The Feasibility of Casting Sculpture in Kirksite

by Lewis Howard Fox

1968

Submitted to the Department of Design and the Faculty of the Graduate School of The University of Kansas in partial fulfillment of the requirements for the degree of Master of Fine Arts.

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B.F.A., University of Texas, 1965
M.A., University of Dallas, 1967

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Elden C Tefft
Instructor in charge

Marjorie Whitney
For the department

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L. H. F.

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CHAPTER I

INTRODUCTION

Kirksite is one of the brand names given to the various zinc die-casting alloys. Kirksite consists of 91 percent zinc, 4 percent aluminum, 4 percent copper, and 1 percent magnesium. It is a bluish-white metal commonly used commercially by the automobile industry in the production of carburetors, grills, and exterior and interior hardware. It is priced to compete favorably with the most common nonferrous casting metals and may be readily obtained throughout the world. Zinc is one of the oldest metals known. The oldest known piece of zinc extant is an idol found in a prehistoric Dacian settlement in Transylvania. This idol was alloyed with lead and had a physical makeup resembling zinkstuhl, a modern zinc alloy.[1]

The ancients probably were unacquainted with zinc; however, in some cases zinc has appeared throughout man's history. In the ruins of Cameros, destroyed 500 B. C., two bracelets found were filled with zinc. In the ruins of Pompeii, destroyed 79 A. D., a fountain partially coated with zinc was discovered.

The Chinese produced zinc as early as 630 A. D., but not until 1820 was the zinc industry well established in Europe. In the United

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[1] H. O. Hofman. The Metallurgy of Zinc and Cadmium. McGraw-Hill Book Company, Inc., New York, pp. 1-3.

States zinc was first produced in 1835.[2] Today the zinc industry plays a major role in the economic, domestic, and military needs throughout the world.

Although kirksite and other zinc die-casting alloys are widely used commercially, little attempt has been made to use these metals in the fine-arts area. This thesis attempts to determine the feasibility of casting sculpture in kirksite.

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[2] C. H. Mathewson. The Metal, Its Alloys and Compounds. Reinhold Publishing Corporation, New York, 1959, p. 4.

CHAPTER II

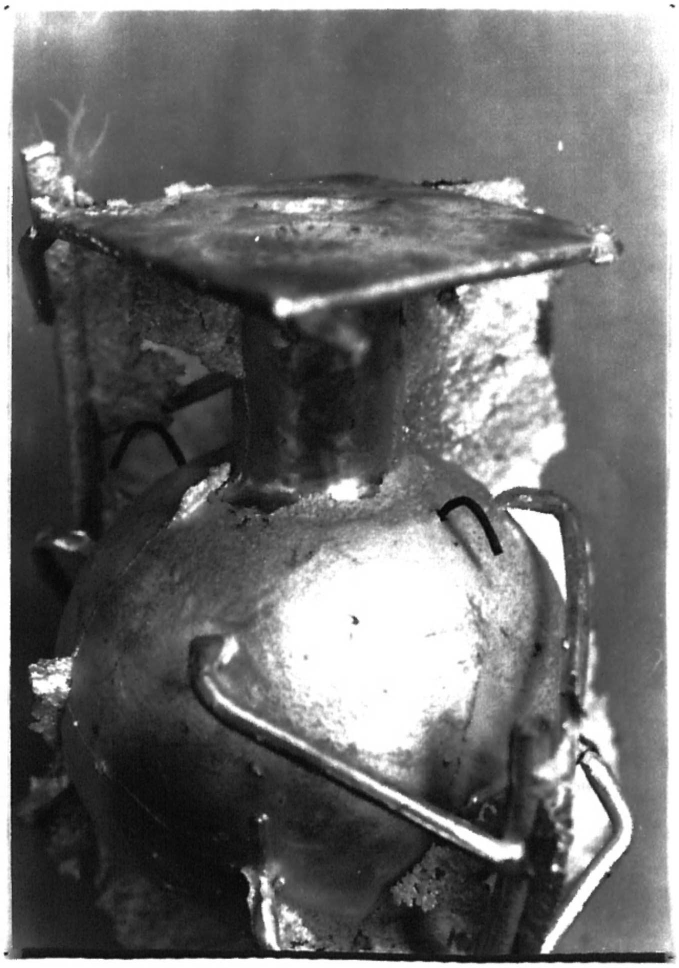
FEASIBILITY OF MULTIPLE POURINGS

Because the sculptor's foundry equipment is generally smaller and not so well equipped as that used commercially, he is forced to solve many problems in economic and original ways. At times he must guess at such things as weight, temperature, and alloy of metal. As a result, often a measurable difference exists in the strength of a cast object made by the sculptor and the same object produced commercially. However, the majority of the sculpture pieces cast in the art foundry are not required to withstand rigorous pressures. Consequently, if the strength safety factor of an art cast object were decreased 10 percent, the safety factor for its required function might still be greater than that of the commercially produced object.

Because the sculptor usually has limited facilities, his problems increase with the size casting he does. Many factors impose limits on the size of the pattern that can be cast. Perhaps the greatest of these factors is the amount of metal that can be melted at one time. Because most casting metals chill rapidly, sections requiring more metal than can be melted at one time with the facilities at hand cannot be poured. Kirksite, in this respect, has a distinct advantage. It has the ability to remain in a molten state for long periods of time. This extended molten period provided the basis for experiments to determine the practicality of multiple pourings.

Experiment 1

In the first experiment, approximately fifteen pounds of kirksite were poured into a thirty-pound pattern. After a fifteen-minute wait, the remaining fifteen pounds were poured. As seen in Photograph 1, the cast was successful; but the transition area between the two pours contained porosity.



PHOTOGRAPH 1

FIFTEEN-MINUTE MULTIPLE-POUR METAL FLASK

In spite of this porosity, the experiment indicated the probability of success when a much larger pattern was poured if the time between pourings remained fifteen minutes or less. Approximately one third of the time is required to melt a crucible of kirksite as to melt the same amount of bronze.[3] If multiple pourings prove feasible, the sculptor could increase the size of his work without expanding his facilities or incurring the problems of joining.

Experiment 2

The second experiment included the construction of a 3/16" (thickness) x 3" (diameter) x 24" (length) cylinder modeled directly in wax and sprued in the traditional indirect feeding pattern. Photograph 2 indicates the design and the spruing pattern.

The cylinder in Photograph 2 was cast in two separate pourings with a fifteen-minute lapse between pourings. In this test the time lapse was held again to fifteen minutes because of the change in the size and the shape of the pattern and the greater area and the heat inside the larger investment. This cast was also successful; however porosity again occurred at the area between the pours (Photograph 3).

The area below the horizontal linear pattern was filled in the first pouring. As the kirksite began to cool, shrinkage also began. Since no shrink feeders were located at this depth on the pattern,

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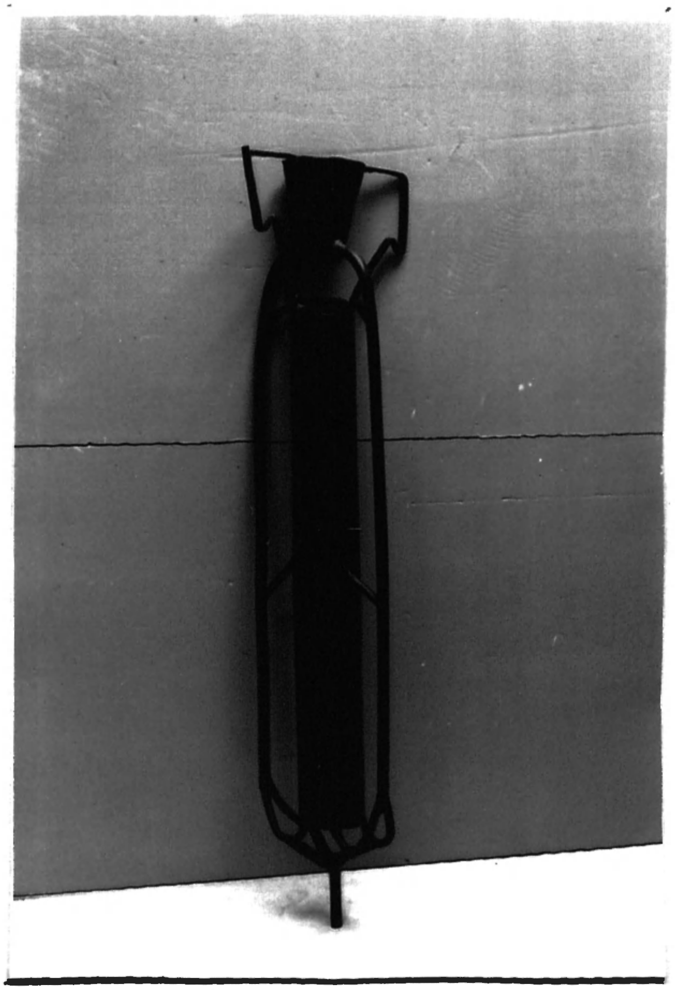
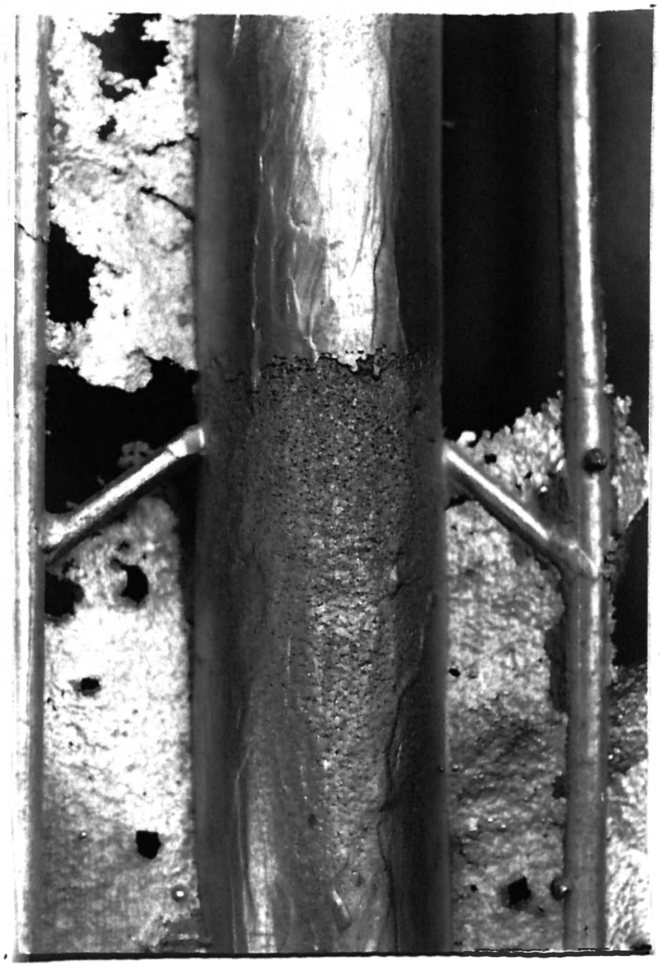
[3] Lewis Howard Fox, Personal Experiments, Foundry at the University of Kansas. The time required to melt a #60 crucible of Kirksite:
First melt, cold furnace--approximately 20 minutes
Second melt, hot furnace--approximately 13 minutes.



PHOTOGRAPH 2

WAX POSITIVE OF FIFTEEN-MINUTE MULTIPLE-POURED CYLINDER

the cooling metal had to deprive the higher parts of the pattern in order to supply the additional metal to compensate for its shrinkage. Note that, although the pattern shows distinct porosity, the spruing system does not. This occurrence can be explained by the difference in the thickness between the pattern and the sprues. In this case the pattern was only 3/16" thick while the main sprues were 5/8" and the lead in runners was 3/8". The thinner metal



PHOTOGRAPH 3

JOINING AREA OF FIFTEEN-MINUTE TEST CYLINDER

naturally cools more rapidly than the thicker metal. The same porosity markings would have appeared on the spruing system if it had cooled longer.

The successful joining of the sprues indicated that multiple pourings would work if (1) the castings were thicker, (2) the time between pourings was decreased, or (3) the mould or the investment was hotter. Increasing measurably the thickness of most casts is impractical because of the added weight, the increased structural pressure, and the additional expense. With the added problems encountered by substantially increasing the temperature of the mould, this method is also impractical. If the investment is taken from the kiln before it has had time to cool properly, cracks will develop in the investment, creating a greater probability of flashing or possible miscast. With kirksite, this problem is especially important because its weight and lengthy molten period usually create additional time for the pressure of the metal to affect the investment. This flashing problem is discussed in greater detail in Chapter III.

The most practical method of correcting this porosity is to decrease the time lapse between pourings; however, unless additional metal can be melted in less than fifteen minutes, this method would also be impractical for castings of this size. A few experiments revealed that the second charge of kirksite melted at a much faster rate than the first one. In the second melt, the furnace was near the temperature it was when the first charge was poured; and the crucible was extremely hot so that full gas and air pressure could be turned on at once.

Experiment 3

The pattern for Experiment 3 was a simply designed form twenty inches long sprued for indirect feeding. This pattern was cast in two pourings with only five minutes' separation between pourings. The cast was successful, and no sign of porosity appeared. Photograph 4

PHOTOGRAPH 4

CAST PATTERN OF FIVE-MINUTE TEST

indicates the design and the method of spruing this test. Because of the complete success with the five-minute delay in Experiment 3, the next step was to determine whether a ten-minute wait could be successful.

Experiment 4

Experiment 4 consisted of a pattern with identical proportions to that in Experiment 3. The cast, completed with a ten-minute lapse between pours, was also a complete success. There was no porosity and no indication of where the two pourings joined. When determining where metals join is impossible, one may reasonably assume that the strength of such a joint is structurally sound. Where some surface disturbance is visible, however, as was the case with the fifteen-minute double pour of Experiment 2, the joining's strength should be questioned. A detailed investigation of this joining problem is discussed in Chapter III.

All tests and experiments conducted apparently indicate that multiple pourings with kirksite are possible and in many situations are very practical. Furnace efficiency and the size of the charge are determining factors; but the tests necessary to determine the practicality of multiple pourings for any specific foundry are simple. The sculptor might simply melt a crucible of kirksite or any of the similar zinc die-casting alloys, pour the metal into ingots, charge the preheated crucible with new metal, and time its melting. If the time required to melt the second charge is ten minutes or less, there should be no question about the success of multiple pouring. If the time is over ten minutes, however, he might consider adjusting one of the following for a casting of this size.

a. Charging the crucible with less metal on the second melt.

b. Charging with smaller pieces of metal because metal in smaller sizes melts at a greater rate than larger ingots.

c. Examining the melting furnace to determine whether it is giving full performance.

A simple thing like the furnace lid's not fitting tightly on the furnace walls can add five or more minutes to a melting time. In larger castings, where the greater mass of the investment retains its heat for longer periods of time, the molten state of kirksite is measurably increased. In such castings, one should be able to fill the pattern in several pours with a lapse of twenty minutes or more between pourings.

In conclusion, multiple pourings are feasible; however, each sculptor must determine whether, and to what extent, multiple pourings are practical in his particular situation.

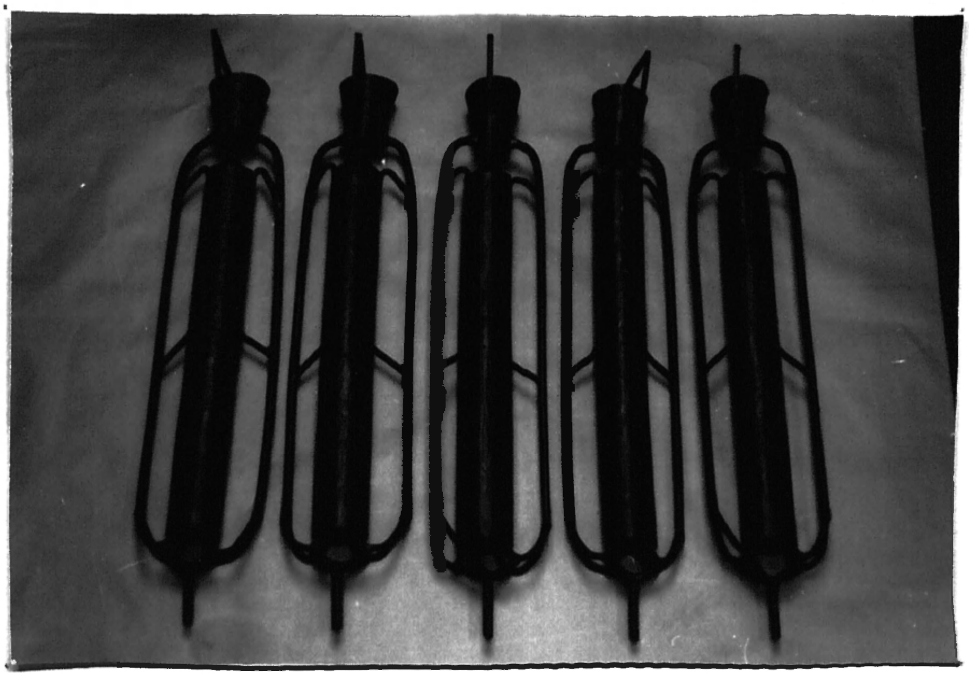
CHAPTER III

STRUCTURAL PROBLEMS OF LARGE CASTINGS

The problems of attaining adequate structural strength increase proportionately with the size of the casting. It would be dangerous to assume that, because a sculpture 3/16" thick and 3' high has adequate structural strength, the same piece scaled upward to 3/16" x 9' would have similar proportionate strength. Because of this change in strength to scale, the following tests were performed. Since lead, aluminum, and bronze are the three metals most commonly used in art casting, they were compared with kirksite. Hopefully, the following tests will help to establish a general rule of thumb to aid the sculptor in determining the proper wall thickness, the best metal, and the most structually sound design for his casting.

Test 1--Construction of Cylinders and Compression Testing

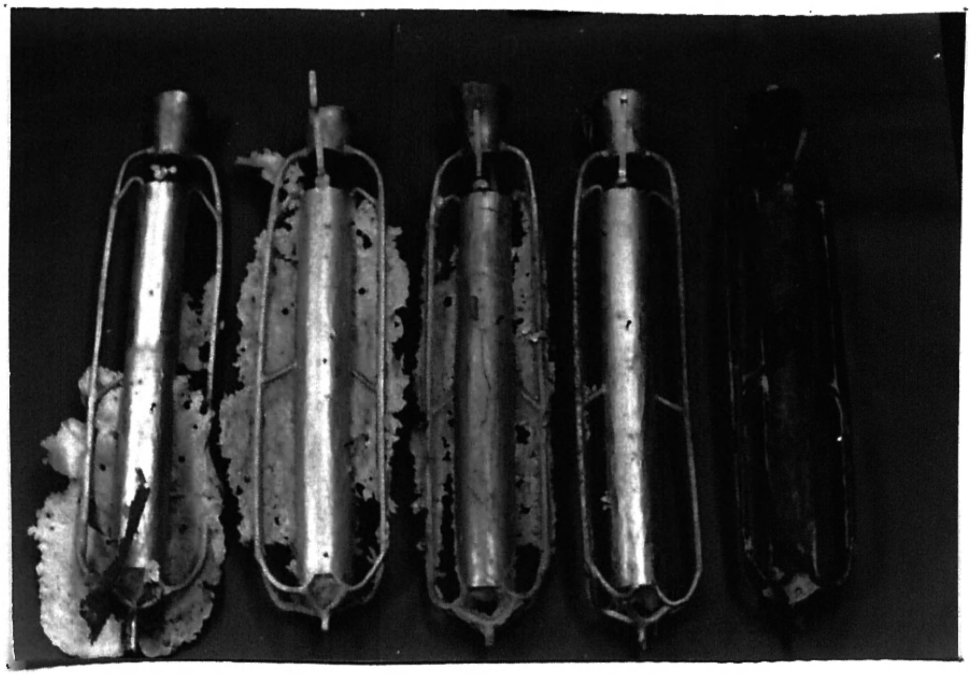
For these tests, five cylinders 3/16" (thickness) x 3" (diameter) x 24" (length) were modeled direct in wax and sprued in the traditional indirect-feeding method. These cylinders were chosen because their design and size could be compared with the lower leg section of a large figurative casting or the supporting section of a large abstract casting. They were designed to undergo cylindrical compression tests to determine the pounds per inch each metal could withstand before the piece collapsed or was deformed. The compression tests were decided upon because a great percentage of the pressure a cast sculpture object must withstand is the continuous downward pressure created by its own weight. Photograph 5 shows the design and the spruing system of the cylinders.



PHOTOGRAPH 5

WAX POSITIVES OF FIVE SPRUED CYLINDERS

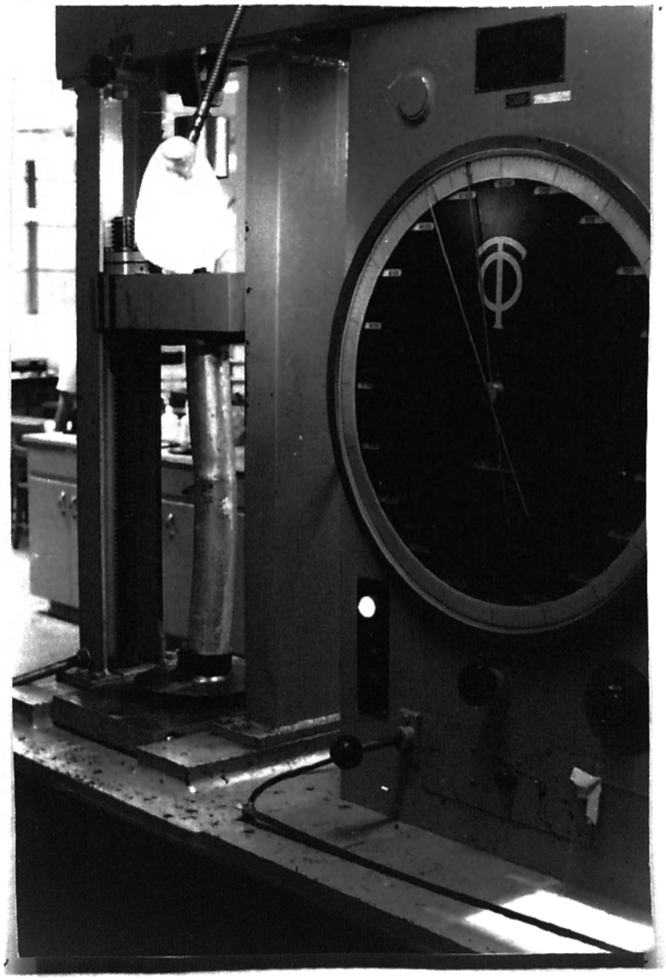
Photograph 6 shows the five cylinders after casting.



PHOTOGRAPH 6

CAST POSITIVES OF FIVE TEST CYLINDERS

The first cylinder on the left in Photograph 6, cast at the same time as the other four cylinders, will be mentioned later in the chapter. The remaining four cylinders from left to right were cast in kirksite, aluminum, lead, and bronze. These cylinders, after being chased and cleaned, were subjected to more than the maximum amount of pressure that their structure would support. Photograph 7 shows the kirksite cylinder as 48,800 pounds of pressure per square inch are being applied.



PHOTOGRAPH 7

KIRKSITE CYLINDER UNDERGOING COMPRESSION TEST

Photograph 8 shows the deformation of the four tested cylinders.

Results of Compression Testing

The results of these tests, combined with additional information, are shown in Table 1 on the next page.

PHOTOGRAPH 8

DEFORMATION OF FOUR TEST CYLINDERS

Table 1

COMPARATIVE RESULTS OF THE COMPRESSION TESTS
(Pounds of pressure per square inch)

	Compression Tests Performed (a)	Column Strength with Dimensional Corrections (b)	Commercial Compression Tests (c)	Projected Column Based on Cylindrical Dimensions (Commercial) (d)
Aluminum	24,750	20,160	22,000	21,270
Bronze	19,000	11,460	11,000	22,800
Lead	5,750	4,880	4,000	4,000
Kirksite	48,800	41,070[a]	93,000	20,430[b]

[a] Personal interviews, experiments, and tests in cooperation with Dr. Robert T. Howard, Professor of Metallurgy and Materials Engineering, University of Kansas.

[b] "Properties and Selection of Metals," Metals Handbook, 1961, I.

Columns (a) and (b) consist of information obtained from personal tests conducted. Column (a) represents the actual readings from the compression test performed. Column (b) represents the column strength with dimensional corrections. These corrections were made to compensate for minor variations from the intended dimensions. Columns (c) and (d) include information gathered from research using commercial readings. Column (c) represents readings from commercial compression tests. Column (d) contains readings from hypothetical columns based on the test columns dimensions but using the commercial readings from column (c).

Kirksite, as seen in Table 1, compared surprisingly well with the three traditional art metals. Its compression strength of 48,800 psi was twice that of aluminum, its nearest competitor. Bronze was next in strength with 19,000 psi, followed by lead's reading of 5,750 psi. Although compression strength is very important, other traits such as density, tensile strength, and brinell hardness must also be taken into consideration. These properties can be seen in Table 2.

Evaluation of Results

The results of this comparison were surprising. Aluminum, because of its inherent low density and high strength, is by far the best metal for casting large-scale sculpture. Bronze, on the other hand, traditionally thought of as the best art metal, ranked low in many of these tests.

Table 2

COMPARATIVE PROPERTIES[a,b]

	Density	Strength to Density	Merit Strength	Tensile Strength	Brinell Hardness
Aluminum	0.1	201,600	6	8-10,000	20-25
Bronze	0.32	35,000	1	30,000	55-65
Lead	0.44	10,980	2/7	2,000	4-6
Kirksite	0.25	164,280	4 5/7	33-35,000	100

[a] Howard. op. cit.

[b] "Properties and Selection of Metals," Metals Handbook, 1961, I.

Bronze ranked third in the compression tests, third in strength to density, third in merit strength, and second in tensile strength and brinell hardness. For these reasons bronze is not a good metal for casting structurally sound works of monumental size. However, bronze does possess many traits that tend to compensate for its relatively poor showing in these tests. It is an unusually pleasing metal to work with because of its malleability, color, and pleasant touch. Because the aesthetic quality of a sculpture is paramount, structural strength is often sacrificed for appearance.

Lead ranked lowest of the four metals, indicating that its use should be primarily for smaller, more intimate castings.

Although kirksite ranked first or second in most of the tests, it does not lend itself favorably to monumental outdoor sculpture. Inherent brittleness, reaction to cold weather, and high density tend to counteract kirksite's most favorable traits. However, both kirksite and bronze can be used for large castings if adequate reinforcement is used.

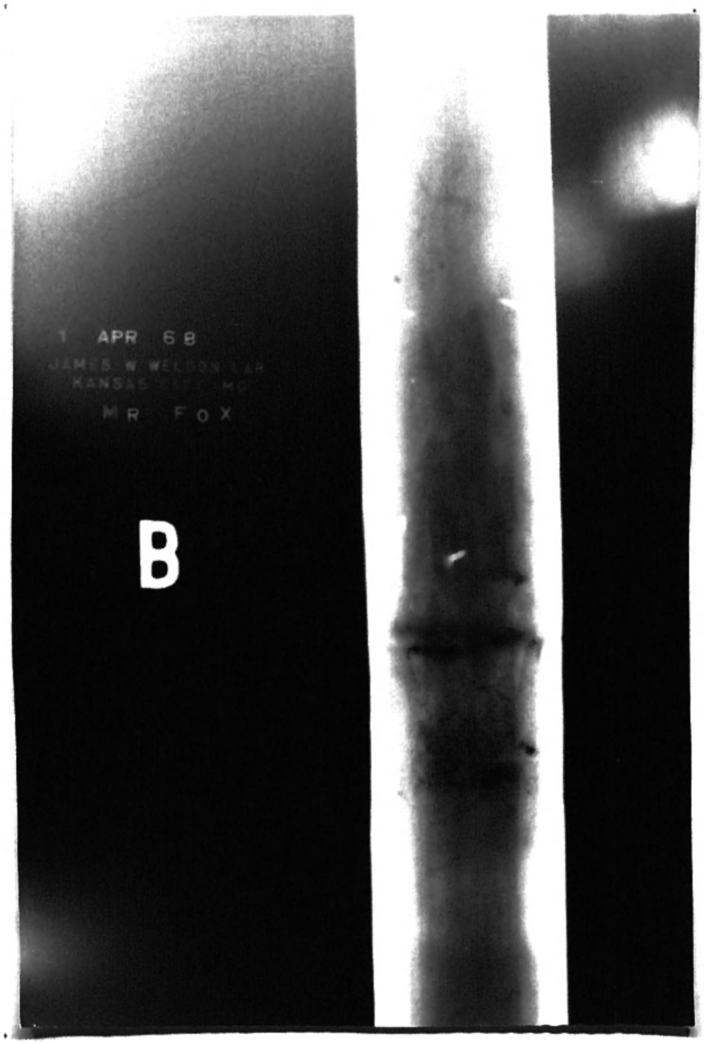
Test 2--Radiograph of Multiple-Poured Cylinder

The second test in the study of structural problems of large castings consisted of a radiograph performed on a cylinder cast in kirksite, which possessed visible evidence of a multiple pour. This cylinder, seen in Photograph 3 and Photograph 6, was cast with a fifteen-minute lapse between pourings. The results of the radiograph may be seen in Photograph 9.

The darker spots in Photograph 9 indicate areas of less density. In those areas collapse or deformation begins. This radiograph indicates that the porosity seen externally continues internally. A casting showing such porosity is structurally unsound.

Flashing Problem

In addition to the problem of attaining adequate structural strength from the cast, the sculptor must also solve many problems less important. One such problem is flashing. As seen in Photograph 6, only negligible flashing occurred on the three cylinders to the left of the photograph. These cylinders have several things in common. Both of the kirksite cylinders and the lead one next to them have very low melting temperatures; they are also somewhat heavier than the remaining two metals. In addition to this, both kirksite and lead remain molten in the investment for a much longer period than bronze or aluminum.



[1]

PHOTOGRAPH 9

RADIOGRAPH OF FIFTEEN-MINUTE MULTIPLE-POUR CYLINDER

A combination of these factors creates the tendency toward flashing in both lead and kirksite. Many investments develop cracking to some degree as they cool and are packed in sand. The fluidity and the weight of lead and kirksite, along with the prolonged cooling time, force open and flood these cracks with metal. The investment

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[1] Don Krenkel, Graduate Student, Metallurgy Department, University of Kansas.

used in the tests consisted of 1 1/4 parts plaster, 2 parts silica, and 2 parts sand. This investment is quite adequate for bronze and aluminum but lacks the strength for casting lead or kirksite. It can readily be adjusted to these heavier metals by adding grog or other large refractory to provide more body. A suggested formula is 1 1/4 parts plaster, 2 parts silica, 1 part sand, and 1 part grog.

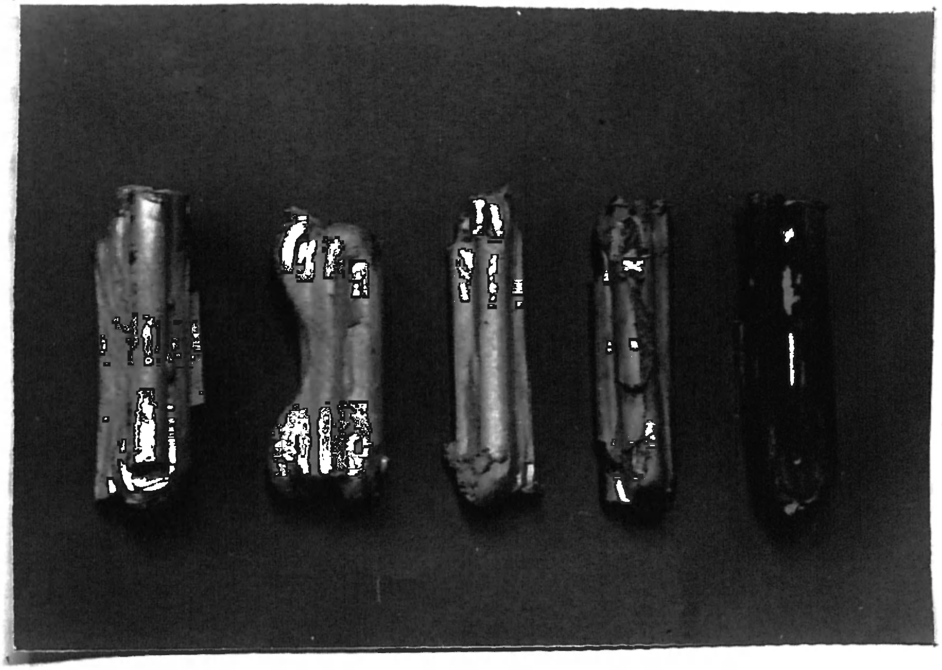
Shrinkage Problem

Shrinkage is another problem that must be solved in the attempt to eliminate repair work on the cast object. Kirksite shrinks more than any of the other metals tested. Photograph 10 shows the shrink feeders from the five cylinders cast.

In both instances the two shrink feeders from the kirksite cylinders (a) and (b) show severe shrinkage while no external shrinkage appears with aluminum (c), lead (d), or bronze (e). The only apparent solution for kirksite's shrinkage problem is the proper placement of the correct size shrink feeders at the highest and thickest areas of the cast. Their placement should be the same as those for bronze castings, but their size should be slightly larger.

Brittleness Problem

Brittleness is another problem that must receive special attention. The entire spruing systems of kirksite casts are extremely brittle and weak; yet the majority of this brittleness occurs only in the spruing system. As mentioned in Chapter II, the spruing system is the last to cool because it is thicker than the actual pattern. The metal is



PHOTOGRAPH 10

SHRINK FEEDERS FROM FIVE TEST CYLINDERS

apparently drawn from the sprues to supply the shrinkage in the pattern as though the entire spruing system serves as a very complex shrink feeder. After clipping and breaking the sprues from the pattern, one is pleasantly surprised to find that chasing is possible. On a good cast the metal can actually be manipulated on the surface in much the same manner as bronze. The pouring temperature also has some effect on this brittleness. The higher the temperature at which the metal is cast, the more brittle it tends to be. Temperatures nearer the freezing point usually render the metal slightly more malleable.[2] The preferred casting temperature is 800 to 850° F.[3] Environmental conditions also have some effect on kirksite even after its casting. At temperatures slightly above 200 F. its tensile strength is reduced 30 percent and its hardness 40 percent. At sub-zero temperatures brittleness increases some, but its impact strength is still in the same range as that of aluminum.[4]

Structural Reinforcement

The brittleness of kirksite can in some ways be compared with that of concrete. Although concrete is an extremely heavy and brittle substance, with the proper construction and reinforcement, large buildings can be erected with it. If kirksite is reinforced properly, large sculpture cast in this metal should function quite well. One of the obvious methods of gaining additional strength is the creation of the proper design for large kirksite castings. In this case a simple design with flowing, well-balanced forms would be preferred to a more complex form precariously balanced and containing sharp points and angles.

A second possible method of reinforcement is the addition of vertical ribs located on the inner walls of the areas under the most stress. The addition of such ribs could easily be done while the pattern is still in wax. Inserting wax strips or ribs along the

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[2] Hofman. op. cit., p. 33.

[3] C. H. Mathewson. op. cit., p. 4.

[4] "Properties and Selection of Metals," Metals Handbook, 1961, I, p. 1158.

inside of the wax pattern would be relatively easy. When the pattern is cast, the ribs automatically cast.

A third method of reinforcement is the addition of mesh wire. With the mesh placed against the inner surface or imbedded in the wax, a fusion occurs with the molten kirksite during pouring and provides a remarkable addition in strength. Mesh wire with a galvanized coating is preferable, but any of the various types of metal mesh wire will work.[5]

In summary, sections should be kept at a minimum thickness and ribs or some form of internal support used for added strength where necessary. To increase the structural strength and facilitate casting, gradual transitions should be made when section thicknesses vary.

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[5] Howard. op. cit.

CHAPTER IV

JOINING OF SECTIONS

Welding and Soldering

Joining sculpture sections is generally approached with reluctance and is not attempted except where necessary. Welding and soldering, which seem to be the most popular methods of joining art castings, can be employed with kirksite; but ordinarily neither process is used except for special needs or repair work. Welding kirksite is difficult, and soldered joints have little strength. When necessary, welding is best done by a reduced flame and welding rods made from the same alloy as the casting. Since kirksite has such a low melting point, the flame must be held almost parallel to the casting.[1] Because kirksite commonly contains about 4 percent aluminum, heating it forms an oxide skin, which creates great difficulty in welding. Heavy fluxing and careful manipulation are the only available means to successful welding. The flux should consist of equal parts of ammonium chloride and lithium chloride.[2] When soldering, use an 82.5 percent cadmium or 17.5 percent zinc solder with no flux.[3]

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[1] Metals Handbook. op. cit., I, p. 1158.

[2] J. F. Lancaster. The Metallurgy of Welding, Brazing and Soldering. American Elsevier Publishing Company Inc., New York, 1956, pp. 224-225.

[3] Metals Handbook. op. cit., p. 1158.

Photograph 11 shows an enlarged section of a welded kirksite joint.

PHOTOGRAPH 11

WELDED KIRKSITE JOINT

Bolting of Sections

When the design permits, kirksite sections can be joined by hidden bolts and interlocking joints. This method provides adequate strength; and, when a camouflaged joint is desired, soldering or wiping the joint proves successful. A narrow temperature range lies between the molten stage of kirksite and its liquid state. In this range the metal can be manipulated and wiped into joints to serve as a filler or a repair metal.

Roman Joint

A more traditional method of joining is the Roman joint. The numerous variations of the Roman joint all work on the same principle. A convex section is firmly fitted into a concave area with the same design. Usually a pin or a dowel is inserted through both sections, firmly locking them together. If desired, the joining line between the two sections may be hidden by soldering or wiping the joint. An example of a Roman joint is shown in Diagram 1.

In conclusion, the problems encountered in joining kirksite sections are numerous; however, most of them arise in joining all nonferrous metals. When iron or steel is welded, the metal turns various shades of red before it becomes liquid. Unfortunately, no noticeable change of color is seen and almost no warning is given before aluminum, bronze, lead, and kirksite become liquid and collapse. The greatest success in joining can be achieved through avoiding all but the most necessary joinings and using ingenuity and patience in joining the remaining sections.

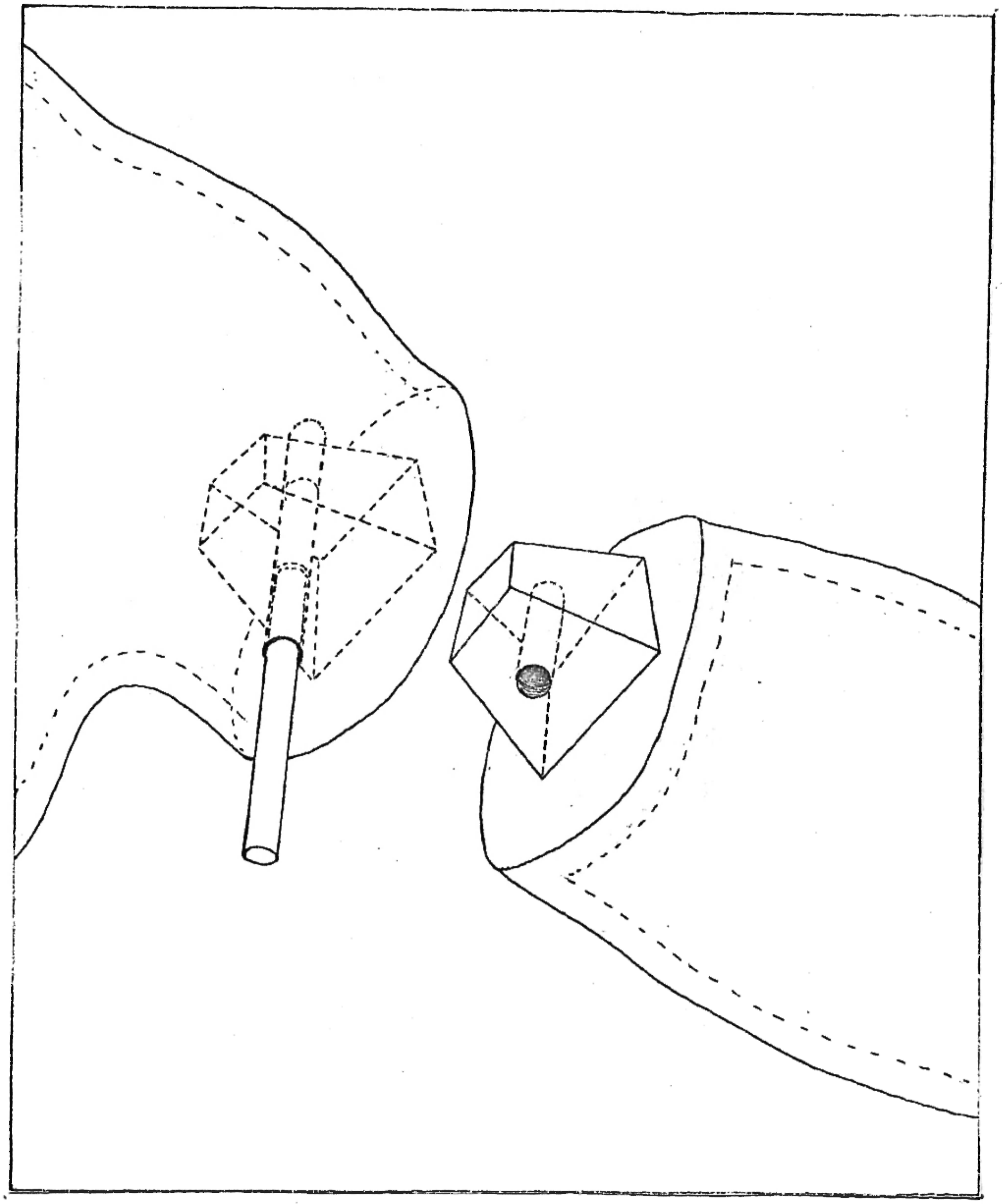

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DIAGRAM 1

ROMAN JOINT

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[4] William Zorach. Zorach Explains Sculpture. Tudor Publishing Co., New York, 1947, p. 136.

CHAPTER V

PATINIZATION AND FINISHES FOR KIRKSITE

Many finishes applied to other metals can also be applied to kirksite and similar zinc die-casting alloys. There is some difference in the formulation and application, but the basic finishing remains similar. The five basic types of finishes applicable to kirksite are: mechanical, electrodeposited, chemical, organic, and plastic. Before the best results can be obtained with any of these finishes, the metal must be thoroughly cleaned. This cleaning can be accomplished by a pickling bath. The following process works quite effectively on zinc alloys that contain aluminum.

Submerge the casting into an alkaline solution containing 10 to 40 percent caustic soda at room temperature. This liquid attacks the base metal only slightly during a five-minute immersion period but is very effective in removing oxides. After pickling, the work is rinsed thoroughly, dipped briefly in dilute nitric acid, rinsed once more, and then dried.[1]

Mechanical Finishes

The various effects achieved with mechanical finishes include buffing, polishing, brushing, and grinding. Kirksite can be given

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[1] Wilhelm Wiederholt. The Chemical Surface Treatment of Metals. Robert Draper Ltd., Teddington., Great Britain, 1965, p. 121.

mechanical finishes rather easily; but, unless the surface is protected, tarnishing will occur more quickly and more noticeably than on untreated parts. For this reason, mechanical finishes are often use only as preparatory steps for other types of finishes. Many brands of clear metal lacquers are available today, and most of them work very well in preserving mechanical finishes.

Electrodeposited Finishes

A second and probably the most interesting finish for kirksite is electrodeposited coatings. Virtually all metals capable of electrodeposition can be applied to kirksite castings. The most common platings are:

Nickel
Black nickel
Brass
Copper
Chromium
Cadmium
Zinc
Tin
Silver
Gold

These platings are most commonly applied for decorative purposes, but they also improve resistance to corrosion and abrasion. All plated coatings are somewhat porous; and, when moisture penetrates through the pores, some corrosion of the base metal usually results. If the plated coatings are too thin, this corrosion will destroy the appearance in a short time; therefore, the satisfaction and the useful life expected from such platings depend on the thickness of the deposit and the method of its application.[2] Mild, ordinary, and severe exposures are the three classes of commercial coatings. These classes denote

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[2] Metals Handbook. op. cit., p. 1158.

specified standard thicknesses for expected uses.[3] For example, severe exposure is applied in the chroming of exterior automobile parts such as bumpers and grills while ordinary exposure is applied for the interior automobile hardware.

Because all plating processes are somewhat similar, only one was chosen to be investigated more fully. Decorative chromium plating is a protective decorative coating system in which the outermost layer is chromium. This layer usually is applied over combinations of plated coatings of copper and nickel. Copper is frequently used as an undercoat for nickel because it can easily be buffed and has protective qualities, surface-leveling characteristics, and "sealer" action. After a coat of copper is put on, nickel plating is applied because it provides a pore-free, continuous undercoat of a ductile metal with good corrosion resistance. When surfaces plated with chromium over nickel are covered with an electrolyte (salt water, for example), the nickel slowly corrodes under the chrome. To prevent this corrosion, thicknesses for nickel generally range from at least 0.3 mil (for indoor pieces) to as much as 2 mils (for outdoor work). Chromium thicknesses of 0.01 or 0.02 mil are normal for decorative finishes.[4]

Colors and Expense

Generally speaking, a copper-plated coat is a prerequisite for nickel plating; and, in turn, all other plated coats require a layer

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[3] Ibid.

[4] "Heat Treating, Cleaning and Finishing," Metals Handbook, 1961, II, p. 446.

of both copper and nickel. Photograph 12 shows six of the most practical platings for kirksite. They are, as seen on the next page from left to right and downward: Brass, gold, copper, chromium, nickel, and silver. Zinc and tin plating are not shown because of the close similarity between their plating and the natural color of kirksite.

The expense involved in electroplating art objects varies greatly with the size, the design, and the amount of surface area involved. The difference among the prices of the various plating metals will vary little on moderate-size castings.

Most plating companies are extremely versatile and pride themselves on being able to do customized plating in a wide range of sizes. For example, one local plating company advertises that it can plate any item up to three feet wide and ten feet long and can plate nickel, chrome, and zinc up to twelve feet long.

Porosity Problem

One problem common to all traditionally cast art objects is porosity. Porosity in this sense is used to denote the looseness of molecular structure in, for example, a lost wax cast as compared with a commercial object cast under pressure. This porosity is of little or no importance except when the object is to be electroplated. Art castings in kirksite will accept all the various plates; however, some are more difficult to achieve with complete success. The problem area takes on a frostlike appearance on portions of the plating. Since setting up pressure casting facilities would be impractical

PHOTOGRAPH 12

PLATED PATINAS FOR KIRKSITE

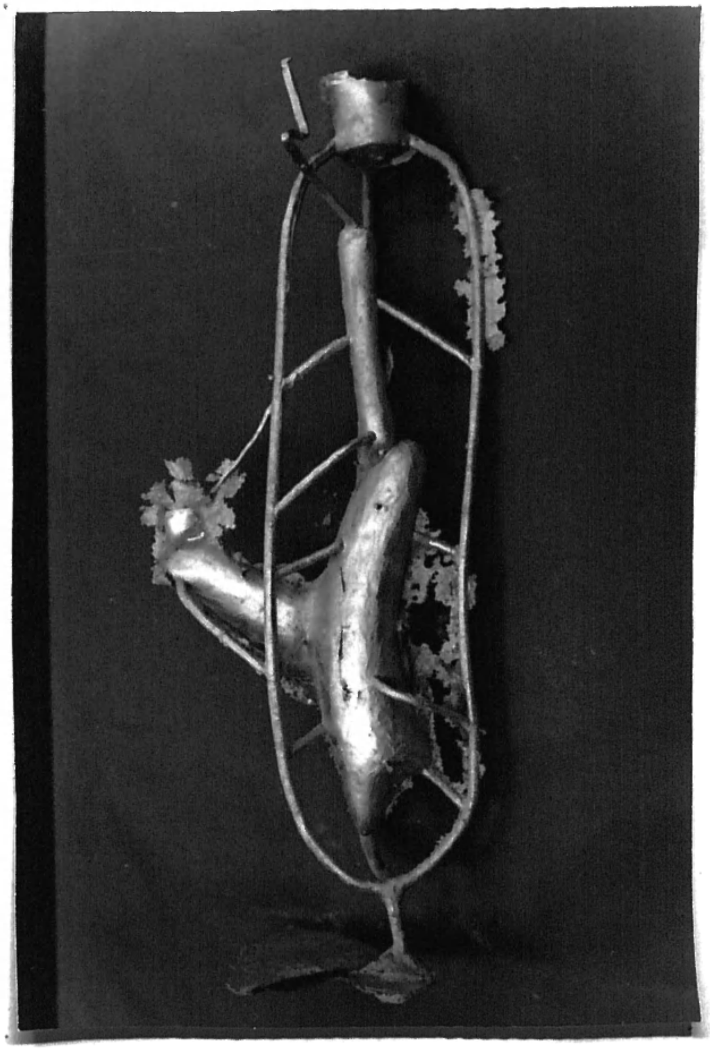
for the majority of art casters, other methods must be devised if this problem is to be solved.

The pattern for the test on porosity consisted of a wax positive form sprued with a version of the traditional lost wax indirect-feeding method. The spruing method was not changed except at the top of the piece. The variation consisted of a simple, yet exaggerated, lengthening of the main gate from the top of the pattern to the pouring cup. Photograph 13 indicates the design and the spruing pattern for this test. The sprues were elongated to increase in the simplest method possible the amount of natural pressure created by gravity. The researcher hoped that this extra pressure would decrease the amount of porosity in the cast. After the cast was poured and devested, it was found to be successful. When compared with an identical object cast in the same material but with the traditional spruing method, the cast with the elongated spruing system proved visibly superior in surface quality and density.

Photograph 14, page 36, containing the traditional spruing method, is similar in form to the one in Photograph 13.

Design for Polishing and Electroplating

When a brilliant and reflective quality of plating is desired, the casting must first be polished to a smooth lustre. To avoid many hours of needless hand polishing, the piece should be designed so that it can be brought into contact with mechanical buffers. If the design is appropriate, the plating company will usually perform this polishing as part of its service. Generally speaking, the



PHOTOGRAPH 13

POROSITY TEST WITH LENGTHENED SPREWING SYSTEM

object should be designed to avoid or minimize sharp points, right angles, and sharp ridges. This method of design not only aids the polishing and the superiority of the plating but also affects the price greatly. The cost of electroplating is often increased by the complexity of the design. Simple shapes can be plated with a minimum of 1.3 mils of copper plus nickel and 0.01 mil of chromium in approximately 50 minutes. To provide minimum thicknesses on complex

PHOTOGRAPH 14

POROSITY TEST WITH TRADITIONAL SPREWING SYSTEM

shapes, longer plating periods, special fixturing, special anodes, and current shields are required. Plating costs are increased in each case even if polishing and cleaning costs remain the same.[5]

To aid and simplify the understanding of some plating problems, Diagram 2, page 37, depicts magnified cross sections and shows how plating deposits on different patterns.

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[5] Metals Handbook. op. cit., p. 458.

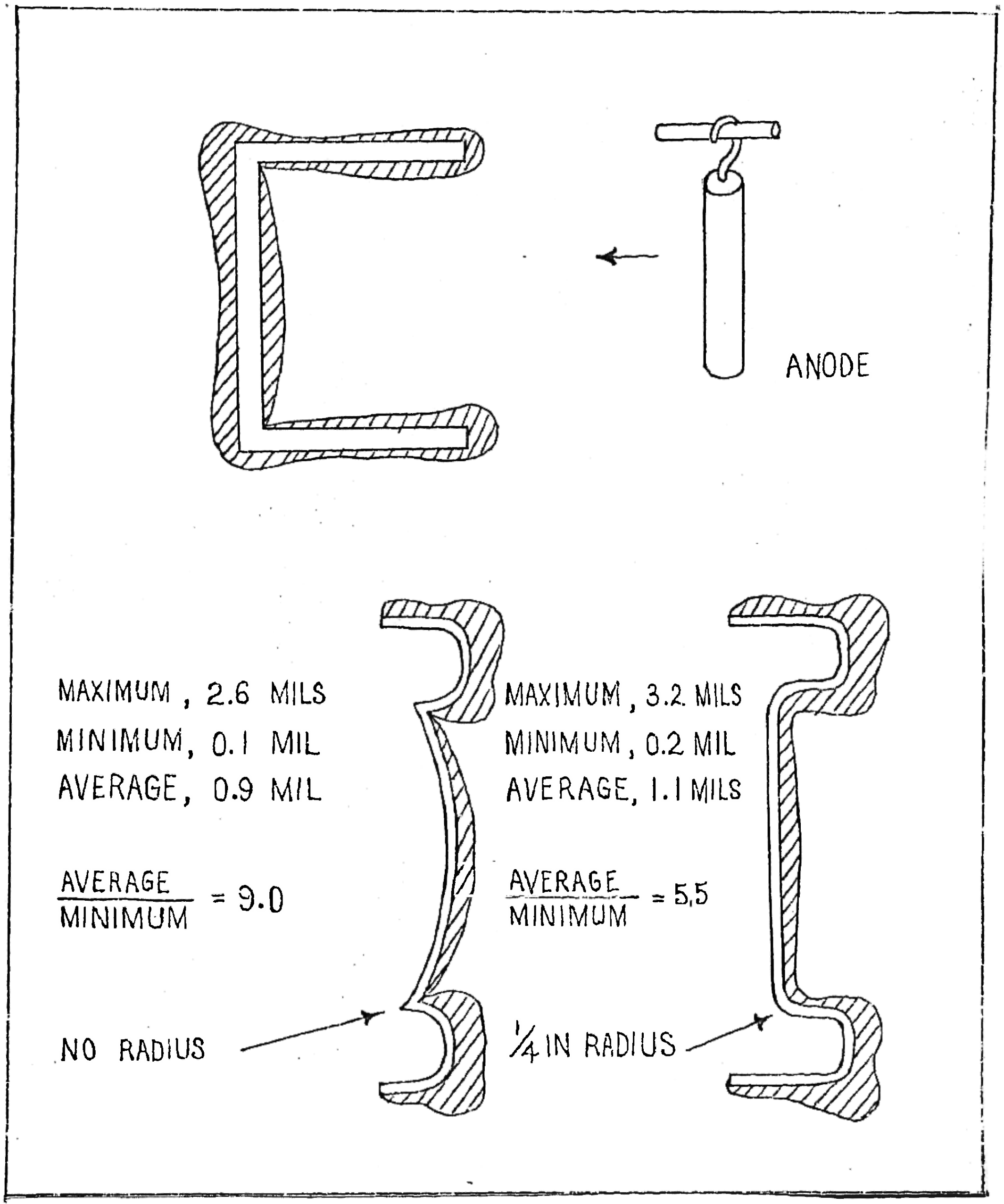

DIAGRAM 2

EFFECT OF RADIUS IN RECESSED AREA ON THE UNIFORMITY OF THICKNESS OF PLATE[6]

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[6] Metals Handbook. op. cit., p. 441.

Chemical Finishes

Commercially Produced Finishes

The third type of finish applicable to kirksite is chemical. Some chemical finishes commercially produced for zinc and its alloys are listed below.

Trade Name	Description
Ker-chro-mite #2	--Produces lustrous yellow coating on zinc or cadmium.
Ker-chro-mite #4	--Produces lustrous uniform protective coating on zinc or cadmium.
Zinc Blu-chro	--Inexpensive single-step chromate conversion process--produces a blu-chrom finish on zinc plate or may be used as a protective coating.
Ker-chro-mite GC	--Single dip olive drab for cadmium or zinc and die castings. Has maximum protection against corrosion. It is excellent as a base for paint.
Molyblack Base	--Produces a jet-black finish for zinc and cadmium.[7]

Experimental Formulas

Because kirksite has been used predominately in the commercial field, there has been little need for the development of patinas that would primarily serve artistic purposes. For this reason, personal experiments are necessary in developing desired patinas. Photograph 15 shows five such patinas, each developed through random experiments with chemicals. The first sample in this photograph has been polished only.

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[7] "Directory for 1967." Metal Finishing Guidebook. Metals and Plastics Publications, Inc., New Jersey, 1966, p. 373.

PHOTOGRAPH 15

CHEMICAL PATINAS FOR KIRKSITE

These patinas were attained with the following formulas that appear in the order of occurrence in Photograph 15.

(All measurements are by part)

1. Kirksite (polished only)

2. Rust Gray

   1/2 part Potassium Chlorate
   5 parts Copper Sulphate
   5 parts Chromic Acid
   10 parts Water

   A hot patina. Brush on preheated surface. Rub immediately.

3. Cool Gray

   1/2 part Lead Acetate
   1/2 part Sodium Thiosulfate
   10 parts Water

   A hot patina. Brush on. Wax is optional.

4. Rusted Iron

   1 part Lead Acetate
   1 part Sodium Thiosulfate
   1 part Potassium Chlorate
   1 1/3 parts Copper Sulfate
   1 1/3 parts Chromic Acid
   28 parts Water

   A hot patina. Brush on. Do not apply wax.

5. Rich Brown

   1/2 part Potassium Chlorate
   1 part Copper Sulphate
   1 part Chromic Acid
   10 parts Water

   A hot patina. Brush on to preheated surface until slightly darker than desired and rub immediately to desired shade. Apply wax while surface is hot.

6. Straw Yellow

   4 parts Cupric Sulphate
   1 part Malachite Green
   2 parts Sulphur
   5 parts Copper Sulphate
   20 parts Water

   A hot patina. Apply patina until a dark red brown is achieved. Then rinse immediately with water until the desired shade of yellow is obtained. Use no wax.

Organic Finishes

Organic is the fourth method of surface treatment for kirksite. Many organic finishes are available, and each offers some particular advantage, such as color, hardness, gloss, adhesion, or weathering. Many of these paints or lacquers are designed for brush application and normal temperature curing, but the most durable and attractive finishes are attained by baking. When baking these finishes on kirksite, however, the artist must pay careful attention to the baking temperature. The properties of kirksite may be adversely affected if the castings are heated for more than 1/2 hour at 220 C. (428 F.); 1 hour at 190 C. (374 F.); 2 hours at 165 C. (329 F.); or 3 hours at 150 C. (302 F.). If the casting is copper, nickel, or chromium plated and given a baked finish, the maximum temperature that can be used without blistering is 125 C. (257 F.).[8]

Plastic Finishes

Plastic finishes represent the fifth and final type of surface finish. When the size of the casting permits, the object may be dipped repeatedly into nitrocellulose or ethyl cellulose solution. When size prohibits dipping, these plastics may be sprayed on. Brush application generally proves unsatisfactory because of its uneven application. Plastic finishes, available in transparent and opaque colors, are several times as thick as other organic coatings

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[8] Metals Handbook. op. cit., I, p. 1158.

and differ from similar base lacquers not only in thickness but also in composition.[9]

From information gathered through research and personal experiments, the finish of kirksite seems to lend itself to a wide range of interesting possibilities. In fact, kirksite's finishing qualities are among its strongest points.

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[9] *Ibid*.

CHAPTER VI

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

In conclusion, kirksite has been proven to be a reliable material for casting sculpture. Like all metals, it has its strong and weak points. Perhaps the weakest point is its brittleness. With proper precautions taken in spruing and casting, this brittleness is not a serious handicap; however, it does become a definite problem when the casting of outdoor sculpture is contemplated. Another weak aspect is welding. Kirksite does, however, possess distinct advantages over the traditional art-casting metals. Its ability to remain in a molten state for long periods of time is one such quality. This extended molten period makes possible multiple pourings in the same investment with as long as ten minutes' delay between pours. With additional experiments, this ten-minute delay might be increased to at least fifteen minutes in castings of this size. The versatility and the ease in attaining various surface finishes is another attractive quality kirksite possesses. The price of kirksite is in its favor since it is below that of lead.

The greatest success with kirksite can be obtained by casting sculpture in up to life-size proportions for indoors, taking advantage of multiple pouring. When casting objects life-size or larger for out of doors, the cast must be reinforced.

During this study, adequate information was found to encourage sculptors to set up personal plating facilities. The materials needed and the expense involved are low enough so that such facilities would not be economically prohibitive. There are various methods of plating, including one that is entirely chemical in nature. With proper research, the sculptor should be able to find a plating method that would be best suited to his needs. The following books will prove useful in setting up a plating facility:

Metals Handbook, Vol. 2, "Heat Treatment, Cleaning and Finishing," 1961.

The Chemical Surface Treatment of Metals

Wilhelm Wiederholt
Clare o'Molesey Ltd. Molesey, Surrey
Great Britain, 1965.

Modern Practices in the Pickling of Metals and Related Processes

Max Straschill
Clare o'Molesey Ltd., Surrey
Great Britain, 1963.

Metal Finishing Guide Book Directory for 1967

Metals and Plastics Publications, Inc.
New Jersey, 1966.

Another facet of this study that deserves further investigation is the process of "slush casting." This process lends itself to only a few metals, of which kirksite is one. Basically the process consists of pouring molten metal of a specified temperature into a negative pattern consisting of two halves joined together. This pattern is usually made of copper or aluminum and is joined by interlocking grooves or hinges. After the molten metal is poured into the cool mold, it is slushed around to provide an even coating of metal inside the mold. The excess metal is poured out; and the remaining metal, now in the form of a thin positive, is taken from the mold. This method is capable of producing numerous extremely thin castings of the same pattern. However, unless many copies of the same pattern are needed, this method is impractical. Before slush casting can be used effectively, the negative patterns must first be cast or machined in copper or aluminum.

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Krenkel, Don, Graduate Student, Metallurgy Department, University of Kansas.

APPENDIX

GLOSSARY

Brinell Machine--An apparatus for measuring the hardness of metals. A steel ball is pressed with a standard pressure (usually 3,000 kilograms) into the specimen under test, the resistance to penetration (Brinell hardness) being expressed by a number (Brinell number) denoting the applied pressure in kilograms divided by the spherical area of indentation in square millimeters.

Charge--To lay or put a load on or in. Such as filling a crucible with metal. The metal used in one heat of the crucible.

Chasing--To ornament or work a surface of metal by embossing, engraving, smoothing, etc.

Crucible--A pot made of very refractory substances, as clay, graphite, porcelain, etc., used for melting metals.

Flashing--In the firing and cooling process, cracks often form in the investment. When molten metal is poured into the mould, these cracks are also filled with metal creating unplanned extensions from the cast.

Investment--A combination of plaster and refractory materials poured around the wax pattern (in the lost wax technique) to form a negative mold into which the metal is poured.

Malleable--Capable of being extended or shaped by beating with a hammer or by the pressure of rollers, etc.

Nonferrous Metals--Metals that do not contain iron.

Radiograph--A picture produced upon a sensitive surface, as of a photographic plate, by some form of radiation other than light. An X-ray.

Shrink Feeder--An enlargement usually near the top of the spruing system that serves as a reservoir from which molten metal may be drawn as the metal pattern shrinks.

Sprue System--The network of passageways through which the metal flows before it reaches the pattern.

Tensile Strength--The greatest longitudinal stress a substance can bear without tearing or deforming.