The role of judgment in the making of glass colors in the seventeenth century

SVEN DUPRÉ

The Role of Judgment in the Making of Glass Colors in the Seventeenth Century

This essay discusses the manufacture of colors in Venetian and *à la façon de Venise* glass that was produced from the fifteenth century and codified in print in the seventeenth century. The focus is on "L'Arte Vetraria", the first printed book on glassmaking, published by the Florentine alchemist Antonio Neri in 1612. In this essay we consider Neri's recipes for making glass colors in light of the issue of color systematization and standardization. I will show that standardization of glass colors was absent in the seventeenth century prior to the multiplication of color systems in the eighteenth and nineteenth centuries. Neri repeatedly emphasized the importance of judgment by the eye in the production of glass colors.

Even today, little is available in terms of practical recipes for the making of colored glass. In the 1950s, Woldemar Weyl, professor of mineral technology, published his book "Coloured Glasses" with the Society of Glass Technology.[1] While this is an excellent introduction to the science of glass colors, it is difficult to translate it into processes of making colored glass. While we do have polychrome glass from antiquity as well as colorful stained-glass windows in medieval churches and cathedrals, little has remained in terms of recipes for glass colors. One important exception is the collection of recipes brought together in a manuscript by Antonio da Pisa around 1400.[2] There is also a long tradition reaching back to antiquity of recipes for making colored glass to imitate gemstones, either fraudulent or not.[3]

In the following, I will limit the discussion of making glass colors to Venetian and *à la façon de Venise* glass as it was produced from the fifteenth century and codified in print in the seventeenth century. The focus is on "L'Arte Vetraria", the first printed book on glassmaking, which the Florentine alchemist Antonio Neri published in 1612. Translated into several languages and issued in editions with additional notes and commentary by Christoph Merrett and Johannes Kunckel, among others, the book remained the most important written source on the art of glass in the seventeenth century.[4] However, the influence of the book is not the main reason for its emphasis. Neri presents about 30 different colors for different qualities and kinds of glass, enamels and glass paints, offering some colors in multiple shades. In total, Neri offers his readers about 75 different

1 *À la façon de Venise* Glass, Antwerp, 1546–1547. →

recipes for making glass colors, created from a relatively limited number of metallic pigments. Neri's book is of particular interest because he shows awareness of contamination in processes of making colored glass, and therefore, Neri pays considerable attention to the purification of his materials.

I will discuss Neri's recipes for making glass colors in light of the issue of color systematization and standardization. One important strand in the development of color knowledge in the eighteenth century was the emergence of color systems, for example in the work of Tobias Mayer, a professor of mathematics at the University of Göttingen, and Johann Heinrich Lambert, a member of the Preußische Akademie in Berlin.[5] Not only were these color systems practice-based, that is, strongly informed by color knowledge developed in the arts, but they were also made for practical use. As Friedrich Steinle has commented, Lambert

> "mentioned merchants of all sorts who might offer their products in all colours, and have control over missing colours, or also their customers, who could deliberately identify the colours they wanted and communicate them to the merchant by means of the colour pyramid. A lady, he imagined, could put the pyramid to her friend's dress, identify the colour and its number, and communicate the number to her tailor. Similarly, dyers could check the hue of their results and compare these with the order, and painters could identify colours in nature and reproduce them later in the studio."[6]

Lambert's imagination of the practical usefulness of his color system might not have been entirely realistic at the time. However, systematization and standardization were key to the "color revolution" following the explosion of production and consumption of synthetic dyes in the nineteenth and twentieth centuries.[7] Moreover, the color system of the nineteenth-century French chemist Michel Eugène Chevreul, developed in connection with color manufacturing, became important for fields of scientific inquiry such as anthropology and ophthalmology.[8]

This is not to say that, before the eighteenth century, attempts at building color systems were completely lacking. There were attempts to achieve standardization, informed by color practice, though perhaps less useful for color consumers. A nice example is the "Table of Colours" (1686) published by Richard Waller, a fellow of the Royal Society in London.[9] Waller's standardization of color terminology was informed by knowledge of making glass colors. He referred to Merrett's "Art of Glass" as a source for a recipe of making smalt by calcination of 'zaffer', which Merrett himself probably obtained from glassworkers when he visited the glass factory at Goodman's Yard. Waller's work served to emphasize the contributions of fellows of the Royal Society such as Merrett. His table made use of craft knowledge, but the use of the "Table of Colours" is still open to debate. Waller's intention was not to standardize the manufacture of glass colors in the way that train signal colors were standardized at Corning Glass Works around 1900.[10] In this essay, I will show that standardization of glass colors was absent in the seventeenth century prior to the multiplication of color systems in the eighteenth and nineteenth centuries. As we will see, Neri repeatedly emphasized the importance of judgment by the eye in the production of glass colors, circumventing even codification.

The Making of a Book and Sites of Glassmaking

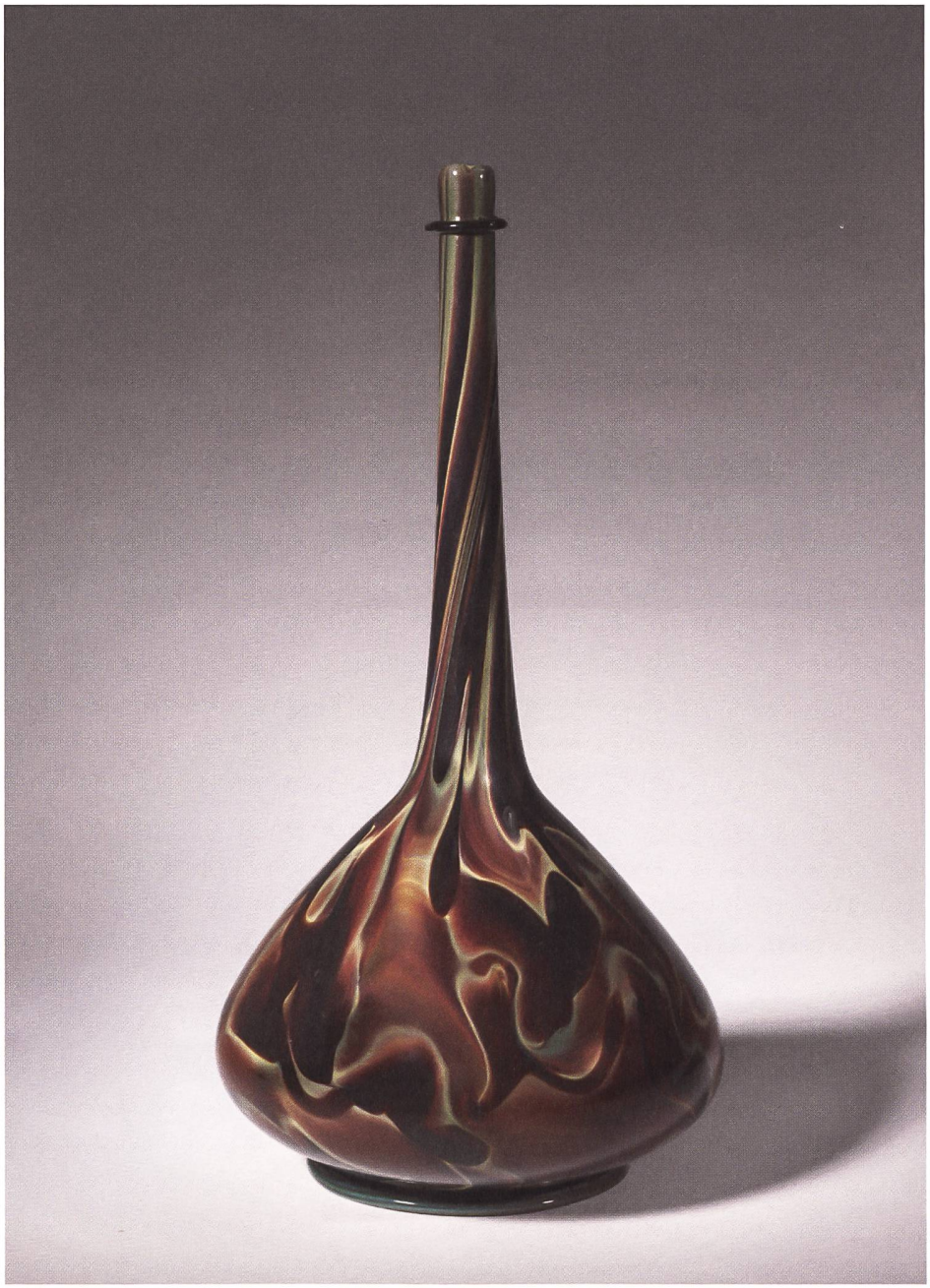
Neri's "L'Arte Vetraria" collected knowledge of glassmaking as developed in Venice on the island of Murano in the preceding two centuries. In the fifteenth century, Venice emerged as the world's leading glass center, largely due to a new type of colorless glass. This glass was known as "cristallo" to denote that it was as clear as rock crystal, and its invention was attributed to Angelo Barovier. Cristallo glass was highly sought after. In Giovanni Pontano's treatise on social virtues of the 1490s, cristallo is listed as exemplifying the virtue of splendor. Like majolica, glass was described as being "sottile", a term that "linked the physical quality in objects – that of delicacy or precision – to an acuteness and subtlety of thought of both artist and owner".[11] Glass and majolica were valued because they were difficult to make, not just for their aesthetic worth, but as objects of virtue.

Nevertheless, Neri's book was not based on direct knowledge of glassmaking in Venice. In the mid-sixteenth century, *à la façon de Venise* glassmaking had spread to other cities as it travelled with Venetian glassmakers who set up workshops and shops in other places to which they were attracted by powerful patrons and privileges granted by urban governments. Two sites in particular were important to Neri: the Medici court in Florence and the glass workshops in Antwerp, where in 1542 the city government had awarded a considerable sum of money to the Italian Giovanni Cornachini to establish Antwerp's first workshop producing "cristallo", turning Antwerp into the glass center north of the Alps.[12]

Medicean glassmaking began in 1569 upon the arrival of the Venetian glassmaker Bortolo alli Tre Mori whom the Medici had lured away from Murano. Francesco I de' Medici not only established the Studiolo, which showed depictions of the invention and manufacture of glass, but also the Casino di San Marco in which he housed the court workshops, including those dedicated to glassmaking as well as those which produced the famous Medici porcelain. In 1598, Antonio de' Medici, son of Francesco I, came to live in the Casino. He acted as Neri's patron, and Neri's "L'Arte Vetraria" is dedicated to him.[13]

In early seventeenth-century Antwerp, the Portuguese merchant-banker Emmanuel Ximenez, whose family had resided in the city for several generations, developed a commercial interest in glassmaking. As one of the Portuguese families residing in Antwerp leading the trade in jewelry, Ximenez's house was a place where merchants and artisans, especially the local Italian glass community and

2 Calcedonio, 1500–1525, Venice.



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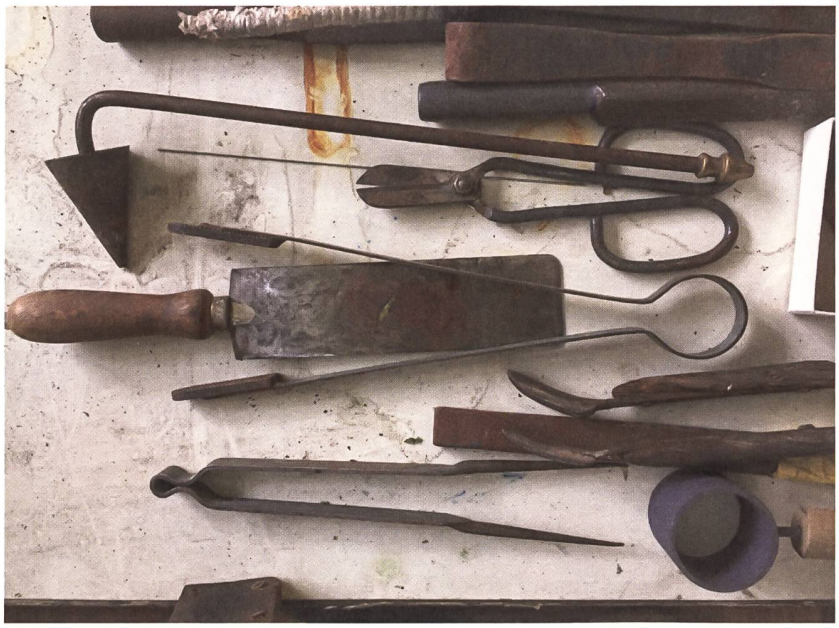
the Portuguese experts in jewelry, met to discuss the newest advances in glass imitations of precious stones. Next to Antonio de' Medici, Emmanuel Ximenez was Neri's most important patron. Neri was Ximenez's guest in Antwerp for eight years in the first decade of the seventeenth century, and he wrote "L'Arte Vetraria" partly based on his experience in Antwerp's glass workshops directed by Filippo Gridolfi.[14]

Thus, Neri's knowledge of making glass colors was based on practices and experimentation with materials in a small number of interconnected advanced centers for glassmaking. This organization of glass manufacturing did not, however, encourage standardization of color terminology.

Imitation of Gemstones and Alchemy

Why glass colors? One important driver behind the manufacture of glass colors was the search for glass imitating precious stones. Not only was glass widely used to imitate gemstones, natural historians and philosophers used materials and processes of the art of glassmaking to understand the nature of stones. The twelfth century natural philosopher Albertus Magnus considered translucent gemstones a type of "glass produced by the operations of nature", comparing the processes of nature with those used for making glass.[15] He argued that transparency is the most important defining characteristic of the class of stones known as gems. Their common material and the cause of their transparency was thought to be water. However, gemstones are not pure water, but a mixture of water with other elements, hence their different degrees of transparency.



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3 Glassmaker's tools.

4 Apothecary jar for iron oxide with painted label and parchment cover.

Nevertheless, "they are of a more subtle mixture and a clearer transparency than glass made artificially", because "art may imitate nature nevertheless it cannot reach the full perfection of nature."[16]

The analogy between making glass and the creation of gemstones was widely accepted in natural philosophy and the arts. Moreover, it was sometimes also extended to the Philosophers' Stone by alchemists who suggested an association between glassmaking and alchemy that went beyond their shared use of metals as coloring agents. In the late fourteenth century, Guillaume Sedacer drew an analogy between the craft processes of glassmaking and alchemy as transmutation.[17] In his "Sedacina totius artis alchimie", the recipes to make glass are followed by recipes for the Philosophers' Stone, using the same materials and processes that he describes for the making of glass imitations of precious stones.

Vanoccio Biringuccio, in his "Pirotechnia" published posthumously in 1540, repeats this nexus of glass coloring, imitation of stones, and alchemy.[18] According to Biringuccio, gemstones' primary nature is watery, and depending on the mixture with other elements, they assume different degrees of transparency. Their other characteristic, color, varies according to the position and proximity of metals. The invention of glass is attributed to the alchemists and to their desire to make gems. Biringuccio relates that the Venetian glassmakers brought the art to such perfection that exposing forgeries became difficult even for experts. In "L'Arte Vetraria" Neri repeats Biringuccio's attribution of the invention of glass to alchemists imitating gemstones.[19] Confident of his art of glassmaking, and in contrast to Albertus Magnus' dictum that art cannot reach Nature's perfection, Neri argues that the qualities of his imitations surpass all those of natural stones, with the exception of hardness. Interestingly, in the seventeenth century, following the progress of Venetian glassmaking in imitating the colors of stones, hardness replaces color as the most important defining characteristic of gemstones in the natural history of Anselm De Boodt.[20]

In "L'Arte Vetraria" Neri identified Isaac Hollandus, whose work he consulted in the library of his host Emmanuel Ximenez in Antwerp, as the source of his recipes for the making of artificial gemstones.[21] In the enigmatic "Physicae et theologicae Conclusiones" (1621), the artist Otto van Veen, master of Peter Paul Rubens, singled out Isaac Hollandus as his most important authority on alchemy.[22] Reading the "Opera Mineralia" by Hollandus must have reinforced for Neri the similarities between glass and minerals, which he also notes in the preface of "L'Arte Vetraria": glass was made by art imitating the processes of nature, while the formation of minerals was likened to the processes of glassmaking. The base material for Neri's artificial gems was either a so-called paste, made of small pieces of rock crystal, or lead glass.[23] Unlike other metals, lead does not add color to the glass, but does make it sparkle. It also makes the glass runny like water when heated and thus much more difficult to work with. He adds 'zaffer' (or cobalt oxide) for sapphires, copper for emeralds, and even other gems (for example garnets). For larger and smaller stones, one must use different amounts of color, but as Neri repeatedly states, "there are no true rules here"; it's a matter of judgment.[24]

The significance of the connection with alchemy is evident in Neri's emphasis on reddish glass. The most celebrated example is his recipe for making a deep red colored glass with powdered metallic gold.[25] Another example is the chalcedony glass whose production held pride of place in "L'Arte Vetraria". The so-called "calcedonio" was glass imitating precious stones such as agates and oriental jaspers. It was produced by a technique based on the superimposing and fusion of layers of molten glass, and resulted in a translucent white, grey or reddish-brown ground with swirls of other colors mixed in a random pattern throughout. Chalcedony glass is dichroistic; it has a varied response to

transmitted and reflected light: in reflected light the glass shows this variegated swirl of colors, while in transmitted light it appears, in Neri's words, "red as fire". Indeed, it displays a fiery orangish-red color.[26] Neri suggests that the color of the glass is identical to that of the Philosophers' Stone.

The Making of Glass: Purification and Contamination

Compared with previous descriptions of glassmaking, such as Theophilus' twelfth-century "De diversis artibus", the manufacture of glass colors had become a much more controlled process in workshops for the production of Venetian and *à la façon de Venise* glass. Neri describes the careful sourcing and preparation of materials for making cristallo. The aim of the process was a colorless glass that could be intentionally colored by adding pigments.

Glass consists of four components.[27] The most important substance for making glass is sand, which artisans in Venice sourced from the Ticino River. The reason for this was purity. Sand was typically contaminated with metals, which tint the glass. In principle, one can make glass from every type of sand, and depending upon the presence of metallic contaminants, it will turn out in different colors.[28] The most important enemy of the seventeenth-century Venetian glassmaker was iron which tints the glass greenish. Unfortunately for the early modern glassmaker, iron was everywhere including in his tools and blowpipes. Neri warns: "Make sure never to place the neck, where the rod attaches to the glass, in the crucible of cristallo, because there are always iron residues that will cause it to turn dark."[29] Glassworkers preferred sand from the Ticino River because it was relatively free of iron and thus they could avoid accidentally giving the glass a greenish tint.

The second component of glass is soda. Sand only melts at temperatures of about 1750 °C, which is too high for early modern glass furnaces. To lower the melting point, a so-called flux is added. For Venetian and *à la façon de Venise* glass the source of soda was coastal plant ashes. They were not locally sourced, but as a major trading center, Venice imported them from the Levant. In Neri's time, the Venetian glass workshops used the ashes of the barilla plant found on the coasts of Spain and Sicily. The use of plant ashes was a major difference setting apart *à la façon de Venise* glass from Bohemian glass. This glass, known as *Waldglas*, was produced in often mobile glass workshops in the Bohemian woods. The ashes of burned local trees were used, typically resulting in greenish tinted glass. Concerned with the purity of his materials, Neri describes a process to wash off the undissolved, excess flux, the so-called alkali salt, which makes the glass 'dark and cloudy'. He also advises the use of dry hardwood, preferably oak, for heating the furnaces to avoid contaminating the open pots of glass in the furnace by smoke or ashes from the fire.[30]

The third component of glass is lime. Mixtures of only sand and soda result in a glass that is not stable and dissolves in water. Neri was not aware of the workings of lime, and it is highly likely that lime or calcium oxide was added to the glass composition unintentionally, for example, by contamination from shells that were present in the sand. Finally, the fourth component of Venetian cristallo, setting it apart from other types of glass, was manganese. Manganese was mined all over Italy, but Neri cautioned that only manganese from Piedmont was to be used, not from Tuscany. Manganese gives the glass a violet tint, neutralizing the greenish hue that is imparted to the glass by contamination with iron.

4

Metals as Pigments for Coloring Glass

To make colored glass, metallic pigments were added to the colorless glass frit. A limited number of metals were used for this purpose: copper, iron, manganese, cobalt, and tin were the most common; occasionally, recipes asked for gold or silver. Today, metal oxides are readily available from specialized shops for purchase as glass coloring agents. This was not the case for glassmakers in the seventeenth century. The availability of metal oxides played an important role in the making of glass colors. It has been shown, for example, that there is a connection between the cobalt mining in the Erzgebirge in the sixteenth century, the making of smalt or blue glass, and the palette of painters, who used smalt to prepare blue paints.[31] Moreover, metallic colors could be prepared in a variety of ways and, depending on the preparation, metallic pigments could result in different color effects.

A nice example is *crocus martis*, which was used as a name for iron oxide. Neri writes that "crocus martis is nothing other than a refinement and calcination of iron. A means by which its pigment, which in glass is a deep ruby red, is opened and imparted to the glass."[32] Iron oxide was indeed used for making sanguine red glass paints, regularly applied in stained glass.[33] However, Neri emphasizes that it can also make all other hidden metallic colors appear. In "L'Arte Vetraria", he gives four different recipes for making *crocus martis*.[34] The first method involved mixing iron filings with sulfur and heating the mixture in the furnace; the second method prescribed the use of vinegar leaving the mixture in the sun for several days instead of heating it in the furnace. The third and fourth ways made use of stronger acids, aqua fortis and aqua regis respectively. While the use of *crocus martis* prepared in the first way results in a red color, Neri used *crocus martis* prepared with vinegar for making green glass. In other recipes, he used *crocus martis* to diminish the green in yellow lead crystal and *crocus martis* prepared with aqua fortis to color glass red as well. Thus, the identical name of a glass coloring agent can hide a variety of different materials; colors were not standardized.

Neri does not give precise measurements or weights of the materials used as coloring agents. His general advice to his readers is to put in colors little by little in a completely controlled fashion. He describes the process of coloring the glass as constantly monitored by testing and judgment of the color by eye. Neri writes:

> "When the color is too weak, give it more of the powder, coaxing [the color] little by little to fruition. Always make sure to test it from time to time. This is the way to add all the colors, because this way you will never fail. In Pisa, I made them without [measuring] weights, but by rough estimate. I have colored every type of glass for every job, enough to elucidate this method."[35]

A nice example of the importance of color testing by judgment by eye during the process is the making of sky blue glass in imitation of turquoise, a semi-precious stone, and according to Neri "a principal color in the art of glassmaking".[36] The process involved the use of particular "black" sea salt which Neri differentiates from the ordinary white salt made in Volterra. To make a turquoise colored glass, Neri adds this salt to aquamarine tinted glass but in a most controlled way, constantly monitored by testing: "Add the doses of salt little by little [...] pausing from one time to the next until you see the desired color. With this, I do not rely on either dose or weight, but only on my eyes. When I see that the glass reaches the desired level of color, I stop adding salt. This all comes with experience", Neri tells his readers.[37]

For this same process of making turquoise colored glass, Neri adds that the vitrified salt makes the glass lose its transparency and that when evaporated the glass becomes transparent again with an ugly color, so the glassmaker should work quickly.[38] Here and elsewhere, Neri shows awareness that furnace temperature and heating times are important factors in the resulting color effects. It was, for example, widely known (and already described by Cellini) that to make a gold ruby glass or enamel, the glass which in its molten state is yellowish should be cooled down and then reheated to bring out the deep red color.[39] However, when fired for too long, glassmakers knew that it would turn black. Again, the timing of these processes was very much a matter of experience and judgment.

5 Maria Roosen, Glass bubbles – Colour Powder, 2017. →

Conclusion

In the seventeenth century, the making of glass colors was a matter of judgment. If Neri's "L'Arte Vetraria" is representative of glassmakers' color knowledge at the time, we can assume that glassmakers were aware of the different factors that played a role in the complex process of glass color production. However, Neri considered it impossible to standardize the recipes for glass colors as he emphasized time and again the importance of testing and judgment by eye. The lack of standardization in color making as well as terminology in Neri's book raises questions about the reasons behind the emergence of color systems and standardization in the eighteenth and nineteenth centuries, which are certainly not limited to the manufacture of glass; the color revolution also brought about standardization in glass colors. However, as far as glass color goes, it seems that an element of testing has remained essential to its production until the present day. In recent years, the Dutch glass artist Maria Roosen created a work that is based on the glass color test bulbs; in a glass studio in the Czech Republic she saw that they are still an integral part of the practice of glassmakers as much as they were in the seventeenth-century glassworks. ■

Related article in the Ferrum archives:
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About the author

Prof. Dr. Sven Dupré

Sven Dupré is Professor of History of Art, Science and Technology at Utrecht University and the University of Amsterdam. He is the Scientific Director of the ARTECHNE project. This project on "Technique in the Arts: Concepts, Practices, Expertise, 1500–1950" has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 648718). His recent publications include "Knowledge and Discernment in the Early Modern Arts" (Routledge, 2017), and "Early Modern Color Worlds" (Brill, 2016).

Utrecht University/University of Amsterdam, Netherlands
s.g.m.dupre@uu.nl

Annotations

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24 Neri, Arte vetraria (see n. 19), p. 79, translation in Engle, The Art of Glass (see n. 19), vol. 3, p. 14.

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26 Ibid., p. 40, translation in ibid., vol. 2, p. 12. For discussion of Neri's recipes for chalcedony glass, see Dupré, The Value of Glass (see n. 21).

27 Alan Macfarlane, Gerry Martin: Glass: A World History. Chicago 2002; Patrick McCray: Glassmaking in Renaissance Venice. The Fragile Craft. Aldershot, Brookfield 1999.

28 This is nicely illustrated in a project of AtelierNL, an artist collective who in search for a sustainable production of glass now that the sources for clear glass are running out, collect sand from all over the world and turn them in to variously colored glasses. See: www.aworldofsand.com.

29 Neri, Arte vetraria (see n. 19), p. 12, translation in Engle, The Art of Glass (see n. 19), vol. 1, p. 27. See Engle: Conciatore (see n. 23), p. 25.

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39 Engle, Conciatore (see n. 23), p. 32.

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1 Rijksmuseum Amsterdam
2 London, Victoria and Albert Museum
3 Vrij Glas Foundation Workshop, Zaandam; photo by the author
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