Key Fundamentals for Sand Preparation and Reclamation

Today's informed foundrymen recognize the importance of careful control of all variables to assure quality sand mold production. Here, many of the fundamentals of sand preparation and reclamation are reviewed in a new light.

Approximately 90% of all castings produced today in the United States are made by the sand molding process. Sand preparation and control require an understanding of the interaction of the various parameters normally measured in a system sand.

Clay and water still are the primary additives to a system sand. Seacoal, cellulose, and starches may also be used to impart specific properties. The most common type of base sand continues to be silica sand. Zircon, chromite, and olivine sands are selected for special applications.

Even today, some foundries still do not have the proper equipment for preparing their molding aggregates, or do not maintain their equipment adequately, or operate it beyond the manufacturer's recommendations with respect to capacity and mulling cycle. Sand technicians should not be asked to short-mull mixtures to meet the demands of molding departments or to resort to the use of additives incompatible with basic technical objectives.

With ready availability of and easy access to today's high-technology instrumentation, all stages of molding sand preparation—including reclamation, cooling, and storing—can be adequately monitored and controlled, lest casting problems be encountered. However, old truths should be viewed in a new light at times, as additional insights develop. With this thought in mind, the following brief reminders are presented.

Premises to Build On—Judicious
thoroughly. Thus, they often are more difficult to compact, and they develop adequate strength only at compaction energy levels considerably higher than was the case with earlier sand mixes. Indications are mounting that production methodology today contributes to increasingly narrower property tolerances; relatively small deviations from specifications are much more likely to lead to production difficulties than was the case earlier. This means that foundry molding sands must be monitored more thoroughly and studied from new points of view.

The advent of new and more productive molding equipment (compaction by shock wave, air impulse, or vacuum) requires a molding sand adequate for the new process, and the situation existing at shakeout has to be taken into account: Dieter S. Leidel, Tanack Enterprises Inc., reminds foundrymen of wide temperature and moisture fluctuations, non-silica contaminants, agglomerates and coarse pieces, and sand grains enveloped by calcined clay.

**Basic Requirements**—It is generally agreed among sand technicians and equipment manufacturers that the most desirable molding sand preparation system will incorporate these basic features:

1. Capacity adequate to meet existing molding requirements and anticipated expansion needs.
2. High and uniform quality of sand, well aerated and free of lumps.
3. Sand temperature below 40°C.
4. Automatic moisture control accuracy to 0.1%.
5. Exact additive (ingredient) metering and good monitoring of aggregate components.
6. Recirculation of valuable fines into the system.
7. Ready accessibility of system components for cleaning and repair, and low maintenance costs.
8. Dust-free and noise-free operation of the installation.

Sand preparation systems, in addition, must satisfy a number of mold functional requirements: The molding aggregate must be flowable enough to pack tightly around the pattern; it must exhibit a degree of plastic deformation without cracking so that the pattern can be withdrawn.

Green sand must have sufficient strength to strip from the pattern and then support its own weight without changes in shape (distortion). Moreover, it must withstand the pressure of molten metal when the mold is poured off and exhibit dry strength (to prevent erosion) as the mold is filled with liquid metal. Finally, the prepared sand in the mold must display refractoriness to withstand the high temperatures without melting or fusible to the casting.

**Viewpoints on Mulling**—As the late E.C. Troy, formerly with National Engineering Co., stated so cogently many years ago, “The foundry sand muller is a specialized production machine, and a foundryman judges the muller by the sand it produces.” Many millions of varied particles must be uniformly intermingled and surface-coated with viscous bond consisting of bentonite plus water. “Water and bond must be kneaded into a dough-like consistency with development of adhesive glue properties so that the glue can readily encompass the sand grains.”

It is generally agreed, based on observations of many muller installations, that regardless of muller type or size—muller cycle times of less than 90 sec are inadequate for ideal parameter control in sand preparation. Counting mulling time should not start until all ingredients of the system sand have been added, including water. (This caveat is frequently overlooked.)

As mulling proceeds, the mixture becomes more uniform with respect to physical and mechanical properties. In most foundries, the extent of mullings is established on an arbitrary time or mulling energy basis, as a function of sand capacity demand. Troy and Matthew J. Granlund, Foundry Systems Control, have said that the mulling process “should cause complete disorder so that the mullled product is uniform throughout when it is sampled and tested.”

Probability laws tell us that some sand grains will not be moved at all in mulling, while a like number will be moved almost continuously. Movement is strictly random, in other words.

The major objective in molding sand preparation is to obtain a uniform, homogeneous aggregate of sand grains completely coated with binder. Clay-bonded molding sands get their correct consistency by preparation with water and binder. It is important to remember that the correct temper water content affects all sand properties and must be monitored reliably and continuously. Checking moldability and compaction is an important way to maintain quality assurance.

**Microwaves for Moisture Testing**—The principal problem with obtaining good on-line control at the muller is the fact that return sand going into the unit is not a single, uniform material. Rather, as Dr. Charles Walker, Pacific Automation Instruments, has pinpointed, five different aggregate streams usually come together, namely shakeout sand, strikeoff sand, sand from broken up unused molds, makeup sand, and used core sand (core butts).

Each of these feeds may have distinctly different properties, temperature, moisture content, and density, and the materials enter irregularly with the result that they vary in active clay, seacoal, and water content. The variations encountered may not be random, either.

Walker has developed an on-line moisture control instrument, for continuous and batch millers, that uses absorption of microwave energy as the basic principle for sensing moisture. (Microwaves interact with the
rotational energy of the whole water molecule which is an electric dipole.)

It is a fundamental principle of statistics that a sample taken from a batch of material provides only an estimate of whatever property of the batch is being tested: if the muller has done a good job, the sample will be accurate.

The portable instrument, designed to work anywhere in the foundry, according to Walker, can be extremely versatile. It can be used to measure shakeout sand, return sand, milled sand at the muller or at the molding machines, core sand, makeup sand, but it does only measure a sample. For core sand and for milled sand, this presents no problem. In fact, a portable instrument is particularly valuable for milled sand because of the inverse relationship between density and compatibility so that it can provide an on-the-spot check of both compatibility and moisture, both at the muller and at the molding machines.

A Word on Bentonite—Sand technicians investigating new methods for controlling foundry sand systems may rely on simple chemical tests to evaluate bentonite quality without realizing that the results may have little or no correlation with the basic functional properties of clays. As L. Edgar Odom, American Colloid Co., has reminded foundrymen recently, the bonding and thermal properties of bentonite are controlled by the chemical composition and exchangeable ion content of the montmorillonite. Moreover, “bentonites even from a single stockpile exhibit a range of variations in bonding and thermal properties.”

“The performance characteristics of bentonite in green sand molding aggregates are best determined in a sand mixture rather than by indirect chemical tests.” According to that view, bentonite properties that reflect quality for foundry application are green, dry, and hot strengths, and exchangeable ions.

Calcium bentonites have higher green strength than sodium bentonites because the hydration of the calcium ion develops more rigidly oriented water layers on the montmorillonite crystal’s basal surface. Sodium bentonites, on the other hand, have higher dry strength because the sodium ion permits the montmorillonite flakes to separate and disperse, giving a more uniform clay coating over the sand grains.

Hot strength properties of bentonites are related to the chemical composition and exchangeable ion content of the montmorillonite. The high hot strengths of Wyoming bentonites are related to high aluminum and sodium content, and the influence of sodium on clay dispersibility.

Wet tensile strength is a characteristic only of sodium bentonites, because the sodium ion tends to develop oriented water layers rapidly when liquid water is present.

Hot Molding Sands—Hot molding sands are a ubiquitous occurrence, responsible for many problems: Aggregates become brittle and stick to the pattern, casting finish deteriorates, and scrap increases. Moreover, long ago it was pointed out by R.W. Heine, King, and Schumacher that molding sands at temperatures over 160 F (71 C) do not null to any consistent degree so that properties can be predicted with assurance. The best sand for molding is cool and fully milled.

The cooling process takes time and is a function of batch size, cooling air, type of muller, ambient temperature, amount of water addition, and rotational speed of the muller. It is widely accepted today that sand should be cooled, preferably to below 100 F (38 C), before it is returned to the muller, and the philosophy of sand preparation is that the entire sand processing cycle is a “dynamic heat transfer system” that must be engineered to avoid the hot sand problem. The sand-to-metal ratio is the key, the experts agree.

Where this ratio is sufficiently high, say 15:1, no hot sand problem will exist. Several methods to avoid any difficulty are available:

- Most common is cooling returned shakeout sand by moisture vaporization either at the shakeout, on conveyors, or in the sand conditioning unit and aerator.
- Heat exchangers are popular, and fluidized bed coolers are typical. (But the sand must be dry enough to be fluidized.)
- Flooding of return sand with fresh system sand is another viable method for cooling. This practice is associated with high sand-to-metal ratios, according to work by AFS Committee 80 A-2. The higher the ratio, the cooler the sand.
- Schumacher and Heine have stated that maximum cooling is obtained by “blending the shakeout and prepared sand together on belts using plows spaced 20 sec apart.”

- A number of other methods, less popular here in the United States, also have been cited in the pertinent literature; however, the general principle in all cases is to cool by water evaporation.

Jerry W. Kucharzyk, Highland Foundry Ltd., Canada, and Leidell said last year that combined cooling, reclamation, and particulation of green sand is a cost-effective method, and that its use can lead to productivity improvement, particularly in small and medium-sized foundries.

It has been recommended that engineers design systems so that the sand

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**Some Potential Problems Caused by Faulty Sand Preparation**

1. High cellulose content or excessive organic additive materials cause penetration.
2. High moisture content combined with high western bentonite content results in penetration.
3. High moisture content combined with low total clay content causes penetration.
4. Use of hot molding sand causes a host of problems.
5. Insufficient mulling (mixing) of the sand increases the susceptibility to "water explosion."
6. As organic additives burn during metal pouring, they create gas and may be a source of porosity.
7. Excessive carbonaceous additives can reduce mold density.
8. Organic additives always require more water for tempering, and many organic additives don’t contribute to the bonding process.
9. It should be remembered that sodium (western) bentonite swells when wetted, whereas calcium (southern) bentonite exhibits minimum swelling when wetted.
10. Excessively high dry strength increases the probability of scabbing and other expansion defects and may cause lumps in the return sand.
temperature does not exceed ambient by more than 15 deg F as the sand enters the muller. It is worth repeating that the hot sand problem can be corrected in any metallic casting plant, because proven procedures and effective equipment are available.

Critical Process Control Variables for Chemically Bonded Sand

- Sand Temperature—Controls chemical reaction speed that sets the sand.
- Sand Feed Rate—Establishes amount of binder needed to get desired strength.
- Binder & Catalyst Temperature—Affects viscosity and pumping efficiency of binder components.
- Binder Flow Rate—In conjunction with sand flow rate, determines amount of binder on the sand and strength of the finished core or mold. Too much binder can lead to wasteful excess and, in extreme cases, gas porosity in the castings.
- Catalyst Flow Rate—Determines reaction rate of most chemical sand binders (exceptions are sodium silicate and phenolic ester-based binders).
- Mechanical Function—Vibration, motor resistance to load, motor speed, etc., affect distribution of binder on sand grains and mixer output.
- Sand Size Distribution—Affects the amount of binder needed to coat sand grains.

Curing rates of all cold-setting chemical binders used in mold and core production respond quickly to any variation in sand temperature. Cold sand delays hardening; hot sand accelerates hardening but may shorten bench life of a mixture, resulting in friable molds and cores. Predictable curing rates can be obtained only through close control of sand temperature.

Sand storage hoppers and silos should be sitz under cover, and silos should be insulated.

Caveats for Reclamation—Sand reclamation must not be misunderstood as a waste treatment process; rather, it is an integral part of the foundry sand preparation system. Today, a major concern of the foundry industry in all highly industrialized countries is the reclamation of molding sand—for environmental and economic reasons—as becomes evident from reading and evaluating the many publications on the subject. Reclamation on the order of 80-90% is possible for chemically bonded sands, if the literature references can be believed. Often overlooked is the fact that the major percentage of cast products is made in inorganic bentonite-bonded sands with a degree of reclamation efficiency on the order of 95-97%. On the basis of practical experience, organically bonded sands require 10-20% addition of new sand as part of the reclamation process, authoritative information sources state.

Most sand recovered from the production of sand castings can today be reclaimed economically when all pertinent costs are considered for the alternative (new sand purchases, transportation costs, trucking to an often remote landfill, fees for landfill use, costs for mandatory paperwork).

The AFS Sand Reclamation and Reuse Committee has warned that “the results of a total reclamation process are influenced by a number of key variables (parameters) such as type of sand, type of binder used originally (and for rebonding), and characteristics of the specific reclamation equipment chosen.” Dieter Leidel has pointed out that the economics of sand reclamation require an organized approach, with a complete material audit being the first step before any equipment vendor is contacted.

Sand reclamation is said to be a money-saving process for any foundry that has sand costs (delivery and disposal included) of $200,000 or more per annum. It may be possible, under certain circumstances, for foundries with annual sand costs as low as $75,000. It must, however, not be assumed that reclamation eliminates environmental considerations; reclamation just changes the focus.

Additional information may be obtained by perusing a special 60-page AFS report, published in 1987 and entitled Total Sand Reclamation. The study reviews environmental considerations, the compatibility of chemical binders, and the economics of sand reclamation.

It cannot be reiterated frequently enough that the costs of inadequate sand control, of which reclamation is an integral part, can be staggering and that sand control involves more than merely collecting data at regular time intervals. No system can be effectively optimized until all variables of the processes involved are under complete control.

The foundry contemplating sand reclamation should determine the following:

1. Amount of sand per hour, day, or week that needs to be reclaimed and is being disposed of now.
2. The characteristics of the sand being disposed of. Does it consist of core sand, molding sand, core butts, or combinations?
3. Labor cost for sand disposal presently in effect.
4. Trucking and dumping area charges for sand disposal.
5. Cost per ton for new sand at the point of usage.
6. Chemical analysis of the mate-
allows operators to adjust production variables as they occur, and sand quality thus is maintained.

Process control system installations, seen in some large Eastern ferrous foundries, display operating data and mixer status with color-coded pilot lights and digital displays. Some systems are not necessarily computers but can transmit production data to a computer.

In the light of customers' increasingly stringent demands, availability of these systems may give a foundry the competitive edge.

An Overall Assessment—Prof. Dr.-Ing. Dietmar Boenisch, Technical University Aachen, West Germany, recently made a comprehensive survey of developments affecting sand-mold properties that focused attention on the significance of selected, production-adapted, sand testing instruments and know-how in the face of disturbing evidence of mold quality deterioration. Boenisch's findings are invaluable also to American foundrymen:

1. Long-term sand and mold deterioration proceeds very slowly and inconspicuously, and difficult to detect with conventional sand testing procedures.
2. Present-day sand testing needs profound revision.
3. Major springback in the age of high-pressure molding is of increasing importance.
4. Sand control cannot be guaranteed by retaining adequate green-sand properties alone.
5. Sand control has to include both achievement and retention of optimum sand properties.
6. Green compression strength is one of the most misleading sand properties, because laboratory test results do not reflect actual mold properties.
7. Foundrymen should realize the usefulness of round sand grains in resisting the beginning of grain fracture.
8. Scanning electron microscope photographs of representative sands reveal increasing deviations from ideal bentonite distribution.
9. The high adsorption power of a bentonite surface absorbs large amounts of distillates from core binders and lustrous carbon formers.
10. The bonding power of bentonite particles is substantially weakened by envelopes of organic condensates, resulting in significant strength loss.
11. Wet tensile strength is of major interest for green sand control.
12. Water containing soluble salts in the molding medium may be the cause of mostly ignored deterioration in casting quality. Electrolytes concentrate in the sand.
13. Use of seacoal raises bentonite consumption.

Mold Venting—To produce sound, high-quality castings, one of the most important manufacturing steps is to vent the mold (i.e., the molding sand) properly to allow gases to escape. In green sand molding, this is accomplished by either pressing a metal pin into the mold or by drilling through the mold at precise locations. A robot can be programmed, by a "teach pendant" device, to perform the venting step of moldmaking. The program is then stored for future use, as A.L. Carr and W.P. O'Neil have suggested in an AFS paper several years ago.

Suggested Additional Readings
Myths, Misconceptions, and Mistakes in Sand Reclamation (AFS Paper 88-01), by Dieter S. Leidel.
Combined Cooling, Reclamation, and Particulation for Improved Green Sand Performance (AFS Paper 88-14), by Jerry W. Kucharczyk and Dieter S. Leidel.
A Foundryman's Perspective of Sand Reclamation (AFS Paper 88-43), by Daryl F. Hoyt.
Total Sand Reclamation, an AFS Special Report (1987) by five authors and Sand Reclamation and Reuse Committee.
The venting function requires a robot capable of only an X-Y positioning and an up-and-down motion. (Offline programming functions for the robot have been incorporated into this operation.)

Mold Spraying—One of the most common applications of robotics in manufacturing is paint spraying. Similarly, in sand molding, robots have been used to spray molds and cores with a wash before drying with gas torch flames. An advantage of this method is consistency of spray deposit and reduction (even elimination) of overspraying. Robot-controlled drying has been found to reduce fuel consumption by over 50% in some instances. Moreover, after each spray, the gun can be cleaned for the next mold, thereby eliminating the downtime that would have been necessary to fix clogged spray gun heads.

In Conclusion—Looked at from a distance, a kaleidoscopic view (through a glass, darkly!) of molding sand systems presents itself with its various facets:
- Hot molding sand still is a fact of foundry life but should not be, because hot sand affects every aspect of green sand molding operations. Preventive measures are available.
- Technology advances in green sand molding machines are outpacing the sophistication of conventional sand testing practices; molding sands need to be monitored differently today than in the past.
- Present-day sand testing needs profound revision; innovative technology is available.
- Installations to reclaim chemically bonded sands thermally are not usually adequate to reclaim green sands.
- The majority of chemical binders currently used by the foundry industry are not water soluble and can therefore not be processed effectively in a wet reclamation system.
- It is universally accepted that sand quality contributes directly to casting quality.
- Both continuous and batch mixers can be equipped with automatic controls to produce a prepared sand satisfactory for the current generation of automatic molding machines.

Design of the sand preparation and distribution system is one of the most important factors affecting the quality of castings produced in green sand.

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