AN EXPERIMENTAL STUDY IN THE USE OF AMALGAMS
FOR CERAMIC DECORATION

A Thesis Presented for the
Degree of Master of Arts

by

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Approved by:

[Signature]
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AN EXPERIMENTAL STUDY IN THE USE OF AMALGAMS
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I. INTRODUCTION

Among all the materials placed at the disposal of man, none has made more contributions to human living than clay. Clay shards speak to us of ancient races, and it is probable that the very earliest tablets have disintegrated because of the action of time and weather. Among man's earliest vessels were those made of clay; the abundance of examples uncovered by the archaeologists' spades give ample proof.

Design in pottery naturally falls into two categories, form, which is of prime importance, and decoration. No amount of decoration and no type of decoration can make a pleasing piece of ceramic ware if the original form was unpleasant. Form, when properly designed, is self-sufficient and can be considered without regard to decoration, but the use of decoration without due consideration for the form can only result in disunity. In any successful piece of ceramic ware, decoration depends upon the form, while good form conversely, is not dependent upon decoration. In truth, a piece is very often better left undecorated.

Unity is of prime importance in all phases of art expressions. Pottery is no exception, even though the form is modified to meet the requirements of function. The simplest means of achieving unity in three dimensional objects is through
the use of such elemental forms as the sphere, the cone, and the cylinder. Almost without exception, however, such primary forms must be adjusted to suit their intended use, and in any adjustment the unity of these forms is destroyed. For example, in considering the sphere as a utilitarian form it will readily be seen that in order to function as a hollow vessel of any kind there must be an opening through which contents can be introduced. But in making the opening, the sphere has been violated and the unity destroyed. It is further necessary to give the piece stability either by making a flat base or by adding a foot rim, and in either case the sphere has again been altered and unity lost. It therefore becomes necessary to arrive at a unified expression through a relationship of parts, building a composite form. From an aesthetic point of view, it will be seen that a sustained interest on the part of the observer is not maintained. This is due, no doubt, to an inherent lack of variety in movement. The eye travels in any direction over the surface of the sphere at a given rate of speed and is never led or given any stimulation through change, since every point of the surface deviates with mathematical regularity from every other point.

Primary forms such as the sphere are fundamental forms from which ceramic shapes are developed, a kind of springboard for the potter's imagination, but from both aesthetic and utilitarian aspects they are neither pleasing nor useful.
Simple ceramic shapes can be made from geometric prototypes, but for any alterations, compensatory adjustments and additions must be made in order to regain the unity lost in the process.

The problem of decoration has been argued for centuries, one school of thought maintaining that ornament is a necessity for fulfilling man's instinctive craving for decoration and to overcome his psychological fear or horror of emptiness. The other school holds that the form should be so designed and the glaze so selected, with due regard for its color and texture, that decoration becomes both unnecessary and irrelevant, and detracts rather than adds interest to the ware.

Decoration can be of value only if it furthers the potter's intention by accenting the salient parts of the pot by calling attention to the regulating lines and the structure of the form. It can never be a thing apart nor of such nature as to feed upon the form, but should be used as an agent of emphasis. The decoration must never call attention to itself but be content with a subsidiary role. There is something fundamentally wrong with any decoration which intrudes upon the observer. There should be awareness of a decorated pot rather than the decoration on a pot.

The potter who sees his work only as a background for decoration should confine his efforts to paper and canvas. Unfortunately, "painters" who have ventured into ceramic art have
been greeted with some acclaim by both art critics and the public; consequently, bad ceramic forms are seen as the backgrounds upon which all types of decorative devices are used or on which a sentimental appeal is made to the buying public. Cases in which a good relationship exists between form and the decoration are all too rare.

Some shapes are benefited by decoration. This usually occurs when the form is made more evident by the decoration used, but certainly no poor form was ever improved by the addition of any ornamentation.

When decoration is used it must be placed so that no element of it detracts from the consideration of the piece as a whole. In general the elements of a decorative scheme should be suggested by the form itself. That is to say, a tall form should generally bear a decoration where the vertical is emphasized, while a short, squatty piece is usually best with horizontal motifs. Some of the finest decoration, however, is that in which the movements are set against each other in a kind of contrapuntal scheme, but these require the mature designer.

Herbert Read advances the theory that all structural ornament may be classified as either (a) fortuitous or (b) factitious.¹ Fortuitous refers to some natural property in the material such as the minute speckles of iron oxide in gray

¹ Herbert Read, Art and Industry, p. 116.
stoneware clay. Ornament is factitious when it is born of the actual process of working. Ridges left on a pot by the thrower's fingers would be a case in point.

One of the most effective means of decoration is that based upon bands and borders. These are usually most telling where there occurs a change of direction in the form. Where many closely spaced bands are used, they are seen more in the nature of a textural treatment, and not as separate bands. This technique properly handled can be most successful.

It is the purpose of this thesis to speak only of decorating methods which involve the use of metals. Much has been written about most methods of decorating on both fired and unfired clay, but little has been published concerning the decorative possibilities of metallic applications.

This thesis takes into consideration the production problems in: (1) lustres, (2) the use of electroplating, (3) Argenta Ware, and (4) one method of applying amalgams as ceramic decoration.
II. NATURE OF METALLIC DECORATION

A: LUSTRE WARE

Lustre ware refers to pottery decorated with a handsome metallic sheen. This effect is obtained by the application of certain compounds over the glaze which deposit an extremely thin layer of minute crystals of these metals on the glaze during the firing. A lustrous sheen is imparted to the ware by the refraction of light by these crystals. On historic wares lustre was obtained by mixing sulphides or oxides of metals with clay or ochre. The finest of the Italian lustres were produced by applying the lustre to a background of yellow ochre. After the ware was fired in a reducing atmosphere\(^1\) of a muffle kiln the greater part of the coating was removed by rubbing the surface of the ware.

It is thought that the art of lustre painting arose during the ninth century in Mesopotamia. Thence it spread to Syria, Egypt, Spain, and so to Persia.

In Italy during the latter part of the fifteenth century, a fine ruby lustre was produced by Giorgio Andreoli. This artist had worked out in detail a formula for decorating his wares. That is to say, certain colors in his palette were always used to express certain objects. In addition he used extreme care in

\(^1\) A reducing atmosphere is obtained by reducing the supply of oxygen in a kiln.
executing his work. The finest of his brushes were said to have been made from the whiskers of mice, a supposition which was probably correct, for the Chinese, who have always made brushes of the finest quality, were then making brushes from that material. Furthermore, Andreoli never did his firing during the wane of the moon because he believed his pieces would then lack brilliance.

Maestro Giorgio worked in Gubbio during the early part of the sixteenth century, and much of his best work was produced at that time. Eventually the art of lustre painting died in Italy because of the tremendous influence of the Renaissance painters with their emphasis on naturalism.

About 1800 lustre became popular in England when it was used on earthenware to be sold at fairs to the country people. This ware was the poor man's approach to the gold plate used by royalty. Factories which produced lustre ware were located in Staffordshire, and also at Swansea, New Castle, Liverpool, and Sunderland.

There are two chief classes of lustre decoration, colorless and colored. The former refers to all the preparations by means of which the surface of the ware is made to acquire a peculiar sheen which is not inherent in the glaze. A mother-of-pearl effect can be obtained by certain combinations of bismuth and uranium. The colored lustres impart a metallic sheen in addition to color.
In modern use of lustre the chemical compositions are compounds of metallic oxides with acids of ordinary pine resins dissolved in a suitable solvent, lavender oil being usually employed for that purpose.¹

These solutions are applied to the glazed ware and fired to a dull, red heat in order to obtain the color effects mentioned above. Unless commercially prepared lustres are used a reducing atmosphere is necessary.

Lustre may be prepared in two ways, by the wet or dry methods. The wet method was used in the work covered by this study, and this seems to be the method preferred by most potters. By this method products of homogeneous composition may be obtained, and all parts of the ware are lustred alike when fired.

The usual manner of making dry preparation is to fuse carefully the metallic oxides - usually in the form of nitrates - with pure pine oil. The addition of lavender oil facilitates the combination of the metallic salts with the resin acids. This mixture needs only thinning to be ready for use on glazed ware. When used over colored glazes, the sheen of the lustre is naturally affected by the color of the glaze underneath it.

The colorless lustres include those made from aluminum, zinc, bismuth, and lead.

The colored lustres include those derived from:

Iron, lustrous red which may be modified light brown or golden tan.

Copper, peculiar reddish brown color.

Gold, usually bright gold, may be bronze, ruby red or pink.

Silver, silver in color.

Nickel, light brown color.

Cobalt, chocolate brown to black.

Uranium, greenish yellow (with bismuth gives mother-of-pearl).

Cadmium, yellowish red at low temperature, (vanishes at high temperatures).

The various lustres for sale on the market under descriptive names are made by mixing the above metallic lustres in various combinations.

In the preparation of lustres by the wet method, the chief ingredient is a solution of sodium resinate prepared by combining sodium carbonate and water. This solution is heated to the boiling point and treated with an addition of powdered pine resin in small quantities at intervals. Resin is added until the saturation point is reached, and the carbonic acid liberated will cause the mixture to froth. The solution thus formed contains nothing but dissolved sodium resinate. In the next step water is added to the liquid and the mixture is boiled again. After cooling to room temperature, the undissolved matters having settled, the
clear, light amber colored solution of soda-resin soap is ready for use in preparing the various metallic resinates.

In this preparation a salt of the desired metallic oxide is dissolved in water and treated with a solution of resin soap until a precipitation settles out. Further additions are made until there is no longer any precipitate formed, at which time this compound is filtered out, washed in hot water and dried.

Alkali resinates are soluble in water. All other metallic oxides are insoluble and are deposited as precipitates. Ordinary daylight affects many of the resinates, causing them to lose their solubility. Consequently, they should be stored in opaque containers and kept in a darkened cupboard, unless they are dissolved in oil at once.

Most popular of all the effects are the ones produced by bright gold with bismuth lustre. Five parts of bright gold and one part of bismuth lustre fired together give a coppery sheen. Two to three parts of bismuth lustre to one part gold give a bluish violet with a gold sheen. As the proportion of bright gold is increased, the blue passes through purple to rose. On the other hand, a combination of one part bright gold to one of bismuth lustre will result in a delicate pale blue.¹ Silver lustre is obtained by mixing silver nitrate

¹ Ibid, p. 207
with lavender oil and nitrobenzol, or by dissolving a saturated solution of platinum chloride in lavender oil. Unless extremely dilute, the solution fires to a silvery lustre which completely hides the underlying glaze.

B: ELECTROPLATING

The term electroplating refers to a means of applying metals by electrolysis. The method has not been used as frequently as lustres, probably because of the fact that the process of electroplating was unknown during the period when metallic decoration was popular. An added reason, no doubt, was the rather high cost of this technique.

Rudolf Hainbach claims to be the first to apply this means of decoration. He describes the method in his book, POTTERY DECORATION.

In the process of electroplating a piece of ceramic ware, the decoration is traced upon thick, soft, paper. A stencil is cut from the paper, and this is applied to the glazed ware with an adhesive. In this way only the parts to be electroplated are left exposed. Fine lines to be used in the design are cut after the paper has been applied. All parts which are to be plated are left exposed so that extreme care must be taken to have the stencil correct. No corrections are possible after the ware receives the electroplating bath.

The prepared piece is then exposed to the sand blast
machine until all of the glaze has been removed from the exposed sections. For an application of gold or silver plating a deeper etch is desirable, and so a portion of the unglazed body should be removed. After the desired cut has been made, the paper pattern is soaked loose in a water bath.

The surfaces to be plated must then be made electrically conductive. This can be accomplished in two ways: either by rubbing finely reduced graphite into the depressions with a small brush, or by using a solution of silver nitrate.

Some experimentation involving the use of graphite was carried on in the Ceramic Art Department at Ohio State University during 1945 by the late Arthur E. Baggs. He came to the conclusion that the use of graphite was probably the better method of the two, but felt that further research should be made before definite conclusions could be drawn.

When using graphite no particular care need be taken to avoid spilling it upon the glazed surface, as the edges of the pattern can be cleaned easily with a soft cloth. However, the excess graphite must be removed.

After the ware is fully prepared it is placed in the electroplating bath, which contains the metal to be deposited in a state of aqueous solution. Any metal which has proved satisfactory for electroplating may be used for this type of decoration. Gold, silver, copper, nickel, platinum, and cobalt
are all possibilities. Of these, gold, silver and copper have been most widely employed.

After the ware has been submerged into the bath, every part to be plated must be connected with the source of current by a number of thin wires, which are coated with varnish except at the ends where they are in contact with the graphite. The bath is then charged with the electroplating solution, and any air bubbles on the ware are removed with a fine brush. The current is turned on and allowed to act until the metal plating is somewhat higher than the surrounding glaze, for the metal is soft and must be compressed. After removal from the bath the ware is washed with care and examined for defects. If these occur the piece must be returned to the bath.

Burnishing the metallic deposits until the surface of the metal is flush with the glaze completes the process. The burnishing imparts a polished finish to the otherwise dull surface of the plating.

It is possible by electroplating to apply several different metals to the same piece by exposing the ware to a different bath for each metal.

This method of decoration has never been used to any great extent commercially because of the cost in both time and money. Some reduction in cost could be made by first plating with copper and then adding a thin plate of the rarer metal.
Another means of utilizing metals for decorative purposes is that introduced in Scandinavia. Interest in the Argenta Ware of Sweden led to the original research described later in this thesis. At the time this study was started practically nothing was known in this country concerning the method used in Sweden. Since that time (1945) the information assembled has been extremely meager.

Wilhelm Kåge is said to have created the process. Mr. Kåge is art manager of the Gustavsberg Porcelain Factory, near Stockholm, and since the introduction of his method of working, that factory has devoted its efforts almost exclusively to the production of this fine ware.

The factory at Gustavsberg, established well over a century ago, still maintains the traditions of the early potters. Here the largest pieces are still thrown on the wheel by men who received their training from their fathers. Although the pottery works at Gustavsberg has been modernized, one still finds workshops in the tradition of the last century. In our own country it is said that it takes three generations to make a fox hunter. The same could be said about the "throwers" of Sweden. Indeed, the work of these men shows a sensitivity seldom duplicated.

Kåge has perfected a method of applying a form of sterling
to glazed ware. He usually applies the silver to a matte or semi-matte green glaze, although some pieces have been glazed in browns, blues and reds.

Whatever Käge's method of applying the silver may be, the metal is reduced to a slip consistency and then applied with a brush. The surface has a naturally dull finish after firing. At this stage the metallic decoration may be chased, and the larger pieces usually receive this treatment. Most of the chasing is so fine that it can be accomplished only with the aid of a magnifying glass. The lower priced pieces are ornamented with line decoration and are left unburnished. In many cases part of the design is polished and the rest left matte in order to carry out the idea of the design.

On one piece of Argenta Ware inspected, the metal proved to be none too stable, for the silver decoration could be scraped off easily. Whether this is true of all the ware is not known. In any case it would seem that these pieces should be handled with some care.

Argenta products have been included in the museum collections at Budapest, Gottenberg, Helsingfors, Kaunas, New York, Oslo, Prague, Riga, Stockholm and Vienna. Several memorial pieces have been executed also. The pieces produced at the factory vary in size from very small ash trays to one globular urn over two feet in diameter. They range in price from a few
to thousands of kroner.¹

The decorative possibilities of Kåge's method seem endless. He is able to apply the metal to large areas, or to restrict it to the merest pinpoint and finest line. Many of the motifs are sea creatures, but geometric designs are used also. His favorite theme is the female form, and he introduces it in an endless variety of ways.

One of the most interesting aspects of the production of Argenta Ware is the degree of cooperation which has been achieved between art and industry in Sweden. Perhaps any country could take a lesson from the results of this collaboration where artists have worked side by side with technical and commercial experts. A piece created in this way is not a lifeless object—one of many in a series. It is an individual work of art in which the artist's conception combined with the craftsman's skill and the perfection of modern technical resources are happily united.

¹Present value of one kroner is $.2783.
III. TECHNICAL STUDY

The purpose of this study was to find some satisfactory method of inlaying a metal in a ceramic glaze. Silver was the metal chosen, and it was hoped that the metal could be chased or left plain in either matte or bright finish.

The first problem to be considered was that of preparing the body to receive the metal. Small shapes of Bedford Shale were used as the body clay in these experiments. A pattern was incised in each test piece to a depth of approximately 3 mm. Necessary care was taken to have a suitable undercutting entirely around the pattern. The design was sketched on the ware while the clay was still wet, and, when the leather-hard stage was reached, the edges were carefully carved. The pieces were fired at cone 06, and glazes, which had been determined to be satisfactory, were applied. The ware was then glost fired at cone 04.

Difficulty was experienced in keeping the incised decoration free from glaze. Flowing glazes were avoided from the start, but the problem of keeping the sprayed glaze out of the carving remained. After other preventive measures proved none too satisfactory, dental wax was used with a fair amount of success.

The most efficient method consisted of applying the wax to the still warm biscuit ware as it came from the kiln.
This left a pool of wax in the incised pattern, which hardened on cooling. Some of the wax was absorbed by the body, but this burned out in the second firing and left no bad effects. It was necessary at this point to prevent the wax from falling on any other part of the ware. After the pieces had been sprayed with glaze, the wax was cut around the edge and lifted out of the pattern. Bits of wax left in the sharp angles of the design caused no concern, but every particle of glaze was carefully removed. This procedure for the preparation of the bodies was used throughout the study.

In the first trials an attempt was made to seat the metal in the cavities by hammering. The elements were cut from 20 gauge sterling silver, and the edges were dressed to a size which fit quite snugly into the body. It became apparent that even if this method were workable it would never be completely satisfactory as only flat or nearly flat surfaces could be treated in this way.

After the silver was annealed\(^1\) the test piece was placed carefully on a sandbag, and the process of inlaying was begun. It was hoped that the sandbag would absorb the shock of the hammer blows. A small dapping tool\(^2\) and a light hammer

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1. Annealing consists of heating the silver to a cherry red color and slowly cooling. By this method the metal is softened.

2. A dapping tool is a small metal rod with a domed head.
were used to spread the metal at the edges.  

The results of five attempts were unsuccessful. In all cases the body was incapable of absorbing the hammer shock necessary to spread the metal and consequently the method was abandoned.  

The second method of procedure involved heat treatment of the metal. In this case a thicker silver (18 gauge) was used, and the pieces were roughly cut to fit the depressions in the body. It was estimated that the size of the metal was ample for filling the cavity if the metal flowed. Since the melting point of sterling silver is 960.5 degrees Centigrade the test pieces were placed in a small test kiln, and the temperature was raised to cone 07 (975 degrees C.).  

When they were cool the pieces were removed from the kiln. Although the silver had melted, it had collected in a ball, and had not spread in the depressions; furthermore, it was badly oxidized.  

The next step was to find an agent which would promote flowing, and for this purpose a small amount of borax was added to the silver. This resulted in the desired flow, but the surface of the metal remained uneven, and was again oxidized.  

In an effort to prevent the oxidation of the silver the third test was made with a mixture of ochre and water laid
over the silver. Only enough water was added to the ochre to make a thick paste. In this test the silver flowed, and oxidation was only slight, but the silver still did not flow evenly. In every case the silver was high at the edges and lower in the center.

This method of procedure was abandoned for two reasons. First, there was too little control of the metal flow. Second, even if successful the silver could be applied only to a horizontal surface.

In the third method amalgams were used and this was the most successful of all the inlaying processes tried. In the experiments with amalgams the same procedure was followed in the preparation of the test pieces.

An amalgam is an alloy of two or more metals, one of which is mercury. The work is derived from the Greek, "malagma", meaning a soft mass. The term was applied to the alloys of mercury because of the increased plasticity and fusibility which mercury imparts to them.

The silver amalgam used for experimentation has the same composition as that used by dentists and is composed of a comminuted metal mixed with sufficient mercury to form a coherent mass. In most silver amalgams a small percentage of zinc is present. The zinc has a tendency to preserve the bright silver color. The slight amount of copper present, working
with the zinc, produces a more free-flowing\textsuperscript{1} amalgam. Neither the zinc nor the copper contributes any particular property to the finished amalgam. In most alloys the content of fine silver is between sixty-five and seventy per cent. Table I of the Appendix shows the percentage-composition of ten leading alloys for sale on the market today. Table II shows the specifications for alloys established by the United States Bureau of Standards.

Extreme care is used in the preparation of alloys. The constituent metals are melted together in the desired proportions and then poured into an ingot mold of suitable size. The ingots are pulverized by cutting on a lathe. A magnet is passed through the filings to remove any steel particles, and the filings are checked for size. This check is of great importance because extremely small filings would disintegrate in the mercury, while those too large in size would not react within a reasonable time limit.

The filings are washed in alcohol and then annealed. This last treatment consists of exposure to a heat of one hundred degrees Centigrade for one hour.

Annealing reduces the rate at which mercury reacts, and is believed to have a desirable effect upon the final amalgam. The slower setting rate of reaction allows more time

\textsuperscript{1}The term, free-flowing refers to the ability of the amalgam to move under pressure.
for manipulation during packing. M.L.V. Gaylor, an English
dental chemist, discovered that dimensional changes occurring
during the setting of amalgams are correlated with the com­
position of the alloys from which they are made.¹

For the experiments reported in this thesis, Minimax
#183 was chosen from the alloys tested. The alloy and the
mercury were purchased at the supply store in Hamilton Hall,
Ohio State University, but they could be obtained from any
dental supply house. The factors considered in determining
the choice of alloy were:

1. Adaptability of the amalgam to the walls of
the design.

2. Dimensional change, which must be slight.

3. Chemical composition, especially the silver
content.

4. Ease of manipulation.

5. Mechanical properties.

The purity of the mercury is essential. It should have a
bright shiny surface at all times, as any foreign substance
will result in a weak amalgam. The most important quality of
an amalgam is its ability to be adapted to the walls of the
incised pattern.

Trituration in a mortar has a tendency to break up

the comminuted filings. This break-up increased the rate of amalgamation by increasing the reacting surface. After the surface of the filings had been amalgamated the solution of the remaining alloy proceeded slowly. Excessively long trituration was avoided for this produced inferior results.

Investigations showed that the mercury-alloy ratio in the final amalgam was a predominate factor in determining the physical properties of the inlay. Elimination of too much mercury after trituration produced a weaker and more brittle amalgam, but insufficient elimination of the mercury proved equally inadvisable since the ability to receive chasing was diminished. It was necessary for the operator, from observation in repeated experiments, to determine at what point the elimination of the mercury should cease.

The amount of mercury used was relatively unimportant. (The proportions recommended by Minimax for #183 are, by weight, six parts alloy to nine parts mercury.) A greater amount of mercury content caused a slight increase in the amalgamation rate and reduced the time for trituration. Subsequent expression\(^1\) of the excess mercury eliminated all danger of imparting too much of this metal in the final product. Packing pressure had a direct bearing on the amount

\(^1\)Expression refers to the pressing out of the excess mercury, accomplished by wrapping the amalgam in a small piece of chamois skin and exerting a wringing motion.
of mercury expressed from the amalgam.

Experiments to determine cleavage strength showed that stronger inlays were obtained if the upper surface of the amalgam was removed for a depth of 0.5 mm. - 1.0 mm. The part removed contained most of the metallic oxides as well as the excess mercury.

Experience showed that the process of inlaying the metal could not be hurried. On the other hand, once the work was started it had to be completed rapidly.

When possible, enough alloy was placed in the mortar to fill completely one unit of the design. The amount of mercury necessary to form the mix was added. If in doubt as to the amount necessary, one should use too much rather than too little, for a second addition of mercury results in a weak amalgam. Pure mercury is indispensable to the formation of a strong amalgam. The pestle should be held with a "pen grasp", and with just sufficient pressure to combine the silver with the mercury. Too great pressure or too long trituration generated frictional heat and weakened the amalgam. At 220 revolutions per minute the operation took about one minute unless the mix was unusually large. Eventually the mix became brilliant, and the friction produced a squeaking sound, reminiscent of boots tramping through snow on a winter day.
Plasticity may be added to the mix by palming. This term refers to the operation of taking the mix in the palm of one hand and rolling it about with the thumb of the other hand. During palming, care should be taken to have the hands absolutely clean. Some authorities advise against the practice entirely because of the acid which may be picked up from the skin. Instead, mulling the mixture in a rubber finger stall is recommended.

After the operation of mixing was completed, the amalgam was rolled out and divided into several parts. One section was picked up with a tamping tool, placed carefully along one side of the design and pressed down. Piece by piece the amalgam was added around the edge of the pattern and worked carefully into the undercutting. After the surface of the unit was covered, the excess mercury in the remaining amalgam was expressed before this amalgam could be added to the central part of the design. The mercury expressed was collected with care and disposed of safely, for in no case should it ever be used again. The excess mercury contained in the amalgam applied first was absorbed by the second, drier addition. These two mixtures were tamped together forcibly, and amalgam was added until the surface was raised above that of the surrounding glaze. This extra amalgam which held all the excess mercury was scraped off and discarded.
Any chasing or carving in the design should be executed at this point. The carving is accomplished by a planing motion of the tools. Finer cuts can be made about twenty minutes after the insertion of the metal. One hour later the metal can be burnished, but the final polishing with pumice should not be done for a week.

Few tools are needed for inlaying amalgams, and most of these can be made as the need for them arises. A ground glass mortar and pestle can be purchased at any dental supply house. It may be that a few tamping tools will be desired also, although adequate pluggers can be made from large nails filed to the desired size and shape. In fact, these handmade tools are more suitable in most cases, because the regular dental tools were designed for use with small amounts of amalgam.
IV. CONCLUSIONS

By their very nature amalgams seem a suitable answer to any need of metal decoration of any depth for ceramic wares. Both the alloy and the clay have their origin in the earth. Both are plastic to a degree whereby they can be molded by the operator to satisfy his desires, and both harden into a relatively permanent material. It would appear that having these qualities in common would justify the use of clay and amalgam in combination.

No tests so far devised have proved any degree of poisoning as a result of mercury used in amalgams. From Germany have come reports of finding the presence of mercury in the systems of patients with amalgam dental fillings. Conclusions drawn from these tests substantiate the theory that there may have been mercury present, but that it could not be traced necessarily to the amalgam fillings. Many foods contain enough mercury to give the required reaction for poisoning from this element, and its presence in minute quantities has never been shown to be harmful. Authorities agree, however, that copper amalgams are more dangerous sources of poisoning than the amalgams of silver. There are two ways for mercury to enter the system. Mercury vapor breathed over a long period of time can cause poisoning, and a chemical solution of mercury could prove poisonous. By the very nature of the use of amalgams for
decoration, neither of these possibilities seems worthy of consideration.

Such decoration, because of its nature, would not be applied to the interior of ware used for the serving of food. There is a possibility that an operator working over a long period of time might show toxic effects after working with mercury continually.

For the most part these experiments have been concerned only with the decoration of pottery and some porcelain, but several small pins and buttons with silver inlay were made also. It would seem that this method of decoration might be used most advantageously for the embellishment of small ceramic articles.

The use of the method of applying silver described in this thesis must be confined to individual pieces only, for at the present time the process is one to be carried on manually, and mass production would be impossible. Thus, it follows that such pieces would be limited in number and rather high in price.

This study was confined solely to the possibilities of using silver amalgam, but it is hoped that further investigation may be made. It is logical that gold and copper amalgams could be used in the same way. Such a study might be of value, and would certainly be of interest. Time did not permit its inclusion in the study undertaken.
APPENDIX
<table>
<thead>
<tr>
<th>ALLOY</th>
<th>SILVER</th>
<th>TIN</th>
<th>COPPER</th>
<th>ZINC</th>
<th>GOLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cleveland Dental Mfg. Co.</td>
<td>70.2</td>
<td>26.3</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. T. J. Dee's</td>
<td>70.0</td>
<td>26.0</td>
<td>4.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>3. Dental Protective S. C. Fellowship</td>
<td>67.9</td>
<td>26.7</td>
<td>4.9</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>4. Harper's Quick Set</td>
<td>68.2</td>
<td>27.1</td>
<td>4.0</td>
<td>0.6</td>
<td>0.04</td>
</tr>
<tr>
<td>5. Minimax Co. #183</td>
<td>66.8</td>
<td>28.2</td>
<td>3.9</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>6. L. D. Caulk's 20th Century</td>
<td>68.7</td>
<td>26.1</td>
<td>5.0</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>7. Myrol Chemical Co.</td>
<td>67.0</td>
<td>23.3</td>
<td>4.7</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>8. Garhart's Royal</td>
<td>66.7</td>
<td>28.2</td>
<td>4.6</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>9. Truecast Dental Mfg. Co.</td>
<td>67.6</td>
<td>26.8</td>
<td>5.5</td>
<td>0.1</td>
<td>0.02</td>
</tr>
<tr>
<td>10. S. S. White True Dental Alloy</td>
<td>66.9</td>
<td>26.3</td>
<td>4.9</td>
<td>1.7</td>
<td></td>
</tr>
</tbody>
</table>
### Table II.

**SPECIFICATIONS FOR AMALGAMS AS ESTABLISHED BY THE BUREAU OF STANDARDS**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>65 per cent minimum</td>
</tr>
<tr>
<td>Copper</td>
<td>6 per cent maximum</td>
</tr>
<tr>
<td>Zinc</td>
<td>3 per cent maximum</td>
</tr>
<tr>
<td>Tin</td>
<td>25 per cent minimum</td>
</tr>
</tbody>
</table>

**FLOW:** must be less than 4 per cent. After 24 hours length must increase from 3 to 13 microns per centimeter.

**CLEAVAGE STRENGTH:** no government specifications but most amalgams lie between 30 and 70 Brinell.

**CRUSHING STRENGTH:** must be above 35,500 pounds per square inch.

**TENSILE STRENGTH:** usually 10 per cent of crushing strength.
BIBLIOGRAPHY


Ray, Kenneth W., Metallurgy for Dental Students, Philadelphia: Blakiston's, Son & Company, 1931.


ILLUSTRATIONS
PLATE I

FIRST SUCCESSFUL TEST PIECES
PLATE II

FLAT BOWL OF EARTHENWARE
WITH COBALT GLAZE

(Loaned by Clara M. Eagle)
PLATE III

LAPEL PINS
PLATE IV
STONEWARE VASE
WITH SALT GLAZE
PLATE V

PORCELAIN BOWL

WITH CRACKLE GLAZE
PLATE VI

LARGE FLAT PLATE

WITH ALKALINE BLUE GLAZE
PLATE VII

SMALL EARTHENWARE POT

WITH URANIUM GLAZE