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Fundamentals of Nobake Sand Reclamation

Introduction

Reclamation is becoming a vitutal nessity in larhe nobake operations. Founrymen just cannot afford to continue paying ten dollars a ton for sand, ten dollars more for freight and then spend still another three to five dollars to haul out the used sand -- if they can find someone to haul it away and somehwere to dump it!

Reclamation Systems

Although there are many brands of reclaimers, there are basically only three types of reclamation techniques: wat, thermal, and dry. The type of reclaimer selected is normally dictated by the binder being used. The most obvious example of this is the sillicate nobake system which is easily reclaimed via wat reclamation, but very difficult to reclaim by dry or thermal proccesses.

Wet Reclamation

Wet reclaimer systems sell for about forty to fifty thousand dollars per ton per hour, and cost about five to ten dollars per hour to operate. They are normally of rather low capacity, in the range of two to five tons per hour. Heat is neccesary to dry the sand and about two hundred gallons of water per ton of sand is required in the process. Water shortages, along with strict EPA standards for water disposal, are sever drawbacks to wet reclamation.

Prior to the development of the modern dry reclaimers there were a few wet reclamation systems installed to recover organic bonded core sands and nobake sands. Although the water does an excellent job of removing fines, it does not efficiently or econmically stip the resin off of these sand grains because the cured, organic binders are insoluble in water.

Thermal Reclamation

Thermally reclaimed sand is usually better than the original sand because many of the sharp, jagged edges on the grains have been removed and most of the indentations have been filled in by the resin coating. Having been heated, the grains are more thermally stable, and the growth caused by the silica crystalline transformations is minimal.

The obvious disadvantage to the process is the need for heat energy or fuel. Work is being done to utilize coal along with oil and/or natural gas to reduce the dependence upon natural gas for thermal reclamation.

The temperature range of thermal reclamations 1200 to 1800 F. About one million Btu per ton is required, but the unburned organic binders have a latent fuel value which can be utilized to save 1/2 to 3/4 of a billion Btu per ton.

Purchase and installation of a five ton per hour unit runs about one million dollars. Operating costs vary from ten to fifteen dollars per ton, depending greatly on the price of fuel.

Dry Reclamation

There are nearly as many dry reclamation processes as there are individual manufactureres of dry reclamation equipment. Some basic thechniques are: dry pan, jaw crusher, pneumatic scrubber, impingment against various types of target devices, vibratory screen, shot blast, fluidized bed and combinations of nearly everything.

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The crushing and scrubbing operations are generally followed by an exhaust step to remove lines and then a mechanical device to separate large particles, metallics and various tramp materials.

Dry reclamation is emerging as the most accepted way to reclaim nobake systems other than silicates. Opertaing costs vary from two to seven dollars per ton. Purchase and installation is about ten thousand dollars per ton per hour of capacity. The total capacities range from three to 30 tons per hour.

Factors Affecting Reclamation

A word of caution -- many foundry workers regard the sand heap as a trash dump and discard all sorts of debris into it. Reclaimers are not designed to remove garbage. Discarded trash results in plugged-up sand orifices, equipment malfunctions, and casting defects. Although reclamation equipment may appear dusty or dirty, it is not a garbage disposal and functions as a piece of processing equipment.

Resin Content

The higher the resin content, the greater amount of resin that needs to be removed, and therefore the more difficult the coated sand will be to clean-up. It is a simple fact that operating with the lowest binder percantage that assures breakage-free core and mold handling results in minimum material costs, maximum reclaimer efficiency, and the best possible casting. The lower the resin content, the easier the sand is to reclaim.

Sand to Metal Ratio

The more binder burned all of the sand by the casting operation, the easier it will be for the reclaimer to operate at maximum efficiency. Sand is an excellent thermal insulator, so it transfers heat at a surprisingly slow rate and establishes very wide thermal gradients in the resin bonded sand core or mold. Thus, heat from the metal normally does not penetrate into the sand to decompose the binder more than a couple if inches from the mold-metal interface. It is not unusual for the sand less than three inches away from a heavy casting section to be completely intact at shakeout.

A sand to metal ratio of about 2.7 to 1 is considered optimum. The ideal situation is to use as little chemically bonded sand as possible in order to produce the casting.

Screen (Thru/on)	Surface Area (Square Feet/Pound)	Grains/Pound (Millions)
12/20	15.8	X1
20/30	22.3	X3
30/40	31.5	7
40/50	44.6	20
50/70	62.9	56
70/100	89.0	158
100/140	126.3	451
200/270	178.5	1,265
270/Pan	232.0	2,838

Table 1: Surface Area and Number of Grains in Normal Screen Distribution for Typical Nobake Silica Sand

The Finished Casting

High pouring temperatures (excessive superheat), types of metals that are slow to solidity, thick casting sections, and configurations that naturally produce a low sand to metal ratio assist the process of reclaimation by decomposing the binder to a greater extent.

Type of Sand

Some sands reclaim better than others. Generally, the coating is more easily stripped from round-grain sands than from the angular sand grains. However, the scrubbing and grinding inherent in reclamation tend to round off the sharper types of sands such as angular silica, olivine and chromite. The newly created, less angular grains have a reduced surface area that requires less binder.

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As indicated in Table 1, line grains (smaller than 140 mesh) have many more grains per pound and a much larger surgace area than the coarse particles. Additional resin is necesaary to cover the high surface area of the small grains. So unless the lines are kept to a minimum the possibility of gas defects is increased by the combination of reduced permeability, increased resin content, and higher Loss On Ignition (LOI).

Additives

Most additives as iron oxide, kaoline, clay, zircon and olivine flours serve a refractory function. Although these dry additives might help break the coating away from the grain, they produce a dusty material, high in binder content that must be removed. This increases the load to reclaimer's dust collector.

Type of Binder Systems

Some binder systems are rather ideally suited to a specific type of reclamation -- wet reclaiming of silicateis the foremost example. However, factors such as chemical difference, resistance to thermal decomposition, and how easily the resin coating (whether burned-up by the metal or still intact) can be stripped away from the sand grains differ among the binder systems and may influence reclamation.

Grouping Nobake Binder Systems

In order to examine how specific binder properties influence their reclamation capabilites it is useful to classify the nobake binder systems according to their chemical characteristics:

I. Acid Catalyzed Furans and Phenolics
II. Phenolic Urethane (Cold box and quick setting urethanes)
III. Oil Urethane (Alkyd-Isocyanate)
IV. Inorganic (Silicate and Alumina Phosphate)

I. Acid Catalyzed Furans and Phenolics

How easily the acid catalyzed furans and phenolics on reclaim depends primarily on how much resin is used to bond the sand and how much resin is burned away by casting operation. Experimental data and experience in dicate that both the furans and phenolics are quite thermally stable. The phenolics tend to resist decomposition more than the furans so they should be more difficult to reclaim. However, the phenolic coating is more brittle, so both the intact and partially burned binder chips away from the grains easier than the furans. The net result is that the furans and phenolics dry reclaim about the same.

II. Phenolic-Urethanes

The phenolic-urethane resin systems are diluted (extended) with a solvent and, therefore, are very low in viscosity. When used at their recommended low lwevels, a very minimal coating is placed on the sand grains. Since some of the solvent ecaporates after coating the sand, the already low resin percentage that needs to be removed from the sand is, in effect, further reduced. This type of coating is also rather brittle, so it easily chips awau from the sand grain surface. The combinatio of the extremely low binder content and the brittleness of the coating makes this group of nobale resins extremely easy to reclaim via dry reclamation techniques.

III. Oil Urethane

Shakeout sand from the oil urethane sustem is usuallt described as "lumpy." Analyzing why these lumps occur leads to an understanding about this system is reclaiming characteristics. The oil urethane systems have as a principal component alkyd resin, which is quite similar to paint. Like its paint cosuin, this component of the binder is rather slow to dry or cure. The most effective way to cure the alkyd material is through exposure to ne. Therefore, when the sand resin coating is heated by the hot metal it, in effect, postcures and increases the binder's strength unless, of course, it becomes so not that resin burns up. The postcure of the oil urethane resin coating by the casting heat is referred to as the "urethane reaction" and is responsible for the lumpy shakeout and tough, hard sand. Whenever the temperature zone of 350 to 650F is not established, there is no tough lumoy shakeout due to the urethane reaction and the system is more easily reclaimed.

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IV. Inorganics

The fourth nobake resin group is comprised of the inorganice binders. Sodium silicate is the principal inorganic binder. Essentially, sodium silicate binder is the high temperature reaction product between silica and soda ash. It is the ratio of silica to soda that dictates most of the sodium silicate's binder properties. Anything that causes this ratio to change results in a variation in binder properties.

Silicates are very diffucult to reclaim by dry or thermal processes, but are well suited to reclaiming by wet techniques. There is an unique problem with wet reclamation silicate bonded sand, in that soda begins to accumulate in the reclaimed sand causing a change in the silica to soda ratio. Changing the silica to soda ratio will change many properties of the silicate resin, but it especially effects the cure rate since higher soda levels accelerate the rate of gelation. When the excess soda builds to more than 0.6 percent, the binder reaction is so rapid that sand does not have sufficient bench life and work time. In order to minimize the effects of the chemical change that occurs during silicate reclamation by wet processes a rather high percentage of new sand addition is neccessary. A fifty percent new sand addition is not unusual when wet reclaiming silicates.

Dry reclaiming sodium silicate sand is rather impractical because the metal casting process temperatures completely dehydrate and vitrify the coating. The vitrified binder, after it has cooled to room temperature, could be so much stronger than it was originally that the material almost defies dry reclamation. Aluminum, when cast in silicate sand, due to the lesser quantities of heat from the casting process, normally will not vitrify the silicate coating. Heavy ferrous sections combined with the properly low sand to metal ratios can establish temperature zones that thermally degrade the silicate sand bond and could theoretically result in a coated sand that may be reclaimed by dry techniques.

It must also be emphasized that there are additives for the silicate systems that improve both shakeout and reclamation. These additives, unfortunately, usually degenerate some other property, such as core storage life, etc.

For many years, the wors "inorganic binder" meant sodium silicate to the foundryman. Now there is under development a second type of inorganic binder, alumina phosphate. Although not much information is available on this system, the shakeout and reclamation properties appear to be very good. Further testing will determine this system's compatibility with other resin systems and just how well it is accepted by the foundry industry.

New Resin System	Type of Reclaimed Sand to be Recoated: Oil Urethane	Phenolic Urethane	Furan Acid	Phenolic Acid	Silicate Ester	Alumina Phosphate
Oil Urethane	C	C	N	N	S	C
Phenolic Urethane	C	C	N	N	N	S
Furan Acid	S	S	C	C	N	S
Phenolic Acid	S	S	C	C	N	S
Silicate Ester	C	C	N	N	C	S
Alumina Phosphate	C	C	S	S	S	C

C = Compatible; N = Not Compatible; S = Sometimes (Test)

Table 2: Coating Reclaimed Sands with Various Binder Systems

Binder Compatability

As foundrymen become more committed to the use of nobake systems, situations sometimes occur where a given type of reclaimed sand must be recoated with a binder other than the one that was originally used.

Table 2 offers some general guidelines for coating reclaimed sand with a different binder system. Applying these classifications of binder systems to Table 2 makes it apparent that the coating's catalyst mechanisms determine the chemical state of the reclaimed sands for purposes of recoating with another system. When mixing the acid catalyzed systems in group I with the urethanes in II or III, some incompatability should be expected because of the completely different types of chemistry involved.

Various phsyical elements will also affect the way one type of resin will coat a reclaimed sand previously coated with another type of resin. The amount of the other resin remaining on the sand to be recoated (as indicated by LOI) is most important. Residual catalyst is another factor, along with the strength or amount of the catalyst in the binder system.

Fines remaining in the reclaimed sand will also influence the recoated properties. Table 3 illustrates how much more residual resin and catalyst by weight percent remains on the fine particles of sand as compared to coarse ones. Obviously, the dines should be removed in order to minimize gas and produce as low an LOI as possible.

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On Screen	LOI (%)
20	X1
30	X1
40	1¼
50	1½
70	2
100	2½
140	3
200	4
270	9
Pan	15½

Table 3: Per Cent Binder Remaining on Reclaimed Sand After Reclamation (53AFS Silica).

The effect of using one type of resin group for coating new sand to produce cores and introducing these cores into a mold made with reclaimed sand from another resin group is a somewhat special case when it comes to recoating compatabilities. Here the chemical influence of the resin coating on the sand will usually be minimal because most of the resin is burned off the core sand. In addition, the percent by weight of cores is usually small when compared to the mass of the molding sand or to the total mass of the reclaimed molding sand system. Thus, when this relatively small amount of thermally reclaimed core sand is mixed into the molding sand, the effects of any chemical incompatibility will be minor.

For thes same easons, moderate quantities of nobake sand and conventional type core sand systems, when introduced into clay bonded molding sand, are not considered detrimental to the green sand system. The core sand additions may be considered as the new sand addition necessary to dilute the clau bonded sand and help dispose of the dead clay created by heat from the casting process.

However, because of residual claus and the moisture present in green sand systems, clay bond sands are not normally dry reclaimed for recoating by nobake resin systems.

Part 2:

As explained in part one of this article, there are a great number of factors affecting nobake sand reclamation. Part two explores the properties that nobake sand should exhibit after reclamation as well as the tests that should be carried out to assure that the reclaimed sand can hold up during the casting process.

Silica Sand Mixed With Other Sands

When chromite sand is reclaimed, or is present in the reclaimed silica sand system, it required special attention. Normally, chromite sand is used in combination with silica sand to produce surface chill or to promote directional solidification. During the recycling steps of the reclamation process, the chromite and silica become thoroughly blended unless some separation device is used.

The amount of chromite present in the silica system varies, but less than one to more than fifty percent chromite are the normally encountered extremes found in chromite-silica mixtures. Research in South Africa several years ago reported that when fine particles of silica are mixed with chromite sand at silica levels from one to seven percent the refractoriness of the blend is considerably lowered and the defect of sand burn-in occurs on the casting surface. Fortunately, since chromite is the smaller portion of the usual system, the opposite situation, with low concentrations of fine particle silica, is not likely to cause the silica-chromite burn-in.

Elemental Iron (Fe) accounts for about twenty percent by weight of the chemical composition of foundry-type chromite sand. At an elevated temperature, and in an oxygen containing atmosphere, the Fe oxides and the chromite sand actually increases in weight. The standard LOI test cannot be run on chromite sand or chromite-silica mixtures because of this increase in weight during the LOI test. This change partially makes up for some of the weight loss because of the binder being burned off.

One final aspect of reclaiming mixtures of silica with chromite, zircon, or olivine is that the other minerals are all denser than the silica sand. This results in the sand's fines often being more difficult to remove from the mass by standard exhaust techniques. Also, the density of the mixture of non-silica minerals and silica sand goes up as the proportion of the non-silica sand to silica increases. This greater densirt mixture generally requires a lower resin percentage by weight to completely coat the grains.

What to Look For and Test For in the Reclaimed Sand

Return Sand Temperature: Heat from the moltern metal and the reclamation process itself will increase the temperature of the sand. So before it can again be coated, the sand temperature must be lowered to a reasonable level. Any temperature in excess of 120F causes unbelievable problems for the recoating operation. As the temperature of the sand increases above the ideal operating temperature for each system listed in Table 3 these problems become more and more serious. Many people will not accept a recoating temperature higher than 15F above ambient. (Average room temperature).

Resin System	Temperature (°F)
Furan-Acid	80-85
Phenolic-Acid	85-90
Oil Urethane	85-90
Phenolic Urethane	75-80
Silicate-Ester	75-85

Table 4: Ideal Operating Temperatures for the No-Bake Binder Systems.

Screen Analysis: The screen distribution for reclaimed sand will usually show that the very coarse and the very fine particles have been removed. A plot of the screen distribution will appear like that shown in Figure 1 when compared to the originl sand. Fines (less than 140 mesh) should be held to less than one percent. Agglomerated or compound grains (found on the 40 mesh or above screen) should be less than three percent.

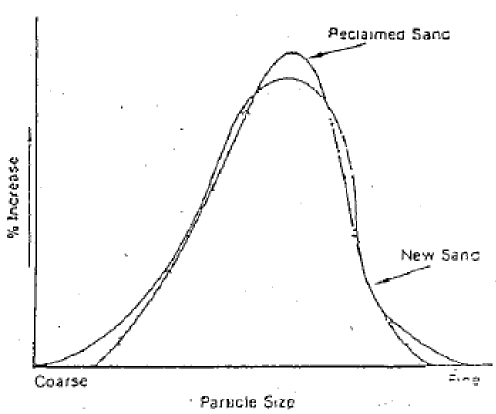

Figure 1

Loss of Ignition (LOI): To determine loss on ignition a small sample of sand, generally weighing five to ten grams, is heated to between 1600 and 1800 F for one hour, and the combustible material that has been burned away represents the loss on ignition. THE LOWER THE LOSS ON IGNITION THE BETTER. Just how low the LOI must be depends upon the type of metal being cast less than 3.5 percent is usually satisfactory for iron and 3 percent or less for nonferrous and steel. The larger the size of the casting the lower the LOI must be in order to guard against excessive gas evolution.

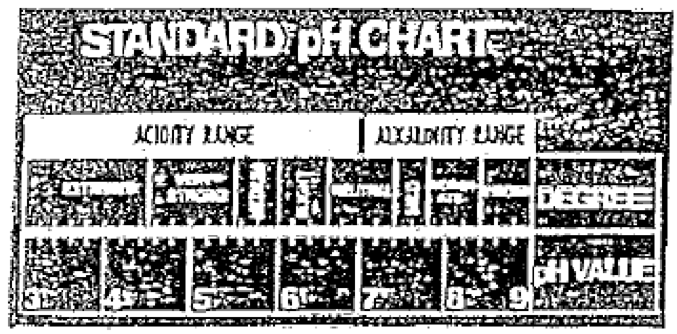

Figure 2.

pH: The pH (negative log of the hydrogen ion content) is a kind of chemical shorthand that uses numbers to express the acid, neutral, or basic state of a material. pH also indicates just how acidic or basic (alkaline) it is. As shown in Figure 2 a pH of 7 is neutral. Less than 7 is acid: the lower the number the more acidic. More than 7 is basic or alkaline: the higher the number the more basic.

The term pH has gained special significance with the advent of reclamation because the surface chemistry of the sand is drastically altered by the amount of the resin-catalyst coating remaining on the sand grains after the reclamation process. These residual acid or basic components of the binder system now dictate the surface chemistry of the sand and must therefore be measure.

The pH of the sand, new or reclaimed, is determined by placing a known amount of sand in a controlled temperature, deionized water, and measuring the pH with a pH meter or a piece of pH paper.

Silicates, oil urethanes, and phenolic urethanes render the reclaimed sand basic. The furans and phenolics cause the reclaimed sand to be acidic.

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Acid Demand Value (ADV): The acid demand test is run on new sand and has special significance for the acid catalyzed nobake systems. Since sand is normally somewhat alkaline, these basic constituents in the sand must be neutralized by a portion of the acid catalyst before it can start to do its job of catalyzing the furan or phenolic resin. The sand demands some portion of the acid to neutralize it before the acid catalyst can begin to react with the resin. The opposite is true with the phenolic urethane systems, where the alkaline components of the sand precatalyzes the resin coating. In this situation the bench life of the cold box sand is reduced, and the liquid catalyzed phenolic urethane has reduced work time.

Table 5 makes it apparent that the smaller particles (140 mesh and liner) contain far more of the higher acid demand elements than do the coarse grains of silica sand. Since there are obviously so many contaminent materials in these finer materials they should be kept to a minimum, or less than one percent if the casting's finish will permit.

The principal difference between acid demand and pH is that the acid demand test is able to measure some of the non-water soluble components on the sand. Since the ADV test procedure calls for the sand to be mixed with an acid solution and then back fitrated with an acidic solution, the first introduced acidic material might dissolve some material that would not show up in a pH less result.

Screens	ADV
30-50	17.8
70-100	17 8
140-Pan	48.7
Base Sand 53AFS	18.2

Table 5: Acid Demand Versus Screen Analysis

Acidid sand will have a negative acid demand value. Once it is coated with a binder system, the orginal surface chemistry of the sand assumes that of the resin coating. Furan reclaimed sand will have a negative ADV becuase of the acidic compenents remaining on the sand grains after reclamation.

Tensile Strength: The tensile strength of a reclaimed sand is affected dramatically by the amount of high surface area carbon left on the sand after it has been exposed to the elevated temperature in the metal casting process. The tensile strength of reclaimed sand is also affected by the screen distribution, the grain shape of the sand (which is made rounder with each pass through the reclaimer) and many other factors. The tensile strength should not vary plus or minus 12 percent once the system is running smoothly.

The often asked question of "How much tensile" generally depends on "How little tensile" strength is necessary to handle the core or mold and withstand the ferrostatic pressures necessary to produce acceptable castings. The numerical value is unique to each operation, machine, and operator. However, in ferrous castings the accepatable minimum tensile strength is usually about 140 psi.

Point Impact Penetration Test, Scratch Hardness, and Heat Distortion Tests: There are many tests used to give an indication of how well the coated sand will hold up to the casting process. Tensile strength is the quality control check most often utilized since tests such as those mentioned here will correlate with tensile strength. However, if the time is taken to run these tests they will generate data indicate the type of casting tha can be obtained with the sand being tested and provide other useful information about the sand system.

Magnatics: The magnetic content for ferrous type metals is determined by stirring a magnet through a known weight of dried sand and then weighing the amount of material removed. A typical reclaimed sand magnetic value in about 0/2 percen. The maximum value should genrally run about two percent, but good cores, molds and castings have been made with a magnetic level of over 10 percent.

Microscopic Analysis: A great deal of information can be obtained by frequent microscopic examination of the coated, raw, and reclaimed sand. A 40 to 100 power microscope is probably the best choice. Unfortunately, it requires a lot of time to peer through a microscope in order to become familiar with what the sand loks like when it is good. Only then can anyone be experienced and confident enought to judge when something is different or bad about the sand.

Reclaim to Cut Costs

The principal objection to any nobake system is the comparatively high cost for the coated sand. One of the best ways to reduce this high cost is through reclamatio and by following the practices suggested earlier, such as using the least amount of resin and the lowest sand to metal ratio.

If you are already using any of the nobake processes or just considering them for your operation, then investigate nobake sand reclamation. Your particular operation may not be able to justify it, but you might be surprised.

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