Patterns and the Molding of Cast Iron Banks

Supplement No. 4: Molding Materials: Sand, Partings, and Facings*

Fritz Kokesh

A. INTRODUCTION

In the article on "Patterns and the Molding of Cast Iron Still Banks"[1] the process of making sand molds was outlined and basic information about molding sand, parting sand, and facing sand was presented. It was explained that a working pattern tree[2] was placed in its match mold. Half of a flask, basically a box with no top or bottom, was placed onto the match mold. A *dusting*# of parting sand was sprinkled onto the pattern to aid in removing it from the mold, the pattern was covered with facing sand, and then molding sand was added above the rim and rammed. Excess sand was trimmed away, a bottom board was put atop the flask, and the entire assembly rolled over (turned upside down). See Figure 1.

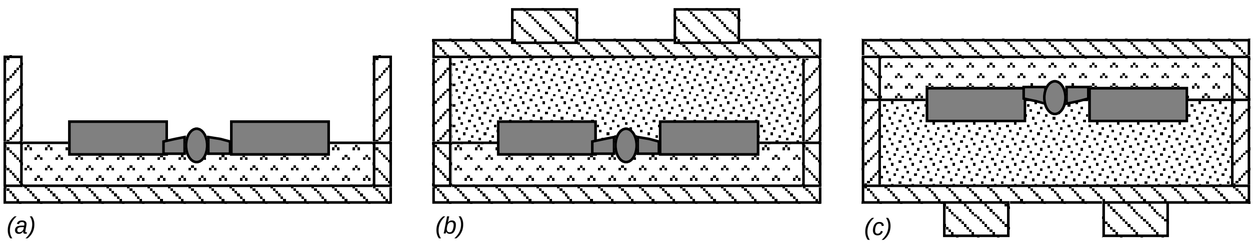

Figure 1. (a) The pattern tree in its match mold with half of the flask installed and (b) after molding sand was added and rammed, and a bottom board placed on top. (c) The flask after being rolled over.

The match mold, which now was on top, was removed and set aside for making the next mold, but the working pattern tree was left in place. (At this point one half of the mold had been formed.) The second half of the flask was placed atop the first one. A thin layer of parting sand was spread on the pattern and molding sand so the two halves of the mold would not stick to one another. As before, *the pattern was covered with facing sand and then* molding sand was added, rammed, and trimmed flush with the rim. See Figure 2.

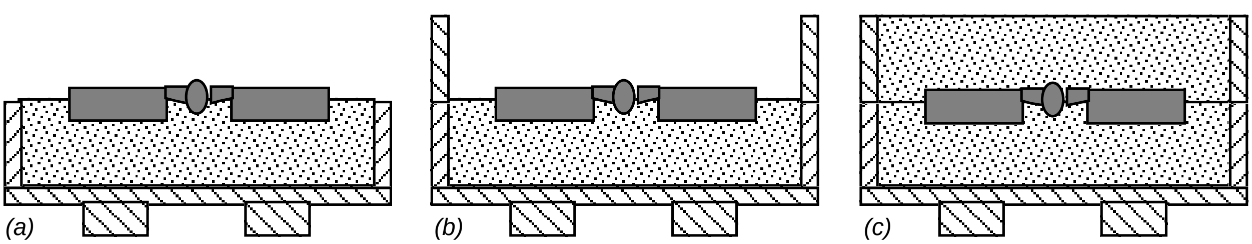

Figure 2. (a) The flask after the match mold was removed, (b) the second half of the flask was installed, and (c) molding sand was added and rammed.

So, between the pattern and the molding sand are layers of parting sand and facing sand. A layer of parting sand also separates the molding sand in the cope and drag (upper and lower portions of the mold). See Figure 3.

In the Introduction, text in italics represents a change in or addition to the text of the original article.

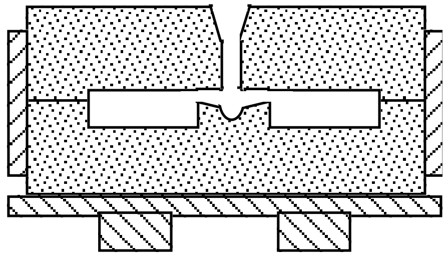

Figure 3. Mold ready for pouring. The seam between the cope and drag has a layer of parting sand. The internal cavity has parting sand on the surface, with facing sand between the molding sand and the parting sand.

The molding sand that formed the bulk of the mold was a natural mixture of silica and clay. Its consistency was adjusted by adding water; the water combined with the clay, which made it sticky and let it hold the sand grains together. Facing sand that was put *nearer* the pattern was finer *than molding sand* so the cast part would be smoother. Unlike molding and facing sand, parting sand was nearly pure silica and was used in a dry form to reduce adhesion between the pattern and mold or between the two halves of the mold.

The current article provides additional details about the purpose, properties, and sources of the molding sand, parting, and facing. It will be explained that although sand often was used for parting and facing, many other materials also were used depending on the part being molded.

B. MOLDING SAND

Performance Requirements

The sand for green-sand molding must meet several performance requirements: the sand must hold the impression of the pattern while the mold is being made and being poured, and it must perform in this way during repeated uses. In addition, unless a separate facing is used, the molding sand also must result in castings with smooth surfaces. The ability of a molding sand to satisfy these performance requirements depends on the sand's physical properties and chemical composition.

What happens inside the mold when the hot metal is poured? Hopefully, very little except for the metal filling the mold and solidifying into a perfect replica of the pattern. However, molten metal is an awesome force. Think of an action movie in which water rushes through a subway tunnel and sweeps along everything in its path. Now recall scenes in the final episode of "Lord of the Rings" in which glowing lava within Mount Doom is the only agent capable of destroying the ring.

Properties

Important physical properties of molding sands include: strength, fineness, permeability, refractoriness, and durability.

Strength. Strength refers to the ability of a mass of tempered molding sand to retain its shape and to break cleanly. ("Tempering" is the addition of water to the sand.) As explained earlier, an experienced molder can judge the strength of a molding sand by squeezing it in his hand. Strength also can be measured by laboratory testing.[3]

The strength of a sand depends on the clay content of the sand, and also on the shapes of the sand grains (sharp *versus* rounded). A "natural sand" (one used more-or-less as mined) with a clay content between 8 and 30 per cent will have adequate strength, but a lower percentage may be sufficient if the clay is a very pure Bentonite.

Fineness. Fineness describes the size of the sand particles. It is determined by sieve analysis. In one method, this involves putting a weighed amount of sand in a fine sieve and agitating it for a specified period of time. The portion that passes through the sieve is weighed, and the portion that does not is transferred to a coarser sieve. The process is repeated using sieves of increasing coarseness. For example, "Secrets of Green-Sand Casting"[4] describes a simple process with six sieves ranging from 100 mesh through 1 mesh. This test produces a "Degree of Fineness" expressed as a percent. The "Grade" of the sand, which can be "Superfine" through "Extra Coarse," is based on dividing possible Degrees of Fineness values into certain ranges. More sophisticated tests[5] involve first chemically removing the clay component of the sand and using a stack of sieves ranging from 6 to 270 mesh to grade the sand on a scale from 1 (finest) to 10.

The fineness of sand in a natural deposit depends on the geologic conditions under which the deposit formed. This geologic setting also determines the size distribution of the sand, and whether particles are sharp or rounded. The best natural molding sands are those created by glacier movement or found in marine deposits.[6]

GEOLOGIC SETTINGS FOR MOLDING SAND[7]

"Sand adapted to molding is either a natural sand found as deposits in old lake and river beds, wind-driven deposits, deposits left by the glaciers during the glacial period, and marine deposits, or it may be made mechanically by mixing silica sand and clay...in some form of power-driven mixer, in which case the sand is known as synthetic molding sand. The highest grades of the natural sands are the glacial deposits, consisting largely of crystalline silica sand grains well mixed with a sufficient percentage of clay. The marine deposits and those from lake and river beds are next in quality, and the wind-driven deposits are of the poorest grade as they contain but a small amount of clay and may contain a large amount of fine material and organic substances, such as tree roots, etc."

Permeability. When molten metal is poured into a green-sand mold, the moisture in the mold is converted to steam. If the steam can escape by flowing between the sand grains or through the vents, no damage is done. If the steam cannot escape defective castings will be produced. (Therefore, in general, the molding sand used should be the coarsest possible that will produce the required finish on the casting.)

Permeability describes the ability of the sand to allow flow between the grains. A sand with high permeability is called "open." The opposite is a "tight" sand. A related property is porosity, which is the measure of the void volume between the grains of the sand.

Is it difficult to accept that sands are porous? Try an experiment; hold a granite stone in your hand and gauge its weight. Now hold the same volume of sand. The rock weighs more, because although the rock and sand are composed of the same minerals, the rock is a solid crystalline mass (without voids), whereas the sand contains pores that are empty when the sand is dry or filled with water and swollen clay when it is tempered.

Permeability is affected by three characteristics of a sand:

> Permeability increases with sand coarseness. Even though the porosity remains about the same as average grain size decreases, the path through the pores becomes more tortuous; that is, the path becomes longer because it involves more zigs and zags.
>
> Permeability decreases as the distribution of sizes broadens. When there is a mixture of grain sizes there is a greater chance that the grains will pack closely and exclude porosity. (For the same reason a tight sand can result if used molding sand is rejuvenated by blending in a new sand that is too fine.)
>
> Permeability decreases with clay content. An excess clay content will result in the pores becoming clogged when the sand is tempered.

By the feel of the lump of sand when squeezed in his hand, an experienced molder can judge the strength of a sand, and by kneading the lump can judge whether the sand feels open or tight. Permeability also can be measured by laboratory testing.[8]

Refractoriness. The refractoriness of molding sand is its ability to withstand high temperatures. The sand near the face of the pattern is subject to temperatures of 2,700º F or more when molten iron is poured into the mold. The molding (and facing) sand must withstand these temperatures without the grains cracking, fusing, or burning into the castings.

MOLDING SANDS FOR NON-FERROUS METALS[9]

"The pouring temperatures of either brass or aluminum are much lower than those of iron or steel. As the general requirements of brass and aluminum castings are that they shall be very smooth, and because fine sand has a low permeability, special venting must be practiced. To promote the venting of a fine sand, it must have a low bonding value; that is, it must have very little clay content. As the bond does not burn out so quickly in brass and aluminum molding as in iron molding, new sand must be added to the used, or heap, sand with care in order to prevent overbonding."

Durability. It may be only sand, but when a mold is shaken out the sand is reused. Often it is mixed with a portion of new sand, but sometimes it is simply sieved. The durability of a molding sand refers to its ability to regain its strength and other properties when it is reused. When molten metal is poured into a green-sand mold the sand loses most of its moisture, some of the sand grains may crack or fuse. The clay component of the sand also loses most of its moisture. The extent to which the sand's strength and other properties can be restored by mixing in new sand and tempering it, and the mixing ratio for old and new sand, depend on the durability of the molding sand.

LOCALES FOR MOLDING SAND[10]

"Molding sand, suitable for medium-weight and heavy green-sand castings, is found in almost every part of the United States. Sand for light work is the most difficult to obtain; for many years light-work foundries were compelled to rely wholly on the fine sand found in and around Albany, New York, but sand suitable for such work is now found in many states. Sand for statuary work in bronze is still imported from France, no suitable substitute having been discovered."

As will be explained in the section on partings, the destruction of the clay minerals is especially great closest to the metal casting where the sand is the hottest the longest. (This is taken advantage of by collecting the "rattler dust"—burnt sand shaken from the castings—and using it as a parting.)

Figure 4. Old newspaper advertisement provided by Bill Jones. The caption reads: "J. W. PAXSON'S SAND DOCKS AT PHILADELPHIA Showing some of their fleet of Steam Barges, Tugs, and Lighters." The J. W. Paxson Company supplied foundry equipment.

Composition

Everyone is familiar with sand. But what is it, exactly? "Sand" is loose particles of sediment with diameters in the size range 0.0625 – 2.0 millimeters. (See "Geological Definitions.") It is a physical form rather than a specific chemical composition. "Silica sand" that is best for molding is composed of silicate minerals such as quartz. But sands also may be based on other mineral families such as zircon or limestone.

Sand used for molding contains clay, but not all sands do. Here again the term "clay" strictly refers to a physical form in which sediment particles are smaller than 1/256 of a millimeter in diameter. The minerals in clay are alumino-silicates that have a stacked structure. That is, the atomic structure is layered like sheets of paper. When clay absorbs water the water goes between the layers, causing the clay to swell and resulting in the ability of the layers to slide over one another. As a result, a swollen clay has a slippery feel.

Other materials present in a sand can include lime, soda, potash, magnesia, and iron oxide. These alkaline materials can act as a flux that lowers the melting point of the silica. Therefore, in a molding sand the amount of these materials should not exceed about 2 1/2 per cent.[11]

Geological Definitions[12]

Sand: Loose particles of rock or mineral sediment that range in diameter from 1/16 to 2.0 millimeters.

Clay: 1. Particles regardless of mineral composition with diameters less than 1/256 millimeter. 2. A group of hydrous alumino-silicate minerals related to the micas (clay minerals).

Clay Mineral: A finely crystalline hydrous silicate of aluminum, iron, manganese, magnesium, and other metals belonging to the phyllosilicate group.

Silica: Silicon dioxide (SiO_2). One of the most common compounds in the Earth's crust. The building block of the mineral quartz and other silicate minerals.

Alumina: Aluminum oxide (Al_2O_3).

Bentonite: A clay formed by alteration of volcanic ash that has an especially great ability to absorb water and swell. It is largely composed of the clay mineral montmorillonite, the family of alumino-silicates that also contain sodium, calcium, or magnesium.

SOURCES OF MOLDING SANDS[13]

"We are miners and shippers of every grade of molding sand, from the very finest brass and aluminum sands to the coarsest grades of Albany, North River and Jersey sands, clays and gravels.

One of the most particular branches of the foundry business today is stove-plate work, and to obtain excellent results, we recommend our No. 0 and No. 1 ALBANY STOVE-PLATE SAND, which is very fine in grade, strong in bond and open, will stand hard ramming, and still allow the gases to escape freely.

Zanesville sand is probably the most generally used of all molding sands in the Middle West. Especially adapted for brass work and brass castings in general.

WINDSOR LOCKS SAND For Patterns. This is an extremely strong, soft, facing sand. It is finer and stronger than most facing sands, being used chiefly in making ornamental iron work, brass, aluminum, also stove-plate patterns."

C. THE NEED FOR PARTINGS AND FACINGS

Silica sand is plentiful and cheap. But its use in green-sand molding involves tradeoffs:

- Silica is refractory, but it is not cohesive. Clay can bind silica particles, but is not as refractory as silica.
- The cohesiveness of a silica/clay sand allows it to hold the impression of a pattern. But it also can cause problems with adhesion between the cope and drag of the mold or the molding sand and the pattern.
- Use of a fine sand will create a smooth surface on the molded metal, but may cause molding problems due to the low permeability of the sand.

These tradeoffs basically point to the need for the molding process to include materials other than just molding sand. Partings are used to control adhesion where it isn't wanted, and facings are used to improve the surfaces of the molded metal.

D. PARTINGS

A parting is any material used to prevent adhesion of the molding sand along the parting line of a mold or of the molding sand and the surface of a pattern. The simplest source of parting is the sand that sticks to the surface of castings (so-called rattler sand). The clay in this sand has been burned, and therefore it doesn't absorb water and become sticky when placed between the damp sand in the cope and drag. A parting also can be simply produced from a fine sand of the sort mined from lakes, rivers, or the seashores (sands that have low clay contents) by drying it on a plate over a hot fire. In either case, the parting sand is put through a fine sieve before it is used.[14]

"**Peerless Parting** Does not gum patterns. It lies perfectly under the metal and does have a tendency to make a nice facing. It overcomes the tendency of sand to stick or clog in the collars or recesses of the pattern, and it makes difficult lifts easy.

Figure 5. Adapted from information in the Obermayer catalog, pp. 29-30. Note the implication that this parting also can serve as a facing.

In iron casting crystalline silica is commonly used as a parting, and has largely replaced lycopodium (a powder made from the pollen of a Russian moss flower) and fine charcoal. Obermayer's "Peerless Parting Compound"[15] is based on "tripoli," another name for crystalline silica. Lycopodium and fine charcoal still are preferred for fine brass castings, and lycopodium also is used in making match molds. Still other materials used as parting are brick dust, pulverized blast-furnace slag, or the dust from foundry rafters.[16]

Parting is applied by scattering it onto the pattern or sand. Just a dusting is necessary. This can be done by hand or with a dusting bag.

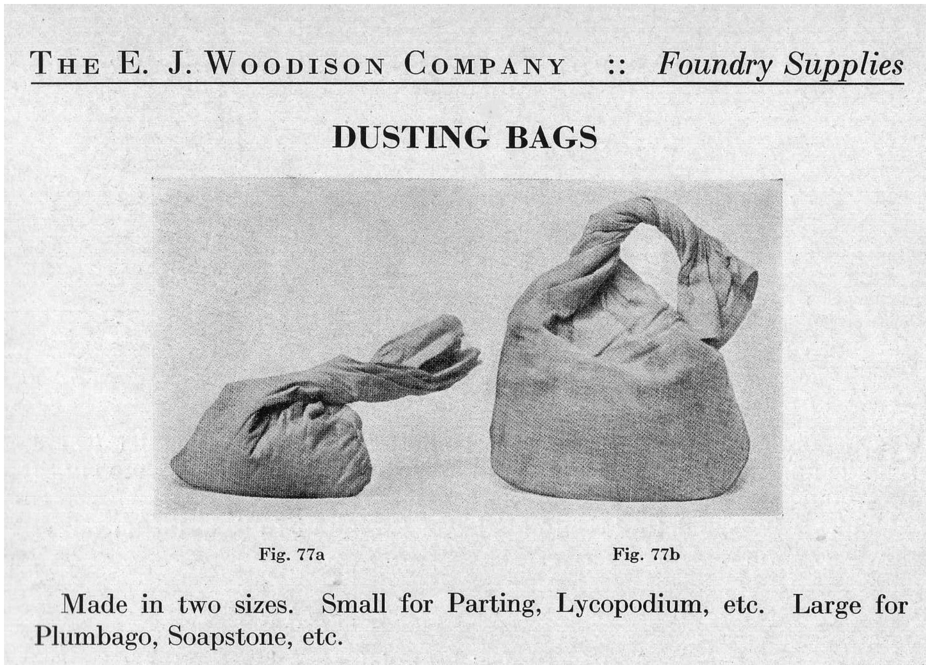

Figure 6. Items in the Woodison catalog, p. 77.

Temporarily back to the future: although crystalline silica made an excellent parting, by the 1930's if was apparent that breathing it caused the lung disease "silicosis" and its use as a parting was phased out in favor of "non-sil parting." [17]

E. FACINGS

Facing is a general term for any material applied to the mold in order to improve the surface of the casting. The purposes of facing are to:

- Prevent the sand in the mold from being burned.
- Resist erosion of the mold by the molten metal.
- Make castings peel so that the sand is left clean.
- Produce castings with smooth surfaces and reduce the cost of cleaning the castings.

Facing can be as simple as just "new" or fresh molding sand. Or it can be a separate material mixed with the sand or used neat. Materials commonly used as facings include sea coal, plumbago (graphite), charcoal, and coke. It is believed that carbonaceous facings act by giving off gases that creates a protective barrier at the surface of the mold. Soapstone (talc), cement, and hardwood flour also is used. Soapstone (talc) and pure silica are effective facings because they are non-reactive and refractory.

Application of a facing can be as simply as riddling molding sand next to the pattern. Or, facing materials can be mixed with molding sand and riddled onto the pattern. For example, a facing can be prepared by crushing, grinding, and sieving (or sometimes bolting) sea coal and mixing it with molding sand in the ratio of about 10 to 1.

SEA COAL[18]

"Obermayer's "Rillton Sea Coal Facing" comes from the Youghiogheny district of Pennsylvania.. It is claimed to be the closest to Cannel Coal found in the United States. The desirable properties are:

Gas Coal
High Volatile Matter
Low Sulfur
Low Ash
High Fixed Carbon

Bolted sea coal is a facing passing through silk mesh of 200 per square inch and is used only where finest of castings are to be made and where sands are exceptionally fine and close, such work as ornamental iron work, extra fine stove plate and such grades of castings."

The alternative is to apply the facing onto the mold after the pattern has been removed. In light work, a process called "printing" is used. This consists of dusting on the blackening and then placing the pattern back into the mold and rapping it in order to press it into the blackening. When the pattern is removed an especially sharp impression is left in the mold.

PLUMBAGO[19]

"Plumbagoes, Graphites, and Silver Leads are synonyms meaning one and the same product. This product of nature is found in its purest forms in the Island of Ceylon, Madagascar, Canada, and parts of the United States. It appears in nature in two forms, Crystalline and Amorphous.

<u>No. 900 Pure East India Ceylon Plumbago</u>

"This is a pure flake or crystalline Graphite ground to a powder and analyzes 90% pure Graphitic Carbon... This No. 900 Plumbago is adapted for such work as ornamental Iron Work, where exceedingly smooth castings are desired."

F. POSTSCRIPT: MODERN IRON CASTING

One often hears that castings of a quality common in the heyday of iron toys cannot be produced today, and that this decline in capability is a result of the best molding sands no longer being available. Is this true?

Robert Saylor[20] believes that it is technically possible for modern foundries to match the quality seen in old cast iron toys and banks, but it not practical for them to do so. The problem is that to achieve the smooth surfaces expected with small parts foundries would need to use a finer sand than is preferred for their usual business of making large parts. Operating with two different molding sands is not practical because of the way molding sand is recycled in a modern foundry. Not only would the mixing of the two sands result in the need to constantly replenish the finer sand, it also would interfere with the molding of large castings. The only possibility would be for the foundry to make only small parts, and in today's world there simply isn't sufficient demand for iron toys for that to happen.

Acknowledgement: The author thanks Robert Saylor and John Mahon for information about sand and parting materials, Saylor also for comments about the ability of modern foundries to produce small castings of the quality common in old iron toys, Ernie Wann for explanation of the process of "printing," and Bill Jones for supplying the old newspaper advertisement.

Please direct comments to Fritz Kokesh at fritz@toybanks.info or 177 Pemberton St. #1, Cambridge, MA 02140.

Bibliography

For the most part, this article is based on sources written through the 1930's, which date marks the end of the period during which production of cast iron toys, including mechanical banks, flourished in the U.S. The article is written in the present tense and describes what was done at the time the sources were current.

"Secrets of Green-Sand Casting," International Correspondence Schools, 1906. Reprinted by Lindsay Publications, Bradley, Illinois, 1983.

William A. Richards, "A Text-Book of Elementary Foundry Practice For Use of Students in Colleges and Secondary Schools," The MacMillan Company, New York, 1912.

William H. Richards, "Principles of Pattern and Foundry Practice," McGraw-Hill Book Company, Inc., New York, 1930.

Harry W. Dietert and James A. Murphy, "Dry-Sand and Loam Molding," Volume 326B, International Textbook Company, Scranton, Pa. 1939.

The E. J. Woodison Company, "A complete Catalog of Foundry, Platers' and Polishers' Supplies and Equipment, Fire Brick and Refractory Materials," 1912 or later (photo of Seattle branch office on p. 9 shows 48-star U.S. flag displayed).

The S. Obermayer Co., "Manufacturers, Everything You Need in Your Foundry," General Catalog No. 51, undated, 1924 or later (on p. 13 is a Dec 2, 1924 patent date).

References

[1] Fritz Kokesh, "Patterns and the Molding of Cast Iron Banks, Seminar by Bill Robison," *Penny Bank Post,* April 2003, p.5.

[2] Robert Saylor has pointed out that the term "pattern tree" is commonly used in shell molding and brass molding, but that for iron molding "gated pattern" is more common.

[3] Harry W. Dietert and James A. Murphy, "Dry-Sand and Loam Molding," Volume 326B, International Textbook Company, Scranton, Pa., 1939, p. 11.

[4] "Secrets of Green-Sand Casting," International Correspondence Schools, 1906. Reprinted by Lindsay Publications, Bradley, Illinois, 1983, Part I, p. 8.

[5] Dietert and Murphy, p. 19.

[6] Dietert and Murphy, p. 1.

[7] Dietert and Murphy, p. 2.

[8] Dietert and Murphy, p. 5.

[9] Dietert and Murphy, p. 51.

[10] "Secrets of Green-Sand Casting," Part I, p. 10.

[11] Dietert and Murphy, p. 4.

[12] Definitions adapted from "Dictionary of Geological Terms, Revised Edition, Anchor Books, Garden City, NY, 1976; and USGS Geology Glossary, http://www2.nature.nps.gov/geology/usgsnps/misc/glossary.html

[13] The E. J. Woodison Company, "A complete Catalog of Foundry, Platers' and Polishers' Supplies and Equipment, Fire Brick and Refractory Materials," unnumbered and undated. Published 1912 or later; pp. 25-27.

[14] "Secrets of Green-Sand Casting," Part I, pp. 30-31.

[15] The S. Obermayer Co., "Manufacturers, Everything You Need in Your Foundry," General Catalog No. 51, pp. 29-30.

[16] Robert Saylor, personal communication, October 23, 2004. Robert reported the related practice in modern steel foundries of collecting parting dust from the catwalks of overhead cranes.

[17] Crystalline Silica Primer, Special Publication of U.S. Bureau of Mines, undated, p. 16.

[18] Obermayer, pp. 6-7.

[19] Obermayer, p. 10.

[20] Robert Saylor, personal communication, October 23, 2004.