KILN-FIRED GLASS IN THE JUNIOR COLLEGE
ARTS AND CRAFTS PROGRAM

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KILN-FIRED GLASS IN THE JUNIOR COLLEGE
ARTS AND CRAFTS PROGRAM

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By

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CHAPTER I

INTRODUCTION

The Problem and Its Purposes

The problem with which this investigation is concerned is the discovery of suitable uses for the enameling kiln in the arts and crafts program at the junior college level in the production of kiln-formed glass and the testing of methods and materials that will permit work of aesthetic merit at a nominal cost to the students and the school.

The Scope of the Problem

This study is limited to the investigation of the uses of the enameling equipment in producing kiln-formed glass, and to the testing of these techniques in junior-college art classes.

Method of Procedure

Historical research and technical experiments related to kiln-formed glass were explored at North Texas State College (now North Texas State University) in the summer of 1960 and 1961. Glass combined with materials that are usually discarded or purchasable at a minimum cost were investigated. From September 1960 until the end of the spring semester in May 1962, the processes and techniques previously explored were
repeated in art classes at Laredo Junior College at Laredo, Texas.

Organization of Material

A logical sequence is followed in organization and presentation of material. The first chapter includes the nature of the problem and its purposes, its scope, method of procedure, organization of material, the students involved in the experiments, and definition of terms. A brief review of the history of glass is presented in Chapter II. The preliminary experiments in glass that were made at North Texas State College (now North Texas State University) are presented and described in the third chapter. The fourth chapter includes the class experiments in glass at Laredo Junior College. Findings and conclusions developed from both phases of the experiments are stated in the final and concluding chapter.

In the method of presentation of the experiments, some condensations are made in order to reduce length of material. In the preliminary experiments, many of these were repetitions or related to previous experiments and for this reason are not presented in detail but in conjunction with the initial experiments in that area. In the Laredo Junior College, the experiments presented are significantly selected examples which represent typical procedures, unusual or unexpected processes or results, or new findings not covered in the
preliminary experiments. As in the preliminary experiments, related experiments are grouped in presentation.

The Students Involved in the Experiments

A total of sixteen classes, ranging in size from twenty to twenty-six students, participated in the experiments. In the 1959-1960 session there were five classes each semester. In the 1961-1962 session there were three classes each semester.

These classes consisted of freshman and sophomore students, the majority of whom were elementary education majors. Classes met for six hours each week.

Most of the students at Laredo Junior College were of Latin-American origin. Spanish was spoken by the students outside the classroom, at home, and in business. Inside the classroom, English was not spoken by the students except in discussions with the instructor. About 10 per cent of the students lacked facility with the English language, and the instructor often found it convenient to use other students as interpreters. Reading comprehension of English was often at an elementary school level. English was a native language for about 4 per cent of the students. About 95 per cent of the students in these classes were female.

The students at Laredo Junior College represent a cross-section of the upper socio-economic levels of Laredo and Webb County; nevertheless, a college education for these
students is often achieved at considerable sacrifice on the part of their families.

While 98 per cent of the students in these classes were elementary education majors, the records at Laredo Junior College show that less than 58 per cent of the students were able to continue their college education. For approximately one half of the students, then, Laredo Junior College was a terminal institution. Of those who did transfer and complete their degrees, the greatest number transferred to Texas College of Arts and Industries at Kingsville, Texas. About 25 per cent transferred to colleges in San Antonio. A small minority completed their education at other Texas state-supported schools.

Before entering Laredo Junior College, fewer than 5 per cent of the students had had any art training. The most fundamental art knowledge and skills, such as the mixing of secondary colors, were generally unknown. It was essential to start the student's art education with the most basic fundamentals.

Definition of Terms

Glass

The simplest glass would be fused silica (Si O₂). By fusing silica with alkali (soda), a glass is obtained at a much lower temperature, and consequently much more cheaply,
but this has little weather resistance. With the addition of lead oxide or lime, the lower temperature is maintained and greater resistance is achieved. Alkali-lead oxide-silica glasses are used for the best quality crystal ware, while the alkali-lime-silica type, modified with magnesia and alumina, is used for commoner glasses such as containers, flat glass and cheap domestic ware. Glass for cooking ware is a borosilicate glass in which the alkali is largely replaced by boric acid. Since chemical and physical properties are controlled by the composition of the glass, glass properties vary over a wide range.\(^1\)

The attributes of glass are transparency, uniformity of properties of all points in its substance, hardness, brittleness, and conchoidal or shell-like markings on fractured areas.

In 1903 Gustav Tammann defined glass as a super-cooled liquid. In the United States glass is defined approximately as follows: an inorganic product of fusion, which has cooled to a rigid condition without crystallizing. Masses or bodies of glass may be colorless or may be made colored, translucent, or opaque by the presence of dissolved material, of amorphous or crystalline substances in suspension.\(^2\)

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CHAPTER II

AN HISTORIC SURVEY OF GLASS

The earliest accurately dated glass objects, as opposed to glazed objects, are beads made in Egypt after 2500 B.C.; however, a green glass rod found in Eshananna, Babylonia, may be as old as 2600 B.C.¹

Actually the production of glass as a substance is of greater antiquity because the composition of glaze, while differing somewhat from most formulae used for glassware, is still a glass recipe.² The beads mentioned above and other small Egyptian glass objects dating before 1500 B.C. were made by a formula customarily used in the manufacture of glass.³

Exactly where or when hollow-ware glass was first produced is not known, but the earliest examples that can be dated with certainty were made in Egypt early in the New Kingdom (about 1500 B.C.).⁴


³Ibid.

⁴Ibid.
This early hollow-ware glass was made by the sand-core method. In this method of production a lump of clay or sand, shaped to conform with the interior opening desired in the glass vessel, was placed on the end of a rod. This was immersed in molten glass. Repeated heating in a furnace permitted subsequent manipulations, the shaping of rims, the additions of handles and feet, and the application of decoration. The characteristic decoration of sand-core glassware was achieved by trailing hot glass threads of contrasting colors in spiral bands around the basic form; these threads were then combed to produce festoons or feathered designs. Then the glass was finished, the rods withdrawn and the core removed. This process gave a granular texture to the interior surface where the glass came in contact with the basic core. Sometimes a fabric wound around the core produced a finer interior surface within the glass vessel. Exterior surfaces were sometimes ground and polished.\(^5\)

Most of the sand-core molds of this early period were of relatively small size, and seem to have been largely used for making jars for ointments and cosmetics.\(^6\) From the tomb of Amenhotep II (1448-1420 B.C.) glass fragments have been reassembled into a two-sectioned vase of about twenty inches in height.\(^7\)

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\(^5\)Ibid., p. 14.

\(^6\)Ibid., Illustrations 1 through 53.

\(^7\)Ibid., p. 14.
Solid glass objects were also produced in the New Kingdom. These were usually made of opaque colored glass that was pressed into molds. Inlaid effects were achieved by using a series of molds, one for each color of glass used, and then molding the parts together.\textsuperscript{8}

So precious were glass materials to the Egyptians that glass in inlaid designs and cloisonné techniques was used together with gemstones on the gold covering of the mummy of the Pharaoh Tutenkhamon.\textsuperscript{9} Life magazine shows a handsome color plate of this beautiful work.\textsuperscript{10}

Mold-pressed glass was another process used in the New Kingdom. In this process a mold plunger was thrust into a terra cotta mold that was partially filled with liquid glass. It was possible to obtain designs on the glass by modeling the surface of the mold-plunger or the surface of the mold.\textsuperscript{11}

Glass vessels were also made in the New Kingdom by carving glass just as one would carve forms out of alabaster.\textsuperscript{12}

At the beginning of the first millenium B.C. the glass industry seems to have retrogressed sharply in Egypt. While

\textsuperscript{8}Ibid., p. 15.


\textsuperscript{10}Life, XXIV (January 19, 1948), 81.

\textsuperscript{11}Cuming, N. Y., op. cit., p. 15.

\textsuperscript{12}Ibid., p. 18.
small glass objects that date from this period have been found in other Mediterranean areas, they do not seem to be Egyptian in style or in type of glass. It was not until the Eighth Century B.C. that a late sand-core glass made its appearance. One of the most pronounced characteristics of the late sand-core glass was that the forms were based on shapes derived from Greek pottery.\textsuperscript{13}

Ornamental objects were being made in Greece by mold-pressing in the Fifth Century B.C. In the workshops of Phidias at Olympia, where he worked on his colossal statue of Zeus, glass has been found in the molds he used on that work. There is also other evidence that his workshop was equipped with a glass furnace.\textsuperscript{14}

The Naples National Museum shows a glass ungentarium decorated with white and yellow enamel that dates from the Sixth Century B.C. This object is proof that the manufacture of glass and the application of enamel to glass were processes known at an early date in Italy.\textsuperscript{15}

By the end of the Third Century B.C. all but one of the four basic methods of constructing glass objects had been devised.\textsuperscript{16}

\textsuperscript{13}Ibid., p. 17.

\textsuperscript{14}Corning, N. Y., \textit{op. cit.}, p. 16.

\textsuperscript{15}Rodolfo Siviero, \textit{Jewelry and Amber of Italy} (New York, 1959), p. 15, plates 25, 27, and color plate.

\textsuperscript{16}Corning, N. Y., \textit{op. cit.}, p. 19.
It was during the First Century B.C. that blown glass appeared.\textsuperscript{17} This last of the four methods of forming glass objects seems to have been an accomplishment of artisans on the Syrian coast.\textsuperscript{18}

By the First Century A.D. Alexandria had become the focus of glass production. Under Roman rule the production centers moved westward to Italy, Gaul, and Iberia, and from Alexandria eastward. Blown glass techniques had made possible the mass production of glass. By blowing glass into molds it was possible to reproduce intricate decorations, elaborate patterns, and bas-relief forms in quantity. First Century glass carried the Hellenistic style to the corners of the earth.\textsuperscript{19}

The dominance of Alexandria in the glass industry during the first centuries of the Christian Era was based on her perfection of a number of types of glass forms. Among these were fused mosaic plaques, \textit{millefiori}, color-band glass, lathe-turned glass, cameo-cut glass, frost-cut glass, and fired and unfired glass painting.\textsuperscript{20}

Full control of color in glass was also achieved at this time. There appeared clear sparkling crystal; brilliant

\textsuperscript{17}Ibid., pp. 43-45.
\textsuperscript{18}E. S. Buschner, \textit{op. cit.}, p. 43.
\textsuperscript{19}Corning, N. Y., \textit{op. cit.}, pp. 43-44.
\textsuperscript{20}Ibid., p. 44.
transparent colors, often in deep shades; as well as opaque colors in white, blue, green, red, and occasionally yellow.\textsuperscript{21}

Fused mosaic plaques of microscopic fineness were made in Alexandria. These were made by laboriously preparing a glass rod which was built up of successive molten elements to form the desired design. Some of the elements used were cast in molds. The entire rod was then drawn out as is done in taffy candy. This reduced the scale of the cross section of the design. Sections cut from the finished rods were used as decorations for furniture, caskets, and other suitable manufactures.\textsuperscript{22}

\textbf{Millefiori} designs were made by the same methods as the fused mosaic plaques but not with the same fineness of detail. Mold pressing techniques made possible the mass production of bowls in \textbf{millefiori} designs in plain and fluted shapes.\textsuperscript{23}

Lathe-cut glass reached its apogee in the first century. Alexandrian work on small cups was superb. Much of the glass for this lathe work was cast in molds before it was cut and polished, rather than carved from a solid block as was previously done.\textsuperscript{24}

\begin{itemize}
\item \textsuperscript{21}\textit{Ibid.}, p. 47.
\item \textsuperscript{22}\textit{Ibid.}
\item \textsuperscript{23}\textit{Ibid.}, p. 48.
\item \textsuperscript{24}\textit{Ibid.}, p. 49.
\end{itemize}
The Portland Vase in the British Museum testifies to the skill of the glass makers of Alexandria who seem to have invented the process of making cameo glass in the First Century B.C. 25

Splashed ware was made by strewing kernels of colored glass on the surface of a glass bubble before it was fully blown. When finished the colors had fused to the bubble and covered the entire form with varicolored glass. By adding preformed medallions and other decorative elements to the glass bubble in the finishing stages, these added elements remained as relief decorations. 26

The Second to the Fourth Centuries A.D. saw the spread of the glass industry to most of the Roman Empire and beyond. Syria and Alexandria continued to produce, but Gaul and the Rhineland produced glass of fine quality. Glass was made in the cities of North Africa, the Danube Basin, the Greek Islands, the Greek mainland, the upper Balkan Peninsula, Asia Minor, in Parthia, and along the Black Sea coast. 27

In glass production during these centuries, mold-pressing was seldom used; core-molding became a lost art, and massive cutting was used only for special effects. The industry was virtually monopolized by the glass blower. 28

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26 Corning, N. Y., op. cit., p. 48.
27 Ibid., p. 108.
28 Ibid.
decorations, pinching, tooled festoons, as well as high relief decorations on the vessels became the most common decorative methods. 29

Glass was largely replaced by stone in mosaics at this time. Fired and unfired painted glass was highly developed, as was gilded glass. 30 Mold-blown glass continued to proliferate in form, especially so in utilitarian objects. The greatest artistic accomplishment of the period was the production of interior-cut glass, the method of which allowed the human figure to be presented in elaborate scenes. This decoration when viewed through the glass made the form appear to be in relief. This work was produced in the Rhineland and in Egypt. 31

By the Fourth Century both the Byzantine Empire and Western Europe contained centers of enameling. In Europe the centers were in the valley of the Moselle, the Rhineland, and at Limoges. Enamels from the Moselle valley, called Moson enamels, used light greens, yellow, and whites with parts of figures outlined in darker enamels. 32

Between the Fifth and Twelfth Centuries, the glass industry declined sharply in Europe. The quality of the glass

30 Ibid., p. 111.
32 Corning, N. Y., op. cit., p. 189.
itself was poor, the artistic merits of the product deteriorated, methods of color control were lost, and techniques in general were debased.\textsuperscript{33}

Islamic Persia became a glass production center of importance between the Ninth and Twelfth Centuries, A.D. The development of lustre and lead glass were the contributions of Islam to the advancement of the glass techniques. In Egypt sometime before the Tenth Century lustre-ware of high quality was produced. The origin of the method is uncertain. Other than this Islam preserved the techniques known under Rome. Work in colored enameled, and gilded glass reached a point of elaborate complexity. Islamic work in cut glass rivaled that of Rome in quality.\textsuperscript{34}

In the Eleventh Century, Venice became a manufacturing center of glass. By 1465 Venice was famous for its enameled glass, which was designed in the Renaissance exuberance. The Venetians manufactured \textit{millefiori}, green and white adventurine glass, and reintroduced glass for mosaics. They achieved all the technical perfection that had existed in ancient Rome, and even copied Roman examples. Venice became famous for the rich blues, greens, and purples achieved by its glass makers. Their greatest achievement was the rediscovery of the methods of manufacture of clear colorless glass, the manufacture of which had not been attained since Roman times. This they

\textsuperscript{33}\textit{Ibid.}, pp. 228-230.

\textsuperscript{34}\textit{Ibid.}, pp. 228-230.
called cristallo because of its resemblance to natural rock crystal. By the Sixteenth and Seventeenth Centuries Venetian Glass reached an astounding virtuosity that charmed Europe and created an enormous demand for her products.\textsuperscript{35}

In crafts as old as glass making, trial and error have resulted, over the centuries, in the development of certain glass compositions which are particularly suited to certain purposes (e.g.: lead crystal glass for lengthy hand-forming operations). The introduction of mechanical methods of forming and shaping have led to the formulation of special-purpose glasses.\textsuperscript{36} The systematic research that has been carried out in the Twentieth Century has created more than 50,000 formulas for glasses using almost every known chemical element.\textsuperscript{37}

\textsuperscript{35} T. S. Buechner, \textit{op. cit.}, p. 48.


CHAPTER III

PRELIMINARY EXPERIMENTS WITH GLASS

Introduction

The purpose of this chapter is to present preliminary experiments in glass made at North Texas State University prior to the experiments made in the laboratory by students in the Laredo Junior College. The experiments included three separate types: (1) the search for temperature ranges, (2) the search for forming and shaping techniques, and (3) the search for decorative techniques.

In working with any kiln-formed glass it is necessary to determine the exact temperature at which the particular glass under consideration reaches the point at which it softens or bends. This virtually precludes the use of any kiln not equipped with a pyrometer. Different pieces of sheet or window glass can vary as much as 100 degrees in this respect. The exact temperature will vary not only with the glass, and its thickness, but also with the particular kiln used. At North Texas State University the kiln temperature of 1450 degrees Fahrenheit was found to be satisfactory, but this temperature was excessive while working with window glass in a different kiln at Laredo, Texas. Differences in the kilns, the pyrometers on the kilns, or in the particular
pieces of glass used could have reduced the required temperature in the Laredo experiment.

In addition to these variable factors, there is also variation of temperatures within the kiln itself. In attempts to increase the capacity of the kiln used at Laredo Junior College, kiln shelves were used. The result of this was that glass placed in the kiln on the lower shelf was matured before glass placed on the upper shelf. This clearly demonstrated variation of temperatures within the kiln.

In experimental tests glass made especially for stained glass windows proved to have a melting point well below that of window glass. This fact is pertinent both in relation to successful use of stained glass alone and in combination with other glass.

Greater success is possible if the glasses combined are closely related in melting points, and if the required temperature is known with reference to the kiln to be used.

Glass to be formed must be placed in the kiln when both the kiln and the glass are at room temperature. If a hot kiln is opened while it contains hot glass, the glass will break. Cold glass introduced into a hot kiln or hot glass removed from a kiln will break.

The kiln temperature should not be raised above the temperatures needed for the particular glass being used. If this precaution is not heeded, the glass will bubble or boil, resulting in surfaces distorted by bubbles or broken craters.
It is characteristic of ordinary window glass that, if heated to approximately 1400 degrees Fahrenheit, it will lose its rigidity and begin to bend. If the temperature is not carried much beyond that point, the glass will be firm enough to hold its general configuration, but soft enough to assume the shape of the surface upon which it is placed, or to bond itself securely to other pieces of glass placed in contact with it. Upon this simple principle the experiments with glass described in this study were based.

Tools and Techniques

An electric kiln equipped with a pyrometer was used at North Texas State University in the experiments with glass.\(^1\) The interior dimensions of the firing chamber were \(8\frac{1}{2}\) inches wide by \(8\frac{1}{2}\) inches deep by 4 inches high.

Other materials and equipment used in the experiments are listed below:

**Glass:** window glass in single and double strength, and frosted window glass, single strength; stained glass fragments; broken bottle glass in brown and green; enamel in eighty-mesh powder, chunks, and thread form in red, dark blue, turquoise, dark brown, light brown, beige, tangerine, light green, and orange and Mexican glass mosaic tiles.

\(^1\)Manufactured by L and L Manufacturing Company, Chester 11, Pennsylvania.
Assorted materials for the preparation of glass: standard hand model glass cutter with a ball end for tapping glass; yardstick for guiding the glass cutter; detergent and cloths for cleaning glass; old newspapers to place over the glass-cutting table, to act as a cushion under the glass and to facilitate the removal of glass fragments and splinters; liquid soap and gum solution for painting designs on glass; hand sprayer for wetting enamel after application; fine-pointed sable brush for painting designs on glass; glass jar for mixing metallic oxides with water; one ounce of black iron oxide powder, and one ounce of cobalt oxide as pigments for painted designs on glass.

Assorted materials for insertion between layers of laminated glass: glass in all the forms mentioned above, carpenter cloth in one-quarter inch mesh, scraps of sheet copper. In the preparation of metal pieces, wire cutters and tin shears were used.

Materials used in applying a protective coating to the kiln: kiln-wash, a mixture of equal parts of kaolin and ground flint, stiff brush for the application of kiln-wash to the kiln surfaces and kiln furniture, glass jar for mixing kiln-wash with water to a consistency suitable for application.
Materials for making glass molds: ten pounds of dry earthenware clay for making terra cotta molds; two-gallon crock with lid for processing dry clay; wooden rolling pin; two sticks of wood 3/8 inches thick by 1 inch wide by 3 feet long; a square yard of oilcloth; palette knife; straight-edge ruler; one flower pot saucer, 3 inches in diameter and one 4 inches in diameter, both of terra cotta.

Kiln furniture: kiln shelf to fit kiln, four shelf supports 1½ inches high, a stainless steel trivet sufficiently large to support the glass molds.

Kiln-wash.—All interior surfaces used in glass work were protected from melted glass by the application of kiln-wash. Kiln-wash acts as a separator, and makes it possible to remove any glass that has spilled on the kiln or the kiln furniture during firing. If the residual glass is not removed from the kiln furniture or kiln surfaces but allowed to accumulate in the kiln during repeated firings, it will eventually dissolve and pit the surfaces with which it has contact. If the removal of the spilled glass causes the kiln-wash to be dislodged, the bare areas should be recoated.
Preparation of Molds for Glass

Athens clay\(^2\) was used in the preparation of glass molds. This clay flour was sifted into water that partially filled a two-gallon crock until a mound of dry clay stood about 6 inches above the water level. The crock was then covered and allowed to stand overnight, in order that the clay might slowly absorb the water and thus avoid any inclusion of air bubbles in the resulting moist clay. Air bubbles have created problems in wedging the clay and in firing the mold forms.

By the following morning the clay had absorbed the water in the crock to the point where all the clay was moist. The clay was then removed to a bat of plaster and balled together. As the clay was too moist to wedge at this time, the ball of clay was flattened out on the plaster bat to dry until it was firmer. That afternoon the clay was turned over on the plaster bat to dry more thoroughly. By that night the clay was dry enough to wedge.

The wedging was done by slicing the clay into two parts by pushing the ball of clay down over a tightly stretched wire and throwing one half of the ball of clay on a plaster bat and then throwing the second half firmly on top of the first portion. This was repeated about fifty times. The wedging removed all air pockets from the clay and gave it a smooth, even texture that was firm but highly plastic. The wedged

\(^2\)This clay was obtained at the Student Trading Post at North Texas State University, Denton, Texas.
clay was placed in the crock, covered, and allowed to remain overnight.

The following day enough clay was separated from the mass to make a ball about the size of a large grapefruit. This was wedged again sufficiently to make it uniformly plastic. Two sticks of wood were placed on a table on top of the reverse side of a square yard of oilcloth. The sticks, 3/8 inch thick by 3 feet long, were placed parallel to each other and about 10 inches apart. The freshly wedged ball of clay was placed between these sticks and rolled out with a rolling pin. The clay was turned over frequently while it was being rolled out to assure a uniform thickness and to remove any air pockets that may have remained. The rolling pin was run back and forth across the wooden sticks. These sticks assured that the clay would be level and of an even thickness. When the rolling pin had rolled the clay flat and flush with the upper surface of the sticks, the resulting clay slab was ready for use. Clay prepared in this manner formed the base for glass molds.

Molds were made by preparing a suitable form of clay or a truncated cone of clay 5 1/2 inches in diameter at the base, 3 1/2 inches in diameter at the top, and 1 inch high. This cone was placed on a plaster bat, covered with a damp cloth, and then carefully covered with the slab of clay. The surface of the clay slab was fitted to the top surface of the cone with the rolling pin and carefully fitted to the curved plane of
the cone with a wooden stick. Using a palette knife and a ruler, the clay slab was trimmed to a rectangle 7\(\frac{3}{8}\) inches square and the resulting flange carefully leveled. Several hours later, when the clay had dried sufficiently to be handled without distortion, the slab, the cloth, and the cone were turned over, and the cone carefully removed by lifting the cloth up and out of the molded clay slab. The clay slab was then turned over to dry until hard. When dry, the clay slab was sanded with fine sandpaper to smooth its surfaces and round off its sharp edges. The finished product was then ready for use as a mold in glass experiments.

Based on this same process, nine other molds varying in size were made. One of these was made with a cone, 4 and 3/4 inches wide at the bottom and 3\(\frac{1}{2}\) inches at the top; the second and third molds were made in the exact manner as described except that the cone was replaced with a flat disk of clay 4 inches in diameter and 3/8 of an inch thick; the fifth and ninth molds differed from the fourth only in that an oval form 5/8 inch thick by 5\(\frac{1}{2}\) by 3 inches was substituted for the flat disk of clay; a sixth mold was made by using a plywood form 3\(\frac{1}{2}\) inch thick by 2 and 3/4 inches square instead of the clay; and the seventh and eighth molds were made alike by using a plywood form measuring 3/4 of an inch thick and 2 and 3/4 inches wide, by 3\(\frac{1}{2}\) inches long.

When all the mold forms were dry, they were fired slowly to 1800 degrees Fahrenheit. The firing was begun slowly with
the door open for several hours to drive off any moisture remaining in the molds. The door of the kiln was then closed and the temperature slowly increased. Six hours were required to reach the desired temperature, and the kiln was left to cool unopened until the following day. The molds were not removed from the kiln until they had cooled to room temperature.

When the molds were removed from the kiln, all surfaces were coated with kiln wash mixed with water to the consistency of light cream. The coating was done with a 2-inch bristle brush.

Preliminary Experiments

Following is a description of experiments with glass conducted at North Texas State College (now North Texas State University), during the summers of 1960 and 1961. The experiments are reported step by step, with findings and conclusions following.

All temperatures given in the experiments are in Fahrenheit. All enamel used is 80-mesh vitreous enamel, prepared for copper enameling. All glass used was cut with a standard glass cutter. All glass was washed and dried to remove dust and grease. All enamel was applied with either a sieve designed for enamel work or applied by shaking through a sieve made of a layer of nylon hose stretched over an embroidery hoop. In all cases enamels were applied to the glass surface after it had been painted with a gum solution, made by
dissolving about \( \frac{1}{2} \) teaspoon of gum arabic in about 4 ounces of water. In all cases the glass was introduced into a kiln at room temperature and removed only after the kiln had been returned to room temperature. All molds, kiln furniture, and kiln surfaces exposed to glass were coated with kiln-wash. When glass dripped on these surfaces, it was recovered immediately after the kiln was used, and the areas retouched with kiln-wash.

The word **objective** refers to the particular experiment, rather than to the over-all objectives. **Materials** refers to the particular materials needed in each experiment, and as such does not include all the materials normally used. In the interest of brevity the kiln, glass cutter, detergent to clean glass, cloth or paper towel to dry the glass, and the trivet placed under the glass or mold are not repeated in the description of each experiment.

Fifty-seven experiments were made in the preliminary studies made of glass at North Texas State University. In classifying these experiments, three categories may be used: (1) the search for needed temperatures for firing, (2) the search for desirable forming and shaping techniques, and (3) the search for decorative techniques. In the experiments, however, many of these categories overlap; the purpose was to learn the essentials for each category by experimentation, and many procedures involved all three categories. The beginning experiment demonstrated that glass
laminated successfully at 1500 degrees. Experiments in forming and shaping utilized this temperature until repeated failures resulted in experimenting with lowering the firing temperature to 1450 degrees. Also, different media were used in attempting to form desirable glass molds; in some instances flowerpot saucers were used, but in others two sheets of glass without a mold were used in experimentation.

Such procedures resulted in a succession of experiments, many of which were not related closely to the preceding one. In presenting the experiments, to avoid confusion in referring to different ones, they are discussed by number or the order in which they were made. In the discussions, related experiments are linked together, with mention made of overlapping categories.

Search for Temperature Ranges

The first twenty-two experiments involved attempts to create desirable glass forms and a desirable range of firing temperatures. Experiments 23 through 42 were centered in the search for desirable materials which could be used with glass to enrich its pattern and design, and Experiments 43 through 57 were concerned mainly with form and design.

**Experiment 1**

**Objective.**--To discover temperatures for glass lamination.

**Materials.**--Two sheets of clear rectangular window glass approximately 3 by 4 inches, pieces of broken blue bottle glass.
Procedure.—The pieces of broken blue bottle glass were placed at intervals on one sheet of window glass, covered by a second sheet of glass, placed in the cold kiln, and fired to 1500 degrees.

Results.—The two sheets of glass adhered together firmly and the broken blue bottle glass melted between them.

Experiment 2

Objective.—To determine the effect of a temperature lower than 1500 degrees on glass lamination.

Materials.—Two sheets of clear rectangular window glass approximately 3 by 4 inches each, pieces of brown broken bottle glass.

Procedure.—Pieces of brown broken bottle glass were placed at intervals on one sheet of window glass, covered by a second sheet, placed in the cold kiln and fired to 1350 degrees.

Results.—The glass began to bend at 1250 degrees but the separate parts did not melt sufficiently to adhere to one another, and when they were removed from the kiln the separate pieces fell apart.

Experiment 11

Objective.—To experiment with stained glass to determine effect of thermal shock.

Materials.—A sheet of window glass 4 by 5 inches and pieces of stained glass fragments.
**Procedure.**—Pieces of the stained glass were placed on the sheet of window glass, fired in kiln to 1500 degrees, temperature held for thirty minutes, and the kiln door opened.

**Results.**—The sheet of window glass was found severely shattered when the kiln door was opened.

A number of related experiments were carried out in an effort to shape varying types of glass. The initial experiment is described in detail, and subsequent experiments described only when there were differences in materials, procedures and results.

A number of the experiments used a flowerpot saucer as a mold. In some instances, the glass was placed in the saucer; in other instances it was placed over it.

**Experiment 3 and Related Experiments**

**Objective.**—To shape a sheet of window glass, using a flowerpot saucer as a mold.

**Materials.**—A 3-inch flowerpot saucer, an octagonal sheet of window glass cut to fit the rim of the saucer, and a piece of broken blue bottle glass.

**Procedure.**—The octagonal sheet of glass was centered on the top of the flowerpot saucer and the piece of broken blue bottle was centered on top of the glass. The entire unit was fired to 1500 degrees.

**Results.**—The sheet of glass had bent around the edges of the saucer during the firing but shattered as it cooled.
Only the center of the sheet where the blue glass had been placed had bent sufficiently to reach the bottom of the saucer.

A related Experiment, 6, attempted to create a circular glass disk about 1 inch thick. To do this broken pieces of window glass were placed in the bottom of the flowerpot saucer, and fired to 1500 degrees. While the heat was sufficient to melt the glass, open areas between the glass did not close to make a solid disk.

Experiment 7 repeated the previous one exactly except to substitute some chunks of broken clear and colored glass for the window glass to determine whether better results could be attained with a different type of glass. Many sharp jagged edges showed in the fired product and many open spaces remained between the fragments.

In Experiment 9, the broken parts of Experiment 6 were fitted together in the flowerpot saucer and broken pieces of window glass were added where there were holes in the form resulting from Experiment 6. The objective was to use more window glass in an effort to create a better form. The unit was fired to 1500 degrees. As a result, some broken areas did not heal, new holes developed where none existed before, and the cracked areas developed wider spaces.

In Experiment 12, the results of Experiment 7 were placed in a flowerpot saucer, fired to 1500 degrees, and the temperature held for thirty minutes. The purpose of the test was to determine the effects of this extended firing time on the glass. The result was shattered glass fragments.
Experiment 10 was an extension of Experiment 9 to determine the effect of the use of another flowerpot in firing. The mass of shattered glass from Experiment 9 was placed in a flowerpot saucer and another flowerpot saucer placed on the glass form. This was fired to 1500 degrees and that temperature held for thirty minutes. The results were that the glass form placed in the saucer had run to the bottom of the saucer and filled it solidly. The saucer placed on top of the glass was broken, as was the resulting mass of glass.

The purpose of Experiment 8 was to determine whether a sheet of glass could be used over instead of inside of a flowerpot saucer to form a desirable mold. Materials used were a flowerpot saucer, an octagonal piece of window glass, liquid soap, powdered black iron oxide, and a small sable brush. After the glass was cleaned and dried, a design in liquid soap was painted on it with the sable brush. Black iron oxide was sprinkled over the surface of the glass to set the design in the liquid soap. The glass was then shaken by hand so that the iron oxide remained trapped only in the liquid soap. The sheet of glass was placed on top of the inverted flowerpot saucer. The entire unit was fired at 1500 degrees with the result that the black iron oxide made a pattern in gray on the glass. The glass had assumed the shape of the flowerpot saucer; however, upon cooling and contracting the glass split into fragments.
In Experiment 13, the shattered glass resulting from Experiment 8 was used as material to test the possibility of mending broken glass fragments inside a flowerpot saucer. The broken parts of glass were carefully fitted together and fired at 1500 degrees. The broken sections did not mend.

Experiment 1 was repeated in Experiment 21 to determine whether a change in the firing temperature would affect the same results or achieve less deformation. Materials and procedures used were exactly the same as in the two preceding experiments, but the firing temperature was reduced to 1450 degrees. The result was that the desired shape was achieved, and the sides showed less deformation.

**Experiment 4 and Related Experiments**

In the search for an adequate procedure for achieving a desirable hollow glass form from several sheets of glass, experiments were performed without the flowerpot saucers, using the sheets of glass alone. The initial experiment in this series is described in detail with subsequent experiments briefly mentioned:

**Objective.**—To create a hollow glass form by using several sheets of glass without the use of any supporting device.

**Materials.**—Two sheets of glass 3 by 4 inches each, six pieces of glass 3 inches by \( \frac{3}{4} \) inch each, and pieces of broken bottle glass.
Procedure.—One of the two larger sheets of glass was placed flat on the kiln shelf. Three of the small pieces of glass were stacked vertically near each end of this large sheet of glass. The second large sheet of glass was centered directly over the first sheet of glass. The entire assemblage of glass was fired to 1500 degrees.

Results.—The entire assemblage collapsed completely and melted into one thick sheet of glass.

This experiment was repeated (Experiment 5) with changes of materials and procedures to determine whether differences in materials would produce more desirable results. Two rectangular sheets of glass, 4 by 5 inches each, four small rectangular glass pieces each approximately 1½ inches square, and broken fragments of brown and green bottle glass were used. The sheets of glass were arranged as in Experiment 4. The fragments of brown and green bottle glass were sprinkled on both sheets of window glass. The entire unit was fired to 1500 degrees. The glass was placed on a kiln shelf in such a manner that it extended 3/8 of an inch over each end of the kiln shelf. When cool the kiln was opened and it was found that the glass had melted flat and sagged over both sides of the kiln shelf. The resulting glass form had split at one edge and sheared off completely where it had melted over the kiln shelf. The remaining form had contracted ½ of an inch in length.
Experiment 15 and Related Experiments

Experiments were now directed toward finding ways to laminate glass that would not fracture during the firing. The initial experiment is described in detail, with succeeding ones only briefly stated except for changes made in the experimental processes.

Objective.—To find ways to laminate glass.

Materials.—Two rectangular sheets of window glass 3 by 4 inches each, some pieces of broken bottle glass, and enamel threads.

Procedure.—Some pieces of broken colored glass and enamel threads were sprinkled on one sheet of glass. The second sheet of glass was placed exactly on top of the first sheet of glass. This was fired at 1500 degrees.

Results.—A smooth integrated rectangle of glass with colored glass between the upper and lower surfaces was obtained.

Since success was achieved in creating a smooth integrated rectangle of glass, other experiments based on the same procedure were carried out. In one, two flat sheets of window glass, 3 by 4 inches each, some rectangles of glass cut from sheets of window glass, a small sable brush, and one ounce of cobalt oxide comprised the materials. The small pieces of glass were painted with a mixture of water and cobalt oxide, placed on one of the sheets of window glass, the second sheet
of glass placed on top of these, and the unit fired to 1500 degrees. The result was a solid rectangle of glass with navy blue color where the cobalt oxide was applied.

In a succeeding Experiment, 17, stained glass fragments were added to determine their effect on the other glass materials. Some small pieces of stained glass and enamel threads were placed on a single sheet of window glass and fired to 1500 degrees. The result was an unbroken surface of clear and colored fused glass.

In Experiment 18 eight pieces of stained glass cut in various shapes from small pieces of stained glass of less than 1\(\frac{1}{2}\) inches in any dimension were arranged in several layers in various points on the single sheet of window glass and fired to 1500 degrees. The single sheet was severely fractured and the stained glass melted over the surface of the window glass, giving the appearance of black molasses.

In another Experiment, 19, a three-layered sandwich was made with three pieces of window glass and small pieces of stained glass and fired to 1500 degrees. The result was an integral block of colored stained glass.

In Experiment 23, the firing temperature was lowered to determine the effects of a lower temperature on the combination of glasses. A four-layered sandwich of glass was made with four sheets of window glass, 3 by 5 inches each, and fragments of stained glass between layers. The entire unit was fired to 1400 degrees. This temperature firmly bonded the window glass
and mildly deformed its shape, so that it fitted down firmly between the stained glass fragments. The stained glass was more deformed than the sheet glass, and was heavily crazed. The window glass had very slight fractures.

Search for Design Materials

Three experiments, 24, 25, 26, studied the most desirable materials for use in laminating flat glass. Materials used were strips of window glass and strips of stained glass. Three different patterns were assembled: strips of window glass in lattice pattern, strips of stained glass in similar pattern, and parallel strips of window glass and stained glass in a third pattern. These groups were fired to 1450 degrees. In all cases the forms were shattered at the areas where the glass forms crossed each other.

Experiments 28, 29, and 30 repeated Experiments 24, 25, and 27 using smaller pieces of glass to determine the effects of sizes of glass on the firing. As in the previous experiments, all the patterns shattered where the glass pieces crossed one another, but the fracturing in the smaller sizes was less severe than in the larger sizes.

In Experiment 27 four-inch strips of stained glass were placed in patterns on a sheet of window glass, 6 and 3/4 inches by 8 inches, and fired to 1450 degrees. When removed from the kiln the window glass was highly fractured. The stained
glass had broken free from the window glass at one end only. It remained firmly attached to the window glass at the other end.

Experiment 31 repeated Experiments 24, 25, and 26 using smaller strips of glass in the lattice patterns to see if open-work patterns in glass could be achieved. As in the initial experiments, all the patterns shattered where the glass pieces crossed each other, but the fracturing in the smaller sizes was less severe than in the larger sizes.

In Experiment 32, Mexican glass mosaic tiles measuring 3/4 inch square, by 1/8 inch thick were introduced between the layers of glass to determine its suitability as a decorative material. A sandwich was made of the window glass with the Mexican glass tiles and the stained glass fragments as filling. This combination was fired to 1400 degrees. A thoroughly bonded unit of glass resulted which contained patterns of crazed stained glass and crazed mosaic tiles.

Experiments 33, 34, and 35 extended the search for design materials useful in laminating glass. In Experiment 33, Mexican glass tiles alone were used with window glass and fired to 1450 degrees. The result was that the tiles were firmly bonded to the sheet of window glass. The process was repeated in Experiment 34 except that brown and green bottle glass fragments were used in the place of the Mexican glass tiles. The bottle fragments firmly adhered to the window
glass after firing, and crazing was confined to those areas where pieces of bottle glass were allowed to overlap, or where they were more than 2\(\frac{1}{2}\) inches in length. In Experiment 35, Experiment 34 was repeated but without any overlapping of the bottle glass. There was very little crazing and the result was highly satisfactory.

The purpose of Experiments 36, 37, and 38 was to reaffirm the effects of overlapping of material. Three sheets of window glass, 3 by 5 inches each, and brown and green bottle glass fragments were the materials. The brown and green bottle glass was arranged on the sheets of window glass. On one sheet the bottle glass was allowed to widely overlap. On the second group, there was very little overlap. On the third group, there was no overlapping at all. These were fired to 1450 degrees. The crazing was in direct ratio to the overlapping. The pattern having no overlapping areas had no crazing whatever. Experiment 39 was made to reaffirm the results of Experiments 36, 37, and 38. A series of small 1-inch squares and 1\(\frac{1}{2}\)-inch squares were decorated with fragments of brown and green bottle glass and fired to 1450 degrees. There was no crazing and the results were satisfactory.

In Experiment 40, squares of Mexican glass tiles were fired on squares of window glass. This bonded the tiles and the window glass firmly together without crazing.
Experiment 41 continued the experiments with decorative glass materials. Triangles of bottle glass and stained glass, ranging from 1\(\frac{1}{2}\) inches to 1 inch in size were cut. Triangles of window glass were cut 1\(\frac{1}{4}\) inch larger than the bottle or stained glass triangles. The triangles of bottle glass and stained glass were placed on the window glass, fired to 1450 degrees. There was no crazing; the resulting triangles were firmly bonded together and resembled carefully made cabochon jewelry stones.

Further experiments with cabochon gem shapes were the purpose of Experiment 42. Small broken fragments of stained glass in dark colors were fired to 1400 degrees. Shapes with deep rich colors and a bright "polish," suitable for baroque or irregular jewelry forms, resulted.

**Experiment 43**

**Objective.**—To test the behavior of frosted glass in combination with brown bottle glass.

**Materials.**—A sheet of frosted glass, 3 by 5 inches, and fragments of broken brown bottle glass.

**Procedure.**—The brown bottle glass was arranged on the sheet of frosted glass and fired to 1400 degrees.

**Results.**—The brown bottle glass was firmly adhered to the sheet of glass which remained frosted. There were no fractures.

In Experiment 44, window glass was added to the broken brown bottle glass and frosted glass. Lines were painted with
a gum solution in a rectangular pattern on a sheet of window glass, 4½ by 7 inches. These were dusted with dark blue enamel, the excess shaken off, and additional areas sprinkled by hand with turquoise enamel. Broken bottle glass was arranged in a pattern over the dark blue enamel. Four strips of frosted glass, 3 and 3/4 inches long and 3/4 inch wide, were placed on the sheet of window glass in areas not covered by the bottle glass. The assemblage was fired to 1400 degrees. All glass and enamel were firmly bonded together without fractures.

**Experiment 45**

**Objective.**—To test the decorative possibilities of copper enamels.

**Materials.**—Two sheets of window glass, 3 and 3/4 inches by 4½ inches each, and enamel threads in black, dark blue, and turquoise.

**Procedure.**—Enamel threads were arranged in a pattern on the larger sheet of window glass and covered by the smaller sheet of window glass. This arrangement was fired to 1400 degrees.

**Results.**—All glass was firmly bonded and there were no fractures.

**Experiment 46**

**Objective.**—To determine the suitability of assorted materials for enclosures in glass laminations.
Materials.—Two sheets of window glass, 3 by 4½ inches each, a piece of ½ inch carpenter cloth cut into strips approximately 3½ inches long by 3/8 inches wide; powdered dark blue and turquoise enamel, both 80-mesh; three pieces of 20-gauge sheet copper cut in different sizes: the first 2½ inches by 1/8 inch; the second cut into a triangle 1 inch long and ½ inch wide at its widest point; and the third sheet was cut 1/3 the size of the second copper piece.

Procedure.—The enamels, carpenter cloth and copper pieces were placed on one sheet of window glass and covered by the second sheet of window glass. Firing was at 1400 degrees.

Results.—A firmly bonded unit of glass with enamel, carpenter cloth, and copper enclosures with no fractures was obtained.

Following these successful experiments in laminating glass and enamel, carpenter cloth, and copper sheets, other experiments were made using these materials in a variety of ways in order to develop additional designs.

Experiments 47, 48, 49, 50, and 51 were variations of Experiment 46 for the purpose of testing additional arrangements of the same decorative material. Satisfactory results were obtained in all cases.

Experiment 52

Experiments were then directed toward work with glass in glass molds.
Objective.—To form glass in a glass mold.

Materials.—The first bisque mold made for glass work, a sheet of window glass 4\frac{1}{2} inches square, gum arabic solution, a small sable brush, and dark blue copper enamel.

Procedures.—On a sheet of window glass a design was painted with gum solution, dusted with dark blue enamel powder, and the excess enamel powder shaken off. The sheet glass was centered on the mold and fired at 1400 degrees.

Results.—The glass had conformed perfectly to the shape of the mold.

Experiment 53 repeated Experiment 52 but included two sheet of glass instead of one. The use of two sheet of glass caused the lower sheet of glass to split across one corner.

Experiment 54 repeated Experiment 52, but used one piece of glass cut to fit the bottom of the same mold used in Experiment 52. This piece of glass was covered by a piece of carpenter cloth of the same dimensions. The larger rectangle of glass was centered on top of the mold. The result after firing was that the increased bottom thickness of the glass had decreased the depth to which the top sheet of glass had to sink. The resulting glass dish had straighter edges than that in Experiment 52 and the glass was not torn.

The purpose of Experiment 55 was to repeat Experiment 54 in order to confirm results, and to experiment with other decorative materials. Following similar procedures, the brown
bottle glass was arranged on the glass in the bottom of the mold, the enamel sprinkled over the design, and the second sheet of glass, 5 inches by 5\(\frac{1}{2}\) inches, centered on the mold. The results of the firing reaffirmed previous findings and demonstrated the suitable use of brown bottle glass in laminated mold-formed glass.

**Experiments 55-57**

**Objective.**—To inbed carpenter cloth in curved laminated mold-formed glass.

**Materials.**—One square foot of \(\frac{1}{4}\)-inch mesh carpenter cloth, wire cutters, two sheets of window glass, and a bisque mold.

**Procedure.**—A pattern was made by carefully fitting pieces of paper to the surface of the mold. When it was completed it was used to indicate the cut of the carpenter cloth. This carpenter cloth was carefully bent and fitted to the mold. Since it was not possible to shape a flat sheet of glass over the carpenter cloth, a sheet of glass, 4\(\frac{1}{2}\) by 3\(\frac{1}{2}\) inches square, was fired into the mold first, then the carpenter cloth form was placed inside this and covered with a second sheet of glass and fired a second time.

**Results.**—The \(\frac{1}{4}\)-inch mesh was not wide enough to allow the glass on the upper layer to contact the glass on the lower layer to bond the sheets together. The sheets of glass were bonded at the edges only. In one of the firings the glass on the upper level shattered where it had melted into
the carpenter cloth. In the other firings the upper layer of glass had pushed the carpenter cloth into the lower layer of glass. In these cases the lower sheet of glass had fractured.
CHAPTER IV

CLASSROOM EXPERIMENTS WITH GLASS

Introduction

The ceramic laboratory at Iaredo Junior College was equipped with three enameling kilns. Two of these were enameling kilns from Ernest Lenick and Company of Chicago. These were not suitable for glass work; first, because they lacked a pyrometer, and secondly because the interior dimensions, with an over-all height of only 2\(\frac{1}{2}\) inches, did not allow for the use of a trivet, mold, or kiln shelf.

The third enameling kiln, made by the American Art Clay Company, was suitable for forming glass. The firing cycle for glass work requires a period of at least four hours. On Mondays, Wednesdays, and Fridays there were two two-hour classes. One followed the other immediately. On Tuesdays and Thursdays there was one three-hour class period. This precluded the use of the kiln by more than one student from a class each day.

Another difficulty arose from the size of the classes in which the enameling and glass work was done. With from twenty to thirty-six students at work, the instructor could not give attention to any one student for any extended period of time.

The combination of these factors made a logical, orderly procedure of investigation impossible. The kiln could not
be used for glass work when enameling was being done. The restricted use of the kiln for glass work at other times made individual work with glass essential. With a total of eighteen class hours each week, for eighteen weeks, it was not possible for all students to do glass work.

Much of the glass work was done without direct observation by the instructor, and strong individual self-reliance on the part of each student was necessary. Information about methods or procedures had to be reconstructed. In view of these conditions, the experiments given below are in many respects hypothetical. They are significantly selected examples, which represent typical procedures, unusual or unexpected processes or results, or they present new findings not covered in the preliminary experiments.

Tools and Techniques

The kiln used at Laredo Junior College was manufactured by the American Art Clay Company of Indianapolis, Indiana. The interior dimensions of the kiln were 6 1/2 inches in width by 7 inches in depth by 4 inches in height. It was equipped with a pyrometer.

The materials used in the glass work by students included all the material used in the preliminary experiments and the following additional materials: liquid gold lustre, glass marbles, ceramic underglazes in several colors, ceramic over-glaze colors, scissors, paper towels, fine-gauge copper wire, and a hand spray gun.
The sheet glass used was furnished by the Laredo Paint and Paper Company or by the maintenance department of the college. Most of the glass was supplied from left-over scraps or broken fragments at no cost to the students. Only in cases where students chose to order glass cut especially for them in specified sizes did the Laredo Paint and Paper Company charge for the glass. Most of the glass was single strength grade "B" window glass or glass prepared for use in picture framing. Both types of glass responded identically in the kiln. There was no perceptible difference in melting temperatures.

The kiln, kiln furniture, and molds were protected by applications of kiln-wash. Whiting was accidentally used by one of the students, because "it looked like kiln-wash." This proved satisfactory and was more easily removed from molds. Another student mistakenly used a high fire glaze intended for use on stoneware in a glass mold. This also proved satisfactory, but much too expensive for normal use.

The clay used for molds made by students was Butcher's white talc clay,\(^1\) which was selected on the basis of its firing temperature, cost and availability. The procedures for making molds were identical to those described under the preliminary experiments.

All temperatures used are given in Fahrenheit.

\(^1\)Butcher's white talc clay was obtained from H. L. Hunt, San Antonio, Texas.
The meanings given to **Objectives**, **Materials**, **Procedures**, and **Results** are identical to those given in the preliminary experiments.

**Experiment 1**

**Objective.**—To produce a design on glass by painting the surface with ceramic underglaze colors.

**Materials.**—Liquid ceramic underglaze colors in black, dark blue, and turquoise, a fine pointed sable brush, a sheet of window glass 4 by 5 inches.

**Procedure.**—A design, using the three underglaze colors, was painted on the sheet glass with the sable brush. When the colors had dried, the glass was fired to 1400 degrees.

**Results.**—The underglaze was thin in some spots. In other areas, the underglaze had broken free from the surface. In all but very few parts of the design the underglaze was dull in appearance and was rough to the touch.

In a companion Experiment 2, the exact procedure and materials were used except for the addition of a second sheet of window glass to test its effect in laminating glass. After the design was painted on the first sheet of window glass and it had been allowed to dry, the second sheet of glass was placed directly on top of the first sheet and the unit fired to 1400 degrees. The two sheets were thoroughly bonded together and the design inside the glass was technically satisfactory.
Experiment 3, a second experiment related to Experiment 1, tested the use of ceramic overglaze as a medium for the decoration of laminated glass. Materials were the same as in Experiment 2 except the ceramic overglaze colors were used instead of the underglaze. The procedure for arranging materials and firing were the same except that the overglaze colors which were dry were moistened so that they could be applied by brushing. After the firing process, the designs painted in blacks and blues remained, but the warm colors had disappeared or remained in traces only. All applications of color appeared weakened, spotty, or thin.

Experiments 4, 5, and 6

Experiments 4, 5, and 6 were concerned with decorating glass panels using assorted materials to produce a laminated dish in a mold.

Objective.—To produce a laminated glass panel.

Materials.—Copper enamel colors, sieve, gum arabic solution, brush for the application of gum solution, paper towels, scissors, and two sheets of window glass, each 5 inches square.

Procedure.—Stencils were cut from the paper towels, dampened with water, and laid flat on a sheet of glass. Gum solution was applied to the glass through the openings of the stencil, enamel applied over the stencil pattern, and the stencil carefully removed. The same procedure was repeated
on the second sheet of glass. One sheet of glass was placed directly over the other. The unit was fired to 1400 degrees.

Results.—The two sheets of glass were firmly bonded together and the enamel was bonded to the interior and top surface of the resulting glass panel.

Experiment 5 repeated Experiment 4 but used assorted materials to determine their suitability as enclosures for lamination. The materials were lump copper enamel in colors, enamel threads, broken bottle glass, and small fragments of stained glass. They were arranged on one sheet of window glass, 5½ inches square, covered by a second similar sheet of window glass and fired to 1400 degrees. The sheets of glass and their enclosures became firmly bonded into one unit.

Experiment 6 was for the purpose of forming a laminated glass tray in a mold. Materials were two sheets of window glass, one 6 inches square, the other 5½ inches square; 80-mesh copper enamels in several colors, gum solution, paper towels, scissors, a brush for the application of gum solution, and a mold for shaping glass. The paper towels were folded and cut to produce a stencil pattern. One stencil was cut slightly larger than the other. The stencil with the larger openings was dampened with the gum solution, applied to the larger sheet of glass, and enamel sifted onto the glass through a sieve. The smaller stencil was used to apply a
contrasting color of enamel to the smaller sheet of glass. When the stencils were removed and the gum solution dry, the smaller sheet of glass was centered on the larger one and the unit fired to 1400 degrees. The two sheets of glass were firmly bonded into a single unit, while the two different stencil patterns combined visually into a single pattern with color variations. Because of the differences in the glass sizes, the result was a laminated panel with a molded border.

Experiment 7

Additional similar experiments were conducted for the purposes of testing various types of materials suitable for glass decoration.

Objective.—To attach a glass marble to an enameled copper lid in such a manner that it would make a handle.

Materials.—An enameled copper lid, gum solution, mortar and pestle, glass marbles, and a small copper tray.

Procedure.—Five glass marbles were placed on a sheet of copper, placed in a cool kiln, and fired to 1400 degrees. This cracked some of the marbles, and flattened them to pumpkin-shaped spheres. One of the most symmetrical marbles was selected for use. The mortar and pestle were used to grind the gum solution and enamel to a heavy paste. The marble was fastened with the gum solution paste to the top of the
enameled lid and allowed to dry. The dry lid and the marble were fired in a kiln preheated to 1400 degrees.

Results.—The marble was firmly attached to the lid.

Experiment 8

Experiments 8, 9, 10, and 11 had for their objectives the creation of glass tiles suitable for mosaic use. Experiments 8 and 9 involved changes in firing temperatures.

Objective.—To produce glass tiles from brown and green bottles suitable for use in mosaic work.

Materials.—Kiln-wash, kiln shelf, shelf supports, broken glass from brown and green glass bottles, and a glass cutter.

Procedure.—The kiln shelf was given a coat of kiln-wash. The brown and green glass fragments from the thick bottoms of bottles were placed on the shelf, and fired to 1400 degrees. This temperature proved insufficient to fully flatten the glass, so the firing was repeated to 1450 degrees. After firing, the glass was cut to 3/4 inch squares to match Mexican glass tiles.

Results.—Glass tiles were produced which could be combined in mosaic work with the purchased Mexican glass tiles.

Experiment 9 was for the purpose of producing gold glass tiles. The materials were two sheets of window glass, a glass cutter, and liquid gold lustre. The two sheets of window glass were placed directly on top of each other and
fired to 1400 degrees. When cooled and removed from the kiln they were coated with liquid gold lustre and allowed to dry for twenty-four hours. The laminated glass was then placed in a cold kiln and fired slowly to 800 degrees. The surface became bright and shiny. The resulting lustre glass was cut into tiles to be used as gilt accents in mosaics.

Further experiments in creating glass tiles were carried out in Experiment 10. The purpose was to produce glass tiles to match the thickness of Mexican glass tiles for use in mosaics. Stained glass was broken into small pieces, placed inside several thicknesses of folded newspaper and hammered to the size of granulated sugar. One sheet of glass, 3 inches square, was painted with the gum solution and sprinkled with powdered stained glass; a second sheet was painted with gum solution and sprinkled with enamel color; and a third sheet was painted directly with pottery underglaze. Each of these three sheets of glass was covered with another sheet of glass and fired to 1400 degrees. All combinations produced laminated glass with color inclusions which were suitable for use as tiles when cut to appropriate sizes.

The objective in Experiment 11 was to produce glass tiles the same size and shape as Mexican glass tiles. A slab of wedged pottery clay was rolled out between two sticks of wood 3/8 of an inch thick on the reverse side of a piece of oilcloth. Mexican glass tiles were pressed their full thickness into the damp surface of the clay to form tile molds.
The clay was trimmed of excess material, dried, and then fired to 1800 degrees. After cooling, the fired clay tile molds were filled with one or the other of three combinations of materials: (1) a thin layer of ground stained glass, covered by a rectangle of window glass cut to fit the mold depression, and in turn covered by a layer of ground stained glass; (2) a thin layer of clear enamel flux, covered by a rectangle of window glass which was painted with pottery underglaze, which in turn was covered by more enamel flux; and (3) a layer of colored copper enamel, a square of window glass, and then a layer of colored copper enamel. These materials were then fired to 1400 degrees. The result was three different kinds of usable glass tiles.

**Experiment 12**

**Objective.**—To reduce the thickness of a sheet of stained glass intended for use with other materials in kiln-fired glass.

**Materials.**—Kiln shelf, four shelf supports 1₂₅ inches high, a thick sheet of stained glass.

**Procedure.**—The shelf was painted with kiln-wash and the piece of glass placed on the shelf allowing space for the glass to spread when molten. The glass was fired to 1400 degrees which caused the glass to ball up and thicken. The glass was refired to 1450 degrees.

**Results.**—The stained glass was reduced to a suitable thinness.
Experiments 13, 14, and 15 tested the use of enamels for glass decoration.

**Experiment 13**

*Objective.*—To produce enameled glassware.

*Materials.*—Gum solution, copper enameling colors, a hand sprayer, a sieve, and three short tumblers not over 3 inches high.

*Procedure.*—The tumblers were cleaned. Paper stencils were prepared, dampened, and applied to the outer surface of the tumblers. The open areas of each stencil were brushed with a thick gum solution; and, the enamel colors were sifted onto the sides of the tumblers through the stencil. The enamel was then sprayed with additional gum solution to insure adherence of the enamel to the tumbler. The tumblers were placed in the kiln upside down and fired to 1400 degrees.

*Results.*—While one of the tumblers was slightly deformed, the enameling was successful. The enameled surface was not smooth but textured like the surface of an orange.

The objective of Experiment 14 was to enamel a glazed piece of pottery. A design was painted with gum solution on the surface of a piece of white glazed pottery. Using a sieve, the gummed areas were sprinkled with enamel powder, and the excess shaken off. The pottery was placed in a cold kiln and fired to 1400 degrees. After the kiln cooled to room
temperature, the pottery was removed. The result was a bright clear design with a brilliance of color not easily achieved with glazes.

The objective of Experiment 11 was to create a pool of glass in the bottom of a pottery tray. Small chunks of broken bottle glass were placed in the bottom of a glazed white pottery tray. Clear enamel flux was filled in the areas between. Red and green enamel colors were placed on top of all the other materials inside the tray. The tray was placed in the cold kiln, fired to 1400 degrees, and not removed until the kiln returned to room temperature. The result was a crazed pool of glass with brilliant red and orange colors floating inside.
CHAPTER V

FINDINGS AND CONCLUSIONS

Preliminary Experiments with Glass

Reactions of Glasses to Heat

Thermal shock invariably results in the fracture of glass. Placing glass in a hot kiln results in fracture, as does removing glass from a hot kiln. The firing time needed for glass forming cannot be speeded up. About two hours are required to bring glass to the proper softening temperature. If the kiln contains several pieces of glass, or thick pieces of glass, a slower rate is recommended. If the kiln has both high and low speed controls, low speeds should be used until 1000 degrees is reached, allowing one hour to reach this temperature. If the rate of increase exceeds this, fractures will result. About three or four hours are needed to bring glass back to room temperature. Any attempt to speed heat reduction, such as opening or venting the kiln door, will fracture the glass. There is little visible reaction of glass to temperatures up to 1000 degrees. At 1200 degrees glass starts to soften, which is evident by a tendency to round off its right-angle edges and corners. This tendency is more fully developed in stained glass at this temperature than it is in window glass.
At 1400 degrees stained glass fragments are fully rounded. In small pieces of stained glass of less than $\frac{3}{4}$ inch in size, a complete cabochon shape will be attained. At 1450 degrees stained glass will flatten and lose its cabochon shape, and begin to form needles protruding from its edges. Window glass will tear at this temperature on inclined sides of molds and will tend to thicken where it has torn. At 1500 degrees stained glass becomes liquid and window glass begins to form needles. Beyond 1500 degrees stained glass boils and window glass becomes liquid, and will begin to boil if this temperature is exceeded.

The temperatures needed in working with glass are critical. A pyrometer on the kiln used for glass work is essential. In the earlier experiments in forming glass, it was found that the glass shattered when the form was fired to a temperature of 1500 degrees. In Experiment 22 the firing temperature was 1450 degrees with the result that the glass did not shatter. Such a small difference in temperatures could not be detected without a pyrometer, but it can make the difference between a few small fractures and many large fractures in glass work. In Experiment 2 the glass was observed to start changing form at 1250 degrees, but 1350 degrees did not prove sufficient to bond glass pieces together. Yet the later experiments at 1400 degrees (after Experiment 42) proved successful.
Experiment 5 demonstrated that window glass expands about \( \frac{1}{4} \) inch for 4 inches of length during the change from room temperature to 1500 degrees. It must be assumed that the expansion will be somewhat less at 1400 degrees, a principle that governs the size of window glass used in shaping glass forms.

Experiment 18 demonstrated that if glasses of two different melting points are used together, in such a manner that the softer glass is used in a greater or an equal amount, the greater expansion and contraction of the softer glass will break the harder glass. On the other hand, if the softer glass is used in lesser amounts than the harder glass, the softer glass will fracture. This is demonstrated again in Experiments 19 and 20.

In Experiment 34 the softer glass was bottle glass and where it was allowed to exceed the thickness of the window glass, it fractured. In Experiments 36, 37, 38, and 39 this was reaffirmed, and the next premise indicated.

Inclusions of softer glass will cause fractures in upper and lower layers of glass in laminated glass forms if the inclusions are thick or used in excessive amounts. If the inclusions are thin or used in light applications, no fractures will result on the outer surfaces. (Experiments 17 and 32)

**Behavior of Glasses at High Temperatures**

Since glass will expand when heated, glass cut for use in molds must be cut at least \( \frac{1}{4} \) inch shorter than the flange or
edge of the mold. If this is not done the glass will expand and become as large as or larger than the mold. When this occurs, the glass will melt or bend over the mold edge. This will always fracture the glass and sometimes fracture the mold. On the other hand a sheet of glass that has softened enough to fit a mold will shrink in the mold on cooling and free itself so that it can be lifted out of the cooled mold or will fall freely from an inverted mold.

Materials laminated between sheets of glass must be of a thinness that will allow upper and lower layers of glass to fit closely together or to be nearly in contact, or they will cut through the soft glass in firing. Difficulty will be encountered if thick chunks of glass broken from the bottoms of bottles, large chunks of enamel, or even thick pieces of stained glass are used. If screen wire, carpenter cloth, or any other metal pieces are used, they must be completely flat, or very small in size; otherwise they will push through the glass when it softens. If these metals are over 1/16 of an inch in any dimension, they cannot be laminated in molded glass or they will cut through the soft hot glass. If metallic inclusions are longer than one inch, even though they are thin and of a metal that expands or contracts at different temperatures than the glass, they will cause the glass to fracture around them. If glass is to be molded, no materials can be laminated at curved areas of the mold except foils, thin enamel threads, copper enamel colors, underglaze
paits, or the very finest of soft wire; anything more rigid will cut through the glass. Thick pieces of glass must be broken, ground to granules or powder, or, as in the case of thick sheets of stained glass, melted in the kiln to thin sections before use.

Fractures in Glass

Glass can withstand small interior fractures, if these fractures are in laminated material. If the glass is not laminated or the fractures are in the outer glass in lamination, the fractures will increase in size as the glass is subjected to shock, either thermal or physical. Refiring a piece of glass will not heal a fracture, because reheated glass will tend to pull away from the fractured areas and increase the size of the separation; however, small fractures can be mended by firing a heavy application of a clear enamel flux over the fractured area. In firing, the enamel will flow into the fractures and seal them.

Classroom Experiments With Glass

Minor injuries and accidents do occur while working with glass in the classroom. However, certain procedures will reduce their number.

All materials used or introduced into the classroom must be clearly and distinctly labeled. In any classroom where pottery, enameling, and glass work take place, the possibility
of confusing dangerous and poisonous substances with innocuous substances is possible. While it is possible that happy accidents may happen, such as the accidental discovery that whiting makes a suitable substitute for kiln-wash in glass work, the possibility of tragic accidents also exists.

When glass is cut there are many small fragments and splinters. It is for this reason a part of the classroom should be reserved especially for cutting glass. This area should include space on a table large enough to allow a full sheet of newspaper to be spread out flatly. It is not practical to pick these fragments up or to brush them away. They should be folded inside the newspaper for disposal. The layers of newspaper also serve as a cushion under the glass, which aids in scoring and cutting glass. It was found that most students needed some instruction in cutting glass. Beginners do well to confine themselves to such shapes as can be made with a ruler and a straight edge. Cutting circles can only be done with special and rather complex equipment. Also, it was found impossible to fit a glass circle to a circular mold so that it remained well centered after it was fired. It is for this reason that all molds for kiln-formed glass are best constructed with a wide flat flange. The effect of the off-centered placement of the molded area is less noticeable.

The factors that limit mold forms are: (1) the size and shape of the interior of the kiln in which they are to be used,
(2) the absence of undercuts in the mold itself, (3) a flange large enough to prevent glass from running over the edge of the mold, and (4) a shallow depression with gently slanting sides that will not tear the soft, hot glass or cause it to fold over at high temperatures.

The depressions in molds can be circular, oval, or rectangular. In addition, they may contain patterns scratched into their surfaces or raised above their surfaces. Raised designs in the mold will result in intaglio designs in the glass formed in them. It was found that a raised design could be produced if the interior surface of the unfired mold form was painted with melted paraffin. When the paraffin had set, the level of the surrounding clay was gently lowered with a damp sponge. This produced an embossed surface. The paraffin will be burned out in the bisque firing.

Many flanges of molds tended to sag while green or in the bisque firing. It was discovered that if the molds were turned upside down both for drying and for bisque firing, this difficulty was obviated.

Embossed clay forms were made for molding and producing designs on flat glass sheets. It is essential in such forms that no undercuts exist on their surfaces. As in the case of other molds, the presence of undercuts would bind and break the glass as it cooled. Similarly the glass placed over these molds must be cut at least \( \frac{1}{4} \) of an inch smaller than
the clay form on all sides. If this is not done the glass will expand during the firing and run over the sides of the form. This could break the form as well as the glass.

No mold used for shaping glass or creating designs on glass can be glazed. If a glazed mold were to be used, the glass fired on that mold would be thoroughly bonded to the glazed surface during the firing.

Although the process is not creative, a mold may be formed over ready-made glass or pottery shapes by use of the draped-slab technique. Molds may also be made on the potter's wheel or by any of the techniques used for shaping pottery.

Loops of small gauge wires of copper, nichrome, stainless steel, or silver may be laminated in glass to make hooks or hangers for finished glass panels. Very thin foils of the above mentioned metals and most other metals, except lead, may be used inside laminated glass for decorative effects.

Designs which will appear to be carved on the undersurface of the glass when viewed through the glass surface may be made by the use of any wire that will withstand firing, if the wire is bent to a desired shape, placed flatly on a kiln shelf, painted with kiln-wash, and used as a mold for a sheet of glass during the firing. If the wire pattern is large and simple, the glass when placed over it and heated to 1400 degrees will form closely enough around the coated wire to pick up the design.
Partial lamination of glass will present a problem for the beginning student, because fracturing will result if the materials used are not of small sizes and do not have similar expansion characteristics. If this rule is not observed the glass blank upon which the material is placed will be fractured either in heating or cooling.

The problem that applies to partial lamination also applies to full lamination in cases where different glasses or varied materials are included. This was demonstrated in an extreme case when one student tried to place a glass marble between two layers of window glass. Every temperature change and every physical vibration in the room caused the upper sheet of glass to shift. While the difficulty is obvious in this example, it is not so obvious when smaller objects such as chunks of enamel glass or glass beads are used, but the principle still applies.

In kiln-forming methods there is a limitation to the thickness of the glass that can be used. No successful firing was achieved where the mass of glass exceeded ½ inch in thickness. Such thicknesses, whether laminated or not, always fractured. The glass fractured even in thick glass formed in the bottom of pottery shapes. In this case, however, the result may be desirable. The decorative effect of pooled glass may be destroyed in any case where opaque glaze or opaque enamel is used. The opaque producing element (tin oxide) may render the pool of glass dull or opaque.
In using glass to decorate pottery, the colors are predictable only when the pottery has a clear transparent glaze. If the pottery has colored glazes, the glass or enamel applied over them will not produce consistent results.

Ceramic underglazes do not contain sufficient glass forming material to produce a glossy surface or to bond themselves well to glass. They are not suited for use on outer surfaces of glass, but are excellent for use in lamination. Ceramic overglaze colors have a firing range of 1220 to 1418 degrees.* This makes them unsuitable for use on glass, unless they are especially refired after the glass has been formed. The higher firing range of underglaze colors makes them more useful than overglaze.

Copper enameling colors were by far the most popular decorative medium with the students. Similarly the formation of simple laminated bowl or tray shapes with decoration in enamel colors exceeded all other glass-forming techniques in popularity.

In working with glass the student's first impulses are to do far too much with decorative techniques, and to attempt impossible and extravagant combinations of materials. It was found to be a far safer approach to explain to students what had been done with success, and then to explain to them that there could be many failures and the reasons for them.

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The most common causes of disaster in the approach to glass work was the desire to laminate incompatible material, to use excessive quantities of material, and to work with material that could not withstand the temperatures required.

Another cause for failures was impatience. Much work was destroyed because students did not want to wait until the kiln had cooled sufficiently after use. The introduction of cold glass into a hot kiln fractured the glass. The desire to remove work from the kiln before it was cool enough had equally unfortunate results. Impatience also caused students to use the kiln without preparing molds or the kiln with kiln-wash before each use, which caused the glass to bind itself to the mold. This may also result in the breakage of either the mold or the glass or both. When kiln-wash adheres to the under surface of glass, it can be removed by scrubbing with a fingernail brush and a detergent solution.

The cost of kiln-fired glass is moderate, the materials and equipment are easily available. The techniques are relatively simple. The end-product has aesthetic possibilities, and is popular with the students. For these reasons it is concluded that kiln-fired glass would make a desirable and useful addition to the junior college arts and crafts program.
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