PROCEEDINGS OF THE THIRD NATIONAL SCULPTURE CASTING CONFERENCE ❦ MARCH 26, 27, 28, 1964 ❦ THE UNIVERSITY OF KANSAS

PROCEEDINGS
OF THE
THIRD NATIONAL SCULPTURE CASTING CONFERENCE

MARCH 26-27-28, 1964

Sponsored by

THE DEPARTMENT OF DESIGN
AND UNIVERSITY EXTENSION
THE UNIVERSITY OF KANSAS

The Third National Sculpture Casting Conference was excellently attended. Not only was our most distant state, Hawaii, represented, but several countries as well, the most distant of which was the Philippines. As a result of this foreign participation, the next conference has been planned as an international event.

The value of the papers supplied for publication coupled with the international development has encouraged aspirations for a more complete Proceedings of the next conference.

The excellent cooperation of those supplying papers was greatly appreciated. Prof. Schnier gave permission for the removal of slide indications from his paper, however, since it was felt they could serve future technical reference, they were retained. Prof. Sigerfoos condensed his presentation for easy reference while Mr. Colton, to avoid similarity to his paper prepared for the last conference, edited the transcription of his presentation. Mr. Gadberry not only supplied us with stencils of his paper, but copies printed by the Midwest Research Institute in sufficient number to supply most of those who attended the conference.

For a more complete account of the proceedings, copies of the tapes recorded at the conference may be obtained from the Bureau of Visual Instruction, 6 Bailey Hall, The University of Kansas, Lawrence, Kansas 66044.

Elden C. Tefft, Chairman

Third National Sculpture
Casting Conference

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But when investment is poured around a wax pattern without splash coat, air bubbles frequently are trapped on the surface of the wax and appear on the finished cast as raised nodules or beads. Since ceramic shell is built up thin layer by thin layer over the wax pattern, surface reproduction is usually excellent.

Perhaps the greatest advantage of all in the use of ceramic shell molds is the remarkably short time that is required to prepare them for casting. The wax melt-out and burn-out time for these molds may be as short as twenty minutes. This, of course, results in a great saving of time and especially of fuel. It is possible to prepare these molds for casting, i.e. to de-wax and burn out the residue, while the bronze is being melted in the crucible furnace. And because of their high resistance to thermal shock small molds can be cast unsupported on a bed of sand. Larger molds only require dry sand or shot poured around them for support. Removal of the mold from the casting is simply a matter of a few light blows with a hammer. Where undercuts and depressions occur in the cast it is more difficult to remove the hard ceramic material than it is to remove the softer investment used in solid molds. But by using sharp points the material can be eventually picked out.

There are various types of ceramic shell materials on the market.* They are not all the same. Some can be thought of as representing different processes. In one process, an aqueous solution of colloidal silica, referred to as silica sol, is the binder which when mixed with a powdered refractory forms the dipping slurry. Dipping the wax pattern in the slurry and then sprinkling it with refractory grains of coarse mesh makes a single layer of the multi-layered ceramic shell mold. The refractory grains used for stuccoing the slurries should have a very low coefficient of thermal expansion so that the mold is not cracked in firing or pouring. One company manufactures a fused silica for stuccoing which is chemically treated so as to instantly gel or dry the slurry coat upon which it is sprinkled. This results in a considerable reduction of time required to build up the shell to full thickness. Where untreated fused silica is used for stuccoing on a silica sol slurry coat, the drying time varies from two to five hours.

Hydrolyzed ethyl silicate is also used as a binder for making ceramic shell slurries. With this binder it is possible to accelerate the gelling or drying of the ceramic coat so that succeeding coats can be applied almost immediately. Another method for accelerating the drying time is to use a silica sol binder to which alcohol has been added. Sodium silicate when added to the silica sol will also cause fast drying upon being exposed to CO_2 gas. But I shall not take up any time to go into the exact chemistry of any of the processes or proprietary materials. The literature available from the manufacturers provides ample information on this matter.

Before describing in detail the step by step phases of the process, I should like to prepare the professional foundry men and manufacturers'

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* 1. Nalco Chemical Company, 6212 West 66th Place, Chicago 38, Illinois
2. Ranco-Sil, The Ransom & Randolph Co., 324 Chestnut Street, Toledo, Ohio

representatives, if any are present, for the sculptor's unorthodox application of the manufacturers' carefully formulated technique. Although the directions for the use of proprietary ceramic shell materials may state that so many ml. of this liquid and so many grams of that solid are mixed together at such and such temperature, I have seldom observed a sculptor who followed such directions. Many of them do not have a scale, a measuring container or a thermometer in their studio. The reason for this is that the artist's objective differs from that of the man in industry. However, it is no better nor worse; just different.

Whereas the foundry man may think in terms of shrinkage tolerance and impermeability to gas or hydrostatic pressures, the sculptor is primarily interested in visual appearances. What might be considered a flaw in industry, may be considered a "find" in art. In industry, the emphasis is on developing techniques that can be taught to any one of fifty or more men. In art, the sculptor is more likely to develop a technique that suits just his own temperament and just his own type of work.

(SLIDE 1) Now, I will start with a description of the process as applied to simple wax sculpture patterns without cores. The molding of hollow patterns will be taken up later. No matter what the surface of the wax--smooth or textured--it is essential that it is thoroughly cleaned with alcohol or other cleaning fluid. The surface of the wax must be free of all oil and grease in order for the slurry to adhere to it. The wetting property of the slurry may be increased by the addition of a wetting agent such as Ultra Wet.* But since this wetting causes foaming of the slurry, it should be used sparingly. (SLIDE 2) Because a fired ceramic shell is extremely durable and resistive to thermal shock it can withstand a flooding of heavy molten metal without erosion or cracking. Pouring, therefore, can be done readily and safely through the mold. This results in a drastic reduction in the spruing and gating system. Usually the pour cup with a short sprue can be attached directly to the top of the pattern. In other instances, where it is necessary to have molten metal flow quickly over a large area, a heavy runner with several gates may be required.

Since ceramic shell molds are highly permeable, it is not necessary to provide for the escape of air or gases that might be trapped in the cavity. Venting is thus eliminated and this again simplifies the gating system.

Pouring funnels may be of wax, styrafoam cups, or prefired ceramic. Styrafoam cups have little strength and where used, must be carefully handled to prevent breaking away from the sprue. However, when the ceramic shell reaches full thickness on the cup and sprue this feature is no longer critical. Where the configuration of the pattern is such that wax does not readily run out of certain sections during the melt-out, separate drains running from these pockets to the pouring cups are installed. These drains also act as supports for the wax pattern during dipping and stuccoing and prevent it from breaking off at the sprue or cup. Risers are not critical in the pouring of sculpture patterns of uniform thickness. Frequently, an

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* Ultrawet 60-L; Oil Products & Chemical Co., (Division of Nako Chemical Co.) 9165 South Harbor Avenue, Chicago, Illinois 60617.

increase in size of pouring cup and runner is sufficient to provide the extra molten metal required by shrinkage of the cast.

(SLIDE 3) Where liquid colloidal silica solution (silica sol) is used as the binder, a very fine refractory powder is added to it to make the slurry. The mixing is done either by hand or with an electric mixer. The flour is extremely fine, 75% passing through 325 mesh and 30% being smaller than 10 microns. Stainless steel is advisable for the container as the slurry causes unprotected steel to rust. Plastic containers may be used, but the flexing of walls causes hard insoluable pieces of the ceramic shell to drop off into the slurry. The bench life of slurry made with silica sol is indefinite. That made of an ethyl silicate base is about seven days.

(SLIDE 4) Patterns for industrial castings are made of extremely hard and strong wax formed in an injector machine. Such patterns can receive rough handling while being dipped without danger of breaking. (SLIDE 5) On the other hand, sculpture wax patterns are usually softer and less strong, and consequently must be handled carefully, especially until the shell coats are sufficiently thick to withstand the strain produced by the weight of the mold over the wax.

(SLIDE 6) Each dip or layer of slurry is sprinkled or stuccoed with fused silica grains. Final coats may be built up thicker, faster and more economically by using a very coarse refractory such as grog. Although some manufacturers specify the use of two different grades of stucco grains--a fine grain for the first two coats and a coarse grain for the remainder--some sculptors are obtaining quite satisfactory results using the coarser grained fused silica throughout. Others use the coarse grain for the first two coats and grog of even a much coarser grain from there on.

(SLIDE 7) Each layer or coat of ceramic shell must be thoroughly dry before the next coat is applied. (SLIDE 8) If a coating is applied to a moist layer, the material will slough off. A good circulation of air accelerates the drying cycle; and blowers, through which heated air passes, are also used. But care must be taken not to heat up the wax of the pattern, otherwise cracking may occur due to wax expansion. (SLIDE 9) Where hydrolyzed ethyl silicate is used as a binder, air circulation is not critical since the material is self-gelling. In order for a dip coat to adhere to a previously dried coat, the entire pattern is wetted with straight silica sol. This also prevents the subsequent layer from trapping air bubbles.

(SLIDE 10) The final thickness of mold or the number of coats, is dependent upon the size and nature of the wax pattern and the melting point of the metal to be cast. Wax patterns with long thin unsupported elements require thicker molds than short compact patterns. (SLIDE 11) Alloyed steels which melt at high temperatures require more coats than aluminum. (SLIDE 12) The latter may be cast in a mold four coats thick. In the beginning it may be wise to make the mold several coats thicker than called for and learn through experience how far to cut back, on later molds.

One method of reducing thickness of large molds is to reinforce them. Slides showing how this is achieved by wrapping the mold with thin stainless

steel wire midway between the first and last coats will be shown later. Another method is to use thin mats of fiberglas dipped in slurry and fitted over the mold. Both these methods will be referred to again later.

(SLIDE 13) Because wax used for patterns expands up to 12% in passing from a solid to a liquid state (or from 75° F. to about 125° F.), conventional burn-out--that is gradual melting of the wax--results in cracking of the thin molds. Therefore, de-waxing with heat is accomplished by shock melting the pattern at a high temperature so that an outer thin film of wax melts almost instantly before the mass of wax can expand and exert pressure on the shell. (SLIDE 14) The nature of the gates and runners can play an important role at this point in the process. By inserting a heated rod through the hollow cup into the sprue a hollow channel can be established to take care of some of the wax expansion.

(SLIDE 15) This is a home-made de-waxing and burn-out furnace made by Mr. Donald Haskin, a member of the sculpture faculty at the University of California. It is constructed from a 55 gallon oil drum lined with refractory brick, supported on three legs, and with a bottom that moves up and down. The burner is made of 2" pipe with a salvaged vacuum cleaner blower fastened to the end. Fuel is supplied from a tank of propane gas which enters the two-inch pipe between the blower and the furnace. A thermocouple from the interior passes through the wall of the furnace where it is attached to a pyrometer to check temperatures.

The cup of the mold is placed directly over a hole in the floor of the bottom plate, then the bottom is moved up into the hot furnace. Different pattern waxes may require different optimum temperatures in order to quickly relieve the stresses caused by the expanding wax. Thermal shock alone will not crack the shell even if temperatures up to 2000° F. are used.

(SLIDE 16) Shock melt-out must be carried out in an oxidizing atmosphere. A standard closed bottom hearth which does not permit draining of wax without burning it is not recommended. Waxes burn so furiously in closed furnaces that the oxygen supply becomes deficient and much carbon is deposited within the pores of mold. This carbon may be very slow to burn later and may interfere with the mold's permeability. A furnace with an open grill or a hole in the bottom so that melted wax drains out, without burning or decomposing, into a bucket of water, reduces the possibility of carbon deposit and results in white clean molds.

(SLIDE 17) Following de-waxing, the temperature is raised and the shell refired to completely burn away any residual wax. Here again, it is important that the shell be in a truly oxydizing atmosphere. (SLIDE 18) In such an atmosphere the carbon burns away as rapidly as it forms from the decomposing waxes. The combination of black wax with a poorly oxydizing furnace atmosphere can result in quite sooty looking shells. With proper atmosphere and heat, the burn-out may be completed in 15 minutes at 1400° F., or in less time at higher temperatures. (SLIDE 19) The temperature need never exceed 2000° F. as all carbon is burned out in 15 to 20 minutes between 1000° and 1600° F., if plenty of oxygen is present. However, if the shell has deep recesses or intricate passageways it may take considerably longer to burn it completely free of carbon.

(SLIDE 21) Ceramic shell is extremely resistant to thermal shock and therefore, if small, will not crack even if poured unsupported on a bed of sand or when held in the pouring tongs.

So far you have seen the application of this shell process to rather small solid patterns. It can also be used for hollow waxes such as head shape forms. (SLIDE 33) This is a hollow shape molded and cast by Donald Haskin. To relieve the pressure of expanding waxes, slits, not more than a pin head in size may be cut through the completed shell and then sealed after firing. In this slide the pattern is inverted; the projection at the top corresponds to the neck. (SLIDE 34) The hollow pour cup is attached to the top of the head-like form. (SLIDE 35) The cup is placed mouth down over the hole in the bottom plate of the furnace, flash melted, and then burnt out. (SLIDE 36) The finished burnt-out mold is now ready for pouring. (SLIDE 37) There are actually two shells to this mold, an outer and an inner hollow core. No core pins were used to support the inner shell. The only support was provided by (SLIDE 38) the thin edge where the inner and outer shells meet (SLIDE 39). The hollow shell was packed with sand to take the pressure of the molten metal striking it from the top. (SLIDE 40) The hollow casting as it came from the mold required only a very light cleaning with the wire brush. (SLIDE 41) The thinness of the wax pattern indicated by the thickness of the metal at the neck was no more than $\frac{1}{4}$" and it was the bottom of the neck that supported the core and kept it in position during the melt-out and pour. (SLIDE 42) Here is an example of my own sculpture--my first casting in ceramic shell. In the absence of a burn-out kiln, a single oxy-acetylene torch was used. By working from the bottom upwards, i.e. from the invested cup upwards, the mold was de-waxed without cracking. It was then placed in the crucible furnace before the bronze was melted, and brought up to red heat. The surface of the cast was so clean upon removal of the mold that it was possible to patinate without further treatment. The experience casting this piece convinced me of the possibilities of ceramic shell for certain sizes and shapes of sculpture compositions.

(SLIDE 43) A great surprise in connection with the application of ceramic shell molding for sculpture was my discovery of Mr. Lynn Smith's Picco Foundry* in Southern California. Here, life size sculptures are cast using this technique. The important variation is that the completed waxes are cut to sizes adaptable to the plant's equipment. After casting, these pieces are welded together with the heliarc. (SLIDE 44) This head from one of two twelve foot tall statues is too large to mold in one piece (SLIDE 45) so it is cut in two below the jaw and along a line easy to weld and chase. (SLIDE 46) The dipping and pouring method of coating patterns is used (SLIDE 47), the first coat being shaken on the edge of a vibrating table to remove all bubbles of air. (SLIDE 48) Stuccoing is done either with a small screen or a fluidizing bed in which air pressure from the bottom of a container keeps the stucco grains suspended in mid air. (SLIDE 49) Small solid waxes are sprued with one or two gates. (SLIDE 50) Large hollow shells have multiple gates in order to get the metal in the cavity in the shortest possible time. (SLIDE 51) Multiple gates also assist in the de-waxing process by providing

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* Picco Industries, 1729 North Chico Avenue, El Monte, California

more outlets through which the melting wax can escape. They also help prevent hot spots. To reinforce these large shells, Mr. Smith uses thin stainless steel wire wound around the mold midway between the first and last coats. (SLIDE 52) To assist in the building up of the hollow cores in large sculpture patterns having only one opening, a large door (SLIDE 53) is cut through the wax at the closed end. The door is invested and cast separately and then welded in place. (SLIDE 54) Mr. Smith believes in generous spruing and gating (four gates are used here) and this may partly account for the high success he is having with his ceramic shell castings. (SLIDE 55) Other patterns, as in the case of standing animals, he may open along the back, cast separately and then weld together (SLIDE 56). (SLIDE 57) In melting, the Picco foundry uses crucible as well as portable electric furnaces. Here a small electric furnace is carried to the molds and these molds are poured directly from the furnace. (SLIDE 58) After the cast has cooled, the outside ceramic shell is easily cracked off. The core requires more time to remove. It is interesting to note that on this industrial casting the pouring cup, which also acts as a riser, is about the same volume as that of the cast itself.

(SLIDE 59) This shows the number of pieces in which a 30" simple vertical sculpture composition is cast. (SLIDE 60) The round holes are core extensions connecting the inside with the outside shell. These serve the same function as core pins in holding the core in place after the wax has been melted. The surface of the bronze has been given a light sandblast to remove the fire seal.

(SLIDE 61) The leg of a twelve foot figure has also been cast in three separate parts. (SLIDE 62) In casting the waxes of large hollow sculpture sections, a very hard wax is used so as to avoid warping of the pattern when it is cut into sections for making the ceramic shell. (SLIDE 63) After the sections are welded, grinding levels down the joints and at the same time, removes the gate stubs which are left high when the sprue and runners are removed.

(SLIDE 64) The ceramic shell process can also be used for making molds of compositions in styrafoam such as this design which is the work of Bruce Beasley, a very talented sculptor of the West. (SLIDE 65) Because foam plastic is extremely light-weight, it lends itself readily to thin elongated and cantilevered forms. (SLIDE 66) Statues in styrafoam may be covered with a thin coating of wax to smooth the rough cellular surface of the material. (SLIDE 67) Or the foam plastic statue may be used as a master pattern from which an edition of waxes is made in a flexible mold.

Styrafoam, like wax, can cause cracking of the ceramic shell and must therefore be dissolved before the mold is de-waxed. This is accomplished by pouring acetone into the cup. Small holes drilled through the low points of the mold allow the solvent to drain off and thus prevent build-up of pressure in the mold cavity.

(SLIDE 68) My main purpose in showing you the next group of slides is to acquaint you with the spraying technique for applying the slurry and building up the mold. Here the fine refractory powder is mixed with the

silica sol. (SLIDE 69) The viscosity of the mix is tested by feel. In this case mixing according to the proportions as listed in the manufacturer's book is not practical. (SLIDE 70) This is a section of a wax pattern from an edition of six which Mr. Beasley made in a flexible mold. It represents just the central section of the composition, as all of the thin projecting elements have been cut off and are to be shell molded separately. (SLIDE 71) The first coat of slurry has been sprayed over a portion of the wax surface, and (SLIDE 72) is now being followed by a spray of refractory grains. (SLIDE 73) By slowly turning the pattern on a revolving stand, more and more of the surface is coated. (SLIDE 74) Another spray of slurry from the gun in the right hand is followed by a spray of fused silica grains from the gun in the left hand. (SLIDE 75) Soon the entire surface is covered with a first layer or coat. (SLIDE 76) The second coat is then started. (SLIDE 77) With the spray technique it is not necessary to wait for the proceeding coat to completely dry. (SLIDE 78) Layers can be sprayed on one after another until the necessary thickness is obtained. The surface of the wax pattern which rests on the support will be sprayed last after full thickness is obtained on the exposed section of the pattern. (SLIDE 79) As soon as spraying is completed, or the metal mixing container is emptied, the spray gun must immediately be cleaned by running a gallon or more of water through it. Failure to do so will cause the binder--the silica sol--to harden in the very small apertures and ruin the gun.* (SLIDE 80) To prevent the mold from cracking and also to reinforce thin sections, fiberglas matting can be dipped into the slurry and then laid over the surface of the ceramic shell. Another method to reinforce the mold is to wrap it with thin stainless steel wire as was shown in the slides of work in progress at the Picco Foundry. (SLIDE 81) Where a burn-out kiln is not available, or where the kiln is not large enough to accommodate large shells, a substitute arrangement can be made with a group of adjustable gas burners. By working from the bottom upwards it is possible to provide space for the expanding wax of the pattern. After the wax has run out, the temperature is raised and the mold completely burned out. (SLIDE 82) Here are a few examples of unfinished castings made in ceramic shell by Bruce Beasley. (SLIDE 83) Since he casts in aluminum he is not too much concerned with weight and therefore does not hesitate to use thick sections of metal in his compositions. (SLIDE 84) All of his castings, made in ceramic shell molds to date, are solid.

Now to summarize.

The ceramic shell mold, because of its high resistance to thermal shock, its strength, and its permeability has definite applications to the casting of sculpture forms, either solid or hollow. Although the cost of materials is very much higher than those used for solid investment, ceramic shell requires a great deal less than does the latter. The amount of mold refuse is negligible. Then there is the matter of its high fidelity to surface detail and texture. But perhaps the most attractive feature of all is the extremely short de-waxing and burn-out time which practically closes the gap between making the mold and pouring the metal.

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* The R-2 spray gun, obtainable from Plaster Supply House, Box 551, Chicago 90, Illinois, may reduce problem of clogging.

HEALTH HAZARDS IN THE FOUNDRY

Jeremiah R. Lynch*

The title of my talk is "Health Hazards in the Foundry" since I felt it would be wise to concentrate on the principal health hazards encountered in general industrial foundry operations rather than to try to anticipate the variety of materials and techniques that would be used in the art and science of sculpture casting. After I have covered these basic hazards, which are common to almost all foundries, I will open the matter to discussion so that I may be able to help with some of the specific problems that may be causing some concern.

Silicosis is the principal occupational disease of founders. This continues to be true even though we have been working on the problem for over 35 years. In a recent survey made by the U. S. Public Health Service it was found that there were over 1600 new cases in 20 States in the period 1950-54. While present data obtained indicate that in some areas of work activity with silicic dust (lead-zinc mining) there has been a reduction of 40 percent in silicosis prevalence in the past 25 years, the disease is not exactly vanishing. However, its significance is due not only to its incidence but also to its severity. Silicosis is an incurable disease and is frequently a major contributing cause of death.

The nature and causes of the disease are fairly well known. The culprit, of course, is free silica, SiO_2, as a dust inhaled into the lungs. Free silica occurs most commonly as the mineral quartz and is found in a variety of rocks and sands. Free silica is the most toxic of the mineral dusts. According to a recent theory the fine particles of silica which penetrate deep into the lungs are caught by the phagocytes, the organisms which keep the lungs clean. However, instead of removing the particle of silica as it would an inert dust particle, the phagocyte dies; probably killed by some toxic property of the silica particle. This leads to the formation of scar tissue down in the air sacs and the ability of that sac to transfer oxygen is impaired. When enough of this destruction occurs, hard nodular masses of fibrotic tissue develop and impair pulmonary function. This is slow and it may take from 10 to 30 years before the disease is detectable. Once this fibrosis has developed it cannot be removed. In later stages it doesn't even help to change to non-dusty work. If the original dust exposure is large enough, the disease may continue to develop even after the exposure has ceased.

The first outward symptom is shortness of breath. This gets worse until the individual is unable to climb a few steps without stopping to catch his breath. Death frequently occurs as a result of some secondary infection such as tuberculosis.

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Four factors determine the likelihood of a case of silicosis. First is the fraction of the dust in the air which gets into the lungs. Second, the percentage of free silica in the dust. Third, is the duration of exposure and fourth is the degree of individual susceptibility.

Several of these factors should be commented on. The amount of dust entering the lungs is not the same as the amount in the air breathed. The body has very efficient mechanisms for protecting the lung from dust. Practically all of the dust larger than 3 μ (1/10,000 of an inch) is caught in the respiratory tract and never finds its way deep into the lung. To give you an idea how small that is; the finest 400 mesh screen has a hole size of about 50 μ. Particles in the micron size range take hours to settle out of the air and thus will remain in a room for long after they are generated unless removed by exhaust ventilation.

Another factor to consider is duration of exposure. There obviously is a difference between a gray iron foundry in Detroit turning out an engine block every few minutes, and a foundry making only a few castings a day. In all long term chronic exposures, the levels which are considered safe are based on the amount a person may withstand without injury for eight hours a day for a working lifetime. In estimating the effect of these hazards we use a time-weighted average which considers the frequency and duration of exposures. Consequently, where operations are intermittent and exposures of short duration, less of a problem may exist than in a production line industry using the same processes. This line of reasoning should be considered in developing health hazard controls in the sculpture casting foundry.

All of these factors which determine the likelihood of silicosis give us indications of the methods of control which may be successful. If we use only new washed sand without any fines, and handle it so as not to produce fines we can reduce the concentration of very small particles in the air. Shaking out of a sand coating and reuse of the sand increases the hazard. If sand low in free silica can be used it will reduce the hazard. Local exhaust ventilation can capture and remove the dust as it is generated and thus reduce exposure. This is probably the dominant method of control in industry.

Metal fume fever is in many respects the opposite of silicosis. Where silicosis is slow in developing and chronic, metal fume fever is sudden and acute. While silicosis often leads to death, metal fume fever never does. It might seem therefore that we could ignore it. However, I am sure that once you have had it you would never want to go through it again.

The most frequent cause of metal fume fever is zinc oxide, although copper, iron, magnesium and tin oxide fumes can also cause it. When the very small particles of a freshly generated fume are inhaled deep into the lungs it is thought that they react with the wall of the lung, liberating a modified protein in the blood, which then causes the characteristic response of the body to a foreign protein. The symptoms include chills and fever as high as 102° F, nausea, weakness and general aching of the head and body. This illness begins within a few hours of exposure, lasts about a day and has never been known to be fatal. Control consists of local ventilation of fuming processes and possibly the use of respiratory protection.

A word of philosophy on the use of face masks and other kinds of respirators. For the long term control of exposure to a chronic persistent dust they are not recommended. It is practically impossible to get someone to wear one for eight hours a day. Few masks are designed for the wearer to talk, so most interfere with voice communication and would be a handicap in a teaching situation. Further, the control of the dust or fume hazard can be better accomplished with local exhaust ventilation. However, in a certain few instances where it is desired to avoid a brief exposure to a toxic contaminant where local exhaust would be difficult, as may be the case in pouring a casting, an approved face mask respirator may be the answer.

A more serious problem from metal fume involves the casting of toxic metals such as beryllium, lead and other heavy metals. The fumes of these metals can lead to serious chronic poisoning and when they are used special precautions are necessary, including local exhaust of known effectiveness, pre-employment and periodic physical examinations, and regular surveillance of the environment.

I have referred several times to control by local exhaust ventilation. This is probably the most effective means of controlling health hazards in foundries. While general ventilation means removal of a contaminant after it has been disseminated throughout the general room air, local exhaust ventilation captures the contaminant before it gets to the worker's breathing zone. By means of hoods and enclosures which control the movement of air we are able to generate capture velocities in the vicinity of the source of the contaminant and remove it before it can do any harm. The precise engineering details of a variety of designs of such hoods are contained in several references which are listed in the bibliography.

As a stimulus to discussion, I would like to mention briefly several other possible hazards. Before I begin, I should emphasize that not all of these would be expected to exist in any single foundry.

Wherever metal is being cast there will be heat and if certain limits are exceeded, heat stress may be a problem. Ventilation and heat shields may be used for control.

Noise is a problem where mechanical equipment such as shakeouts are used. Excessive exposure can cause traumatic hearing loss. Ear protection can reduce the likelihood of damage.

Acrolein sometimes occurs from the decomposition of core oil. It is toxic and very irritating so that you could not be able to tolerate it for more than a few minutes. Ventilation would control the hazard.

Chlorine gas is sometimes used to volatilize impurities in aluminum. This is a very dangerous operation and must be controlled with properly designed local exhaust hood.

Nickel carbonyl is sometimes used to coat patterns and models to improve surface finish. Not only is nickel carbonyl toxic itself but it decomposes rapidly to yield carbon monoxide. These coating operations

should be totally enclosed in a chamber kept under a negative pressure by an exhaust system.

Phosphorus used in making phosphor copper is a chronic poison. The fumes should be controlled by local ventilation.

Resins of the thermo-setting type are occasionally used in shell molding. In addition to toxic fumes produced on thermal decomposition, some of them are capable of producing dermatitis. Local exhaust ventilation and protective creams may be required.

Solvents used for cleaning castings vary as to toxicity. Some like kerosene are relatively harmless while others, such as carbon tetrachloride are extremely dangerous. The best method of control is to substitute a less toxic solvent wherever it will do the job. When this is not possible enclosure of the solvent cleaning operation is frequently practical.

Carbon monoxide, as a result of incomplete combustion of carbon fuels may occur whenever a flame touches a surface that is cooler than the ignition temperature of the gas. Thus the heating of a cold crucible can be a serious source of exposure if it is not properly vented.

This completes the prepared portion of my talk. I will be happy to try to answer any questions you may have on foundry health hazards.

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MEXICAN AND CENTRAL AMERICAN FOUNDRIES

Elden C. Tefft

This investigation not only included Mexico and Central America, but extended to Panama and Colombia in South America.

The primary purpose of my return to Mexico was to obtain photographs to visually align my previous work there with the report which I presented at the last conference on European foundries. I also wished to cover more thoroughly the foundries of Mexico and to check recent developments and trends.

Secondly, I wished to initiate a search for evidence of a continuation or carry-over of pre-Colombian lost wax techniques into contemporary casting.

I found the greatest activity in contemporary sculpture founding centered in Mexico City. However, I encountered intense interest in Costa Rica and Nicaragua and what may be the beginning of a rebirth of sculpture founding in Guatemala.

Although time was too short to carry the search far beyond the foundries, there are a few areas in which (because of the comparatively primitive techniques presently in use) further study should prove interesting regardless of a possible link to pre-Colombian cultures.

As to technical development, while there is still a division in the use of coke and oil for melt, almost all of the foundries use oil for at least part of their burn-out. The furnaces used for this are of the traditional brick build-up type. However, from foundry to foundry there are many interesting minor variations, especially in the burners used.

There seems to be a trend in investing toward the use of metal in place of the earlier brick flasks of Mexico or the hand-built molds of the European or older foundries of the United States.

A development that seems almost universally accepted in Mexico is the use of carbon arc for repairs and joining and, of course, a notable increase in the use of power hand tools.

The following is presented by countries in order of investigation. The non-foundry references are included to indicate the breadth of investigation as well as to point out fringe interest areas.

Mexico

In the Saltillo and Taxco areas where no sculpture casting was found, I surveyed the silver establishments. Although most of them maintain small

melt furnaces, as in the so-called silver factory area of Mexico City I found no casting of significance. However, in Oaxaca the reproduction of the region's ancient gold castings has almost become an industry. Although the equipment is simple, their techniques are considerably removed from that used to produce the originals. Perhaps closer to ancestral traditions are the procedures used by the smiths in the copper village of Santa Clara near Patzcuaro. They produce wrought rather than cast ware; however, I found their hand-powered primitive bellows forges of particular interest.

I also found that some industrial foundries welcome the opportunity and take pride in making bells when the occasion arises. One such foundry is Pizzuto foundry in San Luis Potosi.

Perhaps the high point of the out-of-foundry research in Mexico was my opportunity to visit again with Luis Albarrán y Pliego in his home and studio, Linares 42, Mexico D.F. Sr. Albarran, at an early date, became interested in sculpture casting. He traveled through Europe examining the techniques of the foundries, then returned to Mexico to share his experiences by teaching. I have found no foundry or foundryman in Mexico who has not directly or at least indirectly profited from his teaching. Thus, the origin of sculpture casting in Mexico can be traced primarily through Albarrán to its European origin.

Rodolfo Gonzalez, Plaza de Lapaz 63, (Casa & Taller), Pastita 49, Guanajuato, Guanajuato. Gonzalez, a sculptor who does some casting for others, employs traditional equipment, a buried forced-draft melt furnace fueled with coke and a built-up brick burn-out furnace which, contrary to recent trends in Mexico, is fueled with wood alone. The components of the sprue system used are large, but limited in number. Investments utilize a refractory mined locally and are poured in metal flasks. Perhaps of most interest is Gonzalez's use of narrow triangular shapes or wedges of brass for core anchors.

Fernando Diaz, Calle Rancho de Santa Cruz 142, Colonia Jamaica, Mexico, D.F.--Diaz, owner-manager, teaches at the San Carlos Academy of Art. His foundry, experienced and perhaps at its best doing large works, has done much heroic work, especially for Ignacio Asúnsolo.

Evidence of technical development and change in Mexico was for me most easily observed at the Diaz foundry. Having spent considerable time there in the past, I was well acquainted with previous procedures.

The use of the carbon arc for joining and repair was my first observation, but of even greater interest to me (even though I had noted it in Guanajuato) was the use of the metal flask to replace the brick cylinder previously constructed for containing investments. (This momentarily caused me to wonder if my comments on a prior visit may have encouraged this development.) Since the mold is poured in place, the flask is removed before burn-out. Also when the flask proves to be a bit short, the mold is completed by extending the perimeter with investment which has reached the plastic stage.

Vicente Barron, Av. Ramos Millan, 115 "C", Mexico, D.F.--The Barron foundry recommended by Miguel Miramontes of Guadalajara is perhaps the least permanent of installations visited. It may be for this reason their burn-out was of particular interest. It employed an eliptical version of the traditional built-up furnace. An extremely simple natural draft gravity oil burner constructed of a few feet of standard pipe, fittings and a tinned can, was alternated between the ports centered in each end. These burners, because of their very portable nature, were used for many purposes. Simply propped or staked into position, they were used for heating and melting of wax, gelatin, etc.

Eugenio Ortiz Torres, Calle Maria 177, Colonia Nativitas, Parado Lago, Mexico, D.F.--The Ortiz foundry is a comparatively small operation which enjoys an excellent technical reputation. For control during early stages of burn-out, which is accomplished in single port built-up brick furnaces, the burn-out is by policy always initiated with wood, even though it is often completed with oil. Their burners are a version of the traditional forced draft, dripped oil burner. In spite of this use of oil for burn-out, the melt is by coke.

Fundicion Artistica, S.A., Pablo Portilla Osio, Gerente, Bahia de Chachalacas 7, (Colonia de la Veronica), Mexico 17, D.F.--Fundicion Artistica is one of the older establishments which does industrial work as well as a great amount of very large government sculpture castings, much of it in sand. The number of large projects in progress facilitated observation of their bolted strap iron tie technique used for assemblying large sections of sculpture for joining.

Here again the oil burn-out burner was interestingly varied and slightly refined by taking advantage of a central compressed-air system. Consistent with normal practice, many uses were found for this burner, including heat for patination.

Moises del Aguila, Av. de Las Americas 75, Colonia Moderna, Mexico, D.F.--The Aguila foundry is a residential foundry situation similar to, but larger than, the Ortiz foundry. It is owned and, with the aid of his son, operated by Señor Aguila who was trained as a sculptor as was Diaz and most of the others. Although recommended by Francisco Zúñiga for small work, the foundry also does larger work.

Guatemala

A very pleasant conference was enjoyed with the officials of the National Museum especially Grajeda Mena. However, my chief informant was Rodolfo Galeotti Torres, a sculptor whom I met at the Diaz foundry in Mexico.

Rodolfo Galeotti Torres, (Taller), 33 Av. "A" 29, 22, Zone 5, Guatemala City, Guatemala, and Luis F. Aguilar, 33 Av. 29, 77, Zone 5, Guatemala City, Guatemala--Galeotti, by following our example of the sculptor participating in the actual casting of his own work, may well be initiating a renaissance

of sculpture casting in Guatemala. In his own studio, he is beginning to prepare molds which he transports around the corner to the small Aguilar foundry for burn-out and pour. The one thing that most interested me in this operation was that they were using my publication, Sculpture Casting in Mexico, as a guide for their procedure.

Talleres Fundicion, Fernando Lopez Lopez, Mixco, Guatemala.--Lopez received his lost wax training in Guatemala from an Italian founder. When he casts, he uses a 4-to-1 local volcanic sand, plaster investment which is burned out with charcoal, but has done little sculpture casting in recent years because of costs of labor and materials in Guatemala.

El Salvador

The director of El Salvador's new museum, Tomas Jidias Jiminez, was most cooperative in arranging for me to photograph a number of small sculptural ceramic forms, however, their collection included no gold or other lost wax castings.

Marcelino Alas Fundicion, Calle Mexico 1021, San Salvador, El Salvador. --This foundry was introduced to me by Professor Valentin Estrade of the National Art School. The Alas foundry is a sand foundry which undertakes special projects when they are needed, including sculpture casting. I enjoyed the opportunity to observe the shake-out of a bell which had been poured the day before.

Honduras

An equestrian bronze, located in a central park in Tegucigalpa, was the only bronze I located in the country. I visited a rather pleasant national art school and conferred with, among others, Roberto M. Sanchez, a former cultural official, but found no evidence of even planned casting activity.

Nicaragua

A considerable amount of sculpture activity was found in Managua and a very great interest in bronze casting, particularly in the studio of Edith Gron, Parque San Sebastián, 7a Av. N. C. 612A, and at the Art School in the person of Fernando Sarauia. Both expressed an eagerness to have the techniques available. In fact Miss Gron asked to be informed when installations are complete at the University of Costa Rica.

Costa Rica

Although Costa Rica's history is rich in ancient lost wax casting of gold, only an occasional sand casting of art is done in the government shop today. It was a rather strange feeling to be reinitiating the process in such an area. By demonstrations and tests on local materials, I laid the

groundwork for sculpture founding to be included in the program of the Escuela Bellas Artes as they expand into their new quarters on the main University campus.

The National Museum has an excellent exhibit of pre-Colombian techniques which is part of their fine collection of gold, but it is small compared to the collection at the National Bank.

Colombia

José Domingo Rodriguez, the sculptor of the School of Fine Arts in Bogotá, showed me the school's foundry which has been converted into a carving studio. This is approximately the story of contemporary casting in Colombia, however, their pre-Colombian gold is tremendous in quantity and quality. Since my visit, the National Bank Collection under Luis Barriga has been moved to new quarters, a new building of its own. Perhaps as exciting, however, was the opportunity to handle, as well as view, the private collection of Martha Bauer who is also of Bogotá.

Panama

The director of the National Museum in Panama City, Alejandro Mendez P., allowed their collection of castings to be removed from the vault and be laid on the front step of the museum for photographing. Though the collection is small, this intimacy made it an experience more satisfying than even the grand collection in Bogotá.

Transcription

NONFERROUS METALS

R. A. Colton
Federated Metals Division
American Smelting and Refining Company
Houston, Texas

Colton: Thank you, Mr. Tefft, Ladies and Gentlemen:

I would like first to point out to you that I'm not a sculptor. I have never made a sculpture casting in my life. I know something about metals--not too much. I want to be sure that you understand that I don't know your business as well as you do. The most important thing to me in this meeting is that you get the opportunity to discuss your problems and ask me questions. Interrupt me freely, at any time. This is your meeting. It will be successful only if you chip in and help me. As a matter of fact, I cannot talk very long about what I know; I would prefer this to be your meeting.

I'd like first to take up the particular phase of the casting operation that involves the materials that go into the molds that you've made. Let's take a set of circumstances. You've now spent considerable time making up a mold--and I have great regards for the energy that you put into making up this mold. And now you're going to cast it. What do you do from that point on? We can talk about that for a little while. Something useful may come out of it.

You have a variety of materials available for casting. You can cast with iron, as was so capably described yesterday. I understand that one of the problems with using iron is that when you expose the iron sculpture to the weather you can't be sure of what will happen to it. It may corrode or rust severely, and so far no one has come up with a coating to protect the surface. As a consequence, most of the materials that are used for casting sculpture (with the exception of stainless steel which is probably as difficult to handle as any material we could cast) are nonferrous--that is, they are of the copper-base, aluminum or lead families.

The first group I'd like to mention is lead which is a traditional material for use in sculpture casting--one of the easiest metals to handle because of its low melting point. Lead normally is soft; the color may not be attractive but lead does have the advantage of being relatively easy to handle, readily available and does not require special equipment. You can harden lead by adding antimony to lead, or by adding tin. Hardening lead will improve its durability. There is a family of special alloys of lead that I would like to tell you about because they may be of some value to you in your work. I think the people that cast jewelry may know about these alloys. They are called by a variety of names--Asarco-Lo, Cerro, fusible, or just low melting alloys. This is a group of materials that have very low melting points--from 100° F. and up. I don't know what this suggests to you.

It means that materials with which you work can be much easier to use because of their low melting temperature. These are alloys of bismuth, lead, tin, cadmium and indium. These are the alloys that can be cast into rubber molds or silicone molds satisfactorily, with the temperature of the metal when liquid below the boiling point of water--which could be very helpful to you.

These are intrinsically expensive materials; you probably wouldn't want to make anything very large from this kind of an alloy. They are called fusible because they melt at low temperatures. They are used industrially and they are used in jewelry casting. There is one alloy called "jewel metal" --an alloy of tin which can be cast satisfactorily into rubber molds, and made into jewelry quite satisfactorily. It has the "feel" of gold or of bronze but is quite easy to cast. Some of the alloys you may know, such as Rose Metal or Woods Metal.

One very common alloy of this general family--one that is readily available is that in use by the print shops and is known as type metal. With castings of type metal it is possible to obtain very fine sharp detail, partly because these materials expand slightly on solidification. This means that if you want fine detail in a small casting you may obtain it by using type metal.

Some of these low melting alloys are used in industrial investment casting techniques in order to make their wax impressions, because they produce sharp details. This may suggest something to you.

I want to mention something about handling lead alloys. Any alloy that has lead or bismuth in it should be handled very carefully in melting. The fumes are toxic. Keep this in mind. If you work with lead for any length of time without some protection or good ventilation, you may pick up lead in your system. Lead poisoning is accumulative in humans and can be dangerous. If for any reason you are going to work with lead be sure that you observe the following: do not breathe the fumes; and, after you have worked with lead, be sure you wash your hands before you eat because you can literally "eat" lead and this is one way that may build up lead in your system.

One other thing about lead--and most of these alloys. They can all be soldered, brazed or as we say in the lead business, burned--in other words they weld beautifully, which may be an advantage to you.

The next group of metals that I would like to discuss with you is the alloys of aluminum. Many have worked with aluminum, and its use may grow because of the relative ease of casting aluminum. There are basically two alloys of aluminum that I would consider satisfactory for your work; if you have questions about others, we can also discuss them. As I see it, your requirements of aluminum alloys would be that they have satisfactory color such as white rather than the dark grey color which some of the alloys have. Also, you would need alloys which have relatively good corrosion resistance because aluminum does corrode. Fortunately the corrosion products of aluminum may remain in place so the materials do not deteriorate, but the color may change. The third requirement would be that the material be weldable or repairable.

Of the alloys of aluminum that fit these requirements there are really only three. The first is commercial number 43, which is a traditional aluminum alloy containing 95% aluminum and 5% silicon. This would be an excellent alloy for casting since it has very good castability or fluidity. It also has fairly good shrinkage characteristics. It has a white color and is among the most weldable of all aluminum alloys. In fact, most aluminum welding rods that you buy will be made from this alloy. The next alloy is in somewhat the same family and is known commercially as No. 356, containing essentially 7% silicon and 93% aluminum. It also has a white color, very good casting properties, and can be welded and repaired. The third alloy has the whitest color of the three. The others are closer to blue-white in color. The alloy that has the whitest color of all and the best corrosion resistance is an alloy called No. 214. It is essentially 96% aluminum and 4% magnesium. It is quite difficult to cast, being sluggish. I don't know much about its welding characteristics. I think it probably can be welded but with some difficulty.

These three materials are all readily available, and if you are going to cast aluminum you would be wise to choose one of these three alloys. It came out at the last conference in which we participated that a good many sculptors were buying up scrap aluminum, melting and pouring it into castings; this is also true of scrap bronze. I can't understand how, after you've spent all the time that you do putting a mold together, you can take chances with the material cast into the mold. Scrap materials may not always be compatible. The castings may be brittle, the color may be unexpected, and the shrinkage characteristics undesirable. It seems to me that this is a risk not worth taking. You are far better off to cast only known materials.

Audience: Is it possible to do much working or bending of these alloys after casting?

Colton: Most of the cast materials of aluminum have very low ductility. They have, on the average, what we call 3% elongation which means you may be able to bend them once but probably cannot bend them back. Cast materials generally behave in this fashion. All three alloys described have good ductility and can be bent. There is a special aluminum alloy that can be bent more severely, if one is needed. Most casting alloys of aluminum cannot be bent very much, however.

Audience: What are the properties of 319?

Colton: 319 contains 4% of copper, 6% silicon, and balance aluminum. Alloy 319 is very castable. It has good shrinkage characteristics but, like all copper containing alloys, will turn grey with exposure to the atmosphere. If the color isn't important to you then this might be a very satisfactory alloy since it is a good general purpose foundry alloy that is used extensively by foundries. It does not anodize as well as other aluminum alloys. The three alloys already mentioned can be anodized fairly well. No. 214 alloy takes the best anodized coating of any aluminum alloy. For anodizing the alloy should be silicon and copper free. There are several proprietory alloys of aluminum containing zinc that anodize very well. No. 214 can be anodized and color dyed very satisfactorily. However, when you

anodize castings they must be sound or they may get stain, because if there is any shrinkage porosity under the surface the dye will seep into the porosity and then cause staining. If you are going to anodize just for protection against the weather, you can use almost any aluminum alloy. If you are going to anodize for white finish or color dye the casting, you must select your alloy carefully. For those of you who are unfamiliar with it, anodizing is a technique whereby an oxide coating is deliberately put on aluminum, under controlled conditions. It can then be dyed a variety of colors. You've probably seen some of the most common examples such as beverage glasses made from sheet aluminum that come in green, red, pink, etc. They are anodized aluminum. Anodizing is relatively simple; to get a clear white finish you have to have the correct alloy.

Audience: "You say that alloy 319 will anodize grey; for aesthetic reasons this seems to offer the best possibility because I don't want white anodized surfaces. This would be the worst. Is there anything that can be done available by the way of toning this grey so that we might have for instance a pewter type of grey because this seems to me to offer the best possibilities. I'm ready to write off the white."

Colton: I think this is something that might be adjusted in the anodizing technique. The alloy turns grey partly because of the copper content of the alloy. I believe that the thickness of the anodized film will affect the color. Since most people who anodize do not want the grey color we rarely run into this. I would suggest that if you are going to have the metal anodized by an industrial anodizer it might be left in the bath a little longer. Another alternative would be to color or dye it because if you are looking for something dark you may get it more easily. Light colors are more difficult to control; another difficulty is non-uniform anodizing.

Audience: Is it possible that the amount of copper might take us toward the blue-grey?

Colton: Yes, I think it might. We have very little experience anodizing these alloys. They are rarely anodized. I cannot answer you authoritatively because I haven't seen enough of it. It will be dark. Whether it's grey or blue-grey, I couldn't say.

Audience: To get a blue-grey is the end as far as I am concerned.

Colton: Then you should have a higher silicon content; you take an alloy that contains 4% copper and increase the silicon up to 8%. There is such an alloy called No. 380, which is used for die casting. It normally has a blue-grey appearance.

Audience: What was the alloy again?

Colton: Any of the alloys which have copper and silicon in them will tend to give a blue-grey coloring. There are a wide variety of such alloys--319, 108, 380, etc. All will give you a mottled color because of the copper and the silicon content.

Audience: I think possibly you want to think of the worst possible aluminum from your point of view and that would probably seem to most of us the best (laugh).

Colton: As far as the color, yes, but you might have casting problems. If you want an alloy that gives a dark color, No. 12 is probably the best. No. 12 is 7% copper and 2% silicon. This will come out dark, but there are other requirements. I set up three requirements: castability, color and weldability. No. 12 is castable, but it doesn't weld very well; if you make all your castings so that they require no welding or repairing, then you've got it made, but it will come out dark after casting. Any alloy with silicon and copper in fairly gross amounts will be dark. This is a good general rule.

Audience: (inaudible) Is the grey color permanent?

Colton: Permanent for exposure to outdoor atmosphere? Yes, it gets darker. The surface is principally aluminum oxide which is an interesting material. None of us have ever seen aluminum because aluminum itself oxidizes on exposure to the air. The oxide film that you see is very thin, tight, hard, and abrasive. It is also known as the corundum or carborundum which are abrasive materials. The oxide film in a moist atmosphere becomes a partial hydroxide and becomes a grey coating. This will get darker, as it is exposed outdoors. This would be an aluminum that is exposed to the weather other than being exposed to salt air. Salt air will cause pitting which I don't think any of you would want, but perhaps--(large laugh) ...maybe you would---bring it down to Houston (more laughter). If any of you have driven your car along the Gulf Coast in the summertime, you may have had the experience of having aluminum trim on the car corrode and pit.

Audience: How can you hasten the pitting?

Colton: Bring it down to the Gulf Coast! Or expose the casting to a salt spray. Find some laboratory in your area that has a salt spray testing machine and put the castings in the cabinet, which artificially generates a salt marine atmosphere. The humidity is controlled and the temperature, too. It should be a spray rather than just salt water since there is an oxygen requirement that is essential.

Audience: How can you induce electrolysis in aluminum?

Colton: You can induce it by putting aluminum in contact with another material. Aluminum will corrode to protect a more noble material. Place a piece of copper next to aluminum and the aluminum will pit next to or around the area where the copper is in contact. This is relatively simple to do. It requires a fairly corrosive atmosphere or put the metals in a 3% salt solution, which is a good electrolyte.

Audience: Can aluminum alloys be electroplated?

Colton: Yes, you can plate aluminum with almost anything. The trick in plating aluminum is that first you have to put a chemical zinc coating

on it. And once you have the zinc on it, it's relatively simple to plate copper, nickel or chrome on the aluminum. Most platers today have had experience plating on aluminum.

Audience: Are there means of patinating aluminum?

Colton: There are some other chemical processes that are used to protect aluminum, such as chronic acid which produces a yellow film. This is not too popular now. There are some other chemical techniques that are available. The Electroplaters' Handbook would be a good source material. A copy would probably be available in the University library. The commonest coating process, of course, is anodizing.

Audience: Is there a method of removing anodizing?

Colton: You would have to take a layer of metal off. The anodizing coating is relatively thin. You would have to remove that, which can be done chemically. You could get below it. It scratches fairly easily, as you may know. Most anodized coatings are not hard by conventional standards. They are hard for aluminum, but not compared to steel or to bronze.

Audience: How would you anodize aluminum if you didn't want to send to a regular shop?

Colton: I cannot give you the necessary conditions briefly. It involves use of a dilute sulfuric acid bath, and an electric current, which, under controlled conditions, puts an anodic coating on the aluminum. This is then sealed in hot water. There is a great deal more to the process than this brief description. Some of the people here may do their own anodizing. There are chemical techniques for this and patented processes for anodizing. Anodizing is a patented method developed by one of the aluminum companies. There are a number of techniques available. I would suggest the Electroplaters' Handbook as a good source for information.

Audience: Is aluminum damaged in any way by ultrasonic cleaning?

Colton: No, I wouldn't think so. The vibrations usually are of such magnitude that they won't hurt it. I think it's used industrially to clean aluminum.

Audience: What heading do these aluminum alloys come under? Are these ASTM specifications?

Colton: No, these are the garden variety names. There are ASTM specifications covering these materials, but in the aluminum foundry business, if you mention these numbers, they will know what you are talking about. Anybody that produces or sells the materials will know what you are talking about. There are many other numbers I could give you, but these are the oldest and best known. Incidentally, all of these materials are commonly available either from your local foundry or someone in the business who makes them.

Audience: What kind of welding should be used with aluminum alloys?

Colton: With electric welding and gas welding, the silicon containing alloys are highly weldable. The welding rod most commonly used is also alloy 43 (95 and 5). The original welding technique was, of course, with gas. You will find these alloys are very fluid, and they work well.

Audience: One more question about the shrinkage. Is there any particular difference in the shrinkage rate of these different metals?

Colton: They are all much the same for practical purposes. There are some differences, but I don't think they are in order of magnitude. No. 319 is a good general purpose alloy and 356 is, too. I don't think you would have any difficulty with shrinkage using either one.

Audience: What alloys cast well, have the best malleability for chasing off sprues, vents, etc.?

Colton: Of the three we are mentioning here, No. 43 is probably the best. In the aluminum industry everything is a compromise. Those alloys that cast well usually do not have the other requirements. I could say 43 is probably your best bet, although the other alloys can also be used. When we run into industrial requirements for bending the casting, we usually recommend No. 43.

I'd like to describe now copper base materials. Now we are going back into antiquity because copper alloys have been cast into art work probably as long as copper alloys have been cast. I suppose the first castings were weapons; after that, cast art work. The first casting was probably some kind of a weapon; then a statue cast of the warrior who used the bronze weapon. Wars may have been good for artists. Over a period of thousands of years, a limited group of alloys have evolved that serve your purposes. Today there are two alloys commercially available that I would recommend to you. Before I write them down, may I point out again that you are very foolish to melt down scrap to pour into bronze castings because you are "mixing apples and oranges," and you don't want "fruit salad" in your casting. Buy ingots which cost you very little more than scrap. They are of a guaranteed composition; if something goes wrong, which it may, you would at least have the feeling that what you poured into your mold was satisfactory. You wouldn't want to have a casting that was otherwise satisfactory which would break apart because it was brittle. This is exactly what can happen if you mix the wrong alloys.

The alloy that probably is best for your purpose today because it is most readily available is 85-5-5-5. It contains 85% copper, 5% tin, 5% lead and 5% zinc. This alloy isn't exactly something that metallurgists sat down and worked out. If we took all of the copper base scrap or castings that have been made since the year one or before, and had a furnace big enough to melt them down, we would end up with an alloy pretty close to this in composition. This alloy evolved over the ages, and it turns out to be fairly close to an ideal casting material. It is the easiest alloy to buy and is relatively inexpensive because of its comparatively low tin content.

It casts quite well. Its shrinkage characteristics are no better or no worse than most other alloys, and it takes all kinds of color. In addition, it is highly machinable which to you means it chases well. You can work it, and it is also malleable. This is called "85" in the industry.

The other alloy is called M metal, Navy M, which has a composition of 6% tin, 2% lead, 4% zinc, and roughly 87% copper. The difference here is largely in the lead content which may affect what you are doing with the metal. For this reason, the casting bronzes used by artists historically was closer to "M" than to "85." This alloy can be used quite satisfactorily, but it is more expensive.

Over a period of some 20 years that I've been in this business, we have made up many alloys for sculptors. They usually come in with some variation of these two alloys, and they pay a premium for having it made up. Sometimes they want very little lead, although the lead is what makes the material workable. With lead in the alloy it can be chased, tooled, and machined. Tin is what gives the alloy strength and color, and zinc is what makes it castable. If you left the zinc out of these alloys, they would be very difficult to cast. They would be very sluggish. As far as tin bronzes are concerned, these two materials are pretty much what you ought to limit yourself to.

There is one other alloy that I would like to suggest. I brought it up two years ago. I'll mention it again. It is the general family of silicon bronzes. These are essentially alloys of copper and silicon. Their color is more on the yellow side--the golden side--than bronze. The silicon bronzes are very fluid. They will cast into thin sections very easily. They are good foundry alloys--the best of all copper base foundry alloys. For an intricate casting they would probably be easier to handle than either of the other two materials. Silicon bronzes are known by a group of trade names--Everdur, Herculoy, Tombasil. Everdur, if you are interested, is the kind of material that you can bend back on itself. It will take a 180° bend after casting. Tombasil is actually a silicon brass. It has a yellow color and very good casting properties; one other thing, these materials are highly weldable. If you're going to do any repair work this is the best group.

Audience: I would like to recommend silicon bronze. I have had great results. Can you melt silicon bronze in a silicon carbide crucible?

Colton: Yes. Can you color silicon bronze? Satisfactorily?

Audience: Yes.

Colton: This I didn't know.

Audience: Silicon bronze colors beautifully but it is difficult to chase. It's harder to work than tin bronze.

Colton: These are essentially lead-free alloys, and, as such, are more difficult to work; you can't have everything.

Audience: What about using bell metal?

Colton: It is a difficult alloy to cast for one thing, and it is very expensive. Tin today is $1.80 a pound, which greatly increases the cost of the material. I suppose other than that, I would like some zinc in it to make it castable.

Audience: We've been adding into the crucible little strips of lead to increase the flowability of 85. How far can we go along that route before we reach a critical point?

Colton: Why are you adding the lead? Or what for?

Audience: For a fluidizer--the pouring was sluggish.

Colton: That's not the way to improve it!

Audience: OK then, but it did help.

Colton: Only to this extent. If you build up the lead content of the alloy, it ultimately becomes a so-called "leaded bronze" which may be very fluid, but has other undesirable characteristics. There is the risk of getting what we call "lead sweat," or lead coming out on the surface of the casting. In a few minutes I'll tell you something else that you can put in the alloy that will greatly improve the fluidity.

Audience: What is the composition of silicon bronze?

Colton: It is essentially copper with 4% silicon and may contain zinc. Everdur has 4% silicon, 1% manganese. Herculoy has 4% zinc, 4% silicon. Tombasil has 4% silicon and about 12% zinc. These are trade names for silicon bronzes, any of which will behave very well.

Audience: Are there differences in the characteristics of the different alloys?

Colton: Yes, to this extent. Everdur is the most malleable of all. Tombasil is the strongest. All flow about the same.

Audience: What is the pouring temperature?

Colton: I'll tell you what I tell foundrymen. There is no such thing as a "pouring temperature." It depends on what you are pouring. These alloys can be poured at lower temperatures, however, than other alloys such as tin bronzes. I believe a range of 1900° to 2100° would probably be satisfactory--about the same as used for tin bronzes. At the same temperature, however, they are more fluid. You can tell when they are molten in the crucible. They are lively. And they are clean on top which is important.

Audience: There is one feature connected with silicon bronze that I think would be interesting to the group if you tell them about--the alloys do not require much degassing. They are clean.

Colton: You will forgive me but your choice of words confuses me a bit --such as degassing. I came to the conclusion years ago that for most art work the gas problem that we have in industrial casting is not as acute. Gas porosity is not very serious in your bronze castings, but it may be more so in your aluminum castings. Silicon bronzes do not form much slag or dross during melting. They are very clean metals, and they are fluid. Alloys that form much slag and dross on the molten metal are also the metals that are sluggish in pouring. For example, an alloy of 91% copper and 9% tin would be sluggish because of this. Tin is an oxide former and makes the alloy difficult to cast.

Audience: Is there any tin at all in silicon bronze?

Colton: Herculoy has about 1%, principally for patent purposes.

Audience: Do you lose silicon bronze when you remelt silicon bronze?

Colton: No, as long as you melt the same metal all the time it will be essentially the same in composition. The only thing that you may lose in any of these alloys would be zinc. It is a good practice on remelting these alloys to replace zinc.

Audience: Is there any difference in shrinkage in silicon bronze?

Colton: They are much alike so that you can use the same pattern equipment. We frequently do in the foundry.

Audience: Do you lose much lead in the alloys?

Colton: No. The order in which metals oxidize out is that the zinc goes first, then lead; as long as you have zinc present, you will lose very little lead. Lead is easily replaced.

Audience: What is the effect of temperature? We often overheat a little bit during melting.

Colton: It is hard to answer your question exactly, but I will say this. The principal reason that we object to overheating bronze is that we pick up gas. This is the gas that dissolves in the metal and comes out when the metal freezes. This is not a serious problem, I believe, in art casting.

Audience: We had bad gas bubbles in the casting and were able to eliminate those by using a green aspen stick in the bronze before pouring.

Colton: What you actually did was to introduce gas into the bronze. I would wonder whether the gas bubbles that you talked about were really gas or air. Trapped air. The problem of trapped air can be very confusing. In pouring art castings you have frequently very thin sections to pour. It may be necessary to pour as high as 2400° F. If gas is a problem--and I'm not sure in my own mind that it is, the higher temperature you take the metal the more likely you are to pick up gas. There isn't an easy way to get it out of the metal once you have it in. The gas is principally hydrogen and

oxygen which forms water or steam. As the metal solidifies, the hydrogen and oxygen come out of the metal and form steam and this is what forms the gas bubbles. Hydrogen and oxygen come from the water vapor in the air. At the temperature of the molten metal, water vapor breaks down into hydrogen and oxygen. The moisture comes from the air, and also from the products of combustion of fuel fired furnaces.

Audience: What about yellow brass?

Colton: This is used for color. When you use an alloy like 70/30 brass, you are looking for a pure brass color. You have no gas problem, you have minimum shrinkage problems, but you have others. They are dirty alloys. Zinc forms oxides which may end up on the casting surface. There is enough zinc in these alloys to make sure there is no gas in the metal.

Audience: The hotter you get the more smoke you have in your foundry. Is that right?

Colton: Yes. That may be your biggest problem. The trick is to throw in about one ounce of aluminum per one hundred pounds of yellow brass just before you pour it. Skim the pot first and throw in the aluminum. This will form a film of aluminum over the top of the melt, and it will cut down the smoke somewhat. It also makes the metal more fluid.

Audience: How about putting in some charcoal and antimony?

Colton: This came up once before. We never add antimony to anything. In fact, we spend a great deal of our time taking antimony out of these alloys. Antimony is an impurity. I think this is one of those traditions that have no bearing on the fact at all.

Audience: It was over 30 years ago.

Colton: Yes, that's true. At one time it was thought that antimony was beneficial. However, we know now that antimony affects the physical properties.

Audience: What about charcoal?

Colton: If you would save that question I would like to talk about melting practice a little later.

Audience: I visited a foundry once that poured white bronzes. Someone told me it was magnesium.

Colton: I think he was kidding you or misleading you. We have what we call white bronze which is nickel bronze, or nickel silver, or as it was called before 1918, German silver. This is an alloy of copper, nickel, and zinc. You can change the color from white to various stages of yellow depending on the nickel and zinc content. This is high melting point, refractory material which probably would be beautiful in some kinds of art work because it's very durable. The principal uses are in fountain hardware

and dairy hardware, because it matches stainless steel in color. It is much easier to cast than stainless steel and much less expensive. Magnesium does not alloy with copper for practical purposes. There is an alloy called manganese bronze which is very much like yellow brass in color. It is essentially brass with 1% aluminum. There is no such alloy as magnesium bronze.

Audience: What about using covers in melting?

Colton: I don't think it's essential. This is a matter of personal opinion. It may be that in the foundries in which you are working smoke is a problem and a cover might be helpful. Other than that I do not believe in using covers.

Audience: What kind of a castable alloy is the 60% copper-40% zinc?

Colton: This is a yellow brass alloy which gives you an off-yellow color. It's a little less castable than the brass of antiquity, since it is quite smokey. If you don't have a well-ventilated foundry, melting it may drive you out. Other than that there is no particular problem. It doesn't gas. Shrinkage characteristics are not too bad, and it machines fairly well. But it's difficult to work with all this smoke, and keeping the casting clean could be a problem.

Audience: Do you anticipate any developments in metallurgy which will combat shrinkage?

Colton: We are going the other direction. What we are trying to do in the casting industry is control gas in metals and make stronger castings, get better physical properties. We depend on the gas in the metals to overcome some of the shrinkage problems. So our developments are going in the wrong direction for you. No, there is no way to eliminate shrinkage other than by the way you (I use this word advisedly) "gate" the casting. This is a special art. Metal has a change in volume changing from liquid to solid. This is built in. You can't escape it. This is the principal shrinkage problem. The fact is that when you fill the mold with liquid metal, and it solidifies, the solid metal occupies a smaller volume than the liquid metal and there is no good way of overcoming that behavior.

Audience: There are a number of formulae that call for iron and a little bit of arsenic to get a black bronze. Are there any black bronzes?

Colton: No! Arsenic is an impurity, and can't change the color. Iron we may put into bronze, and there would be iron in all of these alloys. Iron is usually an impurity. The solubility of iron, as we call it--the amount that can be dissolved in a liquid metal--is limited. If you put in more iron, it doesn't dissolve; it ends up as iron inclusions.

Audience: I was told by a fellow who used to work in a copper mine down in Chile that they would use a little spoon on the end of a rod which they dip into the crucible before they pour it, and observe this spoonful of copper; if it sank in the middle it needed more poling. Then, when it was level on the top and didn't sink in the middle, it had been poled enough.

Colton: You are talking about copper, not bronze. In copper manufacturing they control the sulphur and the oxygen content in order to get what we call level-set copper. This is not the same as bronze. Remember there is no tin, lead or zinc in the alloys. They do pole. This is a very spectacular thing. They take trees and plunge them into a copper furnace. This is the way they have been doing it for hundreds of years and it's very spectacular. The purpose of it is to control the set. Whether it shrinks or not. This is not so in bronze. All you are doing is introducing gas. You are working with 99.9% copper. So it just isn't the same thing.

Audience: Why does it eliminate the gas problem?

Colton: It doesn't. They are looking for a level set when they pour wire bars, which is the end product. They want them to be level on the top which requires a certain amount of gas in them so that the gas would compensate for the shrinkage. The shrinkage is internal; when you take a wire bar which is shaped something like a boat and draw it into wire the shrinkage is internal and welded together. They are looking for a level set. They want to control the amount of gas, which is what you want, too, but you can't get it by poling. Not in bronze.

Audience: I recently got a hold of some ingots. How can I find out what they are composed of?

Colton: The only way you could tell would be to take drillings or sawings and send it to a laboratory. There is no way of knowing otherwise. If you bought it from a smelter, just cut it with a saw or take a drill and get yourself about an ounce of turnings or sawings. Keep them clean and free of iron. Put them in an envelope and send them to be analyzed.

Audience: No coding like on steel. What about coding?

Colton: There are numbers but I wouldn't want to start on that because they are not uniform as they are in steel or in aluminum. However, just so you will know, if you ever see these numbers, this is called No. 115 ("85"), this is called alloy 245 ("M"). This is a complicated numbering system. If you have a group of ingots and you want to know what they are, take a sample from each and mix it together and that sample, when analyzed, will give you an idea as to what to expect when all the ingot is melted down together.

Audience: What is the machining quality of nickel bronze?

Colton: It has lead in it so it can be machined. Normally, in a commercial alloy it has about 1% or 2% tin and it may have 5% lead in it. Therefore, it will machine. Monel, of course, is more difficult to handle in the average foundry. With roughly 70% nickel and 30% copper, it requires high temperatures for melting and is usually out of the province of most people in the bronze casting business though some handle it. Monel has very high shrinkage. It has a great tendency to pick up gas which may or may not be a problem to you. The high temperatures, however, are usually what discourage foundrymen. You are almost up to the temperature of cast iron. The color is not greatly different than that of nickel bronze. I don't know if there is any real advantage to using monel.

Audience: Would it be possible to add lead to silicon bronze alloys?

Colton: Yes, you could add lead to them, but you run into the possibility of getting a surface condition, a reaction between the metal and the mold material. Some of the investment materials may react. Generally speaking, for investment casting work we do not recommend adding lead to any silicon bronze alloys. The plaster casters have tried it and they get a reaction with the lead to form a lead sulfide on the surface which may or may not be helpful. (I hesitate to say that to this group!) If you want to get something different in the way of surface finish, then add lead to one of these alloys and you may get it!

Audience: How far can you go with lead, how much can you add before the bronze becomes hot caught short?

Colton: Probably over 1% and you'd be in some trouble. Actually, we don't know because we try and keep the lead out of these metals. Hot shortness is a peculiar characteristic and you can't project it from one material to another.

Audience: What is the formula for silicon bronze?

Colton: Essentially silicon bronzes are copper plus 4% silicon plus zinc. Everdur is 4% silicon, 1% manganese, and Herculoy is 4% silicon, 4% zinc, and Tombasil is 4% silicon and 12% zinc.

Audience: What quality of the silicon bronzes makes it flow?

Colton: I can only give you my theory. Silicon doesn't form a stable oxide at the temperatures involved here. I have a theory which I've never been able to take time to prove; i.e., what effects the castability in bronzes is the oxide present. Tin oxide, for instance, which forms very readily, will impede the flow of the metal. Silicon forms no stable oxide; therefore, you have a relatively clean metal when you pour.

Audience: How do you add silicon to make silicon bronze?

Colton: How do we add it? As electrolytic silicon. You can buy it in several forms--chunks, little platelets. Low iron silicon is what we usually specify. It's not easy to add. You have to be careful when adding silicon to copper since it has to be mixed thoroughly. Silicon has a very high melting point, and you must be sure you are mixing it in properly. I would hesitate to make up the alloy in small volume since you may not have enough heat to work with.

Let's go on now and talk about melting. Incidentally, if you want to know more about these materials, I have another booklet. This is called Brass and Bronze Casting Alloys. It describes all the materials that we have talked about here, and in addition it has a section on the casting properties and also on foundry practices. The melting practice of these materials, both aluminum and copper base alloys, can be, for practical purposes, the same--except that it's not advisable to use the same crucible in

the foundry. Manage to get two, one for aluminum and the other for brass. What a lot of foundries do is use the brass crucible until it gets thin and then use it for aluminum. There is a one to three weight ratio and a #60 crucible will hold 60 pounds of aluminum and 180 pounds of brass. But don't get me wrong. I'm not advising using thin walled crucibles that may break. What I'm going to tell you about melting are general rules that we have found work pretty well. Our problems in making industrial castings are to keep them gas free, to keep them clean and to get maximum strength properties. I don't think strength as such is important to you in a casting. We are required to meet specifications on mechanical properties such as the tensile strength and elongation, which may not be important to you as long as the casting has adequate strength for what you are doing.

Your problem in melting may be a lot simpler than those of an industrial foundry. We will assume for the moment that all of you are melting in crucibles and all of you are using gas or oil. Coke is a great melting medium. We had far less problems in the foundry when we used coke for melting. Coke requires somebody to stand with a shovel and put coke in the furnace, and you just can't find people with a shovel any more! With the exception, perhaps, of a few places in the country that still use coke, most foundries are using oil or gas. These two have their advantages. Gas is the best fuel of all. If you have natural gas available, it is by far the cleanest fuel you can use. Oil has some problems. The residual products of burning oil are dirty. Oil itself is rather messy. So, I would advise in general to use gas if you have a choice, but oil will burn hot and it is a good fuel. We will assume that you are going to melt in a typical crucible furnace which is gas or oil fired. These are the general rules: The first one has to do with what you put into the crucible. Start with clean, dry, known material. Why clean or dry? For a number of reasons. Once again we get back to gas in the metal. We'll have to explore that a little more before we finish here, because I would like to know how serious gas in metal is for you. If it isn't, we can disregard some of these rules. We say, put in clean materials, dry materials, free of oil, moisture or foreign materials. Much of the contamination may be organic, and as they burn they create gas. The gas may then get into the metal as it is melted so we say use clean, dry, known materials. When you cut off spues and leaders from your castings, take a drum or box, mark on the side what alloy is used and make sure the scrap is properly segregated. Don't mix up your materials. You don't improve metals by mixing them. Sometimes you can get away with this. If for instance you mix up 85-5-5-5 and "M" alloy, you have done no serious damage to the material. They are compatible. However, "M" metal is worth about 5¢ a pound more than 85, and you may have lowered the quality of "M" and changed its characteristics as far as color is concerned. Keep your materials separate. Good housekeeping is very important in a foundry. Incidentally, I was very impressed by the pictures of the foundries that are on exhibit here. As I looked at them last night, I thought I have no business talking to people who run such well-designed and well-equipped foundries. I'm amazed and pleased. We have commercial foundries that don't look as good as these.

To return to the subject of melting practice. Melt quickly. The reason we say melt quickly is that we want to avoid exposure of the liquid

metal to the hot gases and therefore reduce the possibility of picking up gas from the furnace. In addition, all of these metals oxidize at elevated temperatures and form slag and dross. In time it is possible to burn away all metal that you have melted. If you start out in the morning with a pot full of bronze and keep it exposed to a 2300° or 2400° temperature all day, you will in time reduce the volume of castable metal considerably. This is a problem in your operation. I would say, do not put the metal in the furnace until the mold is ready. Don't start melting the metal and hope to finish the mold in time because these metals do not improve by standing. Melt quickly. How many of you use pyrometers? Have some predetermined level to which you are going to take the metal. This is important in that the temperature affects three or four things of consequence including the gas content and the amount of metal that burns out. Zinc will burn out; tin will burn out. If zinc burns out of an alloy, it may become sluggish and will not cast well. In addition, if you pour a metal at a higher temperature than you should be pouring, it may "burn-in" a sand mold. This could be important. In an investment mold it is not as likely. But in a sand mold you can make a lot more work for yourself in finishing the casting. I'm assuming for the moment you don't want a rough finish on the casting. But, if you do, just pour at a high temperature and you can get "burn-in" in a sand mold.

Controlling the temperature is important. Keep the metal exposed to the high temperature as little as possible. Normally we have no problem. In the casting of copper base alloys in general, there is very little to be gained by using fluxes or covers on top of the metal. You get very little advantage and you run the risk that anything you put on top of the metal may end up in the casting. I'm sure you would be greatly embarrassed to open up the mold that you have spent so much time on and find slag instead of metal. There is very little benefit to be derived from melting copper base alloys with fluxes, including bottles, glass or sand; sand is one of the worst things you can throw on the top of the molten metal because if it goes in the mold it will probably end up in the casting. Sand in the casting is a problem! It makes cleaning very difficult. You have to take the point of view that anything that is on the top of the metal will probably end up in the mold, even though you are careful to skim it.

With aluminum alloys we have a different situation. All aluminum alloys form aluminum oxide very quickly. When you look at the top of the aluminum bath what you see is an aluminum oxide cover on it. If you leave the surface undisturbed it will stay intact and it won't build up too heavily. If you stir the metal or disturb the surface, this breaks the oxide film which heals over and in the process of doing so forms an additional film. If you stir the metal at all you are probably going to be in trouble. You will be creating oxides. The oxide film of aluminum is a bad actor and gets into your castings and makes it difficult to clean them or to weld them, or even to feed them. I would suggest the possibility with aluminum of using a cover flux. There are commercial cover fluxes available. Don't just pour salt on the metal since wet salt is of very little value. There are commercial fluxes which sell for as little as 15¢ a pound which you can use, and you don't need much of them. But they do help keep the top of the metal reasonably clean, and you can skim them off fairly well. If you are putting back a lot of small pieces of aluminum, you will form a lot more oxides; then the flux may be helpful in cleaning them up. This could be beneficial.

Audience: How about using fluxes with aluminum bronze?

Colton: Yes. Aluminum bronzes cast much like aluminum alloys. They have about 10% aluminum in them, but you have a lot of other problems with them. They are difficult alloys to handle.

Audience: I have a book put out by the American Foundrymen's Society. They recommend not only a cover flux but also a lid.

Colton: I see no value to using a cover flux. You understand that somebody else may have a different point of view. A lid on the furnace is highly desirable.

Audience: The book also recommends not preheating any heated or metal scrap on the top of the furnace.

Colton: This book must be quite old. Preheating is good practice. In foundries we always have a lid on the furnace because it helps control the combustion. We always put our ingots on top to preheat them for two reasons: one, to make sure they are dry--remove the moisture and burn off the oil, and secondly, to preheat the metal so it melts more quickly. By all means I would preheat metal. Solid metal will not absorb gas, for all practical purposes.

Audience: Does melting by induction methods have an advantage?

Colton: Yes, it gives good mixing and as far as the gas problem is concerned you are not producing moisture over the bath. It is probably the best way there is of melting metal. But most foundries don't have induction furnaces. They are quite expensive. A small commercial installation in this country would probably cost $25,000 or more plus rather high power costs. It's a great way to melt if you have it available and very flexible. You could melt steel.

Audience: Instead of pouring metal from the crucible we take it from the bottom of the pot.

Colton: Yes, you use what is called a "tea-pot" crucible. Essentially what it consists of is a built-in barrier; metal comes from the bottom rather than off the top. It is very good pouring, but they are expensive crucibles. Not many people use them.

Audience: Some people bore a hole in the bottom.

Colton: I would be afraid of weakening the crucible. There is another way to do this. Take a crucible, take a block of graphite, or take a block out of an old crucible and make a cover with a hinge on the side. It is more or less just laying a block on the top. We make a cover and hinge it so the cover is free to move. You get the same effect as a bottom pour crucible, but I wouldn't cut a hole in the crucible. I'd be afraid of that.

Audience: What about a plug in the bottom of the furnace?

Colton: This is the way they handle large furnaces. They pull the plug from the bottom and the metal runs out. I don't like it in a small furnace. I'm afraid it is dangerous. Incidentally, let me caution you, molten metals are extremely dangerous to work around without the proper safety equipment. The heat alone makes it desirable for you to wear protective clothing. Also, you never know when hot metal is going to splash; protect your eyes, not with just ordinary glasses; use a face shield or regular safety glasses. Never work without adequate eye protection.

Let's talk a bit about adding fluxes. For aluminum there really isn't anything that you can add to the metal that will change its pouring characteristics. There are no "fluidizers" or "de-oxidizers." In commercial work we may add a little bit of titanium to aluminum to get finer grain size which helps with certain shrinkage problems. We de-gas aluminum. Gas could be a problem to you. The gas in aluminum can come out in such a fashion that it leaves the whole surface full of pin holes. Maybe this is what you are looking for--we are not. We can't live with it. Gas comes out of aluminum as it solidifies. It may distribute itself so that by the time you polish down the surface it has fine pores over it. Now, maybe this is what you want. If you do it is fairly easy to obtain. If you want to get rid of this fine porosity, you probably have to get rid of the gas in the aluminum. One way we do it is by bubbling chlorine or nitrogen through the molten metal. I don't recommend using chlorine to anyone here; it is a nuisance. Chlorine is a noxious gas. It will drive you out of the foundry. You can accomplish the same thing by bubbling dry nitrogen through the molten metal; take a long piece of pipe, drill some holes at the end, coat it if you can with a refractory metal, and you bubble nitrogen from a tank through the pipe at as slow a rate as possible. As the bubble comes up through the metal it presumably has zero pressure in the bubbles. The gases are attracted to the bubbles and they migrate inside this area of low pressure and are carried out of the metal. It works. There is an even simpler way to de-gas aluminum, if this is a problem. There are on the market "solid chlorine pills" of hexachlorethane. It's a solid material that breaks down at room temperature. When you plunge these "pills" (which are small blocks) to the bottom of the pot of metal, they give off chlorine gas. The chlorine bubbles up through the metal and will help remove the gas. Chlorine is more effective in degassing than nitrogen, but more unpleasant to use.

Audience: Do you put these in after you have melted the metal?

Colton: After the metal is taken out of the furnace when it's sitting ready to pour. Normally in a foundry, when ready to pour, we take the crucible out of the furnace and put it on the floor. Usually at that point you have to transfer from one set of tongs to another. Then the "Degasser Pills" are added. You have to make a plunger to hold the pills down and permit the gas to slowly bubble up. The pills have to be held down; otherwise they will float up. You do this prior to pouring. This is a relatively inexpensive and effective way of de-gassing. There is no way that I know other than perhaps the use of vacuum of getting all the gas out of metal. It is better to keep it out. The degasser pills are available at foundry supply houses.

For bronzes, there is only one additive that makes any sense to use. I'm talking now about an alloy that contains tin. That is phosphor copper

which is commercially available, as 15% phosphorus copper, and which is either cast into a waffle which is brittle and breaks up into pieces or it is cast into shot form which makes it very easy to handle. Phosphorus has a very high affinity for oxygen. Therefore, keep in mind what I said before about the effect on fluidity or castability of tin bronzes of oxide formation. When you add phosphor copper to your bronze, you do a number of things. One is to help de-gas it. This is one reason we use it in the commercial foundry. But we also improve its fluidity or castability; to demonstrate this, take a pot of bronze that you have taken out of the furnace, skim it clean to remove slag and oxides off the molten metal surface; it will then form a slag over the top very quickly; take a handful of phos-copper and throw it on the top of the metal bath. The phos-copper will melt and will clean up the surface of the metal. What it does principally is to reduce the tin oxide. At the same time it forms a protective coating on the surface--a phosphorus compound--that is either a vapor or a liquid at these temperatures. The gentleman said yesterday that bronze pours with more difficulty than does cast iron. If you add enough phosphorus to bronze, you can make it pour almost like water. In fact, in sand castings if you want a rough surface, this is one way to get it. Add about 1% phosphorus to any bronze and you will get all kinds of unusual effects, some of which you may want, others you may not. I would suggest to you that if you are casting tin bronze, by all means use phosphor copper.

Audience: Should we stir in the phos-copper?

Colton: You don't have to stir it. We have found over a period of years that if you put it on the top of the bath, the metal is in constant motion anyway and the phosphorus goes through the entire metal bath, diffuses throughout the metal very quickly. I would not stir bronzes ever, aluminum never. We usually add 2 ounces of phosphor copper per 100 pounds of metal. However, if I were casting sculpture bronze I would add at least double that amount. Since you need high castability, you want maximum fluidity.

Audience: Do you have any problems with excess phos-copper?

Colton: Only to the extent that it improves fluidity or causes metal-mold reactions which affect the surface of the casting. This is principally investment or sand molds.

Audience: What about plaster?

Colton: You might have some problems. Phosphorus could form some compounds--I don't know. Four ounces of phos-copper won't bother you, 6 ounces, I don't know.

Audience: You didn't mention phosphor bronze to begin with.

Colton: Phosphor bronze is a kind of a misnomer. What we call phosphor bronze in this country has very little phosphorus in it. It is an English name for an alloy containing 10% tin, 89% copper, and approximately 1% phosphorus. They do not always pour the alloys into sand molds; more often they

pour it into metal molds. The one advantage of the alloy is that it has very good mechanical properties. We never add as much as 1% phosphorus to American alloys because we cast into sand more then they do in England. We make phosphor bronzes that run around $\frac{1}{4}$% phosphorus. However, I see no advantage, other than color, over some of the other alloys, and phosphor bronzes may be more difficult to cast.

Audience: How about adding phos-copper to silicon bronze?

Colton: It is done. No great harm, not much benefit. You don't need it. Melt down silicon bronze and look at the surface; you will see it is clean. There is not much to be gained by adding phos-copper.

Audience: How much above the pouring temperature should the metal be heated?

Colton: This is limited by how much time you need to prepare to cast the metal. There isn't any rule on this other than if it is going to take longer to take the metal from the furnace to the mold, you have to heat the metal higher. It is desirable to have everything arranged so that the delay is minimum. Then you don't have to overheat the metal. However, there is no rule because it depends on how far you have to walk, or how much changing of equipment you have to do to pick up the pot.

Audience: After you have added phos-copper, how long should you wait before you are ready to pour?

Colton: By the time that you add the phos-copper, pick up the bale or use the crane, and pour, you are ready to go. Everything that is going to happen, happens in a matter of seconds. You don't have to stir.

Audience: Should we stir after phosphor copper has been added?

Colton: No, generally, you don't have to. However, if you feel you want to, it doesn't do any harm.

Audience: What about adding an ounce of aluminum?

Colton: Not to red metals, no. You may add aluminum to yellow brass, yes, but never to anything with tin and lead in it. What happens is you may not get any bad effects, but it can cause very severe shrinkage problems. It is possible to take 85-5-5-5 alloy and get very deep shrinks in castings by adding aluminum. Other than that I don't think it would be serious. Add aluminum only to yellow brass.

Audience: I've been using super brass flux on mine.

Colton: If you think you get good results with it, use it. I don't think you need it, but if you are happier with it, use it. I want to mention one other thing here about stirring. Never stir aluminum, never touch the aluminum bath. Once you have melted down, skim it off very gently. Don't disturb the surface, because when the liquid metal is exposed to the air,

you are making dross and oxide. Aluminum oxide has a specific gravity fairly close to that of aluminum. When you stir you are mixing the oxide into the aluminum and it may end up in the casting. This is one thing, even as an artist, you wouldn't want in your castings, because it interferes with the gating or feeding of the casting and may cause severe shrinkage. Don't disturb the surface of aluminum, never stir. Don't stir bronze either--although you don't get into as much trouble if you do!

Audience: On your first point about keeping the bronze clean, you mentioned grease and oil. What about our old sprues and pouring cups that have residue of investment? Should we sandblast them first?

Colton: I suspect the residue will float to the top of the metal and can be skimmed off. There is no danger.

Audience: Is the same thing true if you are casting CO_2 sand?

Colton: The only difficulty here is that anything that is on top of the metal may end up in the casting. There is no real harm to the metal itself, but if you don't get the sand or slag off the surface, then you may get some into the mold.

Audience: How about harm to crucibles?

Colton: Sand will flux crucibles, too. Sand is a great material for fluxing the top of the crucible which means that it will cut into or erode the wall of the crucible.

Audience: You were talking about not using glass. What happens to the glass? Does it float on top?

Colton: It floats on top, fluxes some of the crucible by dissolving a ridge around the inside of the crucible; you may have to thicken the glass to remove it. It is difficult to remove since it is viscous.

Audience: What's the best way to clean the crucible of bronze so that you might be able to use it for aluminum?

Colton: Elbow grease; take a metal rod that has been flattened out at the end so it will scrape and be sure you get every bit of the bronze.

Audience: As a cover flux for aluminum is Rasorite satisfactory?

Colton: No. We use Rasorite industrially in melting bronze. For aluminum Rasorite has too high a melting point and it won't become fluid. Most aluminum fluxes are a combination of chlorides--potassium chloride, sodium chloride and a little cryolite.

Audience: Will impurities settle to the bottom of the crucible?

Colton: No, normally we do not have this problem. Large chunks of iron might, but the specific gravity of bronze is relatively high and most of the materials involved are lighter, so they will float.

Audience: At some foundries you will see the foundrymen touch the surface of the metal with a pine stick and a flame jumps. What purpose does this serve?

Colton: I can't see any at all.

Audience: Was he burning off excess gas?

Colton: No, I don't know what he's doing. He learned that from some old foundryman who also learned it from some old foundryman and none of them know what they are doing. This is the story of the foundry business.

Audience: Do you recommend putting fluxes in a crucible before charging it?

Colton: Is this aluminum or brass melting?

Audience: It is brass.

Colton: It doesn't make much difference, if you are going to use fluxes whether you put them in the bottom or not. Most flux materials melt before the metal does, and they will float on top of the metal. If you feel you need flux it is just as good on the bottom as on the top. You see, I don't really care much about using fluxes.

Audience: What about wax on lead?

Colton: The wax will burn up?

Audience: Will it flux the lead?

Colton: You don't have to flux lead. There is no need for it. Lead forms an oxide which is very fluid. This isn't a serious problem.

Audience: What is the alloy content of yellow brass?

Colton: Yellow brass is roughly 70% copper and 30% zinc.

Let's go back to the reason you may have holes in your castings--if you have holes in aluminum or brass castings. This may be of general interest. There are a limited number of reasons that you have holes in your castings. Porosity (holes) may be caused by gas, entrapped air and shrinkage. Forget the molds. When you break open a casting, if you have holes in it, it probably came from one of these three things--consider aluminum first; air bubbles get trapped in aluminum very easily. When you pour down the sprue, the metal has a tendency to rotate or spin. Normally, you pour to one side. You can't help yourself. As it rotates the metal stream sucks in air. It aspirates air. The air is taken in with aluminum. Air bubbles are then

coated with aluminum oxide. Aluminum oxide is a very tough material. It coats these air bubbles which then may go through the casting and end up somewhere in the casting proper. When you take the casting out it may look good, until you begin to work the surface. Right under the surface you may find bubbles. These are always on the top side. We call it the "cope" side. The air bubbles are trying to get out. This is very common. It is perhaps the largest source of defects in aluminum casting. This comes largely from bad pouring practices, which means that you are aspirating air. In brass casting you can also have air bubbles. It is possible, but for a somewhat different reason. In your molds you probably have a very serious venting problem. It is possible to trap air in the mold because it can't get out. If you can visualize a cushion of air against which you are trying to push metal, there may exist a place where the metal may enclose that cushion of air, and, as a result, you may get an air bubble inside the casting. This is not a common defect. In brass it is less common than in aluminum because of the great specific gravity difference between the metal and the air. And the fact that you don't get a tight film around the bubbles in with most brass alloys.

We get gas holes in bronze castings because the molten metal will dissolve gases which will come out as the metal freezes. The liquid metal has a high solubility for gas. As the temperature falls and as the metal freezes, the metal tries to give up this dissolved gas. At that point the gas has no place to go but to make a gas hole in the casting. The gases that are involved are always hydrogen and oxygen--the only two gases we worry about. Gas holes in aluminum are less of a problem in the sense that we only have one gas--hydrogen--to worry about; as a second source of holes in castings the gas comes out as the metal freezes and may appear as well distributed holes throughout the casting. In bronze gas holes are usually in the center of the casting where they may not give you too much trouble.

Trapped air and dissolved gas are the first two ways that we get porosity in castings. The third source is the one that you probably experience most of the time--shrinkage. What you frequently are calling gas holes I believe is probably due to shrinkage.

Audience: Don't shrink holes have dendrites?

Colton: There is no one who has been able, in bronze alloys, to satisfactorily distinguish a shrinkage hole from a gas hole. What we think may happen is that a shrinkage condition existed first and then gas got in the shrink hole and expanded it. You had to have shrinkage first, however, in most bronze alloys. You cannot tell the difference looking at the holes through a microscope. Gas in metal is a mixed blessing. If we could control it we would have a valuable tool in overcoming shrinkage problems.

Audience: Could not a shrinkage condition also be compensated for by gating?

Colton: This is the right way, yes. But this is sometimes a very difficult problem since with a complex casting you cannot always do what you want in the way of gating.

Audience: Would it be advisable to make buttons by dipping out small ladles of metal until you obtain a level one, and then pour?

Colton: The only thing that is wrong here is that you are not comparing like things. You have a casting that probably has a variety of section thicknesses. You can't be certain that you will have the same volume of metal in the button, or the same section thicknesses. And this test works well only for pure copper.

Audience: You mentioned not to melt down scrap metal. Do you include the precious metals?

Colton: I see nothing wrong with melting scrap if you know what it is. You certainly have to melt your own produced scrap. If you are going to buy gold and silver and melt it down, I would be very careful because there are many alloys of silver and of gold. How do you know what you are melting?

Audience: Before you pour the molten metal you imbed a piece of metal to be part of the final piece. Should the molten metal be higher in temperature than otherwise?

Colton: It may have to be. In general the rule that we use is that you never pour over a chill or any piece of metal in the mold. Pour to the chill in which case you probably won't have any problem, you won't have to raise the pouring temperature. If you pour over the chill, you may cool the molten metal down and have to compensate by using a higher pouring temperature.

UNIVERSITY OF KANSAS

Third National Sculpture Conference

Summary of Remarks of C. C. Sigerfoos at Consultation Session, 8:30 A.M., Saturday, March 28, 1964

(Professor Sigerfoos preceded his technical remarks with a brief showing of foundry pictures taken while he was on leave from Michigan State University and working on U.S. Agency for International Development projects in Costa Rica and Guatemala.)

CONSULTATION SESSION

In starting the discussion in this consultation session, I should first explain that my foundry experience has been in the commercial and technical areas. Of course, I have an appreciation for the luster of cast metal surfaces and the beautiful artistic shapes seen here at the Conference and elsewhere. However, I must confess that my appreciation for many art castings is often in terms of the casting techniques for I often find myself more interested in the gate system or furnace or the mold materials that were used in making the artistic casting.

So far in this Conference, the more or less conventional investment and dry sand molding materials have been discussed for art casting work. Some of the procedures for baking or burning out expendable patterns have also been covered. I would, therefore, like to begin my discussion by calling to your attention some of the new developments in mold or core materials. For example, materials or processes such as oil bonded sand, 'cold-set' bonded sand and sodium silicate bonded sand. These, in my opinion, appear to deserve more attention in the art casting field. Actually considerable information on these molding materials such as their chemical compositions and physical properties has been available for many years. However, their introduction into the foundry and some of the development of techniques for their use is quite recent.

It should be pointed out that these newly developed materials are best suited to the making of molds in sections: that is, where the sculptured patterns are used nonexpendable and the mold sections are separated to remove the patterns.

The mold material referred to as oil bonded sand, could be referred to as a waterless, green molding sand for it has the molding characteristics of common green sand, but it can be rammed or packed to a much higher degree of density without the danger of blow hole defects such as often occur when using common green molding sand. This type of oil bonded sand is therefore an ideal molding material for the beginning student for, in addition to good moldability, this sand does not dry out and it can be easily reconditioned for repeated use. A small amount of the oil burns and smokes when the molds are poured. However, the volume of smoke is small when casting bronze and aluminum pieces and will not be found especially objectionable in a properly ventilated casting area.

The mixing of an oil bonded sand in a commercial foundry is usually done in a muller type machine. The base sand used is washed and dried silica sand and for brass or aluminum it should be of about 130 grain fineness number. First, iron oxide and activated bentonite clay, called bentone, are mixed with the sand. After thoroughly mixing these dry materials, a high flash point costal oil and a commercial alcohol catalyst are added. As the mixing continues, the sand develops strength and moldability. This blending is (or at least should be) done in a ventilated area because, during the mixing, transfer and storage, the alcohol will eventually evaporate.

As mentioned before, the durability of this oil bonded sand is good -- especially when used for brass and aluminum alloys. It does not require rebonding or remixing with each use. In fact, riddling the sand between each use will usually suffice for a number of casting operations. However, when this type of sand does become weak, it is easily rebonded with oil alone or with oil plus a little bentone. The alcohol is often not required for the rebonding operation.

The second process I wish to describe is the 'cold-set' or'air-set' process. This process is very useful when a hard mold or core is desired. Two to four percent of a commercial brand of 'cold-set' core oil is mixed with a fine, dry, clay-free sand. In the final stage of mixing, one or two tablespoons of powdered sodium perborate are added per 100 lbs. of sand. The action of a batch of this sand is similar to ordinary cement in that it eventually hardens without oven baking. The time for working the sand into the desired shape can vary from a few minutes to an hour or longer. This working time or 'bench-life' is controlled by the amount of the chemical activator (sodium perborate) that is added. The temperature of the sand and oil also has an influence on 'bench-life' so normally less activator is used in this type of sand during the summer months.

In our brass and aluminum foundry in East Lansing, Michigan, we use the 'cold-set' process extensively. The molds or cores are usually made in the afternoon. The patterns are drawn from the sand the following morning. We eliminate the oven baking, but usually skin dry the mold cavities with a torch.

The last molding method I wish to mention is the sodium silicate -- CO_2 gas process.

Sodium silicate has a variable composition. Furthermore, when this compound is used in a foundry sand it usually contains a small amount of sugar invert to promote the collapsibility of the sand after the casting is made. I, therefore, recommend that one of the foundry supply house brands of sodium silicate be used.

About three or four percent of the sodium silicate is mixed with a fine, clay-free sand. The sand is molded and then CO_2 gas is forced through the mold to harden the sand. The gas may be applied by attaching a gas hose to the bottom of a rubber cup and then holding the rubber cup against the mold. In other set-ups, a small metal tube is used to inject the gas into the sand.

One rather unique idea used for gasing larger and/or complicated molds or cores is to imbed small perforated steel pipes in the sand. These pipes

can be arranged to efficiently distribute the CO_2 gas and also reinforce the sand. In addition, they also serve as vents for escaping mold gases during the pouring operation.

QUESTION: What is the time required for gasing?

ANSWER: The time required is usually between 10 and 30 seconds.

QUESTION: How long can the mixture of sodium silicate and sand be kept in storage?

ANSWER: The mixture can be stored in a closed container for several days or longer. For short periods it is conveniently stored under a wet cloth. The mixture will gradually dry out and harden when exposed to the atmosphere.

My conclusion to this discussion of mold materials is that they are recommended for more art casting applications because they are relatively inexpensive and the formulas and mixing procedures are easy to obtain through foundry supply agents or, possibly, at a local commercial foundry. Furthermore, molds constructed of these materials can be poured soon and do not require lengthy high temperature drying or burning-out procedures.

QUESTION: Can we get a smooth casting finish with the oil bonded, cold-set or CO_2 processes?

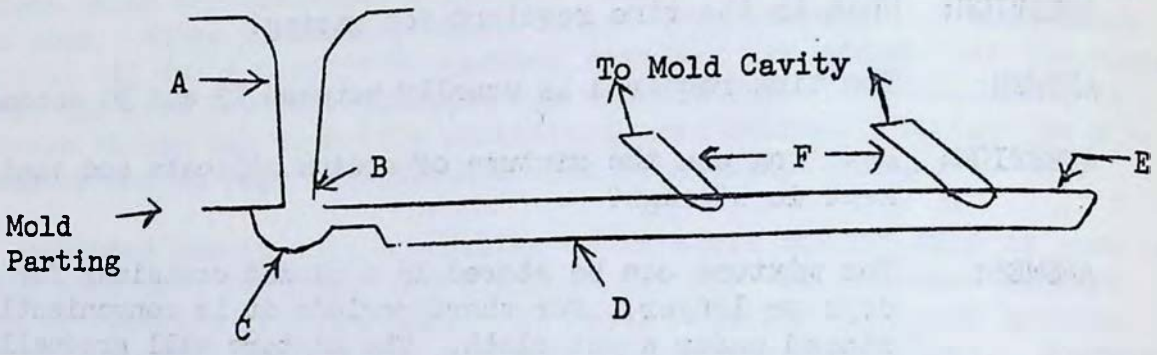
ANSWER: The formulas for these sand mixtures as used in the regular production foundries will probably not give a satisfactory surface finish for art castings. However, very smooth surface finishes are obtainable by adding from 5 to possibly 20 percent of silica flour plus some extra bonding material to these mixtures. Liquid mold coating materials applied on the mold cavities are also very effective in improving casting surface finish.

In concluding this consulting session, I wish to briefly discuss the subject of gating. This subject will be presented as the viewpoint of a commercial foundryman. No doubt a number of these ideas are now being used in your mold gating systems in art casting projects. The use of the complete system shown in the sketch may be impractical or even impossible in the casting of a certain complicated sculptured work because of the size of the piece or the limited space available for the gate system. In any case, certain fundamental principles apply to the gating of all pieces and a comparison of this recommended gate system to the one you use should be interesting.

The main purpose of this system is to provide a quiet flow of metal into the mold cavity and prevent such common defects as dirt and slag inclusions, gas holes, misruns, etc.

Referring to the sketch, the down sprue A should be rectangular (not round) in cross section. It should taper to the choked area at B. The

RECOMMENDED GATE SYSTEM



rectangular sprue reduces the swirl and the possibility of aspirating air into the metal in its downward flow. This is an especially helpful idea when casting light metal such as aluminum. The small choked area at B controls the metal flow. Some foundrymen use metal or mica screens or strainer cores to control the flow at this point. These screens do not screen out the dirt in the usual sense. Their main purpose is considered to be to slow the metal flow and thus trap the dirt elsewhere in the gate system. At the point C (below the sprue) the gate should be enlarged. This also slows the metal flow and prevents the metal from cutting into the mold material as it turns the corner. The horizontal runner D should have two to four times the area of the choke at B. This provides a slow horizontal flow of the metal for some distance which gives the dirt and slag a good chance to separate from the metal before the metal enters the ingates F. Another feature of this gate system is the extension E on the end of the runner. This provides an additional trap for dirt that may be in the gate or in the first metal poured. The ingates at F are often situated at a reverse angle to make the flow of metal reverse itself before entering the mold cavity. Whenever it is possible (at least in industrial gating systems) the aim is to design the gate system so that it is completely full before any metal gets into the mold cavity.

It was a pleasure for me to appear before this group and present this material.

SCULPTURE FOUNDRY DESIGN

Elden C. Tefft

Successful sculpture foundry design requires the cooperation of the sculptor, architect and industrial hygienist. It is hoped that this paper will assist the sculptor in his portion of the task.

The following sketches prepared as a schematic study to serve as a basis for foundry design were prompted by the many requests received for such information. Although the study is based upon the lost wax process, it was assumed that in practice the plan would be expanded by additions to meet special interests such as sand casting, experimental research, etc., as well as expanded by multiplication or reduced by overlapping to meet capacity and space requirements.

The plan was arrived at through careful examination of efficient operational movements in each staging area as well as the relationships and work flow between the areas. The bridge crane system designed to facilitate work flow provides almost total hoist coverage except perhaps in the area between the founding and the prefounding and post founding wings where elevators may be necessary if the founding crane is raised to accommodate special metal handling equipment.

Storage for other than immediate use materials has not been indicated, however, reserve storage which could be out of the area should handle approximately two tons of refractories, one ton of plaster, one half ton of blast grain and perhaps one fourth to one half ton of ingot metal.

The total foundry as sketched is designed to function as part of a greater sculpture studio complex. However, it would accommodate approximately twenty individuals working simultaneously if their work could be so scheduled. The molding, pattern making, and chasing areas have been doubled because of the greater working time required in these stages.

MOLDING

Area 88 square feet per unit; 44 square feet adjoining traffic way.

Benches The top of the fixed bench, as well as the splash wall behind it, is best constructed of a durable smooth material such as polished granite. The adjustable height portable molding stand and its interchangeable tops which are stored beneath the stationary bench allow for convenient handling of work between bench and floor sizes. In most cases a portable splash curtain will be used with the stand to contain over-throw plaster.

Plaster Storage The plaster, stored above work level, is fed either by gravity or mechanical means into dip trays which limit material lost in case of work contamination. The placement of the tray opening at bowl lip work level reduces plaster handling.

Mix Shelf The mix shelf is grated to allow waste plaster to drop into the sink tray below. The hose-type water faucet controlled by a dial temperature selector allows the plaster bowl to be filled in place.

Sinks The bowl and bucket sinks are placed at levels to facilitate work particularly cleaning operations. The sinks are served by swing mixer faucets and a spray unit. The bowl sink is designed to overflow into the bucket sink which is equipped with an overflow drain. The mix shelf sink is designed only for overflow, and, as mentioned above, equipped with a tray to receive waste plaster. All sinks require plaster traps.

Heat Source The level of both electric and gas burners is set low as a safety factor in the handling of hot mold materials. When not in use, covers not only protect the burners, but make the area usable for other purposes. Large electric heating pots could be stored beneath the bench.

Outlets Outlets are supplied not only for electricity but for compressed air which is used particularly for plaster spray guns.

Floor The use of oiled sawdust to assist in dust control as well as help prevent floor build-up necessitates a slightly recessed floor and a grated trap at the traffic way. The floor drain should be equipped with a cover as well as a plaster trap.

Ventilation The exhaust vent slot placed above dip tray openings is for removing air-borne plaster resulting from dipping and mix sifting. The burner area exhaust (not indicated) is for removing fumes and oxidized mold material.

PATTERN MAKING

Area 88 square feet per unit; 44 square feet adjoining traffic way.

Benches The top and splash wall of the fixed bench should, as in the plaster area, be of a durable material. However, it must withstand solvents as well as vigorous cleaning and be constructed with a slight edge to allow flooding. The portable pattern stand, stored beneath the bench, is identical in construction to the portable molding stand.

Sinks The soak sink and the bath sink are equipped with an overflow system similar to that of the molding sinks. Each sink is equipped with a swing mixer faucet and share a spray unit. One large waste trap serves the two units.

Heat Sources The gas and electric fixed burners in the rear are set low for safety in handling hot pattern materials. The adjustable height units in front are designed for the heating of tools. Note, tool rack detail. Similar adjustable heaters for portable floor use may be stored under the bench. Gas air torches (not indicated) may also be stored under the bench.

Outlets Electric outlets should be provided for electric tools, portable tool heaters and flameless torches; and compressed air and gas outlets for gas air torches.

Floor A plastic seal prevents the pattern material from penetrating the floor and a drain facilitates cleaning and soaking of large plaster molds.

Ventilation The exhaust in the pattern area is intended primarily for the removal of fumes generated by the heating of pattern materials (particularly oxidized wax). However, it may be required to remove plastic or other fumes from the bench area.

INVESTMENT PREPARATION

Area 72 square feet; 36 square feet adjoining traffic way.

Bench The batching bench is designed with a recessed bagging shelf which is adjustable for various sizes of bags and batches.

Materials Storage Four important investment materials are to be stored and handled in the same manner as plaster in the molding area. However, the dip trays open onto a weighing shelf.

Weighing Shelf The scales platform is surrounded by a grill which allows waste materials to drop into a tray below. The face of the scales is placed above the shelf at eye level on the plaster bins.

Investment Storage The batched investment storage shelf unit is portable not only so that use may be made of more than one unit, but so that the batched investment can be moved to another area for use or storage. If for some reason the use of a simple graded track is considered infeasible, rocking double casters would facilitate movement of the shelf units over sawdust retaining ledges.

Floor As in the plaster area, oiled sawdust is used to assist in dust control. This will, of course, necessitate a recessed floor, a grated trap at the traffic way and a covered floor drain.

Ventilation The exhaust slot, as in the molding area, is placed above the dip trays. However, in addition a down draft ventilation will be provided in the weighing shelf. The exhaust for blending, installed for use above the bagging shelf, could be a flexible unit.

INVESTING

Area 80 square feet; 40 square feet adjoining traffic way.

Sinks The cleaning sink is deep and set low to accept buckets, while the measuring sink is especially shallow for its primary function is to handle overflow. One swing mixer faucet will serve the sinks; if two spray type units, one long enough to fill the investment bucket while in place on the mixer, are provided.

Mixer The mixer is set high allowing the bucket to be at a convenient filling and pouring level. The casters allow it to be easily moved to the burn-out area for in-place investing.

Investment Storage This portable shelf unit is the same and/or identical unit as described in Investment Preparation.

Floor The investing floor, if independent, should be of the same type described in INVESTMENT PREPARATION.

Ventilation The exhaust, which is very important in this area, should be operated just above the level of the bucket. It is recommended that it be flexible if the mixer is to be moved.

BURN-OUT

Area 207 square feet; 72 square feet adjoining traffic way.

Fixed Furnace A fixed dimension furnace can be, not only convenient for the burn-out of small molds, but when program controlled, very important for research. Most standard furnaces require special loading devices.

Flexible Furnaces Fire brick aprons constructed at floor level on both sides of the fixed furnace at the traffic way serve as bases upon which to erect the flexible furnaces. Each apron is serviced by "under the floor" gas, air, electric, and control lines with outlets located at the front and back outside corners. Controls for each furnace should be installed for easy access on the walls at the traffic way.

Storage A small cabinet provided for each of the furnaces will serve as storage space for burners, hoses, and other accessories. The flexible furnace closure components are to be stacked to the rear along the walls.

Ventilation Since the stack is not as feasible a solution for the exhausting of combustion and oxidized wax fumes from the flexible furnace as the fixed furnace, ceiling exhausts or swing-type adjustable level hoods should be provided. This is not only because of the flexible nature of the furnace, but also due to the crane movement in the area.

FOUNDING

Area 430 square feet; 80 square feet adjoining traffic way.

Furnace The crucible furnaces, #20 and #60, are located in reference to the indicated operational orbits of the covers, appropriate tongs, and the founders. An additional furnace, larger tilting type or cupola, could be installed in the area by employing one-man tongs for the small furnace work. The furnaces are set in pits to lower the hot metal handling level thereby reducing risks.

Splash Pit Designed to retain the metal in case of equipment failure or other spillage, the grated splash trough or shallow pit (approximately 6" to 10" deep with a sand covered floor) is located in the complete molten metal travel area.

Founding Pit The primary function of the founding pit is to allow the mold to be set at a safe and convenient pouring level. However, it also acts as a container for the sand which is rammed around the mold to assist it in withstanding the weight of the molten metal, and, of course, as a container for the metal in case of mold fracture.

To facilitate the handling of the sand, the pit is sectioned by dividers which are adjustable in their height as well as location.

Since usually at the moment of initiating the pour from a full crucible the most convenient mold level is above the floor about the height of the crucible, it is recommended that a flexible flask (interlocking plates) be used to extend the retaining sand to the top of the mold.

The sectional grate used to cover the pit when not in use allows free movement over the pit around the mold during the pour.

Ready Room The ready room provides storage particularly for personal safety equipment and a minimal area for its fitting and adjustment. The top of it is to serve as a charging deck if a cupola is installed.

Galleries The observation gallery is designed to prevent congestion in the foundry which could prove disastrous to both the founder and observer. Shielding glass observation windows and ventilation are vital, because at the raised level where observation may best be accomplished is also where heat and fumes are most seriously concentrated.

Ventilation Ventilation of founding, one of the most hazardous stages of the entire process, may be accomplished in a number of ways. The ceiling exhaust, mechanized or natural draft, is the most convenient because it produces no barriers to the activity. The localized hood is more positive and secure. However, it presents problems of attending the melt as well as in the use of the hoist upon completion of the melt. Regardless of the method employed, masks rated for fumes should be worn when working over the crucible. Ventilation in the galleries has been noted above.

DEVESTING

Area 64 square feet; 32 square feet adjoining traffic way.

Bench The open-bar construction of the devesting rack allows the broken-away investment to drop through into the disposal pit below, as well as allows the dust to be drawn downward. The rods are cushioned to prevent scarring of the new bronze surface. The rack should be adjustable in height to accommodate molds of various sizes.

Disposal Pit The grated pit, which is located under and in the immediate vicinity of the bench, is accessible from the outside for convenient clearing.

Outlets Outlets should be provided for both electric and pneumatic equipment.

Ventilation The down-draft ventilation is designed to draw the dust down and away from the face of the founder, perhaps into a collector. Free movement of the crane through the area is made possible by a trapped passageway at the ceiling. Since this can be integrated into the vent system for make-up air, no seal is necessary.

SANDBLAST

Area 56 square feet; 24 square feet adjoining traffic way.

Equipment Air supplied helmets, gloves and other protective equipment is as important in this area as the basic blast equipment, generator, nozzles, etc.

Walls The walls must be lined with rubber or other resilient materials which will resist erosion by the blast. Screen-protected wire glass observation windows are recommended for purposes of instruction and for safety checks.

Floor The blast grain will drop through the grated floor into a collection pit which is accessible both from the interior and exterior.

Ventilation As in devesting, down-draft ventilation is important. The two areas could perhaps make use of a common dust collector. At the ceiling, trapped passageways allow passage of the crane also, as in the devesting.

WELDING

Area 64 square feet; 32 square feet adjoining traffic way.

Flash Shield Enclosing or shielding the area for use of arc equipment is imperative. This can, however, be accomplished even by the use of fire-resistant curtains.

Benches The welding stands constructed with fire brick tops and adjustable height are intended for independent use or to be used together for larger works.

Equipment The oxyacetylene arc and shielded arc equipment should perhaps not be permanently fixed, but rather provision should be made for moving it to the larger in-place works.

Ventilation The exhaust can be local, but should be of a flexible nature allowing the slot to be positioned to the height and locale of the work.

CHASING

Area 128 square feet; 64 square feet adjoining traffic way.

Benches The benches are to be of heavy construction ($\frac{1}{2}$" steel plate top) and equipped with heavy-duty swivel lock vises.

Safety Shield By placing two workbenches in a single area, it is possible to avoid duplication of some larger equipment such as the floor grinder and flexible shaft grinder indicated. To make this feasible, a safety shield or screen should be installed between the benches to control projected materials especially from power tools.

Tool Rail To allow free movement of the foundry crane, the rail for counter balancing and storage of heavy hand tools could be installed below the crane level. However, to allow the hoist to be moved to the bench, the balancing portion of the rail in front of the bench would necessarily be designed to disengage and swing out of the way. At this time the tools could be moved to the storage portion of the rail along the sides of the room.

Ventilation Small flexible vacuum units to be used at the work are recommended for removal of particles formed by grinding and other operations.

PATINA

Area 80 square feet; 40 square feet adjoining traffic way.

Storage The cabinet storage for chemicals above the bench are in part to be lined with acid resistant materials.

Bench The acid resistant bench top is designed to drain into the bench sink.

Heat Source The gas and electric burners for heating chemicals are positioned low for convenience and safety. They are placed between the acid bench and the floor sink so they may serve both areas.

Torch gas and air outlets (not indicated) are to be situated so torches may be easily used in the floor sink and drain area, as well as in the bench area.

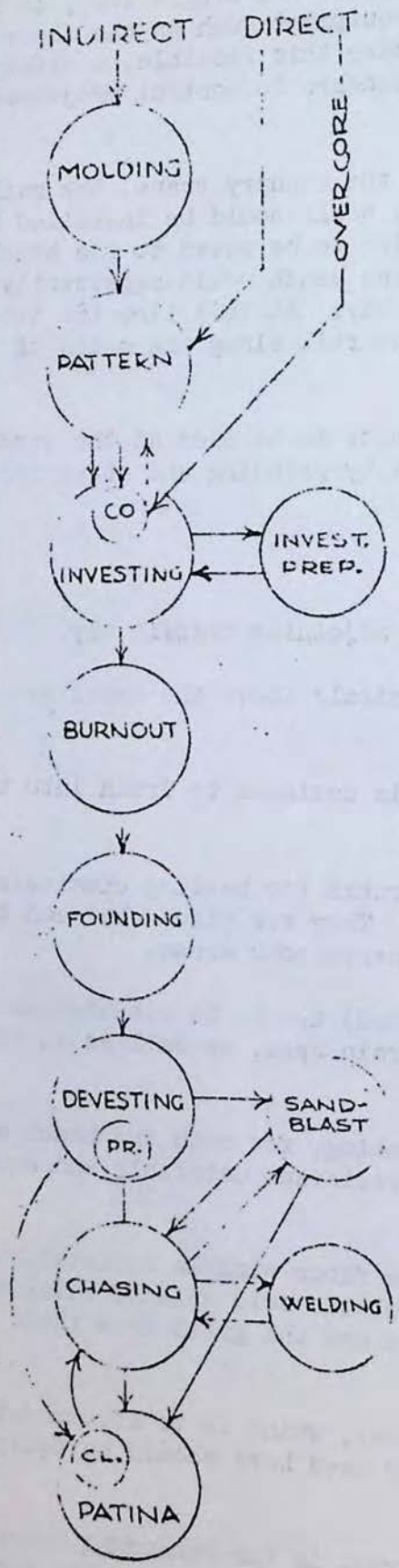
Sinks The sinks, as well as the plumbing, for both the bench and floor sinks are to be constructed of acid resistant materials and equipped with mixer faucets and sprays.

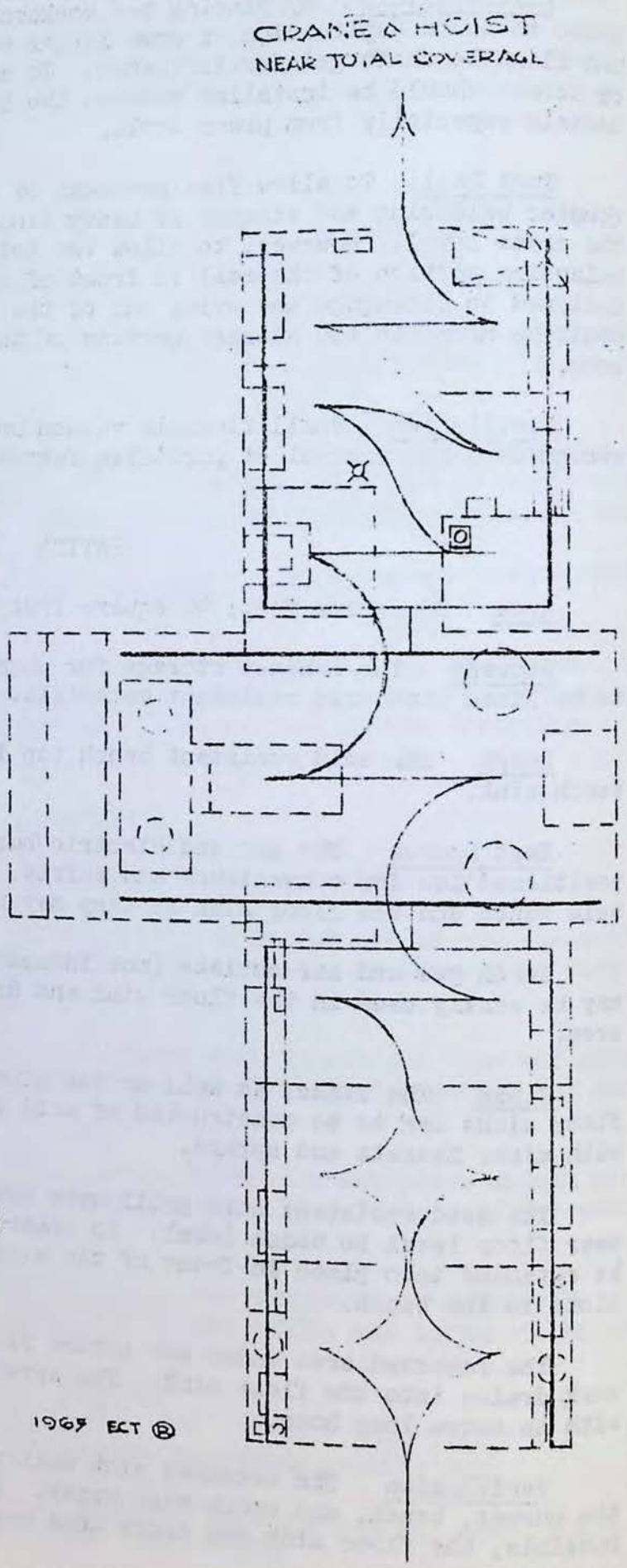
The acid resistant work grill over the floor sink is adjustable from near floor level to bench level. To control the acid splash, shields may be extended into place in front of the sink and the grill from their storage slots in the bench.

The recessed area under the grated floor, which is to accommodate large work, drains into the floor sink. The spray used here should be equipped with an extra long hose.

Ventilation The extended slot wall vent is for exhausting fumes in the burner, bench, and bench sink areas. However, because of the flexibility possible, the floor sink and drain area require a less localized exhaust.

LOST WAX FOUNDING WORK FLOW





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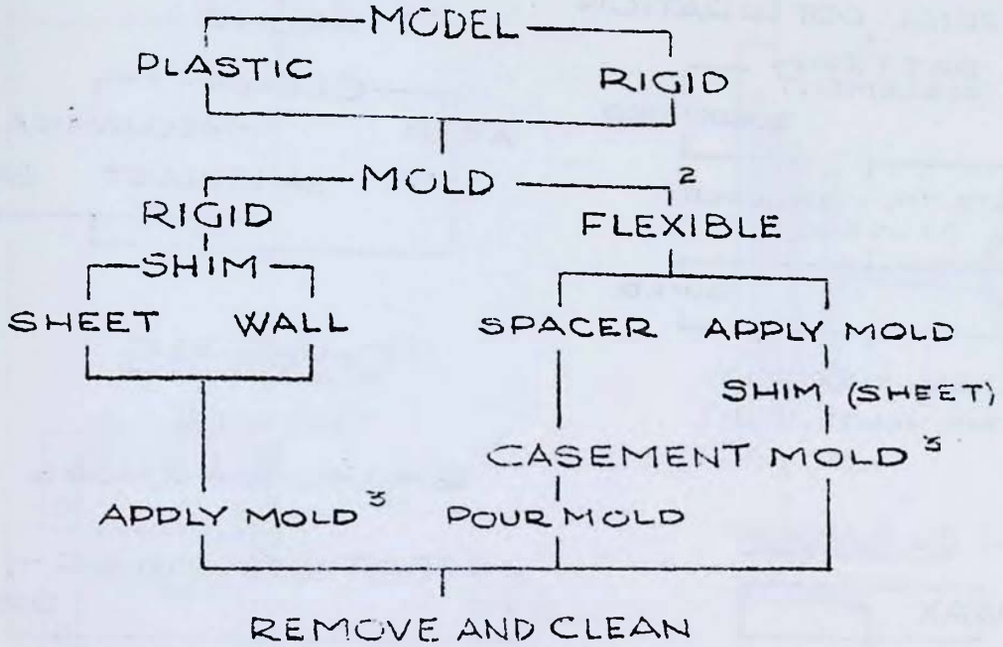
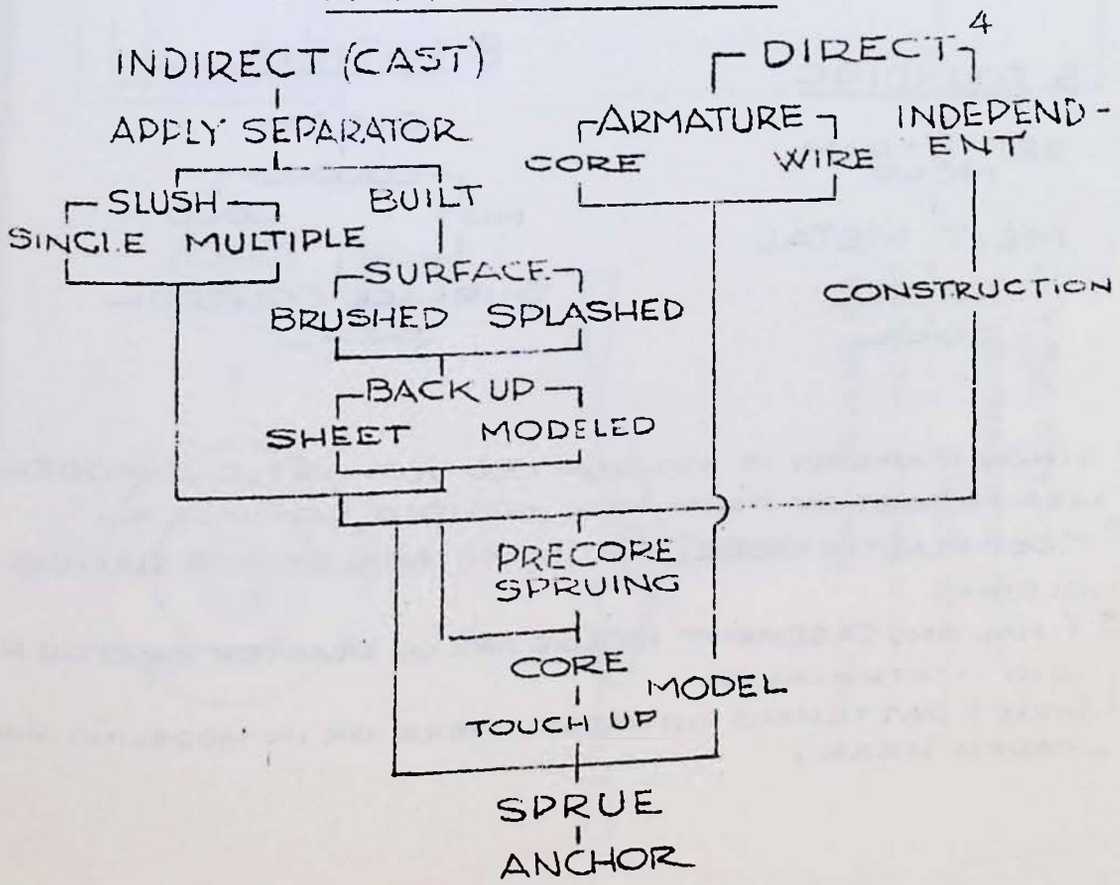
LOST WAX FOUNDING PROCEDURE

1 MOLDING

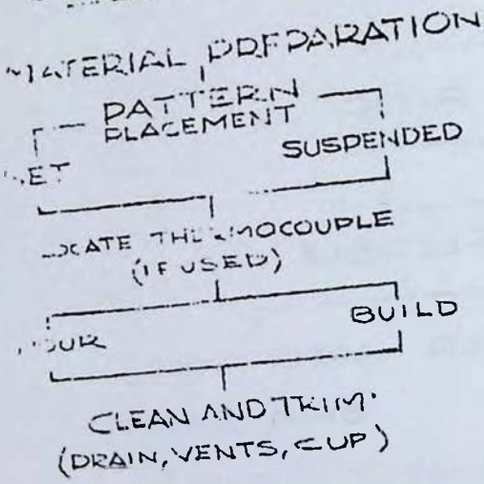


2 PATTERN MAKING

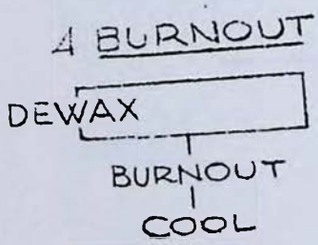


LOST WAX FOUNDRY PROCEDURE - CONTINUED

3 INVESTING

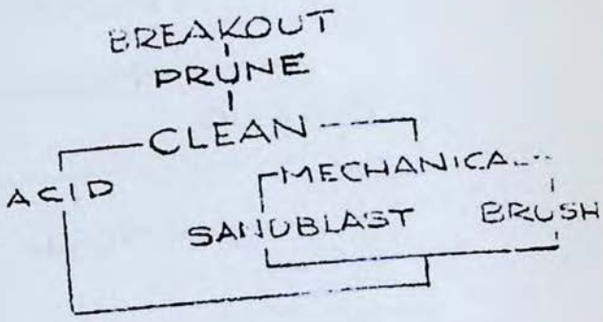


4 BURNOUT



5 FOUNDING

6 DEVESTING



7 CHASING

8 PATINA

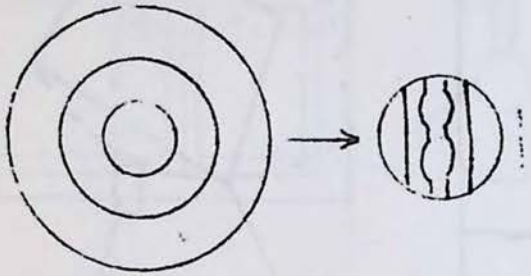
1 WHEN FOUNDRY IS ASSOCIATED WITH STUDIO, MODEL AREA IS PART OF PRIMARY STUDIO COMPLEX.

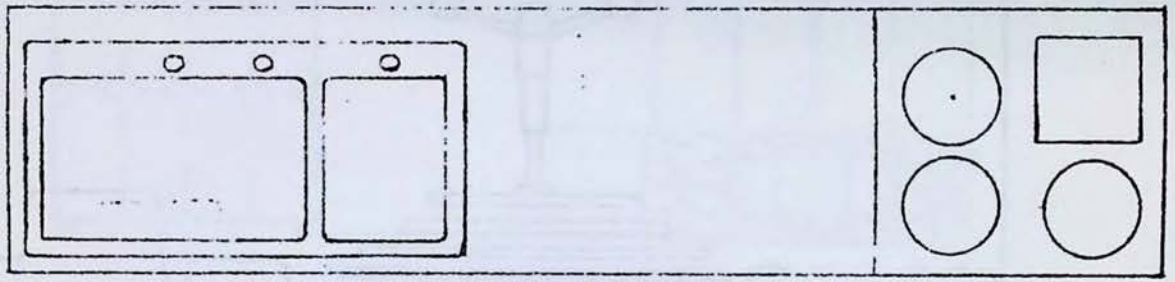
2 MOST PLASTIC MODELS MUST BE SEALED FOR FLEXIBLE MOLDING.

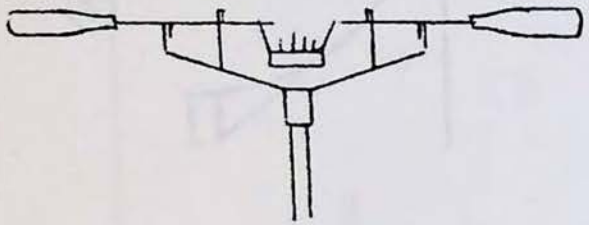
3 FINAL AND CASEMENT MOLDS ARE OF PLASTER OR OTHER RIGID MATERIALS.

4 DIRECT PATTERNS INITIATED HERE OR IN MODELING AND CARVED HERE.

PATTERN MAKING

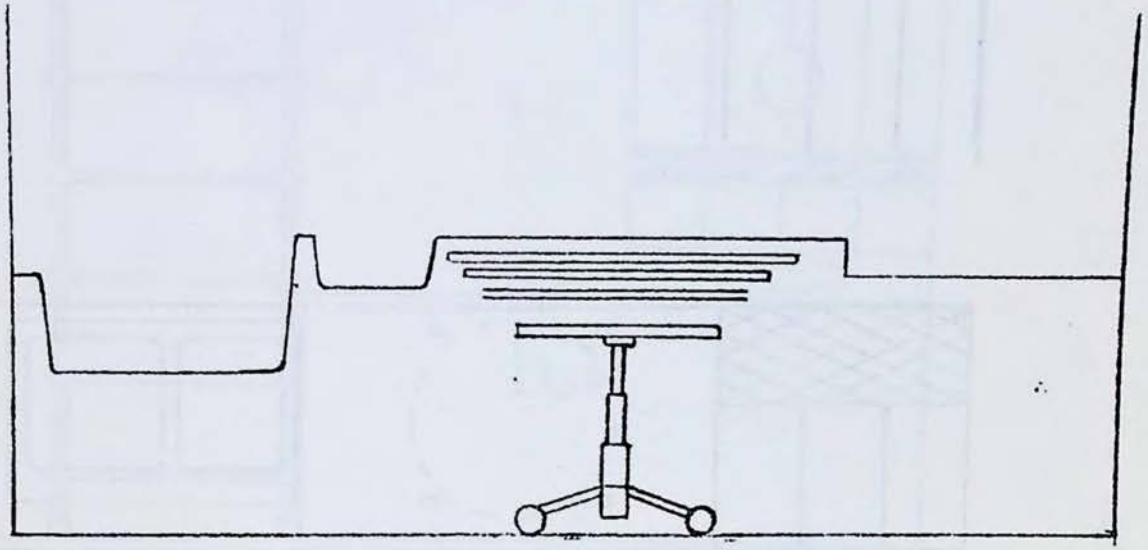






DET. TOOL BURNERS
- ADJUSTABLE HEIGHT
- ONE GAS
- ONE ELECTRIC.

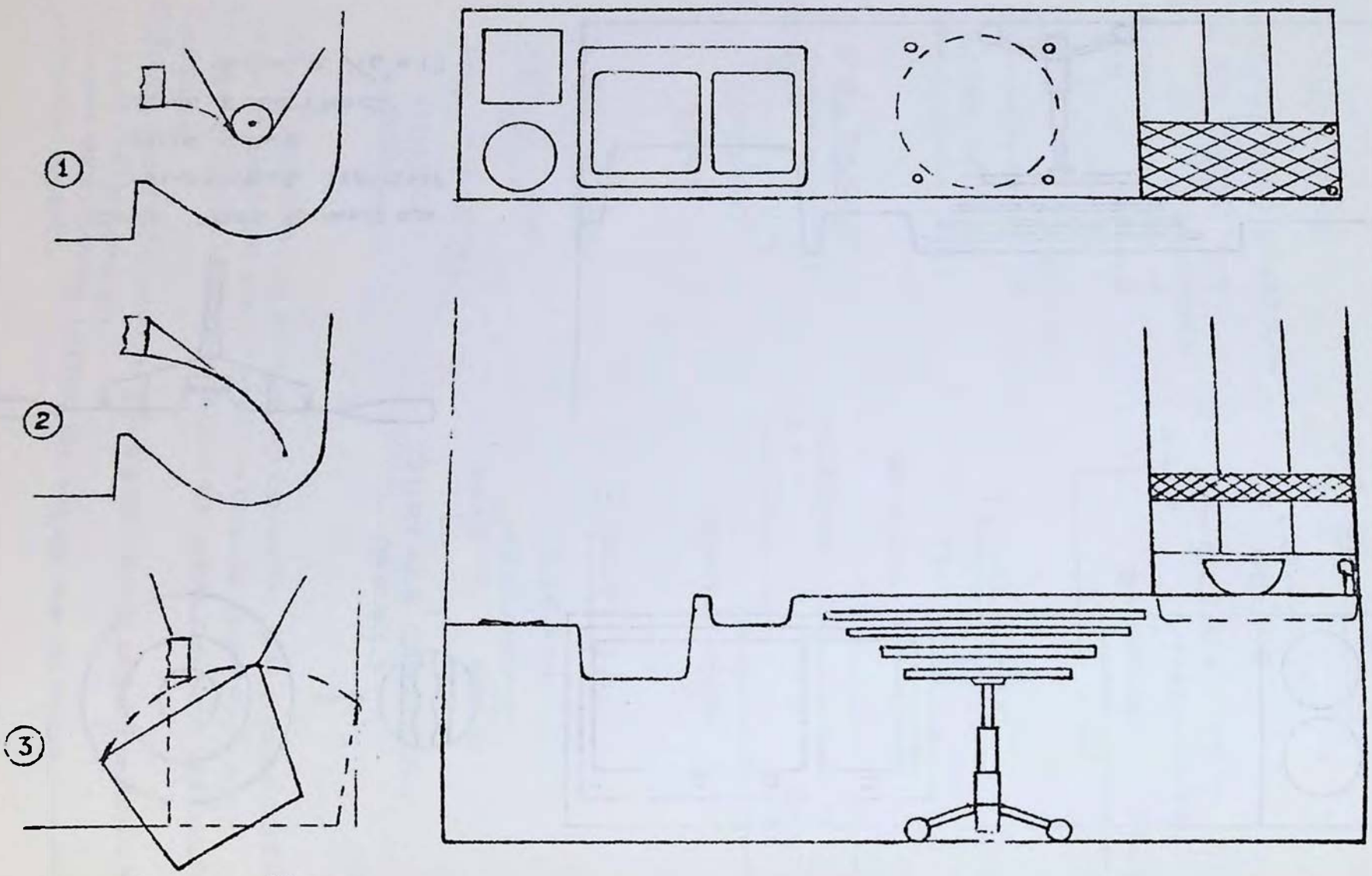
SCALE 1/16" = 1"



SCALE 1/2" = 1'

SCULP. FOUNDRY 64

MOLDING



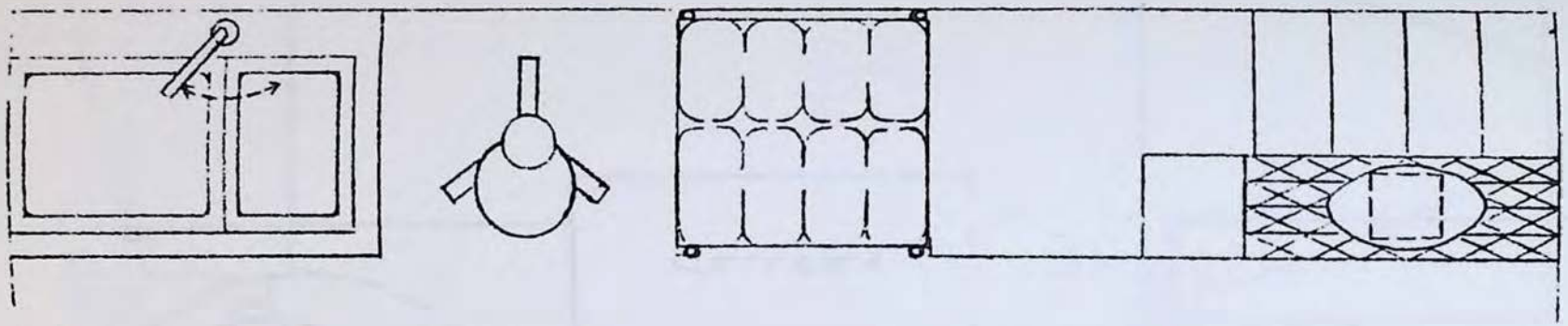
SCALE 1/16" = 1"

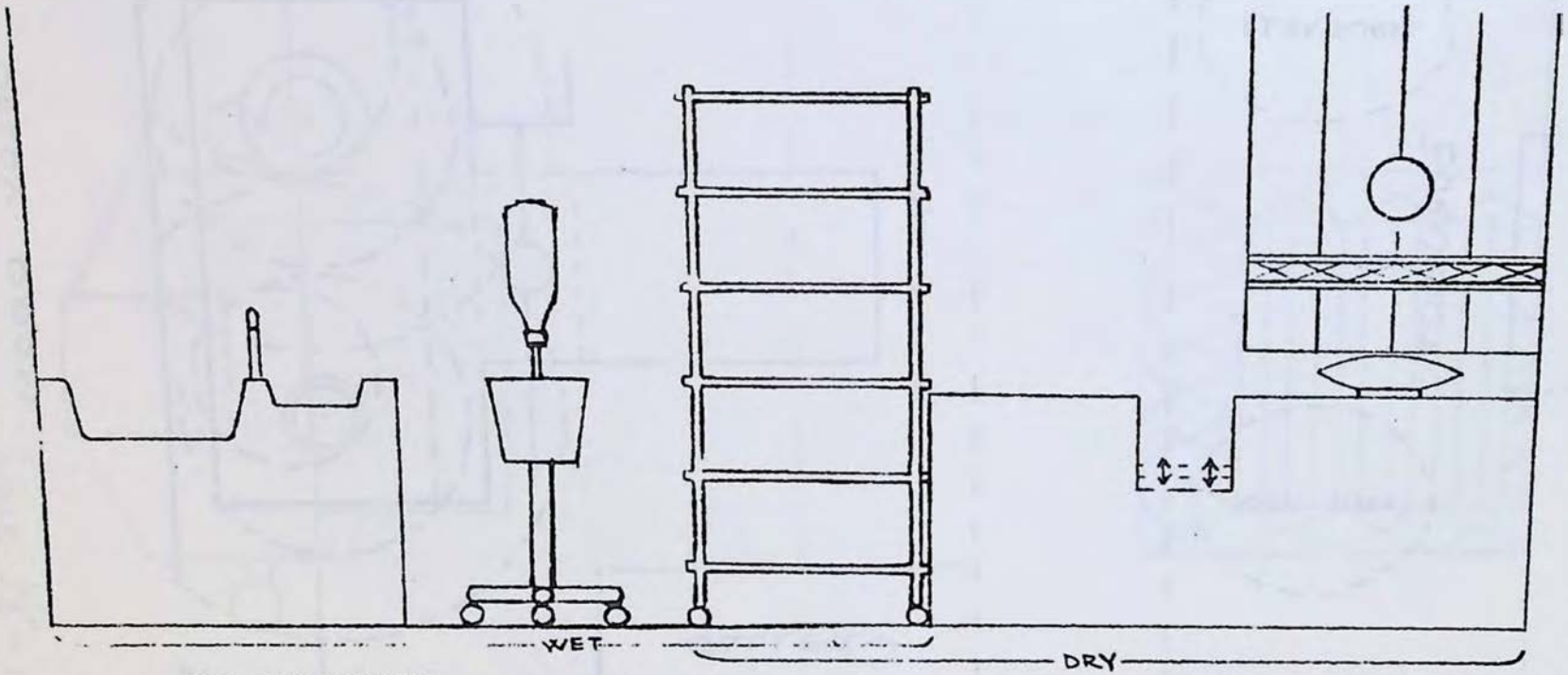
DET. PLASTER BINS

SCALE 1/2" = 1'

SCULP. FOUNDRY G4

INVESTING



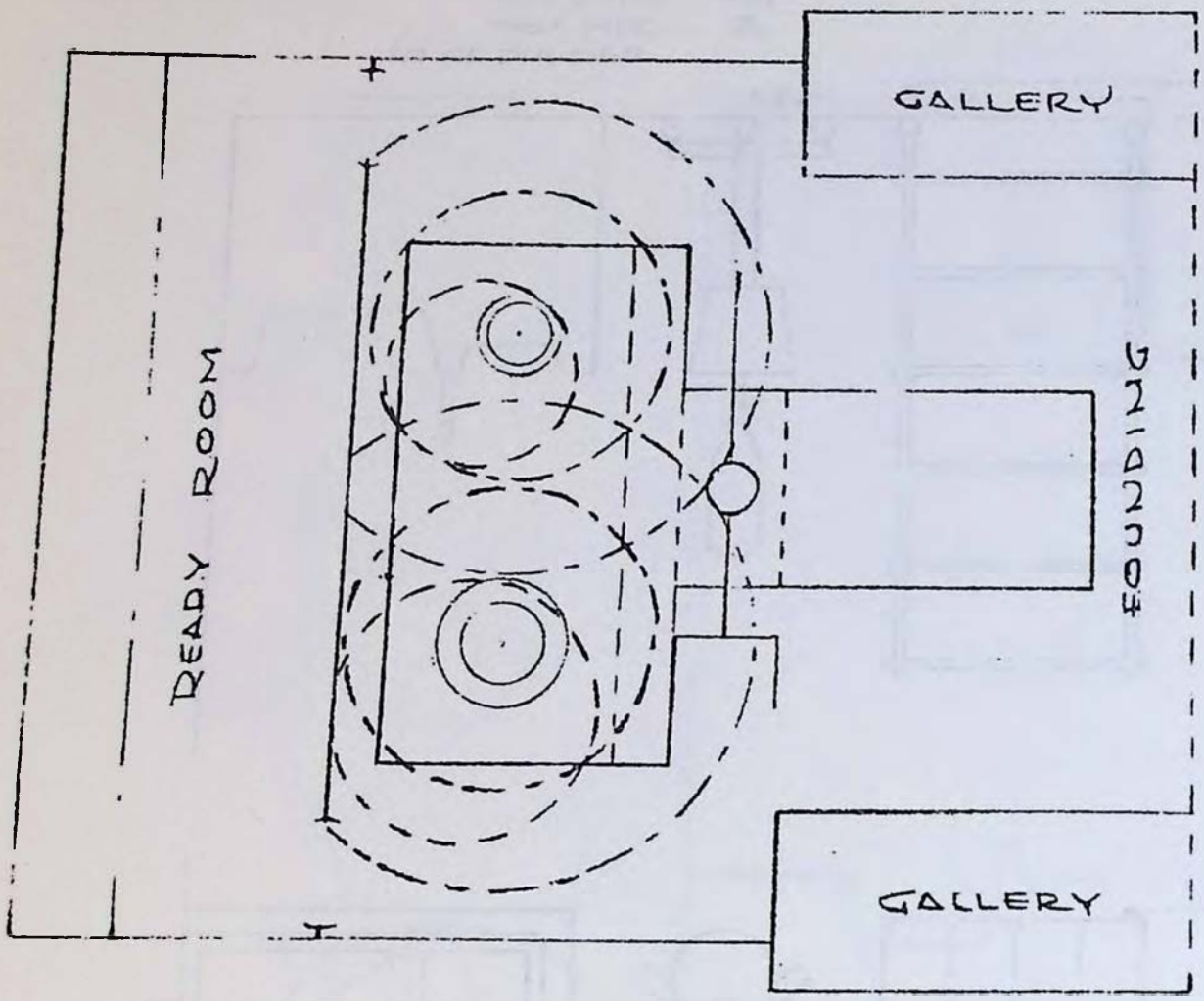


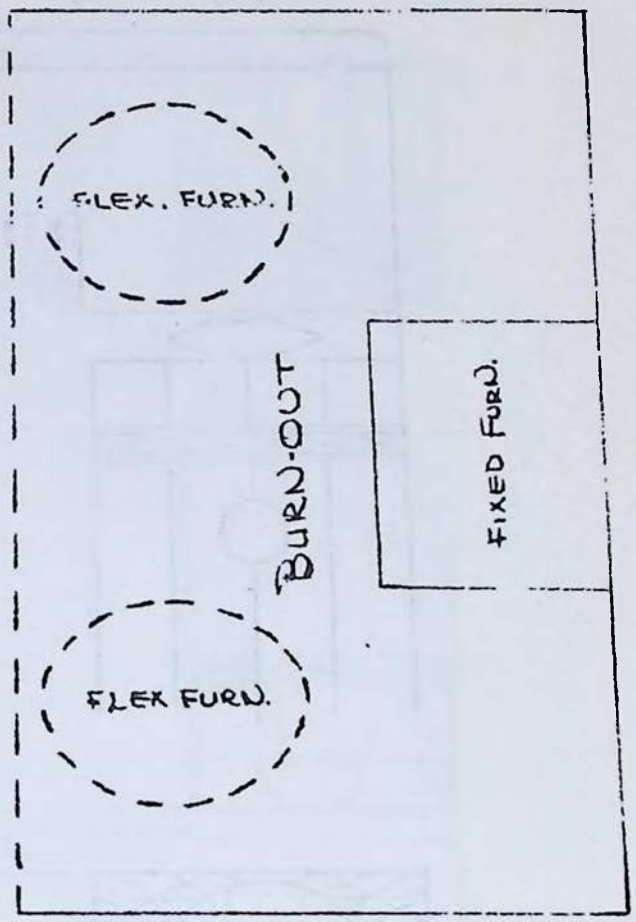
TO BE DIVIDED
DRY MIX - 5'
WET MIX - 10'

SCALE: ½" = 1'

SCULP. FOUNDRY 64

BURN OUT & FOUNDING

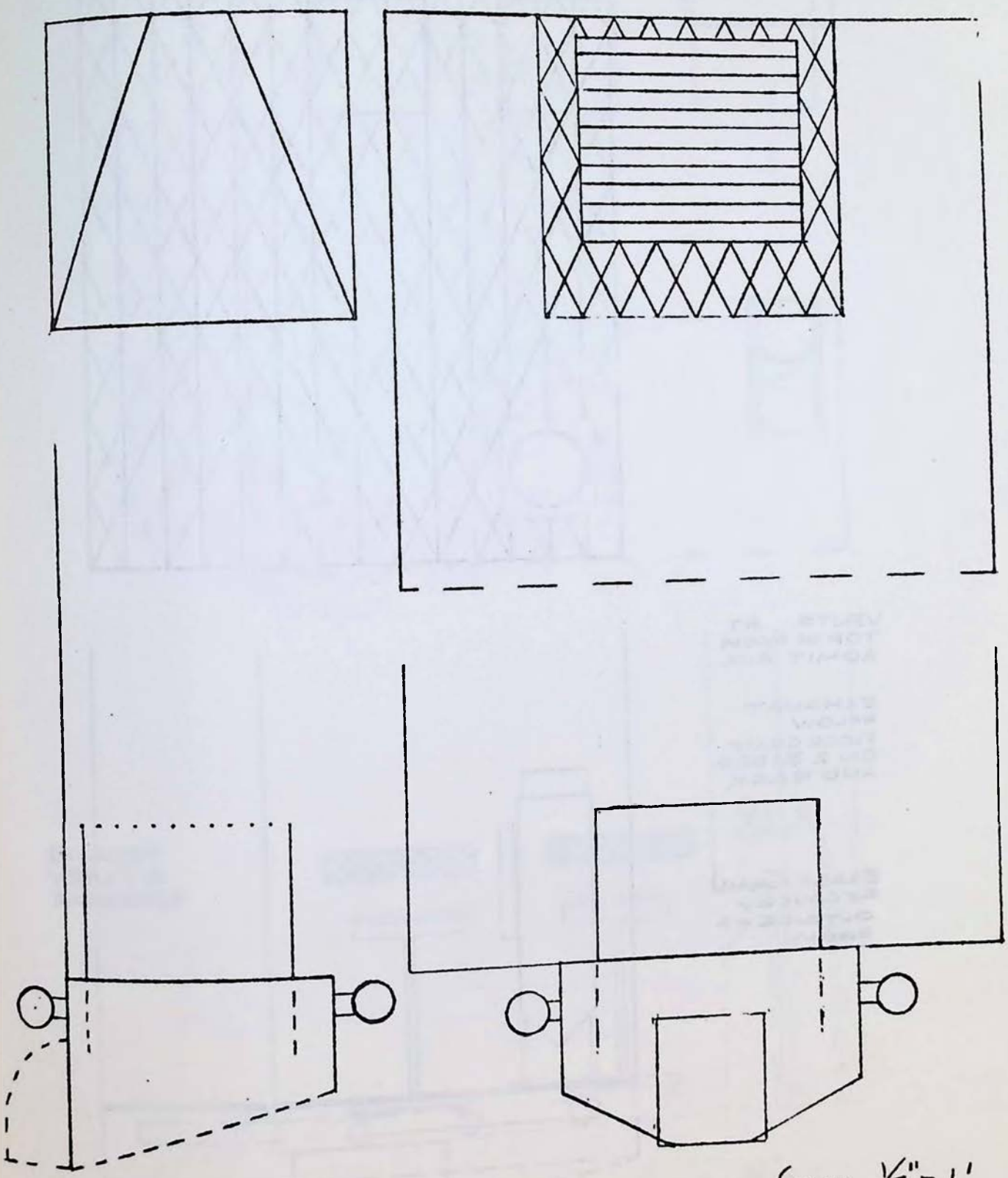




SCALE 1/4" = 1'

SCULP. FOUNDRY 64

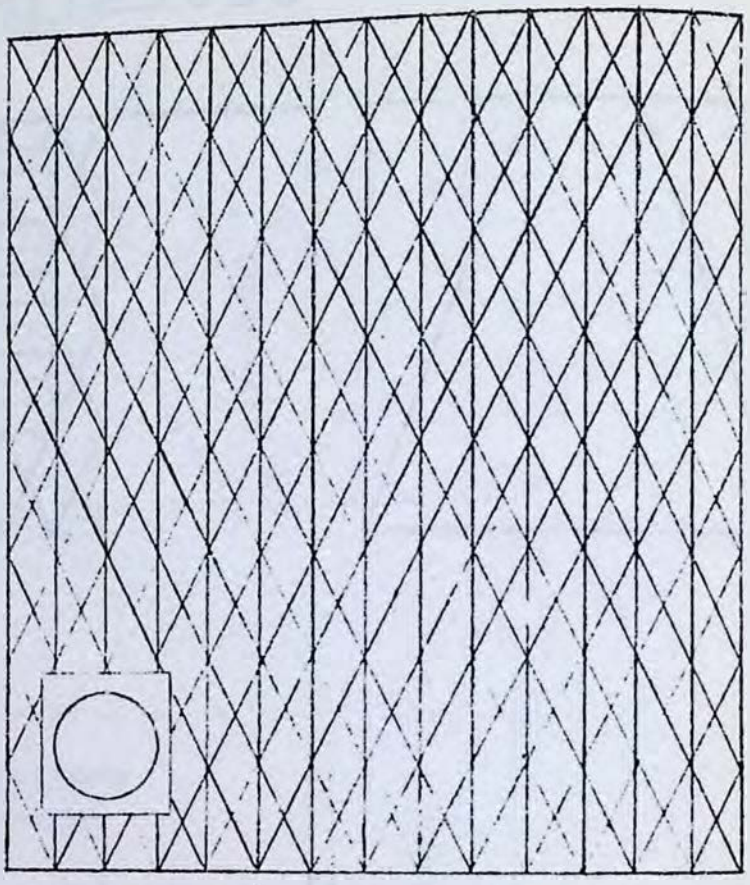
DEVESTING



SCALE 1/2" = 1'

SCULP. FOUNDRY 64

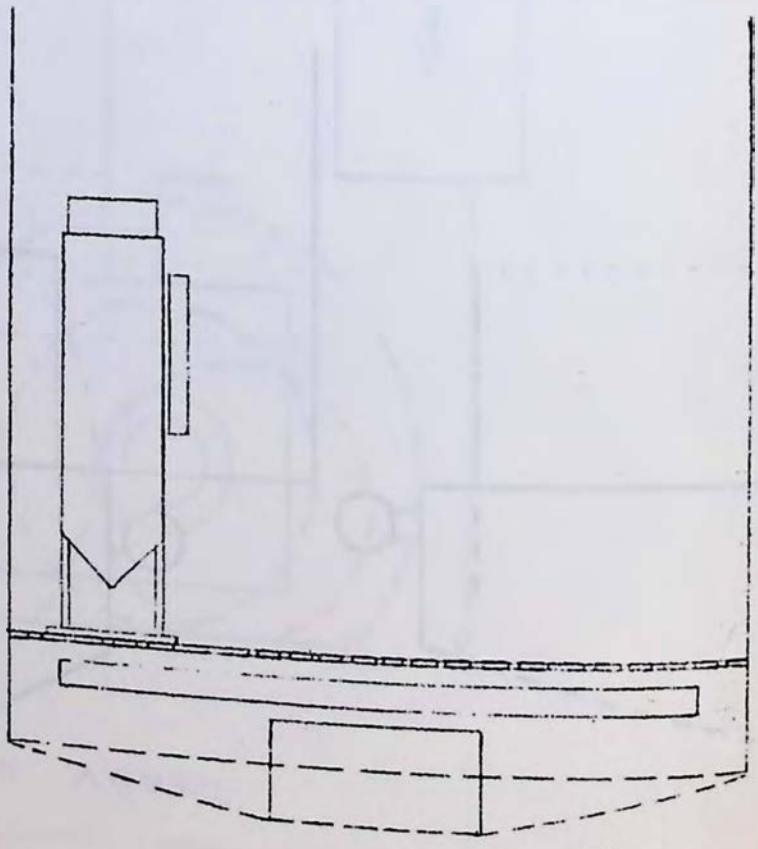
SAND BLAST



VENTS AT TOP OF ROOM ADMIT AIR

EXHAUST BELOW FLOOR GRATE ON 2 SIDES AND BACK

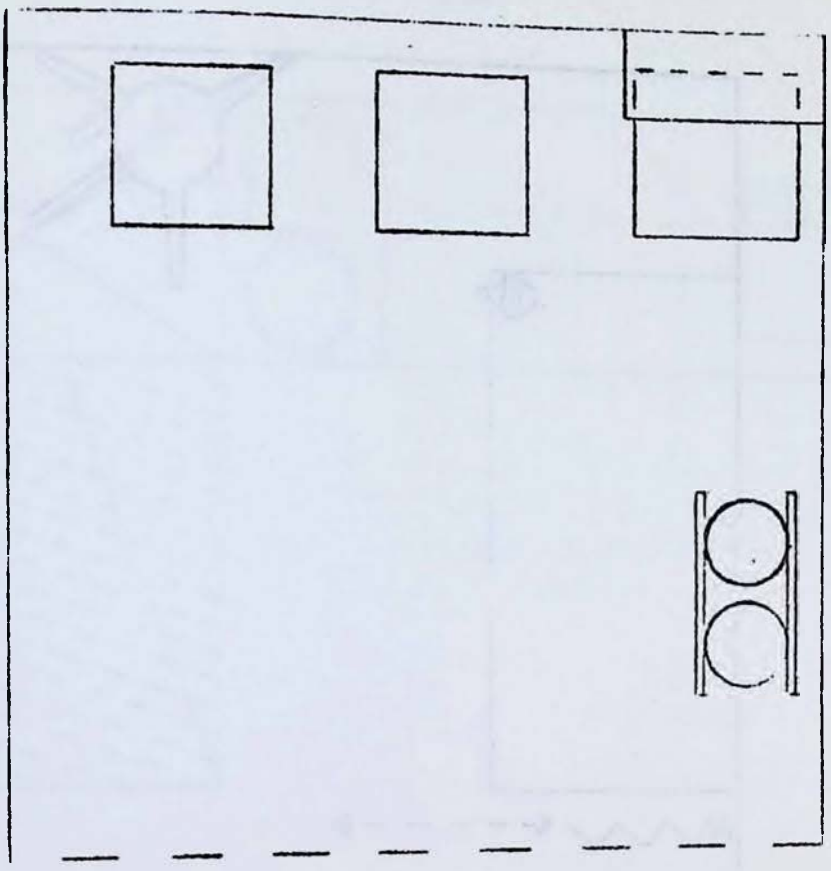
BLAST GRAIN RECOVERY OUTSIDE OF ROOM.

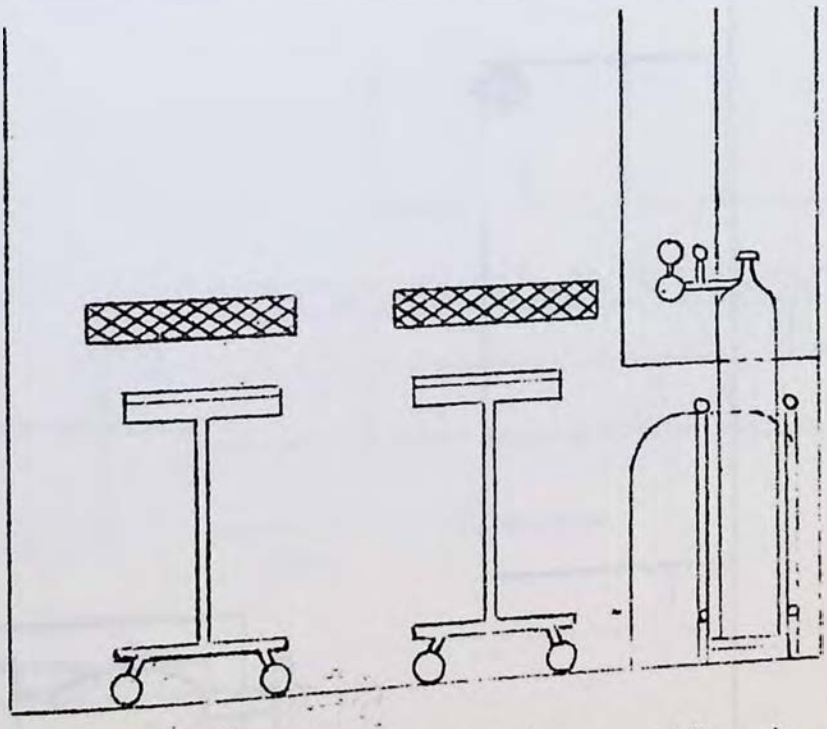


SCALE ½" = 1'

SCULP FOUNDRY GA

WELDING



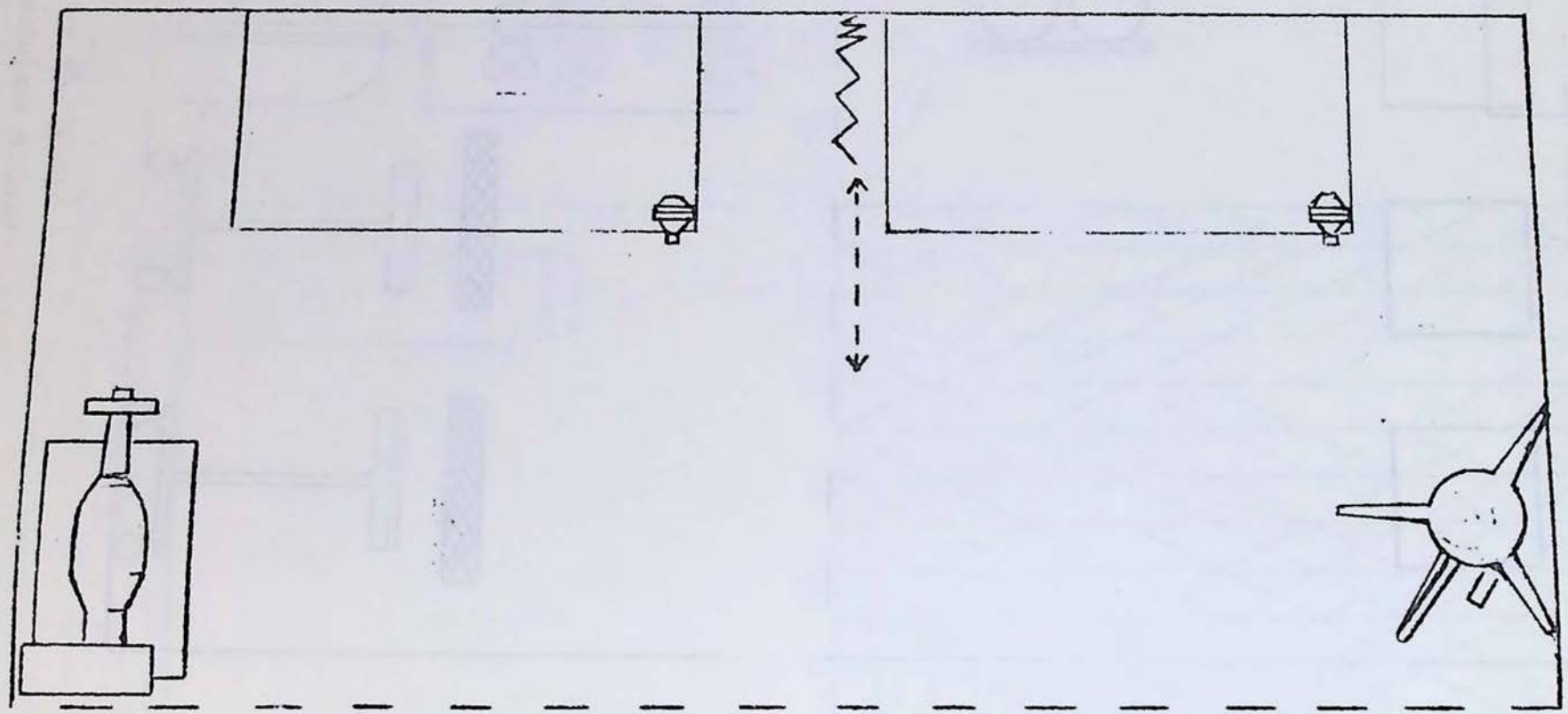


EXHAUST VENTS ADJUSTABLE

SCALE ½" = 1'

SCULP. FOUNDRY G4

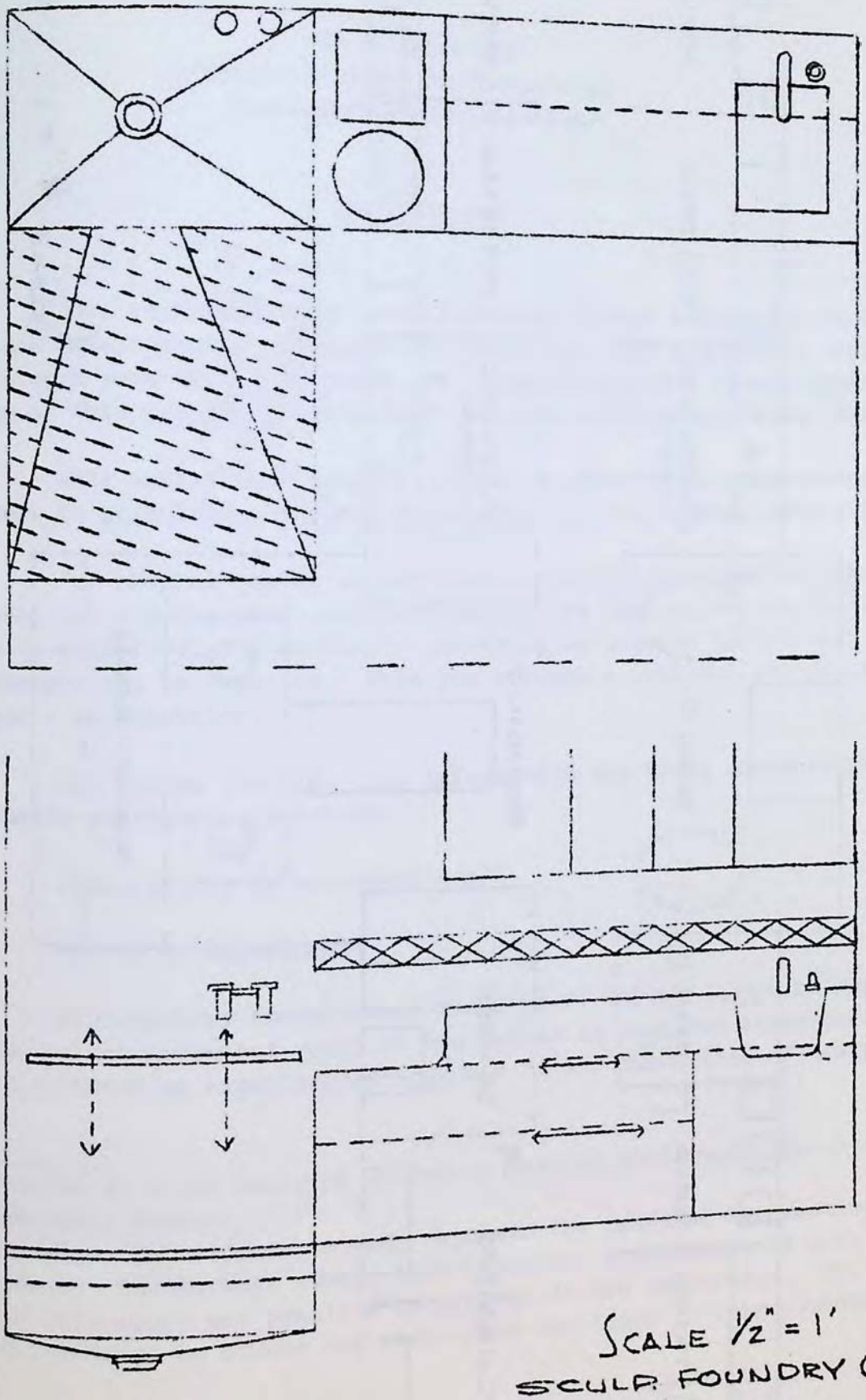
CHASING



SCALE 1/2" = 1'

SCULP FOUNDRY G4

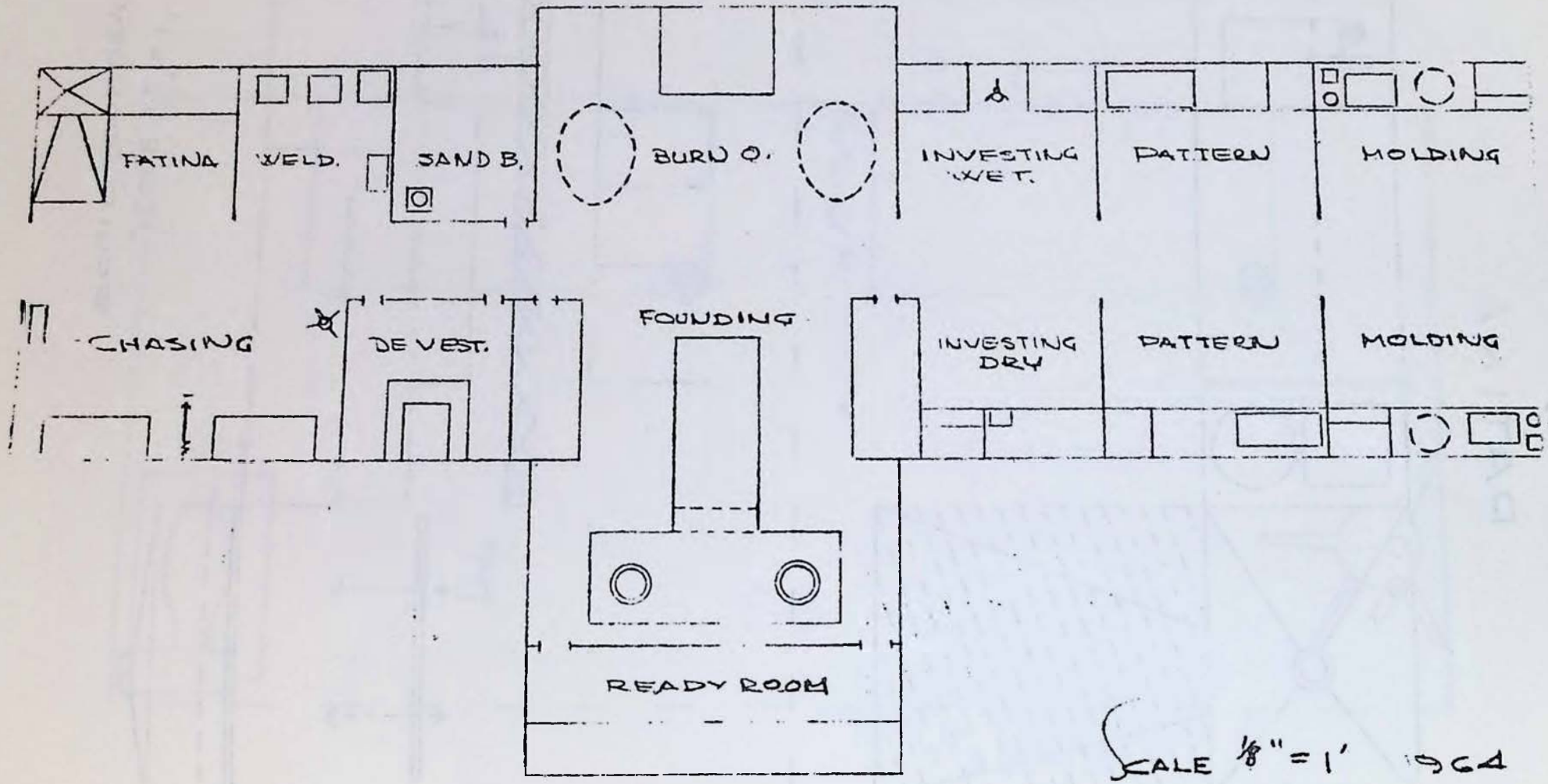
PATINA



SCALE 1/2" = 1'

SCULP. FOUNDRY G4

SCULPTURE FOUNDRY LAYOUT



SCALE 1/8" = 1' 1964

UNCONVENTIONAL AND EXPERIMENTAL SCULPTURE CASTING*

by

H. M. Gadberry
Senior Advisor for Technology
Midwest Research Institute

INTRODUCTION

This report on experimental casting brings together a variety of sculpture developments and activities since the last conference, and also touches upon some exciting trends and possibilities for future experimentation. The aim of this potpourri is to draw out discussion from all the conferees.

Many artists and industry men have contributed information, slides and ideas to stimulate our final colloquy. I want to thank them all personally.

For several months we have been collecting information about unconventional and experimental sculpture activities throughout the United States and in several foreign countries. One thing we learned for certain is that more changes can be expected. When you scratch a sculptor, you uncover an inventor - an innovator.

All during the time this information was being assembled two questions continually presented themselves:

What exactly is unconventional?

Why do we experiment?

Satisfactory answers were found about why we engage in experimental casting, but no agreement could be reached as to what was unconventional, or what constituted an experimental approach to the production of sculpture.

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* Presented at Third National Sculpture Casting Conference, March 28, 1964, Lawrence, Kansas.

Authors note: In response to many requests for detailed information and references for further study, this paper has been annotated with footnotes and references not possible to present at the conference. The author will attempt to answer any additional questions in correspondence.

The trouble with a word like "unconventional" is that the existing sculptural conventions are fairly elusive. The very fact that sculptors are continually experimenting progressively changes our notion of the "standard process" for the production of cast metal sculpture.

Let us, therefore, take as our point of departure, that the process of modeling a work in a plastic medium, replication in wax, proper spruing and venting, investment in a solid refractory body, followed by wax burnout, and metal casting represents the standard sculptural process. Thus, any substantial modification, change or elimination of these steps constitutes an essay into experimental technique. The real key to "unconventional" actually lies more with the artist's intentions than with his techniques.

Examining the question -- "Why do we bother to experiment?" -- is more productive. Grant at the outset that the standard lost wax process will permit us to cast anything that we desire. Why look for new methods?

Reasons cited by sculptors for their experimentation all seem to fall into two general classes -- artistic reasons -- and practical reasons.

Among the more important artistic reasons are:

- To allow more direct work by the artist, that is, closer to finished casting.
- To add new expressiveness to their vocabularies.
- To experience the excitement of exploiting new materials, textures and effects.
- To permit making large or complex pieces with minimum compromise in the design.
- To permit the artist to spend more time on creation and less on the casting craft.

Equally important are the purely practical reasons cited:

- To simplify the technical process of casting sculpture.
- To minimize the handling of heavy investments so that larger pieces can be cast in a given foundry.

- To shorten the time required for casting, thus increasing productivity (or allowing students to complete more pieces).

- To minimize spruing and venting and to eliminate chasing as much as possible.

- To utilize existing foundry facilities or commercial foundries for production of sculptural castings.

All of these seem to be valid and satisfactory reasons for departing from the classic methods of Cellini. Among the examples that follow we can see the ways in which sculptors have approached these various aims.

I suspect, however, that none of these logical reasons is as powerful a motivation as the one pointed out by an earlier speaker-- that sculptors are a contrary lot, and "Mother, they'd rather do it themselves!"

I. SCULPTURAL USES OF PLASTIC FOAM

Recent developments and modifications in the foam vaporization casting technique continue to claim attention in experimental casting. Perhaps the most significant development in this field since the 1962 Casting Conference has not been in the art field at all, but in industry. The growing industrial acceptance of the "Full-Mould" casting process is certain to be of great significance to the sculptor. You are familiar with the history of the process -- starting with the Shroyer[1] experiments in the middle '50's; the development work of Duca, Flemings and Taylor[2,3] at M.I.T., and the eventual acceptance by sculptors of the CO_2-sand process for the direct casting of styrofoam sculpture through foam vaporization. It took, however, the energy and persuasiveness of Professor Wittmosser[4,5] of the Department of Foundry Science at the Institute of Technology, Aachen, Germany, to obtain serious consideration of the process by commercial foundrymen.

I vividly recall my first experiences with the process in 1959 when foam casting was truly considered experimental. It was difficult to get details of working techniques. We had to work out our own techniques for gating, risering and surfacing the styrofoam. And when we discussed foam with commercial foundrymen or suppliers, the situation got even worse. There was a tendency to treat foam casting as a freak or a joke not worthy of serious consideration by the foundry trade.

That situation is certainly due to change. Professor Wittmosser has persuaded many European foundries to use the technique on large castings. The Full-Mould process was introduced at last year's British foundrymen's society meeting and was "a bit of a nine-day wonder." The Pressed Steel Company is busy licensing the Full-Mould process; according to Professor Wittmosser, over 15,000 tons of steel were cast last year by the Full-Mould process. Running true to form, American foundries adopted the process after it had been thoroughly tested in Europe, and the largest single casting by this process, totaling over 15 tons, has been poured by one of the three Detroit licensees.

The principal applications thus far have been primarily limited to "one-off" castings used in automotive tooling and stamping dies. But foundrymen now view the process as attractive for limited run production where the cost of patterns and complex core boxes would greatly increase the cost. There is also a great deal of interest in adapting the foam process to production casting using expanded polystyrene beads to form the expendable pattern.

Another significant development is the use of spherical blind risers for conventional foundry casting.[6] Foundrymen have long realized that the best shape for a blind riser was a modified sphere. This shape combines maximum volume with minimum surface area. Blind spherical risers have not been used to any extent because of the difficulty of pulling them. The German foundry society is promoting a standard for spherical blind risers formed from expanded polystyrene. These can be placed over the pattern in any foundry process and left in place to function as riser and shrink bulb.

What has all this industrial activity got to do with sculpture? Simply that we can expect much more technical information to be forthcoming. Possibly foams better suited for pattern shaping. Improved surface treatments. Better refractory washes for foam, and investment sands with greater flowability more suited for polystyrene pattern packing. I am looking forward to the time when I can take a polystyrene piece to a commercial foundry and have it accepted for casting with no more comment than if it were a wooden pattern or a match plate.

In the meantime, all around the world, foam casting continues to influence the shape and appearance of sculptural design. For example, in Suffolk, Geoffrey Clarke continues his work with very large architectural sculptures. Here we see the artist at work in his Bury St. Edmunds studio.

This slide shows the 35 ft. high sculpture in cast aluminum which stands outside the new Physics Block at Kings College, Newcastle.[7] Geoffrey Clarke describes his idea as an organic foil to the deliberate austerity of the facade of the Physics Building and says that it is an abstract derived "from the idea of swirling nebula, the burning concentrations of gaseous matter

in space." The piece has a metallized steel frame to which the aluminum castings are bolted. Over two tons of aluminum supplied by Alcan was used for the pouring. This piece may be the largest foam vaporization sculpture casting on public display.

Looking at this work it is obvious that the methods and materials used in foam casting strongly interact with the sculptor in shaping his ideas and contributing to the expressiveness of the finished work. Try as I might I cannot conceive of anyone starting out to do a piece like this by the lost-wax method. If they did, it would probably end up looking considerably different. It can be argued that a sculptural piece should communicate only the original intention of the artist; and that the methods, techniques, and materials employed should not show up. Nonetheless, this very exciting major piece to me says "foam" just as clearly as it says "modern physics."

I had assumed that all the endless variations of foam casting were too well known to require comment. However, a brief recapitulation of recommended practices[2] may be in order. These are the rules-- you'll need to know them so that you can go into your foundry and ruthlessly break every one of them.

1. Give the foam whatever surface you wish.*
2. Apply a good refractory mold wash on the pattern.[8]
3. Vent the sand well either with rods or textile venting.[9]
4. Use blind risers.
5. Feed from the bottom; let the metal rise. Pour quickly.
6. Don't just <u>partially</u> burn or melt out the exposed foam.

* * * * *

Jacques Schnier uses thin foam as a veneer over fabricated sand core armatures. The foam is surfaced lightly with wax,** invested in Petro-bond sand and cast.

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* Specimens of aluminum cast from surface treated styrofoam were exhibited. a) Wax surfaced foam, b) tissue paper surfaced foam, and c) commercial expanded "bead-board" packaging. Test specimens cast March 21, 1964, by Don Galbreath of Grandview Manufacturing Company.

** Both brushed-on melted wax and a paste composed of wax in deodorized kerosene (charcoal igniter fluid) that can be spatulated onto the underside of foam surfaces.

You can see the versatility and close control of this method in the next work. By using core block windows and surface detail, Professor Schnier creates "More He Heard, Less He Spoke."

Here we see the start of a composition. After a few design changes, the foam is applied. Through Petro-bond casting we have "The Space Observatory." Another work --"The Watch Tower."

For those who work with smaller more delicate pieces the raw, rough surface texture of styrofoam continues to be a problem. Various workers have partially solved this problem by the judicious application of wax, Glad-Wrap, or thin tissue paper dipped in diluted polyvinylacetate glue and applied like gold leaf -- plus endless other variations and combinations of surfacing treatments including burlap, feathers and gravel.

One of the most interesting new variants comes from two Berkeley graduate students. The surface is first developed in aluminum foil and a foam backing applied. This permits casting thin sections with excellent surface detail. In this technique, the composition (which is usually of a relief nature) is developed in thin aluminum foil. The back surface of the foil is sprayed with a binder, and pre-expanded styrene beads are sprinkled on the surface. This process is repeated until a layer of foam pellets is built up 1/4 in. or more in thickness. The pattern is then packed in sand and cast. Further experiments are planned using thin brass or bronze foil for castings in bronze. If both sides of the design are important, the back is also covered with thin foil. This method is contrary to the theory of foam casting, but it has been quite successful.

II. URETHANE FOAM

The use of polyurethane foam has come into much wider acceptance for sculptural purposes within the past two years. At the University of Manchester, considerable casting has been done using polyurethane foams of 2 lb/cu ft density. These low density urethane foams have much finer pores than styrofoam; and urethane foam cuts, sands, and shapes better with sharp-edged tools than does styrofoam. Urethane is not sensitive to solvents and can be glued with solvent-based adhesives, but is slightly harder to work with hot wire cutters or hot tipped tools.

Foamed urethanes are obtainable in densities ranging from 1.5 to nearly 15 lb/cu ft. The higher density foams, say 6-10 lb/cu ft densities,

provide an excellent carving medium. Students at the University of Montreal report that 7 lb. urethane foam responds to their carving tools about like balsa wood, but is superior since it has no grain structure to cause splitting. Good carving characteristics and excellent detail can be achieved and the foams respond well to sanding and texturing processes. I have samples of 4 lb. and 10 lb. urethane foam here for those who would like to try their pocket knife on it after the session.

The low density urethane foams cast quite well in bronze, iron and aluminum. Because the foam does not collapse as readily as styrene, a higher pouring temperature is indicated. This, in turn, requires the use of a refractory mold coating to minimize burn-on or metal penetration. The British use a special Kemwell coating which I judge is equivalent to our Terra-Paint 55-M.[10] Others have used the zircon washes such as Mold Coat 30-Z in the same way that it is used over styrofoam.

The principal interest in the urethane foam springs from the fact that it can be foamed and shaped in place.

For those of you not familiar with the process of foaming urethane resins I'll take a moment to demonstrate the foam pouring process. The material used is Cook Paint Company's Corofoam No. 460.[11] The foam is designed to have a 60 sec. foam initiation time which permits thorough mixing before placing the foam into the mold. This timing can be altered somewhat by cooling the foam, heating the mold or other techniques. Many other urethane foams are available in a variety of densities.

One of the limitations of direct styrofoam sculpture has been that the pattern is destroyed with the first casting. If you are interested in replicating a particular sculptural element or in producing editions of your works, the urethane foams may be an answer. Alfred Duca at M.I.T. reports[3] that an unlimited number of reproductions with smooth surface finishes can be made by using a silicone rubber impression and foaming polyurethane into the negative mold. I was unable to discover any sculptor in this part of the country using this process so I have prepared one example of a urethane foam molding. One caution here. If you don't use silicone rubber impression material, excellent separators are needed or the urethane will stick to your rubber molds.[12]

One of the most exciting possibilities in the use of the urethane foams is that they can be sprayed in place onto surfaces. This process known as the spray-up method is used industrially for making insulated tanks and buildings. Here is a sample of sprayed-on urethane applied to a vertical wall surface in four almost uniform coatings of approximately 1/2 in. thickness each. I thought this would be ideal for spraying over hand-built sand cores followed by shaping and surfacing before casting. While this may be possible within a

few years, don't get your hopes up too high yet. The equipment for the proper application of these foams[13] comes very high; $2-3,000 will get you started. Current work on adapting pour-in-place foams for this use is somewhat more encouraging. To anyone interested in this process, the best suggestions that I can offer at the moment are: use long initiation time foams; do not use self-extinguishing grades of foam; chill both components thoroughly; mix quickly but thoroughly and apply as rapidly as possible over a pre-built core which has been warmed to about 135°F. Battens of styrofoam covered with Saran wrap will contain and control the foam thickness. The process is not neat, since it requires mixing several batches in order to cover a large core; and the foam density that is obtained varies. Nonetheless, I intend to explore this further and would welcome any suggestions from those who have experimented with it.

III. DRY SAND INVESTMENT

One of the novel departures which has been developed primarily since we last assembled in 1962 is the area of unbonded sand casting. The history of the dry sand process is somewhat beclouded. As nearly as it can be discovered, the first successful castings of this type were made by Tom Smith, Director of Research for the Maytag Company, Newton, Iowa.[14] The process seems to have been independently and almost simultaneously discovered by Professor Wittmosser in Germany and by Henning Dieter in Austin, Texas. At Maytag, while some prototype aluminum castings were being made by the CO_2-styrofoam process, Tom Smith asked the caster why he needed to use a bonded sand if the styrofoam was going to be left in place? The next step was obvious. They got fine white sand and set to work. Here we see a test plate with the critical surfaces given a smooth finish by the application of Mylar draftsman's tape. After pouring, the surface of the styrofoam is accurately reproduced, and the smooth surface of the Mylar tape minimizes machining. Tom Smith says they have applied for patents on the dry sand process and expect them to issue very shortly. An interesting sidelight is that the patent examiner, in reviewing the application, cited the process as being inoperable. It was necessary for Maytag to make some additional castings and photographs and send them along with their revised application. If the patent office examiner for foundry casting believed that the process would not work, this was convincing evidence that the innovation was not obvious to anyone skilled in the art.

There is a considerable controversy among sculptors as to whether the dry sand process is suitable for art casting. Dale Eldred at Kansas City Art Institute reports failure in 2 out of 3 unbonded sand castings. Jacques Schnier reports that the process is "highly unreliable." Alfred Duca at M.I.T. had a perfect casting on his first attempt and then found it necessary to produce 14 more consecutive casts to satisfy the doubters.[15]

Henning Dieter of Austin, Texas, has probably investigated the process as thoroughly as anyone in this country.[16] He has used styrofoam against a pyrex plate to watch the process when casting with zinc. This slide shows how the dry sand process works. The molten metal advancing into the styrene pattern vaporizes partly-depolymerized styrene out into the sand where it condenses to form a temporary bond. As the metal cools and liberates additional heat, the styrene is driven farther out into the sand. When properly done, the result is a clean casting in an unconsolidated sand with no burn-on, little metal penetration, and no need for "shake out." Thus, for the first time to my knowledge, we have available a process which lends itself to the complete automation of the foundry.

The greatest advantage for the sculptor is the fact that dry sand investment does not need to be rammed or packed. The unbonded sand flows into undercuts and details almost like a liquid. Vibration is a considerable help. This flowability minimizes bending and distortion of thin sections of styrene patterns plus, of course, doing away with the relatively expensive muller, gassing equipment, etc. A second advantage is the lack of chill in unbonded sand. Longer runs are possible in dry sand than in, say, green sand.

The process is ideally suited for aluminum casting since the density of the sand and aluminum is not too dissimilar. Mr. Dieter reports[17] that for bronze casting, it has been necessary to go to a zircon sand which with its higher density helps to minimize sand floating. The principal source of trouble thus far seems to be at the pouring cup and principal sprue. The styrene vapor at the start of the pour goes out the pouring cup, not into the sand. By using a refractory casting cup and a large choked spruing system, washing of the sand can largely be eliminated.

It was with this dry sand process that Geoffrey Clarke cast, in October 1963, the two 30 ft. x 9 ft. sculptural screens for the Guards' Chapel at the Wellington Military Barracks.[18] Each screen was cast in 15 pieces and had a total weight in aluminum of 2 tons. Clarke sent Mr. Dieter a description of this process and the difficulties which he encountered. Two excerpts from Geoffrey Clarke's chronicle are particularly illuminating. "The research into fluid sand casting is really something. I tried it yesterday afternoon . . . Our hearts sank when the first pour took what looked like a pint of sand down the feeder with it. Next pour we introduced a large block of styrofoam at the top. This helped. Finally we used refractory sleeves . . . I think the answer is a greater choke. Will try this today. If this fails, I'm going to try a catch plate at the bottom." - - - and later, "Success at last, on a small scale. Perfect results! Practically no ignition with this long rise polystyrene vapor choke system. We tried 11 different feed systems before it worked, then had four out of five absolutely perfect casts."

In summarizing this relatively new area, I think we can agree that it has certain advantages and certain distinct limitations. We don't know enough about it yet to be able to control it and obtain predictable results. Surely within a few years we will learn the extent to which this new process can be employed for the production of sculpture. Watch for a new process that combines dry pourable sand investment and bonding by CO_2 gassing.[19]

IV. UNCONVENTIONAL METHODS OF PATTERN MAKING

Leaving the area of foams, the various techniques of producing sculpture patterns have received considerable attention in the past few years. I assume that the use of room temperature vulcanizing silicone rubber and the precision agar moulage process are too well known to warrant discussion here.

A. Polysulfide Rubber Molding

The search for the perfect flexible molding compound continues. Recent entries in this field are the Thiokol type polysulfide rubber compounds derived from solid propellant rockets and industrial sealants.

George Kratina has been a principal user of this technique.[20,21]* We have an almost self-explanatory series of slides showing the molding of this heroic-sized "Pioneer." The cold setting polysulfide rubber compounds made by Smooth-On Manufacturing Company were used and Mr. Morse of Smooth-On furnished these photos.

The advantages of polysulfide compounds over latex become particularly important when working with sculpture of this size. Latex shrinkage, which could be tolerated on a smaller piece, becomes quite a serious problem. The polysulfide compounds can be applied directly over clay or plasteline without adverse effect on the rubber compound and without requiring lacquer sealing of the plasteline original.

The front of the flexible mold was made in a single piece. The back was in five separate sections. The mold compounds were sprayed on, using a compressed air gun especially designed to handle these viscous resins.[23] First a coat of FMC-100, a light tan compound, was sprayed directly onto the plasteline. When this layer set, a second coat of black FMC-201 was applied with the gun. A total of four coats were put on, alternating light and dark color compounds. Each layer cured in an hour or less. The deepest undercuts and edges

* A detailed description of mold preparation is given in References 21 and 22.

of the seams were filled with a putty-like mixture of the rubber thickened with Cab-O-Sil, a thixotropic agent and containing chopped compound batches that had already cured. Another layer of the light tan mold compound was sprayed over the entire figure and fabric reinforcing was embedded in the compound and covered with a final coat to prevent the plaster case from adhering to the fabric. The plaster jacket was cast over the rubber mold and reinforced by steel rods and pipes. Strategically placed holes were left in the jacket to permit blowing compressed air between the rubber mold and the plaster jacket to assist in separating the two. The jacket is pulled. The flexible mold rolls off, and the Pioneer has been skinned. Back into the plaster case -- the molding job is done. The finished piece was commissioned for the Pioneer Bank of Chattanooga, Tennessee.

B. Roll-Off Plaster Molds

Those who knew Vic Timmerman during his stay at the University of Kansas have probably been introduced to the plaster roll-off mold. This process, originated by Poco Frazer many years ago, so impressed Vic that he has indoctrinated many others who are equally delighted with the technique. This is an elegant, thin-wall version of the plaster waste mold and can be particularly recommended for producing large pieces with deep undercuts. The process uses only small amounts of plaster, and one person can handle quite large molds.

When Jim Clover went to Tulane he developed the technique further and has used it to cast many large pieces, plus teaching it in his classes. In essence the plaster roll-off technique works best over a piece modeled in water clay. The piece is usually shimmed into only two sections. Then the thinnest possible coat of a strong hard gypsum plaster such as art casting plaster is splashed or sprayed onto the surface, and squares of burlap are dipped in thin plaster and applied as a reinforcing patchwork all over the surface of the piece. The edges near the shims are reinforced with sisal rope or twisted burlap to provide strength. The case can be strengthened with bent Copper tube or lead pipe held with plaster ties. When cured the piece is sliced in two and most of the clay scooped out. The remaining clay is washed out gently with streams of water, and the wax is then painted or slush cast in the mold halves. The wax coated shell mold is next immersed in cold water until the plaster is thoroughly soaked. Then, starting at one edge, the mold is rolled off the wax like the skin off a rabbit. If care has been used to keep the thickness of the mold under 1/4 in. and to overlap the burlap sections, the mold can be stripped off over the contour of deeply recessed portions with no difficulty.

C. Wax Steam-Out Process

Also from the New Orleans area, Gary Freeman sends additional details on the wax steam-out process. We heard something about this process from Jules Strupeck and Mr. Leach four years ago. Since that time, the process has been thoroughly tested out at Newcomb. Between Jim Clover and Gary Freeman they have cast well over 100 pieces of all sizes; and Strupeck is teaching it successfully to girls in his advanced classes.

Steam dewaxing and lining the investment with a uniform wax shell offers great advantages to those who work in direct wax.

The wax piece encased in a partial investment is placed on a grate in a container over water, and the unit is heated by a gas burner. Exposure to steam for a relatively brief period dewaxes the piece quite thoroughly. After the investment has cooled to room temperature, it can be shelled by slushing with wax to a uniform thickness of 3/16 to 1/4 in.

The most interesting variation involves Freeman's use of core pins. He employs wooden boat building nails made of bronze. These nails are closely ribbed which helps them to stay in the wall of a cast bronze if you wish to snip them off and chase the pin in place. The chief innovation lies in applying the core pins from the inside after the wax shell has been achieved. In this process the nails are pushed point first through the wax until they just touch the surface of the investment shell. By using many nail points at the correct places, the core is adequately supported just as Chapplets and other core supports are used in steel casting. Sometimes a combination of through pins and surface pins are employed. The major advantage of the surface pins is that it leaves almost nothing to be chased off the cast surface.

D. Foam as a Transitional Armature or Core

A number of sculptors report use of foam as a working armature or core. The following slides show Professor Schnier's use of this technique. The core is shaped in styrofoam and then coated with about 1/4 in. of wax. One way is to melt wax on the surface of a pan of water and repeatedly dip the foam through the wax.[3] After detailing the wax surface, the foam is removed by using acetone or perchloroethylene. The wax shell is then gated, sprued, invested and cast in a "conventional" manner. The "Little Space Prober" is also produced using a temporary foam armature.

A more dramatic use of foam as an armature is represented by the recent work of Nick Koolis assisted by Dale Eldred at Kansas City Art Institute. In this case a large figure was built in wax and cloth, over the styrofoam core. Core pins were inserted and a hand-built, chicken wire reinforced investment applied over the entire outer surface. Then came the moment of truth! With the piece supported over a catch basin, the styrofoam core was set on fire. As it burned, most of the wax and all of the rags dropped out into the catch basin. The final dewaxing was accomplished with steam followed by slush-waxing, coring, burn-out and casting.

E. Vacuum Thermo-Formed Plastic Patterns

The final pattern-making technique has not been used so far as I know for sculpture but is being applied for precision wind tunnel models and thin-walled industrial castings.[24] Briefly the process involves using sheet plastic fashioned by the thermoforming process over the original model. Once the pattern has been formed, it is treated just like wax in the investment casting process. The following slides from NASA s Ames Aeronautical Laboratory show the casting of beryllium bronze wind tunnel models with walls only 0.010 in. thick. The special advantages of the process are simplicity, directness and the extremely smooth as-cast surface of the piece. I have here several pieces that have been cast in beryllium bronze by this technique.

Now that thermoforming machines of large size are available, there is no reason why this technique cannot be applied to making molds over clay or plasteline originals, after which the thin plastic can be lined with wax and handled in a conventional manner.

This plastic replica of a rat was prepared by pinning the body on a wooden block, freezing the rat and vacuum thermoforming sheet plastic over the frozen body. The plastic has captured every whisker and the scales on the tail.

V. WAX PATTERNS IN BONDED SAND MOLDS

Direct investment of wax patterns in bonded sand molds is being employed by a number of sculptors. Some are using CO_2 sand which provides great porosity and permits baking out the wax at higher temperatures.[3] Others are using furfuryl alcohol bonded sands capable of finer detail and having much greater flowability than CO_2 sands.

At Berkeley Jacques Schnier builds wax over sand cores and invests in CO_2 sand. The cores are pre-treated with refractory mold wash to minimize the absorption of wax. A treatment with polyvinyl alcohol solution can be used in a similar way; it is highly resistant to oils and waxes. Melt-out is accomplished at 400°F for 18 hr. Cores are held in place with bronze pins.

A novel variation uses Foamglas as the core. The grooved channels are to aid the flow of the metal. Since Foamglas has closed cells it cannot absorb any wax. However, glass foam cannot withstand bronze or iron casting temperatures. Core pins are of aluminum; and wax melt-out from CO_2 sand is performed in the oven at 400°F. Here is the finished hollow aluminum piece.

While I have had good results using wax in CO_2 sand on small pieces, I'm afraid to trust it on larger works. Somehow I'm uneasy with a pouring ladle full of bronze-- and a mold that I know has 9 lb. of wax absorbed in it somewhere. Tell us-- what results have you had with wax in sand?

It is for this reason that we have just started some work with furfuryl alcohol bonded sand and solvent vapor dewaxing. Small wax test patterns have been satisfactorily tucked in furfuryl sand and a good bond obtained with the gentlest possible hand packing. Dewaxing has been accomplished with perchlorethylene vapor in a homemade vapor degreaser formed from a 55 gallon drum. With these small samples, dewaxing has been completed in about 1 hr. The mold is then placed in a circulating oven which is vented to the outside air and dried of all perchlorethylene vapor. No castings have been made yet, and I would like to hear from anyone who has had experience with the hot solvent dewaxing process.

VI. METALS AND ALLOYS

Newer metals and alloys are being exploited by many sculptors either for their intrinsic properties or for casting expediencies which they contribute.

Experimental casting in ductile iron is going on in Alabama, Georgia, Ohio, Pennsylvania -- wherever ductile iron is being used industrially.[3] I know of no sculptor who produces his own ductile iron, even though the magnesium sandwich ladle process could be adapted to almost any cupola.

Low melting alloys seem to be enjoying a resurgence. Mr. Leiserowitz at Iowa City has developed a complete system for zinc and zinc alloy casting.[25]

This permits setting up a zinc foundry for less than $100 including 150 lb. capacity furnace and burn-out oven. Using specially sprued and vented plaster molds, Leiserowitz has obtained castings of excellent detail.

The attractive combination of low initial investment; fast, simple molding and pouring; and the use of a permanent metal costing about $.10 per pound is hard to resist.

Similarly, sculptors from Montreal report excellent results casting in Zamac and Kirksite. Zamac No. 2 in particular looks promising. Its physical properties, for instance, excel those of 80-10-10 brass (52,000 psi tensile and 8 per cent elongation). It casts at about 800°F.

Calvin Albert of Pratt Institute has developed further his technique of "spray-casting" in low melting alloys.[26-28] Craft Horizon recently called this technique the only new idea found at the recent cast sculpture show.[29] Professor Albert sent along some slides of his recent efforts.

1. "Torsion" 1962 Spray cast, life size, in lead alloy. Sprayed into mold. Will be exhibited in Albert's 1964 one-man show at the Stable Gallery.

2. Untitled. Relief, 3 x 5 feet. Spray cast in pewter-like alloy. To be exhibited at 1964 one-man show.

3. "Monument in Revolt" Combination technique using Modalloy plus direct casting with spray cast lead alloy.

4. "Attack In The Wind" Direct cast lead alloy, 34 in. high. Exhibited at one-man show, Grace Borgenicht Gallery.

5. "Figure In The Wind" Lead alloy spray, 34 in. high, built up on top of a core. Shown Grace Borgenicht Gallery.

These pieces certainly demonstrate that the technique has possibilities far beyond the limitations generally thought.

Calvin Albert has developed his own metal spray guns because the commercial metallizing guns were not suitable, and were too expensive. Here is the new low cost, Fiore gun[30] useful for spraying alloys melting up to about 600°F. The gun uses an electrically heated "solder-pot" and compressed air spraying. Spraying can only be done in a generally downward direction -- so the gun is conveniently supported from overhead. Alloys such as Cerro-True or Cerro-Cast reproduce the finest detail imaginable.

VII. PATINIZATION OF METALS OTHER THAN BRONZE

The final step in metal sculpture is patinization. With so many alloys in use, patinas are needed for metals other than bronze. Most sculptors seem to agree that the appearance of age or decay is not an essential requirement for a patina. What we want is:

- to pull the surface together;

- to give the piece life and suitable color;

- to passivate the surface and make it stable against change, corrosion and deterioration.

Here are examples of a few recent patina experiments.

Dale Eldred finishes his steel pieces with a zinc coating applied with paint brush or spray. The 3 mil coating is 95 per cent by weight metallic zinc, which protects steel as well as would hot-dip galvanizing. About 12 to 15 years outdoor exposure should be obtained before touch up is needed. The dour color complements the work, and the zinc surface weathers gracefully. If you desire, the metal coating can be burnished by rubbing or brushing with soft wire brushes to give bright zinc highlights.

Jacques Schnier's patina for cast iron gives the "Cenotaph" a somber look of inevitability. Or the ruddy glow of rust also is appropriate on cast iron. In this case it is held in check by proper phosphating. Many iron sculptures in the Kansas City area are protected and finished with Ospho,[32] a rust remover and heavy phosphate treatment.

At the 1962 Casting Conference heated discussion turned on whether aluminum was a "hopeless" metal for the sculptor. It casts well and has other obvious attractions, but the raw surface of aluminum is nearly as bad as that of sandpapered plaster!

One West Coast sculptor is pursuing under a grant, the use of aircraft anodic hardcoat for architectural sculptures in cast aluminum.[33] In its heaviest form, hardcoating probably offers the ultimate in durability and abrasion resistance. Here is a specimen of aluminum, partly hardcoated. A knife or file scratches easily into the aluminum, but slides over the oxide which is as hard as a sapphire. The color is entirely developed by optical interference

within the oxide layer -- there is no dye used. So the color won't fade -- ever -- even when exposed to sunlight.

Where extreme abrasion resistance is not necessary, thinner anodic hardcoating gives most attractive colors. Alcoa has provided these examples of their Duranodic 300 process applied to two common casting alloys.[34] Contrary to what was reported at the last conference, the aluminum alloys used in sculpture can be anodized; colors other than the "candy-apple" shades of dyed anodizing can be achieved; and fading is not a problem.

There are now about six hardcoat processes, but they are so new that only a few sculptors will be able to find a local anodizer capable of treating their castings. Cost is a problem too -- about equal to chrome plating.

An opportunity exists to develop simple, low cost, durable, attractive patinas for aluminum castings. Some graduate student could do a fine thesis on this subject. I have been experimenting with conversion coatings, lustre-washes, dyed chemical oxide treatments, zincate dips, antimony and arsenic stains, molybdate blacks and the so-called universal permanganate stains.[35] The last slide shows one of these 356 aluminum works treated with a very brief permanganate stain. By varying the time of treatment, colors ranging from light straw to a deep warm coffee-black have been achieved. The color is due to manganese dioxide in the oxide skin and is not subject to fading. Other colors developed on 356 cast chips are displayed for your examination.

An excellent final sealing treatment for any patina, involves the use of the relatively new thermosetting acrylic coatings intended for finishing architectural aluminum work; a coating far more durable than lacquers, waxes or plastic treatments.[36]

In closing just a few developments you will be hearing more about soon.

- The new Kernwell exothermic crucibles[37] that make possible a complete portable foundry in a suitcase. It's a great teaching and demonstration unit for schools that don't have foundries. And there are times I'd like to melt and pour 20 lb. of bronze in 15 min. just by lighting the fuse.

- The Swedish use of Cellulose ethers[38] to give flowability and plasticity to sands bonded with refractory cements. The oxysulfate in particular looks good-- quite refractory and very cheap.

- The N-process from Japan is like CO_2-sand, but uses no gas.[39] It is too new to tell whether it can be of special advantages to sculptors.

Thank you.

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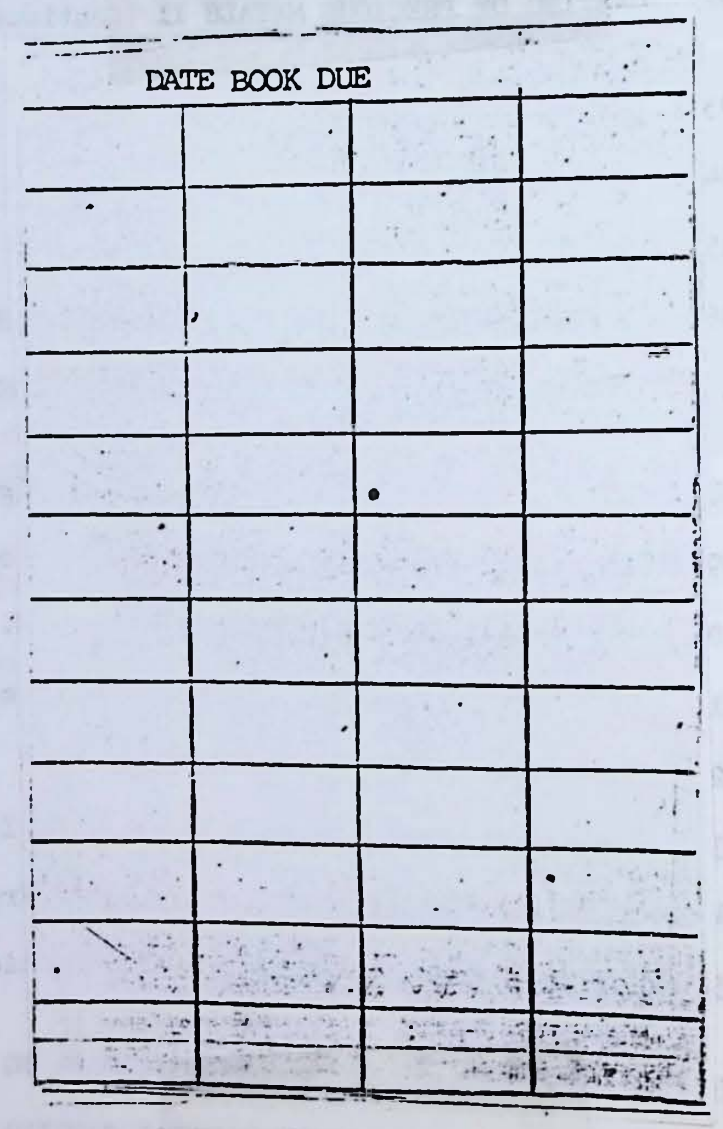
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