COPPER-BASE ALLOY FOUNDRY PRACTICE

Supplement to
FOUNDRY SAND PRACTICE
by Clyde A. Sanders

AMERICAN COLLOID COMPANY
CHAPTER XIII

Copper-Base Alloy
Foundry Practice

Metal cast into sand molds comprises 96% of the total foundry industry; die casting into metal molds represents about 3%; all other methods account for the balance which is about 1%. The ratio in the casting of copper-base alloys is approximately the same. Of the total 503,127 tons of copper-base alloys cast in 1966, 428,241 tons were made by the sand casting process, 14,710 tons were die cast, and the balance was produced by other methods.

Over 21 million tons of ferrous and nonferrous castings were produced in 1966. This represents about five billion dollars of cast products sold to the automotive industry, construction industry, machinery parts, farm equipment, pipe fittings, plumbing fittings, pumps, compressors, ingot molds, and all other casting users. (Fig. 46) The

Figure 46—This faucet was made in a green sand mold produced by modern molding equipment to close dimensional tolerances.

© AMERICAN COLLOID 1967
value of all cast products, when finished and ready for assembly, repre-
"sented about $9.9 billion dollars in 1966. It is significant that the
foundry industry is outranked only by the automotive, steel, aircraft
and chemical industries on the basis of dollar value added to the
U.S. economy.

Copper-base castings have served mankind since the beginning
of the Bronze Age (about 3000 B.C. and extending to about 1200 B.C.).
During the Bronze Age, the techniques of casting were refined and
allowing appeared. "Copper" identifies alloy containing a minimum of
98% metallic copper. "Brass" is a copper-base alloy which con-
tains an appreciable amount of zinc. "Bronze" serves to identify alloys
where alloying elements other than zinc are contained in greater quanti-
ty. "Tin" is the alloying element most prevalently employed in bronze.

A bronze bell weighing in excess of 175 tons was cast in 1734
A.D by Russian foundrymen. In contrast, more recently in the U.S.A.,
a 380 ton steel casting was poured into a sand mold. The casting, when
cleaned and shipped, weighed over 250 tons. While these castings must
be considered feats of accomplishment, they also serve to illustrate that
almost any shape and nearly any weight can be cast with most gener-
ally any metal. In reality, copper-base alloy casting practices have
changed little from the century proven methods. Changes that have oc-
curred have been essentially improvements in the melting and refining
processes.

Melting Equipment

Copper-base alloys are melted in various types of furnaces in-
cluding: electric direct arc, indirect arc, crucible li, crucible tilting,
vertical-ring induction, high-frequency induction, indirect-resistor,
open-flame, reverberatory, and, less used, cupolas.

Trends in Melting

Induction furnace melting techniques are gaining in popularity,
and outstanding results are being obtained. Many companies are ex-
perimenting with, and actually using, a vacuum arc melting system
or some form of vacuum degassing. Cleaner more dense metal is
claimed for this system with less slag and nonmetallic inclusions
occurring.

Oxygen and nitrogen in the atmosphere also are removed from
the presence of the molten bath, thus minimizing the occurrence of
gas-metal reactions which form oxides and nitrides at the bath surface.
Reactions with gaseous products can be more nearly completed in a
dynamic vacuum system, which is a continuously pumped system.
Gaseous, deoxidized products can be pumped away rather than sepa-
rated as slags, thus preventing metallic inclusions.

Most foundries attempt to melt in a neutral or slightly oxidizing
atmosphere. The atmosphere is checked by an Orsat apparatus to
determine quantitatively the amount and type of gases present. Some
foundries use piece of bright zinc and move it through the flame as a
check. If the zinc remains bright, the flame is neutral. If the zinc
becomes smoked, the flame is reducing. If a whitish film forms on the
zinc, an excess of oxygen probably is present which cools the flame.
If the melt is reducing and the condition is discovered too late, it can be
artificially oxidized. This practice purges the melt of reducing gases in
many instances.

The deoxidation procedure should be undertaken carefully. De-
oxidants should be weighed and bagged, then identified on the outside
and stored in a warm, dry area for future use. Damp deoxidizers
added in shot form spoil metal easily. Deoxidizers must have time to
agitate the metal when they are added to it.

Use of a small section chill cast fracture bar gives an indication
of the quality of the melt. Also, the metal may be checked by pour-
ing a slug 2 inches in diameter by 2 inches deep into an open sand
mold. The liquid metal should be poured directly into the cavity and
covered immediately with dry charcoal. The amount of resulting pipe
and metal shrinkage should be determined. This procedure can save
many hours of molding time if it is followed closely. A mediocre
effort is wasted because poor quality metal results in scrapped castings.
Establish a system of controls to predict and, if possible, correct the
physical qualities of the cast metal.

Reduce gas pickup by using a minimum of super heating. Try to
use short cycle melting and apply combustion atmosphere control.
Do not chill a super heated metal to its pouring temperature by adding
an ingot or a returned gate to the holding furnace or ladle. Even warm,
solid metal may cause excess slag and trouble if it is greasy or caked
with contaminants. Take advantage of the slower cooling rate of air
and allow the metal bath to purge itself of deleterious gases.

Excess metal should be pigged in metal molds instead of in wet
sand heaps. This practice reduces contamination and saves metal.
It also gives a more identifiable pig that is easier to handle and store.
Always use clean, dry pouring ladles. Rejected castings often can be
traced to faulty pouring. Use trained pouring crews and keep them
alerted to rigid standards. Clearly written instructions should be avail-
able to assist furnace operators.

Types of Molding

Green sand production foundries agree that green sand molding is
the most economical method to use. Practically all small miscellaneous
castings can be made with this molding method. (Fig. 47) Green sand
molds produce quality castings in any quantity with conventional equip-
ment. Molds can be made at minimum cost, poured, and shaken out in
continuous cycles of short duration.

Green sand molding is a repetitive process. Casting quality pro-
Figure 47—Final casting quality readily reflects the quality of the green sand molding method.

Produced reflects the quality of the green sand molding method used. Each foundry seeks a consistently close control of sand mixtures. Automatic sand preparation with a central control panel is eliminating many foundry errors made in the past because of human factors.

Regardless of whether manual, squeezer, or automatic molding machines are employed, green sand is still the preferred molding method. Nonferrous foundries use many types of squeeze, jolt, roll-over, or draw molding machines to accommodate a variety of pattern changes for castings of different designs.

A pattern made for a mass production foundry may not be adaptable to the equipment in a jobbing foundry without some alteration. If a similar production pattern were placed in a small jobbing foundry, a complete rebuilding would be required before it could be used with the machines in operation.

As a rule, smaller copper-base foundries are not mechanized. Smaller foundries realize that with limited storage space, full economy may not be obtained by using solely synthetic (compounded) sand mixtures, so many still prefer to mold with naturally bonded sands.

Methods of Casting

Copper-base alloys are made by various methods other than green sand molding. The major ones are: 1) skin-dried molds, 2) dry sand molds, 3) baked core assemblies, 4) C-Process (shell), 5) air-set molds, 6) self-curing molds, 7) cement molds, 8) CO₂-sodium silicate molds, 9) investment molds, 10) ceramic molds, and 11) permanent molds.

Automation and Other Molding Methods

Automation in the foundry industry is being adopted at a rapid pace. Electronic brains are taking over, and production scheduling is carried out in advance without human assistance. Raw materials must offer handling ease that coincides with these faster production methods.

Green sand molding continues to diversify as molding machines improve. For example, more light-off spray coatings are now used on green sand molds to produce good surface hardness. Skin-dried molds are being replaced by air-set or self-cured molds. Molds made of self-cured, air-set, chemically set or heat-set sand mixtures are being made thinner and may be backed with green sand. Shell molds or cores are now backed with green sand to complete the mold. The use of CO₂-sodium silicate molding has increased. These thin molds when used in making larger castings are also backed up by green sand so as to reduce overall costs. The gassing of CO₂-sodium silicate molds used as surface shells costs less and casting results improve. Eventually, many castings requiring several cores may use a single shell core as an interface backed with green sand. If one or two complicated single cores can be eliminated by a single shell cover core and backed with green sand, many advantages result.

Shell and CO₂-sodium silicate molding are often better suited for cores rather than for molds. Savings are further realized when these two processes are used in conjunction with green sand molds. There is a decline in the use of loam molds, sweep molds, and open sand molds. Fewer chamotte (compo molding) and cement molds are used. There are always special (but limited) uses for slush molding and the centrifugal casting processes. Castings made in ceramic molds or investment molds, such as plaster, may eventually decline in total tonnage poured, but not in the number of castings produced. The lost wax process will always be used for a limited amount of brass and bronze statuary work. Thin, nonferrous castings are being die cast, but this method of casting is preferred only for casting light metals such as the zinc alloys.

Each molding method has practical limitations, but the method selected depends on the chemistry of the cast metal; the physical requirements of the casting such as size, weight, and section thickness; as well as other factors. The quantity of castings needed, the accuracy specified, and casting finish required also dictate the selection of the molding method.

Time-tested, green sand molding methods, coupled with properly controlled and amply supervised up-to-date equipment, are producing
closer tolerance brass and bronze castings at lower cost. At present, sand casting seems to be the only process which is practically unlimited as to the size and shape of castings which are produced. Satisfactory results are obtained when close cooperation exists between the designer, patternmaker, and the foundryman.

**Flaskless Molding**

A trend towards flaskless green sand molding has developed. There are two methods at present; both are being used and improved at this date. Each of these methods has had much verbal support. But now the first European flaskless machines are actually being used in U.S.A. foundry production. The use of flaskless molding means the elimination of heavy flasks, bottom boards and weights which are important factors in reducing molding costs. With certain molding machines, heavier flasks are needed, so there is a trend to revert from higher squeeze pressures (90 C-mold hardness and over 200 psi. on the sand) to smaller, flaskless molding machines with less castings per plate. More small individual patterns are appearing. This is the opposite from the composite pattern which contains several patterns on a single heavy plate. It is predicted that in the future, green sand molding, when used in conjunction with rapid squeezing, will produce results similar to those being achieved by present permanent mold foundries. Future flaskless green sand molding may squeeze green sand shells which will be backed by a standard permanent metal form.

**Casting Finish**

Casting finish in a nonferrous foundry is governed chiefly by the molding method selected. If a sand method is chosen, grain size and distribution of the selected base sand, as well as the ramming of the molds, govern the casting finish. When the desired casting finish is not obtained from a base sand of the proper size, either some foreign material is present in the sand mixture, or the selection of the grain size is incorrect.

**Base Sand Selection**

At one time, only fine-grained, naturally bonded sands were used by copper-base alloy foundries. Even today, a considerable tonnage of naturally bonded sand is used by smaller copper-base foundries. Naturally bonded sands are used generally only once per day by these smaller foundries. The molding sand is "cut" or prepared in a simple fashion, and enough water is added for the sands to temper overnight. Now, naturally bonded sand is also distributed lightly over the floor or heap to retain some control.

Albany, Tennessee, New Jersey, far Western, and Mississippi naturally bonded sands are used in nonferrous foundries. These systems require large additions of naturally bonded sand to maintain green compression strength. Naturally bonded sand usually has a clay content of only 12% to 15% which generally makes it a weak type of clay addition.

Each time a naturally bonded sand containing 12% clay content is added to a system, the remaining 88% of inert sand serves to further dilute the molding sand system. As long as this practice prevails, the green compression strength can never be greater than the original strength of the added naturally bonded sand. If core sand is diluting the system, then strengths will continue to fall with this type of addition.

Larger, nonferrous foundries that cast plumbing parts, hardware, ornamental fittings, marine castings, statutory castings, or art work have learned the value of sand control by the application of synthetic sand (formulated process) practice. Application of basic sand control principles in foundries using synthetic molding sands results in better economy and less casting scrap.

Because naturally bonded clay additions are expensive and very difficult to control, progressive foundries have sought a more economical method of maintaining proper molding sand properties by adding bentonite to the system sand. This procedure has led more foundries to further use of synthetic (formulated or compounded) sands or semi-synthetic (partly naturally bonded) sand mixtures.

**Sand Selection**

Good sand practice must start with the selection of a base sand that will properly meet the physical and mechanical requirements of the system sand. This sand must be uniform, low in impurities, have refractoriness and must be available from an unlimited source of supply. The usual choices of silica sand may be washed, dried, crude, lake, bank, or special sands other than silica such as zircon, olivine, or chromite (Hevi-Sand).

Any number of sand combinations may be used. Regardless of which sand or combination is selected, it is considered good practice to use the finest, driest, and weakest compounded molding sand which gives the best and most economical casting. The molding sand system should operate with the minimum green, dry, and hot compression strengths necessary to mold, yet produce satisfactory castings.

Ideal foundry practice is to select the base sand which gives the desired results both in the core room and on the molding floor. If such a one-base sand is not available, two or more base sands can be blended to obtain the ideal AFS Grain Fineness Number and AFS Sieve Distribution. The grain spread or distribution is most important. Proper weighing and proportioning equipment may be necessary to ensure it. For example, a proper combination of inexpensive lake and bank sands gives excellent molding sand properties.

**Grain size, shape and distribution** of incoming core sand deter-
mine casting finish and workability of the molding sand system. A wide sand grain distribution of the base sand is regarded as the best sand practice. The simpler the sand mixture, the easier it is to control and the less the total cost.

Olivine Sand

Olivine sand is a green colored, orthosilicate of magnesium and iron occurring in nature as forsterite (Mg₂SiO₄) and fayalite (Fe₂SiO₄) of various ratios along with minor amounts of SiO₂, Fe₂O₃, Cr₂O₃, NiO and MnO.

Olivine is mined as a massive mineral which is crushed and classified into several sizes. The resulting grain is sharply angular. The sand has a high thermal capacity and in the lower temperature ranges, high thermal conductivity. The low, uniform thermal expansion of olivine and its ability to withstand thermal shock without fracturing are of major importance in foundry applications. As a massive mineral, olivine is about 25% heavier than silica. As a bonded sand mixture, properly rammed into a mold, it is about 10% to 15% heavier than a bonded round grain silica sand when rammed under similar conditions.

Olivine has become a useful tool in the nonferrous foundry because it produces a stable green sand mold which does not affect itself when heated as much as silica. A simple, clay bonded, green sand (olivine) mixture may thus produce accurate castings free of expansion defects.

Silicon Carbide and Chromite (Hevi-Sand)

High heat transfer mixtures such as those containing silicon carbide or chromite (Hevi-Sand) are used where chilling of the casting is desired at sharp or right angles, in fillets, around bosses, and particularly in specific cores. Some silicon carbide or chromite mixtures are said to possess three-fourths the chilling power of solid graphite and three times that of silica sand. Still greater chilling can be accomplished by these mixtures if they are rammed or squeezed to greater densities. Metal shrinkage usually is decreased if the pattern has been properly gated so maximum feeding occurs. Chilling with chrome mixtures lowers the demand for feed metal.

Hevi-Sand is a tailored chrome spinel grain derived from specially selected, naturally occurring chrome ores. A great deal of research and development has been undertaken to make Hevi-Sand a chemically and mechanically stable refractory aggregate.

The Hevi-Sand chrome ore grains (FeO • Cr₂O₃) are usually considered as solid solutions of various spinels (RO • RO₂). The compositions are in various orders of (Mg, Fe)O • (Cr, Al)₂O₃...FeO(Cr, Al)₂O₃, which are the most predominant elements associated with the mineral.

Hevi-Sand is not easily wetted by molten metals. It is particularly resistant to metal slag attack and is a superior molding and refractory medium for the casting of difficult nonferrous alloys. Hevi-Sand is very stable, and is difficult to break down or decompose. It has little volume change when subjected to heat shock or sudden cooling. Hevi-Sand has a high heat transfer rate. It has replaced zircon sand as well as metal fabricated and cast chills in many foundry applications.

Hevi-Sand's high permeability and wide sand grain distribution is a distinct advantage in the casting of heavy metal sections. It has been found ideally suited for the production of large castings and intricate cores which are subject to burn-on, penetration, or veining. Cores made with Hevi-Sand clean out easily from copper-base castings. Hevi-Sand has solved many penetration problems. Hevi-Sand has very low binder requirements and is becoming a better known and more widely accepted nonferrous base sand.

Bond Additions

A small amount of bentonite added to a system sand has many advantages. The addition of Panther Creek southern bentonite rebonds incoming core sand more effectively and economically than additional amounts of naturally bonded sands. Volclay western bentonite gives excellent dry and hot properties to nonferrous molding sands, plus green deformation and toughness. New bentonite additions to molding sands should be made regularly to ensure against expansion defects, especially where flat plates or similar castings are made.

Nonferrous foundries using lake or bank sand as the base system sand may use as little as 3% bentonite (based on the total weight of unbonded sand in the system) to obtain the same strength as a naturally bonded sand containing 12% to 15% clay.

Panther Creek southern bentonite mixtures have greater flowability than mixtures containing any of the other well known bonding clays. The lower pouring temperatures of copper-base alloys do not create enough heat to burn-out sands readily, yet nonferrous sands must collapse. Panther Creek bentonite bonded sand mixtures do collapse readily, and usually have high green compression strength combined with excellent flowability.

Because all nonferrous foundries have a certain amount of burnt core sand returning to the system, a sufficient amount of bentonite must be added regularly to maintain a satisfactory working strength. Also, there may be a daily loss of a sizeable amount of beat or system sand at the shakeout because of baked, lumpy molding sand. This loss must also be replaced with new sand and additive additions.

Wet Rebonding

A variation of the popular dry method of rebonding foundry sands is also being used. Many foundries prefer to add the bond (Sperser Volclay) as a liquid rather than as a dry material.
The slurry method is best employed with used system sand. Because a system sand contains some live clay, less bentonite additions are required. Most “used or system” sands contain fines and can stand a higher proportion of temper water. Finally, when used sands are re-bonded while hot, some of the added slurry water evaporates, leaving the bond, thereby aiding the coating of the sand grains.

If the system sand can be sprayed with slurry while traveling on a belt from the shakeout to the muller, the sand grains become slightly cooled as the slurry is re-bonding. Sand control is better when bond and temper water are added simultaneously. Foundries that have adopted the slurry process claim that the bond is easier to handle and there is less dust. They further claim that the earlier addition of slurry to the muller results in improved green compression strength. One-half of the returning sand is placed in the muller, then all the bond and water is added as a slurry. This mixture is mulled for a period, then the other half of the sand is added to the muller. Foundries using this procedure claim superior results, particularly in increased green strength.

Temper Water

The moisture content of a molding sand is often termed a “necessary evil.” Although water is the least expensive lubricant employed to wet and temper molding sands, it can be the most expensive, if used incorrectly.

Hot metal does not lie against free water without causing trouble or defects. High temper water may cause excessive scrapped castings, indicate false plasticity, and generate weak molding sands. Water in a mold is one of the chief sources of oxygen during casting. Its presence can create oxidized metal which, if it vaporizes while the metal is still in a liquid state, may promote pinhole porosity.

Although a number of moisture indicating devices are used in foundry control work, many molders are unconcerned with moisture testing methods and still persist in forcing their hand into the sand heap to predict the moisture content. This ancient method of moisture determination should not be completely discouraged since it measures workability by feel. Moisture control, however, should be verified with instruments only. The drawback of this crude hand method is that the molder who uses it and claims satisfactory results cannot pass his knowledge on to others, since there is no standard that can be used as a guide. Accuracy can only be acquired by time-tested practices. Only machine verification of this crude hand test can assure proper and uniform foundry control.

Mulling-Tempering-Aerating-Cutting

Most nonferrous foundries are improperly equipped for the continuous mulling of all sands. Consequently, foundries depend on bond additions to furnish the necessary working strengths.

If insufficient mulling or muller equipment exists, it is suggested that a large portion of Panther Creek southern bentonite—from 15% to 30% by weight—be milled with a quantity of system sand for a ten-minute period in a slow, vertical wheel muller. This heavily re-bonded sand can then be distributed over a weak system sand and blended into it by cutting, aerating, screening, or turning over by hand before it is passed to the molding floor. Mullers with sufficient capacity should be available for best molding sand preparations. Southern bentonite (Panther Creek) can be used without a muller if mullers of sufficient capacity are not available. However, this type of addition is not scientifically recommended.

One way to revive a heap of “dead sand” is to scatter Panther Creek bentonite lightly over the entire floor and then to cut the molding floor thoroughly. Another method is to sprinkle Panther Creek bentonite on the top of each mold prior to shakeout. Upon shakeout, the bentonite mixes easily into the sand; further blending is obtained on subsequent rehandling. Aeration of sand mixtures is highly recommended for a thorough distribution of the temper water. Aeration gives better flowability and moldability to the molding sand and distributes temper water better.

Balling-Up

Nonferrous foundries usually work with finer sand, whether it is a naturally bonded or a synthetically formulated mixture. However, fine sands tend to promote balling. Any increase of clay bond tends to create clay balls in fine molding sands. The propensity for clay balls increases with greater mechanical handling of finely bonded molding sands. A molding sand that feels “mealy” is too high in clay or fines content. Individual sand grains stick together, thus producing clay balls. Heavy additions of naturally bonded sands containing fines also promote balling. A few recommendations for reducing clay balls are as follows:

1. Work the molding sand as dry as conditions permit.
2. Keep the clay content as low as possible.
3. Avoid excessive inert fines which build up in the system.
4. Constantly control the ash or other inert materials in the molding sand if they are created during casting.
5. Reduce riddling and handling to a minimum.
6. Avoid heavy additions of new naturally bonded sand; add a minimum amount of bond with proper mulling. Add as little new naturally bonded sand as possible to maintain molding properties.
7. Avoid balling-up with small additions of Panther Creek bentonite as a replacement for the required larger amounts of naturally bonded sand.
Properties of Molding Sand

Nonferrous foundry sand mixtures should have good green compression strength, suitable permeability, adequate deformation, but low dry and hot properties.

Green compression strength is necessary to maintain molding workability. Deformation enables molders to lift sand from pockets in the pattern and to avoid mold cracking during handling. Proper permeability is necessary to avoid boiling of the metal within the tempered mold and to allow the proper escape of gases which occur at the mold-metal interface in the mold cavity. Toughness of the sand mixture allows the molds to be mishandled with less danger of drops, crushes, or broken molds.

Molding sand should not feel “mealy.” Sand grains must not group or cluster upon reuse because grouping causes brittle sands which produce rough castings. Therefore, new sand must be added constantly to dilute the buildup of fines and trash in the system. The lime and oxide content in the base sand must be minimal because casting surface problems may develop.

Other Sand Additives

Carbons: Nonferrous foundries are accepting carbon materials as sand additives more freely than they have in the past. Fear of the ill effects from carbon in molding sands has lessened. Greater emphasis is being placed on the use of compounded carbon mixtures in nonferrous molding sands because these mixtures simplify handling problems. Because various sand mixtures require different carbon blends, the recent trend is to blend a cellulose with a fixed carbon and a controlled volatile carbon. The carbon combination additive serves this need.

It is believed that carbons intended for nonferrous use will continue to be blended separately from the clay. It is uneconomical to combine blended carbons with clay bond but such premixtures are being sold. Carbon and clay should be added separately to obtain proper quality control, otherwise, too many waffler changes occur in the base formulation of the system sand. Green Shell Carb is an accepted carbon compound, proven in a number of copper-base alloy foundries.

There may be a future use for various forms of sugars or starches in the nonferrous green sand foundry. These sugars could be produced from economical sources such as cellulose or wood residues. Weak, less expensive cereals and low priced grain products such as Cellfoil that prevent soft, friable mold edges are available. They also aid in the drawing or stripping of the pattern.

Pitch or Gilsonite: Large, nonferrous castings such as propellers, bells, return heads, etc., are cast in coarse base sands, and most often in dry sand molds. Pitch and gilsonite are generally added to sand mixtures to produce strong and hard baked molds. Upon reheating, the poured hot metal radiating through the molding sand softens the pitch or gilsonite contained within the mold, thereby relieving certain stresses or strains in the mold. Most larger, nonferrous castings are made in dry sand molds. Approximately 2% to 4% pitch or gilsonite is used in such dry sand mixtures. Too much gas can be produced to the casting if the base sand is not open, or if the mold is not properly vented. Too many additives also defeat the purpose of using open sands under these circumstances. All dry sand molds are usually well coated with refractory sprays or washes.

Charcoal: Finely ground charcoal is employed when extra fine brasswork for ornamental purposes is being cast. Charcoal is blended with cement or other binders and dusted on the mold surface to achieve better casting finish. This step is unnecessary if correct mold density and good grain distribution of the base sand is observed.

Wood Flour and Cellulose: Nonferrous foundries have found Five Star Wood Flour or Cellfoil (grain cellulose) advantageous in overcoming volume changes in sand molds, thus eliminating buckles, rat-tails, and scabbing action. Rapid volume changes can be controlled by incorporating approximately 1% to 2% Five Star Wood Flour or Cellfoil in naturally bonded sands or synthetic (compounded) sand mixtures. Sand that is too uniform (narrow distribution) promotes expansion defects. A wider sand grain distribution and the use of a reducing atmosphere seems to improve nonferrous molding mixtures. Some grain cellulose (Cellfoil) and the more expensive corn flour cereals are used successfully to improve the mold cavity atmosphere.

Cement: Cement bonding of a coarse sand is used in nonferrous foundries because of its low gas forming rate, particularly where intricately designed pressure bronze castings are cast which may leak or sweat. Temper water can be held below 5% providing the molds are overbaked. Cement molds also chill the metal faster, imparting deeper and denser skin on the castings. Ten percent by weight cement is considered the proper amount for bonding coarse sand. However, a higher temper water content of 5% to 9% is required.

The major disadvantages of cement molding are: 1) the need for greater storage space for molds or cores; 2) the difficult reclamation of cement bonded sand; and 3) high sand losses. Sometimes, cement is selected as the binder because cores or molds can be stored for a long period of time. Very often, cement is used as a shake-on facing to impart high dry strength on the surface of a damp mold.

Waterless Binders: For centuries, nonferrous foundrymen have been aware that the use or abuse of water in green sand molds is a prime cause of casting scrap. Even with the best moisture control, castings of certain design may be scrapped because damaging steam vapor is developed when a casting is poured. Excess steam formation
also necessitates the use of relatively coarse molding sands so as to ensure proper venting.

Waterless binders were developed so that unbonded sand could be mixed with oil because oil has a higher boiling point than water. An inexpensive, non-detergent oil with a relatively high viscosity (over 300 cps) is used. An emulsified oil is also most reliable.

**Neo-Bond**, used by the nonferrous foundry, is such a waterless binder. (Fig. 48) All that is required to lubricate a mixture contain-

*Figure 48 — Marine hardware cast in a sand mixture containing a waterless binder.*

ing 3.0% to 5.0% Neo-Bond (waterless binder) by weight is 1.25% to 1.8% high viscosity coastal or emulsified oil. The amount of coastal oil required depends on the fineness of the base sand. The binder is mixed with a dry, relatively clay-free sand and milled for approximately 2 minutes in a slow, heavy duty, vertical wheel muller. The mixture is milled for approximately 10 to 15 additional minutes after the oil has been added. This develops improved strengths. The mixture is then discharged and is ready for molding. The Neo-Bond molding mixture does not dry out and can stand for long periods before pouring. Light weight copper-base alloys are cast in a mixture prepared in this manner. Heavy copper-base alloys, however, burn water-free sands; the economics have not been fully established for all general nonferrous practices.

**Handling of Sand and Additives**

The rapid trend towards further use of synthetic (formulated) sand is continuing. Pneumatic unloading and transporting of sand and additives is becoming more popular. Use of anti-segregation bins is increasing. Other developments include automatic bond handling equipment from storage bins to the muller.

Bulk handling equipment capable of handling any amount of sand and binders can now be purchased for reasonable amounts. Such an installation eliminates dust, labor, bag handling, and helps eliminate an accumulation of unwanted containers.

Only a few large, mechanized foundries use sand reclamation equipment. Productivity equipment is generally given preference over sand reclamation and storage equipment. Inadequate sand storage is a problem common to most nonferrous foundries. There is also a lack of hopper capacity which is the chief reason for the occurrence of undesirable hot sands in all foundries. This shortcoming is, however, being recognized and rectified in most present installations.

More dust control equipment is being installed around sand conditioning areas. Some foundries have elaborate sand handling equipment. Sand handling operators are being placed in air-conditioned control rooms. Here they operate a large control panel which shows the amount and location of all sand and raw materials passing through the system. The sand handling operator can pull a batch of molding sand and transport it quickly and efficiently to any location in the foundry.

**Gating**

Gating of copper-base alloys follows certain important principles. The liquid metal must be trapped or skimmed otherwise asp may result. The metal must be introduced into the mold cavity without dross or slag, and erosion of the mold or core must be avoided. The
metal must not absorb gas. Various alloys must be gated differently due to differing characteristics. Metal furnace refractories erode easily under thermonuclear activity, temperature, pressure, and abrasion. This erosion contributes to the occurrence of inclusions in castings if the metal is not properly skimmed. (Fig. 49)

Rates of flow through various sized gates are available from many sources, together with the metal's recommended head height. A tapered sprue measuring 1" down to ½" in diameter delivers more metal than a straight parallel sprue, a factor which is important when considering bottom gating.

Scrap Report

This report should be prepared daily and can be consolidated and summarized monthly. The responsibility for preparing the scrap report should rest on two capable men—usually the foundry foreman and the cleaning room foreman. Information should be obtained from one source—the losses or scrap on the inspection table in the cleaning department which fails to meet shipping requirements.

Information should be tabulated after each shift. Rejected castings should be returned to the foundry before the next shift starts. Without a rigid routine, the preparation of this report may be valueless, particularly if rejects are allowed to accumulate over several shifts. The report should be dated. Individual entries for each day should show the customer’s name and the pattern number of the scrapped casting.

Classification of the trouble and scrap, the number of such defects and the weight should be entered in the report. If corrective steps are to be taken, the defect must be described in detail. Evasive and vague descriptions of scrap render the report worthless.

Porosity (For Example)

There is no concrete agreement concerning the reason for porosity in nonferrous metals. Removing undesirable gases in nonferrous metal is a problem so complicated and attached to so many theories, that one easily may develop strong arguments to support individual claims. There are continual differences of opinion on porosity, each supported by little proven evidence. No single remedy works universally for all nonferrous foundries.

Porosity usually is a product of a series of incorrectly applied practices or incorrectly applied fundamental foundry laws. Even though slightly imperfect castings may be salvaged, the time and materials required to reclaim them affects foundry profits. A series of foundry errors may cause porosity, e.g., hot sands cause brittle sands, which erode and promote inclusions, which develop casting pinholes.

It has been claimed that more than six improper operating procedures usually create porosity or gas defects. If an operation was constantly in error on a ten percent average, at the end of ten such operations there would be a 100% source of error. (Fig. 30)

It is often wise to invite an outside service engineer to the foundry when difficulty arises. His investigation is usually impartial. His opinion as to the causes can include sand, molds, cores, metal, ladles, melting practices, and/or other departments in the foundry without need of a defense. This approach to finding a solution is strongly encouraged.

In summary, nonferrous foundry practice is comprised of time-tested rules governing operations. These rules can be determined by evaluation of elementary records and observance of certain practical foundry tests. As the scrap report is introduced, the adoption of a combination of rules automatically establishes the practice to correct and eliminate costly scrap.
Copper-Base Molding Mixtures

Green Sand
LIGHT TO HEAVY CASTINGS

These green sand mixtures are to be used in the casting of various weight copper-base alloys. For general formulae to start a synthetic sand system, these are recommended:

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>Light Castings</th>
<th>Medium Castings</th>
<th>Heavy Castings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 60-90</td>
<td>50</td>
<td>93</td>
<td>89</td>
</tr>
<tr>
<td>Silica or Bank Sand, AFS Gr. Fn. No. 90-120</td>
<td>43</td>
<td>94</td>
<td>89</td>
</tr>
<tr>
<td>Voleay Bentonite</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Panther Creek Bentonite</td>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Plastic Fireclay (ground)</td>
<td>---</td>
<td>---</td>
<td>3</td>
</tr>
<tr>
<td>Pitch (ground)</td>
<td>---</td>
<td>---</td>
<td>2</td>
</tr>
<tr>
<td>Green Shell Carb</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cellfllo</td>
<td>---</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Temper Water</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Mulling:* For new sand mixtures, mull 2 minutes dry and 4 to 5 minutes wet with a vertical wheel muller, but not less than 90 seconds with horizontal mullers. Riddle the mixture over the pattern for improved casting finish.

Green Sand
SEMI-SYNTHETIC MIXTURES FOR SMALL LIGHT CASTINGS

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 90-120 (less than 1% clay content)</td>
<td>73.0</td>
</tr>
<tr>
<td>Natural or Bank Sand, AFS Gr. Fn. No. 250 (less than 12% clay content)</td>
<td>25.0</td>
</tr>
<tr>
<td>Panther Creek Bentonite</td>
<td>2.0</td>
</tr>
<tr>
<td>Temper Water</td>
<td>5.0 - 6.0</td>
</tr>
</tbody>
</table>

Green Sand
SMALL-MEDIUM FLAT CASTINGS

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, or Special Washed Sand, AFS Gr. Fn. No. 115-150 (grade depends on choice of casting finish)</td>
<td>57.5</td>
</tr>
<tr>
<td>Albany Naturally Bonded Sand, Tenn., N. J., or Miss. retained on a U.S. Standard No. 50 Sieve</td>
<td>40.0</td>
</tr>
<tr>
<td>Panther Creek Bentonite</td>
<td>2.0</td>
</tr>
<tr>
<td>Five Star Wood Flour (no more than 5% by weight)</td>
<td>0.5</td>
</tr>
<tr>
<td>Temper Water</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Mulling:* For new sand mixtures mull 2 minutes dry and 4 to 5 minutes wet with a vertical wheel muller, but not less than 90 seconds with rotating horizontal wheel mullers. Riddle over the pattern for improved finish.

Green Sand
MEDIUM CASTINGS

This is an excellent mixture for general floor molding since it is heavier than those prepared for the bench or squeeze machine. It is a good mixture for molding cope and drag patterns where molding machines and molding equipment are provided.

Good moldability is obtained with this mixture if proper mulling is established. It is a general sand mixture for most medium castings. Silicon flour reduces the tendency of mechanical metal penetration.

*See Chapter III, page 69.
where higher ferrostatic pressures are encountered. Cellflo reduces the
cost of cellulose and corn flour and gives better shakeout. Less cutting
or erosion occurs when some silica flour is present in the mixture.

**MATERIALS**

<table>
<thead>
<tr>
<th></th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 60-65</td>
<td>88.0</td>
</tr>
<tr>
<td>Volclay Bentonite</td>
<td>6.0</td>
</tr>
<tr>
<td>Silica Flour (200 mesh)</td>
<td>5.0</td>
</tr>
<tr>
<td>Cellflo (cellulose)</td>
<td>0.5</td>
</tr>
<tr>
<td>Corn Flour (light weight)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Temper Water**

3.5

*Mulling:* Mull dry 2 minutes in a slow conventional muller and at
least 6 minutes wet. Mull 2 minutes minimum in a high
speed horizontal wheel muller.

**Properties**

<table>
<thead>
<tr>
<th>Green Sand Compressor</th>
<th>Dry Compressor</th>
<th>Permeability</th>
<th>Mold Hardness</th>
<th>Moisture % by wt.</th>
<th>Density Grms./2&quot; Sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength, psi. 11-13</td>
<td>70-90</td>
<td>50-60</td>
<td>80-85</td>
<td>3.5</td>
<td>165-170</td>
</tr>
</tbody>
</table>

Green Sand

**Medium Castings**

This is a simple formula to prepare. It should be rammed hard,
particularly around the down-gate (sprue) and the total runner system.
Other ingredients may be added to this formula for specific purposes.
One-half percent wood flour (Five Star) reduces dry and hot proper-
ties; whereas dextrine and resin give harder surfaces on the mold when
the mold is left standing. More green strength and deformation may be
obtained by increasing the Volclay bentonite if improved lifts or
draws of the pattern are necessary. This mold may be coated if better
casting finish is desired.

**MATERIALS**

<table>
<thead>
<tr>
<th></th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 65-70</td>
<td>94.0</td>
</tr>
<tr>
<td>Volclay Bentonite</td>
<td>5.0</td>
</tr>
<tr>
<td>Cereal (light weight)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Temper Water**

3.0 - 3.5

*Mulling:* Two minutes dry, 4 minutes wet in a slow conventional
muller. Mull 90 seconds minimum with a horizontal
wheel muller. *(Properties—Next Page)*

---

**Green Sand**

**Anti-Scar Mixture**

This mixture has low expansion properties. It flows well when
forming the mold and gives good mold density, yet has low volume
change during casting.

**MATERIALS**

<table>
<thead>
<tr>
<th></th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 60-65</td>
<td>91.0</td>
</tr>
<tr>
<td>Volclay Bentonite</td>
<td>4.0</td>
</tr>
<tr>
<td>Panther Creek Bentonite</td>
<td>2.0</td>
</tr>
<tr>
<td>Green Shell Carb (carbon additive)</td>
<td>2.0</td>
</tr>
<tr>
<td>Cellflo (cellulose)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Temper Water**

3.5

*Mulling:* Mull dry 2 minutes with a slow, rotating muller. Mull 6
minutes wet. Mull 90 to 120 seconds minimum with
a faster horizontal rotating wheel muller.

**Anti-Buckle Mixture**

This mixture was created to eliminate defects caused by sand
expansion. Reduce ramming or squeezing so as to give a 70-75 mold
hardness.

**MATERIALS**

<table>
<thead>
<tr>
<th></th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 150</td>
<td>60.57</td>
</tr>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 60</td>
<td>33.00</td>
</tr>
<tr>
<td>Volclay Bentonite</td>
<td>4.0</td>
</tr>
<tr>
<td>Five Star Wood Flour (no more than 5% retained on U.S. Standard No. 50 Sieve)</td>
<td>1.80</td>
</tr>
<tr>
<td>Cereal Binder (heavy weight corn flour)</td>
<td>0.63</td>
</tr>
</tbody>
</table>

**Temper Water**

3.9 - 4.1

*Mulling:* For new sand mixtures mull 2 minutes dry and 4 to 5 minutes wet with a vertical wheel muller, but not less than

---

*See Chapter III, page 69.*
90 seconds with fast horizontal wheel millers. Riddle the mixture over the pattern for improved finish.

Green Sand

ZIRCON FACING MIXTURE

This fireclay-bentonite bonded zircon sand mixture is used in fillet or hot spot areas of certain molds where light veining or metal shrinkage occurs. The mixture applies to all types of molds, e.g., green sand, skin-dried, or oven-dried molds. It is particularly recommended for casting blades, impellers, valves, turbines, steam chests, etc. Hevi-Sand has replaced zircon sand in many foundries where Hevi-Sand was more successful. Volelay bentonite may be used 100% instead of the fireclay; if so, then only 3.0% by weight Volelay is required.

MATERIALS

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zircon Sand, AFS Gr. Fnr. No. 100</td>
<td>96.0</td>
</tr>
<tr>
<td>Plastic Fireclay (ground)</td>
<td>2.4</td>
</tr>
<tr>
<td>Volelay Bentonite</td>
<td>1.6</td>
</tr>
<tr>
<td>Temper Water</td>
<td>2.5</td>
</tr>
</tbody>
</table>

*Mulling:* Mull 2 minutes dry and 6 minutes wet in a slow conventional muller. Mull 90 seconds in a fast horizontal wheel muller.

Green Sand

PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression Strength, psi.</td>
<td>6-8</td>
</tr>
<tr>
<td>Dry Compression Strength, psi.</td>
<td>170-180</td>
</tr>
<tr>
<td>Permeability</td>
<td>40-50</td>
</tr>
<tr>
<td>Mold Hardness</td>
<td>80-85</td>
</tr>
<tr>
<td>Moisture % by wt.</td>
<td>2.5</td>
</tr>
<tr>
<td>Density Gms./2&quot; Sp.</td>
<td>270-275</td>
</tr>
</tbody>
</table>

Green Sand

MEDIUM TO HEAVY CASTINGS
COPE AND DRAG MACHINES

Hevi-Sand is more effective than silica, zircon or olivine when casting certain copper-base alloys. Various grades of Hevi-Sand are replacing olivine and zircon at many leading foundries. The burn-on and penetration which is generally due to the oxide film on the liquid metal is eliminated with Hevi-Sand mixtures, as they resist the mold-metal chemical attack much better than the other sand mixtures. The adherence of the metal's thin oxide slag on the molding sand is less critical when Hevi-Sand is used.

Due to the stable thermal characteristics of Hevi-Sand mixtures, there is less reaction of the mold. Hevi-Sand chills metal faster; fewer fine hot tears occur. There is no sand expansion such as with silica sand mixtures. Because low clay and low water are used with Hevi-

---

*See Chapter III, page 69.

Sand mixtures, the mold collapses reasonably well. Also, less subsurface metal-gas porosity is likely. There may not be a need for a mold coating where Hevi-Sands are used, but many nonferrous foundries prefer a surface protection for many reasons. A zircon or olivine mold coating is preferred over a silica base refractory.

MATERIALS

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hevi-Sand, AFS Gr. Fnr. No. 55-60</td>
<td>72.25</td>
</tr>
<tr>
<td>Hevi-Flour, No. 100 or No. 200</td>
<td>25.00</td>
</tr>
<tr>
<td>Volelay Bentonite</td>
<td>2.50</td>
</tr>
<tr>
<td>Corn Flour (light weight)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Temper Water

2.50

*Mulling:* Mull dry two minutes with a slow rotating conventional muller, continue to mull at least six minutes wet. Mull 90 seconds minimum with a faster horizontal rotating wheel muller.

Dry Sand Mold Mixture

HEAVY CASTINGS

The base sand should not only be selected for economic reasons but also for the casting finish required, the permeability demanded, the type of molding method used, the operating equipment and numerous other requirements. Dry sand mixtures must be worked or molded as wet as possible since resin bonded mixtures are not activated by low temper water. Without high temper water, molds have limited dry and baked strengths which can cause difficulty when the molds are being handled. For harder, denser molds—more clay and temper water are required. Cereal or other organic materials may be used, but not more than 1.0% by weight. Even the temper water may contain goulac, molasses, dextrin or other soluble auxiliary binders.

The following formula may also have a naturally bonded sand added to it to make a "semi-compounded mixture." A 15.0% to 20.0% naturally bonded sand addition gives more workability, improves patching of the mold (if required), and allows easier moisture control. The clay-bentonite addition may be reduced if a naturally bonded sand with high clay content is added to the formula.

*See Chapter III, page 69.*
Dry sand molds must be designed to resist pressure from large quantities of hot, liquid metal entering the gating system. Skin-dried molds may do the job, but since they require much clay, auxiliary binders, and finer sands coupled with larger amounts of water, skin-dried molds may not be safe to use with all sizes of castings or different alloys of metal. This dry sand mixture is strong and resists the liquid metal's eroding and chemical action.

Dry molds are firm and resist metal penetration when standing with hot liquid metal in them. Pitch may replace natural rosin in this formula. The normal substitution is about 4.0% to 5.0% by weight pitch for the rosin in the formula.

Since molten metal exerts a pressure on the sand mold of about 3.4 pounds per square inch per foot of depth below the surface of the metal, rigid dry sand molds must be used for pouring large castings. This dry sand mixture is recommended where mold-wall movement may occur.

**MATERIALS**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PERCENT BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Sand, AFS Gr. Fn. No. 60-65</td>
<td>63.00</td>
</tr>
<tr>
<td>Silica Flour (140 mesh)</td>
<td>20.00</td>
</tr>
<tr>
<td>Fireclay (pulverized bond)</td>
<td>6.00</td>
</tr>
<tr>
<td>Volcaley Bentonite</td>
<td>4.00</td>
</tr>
<tr>
<td>Klean Surf Iron Oxide</td>
<td>4.00</td>
</tr>
<tr>
<td>Natural Rosin (pitch may be substituted)</td>
<td>2.25</td>
</tr>
<tr>
<td>Corn Flour (light weight)</td>
<td>0.75</td>
</tr>
</tbody>
</table>

| Temper Water                  | 6.0 - 7.0         |

**Mulling:** Mull 1 minute dry in a vertical wheel muller, then continue mulling 6 minutes after the temper water is added. Riddle the mixture over the pattern evenly for best results. Some foundries prefer to add one-half the mixture to the muller, then all the water, followed by the other half of the mixture. Mulling is continuous. Higher and quicker strengths are claimed for this method.

**Baking and Drying the Mold**

Most flask molds are dried about 600° F. (315° C.) — no more than 805° F. (435° C.). They are usually dried overnight. The drying time required depends upon the type of flasks used, the ovens available for baking, and other mechanical reasons. Higher temper water additions may require longer baking periods in the oven, but it is the safer practice. Some foundries use temperature pill indicators and/or crayons to denote the actual temperature of the mold baking in the oven. Many of these temperature pills may be placed in a hollowed-out section of the mold to indicate how deeply that particular temperature penetrated the mold. Some foundries imbied thermocouples into the molds or cores to measure the depth of heat penetration during baking. The molds are well vented and a mold wash is applied.

For detailed information regarding raw materials mentioned, please refer to other chapters.

**PROPERTIES**

<table>
<thead>
<tr>
<th>Property</th>
<th>Green</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression Strength, psi</td>
<td>470-475</td>
<td>40-45</td>
</tr>
<tr>
<td>Permeability</td>
<td>45-55</td>
<td>57-80</td>
</tr>
<tr>
<td>Mold Hardness</td>
<td>1-1.5</td>
<td>1.5-3.0</td>
</tr>
<tr>
<td>Moisture % by wt.</td>
<td>6.0 - 7.0</td>
<td>170-175</td>
</tr>
<tr>
<td>Density, gms./in.</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

**Shake-Out—Dry Sand Molds**

Dry sand molding is designed to give a hard, concrete-like mold condition at the shakeout. Otherwise, inclusions, washes and cuts may occur. The hard shakeout sometimes indicates better castings. This is one of the features of dry sand molding that must be accepted. Equipment must be heavy and rugged enough to aid the foundry in this respect. Shakeout which is too easy might indicate that trouble may develop in the castings. Before decreasing dry strength make certain that its decline will not affect casting quality or scrap.

**Olivine Sand Mixtures**

**SPECIAL FACINGS**

**LIGHT TO MEDIUM-HEAVY CASTINGS**

When making molds for nonferrous castings, olivine sand is used for many special applications where a smoother casting finish is desired. These sand mixtures are similar to silica sand mixtures, except that more bond is generally added due to the grain shape of the olivine sand. Consequently, the water content is also increased. Molds that are made with the light facing sand mixture are cast in the green condition. The medium to heavy facing sand mixture may be used either green or as dried sand depending on the size and shape of the casting.

(Continued—Next page)

**Acknowledgement**

The author is grateful to C. A. Robeck, Baltimore, Maryland, for the valuable information he has supplied in the past. Mr. Robeck has learned the value of controls in the alloy foundry and has passed much of his knowledge onto the author. We are grateful for his help.

*See Chapter III, page 69.*
**Light Casting**

25 lbs - 600 lbs.

<table>
<thead>
<tr>
<th>PERCENT BY WEIGHT</th>
<th>MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>94.30</td>
<td>Olivine Sand, AFS Gr. Fn. No. 58</td>
</tr>
<tr>
<td>4.75</td>
<td>Volclay Bentonite</td>
</tr>
<tr>
<td>0.65</td>
<td>Olivine Flour (140 mesh)</td>
</tr>
<tr>
<td>0.30</td>
<td>Dextrine</td>
</tr>
<tr>
<td></td>
<td>Corn Flour (light)</td>
</tr>
<tr>
<td></td>
<td>3.50</td>
</tr>
</tbody>
</table>

**Medium to Heavy**

250 lbs - 1000 lbs.

<table>
<thead>
<tr>
<th>PERCENT BY WEIGHT</th>
<th>MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>89.15</td>
<td>Olivine Sand, AFS Gr. Fn. No. 58</td>
</tr>
<tr>
<td>5.35</td>
<td>Volclay Bentonite</td>
</tr>
<tr>
<td>4.45</td>
<td>Olivine Flour (140 mesh)</td>
</tr>
<tr>
<td>0.70</td>
<td>Dextrine</td>
</tr>
<tr>
<td>0.35</td>
<td>Corn Flour (light)</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
</tr>
</tbody>
</table>

*Mulling:* Mull dry two minutes with a slow, conventional muller; continue to mull at least six minutes wet. Mull 90 seconds minimum with a faster rotating muller.

Western bentonite (Volclay) and olivine sands are compatible. It is claimed that after olivine sand mixtures are properly bonded with western bentonite, very little new western bentonite additions are required to maintain properties. Mulling may also be decreased since there is a chemical effect between the western bentonite and the olivine, a magnesium silicate.

**PROPERTIES**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0</td>
<td>Green Compression Strength, psl. 8.8</td>
</tr>
<tr>
<td>180.0</td>
<td>Permeability 160.0</td>
</tr>
<tr>
<td>3.5</td>
<td>Moisture, % by wt. 4.5</td>
</tr>
</tbody>
</table>

**REFERENCES**


