the most striking was Venice's 16th century expansion in the area of manufacturing (Lane, 1973:309). This is especially notable in well-studied industries such as textile production. This industry grew between 1520 and 1570 with decline finally setting in around the 1620's (Sella, 1968:106-26; Pullan, 1971:17). Venice was making high quality woolen cloth primarily for export markets in the 16th century. Ship building did well until the latter years of the 16th century. New industries such as printing also took hold. Overall, the products of Venetian industry and its industrial growth were directed towards the making of high quality goods with a lesser focus on cost reduction (Lane, 1973:321; Rapp, 1976). This admirable, yet sometimes shortsighted emphasis, on quality will be shown as having implications on Venetian industries including glassmaking. Indeed, several of the factors concerning Venice's economic decline in the early 17th century have consequences for its glass industry.

Earliest opinions of Venice's decline placed it within the mid-15th century and associated it with the fall of Constantinople to the Turks in 1453. This opinion was revised in the early 20th century by Lybyer who suggested that the discovery of the Cape route by the Portuguese was responsible (Lybyer, 1915). Finally, Lane demonstrated that the Portuguese received no real long-term benefit from their discovery (Lane, 1966 for example). By now, it is accepted that the economic culprits which eventually relegated Venice to the role of a mere regional port were not the Turks or the Portuguese but the English and Dutch of the 17th century (Pullan, 1968:20). As more trade routes were discovered by the English and the Dutc and as they developed their own industry, Venice's role in the world-economy declined. These countries also played a substantial role, along with Bohemia, in helping to undermine the success of Venice's glass industry. As a result, the date for the economic decline of Venice was moved to the early 17th century. Later studies have followed Lane's lead (cf. Cipolla, 1968; Braudel, 1979).

There are several reasons, not all of which are economic, for deciding on the latter part of the 16th century as the end of Venice's "golden age". In 1571, the Venetian fleet suffered a defeat to the Turks at the battle of Lepanto. Ship building declined in importance and was soon followed by the woolen industries. The English and the Dutch had succeeded in usurping Venice's commercial and industrial position and her role as the center of the world-economy was over. 1575-77 saw the return of the Plague and 40,000 dead. In 1577, the Doge's Palace was badly destroyed by a fire creating another blow to Venetian morale. The death of Tintoretto in 1594 effectively brought the Renaissance period in Venetian art to a close and was a symbolic death as well. Venice as a city survived all of these events. One of the questions facing Renaissance scholars was that of whether Venice's decline was relative or absolute. The city experienced both a loss in international commerce and in overall industrial output. However, living conditions and population levels remained relatively stable into the 17th century. Therefore, Venice's decline was relative rather than absolute with respect to other nations' economies (Rapp, 1976: 4-6). As Pullan explains, the 16th century was a time of great flux. While other cities of the world continued to grow, Venice stood still in this expanding world (Pullan, 1968:21).

As stated at the beginning of this chapter, the glass industry of Venice and her economy are inextricably linked. Therefore, the end of the 16th century is a good temporal terminus for this study of Venetian glassmaking.

Venetian Industry, Guilds, and the Labor Force in the Renaissance

The 16th century has been called the "heyday of Venetian manufacturing". During this time industrial activity was Venice's primary economic feature (Rapp, 1976:6). Braudel also concedes that Venice was the leading economic center of Europe in the 15th and 16th centuries (1979:136). Ship building and the woolen industries are those most frequently referred to in discussions of Venetian manufacturing. The wool industry, for example, employed fully 1/3 of the Venetian labor force in 16th and 17th century (Rapp, 1976:100). The great expansion of the Venetian textile industry has already been noted. The woolen industry was of prime importance throughout Europe and in other Italian cities such as Florence, as well. The rise of printing in Venice is another example of industrial expansion. The fortunes of smaller crafts such as glassmaking are harder to plot over time. However, Venetian goods oriented towards the luxury market (glass, silk, soap) had long been participants in Venetian trade. Pullan and Rapp both suggest that glassmaking took part in the general industrial expansion of the 16th century (Pullan, 1971; Rapp, 1976).

Only a few manufactured goods in Europe at this time were made in a way that can be described as "industrial" in a modern sense; i.e. requiring capital investment, factory-type production, and considerable division of labor. To this I would add production for a large market (both in numbers and in terms of geographic space).Venice was a leader in all these "modern" industries including ship building and glassmaking. Rapp has characterized Venetian industrial practice during the Renaissance as "state of the art". Numerous examples, besides glassmaking, exist of Venetian industrial techniques being exported elsewhere in Europe. These include printing, dyeing, cloth-of-gold weaving, soap making, and mirror making (Rapp, 1976:109). It is here that consideration of the mode of production becomes a relevant tool with which to examine Venetian industry. Venetian industries such as glassmaking exist in stark contrast to ceramic industries in other parts of Europe which still were primarily cottage industries (Goldthwaite, 1989:8).

Many of the innovations and changes that would characterize modern manufacturing appeared in Renaissance Venice. For example, the *Arsenale* frequently made use of standardized parts and products in the production of ships. Printing, a Venetian specialty, can certainly be seen as a form of standardized production. Glassmaking fits into this pattern as well, if one considers the use of molds and stamps used to impart shapes to the molten glass as "standardized". Standardized glass products used in Venetian taverns, for example, were made on the request of the Venetian government from at least 1295 (Zecchin, 1987:10). The glasshouse certainly required a fair amount of capital investment in terms of tools, raw materials, and firewood to operate. Finally, there was both specialized production and division of labor in the Renaissance Venetian glasshouse. In this sense, I think it is possible to not only characterize Venetian glass production as "modern" in some senses, but also to say that it exemplifies many of the features that would be more commonly adapted in the industrial revolutions of later centuries. In this way, I feel it is appropriate to consider the Venetian glass industry as a transitional form from the older, artisan-oriented manner of production to the full-blown factory style production one would see in the ceramic industries of 18th century England, for example.

Reber offers three main features that he feels characterize the new approach to ceramic manufacturing in the 18th century. These include the growing distinction between preliminary and production work, the use of tools and technology to allow for faster production by workers, and the increasing adaption of experimental methods in the innovation process (Reber, 1990: 279). In a similar manner, McKendrick has written about the "novel" manner in which Josiah Wedgewood stimulated demand via fashion appeal, high quality, and the association of his products with the aristocratic members of 18th century society (McKendrick,1982:100-145). All of these phenomena were present, to some degree, three hundred years earlier in the Renaissance-era glasshouse.

Despite the presence of several industrial features which indicate that Venice's industrial organization and activities had "modern" features, there is still the presence of at least one characteristic which harks back to earlier days - guilds. Guilds existed in Venice by at least the 13th century. A glassmakers' guild is known to have formed by 1224 (Zecchin, 1987:5). Not merely business organizations, the guilds of Venice combined economic, confraternal, and religious functions. They were the result of the joining of two originally distinct organizations. The first, and earliest, was the *scuola*, a devotional society. These were groups of men who gathered for religious practice and to give aid to the needy. The second organization was the *arte*. The purpose of the latter was to regulate craft discipline and production quality, organize professional activity, and to settle inter-craft disputes. The *arti* were created so that the crafts they represented could be better monitored by the government. By the end of the 13th century, the two organizations had merged (Lane, 1934:72).

Unlike the guilds of other Italian cities, such as Florence, guilds in Venice had no governing power in the State's affairs (Goldthwaite, 1980:285; Norwich, 1982:273-74). The structure of the Venetian government was such that it did not allow for representation of labor. Guilds were in a respected but subordinate position to the State. They were able to petition the government, but typically only on matters of guild business and not as a threat to the political stability of the city (Rapp, 1976:15-16). To ensure obedience, it was common practice since the 1260's to have a general oath of fidelity to the State placed within the statutes of the different guilds. This measure was instituted by the Great Council and forbade any craft to form an association against the Doge, the Council, or the Commune of Venice (Lane, 1973:106).

Each guild did have a spokesman, the *gastaldo* or chief guild officer, who was elected and would represent the guild before the government. Typically, the *gastaldo* was elected for one year and would work in conjunction with several other elected officials. The specific organization of each association varied. The *gastaldo* also could act to resolve minor guild disputes. According to Rapp, another feature peculiar to the Venetian guild system was the overriding presence of the government in guild business (Rapp, 1976:15). The effects of this governmental presence on the glass industry will be examined later.

The guilds made different crafts subject to particular sets of rules relevant to their trade. The regulations were the responsibility of the three *Giustizieri* (Justices) organized in 1173 in imitation of practices at Constantinople (Lane, 1973:105). From 1261 onwards, the glassmakers guild was under the supervision of the *Giustizia Vecchia* (Zecchin, 1987:6).

The functions of the guilds in Venice varied with the craft. In the building trades, they acted more along the lines of modern trade unions. In other areas, such as glassmaking, they were more akin to trade associations in which the government had entrusted regulatory powers. Some guild statutes were designed to protect customers while others were written to prevent unfair competition or to ensure the production of quality goods (Lane, 1973:165). The guilds controlled entry into their craft and regulated the labor supply. The taking and training of apprentices was controlled. Immigrants were frequently granted access to guild membership provided the applicant passed the required competency tests, paid the required dues, and so forth (Lane, 1973:165; Rapp, 1976:15).

Typically, only masters could participate in the running of guild affairs. Such was the case for the glass industry. As a result, many persons who were involved in the making of glass were not actually represented by the guild. This included unskilled workers and apprentices. In other guilds, though, such as ship carpenters, almost every adult was a master. Decisions by the guild were subject to approval by the Justices (Lane, 1973:166).

It has been suggested that one of the negative consequences of the guild system was the suppression of innovation that could have improved industrial competitiveness (Sella, 1968:121; Lane, 1973: 320). In the 15th and 16th centuries, guilds acted to both promote and prevent economic growth. Often, they may not have intentionally acted to hinder progress. But Weber points out that one of the functions of a guild is to prevent one master from rising too far above the others.

The guilds system was generally organized so that raw materials took the longest possible path on their way to a finished product. Division of labor was based on the final product and not necessarily on the technical specialization of labor which tended to reduce artisans' abilities to explore technological or organizational innovations (Weber, 1958:110-14). Guild efforts were frequently directed at the improvement of product quality rather than the reduction of production costs. While this certainly had the effect of elevating the status of goods made in Venice, such as silk and glass, it also would have a detrimental effect as other nations such as England and the Netherlands began making lower priced alternatives to such goods (Rapp, 1976:154-64). Cipolla cites the guilds of the 17th century as contributing to a general economic decline in Italy. The control exercised by the guilds prevented the introduction of new forms of organization and production. As the guilds reduced the amount of competition between associates, they presented an obstacle to innovation (Cipolla, 1968:137-8).

By the 16th century, there were over 100 guilds in Venice. This number remained fairly constant through the next century. Of these guilds, 75% had less than 250 members. In 1595, for example, only three guilds (wool workers, silk weavers, and gondoliers) had membership greater than 1000. 24% had fewer than 50 members; the glassmakers' guild is an example (Rapp, 1976:49-106). This obviously is a minute number given the attention the glass industry has received from a variety of scholarly communities. The reasons behind these statistics and an assessment of the size of the Venetian glass industry will be examined in Chapter 8.

Rapp has presented census data for the late 16th and 17th century which examines the size and nature of the work force of Venice (1976). In terms of the overall population of Venice, about 33,000 men were part of the eligible work force at the end of the 16th century. Of these, two-thirds were members of guilds. The remaining third consists either of guilds not included in the census for various reasons, unincorporated craftsmen, or unskilled workers. It is hard to estimate the numbers of this latter category. Romano, for example, estimates that for every guild worker in the shipbuilding Arsenal, there was an unaffiliated workman (1968:75). Dividing guild membership into three basic categories - food, manufacturing, and services - manufacturing accounts for 49% to 58% of employment during the course of the 16th century. According to Rapp, glass and mirror making were two growing occupations during this time (1976:96). Of the approximately 50% of the labor force engaged in manufacturing, most of it can be described as "industrial", requiring division of labor, specialization, and some capital investment. Glassmaking has been described as one of the most industrialized employing large production units, significant economy of scale, and extensive capital investment (Rapp, 1976:99).

A Note on the Venetian Monetary System

In future chapters, we will examine some of the different economic issues pertinent to glass making and glass consumption. Typically, prices of raw materials and finished product are recorded in archival or historical references in Renaissance Venetian currency. Therefore, the reader should have a basic understanding of the Venetian monetary system.

Both gold and silver currency were used in Venice. One coin was a large silver penny called a groat and weighed 2.18 grams. A *lira di grossi* was 240 of these. For retail transactions, there were smaller silver coins called *piccoli*. A *lira di piccoli* was 240 *piccoli* and 12 *piccoli* was equal to what was called a *soldo di piccoli*. Therefore, 1 *lira di piccolo* was equal to 20 *soldi di piccoli*. Over time these smaller coins contained less silver; the grosso was originally worth 26 piccoli which was later increased to 32.

In 1284, Venice minted its first gold ducat which was about 3.5 grams of .997 pure gold. This coin became one of the most widely used and trusted coin of the Renaissance. The Venetian commune switched from a silver to a gold standard in the middle of the 14th century. At this time, the Venetian government declared that 1 ducat was equal to 24 grossi (Lane, 1973:148-50).

The ratio of value between silver and gold (the bimetallic ratio) was not always constant. Therefore, the ratio of lira to ducat depended on current economic conditions. A recent volume provides information for comparing silver and gold currencies (Lane and Mueller, 1985). For example, in 1450, 1 ducat is recorded as worth 114 *soldi di piccoli*. At the rate of 1 lira equals 20 *soldi*, this is equal to 1 ducat = 5 14/20 lire or 1 ducat equals 5.7 *lire*.

The official value of the ducat was made equal to 124 *soldi* in 1455 where it was stable for about fifty years. From 1455 to 1510, Venice had essentially one economic scale in which both silver and gold coins were given their value in *soldi di piccoli*. Because of this long period of stability, Venetian became accustomed to referring to "one ducat" as any combination of coins equal to 124 *soldi* (Lane, 1973:326-7).

Summarized, the values of Venetian money during the Renaissance (c. 1450) are:

1 *lira* = 20 *soldi di piccoli*

1 ducat = approx. 5.7 *lire* = 114 *soldi di piccoli*

Knowing these two ratios should be sufficient for the reader to understand the basic points of the Venetian monetary system as used here.

Luxury Goods and their Role in the Changing Renaissance Economy

The third and final section of this chapter investigates the relations between luxury goods and the trends of a changing Renaissance economy. In order to do this, I think it necessary to develop a different way of viewing the products of Venice's Renaissance glass workshops. Instead of fetished museum pieces, the argument is made here that they should be considered as commodities in both a past and present context. A definitional strategy for terms such as "commodity", "value", and "luxury good' is presented. With this accomplished, we can proceed to the role that Venice's glass, and luxury goods in general, played in the emergence of new Renaissance phenomena such as capitalism and consumerism. But first, is there a better way in which to view the products of the Renaissance Venetian glasshouse than has been presented in the past?

Renaissance Glass as a "Commodity" and the Issue of Value

At this point I will develop a different perspective with which to view the presence and the role of Venetian glassware in both Renaissance and modern society. The glass is typically seen as existing independently of either its producers or users. This is especially true in art historical examinations of Venetian glass, or perhaps more accurately, in the museums which display the glass or in the auction houses where glass pieces are bought and sold. Consider the auction house, for example. Here, the primary interest of both the buyer and seller is the glass piece itself - its characteristics, price, decoration, age, and so forth. This dominant "artifact oriented" mentality is translated, in some form, to either the private or museum collection, affecting such things as how the piece is referred to (value in dollars, for example) or how it is displayed (perhaps on a separate platform showing it to be a "masterpiece"). Yet this is only part of the glass piece's history. At one time, this object was made by someone in response to consumer demand. I suggest that it is more appropriate to view the object as a "commodity". For our hypothetical piece at the auction house, it was at one time, and is on the auction block, just that.

The nature of what a "commodity" is, the process of "commoditization", and their relation to society has been discussed in great detail in various branches of the literature. Here it is necessary only to demonstrate that the glass, both luxury and common, of Renaissance Venice was and is a commodity, to define what is meant by this term, and to note that this distinction is useful for this work.

The best known discussion of the concept of commodities is found in Marx's first volume of *Capital*. Here, a commodity is an external object which, through its qualities, satisfies human needs of whatever kind. Its use comes from its quantity and quality. (Marx, 1977:125-26). It is a product of labor which is to be exchanged in a market transaction and therefore is not the same as a product (Russell, 1980:18). A commodity is distinct from simply products or goods in that it is exchanged. This exchange mechanism can take several different forms including gift exchange, barter, and, of course, commodity exchange in a capitalist mode of production. This exchange is the root of the commodity's value; this will be taken up again in a moment.

For my purposes here, I will define a "commodity" as a component of a technological system (an object or product, labor, or production knowledge) having some type of value, which is intended for exchange, and, by virtue of its properties and qualities, satisfies a diverse range of human needs. Typically commodities in this work are the objects whose existence is the result of demand and productive forces but this need not always be the case. Objects are not always commodities throughout their existence as Kopytoff points out (1986:66-68). An object can move in and out of the commodity state. Consider a piece of glass originally purchased from a 16th century glasshouse. For some time it was used in a variety of activities arising out of the context of Renaissance society. At some point, perhaps, it enters a person's private collection where it has another set of functions. At this point, it is not a commodity. Years later, when this person's estate is sold at auction, this hypothetical glass piece can again enter the commodity state. Whether or not an object is a commodity depends on its context.

The notion of "value" is central to the definition of a commodity and bears further articulation. A commodity has some type of value. Marx offers several different varieties of value for consideration. Labor value, for example, is the economic worth that labor creates. Exchange value is a quantitative measure of the relative worth of a commodity in relation to another on the basis of the amount of labor that is incorporated within each (Russell, 1980:34). Exchange value is the value relation existing between the commodity in question and other commodities. For example- "this glass goblet costs 2 ducats". Yet how does one account for the demand and value of objects such as glass and pottery which were made with relatively inexpensive raw materials and labor costs? Clearly, something other than merely "exchange value" is present. Godelier suggests that the value of a commodity exists before it is circulated. A commodity can enter into relations in which it may be sold for more or less than its exchange value (Godelier, 1977:155).

This leads to the concept of "use value". Unlike exchange value, use value is qualitative. It relates to the purpose which an object has for consumption and use (Russell, 1980:121). Use value is not necessarily inherent or apparent. It is not always a physical or quantifiable property. Rather, how an object is viewed in society and how it functions gives it a certain use value. Use value is a property assigned to an object in a manner that arises out of its social context. It cannot be measured outside of this context. Economic value depends on cultural value and people need to find ways to make certain commodities have value in their lives before these commodities can be sold to them. Part of economic changes of the Renaissance was not just the greater variety of goods produced but the changes in the meanings of these goods and the fact that the search for meanings was both a source of "...cultural confusion and innovation" (Mukerji, 1983:12-13). Use value is something that must be recognized by an individual or group and it is assigned by these person(s) (Renfrew, 1986:158-9). Most importantly, Renfrew states that the social context is often the decisive innovation in the development of a new commodity rather than technical concerns. This is an important factor to bear in mind as I present the changes in the Venetian luxury glass industry. As will be shown, the development of *cristallo* glass in Renaissance Venice was dependent on both societal and technical factors. Demand can endow an object with value which ordinarily would not be worth much in merely an exchange situation (Appadurai, 1986: 31). This demand is determined by social and economic forces, and, vice-versa, demand can also manipulate these forces. Value, like quality, must be recognized. Yet, typically, objects of greater quality have a greater use value.

The fact that use value is related to the functions that a particular commodity has in a defined certain context has certain parallels with Schiffer's ideas of an artifact's functional aspects (1992:9-11). Objects without utilitarian value may operate in the symbolic dimension. Even the traditional dichotomy of function vs. style breaks down as style often is a function. For whom and to what purpose a commodity has use value must be considered. An enamelled Renaissance goblet has several different values as well as functions depending on the context in which it is viewed. In another context, this glass goblet might have sentimental value as a souvenir. The same piece in a museum collection certainly has an exchange value (i.e. the cost of acquiring the object) but it may have other use values to the museum in arenas such as prestige and educational purposes.

To summarize how "use value" is seen here: it is a property arising out of the social context(s) in which the commodity resides. It results from demand, as well as the functions it performs, and is therefore context dependent. Value must be recognized in order for it to exist. In a similar manner, quality must also be recognized. Typically, quality and value are proportional to one another.

So what does the student of material culture gain by advancing past the position of "artifact centrality" and considering the concept of glass as a commodity? Firstly, it allows for an examination of the object's value(s) from different points of view such as the producer, the consumer, the collector, and so forth. Secondly, the use of the "commodity concept" for the study of Venetian glass versus the traditional "artifact centrality" compels one to place the object of interest into the appropriate context. As Appadurai points out, the consumption of commodities is not passive and private; rather it is "eminently social, relational, and active..." (1986:31). This can be extended to the production and distribution of commodities, as well. Thirdly, with regards to a particular manufacturing technology such as glassmaking, there are other materials and services involved, besides the final product, that may also be considered from the perspective of a commodity. There are raw materials and labor, for example. For the production of luxury glassware, in particular, there is also the technological knowledge (i.e. tacit knowledge) associated with its manufacture that was a commodity among other producers. Outside the normal sphere of production, there were consumers such as the Duke of Milan and the Medici of Florence who were also desirous of obtaining the commodity of technical knowledge. All of these commodities relevant to the demand, production, and consumption of Renaissance glassware need to be addressed in order to view it in an integrated fashion. Finally, by considering Renaissance glass as a commodity and moving beyond a more limited "artifact centered" view, we can recognize the presence a phenomenon proposed by Marx in *Capital*- the fetishism of commodities (Marx, 1977:163-67).

Fetished commodities, created and used by humans, assume a independent and disconnected existence (Russell, 1980:38) I propose that some of the previous ways in which the glassware of Renaissance Venice were viewed, as well as how they are sometimes treated today by collectors and museums, clearly fit into this view of commodity fetishism. Gathercole deals with this topic by treating museum artifacts as commodities, which is a fair assumption, and then examining the relations between artifact and curator (1991:73-82). This disembodied perception of an object, alienated from its previous and present social relations, causes the object to appear as a fetished form. What was the product of social relations among people appears before us in a fantastic form which disguises its context. As Marx said, "Value does not have its description branded on its forehead; it rather transforms every product of labor into a social hieroglyphic" (1977:167). By accepting that glassware made in Renaissance Venice is and was a commodity and then keeping proper contextual relations in mind, one can have a greater latitude in studying the objects and avoid the fetished, "artifact centered" perspective of previous studies.

The Question of "Luxury"

The previous descriptions of Venice's position in the Renaissance economy have considered both commerce and industry. Luxury goods played a role in both of these. Northern Italy, and specifically Venice, monopolized the trade of luxury goods imported from the Near East and China and controlled their subsequent distribution throughout Europe. In addition, Venice developed several industries (glass, soap, lace, silk) which were oriented towards the production of luxury goods.

In examining the history of glassmaking over a broad stretch of time, one can discern three major changes in the craft, all of which are directly connected to contemporary social and economic contexts. From its earliest beginnings in the Near East, the production of glassware had a strong connection with high status, luxury goods. The time and effort needed to make the earliest glassware was such that it was rare and costly. This coupled with the social structure of Egypt, for example, in the 15th century B.C., ensured that only society's elites had regular access to this material. The second primary development, that of glass blowing in the early Roman era facilitated the production process. At the same time, the Roman empire had in place a sophisticated system of product distribution along with relative political and economic stability. As a result, glass was available to other classes of society and glass was no longer primarily a luxury item. This paper will demonstrate that, during the Italian Renaissance, new changes occurred in both the production and consumption of glass that would further alter the relations between it and society. These changes also set the stage for the later appearance of factory-type production in glass and other ceramic industries.

I identified earlier that the primary focus of this research work would be on the production and consumption of luxury glassware in the Renaissance. This is the arena where the most important technological changes in the Venetian glass industry took place. This is also where the most notable changes in Renaissance material culture happened. What do we mean, however, by the use of the word "luxury" to describe a particular object or segment of the glass industry?

"Luxury" items are typically separated from another category of goods called "necessities", a contrast which in itself is somewhat problematic (Sombart, 1967:59; Appadurai, 1986:38). "Need" is a very difficult term to define and is entirely context dependent. In the strictest fashion, all glass might be perceived as a luxury as it is not necessary to sustain basic human life. Another pair of contrasts would be that between solely utilitarian commodities and those which perform functions other than utilitarian. Perhaps it is best to distinguish between commodities which are "life enhancing" versus those that are "life sustaining" (cf. Gordon and Killick, 1993:244). In Renaissance society, it may have been necessary to have plain glass bottles for the storing and distribution of commodities such as wine and oil. However, the purchase of finely crafted and enamelled glass goblets for consuming wine can clearly be seen to have more than a utilitarian function, i.e. one which enhances the owner's life. Similar distinctions can be made between a simple earthenware plate and a majolica dish, et cetera.

In his study of the idea of luxury and luxury goods throughout history Berry's definition of the categories of luxury goods -sustenance, shelter, clothing, and leisure- illustrates the fuzzy distinction between luxury and necessity as all four could easily be classified as either (Berry, 1994:5). Artifacts originally intended as "sustaining" can, in some cases, become luxuries. Berry delineates the two by discussing "need" and "want" and describing two of the features of luxury goods: they are refined and they are positively pleasing (1994:11). Both of these are relevant to understanding the "want" for a luxury good such as glass. The refinements that characterize an object such as a glass goblet are "qualitative" or "adjectival" according to Berry. For a good to be viewed as a luxury, possession of it must be seen as "pleasing" (1994:11-12).

Mukerji also presents a distinction between the two general classes of goods, utilitarian versus luxury, referring to them as "mass" goods as contrasted with elite "goods". The study of elite culture is typically the domain of traditional art historians rather than social scientists (cf. Prown, 1982). Yet it is in the realm of mass goods that a more representative view of a particular society is afforded, such as the work presented by the French *Annales* school (Mukerji, 1983:23-25). Changes in the identity of the producers of these broad categories of goods occurred during the Renaissance. In the late medieval period, material culture was produced entirely by artisans. During the Renaissance, some artisans were able to leave the confines of the guild structure and become artists and entrepreneurs, i.e. producers of predominantly elite culture. Mukerji identifies this shift as the emergence of a distinct group of elite culture producers laboring in the workshop rather than the guild (1983:39-40). The generalization described by Mukerji above cannot be seen to explicitly hold for Venetian glass, though. All glass objects, luxury or common, were produced within the confines of the guild system. A distinction between the nature of shop production did exist in the Venetian glass industry with some shops making solely "basic" glass objects while others were more oriented towards the luxury or "elite" market.

Luxury goods are refined goods. Of course, the degree of refinement is very relative; Sombart uses "refinement" to refer to that degree of elegance which surpasses current standards of luxury in goods (Sombart, 1967:60). He described both "quantitative" and "qualitative" luxury types, which are usually combined. The notion of qualitative luxury leads to the concept of "refined" goods. This is any treatment of a product over that which is needed to make it *ordinarily* useful (Sombart, 1967:60) (my emphasis). Luxury goods exist primarily in response to contexts which are political (Appadurai, 1986:38). As such, they have several basic attributes. These include restriction to elites by price or law, complexity of acquisition, regulation by fashion, and the ability to display complex messages. All of these functions are served in some sense by Renaissance Venetian glass, as we shall see.

For the sake of this work, let us view luxury goods in opposition to "life sustaining" or utilitarian commodities rather than "necessities". Luxury goods are more refined than simpler utilitarian objects. The production, use, and consumption of luxury goods involves different and more complex patterns of behavior beyond what one sees for "life sustaining" goods. Luxury goods have functions that typically expand beyond techno-function and which enter social and ideological realms.

Luxury Goods and the "4 C's"

Earlier I discussed the emergence and prevalence of capitalism in Renaissance Venice. But this is not the only new and notable economic development during the Renaissance. Capitalism is part of what I have termed the "4 C's" to refer to the new economic circumstances of the Renaissance economy. These are capitalism, consumerism, and conspicuous consumption. While previously we discussed only capitalism, it is somewhat unrealistic to try and separate these phenomena from one another as they are intimately interconnected. What will be shown is that luxury goods played a significant role in the development of the "4 C's" and vice-versa.

Goldthwaite has extensively discussed the conditions for luxury good consumption in the Renaissance economy and their relation to demand for art objects such as religious paintings and majolica (1984, 1987, 1989, 1993). He notes the comparative difficulty of defining and studying the "Renaissance economy". Yet amidst the confusion surrounding the subject, he identifies the one distinctive economic activity that marks the Renaissance - conspicuous consumption (1984:659).

He states that "...the increased production of art, and luxury goods in general, is one of the characteristics of the Renaissance;...". During the Renaissance, this consciously created art emerged as a distinct category of goods. This new consumerism identifies what was novel in the Renaissance economy and served to separate Italy, culturally and economically, from the rest of Renaissance Europe (1984:660). He notes the relative scarcity of studies which examine the role of luxury production in the Renaissance economy. Typically, these studies focus more on commerce or on industries such as ship building or textiles. Moreover, and more importantly, there has been little investigation into the demand for luxury goods. The demand for goods is harder to research than their production. Understanding demand means that one has to deal with the broader concerns of culture. In addition, economists have typically taken demand for granted, assuming an unlimited market for goods produced, and focussing instead on the supply side. Finally, luxury goods have typically been seen as frivolous and "necessities" such as ships and textiles have been more commonly studied by economists (Goldthwaite, 1984:661). Central to Goldthwaite's work, as well as this present research, is that demand for luxury goods had important consequences, both cultural and economic, and is therefore an essential topic to study.

Typically, the rise of consumerism is located within the industrial revolutions occurring after the Renaissance. One view of consumerism, though, suggests that the desire for goods and conspicuous consumption is a universal norm stimulated perhaps by such social phenomena as increased urbanization and changes in industrial productivity (Veblen, 1953). Even this broad treatment affords a role for consumerism as a social and economic force (Mukerji, 1983:26).

Goldthwaite identifies two essential conditions for the extraordinary consumption of luxury goods that marks the Renaissance economy (1984:663-673; 1993: 13-67). The first of these is the superior overall economic performance of the economy in Renaissance Italy in comparison with those of other European regions/cities. Commercially, Italians controlled the movement of luxury goods from the Near East to northern Europe. Of the various Italian cities, Venice was arguably the most important in this respect. In the sphere of production, Italian cities developed industries which would generate income to balance payments for these Near Eastern luxury goods. These industries also met the increased demand for luxury goods in the West with their own products. From the 13th century onwards, Italian industries developed goods which could compete against Near Eastern luxury goods. Goldthwaite cites an increased variety and quantity of these products along with their continually improving quality (1993:19). Producers of luxury goods learned how to manipulate taste and demand by creating new fashions, designs, and products. Eventually, many of the luxury goods produced in Italy supplanted their rivals from the Levant and the overall flow of luxury goods began to reverse. The Near East itself became a market for Italian luxury goods such as glass from Venice.

In addition to the greater overall wealth of Renaissance Italy, the demand for luxury goods was stimulated by the structure of this wealth (Goldthwaite, 1984:666).

An analysis of the structure of wealth reveals several features which facilitate the consumption of luxury goods. Firstly, money was more widely distributed among a larger number of consumers than was seen previously. These consumers were generally concentrated in urban centers. Italy was not dominated by any one city during the Renaissance and the wealth was correspondingly distributed more widely. The cities are where money was concentrated and it is also, typically, where the majority of luxury goods, whether produced or imported, originated. Secondly, the wealth of Renaissance Italy was more fluid than elsewhere; as a result, the identity of the consumers of luxury goods was constantly changing. As money was more easily transferred from one person or family to another, the level of demand was continually kept elevated. The social mobility of Renaissance Venice, as I have previously noted, is an example of this phenomenon. In other parts of Europe, wealth was predominantly located in land as it was more stable. It was also confined to a largely closed class and was less subject to movement (Goldthwaite, 1984:671). Finally, the economic structure of Renaissance Italy shows that, overall, the rich tended to get richer, especially from the 16th century onwards. As the upper classes had even more money to spend, their consumption reached increasingly greater and more extravagant levels.

The greater wealth of Renaissance Italy and the ways in which it was organized and distributed promoted the extensive demand for and consumption of luxury goods. A larger question is whether this greater demand for and production of luxury consumables was a stimulant or inhibitor on the overall Renaissance economy and the development of capitalism.

One school of thought, the "Depression theorists", holds that the increasing expenditures of money into such areas as luxury goods and decorative arts served to drain capital away from what would be more profitable or productive investments. Braudel compares the effort spent in producing luxury goods to that of an engine running in neutral, creating only "limited and superficial phenomena". Emphasis on luxury production serves to characterize a society and economy that is ultimately limited in growth (Braudel, 1967:124). The greater investment of time and money into luxury goods and their production is seen as a sign that there was a lack of more "productive" economic opportunities (Brown, 1989:767). One of the proponents of this "depression" theory is Lopez who suggested that the great cultural developments of the Renaissance were primarily due to a general economic downturn (1953). As might be expected, this suggestion was not well received by non-economic historians. Economic "hard times" after the devastating attacks of the Plague, were viewed as inhibiting normal economic investment. As a result, more wealth was released for the consumption of art and luxury goods. This consumption allowed men, who were lacking more traditional economic investment opportunities, to achieve greater social status. Upon realization that traditional markets were contracting, Italian investment oriented itself towards luxury items (Cipolla, et. al., 1964). Despite its logic, this thesis is somewhat deterministic suggesting that economic forces are the drivers behind consumption and cultural change. Demand is relegated to a secondary role and is not seen as a motivating force behind production or as a economic stimulant.

A much different and more optimistic alternative to the "depression" school exists. This holds that demand for and consumption of luxury goods such as glass had a causal role in the new economic developments rather than being mere effects. As Mauss states, "...it is not in production that society found its impetus; luxury is the great stimulus". In particular, the work of Werner Sombart, which illuminates the relation between the development of capitalism and the increased demand for luxury goods, is noteworthy (1967). Its focus on the realm of demand and consumption offers an alternative perspective versus the more common approach of studying production. The deliberate focus on "consumption solely" tends to go to other extreme by taking production for granted, however. Mukerji criticizes Sombart's work for this in not considering the material aspects of culture production. By viewing the objects as repositories of cultural values, they tend to be treated as "found objects" (again, the concept of "fetishism"). Mukerji suggests that they be seen as products of an economy whose meanings develop through the production process (1983:27).

Sombart calls capitalism "the child of luxury"; the principal cause of the growth and expansion of trade, industry, and finance capital was the Renaissance society's demand for luxury goods. This demand arose primarily from the courts of Europe, the nobility, and the *nouveau riches* who had no other distinctive quality besides the ability to conspicuously consume. Luxury goods, therefore, represent a social as well as an economic force. In terms of commerce, Sombart cites the retail, rather than the wholesale, trade as being predominantly influenced by luxury goods (1967:129). Retail trade became differentiated from wholesale trade. Shop owners began to display their goods in a different fashion in order to attract trade and to stimulate consumer demand.

However, it is in the realm of industrial production that the influence of luxury consumption was the most profound, according to Sombart (1967:145-55). Clearly, luxury industries are those engaged in the practice of making luxury goods. But, Sombart asks, what are these "luxury goods"? At this point, one must not only consider the primary luxury industry, such as glassmaking, but also bear in mind the secondary and tertiary industries associated with it. For glassmaking, this includes the procurement of raw materials (sand, soda ash, firewood, clay) and the distribution of the finished goods. In this way, attention is drawn to the link between the highly visible luxury industry and the more mundane associated industries. A broader context is created. The demand for luxuries has system-wide implications to the degree that the growth in demand for the primary luxury goods is needed for the expansion of related industries (Appadurai, 1986:39). Sombart also distinguishes between "pure" luxury industries (silk and mirror making, porcelain production) and those of a mixed nature, such as glassmaking, which made both luxury goods and "necessities" or "life sustaining goods" (1967:147).

In what manner did expansion in the production of luxury goods stimulate the development of capitalism? The increase in the consumption of luxury goods greatly influenced the organization of industry. Firstly, the nature of the production process of luxury goods often demands a necessary raw material which can often only be obtained from distant sources thus facilitating commerce and benefitting the"rich and commercially trained entrepreneur" (Sombart, 1967:169). For Venetian *cristallo* glass, this includes almost all of the raw materials consumed: soda from the Near East, sand from Lombardy, and so forth. Secondly, the production of luxury goods is frequently more costly, more labor intensive and complicated, and more of an "art process" than the production of "coarse goods". Therefore, it requires more skilled labor, more technological knowledge, greater managerial skills, and a more refined organization of production (i.e. teamwork and specialization) (1967:170). This multiplicity of required skills along with an increase in the scale of production formed the basis for factory-style production. Thirdly, the consumption of luxury goods is more subject to the whims and changing desires of the consumer. Fashion itself exists a driving force in bringing about technical changes as McKendrick discusses in relation to the 18th century British pottery industry (1982:100-145). I suggest that fashion and consumer preference existed as a stimulant decades earlier in the Venetian glass industry. A luxury industry must be sensitive to the vagaries of fashion and be able to adapt accordingly and quickly. While not mentioned explicitly by Sombart, this resourcefulness must include the ability to create fashion and demand and stimulate consumption (cf. Goldthwaite, 1993). Artisans were now able to manufacture for the market rather than for a limited supply of local customers thereby producing novel goods that may not have appealed to their previous clients

(Mukerji, 1983:11). An industry that is organized in a capitalistic fashion which makes goods in a factory or proto-factory manner with the features previously discussed might be in a better position to respond quickly to market forces than one organized in a "handicraft" or "artisan" fashion due to the resources at its disposal (Sombart, 1967:170).

Other economic historians have echoed and expanded upon the views of Sombart. Pirenne describes how the desire for "new articles of consumption" grew correspondingly with the spread of commerce (1936:81). The growth of luxury industries stimulated the economy in new directions increasing the investment in human labor with positive economic effects. This decreased Italian reliance on luxury imports increased the amount of export goods and helped the social structure of the economy change. This, in turn, fed back into the demand for luxury goods and helped the overall economy expand (Brown, 1989:767). As Goldthwaite has shown, it is these characteristics which link the Renaissance economy to the cultural achievements of this time. The demand for moderately priced luxury goods (as compared with the more extravagant luxuries such as monumental sculpture or architecture) resulting from a greater amount of wealth available to the upper and middle classes helped elevate the "artisan classes" into participation in the consumer revolution (Goldthwaite, 1980:318-19, 396-425, 1984).

<u>Luxury Goods in a Changing Renaissance Society</u>

Material goods help to "generate culture"; consumption and consumerism helped Renaissance society construct its cultural identity (Goldthwaite, 1993:243).

This set of circumstances thus appears to us as a series of effects with feedback and repercussions. Consumerism affected production and industrial organization resulting in a new forms of material culture being produced which in turn helped to shape Renaissance society. This cyclical pattern might seem hard to analyze appearing as an elaborate loop embracing production and capitalistic organization, material culture, expanding consumerism, and the effects on and influences of Renaissance society.

Perhaps a good place to interrupt this cycle is to examine what the underlying impetus behind the increased production of luxury goods such as glass was. An entirely "producer-based" perspective would pre-suppose that demand for particular luxury goods already existed and the industries acted merely to fill this need. This does not make much sense. Pure economic analysis would show that there simply was greater wealth available and people then spent it on luxury goods. This view does little to explain why certain goods were produced over others. A naive cultural analysis could say that people surrounded themselves with luxury goods solely to reflect their status and social aspirations. This simple equation may work for precious materials such as gold. However, this does little to explain why items such as glass and majolica, made from relatively cheap materials, were consumed.

Consumerism and conspicuous consumption created new economic, productive, and social forces. Yet to understand the nature of these new consumer forces, we must come to grips with the underlying basis of these - demand. Demand is usually taken for granted. However, as the preceding section showed, demand is, at many levels, the root of value. What was the nature of this demand? Why were particular items and goods valued and coveted over others? What changes took place in Renaissance society that stirred this demand and validated or rationalized the new tendencies for conspicuous consumption? Why did people want to buy and make Venetian glass? The greater availability of wealth and its wider distribution can explain how people were able to purchase items but it does nothing to explain why they bought what they did. As Goldthwaite explains, pure economic analysis can reveal only permissive causes for consumption but does not illuminate effective demand (1987:19). The goal then is to examine and to "de-mystify" the demand for particular Renaissance goods such as glass.

The appearance of new economic patterns such as consumerism had notable effects on the culture of Renaissance Europe. Consumerism and materialism were forces for social change as well as creating productive forces within the Renaissance economy (Mukerji, 1983:9; Goldthwaite, 1984:664). For example, Mukerji, Goldthwaite, and Braudel all refer to new systems of table etiquette that were invented as the variety of eating implements increased. The new variety of objects and their greater availability created both new uses for goods as well as new values for their use. Yet, typically, historians of early modern Europe recognize that a new range of items was being demanded and produced yet little more is said about this. The qualitative changes in the production of particular objects is generally not connected with overall quantitative variation in economic activity (Mukerji, 1983:31).

Materialism can be described as a cultural system in which material interests take precedence over other social goals (Polanyi, 1957; Sahlins, 1967). The growth of materialism in Renaissance Europe was accompanied by a greater preoccupation with objects (Mukerji, 1983:20). A relation is suggested between materialism and capitalism. For instance, Mukerji notes that as capitalist producers were making new objects to increase sales, the customers were encouraged to attach new meanings to these artifacts and vice-versa (1983:21). New growth in trade and discovery of novel commodities in places such as the Americas and the Far East also forced Renaissance society to come to grips with a bewildering variety of new things.

Blake touches on this question of demand in his discussion of medieval ceramics (1980:5-8). He too identifies the two general ways to consider the subject: supply and demand. He points out that the assumption behind all distribution studies is that consumers wanted to and were able to buy the products. But why did they buy them or buy one good preferentially? This, as Blake and Goldthwaite point out, is a much more nebulous question to address. Yet it is the most essential one. Production pre-supposes demand. Demand and desire are the roots of production. One can not completely study the production organization of a particular commodity, such as glass, without understanding the forces of demand that motivated its manufacture in the first place. Blake concludes by saying that pottery reflects the components of "effective demand". Recognizing this leads to a number of methodological changes in the study of ceramics. Ceramic historians can either study "minor technical adaptions" and distributions or they can play a role in the study of social and economic history (1980:9).

As this study of one component of Renaissance material culture, Venetian glass, hopes to address aspects of the latter, we must examine the general nature of demand. This discussion will lay the foundation for a specific study of the Renaissance demand for glass in a following chapter.

Goldthwaite has discussed in great detail the question of demand for both religious and secular objects in Renaissance Italy, referring to the new social and economic situation as an "empire of things" (Goldthwaite, 1987, 1993). The underlying cause for the emergence of consumerism and materialism can be traced to the switch from the previous "feudal" system to a new urban model. As a result, an alternative set of values emerged that changed society's behavior along with how its money was spent (1987:164).

In the earlier "feudal" model, life was centered around the hall of the lord's house. Consumption was directed towards assertion of status and life was ritualized by elaborate ceremonies. Three arenas of spending existed for the nobility. The first was money spent on arms as part of the expression of the chivalric code. Secondly, luxury goods oriented towards liturgical goods were dominant as the noble demonstrated his special relation with the Church. The final realm of expenditures was for the household as the noble asserted his position among the other members of society. Goldthwaite uses the term "hospitality" to describe the noble way of life;

the hall was open to all and by welcoming others the nobility were able to demonstrate class privilege (Goldthwaite, 1987:158; 1993:153-55).

The level of Medieval or early Renaissance material culture has been described as low as well as stable between about 700 A.D. and 1100 A.D. (Mukerji, 1983:33-36). This is not to imply that it was all the same at the regional level, where traditions and values could vary, but that there was not a pre-occupation with things as would be seen in the Renaissance. Even the great houses of medieval Europe did not have same assortment of dishes, glasses, linens, and furniture that would be seen in later centuries. Items were collected and assembled for different reasons. Chapter Seven examines these motivations in relation to the demand for particular goods. Mukerji notes that even at banquets there were only minor displays of material culture with a few tables and shared bowls of food (1983:37). The accounts of the Italian merchant of Prato in the early Renaissance also confirms this relative paucity of objects (Origo, 1984).

In northern Italy, the towns and cities emerged as the centers of economic and political power. The nobles, like other members of society, were attracted to these new hubs of activity. Once immersed in the urban life it was increasingly difficult for the nobility to stand out. There was not room for the extravagant and spacious living of the previous feudal system. There was less opportunity for hospitality. Venice did not even have a formal court. As a result, the nobility and newly rich were forced to develop new values and behavior (Goldthwaite, 1993:159-76).

Cities such as Venice became the centers of cultural life and a more fluid society emerged based on contract rather than status (Goldthwaite, 1987:164). I have already described how nobility in Venice was a legal status rather than an indication of wealth. The new values associated with urban nobility and *nouveau riches* affected spending patterns in three ways. The first was communal spending on the community in form of architecture. The second was a greater and changed concept of nobility which caused these persons to re-direct their spending habits in a way to separate themselves from other classes. Finally, values and views towards wealth and the expenditure of money on luxury goods were altered to create an atmosphere which condoned the spending of money on these consumables (Goldthwaite, 1993:177-78). These last two effects have definite implications for the demand, production, and consumption of Venetian glass.

The increased expenditures of Renaissance society on luxury items raised moral and ethical questions among contemporaries. Attitudes toward wealth were changing and the accumulation and spending of money became less suspect by religious authorities. It is interesting to note that hedonism and asceticism are two sides of the same coin. They both are concerned with material accumulation. Traditionally, depictions of early capitalism favor that of asceticism, the "Protestant work ethic". Yet, as Mukerji, points out, conspicuous consumption and hedonistic spending did as much to shape early capitalist development. as asceticism and rationality (Mukerji, 1983:2-4). However, it became necessary to justify and rationalize these expenditures.

Wealth became a necessary condition for the exercise of virtue. The central problem was the proper use of this wealth. Treatises authored by Renaissance humanists such as Pontano and Alberti revealed and reinforced these new and emerging attitudes toward luxury expenditures (Goldthwaite, 1993:204-12). In this way, the new consumer habits were justified and condoned. Pontano's work (c. 1500), *I trattati delle virtù sociali*, is particularly enlightening as it includes new virtues related to the accumulation and collection of luxury goods as well as new dining habits - splendor and conviviality. It was perceived by some members of the nobility that they had a duty to live magnificently (*"l'obbligazione di viver con fasto"* as one Neapolitan lawyer phrased it (Burke, 1994:xxii). Magificence was defined in terms of degrees of conspicuous consumption with the house being the center of attention (Burke, 1994: 111-113). We shall return to this and other Renaissance works in following discussion of the demand for Renaissance Venetian glass.

Summary

I have described how there was an economic transformation in Europe at least one hundred years before the traditional Renaissance period as defined by art historians or economists. A world-economy developed with Venice as its center by about 1380. This world-economy was capitalist in nature especially with regards to the modes of production and commerce of commodities such as glass. I defined the rise and fall of the Venetian economy, with respect to historical events, as taking place between c. 1380 and c. 1600. This time frame encompasses the expansion of the Venetian luxury glass industry in c. 1450. The features of the Venetian economy were described, particularly with respect to its industry. In some ways the glass industry incorporated many capitalistic features (standardization, specialization, increased scale of output, et al.) along with some remnants of earlier economic structures (guilds, state support and interference). In this sense, the glass industry may be seen as a transitional state between an artisan-based industry and a factory-style of production. This compelled us to describe the glass industry as "proto-capitalistic" in nature. Finally, the relations between luxury good production and the changing Renaissance economy were discussed. I have shown that, opposed to a fetished or artifact oriented approach, it is useful to consider the varieties of glass made in Renaissance Venice as commodities. By viewing the glass as a commodity, the differing concepts of value (labor, exchange, use) become more apparent and one is encouraged to consider the context of the material culture. Use value arises out of the consideration of objects as commodities and was shown to be a particularly important concept because of its inherent connections to demand, function, and context. We have seen how production of luxury goods is intimately related to issues of capitalism, consumerism and conspicuous consumption. Indeed, it is the issue of demand that must be addressed before one can adequately consider the production aspects of luxury goods such as glass. Finally, I have shown, in a general sense, that demand for the new and expanding world of luxury goods helped generate culture and assisted Renaissance society in constructing its identity. Changes in patterns of consumption helped produce social changes on a broad scale.

Luxury goods are the embodiments of specific cultural values by their role as signs. By de-mystifying demand and considering the proper context of these commodities, following chapters attempt to show how this leads to richer view of Renaissance society's consumption, production, and distribution of glass.

CHAPTER 6

THE ORIGINS AND PRE-RENAISSANCE PERIOD OF THE VENETIAN GLASS INDUSTRY

A great deal of information is available about the Muranese glass industry between the late 10th century up to the beginning of the period that is of central importance here (1450-1550). Much of this information, as is the case for almost all aspects of the Venetian glass industry, comes from the archival research of Luigi Zecchin (collected in three volumes - 1987, 1989, 1990). His work, written and published over 30 years in more than 200 publications, is the primary source of material available that is specifically about Venetian glass industry. Much of it is very oriented towards an understanding of production aspects. I have selected certain features of the Venetian glass industry during the years of its origin and development that are most germane for my later discussion of the industry during the Renaissance. I have tried to include the salient features over this 500 year period before the appearance of *cristallo* glass that are central to the points I wish to make later.

Aquileia and Torcello - Roman Origins?

As discussed in Chapter Three, there is ample evidence for early glassmaking activities in and around the Venetian lagoon. These materials are dated prior to the appearance of the first literary references to glass actually being made in Venice (A.D. 982). In light of the Roman glass found at the Aquileia, about 50 miles northeast of Venice on the Adriatic coast, the commonly accepted hypothesis prior to the 20th century was that the Venetian glass industry had its origins in the glassmaking practices of Rome. Historians advocated the idea that, in the 5th century, Aquilean refugees from invading tribes took the craft with them as they fled to the Venetian lagoon. However, this thesis has been opposed recently (Zecchin, 1987:333-334; Barovier, 1982:9). The last Roman glass works date to the 4th and 5th centuries with evidence of glass being made in the region before this as well.

In addition to its distance from Venice, another piece of evidence which does not support the role of Aquileia in influencing Venetian development is the space of about two hundred years before the next signs of glass activity near Venice. In 1961 and 1962, a Polish-Italian team excavated near the basilica of Santa Maria Assunta on the island of Torcello in the Venetian lagoon. Archaeologists presumably found the remains of four furnaces used for glassmaking located about 35 meters from the church. The site is dated by stratigraphy to between the 7th and 8th century (Gasparetto, 1967; Tabaczynska et al., 1977). The production of the glass furnaces has been associated with the mosaics of the nearby basilica which date to 639 AD. The excavators have suggested that the furnaces were destroyed or transferred elsewhere sometime in the 7th century. The forms of the glass vessels found, especially the small goblets with thin stems and small feet, show similarities to other finds in northern Italy which are associated with the Lombard occupation in the late 6th and early 7th century (Tabaczynska, 1968; Barovier, 1982:9).

Four different furnace structures were unearthed including one of circular form about 3.2-3.5 meters in diameter. Gasparetto concluded that there was a continuity in furnace design and methods of production between the Roman era and the high Middle Ages (1977:75). The Polish team concurred stating the glassmaking of Venice in the 10th century was a continuation of that at Torcello and that the site"...should be considered an important link connecting medieval Venice to the culture of Antiquity." (Tabaczynska, 1968:23). However, as Barovier has pointed out for the production of Aquileia, there is a least two centuries of silence before any documentary evidence of Venetian production emerges (1982:11). As mentioned in Chapter Three, the type of glass made at Aquileia and Torcello, compositionally speaking, is entirely different from that associated with traditional Venetian production. Both sites show glass fluxed with natron, a clear inheritance from the Roman tradition. Natron is a soda-rich mineral found in the Near-East (in Egypt, especially). It was used a flux for glassmaking during the Roman-era. Glasses made with natron typically have values for K_2O and MgO less than 1% (cf. Brill, 1988). The following table illustrates the type of glass compositions found in these Roman and Early Medieval contexts:

Table 6.1. Glass compositions for samples from Aquileia and Torcello (in weight %'s).

Oxide	Average composition of glass from Aquileia (from Verita, 1990:170)	Composition of vessel glass fragment from Torcello (from Tabaczynska, 1977)
SiO_2	68.5	68.2
Na_2O	18.4	17.2
CaO	7.2	7.2
K_2O	0.5	0.1
MgO	0.5	0.1
Al_2O_3	2.3	2.8
Fe_2O_3	0.4	0.1
MnO	0.4	0.1
Cl	1.2	NA
SO_3	0.3	NA
P_2O_5	0.1	NA
TiO_2	0.1	NA
Sb_2O_3	0.1	NA

"NA" means the oxide in question was not analyzed for.

These examples show that glass was being made at these two locations in the Roman tradition with natron as a flux. This conclusion is based on the low levels of K_2O and MgO indicating the use of mineral-based alkali agent. This is in comparison with the Venetian tradition which would almost exclusively use a plant ash with higher proportions of these oxides present in the resulting glass.

The glass found at Aquileia and, especially, Torcello does indicate that glass was being made in the vicinity of Venice from an early time. The glass compositions, however, are part of a different glassmaking technology which had its strongest ties with the Roman/Near East craft tradition. This difference arises from the different type of fluxing agent used and the different resulting glass composition. The long span of time between the activity on Torcello and that in Venice also presents a difficulty in linking the two. Until more excavations reveal glass or glassmaking sites in the time between the 7th and 10th century, the two should not be viewed as being part of the same continuum.

Early Documentary Evidence for Glassmaking in Venice

The earliest evidence providing proof that a glass industry was operating in Venice comes from archival sources dated to A.D. 982. In this document, "*Domenico fiolario*" was present in at a ceremomy recording the donation of a church dedicated to San Giorgio to the Benedictine order. The word "*fiolario*" is an early Venetian term for a glassmakers derived from a type of glass product, a "*fiola*", which is a bellied bottle with a narrow neck (Zecchin, 1987:5). The use of this term to denote a glassmaker continued into the 14th century and was gradually replaced with the more modern "*vetrario*" and its variations.

Two more similar donations or ceremonies, in 1083 and 1090, also record the presence of a "*fiolario*" in Benedictine records (Zecchin, 1987:5-6). This close connection between early glassmakers and the Benedictine order has been noted in previous work (Gasparetto, 1958:38-43, Mariacher, 1961:23). Here, the possibility that communities of monks may have introduced the craft to the Venetian lagoon is suggested. This is not a far-fetched possibility as several other connections between glassmaking and religious orders have been observed. Note that the workshop of Torcello was located in close proximity to the local basilica. The excavations at San Vincenzo al Volturno have also shown the presence of a glassmaking (or working) shop in conjunction with a local 9th century Benedictine monastery in central Italy (Hodges, 1985, 1991, 1992).

During the early Middle Ages, the Church played a very active role in stimulating technological activities such as glassmaking and recording the manner in which these activities were done. Evidence is provided in well-known treatises such as that by the 12th century Benedictine monk Theophilus, *On Divers Arts*. Other evidence linking the Benedictines to the making of glass includes the earliest existing picture of glassmakers working at the furnace in the Monte Cassino library in Italy dated to the early 9th century (Polak, 1975:31). This same monastery, according to a report from 1066, also invited glassmakers from the Near East to either introduce or improve the glass production of the abbey (Hettes, 1960:13). Neither Hodges and Polak suggest that the monks were actually making the glass. Rather, the Church served as both a stimulus for production and a means to distribute the product. Hodges suggests that the Church stimulated demand and helped develop patterns of consumption in a prototype market system. The glass made in monasteries such as San Vincenzo, and perhaps those in Venice, helped send social messages about prestige goods and commodities (Hodges, 1991:85-87). Glass was both of these and it was produced in a manner which exceeded Benedictine demand. The manner in which it was exchanged helped a new market economy emerge and affected society's relationships with goods and meanings (Hodges, 1991:87).

According to Hettes, the presence of Venetian glassmakers as witnesses when drawing up legal documents points to the "high esteem" enjoyed by glassmakers as well as their close association with Benedictine order (Hettes, 1960:13). Within 100 years, glassmakers are no longer recorded in Venice in association with the Benedictine order. By 1158, we have a record of "*Johannes fiolarius*" who was a resident of Santa Margherita, a residential area of Venice, in a notarial deed (Zecchin, 1987:5). Somewhere, in the years between 1090 and 1158 the nature of glass production in Venice seems to have changed.

Early Venetian Guild Activities and the First *Capitolare*

While the fact that glassmakers, according to archival documents, were moving away from their original associations with the Benedictine order provides indirect evidence of changes in the organization of the industry, it is not until 1224 that definite proof exists of this transformation. In May 1224, 24 members of the "*arte fiolario*" were punished for having gone against the rules of the "*giustizieri*". Therefore, we know that by this time the glassmakers were sufficiently well-established in Venice to have their own guild. The "*Ufficio della Giustizia*" was established in 1173 for supervising the various guilds of Venice and was composed of five members (the "*giustizieri*"). In 1261, this "Office of Justice" was divided, on orders of the Great Council, into two divisions, the "Old" and the "New". The

Giustizia Vecchia would retain responsibility for supervising the guilds including the glass guild. The notice of censure applied to the 24 glassmakers does not record what their infractions were but it does provide notice that at least four of them were from locations other than Venice such as nearby Padua (Zecchin, 1987:5; 1989:4).

Another record of the glassmakers' guild is furnished by their July 1268 participation in the festivities for the election of the new Doge, Lorenzo Tiepolo (Zecchin, 1987:6). This scene was described by the chronicle of Martino da Canal as the glassmakers carried "*fiole* and other works in glass".

In February 1271, the first drafting of the statutes for the running of the glassmakers' guild and the general conduct of its members was presented. This was the *Capitolare dei Fioleri* (Regulations for Glassmakers). The original draft contained 46 articles which would be subsequently modified until 1441 when a new *mariegola* (a Venetian translation of the word "*matricula*" which means "register") was drawn up (Zecchin 1989:8, 40).

Article 1 specified that no one was to work in this guild without first taking an oath of loyalty. This oath not only served to bind members to the guild but also asked for their loyalty to the State (Zecchin 1989:8). Article 2 requested that each furnace pay a yearly duty to the Doge of 4 *denari grossi* (1 silver *grosso* was equal to 28 silver *soldi di piccoli* at this time; gold ducats had not been minted yet; see Chapter Five for notes on the Venetian monetary system). Article 5 stated that those who wished to enter the guild must pay a fee of 5 *soldi di piccoli* each; masters must pay 10 Venetian *lire* more and those who wished to go from apprentice to master must pay 2 *soldi di grossi*.

Articles 6 to 8 covered the question of "foreigners" practicing the craft of glassmaking (Zecchin, 1989:9). The articles here are confusing as some have been written over in another hand. One specified that foreigners must live in the city for 14 years before practicing; another says that if they practice they must pay a fee and may have their products confiscated. Finally, Article 8 allowed the practice if they paid additional fees to the guild and the *Giustizieri*. In any case, these rules indicate that there were sufficient numbers of non-Venetians in the craft by now to necessitate special consideration of this problem. Over the course of time, and through the Renaissance period of glassmaking, the issue of foreigners and the conditions surrounding their practicing the craft of glassmaking would continue to be discussed and modified in different editions of the *Capitolare*. The impression one receives is that the guild officers were torn between maintaining an adequate supply of labor at the glass furnaces and keeping the technological knowledge of the craft in the hands of Venetians. There are dozens of cases from archival sources indicating the presence of glass workers in Murano with origins outside of Venice. Often these laborers were from smaller communities in the Veneto such as Mestre, Treviso, Padua, and Verona. At other times, they would come from places in the Adriatic or from Tuscany (Zecchin, 1989:79-84).

Articles 9 and 10 were concerned with the period of work for the glassmakers. The furnaces of Murano were not in operation year round. They were closed for an annual vacation period which, in 1271, was specified to be from the middle of August until the middle of January (Zecchin, 1989:10). This vacation period was frequently modified throughout the next several hundred years. In 1441, the period of work was from December 1 to August 15, for example (Zecchin, 1989:32). Generally, the glass furnaces were shut down in the autumn. At times in the pre-Renaissance period, the vacation period would be entirely abolished and glass would be made year round. These changes in the period of operation generally coincide with the state of the industry at that time (Jacoby, 1993:85).

As with the practice of allowing foreigners into the guild, the question of the annual vacation period was balanced between a need to keep workers working in Murano and a need to control the amount of glass produced. The reasons the furnaces were shut down were technical (often the furnaces would have to be re-built or repaired), organizational (the workers would need a rest and workers would be able to switch employers), and commercial (the glass produced would have to be sold) (Zecchin, 1989:9). The issue of how long the annual vacation time was to be would have implications for the relocation of glassmakers and industrial technology outside of Murano. It was typically during this vacation time that glassworkers would travel to cities outside of Venice to work for extra wages. Worker migration would be one of the primary sources of complaints, regulations, and edicts between the glassworkers, the guild, and the Venetian State and it has its roots in the period of annual vacations. Note also that initially the vacation period was five months long. Over time, it was reduced to about three to four months. No reasons have been suggested for this unusually long initial vacation period. One could speculate that at these early stages of the glass industry, before sufficient demand and markets existed for the glass produced, this long vacation period was necessary to avoid market saturation and a corresponding drop in product prices.

Articles 11 to 14 were concerned with the relations between the owner of the glass shop (the *padrone*) and his workers (*operai*) (Zecchin, 1989:10). Regulations for the hiring of new workers were also stipulated with the idea that an owner cannot lure a good worker away from one shop to another until the middle of August. Workers were to be given three meals per each day of work and were, in turn, to be loyal to their employer.

The various chapters of the 1271 *Capitolare* provide little indication of the technical aspects of glassmaking or the products manufactured. What information is given comes from Articles 15 to 19 (Zecchin, 1989:10). Production and quality of the glass was controlled by limiting the numbers of working holes *(bocche)* available in each furnace. This was initially set at three, later increased to four (1302), and reduced again to three (1403). The number of holes limited the number of crucibles available to gather glass from and, correspondingly, determined the number of glass masters who could work at any given time. Zecchin also suggests that the limited number of holes served a technical function as the glass was heated for a longer time providing for more fusion and melting and, thus, helping eliminate inhomogeneities in the material (1989:10). Glasshouses were also ordered not to use domestic wood and were restricted to willow or alder wood imported into the city. No Venetian was allowed to sell broken or damaged glass with a penalty of three *lire* for each infraction. Finally, glass for the selling of oil and wine was to be marked with a blue ring, presumably at the neck to serve as a demarcation of volume, and the mark of the Republic of Venice.

The largest collection of articles, 20 to 37, were concerned with the management of the glassmakers' guild (Zecchin, 1989:10-12). For example, violators of guild rules were to be fined 100 *soldi* with half going to the guild and half to the *Giustizia*. The election of the guild's chief officer, the *gastaldo*, was open to all members of the guild and was a position elected annually. Actually, the *gastaldo* was typically limited to the owners of furnaces, and not the workers. The *gastaldo* and his officers were elected each year around Easter and were to receive small compensation for their service. The *gastaldo* had the power to levy small fines, to call meetings, and was to remain objective in guild matters.

The final portion of the *Capitolare* concerned an issue that would be a nagging problem to the guild and the state in the centuries to come - the migration of workers from Murano to other locales (Zecchin, 1989:12). It is interesting to note that this was an issue as early as 1271 and the first notice of glassmakers from Venice working outside the city is from 1256 when they appear in Genoa (Zecchin, 1989:20). Workers practicing outside of Venice were fined 10 *denari grossi* and banned from the guild. Workers were requested to take an oath not to practice outside of Venice. It is this problem which surfaces most in archival information about glass workers up to the fall of the Republic in the late 18th century. Venetian workers are recorded in places such as Mestre and Padua, as mentioned, along with Florence, Pisa, and eventually, all throughout Europe. The problem of worker migration is further discussed in Chapter 8 with respect to the cause of decline in the Venetian glass industry.

Over the next 170 years, modification and additions to the original *Capitolare* would be added before its revision in 1441. Those made between 1316 and 1441 have since been lost but Zecchin has offered an idea of what they may have contained on the basis of examining other archival information. All of these changes were based on the original rules laid down in the 1271 version. Some of these modifications provide interesting and important information on the practice of glassmaking before the Renaissance. For example, a provision in 1306 forbade the use of fern ash as a flux for glassmaking under the pretext that it produced a glass of poor quality (Zecchin, 1989:18). Fern ash was also not allowed for making other products such as soap (1989:24). It was also forbidden to export fern ash outside the city under penalties of fines and confiscation. This creates the interesting question of why it was in Venice in the first place. True, there are examples of special concessions granted to glassmakers for the use of fern ash (a 1318 decree for making mirrors, for example). Fern ash was used for making glass elsewhere in places such as Tuscany and France. One reason is that the state was trying to prevent the exportation of any raw material that might be used in the making of glass in locations outside Venice as well as restricting its domestic use.

Rules were also set forth in 1284 about the times that glass might be sold in Venice, restricting this to festivals and Saturdays when it may only be sold in the Piazza of San Marco (Zecchin, 1989:19). By 1436 a special guild had been created to handle the selling of glass (the *Stazioneri*) (Zecchin, 1989:26, 101-105). Besides vessel glass, additions to the *Capitolare* provide evidence that glass for mosaics and windows was also being made (Zecchin, 1989:25).

The penalties for working outside of Venice also increase notably during this time. The banishment of a transgressor was ultimately abolished in 1315 but the monetary fines increased and prison sentences were also eventually included in the punishment (up to six months by 1424) (Barovier, 1982:14). The issue of glassmakers migrating is strange because they were the ones who often petitioned the State for tougher penalties against their own colleagues. For example, an addition to the Capitolare in 1291 complains of the feeble penalties and asks for the banishment to be reinstated (Zecchin, 1989:20-21). It should be pointed out that there was concern not only for glassmakers leaving the city but also for raw materials used for glassmaking. The state would be involved in regulating both and this will be discussed in the next section. The Venetian government at this time does not seem to have been terribly preoccupied with the threat of migrating glassmakers. The state was more content with intimidating them into staying or with enforcing a difficult reinstatement process when they returned. It is the glassmakers that seem most bothered with this problem (1989:22). This suggests that the craft of glassmaking had not yet developed to the point where it was seen worthy of serious state involvement.

Emerging Patterns of State Involvement

It is somewhat artificial to separate the aspect of state involvment in Venetian glassmaking from the preceding of guild rules as they are intimately related. As discussed in Chapter Five, the guilds of Venice did not possess any political power as they did in other Italian cities. Rather, they were a means for the state to control and monitor production. The guilds had the right to petition the state but they did not constitute a political threat to it. Guild rules (the *Capitolare*) had to be approved by the state and the government frequently made decrees which directly affected the fortunes of the glass industry. It will be left to a later section to show the effects of these policies. What I wish to do here is to illustrate that government intervention in guild business, which was quite common during the Renaissance, had an early basis in preceding decades.

The earliest evidence of such involvement can be found in 1277 when Doge Jacopo Contarini made a treaty with the Prince of Antioch. In this pact, reference was made to broken glass (cullet) which was being imported from the Near East to Venice. The treaty specifies that Venetians must pay a duty on any cullet they import from Tripoli (Barovier, 1982:16). An earlier reference from 1255 also alludes to this trade, mentioning both cullet and natron from Alexandria which was being transported to Venice as ballast on trade ships (Zecchin, 1987:5).

In 1285, the Great Council of Venice made stipulations regarding the export of raw materials used for glassmaking outside of Venice. It was decreed that the removal of cullet, "*alumen* and *sablonum*" (fluxing material, either natron or plant ash although this is not specified, and sand) was not permitted without license from the state (Zecchin, 1987:7). They also made tighter restrictions on the type of wood which could be use for "non-domestic use" specifying that glass furnaces must not use any type other than alder.

The most well-known state involvement in the Venetian glass industry, and one that is frequently referred to in all literature associated with the craft, is the decree of 8 November, 1291. The Great Council decided that all furnaces existing in Venice, especially those near the Rialto, were to be destroyed, and glass furnaces were allowed to be erected at other parts in the lagoon. It has been suggested, on the basis of documents which record the presence of glassmakers at Murano before 1291, that there was already a glass industry established there and that this decree did not result in the wholesale movement of glass furnaces to that island (Zecchin, 1987:8-9; Barovier, 1982:15). The following year, the Venetian government softened this decree slightly, allowing small furnaces used for making non-blown glass such as imitation gems and beads, to remain in Venice provided they were at least five paces from any dwelling. What were the reasons for encouraging the location of the glass industry at Murano? The reason most commonly suggested is that such a move reduced the risk of fire in the city. Being on an island also certainly placed the glassmakers in a position where they could be better monitored and controlled.

I would suggest, however, that this was not part of some sinister state plan to cruelly inhibit the privacy of the Muranese, nor to mold "...the glassmakers into a tightly knit, proud, and secretive community." (Klein and Lloyd,1984:68). The mythology of the industry is seen at work when Gardener writes "This isolation was intentional because the industry had become so important to the Venetian economy...any glassworker who left the island was placed automatically under a sentence of death." The glassmakers are described as "virtual prisoners" (Gardener, 1979:33). Rather, I interpret this as part of a deliberate economic plan enacted by the state which affected other industries besides glassmaking. Numerous Venetian industries were structured in such a way so as to be concentrated in one area. Examples include the ship building industry located in the Castello district at the Arsenale, the craft of lace making in Burano, the wool makers at Torcello, and the traditional location of the jewelers and other business activities near the Rialto. This practice, in a general sense, is analogous to the modern creation of industrial parks and suburbs where particular industries cluster alá Silicon Valley. The Venetian state most likely encouraged a phenomenon that would have occurred naturally and more gradually - the nucleation and growth of an industry in a favorable and distinct setting.

Numerous examples exist in the years prior to 1450 of state involvement in the glass trade (Zecchin, 1989:23-28). The establishment of a special guild to handle glass selling in 1436 is a particularly notable one. Special concessions were granted to German merchants as early as 1282 regarding the exportation of glass from Venice. This decree cancels any duties that must be paid by German merchants transporting glass to the north, provided that the value of the glass does not exceed 10 *lire*. As Zecchin notes, this is no small amount of glass; 10 *lire* in 1282 was equivalent to about 1300 pieces of common glass (Zecchin, 1987:7). This ruling also indicates that the glass trade with Germany was well-established by this time. A notice from 1366 states that a "great quantity of glass each year goes from Venice to Germany" and enacts a duty of one *soldo* for every *lira* of glass sold (i.e. 1/20th the value) (Zecchin, 1987:25).

Many more examples exist between the years 1300 and 1450 of state involvement in the industry. I would like to draw attention to two more cases. In April 1384, the Venetian government enacted stronger measures to prevent the export of "*lumen catinum*" from Venice (Zecchin, 1987:29). This is one of the numerous words in the original archives used to denote the soda-rich plant ash imported from the Near East and used in several industries including glass and soap making. The policy of the Venetian government was very protectionist in regards to this material and was designed to eliminate the supply available to other countries. Similar decrees were enacted in 1315, 1332 and 1468 but these must have been of questionable effectiveness as a 14th century merchant's manual lists "*allume catino*" as one of the commodities available for purchase in Venice (Cevidalli and Ashtor, 1983:513; Zecchin, 1990:17). In 1384, the penalties for trading in this commodity increased from fines that were 25% the value of the ash to 100% of the ash's value. In addition, the ship transporting the ash was to be burned and the captain put in jail for six months (Zecchin, 1990:180). The issue of raw materials being exported has been linked to the other major problem of worker migration. In order to induce glassmakers to work outside of Venice, the owners of glass furnaces needed a supply of adequate raw materials. Depriving foreign furnaces of these discouraged worker movement (Jacoby, 1993:72). These new and much more stringent rules regarding the traffic in soda ash has been seen as a sign of increasing interest in the glass industry by the Venetian state which before has been characterized as somewhat tepid (Zecchin, 1990:397).

Further evidence for this increased interest is seen in a ruling from 1403. The Venetian state made three decrees concerning both worker migration and glass quality. The annual vacation period was reduced by about one month to decrease the migration of workers from Murano. Stricter fines were imposed on those who left (100 *lire* and three months in prison). Lastly, the number of working holes at each furnace was reduced to three again to maintain glass quality (Zecchin, 1987:34-35).

As detailed in Chapter Five, during the course of the late 14th and early 15th century the territory of the Venetian Republic expanded, especially to the land east of the city (the *Terraferma*). This expansion was accompanied by a greater number of towns and small cities brought under Venetian control. Many of these towns, such as Treviso and Verona, had active glass industries. The Venetian government was forced to enact legislation allowing these industries to continue to operate but under greater control and scrutiny. The trade in soda ash to these cities was one of the details negotiated with these new territories. In all cases, the glassmaking interests of these towns took a lesser position in comparison with the home glass industry of Murano. The favoring of the Venetian industry over other local competition would go so far as the eventual destruction of glass furnaces in Treviso, Padua, and Vicenza in the late 16th century by order of the Venetian government (Zecchin, 1989:299).

These examples illustrate that the involvement of the Venetian government in activities related to glassmaking was present in the decades prior to 1450. This involvement of the State, coupled with guild regulations, would continue and expand throughout the latter 15th and 16th centuries. The involvement of the government in Muranese glassmaking is one of the characteristic features of the industry. In Chapter 8, it will be shown that this involvement served as both a stimulant and inhibitor on the performance of the industry.

Early Product and Labor Specialization

Another representative feature of the Renaissance Venetian glass industry that has its origins in the preceding two centuries is increasing specialization in both products and labor. In a general sense, the greater specialization of the Venetian guild system in comparison to its contemporaries in other cities has been noted (Goldthwaite, 1980:245). By the beginning of the 14th century, the furnaces of Murano were manufacturing a variety of products. These included, of course, blown glass of both common and luxury categories. In addition, were glass windows, mirrors, enamels, beads, mosaic glass, and glass made in imitation of rock crystal. All are mentioned in pre-Renaissance archival sources. This latter product is particularly interesting for several reasons.

By 1284, the workers of naturally occurring rock crystal had formed their own guild and had written a "*Capitulare de Cristellariis*". Among the surviving guild rules is one which forbade its members from using "*vitrum blanchum*" ("white" or colorless glass) in place of rock crystal (Zecchin, 1987:239). Within 25 years, these rules would be amended to allow the use of glass in the place of rock crystal provided the vendor was honest about identifying it. Imaginably, the products of Murano posed a threat to those working in rock crystal. Rock crystal was used for making beads, vessels, fake gems, and components of a newly emerging technology - optics. Glass, properly manufactured, could be substituted for any of these. The fact that the workers of rock crystal forbade and regulated the use of glass means that glass production had developed to the point where it had begun to rival rock crystal. The invention of *cristallo* glass in the mid-15th century was a further refinement of *vitrum blanchum* and would introduce even greater competition. The concern of the rock crystal workers indicates that, even at a very early stage, the Venetian glass industry had developed specialized and high quality products.

The presence of specialized products may also be considered by looking solely at vessel glass. As early as 1276, there is evidence that Murano was making vessels designed specifically for foreign markets (Gasparetto, 1979:96-97). In the oldest record of glass being exported from Venice to the Near East there is a distinction made between glass beakers with feet for domestic use and those sent to Románia, a name designating the lands of the Imperial Latin Empire (Barovier, 1982:18; Zecchin, 1990:6). Later reference note the manufacture of glass modelled after shapes typical of other regions and cities. For example, there is a notice from 1311 of one thousand "*bicchieri gambassini*" - glasses copying a shape prevalent in Gambassi, a town with local tradition of glassmaking located near Florence (Zecchin, 1987:12). Other similar indications may be found such as the 1425 mention of "*moioli fiorentini*" made in imitation of a popular Florentine form (Zecchin, 1990:143). Other names for glass shapes abound in the various archival sources, several of which are no longer identifiable. This variety of forms, besides indicating ties between the glass industry of Venice and other regions, clearly shows the early presence of specialized production. This type of manufacture would continue to become more specialized during the Renaissance to the point where glass vessels would sometimes be custom made for specific clients.

Besides product specialization, one begins to see greater and increasing labor specialization. This takes the form not only in the categories of jobs that appear in the management of a pre-Renaissance glasshouse but also in the tools being used and modifications made to the working area. Many of these tools developed as production techniques were modified (Zecchin, 1990:173-188). In conjunction with new tools, different categories of workers appear. For example, the term "*stizator*" appears first in 1280 (Zecchin, 1987:7). Later modified to "*stizador*", this was the person responsible for the furnace. Another term for this person was the "*furlan*"; this word is derived from"*friulano*", i.e. a person from the nearby region of Friuli. As foreigners had their work restricted in the glass industry, persons not of Muranese origin often had to settle for simpler occupations. If he worked at night, he was referred to as the "*furlan de note*" (Various, 1985:70). Another term indicating labor specialization appears in 1400 - the *fattore* (Zecchin, 1987:34). This person was the clerk responsible for the business dealings and paperwork of the glasshouse. This person did not participate directly in the making of glass and was, therefore, another position open to foreigners (Zecchin, 1990:68). The job requirements necessitated that the *fattore* be able to read and write. The creation of a special guild for handling the retailing of glass, the *stazioneri*, in 1436 offers another example of further specialization. There were additional labor positions that would develop during the Renaissance; the hierarchy and structure of a Renaissance glasshouse will be considered further in the section on production.

Glass Trade - East and West

During the Renaissance, as will be shown, the glass industry of Venice and its products were exported all over Europe and other parts of the world resulting in a style that glass scholars call *facon de Venise*. This phenomenon has its origins in the development of the industry in the years before the invention of *cristallo* glass in the 1450's.

The unique geographic position of Venice coupled with the city's maturing trade networks and economic structure resulted in the establishment of organized trade with countries and cities in the East and the West. The glass trade between Germany and Venice existed as early as 1282. This trade in glass vessels continued to develop; in 1348 two merchants from Salzburg are noted for acquiring glass at Murano (Barovier, 1982:19). The presence of "*Gregorius teutonicus, ligator vitriorum*" is recorded in 1417. This person, of German origin, served as a commercial mediator between glassmakers and German merchants. The fact that the glass shops of Murano were manufacturing products specifically for the German market is made clear in two archival citations of 1407 and 1446 which mention "*vetri teutonici*" (Zecchin, 1987:37, 48).

An archival reference of 1446 also provides evidence of trade between Murano and France. Here, an inventory list of a glasshouse records 800 "*gobelleti*", a derivation of the French "*gobelet*". An early notation in the inventory of Giovanni di Francia, the Duke of Berry, confirms this trade in the entry " ...a certain quantity of glass made at Venice." (Barovier, 1982:20). Other areas of Europe where Venetian glass was arriving include Vienna (1354 and 1360), Krakow (end of the 14th century), Flanders (1394), and England (1395 and 1399) (Zecchin, 1989:26-27). This last citation is especially interesting as the Venetian ship captains were granted a ten year accord for the selling of glass in English markets.

The expansion of the glass trade was not limited to other parts of Europe. Records exist which clearly indicate Venetian glass was being widely distributed throughout northern Italy. Glassmakers from Murano are recorded in a great number of cities (Treviso, Padua, Verona, Ancona, Mantua, Ferrara, Ravenna, Bologna) despite the efforts of the guild and State to limit their movement. The trade in glass coincided with their movements. A record of 1417 states that glass valued at 630 *lire* was exported from Murano between January and August with 2/3 going to Treviso (Zecchin, 1987:41; 1990:23). A similar list for 1423-24 records the exportation of 2700 *lire* worth of glass in about 180 consignments. These shipments went to Mestre, Treviso, Friuli (500 *lire*), Istria (about 1000 *lire*), Trieste and other cities in the Veneto. The types of glass are not recorded but is reasonable to assume that this record refers to common glass. The quantity of glass exported is impressive. Using prices for *vianardi* ("common" or utilitarian glass) from 1425, 2700 *lire* was equivalent to about 54,000 pieces of glass! This large scale of production is another feature of the Venetian glass industry. After 1450, the scale of production would increase even more leading one to consider adjectives such as "factory-style production" to describe the industry. More will be said about this in Chapter 8.

The traffic in glass and glassmaking materials was not limited to contacts between Venice and the Western cultures. Venice's trade contacts with the East allowed glass products and raw materials to move quite freely. The early export of glass made for Románia in 1276 has already been mentioned. In 1291, the presence of a Greek glassmaker at Murano is noted (Zecchin, 1987:9). In 1345, traffic in glass is indicated in the correspondence of a Pisan merchant, now a Venetian citizen, between Venice and Rodi, an island north of Crete (Zecchin, 1987:20). In this case, the merchant notes having received the case of glass sent to him.

A greater volume of trade, this time with Constantinople, is indicated in correspondence of 1437. In this case, a Venetian citizen received four cases of common glass containing some 2500 pieces of glass for the complete price of 25 ducats. The merchant mentions that he will give some of the glass as gifts and sell the rest at a profit (Zecchin, 1987:46, 242). Commerce with Constantinople was not limited solely to glass. Several documents of the 14th and 15th centuries record the presence of clay or crucibles made from clay which originated in Constantinople (Zecchin, 1990:28,186). An inventory of a glass house in Murano records 13 crucibles made with clay from Constantinople at a cost of one ducat each.

The arrival of clay from Constantinople is an example of a feature that would characterize the Venetian glass industry - the importation of raw materials and the exportation of finished goods. As mentioned earlier, all raw materials for the glass industry had to be imported into the city. The best example of such trade is the importation of high quality plant ash, rich in sodium, from the Levant. It is the availability of this raw material that has been cited by some as one of the contributing factors in the successful development of the Venetian glass industry (Ashtor and Cevidalli, 1983). Records of its use date as far back as 1313 (Zecchin, 1987:13). The continued refinement and processing of this ash, is response to market demand, was also one of the key innovations behind the success of *cristallo* glass in the 1450's (Verita, 1985; Jacoby, 1993).

Finally, another aspect of trade and contacts between the pre-Renaissance Venetian glass industry and the East occurred in the area of glass enamelling. I will discuss this in more detail in the next two sections because of its presumed role in the emergence of the Venetian luxury glass industry. For now, let it suffice to say that the presence of certain glass enamellers as well as their products gives another clear indication of the contact between Venice and the East.

By all accounts, the Venetian glass trade was expanding, especially at the end of the 14th and early 15th century. This increase in trade took place towards the East and West and included the movement of both glass and raw materials. This commerce increased greatly after the mid-15th century. I have shown that the conditions for this expansion pre-existed. The expansion and penetration into new markets contributed to the social and economic circumstances which would encourage the development of *cristallo* glass in the 1450's.

Products and Glass Compositions of the Pre-Renaissance

One of the earliest and most common forms was the *inghistre* (and its numerous paleographic variations). The name is derived from two Greek words - *angusto* (narrow) and *gastra*. This was a long-necked, handleless, globular jug with a splayed foot which often protruded into the body. This vessel was used to hold and dispense liquids (Mariacher, 1964). A 19th century dictionary of old Venetian dialect indicates that the *inghistera* was the measure of wine sold in small quantities in Verona (Zecchin, 1990:163). Figure 6.1 illustrates an example of an *inghistre* excavated from the Venetian lagoon; Figure 6.2 shows 2 other *inghistre* found in better condition. This form was quite durable with respect to time and examples of *inghistre* appear in paintings well into the 16th century. Barovier offers a discussion of the various decorative motifs which would appear on these vessels such as applied threads to the neck and a particular type of bottom (Barovier, 1982:22). A glass house inventory of 1446 provides an a clue to this diversity, recording "*inghistre formade*" (mold-blown), "*inghistre informate*" (free-blown), and "*inghistre todesche*" (made for the German market or made to look like German forms) (Zecchin, 1990:163). Many of these vessels were of various sizes and marked with a blue ring at the neck corresponding to the Venetian government's practice of having glass containers made of standardized sizes for the selling of liquids such as wine and oil. Distribution practices such as these are recorded as early as 1296 when glassmakers were to be paid 5 *lire*/100 pieces by the state for their manufacture (Zecchin, 1987:10).

Another very common form was the *moioli*; this term refers to ordinary drinking glasses usually shaped like tumblers. These were made in the thousands according to inventory lists. A very early mention of this form dates to 1280 (Zecchin, 1987:7). As with *inghistre*, paintings record the continued production of these vessels well into the 16th century. Different decorations applied to these pieces include threaded ornaments, some of which were applied to the base and pincered ("*ghirlanda*") as well as applied drops of glass ("*perle*"). Figure 6.3 provides an illustration of one such 15th century type held at the Museo Vetrario in Murano. Fragments of vessels such as this have been found at sites throughout the Veneto and along the Adriatic coast (Barovier, 1982:23-25). There are numerous examples of variations on the basic *moioli* form. These include "*moioli schietti*" (without decoration), "*moioli fiorentini*" (in Florentine fashion), "*moioli da piede*" (with feet), and, most interestingly, "*moioli cristallini*" (Zecchin, 1990:164).

This latter term appears in an inventory list from a shop in Verona from 1409 (Zecchin, 1989:298). It has been argued that this terminology suggests that the famous *cristallo* glass was invented much earlier than imagined and that the entire development of this material needs to be re-considered (Jacoby, 1993:86-88). This is in disagreement with Zecchin's earlier suggestion that the adjective "*cristallini*" refers to the form and not to the material of the vessel (Zecchin, 1987:237). Zecchin's view is supported by the fact that another inventory list mentions a mold for this type of glass - *forma di cristallini* - from a Muranese document of 1405 (Zecchin, 1987:35). Jacoby argues that the semantic development should indicate the "material" come first followed by the "form". In addition, the price of the glasses that are "*moioli cristallini*" (28 *soldi*/100 pieces) are almost twice as much as those which are "*moioli da filo*" (18 *soldi*/100 pieces and with threaded design) as shown in a list from 1425 (Zecchin, 1990:143; Jacoby, 1993:86-87). Barovier suggests that the term "*moioli cristallini*" simply refers to glass made in imitation of forms traditionally of rock crystal which could account for their high price. Other objects in the same inventory list, of different shapes, are just as or more expensive than those presumably made of "*cristallino*" glass. All of the mold designs mentioned in the variety of inventory lists available refer to shapes and not to the type of glass that would be blown into them. Since we have no indication of what the shapes of these vessels were, this cannot be proved although it seems more likely (Barovier, 1982:25). This issue will be taken up again in a later section and expanded upon when the development of *cristallo* is discussed.

Other types of vessel glass appear frequently in the different inventory lists available between the late 13th and mid-15th century. Often it is not possible to determine exactly what these objects looked like. Examples from a list of 1446 include "*cesendelli*" (hanging lamps), "*gobelleti*", "*vianardi*" (a term for ordinary vessel glass), "*tazze*" (shallow footed bowls) and "*boccali*" (Barovier, 1982:25; Zecchin, 1990:161-162). The majority of glass in these lists, and the prices accompanying them, refers to "common" glass - vessels made for everyday utilitarian consumption.

Until very recently, there has been no typology proposed to account for the variety of glass forms made by glassmakers of the pre-Renaissance (Stiaffini, 1991:179-266). This typology treats the entire scope of Italian glass from museums and excavations from the 8th to the early 15th century. Taking one century for examination here, the 14th, we see expansion in both numbers and forms of glass vessels throughout Italy, mirroring the events taking place in Murano. Besides window glass and lamps, there is a variety of glass made for medical uses (Stiaffani, 1991:225). In Muranese documents, these objects appear as "*ornali*" and presumably were used for diagnostic purpose (Zecchin, 1990:162). In terms of vessel glass being produced in Italy, Stiaffini documents the greater presence of ordinary bottles and drinking glasses as well as lesser amounts of chalices, "*coppe*", "*ciotole*" and other forms (1991:228). The circulation of forms, common to one region such as Florence or Gambassi, into the work shops of Murano, is noted. Stiaffini has divided the different vessel forms of the 14th century into several categories based on form and presumed function. The predominant colors of glass in this typology are clear and colorless with various unintentional tints such as yellow, blue, and green arising from impurities in raw material. Stiaffini detects a Near Eastern influence in many of the forms examined in the course of the entire typology (1991:257). She notes changes apparent in the organization of production throughout the different shops of Italy, citing more diverse forms and greater specialization. The appearance of certain decorative techniques that would figure prominently in Renaissance glass production at Murano are noted such as the use of opaque white glass (*lattimo*) and half-stamping (*mezza stampura*) (Stiaffini, 1991:258). As the typology considers some glass of the 15th century, the appearance of forms which anticipate Renaissance production is present.

Stiaffini's typology is primarily oriented towards a consideration of "common", as opposed to luxury glass. For this aspect, the typology is useful as it considers glass which is largely ignored and under-represented in most museum glass collections. Such collections are largely composed of glass that is the focus of work - luxury glass. In this respect, the preliminary typology proposed by Stiaffini provides a counterpoint to a discussion of these typically more refined and higher quality wares. A good overview of the shapes of pre-Renaissance vessels can be seen in the 1982 catalogue *Mille Anni di Arte del Vetro a Venezia* (Various, 1982:59-71).

Another way of delineating the different glasses products made in pre-Renaissance Murano is by their chemical composition. Verita has published a preliminary study of Venetian glass from the 8th through the 14th century (1990). In his analyses of 31 glass samples from sites in Venice and the Veneto, he identified three basic glass compositional categories, the averages of which are reported below:

Table 6.2. Average glass compositions (in weight %'s) for Venetian samples, 8th-14th century (from Verita, 1990).

Oxide	9th - 13th century	11th - 14th century	8th - 12th century
SiO_2	66.7	63.7	68.6
Na_2O	17.4	13.7	13.1
CaO	7.9	8.0	8.1
K_2O	0.7	2.5	2.3
MgO	1.1	2.4	2.7
Al_2O_3	2.4	4.4	1.8
Fe_2O_3	1.0	1.5	0.6
MnO	0.8	2.0	1.1
Cl	1.0	1.0	0.9
SO_3	0.3	0.1	0.2
P_2O_5	0.1	0.5	0.3
TiO_2	0.2	0.2	0.1

The first group has a composition which is similar in nature to the Roman-era glasses fluxed with natron discussed earlier. Note the low value of K_2O and

MgO. There is archival evidence from at least the 13th century indicating active trade in both natron and cullet from the Near East (cf. Zecchin 1987:5). Manufacture of glass and remelting of cullet with these raw materials would result in glass having a composition similar to the first group.

The second group was produced between the 11th and 14th century using soda-rich plant ash from the Near East as a flux but with a low and variable quality sand as the vitrifying agent. The use of a poor quality sand is evident in the higher titania, iron, and alumina contents. The high iron content was noticeable in similarly dated samples that I examined which all had a strong green or yellow color that was not the result of intentional additives. This group has a much higher percentage of manganese added to offset these impurities. The use of a plant ash flux is confirmed in the higher contents of potassia, phosphorus, and magnesia as compared with the first group.

The third group was also produced using a soda-rich plant ash from the Near East but was made with a much higher quality source of silica. By the 14th century, Venetian glassmakers had switched from the use of sand as a vitrifying agent to quartz pebbles. There are records of this raw material, referred to as "cogoli", being used as early as 1332 (Zecchin, 1987:17). There were several sources of these quartz pebbles, all of which were located outside of Venice. An analysis of one of these stones is given in Appendix One (UA-8). The use of these quartz stones resulted in lower amounts of iron, alumina, and titania with smaller amounts of MnO needed to offset the discoloration normally produced by imputities. These last two groups identified by Verita are compositionally similar to the glasses that would be made at Murano during the Renaissance (1990:174).

The second group would be a glass typically used to make "common" vessels while the third type is an indication of early production of "*vitrum blanchum*". This latter type of glass was intermediate in quality between "common" glass and the more colorless and clear "*cristallo*" glass made in the mid-15th century. These distinctions will be elaborated upon and explained in Chapter 8 concerning Renaissance production. It is the "*vitrum blanchum*" compositions that the rock crystal workers of Venice were concerned with when they specified that no one could fabricate objects of glass and pass them off as rock crystal (Zecchin, 1989:239).

The compositional distinctions between the latter two groups as noted by Verita were also seen in my analyses of glass samples from the sites in Venice. For instance, compare the compositions of a greenish piece of glass from San Leonardo (SL-8) and a piece of clear and colorless glass from San Arian (PE-149). These results are taken from Appendix One which contains more information on the samples and analyses. The first sample dates to between the 11th and 14th century while the second is from the late 13th century.

Both of these glasses were made with a soda-rich plant ash flux as indicated by the higher amounts of K_2O and MgO. The difference between the two is in the amounts of iron, alumina, other minor oxides present in the glass. Notice that PE-149 has a much lower percentage of iron and manganese oxides present. This primarily was the result of the use of lower quality sources of silica in preparing compositions such as SL-8. Because PE-149 was prepared with a higher quality

Table 6.3. Venetian glass analyses of two pre-Renaissance samples showing major oxides (in weight %'s).

Oxide	SL-8	PE-141
SiO_2	65.7	71.7 (0.8)
Na_2O	12.2	12.2 (.04)
CaO	10.0	9.0 (0.2)
K_2O	2.0	1.9 (0.2)
MgO	2.3	2.6 (0.3)
Al_2O_3	4.1	0.8 (0.1)
Fe_2O_3	1.4	0.3 (0.2)
MnO	1.6	0.2
Cl	ND	0.7
SO_3	ND	0.3
P_2O_5	0.1	0.3 (0.2)
TiO_2	0.2	0.1

SL-8 analyzed by ICP-AES; PE-149 analyzed by SEM-EDS; standard deviation for SEM-EDS analysis reported in ( )'s; see Appendix One for more details on the analytical procedures followed.

source of silica, the percentage of this component is greater. Visually, the difference between the two samples is striking. SL-8 has has a strong yellowish-green tint where PE-149 is practically colorless.

Verita's conclusion regarding the different compositional groups used during the pre-Renaissance period in Murano is that a transition occurred sometime between the 9th and 13th centuries from a natron fluxed glass to one made with a soda plant ash (1990:174). This latter composition would become the basis for the glass made in the Renaissance and its continued refinement would ultimately result in the production of *cristallo*. Possible reasons for this transition are not offered by Verita. These could be related to issues of supply or the gradual realization that glass fluxed with soda ash produced a material that was superior, in some manner, to that made with natron. These possibilities are considered later.

Pre-Renaissance references to luxury glass production at Murano are scarce. A large portion of the archival references to glass, as seen from the preceding discussion, are oriented towards "common" glass. For any early indication of luxury glass versus common glass, one must compare the prices of different pieces to obtain indications of differential production. Even this is difficult as a shape that is merely more complicated could result in a higher price. For example, an inventory from 1288 records 4000 "*campanili*" (an unknown form) selling for 30 *lire*. In the same list, 600 cups with feet are priced at 15 *lire*. The latter are worth 3 1/3 as much as the former suggesting some type of differential and stratified production (Zecchin, 1987:6). Also, the use of higher quality raw materials could cause a change in the price. Barovier notes the activity in Venice of late 13th century workers in glass and incised gold leaf. Here, glass was used in place of the more expensive rock crystal. An inventory of 1295 records a glass and gold leaf icon made in Venice in the collection of Pope Boniface VIII (Barovier, 1982:26).

However, Venice was not a center for the production of objects such as these and Barovier notes that their manufacture was not strictly connected to glassmaking.

The best objects to illustrate the differential production between "common" and "luxury" glass in the pre-Renaissance era are a group of late 13th and early 14th century enamelled glass beakers. This category of objects has been discussed quite exhaustively from both a stylistic and compositional perspective in a series of recent publications (ex: Tait, 1979; Whitehouse, 1981; Barovier, 1982; Zecchin, 1990; Pause, 1993; Freestone and Bimson, 1995; Verita, 1995). For this reason, I do not wish to dwell extensively on these pieces but would rather feature the salient points relevant to the question of Renaissance-era glassmaking.

These objects are frequently referred to in the literature as the "Aldrevandin" group. This is because of the inscription on one of the best preserved examples held in the British Museum which has the words in Latin - "Master Aldrevandin made me" - enamelled on it near the rim. This beaker was originally thought to be one of the few surviving pieces of early enamelled glass. Recent excavations throughout Europe have revealed a greater variety and amount of fragments (Pause, 1993). Sherds of similarly enamelled glass have been found in excavations from Ireland to Estonia and from Sweden to southern Italy including the Veneto (Pause, 1993:236).The sherds and whole vessels are dated from about 1280 to 1350 and number about 50. (Verita, 1995). Many of these fragments bear inscriptions similar to the one mentioned above. According to Verita, the general features of the group are:

- the use of colorless and homogenized glass as a substrate for enamelling
- the general, beaker-shaped appearance with a slightly flaring rim
- the practice of enamels often applied to both sides of the glass
- the decoration including coats-of-arms, floral patterns, Latin inscriptions, et cetera.

It was previously thought that such vessels were the product of a Syrian workshop where they had been made for Crusaders (Lamm, 1941). At this time, few examples of such glass were known. Another possibility is that these cups were made north of the Alps due to the large number of finds there but no documentary evidence exists to support this hypothesis (Verita, 1995). As more examples are discovered, the general scholarly consensus has been that they are instead the products of a workshop(s) in Venice (ex: Whitehouse, 1981:172).

This conclusion is based on two bodies of evidence. One is the fact that the beakers do not stylistically resemble objects made in the Near East at this time, although glass enamelling was practiced there. Typically, the enamelling is less sophisticated than that on Islamic pieces. In addition, there is a large body of archival and documentary evidence, most of it brought to light by Zecchin, which shows conclusively that the craft of glass enamelling was practiced in Venice in the late 13th and early 14th centuries (Zecchin, 1990:109-130). The earliest such record is from 1280 which records the presence at Murano of Gregorio of Napoli (a region in Greece near Corinth) who was a "painter of glasses" (Zecchin, 1987:6-7). This craftsman is cited numerous times between 1280 and 1288. In the following years other glass painters are noted as well. For example, there is Bartolemeo of Zara (a town along the coast of the former Yugoslavia) in 1290. This person is recorded as being paid 24 *soldi*/100 pieces for painting "3 figures with a floral motif" (Zecchin, 1990:117). Note that this decorative pattern appears often on these glasses. The brother of Bartolemeo, Donino, is also noted as being a glass painter. Bartolemeo was active until about 1317 in Venice. In 1331, there is the notice of one "*Aldrevandino fiolario*" in Venice, possibly the same as the person's name on the famous piece in the British Museum (Zecchin, 1987:17). A final reference is to "*Petrus pictor*" (Peter the painter) working at Murano in 1348 as a decorator of glass (Zecchin, 1987:23). This is the last record of glass enamelling at Murano for about the next 100 years.

Together, these bodies of evidence suggest quite clearly that glass enamelling was being practiced in Venice on a fairly wide scale. But what evidence is there that these enamelled objects represent a more refined branch of glassmaking? Firstly, the quality of the glass substrate is generally higher than that seen for "common" vessels. Secondly, is the more labor intensive operations required to produce the enamelled glass pieces. Their manufacture required a second heating step to affix the enamels to the underlying glass. The more time and labor intensive production did result in higher prices for these pieces on the market. For example, Gregorio of Napoli painted 3 figures with a floral motif for 24 *soldi*/100 in 1290. This did not include the price of the glass itself. Compare this price with that of 600 chalices with feet which cost 150 *soldi* in 1288 (Zecchin, 1987:8). The cost of the enamelling alone is about equal to the price of these more complicated forms. As Barovier points out, the price of the enamelled wares are about 2 1/2 times that of other glass products suggesting a higher quality group of pieces with more elaborate workmanship (1982:29). The scale of output of these glass painters who worked in combination with Muranese glass workers is quite impressive as well. Based on a citation from 1287, Gregorio painted about 4400 glass objects for "*Geraldo fiolario*" to cancel a debt (Zecchin, 1990:115). A final piece of evidence which clearly shows that "luxury" style glass was being made as early as the late 13th century in Venice comes from the sites where many of these enamelled beakers have been discovered. Pause notes that many of them are found in southern Germany with German coats-of-arms. Similar examples have been found in southern Italy. His conclusion is that they were made for wealthy families of the Middle Ages (Pause, 1993:237).

Another very important connection that emerges from consideration of these objects and their history is the origins of glass enamelling in Venice and its connection with other production locations in the Mediterranean. Several recent papers have addressed this question (ex: Freestone and Bimson, 1995; Verita, 1995). The first, and most obvious, piece of evidence is the origin of several of the glass painters who are recorded as active in late 13th and 14th century Venice. Three of these glass painters are not from Venice, but from places such as Napoli or Zara. These persons were not from the Near East specifically but an intermediate region between the Levant and Venice. The craft of glass enamelling and gilding was well-established in the Near East, in cities such as Aleppo, Tyre, and Damascus, from the 12th century with lustre painting practiced earlier (Tait, 1991:125-131). The glass shops of Byzantium were also active in the practice of enamelling, probably doing so before their counterparts in the Levant (Tait, 1991:130). Zecchin has proposed that the early glass painters, such as Gregorio of Napoli, introduced the practice to Venice (Zecchin, 1990:116).

Besides the origin of the glass painters, the glass vessels themselves indicate ties between Venetian and Near Eastern production. There are two discernible categories among the "Venetian" enamelled wares. The first has a more tapering Islamic form with enamelling on one side only. The other category, the enamelled Aldrevandin group, is typically described as more primitive than their Near Eastern counterparts (Freestone and Bimson, 1995). For example, the enamelling is often done on both sides of the glass surface with the borders and outlines on the outside and the infilling of these areas on the inside. This has been interpreted as a less sophisticated solution to the problem of color separation. This, along with the absence of gilding on the vessels, separates the Aldrevandin group made in Venice, presumably, from those enamelled pieces of the Near East. Several pieces of the Aldrevandin group have a yellow enamel applied in the place of gilded decoration. These differences are seen as part of an experimental rather than established phase of glass production (Tait, 1979:12).

Analyses of the Aldrevandin glass also suggests close parallels with Near Eastern production. The following table illustrates the compositional similarities of the clear and colorless glass used as a substrate for enamelling (from Henderson and Allan, 1990 and Verita, 1995).

Table 6.4. Average chemical composition (in weight %'s) of 10 Aldrevandin beakers compared with 7 Islamic glass samples.

Oxide	Venetian	Islamic
SiO_2	67.9	68.9
Na_2O	12.7	11.7
CaO	10.1	7.9
K_2O	2.5	2.6
MgO	3.4	3.4
Al_2O_3	1.1	1.1
Fe_2O_3	0.4	0.4
MnO	0.5	1.2
Cl	0.9	0.8
SO_3	0.3	0.2
P_2O_5	0.4	0.3
TiO_2	<0.1	0.1

These analyses show a very close similarity in compositions between the Venetian and Islamic glasses. Both are a soda-lime-silica glass type fluxed with plant ash rather than natron. The Venetian glass is essentially a *vitrum blanchum* type of glass, similar to PE-149 described above, and made with a very pure source of silica such as quartz pebbles. The Islamic glasses show a lower amount of CaO, possibly due to the use of soda ashes with a different Ca:Na ratio. The Islamic glasses also have a higher percentage of MnO added as a decolorant, indicating that Levantine workshops probably did not have access to the purer sources of silica available to the Venetians (Verita, 1995).

The compositional similarities between the Venetian and Islamic glasses do not end with the underlying colorless glass. Analyses of the enamels show similarities also. For example, blue enamels of both groups use a zinc-rich source of cobalt. Geologically, zinc enriched cobalt ores are not common. Other examples of zinc-rich cobalt colorants are seen in Syrian ceramic glazes. Freestone and Bimson suggest that a zinc-bearing pigment was traded widely during the late Medieval period (1995). Studies of transparent blue glasses from Venice made in the late 15th and 16th centuries do not have zinc present. Unpublished work by Verita suggest the use of a different source of cobalt that was enriched with tin, arsenic, and nickel, instead. See UA-20 or PE-44 in Appendix One, for example. Also Brill has presented analyses of blue vessel glass from the Gnalic wreck which confirms this (1973). Other colors of Venetian enamels are also quite similar to those from the Near East.

A very close relation between Venetian and Islamic enamelled glass is therefore suggested (Freestone and Bimson, 1995). What was the nature of the movement of technology between the two regions? Did this occur by worker migration or trade of raw materials and finished products? Incremental transfer of enamelling knowledge does not seem likely as there are no examples of enamelled Venetian glass with only one or two colors. The lack of gilding, however, on the Aldrevandin glass shows a difference in technology and taste compared with the products of the Islamic workshops. The craftsmen recorded in Venice are not directly from the Levant. The lack of gilding suggests an indirect link as a craftsperson from the Near East would presumably have had knowledge of both enamelling and gilding. These were commonly practiced in conjunction with each other there. Gilding in the Islamic world was done by suspending the gold in solution and then applying it. When gilding was adopted in Venice, the technique was done differently by using whole pieces of gold leaf which were applied to the vessel. (Tait, 1991:148; Lammon, 1993:3).

Freestone and Bimson suggest an alternative explanation in the form of pigment trade or possibly in the transfer of the prepared enamels themselves (1995). Other traffic in glassmaking raw materials, such as cullet and ash, from the Near East has been noted previously. In 1400, the glass industries of the Near East were essentially destroyed by invaders led by Timur. Presumably, this could have halted the production and traffic of the zinc-rich blue enamelling material, forcing the Venetian industry to find an alternative source and leading to the use of arsenic and nickel rich cobalt ores from Germany as noted (Verita, 1995; Zecchin, 1990:187).

The first period of Venetian production of enamelled glass ended, or at least experienced a marked decline, sometime after 1350. After this date, there are scant documentary references and no enamelled glass pieces until at least the 1460's (Zecchin, 1990:118). Demand for these, the best known of the early Venetian luxury glass production, clearly dropped. As pre-Renaissance demand for glass is not well known, especially in the luxury market, the reasons for this decline are unclear. As for the next period of Venetian luxury glass production, one must next turn to the mid-15th century and the development of *cristallo*.

Questions of Origins and Influence

The possibility that the Venetian glass industry was a direct product of the glassmaking activities at Aquileia and Torcello can be dismissed. There are several centuries of silence in the field of glassmaking between production at these different sites. As analyses of the glass have shown, the glass made at Aquileia and Torcello was derivative of the Roman industry whereas the nascent Venetian glass industry may be seen as having more in common with both Byzantine and Islamic traditions.

The clear connection of the Venetian industry to the Islamic glass workshops is apparent in light of traffic in ash, pigments, and cullet as well as the similarities between Venetian and Islamic enamelled production. The Islamic industry was effectively eliminated in 1400 when the cities of Aleppo and Damascus were taken by Timur. Tait has interpreted these events as helping to stimulate the rise of the Venetian luxury glass industry in the mid-15th century (1979:12). After 1400, little luxury glass is known to have been made in the Near East and the conclusion is that Venice stepped to fill this void in production.

However, this explanation seems too simplistic and does not account for the 50 year gap between the ruin of the Islamic industry and the first hints of a resurgence in Venetian luxury glass production. Indeed, as we shall see, the Venetian glass industry's fortunes were cyclical in nature, and notable declines in production occurred in the first part of the 15th century. Clearly, other forces were at work to encourage the later resurgence and re-establishment of luxury glass production in Venice. This decline, seen in the number of operating shops or in raw materials consumed, suggests that Venice did not immediately fill the void in the glass market left by the destroyed Islamic industry.

The other influence on the early Venetian glass industry was from the Byzantine empire. The best studied glass production site in the Byzantine world is at Corinth. As discussed in Chapter Three, the previous interpretation of this site was that glass was produced here until the 12th century when it was destroyed by Roger of Sicily in 1147. At this time, it was imagined that the glassmakers were relocated to Italy where they continued their style of production (Davidson, 1940:324). More recently, this has been questioned. Whitehouse concluded that the glass shops of Corinth were instead operative the 13th and 14th century and that the only craftsmen carried off in 1147 were silkweavers (1989; 1993). This site cannot be seen as influencing Italian or Venetian production explicitly in the 11th and 12th century.

There are numerous examples of Byzantine contacts with Venice in the area of glassmaking, though. The export of glass from Venice to Constantinople in 1437 is one example. The export of clay from Constantinople to Venice is another. Another contact frequently cited in general treatments of the Venetian glass industry is Venice's participation in the sack of Constantinople in 1204. Among the treasures stolen and brought to Venice were several glass pieces now in the Treasury of San Marco. These include an enamelled wine-red bowl with handles dated to the 10th-11th century (Tait, 1991:146). However, the idea that these incredibly expensive and valued pieces served as direct inspiration for the making of similar enamelled wares in Venice cannot be probable. They were state treasures and may not have been displayed in a manner conducive to direct copying by manual craftsmen. Furthermore, many of these glass treasures may be of Islamic rather than Byzantine provenance (Klein and Lloyd, 1984:55). The Byzantine practice, however, in gilding was to use gold leaf as would be done in Venetian production. Venetian glass production, as is seen in other crafts, certainly does show signs of Byzantine artistic influence. This is only to be expected as Venice occupied an interstitial position between Eastern and Western cultures. Evidence of this influence is seen in the mosaics of Torcello and San Marco and in a group of 200 glass medallions held by the British Museum (Tait, 1979:13-15; 1991:150). The mosaics of San Marco were clearly made by Byzantine workers using glass compositions of differing glassmaking traditions (Freestone, et al., 1988:278). The medallions have a Venetian provenance but are clearly influenced by Byzantine motifs. Further hints of Byzantine influences on Venetian vessel manufacture are not available as very little is known of this segment of Byzantine glass production.

Certainly the emerging Venetian glass industry was influenced both artistically and technologically by the glass industries of the Byzantine and Islamic worlds. However, these influences ended around the beginning of the 15th century. The renewed production of luxury glass in Venice would not notably begin for another 50 years, at least. Other reasons for this resurgence in production must be given other than to rely on the facile explanation that the Venetian glassmaking simply picked up the slack of failed or destroyed industries or that the Venetian production was merely acting in response to other regional influences. Rather than looking to the products of the industry as the sole barometer of change and influence, I propose that trying to analyze the demand and the social uses of glass would be more helpful in understanding this increased and changed production.

The Renaissance Venetian Glass Industry - A Self-catalyzed Phenomenon?

I have spoken about the "increased production" of the Renaissance glass industry and the fact that this industry shows a cyclical pattern in aspects of production and demand. Where is the evidence? In order to talk about a resurgence in the Venetian luxury glass industry in the 1450's, that there were high and low periods needs to be demonstrated.

Evidence for this cyclical production can be found in the archival records of the Venetian and Muranese governments first of all. One way to judge the greater degree of Renaissance production is by examining the amounts of different raw materials consumed. For example, in the 1427-28 glassmaking season we have notice of 2760 *carri* of wood being unloaded and distributed to the glass factories of Murano (a *carro* is a unit of measurement and is equal to about 25 cubic feet or about 1 cubic meter of wood) (Zecchin, 1987:13; 1990: 51). Zecchin has estimated that a glasshouse would typically burn about 8 *carri* a week. This is an increase in wood consumed from the late 13th century which was about 1000 *carri* a year (Zecchin, 1987:12). However, the 2760 *carri* of wood used in 1427-28 is only slightly more than a third of the 7800 *carri* used in 1455-56 during the development and innovation period for *cristallo* (Zecchin, 1990:52). Clearly, changes were taking place in the Venetian industry resulting in a much greater amount of wood consumed.

A similar pattern can be seen in the quantity of soda-rich ash that was imported to Venice from the Levant. This ingredient and its subsequent preparation would be one of the key requirements in successfully making *cristallo*. In the course of the 15th century, Venetian consumption of ash greatly increased (Ashtor and Cevidalli, 1983:511-13). At the end of the 14th and beginning of the 15th century, Venetian cog ships carried no more than 400-800 sacks of ash to Venice per year. By the end of the 15th century, one ship alone is recorded as carrying 1000-1200 sacks with 10,000 sacks/year being consumed overall! The greater consumption of raw materials indicates both greater and differential Venetian glass production.

Other signs of industrial expansion in the 1450's include the production of new compositions other than *cristallo* - *lattimo* and *chalcedony* for example. New decorative techniques began to be introduced more frequently. More writings concerning the glass industry in a variety of sources become available. And archival sources indicate the number of glass houses increased in this period. All of these factors taken together signify a change and resurgence in the industry.

I have mentioned before that the Venetian industry did not immediately fill the void in production left by the destruction of the Near Eastern glass industries. During the early 15th century, the Venetian glass industry experienced a series of setbacks and drops in production. Indeed, I suggest that the rise of the Venetian glass industry owed less than has been imagined to the disappearance of the Levantine industry and its success may have been mostly coincidental with these events.

By 1429, the Muranese glass industry was in a period of what Zecchin describes as a "decline" (1987:49). The amount of wood consumed had dropped by almost 45% from a few years back. The number of active furnaces at Murano had dropped by almost half from 13 shops a few years ago. While this number would rise again in the next decade, those glass shops left were experiencing hard times (Jacoby, 1993:85). For example, the price of soda ash from the Levant went up about 20% between 1427 and 1428 (Ashtor and Cevidalli, 1983:510). Numerous policy changes regarding such questions as the annual period of vacation took place around this time. The annual vacation was actually abolished in 1420 to attempt to induce the craftsmen not to leave. In 1427, the vacation was reinstated but with a shorter length of time. In 1429, the Venetian Senate decided to abolish customs fees on the exports of glass vessels only to later reverse this policy after seeing glass sales not increase and State revenues drop (Zecchin, 1987:45). Jacoby has characterized the next two decades as a period of crisis for the industry as it was caught in a battle between conflicting interests and groups. However, it is not known how Jacoby could also have described these years of crisis and instability for the glass industry as the same ones in which the development of *cristallo* glass took place 30-50 years earlier than previously thought by other glass scholars (cf. Jacoby, 1993:87).

I believe this evidence shows that the Venetian glass industry did not immediately experience a boom after the fall of its Levantine competitors in 1400. Rather, it too was having its own period of difficulties. A resurgence, as evidenced by a sudden and notable increase in glassmaking raw material consumption, began to take place in the mid-15th century. This resurgence was triggered by the development of *cristallo* glass in response to perceived market demand in the 1450's. It has been stated that ceramic technology rises to the level for which there is perceived demand (Kingery, 1984). I suggest this glass "renaissance" was partly a self-catalyzed phenomenon encouraged by the peculiar circumstances of Venetian and Renaissance society as well as the organization of the industry itself.

In order to investigate this idea of self-catalysis, it is necessary to draw upon non-conventional economic theory. Traditional economic theory holds that a market will arrive at a single unique equilibrium point based upon the principles of diminishing returns. This feedback stabilizes the economy and the resulting equilibrium represents the best outcome given the initial circumstances (Arthur, 1990:92). A more progressive view of certain markets is based instead on the concepts of positive feedbacks and increasing returns (Arthur, 1989; Arthur, 1990).

Economic activity is characterized by individual transactions and chance events not reflected in macroeconomic examination. These events can accumulate and be magnified by positive feedback to affect the overall outcome of an economic situation. Arthur uses the example of Beta vs. VHS video recorders to illustrate this characteristic. The initial market was unstable and either technology could have been successful. A series of chance events tipped the balance in favor of VHS and the existence of increasing returns multiplied this advantage (Arthur, 1990:92-93).

Not all markets are susceptible to the forces of positive feedbacks and increasing returns. Arthur has characterized those that are as primarily knowledge-based (as opposed to agricultural and mining activities which are resource-based). Knowledge-based industries are typically described as "high-tech", requiring large initial investments of resources. Once sales begin, incremental production is relatively cheap. The information gained from producing the first units results in more manufacturing experience and more knowledge; additional units are then made even more cheaply (increasing returns). The market, sensing the success of the products, is encouraged to consume more of them, multiplying the effect and further driving the cycle.

Glass production in the Renaissance, especially luxury glass, was a high-technology and knowledge-based industry. Once the process of making *cristallo* glass had been developed, market response operating in conjunction with positive feedbacks and increasing returns reinforced the product's success (invention vs. innovation). Venetian glass manufacture, competing for a market share of glass and luxury good consumption with other industries, gained an early lead, competing technologies and processes were locked out, and the market was cornered. Small and random events, such as State involvement and raw material availability, also contributed to the self-catalyzing success of the Venetian glass industry.

I am not suggesting that this new approach to modern economic theory is entirely applicable to Renaissance manufacture. Yet both luxury glass production and silicon chip manufacture were/are contemporary "high tech" ceramic industries producing in response to perceived demand. Nor do I mean to imply that the Venetian industry was not susceptible to other regional influences such as those from Europe, Byzantium, and the Levant.

The concept of "increasing returns" offers another, and perhaps more applicable approach, to understanding some of the changes seen in Venice's glass industry. What I am suggesting is that the major force behind the relatively sudden expansion of Venetian luxury glass manufacture in the mid-15th century came from within Venice and her economic contacts. This industrial self-catalysis, in response to perceived market demand, was subject to positive feedbacks and increasing returns which helped stimulate production further and create additional innovations (cf. Freeman, 1986). The key feature, and one which has been emphasized throughout this dissertation so far, is the role of demand as an essential prerequisite for initial and subsequent luxury glass production. In order to develop the idea of a possible "self- catalysis" in the Venetian glass industry in response to certain economic and social forces, the general demand for glass must be examined. The following chapter will analyze the nature of demand and use for luxury glass made in Venice as the foundation to understanding subsequent production.

CHAPTER 7

THE DEMAND FOR GLASS IN THE RENAISSANCE

In the previous chapter, the origins and pre-Renaissance history of the Venetian glass industry were presented. This concluded with the hypothesis that the Venetian luxury glass industry of the Renaissance initially developed and changed in response to perceived market demand. As I have noted elsewhere, the question of demand for glass has not been satisfactorily addressed in previous approaches to the subject. Such work has taken demand for granted and focused instead on issues of production, primacy, and provenance. It is assumed here that demand is a necessary requirement for production and, therefore, should be considered first. This chapter analyzes and identifies the forces in the Renaissance which helped create a demand for glass, especially *cristallo* luxury glass.

The simplest explanation of the increased interest of the Renaissance person in glass would follow the argument that more money was available and, as a result, people bought glass which stimulated production and innovation; i.e.,

money existed → demand → production

It is presupposed that money existed for spending in the first place. This line of reasoning says nothing about why certain goods and materials were desired, however. Greater wealth does not explain why people wanted new types of objects or why these objects had value (permissive cause vs. effective cause). Goldthwaite dispatches this type of reductionism is his treatment of construction activity in Renaissance Florence: "The economy determines the context in which spending is possible...The economic variables that impinge upon demand, however, can only shape demand, not create it. Demand itself arises from other sources." (1980:67). Similar work has been presented by Mintz in his comprehensive approach to the production, consumption, and meaning of sugar (1985). The task then is to de-mystify demand which brings us closer to issues of need and taste and fashion. Unfortunately, this lies more in the realm of psychology and social situations of which less information is known and for which inferences tend to be more tenuous. Therefore, the clarification and understanding of demand must be done in a more oblique fashion that will allow inferences about Renaissance culture. Asking the question of the glass - "What did it do?" - and then examining the activities and behaviors from which these functions arose provides one method to address the critical topic of demand.

The Functions of Renaissance Glass

The economic results of demand are reflected on the supply side of the economy. The question of how to analyze demand other than by its effects is problematic, especially when dealing with a culture that no longer exists. Functional analysis of the artifacts offers a place to begin the journey.

The identification of artifact functions is taken from the overall life cycle of an object of which "use" is one stage. Other stages include procurement, manufacture, maintenance, reuse, and deposition (Schiffer, 1992:8-9). Schiffer and

Rathje expanded and improved upon ideas proposed in the 1960's by Lewis Binford. Here, artifacts function in different subsystems of society - technology, social organization, and ideology (Binford, 1962; Schiffer and Rathje, 1982). Binford's concepts were redefined in terms of functional types rather than types of artifacts; any one artifact may in fact fulfill several different functions which are defined with reference to specific activities (Schiffer, 1992:10-11). The three basic functions an artifact may perform are technofunctions, sociofunctions, and ideofunctions. Renaissance Venetian glass performed (and still performs) all three of these.

The different functions that an artifact can perform have typically been viewed as separate from questions of style. As discussed in Chapter Two, style is traditionally seen as a residual category which explains any variability not caused by functional requirements. Style and function are not separated by any clear boundary. In many cases, the style of an artifact serves a function, often in the socio- and ideofunction realms (Wobst, 1977; McGuire, 1981). Therefore, I wish it to be implicit in this and the continuing discussion that mention of the "style" of a piece is not meant to suggest a dichotomy between style and function. In some cases, style is function.

I presented evidence in the preceding chapter that the mid-15th century brought a change in the glass industry of Venice. This question of technological change is one of the key topics this dissertation addresses. Chapter Two detailed numerous methodological approaches to the question of technological change.

Behavioral archaeology suggests that the principal source of technological change resides in the "functional field" (Schiffer, 1992:49-51). This is the array of functions (techno, socio, and ideo) that an artifact must perform. The functional field responds itself to changes in society's activities. For example, changes in eating and dining behavior may have implications in the way food is procured, prepared, presented, and consumed. Another source of technological change is feedback from use activities when the function remains constant. The artisan will continue experimentation with design based on user feedback until a satisfactory one is found. A third source of technological change is "producer pressure". This is more likely to be found in situations when household or local production is replaced by increasingly remote and specialized manufacture. In this system, production is linked to consumers via distribution networks. The disjuncture between producer and consumer can result in these two groups having different sets of design priorities Subsequent design compromises often shift in favor of the producer due to lack of direct contact with the consumer (Schiffer, 1992:57). Producer pressure can be found in situations where artisans are part- or full-time specialists who stand to profit by expanding the market for their goods. Marketplace competition among artisans, even when the basic function of the artifact remains unchanged, helps stimulate further innovation (Schiffer, 1992:50). Although not stated explicitly, Schiffer's comments bring to mind such phenomena as changing fashions and new designs, developed continually for objects whose basic functions have remained constant, in response to perceived market demand. While a functional analysis is used here as a starting point, it should be noted that not all aspects of material culture can be described as clearly defined functions. Aesthetics, taste, and other factors all contribute to demand and to material cutlure development as a whole.

The three different and general types of functions of material culture (techno-, socio-, and ideo-) developed and employed by behaviorial archaeologists are all present, to varying degrees, in Renaissance Venetian glass. By next analyzing the activities that give rise to these functions we can begin to formulate an understanding of demand. These activities fall into three basic categories - economic, behavioral, and psychological.

The economic context of Renaissance Italy that gave permissive cause to consumerism has been discussed in a number of publications by Goldthwaite (1980, 1984, 1987, 1989, 1993). The economy of Venice has been described in relation to Venetian society in chapters Four and Five. The premise that wealth and consumerism helped shape demand rests on the amount of wealth available and its structure. To summarize - Greater wealth was available in Renaissance Italy due to increased activity in both the commercial and industrial sector. By the mid-15th century, Venice was the center of a world economy based in the Mediterranean with branches spreading out in all directions. This greater wealth was coupled with how it was structured resulting in increased demand for luxury goods such as glass. The structure of wealth was based on its distribution, both geographic and social, and its fluidity of redistribution. Three conditions prevailed in Renaissance Italy to help encourage the market for luxury goods. Wealth was distributed among a large number of consumers primarily based in urban markets. Society was organized so that the ranks of consumers were continually changing. This helped to keep demand at a constantly high levels as there was always someone newly rich who wished to purchase fine goods. Finally, the rich tended to become richer resulting in higher levels of individual expenditure (Goldthwaite, 1984).

Consumerism and conspicuous consumption exists as one of the characteristic features of the Renaissance economy and society. The changes that took place in Renaissance society between the 14th and 16th century may be illustrated by comparing descriptions and inventories from persons of similar social standing at different points in time.

In the late 14th and early 15th century, Francesco Datani was a wealthy and influential merchant who resided in Prato, a small town located in Tuscany near Florence. His life and times have been researched and documented (Origo, 1984). Part of this work describes the house Datani lived in along with lists and descriptions of its furnishings (Origo, 1984:224-243). An inventory of 1407 described it as a "handsome house" with a value of 1000 *florins*. The rooms included an office, cellar, guest room, and two *loggias* (these were rooms, at this time a novelty, built for the purpose of entertaining). There were also two kitchens, a hall, a master bedroom, and two other guest rooms. According to Origo, this house was unusually large for its time, as most homes of the wealthy had seldom more than twelve rooms and, typically, five or six (1984:225). Overall, the furnishings of this wealthy merchant's house appear rather meager, as was the case for most homes of this time. The "empire of things" portrayed by Goldthwaite had not quite taken matured (1989). The most important piece of furniture was the bed in the master chamber which was present along with various chests and coffers. A mirror was present along with another in Datani's office. Other ornaments in the master bedroom included three "vases from Damascus", a vase for rose water, a bowl of white glass, a "glass bowl, very well worked in gold", and three sacred pictures (Origo, 1984:233). The main hall was furnished sparsely with table and chairs; some glasses are recorded there. The kitchen inventory shows numerous metal implements for cooking and jars of unspecified material; no glass was explicitly recorded here. Cutlery and dishes for eating are also noted. Forks were a rarity at this time. 12 silver ones were kept locked in the master's room. Most dishes were of pewter. A few majolica bowls with Datani's crest and imported from Valencia are noted as well. Other earthenware dishes and bowls were present. According to the inventory, no glass, other than the pieces mentioned above, seems to have been used in dining activities.

According to Origo, the general impression of the lists is a feeling neither of luxury nor of great taste. The houses of the wealthy at this time had not yet acquired the ornate furnishings and decorative arts that would appear in the next generation. The lists suggest that Datani distinguished objects from one another by virtue of their cost and not by more abstract standards such as taste, skill of workmanship, or splendor (1984:237). Those more extravagant goods such as decorated majolica and silver forks were present not because Datani himself liked them but because they were required in the house of a man such as he. Datani tended to be more extravagant in his public displays of wealth such as his gift of colored glass windows to local churches (1984:239).

A much different picture of wealth and extravagance in terms of accumulating luxury goods is seen in the lists of wealthy and powerful members of Renaissance society such as the Medici and Isabella d'Este. Inventories of d'Este, recorded only about 100 years after those of Francesco Datani, the merchant of Prato, reveal an incomparably greater level of luxury good accumulation. Such lists go on for pages and do not always include more mundane items such as fine glass and majolica, instead concentrating on truly expensive goods such as objects of gold and rare and semi-precious stones. One must turn to other sources such as correspondence between the Marchessa and artisans and intermediaries to find out more about her purchase of items such as Muranese glass (Brown, 1982). Inventories of the Medici, such as one of 1587, reveal hundreds of pieces of fine glass. One entry notes "five cases of glass of all sorts" while another records 59 vases and tumblers of glass in one room alone (Heikamp, 1986:347).

What about members of society who were further down the social scale? Do records indicate greater activity and interest in purchasing goods such as glass in the Renaissance? Unfortunately, records for the less well-to-do members of Renaissance society are imaginably less common than for people such as the Medici. One study documents the house inventories of "middle-class" artists and craftsmen in 16th century Venice (Palumbo-Fossati, 1984). These inventory lists have been interpreted as indicating an general increase in the level of refinement and decoration in Venetian households (1984:149). This increase includes both the number of objects and their relative value. One list from 1582 notes a few items such as a lamp (*cesendello*) placed in front of a portrait of the Virgin and some bottles. According to the author, glass was generally reserved for the wealthier members of society and Venetian homes in general tended to not have much glass. Most was destined for export (Palumbo-Fossati, 1984:123-24). Other inventories of artisans record "two vases of glass and one of majolica" (1581) and "a great cup of rose colored glass" (1579). No mention is made of other types of glass, such as common and cheap kitchen wares, which may have been present in such homes.

Glass was often purchased by members of non-elite classes in order to own objects which imitated those made of other more expensive materials. While artists and craftsmen of Venice might not buy vessels of rock crystal or jasper, they could aspire to own replicas of these materials manufactured in glass. The use of glass to imitate and evoke other materials and forms will be expanded on later. But, clearly, imitation of other more costly materials was one of the functions of Renaissance Venetian glass. While certainly not of the same level of grandeur, these inventories point to the fact that wealth was distributed in such a way that the bulk of Renaissance society could begin to participate in the new emerging consumerism and the purchase of finer goods. It also suggests the role that classes of people such as artists and craftsmen would have in stimulating consumption. As artisans began to participate in the manufacture of goods such as luxury glass, their skills and wages tended to increase allowing them to purchase and consume more goods (Goldthwaite, 1980:425). A system of positive returns can been discerned here with expenditures by all classes helping to further stimulate demand and production. The new economic activities of the Renaissance, such as consumerism and conspicuous consumption, would affect the functional field of luxury goods such as Venetian glass. As activities of Renaissance society developed in the economic sphere, the set of functions that glass would have to fulfill altered leading to further technological change.

A second set of changing activities resulting in different functions for Renaissance Venetian glass may be found in the behavior and habits of Renaissance society. The two primary novel activities I wish to detail here are changes in dining habits in Renaissance Italy and a new interest in collecting.

In 1498, the Neapolitan humanist Giovanni Pontano published a treatise on social virtues (1965). One of the five traits admirable in a Renaissance person of culture was termed "*conviventia*" or conviviality. All of Pontano's essays on virtues are related in some manner to consumption and expenditure. The virtue cited here, along with "splendor" were new, however, to discussions of civilized behavior. Conviviality is the virtue related to conduct and companionship at the dining table (Goldthwaite, 1993:209). This trait includes hospitality and civility in the company of others. From this discussion of a newly emerging "virtue", one may see that this behavior required a new approach to table manners. Novel implements, such as forks, began to appear at tables in Renaissance Italy. While this may seem trivial at first, their appearance and use mark changes in the way in which people approached eating. And as dining habits changed, so did the relations of persons to the people and objects around them. The days of communally sharing a bowl and glass were gone, replaced by a new sense of reserve and civility. Goldthwaite notes that houses in 15th century Florence record complements of forks, knives, and spoons made of silver; the records from the early 15th century merchant of Prato already preserve signs of these changes (Origo, 1985; Goldthwaite, 1989:24). Along with new eating utensils, diners began to have their own plate and glasses. Northerners, such as Montaigne, were impressed that each diner had his or her own napkin and set of silverware. A few years after Montaigne, the Englishman Fynes Moryson noted that the Italians each have their own fork and spoon, made of silver, and their own glass (1907:98). The Italian poet Tasso traveled north to France only to remark that it was curious to have glass windows in French churches rather than at the table "for display and the pleasure of drinkers" (1854:42). Pontano criticized the French of this time for eating without any sense of splendor. Along with this new conviviality, the participants in Renaissance Italian dining expressed "*gentilezza*" or refinement in their eating habits. Consider the description of Niccolo Niccoli given in the 15th century: "When he was at the table he ate from the most beautiful antique dishes and he drank from cups of crystal...There was no house in Florence that was more adorned than his or where there were more refined things..." (Bisticci, 1951:442-3). Whether such goblets were made of glass or rock crystal is really beside the point. Venetian *cristallo* glass was developed, in part, to evoke the visual qualities of the more expensive rock crystal. Persons not able to afford the rock crystal vessels could at least aspire to own similar forms made of the new glass composition. In some cases, it may have even been preferable to have collections of drinking vessels made from glass rather than rock crystal. In addition to written evidence, pictorial evidence, such as paintings by Paolo Veronese, from the 15th and 16th century show an increasing display of luxurious and refined items at expensive Italian banquets.

Clearly, changes had taken place in the dining habits of Renaissance Italians which would eventually spread to other parts of Europe. The use of fine glassware, such as that made in Venice was part of this behavioral modification. In a similar manner, Mintz has chronicled how the adoption and increased use of sugar in England was also connected to changes in eating habits, although this was more associated with *what* was being eaten rather than *how* (1985). The new eating habits and behaviors of the Renaissance Italians also stimulated demand for a greater variety of luxury glassware. Different types of goblets, plates, bowls, and other vessels used to display and serve food and drink at the table began to appear. New and diverse forms and functions for luxury glass objects emerged in the 15th and 16th century partly in response to behavioral changes in Renaissance society associated with eating habits.

In addition to changes in eating behaviors, luxury glass from Renaissance Venice was also a participant in another novel activity that emerged in the 15th and 16th century. This was the increased interest in the formation of private collections for the Renaissance house or palace. A number of different categories of collecting during the Renaissance may be identified - state collections, collection by ecclesiastical bodies, those of lay confraternities - but it is private collecting that is of interest here. Venice had a great number of private collections of objects in Italy during the Renaissance, possibly the largest outside of the Papal court in Rome during the 16th and 17th century (Logan, 1972:152).

As Renaissance society adopted the habits of consumerism, a tendency towards another type of consumption began - collecting. The conscious gathering of objects under one roof in the Renaissance was distinct from the manner in which this was practiced by Medieval elites. Before the Renaissance, the collection of objects was oriented towards displaying wealth as a symbol of power. In the 15th century, Italian collections changed as the nature of goods assembled began to be informed by cultural values other than traditional ones of showing wealth and religious piety (Goldthwaite , 1993:247). These new collections mirrored the changing values of the society that created them. For example, a resurgence of interest in the works and deeds of the Classical era resulted in a market for antiquities from that period. Pontano refers to the collections of Caesar in his treatise on social virtues as a means to justify this new activity (1965:272). The new desire for goods to fill collections became a force driving production and helping generate demand. When goods made of more expensive materials such as rock crystal, agate, or porcelain were not available, one could replicate their visual appearance and form with another. Hence, ceramics, especially glass, rose to the occasion. Pontano mentions both naturally occurring materials and those imitating them (glass) as suitable components to form a collection and demonstrate one's taste and magnificence. In a similar sense, Impey has documented the emergence of porcelain collections as a new phenomena in 16th and 17th century (1992:789-804).

In Venice, and elsewhere in Italy, such collected objects were referred to as *studi* and displayed in a room known as a *studio*. This was more of an intimate study rather than a large gallery (Logan, 1972:153). There is little information available about 15th century collections in Venice although the passion for collecting was already present throughout Renaissance Italy. By the 16th century, a fair amount of information is available. A typical *studio* in this era might contain the following: paintings by local masters with an occasional painting from the Netherlands, antique bronze and marble works, various gems and other natural stones, gold-work, medals, and coins (Logan, 1972:163). Such objects would be displayed in the *studio* in cabinets and organized in a way that was orderly and harmonious to the owner. For example, a 17th century description of the Ruzzini collection in Venice notes many examples of semi-precious stones, "crystal", agate, turquoise, and so forth. Some of this material is part of the collection and some of it is used to decorate the cabinets which contain other goods (Pearce, 1992:94). The *studio* of Lorenzo de Medici offers another example. About 25% of the family inventory made after his death in 1492 consists of objects from his private collections. The objects displayed here are not all of great inherent value or part of a ceremonial display. Rather, they for a private and personal collection of goods that emphasized personal pleasure over public display (Goldthwaite, 1987:171).

These "cabinets of curiosities" assembled by persons of the Renaissance have been interpreted by some as forerunners of museum collections (Hooper-Greenhill, 1992; Pearce, 1992:91-92). A distinction must be made here between the random accumulation of objects and the formation of a cohesive body of goods. Collections were not assembled randomly but were put together from a perspective shaped by current intellectual traditions. The ordering of these cabinets reflected the relationships between subject and object (Hooper-Greenhill, 1992:84). These collections allowed the owners to connect with other times and ideas such as an interest in the Roman era or naturalism (cf. Akin, 1995). Themes and ideas important to the Renaissance person are made manifest in these assemblages. Such concepts include magic, scholarship, order, symmetry, richness, and admiration of craftsmanship. The assemblage of porcelain collections was also done as part of interior decoration as they were often displayed over doorcases or hearths (Impey, 1992:792). The assemblage of collections and the inclusion of goods such as glass were seen as illustrating the order of the natural universe. Their creation was the first step towards classifying and categorizing the new world of things that was present. Collecting presented a means to shape the world. 16th and 17th century discussions of collections draws distinctions between natural and man-made materials and illustrate different types of goods - inorganic, organic, paintings and sacred objects, artifacts, and those which glorify the collector (Pearce, 1992:95).

What role did Venetian luxury glass play in the assemblage of this new manner of consumption? Most contemporary descriptions of collections do not explicitly mention glass, instead focussing on more costly and rare materials. The role played by glass in imitating these types of goods has been noted several times. In this manner, persons unable to afford the original could buy something visually similar for their own personal display. Yet glass itself was also collected for its own sake and by the very wealthy of Renaissance society. Inventories of the Medici record substantial amounts of luxury glass (Brown, 1982; Heikamp, 1986). The correspondence between d'Este and Lorenzo da Pavia, one of her agents in Venice has several notations referring to specific glass objects desired by the Marchessa for her collections. She amassed large assemblages of all types of ceramics including glass and majolica (Marek, 1976). Much of the glass ordered was made according to her own designs and used to augment pieces in her collections made of other materials (Brown, 1982:213-217). The desire to collect Venetian glass in the Renaissance was not limited solely to Italy. Several inventories of Spanish nobility record substantial amounts of glass. For example, in 1549 the Countess of Altamira owned more than 124 pieces of Venetian glass including goblets, decanters, and rosaries (Frothingham, 1963:33-34). The collections of Philip II at El Pardo Palace in 1564 records over 300 pieces of glass from Venice. One of the most famous glass collections was that assembled by King Frederick IV of Denmark in the early 18th century. This collection had several hundred pieces of glass, a fair amount of which was Venetian. It was so admired by the King that he had a special room constructed to display these objects (Bosen, 1960). Similar rooms were also constructed for imported porcelain (Impey, 1992:793).

These examples illustrate that demand for Venetian luxury glass, such as *cristallo*, was partly driven by the new activity of collecting glass. Persons from different social strata collected luxury glass either as a substitute for another material, for the fact that it was glass, or perhaps for both reasons. Similar behavior was exhibited in the collection of other ceramics such as majolica and porcelain. Glass satisfied a demand for luxury goods of intermediate value. Due to its participation in the collecting phenomenon of the Renaissance, glass fulfilled new functions. Many of these would go beyond the easier understood realm of technofunction and be related to social and ideological beliefs. A curious question exists as to why glass, made from common raw materials and being relatively inexpensive, was desired as a material to include in a Renaissance collection. Later parts of this section will address this point.

The premise here is that a functional analysis Venetian glass provides a starting point to unmask the forces of demand. The three general types of artifact function have been discussed along with the fact that glass fulfilled all of these.. The next task was to identify those activities and behaviors from which these functions arose. I have thus far chronicled several new and different types of behavior which developed during the Renaissance that affected the functions performed by Venetian glass. These include new spending habits, new dining behavior, and an emerging interest in collecting diverse types of goods. Glass, as a form of material culture, participated in all these activities. The final locus for examining the source of functions performed by Venetian glass during the Renaissance lies within the Renaissance mind. New attitudes and values held towards luxury goods such as glass emerged at this time.

These new attitudes have been previously described in a study of the general demand for art in Renaissance Italy (Goldthwaite, 1993). Prior to the 15th century, there were two principal forces which prevented excess consumption. One was religious suspicion of the profit economy. The Franciscan ideal of poverty as a path to proper living offers one example of how the clergy presented luxury and conspicuous consumption as immoral. The famous Scrovegni chapel in Padua, 40 kilometers from Venice, illustrates how one wealthy patron of the pre-Renaissance attempted to balance a program of piety and consumerism. The frescoes, paid for by Enrico Scrovegni, represent a series of vices and virtues and have been interpreted as an offering to atone for his father's sins of usury. Another force which helped slow the growth of consumerism was social pressure. Persons were controlled either by indirect social forces (jealously, rivalry, etc.) or by direct sumptuary laws to prevent excessive displays of wealth and power in public (Goldthwaite, 1993:204-5). By the 15th century these attitudes changed and these two primary brakes on consumerism loosened. Once it became socially acceptable to spend one's money, the question became <u>how</u> to spend it.

As early as 1420, a translation of the pseudo-Aristotelian *Economics* by Bruni for Cosimo de' Medici contained the comment that the possession of worldly goods "affords an opportunity for the exercise of virtue" (Hay, 1977:131). Bruni went on to find observations by other writers saying that poverty and penury could restrict one's virtue and that virtue involved owning material goods. Another humanist, Mateo Palmieri, wrote in *Della Vita Civile* that possessions are part of family happiness and that these things must possess certain qualities to enhance one's life. Wealth began to be interpreted as an ingredient of friendship and fame. Alberti concludes that man needs three things: "*la casa, la possessione, et la bottega*" (Hay, 1977:132). Statements such as these offered the Renaissance person justification for conspicuous consumption. While the attitudes contained in tracts such as Alberti's and Palmieri's were most likely not accessible to all members of Renaissance society, they would slowly permeate through the social hierarchy.

At this point, it is useful to turn back to Giovanni Pontano's late 15th century treatise on social virtues. The virtue of conviviality in relation to the new dining habits of the Renaissance Italians has already been described. Another virtuous trait described by Pontano was "splendor". This virtue also appears in other tracts such as the one of Palmieri. It was the complement of magnificence extended from public life into one's private world. Magnificence is seen in forms such as public architecture; splendor exists within the walls of one's home. It is the refinement with which one lives and consists of household furnishings, decorative arts, ornaments, and utensils (Goldthwaite, 1993:249). Clearly, luxury goods such as Venetian glass played a role in fulfilling the desire to exemplify this new virtue. Chapter 4 of Pontano's section on splendor discusses those ornamental objects which can help one in showing this trait. These include statues, gems, paintings, textiles, and objects of "*cristallo*" along with vessels of other materials (Pontano, 1965:272). Another chapter points out the importance of forming collections with an emphasis on natural objects. Sabba da Castiglione wrote in 1555 that all the household ornaments of the Renaissance person contribute to their intelligence, civility, and manners. Commodities like glass were now performing a much broader and sophisticated function other than being a container for one's wine or showing a coat of arms.

The display of splendor, as defined by Pontano, presupposes the spending of money. The question still remains as to what qualities the goods purchased with one's wealth should have. The ownership of luxury goods such as fine tapestries, goldwork, and semi-precious stones and gems are easier to understand as they have a large degree of inherent value. How does one explain the passion for owning and collecting more mundane materials such as luxury glassware? Rather than dwelling entirely on their inherent wealth, the Renaissance person also admired their beauty and aesthetic value. Value lay not in the inherent cost of materials such as glass but in the variety and craftsmanship associated with it (Goldthwaite, 1987:168). Consumption and ownership of refined goods such as glass acted to display social traits and virtues far beyond what could be associated with their inherent value. This is especially true for luxury goods like majolica and glass, made from common clay, sand, and ash, for which the primary production cost was labor time. Other types of value, such as those discussed above, came into play and must be considered when trying to describe the demand for glass along with attempting to understand the particular qualities that were required by the consumer of such items.

The functions that Venetian Renaissance glass would have to perform in the 15th and 16th centuries were, therefore, dictated largely by new activities and attitudes. These include new levels and modes of spending one's money, new habits of collecting and dining, all coupled with a newly emerging mind set towards the types of goods one should have and the rationalization for their possession. The remainder of this section will address, in more depth, the question of "why glass?"; this will be followed by a more detailed description of the demand for glass based on the different categories of available evidence. Once the motivation behind demand has been detailed, we will then be in a position to address issue of production.

Why Glass?

Before the specific question of why Renaissance glass made in Venice was demanded by society, the more general question of why glass, as a material, was desired and seen as having value should be considered. There is little information in Renaissance writings on the comparative worth of materials or how different materials were perceived. To reach some appreciation of how glass, as a material, was valued, it may be useful to consider alternatives to glass as well as features of glass that are not available in other materials.

What was it about glass that people liked? Such valuation cannot lie in the sheer cost of the materials for rarely did a single piece of Venetian glass command a price anywhere near what would be expected for gold work, paintings, and so forth. Through the consumption of relatively inexpensive luxury goods like glass and majolica, Renaissance persons showed their taste more than their wealth. Craftsmanship associated with producing fine luxury glass was also a quality admired as well as the ingenuity of the artisan in making novel forms.

From a selection of Renaissance-era citations, one can have a glimpse of the qualities of glass that made it special and desired in the eyes of a Renaissance person. Four primary qualities are present: the ability of glass to imitate other more precious materials; its innate beauty as perceived by the Renaissance mind; the skill associated with working it and manipulating it to achieve desired forms and visual effects; and the ability of glass to be worked into forms and shapes more readily than or not possible with other materials. Consider the following statements:

> "...they began to turn the materials into various colors and numberless forms. Thence come cups, beakers, tankards, caldrons, ewers, candlesticks, animals of every sort, horns, beads,... there is no kind of precious stone which cannot be imitated by the industry of the glass workers, a sweet contest of man and nature." (Sabellico, *Opera Omnia*, 1500)

> "The best glasswork that is made in our time and that which is of greater beauty, more varied coloring, and more admirable skill than that of any other place is made at Murano. In addition to coloring them all possible tints, they also make them very clear and transparent like true and natural crystal, and

ornament them with painting and other very fine enamels. Thus it seems to me that all the metals must give way to glass in beauty...From this body are the very fine enamels, colored and so beautiful...they are also used to counterfeit emeralds, diamonds, rubies, and all other gems of any color...Thus, in short, to anyone considering it well, all the effects of glass are marvelous. Considering its brief and short life, it cannot and should not be given too much love, and it must be used and kept in mind as an example of the life of man and of the things of the world which, though beautiful, are transitory and frail." (Biringuccio, *Pirotechnica*, 1540)

"Glassmen make a variety of objects: cups, phials, pitchers, globular bottles, dishes, saucers, mirrors, animals, trees, ships...they were all on sale at Murano, where there are the most famous of the glass factories." (Agricola, *De Re Metallica*, 1556)

"There has never been found a more delightful art than that of glass...it is supreme in the renowned and beautiful city of Venice, in a certain locality called Murano..." (Leonardo Fioravanti, 1564)

The citation from Biringuccio's 1540 treatise, *Pirotechnica*, is especially insightful in that alludes to all of these properties with respect to glass. It also draws a comparison or analogy between glass as a material and the transitory life of man and, indeed, of all beautiful things. This reference becomes especially insightful when put into the historical context of the Renaissance when life was short and the ravages of the plague and war were never far away. Glass, as a material, becomes a metaphor for the existence of mankind itself, according to Biringuccio.

A comment should be made with respect to the first quality - the use of glass to evoke other materials. I do not think that the Renaissance person admired glass for this quality in a deliberately deceitful or malicious manner such as the use of glass in place of gemstones with the intent of fooling a naive purchaser. Rather, I see it as an admiration for the cleverness and ingenuity of the person formulating the different glass compositions which so closely imitated nature. The manner in which this fits into the overall appreciation of naturalism in the Renaissance should be apparent (Burke, 1986:184).

With these desired and admired qualities of glass in mind, let us now turn to a comparison of glass, as a material, with respect to other materials available to the Renaissance consumer. The three primary alternatives to glass, cost not considered here as a limiting factor, were metalwork, objects fashioned from rock crystal, and pottery.

One of the functions of glass as a material was to imitate forms and shapes of vessels traditionally made in other materials. This phenomenon is known among archaeologists as "skeuomorphism". This refers to the manufacture of vessels in one material with the intent of evoking the appearance of objects made in another material (Childe, 1956:12). This type of comparison allows the dialogue between different classes of objects to be recorded over time. One of the materials for which glass was a skeuomorph was metal. Figure 7.1a illustrates a *tazza* in metal from an early 17th century Spanish still life. Figure 7.1b shows a very similar form made of glass (from the Corning Museum of Glass) and dated to about the same time. While not contemporaneous, the similarity between the metal and glass *tazze* should be sufficient to make the point that glass was frequently worked into shapes common to metal work. Another example can be seen in Figure 7.2. This illustrates an enamelled glass goblet held at the Corning Museum of Glass and dated to about 1500. The trailed work at the base of the bowl along with the ribbed knop and foot all suggest parallels to Gothic chalices in metalwork. A piece similar in form and made of metal can be seen in the painted wood piece shown in Figure 7.3. Glass goblets of this form were fairly popular around 1475-1525 and numerous examples of them can be found in museum collections. In many cases, the parts of the glass piece which are in closest imitation of metal shapes were gilded so that the color and form matched quite closely to the original metal template. The "feel" of the glass pieces is different from later glass work, as well, being more massive in weight and size and, again, more similar to metal pieces. One senses that the glassmaker was working more towards the imitation of another material rather than exploiting the natural properties of glass. Many of the large bowls examined in this work had straight and spiral ribbed patterns at the base of the bowl which is a feature also seen in metal pieces. The point is the same, however; glass was worked into shapes similar to metal work.

Rock crystal and glass have artistic parallels as well. It should be apparent to the reader by now that the Venetian *cristallo* glass composition was largely developed in response to perceived market demand for a material closely resembling natural clear quartz. The guild of rock crystal workers in Venice expressed concern for glass imitating their own works as early as the 13th century. More commonly discussed in the literature is the use of glass to replace items such as lenses, beads, and so forth (cf. Zecchin, 1989: 239, 244, 250). The reasons for using glass were simple. It had a similar visual appearance and it was cheaper. Zecchin notes that even after glass had been introduced and approved for use in eyeglasses, the wealthy of Venice and elsewhere continued to buy the more expensive ones of rock crystal (1989:250). This again suggests that technofunction was not the sole function that glass had to fulfill. Glass and rock crystal could also be skeuomorphs of one another. For example, there is a small rock crystal *tazza* in London's Wallace collection whose shape is very similar to those common to glass. The piece, made c. 1500, is fairly thin-walled (2-3 mm) for a rock crystal piece. The rock crystal piece imitates a glass vessel almost exactly, right down to the series of mereses present which normally separate the bowl from the foot in a glass object. In this case, the rock crystal piece may be seen as a skeuomorph of a glass vessel. These example illustrate that glass and rock crystal functioned as replacements for one another both in form and visual appearance. More will be said about this latter feature later.

Finally, comparisons must be noted between the pottery of the Renaissance and Venetian glass. The most obvious point is that ceramics (i.e earthenware) and glass of the Renaissance share many common forms. As was the case for glass, ceramics were often skeuomorphs of more expensive metal pieces. A less apparent comparison can be made between two particular types of glass and ceramic objects - painted majolica and enamelled glass. Both of these were made in Venice. There is some question about the overall importance of majolica production in Venice. Wilson states that majolica was not native to Venice and that most pottery made in Venice was incised slipwear rather than tin-opacified, glazed wares (Wilson, 1987:108). Caiger-Smith and Lightbrown offer a different interpretation in their translation of Piccolpasso's Three Books of the Potter's Art. They conclude that Venice was indeed important in majolica production, perhaps even more so than Faenza (1980:xxiii).

The comparison between Italian Renaissance majolica and Venetian glass lies in the nature of the applied decoration. The technology of painterly majolica production has already been explained by Kingery (1993). The innovation lay in the use of a three layer system; a white, translucent tin-opacified glaze was applied over the already fired bisque body. The desired narrative scene was then painted before a second lead-silicate glaze was applied and fixed by a second firing. The result was that hundreds of painted pieces could be fired at one time and in one kiln as long as glaze and pigment preparation were carefully done (Kingery, 1993:43). The pigments do not flow and smudge during firing and the applied lead-silicate glaze wets out over the pigment layer and forms a bright, smooth, reflective surface. Because the pigments do not flow during firing, a level of precision in majolica painting was obtained during the Renaissance that previously had not been possible in painted pottery. It is interesting to note here that many of the raw materials used in the production of both painterly majolica and enamelled glass were the same. There were both technological and artistic parallels between the two materials.

The production of enamelled glassware in Venice was a much more labor intensive operation. Each enamelled piece required its own individual second firing to fuse the enamels on the surface of the glass. The pieces were not all fired together in one kiln as was done for majolica. Correspondingly, levels of production were obtained with majolica manufacture that just were not possible with enamelled glass. Additional comparisons can be made between majolica production, glass enamelling, and the application of enamels to metal substrates (cf. Kingery, 1993:42). Again, the limitations of enamelling on metal were primarily technological. However, all of these luxury goods were similar in that both the surface of the ceramic, the metal, and the glass acted as a "canvas" on which the painted design was applied.

Another similarity between majolica and enamelled glass production lies in the subject matter traditionally depicted on the vessel surface. Both types of goods depict ideas and interests that were a direct adoption of Renaissance themes and philosophies. These themes are frequently based on allegory, mythology, and Renaissance symbolism. There are several cases in museum catalogs of majolica and glass pieces having similar motifs, indicating that they were often derived from a common source. Wilson points out that by 1520, Italian engravings had become the prime source of inspiration for majolica production (1982:113). The illustrations in Figure 7.4a and 7.4b provides an example of this artistic interplay and borrowing. The first figure shows a cold painted plate with the Judgement of Paris from the second half of the 16th century; the second figure illustrates an very similar engraving by Raimondi dated to the first decade of the 16th century. Clarke has already shown the debt that several well-known enamelled glass pieces from Renaissance Venice owe to contemporary painters such as Carpaccio (1974). Figure 7.4 offers an example of such a piece. The similarities in decorative motifs between Venetian opaque white glass (*lattimo*) and Chinese porcelain that was imported to Italy in the 15th century have also been identified by Clarke. It is interesting to note that a concession was granted by the Doge to a Muranese glasshouse in 1457 to produce a white glass referred to *vetro porcellano*. This was the same Doge who had received 30 pieces of porcelain as a gift (the oldest record of porcelain in Venice) fifteen years earlier (Zecchin, 1989:346). The point here is that Renaissance ceramics, including majolica and porcelain, shared decorative motifs and designs with contemporary glass decoration.

While the themes and sources of inspiration for painterly majolica and enamelled glass are common, no one has yet commented on the relative differences between the two in terms of how well the image is represented. In this, I refer to how clearly and well defined the image on the vessel has been represented and preserved as well as to the range of colors that were available to Renaissance artisan working in glass versus majolica. Any objective observation and comparison of even a dozen or so enamelled glass pieces with some majolica should make the distinction quite apparent. The quality of the pictorial representation, the details of the picture, and the available colors are clearly inferior in enamelled glass. Enamelled glass appears cruder and with a more limited palette. Figure 7.5, taken from PE-162 (a glass pitcher from the late 15th or early 16th century, now held at the British Museum) illustrates this. The details in the glass enamelling are not as crisp as what can be done in majolica painting and the colors are much more restricted. Again, the reasons for this are largely technological and relate to the nature of glass enamels and the manner in which they were applied and fired. The pictures on majolica vessels are much more "painterly". In addition they have the advantage of being more permanent. They are protected by a lead-silicate glaze whereas the glass enamels are exposed to the air. Many pieces of enamelled glassware in museum collections has enamels that are either abraded, chipped, or in the process of being corroded. Painterly majolica was better than enamelled glass for the portrayal of images in terms of detail, available colors, and permanence.

An alternative to enamelling on glass, known as cold painting (or *dipinto a freddo*), was employed in 16th century Venetian glass houses. The application of paint to the glass while it was cold (and not to be re-heated) resulted in a product that had good detail and variety of colors approaching that available in majolica manufacture. The disadvantage was that cold painted pieces were even more subject to wear and deterioration. All of the cold painted pieces examined in this work showed marked wear and abrasion. Cold painting sacrificed permanence for better detail and control of the final product. While it has not been explored thoroughly as of yet, perhaps it is not a surprise that the period (early 16th century) which saw a decline in the production of enamelled glass in Venice and the increase in Italian *istoriato* majolica production are roughly the same.

So far, I have offered comparisons between Renaissance Venetian glass and other types of Renaissance-era luxury goods: metalwork, rock crystal, and majolica. What was unique about glass as a material that resulted in it being desired and appreciated in Renaissance society? In the case of two of the materials considered here as alternatives to glass, glass offered a cheaper and more cost effective option. This factor would have been especially important for Renaissance consumers who did not occupy the upper strata of the economy but who still wished to furnish their homes with luxury style goods. Glass and majolica were priced roughly about the same as each other to not make this a factor between the two.

Glass, as a material, was unique in terms of its ability to be worked and shaped into a variety of forms replete with a host of different visual effects. Some of these were in imitation of other forms (skeuomorphs) or materials (evocation). Others were unique to glass only. This ability is derived from the unique viscosity response of glass to temperatures. While it will be discussed more later, many of the surviving pieces of Renaissance Venetian wineglasses are incredibly thin-walled (sometimes < 0.1 cm) and light. This, coupled with their clarity and colorlessness, (especially when made of *cristallo* glass) offered the Renaissance consumer a unique and special tangible quality. Such qualities of Venetian glass, which are subjective and hard to quantify or prove from a documentary context, must be considered when evaluating the demand for glass. In addition to the forms possible with glass, the beauty of the material as perceived from a Renaissance perspective must also have been a factor in demand. The consumption of Renaissance Venetian glass also afforded the Renaissance consumer an opportunity to own objects which exemplify very high standards of artisan skill, cleverness, and craftsmanship. This became especially true, as we shall see, in the 16th century when objects made of glass became even more elaborate and fanciful.

All of these factors - skill, ability to imitate in form or appearance, beauty - are part of the reasons behind the demand for luxury glass in the Renaissance as a material. The next sections explore why the luxury glass that was made specifically in Renaissance Venice was demanded and produced.

Demystifying Demand for Renaissance Venetian Luxury Glass

Three primary sources of information exist which can help with the task of explaining the demand for glass made in Renaissance Venice. These are: written records (diaries, inventories, correspondence, etc.), pictorial representations (mosaics, paintings), and the examination (chemical and physical) of actual objects.

The incorporation of these varied sources of information presents an approach to the study of Venetian glass that is unique. No previous work has utilized these three equally and in conjunction with one another. Giving more-or-less equal weight and validity to each resource is a departure from previous treatments which have typically relied heavily on one source at the neglect of the others. In this manner, this represents a methodological departure from the past in the examintion of technoogical change in the Venetian glass industry.

These sources are each discussed below. From these, a picture of some of the qualities of Venetian glass desirable to the Renaissance consumer will be portrayed.

Written Sources

A number of different written Renaissance-era documents pertaining to the demand for Venetian glass exist and have been published. Many of these, for example, have appeared piecemeal in Zecchin's work (1987, 1989, 1990). What follows is an attempt to collect these in a more comprehensive manner so that broader patterns may be discerned.

In modern-day Venice, the island of Murano is a popular tourist destination. Such was also the case during the Renaissance, especially in the time of interest here (c. 1450-1600). During this period, many high profile persons visited the island, primarily for the sake of seeing the glass workshops in operation. Marin Sanudo was a Venetian patrician who kept an extensive diary of the daily activities of Venice from 1496 to 1533. In a small volume written in 1493 for the Doge, Sanudo lists several popular and noteworthy sites for visitors to see in Venice. Among these is Murano "where they make glass" (Zecchin, 1987:233). During the writing of his diaries, Sanudo records the occasion of several noteworthy visits to Murano. There was the Queen of France in 1502 and the Duke of Urbino in 1532. Both came to see glass being made. At the end of June, 1515, Sanudo records the visit of one nobleman who "came to see Anzoleto Barovier make glass...the most beautiful vases..." (Zecchin, 1987:233). In 1493, Isabella d'Este was visiting Venice during the Feast of the Ascension. While there she toured Murano and stayed with Queen Caterina Cornaro at her home in Murano and visited the glass shops (Cartwright, 1907:100). Other visitors include papal legates (1510 and 1520), Federico Gonzaga of Mantua (1517), the Duke of Ferrara (1531), and numerous archbishops (1518-1520). One visit is particularly interesting - the archbishop of Genoa visited in September 1518 when the glass furnaces were closed for the annual recess. As a courtesy to the guest, the Venetian government allowed the furnace to be in operation at this time so that the archbishop could observe the artisans at work.

From these selected citations, it is clear that Murano was a popular stop on the wealthy tourist's itinerary. Sanudo's 1493 entry acknowledges that a visit by tourists to the glass houses was expected. Many of the visitors to Murano, according to Sanudo, would also stay for some time on the island (Zecchin, 1989:274). Numerous wealthy Venetians had summer homes and palaces on the island where such guests could reside. Such families included the Mula, the Correr, and the Trevisan (Barovier, 1982:35). Agricola concludes his chapter on glassmaking by noting that while in Murano he stayed at the home of Andrea Navagero, a wealthy Venetian who had a summer home there. It has been suggested, quite rightly, that the contact between wealthy Venetian patricians and their guests summering in Murano with the glassmakers of Murano could only have had a stimulating effect on the growth and health of the luxury glass industry (Barovier, 1982:35). What is not considered is the reverse effect. How did the glass artisans of Murano make the most of the presence of all of these cash-rich visitors? Did glassmakers manipulate desire and fashion for the sake of profit? While no direct documentary evidence exists of this, I feel certain this was the case. Several new decorative techniques were introduced to the Venetian glassmaking repertory during the first part of the 16th century: filigree work, diamond point engraving, cold painting. In 1521, the Venetian senate conferred the right, for 10 years, to the daughter of Alvise Vivarini to make ships of glass (Zecchin, 1989:276). Numerous examples of these are found in different museums and objects such as these are still purchased by tourists. I suggest that there were numerous feedbacks between the purchasers of glass in Murano and its producers. The drive to innovate and improve glass production, arising from the presence of wealthy consumers, would have introduced new sources of technological change via "producer pressure" (Schiffer, 1992:50). Production and demand were mutually stimulated.

Wealthy and famous members of Renaissance society were not the only visitors to Murano. Venice was a popular stopping point for pilgrims traveling to the Holy Land. The city also had a number of relics making it a pilgrim destination in its own right. Numerous pilgrim diaries record visits to Murano and the glass shops. Such a practice dates to the 14th century. It is known that Leonardo Frescolbaldi, a pilgrim, visited Venice for 19 days in 1384 on his way to the Near East. His diary records locations of famous religious sites in Venice including Santo Donato and San Stefano at Murano (Zecchin, 1989:275). About 100 years later, in 1483, a German

Dominican monk records a visit to Murano and the glass factories in his travel diary. Here they make "...with the finest art, glass objects of various shapes...In all the world there are not glassmakers like these who make precious crystalline vases and other miraculous things." (Zecchin, 1987:59). Another visitor in 1497 noted the "beautiful enamelled crystal" (Barovier, 1982:33). Such glass would even be purchased in Venice and given elsewhere as gifts. A papal record from 1458 notes that a certain Brother Mariano of Siena purchased *vitro cristallino* as a gift for Pope Pius II and received 30 *florins* of gold as payment (Zecchin, 1987:51). Such pilgrims also served as a conduit for Venetian glass to reach new markets. In 1480, a Milanese traveler to the Holy Land recorded in his diary that "certain crystalline vases" were transported to Damascus for an official of the Mamaluk sultan (Charleston, 1966; Barovier, 1982:51). While the belief that these glasses were of Muranese origin has recently been questioned (they may have been from Barcelona), the possibility that other glass travelled this way certainly exists (Carboni, 1986). In this manner, pilgrims to Venice not only helped spread the reputation of the product but also the glass itself.

The demand for Renaissance Venetian glass can also be seen in documentary evidence from non-Italian sources. For example, a 1592 source mentions that large cups with covers "to be used at the tabernacle" (i.e. reliquaries or to contain the Eucharist) were popular items of export to Germany. The presence of numerous objects in museum collections with enamelled German motifs and coat of arms confirms the German interest and demand for Venetian glass up until about 1550 when German glasshouses run by expatriate Venetians met the demand (Barovier, 1982:71-73). The Spanish affection for glass from Venice has already been cited. Inventories and records of the Spanish nobility document this fashion. According to Frothingham, Venetian "*cristallo*" was incredibly popular in 16th century Spain (1956:16). At Toledo in 1525, the principle export goods received from Venice included glass. Glass was very popular commodity to collect as other inventories of Spanish nobility throughout the 16th century attest. The next section will provide pictorial evidence of the popularity of Renaissance Venetian glass in Spain via an examination of Spanish still life paintings.

The ease of importing Venetian glass into Spain was facilitated by the trade policies of the Emperor Charles and his nephew King Philip (Frothingham, 1956:16). King Philip had an extensive interest in glass. He awarded concessions to Jacomo di Francesco, a Muranese glassmaker, in 1556 to produce glass in the Venetian manner in Spanish Antwerp. Between 1559 and 1561, King Philip also tried to obtain luxury goods from Venice via his ambassador there. These objects included Venetian glass and paintings by Titian. The glass was sent in two shipments; notes about the second from his contact in 1561 record "The glass is in preparation and will be ready at the close of the month, when I shall forward it to the ambassador at Genoa...and I shall write and not cease to press until they are shipped." (Almech, 1952:27-28). King Philip had a collection of over 300 Venetian pieces and an observer of a royal dinner noted that "He drinks from a crystal glass of medium size and empties it two or three times." A dinner for Philip was held in

1570 at which the glass and pottery "were of the highest quality, being foreign pieces" (Mal-Lara, 1570). A later section will examine this observation with regards to the quality of Venetian versus Spanish wares. In addition to using the glass, King Philip also displayed it. While sick in Madrid in 1569, he instructed the cabinetmakers to make cases of walnut so that he could show off and admire his best Venetian pieces (Frothingham,, 1956:20).

The interest of Renaissance society's elites in glass from Venice was not limited solely to ownership. The level of demand and desire for these goods was powerful enough that some members of the nobility expressed a direct interest in its manufacture. While this phenomenon will be discussed more later, this is remarkable given the fact that glassmaking was a manual labor activity. While attitudes towards crafts like glassmaking were changing slowly during this time, the large part of Renaissance society still held that dirtying ones hands with activities like glassmaking was not proper. Yet note the interest of the King of Spain in making sure that production of glass in the Venetian fashion was continued in Antwerp. Another example is the establishment of a Venetian style glasshouse in early 17th century Florence by Cosimo de'Medici (Heikamp, 1986).

What has been presented so far is that the documentary evidence, in the form of inventories, diaries, and shipping records, shows specifically that Venetian glass was a luxury good demanded by Renaissance society. Moreover, visitors to Venice were interested not only in the product but also in its production. This fascination carried over to places such as Spain and Germany. While I have clearly shown via written evidence that there was particular interest in Venetian glass, I have not yet provided more specific or detailed evidence for this demand. For example, what qualities were desired in Renaissance Venetian glass? How were these demands communicated to the producer? The records of Isabella d'Este, marchessa of Mantua between 1474 and 1539, are more comprehensive than others and offer a good picture of these processes.

The life of Isabella d'Este, perhaps more than any other woman of the Renaissance, has been the subject of extensive study (for example, Cartwright, 1907; Marek, 1976; Brown, 1982). What is important about her life for the work here is the passion she had for collecting decorative arts, paintings, and antiquities. By these activities, Isabella provided a stimulus for artistic and craft production as well as functioning as an arbiter of taste. Her role as a collector of luxury goods has been previously documented (Marek, 1976:96-129). Her correspondence with Lorenzo da Pavia, one of her agents in Venice, records her interest in everything from musical instruments to cats. Among these items is, of course, glass from Murano.

Interest of the Mantuan nobility in Venetian glass existed before Isabella d'Este began her collecting activities. A letter from June 1473 by Federico Gonzaga of Mantua to his mother specifically mentions the shop of Marco Barovier and the production of four gilded and enamelled pieces of glass to be used as wall decorations (Bertolotti, 1888; Zecchin, 1987:56). In 1491, Isabella was already engaged in the purchase of glass from Murano. In May, 1494, correspondence between her and another agent in Venice notes that she wanted 12 black *maniglie de vetro* (glass handles) which were to be made in the same pattern as those of gold and silver ones sent as models (Brown, 1982:214). A different agent provided the Marchessa with several cups and buckets in 1495. The letters from Isabella are very explicit with regards to the style of the pieces she ordered. She informed her agents many times when she was displeased with a piece along with its disagreeable features. For example, in 1496 she wrote in regards to 20 glasses that had been sent to her. She expressed satisfaction with their size but not their shape. She asked for another 20 of the same volume but with a more restrained design. Half were to have gilded features while the other 10 were to be made without gold of "*cristallino* both white and beautiful" (i.e. colorless). A few months later she wrote the same man with regards to the manufacture of a glass bucket. She sent a glass piece to Venice via a horseman with the intent of having a matching bucket made, restrained in style, "of beautiful proportion...without a foot...and with a handle of gold." (Brown, 1982:214-215).

Orders for glass from Isabella continue into the 16th century up until her death in 1539. A request from Isabella to Lorenzo da Pavia in 1507 is especially interesting. He was sent a silver soup dish to be copied in five different types of glass. She soon received copies in green and colorless glass with the others to come later as they had not yet been put into the furnace. The use of a silver piece as a model for later glasswork confirms the concept of skeuomorphism discussed above. Other materials served as models for the glassmakers of Murano. Models were sent from Isabella made of metal, wood, clay and wax. The process of ordering pieces is also revealing. The glassmakers were manufacturing pieces specifically for one customer in response to her private and personal tastes. Isabella d'Este's letters are typically very specific with respect to the features her pieces were to have. Isabella's agents were also always on the lookout for new designs. One wrote her in 1525 about four Muranese vases that had "a type of foot that I had not seen before" (Brown, 1982:216). The dual nature of demand and production can be seen at work here. Isabella would send specific designs for the glassmakers to work with. At the same time, they were forming their own new designs with the intent of stimulating demand and purchase. In this manner, one can begin to see how forces such as fashion and taste emerged as influences on both demand and production.

From correspondences such as these, one can also see that the qualities desirable in Renaissance Venetian glass fall into three categories. The first is the form, shape, and style of the piece. The second is the type of decoration applied to the glass. Was it to be gilded, enamelled, or left plain? Finally, for the *cristallo* type glass, qualities such as colorlessness and clarity were desired. A letter from 1510 records her displeasure with six large water glasses with covers as the "glass was not white enough" (Brown, 1982:216). These three features of Venetian glass - form, decoration, and material clarity and colorlessness - can be seen as qualities desired by the Renaissance connoisseur. To the issue of glass quality, in terms of the actual material used to fabricate the piece, we can add information from another source. In 1585, the Bishop of Olomouc in Bohemia ordered several objects from local glassmakers. He later complained that the glass "was not pure enough and that it has not the right proportions and fine shape." A year later when he ordered another piece, he specified that it be "transparent and made in the *facon de Venise*...very clear, without sand, defects, striae, and bubbles." (Hettes, 1963:41). These passages are very important because they offer some of the only known statements by the Renaissance person regarding what was desired in terms of glass quality (the material and not the form). A post-Renaissance letter from England to Venice, in 1672, offers additional proof regarding the qualities of glass that were desired in terms of the actual material. John Greene wrote a request for glass to his Venetian supplier asking that the quality be "... of very good clear white sound Metal for truly the last you sent me the Metal was indifferent good and clear but not so sound and strong as they should have been made..." (Charleston, 1968:158). A later part of this section will examine to what extent these qualities of Renaissance glass held in regard by contemporary society were fulfilled by the artisans.

Pictorial Sources

The use of contemporary pictorial sources to provide information about glass has received some attention. Ciappi has authored two papers which focus on the representation of mostly Florentine glassware in 13th and 14th century paintings (1991a; 1991b). Another example is the use of 17th century Dutch paintings to help provide a chronology of glass *roemers* (Brongers and Wijnman, 1968).

Figurative evidence may be used in a number of ways. The most obvious is the use of pictorial representations to supplement arguments concerning chronology and primacy. In this manner, the painting complements other methods such as the recovery of glass from archaeological contexts and the study of museum pieces. For example, the presence of a particular glass type in a painting of the 1520's may function as evidence that this glass was in use or popular at the time. Another use of figurative evidence is to establish what types of glass were being made at a particular time. Finally, the pictorial representations can illuminate the culture and behavior associated with particular objects. For example, how is glass shown in dining scenes? Is it shown? What types of objects are represented in still lifes?

There are drawbacks to this usage, however. The artist may have used whatever glass was available to depict in the painting. The object in question may have been an "antique", long out of fashion, that was included in the picture anyway. In addition, there may be symbolic or social motives, perhaps less easier to reveal,for the inclusion of particular objects. For example, the use of a glass vessel with light streaming through it without damage has a great symbolic dimension in a painting such as an Annunciation scene. Its appearance can be interpreted as analogous to the Word of God passing to Mary without the loss of her virginity (Cuneo, personal communication, 1995). Glass vessels frequently appear in the center foreground of many Annunciation scenes, frequently with lilies or other plants placed in them. Barovier offers several examples of this throughout her book but does not comment on the symbolic dimension (1982:36, 69, 81). In all the works, the glass is generally given a a prominent location in the painting. This deliberate representation of a particular material and its placement in the scene has symbolic and religious overtones and fulfills much more than a decorative or merely representational function.

The primary difficulty with allowing pictorial representations as evidence boils down to the fact that paintings are not snapshots of Renaissance life. These may have other specific agendas, perhaps only known to the artist or patron, that caused certain aspects of material culture to be shown. The representations may not present an accurate picture of life but instead show some idealized picture. There are degrees of artistic licence and symbolism present in this pictures which were often prepared for specific audiences. In this sense, it is not possible to "read" them in the same manner as one might approach the use of written evidence.

With these caveats in mind, I should like to use two categories of pictorial representations to provide information and evidence about the demand for Venetian glass in the Renaissance. The two genres of paintings are Italian dining scenes from the 14th through the 16th century and Spanish still lifes from the 16th and 17th centuries. These genres were selected for several reasons. There are numerous examples of each readily available for study. The two categories cover a time period from the 14th through the 17th century and also afford the opportunity to examine differences and similarities in Italian and non-Italian societies. Artistically, the two are related in that still lifes as a tradition arose from the increasingly detailed representation of objects in paintings such as dining scenes (Spike, 1983:12-14). One reason for selecting the Spanish still lifes over German or Dutch paintings is because the glass objects depicted in the Spanish still lifes are quite varied in form and show a very clear Venetian style and influence. This is not as apparent in the Dutch or German works. With that in mind, let us turn first to representations of dining scenes in Italian paintings.

In the course of this work, over 100 Northern Italian dining scenes or "sacred suppers" from before and after 1450 were examined. While there is no way to definitively prove that the glass in the paintings is Venetian, this certainly seems likely in many cases as Venice was the largest center of glassmaking in Italy. Furthermore, there were no centers of glass production in Northern Italy which were not heavily influenced by Venetian practices. These pre-Renaissance "sacred suppers" are not of tremendous use in establishing typologies of Venetian glass, especially of any luxury wares. The pictures themselves often lack the detail needed. In addition, the variety of the pieces represented is not very large. Ciappi claims greater success in using 13th and 14th century paintings to create and supplement chronologies of Tuscan glass (1991a; 1991b). As noted in Chapter 3, this situation is aided by a greater amount of organized excavations and archaeological research in this region.

Figures 7.6 and 7.7 depict two early or pre-Renaissance examples of such work. The first is a version of the *Last Supper* (circa 1320) by an unknown painter; the second is *Dinner of Abbot Guido*. Both paintings are from a monastery near Ferrara (Ciappi, 1991b:340) In the first, the scene is one common to Last Supper paintings - Christ seated at the table, surrounded by the Apostles in various poses. Laid out in front of them is the supper along with associated tableware. The glass objects shown in the painting are very simple and consist of an *inghistra* with several small glass tumblers. The depicted forms are utilitarian in nature and have little or no decoration applied. In this manner, they typify glass products of the 14th century based on information from shop records and inventory lists. The glass shown is clear and colorless; little attention has been paid to it by the painter with the emphasis instead on illustrating the figures. Figure 7.7 depicts similar glass tumblers, some filled with wine, laid out on a table with other wares. The glass here is also unremarkable and presumably typical of common wares made at the time. However, note the figure on the left is holding a vessel, probably of metal. Also depicted on the table is a ceramic pitcher with applied decoration. A few table utensils are seen as well. A distinction in materials, between glass and other types, such as ceramics and metals, is present. Another 14th century painting, the *Conversion of Water* by Menabuoi, also portrays a similar distinction. While not shown here, the disciples are all seated around an "L" shaped table. In the foreground someone is drinking newly converted wine from a plain tumbler filled from a much more ornate jug. A slightly later Last Supper scene by Paolo Veneziano (c. 1340) also illustrates these same basic glass types. Figure 7.8 shows an *inghistra* with tumblers based on a truncated cone form. These forms are also typically shown in other media such as mosaic work; Figure 7.9 illustrates simple table glass as shown in a mosaic from San Marco Basilica in Venice, c. 1350. The types of objects shown are also very typical of the Venetian medieval glass found in excavations (cf. Gasparetto, 1977, 1979)

The fundamental feature of these pre-Renaissance paintings lies in type and amount of glass shown. The glass represented in these works is typically very plain in form with little or no applied decoration; ordinary utilitarian *inghistre* and tumblers in clear glass are most commonly shown; other objects of metal or earthenware, sometimes more elaborate in form, are occasionally shown; little in the way of eating utensils are illustrated; and the overall level of "splendor" as shown in these works is minimal by later standards. The type of glass represented supports Ciappi's statement that medieval glassware "...seems mainly concerned with the production of everyday objects..." (Ciappi, 1991b:333). The medieval artist was still an "artisan" and painted those objects in common and familiar use.

Painters as artisans still continued to depict what was familiar, but by the end of the 15th and into the 16th century, the nature of glass as depicted in dining scenes changed. Evidence of this can be discerned in figurative works leading up to the 16th century. For example, a Last Supper painting from the early 15th century in Venice shows the same familiar arrangement of Jesus and the Apostles. In Figure 7.10, the table is shown with more glass objects; those depicted are not as simple as before. A careful look at the beakers and decanters suggests that the painter may have tried to represent them as decorated with surface ribbing. Another painting by Uccello from about the same time shows *inghistre* with spirally, ribbed neck designs, something not represented in earlier pictures. Two other paintings from the mid-15th century by Fra Filippo Lippi also reveal changes. The one painting by Lippi shows a meal at the house of Herod and depicts a shallow bowl with a dark thread around the outsplayed rim. The second painting, the *Annunciation* (c. 1440), places a large glass *inghistra* in the center foreground, giving it a very prominent location and a symbolic function, as well.

Not all of these painters mentioned were Venetian and there could certainly be other reasons for the types of objects depicted. However, I believe that evidence such as this supports the basic point I wish to make by using these paintings as evidence. A change was underway in the manner in which people viewed material culture such as glass and this can be seen, in some manner, in pictorial representations. As before, these later paintings provide evidence for the types of wares in fashion and their respective chronologies. These new forms and decorative techniques appear contemporaneously with the older forms as shown in Figure 7.11. The one on the left is a more elaborate design with applied twisted thread around the base and neck; the neck itself it spiraled. The other figure shows a plain *inghistra* with a pronounced kick in the older fashion. Both paintings are dated after 1450 and the invention of *cristallo*.

Once *cristallo* glass had been invented, the types of objects represented in pictures change even more. An early example of this trend is shown in Figure 7.12. This is an enamelled beaker with vertical ribbing painted by a Venetian artisan in the late 15th or early 16th century. In Venetian documents, this type of glass appears several time such as in 1485 ("enamelled beaker with ribs") or in 1508 ("glass with enamelled ribs") (Barovier, 1982:70). Other categories of Venetian glass appearing more frequently or for the first time include a clear and colorless pitcher with a pincered base (seen in a 1515 painting by a German artist). The *Baccanale* of Titian (c. 1518) illustrates a similarly shaped pitcher with a different base. A servant in the c. 1544 Tintoretto work, the *Feast at Belshazzar*, is depicted carrying two *inghistre* of the old design with two wide shallow footed goblets. New decorative techniques used in conjunction with cristallo, in addition to enamelling, are also seen. For example, a detail in the 1537 *Crucifixion* by Gaertner, a 16th century Swedish painter, at the Walters Gallery in Baltimore, shows a covered beaker with filigree work. The date of the painting is about 10 years after this glassworking technique became popular in Venice.

Many other examples from the late 15th and 16th centuries in the works of painters such Veronese, Titian (Figure 7.13), Tintoretto, Crivelli, Caravaggio (Figure 7.14), and Bassano exist which all illustrate the same point. The types of glass shown in paintings change significantly from the previous century. The forms become more elaborate and varied. New designs appear whereas the glass in the 14th and early 15th century paintings was very simple in appearance. The artists who include glass in their paintings appear to have taken greater pains to represent the objects. Often the pieces were given more prominent locations in such pictures. Barovier has noted that the type of glass shown in these paintings is almost always plain and unadorned "*cristallo*-type" glass, i.e. clear and colorless (1982:52). Rarely are other compositional types shown and when they are they are usually based on *cristallo* (the depiction of applied enamelling on a clear and colorless beaker, for example). The reasons suggested for this are three-fold. *Cristallo* glass (or at least clear and colorless glass) was very popular. Its inclusion in paintings was a way of conveying elegance. Finally, it provided a way for the painters to demonstrate their artistic capability. It was much more difficult to represent a three-dimensional colorless and transparent object than a colored one.

The increased variety of Venetian glass in such representations coincides with several ideas put forth earlier in this work. It was suggested that the mid-15th century witnessed a change in glass production as it responded to greater consumer demand. New fashions and demand had a synergistic effect on one another. The invention of *cristallo* glass in response to demand was cited as the primary force behind the greater number of designs and the overall resurgence in luxury glass production. All of these are confirmed with supporting evidence from pictorial representations.

So far, attention here has been directed towards looking at changes in how glass was depicted in Renaissance Italian dining scenes over time. This has been oriented with regards to the types of glass shown along with how much is represented with respect to other types of goods. Before moving away from the genre of Italian dining scenes in paintings, I would like to briefly consider how Venetian glass is represented in the painting of a particular Venetian artist after the resurgence in the demand for luxury glass. I do this because I believe that it offers an example of how these later "sacred supper" paintings illustrate the changing and increasingly extravagant Italian tastes with respect to luxury and splendor as indicated in the written sources.

Paolo Veronese (1528-1588) painted several very large (up to 18' by 42') banquet scenes in the latter half of the 16th century. Figure 7.15a illustrates one such work along with two details (7.15b and c). This portrayal of the wedding feast at Cana was done by Veronese in 1562-64 and is now on display at the Louvre in Paris. While intended to decorate a monastic setting (San Giorgio Maggiore in Venice) and to represent a religious event, Veronese's painting also provides a picture of the extravagances of Renaissance Venetian society. In this manner, it corresponds with some of the details recorded in contemporary textual sources regarding splendor and dining. There are a number of possible artistic and historical reasons for why Veronese and his patrons chose to show such detailed splendor in a painting commisioned for a monastery. One plausible set of inferences, however, that may be drawn from the painting is connected to how the dining habits of wealthy Renaissance society and the material culture associated with these had changed. In this manner, the scene may be interpreted at some level as showing a modification in attitudes toward splendor and the display of luxury goods.

Note the large number of glass objects on the table. Far from the common tumblers and *inghistre* of 14th century paintings, we now see many dinner guests in possession of fine Venetian wineglasses. The glasses shown in 7.15b are just part of the overall ensemble of luxury goods that Veronese uses to signal great richness. These include elaborate metalware, jewelry, and ceramics (Various authors, 1992:280-286). The painting illustrates changes in dining behaviors; note the woman in 7.15b in the back using a fork. The dining scene is depicted so that many guests have their own individual wineglass. These examples corroborate the changes in dining behavior noted in Renaissance written sources. The man in 7.15c holds his glass up to note the transformation of water to wine; is he admiring the glass or its contents?

What are some of the characteristic features of the glass depicted by Veronese? The wineglasses depicted in this work are clear and colorless. They are also very well proportioned in form and shape with an elegant and delicate design. Such qualities are considered by museum curators as the hallmark of fine Venetian glassware of the Renaissance (Tait, 1979). This design must have been a very durable one, fashion-wise, as it appears in the Caravaggio painting shown in 7.14 about 30 years later. While perhaps common in occurrence, the form is much more refined and complex in terms of the effort required to make it when compared to the simple tumblers discussed earlier.

The type of glass and the manner in which it is depicted by Veronese in this and other similar paintings by him suggests several ideas. The habits and behaviors associated with eating had clearly changed. A vast display of conspicuously rich and extravagant material culture associated with dining is shown by Veronese. Glass was considered sufficiently luxurious to be included with other items such as metal dishes and tureens, gilded forks, and fine ceramics. The types of glassware shown had changed. It is no longer shown just occupying space on a table. Dinner guests are depicted holding wineglasses, interacting with them, and appraising them and their contents. Glass is depicted as part of the overall ensemble needed to dine and entertain in a luxurious fashion, which is also confirmed by the written sources. Finally, qualities such as clarity, colorlessness, and proportion are inferred from these details to be important to the Renaissance consumer.

A second genre of paintings worth considering in order to understand demand for Venetian luxury glass is Spanish still life paintings, primarily from the late 16th and 17th centuries. These paintings are valuable to consider for several reasons. They provide examples of glass being displayed rather than used (i.e. a different set of functions). The effect that Venetian glassworking techniques had on the Spanish artisans may be noted. Finally, Spanish still lifes give a window into the world of fashion and demand and the influence that Venetian glass had on a non-Italian culture. Venetian glass was a highly valued imported item in Spanish society (Frothingham, 1963:14). These paintings allow one to infer the popularity and demand for Venetian-style luxury glass.

Obviously, Spanish still lifes can also be used to establish chronologies and typologies of glass with all of the caveats given previously applying. Little attention will be paid here to this use. Instead, I would focus on "what" is shown and "how". There are numerous documentary sources indicating that Venetian glass or glass made "*facon de Venise*" was a valued import item in Renaissance Spain. I have already described the great variety and amount of Venetian and *facon de Venise* glass that was present in the inventories of the Spanish nobility. For example, the Countess of Altimara had over 120 Venetian pieces at the time of her death (Anon., 1932, see Frothingham 1956:17). The interest of King Philip in collecting and producing Venetian styled glass has been noted. His inventory of 1563 lists at least 320 *vidrios de Venecia* (Cantón, 1934:73-75). Frothingham's work provides numerous other examples (1956, 1963).

Venetian or Venetian-styled glass is frequently shown in Spanish still lifes in conjunction with other valuable import goods such as the Chinese porcelain in Figure 7.16 (*Still Life with Artichokes and Vases of Flowers*, 1627, van der Hamen). Other examples, not shown here, place the glass next to luxurious vases in semi-precious stones or scrolled metal work. The principle of skeuomorphism exists as several metal or ceramic shapes are echoed by glass in other paintings.

Venetian-style glass is very common in Spanish still lifes of the 17th century. A recent catalogue of such paintings exhibited at London's National Gallery (Jordan and Cherry, 1995) shows that glass objects appear in at least 1/3 of those from the 17th century. Many display glasses with decorative techniques (filigree work and distinctive molding, for example) derived from Muranese practice. For example, the wineglass in Figure 7.17 with its distinctive hot-worked handles is clearly a Venetian-derived decoration if not a direct import from Venice (*Still Life with Peaches and Glass of Wine*, 1654, de Camprobín). Spanish still lifes provide an opportunity to observe the use of Venetian decorative motifs and their alteration by Spanish glassmakers in response to domestic demand. Figure 7.18 shows this feature (*Still Life with Sweets and Glassware*, 1622, van der Hamen). The decorations applied to the glass in this painting - filigree threads, molded stems, ribbing - are all quintessential Venetian practices. Yet the shapes of the vessels are distinctively

Spanish, based on comparison with surviving glass pieces attributed to Spanish workshops. In some cases, one may see how Spanish glassmakers adopted particular Venetian decorative practices and applied them to vessel forms more familiar to the domestic market.

In addition to being placed in close proximity to more costly luxury goods, Venetian-style glass was sometimes given very prominent locations in these pictures. A striking example can be seen in Figure 7.19 (*Allegory of Lost Virtue*, c.1650, de Perada). Note the three glass vessels in the center foreground. Most prominent among them is an elaborate winged, Venetian-style serpent goblet with blue threaded decoration and a gilded knop. It is placed in almost the exact center of the picture and is clearly displayed. Its presence serves to divide the space between the young man and the maid. Other vessels of foreign origin are clearly visible, too, such as the German stoneware and the Mexican or Spanish terracotta (Jordan and Cherry, 1995:91). But the Venetian glass piece is given the central spot.

All of these paintings corroborate the previously cited documentary sources indicating that Venetian-style glass was highly valued in 16th and 17th century Spanish society. The types of glassware shown is typically quite elaborate with fancy decoration and stemwork. Few common or rustic glass items are depicted. This is in opposition to other ceramic wares depicted which can be quite ordinary at times, especially in kitchen scenes. The qualities inferred from these paintings as desirable include the form, proportion, and the type of decoration applied. Clear and colorless glass, as was the case for the Italian paintings, is most frequently depicted.

Despite the other varieties of glassware being made in Europe at this time, it is the Venetian-style which is typically selected by Spanish artists as the type to show in their still lifes. This alone should say much about the demand for, the value, and the popularity of Venetian-style glass in fashion-conscious Spanish society. Two final notes: the presence of glass so frequently in Spanish still lifes brings up another, hitherto unmentioned, function of these paintings. While it has not, and perhaps can not, been proven, these paintings may have provided Spaniards a means to immortalize their Venetian treasures. Venetian glass was, and is, notoriously delicate. Perhaps still lifes gave greater permanence to a luxury good not so easily preserved? Another possibility is that paintings of glass satisfied the demand for a good which was not readily available. King Frederick IV of Denmark, for example, who had little porcelain overcame this problem by having an oil painting of an imaginary porcelain collection prepared (Impey, 1992:795). Could paintings of Venetian glass served the same purpose in Spanish culture?

In this section, we examined how Renaissance Venetian glass was represented in two genres of pictorial representation: Italian dining scenes and Spanish still lifes. Both genres, with a cautious interpretation, can be used as evidence for chronologies and typologies of glass pieces. Examined more closely, such pictorial representations may also communicate information about the demand and use of glass and the behaviors associated with it. The Italian dining scenes, for instance, document not only the changing types of glass depicted in paintings but its relative frequency. The glass shown became more elaborate and more prevalent in works post-dating 1450. The glass was depicted in much greater detail and variety. It also seems to be connected to changing behaviors regarding dining and luxurious display. The Spanish still lifes illustrate the function that Venetian-style glass had as a luxury export item used for decoration and display in Spanish society. The adoption and adaptation of Venetian manufacturing techniques by Spanish artists can be noted at times. The frequency with which glass is shown suggests something unique about the attitudes of the Spanish towards it. Spain was just one export market for Venetian glass in the Renaissance. Still lifes could be presented from other locations, such as the Netherlands which also depict glass made in the Venetian manner. In all of Renaissance works examined, Spanish and Italian, Venetian glass emerges as a symbol for luxury normally reserved for objects made of more costly materials.

Physical Examinations

In this section the objects themselves are presented as the third source of information regarding the demand for Renaissance Venetian glass. The methodology employed in this work for the examination and interpretation of the glass objects is introduced. The information gained from the examinations is considered in relation to that presented previously from the documentary and pictorial sources. It is hoped that, by the end of this section, the reader will have a clearer idea of the qualities desired from both glass, as a material, and Renaissance Venetian glass specifically. The examination and study of actual objects provides indications and confirmation of how these qualities were embodied in the glass.

From the previous survey of the written and pictorial evidence, several desirable attributes of glass and Venetian glass have been identified. Among these were:

a. Skill and workmanship associated with the piece

b. Form, shape, design, and/or proportion; also the "feel" of the glass

c. Evocation of other materials (rock crystal, et al.)

d. Colorlessness and clarity; relative number of defects present in the "material"

The documentary sources provide specific evidence for each of these qualities being a consideration in the demand for glass. Some of these appear in these sources more often than others. Others, such as price and ability to perform a required function, may not be mentioned specifically but arise from common sense. The objects must have been affordable to at least some members of Renaissance society. They also must have performed certain functions successfully in order for them to have continued being made. Many of the qualities indicated by the written sources as important can also be inferred from the paintings examined. Colorless glass is most often represented. The objects all display a high degree of symmetry and proportion. The glass depicted in the Veronese work is both elegant and functional. Much of the surviving Spanish glass from the Renaissance illustrates the influence of Venetian styles and decorative techniques on the Hispanic glass industry. These forms and decorative techniques appear in Spanish still lifes in as glass objects are shown which are primarily "Venetian" in style as well as those which have taken Venetian ornaments and re-worked them into a Spanish style.

Burke discusses the qualities that are essential in the Renaissance arts (1986:143-152). While his analysis is aimed primarily at the visual arts, several of the concepts he identifies are applicable to Renaissance crafts such as glass. Dozens of terms have been employed in Renaissance writings to describe paintings, sculptures, and buildings. These keywords cluster around five different artistic concepts. These are: naturalism, order, richness, expressiveness, and skill (Burke, 1986:144).

All of these broad concepts are manifest, to some degree, in both the qualities desired of Renaissance Venetian glass by society as well as in the glass itself. For example, the concept of "naturalism" is seen in the requirement that glass imitate or evoke some type of naturally occurring material. "Order", "symmetry", and "harmony" may all be inherent in attributes such as form and design. "Richness" encompasses such terms as "splendor" and "variety". The notion of "skill" as relating to quality of workmanship and competence is apparent. The point here is threefold - the qualities identified as desirable in Venetian glass are not unique to glass. Rather, they arise from, and should be considered in the context of, broader and more general Renaissance artistic qualities. Secondly, the same concepts that form the working vocabulary of the Renaissance art historian, who may focus on the more familiar forms of paintings and architecture, are equally valid for other media such as glass. The same values and attitudes, for instance, that informed desire and demand for sculpture were also at work in the demand for glass. Finally, the reader should be aware of these broader concepts in the examination of specific glass objects.

The study of the glass objects for the consideration of issues beyond the familiar and more mundane questions of production, primacy, and provenance is uncommon. Once the glass objects are admitted as evidence, the question next becomes how to examine them and how to interpret the findings. The use of a "performance matrix" approach, described in Chapter Two, is not explicitly applicable here. For the case of Venetian glass, the qualities associated with the demand for it have already been identified or inferred. What is needed here is to examine each of these qualities to see how and if they were fulfilled for the Renaissance consumer by the producer. As each of these qualities is considered, there are three basic oppositions to bear in mind: the use of glass versus another material; the demand for Venetian versus non-Venetian glass; and the demand for Venetian luxury glass versus Venetian common glass.

During the summers of 1993-1995, over 200 physical examinations (PE's) were conducted of mostly Renaissance-era glassware. This glassware included whole vessels, individual sherds, and some groups of similar sherds. Glass made in Venice as well as *facon de Venise* glass was studied. These examinations were carried out with the permission and assistance of the following museums:

- Museo Internazionale delle Ceramiche (Faenza, Italy, 1993)
- Museo Vetrario (Murano, Italy, 1994)

- The Corning Museum of Glass (Corning, U.S.A., 1994)
- The Metropolitan Museum of Art, The Robert Lehman Collection (New York City, U.S.A., 1995)
- The British Museum (London, England, 1995)
- The Victoria and Albert Museum (London, England, 1995)
- The Ashmolean Museum (Oxford, England, 1995)

Appendix B describes in detail the protocol followed for these physical examinations, the techniques used, and the methodology for the classification of the different pieces. Essentially, the PE's focussed on the form of the object, the quality of the glass used to make it, its color, state of preservation, and evidence of workmanship. Appendix B explains all of these characteristics. There are several caveats and pitfalls to conducting such a survey detailed in Appendix B as well. The primary one is that all of the objects examined came from a museum context. Only the sherds originated from archaeological sources. The Venetian glass objects preserved in museums were the only ones available for study. However, the reader should be made aware of the bias in quality and form inherent in examining museum quality wares. It is almost certain that many types of glass made in Renaissance Venice have not found their way to museum storerooms. My conclusions regarding vessels attributed to different centers of production was very dependent on the provenance assigned to that piece by the museum. Furthermore, different museums certainly have their own agendas in choosing what objects to collect, display, and allow access to. The pieces that I chose to study were not selected by me for any personal reasons other than that they were accessible and represented the type of material that was of interest to this work - namely, Venetian glass of the Renaissance with a focus on the luxury wares. While the biases present in a museum collection were largely unavoidable in this work, I wish the reader to be aware of them and bear them in mind as such issues as "quality" and "workmanship" are discussed.

Below, an examination of several different qualities identified as relevant to the demand for glass is presented based primarily on the PE's and supplemented by other sources.

a. Skill and workmanship

A recent article on the development of the Renaissance Venetian glass industry concludes with the assertion that the fame and prosperity of the Muranese industry did not derive only from the use of carefully selected raw materials. Instead the author cites the "inventiveness and dexterity of the glassmakers" as primary cause for the success of Murano glass (Jacoby, 1993:90). While Jacoby is largely incorrect in naming any one factor for the popularity of Muranese glass, the documentary sources cited previously all indicate that the manner in which Venetian glass was produced was a part of the overall demand and desire for it.

The respect for the craftsman's skill in manipulating raw glass into an finished product is what Lucie-Smith calls the "most disconcerting aspect of Renaissance attitudes towards the crafts" (1981:160). In the Renaissance, the life of the mind was opposed to the life of the body with intellectual activity seen as superior to manual working. Yet this apparent disdain for physical work was opposed by the Renaissance person's love of virtuosity. The Renaissance glassmaker's aim in seeking the respect of his customers and peers was to display his skill by forcing and coaxing obedience from the material. This included everything from imitation, refinement, and the ability to surprise the public with unexpected forms (Lucie-Smith, 1981:160).

Artisan work skills combine differing proportions of four components - dexterity, judgement, planning, and resourcefulness (Gordon and Malone, 1994:39). Superior workmanship is the result of the artisan understanding the properties of the materials he is working with which does not require an explicit "scientific" explanation. A central part of this skill is the ability to successfully create objects, such as luxury glass, in the face of incomplete information and understanding (Gordon and Malone, 1994:38-39).

Almost any study of Venetian glass can be found to have many superlatives present which allude to the skill with which the glass was worked. Words such as "elegant", "precise", "terse", and "spectacular" are all repeated throughout the basic descriptions of the glass. Little attempt has been made to further quantify exactly what elements of form and design are present in the Renaissance Venetian pieces. How do these pieces differ from *facon de Venise* pieces in terms of how they were assembled? What qualities were there in the Venetian pieces in terms of skill that the Renaissance person found appealing or desirable? Is there a particular manner of working the glass that identifies the style, the object, or the workmanship associated with it as "Venetian"? This last query becomes especially relevant in the examination and display of museum pieces. Much of the attribution of particular objects to specific locales of manufacture is done on the basis of the form and workmanship. What qualities does the curator or connoisseur look for?

Needless, to say the entire question of what constitutes skill and quality workmanship is thorny. Many of the answers lie in the realm of the subjective and personal taste. However, one way in which questions may be provided is to approach the question of "skill" from the position of someone who has regular and intimate knowledge of glass and the manipulation of it as a material. For this purpose, the opinions and judgements of several different glassmakers were gathered in 1994 and 1995 - Alysia Fischer and Tom Philabaum in Tucson, Arizona; Bill Gudenrath in Corning, New York. The comments of Gudenrath were especially insightful as he has concentrated his production in the past 15 years on the manufacture and replication of Venetian production techniques. These opinions were carried out in conjunction with the examination of various Venetian and *facon de Venise* objects in the form of pictures, sherds, and whole vessels.

This section does not describe the different steps of assemblage involved in making glass. It is assumed here that the reader is familiar with such stages as gathering, marvering, blowing, etc.. For a complete discussion of techniques, a recent publication offers a step-by-step treatment of the production processes associated with glassmaking (Tait, 1991:213-247).

On the basis of conversations with different glass blowers, it became possible to identify several features of glass made in the Venetian style that require specific techniques and skills. Many of these techniques were carried outside of Venice during the Renaissance to other venues of production where non-Venetian glassmakers attempted to duplicate them. Are differences seen between the skills associated between Venetian and *facon de Venise* pieces?

The answer must be a cautious "yes". This answer is tempered with the knowledge that quality glass was made at all times and places during the Renaissance. One cannot simply say that all of the Venetian pieces are of a higher quality and display a greater level of skill. Numerous examples can easily be found in museum storerooms of Venetian pieces displaying sloppy production techniques or of Spanish pieces which are flawless imitations of Venetian technique and form. Yet general patterns and trends may be seen which are associated with the high degree of glassmaking skill in Venice during the Renaissance which glassmakers in other places tried to imitate.

One of the features especially cited by the different glassmakers consulted lies in the thinness of the Venetian luxury pieces, especially in the clear, colorless, and relatively unadorned pieces described often in museum catalogs as *cristallo*. The production of these extremely thin pieces, left un-enamelled or decorated with blue trails, can be considered to have begun, on the basis of the dates given in museum descriptions, by the early to mid-16th century. Consider one such object that was examined at the Museo Vetrario in Murano, shown in Figure 7.20 and 7.21. This wineglass is dated to the second part of the 16th century. It is an excellent illustration of the techniques and features that represent Venetian glassmaking skill in the Renaissance. The thinness of the object as measured at the vessel wall is only 1 mm thick. Other Venetian pieces examined in this work were as thin as 0.7 mm. The result of having such a thin vessel is that it has a very tangible "weightless" quality to it; this contributes, in part, to the overall "feel" of the piece that curators sometimes use to classify glass objects. The production of vessels as thin as this creates numerous difficulties and opportunities for the glassmaker. The most apparent may be that a very thin vessel, as it is worked and assembled on the blowpipe, is going to be more easily deformed by careless overheating. The walls of a thin vessel will cool more quickly making the timing of the glassmaker more important. The production of very thin glass pieces reduces the margin of error that is available to the glassmaker in terms of making mistakes. The thinness of the piece carries over into the delicate foot as well resulting in an object which is very fragile and easily chipped. While making the glass more difficult to produce, the thinness of the vessel affords the glassmaker a chance to demonstrate his skill. All of the 20th century glassmakers consulted cited the thinness of the objects as one of the representative features of Venetian glass. It is only fair to mention that numerous *facon de Venise* pieces examined had comparable walls thicknesses, as well. The skill with which the Venetians were able to manufacture thin-walled vessels was also duplicated outside of Venice.

A second feature of Venetian glass cited by modern glassmakers is not as clearly seen in non-Venetian pieces, however. This is the skill with which the different components of the vessel are assembled along with resultant overall "lines" and symmetry of the piece. Recall that symmetry was one of the qualities cited by Burke as representative of Renaissance art forms (1986:144). Consider the vessel shown in Figure 7.20 again. Note the very high degree of symmetry and balance in the piece. The large majority of Venetian glass pieces examined for this work displayed these qualities. The rims were almost without exception very flat and even. The production of an uneven rim results from the glassmaker being unable to control the glass while it is hot. One must remember that the glass piece, while being assembled on the blowpipe, is kept in constant rotation to keep the object from slumping in one direction. An analogy exists between the potter's wheel and the glassmaker's blowpipe as they both employ circular or rotating motions to shape the piece. The stem of the wineglass shown in Figure 7.20 is separated from the foot and the body by two mereses (flat circular disks of glass used to separate different parts and to give strength to the vessel). The assemblage of the different vessel parts has resulted in an object perfectly balanced around a vertical axis placed through the center of the bowl. As with making a very thin-walled vessel, the production of a symmetric object demands complete control of the glass while it is being worked. Once off-center, it is very hard to realign the piece back to a symmetric form. Making a balanced and symmetric form requires control of both the rotation of blowpipe, in terms of speed and consistency, and the temperature of the piece which must be kept fairly constant throughout the object. When the object is reheated at the glory hole it must be kept balanced on the blowpipe with care so that it does not slump to one side. During the entire assembly process, the piece is moving and spinning. Assembly of a balanced and centered piece is an indication of a higher level of craftsmanship and is more difficult to attain.

Keller discusses the process of visualizing and executing a finished craft object (Keller, 1994:63-65). While his article dealt specifically with the products of a blacksmith's forge, the general principles apply here. The first step of the manufacturing process is for the artisan to visualize or know what the finished object *should* look like. This is usually not in the form of drawings but rather a defined mental image. The manufacturing sequence then proceeds through a series of steps that Keller refers to as being subjective rather than defined chronometric units (1994:65). In these steps, the difference between an experienced craftsman and one who is a novice is that the latter frequently does not detect the development of problems in the piece until it is too late to correct them. An experienced glassmaker who is familiar with the material and the intended design is able to recognize when there is too much heat or when the object is slightly off-center. Gordon and Malone refer to this ability as essential components of judgement and planning (1994:39). This familiarity with the medium and the form is what I believe is partially responsible for the differences in skill seen at times between Venetian and non-Venetian Renaissance glass. This especially is true as glassmakers from other areas attempted to replicate the Venetian designs. Additional complications certainly emerged as different glassmaking areas had differential access to the same raw materials used in Venice and were forced to make modifications and substitutions. For example, the Bohemian glassmakers of the 16th and 17th century did not have access to the same fluxing material used in Venice. Hettes notes that they modified their raw fluxing materials via purification and filtration in the same manner as was done in Venice (1963:41).

Many of the non-Venetian pieces examined in this work did not show the same degree of symmetry and balance as seen in the objects attributed to Venetian craftsmen. Figures 7.22 and 7.23 show two similar goblets in the Corning Museum of Glass collections; they are attributed to an unknown *facon de Venise* workshop of the 17th century. Both are asymmetrical with respect to being centered around a central vertical axis. The vessel in Figure 7.22 has an uneven rim which is not circular. The wineglass in Figure 7.23 has a smooth rim but the stem is off-center with the foot which is also acircular and poorly executed. Note that both objects were made in imitation of the Venetian style yet they do not meet the same level of quality craftsmanship. In addition to being off-center more frequently, the non-Venetian pieces examined are not joined together as well. The seams may be more visible or perhaps more glass than necessary may have been used to attach the different parts together. In general, the non-Venetian pieces examined in this work did not possess the same degree of balance and symmetry as those which were attributed to Murano. The concept of form and design will be picked up again shortly in relation to the overall proportions of Renaissance Venetian glass.

Other qualities of the Venetian glass examined can be cited which further illustrate the qualities of skill and craftsmanship inherent in the glass. Consider the vessel shown in Figure 7.24 or the detail in Figure 7.21. Both display another feature of Venetian glassmaking production that exemplifies the skill of artisans. Both objects feature glass that is applied as decoration while hot ("bit working"). The use of this style of decoration requires very precise handling of the glass. Because the applied decoration is thin it cools very quickly. Therefore, it must be applied and worked with great speed and confidence. Using only a very simple tool kit and a small gob of glass, the glassmakers were able to manipulate it into a design that is both detailed and balanced. Bill Gudenrath (1994) described this manner of working as quintessentially Venetian. The glassmaker took full advantage of his medium and incorporated the inherent fluidity and spontaneity of the glass into the object as decoration.

Another very "Venetian" manner of glassworking was the assembly of complex objects on the blowpipe. The Venetian-styled "serpent goblet" shown in the Spanish painting (Figure 7.19) is an excellent illustration of this. I observed Gudenrath fashioning several replications of this style in his studio. Each, on average, took about an hour to assemble. The total number of components incorporated into the finished vessel was about ten to twelve. All of these parts must be carefully joined and aligned in order for the piece to be considered a success. Numerous examples of these goblets exist in museum collections and are attributed to both Venetian and *facon de Venise* workshops.

Other signs of artisan skill and ability can be revealed through a detailed study of glass objects. For example, in the course of conducting the physical examinations, signs of working and shaping could sometimes be seen. This evidence included such phenomena as tool marks still visible in the glass, evidence of joins, presence of a double or single pontil mark, and so forth. With regards to these features, there was little observable difference between the Venetian luxury glass studied and those of *facon de Venise* provenance. Many such marks are the natural result of working and shaping the glass and may be largely unavoidable. In some cases, gross defects with regards to tool marks and so on were seen but there was no clear pattern between the Venetian and non-Venetian wares. All of the glass examined, except for a few sherds and waste pieces, were well-annealed which is not surprising given their survival into the present time.

The *filigree* work and "bit work" of the vessel shown in Figure 7.25 (Museo Vetrario, late 17th century) is an example of how different decorative techniques were incorporated into one object. The ultimate success of a piece such as this would require a very high level of skill and precision. This is especially true of vessels such as this which incorporate white opaque glass (*lattimo*) threads into a colorless glass matrix. The resulting *filigree* glass has white threads which create a very regular net or mesh-like effect. Careful control of the spacing and incorporation of these white threads is crucial for the piece have the most visual impact. Furthermore, this particular piece incorporates glass of two different colors. Due to compositional differences, differently colored glass will respond variably when heated to the same temperature making the judgement and ability of the artisan even more important. While probably not a big factor for this particular piece, as the red decoration at the rim was probably trailed on near the end of the production sequence, other Venetian pieces might have a bowl and foot in one color and a stem section in another.

There is another aspect of glassmaking skill and craftsmanship that has not been mentioned yet. This is the ability of the artisan to produce a quality "material" with which to fashion an object. Here, the term material is adopted from work by Harden in which it was taken to mean the condition and state of the glass at the time of manufacture and independent of how the glass itself was subsequently worked and manipulated to form a distinct object (cf. Harden, 1936). In sense, the quality of "material" refers to such things as the number of defects present (bubbles, cord, stones, striae). These defects, and therefore the quality of the "material", arise from the beginning stages of the production sequence before the glass is worked. Choices made with regards to the type and quality of the raw materials utilized, furnace conditions, and so on have much to do with the final quality of the object in terms of the glass used to fabricate it. Because they are more associated with glass production, I would like to postpone detailed discussion of this expression of artisan skill until the next chapter which discusses this explicitly. For the time being, it is known from the documentary sources that a defect free and colorless glass was one quality that was looked for in a quality Venetian glass piece. The results of my physical examinations of Renaissance glass objects indicate that this quality of "material" can be expressed in a semi-quantitative fashion and that some differences between Venetian and *facon de Venise* production can be seen. More will be said about this in Chapter 8.

b. Form, proportion, and "feel"

The form and design of Renaissance Venetian glass is another criteria that the documentary and pictorial sources indicate was a desired feature and therefore part of the overall demand for glass. These attributes are also part of the mental template that museum curators use to establish provenance for Renaissance glass. Does it look "Venetian"? Does it have stylistic parallels with other pieces? How does it "feel" (literally)? This last criteria is especially interesting in light of a conversation I had with one museum curator in 1995. In comparing several pieces and discussing whether they were *cristallo* or *vitrum blanchum*, the museum curator noted that the one was lighter in weight (it was also thinner!) and must therefore be *cristallo*. Further questioning revealed that the heft of an object was one criteria for determining whether a particular object was *cristallo*. Identification of *cristallo* objects has important consequences for glass conservation as they are more likely to corrode in a museum environment due to their reduced CaO and MgO content. However, this can best be ascertained via chemical study. The density differences between *cristallo* and the other "colorless" glass made in Venice are not significant enough to allow identification via the "feel" of the piece. This anecdote serves to underline the point made at the beginning of this chapter that there are different communities involved in the study of Venetian glass. Often, they carry out their work independent of the other group's work. As a result, definitions on such issues as what constitutes a particular type of glass, for instance, have often been vague until more recently.

In his broad discussion of Renaissance taste in art, Burke identifies order and harmony as one of the hallmarks. He cites Renaissance artisans like Alberti and Ghiberti who use terms such as "harmony", "symmetry", and "proportion" to describe beauty (Burke, 1986:145). Burke points out that the Italian preference for symmetry in painting began to break down in the 1520's. Eventually, such trends would become manifest in Venetian glass which became more fanciful and elaborate through the course of the 16th century, almost to the point that their decoration would interfere with any possible technofunction. But at least in the late 15th and first part of the 16th century, measure and form and the relation of the parts to the whole are clearly seen in Renaissance Venetian glass. For example, Charleston describes the overall qualities of a 16th century wineglass as a classic form, "an object that is perfect in the harmonious balance of its constituent parts" (Charleston, 1993:92).

In order to illustrate the careful design of Venetian glass in attaining the balance of form and proportion, I have selected one particular class of objects from the physical examinations conducted. These objects, made over a fairly broad span of time, maybe 30 to 50 years, and presumably at several different workshops indicate that proportion and form was a concern and that pains were taken to ensure that there was a balance of parts to the whole.

The objects selected are Renaissance Venetian *tazze*. These are shallow bowls or plates mounted on short spreading feet. The *tazze* that I wish to use to illustrate my point were all made in the late 15th or first quarter of the 16th century. 15 tazze were examined from this time period. Figure 7.26 illustrates two *tazze* examined at the British Museum in 1995. As a separate group of glass, these objects are especially interesting to examine for a number of reasons. They are generally made of "colorless" glass often identified as "*cristallo*" in museum descriptions. They employ a wide variety of decorative features including gilding and enamelling. Both objects in Figure 7.26 have this type of decoration. Typical enamelled scenes include coat-of-arms (ones with the Papal/Medici design from either the reign of Leo X [1513-1521] or Clement VII [1523-1534] are quite common); animals and religious/mythological scenes are also very common. The bodies of the *tazze* are decorated in a number of ways while being worked. The body may be left plain or a pattern of ribbing (straight or spiraling) might be used via a technique known as half-stamping (*mezza stampura*). The number of ribs might vary anywhere from 12 to 20 to 40. In other cases, a molded diamond or "lozenge" pattern was used. At other times, a design known to glass scholars as "nipt diamond waies" was employed. The foot rims of the *tazze* were often given folds as were the rims. What emerges from these descriptions is that these objects were made over an extended period of time. The different coats of arms present indicates that they were made for domestic use as well as being exported. They exhibit a wide range of decorative techniques. Their presence in museum collections around the world suggests that the form was fairly common. The form, as discussed early, is a skeuomorph of a shape originally made in metal with the ribbing being a carry-over from that medium. And yet the form and proportion remain very stable over time.

To prove this, measurements were made of 15 *tazze* dated from the late 15th to early 16th century. All were attributed to Venetian workshops. The height, rim diameter, and base diameter was recorded along with the thickness. The results are presented below:

Table 7.1. Dimensions of Renaissance Venetian *tazze*.

Ht. (cm)	Base Dia. (cm)	Rim Dia. (cm)	Thickness (mm)
6	11	23	2.3
6	12	25	2.3
6	12	25	2.3
6.8	12	27	2.2
7.5	11	27.5	2.2
5.5	11.5	22	2.2
6.5	12	23	2.5
6.5	13	25.5	2.2
6	11.8	23.5	2.3
7.5	12	23	2
5.2	11	23.5	2.2
5.3	12	23	2.2
5.5	11.5	24.2	2.2
6.9	13	28.3	4.5
6	13	24	3.5
avg. = 6.2	avg. = 11.9	avg. = 24.3	avg. = 2.5
std. dev. = 0.7	std. dev. = 0.7	std. dev. = 1.8	std. dev. = 0.7

From these measurements, it may be seen that the dimensions for *tazze* manufactured over the span of some 40 years or more remained fairly constant. It may also be seen that the glassmakers who fashioned such articles followed a fairly consistent ratio of parts to the whole. Note the ratio of the height to the rim diameter to the base diameter in the Venetian *tazze* examined here is essentially 1:2:4. A very explicit and clear mental template with regard to dimensions was followed. While the decorative features and motifs of the *tazze* varied, the overall shape and proportion remained constant over time.

Similar patterns may be discerned in other classes of Renaissance Venetian vessels. The effect is seen most clearly in the *tazze* however (they are also very well-dated and provenanced). The point remains that proportion and form were essential components in the demand for glass. The glassmakers of Murano recognized and responded to this criteria in the manufacture of luxury glass.

c. Evocation of other materials

It is known from the documentary sources presented earlier that the Muranese glassmakers were well-known for their ability to imitate other materials with their glass compositions. Recall that Sabellico noted that the glassmakers were able to imitate almost any precious stone while Biringuccio comments on the resemblance of fine Venetian glass to natural crystal. The materials that glassmakers imitated were both naturally occurring (rock crystal and agate) and man-made (porcelain). The production of glass as imitation gemstones was a large part of the glassmakers' repertoire. This observation is based on the number of recipes for colored glass which are to found in Renaissance-era manuscripts such as Neri treatise and the Darduin book (Barovier, 1982; Zecchin, 1986).

The culture and technology of Renaissance Venetian chalcedony glass made to evoke semi-precious stones like agate and jasper has already been researched (McCray, et al., 1995). For the purposes of the present research, I focus on the production of *cristallo* and other "colorless" compositions in imitation of rock crystal. How does the Venetian glass compare with the rock crystal from perspective of physically examining it? Unfortunately, there were no rock crystal pieces available in the museum context to closely examine. In comparison to glass, such pieces are rare. Some especially well-known pre-Renaissance Islamic or Byzantine rock crystal pieces, approximately 15 in all, are housed at the Treasury of San Marco in Venice. However, these are city treasures and access is quite difficult to come by. Other examples of work in rock crystal were observed at the British Museum, the Wallace collection, and the Victoria and Albert Museum in London as well as at Amsterdam's Rijksmuseum. Therefore, observations must be limited to a comparison in form and design between the two materials coupled with what can be seen of the quality of the rock crystal through the display case of a museum.

Rock crystal working and glassmaking are part of separate technological traditions. This can be seen merely in the manner in which the materials are worked. Rock crystal is crafted in a traditional stone working fashion; i.e. while cold and via a series of cutting, grinding, and polishing steps. Glass, of course, is worked while hot and is receptive to an entirely different set of production techniques which developed in response to consumer demand. *Cristallo* and *vitrum blanchum* glass in Renaissance Venice, as I have shown, was capable of being manipulated into a wide variety of objects. These objects could be quite elaborate and fashioned with very thin walls. The result could be an object that was very light and elegant. If one is to hold a fine Venetian wineglass in one's hand, one is acutely aware of it its extreme fragility and delicateness.

Rock crystal, on the other hand, was not capable of being worked into such thin-walled and delicate forms. All of the rock crystal pieces seen in this work were much more massive in form with much thicker walls. As glass and rock crystal have similar densities, the difference in thickness results in rock crystal pieces being much heavier. The quartz *tazza* in London's Wallace Collection bears a strong resemblance in design to glass vessels but the walls, while thin for the medium, are still much thicker that what could be accomplished with glass. In terms of production, the making of a rock crystal piece was a much more time and labor intensive operation than the production of a similar form in glass. While I found no specific prices for rock crystal objects, it is without doubt that the inherent rarity of the material and the time associated with fashioning should have resulted in an object with much higher prices than those for glass. Zecchin comments on the relative price of lenses fashioned in rock crystal versus those in glass with the former being preferred by the richest members of society (1989:250). The inventory lists of Isabella d'Este contain several mentions of "*cristale*", often in conjunction with other precious materials such as pearls or silver. Glass is not recorded as such and presumably these pieces are fashioned from rock crystal.

Renaissance Venetian glass, while it comes close at times, is never comparable to rock crystal in terms of the overall quality of the "material". Glass, at least that made in Renaissance Venice, always has some defects present. These may be bubbles, cord or striae, or stones. Minor and unintentional tints may be present. All arise form the production process and are quite difficult to eliminate entirely from the glass. Rock crystal does not have these defects in the same quantity. Occasionally, an small inclusion in the material may be seen but the overall effect is of a waterlike solid with extreme clarity and lack of color. For all of the comparisons to rock crystal, glass was inferior in terms of material quality. It was only with the English development of lead crystal glass in the late 17th century, using techniques partially derived from the Venetians, that a glass was produced which truly approached and rivaled rock crystal in terms of its overall appearance. A letter from Girolamo Alberti, the Venetian secretary in London, wrote home in 1674 that the English glasses were now capable of rivaling the Venetian products. They are "...very white and thick, in imitation of rock crystal...and they surpass those of Venice." (Charleston, 1968:158). The next section on production will address this question of defects and "material quality" as they relate to the manufacturing process in much more detail. For now, I wish to conclude with the comment that glass was able to imitate many materials quite well. However, and especially for the case of *cristallo* glass, it was possible to differentiate between the real and the imitator. However, the success of glass cannot be measured solely on its ability to imitate flawlessly. Other factors such as availability, cost, and the fact that it was glass (versus another type of material) must be considered.

The most significant parallel between rock crystal and *cristallo* is, of course, their color (or lack thereof) and their clarity. The optical qualities of *cristallo* must also be considered in comparison to the other compositional types being made in Venice at the same time. These considerations are presented below.

d. Color and clarity

One of the characteristics noted in the Renaissance glass that was physically examined in this work was the optical quality of the material. The documentary sources cited earlier indicate that clarity and colorlessness were desirable features in Venetian glass. How well do the glasses examined in this work fare in this respect? What do the physical studies of the glass say about the ability of the Venetian glassmakers to respond to and fulfill this criteria? What types of optical variability is noted between the different types of Renaissance Venetian glass compositions or between rock crystal and glass?

From a perspective of optical quality in terms of colorlessness, transparency, and clarity, objects fashioned from rock crystal are clearly superior to those made of Venetian glass. Figure 7.27 presents a 10th century rock crystal ewer of Islamic origin from the Treasury of San Marco as an example of the excellent visual appearance of rock crystal. None of the defects so often seen in Renaissance Venetian glass such as bubbles or waviness are present beyond a few small black inclusions in the quartz. The rock crystal also has none of the yellow, green, or grey tints seen at times in Venetian glass, most notably in the *vitrum blanchum* compositions. The only flaw in the appearance of the quartz pieces are areas not as well polished as others and with a dull surface appearance due to the presence of scratches.

Accepting, therefore, that the visual appearance of rock crystal in terms of colorlessness and clarity was superior to that obtainable with glass, the next comparison is how the different glass compositions made in Venice compare with one another in terms of visual quality. In order to place these comparisons on a more quantitative footing, different glass samples from the pre-Renaissance and Renaissance period had their percent transmission of light measured over a range of different wavelengths. Tests such as these have never been presented before in relation to Venetian glass.

The details of the testing procedure, a description of the samples analyzed, and their average chemical composition are provided in Appendix A. A total of 13 samples were studied with this technique. The results of all of the tests are shown in the appendix and only selected ones are reproduced here as needed.

From the viewpoint of overall optical appearance, the pieces examined in this work (both sherds and vessels) that were known to be of a *cristallo* composition were superior to those of other Renaissance "colorless" compositions. The *cristallo* glass was more "colorless" and had greater clarity. Frequently, these other compositions, while fashioned into the same forms as the *cristallo* wares, were optically different. They typically had some variety of tint present with grey, yellow, or greenish-blue being the most common. The exact causes of these tints relate to choices made regarding raw material selection and manufacture. In some cases, these gross visual differences were reflected in the % transmission vs. wavelength tests conducted.Colorlessness and clarity were qualities demanded by Renaissance consumers and *cristallo* glass was the closest the Venetian glassmakers came to achieving this desire. The results of the tests are therefore best presented by comparing the other glass analyzed with the results of **sample #1** which, as described in the appendix, is a known *cristallo* composition. These comparisons were done to illustrate that the superior optical qualities of *cristallo,* noted earlier in a subjective fashion, can be seen in a more quantitative manner.

Note that what is being shown in the plots is the relative differences between the samples. Certain samples might show overall lower transmission which is largely due to the nature of the specimens themselves. Factors such as thickness, surface products, and geometry all influence the overall transmission. Appendix A explains these factors in more detail. The utility of the plots is not in comparing overall percent transmission but to look at the relative differences in transmission in certain wavelength regions.

Figure 7.28 shows the % transmission vs. wavelength (λ) for the *cristallo* glass for λ's between 200 and 900 nm. This represents the response of the glass to light in the near-UV through the visible region and into the near-IR. From this plot, several features can be identified. First of all, the UV cutoff for this sample was about 307 nm. This refers to the λ at which the sample begins to be transparent to radiation. Below 307 nm, the glass is essentially opaque to light. Other than the test sample (a piece of 20th century microscope slide with a UV cutoff of 255 nm), the *cristallo* glass had the lowest UV cutoff. However, it was not much different from that observed for several other samples. For example, the sample of pre-Renaissance *vitrum blanchum* (sample #2) had a UV cutoff of 310 nm and numerous other samples had cutoffs around 325 nm. The differences in UV cutoffs between the glasses are small enough so as not to be considered behaviorally significant. In any case, the UV cutoff is of questionable significance since the range of detection of wavelengths with the human eye ends at about 370 nm.The cutoffs observed are all below this value meaning that the eye cannot register them.

Another feature seen in Figure 7.28 are two small decreases in transmission around 400 nm. These absorption peaks occur are said to occur at 380, 420, and 435 nm due to the presence of Fe^{+3} ions (Bamford, 1977:35). Iron can be present in glass in either the +2 (ferrous) or +3 (ferric) state; the latter gives the glass a greenish-blue tint while the latter is associated with a weaker yellowish tint (Brill, 1988:269). All of the samples showed some drops in transmission in this wavelength region. This effect was less noticeable for some samples and could be correlated to sample color. Samples with greenish or bluish tints have a lower ratio of Fe^{+3}/ Fe^{+2} ions and less of a drop in transmission at these points.

Figure 7.29 provides a good illustration of this effect with two types of glass: *cristallo* (PAT1) and Renaissance-era "common" window glass (PAT3). Note that the *cristallo* glass has a more prevalent absorption peak series around 400 nm. This is not so noticeable for the other sample. The window glass sample is also differentiated by a peak in transmission around 550 nm which is not seen in the *cristallo* glass. Brill attributes this peak to a ferri-suphide complex coupled with Fe in the +2 state (1988:273). This corresponds with the composition of the window glass, as shown in Appendix A, which has iron and sulphur present in greater amounts than for the *cristallo* glass. This comparison between these two glass compositions suggests the Fe^{+3}/Fe^{+2} ratio in sample #1 (the *cristallo*) is greater than in sample #3 (window glass).

This difference can be correlated to aspects of production such as the amount of manganese present in the glass along with the furnace conditions when the glass was made. The origin of the ferrous (+2) coloration in glass is actually a strong absorption peak in infra-red region. Additional tests conducted on the samples at the Consiglio Nazionale delle Ricerche in Florence, Italy showed a broad decrease in transmission for sample #3 around 1100 nm again indicating a greater amount of Fe^{+2}.

The point is that the *cristallo* and the window glass have different Fe^{+3}/Fe^{+2} ratios due to choices in raw materials and furnace conditions. These effects can be seen in the plots.

Similar effects can also be seen when one compares the plots for sample #1 (the *cristallo*) to those for the pre-Renaissance samples of "common" vessel glass (#4 and #10) in Figure 7.30. Both samples #4 and #10 had strong green or yellowish-green tints due to the significant amounts of iron present (> 1%). The % transmission vs. λ plots confirm this coloration as they show a peak in transmission around 550 nm followed by sharp decrease in the red regions. This contrasts with the plot for the *cristallo* glass in which the % transmission is more or less equal and stable between 400 and 800 nm.

The % transmission vs. λ measurements can shed further light on the visible differences between the optical qualities of the *cristallo* glass as compared with Venetian "common" glass compositions. What differences are seen between the *cristallo* glass and the intermediate *vitrum blanchum* compositions? Figure 7.31 presents % transmission vs. λ information for a *cristallo* composition (sample #1) and two *vitrum blanchum* glasses (samples # 5 and 10).

Both types of glass show drops in % transmission around 400 nm due to the presence of Fe^{+3} ions in the glass. These drops are more noticeable for the *cristallo* glass perhaps indicating a greater amount of ferric ions. The behavior of the glasses from about 435-900 nm is interesting. The % transmission of the *cristallo* glass remains relatively constant and stays between 76 and 82 percent (Δ = 6%). Essentially, the different wavelengths of light transmit about equally. The effect is similar to what one sees if a rock crystal specimen is analyzed for % transmission vs. λ.

The *vitrum blanchum* compositions show a % transmission that is variable from 400 to 800 nm and steadily increasing from about 5% to 22% (Δ = 17%). The *vitrum blanchum* samples did not transmit as well as the *cristallo* glass in the lower wavelengths corresponding to violet, blue, and green light. The % transmission of both samples increases with increasing λ but this effect is more noticeable for the *vitrum blanchum* glass. Not all wavelengths were transmitted as equally in the *vitrum blanchum* glass as in the *cristallo* glass. The *cristallo* would appear to have less tinting and greater overall colorlessness as all wavelengths of light were transmitted about the same and with less variability. "Cooler" colors such as blue and violet would be transmitted more in the *cristallo* glass, as well, resulting in a different visual appearance. White light shining through *cristallo* glass should emerge with absorption/transmission more equally balanced over all of the different wavelengths of light. The *vitrum blanchum* would selectively transmit a greater proportion of higher wavelength radiation such as yellow and red and perhaps appear "warmer" . Furthermore, many sherds of glass studied in this work were tinted grey, yellow, or pink. These sherds were later shown to be *vitrum blanchum* compositions. The overall conclusion is that the *cristallo* looks better because it transmits light more equally, and has a lesser degree of tinting than that seen for the other types of glass studied. Only modern glass, tested in the form of a microscope slide, had optical qualities similar to and better than *cristallo*.

The study of *cristallo* glass via transmission tests versus the other types of glass made in Renaissance Venice confirm what was seen in the physical examinations. The optical properties of the glass are superior to either the "common" or *vitrum blanchum* compositions in terms of absence of tinting and colorlessness. While rock crystal was superior overall with respect to these properties as well as homogeneity and clarity, the Venetian *cristallo* glass came closer than the other glasses studied in imitating its qualities. It would be very interesting to compare the results of the Venetian *cristallo* with English lead crystal should samples of the latter become available.

Summary

This section was based on the assumption that an understanding and analysis of the demand for Venetian Renaissance glass must be provided before aspects central to production could be considered. The demand for Venetian glass was part of a new set of activities and behaviors in society. These included a greater willingness to accept consumerism and conspicuous consumption as valid and worthy social traits. Activities with respect to dining and collecting also changed resulting in glass, and luxury glass in particular, being in greater demand. Finally, new attitudes toward wealth, splendor, and refinement emerged in Italian culture. Glass, as a material, was seen to have attributes and possibilities which were not available in other materials. Essentially, these relate to the skill of the artisan in working the glass, the use of glass to imitate other materials, and its inherent beauty. Three primary sources of information were then used to analyze the specific demand for Venetian Renaissance glass. Analysis of the written and pictorial sources identified skill/workmanship, form and design, and particular visual appearances as central to the demand for Venetian glass. Physical examinations of the glass suggested ways in which these criteria and desires held by the Renaissance consumer were fulfilled by the Muranese glassmaker.

At this point, I wish to turn away from the Renaissance consumer and shift attention to the glassmaker and the glassmaking technology developed at Murano in response to these demands. Chapter 8 will use a variety of sources to provide a contextual picture of glassmaking as practiced in Renaissance Venice.

CHAPTER 8

GLASS PRODUCTION IN RENAISSANCE VENICE

One of the themes of this research is that an understanding of the nature of demand is necessary to describe production. The previous chapter analyzed the forces of demand using a variety of sources. Qualities inferred to be relevant to the Renaissance consumer's demand for Venetian glass were identified. These included a colorless, clear, and defect free material which was skillfully worked into a pleasing and well-proportioned form. Indeed, demand is best characterized before production is defined and explained (Costin, 1991:13). At this point, it is possible to turn to issues relevant to production. While several of these topics have been alluded to in previous chapters, this section will give a comprehensive picture of the production organization and processes of Venetian Renaissance glassmaking. This treatment is organized into two primary parts. The first part of Chapter 8 discusses the organizational and economic context of production. The second covers what can best be described as the "materials science" of Venetian glassmaking. Topics like raw material procurement and processing, furnaces and tool design, glass recipes, and glass analyses are described.

Organizational and Economic Context of Production

a. General approaches

If one were to believe the two-dimensional accounts of the industry published with no verification of historical facts, the picture is that there was a glass industry at Murano during the Renaissance which employed thousands and was of great economic importance to the Venetian state. I find it very peculiar that for all of the work that has been done on aspects of production, there has been little attempt to place it in a larger context. Only Barovier's work (1982), which draws heavily upon the archival research of Zecchin, has attempted to achieve this goal. Still, there is little attention paid to how a Venetian glasshouse was organized or how the industry fit into the overall economy of Venice. As economic historians from Marx onward have noted, production systems should not be studied in isolation from their complementary distribution and consumption aspects.

Before undertaking a description of the technological aspects associated with glass production in Venice, I wish to present a contextual framework in which to consider it. As described in the Introduction, previous general studies of Venetian glassmaking have typically focussed on issues of primacy (who made it first?), provenance (where did they make it?), and production (how did they make it?) (ex: Tait, 1979). Studies that have attempted to provide a context for production have been marred by an inadequate understanding of the "technoscience" associated with glassmaking (Jacoby, 1993). Conversely, articles dealing with the "materials science" of Venetian glassmaking have left little room for social or contextual analysis (Verita, 1985).

The general framework presented in the first part of this chapter develops along the following lines: The function of the glassmakers guild is presented with the intent of showing changes in its regulations in the years following the production of *cristallo*. The production organization of a Renaissance Venetian glasshouse is described with an emphasis on illustrating the number of shops in operation during the 15th and 16th centuries as well as the number of workers employed. The economic prerequisites for owning and operating a glass factory are considered. This leads to the question of whether the glasshouses of Venice can rightly be described as factories. Understanding the context of production is essential if one accepts the thesis presented here that the Venetian industry represented a transition between artisan/cottage based ceramic industries and a factory-like mode of production. Finally the interaction of the glassmakers, the guild, and the state is described with the intent of proving that the guild and state had both positive and negative effects on the industry along with attempting to account for the glass industries eventual decline.

A comprehensive study of production organization in the Venetian glass industry is hindered, to some extent, by its place in the continuum of ceramic history. Ceramic production, specialization, and standardization have all received great attention from anthropologists and archaeologists for decades. Yet many of the general concepts arising from studies such as these are not explicitly applicable to this work as they were originally conceived to explain phenomena in prehistoric or less complex societies than that of Renaissance Europe. Other ideas were developed specifically for the study of pottery. Previous work on porcelain and Wedgewood ceramics has been more oriented towards placing these materials in the context of the emerging Industrial Revolution (cf. Kingery and Vandiver, 1986; McKendrick, 1987; Reber, 1990). While valid for studies of specific materials and innovations, such research has not produced general models of organization and specialization that can be applied elsewhere. The glass industry of Renaissance Venice occupies, it would seem, an isolated niche between prehistoric and primitive pottery studies, the production mythology of Venetian glass, and the ceramic industry with the Industrial Revolution of the post-Renaissance period.

At this point, let us leave the general discussion of production organization and specialization and address the specific topic of this research. There are two levels at which the organization of glass production in Venice can be discussed. One is at the level of the guild with respect to its roles and rules. The other is at the level of the individual glasshouse as it operated within the guild system in Renaissance Venice.

b. The glassmakers' guild in the Renaissance

Guilds are defined by the particular economic activity that brings the members together. A guild's primary goal is the defense of its own interests. The guild, therefore adopts measures which support this end. It often has monopolistic and exclusionary tendencies. Almost all towns in Italy show a tendency for the number of guilds to have increased during the Renaissance and Venice was no exception. Guild specialization is said to have reached its highest point in Venice (Goldthwaite, 1980: 241-45).

Earlier in this chapter, I discussed the activities of the glassmaker's guild in the pre-Renaissance period in conjunction with the first edition of the guild rules (the

Capitolare of 1271). The *Capitolare* provides the most fundamental knowledge regarding the rules by which the glassmaker's guild operated. It formed the basis for all future editions of the guild rules and also served to link the guild and the state as the Venetian government had to approve modifications and changes to the *Capitolare*. Fifty more articles were added to the original Capitolare between 1271 and 1315, typically dealing with circumstances of the organization as they arose. The modifications made to guild rules between 1315 and 1441 have been lost.

In 1429, the guild rules for several Venetian crafts had become so confusing that the Senate decreed they should be re-examined and re-written if necessary. The result was that the glassmakers' guild received new statutes in 1441. These consisted of 63 articles; however, Zecchin notes that the chapters are still somewhat unclear and that the new version was not a success in eliminating organizational confusion within the guild (1989:29). In many instances, old and new regulations are not coordinated or are at odds with one another. The 1441 *Capitolare dei Vetrai* has two primary parts: one is concerned with the direction and management of the guild and the other with the practice of glassmaking.

The first part describes the election of guild officers, their rights and responsibilities, and role of the guild in community affairs. Venetian guilds were a combination of two different organizations which had merged by the 13th century. The *Scuola* was a devotional society oriented towards religious practice and charity. The *Arte* was responsible for representing the craft. Elements of both organizations can be seen in the 1441 *Capitolare*. For example, there are provisions for the symbolic distribution of bread using *Scuola* monies and the funding for members' funerals (Zecchin, 1989:30).

The second part of the *Capitolare* contains provisions that are more relevant to the practice of the craft. To exercise the art of glassmaking in Venice it was necessary to enroll in the guild. One had to be at least 14 years of age and take an oath of loyalty to the guild, the state, and the city. Apprentices in the guild were required to pay 5 "small coins"; upon becoming a *maestro*, one paid "two big coins" extra. Owners of glasshouses were obliged to pay 10 *lire* and to be knowledgeable of the trade. This money went to the guild for "the support of the poor of the *scuola* and other expenses". Foreigners, in the 1441 rules, were allowed to practice the craft at Murano. Their entrance fee was slightly higher and they were, on becoming shop owners, required to know all aspects of the craft as well (Zecchin, 1989:32). Chapter 31 of the *Capitolare* clarifies the relation between the owner and his workers, stipulating that they must mutually respect one another and that workers were be hired (and fulfill their contract) for a certain period of time, usually one working season. The rules for the selling of glass are essentially unchanged from earlier versions. No broken or faulty glass was to be sold. Glass could only be sold on Saturday in San Marco Piazza or during weekdays elsewhere in the city. Glass made outside of Venice was not allowed to be sold anywhere and no glass was to be sold in the Rialto district.

Regulations regarding raw materials are also found. Owners with excess wood available were encouraged to sell it to their colleagues. Other provisions exist in the 1441 *Capitolare* with respect to the clay used for constructing furnaces. Its transportation was to be done in conjunction with officials from the copper-making guild. The prohibition regarding the production of glass from fern or beechwood ash is repeated as well as the rule forbidding more than three glass pots in the furnace at one time. Rules such as these emphasize interest in both the quantity and quality of the glass being made. Finally, no materials connected with the glass industry, from raw materials to the actual products, were to be taken from the city without permission (Zecchin, 1989:33).

The latter rule, of course, also applied to the migration of glass workers from Murano to other locations. This phenomena was a perpetual problem for the industry. The 1441 edition proscribes a harsher penalty of 100 *lire* and 3 months in prison for those practicing the craft outside of Venice. Zecchin claims that the replacement of the previous penalty of banishment with one of prison was a sign that the State was beginning to become more protective of its craft.

The 1441 *Capitolare* also alludes to the process through which one could rise from an apprentice position and become a *maestro*. The promotion examination took place in front of the guild officers. In 1544, additional rules regarding promotion note that the committee consisted of two shop owners and two *maestri* with voting to be done secretly. A major concern was that admissions to the rank of master would exceed the need for such persons. Another was that the quality of glass produced in the Muranese furnaces would decline. In fact, Zecchin notes that texts after 1550 affirm these trends due to a relaxation in discipline and a decline in the quality of masters (1989:109). There are penalties outlined for pretending to be a master (100 ducats) and the tax of promotion is now set at slightly more than 3 *lire*.

Information available in the archival sources regarding the promotion to master illustrates several trends. One is the increasing industrial specialization within the rank of *maestro* itself. Another is the differential level of skill required to be a master who made luxury glass. These persons were required to know more forms and designs for their promotional test. Finally, from the mid-15th century onwards, the process of becoming a *maestro* was more codified than was previously the case. While there is no evidence from Renaissance sources as to what the tests required for promotion consisted of, information from the mid-17th century gives us some ideas. By this time, the Venetian glass industry had become specialized enough that there were recognized differences between types of *maestri*. There were masters of *cristallo* (presumably luxury glass), of common blown glass, of mirrors, and of glass canes. The *maestri di cristallo* were required to fabricate 18 different types of vessels and the makers of common glass had to know how to make 13 types. Workers of fine luxury glass were therefore required, on the basis of this information, to have a greater repertoire of glassmaking skills. Examples of vessels made of *cristallo* glass included a vase for flowers with handles and crest and a chalice in the French style with stemwork (Zecchin, 1989:110-111).

The *Capitolare* (or *mariegola* as it was later called) of the glass guild was revised and added to numerous times throughout the 15th and 16th centuries. Many of these additions were necessary because of the changes seen in the craft with the innovation of *cristallo* glass in the 1450's (Zecchin, 1990:375). Such rules must be interpreted as a sign of the changing nature of production as the industry began to produce more luxury glass. In addition, the Venetian state, through the guild system, was beginning enact more protectionist policies. The development of *cristallo* glass in the 1450's was a catalyst for these changes.

For example, several rules concern the restriction of the craft to those of Muranese origin. For example, a Ducal letter sent to the Podesta of Murano in 1469 resulted in several additions or re-affirmations of previous rules. For example, soda ash, an important ingredient for *cristallo*, was not allowed to be removed from the city. The working of *cristallo* glass was determined to be a privilege reserved for Muranese citizens. The conduction of any business associated with glass was to be handled by a Muranese or Venetian citizen (provided that they know the trade). Finally, the re-heating of enamelled or gilded glass could only be done in shop furnaces from where the glass originated (i.e. Giovanni's furnace could not re-heat enamelled wares destined to be sold at Giuseppe's shop) (Zecchin, 1990:376-77). Note that these new rules contain several provisions explicitly relevant to the newly re-vitalized luxury glass industry. There is mention of gilded and enamelled glass which was very popular in the late 15th and early 16th century. Finally, the guild regulations were beginning to specifically restrict access to *cristallo* glass in terms of who was allowed to make it.

c. The organization of a Renaissance Venetian glasshouse

Despite the predominant focus on production in studies of Venice's glass industry, almost no attention has been paid to several key issues. For example - there has been little attempt to arrive at a soundly based number representing either the size of the labor force employed by the glass industry or how many shops were in operation. At the same time, there has been no discussion with regards to how the labor force of a Renaissance glasshouse was organized. Some attention has been paid to the furnace technology but in a very restricted fashion (Charleston, 1978). This overall disinterest is curious as questions such as these are central to understanding production. Again, priority has been placed on the objects themselves, removed from the very activities which were responsible for their creation.

Information regarding the organization of production can be found in the research of Zecchin (1987, 1989, 1990). The difficulty, as with all of his writings, is that the information is presented in a piecemeal fashion. It requires sifting through 20 years worth of papers to assemble any sort of complete contextual picture. Even this is difficult as Zecchin never explicitly addressed the day-to-day activities of a Venetian glasshouse.

One of the first issues needing attention is the number of shops in operation during the late 15th and 16th century. Given the wealth of detail that is available in the archival sources, arriving at reasonable figure is surprisingly difficult. More information is available for the later part of the 16th century or the 17th century. This is mostly due to the relative cessation of archival work in Venice following

Zecchin's death in the mid-1980's. Such information is probably available in the Venetian archives, requiring the talents of somebody knowledgeable in glass history as well as someone capable of reading handwritten 16th century Venetian dialect to recover it. Zecchin's work discusses certain 16th century Murano families who were important in the development of the craft. However, it is not possible to construct a complete picture of the actual number of owners and their shops from these family histories. Another part of the difficultly lies in the specialization of the industry. In addition to vessel glass, mirrors, beads, and lenses were also fashioned. There was even production hierarchy within the vessel glass segment as certain masters worked with luxury "*cristallo*" glass and others made more utilitarian items. Manufacturers of many of these products even had their own guilds. The *spechieri* (mirror makers) and the bead makers are two examples. As a result, it is hard to determine the actual numbers of shops making vessel glass.

One source of information can be found in the archival sources related to the unloading and purchase of wood by glass shop owners. Earlier in this chapter, these records were used to illustrate the relative decline in the Venetian glass industry in the early part of the 15th century. Other records relate to matters of discipline in the glassmakers' guild. Looking at how the number of owners varies with time we see:

1424 = 14 owners (Zecchin, 1990:24)

1427 = 13 owners (Zecchin, 1987:44)

1429 = 6 or 7 owners (Zecchin, 1987:45)

1444 = 12 owners (Zecchin, 1990:33)

1454 = 14 owners (Zecchin, 1987:50)

1468 = 16 owners (Zecchin, 1987:53)

1470 = 15 owners (Zecchin, 1987:54)

1482 = 19 owners (Zecchin, 1990:45)

1490 = 16 owners (Zecchin, 1987:63)

These records only list the names of glass furnace owners who were licensed to receive wood or else received some type of disciplinary action for that year. It is completely possible that there were more owners than this who might not have been on the list for any number of reasons. This data is also only for the owners and not the number of furnaces in operation. It is possible that a particular glasshouse may have had more than one set of furnaces in operation. Overall, the number of glass shop owners, according to Zecchin, remains relatively stable except for the period of marked decline in the late 1420's which has already been discussed. There appears to have been an increase in furnace owners after the innovation of *cristallo* in the 1450's, however. And, as mentioned earlier in this chapter, this period coincides with an increase in the overall consumption of wood used to fuel the glass furnaces along with greater import of soda ash into Venice (Ashtor and Cevidalli, 1983:513). A plausible conclusion is that the greater number of shops in operation and the increased raw material consumption are connected to re-vitalized production of luxury *cristallo* glass.

Other evidence about the number of furnace owners comes from earlier archival work that done in the 19th century by Abbot Vincenzo Zanetti who was interested in Venetian glass history. Zanetti was also the first director of Murano's glass museum. While Zecchin and other authors have corrected some of Zanetti's work with later research, his *Guida di Murano*, published in 1866, does contain references to the number of glass house owners based on archival work conducted by Zanetti. Here, the figure given by Zanetti for the number of active owners of glass furnaces in 1568 is 37 (1866:265). This is, of course, a significant increase from about 50 years earlier. In 1581, the glass house owners presented a petition to the Council of Ten to address grievances; the document contains the signatures of 28 *padroni* (Zecchin, 1989:45). Again, this figure is an increase from a century earlier.

Zanetti does not cite the specific archival reference that this figure came from. The veracity of Zanetti's claim can be examined somewhat by looking at his figures for previous years. For example, in 1440 he claims that there were 11 active furnace owners (1866:265). This figure is close to the 12 owners Zecchin reported for 1444. However, there are discrepancies when one examines the actual names recorded. In short, there are several names found on Zanetti's list which are not on Zecchin's and vice-versa. Glass furnaces in Murano were essentially family affairs and they tended to stay active for long periods of time. The possibility that one or two shops may have quit the business between 1440 and 1444 exists but this cannot explain all of the differences between the two lists. A comparsion and cross-checking of the two lists from 1440 (Zanetti) and 1444 (Zecchin) shows that there are 19 different owners in these years between these two lists.

It is probable that the lists Zecchin compiled are only partial listings of the total number of glass furnace owners. His lists typically record only those persons receiving wood or named in some disciplinary action. At the same time, the fact that Zanetti's list for 1440 does not contain names which Zecchin's does throws some doubt on his unnamed sources as well. The conclusion must be that neither Zecchin's nor Zanetti's list is entirely complete.

An additional clue with regards to the number of furnaces (which may not correspond to the number of owners) may be found in the *Isolario dell'Atlante Veneto* written by Father Coronelli (1650-1718) in 1696 (Zecchin, 1989: 290-94). In addition to containing some technical notes on glassmaking, this book also discusses the condition of the glassmaking craft at the end of the 17th century. He notes that there are now only 30 glass furnaces in operation at Murano where in the preceding decades the number was closer to 50. In 1666 and 1670, Zanetti records 29 and 32 active glass furnace owners respectively lending plausibility to Coronelli's recollections (1866:266-67).

Coronelli's remembrance of the number of furnaces, of course, does not clarify if he was counting actual furnaces or whether he was using the word figuratively to refer to the number of shops in operation instead. While the available information does not allow one to form a precise picture of the number of either owners or furnaces active in Renaissance Venice, the numbers presented by Zanetti and Zecchin seem to indicate that the number of furnace owners increased substantially in the 16th century. It is also possible to see how the number of furnace owners fluctuated noticeably over the years. This variability may either represent actual economic circumstances or may just result from the source from which the information is taken. However, there are signs of a greater level of activity following the invention of *cristallo,* and the renewed manufacture of luxury glass. This is also indicated in the increased amount of raw materials consumed (especially wood and soda ash) as seen in the inventory and shipping lists recovered. A general trend may be inferred of increased production activity based on these sources of information but a statement of clear and confirmed figures, if possible, may have to wait for further archival study.

If one finds the determination of the number of shops in operation frustrating and confusing, a determination of the actual number of workers in the glass industry is even more so. Secondary reference sources on Renaissance Venetian glassmaking have claimed that the total number of persons connected with the industry was about 3,000 out of the total Muranese population of roughly 7,000 (Polak, 1975:56; Klein and Lloyd, 1984:68). None of the authors cited give a primary reference to substantiate their claim. A relatively contemporary source, Father Coronelli, wrote in 1696 that the glass shops of Murano currently employed some 1,000 persons (Zecchin, 1990: 293). These 1,000 persons were, of course, working at the 30 furnaces Coronelli claimed were in operation in the late 17th century. Decades earlier, according to Coronelli, some 50 furnaces were active and, presumably, many more Muranese were employed in the industry.

A study presented of the 17th century Venetian economy attempts to provide employment statistics based on various census records (Rapp, 1976:54-74). The total guild membership of the *Veriei* (the title of the glassmakers' guild at Murano, according to Rapp) over the 16th and 17th century was:

1595 = 30 members

1603 = 53 members

1660 = 39 members

1672 = 45 members

1690 = 30 members

While the figures are claimed by Rapp to represent total guild membership, they are much too low for this to be true. Note that they are very close to the number of shop owners cited by Zanetti and Coronelli. It is therefore more likely that the guild membership figures given by Rapp represent, instead, the number of shop owners. They should not be interpreted as an indication of the percentage of the labor force associated with vessel glassmaking.

A better indication of the overall number of persons involved with glassmaking can be found if one approaches the question from a different perspective. Rather than attempt to arrive at a definite figure via census studies, it is possible to estimate the number of persons active in the craft by considering the organization of an individual glasshouse.

The best notice of the number of workers employed at a Renaissance Venetian glass furnace comes from 1569. In this year, Bortolo di Alvise, who owned a glass factory in Murano, was lured to Florence by Cosimo de'Medici. Bortolo re-located to Florence and opened a glass shop that was in operation until at least 1579. Inventory lists of the shop indicate that it was primarily producing luxury-type glass (Zecchin, 1989:171-74). In his negotiations with Cosimo de'Medici, Bortolo requests an adequate supply of skilled and able labor to staff the factory. His request for workers includes (Heikamp, 1986:344):

6 *maestri*

1 *conciatori*

2 *garzoni grandi*

2 *calcarari et tagliare legne*

The first category of workers are the glass masters who will be working the material and fabricating the pieces. The second category (the *conciatori*) refers to the person responsible for the technical aspects of glassmaking. This included measuring and mixing the raw materials which would be used to make particular glass compositions (Zecchin, 1987:48). This person also had the responsibility of adjusting the glass batch for any inconsistencies in raw material quality. As Renaissance-era glass shops did not have acess to industrial-grade materials of high purity, this task was important. The *conciatori* also had to become familiar with the new glass compositions introduced in the Renaissance. Neri refers to these duties of the *conciatore* in Chapter 9 of his treatise *L'Arte Vetraria* published in 1612. The next category of workers, literally "big boys", most likely assisted the *maestri* and did other tasks around the shop. Finally, the "*calcarari*" and "*tagliare legne*" would be responsible for much of the hard manual labor: running the *calcar* (a type of furnace) where the frit was prepared and cutting the wood for the furnace.

Bortolo di Alvise's list from 1569 includes 11 workers (12 including Bortolo) divided among four categories as required to run Cosimo de'Medici's furnace in Florence. Additional lists of employment records at Venetian-style furnaces in Florence from the early 17th century suggest that the workforce had 12 or 13 persons (Heikamp, 1986:374). Are these number representative of the typical labor force at a Venetian glass shop? I would suggest that the 11 workers represent the low end of the labor force employed at one factory. The furnace established by de'Medici was not a purely commercial enterprise. The Florentine furnace was also established for reasons of prestige and personal interest in the craft by Cosimo. One of the requirements stipulated by Cosimo in his agreement with Bortolo di Alvise was that two glass pots must be kept ready to be used at his disposal. Additional furnaces were established in the same era by Cosimo at Pisa. These were also staffed by Venetians and were, presumably, more commercially oriented (Barovier, 1980:xliv). The list given by di Alvise also does not include some job types commonly found in Venetian shops. There is no *fattore* (clerk) or *stizador* (person responsible for running the furnaces) specifically listed.

On the basis of the information presented here, coupled with what is known about the job categories and labor needed to make Venetian style glass, I suggest that the average glass factory in Venice had between 15 and 20 persons working at each. This figure is not unrealistic in light of the 30 workers reportedly used to staff a modern gas-fired Muranese glass shop in the 1950's (Gasparetto, 1958:220-21). The number of workers, of course, would vary with the type of glass being made. Luxury glass, due to the more intensive time and labor needs required to produce the melt and the objects, would typically have more persons. Conversely, a shop which used pre-fabricated glass rods to make beads might imaginably employ fewer persons. It is known from the records of wood ordered and consumed that the output of each vessel-producing shop was highly differential. Certain shops consumed far greater amounts of wood than others (Zecchin, 1990:52). This greater consumption can be correlated to either larger scale of production or to the types of products being made (or, most likely, both factors). Such shops would, imaginably, employ more persons. In any case, it is possible to see two things: First, the size of the labor force (about 50 persons) described by Rapp as employed in vessel glass production is very understated (1976:54-74). Secondly, the number of persons employed in the 30 to 50 furnaces at Murano in the 16th and 17th centuries was substantial in relation to the overall population of the island, said to be roughly 7,000.

It should be noted as well that the number of persons directly involved in glass manufacturing does not take into account those who were employed indirectly. There were people involved at all stages of vessel production and distribution. This includes raw material procurement and transport, packing the products for shipment, and their distribution and selling. The production of specialty wares, like enamelled or engraved glass pieces, would introduce additional labor requirements as the decoration was typically done outside the glass shop and then returned for re-heating and/or finishing (cf. Zecchin, 1990:120). In all, the numbers claimed in secondary sources as to the size of the labor force (typically given as 3,000) are plausible if perhaps overstated by a factor of two or three (Polak, 1975:56).

How does the average size of the labor force of a Renaissance Venetian glass factory compare with a similar industry, say painterly majolica production? In order to run a average workshop which made majolica, the labor required was (Lightbrown and Caiger-Smith in Piccolpasso, 1557:xxii):

1 foreman or manager

2 throwers

2-3 painters

1 kiln man

2 general workers

About eight or nine workers were therefore needed for general and balanced production. A pottery workshop which made less sophisticated earthenwares was most likely smaller. Majolica shops, of course, could be much bigger depending on the nature of production and the scope of demand. Goldthwaite mentions shops in Faenza and Deruta which, based on their output, would have been much larger than the example given here (1989:8). However, the overall picture that emerges from this comparison is that the labor force and corresponding production organization of a Renaissance Venetian glasshouse was relatively larger than that seen in a Renaissance majolica workshop which also produced luxury-oriented ceramic wares.

A large part of the organizational differences was dictated by the nature of the production process. The typical majolica workshop described above could have been supplied by two throwers capable of producing enough wares to allow for one biscuit and one glaze firing a month (Lightbrown and Caiger-Smith in Piccolpasso, 1557:xxii). The rest of the time was spent painting the wares, preparing raw materials, and enacting furnace repairs. Glass production was a more immediate operation requiring the full attention of the workmen during the entire time the furnaces were being fueled and fired. This tradition dates back to the rules of the original *Capitolare* which stipulates that the workers must fulfill 12 hour shifts as long as the furnaces are in operation and that these were to be staffed "day and night" (Barovier, 1982:14; Zecchin, 1989:). Furthermore, a glass piece, while it is being formed is generally worked start to finish, with few chances to pause during the process. Glassmakers did not have the "luxury" of the potter to fabricate wares, wait a period of time while they dried, decorate them, and then wait some more if desired before firing them a second time. As a result, a glass factory would have required additional and more specialized workers to perform clearly defined tasks in a timely manner. This becomes especially true for the fabrication of some of the more elaborate Venetian luxury pieces where a *maestro* may have worked in conjunction with one or more assistants.

This discussion of tasks leads to a concept that should be reasonably apparent already. Within the organizational structure of the Renaissance Venetian glass factory, there was a noticeable degree of job specialization. There were, for example, defined levels of ability within the ranks of those who worked the glass. The *maestri di cristallo* were different from the *bufadori* who worked "common" glass compositions into primarily utilitarian objects. There were those who were given basic manual tasks to do such as stoking and maintaining the furnace (the *stizador*) or cutting wood. A glass factory also had a clerk (the *fattore*). This person maintained financial records, ordered raw materials, and made sure the glass factory followed the rules of the guild and state (Zecchin, 1990:68). This person did not actually work glass. In the same vein, a glass factory had the *conciatore* who was responsible for formulating the glass compositions which would be worked by the *maestri*. Finally, each shop had an owner (the *padrone*). Some of these categories were present in the Venetian glass house since the 13th century. Others appear to be more recent developments in job specialization. The *conciatore*, for example, was first mentioned as a specific job category in 1444, shortly before the invention of *cristallo*.

At the same time as there was an expansion in the job categories and the number of workers employed, the overall glass industry of Murano experienced continued and greater product specialization in response to demand. In addition to vessel glass, objects such as beads, mirrors, chemical apparatus, and lenses were also made. Several of these products developed into their own separate industries, most notably bead and mirror making. Both of these were organized into their own guilds separate from the vessel glassmakers by the 16th century. Specialization is also visible among the different glasshouses of Murano. Examination of shop inventories shows a differential variety of glass types. For example, the Dragani shop in the early 16th century shows very little "common" glass and has much more, in terms of monetary value, luxury glass (Zecchin, 1990:58-60). An inventory of the shop of Niccolo dall Aquila reveals several glass objects made for either distilling or alchemical purposes (Zecchin, 1989:176-77). Other shops specialized in bead production (Zecchin, 1990:85). This specialization within the glass industry can be viewed as a microcosm of the overall tendency towards greater specialization within the entire guild system throughout Renaissance Italy. This trend reached its highest point in Renaissance Venice (Goldthwaite, 1980:245).

Concordant with increased specialization, there were also trends toward greater standardization and complexity with respect to the products of the glass factories. I have already shown how Venetian *tazze*, manufactured over 30-50 years, were made with a recognizable ratio of body dimensions. A related argument can be made for stating that these vessels also exhibit definite signs of standardization with respect to their forms. The presence of metal molds in Renaissance-era glasshouse inventories is another sign of such standardization. These "*forme*" made of bronze, were used to impart a regular and standardized decorative pattern into the surface of the glass paraison being shaped. Measuring the patterns produced by such molds, along with their irregularities, has been suggested as a possible way to attribute museum pieces to particular workshops (Lanmon, 1993:6). Another example of standardized production may be seen in the "common" utilitarian glass vessels made by Muranese shops for local taverns and hotels (Zecchin, 1987:10). These vessels had standardized sizes and were used to sell controlled volumes of wine or oil.

In addition to being made in a more standardized fashion, the luxury vessel glass products of Renaissance Venice became more elaborate and complex from the 16th and into the 17th century. Examples of this trend can be seen by comparing the vessels shown in Figures 7.20 or 7.25 (late 16th or 17th century) with the wineglass in Figure 8.1 (middle 16th century). The later glasses, with their elaborate hot work and decorative additions, were much more complicated to make. Even the wineglass in Figure 8.1 is a much more involved production than the pieces of the pre-Renaissance or middle 15th century shown previously. Such complex designs required not only greater skill on the part of the glassmaker but also a smoother running and better organized production team on the whole.

Eventually, the shapes produced by the Muranese glassmakers became so involved that the functions of the object became obscured. Figure 8.2 shows a "trick glass" of the early 17th century. A similar vessel is seen in a 1620 Spanish still life by Velázquez (*The Waterseller of Seville*). Drinking out a vessel such as this, while amusing, would have also been quite messy. Such a piece does provide the glassmaker with a means to demonstrate his technical skill however. Charleston has described the glass of the late 16th and 17th century as "...progressively fretful and positively fussy..." (1993:92). While perhaps true from a connoisseur's perspective, such complicated designs signal continued modifications to the glassmakers' organizational structure and production sequences in order for them to be manufactured.

As the glass shapes and decorative features became more standardized, the glass compositions themselves were recorded in a more orderly fashion in the years after 1450. While glass recipes have been recorded for centuries prior to the Renaissance in other locales, the first precise notice of such writings in a Venetian context comes from 1446 (Zecchin, 1990:34). In the following decades, numerous examples of recipe collections would be published by such authors as Agricola, Biringuccio, and Neri. Other examples would survive to the present as collections passed from one glassmaking father to his children. The recipes assembled by the Darduin family in the 16th and 17th century are an especially good example of this phenomenon (Zecchin, 1986). While there is a distinction between recipes assembled and published by those who were not professional glassmakers and those who made their living from the glass industry, both categories represent an attempt to codify glassmaking knowledge in a standardized and reproducible manner. Chapter 9 will examine the cultural and technological significance of different glass recipe collections in more detail.

d. The economics of a Renaissance Venetian glass factory

The easiest and most direct way to discuss the costs associated with operating a Renaissance-era glass factory in Venice is to examine an inventory of one. Such records were frequently prepared when the owner died and the capital goods were going to either be sold or transferred to another family member. Inventory lists offer a means to examine what was required finacially in order to start and run a glasshouse. In addition to durable goods such as tools and furnaces a steady and regular supply of consumables was needed. In addition, the wages paid to competent workers in the Renaissance glasshouse were quite good by the standard of the day making the running of such an operation not a trivial affair.

A good example of such an inventory list is that of the Dragani family. This was prepared for Tommaso Dragan and his two sons in October, 1508 (Zecchin, 1990:58-59). Their glasshouse was very prominently located in Murano as it was the first shop one encountered after disembarking the boat from Venice. The list is especially relevant as the Dragani family, as indicated by the types of objects appearing in the inventory, primarily made luxury vessel glass. The list can be divided into two parts. One part itemizes the different pieces of glass in the Dragani family shop and the other part inventories the tools and raw materials present. The total value of this glass factory inventory comes to approximately 700 ducats (or about 4300 Venetian *lire*). The breakdown by item category is as follows:

Glass vessels = ~145 ducats (20% of total)

Tools = ~ 100 ducats (15%)

Raw materials = ~ 450 ducats (65%)

As I am interested here in discussing the investment and capital needed to run a Renaissance glass factory, I will postpone detailed discussion of the actual glass in the inventory until Chapter 9. For now, let it be noted that the production of the Dragani family was luxury glass oriented and about 900 or so such pieces were counted in the shop on this date. Of these products, only 3 ducats worth of "common" glass was recorded. While this may have been a very large number of "common" pieces (in 1471, 3 ducats was equal to about 2,000 pieces of common glass (Zecchin, 1990:44)), monetarily it was not a significant part of the Dragani family's investment. Examining the different categories of the inventory more closely, it shows (translated from the Italian) for tools:

50 clay crucibles = 20 ducats

3 copper caldrons for boiling the soda ash = 30 ducats

Misc. tools = 30 ducats

7 bronze molds = 5 ducats

3 furnaces = 16 ducats

and for the raw materials:

Wood (>600 *carri)* = 150 ducats

Clay and other goods = 10 ducats

Quartz pebbles = 16 ducats

2 sacks of manganese = 6 ducats

Prepared frit = 170 ducats

Soda ash = 100 ducats

This inventory suggests several points. Raw materials, especially wood and soda ash, appear as the most expensive investment for a glass factory making up over two-thirds of the overall value of this particular shop. These were also consumables which would have to be replenished periodically. Tools, and even furnaces, were not a significant part of the glassmakers' capital. Also, items such as metal molds and tools were relatively durable. Only the furnaces would have to be re-built or repaired during or at the end of the production season. Other available glass inventories translated and studied for this work confirm these trends (cf. Zecchin, 1990:36-37).

Besides raw materials and tools, the other investment required to run a Renaissance Venetian glass house was an adequate supply of skilled labor. While the different job categories have been discussed previously, I have said nothing of the wages these occupations commanded. Rapp concludes that labor costs were the predominant capital input required of Venetian industries in the 16th and 17th century (1976:126-27). The subject of Venetian wages has been the focus of several articles (Pullan 1968b; Pullan, 1971; Rapp, 1976). The conclusion has been that Venetian workers, overall, earned the same or more than their counterparts in other economies such as England (Rapp, 1976:135). These higher wages would have had the effect of increasing the overall production costs associated with making glass in Venice.

Again, archival evidence provides a means to evaluate the wages paid to workers in the glass industry. It is possible to compare the wages paid to a glass master versus those given to a relatively unskilled worker. For example, the wages paid in the 1450's at the Cappa glass factory to a furnace stoker *(stizador)* were 5 *soldi*/day (1/4 of a *lire* or about 0.04 of a ducat). At the other end of the pay scale, a *maestro* in this shop earned between 22 to 26 *soldi* per day (Zecchin, 1990:38).

This is an increase in pay for a *maestro* from about 14 *soldi*/day in 1350 (Zecchin, 1990:15). Assuming a working year of about 200 days, this figures out to be about 42 ducats a year for a master working at this shop in 1450. Glass workers also received bonuses for signing on with a particular glasshouse which would vary with their ability and circumstances. The yearly pay of a glass master hired to work for Taddeo Barovier in 1460 was 100 ducats (620 *lire*). About 100 years later, in 1569, Bortolo di Alvise requested yearly wages of 200 ducats with a bonus of 50 ducats ("*in anticipo*") to be paid by Cosimo de'Medici (Zecchin, 1989: 171). The regular *maestri* employed by the Medici in the early 17th century were paid about 140 *soldi*/day (7 *lire*) while regular workers got about 50 *soldi*/day (5 *lire*).

How do these wages compare with what workers in other Venetian industries received? According to Pullan, Venetian master builders received about 30 *soldi*/day in the 1550's which is only a little more than what a Venetian glass *maestro* was paid 100 years earlier (Pullan, 1968b: 173-74). A master shipwright in Venice, c.1500, received about 145 ducats annually while an apprentice shipwright at the same time was paid about 8 ducats per year (Burke, 1987:218-19). Skilled builders in Florence were paid about 30-40 *soldi*/day at about the same time that the glass *maestri* at the Medici shop were being paid at least three times that amount (Goldthwaite, 1980:320-21). All of this evidence suggests that the glass workers of Venice, especially the *maestri*, were paid very well, by contemporary standards, for their labors. While their situation was anomalous compared to the regular production at Murano, those workers lucky or bold enough to leave Venice and work for the Medici in Florence were paid exceptionally well.

Factory Production in the Venetian Glass Industry?

Few 16th century European industries could be referred to as "industrial" in the modern sense (Rapp, 1976:6-7). Criteria include considerable capital equipment, factory-type production, and division of labor. Activities such as ship building, textile production, and glassmaking are examples of Venetian specialities which can, indeed, be called "industrial". As discussed in Chapter 5 and in this chapter, to this list of industrial attributes I would add a higher degree of standardization, a greater-than-average size production unit, a large market for the goods produced in terms of numbers and in geographic space, and a tendency for the activity in question to be relatively "high-tech". Venetian glass production, especially during the Renaissance, embodied many of the features which would characterize "modern" ceramic manufacturing seen in the industrial revolutions of later centuries. Coupling these features with the private ownership of the Venetian glasshouse staffed by persons employed by the *padroni* who used them to produce profitable commodities can lead to only one conclusion - the glass manufactured in Renaissance Venice was produced via a "factory-style" manner organized with many proto-capitalistic features.

Reber has presented three main features which characterize a "new" approach to ceramic production in the 18th century (1990:279). One of these is the greater distinction between preliminary and production work. Evidence of this can be seen in the glass factories of Murano. There were clear divisions of labor between those who made glass and those who assisted in the preparation process. Such latter tasks included cutting wood, fueling the furnaces, preparing and procuring the raw materials, and developing the recipes for making the actual glass melt.

Another feature cited by Reber is the use of tools and technology to allow for faster production. Glass makers have employed molds and stamps for centuries in order to facilitate production. The Venetian coupled these tools with a more specialized production hierarchy both on the level of the entire industry and at the scale of the individual glass house's organization. A difference exists though as the molds and stamps employed by Wedgewood, for example, were part of an effort to reduce the skills required of his workers (Reber, 1990:281-82). Those molds and stamps in use at Venice were part of an effort to produce specialized and standardized decorative effects in an easier and more reproducible fashion. The skill of the glassmaker was still very essential to the production process. The use of molds and other such tools in Venice should not be seen as an attempt at de-skilling the workforce but rather as a technique of decoration. The successful use of such tools was not a simple task and inexpertise with the techniques of molding and stamping could easily result in a poorly made piece. The continued ability of the Muranese glassmakers to construct objects with such techniques can clearly be linked to the overall high level of skill and ability seen in the Venetian glass examined.

Finally, experimental methods are cited by Reber as part of the new mode of ceramic production in the 18th century. These investigations were not done for scientific purposes but were rather oriented towards industrial utility (1990:281). The goal was to reduce the production process, via pure empiricism, into definable and predictable activities and to codify these steps. These attributes were present 300 years earlier in Renaissance Venice. The owners of the glass furnaces, along with their *conciatori*, developed both new glass compositions and new decorative techniques in the decades following 1450 in response to consumer demand. The role of Angelo Barovier, the best known of the Renaissance glassmakers, in the creation of new glass compositions such as *cristallo*, *chalcedony*, and *lattimo* is an excellent example of this trend (Barovier, 1982:35-50; McCray, et al., 1995b). This information became more codified and standardized. Eventually, these glass recipes were recorded in manner that allowed for their transfer to subsequent generations and eventually to publication. While not present at the same scale as what was seen in Wedgewood's ceramic workshops, the glass factories of Murano displayed many of the same organizational and production innovations.

Rapp cites "factory-style" production as a necessary feature for a business organization to be considered "industrial" in 16th century Europe (1976:6). I should like to consider this concept in relation to Venice's glass industry. One characteristic cited as part of factory production is industrial experimentation which has already been discussed (Rapp, 1976:112-116). A second is capital equipment and investment in industry. The survey of the 16th century Venetian glass house previously has demonstrated that a significant investment in terms of tools and, especially, in raw materials was needed to operate a glass factory. In addition to these costs, there are wages to consider. Not counting the value of the glass in the Dragani shop, the total value of equipment and consumables was about 550 ducats or about what a glass master could earn in about 5 years. Rapp discusses the inventories of numerous other craft enterprises in 17th century Venice in terms of their investment in equipment and consumables. These include printshops, dyers, and gold-thread spinners (1976:120-121). In all cases, the value of the capital in the Dragani glass factory, 100 years earlier, is roughly equal or greater.

The scale of production is another factor to consider when debating the presence of a "factory-based" style of production. The average workforce needed to staff a Renaissance-era century glass factory has been estimated at about 15 to 20 persons. This is small by modern standards but must be considered in relation to the size of other production units. In comparison to the size of production units in the wool-weaving (3-4 workers on average), tanning (3 workers), or soap-making industry (13-15 workers), the scale of employment in the Venetian glass factory was typically larger (Rapp, 1976:122-23).

The scale of production can also be considered in another way which relates to a "factory-style" of manufacture. This is the overall output of a glass factory over the course of a working season. From the 13th century onwards, inventory records and price lists allude to overall large scale of production. Prices of "common" glass are often given at a few *lire* for 100 or even a 1000 pieces (cf. Zecchin, 1987: 7, 20, 21). An inventory of a glass shop in nearby Verona made in 1409 records over 40,000 pieces of mostly "common" glass (Jacoby, 1993:83)! The high degree of production output continued and, if the greater amount of wood and ash consumed is any indication, expanded in the late 15th and 16th centuries. The combined inventory of one Muranese *padrone* in 1446 was over 25,000 pieces of both "common" and more refined glass pieces (Zecchin, 1990:161). In 1540 and 1541, the shop of the Bortolussi family shipped 11 cases of glass, both "common" and luxury wares, to Milan. The total number of pieces sent over an 18 month period came to nearly 11,000 pieces (Zecchin, 1989:186-88). Even the inventory of the Dragani shop, which specialized in more complex and harder to manufacture luxury glass, records some 900 pieces of glass in 1509 (Zecchin, 1990:59). The picture that emerges from these figures is that there was a tremendous amount of glass produced yearly at Murano. This high level of output is even greater if one considers other glass products such as beads and mirrors. Such extensive output indicates a very high level of demand for Venetian glass. It also alludes to manufacturing organization and production that clearly can be called "factory-like".

Interaction between the Glass Industry, the Guild, and the Venetian State

Thus far, several economic aspects of the Renaissance Venetian glass industry have been presented. These included the number of shops in operation, the size of the labor force engaged in glass production, factory organization, and the financial aspects of operating a glasshouse. This section will examine the overall relation of the glass industry with the glassmakers' guild and the government of Venice. Before this is done, I would like to present a picture of the glass industry's role in the overall scale of the Venetian economy.

The best and most comprehensive source of information on this subject can be found in the writings of Lorenzo Usimbardi to Ferdinand I de'Medici in the 1592 *Memoria di Vetrerie che si cava di Venezia* (Corti, 1971). Usimbardi was the granducal secretary for the Medici and resided in Venice. Ferdinand was interested in new commercial ventures that would bring revenue to Florence. One of these ideas was to restore and revitalize glass furnaces set up by the Medici in Pisa earlier in the century. Ferdinand de'Medici asked for information about the quantity, quality, and prices of glass produced at Murano - in short, what today would be called a market analysis. The figures given by Usimbardi for the amount of glass sold show:

Venice = 25,000 ducats (14%)

Other parts of the Veneto = 15,000 ducats (8%)

Other parts of Italy (Rome, Naples, Sicily) = 12,000 ducats (7%)

Turkey = 10,000 ducats (5%)

Egypt = 5,000 ducats (3%)

Germany = 3,000 ducats (both luxury and common glass) (< 1%)

Portugal = 10,000 ducats (5%)

Spain = 12,000 ducats (including mirrors and beads) (7%)

Spanish "Indies" = 30,000 ducats (16%)

Syria and Aleppo = 20,000 ducats (11%)

Overall value of mirrors made = 40,000 ducats (22%)

It is interesting to note that Usimbardi alludes to the Venetian industry being in a decline at the moment. A few years ago, he notes, there were some 40 furnaces in operation and now this figure has been reduced to about 24. These figures for the number of furnaces in operation fits well with the evidence presented earlier.

In any event, the total value of glass made at Murano and sold was about 182,000 ducats in 1592. Of this total, almost 25% is explicitly identified as mirror or bead glass. Other categories include bead and vessel glass together with no way to distinguish between the two. Vessel glass sales, both for domestic consumption and for export, were, according to this source, not more than 142,000 ducats in 1592.

How does this figure compare with those from another Venetian industry? Do the figures presented by Usimbardi indicate that the Venetian glass industry was a major part of the overall economy? Consider the output and sales from an accepted major industry in Venice in 1592 - the woolen cloth trade. Workers in the textile industry made up a full 1/3 of the overall Venetian labor force in the late 16th century (Rapp, 1976:100). In 1592, 27,300 woolen cloths were produced in Venice (Sella, 1968b:109). The average price of one of these was about 79 ducats (Rapp, 1976:140). This amounts to a total of some 2.2 million ducats generated from the sale of woolen cloths alone. This is nowhere near the most optimistic economic value of glass made and sold at this time. Furthermore, glass is specifically mentioned in none of the duties, tax lists, etc. from this period while other goods such as textiles figure prominently in trade duties (Rapp, 1976:141). While it certainly had some importance to the Venetian economy, it was not a key industry in the same sense that textile production was. Claims that Venice's glass industry was of great monetary importance to the overall economy must be considered as exaggerated.

However, the fact that Venice's glass industry was not a prime contributor to the overall state economy does not imply that the government had no interest in the craft. The mere fact that the government had to approve the guild rules is proof of state involvement in the industry. This involvement in the glass industry must be considered to have originated from reasons not solely related to economic importance. In the realm of late 15th and 16th century manufacturing, glassmaking stands out as being relatively "high tech" in comparison with more traditional industries such as wool production. The factors presented earlier such as industrial organization, empirical experimentation, and specialization are proof of this. Reasons for this interest, aside from economic concern, can be seen as partially connected with the prestige the industry brought to the city. Recall that the glass houses of Murano were an integral part of the tourist's visit to Venice in the Renaissance. Official state documents of the middle 15th century refer to the glass industry as "a worthy ornament to our State" and as the "glory and ornament of the City" (Polak, 1975:65). Other examples of such superlatives directed at the glass industry can be found in writings of the 16th century. In addition, having "high-tech' industries such as glassmaking in Venice resulted in diverse economy that was not dependent on one sector for its existence.

The function of the glassmakers' guild as an instrument through which government policy was enacted has already been described. What was the effect of the government's involvement in the glass industry? I propose that the policies of the state, enacted directly or through the guild system, had a variable effect. The Venetian state served both as a stimulant/protector and as an inhibitor on the industry. How was this duality of competing actions achieved?

To answer this, it is convenient to examine the offices of the government that handled relations with the glassmakers' guild. With the transformation of the *Ufficio della Giustizia* into two branches, the "Old" and the "New", management of the guilds passed to the *Giustizieri Vecchio* (the "Old" branch) in the 13th century (Zecchin, 1989: 28-29). In the mid-15th century, another office assumed control with the *Giustizieri Vecchio* - the *Provveditori di Comun*. However, after the innovation of *cristallo* glass in the 1450's and the resurgence of luxury glass making, glass production began to fall increasingly under the supervision of the Council of Ten and its three heads, the *Capi*. This pattern is consistent with the greater overall transfer of power to the Council of Ten in the 16th century (Lane, 1973:256).

There is enough evidence gleaned from archival sources to support the assertion that the Council of Ten took an increasingly prominent role in matters pertaining to the glass industry. Consider, for instance, the actions taken by the

Council in a decree of January, 1482. After praising Murano and its industry for working for the "honor of the Republic", the *Capi* of the Council of Ten repeat the previous decree forbidding glass furnaces in the city of Venice proper (Zecchin, 1987:58). Later that year, they decreed that only merchant and citizens of Murano can sell glass beads among other products. That same year, a disposition was presented by the *gastaldo* of the glassmakers' guild to the Council of Ten. This request, a repeat of a similar request from 1469, asked that no foreigners be allowed to practice the craft of making *cristallo* glass (Zecchin, 1989:36). In effect, non-Muranese would be restricted to only working with "common" glass compositions. The Council approved this request. Later, in 1490 and 1502, the decision would be temporarily reversed, due to a supposed manpower shortage, allowing foreigners to work glass of all types provided that they met certain requirements. The rules of 1490 state that they must have practiced glassmaking in Murano for 15 years and have a house and family there (Zecchin, 1989:39). Zecchin has interpreted the events of 1482 as the beginning of the Council of Ten's marked interest in the craft (1989:36).

Continuing involvement of the Council of Ten can be found throughout the 16th century. One of the areas in which the Council was the most involved was the selling of glass. The selling of "common" glass had been the responsibility of the glass sellers' guild, the *Stazioneri*, since 1436. In 1510 and 1523, the Council of Ten reaffirmed the privilege of selling *cristallo* glass as belonging only to the Muranese owners of glass shops (Zecchin, 1989:41). Later in 1523, the Council decided to appoint a three member commission whose job it was to ensure that this policy was obeyed. This regulation would be modified and made less restrictive, on the Council's orders, during the 16th century (Zecchin, 1989:43). The Council of Ten also intervened in other glass matters such as the problem of workers leaving Murano (1547, 1597), administration (1587), and charity for glass workers during the annual vacation period (1555). Numerous other dates and decrees relevant to the Council's involvement in glass activities can be cited. However, the message remains the same. In the decades following the invention of *cristallo*, and particularly in the 16th century, the Council of Ten assumed a direct and prominent role in determining policies relevant to the glass industry.

What was the effect of this state involvement? As mentioned above, I propose that it had both a positive and negative effect on the glass industry. The Venetian government had a very clear protectionist policy with respect to its glass industry. There were, of course, regulations preventing the import of glass made elsewhere into Venice. The government tried to prevent the removal of any raw materials which could be used in glassmaking to other parts of Italy and Europe (Jacoby, 1993). One of the most important of these materials was the soda ash imported from the Levant. Its use and proper preparation was one of the keys in the development of *cristallo* glass. The importance of this ingredient will be explained later in this chapter. Glassmakers outside of Venice were forced to either procure the ash through various black market sources or turn to the use of materials such as wine lees or beechwood ash which were inferior. The Venetian government also attempted to maintain a certain level of glass quality. The making of glass using fern ash, for example, had been forbidden since the 14th century (Zecchin, 1987:12). The number of furnace holes and pots allowed to be in a furnace was restricted as well (Zecchin, 1987:34). By limiting the number of glass pots in the furnace, longer heating times would be achieved producing a more uniform and homogenous glass. In the same, manner, glass output was restricted. The Venetian government also granted concessions and monopolies to particular glass factories. For example, the Catani family petitioned the state in 1527 for a 25 year right to make filigree glass ("*con retorti a filo*") (Zecchin, 1989:182). Similar concessions had been granted to Angelo Barovier and Nicolo Mozetto in 1456 to make *cristallo* glass during the period when the glass furnaces were traditionally shut down (Zecchin, 1987:239-41). In many ways, this may be interpreted as an example of state sponsored research driven by the desire to see the development of a product with perceived commercial potential. A final, and perhaps, the ultimate case of state support for the Venetian glass industry can be seen in a request made to the Council of Ten in 1587. In this year, the *gastaldo* of the glass guild requested that competing furnaces in neighboring Treviso, Padua, and Vincenza be destroyed! The Council approved and the owners of the offending furnaces complied (Zecchin, 1989:45). It should be clear, though the examples given, that the Venetian government, motivated by economics, mercantile intent, and prestige, enacted policies which, at times, favored the welfare of the Muranese glass industry.

Not all of the Venetian government's policies had positive effects on the glass industry. Many of the decisions cited above as beneficial can also be seen to have had negative or damaging effects on the industry. Often, these negative effects would only become manifest over a much broader span of time. Almost all of the policies of the Venetian government construed as negative can be basically generalized as limiting and restricting the development of a free market system. The entry of foreigners into the craft was regulated during the Renaissance. At times, foreigners were prevented from working the glass compositions that were on the "cutting edge" of Renaissance glass technology such as *cristallo* (Zecchin, 1989: 38-39). Product distribution was controlled in terms of who could sell glass, and where and when (Zecchin, 1989: 103-6). Output of the glass factories was artificially regulated via a variety of means. This ranged from setting the number of working posts or glass pots that any one furnace could have to rules regarding the promotion to the position of *maestro*. Another way of limiting output was to enforce the industry-wide closure of the furnaces during the autumn months. While it allowed for the re-arrangement of the workforce and the repair of the furnaces, it also provided a convenient time for the glass workers to leave Murano and take their skills elsewhere. This is a classic example of a governmental/guild policy designed for a short term benefit but instead having long term negative consequences. The annual recess may have had even longer term drawbacks if one accepts Costin's supposition that full-time producers will have an edge over part-time producers (1991:16). For example, full-time production (i.e. year-round) can yield greater output and lower per-unit cost of production. Over the course of centuries, the migration of glass workers from Murano to less regulated centers of production would be one of the chief causes of the industry's overall decline. The migration of workers resulted not only in the loss of skilled labor but also in the transfer of production knowledge to competitors. Furthermore, all of these practices described above served to control the amount of glass produced and available for consumption rather than allowing the market to determine this. Correspondence between Isabella d'Este and her agents refers to the difficulty, at times, of obtaining Muranese glass (Brown, 1982:213). Similar complaints were made by the Gonzaga family in the later part of the 16th century. Eventually, the Gonzaga turned to other centers of glass production, such as Bohemia, to satisfy some of their needs (Bertolotti, 1888:1012-14).

The glass industry of Venice was not the only one to have its overall output determined, in part, by the government. A 1491 regulation prohibited silk weavers from having more than six looms under one roof; similar regulations were levied against the wool industry (Rapp, 1976:124-25). While limitations like these were emplaced with the intent of maintaining fairness and quality, they also served to restrict efficiency and innovation. Some aspects of the older, more artisan-based mode of production clearly remained.

In the 17th century, there was a decline of the Venetian glass industry. What was the culpability of the guild and the state in contributing to it? Rapp has identified three primary and interrelated factors which were responsible for the overall decline in Venice's economy in the 17th century. These are commercial and industrial competition which denied Venice her traditional markets for exports; an aging labor force which lowered productivity; and mistaken government policies. While the second cannot be discussed in specific relation to the glass industry, due to a lack of information, the first and the third are certainly relevant in the decline of glassmaking. Over time, as more and more Venetian glassmakers migrated to other parts of Europe, the production technology and tacit knowledge became better known outside of Venice. This transfer of information, as discussed later, was aided by the publication and dissemination of technological treatises by Biringuccio, Agricola, and Neri which specifically explained the actual practice of glassmaking. Many of these foreign industries, set up with either Venetian workers and/or using Venetian techniques achieved their success with what the Venetians described as unfair practices (Sella, 1968b: 119-20; Rapp, 1976:155). The general pattern was to introduce products - clothes, soap, and glassware, all former Venetian specialities - into Levantine or European markets at bargain prices. The Venetians, of course, resented the superficial resemblance of these cheaper products to their own goods. In some cases (although not, as far as I know, for the case of glass), counterfeit trademarks of Venice were used to mark these newer and cheaper goods. The production of *facon de Venise* glass was part of this overall pattern. Made in the Venetian style, this glass was produced outside of Venice and exported all over Europe. As I have shown before, the quality of these glass pieces did not always measure up to that of the Venetian wares. These cheaper imitations, in glass and other products, was doubly damaging to Venice's economy. Not only were they being undercut in terms of prices but the shoddy quality passed off in imitation of true Venetian products further damaged Venice's reputation and economic potential (Rapp, 1976:155).

In one case, the actions of the Venetian government actually served to stunt the growth of a potentially successful branch of the glass industry. Ilardi has described Florence as the "optics capital" of the Renaissance (1993). This is in contrast to Venice's domination in almost all other aspects of glass production. Furthermore, we know that Venice had been active in the manufacture of glass and rock crystal lenses since the late 13th century. Yet, by the middle of the 15th century, Florence had emerged as the center of production for the best eyeglasses. For instance, the Gonzaga family, who purchased numerous pieces of fine luxury glass from Venice, chose instead to buy their eyeglasses from Florentine sources (Ilardi, 1993:526). The optics industry of Florence received substantial support from the Medici family. A specialty industry given to the production of scientific glassware and lenses developed with this support (Ilardi, 1993:536). With the backing of Cosimo II and the development of new methods of lamp working, the Florentine artisans made instruments that were not produced as often in Venice. Ilardi notes that the mirror-makers of Venice were uninterested in making telescope lenses despite the efforts in the early 17th century of Galileo and his wealthy friend, Giovanfrancesco Sagredo to encourage them to do so (1993:36). They also resisted attempts to develop a purer and more optically homogeneous glass for lenses.

Instead, the Muranese concentrated their efforts on the production of more traditional and profitable glass and glass compositions for mirrors or blown wares (Zecchin, 1989:255-65).

Why the sluggish interest in this field among Venetian policy makers and glass producers? The Venetian government does not seem to have readily recognized the potential of this new market for "scientific" glass. Few Muranese glassmakers responded to the demand for such glass. Ilardi notes the gradual decline in the support of creativity in Venice as the city's power began to wane. Venetian nobility were increasingly bound by tradition and discouraged over the loss of Venice's political and economic power. They did not or would not seek out new business opportunities as aggressively as before (Cozzi, 1987). Cozzi notes that many Venetian intellectuals such as Benedetti and Galileo were lured away from Venice at this time. The long term consequences of Venice not investing time and money into making a glass suitable for optics would be profound for its glass industry. Within 70 years, the English, using techniques derived from Venetian sources, would develop lead crystal and replace, to a large extent, the Venetian *cristallo*. The Bohemian glass industry would refine its potash-chalk composition, also offering competition in the arena of "colorless" glass (Hettes, 1963). Rather than being ahead in the field, as it had been for centuries, the Venetian glass industry would have to scramble and develop compositions that could rival the new English and Bohemian compositions (Moretti and Toninato, 1987). Because of the lack of state support and a pursuit of short term profits, the Venetian glass industry allowed a weaker and less developed industry to gain a competitive edge (Ilardi, 1993:537). This shortsightedness had long-term effects in the industry.

The strategies of Venice's competitors in the glass industry, and in other industries, was to obtain the technology necessary for production and then make cheaper imitative versions of the original Venetian products. One of the general responses of the Venetian government to this commercial challenge was to actually increase quality control. Rather than try to match their competitors' greater output, and lesser quality and prices, attempts were made to enact more regulations and rules and to further limit any advances which would increase competitiveness at the cost of quality (Sella, 1968b:121). Rapp has provided examples of such policies in the woolen and silk industries of 17th century Venice (1976:155-159). The building guilds of Venice also played a role in the regulation of quality (Goldthwaite, 1980:263).

In relation to glassmaking, I have found no direct evidence, either in the archives or in the examination of actual glass objects, to indicate that glass quality substantially increased in the 17th century. No guild or state documents make direct references to glass quality although their concern with this issue is implied in the various regulations enacted throughout the late 15th-17th century. Some documentary sources actually indicate a decline in glass quality. A London glass seller wrote to Venice in 1671 warning that the quality of the glass being sent should be quite good as they were now making very good glass in England which rivalled the Venetian wares (Moody, 1988:205). An English manuscript in the British

Museum also alludes to this decline in quality in a discussion of glass used for telescope mirrors. It states that "No cristal, nor the best Venetian glass of this present age (1660) is so good [for telescopes] as the old Venetian glass" (Verita, 1994, personal communication). Furthermore, there is evidence that the raw materials used by the Muranese glassmakers were not of the same high quality as in previous centuries. The glassmakers, based on recipe information, began to use lower quality sources of sand and, over time, the quality of soda-rich ashes being imported from the Levant began to decline (Ashtor and Cevidalli, 1983; Zecchin, 1987:37).

The Council of Ten, coupled with the glass guild, continued to enact numerous new rules and decrees of limited beneficial effect to the industry. Instead of opting for a freer and less restricted practice of the glass craft, the government chose to attempt to achieve success via greater regulation. As mentioned previously in connection to the optics industry, the nobility of Venice had a damaging role in not recognizing when industrial and market changes were afoot. The nobility, and the government it controlled, have been described as too conservative in terms of their commercial policies (Rapp, 1976: 154; Ilardi, 1993:536-38). Instead of furthering innovation, Venetian patricians tended to relive past glories and support outdated policies (Cozzi, 1987).Of course, this analysis does not absolve the glass workers of Venice from any guilt in the overall decline of the industry. In comparison with other European workers, the wages paid to glassworkers, among others, in Venice was relatively greater (Cipolla, 1968:137). Furthermore, the very presence of a well-developed guild system within the glass industry had some negative effects. Acting on the wishes of the state, guilds typically directed their efforts at improving quality rather than reducing costs. Much of the discussion regarding the hindering effects of the guild system in Venice has been centered around the woolen industry (cf. Sella, 1968; Sella, 1968b, Cipolla, 1968). But the general conclusions drawn there can also be applied to the glass industry. Cipolla has identified the guilds as contributing to overall economic decline experienced in Italy (1968:137). As they tended to reduce competition between members, innovation and new forms of production were suppressed.

The glass industries in England and the Netherlands were organized differently in the late 16th and 17th century than in Venice. However, neither the English or the Dutch system can be described as purely capitalist in nature. Each, at least initially, relied on the importation of skilled Venetian workers and materials and the extensive use of enforced long-term monopolies and patents granted to groups or individuals to achieve success (Charleston, 1968; Macleod, 1987; Baart, 1991). The continued migration of workers to other centers of production (England, the Netherlands, Florence, Germany) gave many of these places the extra advantages they needed to compete with their Venetian glassmaking. Furthermore, the success of the English and Dutch glass industries was enhanced and furthered by their expanding role in the changing world economy. The "art-oriented" literature on Venetian glassmaking offers a much more naive and simplistic evaluation of the industry's decline. The blame is laid to rest on the shoulders of the glassmakers and their products. For example, Charleston writes that a concentration on "virtuoso effects could force a style into an imbalance which could readily cause it be toppled into disfavor." (1979:400). Such an analysis does not even begin to consider the nature of the market, the effect of government policy, or the availability of raw materials as part of the decline of the glass industry.

By the 1670's, the Venetian ambassador in London, Alberti, unhappily wrote home with the news that "the glass trade from Venice...now suffers from the extreme beauty of the English drinking glasses. They are white and very thick, in imitation of rock crystal...they strike the eye and surpass those of Venice." By 1674, Alberti noted that the glassworkers of Murano residing in London "are unemployed; they die of hunger or emigrate" (Moody, 1988:204-5).

I do not believe that any single factor can be cited as the key cause of Venice's declining glass industry in the 17th century. In some fields, such as mirror-making, the glass industry of Venice continued to be successful. The previous discussion also has not considered any of the social factors that would be essential in comprehensively explaining the success of foreign glass industries. For example, taste and demand must have changed for the new glass products of the English and Dutch industries to have been successful. In the failure to respond to new market practices, in the continued confusions over quality and regulation, and in the loss of workers and technological practices, the failure of Venice's superiority in glassmaking can be seen as at least partly self-inflicted.

Summary

The previous section has provided the economic and social context of glass production in Venice. I have shown that during the 15th and 16th centuries, there were changes in the glass industry with respect to production organization, complexity, specialization, and output. The nature of production was described in a manner that shows the Venetian glass houses, in some senses, to be factories. This analysis places the glass workshops of Venice in a transitional position from an artisan based manner of production to a more factory-oriented mode. Many of the features that scholars would later use to characterize the modernity of 18th and 19th century ceramic production - response to consumer demand and reciprocal shaping of demand via marketing techniques, high degree of output, distinction between preliminary and production-line work, specialization, standardization, use of empirical investigation, state-encouraged research with mercantile intent, etc. - have been shown to have existed centuries earlier in the glass houses of Venice (cf. McKendrick, 1982; Reber, 1991).

The number of these factories was shown to have increased in the decades following the invention of *cristallo* glass in c. 1450. The number of workers employed at a glass factory as well as the economic capital needed to run such an operation was examined. Finally, the relations between the industry and the guild/state system was clarified. It was shown that, while significant, the glass industry was not of prime economic importance to the city of Venice during the Renaissance. Reasons for its support from the government must be considered from more than just a purely economic standpoint, and include factors such as prestige and tradition. Furthermore, the state was shown to have a dual effect on the industry in terms of the policies it enacted. The state could be both a stimulant and inhibitor on the success of glass production. Finally, the relative decline of the Venetian glass industry during the 17th century was examined. While no key factor was identified, the migration of workers and technological knowledge to other parts of Europe, in response to a number of circumstances and state policies, was a significant part of this decline.

This section examined the social and economic context of glass production in Renaissance Venice. In the next part of the dissertation, a comprehensive survey of glassmaking practice in Venice is given. The focus here is not on demand or use but on the activities such as raw material selection, procurement, and treatment coupled with subsequent manufacturing technology. The research sources used to assemble this treatment are varied - documentary sources of glassmaking such as those found in recipe books and Renaissance-era technological treatises, pictorial representations of glassmaking, and an examination of the glass itself.

The "Materials Science" of Renaissance Venetian Glassmaking

It would be possible to treat the subject of glassmaking in Renaissance Venice by relying solely on documentary and pictorial information and with little reference to the glass itself. Such an approach, however, would be limited and incomplete. A detailed study of the glass, both chemically and physically, coupled with other sources of information not only presents a more comprehensive and balanced picture but it also allows for the firmer support of particular ideas this work presents. For example, chemical analyses of *cristallo* glass in conjunction with an examination of the glass as a material provides substantial support for the conjecture that *cristallo* glass was much more time and labor intensive to prepare than other glass types. As a result, the use of techniques from the discipline of materials science becomes a very important tool in the study of technological change and process in the Venetian glass industry.

The use of glass as a source of information is based on two primary approaches. The first is the use of chemical and optical characterization techniques. From these studies, it was possible to infer numerous properties of the glass. Secondly, over two hundred whole objects were examined along with numerous collections of sherds. These physical examinations (PE's) coupled with the other sources of information yield a more comprehensive picture of Venetian glassmaking technology than has been previously presented. The experimental procedures and protocols for conducting the various analyses are outlined in Appendices A and B.

The premise throughout this work has been that the significant technological changes in the Venetian glassmaking took place in the luxury segment of the industry. Other branches of the industry changed as well but, in terms of new demands, new glass compositions, and new decorative techniques, the luxury glass industry saw the most noticeable transformations between c. 1450 and c. 1550. Furthermore, Venetian *cristallo* was the impetus for many of these changes and the subsequent success of the glass industry. As a result, the emphasis in this dissertation has been on the demand and production of "colorless" vessel glass. This section will therefore focus primarily on the technology relevant to the making of *cristallo* and "colorless" vessel glass and the subsequent examination of it. Other types of glass compositions were employed to fashion vessels and have been described elsewhere (McCray et al., 1995a, 1995b). Many of these different compositions (*chalcedony*, *lattimo*, *girasole*) were based, to some degree, on the use of Venetian *cristallo*. More specifically, the recipes for other Venetian glasses such as *lattimo* (an opaque white glass) or *chalcedony* (a variegated glass of many intermingling colors) often specify that the starting glass material, to which different colorants or opacifiers are to be added, should be *cristallo*. This gives further justification to the exclusive focus on *cristallo* glass, and its variants, in this research.

It should be remembered from Chapter One that there were essentially three different "colorless" (i.e glasses not intentionally colored with the deliberate addition of other materials) glass compositions made in Venice during the Renaissance. The first was "common" glass used for the production of utilitarian glass objects. It is easily distinguished from the other two by its characteristic greenish-blue tint. The other two are *vitrum blanchum* and *cristallo* which , as described throughout the text, are frequently confused with one another in the museum context. The differences between all three glass types and the implications in terms of their properties and material quality are presented here. Furthermore, the quality and properties of Venetian *cristallo* is compared with other competing glass types from the 15th to 17th century such as English lead crystal and Venetian *vitrum blanchum*.

This section is organized into three main topics:

- the raw materials (selection and preparation)
- furnaces/tools and the manufacturing process of "colorless" glassmaking
- the glasses (recipes, chemical and physical studies)

The Raw Materials of *Cristallo* Production

The production of "colorless" glass in Renaissance Venice required three primary raw materials - a source of silica, a fluxing agent, and a decolorizer. These are described below. What emerges from this detailed examination of the raw materials used in glassmaking serves to connect and support certain claims about *cristallo* glass made throughout this work. It suggests that the processes associated with *cristallo* production were more time and labor intensive than those for other glass types. The selection, preparation, and processing of the raw materials required more time and care. This required a more skilled and knowledgeable workforce, particularly on the part of those responsible for mixing and preparing the right proportions of raw materials (usually the *conciatore*). All of these materials had to be brought into Venice, supporting the earlier idea of importing raw materials into the city and exporting finished goods to the regions supplying them. Finally, it offers further proof of *cristallo* glass as a luxury product with a relatively high price, partially due to the more extensive selection and treatment of the required raw materials.

a. Silica sources

In pre-Renaissance Venice, there were two primary sources of SiO_2. One was the use of natural silica-rich sand. Documentary sources from 14th century suggest Sicily was one place from where this material was imported (Zecchin, 1990:176). The other primary source of SiO_2 in Venice was the use of quartz pebbles found in river beds. These pebbles or small stones are referred to as *cogoli* in Venetian recipe books and documents. The first notice of the use of these pebbles comes from 1332 when a Venetian glassmaker received a shipment of these pebbles which had been ground for his use. These river pebbles generally came from two rivers in northern Italy - the Ticino and the Adige (see Figure 3.3). The Ticino River reportedly gave the best material but it was located some 120 miles away from Venice near Milan at the town of Pavia. The Adige was located closer to Venice but the pebbles were said to be of lower quality (Verita, 1989:57). The use of pebbles from the Ticino River occurred as early as 1394 based on recent research (Jacoby, 1993). Another later source of pebbles for glassmaking was the town of Verona. A recipe book from 1536 records their use but states that the quality of these was not as good as those from Ticino (Zecchin, 1987:239) They are noted as being "greasy" and tending to make a yellow glass. This latter fact indicates that they contained more iron than the pebbles from Ticino. Other sources for SiO_2 have been found in various recipe books, particularly those of Tuscan origin. These include the use of marble, pumice, and rock crystal as a source for SiO_2 (Zecchin, 1987:250; Zecchin, 1990:217). Their use in Venetian practice was appears to have been quite limited.

Analyses of pre-Renaissance glass has showed that it is possible to tell the difference between the which source of silica was used (Verita and Toninato, 1990). These differences were also confirmed in this research. For example, compare the results of SEM-EDS and WDS analyses as shown in Tables 6.2 and 6.3. These illustrate the differences between glasses made with the two different materials. Those made with river pebbles typically have less Fe_2O_3, MnO, Al_2O_3 and TiO_2 present as impurities.

Studies of river pebbles from the Ticino River have been conducted which indicate that it was a source of almost pure SiO_2. Table 8.1 below illustrates this. This table shows the results of analyses conducted on a fragment of *cogoli* (sample # UA8) found near Venice and associated with other glass waste of the 15th century.

Table 8.1. Results of EDS analysis (in weight %) for Venetian *cogoli.*

Oxide	**SiO_2**	**Fe_2O_3**	**MnO**	**TiO_2**	**Al_2O_3**	**MgO**	**Other**
Amount	~99.1	0.2	0.2	bd*	0.3	0.2	bd

* "bd" means that the oxide(s) in question were detected but in amounts below the minimum detection limits of the technique.

ICP analysis of the same sample confirmed these values (reported in Appendix A). The results of the analyses are also very similar to those which have been reported elsewhere (Verita, 1985). As a very pure source of SiO_2, *cogoli* has very few impurities which could impart unwanted color to the glass.

As documented by Jacoby (1993), the use of river pebbles from Ticino complicated the manufacturing process in several ways. First of all, an adequate and regular supply of them was needed in order for the quality of the Venetian luxury glass to remain consistent. This supply initially came from territory outside Venetian control. This land was controlled in the late 14th and early 15th century by the lord of Milan, Gian Galeazzo Visconti. In May of 1402, Visconti granted a one-year monopoly on the gathering and selling of this material. Similar concessions were probably granted previously. The death of Visconti later that year coupled with continued Venetian expansion to the west improved the access of the Venetian glass industry to this material (Jacoby, 1993:80). By all accounts, pebbles used for glassmaking were imported to Venice for the glass industry in very large amounts. For example, a merchant from Verona promised a delivery of about seven and a half tons of pebbles in 1438 (Zecchin, 1990:180). Another delivery in 1424 records 14.3 tons being transported to Venice (Zecchin, 1990:23).

The manner in which these pebbles suitable for glassmaking were selected is partially known. Biringuccio notes in 1540 that such river stones were to be "sparkling white...clear and breakable with a certain resemblance to glass." (Smith and Gnudi, 1942:127). It is also possible that flint tests were used in addition to color. Neri's book on glassmaking says that the glassmakers at Murano use stones from the Ticino River. He also notes other sources for stones, most in the Tuscan region. His criteria for selecting stones is that they be able to strike a fire with a steel; those that do not "strike a fire" are not suitable for glassmaking (Neri, 1662:7). He also notes that they should be free of black or yellow veins. Once selected, the normal processing procedure was to heat the stones until they glowed and then cast them into water. Once this was done, they were then ground and sieved. The crushing and grinding was done at times with the aid of water-powered mechanical mills as early as 1332 (Zecchin, 1987:17; Jacoby, 1993:74). This may have been one of the first uses of mechanically powered devices in the glass industry (Turner, 1963:201). Often, the same river used to supply the power for crushing the stones was also used to transport the material to Venice.

The use of river pebbles, as opposed to regular sand, complicated the production process due to the need for more careful materials selection followed by a more involved preparation process. The result of this extra labor was that the source of silica employed at the Muranese factories for the production of finer luxury glass had less impurities in it. A clearer and more colorless glass could be obtained than was possible previously. Also, less iron in the SiO_2 source meant that less MnO_2 had to be used as a decolorant.

The price of the prepared *cogoli* was not that expensive in comparison with the other items present in a Renaissance glasshouse. The value of the quartz pebbles in the 1508 inventory of the Dragani glasshouse was 16 ducats for what is believed to be about 10,000 pounds although there is some difficulty in deciphering the Venetian dialect of the inventory list (Zecchin, 1990:60). A figure from 1470 gives a clearer indication of the cost of *cogoli*. Here, the value of 900 *libbre* (a *libbre* was equal to 477 grams or about a pound) was almost 14 *lire* (or about 2.25 ducats) (Zecchin, 1987:54). This price was about the same as the 1508 record.

A recent publication has clarified the date of when *cogoli* from the Ticino River was first used in Venice, placing its appearance at 1394 at the latest (Jacoby, 1993). However, the author goes on to suggest that the early use of *cogoli* is cause for re-dating the introduction of *cristallo* glass, traditionally thought to have taken place in the mid-15th century. This suggestion is based on the fact that the other raw material used in *cristallo* production, soda ash from the Levant, was also in use in Venice by this time (Jacoby, 1993:87). Jacoby's work with archival materials is commendable in allowing the re-dating of the use of a particular raw material, essentially confirming what has already been inferred from analyses of actual glass samples. His conclusion, however, in addition to being somewhat ignorant of the technical steps involved in the production of *cristallo* as well as not considering demand for the *cristallo* material in the first place, is wrong. Other parts of this section will further support this conclusion.

b. Fluxing agent

As the previous paragraph alludes to, the use of a soda rich plant ash from the Levant as a fluxing agent was a key ingredient in the development of *cristallo* glass and in the Venetian glass industry as a whole. There were numerous types of fluxing materials available to the Renaissance-era glassmaker. The use of natron, a mineral rich in sodium and typically found Egypt, had ceased to be used in the Veneto by about the 12th or 13th century. In other parts of Europe, potassium-rich plant ash was used such as that produced by burning beechwood trees. Another possible fluxing agent was the use of wine lees which was employed in Florentine glass industries as well as in Italian majolica production. By the end of the 13th century, documentary sources from Venice indicate that a soda-rich plant ash produced by burning certain coastal plants was imported from the Levant and used in the glass industry (Zecchin, 1987:5). The freedom of Venetian glassmakers to experiment with different fluxing materials was curtailed by the guild and the state as they stipulated that only this flux was to be used for vessel glassmaking. Other fluxes, such as that produced by burning ferns or trees, was prohibited on the basis that it yielded a dirty or smoky glass.

Recipe books such as Neri's and other lesser known Venetian texts refer to a bewildering array of materials which can be used as fluxes in glassmaking (wine lees, saltpetre, fern ash, and so forth). The use of some of these in glassmaking has been described elsewhere (McCray, et al. 1995a). However, the focus here will be on the soda-rich plant ash from the Near East as its use and preparation were essential in the making of *cristallo* glass. This fluxing material, imported from the Levant, is given several names in the different archival and recipe sources (Ashtor and Cevidalli, 1983:482). The most common name, and the one that will be used here, is "*alume catino*". It should be noted here that *alume catino* was also an important ingredient in Venetian soap making, another luxury and export oriented industry. Furthermore, Piccolopasso's book on pottery notes that the majolica industry in Venice was different from others in Italy as they used "Levant ash" (1557:64). The Muranese glass industry, undoubtedly one of the heaviest consumers of this raw material, was not the only craft in Venice requiring its availability.

There were other names for materials rich in soda which were used in the Venetian and other Italian centers of glass production. These will be mentioned here to avoid confusion. For example, in Neris' book, the terms "*polverino*" and "*rochetta*" appear. While they both refer to essentially the same material (*alume catino*), the former was coarser and used in the making of "common" glass. The latter was a finer grained version of *alume catino* and used in the making of more luxury-oriented compositions (Barovier, 1982:lv). Neri's book also refers to *barilla* which was imported from Spain. This also was a soda rich plant ash. Neri notes that *barilla* is inferior to the soda ash from the Levant as it makes a glass which is more noticeably tinted with blue (Neri, 1662:17). A letter from 1621 describes the production of *barilla* ash. After selecting and picking the plants, they were roasted in a pit until a hard ashy residue remained (Howell, 1754). Some glass catalogs have suggested that natron was employed during the Renaissance but glass analyses and archival references do not support this (cf. Tait, 1979:11).

A fair amount of research has gone into identifying the actual plants from which the *alume catino* was derived (Ashtor and Cevidalli, 1983:494-98; Verita, 1985). This work was done by collecting samples of plants which were available to the Renaissance glassmaker, burning them to produce an ash, and then analyzing the residue. In both studies, the plants were selected to represent three basic environments: inland, coastal, and marine. The results for fern ash indicate that it was high in potassium with very little sodium present. The use of fern ash was prohibited by the state for vessel glassmaking due to the lesser quality glass it yielded. The analysis of marine plants (seaweed) also yielded a product that was unsuitable for glassmaking. While available locally, neither of the above two plant types were suitable to provide a fine soda-rich ash for glass production. As a result, the glassmakers of Murano were obligated to turn to other regions to obtain the necessary material. Ashtor and Cevidalli conclude that the plant *alume catino* was derived from was most likely *salsola soda* (1983:500). It is possible that another similar plant, *salsola kali* was also the source. Verita concluded that *salsola kali* bore the closest resemblance the composition of *alume catino* as determined from analyses of the glass fragments (1985:20).

Both *salsola soda* and *salsola kali* are small annual bushes (20-60 cm) which belong to the same botanical family. These bushes grow in the Levantine region. Ashtor and Cevidalli note that both grow in a fragile desert ecosystem and that *salsola soda* is a very rare plant today. They go on to speculate that its continual harvesting over the centuries has contributed both the rarity of the plant species as well as the possible difficulties the Venetian glass and soap industries had in obtaining consistently good raw materials (1983:500-501). I find it likely that both plants were collected and used in glassmaking based on the similar appearance and occurrence. The plants were typically gathered by Bedouin tribes in the Syrian desert and brought to towns to be sold. During the Renaissance-era, the Bedouin would come to Aleppo ten times a year in large caravans to peddle the ash which had been converted by burning into solid lumps suitable for shipping. An account from 1572 describes how the Bedouin collected the plants, burnt them, and then sold them to Venetians by the ship load. The Venetians, in conjunction with the Syrians, maintained a virtual monopoly on the trade in this ash. In this way, local Levantine glass industries were often deprived of suitable materials for production, as well (Ashtor and Cevidalli, 1983:487-89).

Verita has analyzed the ash residue of modern-day coastal desert plants similar to those used in Renaissance glassmaking (1985:20). The analysis of *salsola kali* from a coastal region in Sicily yielded the results shown in Table 8.2.

Table 8.2. Analysis (in weight %'s) of *salsola kali* used in Renaissance Venetian glassmaking (from Verita, 1985).

Oxide	**Na_2O**	**K_2O**	**CaO**	**MgO**	**Cl**	**SO_3**	**CO_2**
Amount	17.0	9.0	16.0	11.0	0.3	2.2	33.0

The two primary constituents of this material are sodium and potassium, present in the form of carbonates. Calcium and magnesium are also present in the ash in fairly substantial amounts. It should be noted that the composition of the ash produced by burning plants can be highly variable. These differences can depend on a number of factors: the species of plant, the parts of the plant being burned, as well as the nature of the soil that the plant was growing in (Newton and Davison, 1989:57) . These factors should be kept in mind when considering analyses of the fluxing agent used in glassmaking.

As with the use of *cogoli* in Venetian glassmaking, the preparation of *alume catino* for the production of *cristallo* involved extra steps which contributed to the complexity of the glassmaking procedure. As will be demonstrated later in a discussion of the glass analyses for *cristallo* and *vitrum blanchum* glass, there is a noticeable compositional difference between the two. It is this difference which allows one to identify *cristallo* glass. It is also this difference which is frequently not recognized in either glass catalogs or in the museum context when Venetian glass pieces are displayed. A significant part of this compositional difference originates in the manner in which the *alume catino* is prepared.

The extra processing step required for the successful production of *cristallo* glass was a <u>purification</u> of the *alume catino* fluxing agent. This purification sequence has been identified as one of the key, if not the most important, aspect of *cristallo* glassmaking (Verita, 1985:16; Verita, 1989:158). This purification allowed for the successful manufacture of *cristallo* and it produced a glass that was chemically distinct from the other Venetian vessel glass compositions. The process of ash purification largely served to distinguish between the manufacture of *cristallo* glass and the other types of "colorless" glass made in Venice, such as *vitrum blanchum*.

In Western glassmaking practice, there is no indication that a purification of the fluxing agent was carried out prior to 1450. A Tuscan recipe book from c. 1450, with clear Venetian influences in terms of technique and terminology, contains one of the first references to this purification procedure (Zecchin, 1990:217-219). Other recipe books after this date mention the purification of the ash as part of the making of *cristallo*. Gradually, other glassmaking areas, such as Bohemia, would adopt this step using other fluxing agents due to Venetian restrictions on trading in *alume catino* (Hettes, 1963).

The process outlined by Neri in his glassmaking treatise of 1612 (Chapter 1, Book 1) provides a good basic description of the purification technique:

> Powder the ashes and sift them with a fine sieve that the small pieces do not go through but only the ashes. The finer the sieve, the more salt is extracted...Set up brass coppers (vats)...fill these with fair and clear water and make a fire with dry wood. Put in the sifted *polverine* (*alume catino*) is just quantity and proportion to the water, continue the fire and boiling until a third of the water is consumed, always mixing them at the bottom with a skimmer...then fill the coppers with new water and boil it until it is half consumed.

Brill's analyses of colorless glass from the Gnalic ship wreck found small amounts of copper ($\sim$0.01 weight percent) present which he attributed to the use of these large copper vats in the purification process (1973:96) This ashen material (referred to as "lees" by Neri) is then labeled out into shallow pans which are left to stand for

10 days. This is then decanted and left to stand for 2 more days. This decanting is repeated 3 more times. This material was then boiled gently and filtered after about another 24 hours. One is to continue this basic process of boiling, decanting, filtering, and re-crystallizing until all of the salt is extracted. The final product, after drying, is a white salt which is referred to in Venetian recipe books as *sal alkali* or *sal di cristallo*. The basic procedure for purification can be described then as: grinding, sieving, boiling and dissolving in water, filtering, and drying.

Analyses of a soda-rich plant ash have been conducted which illustrate the effects of the purification process. These are shown in Table 8.3 (from Verita, 1985:20).

Table 8.3. Analyses (in weight %'s) of soda-rich plant ash before and after purification.

Oxide	Na_2O	K_2O	CaO	MgO	Fe_2O_3	Cl	P_2O_5	Al_2O_3
Before	23	5.7	9	2.5	1.3	9.0	0.6	1.3
After	44	5.5	0.4	0.1	0.1	10.0	0.1	0.1

The data in Table 8.3 shows that the ash purification step greatly changes the composition of the ash. Following the purification, the resulting product is much richer in Na_2O (again present as a carbonate). Such a very soda-rich material would be a more powerful fluxing agent and its use would result in a glass with a greater Na_2O content, all other factors remaining equal. The purification step also reduces the amount of Fe_2O_3 present by about an order of magnitude. The use of purified ash coupled with a very pure source of SiO_2 would yield a glass with a much reduced Fe_2O_3 content. As a result, the *cristallo* glass produced would have greater clarity and be freer from any undesirable blue, green, or yellow tints caused by iron. The percent transmission vs. wavelength tests for *cristallo* (as compared with other glass types) presented earlier in Chapter Seven illustrated this result in a more quantitative fashion. Other properties relevant to the glassmaker were affected by the use of the purified ash; these are explained shortly.

The ash purification step also reduced the amounts of certain constituents which are necessary to make a chemically stable glass - namely, CaO, MgO, and Al_2O_3. Their presence in glass makes it less prone to corrosion and decay by moist or humid air as well as water. Their absence would have been easily noticed in glass made in the damp and humid environment of Venice. In order for *cristallo* glass to have been successful, the Muranese glassmakers had to find a way to offset the depletion of this constituents.

The process of boiling, filtering, and decanting the ash so as to purify it was one of, if not <u>the</u> key step in the ability to make *cristallo* glass. It resulted in a glass that was chemically and visually distinct from the other Venetian vessel glass compositions. There is no evidence in any recipe books for the use of this purification step prior to c. 1450. The importance of this step in making *cristallo* was not recognized by Jacoby when he suggested a re-evaluation for dating its invention. His suggestion that the merely having the proper raw materials resulted in the invention of *cristallo* as early as 1394 appears to be unfounded.

As has been mentioned, the purchase and sale of soda-rich ashes from the Levant was a monopoly controlled mainly by Venice and Syria during the Renaissance. The Venetian government attached great importance to a steady supply of high-quality ash from the Near East. Policies forbidding or regulating the export of ash outside of Venice have already been described. A regulation from as early as 1308 describes how cog ships departing from the Alexandria, Damietta, or Tinnis for Venice should only load this material (Ashtor and Cevidalli, 1983:489-90). By the 15th century, the preferred place of purchase were the Syrian towns of Aleppo, Beiruit, and Tripoli, among others. Ashes from Egypt were used but considered to be inferior to those coming from Syria. Those from Egypt came in large black blocks rather than sacks and, by the 15th century, a Venetian merchant noted that they were fit only for soap, and not the glass industry.

The amount of ash imported from Syria increased greatly during the 15th century. This increase coincided with the resurgence of the Venetian glass industry. Ashtor and Cevidalli conclude that over 10,000 sacks of this raw material were being exported to Venice each year by the end of the 15th century (1983:510). This is in stark contrast to the amount brought to Venice about 100 years earlier - about 400-600 sacks.

As more ash was brought to Venice, the freight costs associated with its transport declined. The overall price of ash appears to have risen somewhat during the mid 15th century. The prices of a *migliaio* (477 kilograms) of ash in certain years was (Ashtor and Cevidalli, 1983:510):

1428 -	10.5 ducats
1449 -	18 ducats
1452 -	16 ducats

The cause of this increase in price is not specified but it would have added to the cost of glass products made in Venice. This is especially true for *cristallo* glass which used the purified residue of the ash. Only about 25-30% of the ash was able to be converted to *sal di cristallo* (according to Neri, Chapter 1, Book 1). In this case, more ash would have to be used in making *cristallo* making it even more expensive. The greater amount of ash required probably contributed to the overall increase in the importation of this material after 1450.

The value of soda ash as compared with that of *cogoli* in the Dragani family glasshouse inventory in 1508 was about 6-8 times greater. This would indicate that soda ash was one of the most expensive raw materials used in the fabrication of Venetian luxury glass.

c. Manganese

A third raw material needed for the production of *cristallo* (as well as other glass types) glass was manganese. The addition of manganese to glass melts had been practiced for centuries prior to the Renaissance in Venice as well as other glass producing centers throughout Europe and the Mediterranean (Newton and Davison, 1989:59). In glass, manganese can serve two functions. When present in certain oxidation states and amounts, manganese dioxide can produce colors ranging from purple to brown. The exact results depends on several factors such as the furnace conditions, amount present, and the melting time.

Manganese can also serve as a decolorant in glass. Its use in this capacity has been documented from glass analyses from about the 1st century AD. We have already seen how, on the basis of the raw materials used in the making of Venetian glass, there was bound to be some degree of iron present. This iron originates from the use of less than pure raw materials and its presence, at least to some degree, is unavoidable. The careful selection of *cogoli* and refinement of the *alume catino* served to minimize the amount of Fe_2O_3 as much as possible. The addition of manganese (MnO) to the glass melt could act to further mask the effects of the iron on the visual appearance of the resulting glass; i.e. it could hide the blue, green, or yellow tints caused by the iron. The reaction that takes place in the glass and the corresponding colors when both Fe_2O_3 and MnO are present are (Brill, 1988:276-77):

Fe^{+2}	+	Mn^{+3}	$\rightleftarrows$	Fe^{+3}	+	Mn^{+2}
blue		pink		weak yellow		weak yellow

Two coloring effects occur. First the manganese oxidizes the iron and reduces the amount of the stronger coloring Fe^{+2} ions. If the reaction proceeds properly, a balance is then achieved between the four colors. The result is a relatively flat percent transmission curve corresponding to a more neutral grayish tint. Through its effects, MnO is often called "glassmakers' soap" as it "washes" the glass of undesired tints caused by iron. In order to achieve this balance, several conditions must be met. The proper amount of MnO must be added. Brill suggests that an amount roughly equal to the amount of iron present works well (1988:277). This would have been hard to accomplish in a Renaissance glass house for several reasons. First of all, the glassmakers were not using raw materials of 20th century purity. One batch of raw materials might easily be different from the last and modifications would have to be made to amount of MnO added. Analyses of the raw materials were not available to the 15th century glassmaker so he would have to estimate the proper amount of MnO to add. The furnace conditions must be such that the reaction tends to proceed strongly to the right; i.e. oxidizing conditions. If these requirements are not achieved, the MnO will not be as effective. Adding too much or not enough MnO could result in the glass having a range of tints from grey to yellow to pink. The physical examinations carried out in this work showed many museum pieces with these tints, indicating that the proper balance of iron to manganese was not always achieved. The percent transmission tests shown in Figure 7.30 and 7.31 further illustrate the difference between the variety of "colorless" glass made in Venice.

The presence of these tints and the percent transmission plots suggest another observable difference between *vitrum blanchum* and *cristallo* glass which is seen in glass analyses. As will be shown, *vitrum blanchum* glass has a significantly greater amount of MnO than the *cristallo* glass. We have seen how the purification of the *alume catino* resulted in an ash with less Fe_2O_3. This, therefore, necessitated the use of less MnO as a decolorizer. Adding less MnO also reduced the chance that undesirable grey or pink tints would occur. The end result was that the *cristallo* glass would have had a greater clarity and degree of colorlessness. Many of the objects in museum collections identified as *cristallo* have very noticeable pink, grey, or yellow tints. Many of these effects are due to the presence of too much MnO - one conclusion is that such pieces, if they were able to be chemically analyzed, would be revealed to be *vitrum blanchum* rather than *cristallo*.

Glass analyses confirm the use of MnO as a decolorizer in Venetian glass since the 13th century. It is present in Muranese documentary sources since 1405. In that year, a Muranese glassmaker paid 25 ducats for an undetermined amount of "*maganenesium*" (Zecchin, 1987:35). Like the other raw materials used in the production of cristallo and other Venetian vessel glasses, the supply source of MnO was not near Venice. It, too, had to be imported to Murano for use in glass production. Two years later, the transport of 1480 *libbre* of manganese to Venice is recorded (Zecchin, 1987:38). In 1452, a vein of manganese was discovered near Vicenza and the Venetian state awarded a 10 year monopoly on its extraction (Zecchin, 1987:50). The best manganese according to Renaissance-era recipe books came from the Piedmont region near the modern Italian-Swiss-French border (Zecchin, 1990:187). Neri's 17th century glass treatise says to "use manganese of Piemont, for this is the best of all the manganese...at Venice there is not always plenty and at Moran (Murano) none other is used. In Tuscany and Liguria, there's enough but that holds much iron and makes a black foul color." (1662: 28).

Manganese was not an expensive part of the glassmaking process. Little was required in order to make a batch of glass. The Dragani inventory shows that two sacks of manganese were values at about 6 ducats. Other inventory and purchase records confirm it relative cheapness in comparison with *alume catino*. For example, a 1446 lists its cost as 12 ducats for 1000 *libbre* (Zecchin, 1990:187).

d. Comments on the raw materials:

The preceding descriptions of the raw materials used in the production of *cristallo* and other Venetian vessel glass compositions reveals several features. First of all, the raw materials used in the production of "common" glass, *vitrum blanchum*, and *cristallo* were very similar. A large part of the difference between the three different basic glass types lies in the selection and preparation of the raw materials used in the making of *cristallo* (and of *vitrum blanchum*, to some degree). The raw materials used for *cristallo* glass had to be selected with a greater degree of care.

Another degree of differentiation lies in how the raw materials were processed. Those used for *cristallo* required a more time and labor intensive series of preparation sequences. "Common" glass could be made with ordinary sand if desired. *Cristallo* and *vitrum blanchum* required the use of crushed and ground river pebbles. The production of *cristallo* also entailed the lengthy step of purifying the *alume catino* to remove impurities which could diminish its colorlessness.

The discussion of the raw materials used for *cristallo* shows without a doubt that the processing steps required were more complex and time consuming. A greater degree of skill and technical knowledge on the part of the Muranese glassmakers would have been required to successfully make *cristallo*. By attempting to limit access to raw materials and skilled craftsmen, the Venetian state hoped to maintain a monopoly over its production.

Another important factor which emerges is that all of the raw materials used for making *cristallo* glass had to be imported into Venice. The importance of Venice's trade contacts and political power in securing adequate raw materials cannot be overlooked. Neither can the industry's dependence on raw materials imported from outside the Veneto. The pattern of Venice's glass industry importing raw materials and exporting finished products is readily apparent.

Venetian Furnace Technology and the Glassmaking Process

In comparison with some of the other aspects of glassmaking technology in Renaissance Venice, a fair amount of information concerning furnace technology has been presented previously (Charleston, 1978; Newton and Davison, 1989 for example). Much of this is descriptive based on surviving documents, pictures, and some archaeological work. A review and integration of this material into the larger context of production is given here. The previous work, however, does neglect certain other issues of furnace technology. One is the question of the evolution of furnace design and its accompanying variability. Another is the specialized nature of the furnaces and the crucibles in light of the time and effort required to make them. Finally, as with the other raw materials of glassmaking, materials for furnaces and crucibles were also imported goods upon which the Venetian glass industry was apparently dependent. Some of these less commonly referred points are further considered here and in a related work (McCray, 1996).

As discussed in Chapter 3, there have been no excavations in or near Venice which have yielded furnace remains with which to reconstruct an explicit picture of Renaissance glass furnace design and technology. Fortunately, this lack of information from archaeological sites can be surmounted by incorporating evidence from written and pictorial sources. A very general understanding of glass furnace design has emerged in which the size and shape of furnaces has been presented as diverging into two separate traditions after the end of the Roman empire. In northern Europe, the furnace designs are generally described as rectangular while in southern Europe and the Mediterranean a round shape is thought to have been typical (Newton and Davison, 1989:110). There were, of course, exceptions to these designs but excavations and pictorial evidence show that this was the basic pattern followed.

A very early indication of the shape Venetian glass furnaces would assume is found in a Syrian manuscript held at the British Museum. Dated no earlier than the 9th century A.D., this describes a furnace round or cylindrical in shape. Consisting of three levels, the bottom was a fire chamber, the middle was the central story in which the glass was melted and gathered, and at the top there was a third compartment in which the finished vessels were annealed (Charleston, 1978:11). The earliest illustration of a glass furnace, found in the *De Universo* manuscript held at the Abbey of Monte Cassino, confirms the impression given by the Syrian document. What appears to be a cylindrical structure, based on the elliptical glory holes (where the glass was gathered and worked) in the walls of the furnace, is depicted with three different levels. This is shown in Figure 8.3. The excavation of the 7th century glassmaking site at Torcello in the Venetian lagoon had the remains of a furnace in a circular plan as described in Chapter 3.

Other excavations carried out in northern Italy outside of the Veneto have provided additional evidence for the design and construction of Renaissance-era glass furnaces. For example, a furnace excavated at Monte Lecco near Genoa is dated to the late 14th or early 15th century (Mannoni and Fossati, 1975). Service and industrial areas were identified including the remains of an "igloo-shaped" furnace with a variety of associated glass waste associated. A circular fire trench ran between two solid furnace sieges on which the glass pots would have been placed. Other structures were found that are not thought to have been associated with glass production; as a result, a three-storied structure like those described above seems most plausible. Another excavation has revealed the presence of a glass furnace dating to the latter half of the 16th century at Pisa (Redi, 1991). One of the buildings uncovered was a furnace structure that was circular in shape with a diameter of about 3 meters.

Documentary sources coupled with iconographic evidence from the Vatican Library gives a very detailed picture of how Italian glass furnaces were built and what they looked like in the late 15th and early 16th century. Two illustrations from late 15th century Vatican manuscripts show glassblowers sitting on stools in front of the furnace. A stoking hole is at the bottom level while the two upper stories are depicted as being slightly set back from the first. In this manner, a ledge running around the circumference of the furnace was created on which tools and the marvering slab could be placed. In the early 16th century, a Swedish priest, Peder Månsson, living in Rome compiled an account of that city's glass industry. While different in some respects from glassmaking as practiced in Venice, his description of the Roman furnace is similar enough to written descriptions of Venetian structures to be considered here (Månsson, 1520).

Månsson mentions two furnaces. One is the working furnace in which the glass is melted and gathered. The other, presumably, was the fritting furnace where the ash and sand were first heated together. This was the practice of preparing the raw materials in Venice, as we shall see, and at least two furnaces were normally found in a Venetian glass factory as well. The primary furnace where the glass was melted and worked is described as circular and about 12 ½ feet in diameter. This is comparable in size to those at Torcello, Monte Lecco, and Pisa. The furnace, as depicted in the Vatican drawings is described with three levels - one for the fire, one for the glass pots, and an annealing chamber where the finished products are cooled.

In 1540, Biringuccio published his treatise *De la Pirotechnica* (printed in Venice, incidentally). Along with describing the process of glassmaking, the author also offers a rendering of how the furnaces used in Venice were designed. The first furnace (known as the *calcara*) was used for making the glass frit and is described as (Smith and Gnudi, 1942:128):

> ... a reverberatory furnace made for this purpose, three *braccia* long (a *braccia* was about 22 inches), two wide, and one high, and apply enough of the strong flames of a wood fire by means of a reverberator so that this composition is melted well and converted all into one mass. When this operation is done it is cooled and then taken out and broken into pieces. This is the material that is called frit by the workers....

This type of furnace is shown in Figure 8.4, taken from Agricola's 1556 *De Re Metallica*. Note that there are only two levels to the *calcar*. The worker is shown in the process of breaking up the solid mass of frit.

The second furnace (the *fornasa*) in which the primary melting and working is done is described by Biringuccio in a manner that coincides with the evidence presented thus far from other sources:

> "Now in order to complete the purification, a round furnace is made, built of rough bricks made from a clay that does not melt or calcine with fire."

Jacoby notes that a Milanese petition of 1394 records the presence of "large slabs of dead stone from Custoza in the territory of Vicenza". At this time, Vicenza was under Milanese rule. It was under Venetian control by 1404 (Jacoby, 1993:79-80). These large slabs of stone had a matte (dead) appearance and were supposedly used in the construction of various structures, including glass furnaces. While no examples of this material have been excavated so that analyses could be done, it is imagined that these slabs of stone were desired for their refractory properties. Jacoby states that these slabs were used to make the bench in the main furnace which separated the heating and melting chambers (1993:79). Two Muranese documents of 1415 refer to these stone slabs (Zecchin, 1990:181).

The round furnace described by Biringuccio had (Smith and Gnudi, 1942:128):

> ...a vault with a diameter of four *braccia* and a height of six *braccia*. It is arranged in this way. First a passage for the fire is made which leads the flames into the middle of the furnace; around the circle at the bottom a shelf 3/4 *braccio* wide is made on which are to be placed the pots which hold the glass, and this must be one *braccio* above the ground. Around this five or six well-made little arches are built as supports for the vault, and under these are made the little openings which allows one to look inside and to take the glass out for working at will. Then the vault is continued to cover the glass...above this vault another vault is made which seals up and covers the whole...this is the cooling chamber...at the back of this is a trumpet shaped opening made into the circular shelf on top of the vault inside. The finished objects are placed here and can be skillfully drawn out with a long iron tool...after they have cooled.

Figure 8.5 shows a depiction of the furnace described by Biringuccio, again taken from Agricola's treatise. The "trumpet shaped opening" mentioned by Biringuccio is thought to be the beginnings of another element of the Italian furnace that would develop later - the lehr (Charleston, 1978:17-18). This was the long, horizontal, and tunnel shaped appendage to the glass furnace in which objects were placed to cool after the first cooling in the third story of the glass furnace. The objects were moved along this tunnel towards the opening, cooling ever more in the process. In a sense, the lehr is a derivation of the third story of the Venetian style furnace. By the 17th century, translations to Antonio Neri's *L'Arte Vetraria* were being published with illustrations showing a three-level furnace with a tunnel lehr extending from the back or side. Figure 8.6 gives an example, taken from an 18th century French translation of Neri's book.

In the Palazzo Vecchio in Florence, there is a painting which is part of decorative cycle executed in the 1570's by Giorgio Vasari and his school (most likely by Giovan Maria Butteri). The concept behind the painting is the Aristotelian conception of air, earth, water, and fire. The paintings were used to decorate the *studio* of Francesco d'Medici. On the side corresponding to fire, the artist has chosen to represent some glassblowers (possibly Bortolo di Alvise and his colleagues) laboring in front of a Venetian style furnace (Barovier, 1980:xliv). A detail of this painting is shown in Figure 8.7. In addition to showing the manner in which 16th century glassmakers carried out their activities, one may see the three-storied furnace as described in the above sources. The glass masters are shown seated on three-legged stools before the furnace's glory holes with wooden slats strapped to their legs. These pieces of wood were the fore-runners of the bench at which the glass master would sit. The pieces of wood provided support for the blowpipe and an easy place for the pipe to be rolled back and forth while it was rotated. Clay screens protect the workers. To the extreme left, one may see an assistant placing a finished piece in the top story to cool. Workers in the forefront grind the raw materials and bring wood to the furnace. Towards the rear of the furnace is a tunnel-shaped appendage or overhang which may have been the precursor to the tunnel-lehr described above (Charleston, 1978:16).

In short, a summary of the Venetian style glass furnace may be offered - it was a three story furnace with a fire chamber, a main furnace chamber, and a top story for annealing the finished products. While originally circular in shape, this was later modified from the mid-16th century onwards to incorporate a structural addition that would allow for easier and more controlled annealing. In addition to the main furnace, there was a second, subsidiary furnace with two chambers. This *calcara* was used for the preliminary preparation of the raw materials into a frit which was later re-heated a second time and melted in the *fornasa*. Renaissance-era inventory lists confirm the presence of two, or sometimes three, furnaces in a Muranese glasshouse.

Previously, we have seen how the raw materials required for glassmaking in Renaissance Venice were imported into the city. The same set of circumstances existed for the refractory materials used in the construction of the glass furnace. We can now turn to a discussion of the clay used in fabricating the glass pots (or in the Venetian dialect, *padelle*) in which the glass was melted. This, too, was a raw material procured from sources outside the city.

One recorded source for the clay used to make crucibles was the town of Valenza (sometimes called Valencia) (Jacoby, 1993:78). This town was located about 60 kilometers southwest of Milan. In addition to being used in the fabrication of clay crucibles or *padelle*, the clay was also used to line the inner walls of the glass furnace. It is known from a Milanese petition of 1394 that clay from Valenza was being exported to Venice for use in the glass industry. By the early 15th century, another source for a suitably refractory-type clay was Constantinople. Zecchin notes that the first indication given of clay coming from this location dates to 1405 (1990:181). Presumably, only the raw clay was imported into Venice rather than finished crucibles to minimize risks of breakage during shipping. Inventory lists record the presence of clay from Valenza side by side with clay from Constantinople. For example, an inventory of 1446 has 4500 *libbre* of "*creda da Valenza*" along with 12000 *libbre* of clay from Constantinople. The price of *padelle* made from the Valenza clay was slightly less than those made with clay from Constantinople (Zecchin, 1990:187). This variability in price resulted most likely from either the longer distance the clay had be shipped or the better quality of the Constantinople clay. In 1508, 50 crucibles "of all sorts" were assessed at 20 ducats or about 2.5 *lire* each.

Jacoby suggests that the crucibles used in the glassmaking process were not made by the glassmakers' themselves but were rather fashioned and fired by specialists (1993:78). This supposition is based Biringuccio's text which describes how the pots are fashioned (Smith and Gnudi, 1942:128-29):

> The aforesaid pots or vessels are made on the wheel by master potters with this clay [described earlier as from Valencia] after it is well prepared. In

> size, they are 3/4 *braccio* high [Smith and Gnudi have suggested that this refers to the diameter], ½ *braccio* wide at the mouth and the bottom...and one *braccio* high. These are made uniformly thick, and then left to dry out gradually in the shade.

The final step of preparation appears to have been completed by the glassmakers:

> After six or eight months from the time when they were made, when you wish to put them in the furnace to begin work, that place which you left open under the arches (a hole in the furnace) is a quarter closed with a wall and only enough space is left to allow one of the said vessels to enter. Then fire is applied and continued until the whole furnace is thoroughly red-hot (700-900°C) and at the same time all the vessels that you wish to place in the furnace are placed in the reverberatory furnace where the frit was made and with a slow fire they are started to warm and the humidity is driven off.
>
> Then the fire is increased so that they become hot and very red.

Once the glass workers were satisfied that the crucibles could withstand the heat of the furnace without cracking, the pots were transferred from the *calcara* to the *fornasa* with special iron tools and then charged with frit and/or broken glass. Biringuccio goes on to remind the reader to ensure that the pots were not broken or leaking glass. Not only would this cause "great loss instead of profit" but it would make the pots stick to the shelf on which they rest. In addition to the very corrosive glass damaging the furnace, their sticking to the shelf would make their subsequent removal most difficult (Smith and Gnudi, 1942:130). Like many of the other operations in the glasshouse, the preparing and transfer of the glass pots was an activity that required the concentrated teamwork of several workers at one time.

In comparison with the number of analyses of Renaissance Venetian glass that have been published, little compositional or structural information is available regarding the secondary materials related to glass production such as the refractories or crucibles. Verita (1985:27) presented analyses of three crucible fragments found at Fusina in conjunction with glass debris of the 15th and 16th century. These are presented below in Table 8.4 along with SEM-EDS analysis of another small crucible fragment (PE-150) also from Fusina. All of the crucible samples were coated on what would have been the interior with a very thin and adhering layer of glass.

Table 8.4. Crucible analyses from Verita (1985) and of PE-150 (in average wt %'s).

Oxide	Verita A	Verita B	Verita C	PE-150
SiO_2	71.0	82.2	80.7	70.8
Na_2O	2.1	0.9	0.6	1.7
CaO	0.6	0.5	0.3	2.0
K_2O	3.2	2.1	1.1	3.0
MgO	0.9	0.6	0.5	1.3
Al_2O_3	20.3	12.3	14.7	19.5
Fe_2O_3	1.0	0.6	1.4	1.7
TiO_2	0.7	0.2	0.5	0.3

XRD studies were also done with the crucible samples Verita analyzed. These showed the primary phases as mullite, quartz, and a vitreous phase along with traces of cristobalite. The author also carried out XRD work which yielded the same results. Overall, the composition of the crucible fragments suggest a good refractory material typical of fire-clay brick. These compositions generally consist of fine mullite crystals in a siliceous matrix. Other oxides such as Fe_2O_3 or Na_2O combine with the siliceous material to form a low-melting glass which decreases the material's refractoriness (Kingery, et al. 1976).

Petrographic study of additional crucible sherds provided information with regards to the microstructure and temper types present in the fragments. In some samples, signs of prolonged heating at high temperatures were observed in the form of partially transformed quartz particles, evidence of vitrification, and the formation of fine mullite crystals. Temper types and sizes varied widely among the samples examined and included basalt, grog, quartz, and the possible addition of a slag or glassy-like material to the ceramic fabric. Refiring experiments done on two fragments suggested that the maximum temperature seen by them was in the neighborhood of 1150° to 1250°C. These observations were supported by inferences based on viscosity-temperature relations as discussed later in this chapter. More detailed work on Venetian glass crucible materials has been presented elsewhere (McCray, 1996).

As with the crucibles and refractories, little attention has been paid to one of the most obvious and essential components of the glass industry - namely a steady supply of wood for the industry. Like all of the other raw materials, this had to be imported into the city for use by the glassmakers. The guild rules of the glassmakers specify that only certain types of wood were to be burned in the furnaces. Originally, only alder and willow were burned; this was later amended so that the furnaces used only alder. The ability of the glass furnaces to acquire an adequate supply of wood does not, from the archival information at least, appear to have been a major problem. This is despite the fact that the circumstances of the Venetian glass industry after 1450 would have increased the consumption of wood greatly. This is not only due to the greater number of shops thought to have been in operation but also the lengthier processing and preparation steps required for making *cristallo*. All of these would have contributed to greater wood use and scarcity. There are only a few sources for wood described in the archival material. A notation from 1331 says that wood was obtained from the area near Cervignano as shown in Figure 8.8 and transported by water to Venice (Zecchin, 1987:16). This town was about 80 kilometers from Venice. Other references from the mid-15th century note the towns about 50 kilometers northeast of Venice as additional sources (Zecchin, 1990:180). Some disputes among glassmakers regarding wood supplies are seen. These do not appear to indicate a chronic shortage of materials but rather specific disagreements regarding distribution. The 1508 inventory of the Dragani workshop does show that wood was a fairly major part (about 22%) of the overall value of the shop (Zecchin, 1990:60).

The various shipping lists from the 14th and 15th century published by Zecchin give an indication of the overall amount of wood consumed in Venice's glass factories in a given year. As described in Chapter 6, this consumption has been shown to have increased notably after c. 1450. For example, in 1447 wood consumption was some 4070 *carri* according to the receiving lists in the archives (Zecchin, 1990:51). By 1455, this had increased to about 7800 *carri*. The amount of wood received by any one shop varied depending on their degree of output and the type of glass objects they were fashioning. The list of 1455 ranges anywhere from Taddeo Barovier's shop (1340 *carri*) to Antonio Parisi's furnace (45 *carri*). The wood supply at the Dragani shop in 1508, which largely made luxury glass, was some 600 *carri*.

Thus far, I have described the materials and furnace technology employed in the manufacture of *cristallo* glass in Renaissance Venice. The raw materials used in Venice's glass industry were similar in that they all were imported items. A description of manufacturing process with respect to the making of *cristallo* glass is provided below. To give a comprehensive picture, a wide variety of sources needs to be integrated including descriptions of chemical reactions, information taken from different glass recipes for *cristallo*, furnace conditions, the types of tools used, and so forth. Before undertaking this, I would like to digress slightly and first consider the historical context of the development and innovation of *cristallo* in the years between 1450 and 1460. In addition to providing the appropriate context, this information will hopefully make the description of the technological processes involved in *cristallo* production more intelligible.

The Introduction and Innovation of *Cristallo*

The name most frequently associated with the development of *cristallo* glass in the 1450's is Angelo Barovier. This association is due to a number of factors, some of which are justified and some of which are part of the mythology surrounding Venetian glass production. Angelo was a member of a glassmaking family that had been involved in the glass industry since at least 1331 (Zecchin, 1987:17). Several members of the family, including Angelo, were elected to the head position (the *gastaldo*) of the glassmakers' guild. Angelo was connected in a variety of ways with the development of several new glass compositions in the mid-15th century including *cristallo*, *chalcedony*, and *lattimo* (McCray, et al, 1995b). In addition, a more than average amount is known about the activities of the Barovier family in the field of Renaissance glassmaking. Not surprisingly, a fair amount of half-truths regarding Angelo Barovier and his family have developed as well, as described in Chapter 1.

Zecchin has written extensively on the history of the Barovier family and their involvement in the glass industry from the 14th century onwards (Zecchin, 1989:199-232, most notably). This material will be drawn on here with regards to the development of *cristallo* glass. While Angelo Barovier was certainly involved in this innovation, it will be seen that he shared the stage with other individuals and organizations in its success.

A certain amount of interest has surrounded the life of Angelo Barovier because of his connections to Paola de Pergola. Paola de Pergola was a 15th century humanist philosopher who is known to have taught and lectured in Venice. He was the holder of the teacher's post in philosophy founded by the Republic of Venice around 1445. He also cited in a Latin text from 1500 (the *Chronicorum Sive Historiis Aetatum Mundi Opus)* as being one of the most learned and illustrious men of that time (Zecchin, 1990:378). Among de Pergola's students and disciples was a "a distinguished man of Murano, of the name of Angelo, owner of a glass shop with the insignia of an angel" (i.e. Angelo Barovier). The text from 1500 goes on to say how Paola de Pergola lectured on the combinations and transformations of metals; Angelo reportedly took "..the fruit of this speculation and put it into practice." (Zecchin, 1990:378-79). This connection to humanist philosophy and alchemy is interesting for a number of reasons. It clarifies somewhat Angelo's role in the glass industry. It suggests that he was not so much a worker of glass but rather an owner of a glass shop who in turn conducted empirical experiments with different compositions. Numerous records of his ownership of a glass furnace exist as well as for his family (ex: Zecchin, 1987:43, 50). As such, it places him in a much different position than one whose job it was to work the glass. Rather, he appears more as an experimenter and entrepreneur, in some senses. The connection with Paola de Pergolashould also appeal to writers on glass history and technology in that it connects him in some fashion with current trends in philosophical and nascent scientific thinking.

There is little doubt that Angelo Barovier achieved great fame during his lifetime due to his glassmaking activities. Upon his death in 1460, his tombstone stated that he "knew all the secrets of glass" (Zecchin, 1989:223). Similar praise came from Ludovico Carbone, another Renaissance humanist and Antonio Averlino, a court appointed architect at Milan in the 1450's and a friend of Angelo's. Other evidence in which his abilities as a glassmaker appear may be seen is the interest of parties outside of Venice in obtaining his services. For example, he is known to have traveled to Milan in 1455 to demonstrate his skills at the court of Francesco Sforza. Averlino, in his *Trattato di Architettura*, writes of his friend "whom is called master Angelo from Murano" and who makes the most beautiful works of "crystal glass" (Zecchin, 1989:222). After Angelo's return to Murano in December 1455, Duke Sforza appears to have been so eager for him to return that he kept Angelo's son at Milan for a short time (Barovier, 1982:43). Shortly before his death, Angelo had to postpone a planned visit to the Medici court in Florence after accepting an earlier invitation to "present the art of glass" (Zecchin, 1989:223). By all accounts, Barovier must have earned some privileges as the Venetian government does not seem to have interfered with his travels. However, this is a curious policy as the state would shortly attempt to restrict certain aspects of *cristallo* production. I have no explanation for why the government would allow Barovier to travel and then later attempt to limit *cristallo* production to Muranese citizens, introduce further rules regarding the export of raw material for the glass industry, and so forth.

Other than the facts Zecchin has unearthed in the Venetian archives regarding Angelo's personal life and professional involvement in the glassmakers' guild, there is little information regarding the running of his shop. For example, there are no inventories of his workshop. Some records have survived which provide inferences as to the output of his shop. For example, lists from 1454-55 record the unloading and distribution of wood to the Muranese glassmakers. This came to some 10590 *carri*. Of this, Angelo's workshop received 740 *carri* which is about in the average in terms of the amount received. Zecchin has interpreted this, perhaps rightly, as indicating that Angelo's shop was not among the biggest glass producers at Murano but was rather oriented towards a "production of quality" (Zecchin, 1989:222). As we have no records of his shop production, this must remain speculation for now. It is known that Angelo's sons stayed in the glass business. Their shop records indicate a fairly sophisticated level of output in terms of the glass compositions used. For example, Taddeo Barovier's shop was involved in the production of both *cristallo* and *chalcedony* (Zecchin, 1989:226-27).

The archival evidence presented by Zecchin and other writers allows a fragmentary and confusing account of the development of *cristallo* to emerge. Angelo Barovier appears as one, but not the only, person involved in its development. The duke of Milan wrote his brother Alessandro in December 1455 about having Antonio del Bello come to Milan to make "*vetro cristallino*" (Zecchin, 1987:238). This glassmaker shortly disappears from the archival sources, possibly due to illness or death. Jacoby suggests that this is why del Bello was unable to honor his contract with the Milanese duke (Jacoby, 1993:88). Zecchin, on the other hand, proposes that del Bello really didn't know how to make the glass and that this is why he backed out of the deal (Zecchin, 1987:239). This letter, coupled with Barovier's visit to Milan in 1455, suggests that the techniques for *cristallo* production may already have been in the process of leaving Venice.

A notice is given in the Venetian archives from February 1457 that Angelo Barovier was awarded a concession by the Venetian government to make "works of *cristallo*" during the period that the glass furnaces were normally closed (i.e. the autumn of 1456). Another Muranese glassmaker, Nicolo Mozetto, received a similar concession. Notice of this unusual concession given to these two men comes indirectly from the February 1457 award in which Jacopo d'Anzelo was given similar permission "to make and work *cristallo* and *lattimo* (*vetro porcellano*, in the original) glass at the time when glassmakers cannot make other glass" (Barovier, 1982:39; Zecchin, 1987:51). This shows that by 1457 the techniques surrounding the making of *cristallo* glass were becoming even more widely known.

There have been several speculations for why the Venetian government granted these concessions to make *cristallo* and *lattimo* glass in the first place. Tait has speculated that the production of *cristallo* was still in its formative stages in 1457. Angelo Barovier, with the help of the Venetian government and Nicolo Mozetto, was in the process of working out the details of *cristallo* production. At this stage the government was only prepared to give them encouragement as long as their regular production activities were not interrupted (Tait, 1979:26). Jacoby's premise is that the Venetian government encouraged the production of *cristallo* in the normal recess period to increase state revenue. However, I have shown that glassmaking was not a fundamental part of the overall Renaissance Venetian economy. Moreover, prolonged manufacture of any glass type in the annual vacation period would have violated centuries of Muranese tradition. As the text for the concessions of 1456-57 mentions the production of glass "as a worthy ornament of the city" perhaps reasons beyond pure financial ones were motivating the Venetian government.

The archival references do not provide an exact date for when *cristallo* glass was first developed. Indications of its introduction can be seen in letters and inventory lists of the 1450's and 1460's such as the letter by the Duke of Milan and the citation by Antonio Averlino. Zecchin's premise throughout his writings was that *cristallo* glass was developed from the previous *vitrum blanchum* composition sometime in the early 1450's primarily by Angelo Barovier (1987:239).
Jacoby offers a much different interpretation of these sources. His theory is that *cristallo* glass developed in the very early 15th century. It was not an isolated leap forward (something that Zecchin notes as well) but rather occurred though an incremental process of development. Jacoby notes that the raw materials used in the production of *cristallo* had been available in Murano since about 1400. As he explains, the main elements for the manufacture of this glass, except the purification of the ashes were known in Murano quite some time before 1450 (1993:87-89). What Jacoby does not realize is that this was a crucial step in the process (Verita,

1985). There is no evidence of this purification step being carried out before about 1450. Furthermore, the successful production of *cristallo*, as the next section will show, involved more than just using the right materials. There were several other steps involved in its successful production (Zecchin, 1987:239).

Jacoby's attempt to re-date the introduction of *cristallo* also lies in his interpretation of Renaissance-era references to different glass types and compositions. For example, a Muranese document of 1405 mentions a mold or *forma di cristalini* (Zecchin, 1987:35). Such molds were used to impart certain shapes to the glass as it was worked. There are numerous examples of molds with different adjectives ascribed to them. These descriptive terms are often related to certain localities. There are molds describing glass shapes in the forms common to Florence or Gambassi or Germany (Zecchin, 1987:12, 13, 17, 35, 36). Jacoby's point is that the reference to the *forma di cristalini* and the appearance of *mioli cristalini* a year later does not come from the shape of the glass but rather the type of material it was fashioned from. His argument is that there was a transition from the material of which the glass was made to the name given to the form the glass was made in. That is to say that the name of the mold given in the 1405 reference refers not to the shape of the glass but rather the type of glass that would be blown into the mold (Jacoby, 1993:86).

Zecchin has argued the reverse saying that the form of the glass is what the name of the mold (*forma di cristalini*) represents and that only later did the term *cristalini* come to mean a particular glass type (1987:237). I believe Zecchin's presentation carries more weight for several reasons. All of the other mold (or vessel) names refer to shapes imparted by the mold. From a glassblowing perspective, it does not seem reasonable to think that a special glass mold would be developed for a new glass composition. The term *forma di cristalini* could also mean a type of glass blown and worked into a shape common to rock crystal pieces - what the *cristallo* glass was trying to imitate in terms of appearance in the first place.

Confusing the different glass types made in the Renaissance is easy to do as there are numerous terms for the different glass types in Renaissance sources. These can also vary depending on the author's origin. This is complicated by the fact that the authors of recipe books or inventories may not have been intimately acquainted with the different glass types. Such authors could also have been misled on the basis of the similar raw materials used or on the appearance of an object while recording an inventory or shop list. In many cases, the terms *cristalini*, *cristalli* and *cristallo* appear contemporaneously and one can never be exactly sure what is being referred to. However, Jacoby does not seem to have recognized the clear difference between the nature of the *cristallo* glass composition and the earlier *vitrum blanchum* glass. Neri, in his 1612 glassmaking treatise which was heavily influenced and derived from Venetian glassmaking practices delineates the three different types of colorless glass available. There is "white glass, also called common glass" and there is *bollito*, a term used by Neri to refer to *cristallo*. The third type is *cristallino*, a type that lies in between the other two in terms of appearance and is only moderately refined (Barovier, 1980:lv; Neri, 1662:23). This tends to support Zecchin's thesis that name of the mold refers to the shape and the meaning was gradually altered to refer to a particular type of material.

All of this evidence (the importance of the purification process, the reference to Angelo Barovier and his colleagues in the 1457 concession, the evidence regarding the types of molds used) taken together does not appear to support Jacoby's idea that *cristallo* glass had been invented before 1400. Granted, the general accounts of its development in the connoisseur-oriented literature tend to present a two-dimensional view of the early production of *cristallo*. However, I do not think there is enough evidence to lend credibility to re-dating its earliest production before about 1450.

It was the combination of these different preparation and manufacturing steps, most likely in the 1450's and with the involvement of Angelo Barovier, that led to *cristallo* production. No one element of the process was responsible for its successful manufacture. Rather it was the incremental and informed combination of different techniques throughout the 14th and 15th centuries into a production system that resulted in the creation of Venetian *cristallo*. Gordon and Malone draw attention to the fact that invention and innovation as seen in the archaeological or historical record is often the sum of incremental improvements in techniques made by many individuals (1994:38). The innovation of Venetian *cristallo* reflects this pattern.

This is not to suggest that the process of invention and innovation was a linear progression of increasingly successful steps. It is more reasonable to suppose that there were a variety of steps tried and discarded because of their lack of utility.

Unfortuanately, at this point incomplete information and gaps in the documentary records do not allow for complete reconstruction of the technological "blind alleys" that Renaissance glassmakers wandered into and out of.

The Science and Technology of *Cristallo* Production

The previous section described how the development and innovation of *cristallo* production was not the result of one isolated leap forward but rather was the result of a series of gradual steps and refinements in glassmaking technology spurred on primarily by consumer demand. While the most important of these was the introduction of the ash purification process, there were several others steps that the Renaissance glassmaker chose to follow in order to successfully make *cristallo* glass once the raw materials had been selected and prepared. Glass recipes for *cristallo* production have been presented in several publications (ex: Verita, 1985, Moretti and Toninato, 1987). Perhaps the best way to illustrate the sequence of steps involved in the production of *cristallo* glass is by examining a few of these recipes from the 15th-17th.

Before discussing glass recipes as a source of information regarding glassmaking practice, it is important to address certain limitations inherent with them. Glassmaking is an activity that one best learns by doing. It is not possible to fully understand the manner in which the materials are prepared, the color of the furnace at a certain temperature, and the feel of the glass by reading about it. Glass recipe formulation and glassmaking therefore involve a substantial amount of tacit knowledge that one can only gain from experience. The recipes concerning glass production must therefore be viewed as limited or idealized pictures of a complex technological operation. They only offer a blueprint for the glassmaker to follow. Variations in raw material supply or quality, the conditions of the furnace, and the habits of the glassmaker would all have been contributing factors to deviations from these generalized descriptions. In many cases, the author or recorder of the recipes is not known nor is their intent. Were they a glassmaker preserving family secrets or were they an anonymous copier of some curious observer's notes? These facts should especially be borne in mind when the chemical analyses of the glass is presented in the next section.

In the State Archives of Florence, a manuscript (M.S. 797) is preserved which pertains to the practice of glassmaking. The manuscript is composed of three parts written by a variety of authors at different times in the 15th century (Zecchin, 1990:213-226). The first part dates to the early 15th century and the recipes are of Tuscan influence. The second was written shortly after 1450. The terminology and recipes indicate that the author was Tuscan but had some contact with Venetian glassmakers and glassmaking practice. Both parts are written in a very confused and ambiguous manner. The second part of M.S. 797 contains several references to the production of *cristallo*. The author describes a process for the purification of the soda ash which is the earliest recorded example of this technique (Zecchin, 1990:218). However, the author of the manuscript seems confused about this new glass. There are other citations of *cristallo*, at times referring to it as a product and others referring to it as a raw material.

The third part of M.S. 797 contains what Zecchin has described as the best early recipe for *cristallo* glass. This is found in a collection of writings in the manuscript which has been attributed to about 1470 (Zecchin, 1990:221). Zecchin has described the recipe as Muranese in substance but Tuscan in form. Terminology is used which indicates clear Venetian contact but at the same time the author also refers to some glassmaking terms in a Tuscan style. The idea that there were exchanges in glass recipes between Murano and Tuscany has been suggested previously (ex: Barovier, 1987). These is evidence for this connection as recipes from the two regions share certain common features in practices described and in the usage of terms specific to the making of glass. For example, there have been similarities noted between the Montpellier recipe book (Venice, 1536) and the Neri's treatise on glassmaking (Florence, 1612) (Zecchin, 1987:251).

The recipe for *cristallo* is found in three chapters (79, 80, 86) of M.S. 797. Transcribed it essentially says (Zecchin, 1990:225):

> Dissolve in hot water 200 *libbre* of soda, filter the solution and allow to boil until a salt is deposited. Place this salt to dry in a clay basin. This is then finely ground and mixed with 150 *libbre* of *cogoli* from Ticino which is also ground. To this 40 *libbre* of *tartaro* is added along with 7 *once* of manganese. To this a little water is added and small "cakes" are made. These are dried and placed in the *calcara* and then in the furnace to melt. Once melted, the glass is poured into a container of water to get rid of the excess

salt. It is then put back into the furnace to be refined and remelted.

Additional manganese can be added if the glassmaker feels it is needed. From this early recipe for *cristallo*, several features relevant to the production of the glass can be seen.

Firstly, the recipe differs somewhat from Venetian recipes in that it calls for the addition of *tartaro*. This is calcined wine lees which are composed mostly of K_2CO_3 and CaO (Verita, 1985: 20). The use of this material in the making of *cristallo* does not always appear in Muranese recipes such as an anonymous recipe from the 16th century or in the recipe given by Biringuccio (Smith and Gnudi, 1942; Morretti and Toninato, 1987). However, the use of this material was known in Venice. Some recipes for enamels from the 17th century contain it as a raw material (Zecchin, 1986). It is not known for certain whether it was incorporated into the Venetian production of *cristallo* as the Venetian government had rules stating that only *alume catino* was to be used in glassmaking. Analyses of Venetian glass do show a fair amount of K_2O but, as potassium was also present in the purified *alume catino* (at about 5% as shown in Table 8.3), one cannot say whether the K_2O came from the *alume catino* or was the result of adding *tartaro*. Neri's recipe for purifying the *alume catino* mentions the addition of *tartaro* (Chapter 1 of Book 1). However, his recipes, while influenced heavily by Venetian practices, are also based on Tuscan traditions. One should remember that the Venetian government had trade policies in effect which limited the availability of *alume catino* to other glassmaking centers in Europe. It is possible that the Tuscan shops used *tartaro* to compensate for an inadequate supply of *alume catino*. Finally, analyses of Venetian *cristallo* and *vitrum blanchum*, as will be shown in the next section, have levels of K_2O typically between 2 and 3 weight %. The amounts described in the Florentine recipe from M.S. 797 and in Neri's work would have most likely given a glass with a higher K_2O content. Therefore, it seems probable that the addition of *tartaro* described above was more in line with a Tuscan glassmaking tradition. Other than this discrepancy, one can see that the raw materials used in making Venetian *cristallo* in the 15th century were essentially those described earlier - *cogoli* from the Ticino River, *alume catino*, and a small addition of manganese.

The recipe for *cristallo* in M.S. 797 describes how the purification of the *alume catino* was done using a series of boiling, decanting, and filtering steps which resulted in the formation of a white, soda rich *sal di cristallo*. The importance of this step and additional details about it have already been presented.

Another aspect of Venetian *cristallo* that can be examined via glass recipes is the ratio of the different primary raw materials used in the mixing stage. The recipe from M.S. 797 calls for 200 *libbre* of soda and 150 *libbre* of *cogoli*. This is an imprecise indication of the overall amounts of the two constituents as we have no means to determine how much *sal di alkali* would be obtained from the raw soda after it was purified. If we assume a conversion rate of ash to *sal di alkali* of about 33%, one arrives at a ratio of 4:1.

We can also turn to other recipes to see what ratios are prescribed. An anonymous recipe book from the second half of the 16th century that is in private collection calls for 150 *libbre* of *cogoli* and 100 *libbre* of *sal di cristallo* - a 3:2 ratio (Moretti and Toninato, 1987:33). Biringuccio's 1542 text has a recipe for glass; although it is not explicitly identified as *cristallo*, the purification process described by suggests that this is the case. Here the ratio suggested is 2 parts *cogoli* and 1 part *sal di alkali*. Finally Neri's text from 1612 contains a recipe for cristallo in which the ratio of *cogoli* to *sal di alkali* in the preparation of the frit is 3:2. On the basis of these observations, a standard ratio of raw materials does not appear to have been employed

From the 15th century *cristallo* recipe in M.S. 797, one can also see how the heating and melting steps were carried out in two stages. The first operation was the preparation of the frit. This operation was carried out in the first furnace (the *calcara*). An intermediate heat (about 700-800°C) was applied to a mixture of the *cogoli* and purified *alume catino*. This was done for several hours and the mixture was carefully monitored and continuously stirred to avoid the formation of a liquid (Verita, 1991:58). Neri states in his text (Chapter 2, Book 1):

> ...put them into the *calcara* which at first must be well heated...at first for an hour make a temperate fire and always mix the frit with the rake that it may be well incorporated and calcined; then the fire must be increased always mixing the frit with the rake for this is a thing of great importance and you must always do this for five hours, still continuing a strong fire.

The fritting furnace (the *calcara*) had to be heated prior to introducing the raw materials due to the insulating character of the finely powdered mixture (Turner, 1963:189). The end product of the fritting process was a solid mass which was broken up and stored in a clean, dry place. The importance of a "temperate fire" appears in more of Neri's recipes as well. The formation of a liquid would be bad in several senses. As the calcination of the raw materials was done on the shelf of the *calcara* and not in crucibles, liquid formation would result in the loss of material. Any liquid formed would be much harder to handle and it would have a very corrosive effect on the furnace itself all while absorbing impurities from the refractory material (Turner, 1956b).

While the events taking place inside the fritting furnace would depend on a collection of factors such as the furnace atmosphere, purity of the raw materials and so on, a general picture can be presented. The main constituents would be SiO_2 along with Na and K in the form of carbonates, sulphates, and chlorides. Reactions between these materials are slow until between 800 and 900°C. The solid material remains as a powder below 700°C and only begins to assume a sintered or fritted state around 750° C. The melting point of Na_2CO_3 is 851°C and that of NaCl is 801°C. Therefore to avoid forming a liquid the temperature would have to be maintained around 750°C and kept there for some time to allow time for the reactions between the various constituents to occur (Turner, 1956b:292). At this temperature, little loss of NaCl could be expected and the potassium and sodium in the form of sulphates would probably also be unaffected. As a result, most of the chlorides and sulphates would pass over to the glass-melting crucible unchanged.

Once the frit had been prepared, it could then be melted. This process was carried out in the main furnace. The frit was mixed with cullet to aid in the melting process (Verita, 1991:60). It would then be heated to a much higher temperature, probably around 1100-1200°C.

Based on the study of model glasses (75%SiO_2-10%CaO-15%Na_2O), additional reactions taking place in the melt can be described. In the melting process, the alkali salts would liquify, dissolve into one another, and take calcium and magnesium carbonates into solution. These would rapidly decompose and reactions between K_2CO_3 and Na_2CO_3 with SiO_2 would occur (Turner, 1956b:294-95). The chlorides and sulphates were still present after the fritting step. These have limited solubility in the glass. For example, the solubility of NaCl in the model glass as reported by Turner was 2.3% at 1400°C. The solubility would be further decreased at the lower temperatures attainable in the Venetian furnaces.

As a result, two additional processing steps were used to get rid of excess chlorides and sulfides in the glass melt. One step was to skim the top surface of the glass melt and remove any impurities. There would typically be a floating molten layer formed by unreacted and undissolved chlorides and sulphates which did not mix with the molten glass (Verita, 1991:60). The Venetians used a long-handled tool called a *partégola* to skim the surface of the glass.

The second step used to further purify the glass melt was known as "*traghettare il vetro in acqua*". Documentary sources from as early as 1348 mention that this was done during the melting process (Zecchin, 1990:179). The molten glass was ladled out of the crucible or dumped into vats of water. This had the effect of dissolving and removing unwanted chloride and sulphate impurities. The recipe from M.S. 797 prescribes the use of this procedure. Neri elaborates further on it in his recipe called "To make crystal in full perfection, the way I always practice" (Chapter 9, book 1):

> To make a fair crystal, when it is well-melted take it from the pot and cast it into great earthen pans or clean bowls full of clean water. To this end the water may take from it a sort of salt called sandever which hurts the crystal and makes it obscure and cloudy...then put it again into a clean pot and cast it into water which is to be repeated as often as needed.

In the production of *vitrum blanchum* and "common" glass, Neri also suggests using this step but says that it only needs to be done once. The production of *cristallo* required additional labor and time to prepare sucessfully resulting in a different appearance and composition. Turner notes that these methods of refining the glass continued into the 19th and 20th centuries (1956b:296).

The product that results from pouring the glass into water and removing the chloride and sulphate impurities is called *cotizzo* (Moretti, 1983:182). This word stems from the Italian for cooking - *cottura*. The English translation of Neri's book, prepared by Merrit in 1662, notes that the sandever was an article of commerce in the 17th century. This word comes from the France term *suin de verre* meaning "the fat of the glass". This was exported from England to France and used as a flux for metal working, as a weed killer, and as a food preservative (Turner, 1956b:295)!

The number of times that the molten glass had to be cast into clean water was at the discretion of the person in charge of preparing the glass melt, the *conciatore*. In addition to this stage and selecting the proper raw materials and the ratios in which to mix them, this person had the responsibility of maintaining watch on the glass batch as it was prepared and making changes as they became necessary. One of the duties of this person was to add an appropriate amount of manganese to serve as "glassmaker's soap". Neri states that the final stage in the preparation of *cristallo* should proceed in the following fashion (Chapter 9, Book 1):

> ...but that it might come forth white, shining, and fair, when you put the frit into the pots in the furnace, then cast in a quantity of manganese as needed [this is also described in the recipe from M.S. 797]...for this lies in the practice of the able and diligent Conciatore and belongs to his office. The quantity of manganese and of all other colors to be put into the frit cannot be precisely determined by weight or measure but must be left wholly to the eye and judgement, trial and experience of the Conciatore.

Neri's comments allude to an important feature regarding the use of recipes in the preparation of glass. The recipes really are only able to provide a general explanation of how the *cristallo* glass was prepared. The raw materials used by the glassmakers, despite efforts to control their quality and consistency, were variable over time. This may have been even more problematic with respect to *alume catino* used, especially after having been purified. Varying or altering the purification process would have affected the overall amounts of Na_2O, CaO, and MgO present in the *sal di alkali*. All of these components have important effects on the resulting properties of the glass such as viscosity-temperature relations, working ability, and chemical durability (all discussed in a following section). The correct addition of manganese also would have been crucial to the overall visual appearance of the glass. Too much or not enough MnO, when compared with the amount of Fe_2O_3 present, could cause unwanted tints in the glass. Despite the efforts of the glassmakers to codify and standardize their procedures via the use of recipes, a large part of successful glassmaking still depended on "trial and experience" as Neri states. The importance of having a skilled *conciatore* during the manufacturing steps is apparent. This aside by Neri also serves to illustrate the supreme importance of tacit knowledge and experience in successful glassmaking.

Once the *cristallo* glass had been melted and cast into water to remove any impurities, the next stage in production was the refining and homogenizing stage. This was carried out by maintaining the furnace at the highest temperature possible (1100-1200°C) for a long period of time. The exact duration is not specified in the recipe from M.S. 797. Neri notes that the should be melt "should be let to boil 4 to 6 days" (Chapter 9, Book 1). The recipe for glassmaking in Biringuccio's work prescribes a time of about two days (Smith and Gnudi, 1942:130). While the glass is being heated and refined, several different steps are carried out. The melt as a whole was continually stirred using a long tool called a *reauro* or a *spiandori* (Zecchin, 1990:184).

The purpose of this stirring was to eliminate the different defects that can occur in the glass, as a material, during the melting process. As will be discussed more in the next section, two of these possible defects are bubbles (very small bubbles are called seed) and cord (striae is the term given to finer sized cord). Bubbles become trapped in the melt due the evolution of gases during the melting process. This would have especially been a problem as the Venetians used a sodium based fluxing agent made primarily of carbonates. During the heating and melting process, CO_2 gas would have evolved. While air bubbles, in time, can rise to the surface of the melt and escape, this speed of this process depends on their size and the viscosity of the glass, among other factors. Stirring the melt continually would have helped eliminate these by bringing them to the surface where they could escape. Cord and striae result from a poor mixing of the glass melt. These can be seen in the finished product as wavy striations or streamers. They are essentially caused by compositional differences in the glass resulting in localized regions having a different index of refraction (Brill, 1988:282). Stirring the glass melt over a period of time would have helped homogenize the composition of the glass and made it more uniform. Eliminating these inhomogeneities gave a glass with greater clarity and a more uniform appearance. Because the glass furnaces used in Venetian production were not capable of attaining the high temperatures of modern, or possibly even 18th century coal fired furnaces, the homogenizing and refining of the *cristallo* glass melt through continual and sustained stirring was an integral part of successful production.

As the glass was stirred, it was continually monitored by the *conciatore*. Neri notes towards the end of Chapter 9 of Book 1 that additional manganese may be added if the glass still has a greenish color due to iron impurities. Also, during the entire melting and refining process, it was important to maintain the proper furnace conditions. Moretti and Toninato have cited an anonymous 16th century recipe book from a private Venetian collection which instructs that the furnace was fired so as to have bright white flames and to be free of smoke or soot which could cloud the glass (1987:33). Neri gives similar directions in his original 1612 version which were not copied directly in the English translation. Again, the furnace is kept hot and stoked with "strong and dry wood" (Barovier, 1980:13). One is also to guard against fumes; Merrett's version of Neri's work has comments at the end offered by the translator and essentially confirms the importance of maintaining these furnace conditions. In addition to keeping the furnace as hot as possible, all of the instructions note that the furnace should be free of smoke and fired with dry wood. If carried out, these instructions would have created a fairly oxidizing atmosphere inside the furnace. This would have helped drive the reaction between the iron and manganese

$$Fe^{+2} + Mn^{+3} \rightleftarrows Fe^{+3} + Mn^{+2}$$

to the right. In this manner, even more of the greenish-blue tint caused by the Fe $^{+2}$ ions could be eliminated.

From the preceding discussion, it can be seen that the successful production of a *cristallo* glass melt suitable for working into luxury glass was a complicated and lengthy process involving a great amount of judgement and tacit knowldge. It incorporated the systemic use of steps beginning with the careful selection of the proper raw materials and concluding with an attentive eye on the furnace conditions. Obviously, there were many places in this chain where problems could arise. Therefore, the ability of the Muranese glassmakers to produce quality and relatively colorless glass must described as a "team effort" requiring informed decisions on the part of everyone from the *stizador* who watched the furnace to the *conciatore* who prepared the glass batch.

Specialization appears in many aspects of Venetian glass production and the tools used in the Renaissance are no exception. Basically, the tools used in glass work can be divided into two basic groups: there are those tools which are used in the making of the glass frit and melt and those used in working the molten glass into objects. For example, there was a long rake-like tool used in mixing and removing the frit from the calcar. The *partégola* was used to skim the surface of the molten glass and remove impurities while the *reaura* was used to stir the melt. Figure 8.9 shows these two tools. A shovel-like tool (*spignauro*) was used to add frit to the pots as well as coloring agents if needed. The name of this tool led to the phrase *dar a spignauro* - basically, to give a shovel-full - used in Venetian glassmaking.

The tool kit of the glass *maestro* was quite simple and changed little over the centuries. Tait, in conjunction with Bill Gudenrath, has presented a clear picture of many standard production sequences used by Venetian glassmakers to assemble objects (1991:230-40). The blowpipe, of course, was an essential component and these are listed in the old inventories as *ferri* or *canni*. The manufacture of vessel glass required that the rim be finished on a pontil rod which appears in the Venetian archival sources as a *puntello*. A wooden paddle (the *palétta*) was used to shape the rims and vessel bottoms at times. There were scissors (*tagliante*) and jacks (*borsella*)used in additional forming and hot working procedures, also. The glass master worked with a wooden slat attached to his leg in place of the traditional gaffer's bench (*scagno*) which would not be invented until about the 16th century. As mentioned earlier, a marvering surface (*malmoro*) was employed, usually a pieces of marble stone. By the 14th century, there are references to bronze molds of various shapes and types (open, closed) in the archival records, as well (Zecchin, 1987:13). Zecchin has presented several papers which trace the development and history of these and other tools (1990:173-188). The essential point here is that the original glassmaker's kit was a fairly simple affair. The Venetian glassmaker's modified these tools in a variety of ways to coincide with their manner of glass working. This tended to favor, for example, the construction of objects on the blowpipe and the application of hot-worked detail (Gudenrath, personal communication, 1994). Additional refinements and specialty tools appeared in the preparation of the glass melt and the additional steps required to make *cristallo*.

Over time, the recipes and materials used for making Venetian *cristallo* would change. For example, the third part of the Darduin recipe book has a recipe for *cristallo do rocca* (#241) which was recorded July 1697 (Zecchin, 1986:228). By this date, the raw materials used in cristallo making had altered considerably. The recipe calls for:

36 *libbre* of *cogoli di Tesino*

17 *libbre* of $PbCO_3$

27 *libbre* of *salnitro* (KNO_3)

4 *libbre* of *boraso* ($Na_2B_4O_7$)

1/3 *libbre* of *arsenico*

By the end of the 17th century, the vessel glass being made in Venice was no longer a soda-lime-silica glass. Rather it had a composition that was very similar in terms of ingredients to English lead crystal glass (Charleston, 1968). Other recipes from this period confirm the gradual changes and modifications in the Venetian *cristallo*. Such changes suggest some type of interaction, in terms of glass compositions, between Venice and England. Other recipes suggest technological connections between Venice's glass industry and those of Bohemia in the late 17th and 18th century (Moretti and Toninato, 1987:39).

One general observation, therefore, is that the Venetian glass industry employed a considerable range of raw materials in it's production of vessel glass. While the predominant vessel glass type of the 15th and 16th centuries would appear to a soda-lime-silica glass made using *cogoli* and *alume catino*, there were variations. The great compositional variety extended into the making of other glass types such as enamels and beads as evidenced by the different recipes in the Darduin book. Furthermore, the picture provided from the few available collections of well-dated recipes is that the original *cristallo* composition changed considerably over time. A greater understanding of the interactions between Venice's glass industry and those of England or Bohemia is limited due to the paucity of available and well-dated samples for analysis. While this topic cannot be explicitly addressed in this work, it certainly is an open area for future study.

The incremental combination of these steps with the necessary purification of the *alume catino* in the 1450's allowed for *cristallo* glass to be made in response to perceived demand. The purification of the *alume catino* ash was the key step that allowed for *cristallo* production in the 15th and 16th centuries. However, other steps were involved: the careful selection of a source for SiO_2, the addition of the proper amount of MnO, the use of a fritting process to overcome the limitations imposed by the temperatures attainable in a wood-fired furnace, the process of passing the glass melt several times through water, careful and sustained stirring of the melt, and conscientious attention paid to furnace maintenance. Most of these steps had been employed in the Venetian glass industry since the 14th century and their use allowed the Venetian to produce a reasonably high-quality *vitrum blanchum* glass before *cristallo* was made.

Renaissance Venetian Glass - Chemical Analyses and Physical Examinations

The previous section showed two basic features related to Venetian *cristallo* production. The first was that the manufacture of *cristallo* was a very lengthy and labor intensive process. The second aspect was that there were significant differences, in terms of production sequences, between the three different basic vessel glass compositions made in Venice - *cristallo*, *vitrum blanchum*, and "common" glass. The first part of this section will quantify these differences through the presentation of analytical results. The second part, which deals with the quality of the glass as a material, will be based on evidence accumulated through the physical examinations conducted. The discussion of this evidence will be done in conjunction with the previous evidence and material derived from a consideration of the glass recipes and manufacturing steps.

<u>a. Chemical analyses of Venetian glass:</u>

Besides the connoisseur oriented literature which considers Venetian glass, a fair amount of attention has recently been given to chemical analyses of the glass (Verita, 1985, 1989, 1992; Verita and Toninato, 1990; Moretti and Toninato, 1987; Toninato and Moretti, 1990) . The majority of this work has been done in the past ten years. Other than this previous research, which is largely due to the efforts of scientists at the *Stazione Sperimentale del Vetro* in Murano, analyses of Renaissance Venetian glass have been presented piecemeal or with little informed or contextual integration. Verita's 1985 paper on the invention of *cristallo* was particularly important as it showed that *cristallo* glass was chemically distinct from the other Venetian vessel glass types. This conclusion, while still not fully appreciated by the art or museum communities, has important ramifications, as we shall see, for the Renaissance production of this glass as well as modern-day conservation and treatment issues.

Analyses clearly do show defined compositional differences between certain samples. These variations can be correlated to both visual information and what one might expect from an examination of the recipes. On this basis, one can categorize analyzed samples into different compositional groups. Appendix A describes the sampling and analytical procedure for the chemical analyses conducted. It also offers a brief description of sample origin, the analytical results, and comments on the analysis of each sample. For this research, over 80 different Venetian samples were analyzed via SEM-EDS, WDS, and ICP-AES. The majority of these were "colorless" glass; several white, red, blue, and "special" glass samples were also examined for comparison. In addition, about 20 *facon de Venise* samples from sites in Amsterdam were also studied. The results of these latter analyses are presented in Chapter 9.

For this section, the results for several selected analyses of Venetian samples are given in order illustrate the basic chemical differences between the three different vessel glass types. These are presented below in Table 8.5. All of the samples presented below were excavated from 15th and 16th century sites in the area of Fusina (see Chapter 3 or Appendix A for further description). The average composition of each sample is given along with the standard deviation when this was greater than 0.2 %.

Table 8.5. Selected analytical results for Venetian vessel glass (in weight percents).

Sample #	**UA-16**	**PE-41**	**PE-151b**	**UA-7**	**PE-153b**	**UA-17**	**PE-43**
Type	***cristallo***	***cristallo***	***cristallo***	***vitrum blanchm***	***vitrum blanchum***	**"common"**	**"common"**
M.o.A.*	**SEM-EDS**	**SEM-EDS**	**WDS**	**SEM-EDS**	**SEM-EDS**	**SEM-EDS**	**SEM-EDS**
Oxide							
SiO_2	75.1 (.6)	70.7 (.6)	70.2	69.9 (.3)	66.8 (.6)	67.7	67.8
Na_2O	13.7 (.3)	18.3 (.3)	19.3	12.0 (.4)	12.6	13.8	11.3
CaO	4.6	3.6	4.1	8.9	9.7	8.8	11.4
K_2O	2.3	2.9	2.5	2.5	2.2	3.6	2.2
MgO	1.3 (.3)	1.1 (.3)	1.7	2.7	3.1 (.3)	1.9	3.0
Al_2O_3	1.1	0.8 (.4)	0.6	1.5	2.0 (.3)	1.6	1.7
Fe_2O_3	0.3	0.4	0.2	0.6	0.7	0.7	0.7
MnO	0.6	0.3	0.3	0.5	1.3	0.9	0.6
Cl	0.8	0.9	1.0	1.0	0.6	0.9	0.6
SO_3	0.2	0.4	0.3	0.2	0.6	1.0	0.3
P_2O_5	bd**	bd	0.2	bd	0.4	bd	bd
TiO_2	bd	bd	0.04	bd	bd	bd	bd

* "M.o.A." means "mode of analysis".
** "bd" means that the oxide in question was detected but in an average amount below the detection limits of the technique (0.2 weight % for SEM-EDS).

The results of the analyses presented below, as well as the others in Appendix A, are in good agreement and fall within the ranges of those presented elsewhere (Verita, 1985 for example). The range of compositional variety for *cristallo* glass seen in my analyses and those conducted by others suggest only limited compositional variety for different glass types. The largest variations are typically seen in the SiO_2 and Na_2O amounts present. From these selected analyses offered for comparison, it can be seen, first of all, that the composition of *cristallo* is clearly different from the other two vessel types.

Let us first consider the key differences that distinguish the *cristallo* samples from the other glass types:

1. On average, the *cristallo* samples have a greater amount of Na_2O present. While not as noticeable in UA16, this is clearly seen in PE-41 and PE-151b. These latter two samples have combined Na_2O + K_2O amounts approaching 22% which is quite high. This large amount of Na_2O can be traced back to the recipes. In the case of the anonymous 16th century recipe book, the ratios of *cogoli* to soda ash for both *cristallo* and "common" glass were the same - 2:1 (Moretti and Toninato, 1987). The difference lies in how the glass' flux was prepared. For making *cristallo*, the ash was purified which had the effect of enriching its Na_2O content. Verita reported that this increased from about 23% to 44% (1985:20). Making a glass using purified ash but in the same ratio as for "common" glass would make it have a higher Na_2O content. The *vitrum blanchum* and "common" glass, on average has a Na_2O level about 3-4% lower than the *cristallo* glass. This difference in sodium levels would cause a difference in the properties of the *cristallo* glass such as its viscosity and working range.

2. The *cristallo* glass, on average, has a higher amount of SiO_2 present. This could have been inferred from above. If a more powerful fluxing agent, such as *sal* *di alkali*, were used, the glassmakers of Venice could afford to slightly increase the relative amount of *cogoli* added. While making the glass a little more difficult to work and melt, it would have made a more durable glass (Verita, 1985:24). This fact is interesting to note in light of the next point.

3. One of the primary means to distinguish the *cristallo* samples from the other types is by its significantly lower CaO and MgO contents. The amounts of these two oxides are on average 50% lower in *cristallo* than those for *vitrum blanchum* and "common" glass. This reduction in the amount of alkaline earth oxides present has an important effect on the chemical durability of *cristallo* glass. An insufficient amount of CaO and MgO will cause the glass to become "sick" over time. This is seen as a gross form of surface deterioration (Brill, 1975). While the exact mechanisms and nature of glass corrosion by humid air and aqueous solutions are still under investigation, one of the basic functions of CaO and MgO in glass is to improve its chemical durability (for example, Wolf, 1984:250, 267; Newton and Davison, 1989:143). For soda-lime-silica glasses such as the Venetian compositions, the optimum CaO content is around 10% (Newton and Davison, 1989:143). The reduced amounts of CaO and MgO in the *cristallo* glass occurs primarily because of the ash purification used in preparing the *alume catino*. The percentage of CaO and MgO in the flux decreased by more than an order of magnitude following purification. What is quite interesting to note is that the overall amounts of CaO and MgO contents in the *cristallo* glass are significantly higher, however, than what one would expect if the recipes for it were followed exactly. This suggests that the

Muranese glassmakers recognized the instability of their glass and took steps to correct it in some manner. Possible manners in which this was accomplished are discussed shortly along with a further consideration of the chemical durability issue.

4. The amounts of $Fe_2O_3$and MnO in the *cristallo* samples are consistently lower than that seen in the other two glass types. Again, this difference stems from the careful selection of raw materials coupled with the ash purification process which tends to reduce the Fe content. As described earlier, a lower Fe_2O_3 content meant that less MnO had to be added as a decolorant to the glass melt as it was prepared. The lack of MnO in the *alume catino*, both raw and purified, eliminated a possible source of this constituent and simplified the production process for the Venetians. Had MnO been present in varying or excess amounts in the fluxing agent, it would have complicated the decolorizing process or possibly caused undesired tints in the *cristallo* glass.

The general conclusion that one can reach on the basis of comparing the analyses of the different glass types is that the variability noted between them is due to the different manufacturing sequences followed in making the *cristallo*. The purification of the *alume catino* ash emerges as the single most important and identifiable step causing the difference in chemical composition between the glass types.

Vitrum blanchum glass was intermediate in quality between *cristallo* and "common" glass. Recipes for *vitrum blanchum* glass, such as those in Neri's book, indicate that it was made using the same raw materials as *cristallo* but without the ash purification step. The instructions show that the molten *vitrum blanchum* glass was usually only passed through water once to remove impurities. In addition, Neri's recipes in Chapter 10 of Book 1 suggest that more MnO was added to *vitrum blanchum* to eliminate any tints present. Note, for instance, the high amount of MnO (1.3%) in sample PE-153b as compared to the *cristallo* samples. "Common" glass, imaginably, received even less attention than the other two compositions. Its use was generally reserved for utilitarian items and beads, for instance. All of the samples of "common" glass had distinct greenish-blue tints due to higher amounts of Fe_2O_3 present, as confirmed by the analyses.

What other features relevant to glass technology can be discerned from the analyses? All of the glass types show a generally low level of alumina indicating a controlled selection of raw materials as well as minimal pot corrosion (Verita, 1985). In the same vein, the amount of Al_2O_3 in the *cristallo* samples is even lower, attributable to more careful raw material selection and processing as well. Furthermore, the compositions of the glasses analyzed, as can be seen in the Table 8.5 and in the tables from Appendix A, show the glass compositions overall to be fairly consistent over time. This, in many ways, is to the credit of the Venetian workers who prepared the glass melt. The raw materials used in glass production came from natural sources such as river stones and plant ash. The composition of these raw materials certainly varied with time. The ability of the glassmakers to maintain a consistent composition over time when faced with these difficulties is quite remarkable. A similar level of skill is detected in the ability of the glass *conciatore* to add the right amount of MnO to offset the undesirable tints due to iron in the *cristallo* and *vitrum blanchum* glass. Some doubts have been expressed about the ability of ancient glassmakers to add raw materials in amounts less than 1% and to disperse this uniformly throughout the melt (Newton and Davison, 1989:60). However, small amounts of MnO are seen in the analyses of the glass here and elsewhere (ex: Verita, 1985, 1987). This is coupled with the fact that the percentage of MnO is in amounts roughly equal to the iron content (sample PE-153b, which had a noticeable grey tint due to too much MnO added is clear exception) - what Brill has described as the most effective manner in which MnO can be used as a decolorant (1988:277). This is further evidence of the Venetian glassmakers' control over the glass they were making.

The three different vessel glass compositions used in Renaissance Venice have distinctly different chemical compositions, especially when one considers those for *cristallo* as compared to the other two. These differences are due to the manner in which the glass was prepared. Is it possible to visually see a difference between the different glasses? There are distinctions, visually, between the *cristallo* and *vitrum blanchum* compositions. The percent transmission vs. wavelength plots presented in Chapter 7 provided one example of how the difference in optical properties could be demonstrated. Unfortunately, it is very difficult to illustrate these with pictures. In some cases, the differences, while present, are slight and somewhat subjective. What one person sees as relatively colorless another sees as having a grey or pink tint. Visually, these differences are often most noticeable in person and when the glass is held against a white background and by varying the source and direction of the light. This should be kept in mind when considering the following two figures. Figure 8.10 shows a sherd assemblage from the site of Fusina.These samples were all shown via chemical study to be a *vitrum blanchum* type glass. In this picture, it is possible to see that there is a great variety of possible tints. An even better illustration of the visual differences between glass types can be seen in Figure 8.11 which shows two sherds. Sample UA16 (*cristallo*) was taken from the one on the left and UA17 ("common") was taken from the other sherd.

Cristallo glass, as a distinct composition, was not just fashioned into clear and colorless vessel glass. In many cases, *cristallo* glass frit formed the basis for the manufacture of other luxury glass types. Evidence of this can be found in both glass recipes and in compositional analyses of glass samples. Many of the recipes for colored and opaque glasses in the 1536 Montpellier recipe book, for example, either call for the addition of *sal di cristallo* or the use of a *cristallo* frit to which colorants were added (Zecchin, 1987:253-276). Later recipes from the Darduin book do the same (Zecchin, 1986). In a similar fashion, Neri's recipes for colored glass, *chalcedony* glass, glass for enamels, et al. specify that either "crystal" frit or cullet be used. This documentary evidence is supported by analyses carried out of different Venetian opaque and chalcedony compositions (McCray, et al., 1995b for example). Consider the analyses presented in Table 8.6.

Table 8.6. Compositional data (in weight %'s) for colored glasses based on *cristallo*.

Oxide	*Lattimo* (UA6)	*Lattimo* (UA15)	Opaque Blue*	*Chalcedony* (PE-148a)
SiO_2	42.1	46.5	52.8	72.8
Na_2O	10.2	12.6	12.5	16.9
CaO	4.0	3.0	3.5	3.0
K_2O	1.4	1.6	2.1	2.7
MgO	1.4	1.3	0.8	1.2
Al_2O_3	0.7	1.3	0.8	1.7
Fe_2O_3	0.2	0.4	0.3	0.3
MnO	0.2	0.2	0.2	bd
Cl	0.8	0.9	0.6	0.9
SO_3	bd	bd	0.3	0.3
SnO_2	8.1 (2.2)	10.9 (1.9)	11.4	bd
PbO	14.3 (0.6)	21.3 (0.6)	12.5	bd

* The data for the opaque light blue glass was given to this study by Ian Freestone at London's British Museum

The opaque blue and *chalcedony* glasses in Table 8.5 also had small amount of coloring oxides present such as Cu and Co which are not shown in the table. However, all of the glasses in Table 8.5 have the compositional characteristics which distinguish *cristallo* glass from the other Venetian compositions - low CaO, MgO, Fe_2O_3, and MnO contents and comparatively high Na_2O amounts, for example. These colored and opaque glasses were used in a variety of ways including vessel glass manufacture, bead production, and enamelling. As *cristallo* glass was a relatively "pure" glass and was free of contaminants such as iron and managnese which could introduce unwanted shades and tints into the colored glass being made, it made an ideal starting material. In this manner, the technology and knowledge associated with making colorless *cristallo* glass for vessel production had ramifications for the production of several other glass types in Renaissance Venice.

b. The question of a "durable" glass:

I have illustrated the basic chemical differences between the vessel glass compositions made in Renaissance Venice. Now I would like to return again to the issue of the low CaO and MgO levels in the *cristallo* glass, one of the distinguishing chemical features of the *cristallo* glass. This has important consequences for the overall durability of the glass as well as museum conservation protocol.

There is a great volume of literature on the durability of glass from both a materials science and conservation perspective (see Brill, 1975, Newton and Davison, 1989, and Rogers, et al. 1993, Ryan et al. 1993 for treatments of this issue which touch both fields). While the actual mechanisms and conseravtion treatments are still under review, some general observations can be offered. It should be mentioned that glass durability, even for simple "model" glasses is very complex and difficult to predict. For this reason, I wish to keep this section primarily qualitative as the actual process of decay and corrosion would vary widely depending on the particular circumstances of each individual piece.

Water is the primary agent which is responsible for glass corrosion (Newton and Davison, 1989:135). This can be either humid air or actual contact with an aqueous solution. Both have important consequences for Venetian *cristallo* as it was made and sometimes stored (even today) in a relatively damp or humid environment. This also has implications for its use as Renaissance glass came into contact with liquids such as water and wine. The primary factors which affect the durability of glass are its composition and its environment. As the environment of Venetian glass would vary depending on the piece, the first factor is the main concern here. Another variable to consider is that of time. Would decay occur rapidly enough in order to be noticed by consumers? This, largely, would be determined by the degree and nature of use of an individual piece. Was it displayed in a cabinet or was it part of an often used dining service? Tests carried out under high humidity conditions indicate that the visual appearance of a soda- lime-silica glass can markedly change over a period of a few weeeks, for example (Rawson, 1980:272-75).

The three basic roles that the oxides found in glass can have are as: glass formers, modifiers, and intermediates (Kingery, et al., 1976:97). The glass former in *cristallo* glass is SiO_2 while oxides such as Al_2O_3 and Fe_2O_3 act as intermediates. It is the relative amounts of the different modifiers which affects the glass durability most. Modifiers are oxides with relatively low bond strengths; these fall into two groups - fluxes (oxides of Na and K) and stabilizers (CaO and MgO for example).

An excess of alkalis and a deficiency of stabilizers can result in a glass which is *sick* (Newton and Davison, 1989:141). The symptoms of this problem are varied and well-described in the glass conservation literature. For example, the glass may exhibit *weeping* in which drops of moisture continually form on the surface of the glass causing a sweaty appearance. *Crizzling* may take place and is observed by the formation of fine surface cracks in the glass. Overall, the result is a glass with a diminished transparency (Brill, 1975). Many of the glass objects examined in this work showed some signs of chemical instability. This ranged from light patches of dullness and weathering on the surface to pieces which displayed acute weeping and had severely diminished transparency. Figure 8.12 shows a moderately weathered 16th century goblet.

What compositional factors contribute to or inhibit glass durability? A total amount of network formers that is below about 62 mole % is likely to decrease durability; this generally is not a problem in *cristallo* glass.The presence of two types of alkalis (suchas Na and K) in the same glass typically increases durability as well (mixed alkali effect). Small quantities of Al_2O_3 or P_2O_5 have been observed to minimize the corrosion reactions with the most significant reduction observed with between 2 and 5 weight % of Al_2O_3 (Newton and Davison, 1989:142). Venetian *cristallo* glass has both minor amounts of Al_2O_3 and P_2O_5 along with a mixture of alkali oxides. Other than the low levels of CaO and MgO present in *cristallo*, this glass would be a good candidate for a durable material.

The low levels of these two oxides account for its overall instability. In soda-lime-silica glasses, the addition of CaO up to amounts around 10 weight % results in a general increase of the glass' stability. The cause of this stability has been ascribed to the CaO increasing the coupling of the vibrational modes of the silica - nonbridging oxygen modifier bonds to the bridging of the Si-O-Si network (Newton and Davison, 1989:143). Venetian *cristallo* glass typically has about half of the optimum CaO content. A lime content of less than about 4 weight % is described as very unstable by modern standards (Brill, 1975:123); most *cristallo* glass falls in this regime.

The very low amounts of CaO and MgO in the purified ash would not result in a final *cristallo* glass composition that had levels of CaO and MgO present around 4-5 % and 2-3 % respectively. While there is not enough CaO and MgO to make *cristallo* glass resistant to crizzling, weeping, etc. over a long span of time, it apparently was sufficicient to make the glass durable enough to be sold and purchased without significant complaint. The initial failure of George Ravenscroft's lead crystal glasses (c. 1670) due to crizzling and instability problems has been noted several times (ex: Charleston, 1983). In this case, the glass deteriorated so quickly that consumers demanded refunds. Exactly how long the glass would resist corrosion and maintain its original appearance would depend greatly on its environment and use.

It is probable that the glassmakers in Renaissance Venice were able, in some manner, to adjust the amounts of CaO and MgO present in *cristallo* so that the glass was moderately chemically stable, at least over the short run. This raises two main questions: First, were the Venetian glassmakers cognizant of the issue of chemical durability and did they recognize that the purification of the ash could create problems with glass instability? Secondly, while it is obvious that they were able, in some fashion, to make a minimally stable glass, how was this accomplished (or was it by a fortuitious accident somewhere in the production sequence)?

Various written evidence from the Renaissance period suggests that glassmakers, along with those who sold the products, were aware of the issue of glass durability, at least on a basic level. For example, a letter from a London glass seller in 1669 to his Venetian supplier asks that the glass "...be carefully packed up and with thoroughly dried weeds for if the weeds be not well dried or become wet after they be packed they stain and spoil the glass." (Charleston, 1967:190-91). An earlier letter from 1595, also concerning glass sent from Venice to London, notes that 200 dozen of the glasses arriving were either broke or "in bad condition", possibly referring to their corrosion in the damp shipping environment.

Neri's original glassmaking text and the later English edition also contain comments concerning the instability of glass. For example, Chapter 2 of Book 1 describes how the *cristallo* frit must be stored in a dry place or else the "...frit suffers much" and cannot be used for glassmaking. Merrett's comments at the end of his translation of Neri's work notes that "...furthermore, in the finest glasses, wherein the salt is most purified (my emphasis), and in a greater proportion of salt to sand, you shall find that such glasses standing long in subterranean and moist places will fall to pieces, the union of salt and sand decaying." (Merrett in Neri, 1662:211). This evidence suggests that both glassmakers and the persons selling the finished product were aware of the problems of unstable glasses. Merrett's comment is especially interesting as it specifically points to how Venetian *cristallo* was susceptible to these problems.

Despite the fact that the amounts of the stabilizing oxides in *cristallo* are lower than those in the *vitrum blanchum* and "common" glass, Venetian *cristallo* contains more CaO and MgO than would be expected if the glass recipes described earlier were followed without some form of modification. These two facts suggest that the glassmakers of Murano somehow were able to compensate for the reduced CaO and MgO contents of the *cristallo* glass due to the purification of the *alume catino* flux. This is especially interesting as the great majority of *cristallo* recipes make no mention of any special extra step that must take place in order to avoid an unstable glass. The more general accounts of Venetian-style glassmaking, such as those of Biringuccio or Agricola, certainly make no allusion to this possible problem. When hints as to resolving this difficulty are found, they are in compilations of recipes collected and prepared specifically for glassmakers. This suggests that the remedy for preventing an unstable glass was either a trade secret or else it was part of the tacit knowledge associated with successful glass production.

The possible ways in which the proper amount of CaO and MgO could have been added to the *cristallo* glass have been discussed in a number of publications (Verita, 1985; Moretti and Toninato, 1987; Zecchin, 1987:250). One is by a fortuitous inclusion of CaO and MgO from some accidental reaction or stage in the glassmaking process. For example, the use of river pebbles which may have contained mixtures of quartzite and quartzite-calcareous stones as a raw ingredient is a possibility. While Verita suggests that more study of these pebbles as a raw material would be helpful, it is unlikely that the CaO and MgO came from here. These oxides appear in fairly regular amounts and it seems inplausible to suggest that they were incorporated accidentally. Another possible source of CaO and MgO was the subsequent corrosion of the glassmaking crucible during the production process which could have caused additions of calcium and magnesium. If this had occurred, other materials such as Fe_2O_3 and Al_2O_3 would have also been added to the melt resulting in a contaminated melt. Correspondingly, this does not seem to have been the case.

Another hypothesis offered by Verita appears more likely - the deliberate addition of certain material(s) to the glass batch causing it to have a higher than expected amount of CaO and MgO (1985:28). One possible source is the addition of *vitrum blanchum* glass cullet at the beginning of the melting process. Certain recipes, as well as the relatively low furnace temperatures attainable, indicate that cullet additions were necessary. The addition of sufficient *vitrum blanchum* cullet, with its higher CaO and MgO contents, would have raised the level of glass stabilizers present to a reasonable amount. This would have caused some loss of clarity and transparency while still yielding a higher quality product (Verita, 1985:28). Also, small additions of unpurified *alume catino* ash (which had a greater CaO and MgO content) may have been incorporated into the batch.

Other authors have commented on possible means in which the Venetian *cristallo* was temporarily stabilized. The addition of a raw material referred to *allume di rocca* to a *cristallo*-type glass is found in Montpellier recipe book of 1536 (Zecchin, 1987:250, 258). Recipe #56 refers to the manufacture of a glass which neither "fumes or spits salt". The recipe calls for 10 parts of *allume di rocca* to be added for every 100 parts of *sal di cristallo*; the result is a very "clear glass which does not spit". Neri's book also lists this as an ingredient in different, non-*cristallo* glass compositions. The glossary accompanying Barovier's 1982 edition of Neri's book identifies *allume di rocca* as an aluminum potassium sulphate ($AlKSO_4 \cdot 12 H_2O$). No other information could be found regarding how this material was identified as such. Other than giving a glass with a higher Al content, which would make a slightly more stable glass, I am unsure how this would improve the glass durability. It does not seem as if it would introduce a significant amount of CaO or MgO. It does, though, provide further written indication that glassmakers were aware of the issue of glass stability as early as the first part of the 16th century and that steps were made to improve the glass in this respect. It is unlikely, based on conversations I have had with modern glassmakers, that chemical durabilty was a central issue to ancient glassmakers. Other properties directly connected with the ability of the glass to be worked and shaped along with its color and appearance were probably viewed as more important.

Neri's book (Chapter 7 in Book 1) suggests that lime was added at times directly to the glass batch. He describes how one would take "...salt of lime, which serves for building, and this salt purified and mixed with the ordinary salt of *polverine* of the Levant...". Neri suggests adding 2 parts lime salt for every 100 parts of the *alume catino*. However, Moretti and Toninato rightly note that this is a fairly insignificant amount and would not account for the levels of CaO and MgO observed in the *cristallo* analyses (1987:35).They go on to consider Verita's suggestion that the extra CaO and MgO came from the deliberate addition of either unpurified ash or of frit made with the same.This suggestion is further supported by several recipes from Neri's text which describes how mixtures of different frits were used. For example, recipe #22 for making sea-green colored glass calls for a mixture of 1/2 *cristallo* frit and 1/2 *vitrum blanchum* frit. Other recipes from 17th and 18th century also call for different frit mixtures to be used. It should be noted that none of this recipes are for colorless glass. Therefore, the mixture of *cristallo* and non-*cristallo* frit could also have been a way for the Muranese glassmakers to economize on the use of the harder to prepare *cristallo* material.

Ultimately, neither of these explanations is entirely satisfactory. I find the idea that the Muranese glassmakers deliberately added some unpurified ash /frit (or cullet made with the same) most plausible as this would have been the easiest means to increase the CaO and MgO content. The glass analyses certainly suggest that definite steps were taken to make a moderately stable glass. Furthermore, the analyses done by myself and other show that CaO and MgO was added in fairly regular but not completely standardized amounts. None of the recipes for *cristallo* glass offer definite evidence of this addition process, however. It seems fairly likely that something was consciously added to the glass but what and how is not exactly known. The recipes, which are generally explicit with respect to all other aspects of glassmaking, offer no good answers. It is quite possible that the process by which the Venetian *cristallo* was made stable was part of the trade "secrets" or tacit knowledge surrounding its production.

c. Physical examinations of the glass as "material":

When scholars have taken the time to actually examine Venetian glass from the Renaissance, these efforts have usually gone in two directions. One falls in the realm of curatorship and connoiseurship. This typically concerns such issues as the form of the piece, the nature of the decoration applied, its provenance, and so forth. The other, more recent, approach has been to study the chemical composition of the glass, sometimes within a cultural context (Verita, 1985; McCray, et al., 1995a, 1995b). This section offers a different approach to the study of the glass. This is a consideration of the quality of the glass, as a material, that was to be later worked into various shapes.

This type of questioning is something new that this research has brought to the study of Venetian glass.While the art-oriented literature abounds with superlatives for the quality of Venetian glass in terms of form and design and the skill with which it was worked, almost no attention has been paid actually to examining the material quality of the glass. Accepting for now that the glassmakers of Murano were masters of the craft in the 15th and 16th century, what can be said about their ability to make a high-quality and defect free glass?

The presentation and examination of the written sources concerning Venetian glass in Chapter 7 identified several desirable qualities in the glass as part of the demand for it. Some of these such as colorlessness and form have already been presented. In order for the glass to be visually superior it was also necessary that it also be relatively free of defects. Recall the quote from 1585 when the Bishop of Olomouc in Bohemia ordered several objects from local glassmakers. He eventually complained that the glass "was not pure enough and that it has not the right proportions and fine shape." A year later when he ordered another piece, he specified that it be "transparent and made in the *facon de Venise*...very clear, without sand, defects, striae, and bubbles." (Hettes, 1963:41). It is only logical to assume that a glass free from defects such as these was in demand along with one that was colorless and with good clarity. This was necessary if the glass was to successfully imitate rock crystal. Furthermore, a visually appealing glass, in any case, would have a minimum number of noticeable flaws.

The consideration of Venetian glass as a material, and in terms of its quality in this sense, provides another opportunity to assess the skills and labor power of the Muranese glassmakers. It also offers another characteristic with which to compare Venetian and *facon de Venise* glass from the Renaissance. In this manner, I hoped to address questions such as:

- Is it possible to objectively measure the "quality" of the glass?
- How good is Venetian glass with respect to the quality of the material?
- Does the glass change with respect to the number/types of defects over time and place?

- What are the predominant defects and how do they relate to the production process?

The basic methodology and examination procedure that was employed in the physical examintions (PE's) of over 200 Renaissance glass objects is presented in Appendix B along with further issues related to the concept of "quality". This appendix also presents some basic results of these studies which will be drawn upon here as needed.

What exactly is meant by the study of the glass as a material? This was developed from a principle first put forth by Harden in his examination of Roman glass from Karanis. Here, "material" was taken to mean:

> The condition and state of the glass at the time of manufacture and independent of how the glass itself was subsequently worked and manipulated to form a distinct object. (cf. Harden, 1936:11-12)

That it to say, "material" refers to the condition of the raw and unworked glass as it was used to form a wineglass, window, or water jug. Therefore, a judgement about the quality of the "material" does not refer to any defects or characteristics of the glass due to use, weathering or manufacturing processes. For instance, certain stages in the fabrication of glass objects could introduce flaws in the finished product. For example, excessive working of the glass at the rim might cause tool marks or perhaps a very bad pontil scar. These are not the primary consideration here. When considering the quality of the glass, these later defects and blemishes in the glass were overlooked as they do not relate to how well the glassmakers were able to control the quality of the glass as it was made. In this way, a very basic measurement of glass quality was made by examining the different glass pieces in terms of defects present - number of bubbles, presence of stones in the glass, degree of mixing based on the presence of any cord or striae, etc.. Futhermore, other aspects of the manufacturing process such as how well the glass was annealed are also part of examining the quality of the glass as a material.

It should be seen immediately that there are a number of rather thorny problems that appear when one claims to undertake an "objective" examination of "quality". The very inability to define quality might make the whole operation suspect. The defects I proposed to examine in the glass, however, were selected partly on their ability to be quantified. If one admits that a large number of bubbles and stones would result in a visually unappealing glass, one can thereafter proceed to count such defects. On this basis, a glass with a lesser amount of countable defects could be presumed to have a higher quality material. This says nothing about what was done with the glass after that point. The best and most defect free material may have been worked into the homeliest object and vice-versa.

The study of the glass required the develoment of a consistent and thorough protocol for the examination of glass objects. As there was almost no information in the literature, this was largely a trial and error process. By time I took my second trip to Venice, I had examined enough "non-Venetian" glass objects as to have an appreciation of the tools required and the evidence to look for. Again, Appendix B describes this in detail.

Finally, two other issues developed once the examinations began. As one of the goals was to look for changes in quality over time and place, a good indication of the date and provenance of the examined pieces was needed. Unfortunately, the information that was available in this respect was not the best. In this respect, I was very dependent on the information supplied to me by museums and collectors in possession of the glass objects. In a few cases I was able to offer a better interpretation of the either the date or provenance of a piece. More frequently, I had to rely on the all-too-vague descriptions in museum records. For example, I examined a very large number of Venetian style wineglasses. In many cases, the date attributed to the object would simply be "16th-17th century". The complications that this introduces into trying to observe changes over time are obvious. The provenance of pieces presented a similar, but not as intractable, problem.

The second consideration concerned the type of glass that was being examined. It is quite simple to identify *cristallo* and *vitrum blanchum* glass from "common" glass. In some cases, when the *vitrum blanchum* glass is heavily tinted, it can be distinguished from *cristallo* glass. This becomes more complicated, however, as the tints are somewhat subjective. Furthermore, exposure to bright sunlight for an extended period of time can also introduce tints in both *cristallo* and *vitrum blanchum* glass through the process of solarization (Newton and Davison, 1989:153). The only way to definitely determine what type of glass is being examined is to remove a sample for later chemical analysis. While it was possible to do this with the sherds studied, this simply was not permitted with whole vessels in museum collections. For reasons which will be explained later, the great part of excavated glass sherds are not *cristallo* but are *vitrum blanchum* glass. As a result, it is not possible to offer any conclusive results on the varying nature of the quality of the glass in correlation with its chemical composition. Despite all of these caveats and difficulties, the physical examination of the glass objects did provide some interesting results concerning material quality and its changes. Furthermore, the continued handling of numerous glass pieces and their detailed study certainly gave the writer a better appreciation of the glass in terms of its "feel", form, and the way in which pieces were assembled. With that information in mind, I would like to turn to a more detailed examination of the different defects found in Venetian glass as a "material" and their connection with glass quality.

1. Bubbles

Bubbles of varying sizes were the predominant material defect found in the Venetian glass pieces examined. They were also the primary defect in the *facon de Venise* glass as well. The physical examination of the glass objects in this work with respect to bubbles in the material focussed on several aspects.

The first was to estimate the number of bubbles per cm^3 in the glass. Secondly, the size range of the bubbles in the glass was determined. For higher quality glass pieces, both the number and overall size of the bubbles present was be relatively small. The size range of the bubbles ranged from barely visible pinprick size bubbles (called seed) to those larger bubbles which had been stretched or elongated during the working of the glass to several millimeters in length. The higher quality pieces examined typically had bubbles below 0.5 mm in size and in an amount less than 100/cc on average.

Along with the size and number of bubbles in the material, several other features were noted. These included the location of bubbles; i.e. whether they were scattered randomly throughout the piece or if they were concentrated locally in one place. In almost all pieces examined, the bubbles present were mixed throughout the material in a random fashion. The shape of the bubbles was also recorded. This becomes relevant in helping determine how a particular piece was fashioned. Bubbles in glass typically have a spherical shape. Deviation from this shape indicates that some force was applied to the glass in that location while the object was worked. For example, bubbles near the rim tend to be elongated horizontally as tools were applied to the rim while it was shaped. If the glass was blown while the blowpipe was held downwards, the bubbles may be stretched vertically. Forcing the glass into a mold can also impart a predominant orientation and shape to the bubbles present.

Figure 8.13 provides a clear example of the preferred shape which can be imparted to bubbles due to the molding treatment the glass receives. Note the unusually large (> 2 cm) and horizontally elongated bubbles in the bottom, ribbed portion of this footed glass bowl. These types of very visible and large elongated bubbles are frequently seen in large ribbed bowls such as this. The process by which the ribs are formed (known as half-stamping or *mezza stampura*) requires that the glass be forced into an open optic mold twice (Tait, 1991:235). If not done right, this can result in the glass ribs overlapping and creating large "artificial" bubbles in the material which then become stretched during subsequent working. These very large and prominent bubbles are typically found only in the ribbed region whereas the rest of the glass has bubbles of more ordinary sizes (< 1 mm). In this sense, defects such as these are not due to problems with the "material" but rather result from its later working and shaping. Flat bubbles may also form between the layers of sucessive gathers of glass which can also become stretched during working. In some cases where the bubbles lie near the surface, defects known as blisters may form and, in some case, break open. These open spots on the surface may be sites for additional weathering (Newton and Davison, 1989:188).

More typical bubble structures are shown in Figures 8.14 and 8.15. The former picture shows a fairly typical spherical bubbles structure as seen in a small fragment of light blue vessel glass. Figure 8.15 shows an SEM micrograph taken in back-scattered mode which shows a few bubbles in a preferred elongated orientation which is typical of the bubbles structure seen at worked rims and bases for example.

The presence of a large number of bubbles or big bubbles in the glass material can give rise to a secondary defect which can affect the overall appearance of the finished piece. The glass paraison must be turned and rotated during the production sequence to prevent it from slumping to one side. In this manner, the glass object is kept centered on the blowpipe. In some cases, depending on the speed of rotation and the condition of the material, circular spiralling streaks or patterns can be seen in the glass as the bubbles (or other defects) move through the material.

These are called blowing spirals. They can be seen most easily by holding the glass up to the light and varying the viewing angle. Their presence results in the glass having a more pronounced waviness. Figure 8.16 shows a typical pattern produced by blowing spirals in the foot of this colorless goblet. While blowing spirals are not an intrinsic defect of the glass as a material, they are caused by a significant number or size of defects.

The raw materials and processing steps used in the production of Renaissance Venetian glass served, in some ways, to accentuate the number of bubbles present. As described earlier, the primary fluxing agent in the *alume catino*, purified or not, was Na_2CO_3. As this was heated, carbon dioxide evolved which, unless released to the atmosphere, stayed behind in the glass as bubbles. Other sources for bubbles in the glass material include air entrapped between batch particles (Peddle, 1927:33) While stirring (which can also entrap air in the melt) and extended melting were both practiced at Murano and helped alleviate the problem of bubbles, not all were able to be removed. This was especially true for the smallest bubbles. The rate of bubble rise in the melt is proportional to several factors. For example, the speed generally varies as a function of the $(\text{radius})^2$ and is also inversely proportional to the viscosity. That is, large bubbles disappear faster and the overall rate of bubble removal is increased at higher temperatures. High temperatures not only decrease the viscosity of the glass allowing for the bubble to move more easily but the gas in the bubble expands making it larger. The temperature attainable in the 15th and 16th wood-fired Venetian glass furnaces is thought to have been around 1200°C which is probably lower than that used in English coal-fired furnaces, for example, and in modern glassmaking practice. This connection between bubbles size, temperature, and rate of removal helps explains why most of the Venetian glass examined did not have large bubbles but almost all pieces had some number of pinprick size ones.

Peddle discusses the persistence of bubbles in glass which is said to depend on several factors: the kind of glass in the bubble, the type of glass, the condition of the batch, the bubble size, and the furnace conditions (1927:35). As mentioned above, carbon dioxide would have been the most typical gas trapped in the glass although the presence of some sulphur in the glass makes SO_2 another possibility. Certain types of glass are more easily refined. For example, it is generally easier to remove the bubbles from a lead glass than a soda-lime-silica glass such as Venetian *cristallo* (Peddle, 1927:36). This point become important when *cristallo* is compared to the defects in English lead crystal for example. A damp batch will also tend to result in the formation of more bubbles as water vapor is formed during heating. This explains, in part, the instructions in the different glassmaking recipes for the frit to be stored in a dry place.

2. Stones

The next two types of glass material defects, stones and cord, were not found to any great extent in the majority of glass pieces examined. Quite often, while an individual piece would have many dozen bubbles per cm^3, it might have little or no stones present. Stones are inclusions of foreign material into the glass melt. These may include unmelted sand particles, unreacted batch products, and bits of crucible fragments that have been detached from the crucible walls during the melting process. Other types include accidental inclusions in the glass such as soot as well as any products that may have formed by divitrification.

The number of stones, if present at all in the glass, was not generally large enough to make counting them on the basis of the number/cc meaningful. Instead, during the course of examinations, the presence of any stones were noted along with an indication of how many were visible overall (very few - moderate - very many). The size range of stones present was also recorded along with any preferred location. Finally, attempts were made to identify the type of stone present. Sandy impurities generally appear as round and brown specks of sand. Stones that were the result of refractory dissolution into the glass melt are often seen as blobs of opaque white material (Clarks-Monk and Parker, 1980).

What effects does the presence of stones in Renaissance Venetian glass have? Besides being visually unappealing, they can also serve as a source of weakness in the final product. The glass immediately adjacent to stones is usually in a state of strain due to a difference in the rate of contraction between the glass and stone as the object cools (Peddle, 1927:49). In several of the objects where large stones were observed, this strain was visible in the glass surrounding the stone when viewed with a strain viewer (cross polarized lens). In many cases, the region around the stone appears to naked eye as having a different index of refraction due to the induced strain. Stones can also cause the formation of blowing spirals in the same manner as bubbles as they are dragged through the glass.

As mentioned, the large portion of glass objects examined in this work contained very few (maybe 1 or 2 visible in the entire piece) or no visible stones. When present, the majority of stones seen were of the sandy type. Sand particles appeared in the glass as very small brown specks. Generally, these were barely visible with the naked eye and could really only noticed with a low power hand lens. Figure 8.17 shows an SEM micrograph taken in the backscattered mode. In this image it is possible to see a small round feature in the glass matrix which was shown by later EDS work to a small piece of sand. A particle of this size (~0.2 mm) would be barely visible without a hand lens in the finished product. Refractory stones were less common. This is possibly connected to the extensive lengths taken by the Venetian glassmakers in ensuring that their crucibles were well made and could withstand the temperatures of the furnace. Recall that the clay for crucibles was imported to Venice from as far away as Constantinople.

In a few notable cases, there were objects which had stones as the primary defect. Consider the details of PE-194 shown in Figure 8.18 and 8.19. This is a 16th/17th century wineglass which has a large (1 cm by 4 cm) patch of stones in the bowl part of the goblet. In Figure 8.19 it is possible to see how the presence of stones leads to small areas around them with differing indices of refraction. Figure 8.20 shows a *facon de Venise* wineglass of the 17th century at the Corning Museum of Glass. It is easy to see the large (~2 cm) stone in the vessel wall. This stone was very white and blobby in nature and was most likely the result of a small piece of refractory material breaking off into the glass melt.

In quite a few of the pieces examined, I was able to observe the presence of very small (< 0.5 mm) black flecks in the material. My first impression was that these were small bits of soot that had become incorporated into the glass. A later conversation with an experienced glassmaker suggested instead that these might be small bits of iron/rust/metal that had detached from the blowpipe, punty or other tool and had been worked into the glass (Gudenrath, personal communication, 1994). This explained why, in some cases, these flecks were accompanied by reddish and rusty looking streaks in the glass interior. While hard to photograph, Figure 8.21 shows some of these black flecks in the bottom of a bowl. Generally, a glassmakers will keep his tools in a condition where the material will not be contaminated with this material. Generally, the presence of such matter in the glass is not the sign of a poor quality material but is rather connected to the use of poor quality tools (Brill, 1988:283).

3. Cord and striae

The third basic category of material defects which can occur in glass is cord. Smaller and less apparent varieties of cord are called striae. Cords are striations in the glass giving it a wavy appearance. They also serve to reduce the clarity of the glass. Cord and striae are parts of the glass which differs in chemical composition (and has a different density) from the surrounding matrix (Clarks-Monk and Parker, 1980:126). This produces a change in the refractive index of the glass at the location of the cord and diminishes the appearance of the object. Peddle offers an analogy which best explains how cord appears in the glass - imagine a beaker full of water into which some glycerine or alcohol is added (1927:10). As the beaker is stirred, streaks or cords are visible in the liquid as the two materials intermingle. After enough stirring, it is no longer possible to see these. As the cords are removed by stirring, this suggests not only that the glass which has these is compositionally inhomogeneous at some level but also that, if stirred enough, the cords and striae will disappear. Besides improper mixing of the glass melt, the use of cullet which has a different composition than the glass batch can also introduce problems of compositional inhomogenity. Sufficient stirring will also alleviate this defect.

Cords and striae in a finished object can be quite hard to see at times. One of the best ways to notice them is to hold the object up to a background where there is a source of light with a dark edge such as a window. By moving the glass up and down, any cord present are usually visible. As cord and blowing spirals look alike, one must take care to distinguish between the two.

Therefore, one can infer that the presence of cord or striae in a finished object indicates that the glass melt from which it was made was not stirred well enough. For the most part, the great majority of Venetian objects examined in this work showed no significant amount of cord or striae. If they were present, it was usually in a very small and localized region. Only in very few cases were cord the predominant defect in the material. Figure 8.19 shows a Venetian piece that has very visible section of cord running across the bowl region. Figure 8.22 provides an even more dramatic example of cord as seen in an Renaissance object fashioned in an 17th century English workshop. Note the very pronounced and swirling waviness in the bowl region. Several other English pieces dated to the same period and displayed with this piece also showed long and undulating cords in the material.

Backscatttered SEM images were made of the colorless glass that was chemically analyzed in this work. If there were gross compositional differences in the sample's "material", these would show up in the image as regions of light and dark. In none of the images was any significant contrast observed. This is typical of a well-homogenized glass. The image shown in Figure 8.23 is representative. On the other hand, several of the *facon de Venise* glass pieces examined did contain cord or striae as significant defects. These included glass made in England, Spain, and France. It suggests, based on the pieces examined, that the artisans who made these pieces had not taken the time to sufficiently homogenize and stir the glass.

All of this information gathered from the physical examinations of Venetian glass in terms of its material supports several ideas put forth earlier. Overall, the general lack of cord and striae in the Venetian glass pieces examined correlates with the description of the glassmaking process given in the recipes. These texts call for a very long period of refining during which the melt was to be continually stirred. This stirring would have had the effect of homogenizing the glass, eliminating any compositional gradients, and reducing or eliminating possible cord/striae problems. The fact that the Venetian glassmakers took the pains to incorporate this lengthy step is preserved in their well-homogenized glass that typically has good to excellent clarity. The careful steps of raw material selection and preparation in the making of *cristallo* and *vitrum blanchum* glass described in the recipes are seen in physical examination of the glass. In this manner, these two lines of evidence concerning the skill and care that went into the making of Venetian luxury glass support each other.

4. Other defects in the "material"

Besides the three main categories of material defects discussed above, the physical examinations also provided evidence about secondary aspects of the manufacturing process which were not directly related to the fritting, melting, and refining stages. One of these was the degree of annealing. Sucessful annealing is a critical stage of the glass production process. If the glass is not cooled slowly enough, the sudden change of temperature can either break the object or introduce weaknesses in the material causing it to crack at a later date. This would have been especially important for the production of the very thin-walled Venetian luxury glass which would have cooled very fast to begin with.

All of the glass objects examined were studied with a portable stress viewer (two cross polarized lens mounted to a flashlight unit) to see if any residual strains could be detected. Glass which is subject to strain becomes bi-refringent and has two different indices of refraction (Newton and Davison, 1989:190). Almost none of the objects examined had any significant amount of visible strain present. The few pieces that did contain a substantial number of cord and striae also had an appreciable amount of strain present. In addition, some objects showed very minor amounts of strain at the points where two parts of the vessels were joined -for example, certain areas in stemwork or sometimes where handles or decoration were joined to the main body. Overall, the general lack of strain and the overall well-annealed state of the glass is not surprising. Annealing is one of the fundamental steps in the production process and the Venetian glassmakers should have been quite adept at it. Furthermore, poorly annealed pieces do not survive for very long and would probably not make it into the museum context. This point is supported by the fact that several of the sherds examined did contain some residual stresses. As many of these sherds were deposited as industrial waste, these pieces could represent the remains of objects that did not have a successful annealing. Another possible defect that could occur during the annealing process is the possible deformation of finished objects if the temperature in the annealing chamber was not carefully monitored. Consider the glass bowl shown in Figure 8.24 and note how it slumped to one side. This deformation could have resulted from too intense of a heating in the annealing chamber. Another possibility is that it was just poorly assembled and it shifted to one side during the assembly process.

Other signs of manufacturing were visible on the examined objects. In some cases, slight tool creases were seen in the rim region. Other tool marks were visible at times as well. For example, the use of a wooden paddle to shape the rim or sides occasionally would leave a brown or black streak in the material although this was not common. Almost all of the objects examined had a pontil scar on the base; it was necessry for a pontil rod to be attached in order for the rim to be finished.

Work by Gudenrath that is referred to in a recent museum catalog sheds further light on what the close study of finished objects can say about the stages of the manufacturing process (Lanmon, 1993). For example, his work helped explain the existence of a double pontil scar on some enamelled pieces. Figure 8.25 shows a slight overlapping of the punty mark. This double mark was the result of the second re-heating that enamelled pieces had to undergo. This second heating was required to fuse the enamels to the surface of the glass and the object was attached at its bottom to a pontil rod for this to be carried out. This process, evidence of which is seen in certain glass pieces is also confirmed in written sources which describe the enamelling process (Lanmon, 1993:5).

Other evidence connected with the enamelling process has been noted by Gudenrath and was seen in several of the examinations I carried out. For instance, the application of the final parts of the pieces, such as the handles, was usually done last. This explains why some enamelled pieces have handles applied over the enamel or gilded decoration; see Figure 8.26 for an example. Furthermore, many of the glass *tazze* (shallow and wide footed bowls; described also in Chapter 7) examined in this work had some type of enamelling and gilding applied to the rim and body region; see Figure 8.27. The drops of enamel applied to the glass would typically assume a round shape which is what one sees in the enamelled decoration away from the rim. The enamelled drops at the rim, however, have assumed an oval or ellipsoid shape. Gudenraths's replication work, some of which has been published (ex: Tait, 1991) shows how these *tazze* were originally made into goblet forms which then had their gilding and enamels applied to them. During the second re-heating stage the *tazze* were spun by the glassmaker who used rotational force to open the sides of them out into shallow bowls. This spinning of the glass and the flaring of the sides caused the enamelled dots at the rim (the region which would be hottest as the glass was attached at the base with the punty and held rim first near the furnace hole) to spread and stretch slightly.

One of the other curious features observed in a few of the glass pieces examined was that the quality of the glass in the body seemed different from that in the foot or base region. For example, PE-57 (shown in Figure 8.1) has a base with an average of about 150-175 bubbles/cc. On the other hand, the body of the same wineglass has only about 30 bubbles/cc. This differential amount of defects present was clearly the exception and not the rule. It does suggest, though, some ideas about the nature in which pieces were assembled. For example, a gather of glass may have been taken from one glass pot to produce the body while another gather for the base may have been gathered from a different pot which had a glass of lower quality in it. A further speculation is that the bases of some objects may have been made by one person working out of one glass pot (perhaps an apprentice as making bases is relatively simple) which were then attached to the body already prepared by the *maestro*. In this manner, a certain aspect of assembly-line or mass production work may be discerned. This is, however, speculation. Only a few of the pieces examined had parts which were different in terms of quality. The continued examintion of more objects with attention paid to these types of details might make these ideas more plausible.

Finally, one of the most notable features of the Venetian luxury glasses from the Renaissance is their very thin walls, often less than 1 mm. This aspect was discussed earlier, as well, in conjunction with the skill required to be able to manufacture such consistently thin and fragile pieces. This thinness was in sharp contrast to rock crystal pieces, the material that the *cristallo* was made to imitate, which are much thicker due to the carving and grinding processes associated with making them. The thinness of the *cristallo* and *vitrum blanchum* vessel made them exceptionally light and fragile. This delicate and etheral quality of the glass was one of the reasons behind their popularity during the Renaissance and this feature is frequently referred to in connoisseur-oriented works (ex: Tait, 1991 or Charleston, 1993). The thinness of the Venetian vessels also, and perhaps unconsciously, benefitted the glassmaker in several ways. First, the manufacture of a thin-walled vessel uses less glass material than a thicker one. In this manner, the glassmaker was able to make a batch of prepared glass produce more pieces. This "economizing" would have been especially valuable in the production of *cristallo* vessels as this composition required more time and labor intensive operations to prepare. A second benefit from having a thin-walled vessel is that there are less defects in the glass per unit thickness. A vessel with 150 bubbles/cc that is only 0.7 mm thick will appear more defect-free than one that is 1.5 mm thick. Very thick glasses with large amounts of bubbles/cc would have less clarity and not have been as visually appealing as thinner ones. In a similar manner, if the glass had any residual tints, as *vitrum blanchum* often does due to its higher manganese or iron contents, making the glass thinner would minimize these effects. Therefore, the production of very thin-walled pieces, made possible by the skill of the Venetians and the type of material they were working with and in conjunction with societal demand which favored the very light and delicate pieces, resulted in a favorable situation for both the producers and consumers. The final product appeared more defect and tint free and required less material to make.

5. Changes in quality spatially and temporally

One of the goals in carrying out the physical examination of so many glass objects was to attempt to see changes in glass quality over time and between glass made in different places. The approach to glass quality that was established in this work made use of a quality index to describe the overall impression of the glass material. This index ranged from 1 to 5 and only concerned the material in terms of defects. Being somewhat subjective in nature, as described in Appendix B, it did not consider any of the more impressionable categories such as quality of workmanship, skill of assembly, decoration, or form - all qualities more in the realm of connoisseurship. The idea was to be able to give the quality of material with which each piece was made a number so that it could be compared to other pieces. Using these numbers in conjunction with well-dated and provenanced pieces might reveal some changes in quality over time and place. Questions such as whether 15th century Venetian glass was "better", material-wise, than 17th century Bohemian glass could be addressed. As described earlier, the vague dating and uncertain provenance did not make this plan as successful as was originally hoped.

Appendix B describes this practice in more detail and presents some of the data from the examinations with respect to what types of glass was studied, where it came from, and some idea of the dates involved. Here, I would like to draw on some of the broad conclusions reached and their implications. The reader is referred to the aforementioned appendix for more information.

There was a noticeable difference in the material quality of glass made before about 1400 and the later, primarily luxury glass, of the 15th to 17th century. The earlier material is much more bubbly and has many more visible defects such as stones. This is not terribly surprising as the early glass studied as primarily "common" glass made for utilitarian purposes. This type of glass should not reasonably be expected to have the same quality as 16th century *cristallo* or *vitrum blanchum*. Unfortuanately, there are very few existing sherds of pre-Renaissance "luxury" glass which is colorless and refined. A few samples, PE-149 most notably, were given to this work and no reliable conclusions can be drawn from such a small sample size. None of the museums visited had any accessible or available pieces of pre-Renaissance Venetian glass.

Along the same lines, there very few examples of "colorless" glass available for study which were dated to between 1450 and 1475. Several pieces, mostly enamelled cups and *tazze* dating from 1475 to 1525 were studied however. The quality of these pieces did not vary much from the later luxury glass pieces so no clear trend could be discerned there. For example, the average index of quality for glass dated from 1475 to 1525 was essentially the same as those pieces dated to the last 3/4 of the 16th century. Overall, the very broad and sometimes vague dating of the glass made establishing any sort of pattern impossible.

Some changes in material quality were seen in Venetian vessel glass which was dated later, from about the late 17th to late 18th century. For example, several glass tumblers of the type shown in Figure 8.28 were studied. Glasses such as these are often attributed to the workshop of Osvaldo Brussa, an Italian glass painter of the 18th century (Barovier, 1982:160). The nature of defects in these glass pieces was different from the earlier vessel glass in that stones were much more common. Some pieces had as many as 10 refractory stones scattered throughout. In addition, as can be seen in the figure, the material is generally less bubbly. The glass vessels, overall, are thicker walled as well. While no compositional analysis could be done, the relative lack of bubbles and the large amount of stone suggests a different composition. Recipes from the 17th and 18th century indicate that the nature of Venetian *cristallo* had changed by this time to a lead-potassium based glass instead of the earlier soda-lime-silica glass. This might account for the types of defects seen (Moretti and Toninato, 1987). Lead glasses, as Neri warns, are supposed to be much more corrosive when in contact with the melting crucibles perhaps leading to more stones being present in the material. Compositional analyses of glasses such as that shown in Figure 8.28 would be helpful in proving this.

Similar points can be drawn when comparing the Venetian and *facon de Venise* pieces. The latter are generally just as or more bubbly as their Venetian counterparts. Many of the non-Venetian pieces examined had noticeable cord suggesting that the melt was not sufficiently homogenized. As with the Venetian pieces, changes in terms of the defects present can be seen in some of the non-Venetian glass over time. Consider the English glass examined in this work.

Figure 8.29 shows a detail of an English glass dated to 1580 (an engraved date on the piece accounts for this unusual accuracy) and attributed to the London workshop of Giacomo Verzelini. He was a Venetian born glassmaker who left Italy and travelled to London where he operated a glasshouse until about 1592. About 12 Verzelini pieces are known to exist (Charleston, 1984:50-58). These pieces, said to be a soda-lime-silica composition, are all comparable to Venetian glass from the same period in terms of material quality. The detail shown in Figure 8.29 is moderately bubbly and without any other noticeable defects.

By the end of the 17th century, this situation had changed. The English development of lead crystal glass, partially using Venetian techniques, by George Ravenscoft in the 1670's has been credited by glass historians as one of the more important developments of glassmaking after the innovation of Venetian *cristallo* (ex: Polak, 1975*)*. Figure 8.30 shows an example of English lead crystal from the 18th century. The successful production of this glass resulted in a product that was visually much more similar to natural rock crystal than the the Venetian *cristallo* or *vitrum blanchum*. Typically made into more massive and less delicate forms than the Venetian glass, the English lead crystal was free from the tints that were fairly common in some of the Venetian glass, especially the *vitrum blanchum*. I visually inspected dozens of English glasses such as these in their museum showcases. Despite their very thick walls, the glass still retains a very water-like and colorless nature. The glass material, as can be seen in the figure, was relatively bubble free. This is in contrast to the Venetian material which has many more bubbles visible despite its thin-walled nature.

Lead glasses are generally more easy to refine than their soda-lime-silica counterparts (Peddle, 1927:36). Assuming that the English coal fired furnaces attained higher temperatures than the earlier wood-fired Venetian furnaces, the lead glass melt, already quite fluid because of the lead content, would be less viscous and bubbles could rise to the surface more easily. In addition, the English glassmaking process by this time used potassium nitrate as a flux (Watts, 1990). Potassium nitrate decomposes and melts at a lower temperature than the Na_2CO_3 which is the primary constituent in the *alume catino* ash used in Venice. As a result, gases evolving in the English lead crystal batches would have more of a chance to escape giving a less bubbly melt. Unfortunately, few analyses of English glass have been done or published and little information is available about the specific technical aspects of production. In some senses, this aspect of glass history is rooted more in connoisseurship than Venetian studies.

Another notable feature in the English glass was the more frequent presence of stones as compared to the Venetian or early English glasses. Typically, these stones appeared to be refractory material that had become incorporated into the melt. Neri's comments regarding the corrosive nature of lead glasses and the manner in which they attack crucible linings certainly fits in well with this observation. Watts also notes the anti-corrosive effects that adding potassium nitrate to lead-based glasses has and cites this as one of the crucial steps in the successful making of lead crystal (1990:211).

Some general conclusions may be offered based on the physical examinations carried out in this work. The first is that the careful study of glass objects can tell one much about the manner in which the object was assembled. In many cases where sampling and chemical analyses are not permitted, a careful physical study may be the most intensive level of attention a piece receives. Further examination of the glass material can also be correlated to stages of the production and assembly process. By considering the "material" the piece is made from as an integral part of object, one can at least semi-quantitatively propose to measure the quality of the glass. Previous connoisseur-oriented studies of Venetian glass have neglected this level of structure, instead concentrating on issues of provenance, form, and decoration. Assuming proper dates and provenance of examined vessels are available, the information from a detailed physical study can be used to look at changes in the glass over time. As for the case of the later English and Venetian materials, these observations can be correlated to compositional data and information obtained from documentary sources. When rigorous dating and provenance information is not available, as was the case for many of the pieces studied in this work, the detailed physical examination of glass still provides useful evidence. Until this work, no mention has been made of the quality of Venetian glass from a "material" perspective. Comparisons between Venetian and non-Venetian pieces show the additional labor and work that the Muranese workers incorporated into their production as seen, for example, in the very well-homogenized and cord-free glass.

A more general conclusion, however, must be that the Venetian glass, as a "material" was not significantly better than glass made elsewhere so as to completely account for its success. The skill and generally high degree of workmanship found in Venetian glass and the ability of the Muranese to work it into desired shapes and forms must be thought of. Of course, the overall success (and later decline in popularity) of the glass does not rest with the glassmakers alone but is instead shared among all of the groups involved in its demand and production - the consumers, the glassmakers, the guild, the state, etc.. In addition, other factors must be considered which are more connected with the properties that it had for both the user and producer. The next section looks at some of the most relevant of these.

Renaissance Venetian Glass - Physical Properties and Comparisons with Other Compositions

Before one can address the question of properties, one must consider the different groups of people for whom these properties were relevant. Earlier in Chapter 2, one of the methodologies presented as part of the study of technological change was the "social construction of technology". One of the features of this approach was the identification of social groups relevant to the artifact or technology in question. The basic requirement for a certain social group to be distinct is that its members share the same set of meanings attached to a particular artifact (Pinch and Bijker, 1987:30). The design (or other aspects of use/production/demand) of a particular artifact is explained by focusing on the problems and needs that these relevant social groups have with respect to the artifact. As described in Chapter 2, there are numerous social groups which can be identified as having interest in Venetian glass production and demand - the consumers, the glassmakers, the guild, associated industries, and the government. Chapter 7 identified and discussed certain qualities and properties of Renaissance Venetian glass that were deemed relevant to the consumer - the demand aspect. The focus in this section will be on the properties of the glass that would have been relevant primarily to a person involved with producing a glass to meet these perceived consumer demands.

In order for Venetian luxury *cristallo* glass to be a successful innovation, it was necessary for the producers of Venetian glass to meet the perceived demands and needs of the consumers. These requirements on the part of the consumer and the manner in which they were dealt with were detailed in Chapter 7. Many of these were associated with the visual appearance of the glass. Consumers were interested in having a glass that was colorless and defect free. These demands were met by the Muranese glassmakers in a variety of ways - careful raw material selection, prudent furnace maintainance, longer refining and homogenizing times, etc.. The discussion of the glass' percent transmission vs. wavelength tests in Chapter 7 illustrated that these extra steps made a difference in terms of the optical quality of the glass. *Cristallo*, on the basis of the samples examined, was shown to have a different % transmisison plot than those for *vitrum blanchum* or "common" glass. Figure 8.31 shows a fragment of a Venetian wineglass stem whose composition is a *vitrum* *blanchum* type (PE-156). Note the strong grey tints present due an excess of MnO required to offset any iron tints. In comparison, Figure 8.32 shows a very small fragment of *cristallo* glass (UA16); note the extreme coloressness and clarity. Even in this small sample, only about 0.5 cm long and very thin, several bubbles may still be seen.

There are other properties of the glass types made in Venice which would have been solely relevant to the producers of the material. These are properties related to manufacturing aspects. For example, the luxury glass sold needed to have a certain minimum level of chemical durability. The general instability of the *cristallo* glass due its lower CaO and MgO levels has already been presented. It would not have been possible to sell many wineglasses, for example, if they began crizzling with 2 months of purchase. Therefore, it was necessary for the Muranese glassmakers to adjust the glass composition in order to acheive some marginal level of stability. However, this assumption is based somewhat on modern perceptions of glass quality. There is little indication from a consumer point of view that moderate amounts of weathering were anything more than a nuisance that could be removed simply by wiping off the corrosion products (Simon Hogg, personal communication, 1996). At the same time, accounts of the development of English lead crystal suggest that its overall instability was large factor in the re-formulation of the glass composition (Watts, 1990).

The glass property that would have been of primary interest to a Venetian glassmaker (and one that is still quite relevant to a modern glassblower) is the relationship between glass viscosity and temperature. This correlation, which has never been quantitatively discussed before, is of supreme importance to successful glassmaking. The relation between glass viscosity and temperature, along with how quickly the viscosity changes as it cools, determines several key features of glass production. For example, the temperature at which the glass becomes fluid enough to gather on the blowpipe affects the furnace design. If the furnace cannot be fired to a high enough temperature to allow working, the glassmaking operation is hardly going to be a success. Understanding the relation between the glass viscosity and temperature can allow one to make several inferences about the manufacturing process that would otherwise not be possible - the temperature of annealing chamber or the quickness with which a glass "sets" are all relevant. However, in order to make predictions about the glass' response with temperature, it is necessary to know the chemical composition of the material. With this information, one can use studies of glass viscosity found in the materials science literature to construct appropriate models.

This was the approach taken here. A suitable model for glass viscosity was found. This could then be used in conjuction with the compositional information obtained from the chemical analyses presented. In this manner a plot of the predicted glass viscosity at particular temperature intervals could be made. This was then used to make inferences about the different stages of the manufacturing process. Provided a suitable model is found, it can also be used to compare the viscous behavior of different glasses. For example, how did the temperature-viscosity correlations between Venetian *cristallo* and English lead crystal vary?

Numerous models for glass viscosity exist in the literature (Scholze and Kreidl, 1986). Several different ones were tried and one thought most suitable to the work here was selected (Lakatos, 1972). This was chosen for several reasons. First of all, it was relatively simple to use. It allowed for wide variety of glass constituents to be incorporated into the calculations including lead. Many models are based on very simple glass systems or else designed for a very narrow compositional range. The model chosen was especially good in that it could be applied over a fairly wide range of glass compositions. It also accounted for about 98% of the constituents in a typical soda-lime-silica glass, including all but one of the constituents which would have the most noticeable effects on viscous behavior. The only component not accounted for was chlorine, which was generally found in the glasses analyzed in amounts of about 0.8 to 1 weight percent. This would affect the accuracy of the model slightly as chlorine serves to breakup the glass network and reduce the viscosity slightly at any given temperature. However, as chlorine was present in all of the glasses and not accounted for in the model, the error would be roughly the same for all glass types and still allow for reasonable comparisons to be made.

The model was taken and adapted to be part of a spreadsheet program. After manipulation, it was possible to input a particular glass composition and the program would then give the predicted temperature at which the glass would have any given glass viscosity. The model and the spreadsheet program were tested using glass compositions for which the glass viscosities had been measured and published (Bansal and Doremus, 1986). Table 8.7 shows the comparison between predicted and measured results for a standard 70 mole % SiO_2- 20 mole % Na_2O - 10 mole % CaO glass.

Table 8.7. Comparison between measured and predicted viscosity values; temperatures given in °C, viscosity given in log poise.

Viscosity	13	11	9	7	5	3
$T_{measured}$	515	555	615	692	826	1081
$T_{predicted}$	508	547	600	680	809	1059

The agreement between the predicted and measured temperature values is very good for the model glass, typically within 3%. What glassmaking operations do these values for viscosity refer to? According to Brill (1988:280):

log viscosity	= 3	gathering
" "	= 3-4	blowing, drawing threads
" "	= 4	mold pressing
" "	= 5	shearing, folding rims
" "	= 7.6	softening point
" "	= 10	hot pieces will join on contact
" "	= 11-14	annealing range
" "	= 14.5	strain point

Having found a suitable model, the next step was to examine the viscosity values for different Venetian glass compositions. As described elsewhere, the three basic glass types are *cristallo*, *vitrum blanchum*, and "common" glass. The glass compositions selected to use in the model were PE-41, UA7, UA17. These represent typical compositional values for these glass types. Using the compositional data for these glasses (listed in Table 8.5) and the aforementioned viscosity model, one obtains the following predicted temperatures.

Table 8.8. Viscosity - temperature correlations for different Renaissance Venetian glass compositions; temperatures given in °C, viscosity given in log poise.

Viscosity	13	11	9	7	5	3
cristallo	486	533	597	692	846	1140
vitrum blanchum	552	601	668	765	919	1200
"common"	567	614	678	776	917	1182

Two general features can be seen from this information immediately. First, the *vitrum blanchum* and the "common" glass had very similar viscosity-temperature correlations due to their close compositional resemblance. I have represented the data points in Table 8.8 graphically in Figure 8.33. Only the data for *cristallo* and *vitrum blanchum* have been used for greater clarity and because of the similarity between the *vitrum blanchum* and "common" glasses. Another point is that the temperature at which the *cristallo* glass had the same viscosity as the two other types is substantially lower, typically by about 70-80 °C. In this sense, the *cristallo* glass would be able to have all of the glass working operations associated with it performed at a slightly lower temperature. For example, mold pressing is generally done at a log viscosity of about 4 (Brill, 1988:280). For *cristallo* glass this corresponds to a temperature of about 980°C while it is around 1050°C for *vitrum blanchum* glass. This difference in temperatures for certain operations is primarily due to the greater percentage of Na_2O found in the *cristallo* glass which would create more non-bridging oxygens. While CaO and MgO occur in *cristallo* glass to a lesser extent, they are not as effective in breaking up the glass network and lowering the viscosity as Na_2O or K_2O are.

This point is perhaps academic as there is no way of knowing the exact temperature at which glass operations were carried out. Plots of viscosity vs. temperature can only suggest the possible ranges at which operations were done and should not be used to provide absolute values. The glassmakers themselves only knew of the relative differences in furnace temperature which was judged using subjective means such as the heat given off and the color of the flames (Kingery and Vandiver, 1986:256).

Finally, from the predicted viscosity values, one can have some appreciation of the temperatures at which different glassmaking operations were done. For example, glass gathered on a blowipe typically has a log viscosity of about 3. This indicates that the blowing of glass in Venice would have required a furnace capable of reaching at least 1150° to1200°C. At the end of glass shaping and working, the finished objects would have been annealed around 500° to 600°C. In this manner, more detailed information about the glassmaking process not obtainable from written sources can be inferred.

Other than being able to be worked at a slightly lower temperature, was there any other advantage afforded to the glassmaker working with a *cristallo* glass vs. a *vitrum blanchum* glass? Glassmakers use the terms "short" or "sweet" to describe the working characteristics of a particular composition. A "sweet" glass is one that has a longer range in which it can be worked while a "short" glass has a narrower one. For a glassmaking operation oriented around extensive hot working, tool working, constructing objects on a blowpipe, and applying threaded decoration (all common Venetian practices), it would have been desirable to have a "sweet" glass with a longer working range. This would allow the glassmaker more time in which to carry out working and forming operations.

The "sweetness" of a glass may be evaluated by plotting the log viscosity versus 1/temperature (Vogel, 1985:290). A generally straight line results and the slope is proportional to the activation energy (Q) for viscous flow. Glasses with low values of Q (smaller slope) are "sweet" and have broader softening ranges. This type of calculation was done for the *cristallo* and *vitrum blanchum* compositions. When log viscosity was plotted versus 1000/T (to make the values on the one axis more readable), it was seen that the slope for the *vitrum blanchum* glass was about 15% greater (8.5 vs. 10.2).

This means that the *cristallo* glass, based on the compositional data and the viscosity model described above, was a more user-friendly glass in terms of being suitable for the types of glass working operations favored by the Venetians. It would have tended to remain softer over a longer period of time and allow the glassmaker a greater opportunity to work the glass into more elaborate shapes. In short, the *cristallo* glass, in terms of its viscosity properties, was well-suited to the types of glassmaking favored by the Venetians.

The description of *cristallo* production taken from written sources suggests that, from another aspect, its production may have been disadvantageous from a glassmaker's experience. The manufacture of *cristallo* glass was much more time and labor intensive than *vitrum blanchum* or "common" glass production. It entailed a much more complicated set of sequences beginning with careful material selection and purification processes and finishing with lengthy refining and homgenizing steps. All of this would have required a greater expenditure of labor wages, firewood, and furnace time et al..The result was a glass that was more suitable for elaborate working and had greater clarity and colorlessness. These attractive features of *cristallo* glass, from a producer perspective, were not without their attendent costs, however.

This brings to mind an observation made with respect to the frequency of *cristallo* glass production. How often was it actually made? This is a very difficult question to answer. Documentary sources comment on the beauty and clarity of Venetian glass but we really have no way of knowing exactly which composition this praise refers to. Well prepared *vitrum blanchum* glass can visually pass for *cristallo* glass. Shop records refer to some pieces as *cristallo* while others record only the form and decoration of a piece (ex: Zecchin, 1990:59-62). If only the archaeological record were considered, it would seem as if *cristallo* glass was hardly ever made. The inherent chemical instability of *cristallo* glass does not result in it being well preserved in archaeological contexts. This is especially true for glass found in the Venetian lagoon due to its damp nature. Very few of the archaeological samples donated to this work were found to have a *cristallo* composition. *Vitrum blanchum* was much more common, for example. Whether this represents the actual frequency of production or is merely a reflection of formation and preservation processes is hard to answer, although I favor the latter.

A much better indication could be given if one were able to sample the well preserved pieces in museum collections. Colorless Venetian glass pieces in a museum context are typically referred to in their descriptions of catalog entries as *cristallo*. Is this true? Many of the museum pieces examined had noticeable tints suggesting they were *vitrum blanchum* and not *cristallo*. At the same time, quite a few had some degree of decay and corrosion present giving an indication of a *cristallo* glass. Statistical sampling and chemical analyses, unfortunately not possible given the reluctance of museums to allow for any type of sample removal, would certainly shed light on exactly how often the glassmakers of Venice took the extra steps needed to make *cristallo* glass. Was it made often? What types of glass objects was it used for? For example, would Muranese glassmakers have chosen to use valuable *cristallo* glass for objects which would not take advantage of its colorlessness and clarity? Was it enamelled or decorated with filigree work, both of which would have have "obscured" the purity of the material? Perhaps the glassmakers reserved its use for objects that were to remain undecorated such as that shown in Figure 8.1.

With those comparisons in mind, the next question was how well the Venetian *cristallo* glass performed, viscosity-wise, to the other glass compositions of the 17th century that it was in competition with. In order to address this, three other glass types for which some compositional data was available were selected for comparison. These were a 17th century French potash composition (Brill, 1975), a Bohemian 17th century potash-lime glass composition (Hettes, 1963), and an English 17th century lead crystal glass (Theurkauff-Liederwald, 1994 [catalog # 146]). The reduced compositions of these three non-Venetian glasses are shown below:

Table 8.9. Reduced composition of three non-Venetian glasses (in weight percents).

Oxide	**French glass**	**Bohemian K-Ca glass**	**English lead crystal**
SiO_2	76.0	48.0	55.8
Na_2O	0.9	2.0	0.4
CaO	0.2	23.0	0.1
K_2O	18.7	25.0	8.7
MgO	0.1	NA	0.2
Al_2O_3	0.5	NA	0.5
PbO	0	NA	33.8

"NA" means that the oxide in question was not analyzed for.

Using this compositional information, viscosity data was produced using the same glass model (Lakatos, 1972). Some caution must be used in interpreting results from the model at this point as several of the constituents for certain glasses are outside of the range for which the model was developed. For example, the English lead crystal glass has a PbO content of about 34%; this almost 3 times the amount that the viscosity model was designed for. The glass model used was checked numerous times with data for viscosities and temperatures taken from glass handbooks and other reference publications (ex: Bansal and Doremus, 1986). While the accuracy of the model was not as good as seen in the case of the Venetian soda-lime-silica compositions, the values predicted by the model were generally within 10-15% of the actual ones. In this sense, the comparisions between these different non soda-lime-silica glasses with Venetian *cristallo* should be viewed as an approximation.

The viscosity - temperature relations between these non-Venetian glasses and the *cristallo* composition is presented in in Table 8.10.

Table 8.10. Comparison between Venetian and non-Venetian glass in terms of viscosity and temperature; temperatures given in °C, viscosity given in log poise.

Viscosity	**13**	**11**	**9**	**7**	**5**	**3**
cristallo	486	533	597	692	846	1140
French glass	545	606	690	814	1011	1378
Bohemian glass	595	623	660	714	797	941
English glass	489	544	619	729	902	1218

Again, the viscosity-temperature correlations provided above allow for the same types of inferences presented previously to be made. One can use this data to estimate possible furnace ranges, annealing temperatures, and the temperatures at which certain operations were carried out. For example, the French composition would have been rather difficult to work with in terms of gathering it on a blowpipe. The high temperatures suggested from the viscosity model that were needed to acheive a log viscosity of 3 (gathering region) was about 200 degrees greater for the French glass (1378°) than that predicted for the *cristallo* glass (1140°). Either the French furnces had to be operated at these high temperatures resulting in greater fuel consumption, worker discomfort, and improved furnace design or else the glassmakers had to adapt to gathering a glass and working it in a less fluid state. In the same manner, the Bohemian glass would have required relatively lower furnace temperatures.

Another condition of the glass that would have been of great interest to the glassmaker was the range over which the glass could be worked - its "sweetness" or "shortness". As before, this was evaluated by making plots of log viscosity vs. 1000/T with the slope representing the activation energy for viscous flow. Again, a larger slope indicate a shorter working range and a generally more "unfriendly" glass composition. The values for these numbers are shown below.

Table 8.11. Slopes for different European glass types calculated from log viscosity vs. 1000/T plots.

Glass type	***cristallo***	**French potash**	**Bohemian K-Ca**	**English Pb crystal**
Slope (~Q)	8.47	9.02	16.19	8.17

From this data, it can be seen that the Venetian *cristallo* and the English lead crystal glasses were fairly similar in terms of having a broad working range. The English glass was a little "sweeter" due to the large amount of lead present which typically broadens the possible working range (Scholze and Kreidl, 1986). As the English glasses were also generally thicker walled they would have cooled even slower than their thinner Venetian counterparts allowing more time for working. At the other extreme, the Bohemian potash-chalk glasses must have been quite difficult to work with. The large amounts of Ca present in the glass would have given a glass that set up rapidly on the blowpipe or punty as it was being worked. This would have necessitated shorter working periods and more frequent re-heatings.

From technical perspectives, the English lead crystal may be seen as a superior glass when compared to the Venetian *cristallo*. The two shared similar working ranges yet the English glass had much better clarity and transparency and had fewer bubbles. In this sense, the English glass was much closer in visual appearance to rock crystal and was a natural successor to *cristallo*. The large amount of lead would have made a more "brilliant" glass due to its greater index of refraction. Lead would also give the English material a characteristic "ring" when tapped. Finally, as lead glasses are softer than their soda-lime-silica counterparts, they, along with the Bohemian K-Ca material would have been more suited to engraving (Volf, 1984).

This type of comparison does not really hold, however, once the larger context of demand and production is considered. Venetian *cristallo* was developed more than two hundred years before the English glass and in response to different market tastes and consumer demands. Venetian glass was much more delicate in appearance and form than the more "massive" English glass. Correspondingly, it was shaped, decorated and worked into a totally different style of glass. With respect to drinking glasses, a new order of form developed with the introduction of the English lead crystal composition. The decorative focus shifted from the bowl to the stem. The glassmen made use of the large difference in refractive indices between the glass and air to create contrast. Instead of a blown stem, this was now solid and often had bubbles of air deliberately trapped by pricking the material (Charleston, 1984:133). The point here is that the nature of the material and current fashions worked in synergy to create new forms and decorative techniques. English lead crystal, as I have shown with Venetian *cristallo*, developed in response to perceived demand and this demand was informed by current tastes, functions, and meanings.

All of the factors discussed in this chapter and in chapter 7 can be seen as contributing to the documented popularity of Venetian glass - the skill with which the glass was worked, the form and proportion of the finished piece, clarity and colorlessness, the intricate and delicate hot working, the quality of the material, the new compositions developed which were able to imitate other materials, the fact that these new compositions had property-composition correlations favoring their workability, and so forth. Guild and state policies with respect to selling the products were also a factor. In short, no one aspect of Venetian glass can be identified as the root cause of its success. It lies neither solely with the skill of the glassmakers, the quality of the glass, or the taste of the market (cf. Jacoby, 1993:90). Once *cristallo* glass had been developed in the 1450's in response to perceived market demand, the glassmakers of Venice and the buying public moved cooperatively, each influencing the other, in the creation of new decorative techniques and styles. In order for glass to be produced (Chapter 8), it had to be wanted first (Chapter 7). The next obvious phase of this sequence would have been the distribution of the glass and the knowledge associated with making it. These activities are discussed in the following chapter.

CHAPTER 9

THE DISTRIBUTION OF VENETIAN GLASS AND GLASSMAKING KNOWLEDGE

The two previous chapters have been constructed around the premise of separating particular aspects - demand and production - of the culture and technology of glass and glassmaking in Renaissance Venice. The last major activity which bears consideration is the distribution of the manufactured product - Venetian luxury glass. This is the focus of this chapter. While presented here in separate chapters for the sake of organization, there is clearly a system of feedback and interplay between all three basic activities which must be kept in mind.

As described elsewhere in this dissertation, much of the connoisseur-oriented literature concerning Venetian glassmaking has focussed on issues of provenance, primacy, and production. The great interest of curators and collectors on the first aspect ("where did it come from?" and "how did it get there?") has, perhaps not surprisingly, resulted in a fair amount of information concerning the distribution of Venetian glass (ex: Carboni, 1986; Charleston, 1963; Charleston, 1966a; Charleston 1966b; Charleston, 1977; Lamm, 1941; Pause, 1993; Zecchin, 1989:101). For this reason, I wish to shift my focus towards those aspects of distribution which have received less attention.

While not readily acknowledged in scholarly treatments, there are actually <u>two</u> aspects of distribution to consider. The first, obviously, is the selling and trading of the actual glass objects. While much previous work concerning the distribution of Venetian glass has considered where it was being sold and transported to, there is not nearly as much discussion concerning issues such as the manner in which selling and trade was regulated, the prices for luxury glass, and the response of the Venetian industry to different markets. My primary concern with these latter issues arises from the description given earlier of glass as a commodity in Renaissance society.

The second aspect is that of the distribution and dissemination of the skills and knowledge associated with making Venetian glass. Here again, the issue of commodity arises. However, in this case the nature of the commodity - labor skill and knowledge - is less tangible than physical artifacts. Yet, as I will show, it was every bit a "product" that was distributed and purchased. While distribution of glass or the knowledge required to make it result in essentially the same final outcome - the acquisition of Venetian glass - the two are very different in process and nature.

The Distribution of Glass

Venetian glass was widely distributed outside of Venice during the 15th through 17th centuries. In a sense, this practice was a continuation of previous Venetian policies regarding traffic in glass as there are numerous accounts of Venetian glass being exported before the development of *cristallo* glass. Evidence for large scale distribution of Venetian glass can be found in both documentary and archaeological contexts.

In Chapter 8, I discussed the relevance of the 1592 *Memoria di Vetrerie che si cava di Venezia* in relation to the importance of the glass trade in Venice's economy (Corti, 1971). This document also offers convincing proof that Venetian glass was a commodity widely distributed throughout the world in the late 16th century. Usimbardi's report to the Medici mentions such locations as Spain, Germany, the Near East, Turkey as well as parts of Italy as recipients of glass from Murano.

Other documents, as well as archaeological finds, offer more than convincing evidence that Venetian glass also found its way to many other parts of the world. Glass is mentioned in English shipping documents from the late 14th century onwards (Zecchin, 1987:34) and it also appears in English archaeological excavations. Venetian vessel glass and beads also appear in New World archaeological contexts suggesting that Spanish explorers carried these as articles of trade or as part of household assemblages of goods. For example, the Corning Museum of Glass has several sherds of Venetian (or *facon de Venise*) glass found on the Porto Bello trail in Panama and dated to the 16th or 17th century (Corning Museum of Glass, personal communication, 1994). Venetian beads also turn up frequently in African archaeological assemblages (David Killick, personal communication, 1994). Nor surprisingly, Venetian and *facon de Venise* glass also traveled east into Asia during the 16th and 17th centuries. There is substantial documentary evidence, for example, of the transport and trade of Venetian glass by Jesuit and lay officials into China during the Ming and Qing periods (Curtis, 1993).

For instance, in 1656 the Chinese emperor Shunzhi received "three goblets of Venetian glass" from Dutch ambassadors (Curtis, 1993:92). Western-style glass apparently became quite popular in 17th century China among the wealthier classes who spoke highly of "its durable properties and crystal clear finish" (Boda, 1991:134). It is quite interesting to note, in relation to the previous discussions concerning the demand for glass that was relatively defect-free, that Chinese consumers favored the Venetian and Western products while complaining about the defects in their own domestic glass products. Apparently, some of the same aesthetic tastes with regards to what was desirable in a glass vessel were present in both the East and West.

The majority of information concerning the manner in which the selling of glass was carried out and regulated can be found in the rules and regulations of the glassmakers' guild. Here, there are hints and information about the glass trade from as early as the 13th century (Zecchin, 1987:19-20). For example (and not surprisingly), the first edition of the *Capitolare* forbids the selling of broken or defective glass. More importantly, there are rules concerning the specific manner in which glass selling was to be done, who could sell it, and who could buy it.

Already at this early date, it is possible to see particular patterns with respect to the manner in which the Venetians carried out the selling and distribution of their glass products. They were inclined to remain in control of the trade as much as possible and favored having merchants come to Venice in order to buy it. The selling of glass outside of the city was not favored and local trade was encouraged and well-regulated by the state through the guild mechanism. For example, an addition to the *Capitolare* in 1284 states that glass cannot be sold in the business district near the Rialto; another very popular and public place, the Piazza di San Marco, was also off-limits for glass merchants except on Saturdays and during festivals. Of course, the selling of glass in Venice that was made elsewhere was forbidden and those doing so were liable to be fined (Zecchin, 1989:20). Later additions to the guild rules in 15th and 16th century would essentially conform to these earlier regulations.

The glass trade with German merchants in Venice was the subject of a number of guild regulations. For example, there is a ruling from 1282 stating that German merchants were not subject to a tax if they purchased more than 10 *lire* worth of glass and transported it from Venice on their backs. It should be remembered that 10 *lire* of common glass in the late 13th century was equivalent to about 1300 pieces of common glass (Zecchin, 1987:7)! At this time, glass was able to be sold by both the furnace owners as well the *maestri* during the off-season. Zecchin describes this system as allowing the glass masters to earn money during the time when the furnaces were inoperative (1989:20).

While there is a lack of detailed information concerning the practice of glass selling through the 14th and early 15th centuries, there is enough unconnected archival references to suggest that the glass trade was fairly healthy. By the end of the 14th century, there is evidence for glass exportation to Vienna, Flanders, and England. The selling and distribution of glass in Venice itself changed somewhat in

1436 with the establishment of the *Stazionieri*, a guild organization responsible for the retail selling of glass (Zecchin, 1987:45). Information on this organization does not explicitly state what type of glass they predominantly handled (luxury versus common glass).

The conditions and rules associated with the selling of glass in Venice and the glass trade continued to change, especially after the development of *cristallo* glass and the resurgence in the luxury glass industry in the mid-15th century. For example, a decree from 1510 stated that the retail glass shops of the *stazionieri* were not able to sell *cristallo* glass. This was a privilege controlled and held by the owners of the Muranese glass shops. This rule was again repeated in 1523 and said that only the owners of furnaces could sell *cristallo* glass at locations in Venice and Murano. Finally, the Council of Ten appointed a special commission, with the blessing of the furnace owners, to ensure that only "common" glass found its way to the stalls of the *stazionieri* (Zecchin, 1989:41).

The desire of the Muranese glassmakers to keep *cristallo* glass under their own control was displayed in many ways. For example, I have shown how the raw materials used in its production were carefully controlled and monitored by the guild and the state. The guild had rules concerning who was able to work and sell *cristallo* glass with the privilege more frequently given to native Muranese. There were rules preventing "foreigners" from having anything to do with *cristallo* although they were not always enforced. It seems only logical, therefore, that the glass guild and the glassmakers, besides controlling aspects of luxury glass production, should also be concerned with controlling its distribution.

As with other aspects of the Venetian glass industry, issues related to distribution saw increasingly more involvement of the Venetian state, especially on the part of the Council of Ten. For example, the Council intervened in 16th century disputes between the manufacturers and distributors concerning the quality and type of glass being delivered to shops in Venice (Zecchin, 1989:103-103). As alluded to in the information presented above, this suggests not only commercial competition between the glassmakers and those who sold the finished goods but also that there were attempts on the part of the glassmakers to keep the higher priced and presumably more profitable luxury goods for themselves to sell. Evidence of this latter condition may be seen in a 1546 petition of the glassmakers presented to the Council of Ten. This referred to a request made by *stazionieri* to retail *cristallo* glass at a higher price than they acquired it wholesale which the glassmakers opposed. In this matter, it would appear as if the Council of Ten respected the wishes of the glassmakers (Zecchin, 1989:105).

The information concerning luxury glass distribution and selling in Renaissance Venice is not very comprehensive or well-connected, being scattered instead through a variety of archival sources. It does allow for the formulation of general picture of distribution, however. One can see that there was considerable differentiation between luxury and common glass, especially after the innovation of *cristallo*. The glassmakers guild was very interested in retaining control over its distribution and the Venetian state appears to have been at least moderately sympathetic to this desire. As with many other aspects of Renaissance Venetian glass production, there were extensive written regulations concerning distribution accompanied by increasing state involvement in the 16th century.

Throughout this dissertation I have made the distinction between luxury glass versus common glass. Earlier, in Chapter 5, a discussion was given concerning the nature of luxury goods and their role in the Renaissance economy. All glass objects, luxury or common, were produced within the confines of the guild system. A distinction between the nature of shop production was shown to exist in the Venetian glass industry with some shops making "basic" glass objects while others were more oriented towards the luxury or "elite" market. Luxury goods were defined as refined goods. This is any treatment of a product over that which is needed to make it ordinarily useful (Sombart, 1967:60). As such, luxury goods have several basic attributes. These include complexity of acquisition and restriction to elites by price. The preceding discussion has shown that buying Venetian luxury glass was not entirely a simple matter. Glass was not always for sale and Venice and was restricted by time and place with respect to its distribution. The purchase of "common" glass through the street stalls of the *stazionieri* appears to have been more straightforward. What of the price such luxury glass objects commanded on the Renaissance market? How financially difficult was it to own a piece (or several) of fine Venetian glass in the 15th or 16th century?

It is fortunate that several examples of shop inventories and shipping lists exist which allow one to see the costs of purchasing certain types of luxury glass objects as compared with the prices for "common" glass. All of these sources confirm what may already be imagined - the Venetian luxury glass, either *cristallo* or *vitrum blanchum*, garnered a much higher market price than "common" glass. For example, an inventory list from 1458 records the value of 17 pieces of glass made "*de cristalo*" and listed separately from other glass pieces described as "common". These 17 vessels were priced at 12 *lire* or about 0.7 *lira* each (Zecchin, 1990:146). At about the same time, common glass pieces (*bicchieri*) were priced at about 0.005 *lira* each (Zecchin, 1987:50). In other words, this type of comparison suggests that an object made from the new *cristallo* glass was worth more 100 common glass tumblers. While we do not how complicated these *cristallo* forms were (therefore the comparison I am making here may therefore be somewhat unfair), this clearly suggests the higher market value accorded to the new glass type.

Other examples of prices for *cristallo* glass may be found throughout the latter part of the 15th century. For example, Pope Pius II received a shipment of *cristallo* glass as a gift that was valued at 170 Venetian lire (Zecchin, 1990:146). Another later record from 1462 allows us to see how the price of *cristallo* glass vessels varied with the form. For example, a *cristallo tazza* was worth about 4 *soldi* apiece and a cup with a knop and foot was worth about 10 *soldi*. These values are much more (one hundred times as much in some cases) as their counterparts in "common" glass.

Another useful point to consider, other than the fact the luxury or *cristallo* glass was worth a greater market value than "common" glass, is how the price of luxury glass varied with its form and decoration. To evaluate this question, I wish to return to the early 16th century shop inventory of the Dragani family to which I have previously referred. The Dragani family, on the basis of the glass inventoried in their shop on two separate occasions (1508 and 1532), would appear to have been largely producers of higher quality and more expensive luxury type glass (Zecchin, 1990:59-61). While it is hard to decipher all of the forms and shapes referred to as well as the different decorative techniques (the list is in 16th century Venetian dialect), the few examples I have selected offer some illustration of how vessel price varied with decoration and shape.

From 1508:

40 footed *cristallo* bowls with gilded ring = 18 *lire* and 12 *soldi* (or about 0.5 *lira* each)

35 footed bowls of blue or *cristallo* gilded glass = 43 *lire* and 8 *soldi* (or about 1.25 *lira* each)

33 cups (of undeclared glass type) with cover, gilded ring = 31 *lire* (or about 1 *lira* each)

40 cups of *cristallo* glass with cover, gilded ring = 60 *lire* (or about 1.5 *lire* each)

60 blue or *cristallo* cups with feet and cover, enamelled and gilded = 93 *lire* (or about 1.3 *lire* each)

From 1532:

17 cups of *chalcedony* glass = 31 *lire* (or about 1.8 *lire* each)

18 cups of gilded *lattimo* glass = 57 *lire* (or about 3 *lire* each)

Cristallo glass was frequently decorated. The clear and colorless glass often served as a canvas for other types of decoration. These few selections from the Dragani inventory offer a few clues as to how glass prices varied with type and decoration.

Firstly, it may be seen that pieces with gilding and enamelling, as may have been expected, cost more than those with no extra decoration or those with gilding alone. A reference from 1474 confirms this pattern as the price of glass tumblers is given at 22 *lire*/100 if undecorated and 45 *lire*/100 "with figures" (Zecchin, 1990:151). This extra cost was due to both the extra steps of decorating the glass as well as the second re-heating required to fuse the enamels to the glass substrate. An archival reference from 1487 gives a clue as to the cost of decorating the glass and the re-heating step; each step is noted as costing 10 *lire*/100 pieces (Zecchin, 1990:122). Furthermore, it is possible to see how the price of an enamelled object varied with the complexity of the decoration. An argument between glassmakers which found its way into the archives reveals that the price of a single tumbler with gilding was 4.5 *soldi*. One that had two enamelled figures on it was 9 *soldi* and a much more involved piece with an imaginative scene (such as nuptial piece or one depicting the Annunciation) cost 40 *soldi* (Zecchin, 1990:127).

Secondly, *cristallo* glass, even when it was gilded or enamelled, is not thought to have been as costly as other types of luxury glass compositions such as *chalcedony* (a multi-colored and variegated type of glass) or *lattimo* (an opaque white composition). While both of these glass types had compositions that were nominally based on *cristallo* glass, as discussed in Chapter 8, they required extra steps to prepare and incorporated more costly raw materials such as copper, silver, lead, and tin (cf. McCray, et al., 1995b).

Cristallo and other luxury glasses were more expensive than "common" utilitarian glass, sometimes by factors as much as 100. This was due to several reasons. One was that *cristallo* glass required extra care in raw material selection and more time and labor was needed to prepare the materials. The fritting and melting stages all required extra attention with ash purification being especially notable. The additional steps of decorating or working the glass into more elaborate forms contributed to the added cost. Another reason was connected to laws of supply and demand. Isabella d'Este's correspondence, for example, notes that fine Venetian glass was not always in sufficient supply (Brown, 1982:213). Finally, the different notions of value (not strictly monetary) placed on Venetian glass by Renaissance society probably added to its cost.

Another point to consider with regards to the price of luxury glass in Renaissance Venice is how these prices compared to other luxury items. As mentioned earlier, one must bear in mind the question of for whom this was a luxury? Clearly the price of even the finest and most skillfully decorated luxury glass was nowhere near the price of gold or silver plate. Consider the cost of Venetian *cristallo* in relation to that of Italian majolica, another luxury ceramic item. In his catalog, Piccolpasso (c. 1550) lists large and decorated majolica plates costing no more than 2 ducats. A table service of 84 pieces purchased by the wife of Filippo Strozzi in 1517 cost only about 6 ducats (Goldthwaite, 1989:20). In comparison to the amount of gold required to make a plate (a ducat, or about 6 lire, only contained about 3.5 grams of gold), glass and majolica do not begin to compare in monetary value. With the average worker, for example a builder, in Venice earning around 1 1/2 *lire*/day, ownership of moderately refined glass products among the middle classes was not completely out of the question.

While much more expensive than "common" glass, the relative cheapness of Venetian luxury glass in comparison to precious metals, for example, must be considered in relation to the differing concepts of value presented in Chapter 5 and 7. Clearly, other types of value besides sheer monetary worth were attached to Venetian glass in order for it to be highly regarded and desired. This type of value arises from the different activities, behaviors, and functions that Venetian luxury glass became associated with in the Renaissance. In Chapter 5, I differentiated between what Appadurai calls "prime" value and "use" value (1986:31). "Use" value is a property arising out of the social context(s) in which the commodity resides. It results from demand, as well as the functions it performs, and is therefore context dependent. New attitudes towards wealth and splendor, emerging patterns of consumption, modifications in dining behavior, and new hobbies such as collecting all contributed to the "value" of a luxury good such as glass.

The final issue relevant to the distribution of Venetian glass that I wish to address here is the question of how the Venetian glass industry responded to the demands of its consumers, particularly those in foreign markets. As Usimbardi's 1592 report to the Medici suggests, a large portion of glass produced in Venice was for export. The question of industrial response to foreign demand is rather difficult to treat with as there are very few specific records relevant to the subject. Instead, one is left with letters and shipping orders from which inferences must be drawn.

The glass industry of Venice made luxury pieces for a variety of market scales ranging from particular geographic locations to individual customers. Evidence of the former can be found in different inventory lists which describe particular types of vessels as having been fashioned in the manner or style peculiar to a particular place. For example, an inventory from 1468 records the presence of pieces made in a variety of styles including "*inghistre da Padua*", glasses "from Milan, Rodi, and Corfu" as well as those made in a Spanish or Catalonian form (Zecchin, 1990:148). Other documents record pieces made in German or French styles. There is no way of telling whether these particular pieces were in fact destined for the export market, however. While this cannot be ruled out, it may be possible that these pieces made in particular regional styles were also popular in Venice and were destined for the domestic market.

The glass factories of Murano also made pieces in certain regional styles for particular international customers. One such record concerns a relatively large consignment of glass made in Venice and shipped to Turkey. In 1569, the Venetian ambassador to Constantinople wrote that the Turkish Grand Vizier had "asked of me 900 lamps for a mosque he is building...300 of the larger shape...300 of the long shape and another 300 half as big again as the said long shape..." (Charleston, 1966b:18). A number of lamps from this shipment, or similar ones, are thought to have survived in Turkey. The glasses incorporate decorative techniques that were Venetian specialties, such as filigree work and enamelling, but the design and execution is more Eastern in appearance. Another example of how the Venetians modified their wares for the Levantine market can be found in the glass of the Gnalic shipwreck which was destined for Eastern locations. Many pieces of the surviving glass recovered have markedly Eastern shapes (Petricioli, 1973:92).

It is interesting to consider the manner in which the designs for glass made in Murano and exported to other regions were communicated to the artisans. One method by which this was accomplished was to send drawings of the desired forms to the glass shops. This was the manner, for example, in which the Venetian ambassador communicated the Grand Vizier's wishes to the shops at home. Two drawings were sent with the writer remarking that the dimensions are only approximate and that the glassmakers were to use their own judgement in interpreting them (Charleston, 1966a:165).

In other cases, the requests for particular glass shapes and styles on the part of import-export businessmen to the artisans in Murano were quite explicit. In the later part of the 17th century, for example, the Englishman, John Greene, sent several letters to Alvise Morelli. Morelli was a member of a Venetian glassmaking family who was apparently wealthy enough to own three ships used to send glass overseas (Charleston, 1984:104; Zecchin, 1989:58-59). Greene's letters to Morelli were accompanied by over 400 drawings which note the shapes of the glasses desired and the quantities. The drawings are to scale and are very particular with regards to the exact decorations and shapes such pieces should have. Charleston has noted that Greene's letters detail all aspects of the glass ordered including the bowl shape, the type of stem, and the nature of the foot (1984:105). In addition to being very specific about the form, Greene also ordered a wide variety of glass from Venice. While most were to be in clear and colorless glass, perhaps *cristallo* or *vitrum blanchum*, other orders call for *chalcedony* and *lattimo* vessel glass in addition to beads and mirrors. Besides the variety of glass manufactured in Murano and sent to England via Morelli's boats, the quantity requested by Greene is impressive. One letter asks for over 5400 vessels in addition to ordinary tumblers and miscellaneous objects. Other examples of drawings and records of glass designs can be found in Italian collections such as the *Bichierographia* of Giovanni Maggi from the early 17th century or the 16th century drawings of Jacopo Ligozzi (Laghi, 1987; Zecchin, 1987:103, 148).

At a much smaller scale, there is little doubt that the glassmakers of Murano also custom-made pieces for individual customers as well as specific historical or social events. Earlier, in Chapter 7, I described how Isabella d'Este, directly and through her contacts in Venice, ordered specific pieces from Muranese artisans via detailed instructions. At times, such glass objects were described as being part of a larger overall dining set or a matching counterpart to a metal object (Brown, 1982).

Of all of the surviving pieces of glass thought to be Venetian in museum collections, it is the enamelled wares which give the best indication of how the glass factories of Murano made vessels for specific customers or events. For example, there are several surviving glass *tazze*, similar to that shown in Figure 7.26, which have an enamelled coat of arms of one of the Medici popes (either Leo X or Clement VII) who held office between 1513 and 1534 (Barovier, et al., 1982:105-107; Lanmon, 1993:27-28). While there are slight variations between the different pieces, they are thought to have been made as part of a dining service or services for one of the new popes. They served both to commemorate the new papal election and to stand out as glass pieces made for a particular customer. There are numerous other examples of enamelled glass vessels from the 15th and 16th century which contain a wide assortment of armorial and coat-of-arms decorations. While some of these are for Italian families, a good number contain the familial motifs of certain German families (Barovier, 1982). Some German families (the Imhoff family, for example), via correspondence, requested sets of majolica from Venice in the 16th century. Barovier suggests that some of these majolica settings served as sources of heraldic information for Venetian glass decorators (1982:71). After about 1550, this practice may have slowed somewhat as there were glass houses operating in Germany and staffed by expatriate Venetians. As a result, German nobility desirous of having their coats-of-arms on glass vessels could have these prepared closer to home. In addition to making tumblers and *tazze* with German motifs on more traditional Venetian forms, the Muranese workshops also modified their export vessel styles to conform with popular German shapes. The most notable example of this are the enamelled *stangenglas* or long cylindrical drinking vessels (cf. Tait, 1979:44-45).

In addition to being made for specific customers or families, the Venetian glass industry also responded to the demand for glass to mark special events such as weddings. There are several examples of such nuptial vessels including the famous (and mis-named) Barovier Cup. Such vessels were also made to mark events and ceremonies taking place in other countries. A well-known example is the Beheim beaker at the Corning Museum of Glass. This enamelled and gilded piece was made around 1495 to mark the wedding of Michael Beheim, son of a wealthy Nuremberg family, to Katerina Lochner.

This discussion of the manner in which the glass industry of Murano responded to markets which differed both regionally and in scale sheds light on the ability of the industry to respond to perceived demand. The evidence presented suggests that the Muranese industry was very flexible. It manufactured glass objects in an almost bewildering variety of forms and decorative techniques, responding to the tastes of particular markets and customers. Furthermore, the Venetian glass industry was able to make glass for markets that varied widely in scale. While hundreds or thousands of bottles or glasses were made in the "Florentine manner" or "French style", for example, the glass factories also custom-manufactured glass for individual consumers or unique social or religious events. This adaptability adds another dimension to the question of specialization in the Venetian luxury glass industry that has already been presented.

The Dissemination of Glassmaking Knowledge

While the preceding discussion has focussed on the manner in which Venetian luxury glass was sold and distributed as a commodity during the Renaissance, this section will examine another mode by which glass was disseminated. In addition to actual glass pieces being sold and traded throughout the world in the 15th through 17th centuries, another aspect of glass distribution was the dissemination of the knowledge associated with making it. This occurred in two forms. The first was the spread of glassmaking knowledge through the written word; the second was the migration and relocation of Muranese craftsmen who took with them the trade practices associated with making Venetian style glass.

While other treatments of Venetian glassmaking have considered the distribution of the products in some fashion, none has explicitly addressed the nature of glassmaking knowledge as a commodity. I believe this absence stems from a fetished and artifact-centered interest in Venetian glass in its physical form. Yet the spread of glassmaking knowledge is very important to address as this is one of the primary means through which other manufacturing areas were able to compete with the Venetian industry. Describing the manner in which skill and knowledge were able to be re-distributed is also important in considering the eventual decline of the Venetian glassmaking industry. From a broader intellectual perspective, the issues of worker movement and the utility of printed material in transmitting knowledge are clearly relevant to such questions as the nature of technological transfer, the value of worker skill and input, the role of tacit knowledge, and impact of new technologies such as printing on craft development.

Glassmaking in Print during the Renaissance

Earlier, in Chapter 8, recipes for glassmaking were introduced as an idealized source of information regarding certain technical aspects of glass production. These included raw material selection, the manner in which the materials were processed, instructions and hints for furnace operation, etc.. In this manner, recipes may be interpreted as a technological representation (Lubar, 1995b:55). Recipes allow for the situation of technological knowledge into a more managerial context oriented towards better controlling the work process. The recipes for glass production were described earlier as inherently incomplete or inaccurate because glassmaking is a technology that relies heavily on the experience and tacit knowledge of the artisan. There are many aspects of the craft which cannot be recorded succinctly in words and which were instead passed on through the apprentice system, trial and error, and shop practice. Finally, recipes for crafts such as glassmaking, pottery, and metal working are valuable as they are sources for the history of techniques and are also connected with contemporary intellectual trends (Long, 1991:320).

The first documentary appearance of a recipe book in Renaissance Venetian sources occurs in 1446 (Zecchin, 1990:34). Recipes, as part of European glassmaking practice, have a long history that pre-dates the appearance of Renaissance texts, however. Examples include the *Mappae Clavicula*, the *Speculum Majus*, and other medieval writings (Stillman, 1960:184-299). With the exception of Theophilus' excellent *On Divers Arts* (c. 1122), most of the pre-Renaissance writings which mention glass fall into two categories. Some are oriented towards philsophical speculations on the nature of glass as compared to other materials. Others treatises exist as collections of recipes, often very alchemical in nature, which are of little practical use. In many cases, the texts are merely compendia of all types of recipes with little indication that the author had tried them or was even a glassmaker. The writings on glass made during the 15th-17th centuries began to vary from these patterns. The purpose of this section is to return to the recipes for glassmaking and examine them further as a mechanism by which Venetian practices for making glass were distributed to other centers of glass production.

Finally, the issue of recipes and instructions for relatively "high-tech" Renaissance industries such as glassmaking is inherently important because of their appearance against the backdrop of other broader societal changes. These include the changing status of artisans and craftsmen in Renaissance society, the interest of the wealthy in technologies such as glassmaking, the increased value accorded to empirical observations, and the emerging Scientific Revolution (cf. Rossi, 1970). Obviously, these topics are not trivial. Their complete and thorough study in connection with even one craft, such as glass production, is beyond the scope of this present work. What I wish to present here is a general overview of the historical context in which these recipes appeared, their utility in the practice of glassmaking, and the manner in which glassmaking knowledge was distributed via printed material. Other topics will be alluded to or briefly mentioned with the intent that they remain the topic of future work.

In 1556, Georgius Agricola published his well-known treatise on mining and metallurgy *De Re Metallica*. One of the themes in his writings is a defense of the practical or "mechanical" arts against charges that they were base and constituted more labor than skill or knowledge (Rossi, 1970:55). About the same time (1580), the French potter Bernard Palissy published the *Discours Admirables*. In this it was argued that many currently "accepted facts" of the day were erroneous and that philosophers would do well to reject theory in favor of empirical observation and experimentation.

Similar ideas are found in other technical writings from the 16th century such that Rossi has identified three common themes. The first is that the procedures of artisans and craftsmen are valuable for the advancement of human knowledge. Secondly, such recipes and procedures have the status of cultural facts. Finally, men of culture and learning were repeatedly called upon, either directly or indirectly, to give up the traditional, Aristotlean-based disdain for "mechanical workers" as this led to contempt for techniques and practical arts in favor of more rhetorical or contemplative knowledge (Rossi, 1970:10-11).

This latter point has particular significance for the status and perceptions of glassmaking in Renaissance Venice. I have already detailed how Murano and its glass furnaces were a featured stop on the wealthy tourist's visit to Venice. 15th century Murano was a place of leisure, in some senses, for the nobility of Venice and the site of a number of palaces and summer residences. The glassmakers of Murano were granted special rights and concessions such as the ability to marry into the nobility and have their family name inscribed in the Muranese *Libro d'Oro*. In addition to these incidental social connections between the nobility of Venice and the practitioners of glassmaking, there are several instances of direct noble interest in the craft which illustrate the third trend noted by Rossi. For example, the Medici family had specific interest in opening a series of glass furnaces in and around Florence in the late 16th century. I do not think the interest shown by the Medici was motivated solely by mercantile intent. For example, part of the arrangement made with Bortolo di Alvise in 1569 was that Cosimo de Medici have "one or two glass pots" at his own private disposal to work with (Heikamp, 1986:344). It is interesting to note that the best-known treatise on glassmaking, Neri's *L'Arte Vetraria* (1612), was based in part on work carried out by Neri while working at Medici supported glass houses in Pisa and Florence (Barovier, 1982:xlii). Glass was not the only craft with which the Medici were involved. They also were instrumental in the development of some of the first European porcelain compositions (Kingery and Vandiver, 1986).

At about the same time (1563), the Emperor of Austria's son, Archduke Ferdinand, set up his own glass-house in Innsbruck. His workers were drawn from the glass factories of Murano. Tait and Polak both describe the Archduke's glass house as not existing for commercial reasons but as a personal source of enjoyment (Polak, 1975:71; Tait, 1979:9). The Venetian Council of Ten was advised by Ferdinand to select *maestri* who had the most imagination and fantasy (Polak, 1975). The historical record is unclear as to why this was permitted by the Venetian government as would have clearly violated several long-established guild rules and state policies. In any event, at least one vessel thought of as an object made by Ferdinand himself has survived to the present day. The interest of the German and Austrian nobility in glassmaking foreshadows their later interest in 18th century porcelain manufacture. Examples such as these illustrate not only the intermingling of royalty with the crafts but their participation may also serve as a sign of the changing status of the technological or mechanical arts.

The publication of trade secrets related to glassmaking has parallels to a trend noted by Long in her study of 16th century writings on mining and metallurgy (1991). She describes the authors of Renaissance-era technological treatises as occupying a border area between learned, elite, and craft cultures. It was necessary for such an author to be literate as well as familiar with a particular craft or crafts (Long, 1991:352). This trend can perhaps be best seen in the writings of Biringuccio or Agricola, for example, where the author is both verbally and technically adept. She goes on to describe such technical writings as part of a new tradition of "openness" in terms of transmitting and communicating technical information. Craft secrecy and alchemical obfuscation were remnants of an older mode of production and knowledge and were looked down upon. Technical knowledge was associated with new beliefs in industrial capitalism and was connected to high levels of skill, precision measuring, and honesty were all necessary to increased productivity (Long, 1991:353).

Finally, the increased appearance of more detailed written information concerning glassmaking and other mechanical arts can possibly be connected to events and circumstances surrounding what is best known as the Scientific Revolution. Zilsel notes that before 1600, the "methodical training of intellect" was reserved for the upper classes while "experimentation and observation were left to more or less plebeian workers" (1942:553). Eventually these barriers broke down such that the empiricism and experimentation of the craftsman was adopted by trained scholars leading to the development of "true science" (Zilsel, 1942:554-55). Crafts such as glassmaking were clearly part of these trends towards empiricism and observation and glass recipes represent an attempt to record and codify the results of experiments and manufacturing processes.

The best practical writings on glassmaking from the Renaissance era are those in which the author has direct experience with the subject such as the writings of the Darduin family or Antonio Neri. These may be considered in opposition to earlier medieval writings where the author was merely copying down mixtures of materials for the sake of collecting them and with little or no knowledge of whether the recipes actually worked. The Darduin family text, for example, contains notes in several places where the author has made comments on the usefulness of the recipe or whether it actually works (Barovier, 1982:liv; Zecchin, 1986). This fits in well with trends towards experimentation, testing, and empirical observation that would become part of the scientific method. Recipes for glass such as those of Neri and Darduin also do not attempt any theorizing on the nature of the materials they are working with; what is presented are clear instructions along with rational explanations of observed phenomenon. Smith has interpreted medieval and Renaissance artisans "...as the true scientists of the period, and if they lacked the flash of genius to produce a consistent theoretical framework, it must be remembered that even genius could do nothing without the reserve of established fact" (Smith and Gnudi, 1942:xv). Such recipes may be interpreted as the forerunner of later attempts to codify, explain, and standardize knowledge related to ceramic production. Reber notes the increasingly rigorous experimental methods used in 18th century European ceramic production (French porcelain and Wedgewood wares specifically). (1990:279). The roots of such patterns can be seen decades earlier in the recording of Venetian and Italian glassmaking knowledge.

Stillman notes that as far back as the Middle Ages there were two classes of chemists: those with a philosophical inclination and those with no such pretensions who were engaged in "practical" applications (1960:184). The same type of division may be seen in Renaissance-era writings concerning glass. There are those which are speculative in nature. These are mainly concerned with the nature of glass as a unique and distinct type of material and tend to be much more abstract. There are numerous examples of such a treatise. For example, in 1596 Caesalpinus published his *De Metallicis libri tres* in which he considers the nature of glass as similar to a metal but different due to its fragility when cool (Barovier, 1982:li). Another Italian example is the *Magiae naturalis libri viginti* by Della Porta (1589). While many glass recipes are presented there is little here to directly interest the practicing glassmaker. Even Merrett's 1662 English translation of Neri's text contains a section by Merrett in which he provides a discourse on the nature of glass and lists several features unique to it ("'Tis artificial"; "it receives polishing", "'Tis diaphanous either hot or cold", et cetera).

The other type of writing is that which would have provided direct advice and instructions to a person wishing to make glass. While the examples of first type are quite interesting to read, it is the second category which was the most influential in facilitating the transfer and spread of technical knowledge. Even within this category there is considerable variability with respect to the social and technical background of the authors in addition to their intended audience. It is therefore along these lines that I wish to consider the more practical collections of recipes for glassmaking. To do so, I have selected two different yet well-known recipe books - the Darduin family recipe book (Zecchin, 1986) and Neri's *L'Arte Vetraria* (Neri, 1662; Barovier, 1982). One is an example of glass recipe book which was kept in private hands and the other was printed and ditributed widely.

The Darduin book is an example of a collection of glass recipes assembled by a glassmaking family. It was written over the course of about a century with the earliest recipes coming from the 16th century and the later ones from the early 18th century. As the Darduin family was primarily engaged in preparing colored glass compositions to be used for enamels, there is great wealth of information illustrating the wide variety of raw materials employed and the very specialized manner of preparing them. The authors themselves were all practicing professional glassmakers whose living depended on their ability to successfully make a wide variety of different types of glass. As a result, their collection represents the whole of knowledge based on years of practical experience. The value of experience is in fact noted at one point in the text as Giovanni Darduin states that "in everything, experience is more necessary than science" (Zecchin, 1986:174).

As opposed to Neri's work, as well as other technological treatises which address glass production (such as Biringuccio and Agricola), the Darduin book was never meant for publication and was aimed at a private and small audience. While the authors were artisans, the book is written in Italian (Venetian dialect). The book, according to the one of the writers, Giovanni Darduin, was designed to "gather all the secrets concerning enamels drawn from the books....of my beloved father [who died in 1599]...in separate lists of colors...so that if one wishes to make one kind of enamel, one can find it..." (Barovier, 1982:liii). The purpose of the book, besides organizing the family recipes, was to serve as a working shop manual. Therefore, the material is presented in clear technical terms with the exact raw materials and amounts specified. The authors have also included their own personal observations on the utility of certain recipes with notations such as "I do not place any trust in this one" present in some places. In many senses, therefore, the recipe collection of the Darduin family may be viewed as a tool used in the Venetian glasshouse, in much the same manner as a marver or blowpipe. It was more of a way for the glassmaking family to collect and pass on information intergenerationally than it was a means to distribute glassmaking knowledge outside of Venice.

While Antonio Neri's 1612 treatise, *L'Arte Vetraria*, is also an example of the practical/empirical (as opposed to speculative/philosophical) type of technological treatise, it is oriented towards and written for a different purpose. Where the Darduin recipe book was a private collection of practical information for use in the family business, Neri's book was deliberately intended for publication. The Forward to the treatise, which Neri dedicates to Lord Don Antonio Medici, states that "Having taken much pains for many years about the art of glass...I have compiled a treatise of them, with as much clearness as I could, to the end to publish it to the world, to please and delight...". The book is also different with respect to the author. Neri was a Florentine priest who traveled extensively around Europe in his lifetime. In 1601 he was employed at the Medici glasshouses in Florence and Pisa where he conducted experiments on different Venetian-style glass compositions. In 1603 he made a journey to the Netherlands, possibly making a stop in Venice along the way. There, Neri was also engaged in the production of Venetian-style luxury glass compositions " in the glass furnace in Antwerp, the working place of Sir Filippo Ghiridolfi...". He is thought to have stayed in the Low Countries for several years, returning to Florence around 1611 and dying there in 1614.

Neri's book was written and published in Florence in 1612. While it was the first known book written on the practice of glassmaking and intended for public dissemination, it does not seem to have initially aroused much interest (Turner, 1963:199; Barovier, 1982:lix). Despite this early lack of success, Neri's book can be favorably compared to other 16th and 17th century technological treatises which also address specific crafts from a practical point of view. Examples include Biringuccio's *Pirotechnica* and Agricola's *De Re Metallica* (both mainly concerned with mining and metallurgy) and Piccolpasso's *Three Books of the Potter's Art.* All were intended for publication and with the intent of providing a careful, systematic, and empirical based set of instructions for a particular craft.

L'Arte Vetraria fell into oblivion for about half a century only to be re-discovered around 1662. While not as appreciated in Italy, Neri's book appears to have been of considerable interest to other European countries which were attempting or continuing to make luxury glass in the Venetian style (Barovier, 1982:lix). This was primarily due to the first English translation made of the book by Christopher Merrett, an English doctor and naturalist. Both Turner and Barovier cite Merrett's translation of Neri's book as instrumental in the successful development of English lead crystal in the latter part of the 17th century. The revitalization of Neri's text was also encouraged by a 1679 German translation of the Neri-Merrett version by Johann Kunckel, a German glassmaker who is perhaps best known for his successful application of Venetian techniques for making gold-ruby glass. In the next 80 or so years, there were no fewer than 12 different editions of Neri's book, appearing in several different languages including English, German, Latin, French, and Spanish (Turner, 1963:200). In this fashion, *L'Arte Vetraria* opened the way for the general distribution of Venetian glassmaking technology to all parts of Europe. It was, until the late 18th century, the standard technical manual for glassmaking and excerpts from it appeared in several different 18th century encyclopedias concerning glass production (Barovier, 1982:lxiv).

Clearly, Neri's book was, from a "marketing" point of view, different from the Darduin book. The information collected by the well-educated and well-traveled Neri was intended for publication and his work eventually became well known throughout Europe. The Darduin manuscript was kept in the family and only became public with the Zecchin's writings on the subject (cf. 1986). Despite this, the two texts share several common features.

The first is that Neri's book is clearly based on information derived from Venetian sources and is based primarily on the Venetian style of glassmaking. While Tuscan and Venetian styles of glassmaking were somewhat distinct from one another, Neri had ample contact with Venetian craftsmen employed by the Medici and this shows in his writing. He refers several times to the types of raw materials used at Murano and his descriptions of processes are well within the Venetian tradition of glassmaking (Barovier, 1982:xlvi; Barovier, 1987:478).

This intermingling of Tuscan and Venetian glassmaking traditions is visible in several ways. Archival documents record the presence of Venetian glass workers in Tuscany and vice versa throughout the Renaissance. Moreover, the examination of different Tuscan recipe books from the 15th century clearly suggests that they are based on Muranese sources as evidenced by the Venetian terms for raw materials and technical processes found there (Zecchin, 1990:213-220). Zecchin has also suggested, perhaps not surprisingly, that there was significant traffic and trade in glass recipes throughout Italy. He notes that a recipe for red glass (#21) in the Montpellier collection (1536) is essentially repeated in Neri's book (Chapter 121). This not only confirms the Muranese source for Neri's information but suggests that Neri may have either copied older Venetian recipes into his text or based his experiments on Venetian recipes. In the same sense, some of the recipes in the Montpellier book are found in other Italian sources, again suggesting a common source or trade in recipes. It is interesting to note that the Montpellier collection, the Darduin family book, and Neri's text are largely concerned with the manufacture of different colored glasses, perhaps saying something about the importance and difficulty in successfully manufacturing these.

Other than being part of the same technical tradition, the Darduin book and Neri's text are alike in that they are both written from the perspective of one who has personally tried the recipes. Neri's concluding remark to the end of Chapter 6 states that "Experience makes one discover and learn far more than do long studies.", a sentiment also shared by Giovanni Darduin. Both texts are generally free from any type of speculation on philosophy or the nature of glass. These are both shop manuals directed towards helping the busy glassmaker produce successful glass compositions at the lowest cost. Neri reports in Book Two, when he gives a recipe for nitric acid, that this is done so "the experts and the curious can do everything themselves in the most perfect way and at the lowest cost". The recipes in Neri's book and the Darduin collection both offer numerous recipes for the same glass compositions which can be made with variable results and costs depending on the needs of the glassmaker. Finally, in the tradition of technological "openness", both texts are free from the use of secretive or ambiguous language in their description of particular processes (cf. Long, 1991). This quality is also shared by other technical authors in the Renaissance such as Piccolopasso, Biringuccio, and Agricola. In conclusion, while the Darduin book and Neri's *L'Arte Vetraria* were written for different audiences by authors from disparate social backgrounds and education, both share many similar features in the type of material presented, the way in which it is organized, the goals of the author, and the manner in which the technical information is presented to the reader.

The question must be asked as to how effective such collections of recipes for glassmaking were in spreading technical knowledge. I have already described the inherent limitations of learning the craft from a series of written recipes. Glassmaking is a skill gained, as Neri and Darduin say, from experience. There is a tremendous amount of knowledge required to make glass objects successfully and cost-effectively that is tacit-based and which cannot be communicated through the pages of a book. Neri refers several times to a particular operation being carried out at the wishes or on the judgement of the *conciatore*, for example. In this sense, the recipes are of limited utility as they would only have been of use to someone who had prior experience in a glass factory. The books of Darduin and Neri are very specific, instruction-wise, and are different from the treatises of Biringuccio and Agricola. Books by these latter authors also contain instructions for glassmaking but from a very basic and "ground-up" perspective. For instance, neither Neri's nor Darduin's text contain instructions for building a glass furnace yet these are found in the *Pirotechnica* or *De Re Metallica*. While dealing nominally with the same subject, Neri's or Darduin's book is fundamentally different in the type of information they present and the level of experience and knowledge their texts presuppose. In this sense, they share a lot in common with Theophilus' earlier *On Divers Arts*. They are all examples of instructions books intended to be shop manuals for the practicing artisan and assembled, organized, and presented by one who had firsthand experience with the difficulties and successes of craft production.

The Spread of Glassmaking Knowledge via Worker Migration

In addition to the distribution of glassmaking knowledge and techniques via written works, Venetian glassmaking technology was also spread through the more direct method of worker migration and re-settlement. I have already made note of the issue of worker migration at other points throughout this work - in connection with glassmaking mythology, guild rules, the influence of the Venetian state, and the role of worker migration in the decline of the glass industry. This section examines the question of worker movement as an vehicle of technological transfer.

As observed in Venetian documentary sources, Muranese glassmakers in the Renaissance were found all over Europe. There are records of them throughout Italy, along the coast of the Adriatic, Spain, Germany, Austria, England, and the Low Countries. While in some cases the Venetian government consented to their movement (for example, the donation of *maestri* to the private, non-commercial glasshouse of Archduke Ferdinand), generally their relocation was frowned upon, as discussed previously. Here I wish to examine the circumstances surrounding the movement of Muranese workers to a particular European city (Amsterdam) in the late 16th and early 17th century. I have selected Amsterdam because there is sufficient documentary evidence in addition to a fair number of archaeological publications concerning Renaissance *facon de Venise* glass recovered from Dutch sites (Baart, 1987, 1988, 1991 for example). As a result, I was able to examine, sample, and analyze a large number of Dutch glass pieces (the complete analytical results are presented in Appendix A). This permitted the integration of a variety of sources of information in the same manner as was done for the Venetian material.

Before about 1575, the presence of glass in Dutch material culture was primarily as a luxury item with an unequal social distribution (Baart, 1991:423). Within the next 50 years there was a shift with respect to the appearance of glass in different levels of society. Baart connects this process to the changing role of

Amsterdam in the world-economy (1991:424). Trade contacts between Amsterdam and Venice also stimulated demand for glass as well as Italian majolica. This increased demand and available wealth had the effect of stimulating local industry and attracting foreign workers including glassmakers to the city.

At about this time, there are archival records which record the presence of Italian glassmakers in Dutch cities and towns such as Amsterdam, Antwerp, and Middelburg. The first known glasshouse in Amsterdam is noted in 1597 and is mentioned in connection with two Italian glassblowers. Another Italian, Verezlini, worked in Amsterdam before moving his glass business to London in 1573 (Baart, 1988:69). After 1600, the number and output of Dutch glasshouses working in the Venetian manner appears to have increased. The shop of Jan Soop, for example, operated from 1601 to the 1620's making vessel glass, mirrors, and beads. Soop is said to have employed some 80 families of glassmakers, both locals and relocated Italians.

In addition to archival references, glass recovered from archaeological contexts provides a good source of information on the output of the glass shops, the types of glass in fashion, and the level of demand. The large number of glass pieces excavated from Amsterdam is in stark comparison with the paucity of glass recovered from well-dated archaeological sites in Venice. Baart has written extensively on the number and types of glass recovered which will therefore only be summarized here. To give the reader some idea of scale, the single site of Kg-10 in Amsterdam (excavated by Baart and his colleagues in 1981) yielded over 50,000 samples of glass! The site itself could be securely dated to between 1592 and 1610 and was most likely a dump from a glasshouse somewhere in the city, perhaps that of Jan Soop (Baart, 1988:70).

The nature of the glass recovered from the Dutch excavations suggests a very diverse demand for glass. Along with over 30 major types of beads, there is a wide variety of vessel glass. In addition to the remnants of products, there is also a large amount of production waste including glass droplets, glass paste, and crucible fragments. The character of much of the vessel glass recovered is Italian (specifically Venetian) in style, and is typical of *facon de Venise* glass production in Northern Europe. For example, there are a great many fragments of *filigree* glass, incorporating both blue and white canes into a clear and colorless glass. There are examples of molded designs which were also common in Venice such as lion's masks placed as decoration on the glass vessel. "Ice glass" fragments were also recovered along with a few examples of *millefiore* glass (Baart, 1991:427-30).

Documentary records suggest that the Amsterdam vessel glass was of great value from a number of points of view. For example, one list notes that a Dutch piece was worth 14 "stuivers" while a German wine glass is listed as costing only 1 "stuiver". Moreover, the Dutch goverment apparently was proud of its emerging glass industry, giving pieces of "*vetro ghiacchio*" and "*vetro a fili*" away to visitors alluding to a different aspect of value (Baart, 1991:430). In many ways, these references to prices and prestige are very similar to the position and function of glass in Venice.

Over two dozen samples of glass recovered from Dutch excavations including Kg-10 were donated by Baart in 1993-95 to this work. These included fragments of vessels and beads along with waste fragments resulting from production processes. These were physically examined and their chemical composition determined. This, in turn, was supplemented with the physical examination of Northern *facon deVenise* objects, including some of supposed Dutch origin, in museum contexts.

The chemical compositions (as determined by SEM-EDS) of three examples of Dutch glass are presented below. While several samples of colored glass were studied, I have selected three samples of clear and "colorless" glass whose compositions can be compared to those of Venetian provenance presented in Chapter 8. Sample descriptions are given in Appendix A.

From this selection of glass analyses presented, it can be seen that the chemical composition of the Dutch glasses are very similar to either Venetian "common" or *vitrum blanchum* glass types. Because of the compositional similarities to the Venetian compositions, the working properties, et al., of the Dutch glass would have therefore been quite similar as well.

None of the Dutch samples had compositions that were comparable to the Venetian *cristallo* glass composition. This suggests two possibilities. One is that the Italian and Dutch glassmakers working in Amsterdam were not making *cristallo* glass. This may have been the case due to an inadequate supply of raw materials (Venice was loath to allow glassmaking materials, especially those for *cristallo*, outside of its territory) or a lack of technical ability. However, there are surviving

Table 9.1. The average chemical composition of "colorless" Dutch *facon de Venise* glass samples (in weight percents) with an analysis of Venetian *vitrum blanchum* (UA-7) glass offered as comparison.

Oxide	UA-N1	UA-N2	UA-N3	UA-7
SiO_2	66.7 (.7)	68.1 (.6)	67.8 (.6)	69.9 (.3)
Na_2O	14.1 (.4)	14.1	14.1 (.5)	12.0 (.4)
CaO	8.1	7.1	8.1	8.9
K_2O	3.8	3.6	2.8 (.4)	2.5
MgO	3.0	2.5	2.9 (.4)	2.7
Al_2O_3	1.9 (.3)	1.8	1.5	1.5
Fe_2O_3	0.5	0.8	0.7	0.6
MnO	0.5	0.6	0.6	0.5
Cl	0.8	0.8	0.9	1.0
SO_3	0.2	0.2	0.3	0.2
TiO_2	bd*	bd	bd	bd

* "bd" means that the oxide(s) in question were detected but in amounts below the minimum detection limits of the technique.

pieces of Dutch glass from the later 17th century which exhibit signs of gross deterioration and decay. While analyses of these pieces are not available, their appearance is consistent with that of crizzled *cristallo* pieces (ex; Charleston, 1993:127). Another possibility is that any *cristallo* glass made had long since deteriorated in the wet environment of the Kg-10 site.

I have found no evidence of the nature of the raw materials used in Dutch glassmaking other than a brief note by Baart that the glass, until about 1640, was made with sand and soda in the Venetian manner (1988:69). After this date, Baart says that the Dutch began to make green tinted "forest glass" in the German style using sand and potash along with the continuing production of the previous soda-based glass. This is an area that should receive additional work as it would help explain the manner in which the migrating Venetian glassmakers were able to either procure traditional raw materials or adapt to using novel ones.

All of the Dutch samples analyzed are consistent with a soda-lime-silica glass fluxed with a plant ash in the Venetian style. The glass is either tinted green in the manner of Venetian "common" glass (UA-N2) or else is colorless with slight tints as is seen with *vitrum blanchum* glass (UA-N1 and UA-N3). One exception was seen (sample UA-N24) which was a fragment of dark blue vessel glass fluxed primarily with potassium instead sodium which is more of a northern European tradition. The technology of the Dutch glass, in terms of colorants and opacifiers, is also consistent with that seen in Venetian samples.

In terms of material quality, as defined in Chapter 8, the Dutch samples and museum pieces examined are not notably different from average quality Venetian materials. Bubbles are again the primary defect and few stones and cord were found suggesting that steps were taken to ensure adequate homogenization and careful furnace maintenance. The skill with which the Dutch *facon de Venise* vessels were assembled, based on those that I was able to examine, is roughly in accord with those thought to have been made in Venice. The pieces are assembled with skill and are typically well-proportioned and centered in a manner consistent with quality glasswork. In a few cases, the pieces display very adept handling and working of the glass while hot, a particular Venetian specialty as described earlier. One type of object, the wineglass with a serpent stem (such as that depicted in the Spanish still life in Figure 7.19, see also Figure 9.1) was made in both Venice and in the Netherlands during the 17th century. Such pieces are extremely complicated to make and require the joining of six or more individual parts. Bill Gudenrath has made numerous replicas of these "dragon stem" goblets (see Tait, 1991:232-33) and I had the occasion to observe their manufacture several times. Each vessel took on average about an hour to make and involved a complicated series of heating, forming, and joining steps, any of which, if done improperly, could ruin the piece. In short, the overall quality of the Dutch *facon de Venise* pieces, in terms of material and assembly, is comparable to objects being made contemporaneously in Venice.

Baart has discussed the success of the Dutch glass industry in the 17th century n a more macroscopic sense. Archaeological excavations have uncovered *facon de Venise* glass, presumably made in places such as Amsterdam, in other Dutch urban centers. He concludes that glass from Amsterdam was sold not only in these cities but was also exported to other countries such as Germany and the New World (Baart, 1991:435). The success of the industry was also aided by the selling of glass to the upper and middle classes of Amsterdam. Ultimately, the growth of the Dutch glass industry can be seen as happening against the background of a world economy that was becoming centered around the Amsterdam at this time (Braudel, 1979:175-275). The rise of the Dutch glass industry with the role of Amsterdam in the world-economy has obvious parallels to the success of the Venetian industry, the invention of *cristallo* in response to consumer demand, and the dominant position of Venice in the 15th century world-economy.

In addition to the increasing importance of Amsterdam in the world-economy, what other factors affected the success of the Dutch glass industry? Clearly the technical expertise derived from the Venetian glass industry played a role. The Dutch were able to secure glassmaking technology based on Venetian practices through both the migration of craftsmen and the availability of glassmaking information in print. Furthermore, Baart has noted that the Dutch employed a "proto-capitalistic process of production" with respect to their glass industry (1991:436). Initially, a monopoly-based system was used whereby one shop was run more like a factory than a workshop. It employed all arriving glass workers and was thereby able to charge higher prices for its products. While this concept of factory-based production is very interesting in light of the information concerning the Venetian glass industry presented previously, Baart does not clearly elaborate upon it. A clearer indication of perhaps what he is alluding to can be found in another study concerning ceramic consumption and supply in early Amsterdam (Baart, 1990). The organization of another luxury pottery industry in the 17th century, that of Chinese-styled porcelain, is described as similar to "modern factories" (1990:80). This description is based on the mode of production which featured extensive division of labor, orientation towards exportation, relatively high technology, and the presence of a merchant/manager/owner.

The physical and chemical comparisons made thus far lead one to infer that the Venetian glassmakers who migrated to Amsterdam and the Low Countries were able to adapt to new working conditions successfully. It is also plausible to accept the fact that the Venetian glassmakers would have instructed their Dutch colleagues in terms of how to make and work Venetian-style glass. The fact that Antonio Neri made different and hard-to-prepare luxury glass compositions in the Venetian manner while living in Antwerp also suggests that such techniques were successfully transferred from Venice to the Netherlands. The combination of worker migration and the availability of glass recipes, either in print or through the knowledge of someone like Neri, resulted in a successful technological transfer. This success was further aided by the manner in which the Dutch glass industry was organized. It embodied many of the organizational features which I have already noted as present in a nascent form in the 15th and 16th century Venetian glass industry.

In considering these features - the relocation of Italian workers to Amsterdam, the availability of Venetian-styled recipes in print or through relocated workers, the compositional similarities between Venetian and Dutch *facon de Venise* glass, and the possible organization similarities in workshop and industrial organization - the Amsterdam industry appears, in many ways, to be a successful and closely modelled copy of the Venetian industry working in response to the newly emerging Dutch demand for luxury glass. In short, many of the demand and production characteristics of the Venetian luxury glass industry described in

Chapters 7 and 8 were also present in 17th century Amsterdam. This must have helped other places of glass production such as Amsterdam or England to effectively compete with Venice for a share of the luxury glass market.

CHAPTER 10

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

Overview of Dissertation research and General Conclusions

At the beginning of this dissertation, I outlined several goals essential to the successful presentation of my research. A primary objective was to examine the nature of technological change in the Renaissance Venetian glass industry. It had already been generally established in previous work that there was a significant transformation in the types of glass made which occurred in the middle of the 15th century. This was coupled with a sudden increase in new decorations and styles. The primary locus of these technological changes was identified as the Venetian luxury glass industry. Furthermore, this was seen to be directly connected with the appearance of a new glass composition, c. 1450, called *cristallo*. The question of "why" these transformations took place and the context in which they occurred was perceived by myself to be inadequately understood and at times burdened with reliance on outdated references and what I have described as material culture mythology.

Therefore, I wished to present a more comprehensive and balanced treatment of the nature of technological change in the Renaissance Venetian luxury glass industry. In order to do this, it was necessary to integrate material from a wide variety of sources. These included written material in the form of archival references, diaries, shipping records, and contemporary recipe books. In addition, pictorial representations of glass in Renaissance-era visual arts were considered. Finally, the use of chemical analyses and the thorough physical examination of museum and archaeological glass pieces were included.

In Chapter Two, previous approaches to the questions of technology and technological change were presented. All of these were oriented around the necessity of presenting the contextual aspect of a technology as opposed to outdated deterministic or decidedly evolutionary models. Several of these contributed ideas that were useful in the later development of my work. For example - the identification of relevant social groups in understanding technological change (Bijker, et al., 1987), the contributions of behavioral archaeology (Schiffer, 1992), and the role of the aesthetic in promoting invention and innovation (Smith, 1982; Kingery and Vandiver, 1986). Ultimately, however, none of these approaches was explicitly applicable and able thoroughly to address my questions concerning the changes in the Venetian glass industry.

Chapter Three through Five presented background material necessary in order to understand the social, archaeological, and economic context of the Renaissance Venetian glass industry. For the eventual development of my ideas concerning technological change, the material in Chapter Five was perhaps the most crucial as this created the context in which activities such as demand, production, and distribution could be examined. A world-economy was described with 15th century Venice emerging as the dominant and central city. This geographic, political, and economic position of dominance was an essential component of the changes in the Venetian glass industry. As the center of the new world-economy, Venice embodied several notable key features in its commerce and industry that were described as "proto-capitalist" in nature. From an industrial standpoint, these included a large degree of specialization, standardization and an increased industrial output. At the same time, Venice's industry had features of the older, artisan-based system with its guilds and extensive state involvement.

Moreover, while Venice was the center of the 15th century world-economy, there were significant changes with regards to newly emerging economic/social trends. These were presented as the "4-C's" - capitalism, consumerism, and conspicuous consumption. Luxury goods, such as Venetian glass, were described from several perspectives. Their role as an economic stimulant was considered. Socially, they were part of new societal attitudes which condoned their widespread purchase and ownership (cf. Goldthwaite, 1993). Finally, Venetian luxury glass was presented in a different form than seen in previous treatments of the subjects - that of a commodity. Considering Venetian glass as a commodity (versus a minor art form or some type of fetished museum object) permitted a wider perspective on the subject. Issues such as demand, production, and distribution emerged from the shadows as the central components of glass as material culture and technology.

Before the specific question of technological and material culture change in the Renaissance Venetian glass industry was addressed, the origins and pre-Renaissance aspects of the craft were presented. This became important for several reasons. Glassmaking, as is the case for many artisan-based industries, is relatively conservative. The dependence of one's livelihood on the ability to successfully and consistently make glass objects in a certain manner does not typically foster the environment for rapid change. How then to account for the perceived changes in the industry from c. 1450 onwards?

Examining the pre-Renaissance basis of the glass industry revealed that several of the features that would characterize Renaissance production existed centuries earlier. These included extensive guild rules and interaction, patterns of state involvement, well-developed trade in glass and glass-related materials and early product and labor specialization. Historically, and in opposition to general, accepted models of development, the Venetian glass industry did not immediately take over the position of dominant supplier of luxury glass after the destruction of the Near Eastern glass industry by Timur in 1400. Research by both Zecchin and Jacoby (1993) suggests that the years from 1400 to 1450 were instead marked by ups and downs in the Venetian glass industry. The rise of the Venetian craft cannot be explicitly traced to Levantine or Byzantine craftsmen merely moving to Venice or to basic models of influence and imitation. While certainly present to some degree, these elementary "diffusion" models mask the underlying complexity. In contrast, I have suggested that the rise of the Venetian glass industry c. 1450 was more of a self-catalyzed phenomenon spurred by economic and societal circumstances. Specifically, the resurgence in the production of luxury glass and the development of *cristallo* was primarily connected to Venice's position and role in the world-economy and emerging patterns of capitalism, consumerism, and conspicuous consumption. The changes noted in the industry came from inside Italian/Venetian society and are strongly connected to issues of demand. Therefore, instead of pre-supposing an endless supply of consumers, as past treatments have generally done, it became necessary to examine the question of demand and how this element facilitated the maturation of the Venetian glass industry. This represented a break with previous work.

Economic analysis only shows permissive, not effective cause (Goldthwaite, 1987). Merely noting that people of the 15th century were buying things because there was more money available does not explain why they bought something such as glass. To address the issue of effective cause, I began with a functional analysis - asking the question of the glass "what does it do?". The demand for glass was found to be rooted in a host of new and emerging behaviors, attitudes, values, and activities. These included new attitudes toward wealth, splendor, and the ownership of luxury goods. Along with these emerging ideas, new patterns of spending coupled with increased consumerism appeared. Circumstances in some levels of Renaissance society were forming in which the possession of commodities such as luxury glass was not only condoned but expected. The habits of the upper classes of Renaissance society were changing. This was seen in new dining and collecting behaviors, in which Venetian glass played a role. The importance of these new attitudes and behaviors on the part of the Renaissance consumer should not be seen as deterministic or one-sided. The actions of producers in stimulating demand and fashion was also considered.

These points are directly related to the more abstract question of "why glass" - why was glass, made from relatively cheap and common materials in demand? Furthermore, why Venetian glass? To answer this, a variety of sources (written, pictorial, and the glass itself) was considered and taken together as evidence. This approach was unique; most previous studies have traditionally used one source of information primarily while paying less attention to others. Glass, as a material, was seen as valued for several reasons - its ability to imitate other more costly materials, its ability to be worked into complex and elaborate shapes, and its inherent beauty.

In terms of the qualities desired by consumers of Venetian luxury glass, such objects were shown to have societal appeal on several levels. As described in the text, Venetian *cristallo* was made in imitation of rock crystal. *Cristallo* glass was shown to have different optical properties that set it apart from other types of glass compositions made in Venice (common glass, *vitrum blanchum*). Its clarity and colorlessness put it in a position where it was the "canvas" on which a wide variety of decorative techniques were applied. Demand for novel types of decoration, varied and increasingly complex glass shapes, and adherence to well-proportioned and symmetric forms were part of the general overall appreciation of the glassmaker's technical skill. This was observed in the physical examinations conducted in such features as skill of assembly, careful joining of parts, and the extreme thinness of some pieces. The physical examinations performed showed that the Venetian pieces were often of better quality than their *facon de Venise* counterparts in terms of both "material" and assemblage.

Once certain qualities and features relevant to the demand for Venetian glass were identified, the next step was to consider them in the larger context of production. This was undertaken with the intent of not only showing the economic and social context of glassmaking, but also to examine how consumer demands were met by the producers. Aspects of glass production have formed the large basis for much previous work in Venetian glass. Typically oriented around issues of provenance, primacy, and the technology of production, such studies have generally not dealt in depth with the social/economic context of glassmaking.

In addition to considering the role of the glassmakers' guild as a mediator between the workers and the state and as an instrument of state policy, other features of production organization were presented. I attempted to establish a basis for the importance of glassmaking in the Renaissance Venetian economy. The number of shops in operation and the number of workers employed was discussed. Trends in standardization, specialization (labor, tools, and products), codification of knowledge via recipe books, industrial experimentation, and trends towards greater complexity were all noted. These features led me to conclude that the 15th or 16th century Venetian glasshouse represented a transitional mode of production between older, "artisan-based" production and a later factory-style mode of production. Many of the features that would characterize "modern" 18th century ceramic production therefore had their roots in the glass and ceramic workshops of Renaissance Italy.

In relation to the overall economy of Venice, I presented economic data which suggests that the glass industry was not of prime economic importance to the city, as some connoisseur-oriented works would suggest. Other aspects of value besides monetary must be considered when assessing the importance of the industry. These included the glass industry as a tourist-attraction, as an object of civic prestige, and as part of a balanced economic base.

Addressing the social and economic context of production concluded with a discussion of the industry's relative decline in the 17th century. The state was portrayed as having both a stimulating and inhibiting role on the industry. The roots of decline can be found in several places - worker migration, loss of trade secrets via worker movement and printed material, and the ability of other regions to make *facon de Venise* glass of (sometimes) lesser quality while incorporating certain features of Venetian industrial organization in conjunction with other methods (monopolies, state support). All of these factors contributed to the successful transfer of glassmaking technology from Venice to other parts of Europe such as England and Amsterdam.

Besides the contextual aspects of production, issues central to the "materials science" of glassmaking were presented. This was done the intent of connecting glass compositions, physical analyses, and properties to the larger context of what qualities were expected by the consumer and the manner in which the producer attempted to fulfill these. A detailed study of the glass, both chemically and physically, coupled with other sources of information resulted in a more comprehensive and balanced picture while allowing for firmer support of conclusions this work attempts to prove.

Cristallo glass was shown to be significantly different both physically and compositionally from the other types of vessel glass being made in Renaissance Venice. This is a fact not often appreciated in the museum context (outside of the conservator's workroom). Evidence from chemical analyses and written sources showed that *cristallo* glass was much more complicated to make than other types of Venetian vessel glass. This greater complexity lies both in the nature of the raw materials required (all imported), the more elaborate steps of processing them (the purification of the soda ash being the most notable), and the more time and labor intensive steps related to fritting, melting, homogenization, and working. The manufacture of *cristallo* glass required greater technical sophistication. The result of all this extra work was a compositionally different glass with notable differences in colorlessness, homogeneity, and clarity - all qualities seen as desirable by the Renaissance consumer.

In addition to chemical analyses, extensive physical examinations following an established and detailed protocol were carried out. These shed light on the predominant material defects of Venetian glass relative to other glass types and the stages of the production process responsible for them. The information gathered from the physical examinations of Venetian glass in terms of its material supports several ideas put forth earlier about the quality of glass made in Venice and elsewhere. Overall, the general homogeneity in the Venetian glass pieces examined matches very well with the description of the glassmaking process given in the recipes. The careful steps of raw material selection and preparation in the making of *cristallo* and *vitrum blanchum* glass described in the recipes are also reflected in physical examination of the glass. In this manner, these two lines of evidence concerning the skill and care that went into the making of Venetian luxury glass support each other.

As described earlier, incorporating ideas from the "social construction of technology" paradigm suggested the need to identify relevant social groups, i.e. consumers and producers in this case. The final aspect of describing production was to examine the properties of Venetian and *facon de Venise* glass from the perspective of the purchaser and the producer. For instance, the viscosity and working properties of Venetian glass were properties of direct interest to the glassmaker. It was shown that Venetian *cristallo* had very "user-friendly" working properties that allowed it to be manipulated into complex shapes and thin-walled vessels. The same very workable composition, made from purified soda ash, had viscosity-temperature properties permitting it to have a greater degree of homegenization, bubble removal, and clarity than possible with other available glasses. On the basis of the viscosity models employed and the glass pieces examined, only 17th century English lead crystal was comparable in terms of working and optical properties to the Venetian *cristallo* glass.

Finally, attention was paid to aspects of distribution that were not typically addressed in previous studies. This included information regarding prices for Venetian luxury glass. Luxury glass was shown to be much more expensive than other glass types yet nowhere near the prices for other truly rare and luxurious items such as gold or silver plate. Moreover, the distribution of glass concerns more than just the movement of glass objects as commodities. The knowledge and technical skill associated with glassmaking and the glass workers themselves were also commodities that were also in demand and distributed throughout Europe. In this manner, the technology and skills associated with Venetian luxury glass production were able to be successfully transferred to production locales such as Amsterdam.

In conclusion, the technological changes that took place in the luxury glass industry of Renaissance Venice arose primarily out of perceived consumer demand and desires. Social and economic circumstances particular to Renaissance Italy, and Venice specifically, created an environment in which a technological development of a luxury such as *cristallo* glass could take place; i.e. technological changes followed in the wake of social and economic transformations. This conforms very well to observations made in the study of many other ceramic innovations - traditional ceramic manufacturing is fairly conservative and tends to a follower and not a leader of social change. At the same time, this view must be tempered with the fact that the glass industry of Venice incorporated many nascent organizational features that would become more common in the 18th and 19th century ceramic production.

In this manner, the invention of *cristallo* glass became a successful and influential innovation in the luxury ceramics market. The success of the *cristallo* glass, and Venetian luxury glass in general, therefore was not the result of a single individual or altered process. Rather, the incremental changes in glassmaking technology in response to consumer preference and demand over the course of centuries culminated in the manufacture of *cristallo* glass by Angelo Barovier, Nicolo Mozetto and other Muranese glassmakers. The success of the industry in the 15th and 16th centuries can be found in the fruitful interplay between consumers and producers, the manner in which the glass industry was organized, coupled with the skill of the Muranese glassmakers to make and work new glass compositions into a variety of desired glass objects.

Areas of Suggested Future Work

Even after finishing a project of this size and duration, there are still certain areas could bear additional study and investigation. Many of these were of great interest but were just simply outside the scale of this research. For the sake of presenting them briefly, I have organized them from essentially microscopic to macroscopic in perspective.

- The trace element work (ICP-AES) presented in Appendix A is the first time this technique has been applied to a large number of Venetian samples. It would be useful to have additional analyses done as a possible means to identify or distinguish between Venetian and *facon de Venise* glass, as a way to source raw materials (especially via lead isotope work), et cetera. In the same vein, it would be good to see additional work done with the optical properties of Venetian glass, perhaps as a means to distinguish *cristallo* from *vitrum blanchum* glass.
- There is a lot of potential work that could be done in relation to the history and lives of Renaissance glassmakers. Further clarifying the number of shops

and workers in existence would be a good start. More importantly, can anything be said about the personal lives of those making glass in Venice? Tracing the history of one family by expanding on Zecchin's archival work would be a place to begin.

- With this work and Verita's publications (1985, 1990, 1995, et al.), the chemical compositions of Venetian vessel glass is basically understood. The nature of the specialty glass industry (enamels, beads, mirrors) could bear further scrutiny. In addition, I feel examining the technological evolution of Venetian *cristallo* as it changed in response to different economic and social pressures would be worthwhile.
- The nature of technological transfer, with regards to glassmaking, to places such as Amsterdam and England is quite interesting. What was the role of worker migration and the printed word in influencing the development of English lead crystal for example? How did expatriate glassmakers adapt to the use of different raw materials? What were these? How effective were recipe books as a means of facilitating learning? Can the relation between glass technology and nascent scientific thinking and activity be better clarified?
- Finally, there are ways in which to connect the past practices of glassmaking in Venice with the present. Glass is still made there in a very traditional fashion. This could possibly be the subject of an ethnographic project. Moreover, I have presented the concepts of material culture mythology with

respect to Venetian glass. What more can be said about this? What of the role that glass and other luxury goods play in the modern museum environment? What are the functions of Venetian glass in a modern-day museum?

Certainly, my work will not be last word on the subject. It is hoped that suggestions such as those above will broaden the scope of investigation and result in new approaches to the question of technological and material culture change.

APPENDIX A

Chemical and Optical Studies of Renaissance Venetian and *Facon de Venise* Glass

Introduction

This appendix presents the procedures, results, and comments for all of the chemical and optical analyses of Renaissance-era glass samples performed in this research. These results are organized according to the type of analysis. Three primary characterization techniques were utilized: SEM-EDS and WDS, ICP-AES, and optical testing (percent transmission vs. wavelength). The first provided a semi-quantitative and quantitiative analysis of the glass' composition, the second gave primary, secondary, and trace element information, and the third yielded information about the optical qualities of the different glasses examined.

Before these characterization techniques and the accompanying results are presented, some discussion of the samples used for the analyses is required. There were three different general sources for the samples analyzed here. The majority of the glass samples came from archaeological sites in either the Venetian lagoon or in Amsterdam. A smaller portion were donated to this study from the private collection of Rosa Barovier Mentasti of Venice, Italy in 1994. Finally, a very small number of samples were removed from glass fragments in different museum collections with the proper permission. No fragments were removed from whole vessels in museum collections. As the bulk of the samples are from excavations, the next section provides information about the different sites which yielded glass for this study.

Archaeological Samples

Samples were provided from archaeological excavations in both Venice and Amsterdam. All samples were donated to this study between 1993 and 1996.

Venetian Excavations

The difficulties associated with archaeology and the recovery of glass samples in the Veneto has already been discussed in Chapter 3. To review - The geography of Venice and its lagoon makes the recovery and accurate dating of glass samples quite difficult. All of the sites which provided samples for this work are or were under water for a substantial period of time. The combined effects of tides, floods, and human activity have introduced a whole host of formation processes which make interpreting the sites difficult. For glass, these problems are accentuated by the corrosion and sample preservation questions this environment creates. Quite a few of the samples excavated are at least somewhat degraded by aqueous corrosion in the intervening centuries between deposition and recovery. This especially creates a problem for the Venetian *cristallo* glass which is, by nature, only quasi-stable with respect to the effects of "crizzling", "glass disease", and other weathering mechanism (Brill, 1975). The dating of samples can be problematic at times, as well, due to the poor stratigraphy of some of the sites. Dating of the samples was done on the combined basis of stratigraphy, stylistic comparison of the pieces, comparison of the chemical composition with other fragments of more secure dating, as well as other associated debris (coins, ceramics, metalwork).

As outlined in Chapter 3, there were three primary sites which were sources for the samples analyzed in this work. These sites were discovered and excavated primarily by Ernesto ("Tito") Canal, an Italian archaeologist living in Venice. The glass pieces found by Canal represent the majority of Venetian glass that has been chemically analyzed and published elsewhere (cf. Verita, 1985; Verita, 1990; Verita and Toninato, 1990). These three sites along with others that yielded glass and ceramic fragments have been detailed in earlier publications (Gasparetto, 1979; Lazzarini and Canal, 1983:22-25; Verita, 1985). Additional information was provided by unpublished site reports for the City of Venice and personal communications with Canal. The three main sites are:

1. San Leonardo in Fossa Mala: This site was excavated by Canal in 1968 and again in 1985. The site is now a submerged island and was formerly the location of a monastery between the 11th and 14th centuries. In 1348, it was abandoned and it later became the burial ground for numerous plague victims. Glass from this site therefore dates to between 11th and 14th centuries.

2. San Ariano: This area was discovered and excavated by Canal in 1980. This island corresponds to the medieval site of Costanziaca and was situated near Torcello in the eastern part of the Venetian lagoon. It contains the remains of the monastery of San Ariano founded in 1160. Only one sample (PE-149) came from this site and it was dated to the middle-13th century on the basis of a coin with the likeness of Doge Renier Zeno (1253-1268) found in the same context.

3. Fusina-Marghera: This site was the source for the majority of the samples examined in this work. It was discovered in 1960 and excavated in the following years before it was destroyed by construction activity. The site was at the embankment of the Brenta River where it empties into the lagoon. This embankment was constructed between 1360 and 1372 and then again in 1433 and 1439. Its purpose was to divert the river and to prevent the deposition of silt into the lagoon which would impede ship navigation. The site is located about 3-4 km north of the main city of Venice near the modern day city of Mestre (see Figure 3.4). The original embankment was constructed from clay but it was continually reinforced with solid waste from Venice in the 15th and 16th centuries. A large portion of this waste came from the ceramic and glass workshops of Venice and Murano. The embankment was abandoned in 1610 with the construction of the Canale Nuovissimo which provides a terminus date for the materials found at the site. Mr. Canal estimates that about 99% of the material found here is datable to the 15th or 16th centuries while the rest comes from prior centuries.

Amsterdam Excavations

In addition to analyses of Venetian glass, studies were done of *facon de Venise* glass made presumably in Amsterdam and excavated there. These samples were donated by Dr. Jan Baart and his colleagues at the Afd. Archeologie in Amsterdam between 1993 and 1995. The glass came from two sites within the city of Amsterdam, WLO-155 and Kg-10, which were excavated in 1981. Additional information about these sites and the glass found has been published by Baart (1988, 1991).

Material from both sites dates to the very end of the 16th century and the beginning of the 17th. Due to construction activity, the one site (Kg-10) was covered in 1610 by about four meters of dirt. The pre-1610 date was also confirmed on the basis of other associated material. This time period corresponds to the establishment of glasshouses operating in the Venetian tradition of manufacture and often staffed by expatriate glassmakers from Murano. One site (Kg-10) had no structural features associated with it making it likely that it was a dump from a glasshouse in the city (Baart, 1988:70). It is possible that this site represents debris from the workshop of Jan Soop, the owner of the first glasshouse in Amsterdam known to make beads. Material from both sites includes glass that has stylistic traits identical to Venetian products of the time and is therefore glass made in Amsterdam in the Venetian style i.e. *facon de Venise*.

SEM-EDS Studies

The majority of chemical analyses in this work were done by using SEM-EDS at the University of Arizona. This section presents the results of these analyses along with other information. This section is organized in the following manner:

a. experimental procedure followed

b. sample description and comments on analyses

c. results of analyses broken down by type of glass:

a. <u>Experimental procedure</u>

The samples examined using SEM-EDS were analyzed in the following manner: A small fragment of glass was removed from the primary sherd so as to expose an unweathered fracture surface. This sample was then mounted in epoxy resin. The sample was exposed by light grinding and then polished to a mirror finish using SiC paper (320, 400, 600 grit), diamond paste (6 micron) and a CeO suspension. Once polished, the sample would be carbon coated to prevent charging.

Sample analyses were carried out at the University of Arizona's Arizona Material Laboratory. A scanning electron microscope (JEOL JSM-840A) with an energy dispersive spectrometer (Tracor Northern TN5502) was used. Typical operating conditions were: 22kV accelerating voltage, dead time of between 20 and 30% by using a probe current of about 10^{-10} amps, and an acquisition time of 180 seconds. A standard ZAF correction program was used to obtain the quantitative composition of the sample in weight %'s of oxide present. Five analyses of each sample were done; the average and standard deviation was calculated and recorded in a QuattroPro® spreadsheet.

The accuracy of the SEM-EDS was checked by using common glass standards developed specifically for ancient glass studies by Corning, U.S.A. and supplied to me by Dr. Robert Brill. Corning Standard B was closest to a typical Venetian composition and was used most frequently. The agreement between the recommended compositions of the standards and what was obtained from my SEM-EDS work was typically within 5%. That is, for example, if the recommended amount of Na_2O was 15% in a standard, the results obtained with the SEM-EDS equipment were typically within 5% of this value - 15% +/- 0.75%. The agreement between measured values and the recommended values was best for Si and heavier elements, in general. The lightest elements, such as sodium and magnesium tended to deviate the most from the recommended composistions. The results obtained here are similar to what has been reported elsewhere for similar analytical techniques (Verita, et al., 1994). The minimum detection limit of the instrument was shown to be about 0.2 weight %. It was possible to detect oxides in amount below this but the results were interpreted as only indicating that the oxide was probably present. Oxides detected but in amounts below the minimum detection limits of the equipment are noted with the abbreviation "bd" (barely detectable) in the tables. Oxides not detected at all are noted as "nd" (not detected) in the tables.

b. SEM-EDS sample descriptions and comments on analyses

Provided below is a brief description of the sample analyzed along with comments on the subsequent analyses. The data from the actual analyses is provided in part "c" which follows after this. The abbreviation "SLS" refers to a soda-lime-silica glass. Unless noted, all Venetian samples analyzed were from Fusina-Marghera and should be assumed to date to the latter 15th or 16th century. Dutch samples were either from WLO-155 or Kg-10 and date to the late 16th or early 17th century. All samples are from vessel glass sherds unless otherwise noted.

Glass from Venetian Sites
Collected 1993

UA5 Bead fragment

- clear and colorless glass: "common" glass; SLS type; higher amounts. of Fe_2O_3 and MnO; traces of P_2O_5 and TiO_2.
- blue glass: cobalt colored SLS type; Fe and Pb present in substantial amounts; higher than average K_2O (5.1%) .
- opaque red glass: SLS type colored with iron and copper; PbO present also(5.2%).
- white glass: Si-Pb glass type with 50.8 % SiO_2; Pb-Sn ratio about 2-1.

UA6

- clear and colorless glass: SLS and probably *vitrum blanchum* type; low Fe and Mn contents (0.4% each) and CaO content higher than cristallo composition.
- blue glass: SLS type; colored with CoO (0.3%); also Pb present and higher than average Fe and Mn.
- white glass: Pb-Si glass (25.4% and 42.1%); Pb-Sn ratio about 2-1; very low Fe and Mn (0.2%).

UA7

- clear and colorless glass; probably *vitrum blanchum* type; with low Fe and Mn and higher CaO content.

UA8

- sample of "cogoli"; over 99% SiO_2 with next largest components being Sn and Mg.
  Also analyzed via WDS-EPMA in Venice and ICP-MS at off-campus site.

UA9

- red glass from filigree cane; colored with Fe and Cu.

UA10

- *chalcedony* glass; SLS type with cristallo composition (low CaO and MgO); small amount of CuO (0.2%) present.

UA12

- clear and colorless glass: SLS type with "*cristallo*-like" composition (low MgO but CaO not as low as normally seen - 7.1%).
- blue glass: composition almost same to clear and colorless glass but with CuO as colorant (1.2%).

UA13 Bead fragment

- clear and colorless glass: SLS type with "common" composition.
- blue glass: SLS type with "common" composition and only 0.7% Fe_2O_3 as possible colorant found.

- opaque red glass: Si-Pb type; Fe and Cu as colorants.
- white glass: Si-Pb glass with Pb-Sn ratio about 2-1.

UA14

- light blue glass; SLS type with only 0.1% CuO.

UA15

- clear and colorless glass: perhaps *vitrum blanchum* but with high (1.4%) MnO and Al_2O_3 (1.7%).
- white glass: Si-Pb glass; 2:1 ratio between Pb and Sn; low Fe and Mn contents.

UA16

- *cristallo* glass; low Mn and Fe contents; elevated SiO_2, Na_2O and reduced CaO, MgO contents.

UA17

- "common" glass of SLS type; compare with UA16 for good contrast between. 2 basic types.

UA18

- clear and colorless glass with yellow tint: SLS type with high (13%) CaO content; higher Fe and Mn content.

UA20

- dark blue glass: SLS type with Fe, Mn present at 1.1% and 1.4%; Cu and Co present as colorants; presence of Pb and Sn also; analysis is very similar to analysis of blue glass reported in Brill (1973).

UA21

- clear and colorless glass: SLS type with "common" or *vitrum blanchum* composition; high (1.8%) MnO content; perhaps responsible for grey color or added to offset iron tints.

Venetian Glass
Collected 1994

PE-41

- clear and colorless glass; *cristallo* composition; high (18.4%) Na_2O and low (3.6%) CaO; low iron and manganese amounts also consistent with "cristallo" recipe; compare results with those of with UA-16.
  Sample removed from sherd at Museo Vetrario, Murano, Italy.

PE-43

- clear and greenish colorless glass; "common" glass composition; compare with UA-17.
  Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-52

- clear and colorless glass; *vitrum blanchum* composition; 0.6 % SnO_2 present.
  Also analyzed via WDS-EPMA in Venice and ICP-MS at off-campus site.
  Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-54

- clear and colorless glass; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice and ICP-MS at off-campus site.
- white glass: Si-Pb glass with Pb-Sn ratio about 2-1.
  Samples donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-55

- clear and colorless glass with light. yellow tint; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice and ICP-MS at off-campus site.
  Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-92

- clear and grayish-colorless glass; similar to *vitrum blanchum* composition but with very high (1.5%) MnO content responsible for grey tint.
  Sample removed from sherd at Museo Vetrario, Murano, Italy.

PE-97

- clear and colorless with *vitrum blanchum* composition; low iron content but with appreciable and variable P_2O_5 content.
  Sample removed from sherd at Museo Vetrario, Murano, Italy.

PE-148a

- *chalcedony* glass; analyses done on both polished fracture surface and unpolished surface region;analysis of polished region had composition indicative of the use of a "cristallo" frit or base composition (high SiO_2 and Na_2O and reduced CaO, MgO); glass sample appeared to be made of different layers of colored glass; thicker underlying glass layer was orange-yellow with Fe_2O_3 seen as colorant; analysis of lighter colored streak in glass revealed traces of BaO, CuO, and CoO; analysis of unpolished surface showed layer of glass with elevated SiO_2, Al_2O_3 content and reduced Na_2O content (< 4%); surface appearance showed scales, pits, and "furrows" in the glass (photos taken); the appearance of the surface is streaked with different colors ranging from light purple to light greenish yellow; analysis for colorants showed presence of CuO as well as traces of BaO, CoO, NiO, CrO.
  Sample of PE-148 (a) also submitted for trace element analysis via ICP which did not reveal any more significant information.

PE-148(b)

- chalcedony glass; "*cristallo*" base composition; CuO present as colorant along with Fe, Mn and occasional Co and Ba.

PE-148 (c)

- chalcedony glass; "*cristallo*" base composition; CuO present (.23%) along with substantial MnO (1.5%); CoO detected as well.

PE-149

- clear and colorless glass; early *vitrum blanchum* type composition; low in iron and manganese (< 0.3%). Sample was found at San Ariano and dates to mid-13th century.

PE-153(a)

- colorless glass; *vitrum blanchum* composition; high in CaO (10.6%).

PE-153(b)

- colorless glass; *vitrum blanchum* composition; high in MnO (1.3%).

PE-154(a)

- colorless glass; *vitrum blanchum* composition; high in Fe_2O_3 and MnO (1.4% and 2.3%).

PE-154(b)

- colorless glass; *vitrum blanchum* composition.

PE-155

- colorless glass; *vitrum blanchum* composition.

PE-156

- colorless glass; *vitrum blanchum* composition.

Glass from Amsterdam sites
Collected 1993

UA-N1

- clear and colorless glass: SLS with composition similar to *vitrum blanchum*; traces of P_2O_5 higher than that seen for Venetian types.
- blue glass: SLS glass, cobalt colored with 1% Fe and NiO and As_2O_3 present (0.4 and 0.2 % respectively).
- white glass: Si-Pb glass with Pb-Sn ration of 1:1.

UA-N2

- SLS glass with greenish tint; Fe_2O_3 present at 0.8%.

UA-N3

- clear and colorless glass of SLS type similar to *vitrum blanchum*.

UA-N4 Bead fragment

- opaque red glass: colored with copper and iron; PbO present (3.8%).

UA-N5 Glass cane fragment

- clear and colorless glass: SLS type with P_2O_5 present (0.3%); lower than average CaO (5.7%).
- white glass: Si-Pb type; low CaO (4.1%); Pb-Sn ratio approx. 1:1.
- blue glass: SLS type with PbO present and Co colored.

UA-N6 Glass cane fragment

- clear and colorless glass: SLS type; "common" glass.
- white glass: Si-Pb glass; Pb-Sn ratio about 2:1.

UA-N8 Glass paste fragment

- clear and colorless glass: SLS type of "common" or *vitrum blanchum* composition; higher (0.6%) TiO_2 amount.
- blue glass: SLS type; colored with CoO; Fe_2O_3 present (1%) as well as PbO (1.7%) and NiO (0.3%).
- white glass: Si-Pb type; ratio of Pb-Sn is 13:9.

UA-N9 Glass paste fragment

- SLS type; only Fe present as colorizer; PbO present (6%).

UA-N13 Bead fragment

- opaque red glass: SLS glass with 9.7% PbO; Fe and Cu as colorants.
- white glass: Si-Pb glass with Pb-Sn ratio 3:1.

UA-N14 Bead fragment

- blue glass: SLS present; 0.4% CuO; PbO present (8.3%).
- white glass: Si-Pb glass with ratio of Pb-Sn 2:1.

UA-N15 Bead fragment

- blue glass: Cu and Fe as colorants; PbO present (6.7%) as well as SnO_2 (4%).
- white: Si-Pb glass with Pb-Sn ration approx. 2:1.

UA-N16 Bead fragment

- blue glass: SLS type with CoO and CuO present as well as PbO and SnO_2. somewhat similar to UA-N16 except that this one has Co present.

UA-N17 Bead fragment

- clear and colorless glass: SLS type with higher than average (0.9%) MnO_2.

Glass from Amsterdam Sites
Collected 1994

UA-N19

- clear and colorless glass; SLS type similar to *vitrum blanchum* and with high Na_2O (15.5%) and low MnO.
  Also analyzed via ICP-MS at off-campus site.

UA-N20

- clear and colorless glass; SLS type similar to *vitrum blanchum* with higher phosphorus content (0.3%).
  Also analyzed via ICP-MS at off-campus site.

UA-N21

- clear and colorless glass; SLS type similar to *vitrum blanchum* with higher phosphurus content (0.3%).
  Also analyzed via ICP-MS at off-campus site.

UA-N23

- light blue glass; SLS type with very small amount of CuO and CoO present.
  Also analyzed via ICP-MS at off-campus site.

UA-N24

- dark blue glass; potassium-lime-silica glass; 10.4 % K_2O and 1.7% Na_2O; 15.5% CaO; small amount of CoO as colorant.
  Also analyzed via ICP-MS at off-campus site.

c. <u>Results of SEM-EDS analyses</u>

Presented in Tables A.1 to A.9 below are the results of the SEM-EDS compositional analyses of the glasses given to this study. Samples are identified by the labels used in the preceding section and the data is given in terms of weight percent. Standard deviations are given in brackets only when greater than 0.2 weight %. The abbreviation "bd" means that the oxide in question was detected but was below the minimum detection limits of the instrument (about 0.2 weight %) and may not be reliable. The abbreviation "nd" means that the oxide in question was not detected. The results are divided according to the type of glass: "colorless", blue, opaque red, opaque white, and special samples. "Colorless" glass, by far, represents the largest group of samples analyzed via SEM-EDS. This category includes glass that is truly color-free along with glass having slight colored tints (green, grey, and yellow are the most common) resulting from the presence of impurities and presumably not due to deliberate additions of coloring oxides.

Table A.1. SEM-EDS Analyses of "Colorless" Venetian Glasses

Oxide \ Sample	UA-5	UA-6	UA-7	UA-12	UA-13	UA-15	UA-16	UA-17	UA-18	UA-21
SiO_2	65.9 (.5)	67.9 (.5)	69.9 (.3)	69.5 (.5)	65.6 (.9)	67.0	75.1 (.6)	67.7	66.9 (.7)	64.8
Na_2O	13.7	14.3	12.0 (.4)	15.2 (.3)	15.0 (.4)	13.1 (.3)	13.7 (.3)	13.8	10.3 (.3)	13.9
CaO	10.2	9.0	8.9	7.1	10.3	9.7	4.6	8.8	13.0 (.3)	9.7
K_2O	3.0	2.4	2.5	4.1	2.5	2.7	2.3	3.6	2.1	3.0
MgO	3.0	3.1 (.3)	2.7	1.0	3.1 (.3)	2.8	1.3 (.3)	1.9	3.2 (.3)	2.8
Al_2O_3	1.6 (.4)	1.2 (.3)	1.5	1.0	1.3 (.3)	1.7	1.1	1.6	1.6	1.6
Fe_2O_3	.7	.4	.6	.3	.6	.7	.3	.7	.7	.8
MnO	.6	.4	.5	.6	.4	1.4	.6	.9	.8	1.8
Cl	.7	.8	1.0	1.1	.6	.8	.8	.9	.8	.8
SO_3	.5	.4	.2	.2	.4	bd	.2	1.0	.4	.7
TiO_2	bd*	bd	bd	bd	bd	bd	bd	bd	bd	bd
P_2O_5	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd

*detected, but at minimum detection limits

Table A.1. SEM-EDS Analyses of "Colorless" Venetian Glasses--(Continued)

Oxide \ Sample

	PE-41	PE-43	PE-52	PE-54	PE-55	PE-92	PE-97	PE-149	PE-153a	PE-153b
SiO_2	70.7 (.6)	67.8	68.0 (.5)	67.6 (.7)	67.8 (.3)	69.2 (.3)	67.8 (.7)	71.7 (.8)	66.8 (.5)	66.8 (.6)
Na_2O	18.3 (.3)	11.3	13.8 (.4)	14.0	12.4	12.3 (.5)	15.2 (.4)	12.2 (.4)	12.5 (.5)	12.6
CaO	3.6	11.4	8.4	9.2	9.3	7.8	7.7	9.0	10.6 (.3)	9.7
K_2O	2.9	2.2	2.4	2.8	4.5	4.5	4.2	1.9	2.4	2.2
MgO	1.1 (.3)	3.0	3.1 (.3)	3.1 (.4)	2.8	1.3	1.2	2.6	4.0 (.4)	3.1 (.3)
Al_2O_3	.8 (.4)	1.7	1.6	1.1 (.4)	1.3	.9	1.2	.8	1.2	2.0 (3)
Fe_2O_3	.4	.7	.6	.4	.4	.7	.3	.3	.5	.7
MnO	.3	.6	.5	.4	.4	1.5	.5	.2	.6	1.3
Cl	.9	.6	.6	.7	.7	.9	1.2	.7	.6	.6
SO_3	.4	.3	.6	.4	.2	.2	.2	.3	.6	.6
TiO_2	bd*	bd	.2	bd	bd	bd	bd	bd	bd	bd
P_2O_5	bd	.2	.2	.3	.3	.8	.6	.3	.2	.4

*detected, but at minimum detection limits

Table A.1. SEM-EDS Analyses of "Colorless" Venetian Glasses--(Continued)

Oxide \ Sample

	PE-154a	PE-154b	PE-155	PE-156
SiO_2	67.5 (.4)	68.2 (.4)	69.5	69.1 (3)
Na_2O	12.0 (.5)	11.9	11.9	12.6 (.3)
CaO	8.6	7.7	10.4	9.8
K_2O	4.2	2.2	1.9	1.8
MgO	2.9	1.4	3.2	3.4
Al_2O_3	1.9	3.6	1.0	1.3
Fe_2O_3	.7	1.4	.3	.3
MnO	1.0	2.3	.3	.3
Cl	.6	.8	.9	.7
SO_3	.3	.2	.4	.4
TiO_2	bd*	bd	bd	bd
P_2O_5	.3	.3	.2	.3

*detected, but at minimum detection limits

Table A.2. SEM-EDS Analyses of White Venetian Glasses

Oxide \ Sample

	UA-5	UA-6	UA-13	UA-15	PE-54
SiO_2	50.8 (.2)	42.1 (.7)	45.6 (1.4)	46.5 (1.1)	46.1 (.7)
Na_2O	11.8 (.4)	10.2	11.5 (.5)	12.6 (.3)	10.8 (.6)
CaO	7.5	4.0 (.3)	5.9	3.0	4.3 (1.3)
K_2O	2.1	1.4	3.2	1.6 (.3)	1.6
MgO	2.4	1.4	2.1 (.4)	1.3	2.4
Al_2O_3	1.0	.7	.8	1.3	1.8 (.5)
Fe_2O_3	.8	.2	.4	.4	.3
MnO	.3	.2	.2	.2	.2
Cl	.7	.8	.7	.9	.6
SO_3	bd*	bd	bd	bd	bd
TiO_2	bd	bd	bd	bd	bd
P_2O_5	bd	bd	bd	bd	bd
SnO_2	8.1 (2.2)	13.6 (.8)	10.4 (1.0)	10.9 (1.9)	11.8 (1.6)
PbO	14.3 (.6)	25.4 (.6)	19.2 (1.2)	21.3 (.6)	19.2 (1.0)

*detected, but at minimum detection limits

Table A.3. SEM-EDS Analyses of Blue Venetian Glasses

Oxide \ Sample

	UA-5	UA-6	UA-12	UA-13	UA-14	UA-20
SiO_2	64.5 (.8)	69.0 (.5)	69.0 (.6)	65.4 (.4)	66.4 (.5)	64.8 (.5)
Na_2O	11.9 (.5)	13.3 (.4)	6.9	9.9	9.6	13.3 (.4)
CaO	9.3	8.0	6.9	9.9	9.6	8.4
K_2O	5.1	2.7	4.0	2.4	2.8	2.5
MgO	3.0 (.4)	2.7	.9	3.3	3.0	3.3
Al_2O_3	1.2 (.4)	1.4	1.0	1.4	1.4	1.6
Fe_2O_3	1.3	1.0	.4	.7	.6	1.1
MnO	.6	.8	.6	.2	.5	1.4
Cl	.7	.4	1.0	.8	.7	.6
SO_3	bd*	bd	bd	.7	bd	bd
TiO_2	bd	bd	bd	bd	bd	bd
P_2O_5	bd	bd	bd	bd	bd	bd
CuO	-	-	1.2	-	bd	.3
CoO	.7	.6	-	-	-	.3
PbO	1.7	.6	-	-	-	2.5
SnO_2	-	-	-	-	-	1.7

*detected, but at minimum detection limits

Table A.4. SEM-EDS Analyses of Red Venetian Glasses

Oxide \ Sample	UA-5	UA-9	UA-13
SiO_2	58.1 (.5)	69.0	58.4 (.4)
Na_2O	13.6 (.4)	12.3	13.9
CaO	7.6 (.3)	8.9	7.7
K_2O	2.6	3.7	2.6
MgO	2.6	2.2	2.9
Al_2O_3	1.3	1.2	1.2
Fe_2O_3	4.9	.4	3.1
MnO	.4	.3	.3
Cl	.7	.9	.7
SO_3	bd*	bd	bd
TiO_2	bd	bd	bd
P_2O_5	bd	bd	bd
CuO	3.0	.7	.8
PbO	5.2	-	8.4

*detected, but at minimum detection limits

Table A.5. SEM-EDS Analyses of "Special" Venetian Glasses

Oxide \ Sample

	UA-8	UA-10	PE-148a	PE-148b	PE-148c
SiO_2	99.2 (.3)	72.8 (.5)	72.8 (.5)	68.5	69.7
Na_2O	-	16.4	16.9	16.3 (.4)	17.9 (.4)
CaO	-	4.7	3.0	4.8 (.3)	3.2
K_2O	-	3.6	2.7	4.1	3.3
MgO	.2	1.6	1.2	1.5	1.0
Al_2O_3	.3	1.5 (.4)	1.7	1.5 (.4)	1.2
Fe_2O_3	bd*	.5	.3	.7	.5
MnO	-	.3	bd	.7	1.5
Cl	-	.5	.9	.5	.5
SO_3	-	.5	.3	.5	.7
TiO_2	-	-	bd	bd	-
P_2O_5	-	-	bd	.2	-
SnO_2	.2	-	-	-	-
CuO	-	.5	bd	bd	bd

*detected, but at minimum detection limits

Table A.6. SEM-EDS Analyses of "Colorless" Amsterdam Glasses

Oxide \ Sample

	UA-N1	UA-N2	UA-N3	UA-N5	UA-N6	UA-N8	UA-17	UA-N19	UA-N20	UA-21
SiO_2	66.6 (.7)	68.1 (.6)	67.8 (.6)	68.7	67.8 (1.2)	66.2 (.9)	66.6 (.8)	64.6 (.3)	67.7 (.4)	66.8 (.4)
Na_2O	14.1 (.4)	14.1 (.3)	14.1 (.5)	14.4	13.6	13.7 (.8)	13.2 (.5)	15.5 (.3)	11.8	14.6
CaO	8.1 (.3)	7.1	8.1	5.7	9.0 (.3)	9.8	9.4	8.2	9.4	9.6
K_2O	3.8	3.6	2.8 (.4)	4.2	3.5 (.4)	3.8	3.5	4.7	5.0	4.0
MgO	3.0	2.5 (.3)	2.9 (.4)	2.2	2.2	2.2 (.4)	2.1 (.4)	3.4	2.5	2.3 (.3)
Al_2O_3	1.9 (.3)	1.8	1.5	2.2	1.1	1.2 (.7)	1.0	1.4	1.2 (.3)	.8
Fe_2O_3	.5	.8	.7	.7	.5	.6	.4	.5	.5	.3
MnO	.5	.6	.6	.6	.7	.6	.9	.3	.7	.3
Cl	.8	.8	.9	.7	.9	.6	1.0	.9	.7	1.0
SO_3	.2	.2	.3	.3	.5	.7	.5	.1	.1	.2
TiO_2	bd*	bd	bd	bd	bd	bd	bd	bd	bd	bd
P_2O_5	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd

*detected, but at minimum detection limits

Table A.7. SEM-EDS Analyses of White Amsterdam Glasses

Oxide \ Sample

	UA-N1	UA-N5	UA-N6	UA-N8	UA-N13	UA-N14	UA-N15	UA-N17
SiO_2	43.0 (1.3)	49.6 (.3)	44.6 (.4)	49.6	50.0 (.3)	51.4 (.7)	52.2 (1.0)	46.7 (1.5)
Na_2	12.3 (.4)	12.0 (.3)	12.3 (.3)	11.8 (.4)	12.2 (.6)	11.4 (.4)	11.5 (.4)	11.3 (.8)
O	5.2 (.3)	4.1	6.5	8.7 (.9)	5.1	6.2 (.5)	6.4 (.3)	7.2 (.5)
CaO	2.5 (.4)	3.0 (.3)	2.5	3.2	3.2	3.2 (.3)	1.9	2.2
K_2O	2.5 (.4)	2.0 (.3)	1.8	2.1 (.3)	2.2 (.3)	2.5 (.3)	2.5	1.7
Mg	1.5 (.3)	1.7 (.3)	.6	.9	1.5 (.3)	1.6 (.4)	.9	.7
O	.5	.7	.3	.4	.6	1.0	.5	.2
Al_2	.2	.4	-	.2	.2	.3	.2	-
O_3	.8	1.0	1.12	.9	1.0	.6	.8	1.1
Fe_2	bd*	bd	bd	bd	bd	bd	bd	bd
O_3	bd	bd	bd	bd	bd	bd	bd	bd
Mn	bd	bd	bd	bd	bd	bd	bd	bd
O	16.7 (.9)	14.5 (.3)	20.7 (.5)	13.4 (.4)	18.3 (.5)	14.0 (.6)	14.7 (1.7)	16.1 (2.3)
Cl	15.0 (2.2)	11.0 (.4)	9.4 (1.8)	8.7 (.6)	5.8 (.9)	7.6 (.9)	8.0 (1.3)	11.8 (3.5)
SO_3								
TiO								

*detected, but at minimum detection limits

Table A.8. SEM-EDS Analyses of Blue Amsterdam Glasses

Oxide \ Sample

	UA-N1	UA-N5	UA-N8	UA-N9	UA-N14	UA-N15	UA-N16	UA-N23	UA-N24
SiO_2	67.3 (.7)	67.7 (.3)	66.7 (.9)	62.8 (.4)	62.7 (1.0)	61.3 (.7)	58.2 (1.9)	64.2 (.6)	65.1 (1.3)
Na_2O	12.8 (.7)	13.3 (.3)	12.2 (.8)	12.5	12.0 (.3)	11.1 (.3)	12.8 (.6)	13.9	1.7
CaO	7.9	5.2	8.7	7.6	6.5 (.3)	7.8 (.3)	9.5 (.4)	9.0	15.5 (.8)
K_2O	4.1	4.3	3.6	4.6	3.5	3.1	3.3 (.3)	4.8	10.4 (.5)
MgO	2.9	3.2	2.0 (.4)	2.6 (.3)	2.7	2.6 (.3)	1.9	2.3 (.3)	2.6
Al_2O_3	1.8	2.5	1.4 (.7)	1.8 (3)	1.6	1.3	.9	3.0 (.3)	1.7 (.3)
Fe_2O_3	1.0	1.5	1.5	.9	1.1	.8	.6	.5	.6
MnO	.4	.2	.2	.3	.3	.1	.5	.3	.8
Cl	.7	.8	.8	.9	.7	.7	.9	.9	.2
SO_3	bd*	bd	bd	bd	bd	bd	bd	bd	bd
TiO_2	bd	bd	bd	bd	bd	bd	bd	bd	bd
P_2O_5	bd	bd	bd	bd	bd	bd	bd	bd	bd
CuO	-	-	-	-	-	.3	bd	bd	-
CoO	.4	.4	1.0	-	-	-	.3	bd	bd
PbO	-	.6	1.7	6.0	8.3 (1.3)	6.7 (.3)	7.2 (1.4)	-	-
SnO_2	-	-	-	-	-	4.0 (.6)	3.7 (.7)	-	-
NiO	.4	-	.3	-	-	-	-	-	-
As_2O_3	.2	-	-	-	-	-	-	-	-

*detected, but at minimum detection limits

Table A.9. SEM-EDS Analyses of red Amsterdam Glasses

Oxide \ Sample	UA-4	UA-13
SiO_2	60.5 (.3)	57.3 (.6)
Na_2O	13.1	12.7
CaO	8.8	6.0
K_2O	3.5	4.1
MgO	2.2	2.6
Al_2O_3	1.4	3.6
Fe_2O_3	3.3	.3
MnO	.4	.7
Cl	.7	1.5
SO_3	bd	bd
TiO_2	bd	bd
P_2O_5	bd	bd
CuO	2.2	1.5
PbO	3.8	9.2 (.3)

*detected, but at minimum detection limits

ICP-AES Studies

a. Experimental procedure

In addition to SEM-EDS study, certain samples were selected for secondary and trace element analysis by inductively coupled plasma atomic emission spectrometry (ICP-AES). These included both Venetian and Dutch glass samples. A total of 32 samples were analyzed with this characterization technique.

The samples were sent to an off-campus laboratory (Skyline Labs; Tucson, Arizona). In addition to the Venetian and Dutch samples, two Corning glass standards were also provided. The initial results provided by the laboratory showed very good agreement for most elements with the recommended composition given by Corning.

The samples were analyzed for 25 different elements ranging from primary to secondary to trace constituents. The oxides chosen along with the minimum detection limits reported by Skyline Labs (assuming a 200 mg sample) were:

K	500 ppm
As	200 ppm
Na, Ca, Mg, Al, Fe, Bi, Zr, P	100 ppm
B	50 ppm
Ni, Li, Cr, Pb, Sb	20 ppm
Mn, Sr, Ag, Ba, Ti, V, Sn, Co, Cu, Zn	10 ppm

The results from Skyline were reported in terms of oxides in weight %'s. SiO_2 was calculated by difference and is an estimate of the silica content. The ICP analyses also did not account for the presence of Cl and SO_3, both of which are common constituents in ancient Venetian glasses. As a results, the % SiO_2 content has been artificially lowered in Table A.10 by 1.2%. This is a representative average value for the chlorine and sulphur trioxide amounts which typically occur in Venetian and *facon de Venise* glasses.

The samples were analyzed in two separate batches done about two months apart in 1994-95. Three primary problems exist with the ICP data. A first difficulty is that, in presenting the trace element results, there is no information in the literature with which to compare them other than analyses presented on a small group of Venetian glasses from the Gnalic wreck (Brill, 1973). As a results, the ICP-AES numbers, at least for now, must stand by themselves until more studies are done which will allow for comparison.

The second problem was related to small weight of certain samples. This can cause slightly erroneous readings, especially for the lighter elements. A third and more serious problem occurred in the analysis of the second batch of samples (Spring 1995). The off-campus laboratory had an equipment malfunction while doing the tests. This caused several oxides (Na and P most notably) to be reported as lower than expected. This in turn affects the final calculation of % SiO_2 by difference. Fortunately, these same samples were given to me by Dr. Marco Verita of the *Stazione Sperimentale del Vetro* in Venice after he had already done compositional studies of them using WDS. WDS measurements done by Verita are included in Table A.11. Tables A.10 and A.11 also provide an opportunity to compare the results obtainable with the two techniques. While the ICP-AES techniques is capable of analyzing for more elements, comparison of the results from the two techniques with values from this work and the literature suggest that the WDS work is more accurate. It also has the added benefit of allowing the same sample to analyzed numerous times while the ICP method completely destroys the sample.

b. ICP-AES and WDS sample descriptions

Glass from Venetian sites
Collected 1993-1995

A
- Corning Standard A.

B
- Corning Standard B.

UA-8
- sample of "cogoli".

PE-44
- dark blue glass.
  Also analyzed via WDS-EPMA in Venice.
  Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-52
- clear and colorless glass; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice.
  Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-54
- clear and colorless glass; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice.
- white glass: Si-Pb glass with Pb-Sn ratio about 2-1.
  Samples donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-55
- clear and colorless glass with light. yellow tint; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice.

Sample donated to this study by Rosa Barovier Mentasti of Venice, Italy.

PE-131

- clear and colorless with green tint; "common" glass composition; low K_2O and MgO contents suggest natron as fluxing agent and therefore probable Roman glass.

PE-132

- clear and colorless with green tint; "common" glass composition.

PE-133

- clear and colorless with green tint; "common" glass composition.

PE-138

- clear and colorless glass; *vitrum blanchum* type.

PE-139

- clear and colorless glass with grey tint; *vitrum blanchum* type.

PE-140

- clear and colorless glass with yellow tint; *vitrum blanchum* type.

PE-141

- clear and colorless glass with yellow tint; *vitrum blanchum* type.

PE-144

- clear and colorless glass; *vitrum blanchum* type.

PE-151(a)

- colorless glass; *cristallo* composition.
  Also analyzed via WDS-EPMA in Venice.

PE-151(b)

- colorless glass; *cristallo* composition.
  Also analyzed via WDS-EPMA in Venice.

PE-151(c)

- colorless glass; *cristallo* composition.
  Analyzed via WDS-EPMA in Venice.

PE-152(a)

- colorless glass; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice.

PE-152(b)

- colorless glass; "vitrum blanchum" composition.
  Also analyzed via WDS-EPMA in Venice.

PE-152(c)

- colorless glass; *vitrum blanchum* composition.
  Also analyzed via WDS-EPMA in Venice.

SL-8

- greenish glass
  From San Leonardo site.

SL-9

- greenish glass
  From San Leonardo site.

SL-10

- yellowish glass
  From San Leonardo site.

SL-12

- yellowish glass
  From San Leonardo site.

SL-14

- colorless-yellowish glass
  From San Leonardo site.

Glass from Amsterdam Sites
Collected 1993-1994

UA-N19

- colorless glass; SLS type similar to *vitrum blanchum*.

UA-N20

- colorless glass; SLS type similar to *vitrum blanchum*.

UA-N21

- colorless glass; SLS type similar to *vitrum blanchum*.

UA-N23

- light blue glass; SLS type with very small amount of CuO and CoO present.

UA-N24

- dark blue glass; potassium-lime-silica glass.

c. Results of ICP- AES studies

The results of the ICP-AES are presented in Table A.10 on the following pages. Complementary WDS analyses are given in Table A.11.

Table A.10. ICP-AES Analysis of Renaissance Glasses

Oxide / Sample

Oxide	A	B	UA-8	PE-44	PE-52	PE-54	PE-55	PE-131
SiO_2*	~66.0	~62.0	99.49	66.06	64.26	68.79	66.02	71.34
NaO_2	14.3	17.1	0.06	10.7	12.7	12.3	11.8	15.6
CaO	5.15	8.90	0.04	10.4	10.75	10.0	10.8	7.9
K_2O	2.70	0.89	0.23	4.0	4.0	2.95	5.25	0.23
MgO	2.67	1.08	0.02	3.65	3.85	3.3	3.1	0.53
Al_2O_3	1.02	4.17	0.12	1.9	2.0	0.75	1.05	2.51
Fe_2O_3	1.12	0.38	0.04	1.25	0.7	0.34	0.46	0.34
MnO	0.95	0.24	<0.01	0.85	0.75	0.41	0.36	0.41
TiO_2	0.70	0.10	<0.01	0.07	0.06	0.032	0.047	0.05
P_2O_5	0.32	0.73	<0.01	0.01	0.01	0.01	0.01	0.01
SrO	0.11	0.02	<0.01	0.06	0.08	0.075	0.07	0.05
BaO	0.48	0.08	<0.01	0.044	0.028	0.04	0.023	0.03
V_2O_5	<0.01	0.03	<0.01	0.004	0.01	0.004	0.006	<0.01
NiO	0.03	0.09	<0.01	0.05	0.011	0.003	0.003	<0.002
CoO	0.18	0.05	<0.001	0.13	0.011	0.004	0.003	<0.001
CuO	1.17	2.72	<0.001	0.25	0.016	0.01	0.006	<0.001
SnO_2	0.20	0.03	<0.01	1.15	0.39	0.05	0.01	<0.01
PbO	0.07	0.47	<0.001	1.2	0.38	0.05	<0.002	<0.001
AgO	0.003	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ZnO	0.05	0.20	<0.002	0.018	0.011	0.003	0.002	<0.002
Sb_2O_5	1.40	0.41	<0.002	0.004	<0.002	<0.002	<0.002	<0.002
As_2O_3	<0.01	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01
Bi_2O_3	<0.01	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01
ZrO_2	<0.01	<0.01	<0.002	<0.01	<0.01	<0.01	0.01	<0.002
B_2O_3	<0.01	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005
Cr_2O_3	<0.002	0.01	<0.002	0.002	<0.002	<0.002	<0.002	<0.002

*% SiO_2 calculated by difference

Table A.10. ICP-AES Analysis of Renaissance Glasses--(Continued)

Oxide / Sample

Oxide	PE-132	PE-133	PE-138	PE-139	PE-140	PE-141	PE-144	PE-151a	PE-151b
SiO_2	62.6	67.0	67.11	69.46	65.47	64.64	65.4	70.63	70.80
Na_2O	15.4	12.1	10.9	12.6	15.4	11.4	11.7	17.5	15.1
CaO	10.4	10.6	12.7	9.75	10.3	13.3	10.8	5.4	6.0
K_2O	2.14	2.04	1.9	1.85	1.82	2.43	5.75	2.5	3.05
MgO	3.46	4.07	3.56	3.42	3.78	4.25	2.89	1.75	2.05
Al_2O_3	2.17	1.92	1.37	0.96	0.89	1.07	1.43	0.75	1.4
Fe_2O_3	1.0	0.77	0.64	0.38	0.57	0.66	0.49	0.25	0.32
MnO	1.58	0.31	0.61	0.39	0.58	1.01	0.39	0.15	0.18
TiO_2	0.09	0.08	0.08	0.04	0.05	0.06	0.06	0.02	0.042
P_2O_5	0.03	0.03	0.04	0.04	0.04	0.04	0.02	0.01	0.01
SrO	0.06	0.06	0.07	0.06	0.07	0.11	0.06	0.03	0.036
BaO	0.03	0.01	0.02	0.02	0.03	0.03	0.01	0.006	0.006
V_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.003	0.004
NiO	0.009	0.009	<0.002	<0.002	0.007	<0.002	0.006	<0.002	<0.002
CoO	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CuO	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	0.026
SnO_2	0.04	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	0.01	0.01
PbO	0.17	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	0.01
AgO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ZnO	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.003
Sb_2O_5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.007
As_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02
Bi_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZrO_2	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01	<0.01
B_2O_3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr_2O_3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table A.10. ICP-AES Analysis of Renaissance Glasses--(Continued)

Oxide / Sample

Oxide	PE-151c	PE-152a	PE-152b	PE-152c	UA-N19	UA-N20	UA-N21	UA-N23	UA-N24
SiO_2	65.97	67.22	72.21	67.15	64.34	66.72	65.97	64.01	61.31
Na_2O	14.2	13.6	12.3	11.1	14.0	10.8	13.2	12.3	1.1
CaO	10.7	10.6	8.65	10.25	9.2	10.6	10.85	10.35	17.8
K_2O	2.5	2.2	2.0	4.9	4.85	5.55	4.4	5.75	12.8
MgO	3.85	3.35	2.35	3.0	4.0	2.85	2.5	2.65	2.6
Al_2O_3	0.95	1.2	0.8	1.25	1.6	1.2	0.95	2.95	1.55
Fe_2O_3	0.39	0.39	0.33	0.55	0.5	0.47	0.41	0.55	0.55
MnO	0.24	0.29	0.25	0.65	0.32	0.6	0.55	0.26	0.9
TiO_2	0.035	0.037	0.036	0.05	0.075	0.1	0.06	0.1	0.1
P_2O_5	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SrO	0.085	0.075	0.045	0.065	0.08	0.06	0.07	0.05	0.07
BaO	0.025	0.021	0.012	0.021	0.02	0.04	0.03	0.015	0.21
V_2O_5	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.004
NiO	0.003	0.004	0.003	0.004	<0.001	0.002	0.004	0.01	0.031
CoO	0.003	0.003	0.002	0.005	0.001	0.002	0.006	0.026	0.13
CuO	0.04	0.012	0.014	0.007	0.004	0.011	0.004	0.003	0.017
SnO_2	0.07	0.01	0.01	0.07	0.12	0.37	0.55	0.01	0.02
PbO	0.08	0.006	0.007	0.085	0.31	0.65	0.8	<0.002	0.048
AgO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ZnO	0.006	0.005	0.007	0.004	0.004	0.08	0.005	0.004	0.025
Sb_2O_5	<0.002	<0.002	<0.002	0.002	0.008	0.009	<0.002	0.012	<0.002
As_2O_3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bi_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
ZrO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
B_2O_3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
Cr_2O_3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table A.10. ICP-AES Analysis of Renaissance Glasses--(Continued)

Oxide / Sample

Oxide	SL 10	SL 12	SL 8	SL 9	SL 14	SL 15
SiO_2	65.39	61.35	64.69	66.6	69.33	68.69
Na_2O	18.4	14.6	12.2	12.1	12.5	13.9
CaO	4.45	6.15	10.0	8.45	8.9	8.4
K_2O	1.47	3.06	1.99	2.18	2.52	2.07
MgO	2.05	2.31	2.31	2.69	3.17	3.31
Al_2O_3	3.92	7.25	4.08	3.14	1.53	1.32
Fe_2O_3	1.91	2.01	1.42	1.34	0.42	0.42
MnO	0.83	1.8	1.6	2.19	0.46	0.71
TiO_2	0.28	0.28	0.18	0.17	0.06	0.08
P_2O_5	0.01	0.03	0.01	0.02	0.02	0.02
SrO	0.04	0.05	0.07	0.07	0.07	0.06
BaO	0.25	0.11	0.04	0.05	0.02	0.02
V_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	<0.002	0.006	<0.002	0.009	0.009	0.005
CoO	<0.001	0.002	<0.001	0.001	<0.001	<0.001
CuO	0.001	0.001	0.03	0.004	<0.001	<0.001
SnO_2	<0.01	<0.01	0.04	<0.01	<0.01	<0.01
PbO	<0.001	<0.001	0.38	<0.001	<0.001	<0.001
AgO	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ZnO	0.007	0.004	0.018	0.004	<0.002	<0.002
Sb_2O_5	<0.002	0.007	<0.002	<0.002	<0.002	<0.002
As_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bi_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZrO_2	0.032	0.026	0.006	0.01	0.002	0.006
B_2O_3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr_2O_3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table A.11. WDS Analysis of Renaissance Glasses

Oxide / Sample

	PE-44	PE-52	PE-54	PE-55	PE-151(a)
SiO_2	62.5	66.4	64.8	65.8	68.8
Na_2O	12.2	13.9	15.2	12.6	18.8
CaO	9.8	9.7	10.0	10.0	5.4
K_2O	3.5	2.5	3.1	4.95	2.9
Mgo	3.7	3.1	3.9	3.7	1.75
Al_2O_3	1.7	1.3	0.8	1.05	0.55
Fe_2O_3	1.15	0.55	0.3	0.35	0.15
MnO	0.75	0.75	0.44	0.38	0.16
Cl	0.5	0.5	0.8	0.74	1.05
SO_3	0.3	0.2	0.28	0.22	0.33
P_2O_5	0.2	0.4	0.35	0.37	0.21
TiO_2	0.05	0.06	0.05	0.06	0.03
PbO	1.2	0.2	-	-	-
CuO	0.24	0.03	-	-	-
SnO_2	1.6	0.6	-	-	-
CoO	0.1	-	-	-	-
As_2O_3	0.1	-	-	-	-

Table A.11. WDS Analysis of Renasissance Glasses--(Continued)

Oxide / Sample

	PE-151(b)	PE-151(c)	PE-152(a)	PE-152(b)	PE-152(c)
SiO_2	70.2	69.8	71.2	66.2	66.2
Na_2O	19.3	16.0	13.6	14.4	12.5
CaO	4.1	5.7	8.05	10.1	9.6
K_2O	2.45	3.65	2.3	2.75	4.8
Mgo	1.7	2.1	2.5	3.4	3.1
Al_2O_3	0.58	0.85	0.67	1.05	1.18
Fe_2O_3	0.23	0.28	0.25	0.32	0.47
MnO	0.27	0.15	0.23	0.27	0.62
Cl	1.0	0.95	0.78	0.9	0.88
SO_3	0.3	0.23	0.25	0.22	0.15
P_2O_5	0.15	0.15	0.21	0.35	0.27
TiO_2	0.04	0.05	0.04	0.06	0.06
PbO	-	-	-	-	-
CuO	-	-	-	-	-
SnO_2	-	0.03	0.04	0.03	0.09
CoO	-	-	-	-	-
As_2O	-	-	-	-	-

Optical Studies of Venetian Glass

The optical properties, specifically the percent transmission and absorption versus the wavelength of light, for several Renaissance Venetian glass were studied. Analyses were done at the University of Arizona and the *Consiglio Nazionale delle Ricerche* in Florence, Italy.

The analyses at the University of Arizona were made using a Perkin-Elmer Lambda 3B ultraviolet/visible spectrophotometer. This allowed for measurement of % transmission (or absorption) vs. wavelength from 190 nm to 900 nm. The equipment in Florence was similar and allowed for measurements between 400 nm to 2500 nm. In this manner, the response of the glass to electromagnetic radiation could be studied from the ultraviolet through the visible and into the infra-red region.

Samples were selected which represented a broad cross-section of glass compositions; these included pre-Renaissance era common and "colorless" glass, Renaissance era *cristallo*, Renaissance *vitrum blanchum*, Renaissance "common glass" compositions, and post-Renaissance Venetian glass. The samples studied are described below; all were essentially "colorless" unless noted. The average compositions of the glass samples as determined by either SEM-EDS or ICP-AES is presented below as well in Table A.12.

Sample #1 - Venetian *cristallo* glass, PE-41

" #2 - Venetian pre-Renaissance "colorless" glass, PE-149, from San Ariano

" #3 - Renaissance-era common window glass from Fusina, greenish -blue tint

" #4 - Vessel glass from San Leonardo, pre-Renaissance, SL10, yellowish-green tint

" #5 - Renaissance-era vessel glass from Fusina, *vitrum blanchum* composition

" #6 - Renaissance-era vessel glass from Fusina, PE-145, *vitrum blanchum* composition

" #7 - Post-Renaissance vessel glass from San Giuliano

" #8 - Test sample, microscope slide, 20th century

" #9 - Post-Renaissance vessel glass from San Giuliano, SJ1

" #10- Vessel glass from San Leonardo, pre-Renaissance, SL8, yellowish-green tint

" #11 - Renaissance-era vessel glass from Fusina, *vitrum blanchum* composition, PE-138

" #12 - Blue (cobalt colored) Renaissance-era vessel glass from Fusina, PE-55

" #13 - Renaissance-era glass from Fusina, section of cullet or waste, most likely a *cristallo* composition

Table A.12. Average chemical composition of optical test specimens, major components only

Samp #	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	MnO	CoO	SO_3
1	70.7	18.3	3.6	2.9	1.1	0.8	0.4	0.3	0	0.4
2	71.7	12.2	9.0	1.9	2.6	0.8	0.3	0.2	0	0.3
3	62.8	14.9	12.5	2.1	3.3	1.6	0.6	0.6	0	0.4
4	67.1	14.6	7.3	2.3	0.9	3.7	1.1	1.2	0	0.1
5	62.5	15.6	12.5	2.4	3.1	1.3	0.5	0.4	0	0.4
6	65.4	11.7	10.8	5.6	2.9	1.4	0.5	0.3	0	0.4
7	63.8	15.3	10.5	2.3	2.7	2.4	0.6	1.1	0	0.3
8	71.1	10.2	4.3	0.7	2.3	1.3	0	0	0	0.3
9	67.2	15.5	8.1	3.9	2.0	1.2	0.3	0.3	0	0.2
10	64.7	12.2	10.0	2.0	2.3	4.1	1.4	1.6	0	?
11	67.1	10.9	12.7	1.9	3.6	1.4	0.6	0.6	0	?
12	62.5	12.2	9.8	3.5	3.7	1.7	1.2	0.8	0.1	0.3
13	64.8	19.5	8.6	2.6	1.6	1.1	0.3	0.1	0	0.3

The results for most of the tests are shown in Figures A.1a through A.1k in the following pages. In the figures, the results show percent transmission versus wavelength on the same scale for the sake of easier comparison. The tests represent optical behavior in the wavelength range between 190 and 900 nm. Only the results of the tests done at the University of Arizona are shown. The measurements done in Florence confirmed the results shown here and extended the range of testing into the IR.

The dissertation text, primarily Chapter 7, discusses these measurements in their cultural and technological context. What follows here is a brief summary of the theoretical aspects of these measurements along with the peculiarities and problems of using this type of test for archaeological glass.

The total amount of light incident upon an object will either be reflected, absorbed, or transmitted. It is the relative amounts of these components which determines and our perception of them which determines our emotional and aesthetic response to a particular object. The percent transmission of a material is given by the Beer-Lambert relation:

$$\% \text{ Transmission (T)} = I_{out}/I_{in} = \exp(-\beta x)$$

where I_{in} is the initial intensity of the light and I_{out} is the transmitted intensity. β is the optical absorption coefficient and x is the path length which basically equals the thickness of the sample. β is further defined as:

$$\beta = -4\pi k/\lambda$$

where k is the index of absorption and λ is the wavelength of incident radiation. These relations assume an optically homogeneous sample which is not the case for the samples studied here. The samples in this work all had various inhomogeneities, such as bubbles, present in the glass. As a result, some light was lost due to scattering. Furthermore, the usual procedure for making percent transmission tests involves a thin polished sample. Efforts were made to imitate this protocol when possible; sample availability and size placed limitations on this however. Some light will be lost to reflectance as well. This presents a problem as the samples came from an archaeological context. Most had visible corrosion products on the surface. These were removed as much as possible by cleaning and polishing before measuring percent transmission or absorption.

Therefore, there are five factors which will affect the percent transmission of a sample. The first is wavelength as it appears in the equation for β. As all of the tests were done over the same wavelength, this variable drops out. The second is reflectance. Efforts were made to control this by removing possible surface corrosion products. There are also losses due to scattering caused by inhomogeneities in the glass. There is no way of adjusting for this due to the nature of archaeological samples. A fourth variable is thickness. Efforts were made to take measurements at the thinnest region of the sample. However, many of the thicker samples still showed a greatly reduced overall transmission when compared with other samples. Again, this is the due to the nature of the samples studied and little can be done about this. Finally, percent transmission tests are typically done on flat samples. Archaeological samples often exhibit some degree of curvature; efforts were made to select samples that were as flat as possible or to test them in the region with the least curvature.

Examination of the % transmission plots show that the overall transmission varied greatly from about 80% in sample #1 to less than 10% in sample #3. The variables cited above are responsible for this. However, for the purposes here, it is not as important to compare the overall relative intensity transmitted. In light of the variables described above this is probably not even possible with the selection of samples available for study. Rather than looking at the overall percent transmission, the plots were used to compare the samples by observing the locations in terms of wavelength of where peaks and valleys occur. For example, almost all of the samples show minor drops in transmission around 400 nm. These decreases are associated with the presence of ferric (+3) iron in the glass which has characteristic weak absorption at 380, 420, and 435 nm (Bamford, 1977:35).

The characteristic peaks and valleys of one sample in comparison with those for other samples are therefore what was focussed on in the interpretation of these analyses. In this manner, the relative differences in terms of what wavelengths of light were transmitted could be seen. As the focus of this research is on the *cristallo* compositions (sample #1 and possibly #13), the relative differences and similarities between this analysis and the others was of primary interest. As was the case for the ICP-AES analyses done in this research, no data concerning the optical properties of Venetian glasses has been presented in terms of percent transmission versus wavelength. The most comprehensive study of the optical properties of ancient glass is found in the section authored by Brill for the glass excavated at Jalame, Israel (1988). All other descriptions of Venetian glass which refer to the optical characteristics make use of a subjective approach using adjectives such as "clear", "colorless", and "tinted". The graphs presented here are the first known effort to quantify the optical properties of the glass. Until further work is done with well-dated and chemically analyzed samples, the data presented here should be viewed as "work in progress".

APPENDIX B

Physical Examinations of Renaissance-Era Glass PiecesIntroduction

This appendix presents the rationale, the protocol, and a general summary of the physical examinations for over two hundred Renaissance-era glass vessels and sherds. The overall intent of these examinations was to measure the "quality" of Venetian glass in a more quantitative manner than had been attempted by previous researchers.

The very use of the phrase "to measure quality" introduces a number of easily imaginable difficulties to the process. A definition of quality is not immediately evident or readily definable. Yet glass pieces are continually described in the literature as being of "high quality" or of "inferior quality", supposedly in a comparative manner. Yet the criteria for these descriptions are rarely specified with the assumption being that a connoisseur of glass will easily recognize a "quality piece". As the director of the Corning Museum of Glass told me, " Quality glass was made at all times in history." (Whitehouse, personal communication, 1994). One who is skeptical of this attempt to study quality will have no problem in pointing out the immediate limitations of this effort: the realization that quality is entirely subjective, that aesthetic ideals are culture and time specific, and so forth. So with an understanding that this process is not without methodological difficulty, I should like to continue and describe the reasons and procedures for doing these examinations.

Purpose

The original goal of these studies was to measure the quality of Venetian glassware in a more quantitative fashion. It quickly became apparent that this could not be done on an entirely objective and still meaningful level so quality soon assumed subjective and objective components. The objective measurements of the glass quality were oriented around the quality of the "material". Developing a principle first put forth by Harden in his examination of Roman glass from Karanis, "material" was taken to mean the condition and state of the glass at the time of manufacture and independent of how the glass itself was subsequently worked and manipulated to form a distinct object (cf. Harden, 1936).

That it to say, "material" refers to the condition of the raw and unworked glass as it was used to form a wineglass, window, or water jug. Therefore, a judgement about the quality of the "material" **does not** refer to any defects or characteristics of the glass due to use, weathering or manufacturing processes. In this way, a very basic measurement of glass quality was made by examining the different glass pieces in terms of defects present - number of bubbles, presence of stones in the glass, degree of mixing based on the presence of any cord or striae (see Examination Protocol below for more details).

From this point, the study of quality became increasingly subjective as questions such as how well the piece was assembled, the degree of annealing, and the clarity of the piece were considered. Also extremely important was the opportunity to gain a "feel" for the glass pieces during the course of these physical examinations. It is one thing to study the form and decoration of an enamelled Venetian goblet in a museum catalog but it is entirely different (as well as more informative) to actually hold the piece in one's hand, to feel the shape, and to appreciate the near-weightlessness of some of these objects. One cannot begin to appreciate and study material culture such as glass in any sort of context without actually handling the material. The actual suggestion of one museum that they manipulate the object for me while I observed can be seen as nothing other than a dreary and almost useless exercise. I took it to be very encouraging that my tacit understanding and knowledge of Venetian glassware changed and increased with the number of vessels studied. This knowledge is the type that does not lend itself to articulation in the form of graphs and charts but rather occurs at a deeper level of appreciation, perhaps the beginnings of connoisseurship that is the basis of a curator's role.

With these observations, both objective and subjective, it was hoped to address several questions central to the demand for, production, and consumption of these pieces. For example:

- Is it possible to objectively measure "quality"?

- Are there observable changes in glass quality over time (i.e. does the "material" change with respect to the number and types of defects)?

- What are the predominant defects and how do they relate to the production process?

- Does glass from different places (England, Venice, et cetera) show different patterns of quality?

- How does Venetian *cristallo* glass compare with its counterparts in this different places?

- Is the Venetian reputation for "quality glassware" deserved or is part of the industry's mythology? Does this quality relate to the "material" or the way in which the material was worked?

- What types of features would a consumer of Renaissance Venetian glassware be looking for? Are these wishes fulfilled? How are customer demands reflected in these studies of quality?

- Can the quality of the glass be connected to the "labor power" of the artisans making it?

These are examples of the types of questions that were deemed essential to this research. It was hoped that answers might be suggested by the careful study of individual glass pieces. The following section outlines the protocol followed during the course of these examinations.

Examination Protocol

During the summers of 1993-1995, over 200 physical examinations (PE's) were conducted of mostly Renaissance-era glassware. This glassware included whole vessels, individual sherds, and some groups of similar sherds. These examinations were carried out with the permission and assistance of the following museums:

- Museo Internazionale delle Ceramiche (Faenza, Italy, 1993)

- Museo Vetrario (Murano, Italy, 1994)

- The Corning Museum of Glass (Corning, U.S.A., 1994)

- The Metropolitan Museum of Art, The Robert Lehman Collection (New York City, U.S.A., 1995)

- The British Museum (London, England, 1995)

- The Victoria and Albert Museum (London, England, 1995)

- The Ashmolean Museum (Oxford, England, 1995)

The procedure used for conducting the PE's was as follows:

1. Specimen and representative details photographed when permitted; piece assigned an examination number (ex: PE-41).

2. Dimensions (rim & base diameter, height, average thickness) measured.

3. Specimen sketched with notes added as examination proceeded.

4. Features described in terms of rim, body, and base shape with characteristics such as decoration, assemblage of pieces, use wear, and so on noted as well.

5. The bulk (or "material") of the glass was examined with a hand lens and binocular microscope when possible. The glass was examined for defects, noting the presence and relative number of stones and cord/striae along with location. For defects such as stone and cord, it was not practical to measure in terms of #/cc. A specimen might only have one striae or the stones might be so widely spaced that #/cc would be misleading. Instead, these were assigned values from very few to

moderate to very many. When these defects were present, their character, quantity, and location was described. The type of stone was noted. The number of bubbles/cc was also recorded based on an average of three randomly located measurements typically in the body of the piece. Size, shape, and orientation were recorded along with the predominant type of defect present.

I explored the usefulness of a hand lens vs. a binocular microscope and found that for counting bubbles, et cetera, the results from a hand lens and that of a microscope were in very good agreement.

A relative number corresponding to the overall quality of the specimen's material was assigned (from 1 to 5; see below).

6. The surface character of the glass and its state of preservation was recorded noting such attributes as dulling, weathering, weeping, crizzling and so on.

7. Next, the specimen was examined for evidence of manufacture. This includes pontil marks (double or single), blowing spirals, mold marks, evidence of free versus mold blowing, assemblage of parts, degree of annealing (observed with two cross-polarized lens).

8. The optical qualities of the glass was noted including color and clarity (measured subjectively with either white or black backgrounds) as well as the presence of any unusual optical features.

a. "Material" quality index

In order to be able to easily compare pieces, a relative scale was developed to indicate the quality of the material. "Material" refers solely to the condition of the glass at the time of vessel manufacture. It does not include defects incurred during manufacture of the piece and the manipulation of the material nor does it include defects that occurred to the vessel due to weathering and use. Generally, the scale is useful only for the types of vessels examined in this particular work as it is entirely relative and developed during the course of the physical examinations that were done.

The scale is simple; a number (1 to 5) representing a "quality index" is assigned to the vessel based on two considerations. First, the number and types of defects measured empirically in the vessel (number of bubbles/cc, number of and size of stone and cord, et cetera). Secondly, there was a subjective element involved based on my impressions of the quality of the glass' "material" and my response to it. For example, a vessel with a very large number of pinprick size bubbles that were visible only with a microscope would have an empirically greater number of defects than one with 5-10 large refractory stones near the rim as a principle defect. Yet, it would probably be given a better "quality" rating as the defects would not have been as evident to the Renaissance eye (or modern) and, therefore, not as "behaviorally significant" (cf . Schiffer, 1992:60)

The scale that was developed is as follows:

Class 1: Excellent quality, glass approaching modern quality, bubbles almost all pinprick size; lens typically needed to see bubbles or stone; very few cord or stone with no cord visible to eye; if bubbles are primary defect, number is <40/cc.

Class 2: Very good; bubbles mostly pinprick size with few larger and visible without a lens; stones/cord may be present but few and widely scattered typically; blowing spirals begin to be slightly visible; if bubbles primary defect; number is 40-80/cc.

Class 3: Good or average quality; mixed bubble size typically in .5 mm range; moderate bubble amount; lens not needed to see most defects; moderate amount of stone/cord can be present; blowing spirals noticeable; stones are larger, beginning to see larger refractory/sand stones with stress fields; if bubbles primary defect, number typically 80-150/cc.

*After this point, defects begin to noticeably affect "material" quality and detract from the overall appearance of the piece.

Class 4: Fair to poor quality; bubbly; many defects including very noticeable stone/large bubbles/long thick striae; number of larger bubbles and stone (> 1 mm) present; very distinct blowing spirals; cord easily seen and long; clarity of glass reduced; if bubbles primary defect, number typically 150-200/cc.

Class 5: Poor to very poor quality; very bubbly; majority of defects are large and very noticeable; large bubbles may intersect surface and form blisters; very many long/large stones and cord; thick/long striae and cord; basically, defects present are very large and very many; number of bubbles typically 250-300+/cc.

This scale provides an effective way to compare the quality of different vessels' "material". A similar approach, although less empirical, was used by Harden to compare and rank the quality of Roman glass from Karanis (1936:11-12).

Clearly, not all pieces fit neatly into one of these categories and there is certainly some grey areas between different rankings. I began to develop this scale in Venice (1994) and continued to refine and define the meaning of the different categories as the research went on. I discussed my system with different curators and glass scientists during the course of research and all felt it gave a good and basic way to compare similar pieces.

Numbers, Categories, and Quality Indices of Pieces Examined

214 physical examinations were done of vessels, sherds, and sherd groups. As no typology of Renaissance Venetian glassware has been proposed by glass scholars, a very general system is put forth here based primarily on the shape and form of the piece and also, somewhat, on its imagined function. A similar system could certainly been developed with different criteria such as function, size, decoration, et cetera. This typology is only intended to allow the different PE's to be categorized and discussed in the dissertation text. It is by no means a definitive or comprehensive system for Renaissance glassware. It only begins to hint at the myriad number of shapes and designs present in glass between 1400 and 1700. A complete typology would require the examination of hundreds more pieces and would have many sub-categories based on manufacturing technique and so on.

Thirteen different general categories were used to distinguish between the different glass objects studied. They are:

1. Bowls with feet (bowls are distinguished from plates on the basis of the depth and curvature of their "body")

2. Bowls without feet

3. Plates without feet

4. Plates with feet (includes *tazze*; essentially any plate or very shallow bowl with a foot)

5. Wine glasses, chalices, and goblets (essentially any object used primarily for drinking and having some type of stem between the bowl and the foot)

6. Pitchers and jugs (typically with a handle and a lip for pouring)

7. Bottles

8. Buckets, typically with a handle

9. Vases and flasks (distinguished from pitchers and bottles usually by presence of a base or foot, a lid, or the neck design as well as a curved body)

10. Reliquaries (possibly confused with chalices or goblets; marked by a typically straight-sided body and, frequently, accompanied by a lid)

11. Cups, beakers, tumblers (a vessel, lacking any substantial foot, and intended for drinking)

In addition, there were two other categories:

12. Non-Venetian (*facon de Venise*)pieces (includes all forms from all non-Venetian locations of manufacture as well as could be determined)

13. Sherds (of Venetian and non-Venetian origin)

The statistical distribution of the different vessels and sherds examined is as follows:

a. By date (vessels only)

For all vessels-

Pre-15th century	n= 2
15th century	n= 6
late 15th-first 1/4 16th century	n= 38
last 3/4 of 16th century	n= 52
16th and 17th century	n= 42
17th and 18th century	n= 33

Only Venetian vessels-

Pre-15th century	n= 0
15th century	n= 6
late 15th-first 1/4 16th century	n= 38
last 3/4 of 16th century	n= 45
16th and 17th century	n= 32
17th and 18th century	n= 13
18th century	n= 11

It should be noted here that there is considerable difficulty in dating Venetian and *facon de Venise* glass. This is especially true for ubiquitous forms such as certain wineglass styles which remained in vogue for some time. The dates suggested by the respective museums for the different pieces were used unless there was sufficient evidence to propose a different date. Still, many of the pieces are dated to lengths of time (ex: 16th to 17th century) that make it next to impossible to place them into a more narrowly defined time period.

b. By type

A distribution of the different categories is:

Bowls with feet	n= 15
Bowls without feet	n= 6
Plates without feet	n= 8
Plates with feet	n= 22
Wine glasses, chalices, goblets	n= 44
Pitchers and jugs	n= 7
Bottles	n= 4
Buckets	n= 3
Vases and flasks	n= 9
Reliquaries	n= 12
Cups, beakers, tumblers	n= 15
Non-Venetian pieces	n= 28
English	n= 3
French or Dutch	n= 10
Spanish	n= 8
German, Austrian, or Bohemian	n= 5
Other or not distinguishable	n= 2
Sherds or sherd groups	n= 41

c. <u>By Index of quality</u>

The different indices of quality assigned to the glass vessels studied were used to see if any significant changes in "material" quality occurred over a broad period of time (roughly, 1450 to 1750). The average index of quality for the different time periods is:

For all vessels-

Pre-15th century (vessels only)	n= 2	average= 5.00
Pre-15th century (including Venetian sherds from the San Leonardo site, 11th-14 century)	n= 17	average= 3.76
15th century	n= 6	average= 3.17
late 15th-first 1/4 16th century	n= 38	average= 2.85
last 3/4 of 16th century	n= 52	average= 3.03
16th and 17th century	n= 42	average= 3.11
17th and 18th century	n= 22	average= 3.04
18th century	n= 11	average= 2.61

Only Venetian pieces-

Pre-15th century (including Venetian sherds from the San Leonardo site, 11th-14th century)	n= 15	average= 3.63
15th century	n= 6	average= 3.17
late 15th-first 1/4 16th century	n= 38	average= 2.85
last 3/4 of 16th century	n= 45	average= 2.83
16th and 17th century	n= 32	average= 2.98

17th and 18th century	n= 13 average= 2.94
18th century	n= 11 average= 2.61

Summary

A protocol for the examination of Renaissance-era glass vessels was developed for this research. This method of study recorded the dimensions and form of the piece along with signs of manufacturing technique. An empirical approach for analyzing the quality of the glass as a "material" was utilized. In this fashion, a more objective approach to the issue of quality was provided via the careful observation of material defects. The semi-quantitative examination of these defects resulted in the assignation of a quality index to the glass in the hope of seeing changes in "material" quality over time.

As can be seen from the above figures, there were only slightly discernible changes in material quality during the course of the Renaissance. These changes are a little more obvious if one looks solely at the results for the Venetian vessels. As mentioned, interpretation of the average indices of quality is made more difficult by the very broad dating of many Venetian and *facon de Venise* glass pieces in museum contexts. This general consistency in quality suggests that one must look to other factors besides the empirical consideration of "material" defects, to understand the demand for glass in the Renaissance. For example, aspects such as workmanship, form, and fashion, all of which cannot be expressed empirically, are critical factors to consider when evaluating the "quality" of a piece. For example, a poorly assembled piece will be less aesthetically pleasing regardless of how good the "material" quality is.

There are noticeable changes in material quality, however, if one compares glass from pre-Renaissance context to Renaissance wares. This comparison, it should be noted, is somewhat unfair as the sherds from San Leonardo are a mixture of fine and common glass while the Renaissance glass pieces are from a museum context and are predominantly luxury wares. A general remark that the quality of the material (pre-Renaissance vs. Renaissance) did improve over time with respect to defects is probably valid though. Glassmakers of the Renaissance, based on recipe information, went to greater lengths to improve, refine, and homogenize their glass melts, generally speaking. This general refinement becomes even more noticeable when more subjective qualities such as clarity and colorlessness are considered. Finally, the examination of the objects following the described protocol identified prevalent types of defects in Venetian and *facon de Venise* glass. The prevalent defects vary both temporally and geographically. These points, and others related to the physical examinations performed, are taken up at much greater length in Chapter 8 of the dissertation text.

APPENDIX C

FIGURES

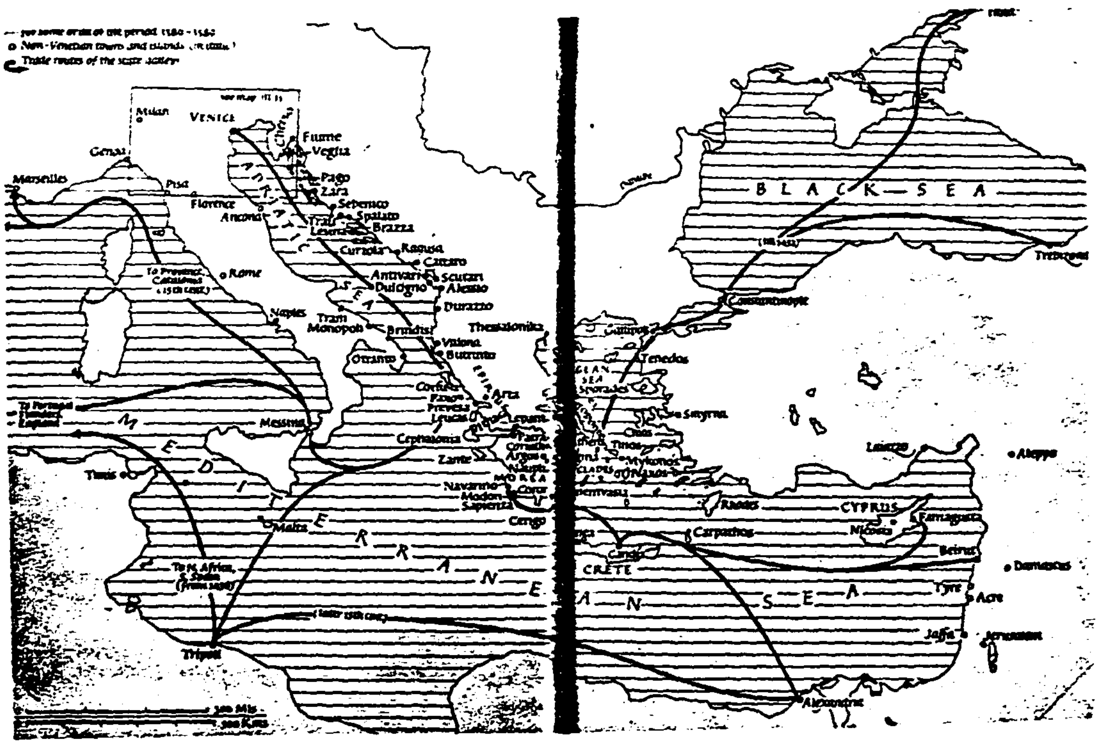

Fig. 3.1. Map of the Adriatic region (from Chambers. 1971)

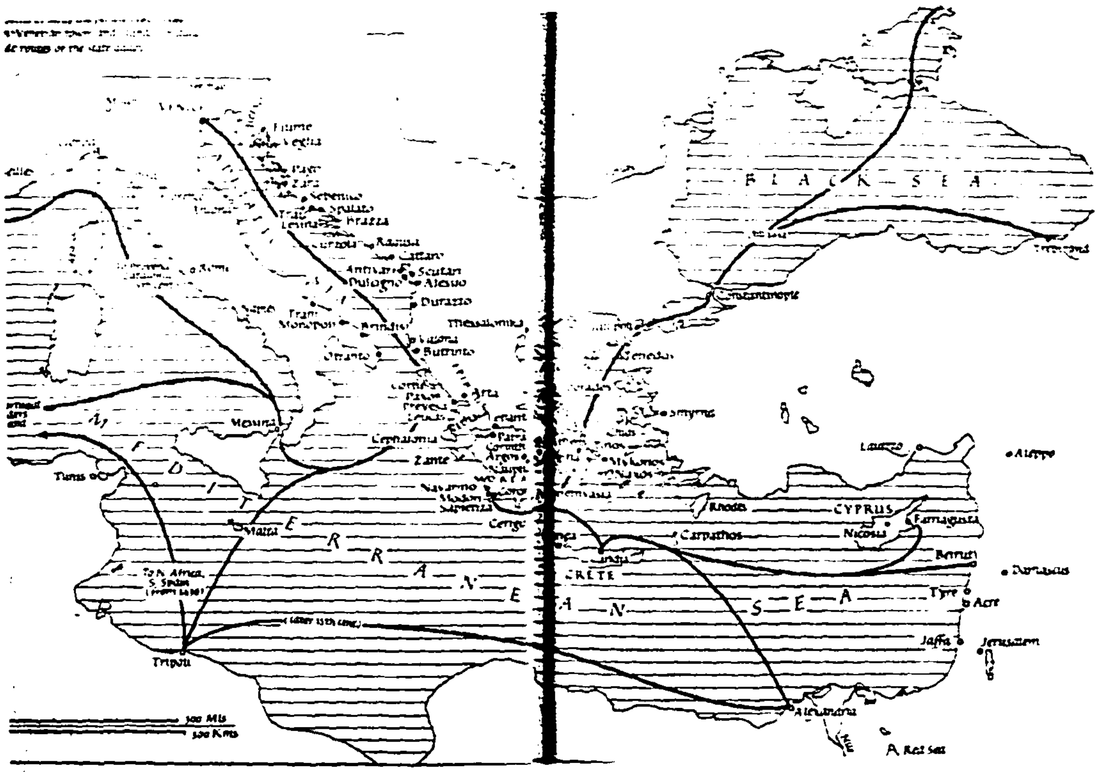

Fig. 3.2. Map of the Veneto (from Chambers. 1971)

Fig. 3.3. Map of the Veneto (from Jacoby. 1994)

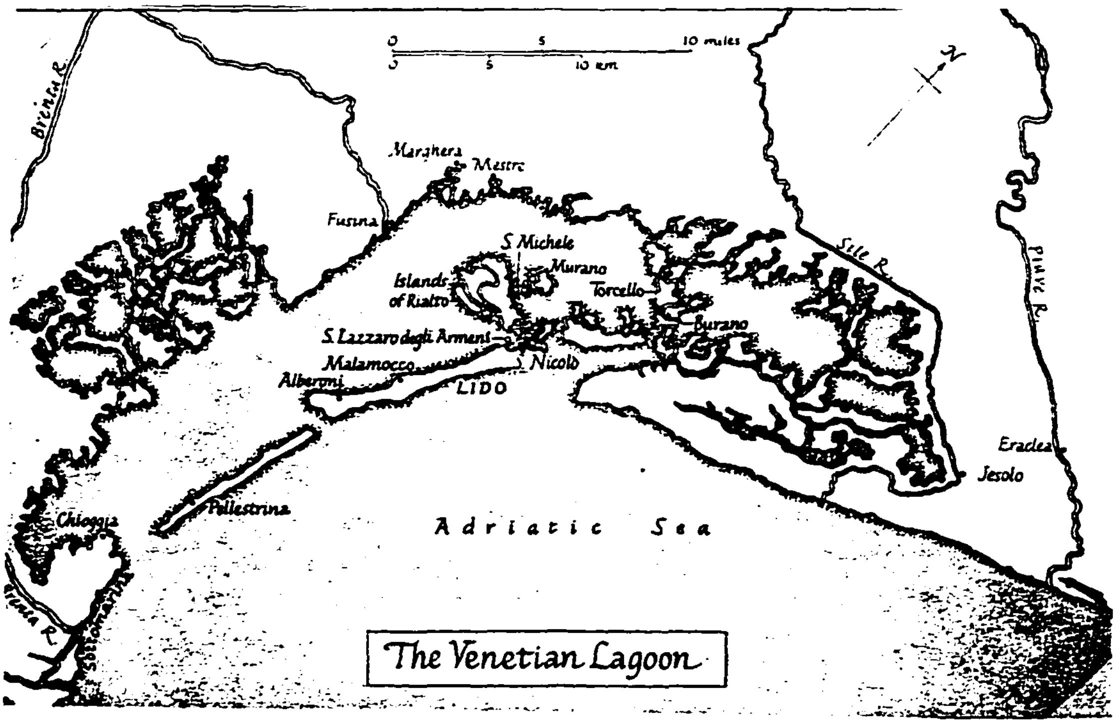

Fig. 3.4. Map of the Venetian lagoon

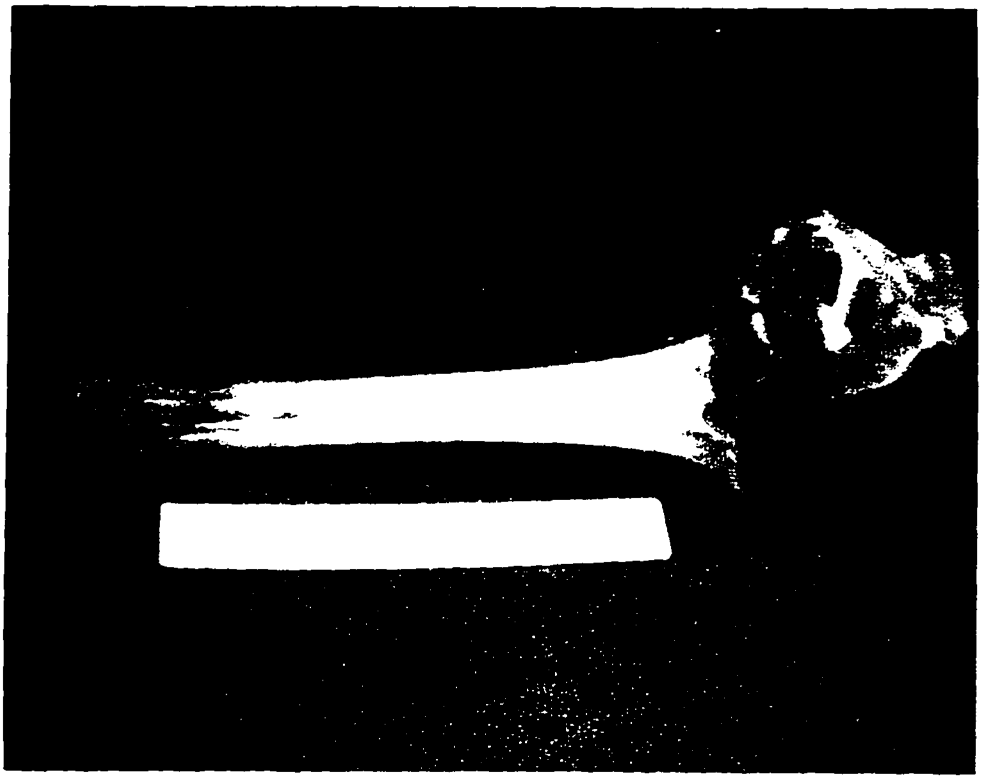

Fig. 6.1. Remnants of an *inghistra* found in the Venetian lagoon

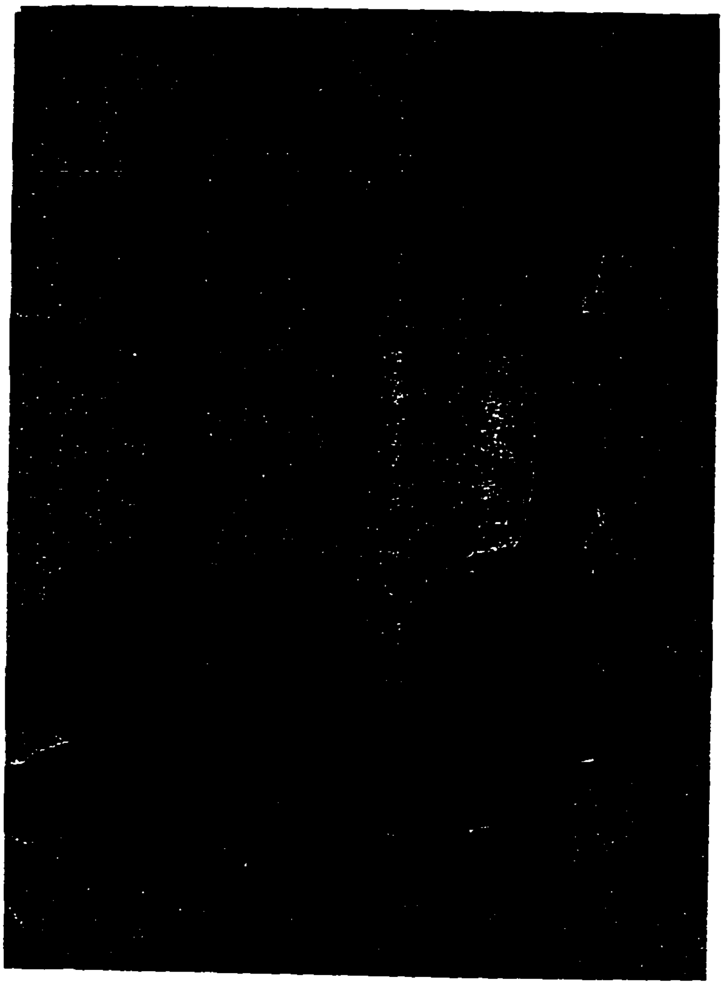

Fig. 6.2. Two intact *inghistre* found in Cremona

Fig. 6.3. Example of a Venetian glass tumbler (*moioli*)

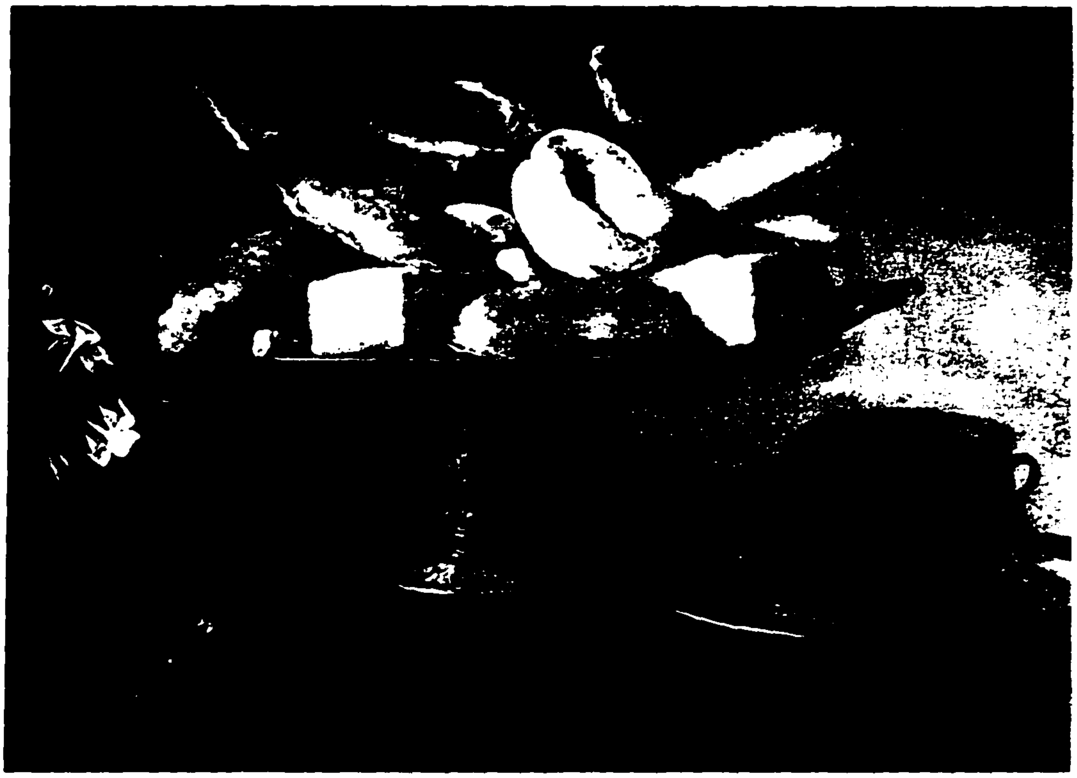

Fig. 7.1a. Metal *tazza* as shown in a Spanish still life

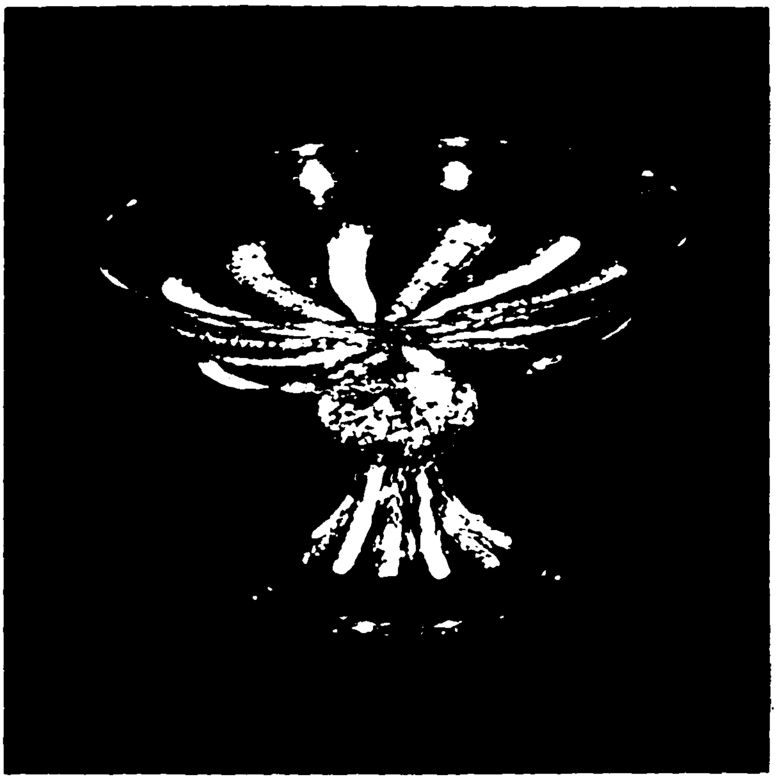

Fig. 7.1b. Glass *tazza* from the collection of the Corning Museum of Glass (PE-124)

Fig. 7.2. Glass goblet from the Corning Museum of Glass (PE-128) and dated to the late 15 or early 16th century; note similarity to the Gothic metal work shown in Figure 7.3.

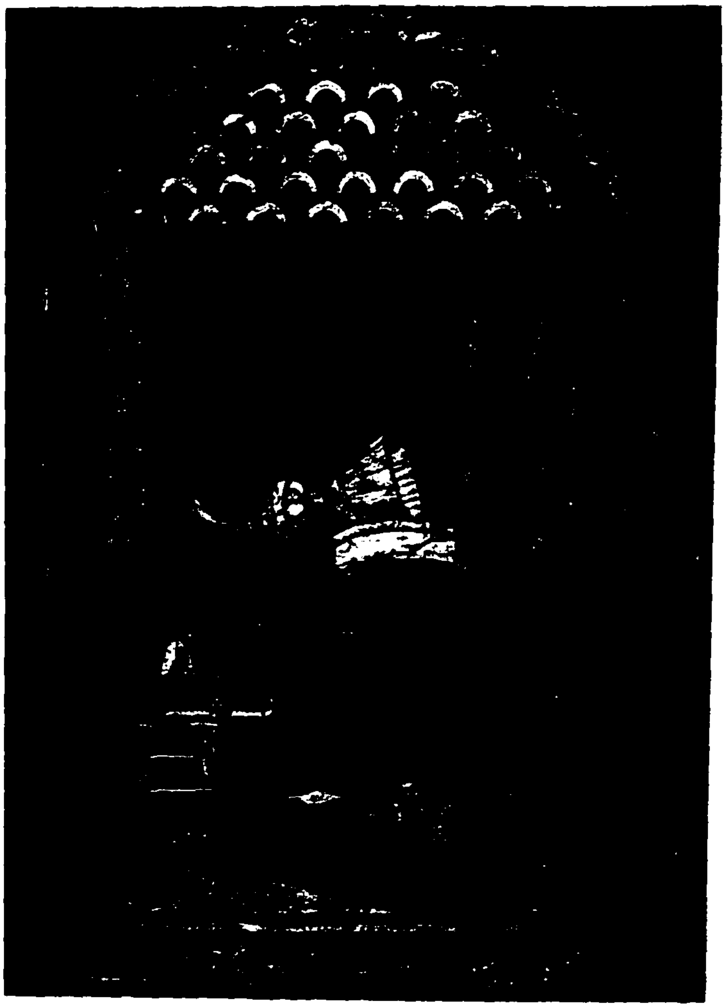

Fig. 7.3. Metal cup as shown in a 16th century Italian *intarsia*

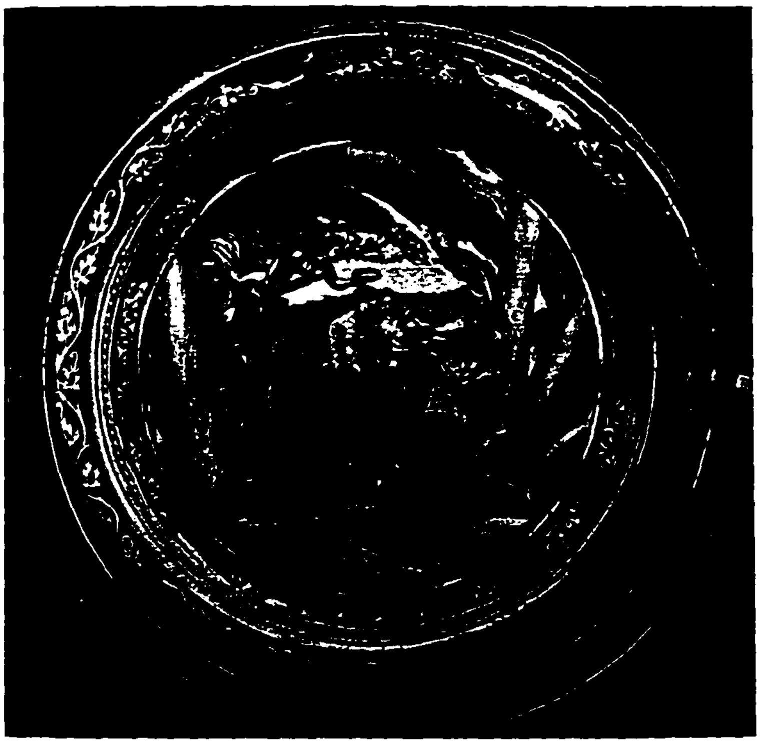

Fig. 7.4a. Glass plate with cold painting showing a mythological scene

Fig. 7.4b. Engraving with the bottom frame showing source for the design in Figure 7.4a

Fig. 7.4c. Opaque white glass cup with a Carpaccio-influenced design

Fig. 7.5. Detail of PE-162 showing enamelling on glass

Fig. 7.6. Italian dining scene dated to 1320

Fig. 7.7. Italian dining scene from the early 14th century

Fig. 7.8. *The Last Supper* by Paolo Veneziano (c. 1350)

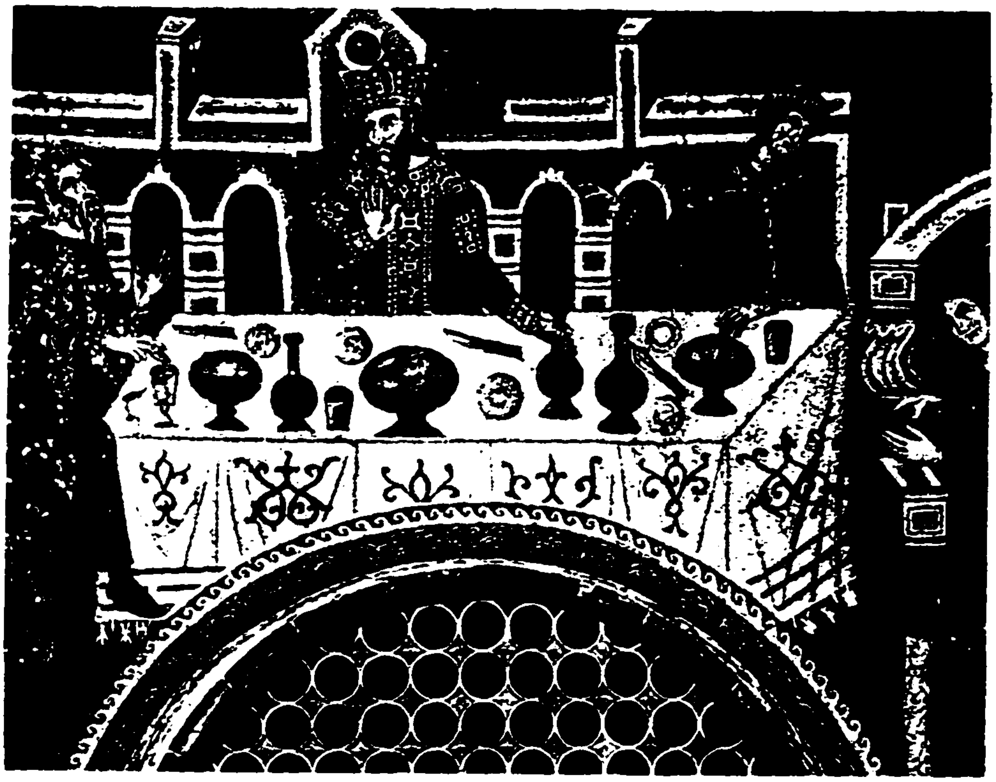

Fig. 7.9. Glass vessels as shown in the mosaics of San Marco Basilica, Venice

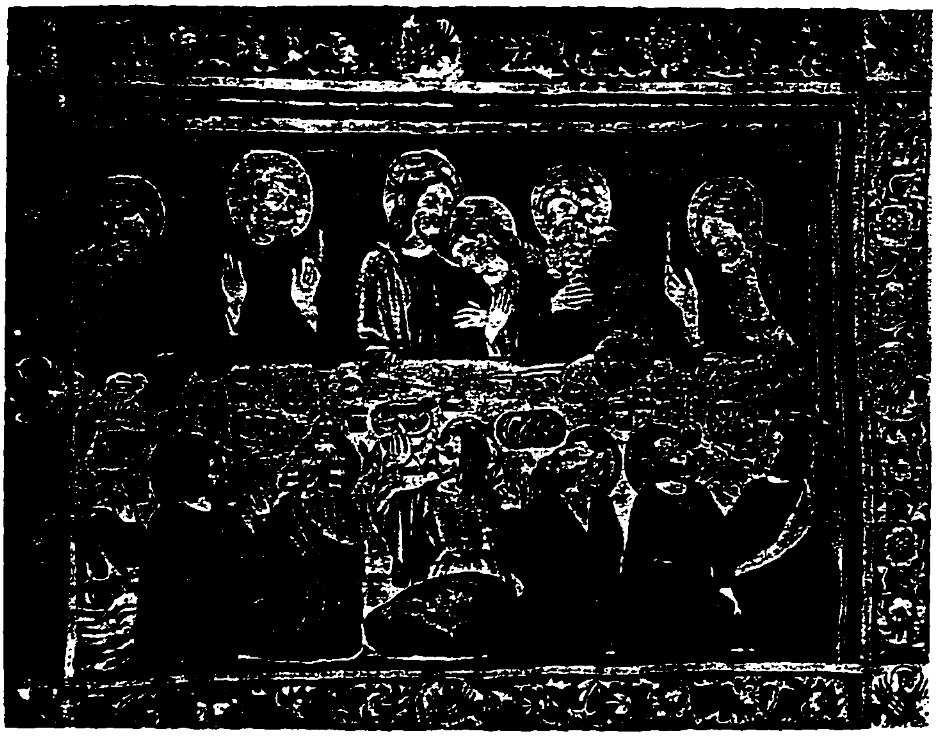

Fig. 7.10. Last supper scene from c. 1400

Fig. 7.11. Two examples of *inghistre* as shown in early Renaissance paintings

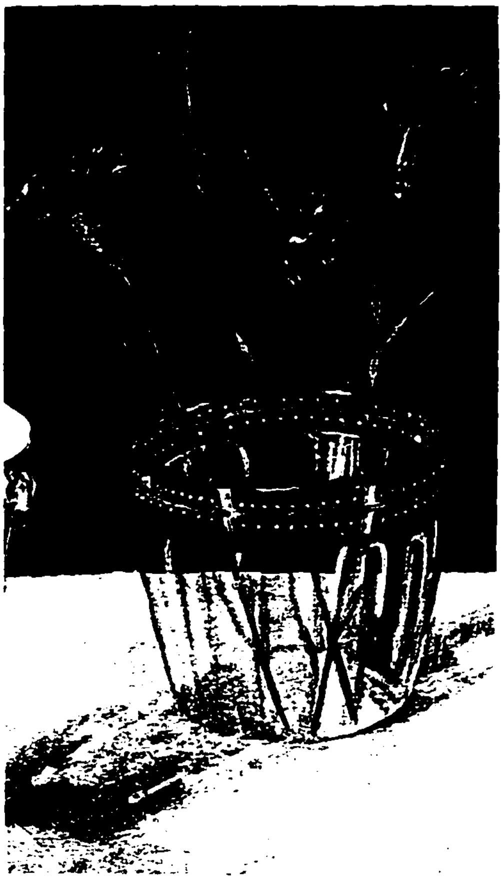

Fig. 7.12. Pictorial representation of an enamelled glass cup

Fig. 7.13. Glass jug as shown in a Titian painting

Fig. 7.14. Wineglass as shown in a work by Caravaggio; note similarities to actual vessels shown on the left

Fig. 7.15a. *The Wedding Feast at Cana* by Veronese

Fig. 7.15b. Detail of 7.15a

Fig. 7.15c. Detail of 7.15a

Fig. 7.16. Spanish still life by Van der Hamen

Fig. 7.17. Spanish still life with Venetian-style wineglass shown

Fig. 7.18. Spanish still life with glass vessels incorporating Venetian decorative motifs

Fig. 7.19. Spanish still life with a Venetian-style dragon stem goblet featured prominently

Fig. 7.20. Venetian wineglass (PE-25)

Fig. 7.21. Detail of Figure 7.20 showing exquisite hot-worked detail

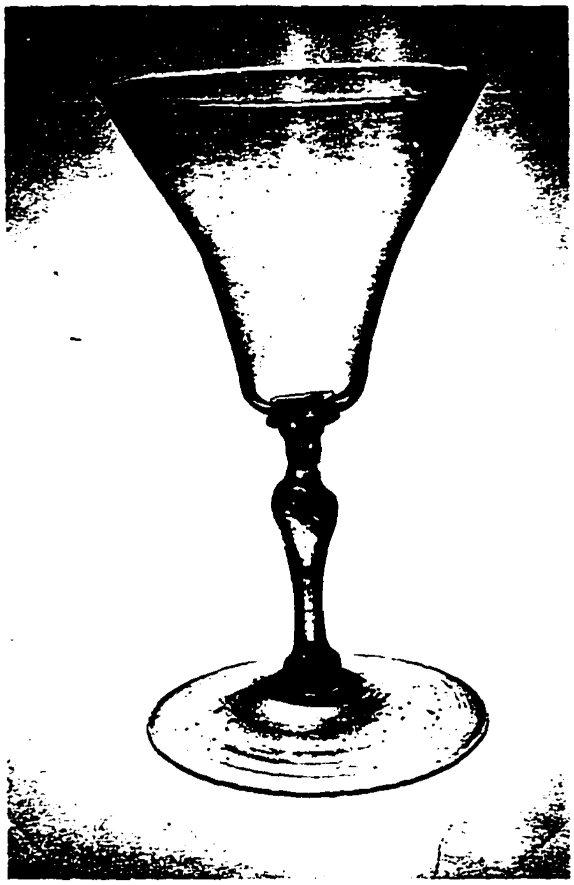

Fig. 7.22. Mis-shaped *facon de Venise* wineglass from the Corning Museum of Glass collection (PE-120)

Fig. 7.23. Mis-shaped *facon de Venise* wineglass from the Corning Museum of Glass collection (PE-123)

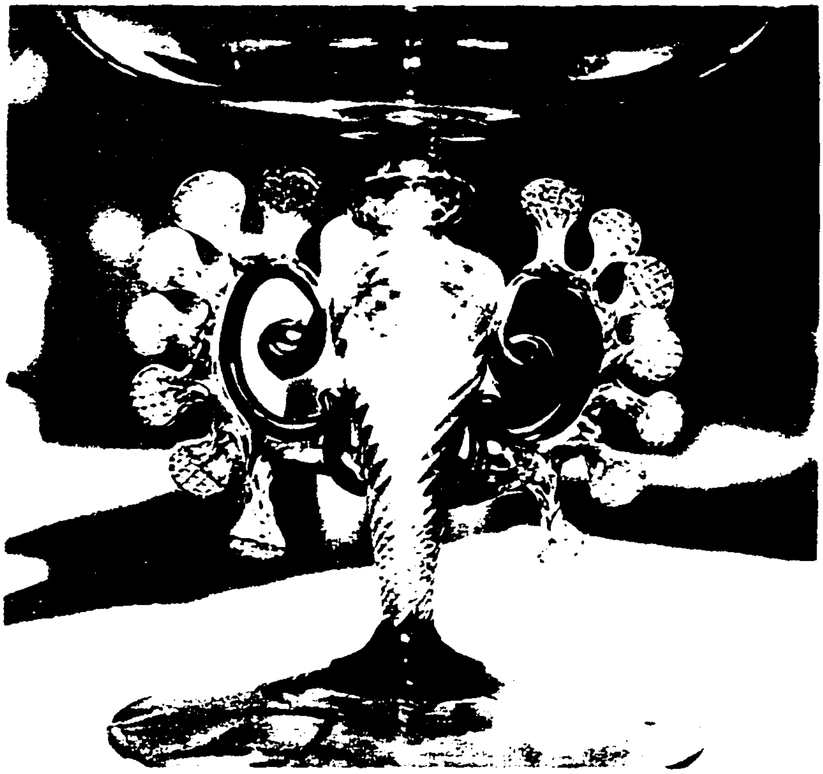

Fig. 7.24. Detail of PE-95 showing hot-working

Fig. 7.25. Filigree work and bit-working in one piece (PE-96)

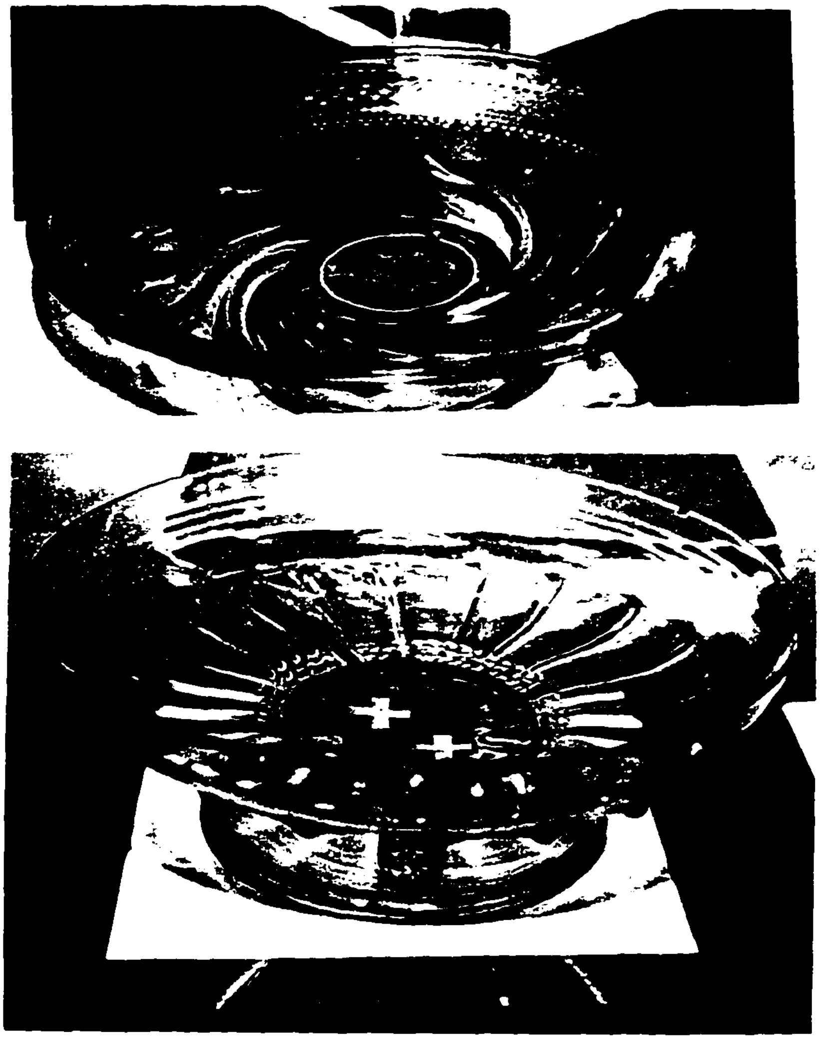

Fig. 7.26. Two examples of Venetian *tazze*

Fig. 7.27. Rock crystal vase held at the Tesoro di San Marco

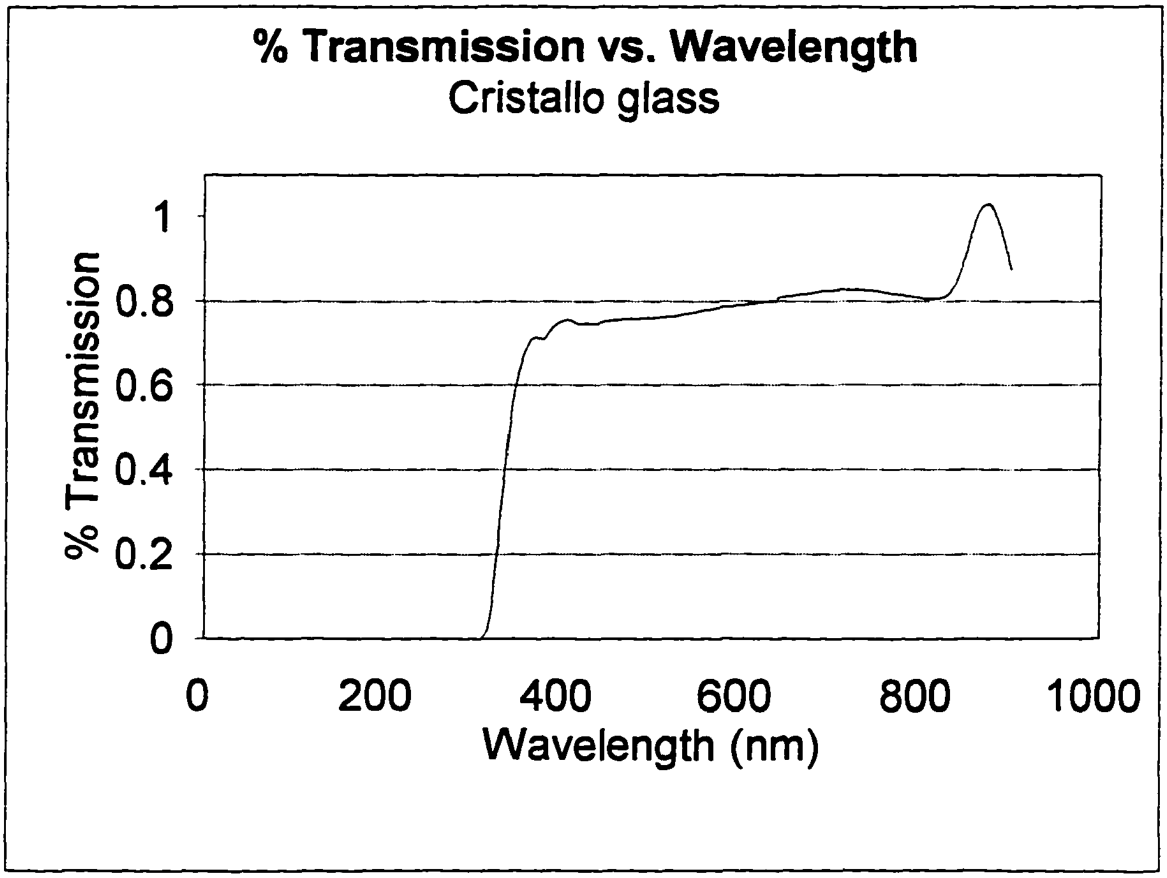

Fig. 7.28. Percent transmission versus wavelength for Sample 1

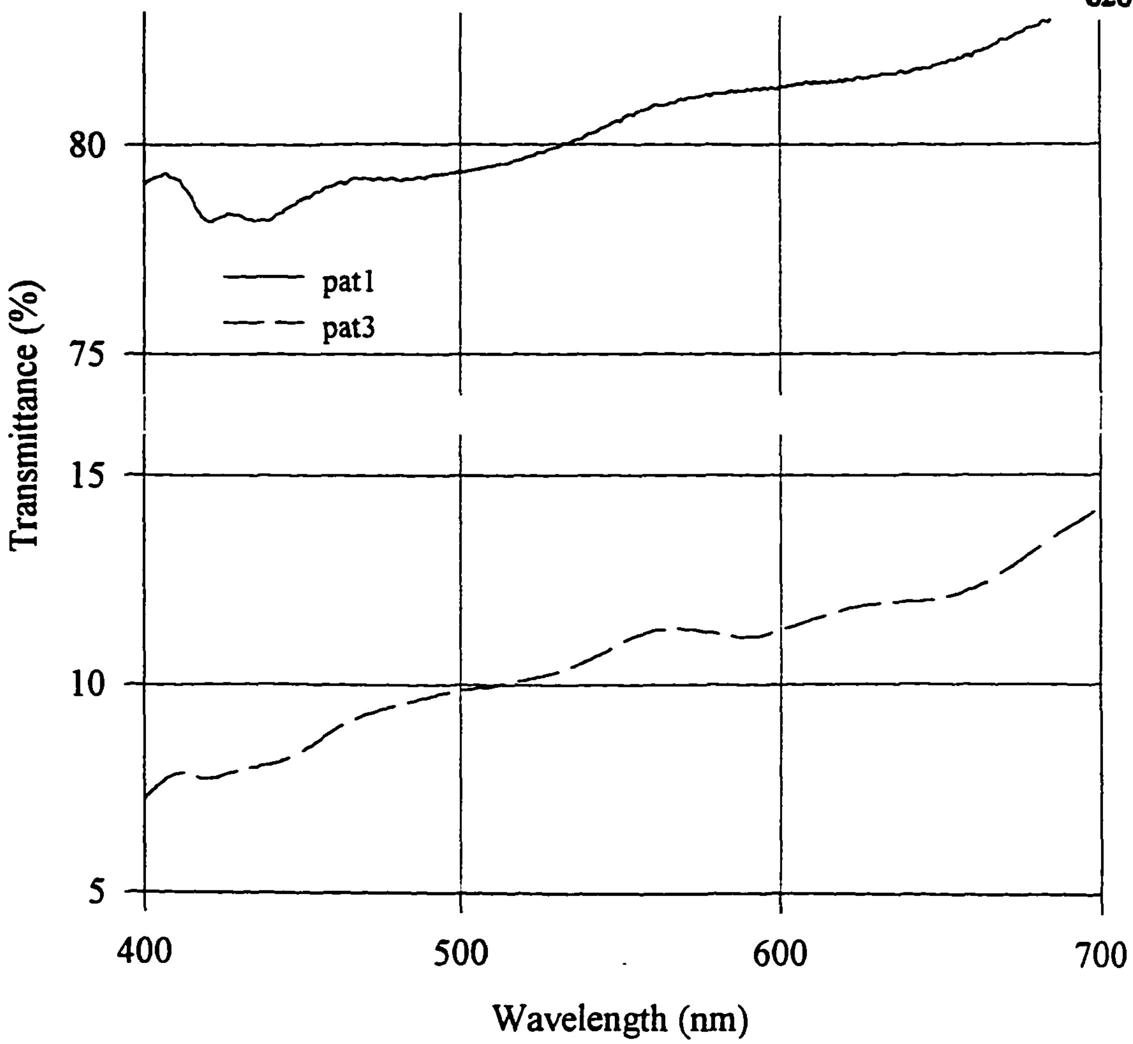

Fig. 7.29. Percent transmission versus wavelength for Sample 1 (PAT1) and Sample 3 (PAT3)

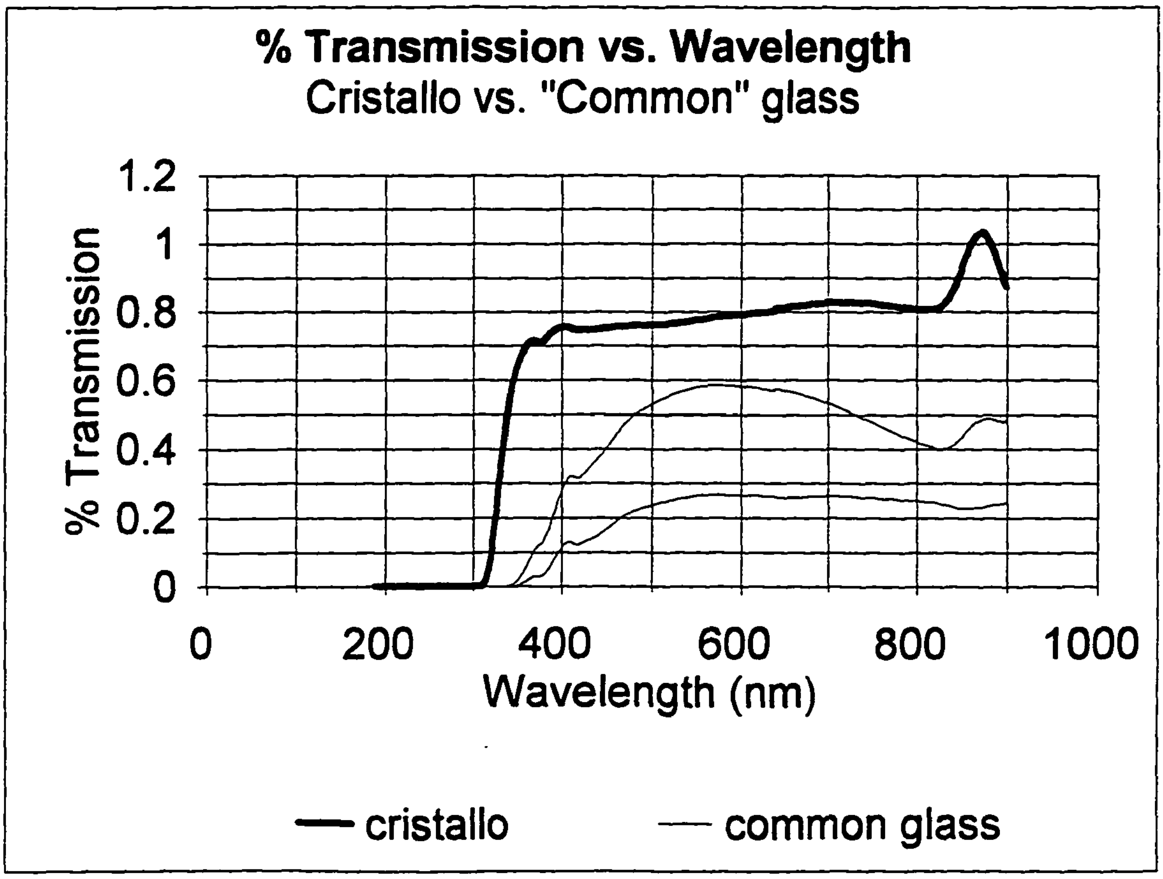

Fig. 7.30. Percent transmission versus wavelength for *cristallo* and common glass

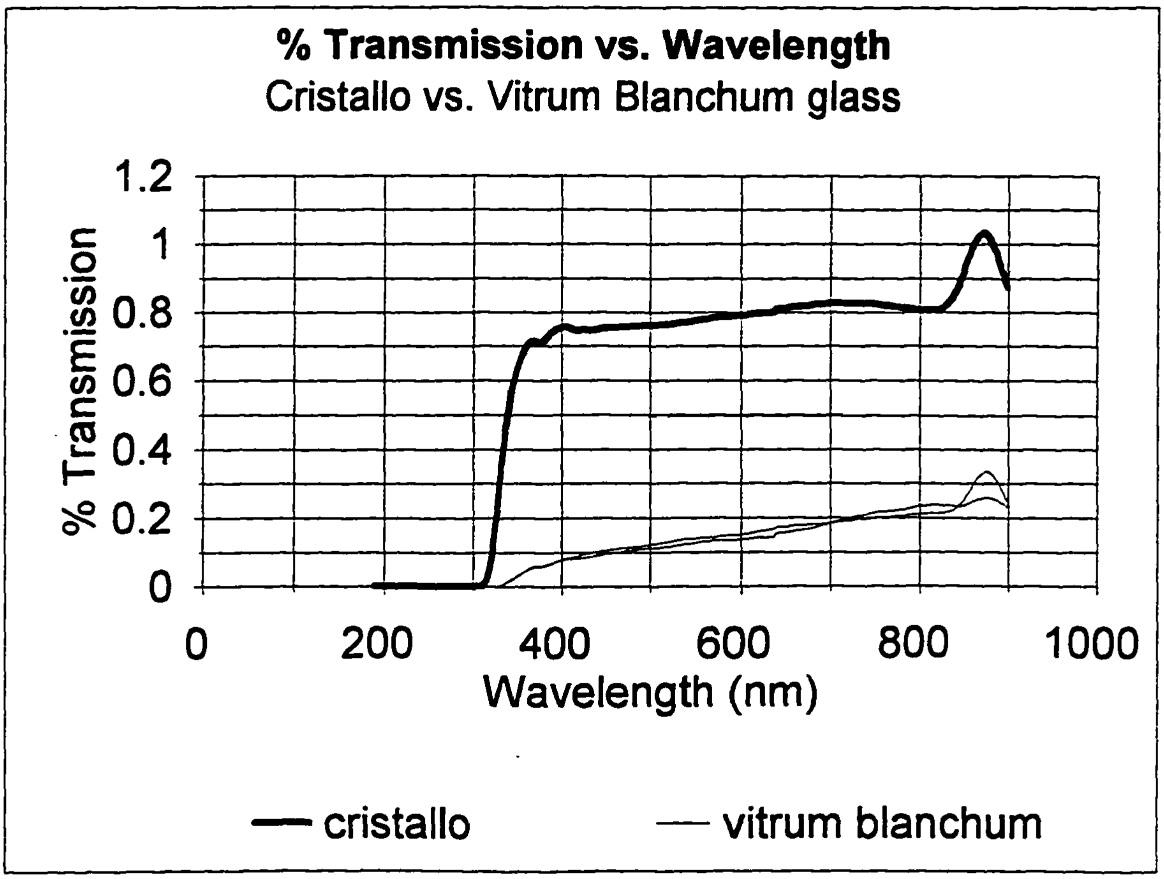

Fig. 7.31. Percent transmission versus wavelength for *cristallo* and *vitrum blanchum* glass

Fig. 8.1. 16th century Venetian wineglass from the Museo Vetrario (PE-57)

Fig. 8.2. Trick glass (detail)

Fig. 8.3. Glass furnace from the *De Universo* manuscript

Fig. 8.4. Fritting furnace as shown in Agricola's *De Re Metallica*

Fig. 8.5. Primary furnace from Agricola's manuscript

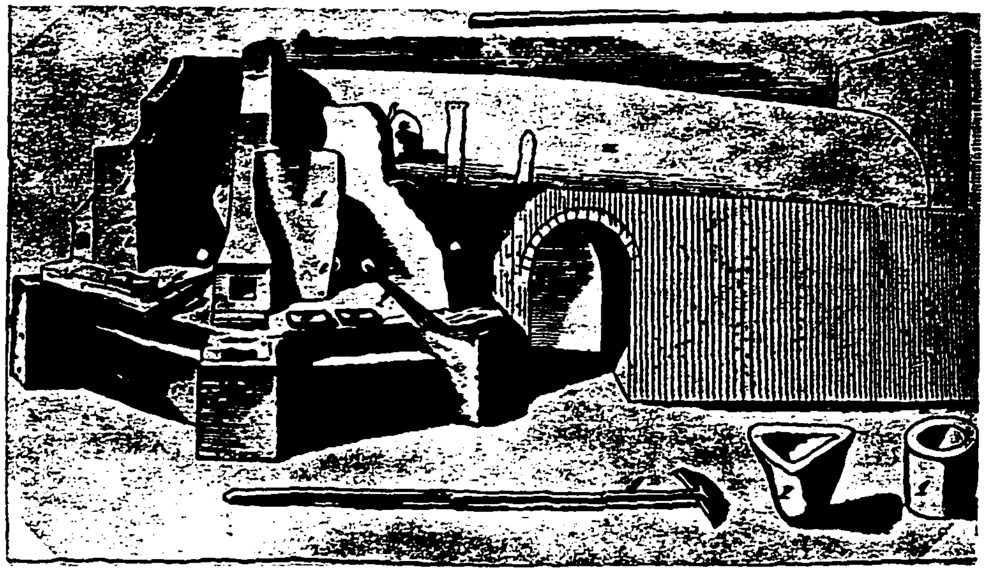

Fig. 8.6. Primary glass furnace as shown in a French translation of Neri's L'Arte Vetraria

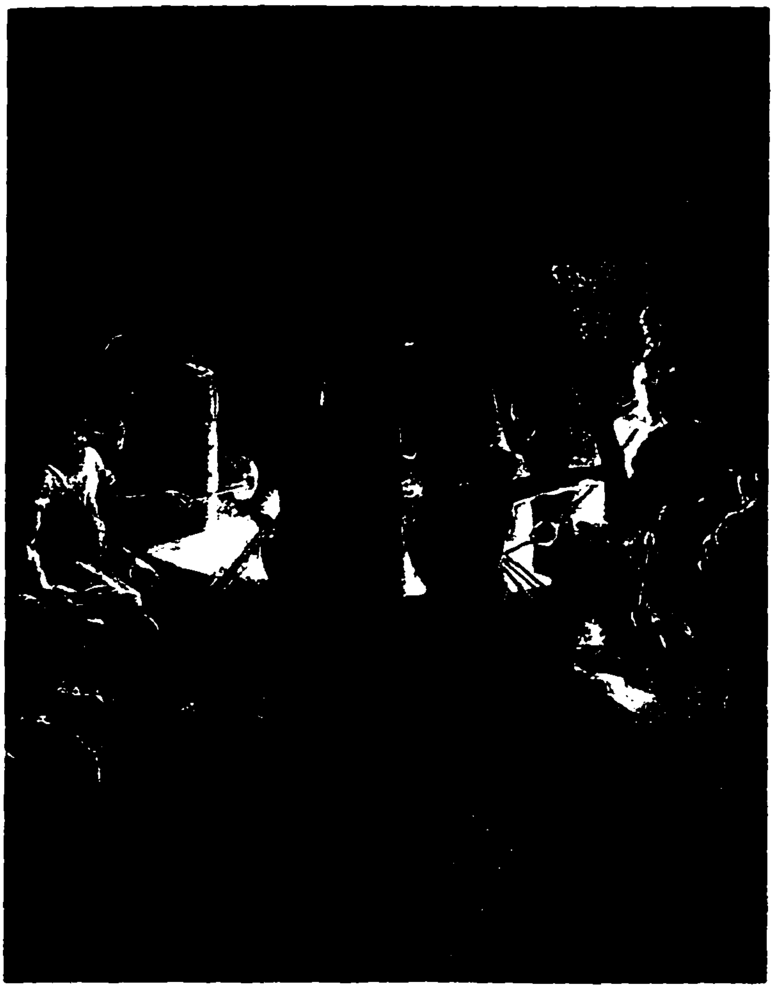

Fig. 8.7. Venetian style glass furnace as shown in a 16th century Florentine painting by Butteri

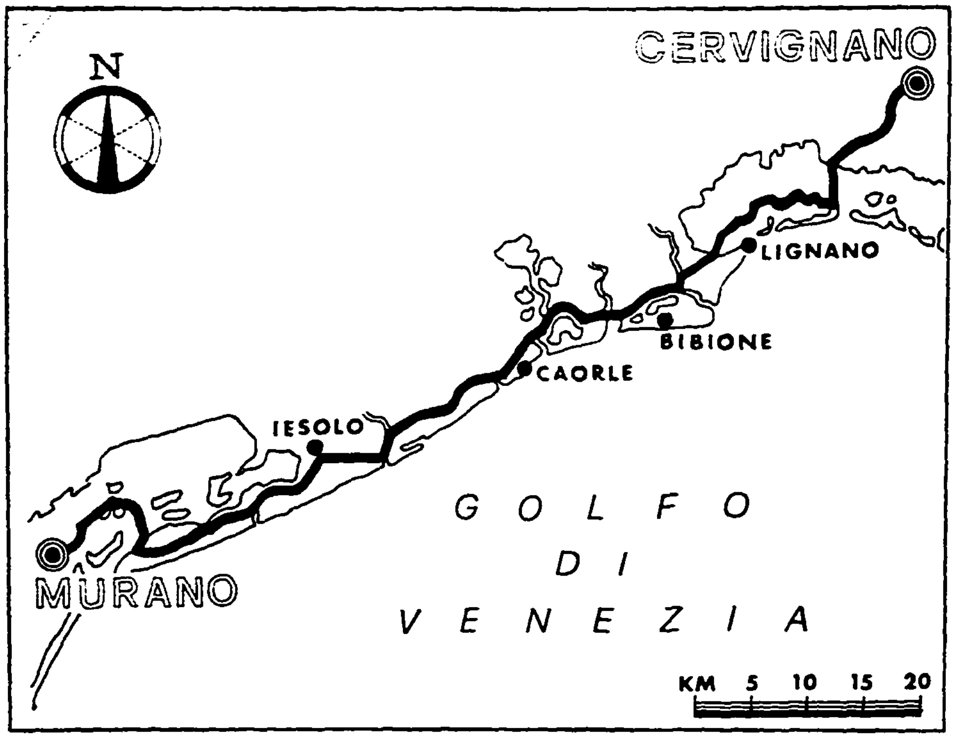

Fig. 8.8. Wood supply line to Venice (from Zecchin, 1987)

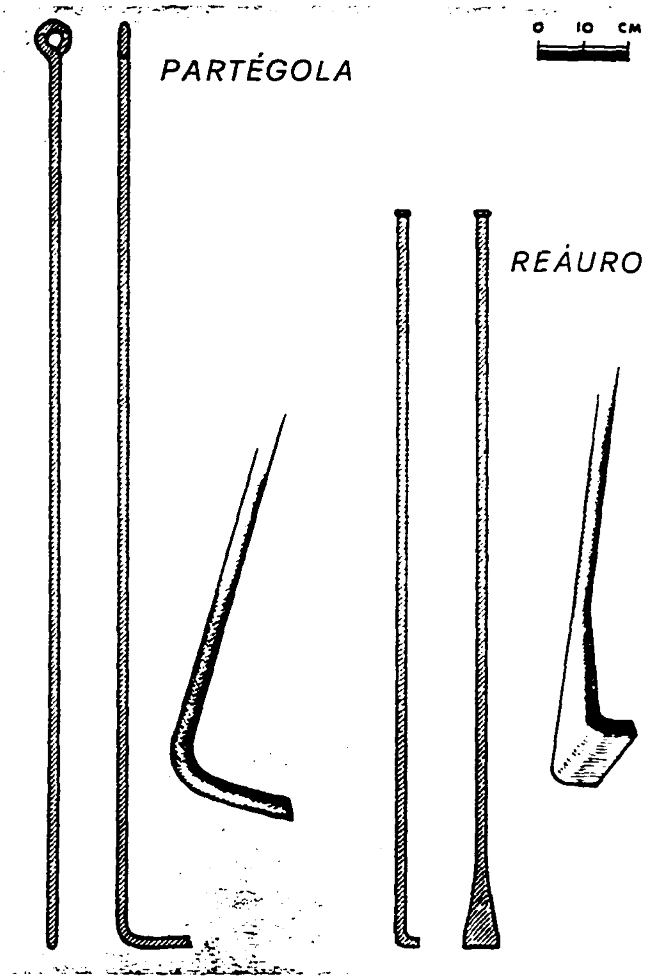

Fig. 8.9. Reaura and partegola, two Venetian glassmaking tools

Fig. 8.10. Sherd assemblage of *vitrum blanchum* glass

Fig. 8.11. Samples UA-16 and UA-17 showing the difference between common and *cristallo* glass

Fig. 8.12. Weathered glass in bowl (PE-193)

Fig. 8.13. Large bubbles in ribbed section of a glass bowl (PE-9)

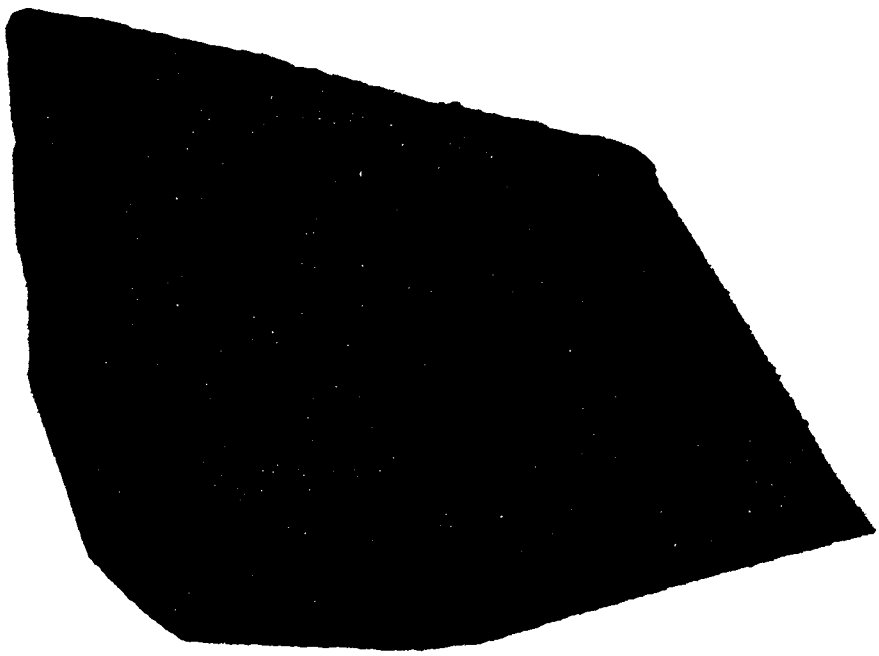

Fig. 8.14. Spherical bubbles in light blue vessel glass (UA-14)

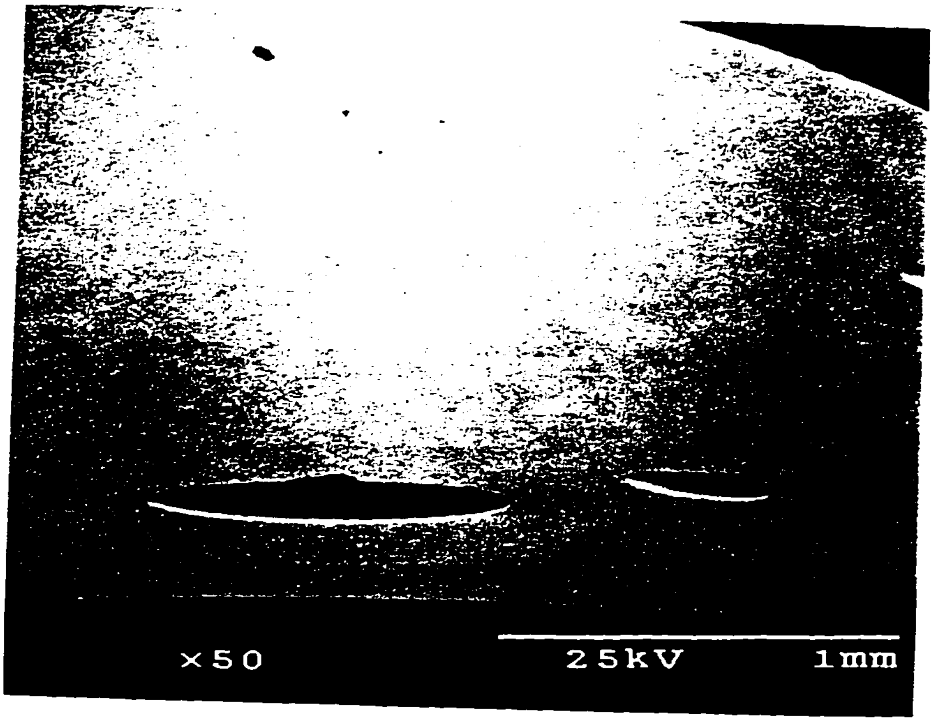

Fig. 8.15. Elongated bubbles as seen in an SEM micrograph

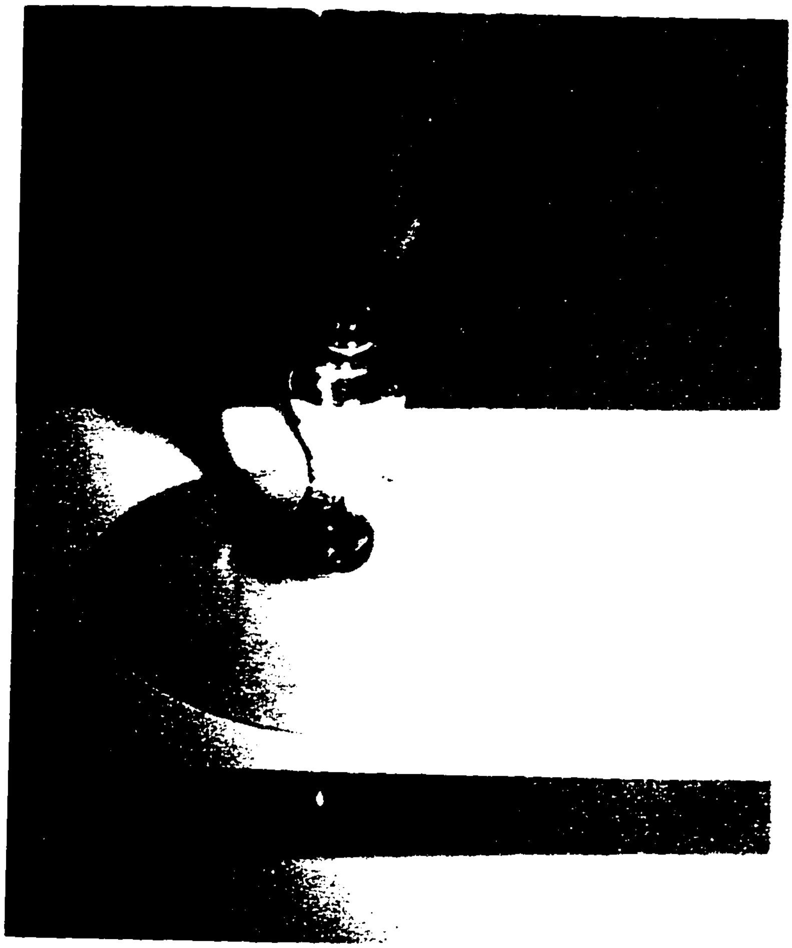

Fig. 8.16. Blowing spirals (PE-50)

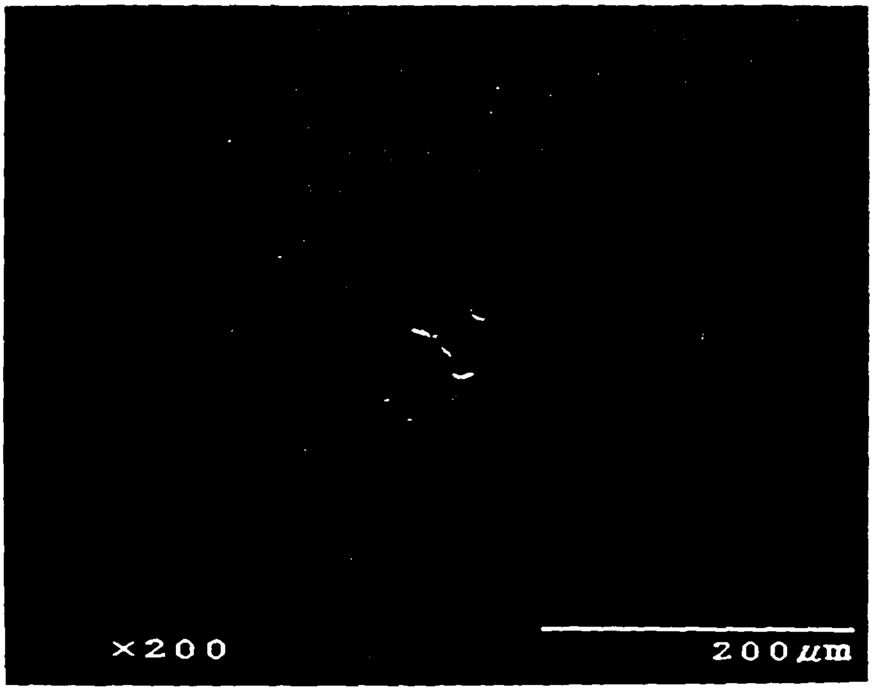

Fig. 8.17. Examples of a sandy type stone in vessel material

Fig. 8.18. Stones in glass (PE-194)

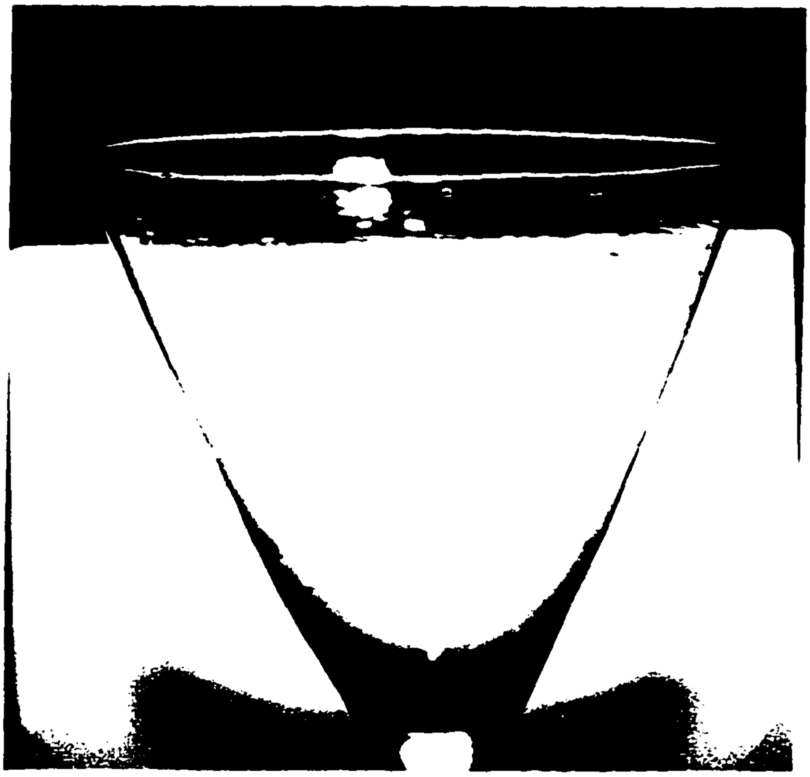

Fig. 8.19. Stones and cord defects in glass (PE-194)

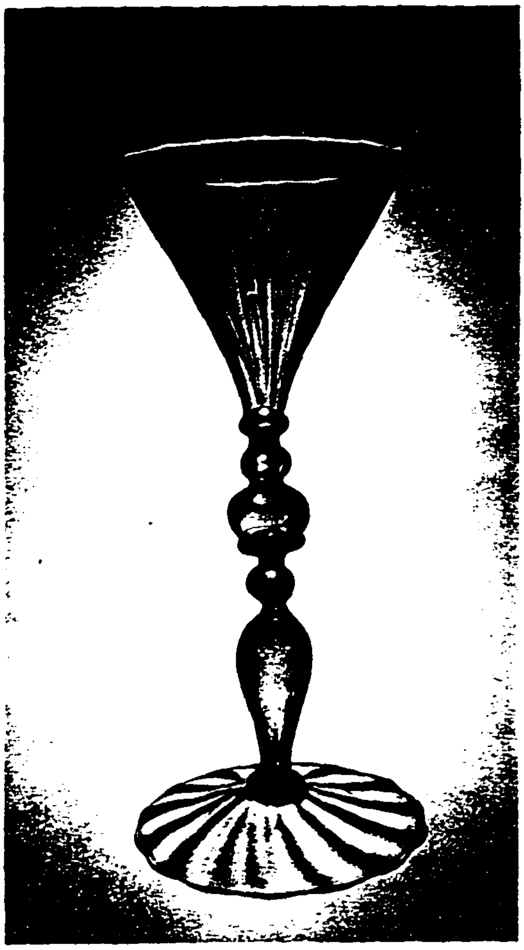

Fig. 8.20. Stones in glass (PE-130)

Fig. 8.21. Black flecks in glass, most likely the residue from tool-glass contact

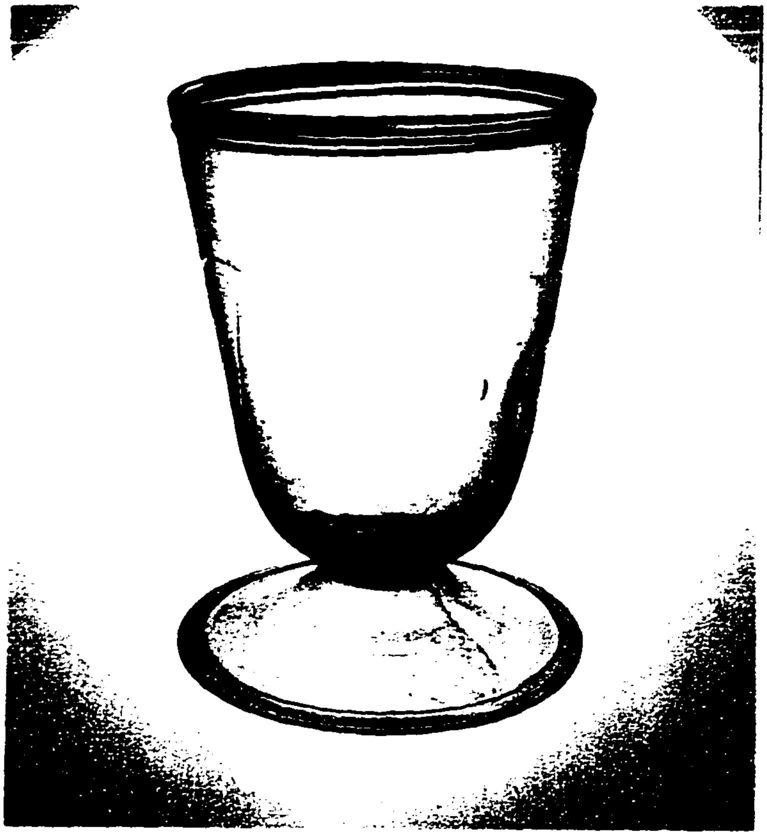

Fig. 8.22. Large cord in glass (PE-114)

Fig. 8.23. Back-scattered SEM image showing homogeneity in glass

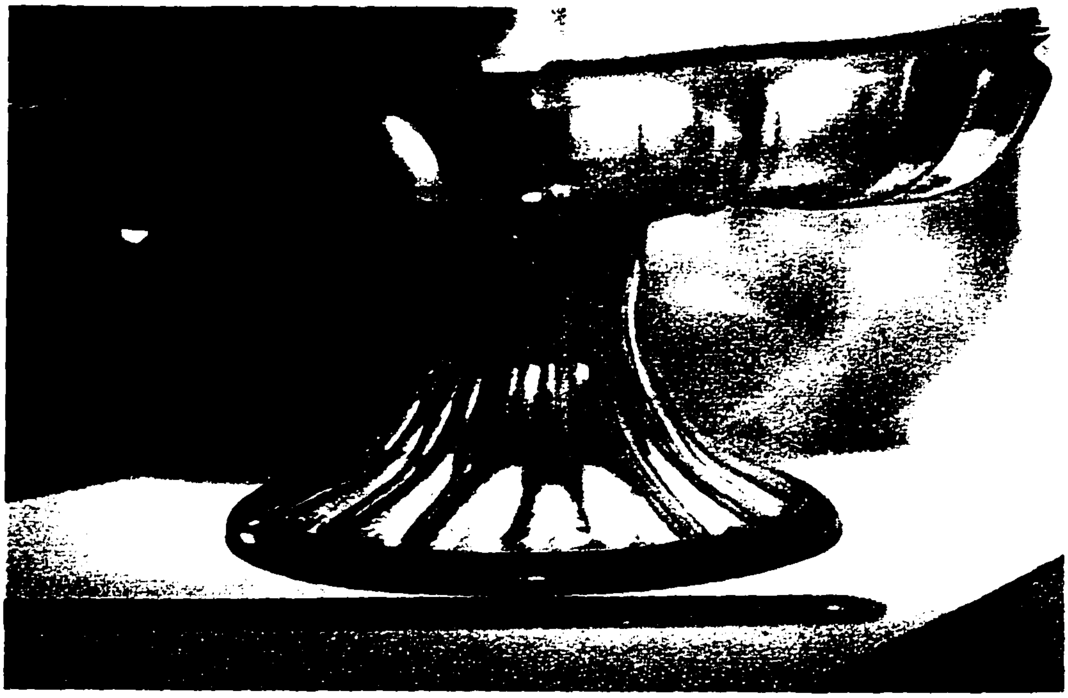

Fig. 8.24. Deformed Venetian glass bowl

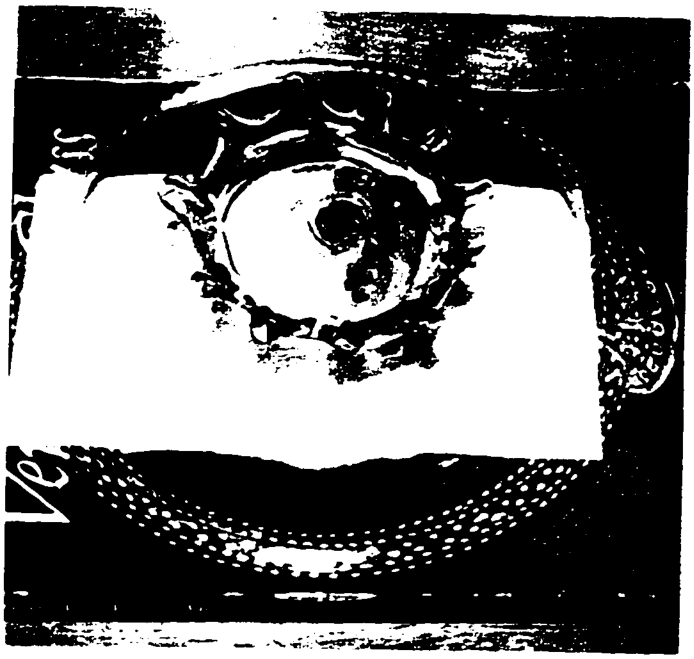

Fig. 8.25. Double pontil mark

Fig. 8.26. Example of further glass work (in this case, a handle) applied over enamel

Fig. 8.27. 18th century Venetian glass tumbler

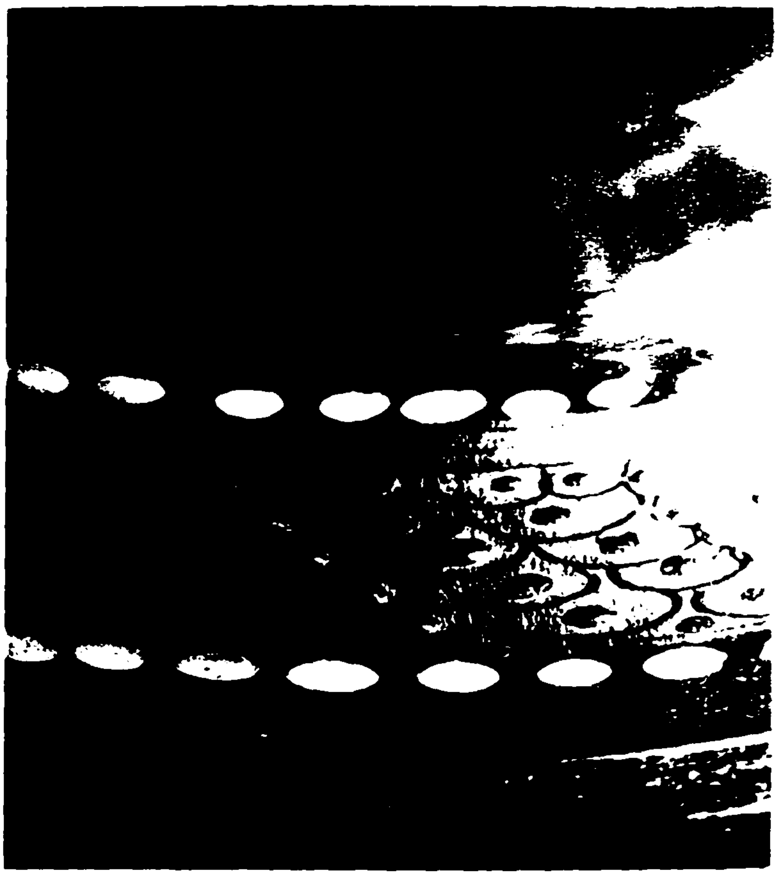

Fig. 8.28. Detail of enamelling and gilding on a Venetian piece

Fig. 8.29. Example of a Verzelini *facon de Venise* piece

Fig. 8.30. Example of English lead crystal from the 18th century

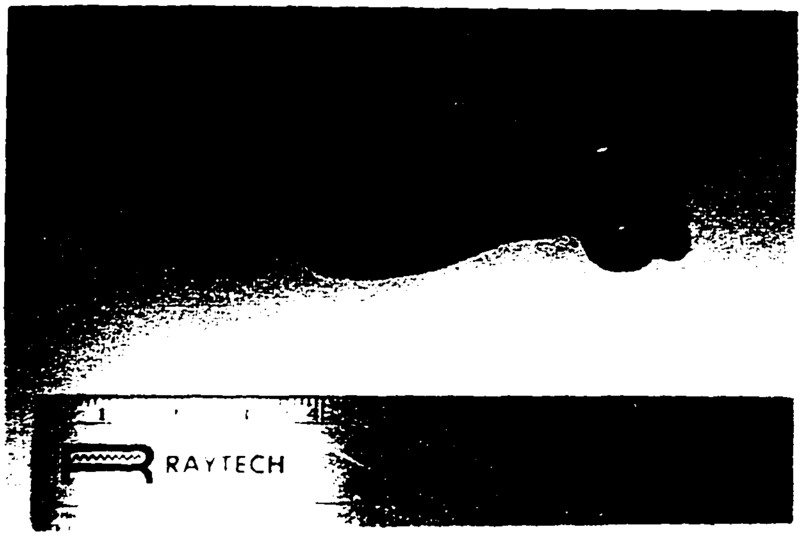

Fig. 8.31. Venetian wineglass stem (16th century) made of *vitrum blanchum* glass

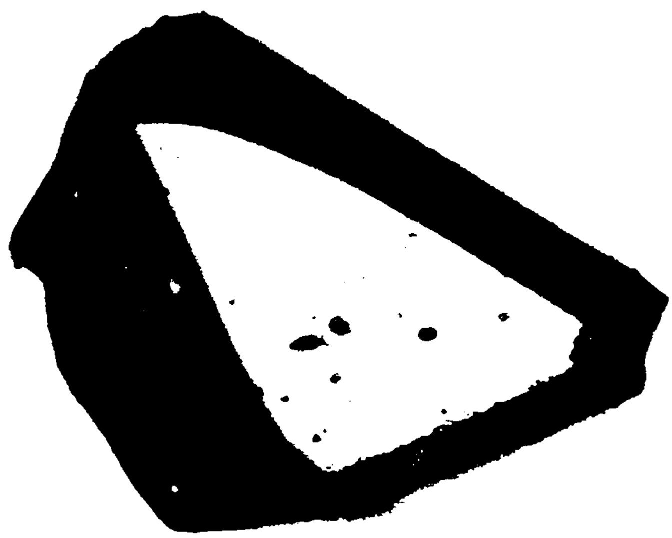

Fig. 8.32. Example of *cristallo* glass sample

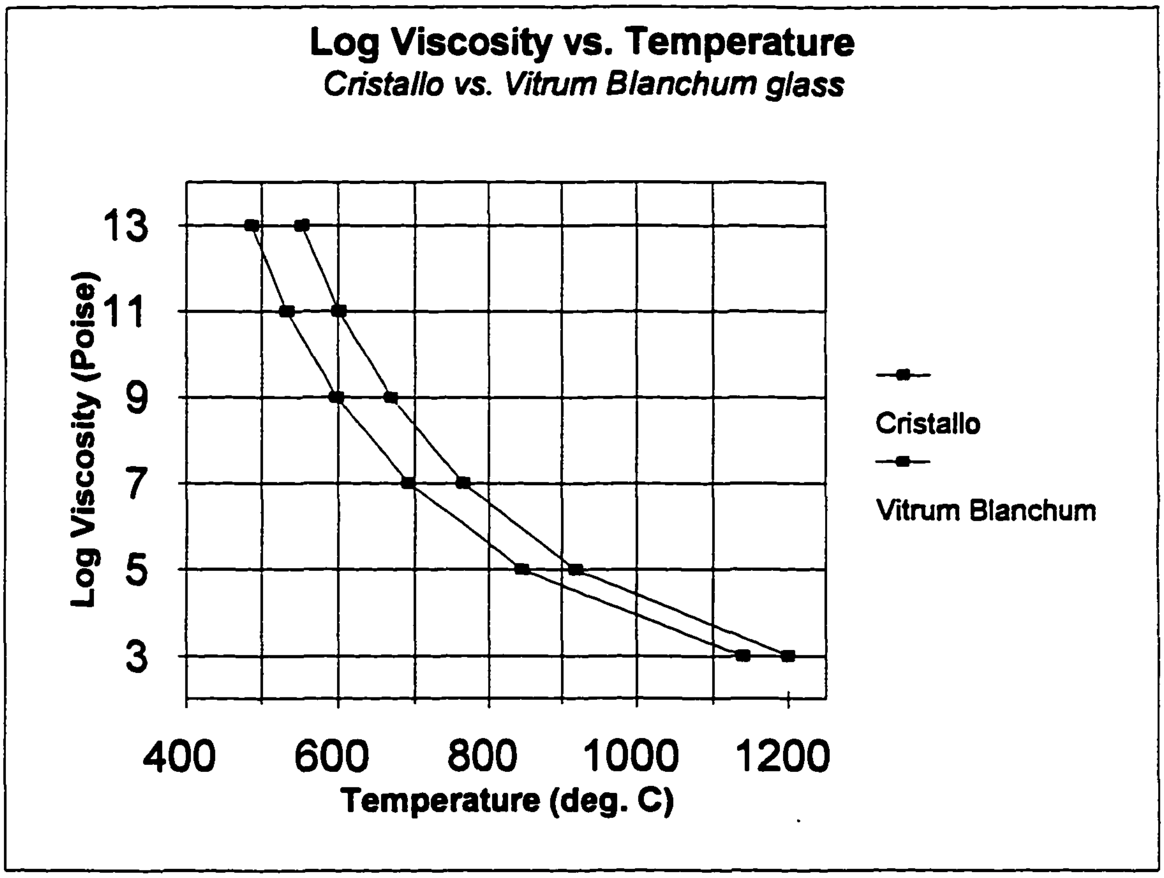

Fig. 8.33. Viscosity-temperature plot for *cristallo* and *vitrum blanchum* compositions

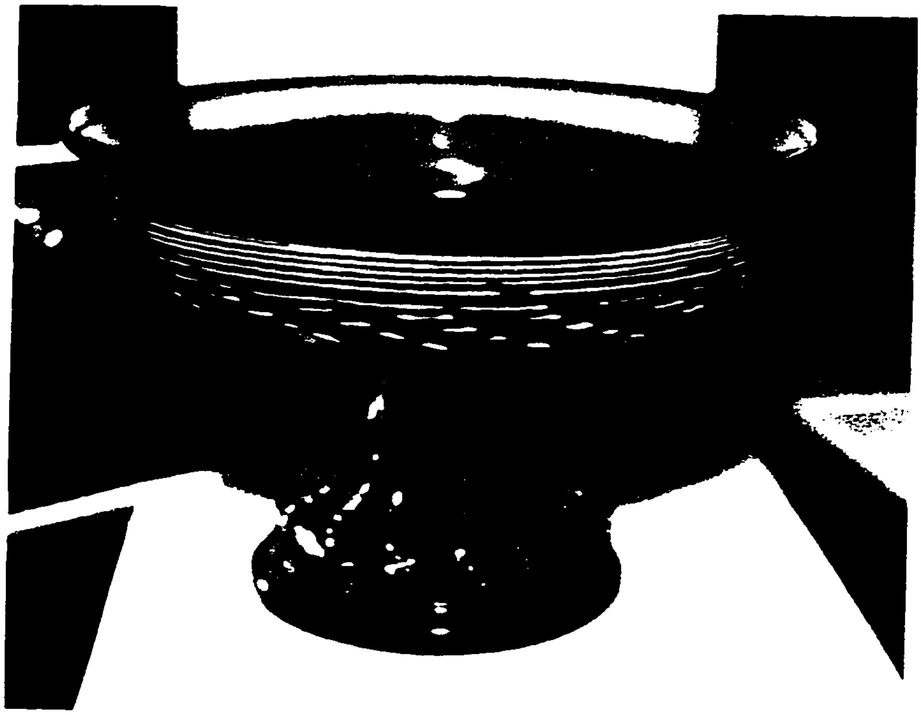

Fig. 8.34. Glass with accompanying metalwork

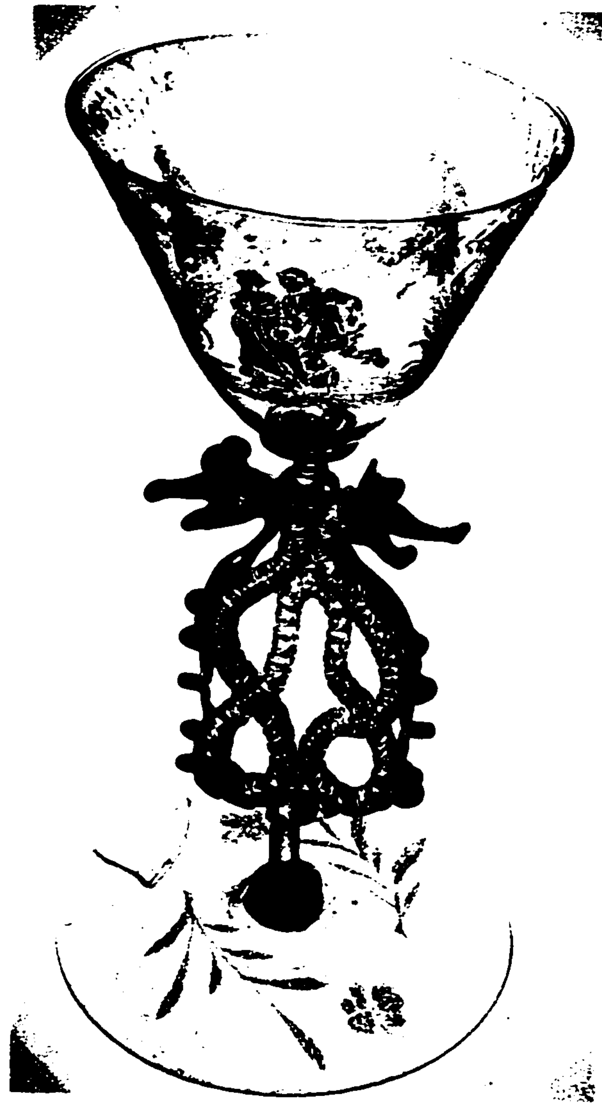

Fig. 9.1. Venetian dragon stem goblet

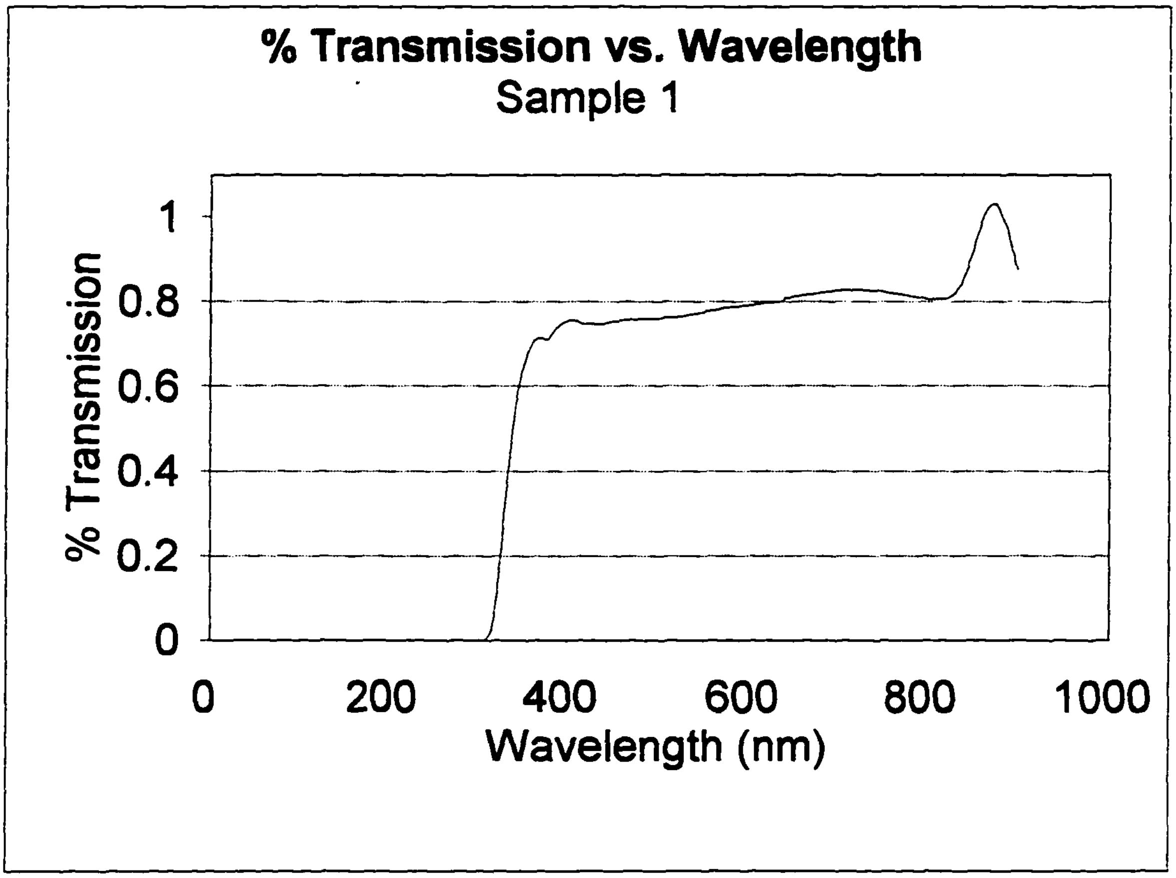

Fig. A.1. Percent transmission versus wavelength plot for Sample 1

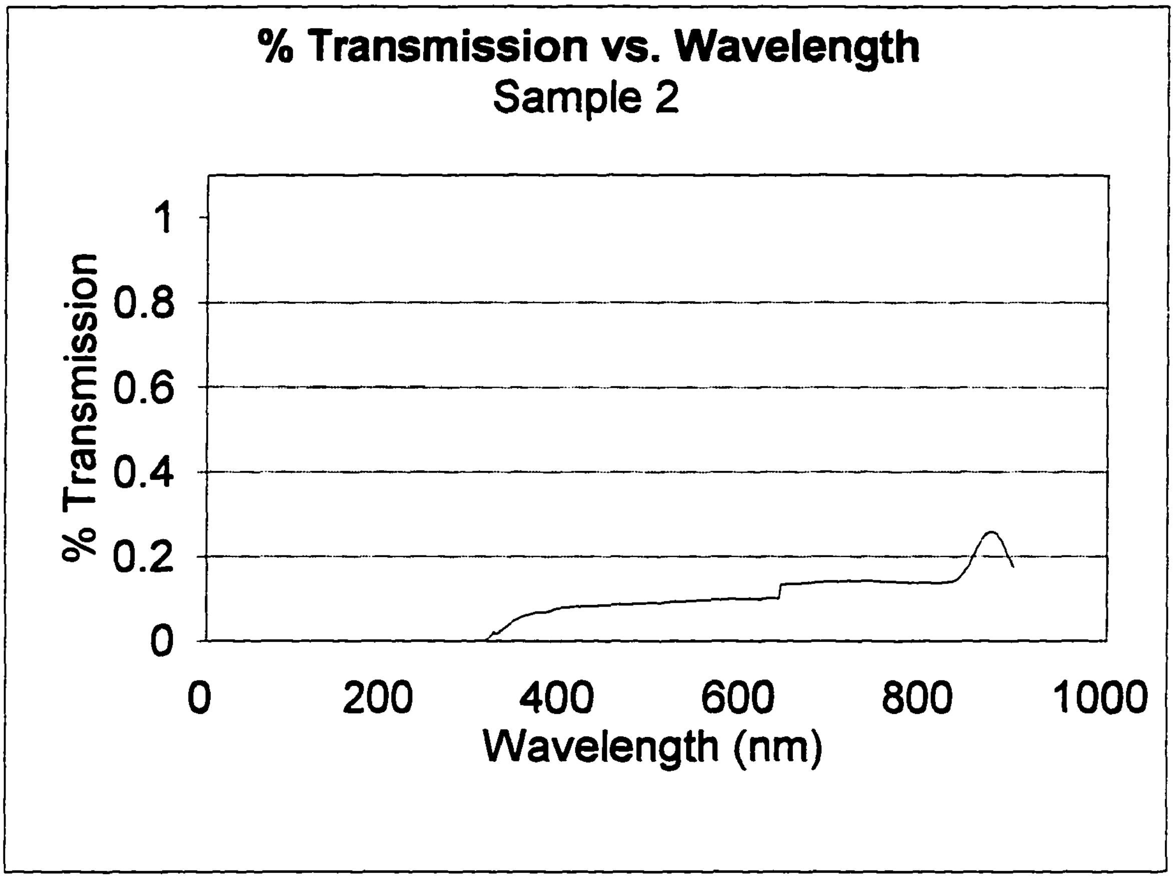

Fig. A.2. Percent transmission versus wavelength plot for Sample 2

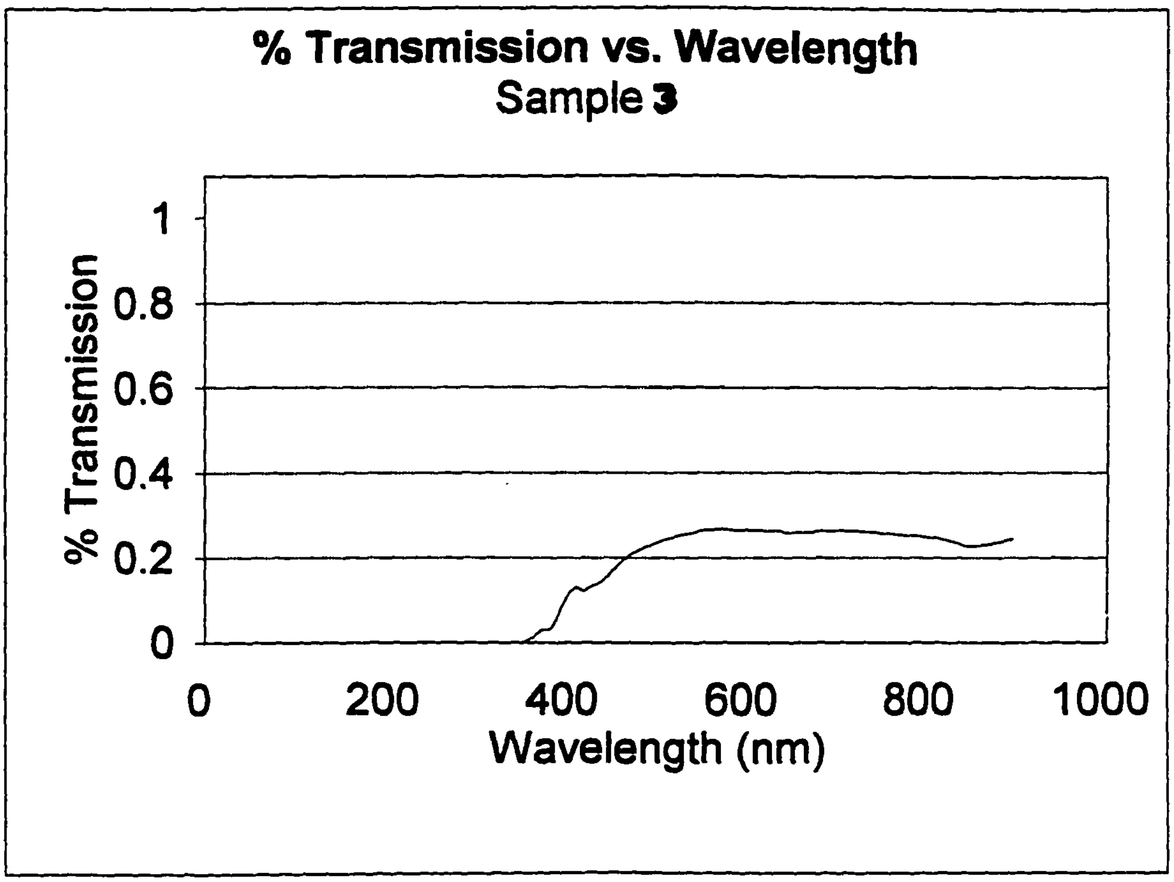

Fig. A.3. Percent transmission versus wavelength plot for Sample 3

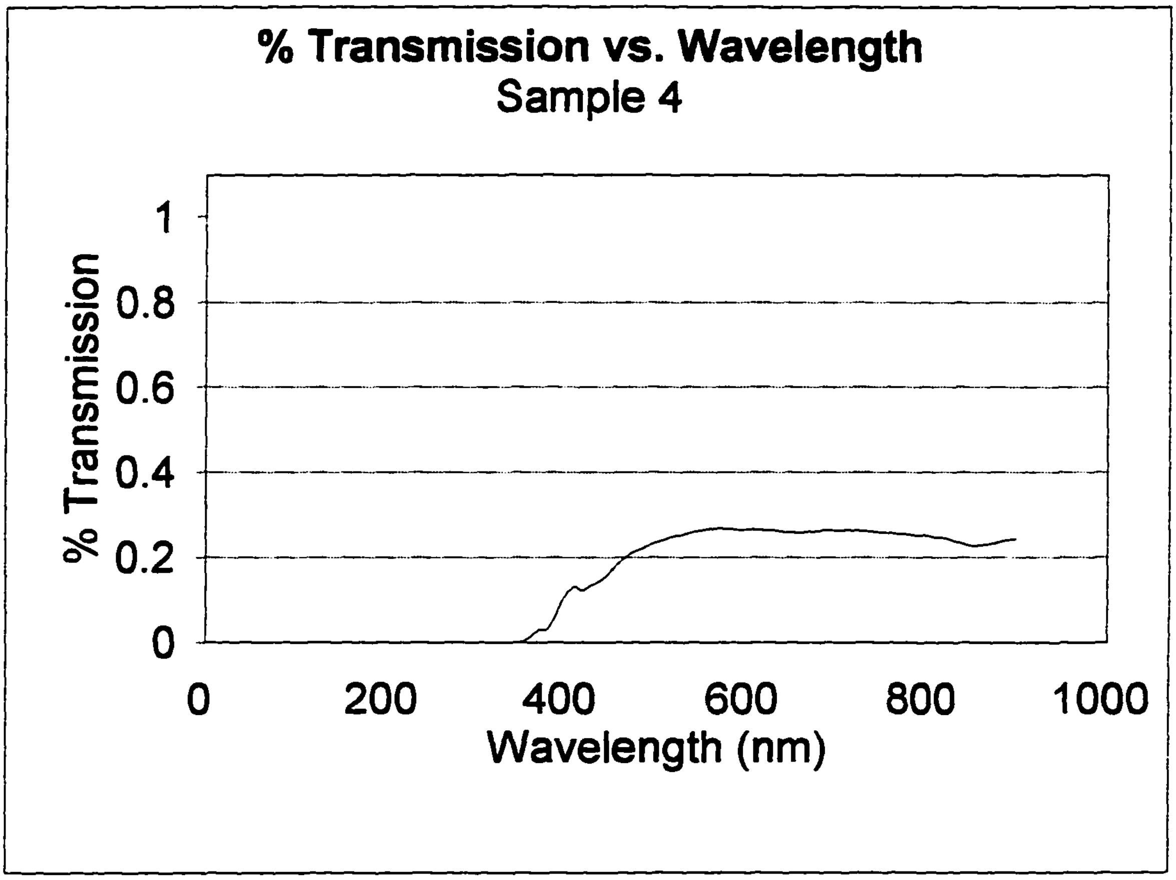

Fig. A.4 Percent transmission versus wavelength plot for Sample 4

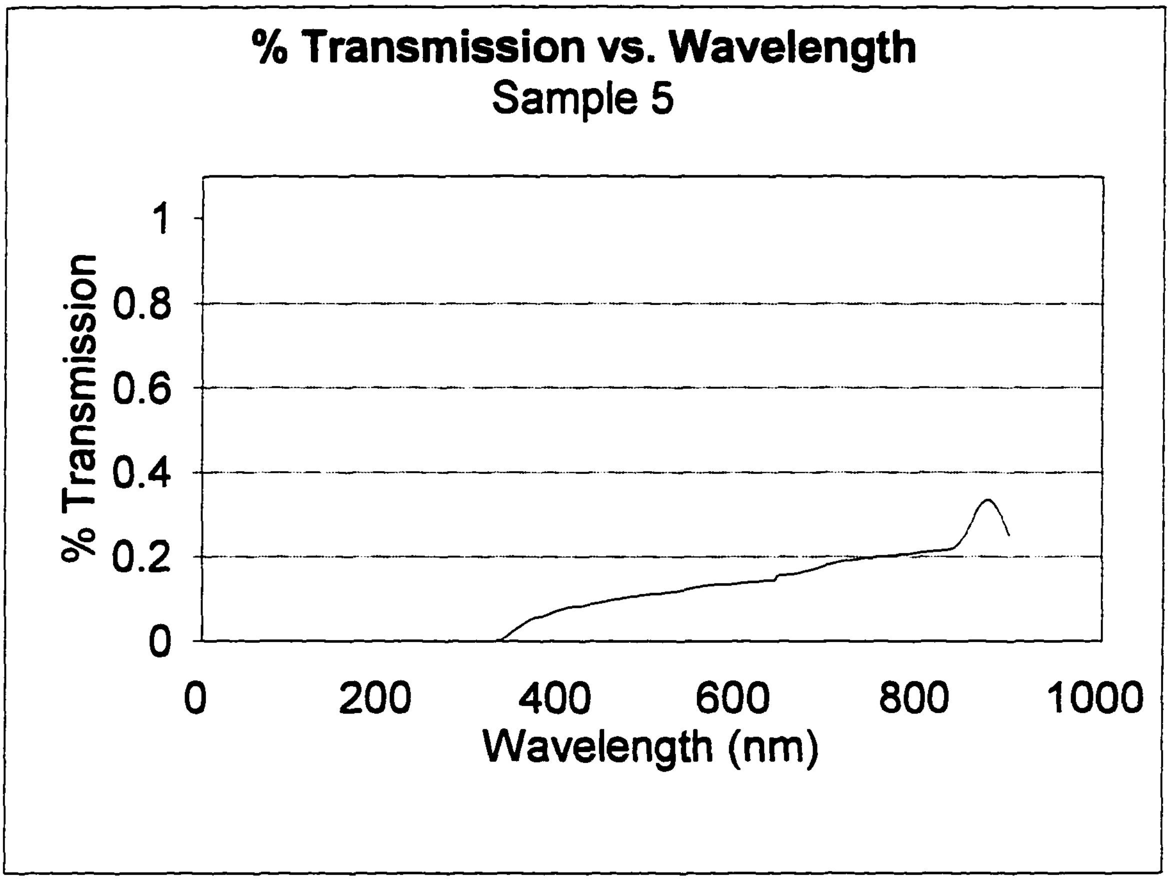

Fig. A.5. Percent transmission versus wavelength plot for Sample 5

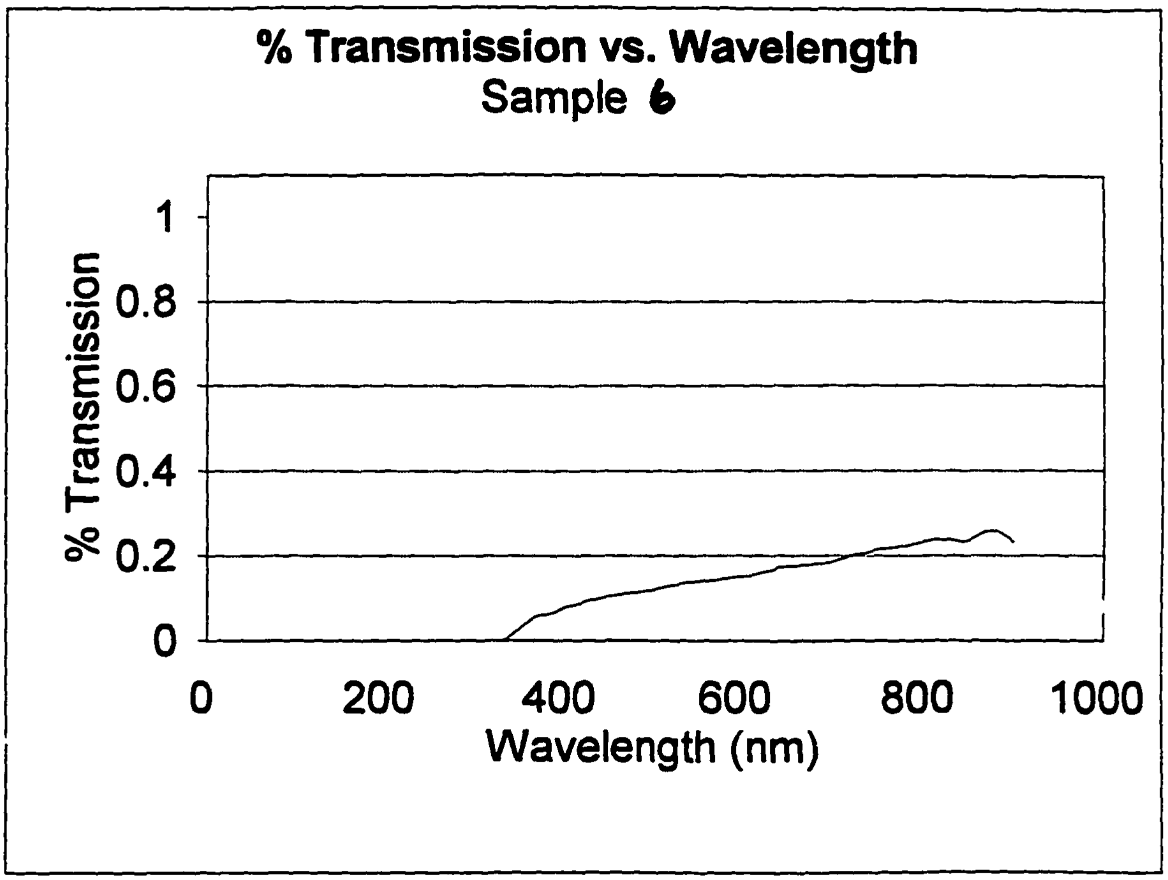

Fig. A.6. Percent transmission versus wavelength plot for Sample 6

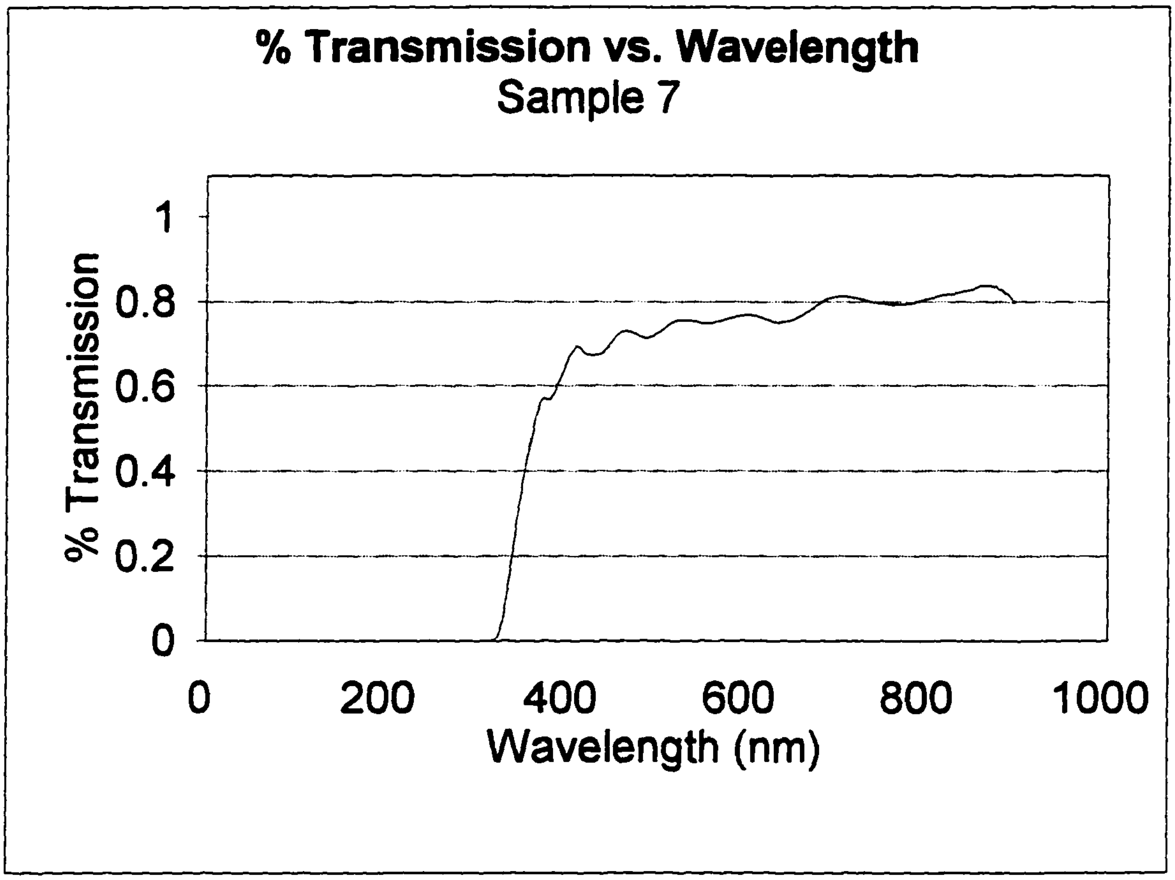

Fig. A.7. Percent transmission versus wavelength plot for Sample 7

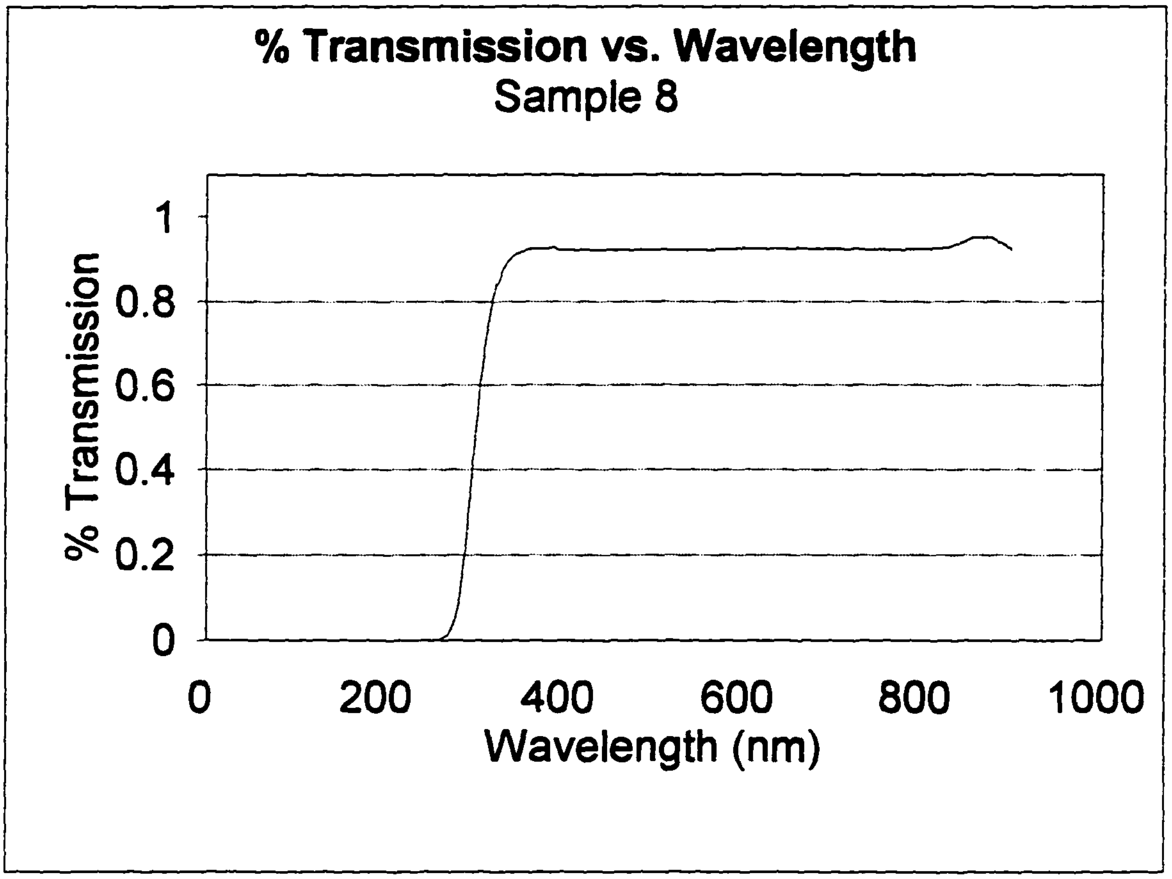

Fig. A.8. Percent transmission versus wavelength plot for Sample 8

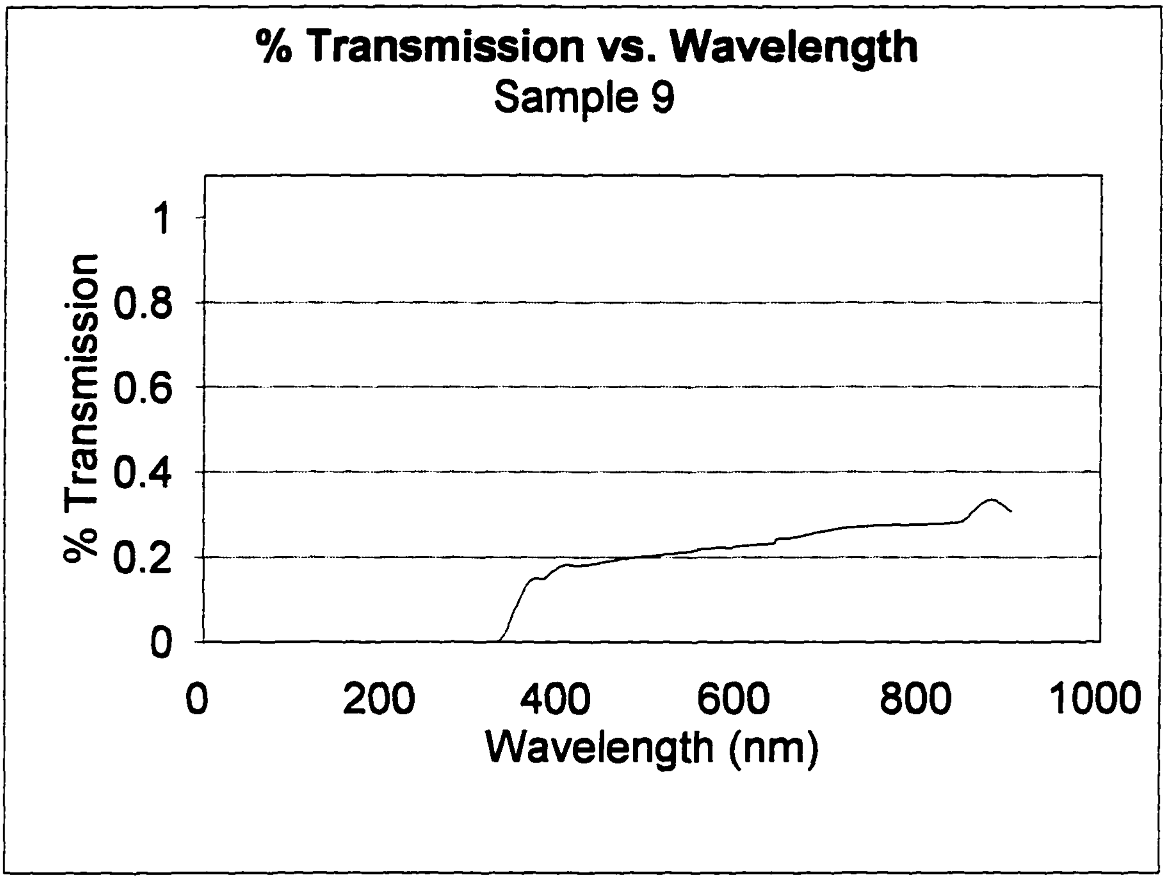

Fig. A.9. Percent transmission versus wavelength plot for Sample 9

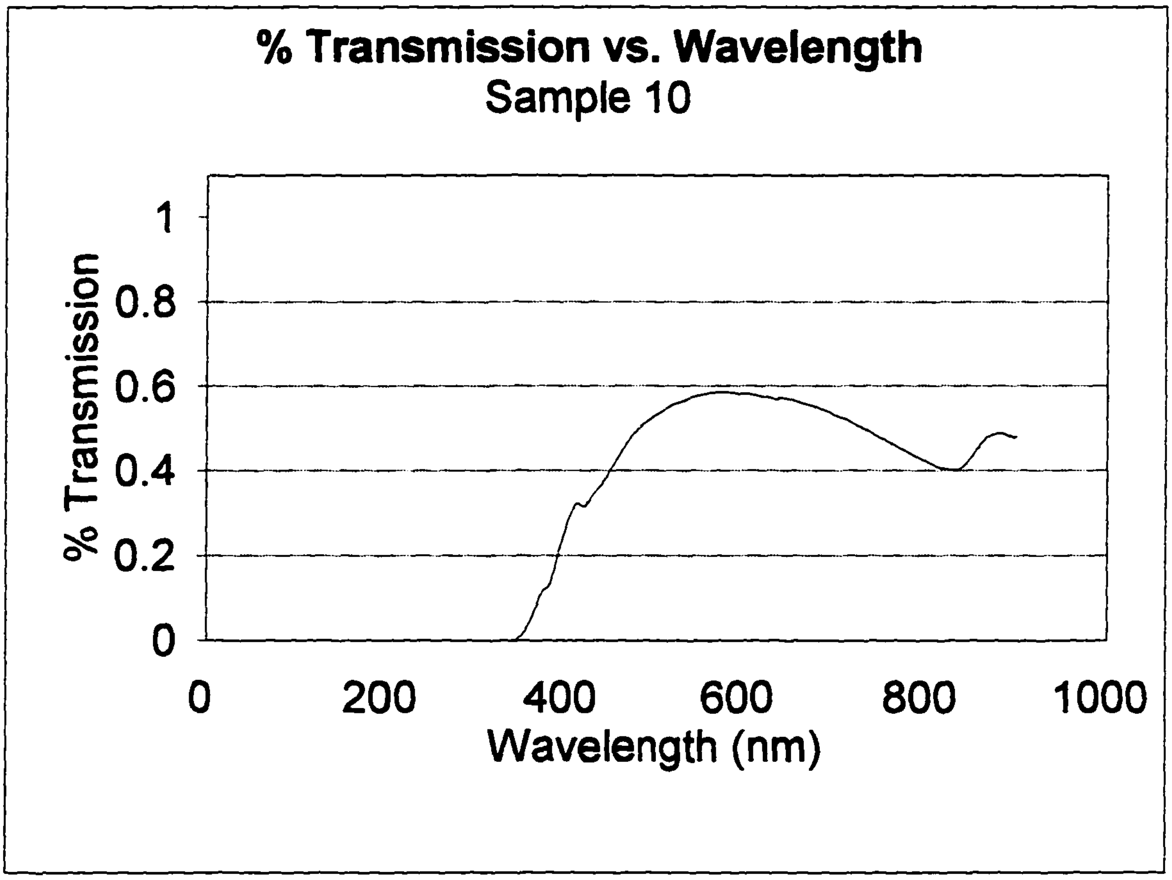

Fig. A.10. Percent transmission versus wavelength plot for Sample 10

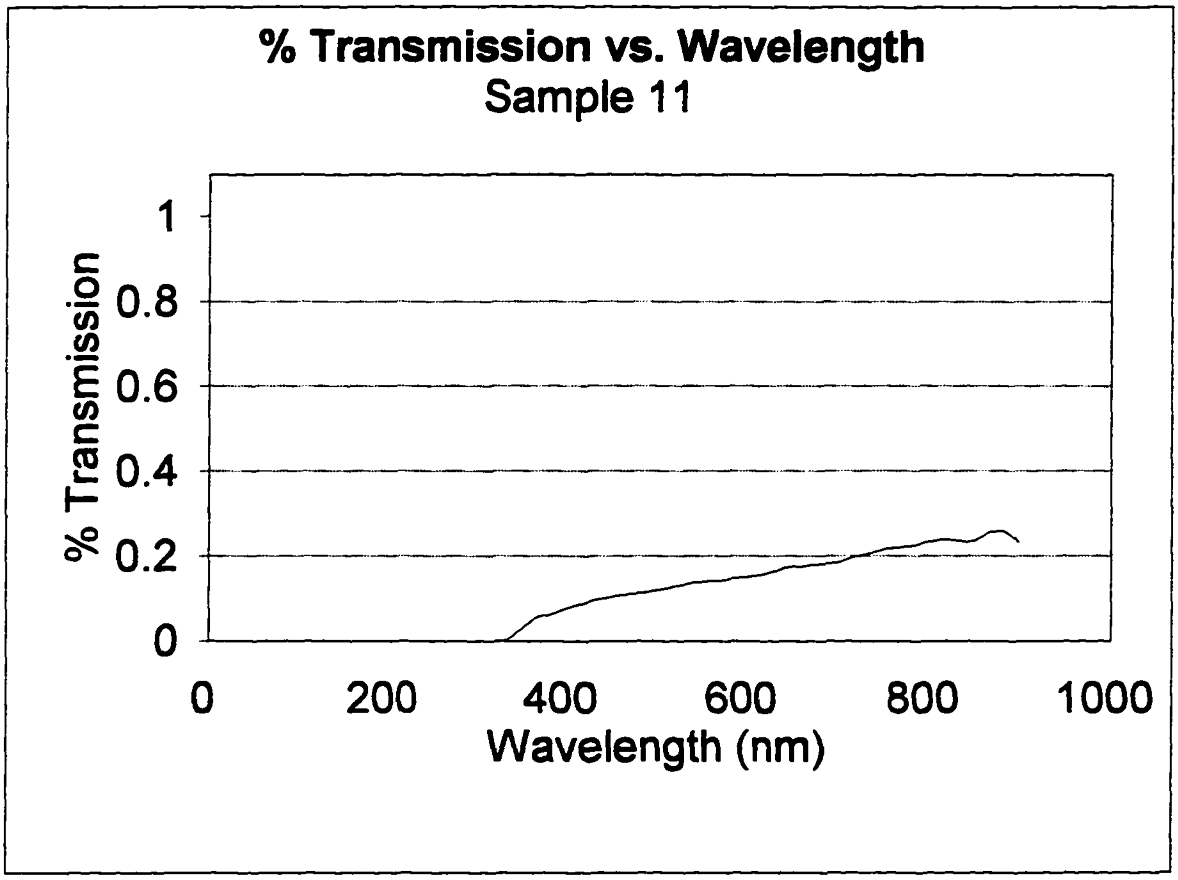

Fig. A.11. Percent transmission versus wavelength plot for Sample 11

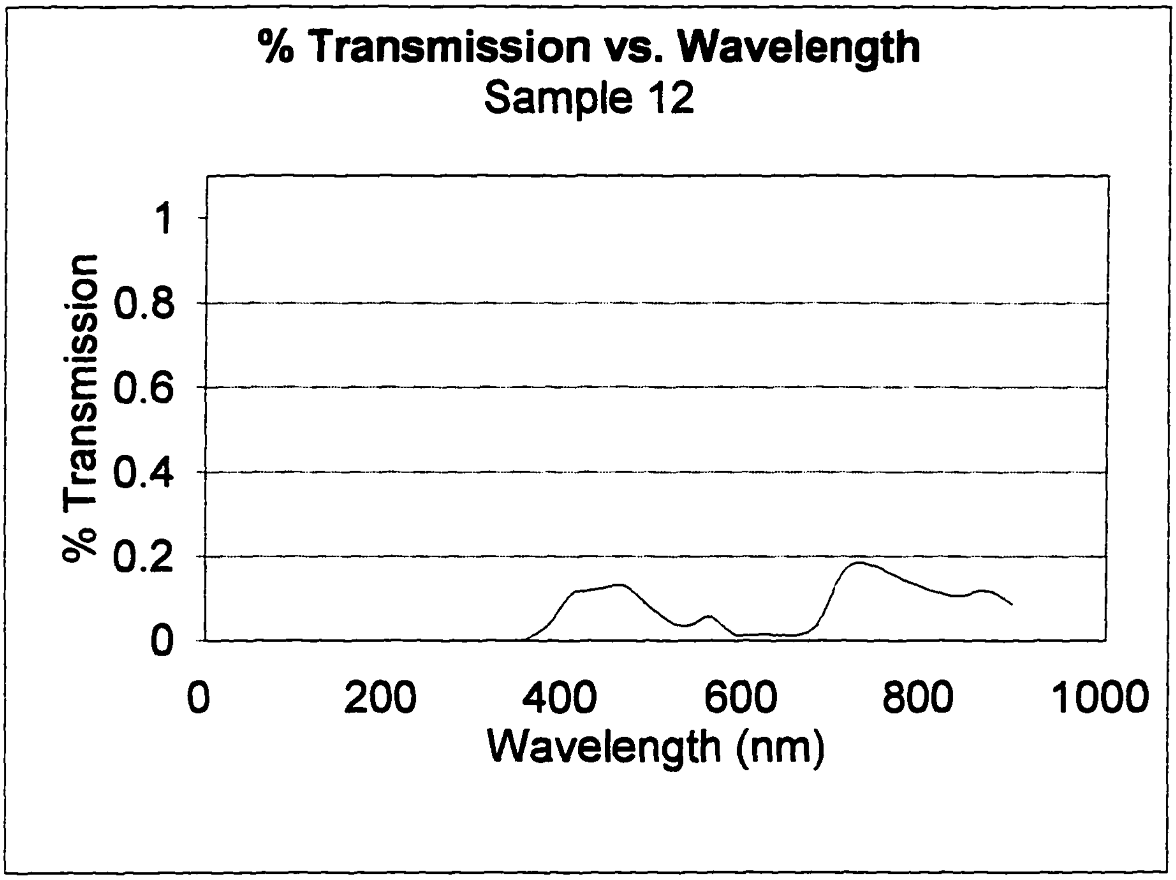

Fig. A.12. Percent transmission versus wavelength plot for Sample 12

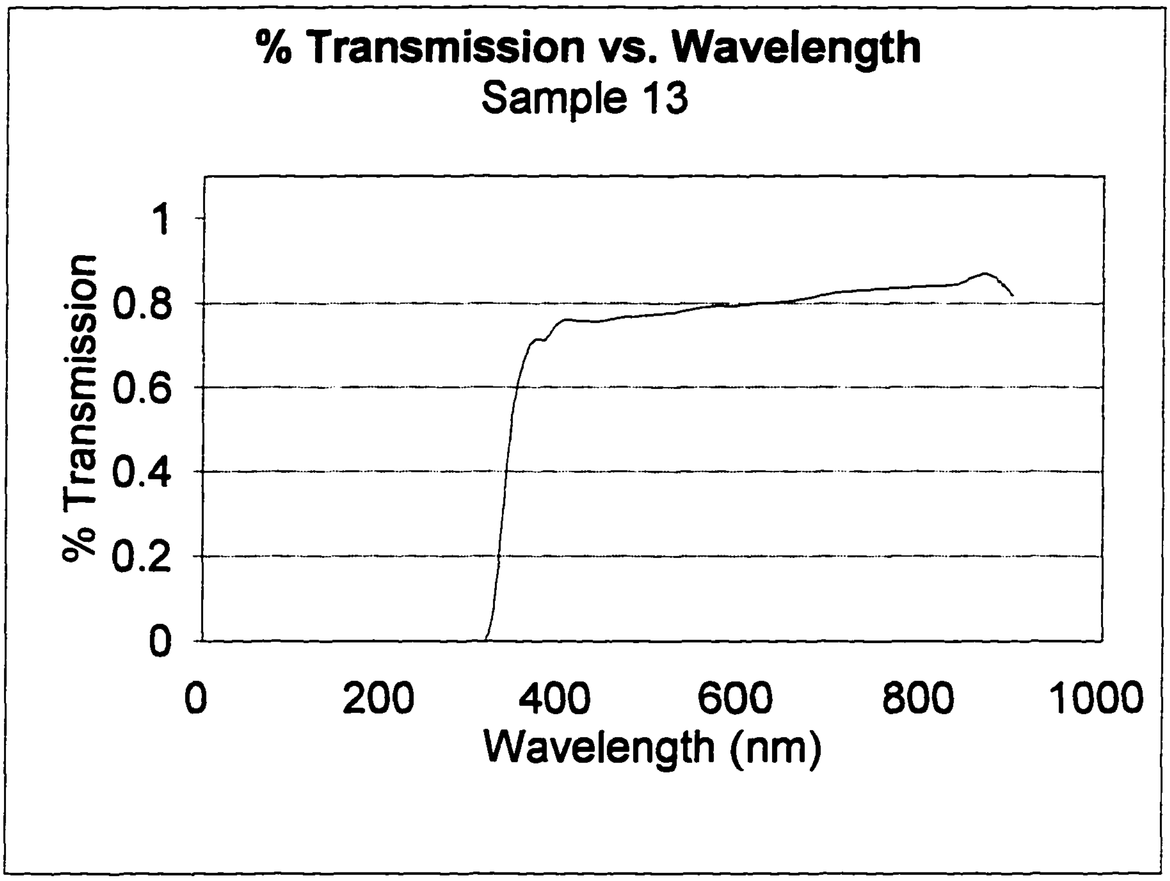

Fig. A.13. Percent transmission versus wavelength plot for Sample 13

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