Evaluation of Sands for the Coremaking Process: A Practical Approach

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ABSTRACT

Today foundries are faced with shrinking profit margins and ever-rising costs of raw materials. More than ever foundries need to examine their way of producing their castings and determine if they are using the best-suited materials for their casting process. Our foundry decided to test various types of sand to ensure that we were using the most economical sand without sacrificing our quality in casting finish.

Cost of the raw material should play a part in deciding which raw material is used, but performance of the sand should be more important especially if a cost savings can be realized due to reduced resin consumption, less sand needed to produce a core, improves casting finish, etc.

This paper will outline tests used to evaluate various sands, which are used to determine the best material for our foundry. The following tests are used at our foundry to compare sands and find the best performing sand within the foundry's environmental conditions and current resin system.

INTRODUCTION

With the increase in cost for our current sand system, we tested other sands against the current product using the tests outlined below. The following tests are what we as a company use to evaluate sand. All sands were tested with our current resin system, which is a phenolic urethane cold box system.

Our sand analysis is grouped into 3 phases. Phase I tests are performed on raw sand. They are the following: sieve analysis, pH/Acid Demand Value (Adv), dry density, and turbidity. These tests will give some initial insight into the sand system itself. Sieve analysis with theoretical surface area, dry density, and turbidity will help determine the resin level that will be needed to make a core with adequate 60 second out of the core box tensile strength. The pH/Adv results will give insight into bench life issues for the prepared sand.

Phase II tests use dog bones or cores to analyze prepared sand characteristics. They are the following tests: immediate tensile strength, core density, cure speed, bench life, hot strength, permeability, delayed tensile strength, and humidity resistance.

These tests are used to compare the current sand system to the competing sands. If the new sands can surpass the current sand system or be as good but have some other benefit such as (less expensive, environmental reason, or better reclaimability they will advance to phase III.

Phase III is making 2 inch by 2 inch cores and pouring test castings to evaluate the casting quality of the core. If the core produces veins the surface area is measured along with surface quality of the casting.

All sand systems are tested together to ensure they are analyzed under the same conditions.

PHASE I

The following tests, sieve analysis, pH/ADV, and sand density are used to screen raw sands before a core is produced.

SIEVE ANALYSIS

Before analyzing for distribution, the sand needs to be mixed so the sand is homogenous. Sand tends to become segregated when being transferred into a container. The larger grains tend to roll while the fine grains interlock causing segregation. Before the sand is analyzed, a sand splitter is utilized to ensure the sand is thoroughly mixed before a sample is taken. Sand should be split three times to ensure the sand is homogenous (Mold and Test Handbook, 1989)[1]. After the sand has been split, a known amount of sand is taken and used for sieve analysis. A sieve shaker is used to sift the sand by rotating and tapping the top of the lid causing grains of sand smaller than the sieve size to fall through to the next screen (Mold and Test Handbook, 1989)[2]. After the sand is sifted, the screens are cleaned and the retained sand is weighed. The percent of sand and the multiplier for each sieve size gives a quotient. The quotients are added together to derive a grain finess number (GFN) (Mold and Test Handbook, 1989)[3].

Generally our foundry prefers a three-screen or four-screen distribution for making cores. Three or four screen sands will make a denser core than a two-screen sand, which should help in reducing resin due to more sand grain to sand grain contact when making a core.

Along with screen distribution, we like to use as fine of a sand as possible since the finer the sand (higher GFN) the better the casting finish. But the tradeoff sometimes with a higher GFN is that the surface area will be greater; therefore more resin may be needed to coat the sand grains to produce a core, which will increase cost and possibly cause casting defects with excess gas evolving from the resin. So there is a balancing act between casting finish and resin consumption, does a foundry pay in resin costs or cleaning process of the castings due to surface finish defects.

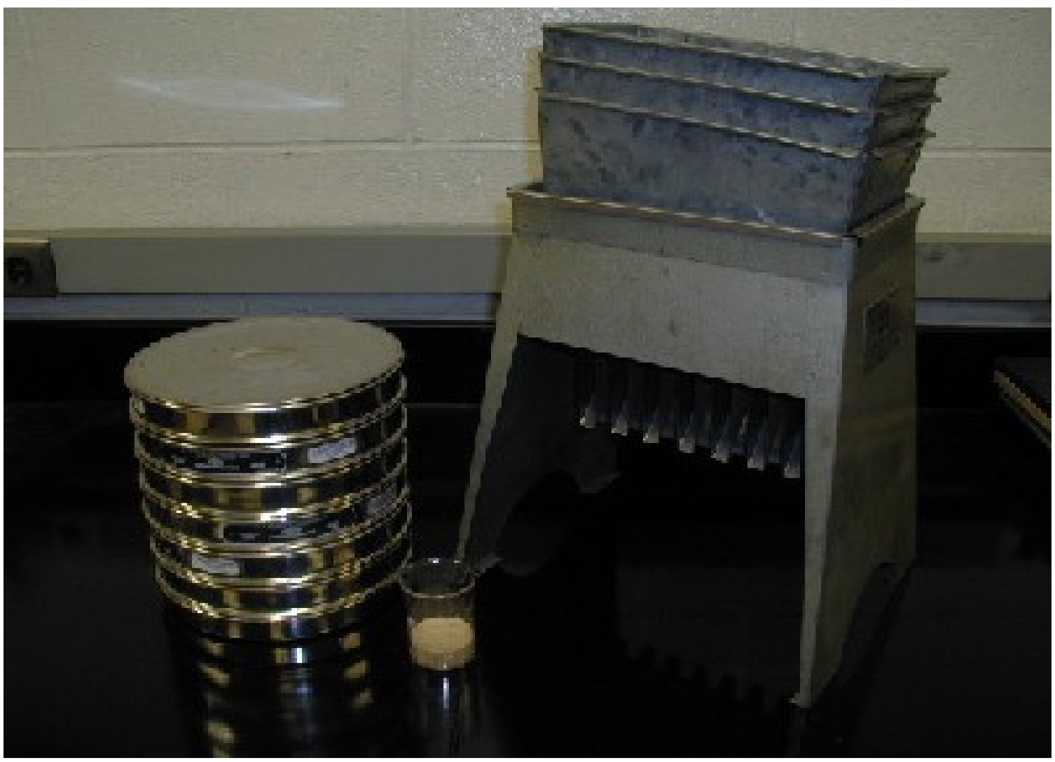

Figure 1
Sieve Analysis equipment.

SAND PH/ADV

Place 25 grams of sand into a glass beaker with a magnetic stir bar along with 75 milliliters of de-ionized water. Mix the solutions for 5 minutes using a magnetic stir plate. After 5 minutes, place the pH probe into the mixture and wait for the pH to stabilize. (Mold and Test Handbook, 1989)[4]. The pH measures the water-soluble alkaline material in the sand. The sand pH is extremely critical for bench life in a cold box system. The more basic the sand the less bench life the prepared sand will exhibit.

To measure Adv place 50 grams of sand into a glass beaker containing 50 milliliters of de-ionized water. While mixing add 50 milliliters of 0.1N HCl and continue to mix for 5 minutes. After 5 minutes place the pH probe into the mixture and begin back titrating with 0.1N NaOH. Back titrate until the pH probe reads 7.0 and stabilizes. Adv is determined by subtracting the milliliters of NaOH used from the 50 milliliters of HCl. (Mold and Test Handbook, 1989)[5]. Adv measures the alkalinity of the sand that is not water-soluble but acid soluble. The lower the Adv the more acidic the sand. Adv is as critical as the pH for the amount of time the sand is workable to make a core in a cold box system.

It is important to note that Adv and pH are not always in direct proportions. If pH is high, Adv will not necessarily be high also. Both pH and Adv should always be analyzed together, do not rely on just one of the tests. The pH and Adv results will give an indication of how long the prepared sand will be workable for making cores.

The pH/Adv of sands are critical if during production a problem arises. The more basic the sand the less time the sand will be usable because the high pH causes the resin to react sooner than normal. The sand will set up in the hoppers before the sand can be used to make a core. With our current resin system, the sand should be neutral to slightly acidic for prolonged bench life, which will help during production interruptions.

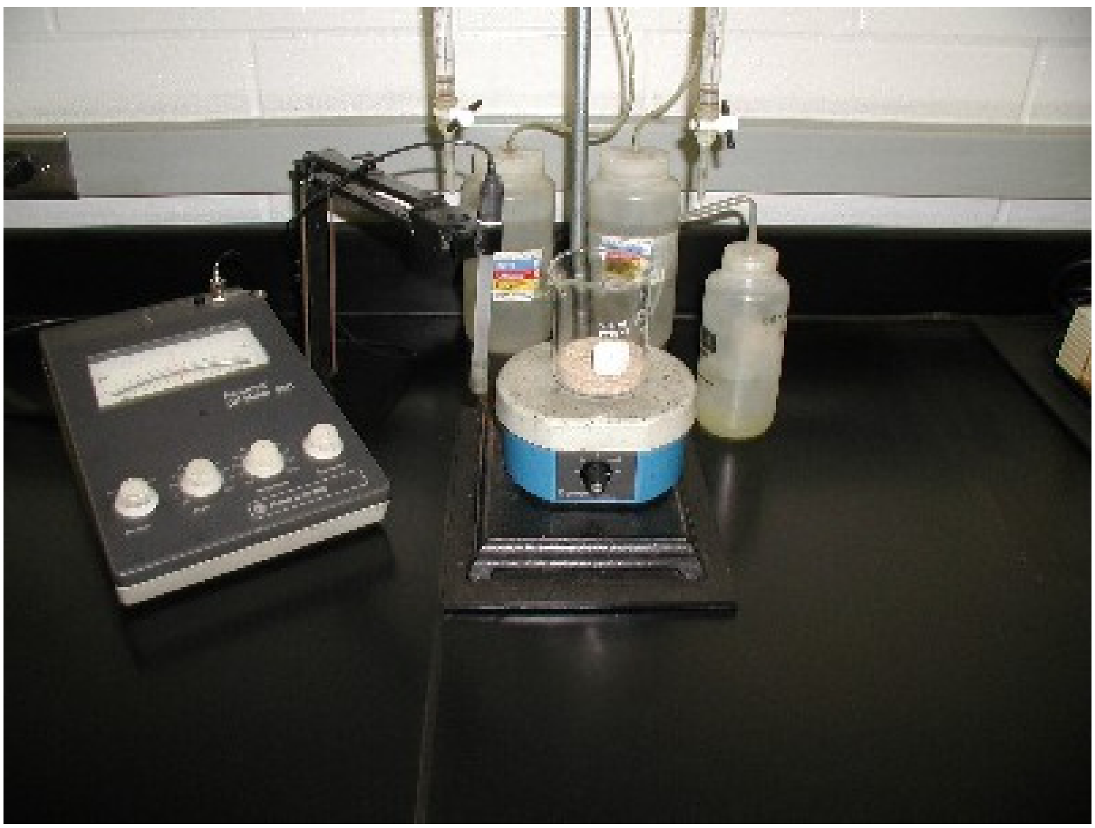

Figure 2
Equipment used to measure Adv/pH.

DRY SAND DENSITY

To measure density use a container with a known volume, fill the sand to the top of the container and strike off excess sand. Weigh sand in the container and divide by the volume of the container. Understanding the density of the sand will help when comparing the incumbent sand to the new sands. If the densities of sands are different, a direct comparison of resin percentage cannot be done. The resin amount will have to be calculated by using volume. This will be important when it is time to evaluate tensile strengths of various sands.

Density will also play a part in costs of the sand. More dense sand will cause a foundry to use more of the sand as compared to less dense sand in making the same core, which could raise the cost for the more dense sand if blow pressure remains the same.

TURBIDITY

We use this test to compare fines. This is an unconventional test using de-ionized water, 10 ml graduated cylinder, and a refractometer.

Add sand to the 5 ml level of the cylinder and add de-ionized water to the 10 ml level. Cap the cylinder and shake vigorously for 20 seconds. Allow the sand to settle for 10 seconds then remove the top layer of the solution after this period and measure using the refractometer.

This test is strictly a comparison test; it will help in comparing fines with the different sand systems. The more fines the cloudier the water. The refractometer reading will then be higher. This test will assist in identifying which system has more fines and will help when attaining the correct resin level for the immediate tensile strength in phase II.

PHASE II

The following tests are performed after sands have been screened in phase I tests.

Several tests are used for how well the prepared sands will compare to the current system. They are as follows: immediate tensile, dip redry tensile (if coatings are used), core density, cure speed, 60 minute bench life, hot strength, delayed tensile and humidity resistance. When doing these tests, the sand should be prepared at the high side of your sand temperature specifications if you use sand heaters, or at the warmest ambient temperatures if you do not used sand heaters. The sand should be heated above the desired temperature since during the mixing the sand temperature will be lost.

A typical mixing cycle is as follows:

1 Weigh sand
2 Add anti-veining agent (if necessary)
   a. Mix 15 seconds turn over sand
   b. Mix 15 seconds
3 Add part I resin
   a. Mix 45 seconds turn over sand
   b. Mix 45 seconds
4 Add part II resin
   a. Mix 45 seconds turn over sand
   b. Mix 45 seconds

The sand temperature should then be checked to assure you are within range. We typically use 95^{o}F as a set point for prepared sand. This means raw sand will be heated to around 105^{o}F to reach the desired prepared sand temperature.

The typical settings for our core-making machine we use at our foundry, has the following set-up.

1	Blow time	0.5 second
2	Blow pressure	60 Psi
3	Gas time	1 second
4	Gas pressure	10 Psi
5	Purge time	15 seconds
6	Purge pressure	20 Psi

TENSILE EVALUATION

Immediate tensile strength needs to be established first before any other testing is performed. Immediate tensile is defined as 60 seconds after the core has stripped from the core box.

The same front-end tensile value should be used for the incumbent sand and as well as the new sand for the evaluation to be valid. Typically the immediate tensile strengths need to be within 6 percent. We use 6 percent due to the variation that is seen in tensile strength with our core-making machine. Several attempts may be needed to get the correct level. To achieve the same immediate tensile strength, the following attributes need to be taken into account: 1) the GFN of the sand along with the theoretical surface area, 2) grain shape, and 3) screen distribution. These properties will affect how much resin is needed to produce a sufficient immediate core tensile strength.

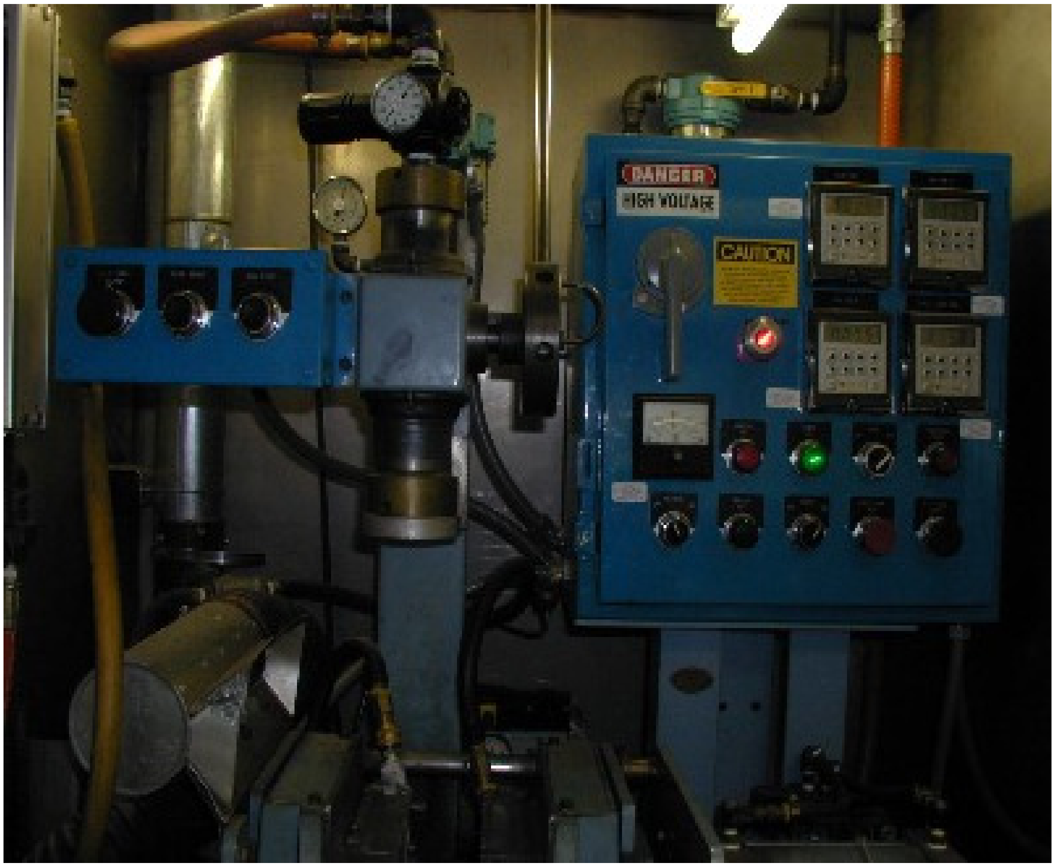

Figure 3
Core making machine.

DIP REDRY TENSILE STRENGTH

To measure dip redry tensile strength, a set of cores are made with the correct immediate tensile strength. The cores are then coated with a core wash. The core wash should be checked to assure the correct Baume level. The cores are submersed for a count of 3 and placed onto the conveyor to be dried in the production oven. Using a production oven is preferable to lab oven but a lab oven can be used, the oven should be at least 250^{o}F. If using a lab oven, the cores are placed into the oven and remain in the oven for 2 hours to ensure that the cores are dry. The cores need to be left in the laboratory oven for this period of time since there will be no air flow to help remove the moisture from the core wash. After the cores have dried, they are allowed to cool to the ambient temperature. The cores are then broken to record their tensile strength. The tensile strength of the cores should increase from their respective immediate tensile strength. This increase in tensile strength is typical for the current resin system and sand system that is used in our foundry. This is due to the heat causing the solvent to evolve from the resin.

CORE DENSITY

After the resin level has been established to accommodate for the tensile strength, core density needs to be identified at the current blow pressure (60 Psi) used for testing and a lower blow pressure (30 Psi) to identify if the pressure can be lowered and still produce a quality core. This will measure the flow ability of the sand with the resin for making a core. The more rounded the grain of sand is the easier the prepared sand will flow. A rounded grain of sand will allow for less resin to be used as compared to a sub-angular grained sand due to less surface area and more compactibility.

If a new sand system can achieve the same density at a lower blow pressure, this will reduce the cost of the sand since less sand will be used to make a core.

CURE SPEED

Cure Speed is used to measure how fast a core will be able to cure at the current resin level and core density. To measure cure speed lower the purge time when making a core. Typically 1-second gas time and 15 seconds purge time is used to cure a core in our laboratory testing, turn the purge time to 5 seconds and leave the gas time at 1 second. The objective is to have a core that has not completely cured. Weigh the solidified core and divide by the gas and purge time to calculate the cure speed.

When comparing cure speeds of sands, the density of the sand needs to be taken into account. Do not compare cure speed rates directly to each other. What needs to be evaluated is how fast will it take to cure a complete core, this should be done because a fast cure rate with a high density sand may not be as quick to cure a core as a sand with a low density and a cure rate that is slower. This is important because cure speed will effect the production cycle times in the core room.

Figure 4
Weigh cure portion of the cores to measure bulk cure speed.

BENCH LIFE

This test is used to provide information on how long the sand will live or make a core with enough tensile strength to strip from the corebox. A humidity chamber that can maintain a temperature around 100^{o}F and as much humidity as possible will show conditions seen during summer which is the hardest on core production.

Prepared sand is placed in a humidity chamber and sand is removed every fifteen minutes up to 1 hour or longer if desired to evaluate tensile strength. The tensile strength of the core is evaluated 60 seconds after being stripped from the core box. Compare the tensile strengths to their respective immediate tensile to evaluate the reduced tensile strength and how long the sand will be useful for core production. Tensile strengths within 6 percent are not considered a significant difference due to variability of producing dog bones.

Figure 5
A bench life study with high temperature and elevated relative humidity.

HOT STRENGTH

For evaluation of hot strength, a 900^{o}F muffle furnace or warmer is needed. Place the cores in the furnace for 10 minutes, remove the cores from the oven and immediately evaluate the tensile strength. The test needs to be repeated three times to ensure an accurate reading. A delay of a couple of seconds between the transfer of the oven and testing of the tensile strength will give a false high reading.

This test will give some insight about the strength of the core when metal is introduced. Compare tensile strength with the current sand system. If the hot strength is significantly higher, there could be the possibility of problems during shakeout. The core may not degrade so the internal section of the casting can be cleaned or possibly crack the casting. Conversely if the hot strength of the sand system is considerably lower than the current system the core may degrade to fast and not produce a dimensionally correct casting. We use the current systems hot strength as a reference.

PERMEABILITY

This test is used as a tool to help measure the density of the core; high permeability means the core has voids for the air to pass through producing little or no resistance (Mold and Test Handbook, 1989)[6]. One theory is that a core with a high permeability will gain strength faster than a low permeable core because the solvents can evolve more rapidly due to the voids in the core. Permeability will also affect the cure speed of a core. The denser the core, or the core with a lower permeability, will take longer to cure than a high permeability core. This occurs because the catalyst can travel through the core faster if the core is more porous. But the downside to a core with high permeability is that the higher the permeability the more problems with metal penetration. To compensate for high permeability a different core wash may be needed and possibly raise the cost of the core wash.

High permeability can also be a problem if no coating is being used. The voids that allow the core to evolve resin solvent will be a hindrance with penetration defects when metal is introduced.

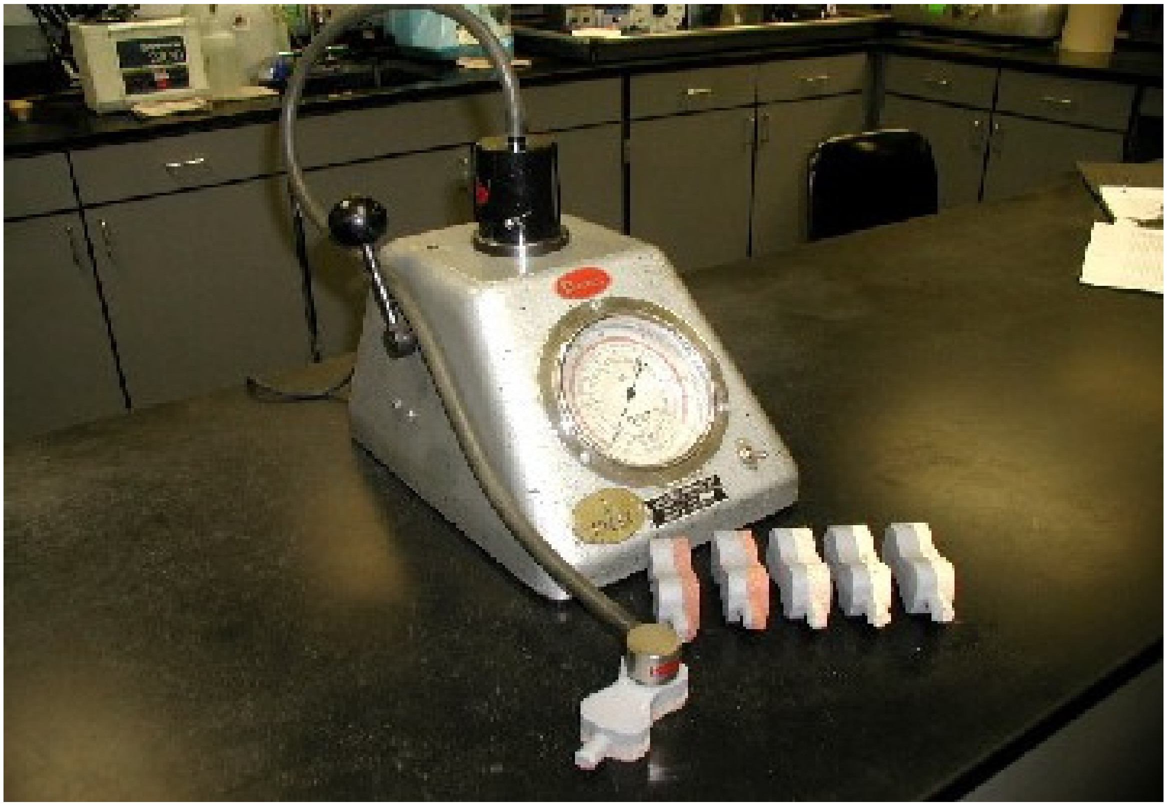

Figure 6
Measuring permeability for cores.

DELAYED TENSILE STRENGTH

Cores are made and evaluated after 1 hour, 4 hours, and 24 hours. After the cores are made, they should be stored in ambient temperature. As the cores are exposed to the environment, they will gain tensile strength. The core will gain strength due to solvents evolving from the core. At some point however, their tensile strength will plateau. How fast the core reaches the plateau for tensile strength depends on the permeability and resin level. The more permeable the core the faster the core will plateau because the solvent can escape more rapidly than a core with low permeability.

These cores will be used to evaluate the cores stored in the humidity chamber. The delayed tensile strengths will be directly compared to the humidity chamber tensile strengths at the same interval. For example, sand system A will use delayed tensile from the laboratory environment and humidity chamber at 24 hours as well as at a week and compare tensile strength to assess the difference between environments.

HUMIDITY CHAMBER

This test is used to evaluate how the core reacts to high humidity and elevated temperature over a period of time with respect to tensile strength.

A humidity chamber can be made using a steel drum, a metal bucket, and heat tape. The heat tape is used to heat the water in the metal bucket to raise the humidity. A thermo-hygrometer is placed in the drum to measure the environment. We have been able to maintain a constant 100^{o}F and relative humidity of 85% inside the chamber. It is important to note that the warmer the atmosphere the more moisture that can be absorbed. So 60^{o}F with 100% relative humidity does not have as much moisture as 100^{o}F with 85% relative humidity.

We run several tests with the humidity chamber, cores set in the chamber for a period of 1hr, 4 hrs, 24 hrs, 1 week or longer. The humidity chamber core's tensile strength should always be compared to the tensile strength of cores in the laboratory environment's delayed tensile strength. The 24 hr lab tensile strength is compared to the 24 hr humidity chamber. If the humidity chamber is run for a longer period a separate set of cores should be in the laboratory environment also. This will give a direct comparison for evaluating the sands and how humidity affects the core tensile strength.

This humidity chamber test is useful, since cores may set in storage as little as few hours or as long as 2 weeks before being used. So the environment in which the cores are exposed is very important to the tensile strength and ultimately the quality of the casting being produced.

Figure 7
Humidity Chamber used to expose sand to elevated temperature and relative humidity.

PHASE III

TEST CASTING

A test casting is made for evaluations of core material. This is a less expensive way to test the sands before actual production casting are made. This test casting is used to measure the veins surface area and surface finish for each core that is evaluated. The new sands will be compared to the current material. The current material will be used as a standard and placed in every test castings for evaluation. When making a test casting, we made sure that our current sand would have minimal veining so it would be easier to evaluate. This also would be a quick way to see if the other sands would measure up to the current system.

Our test casting holds six cores with the same amount of gray iron around each core so as to evaluate veining. When the casting has cooled, the sand is carefully removed from the test casting, trying not to disturb any veins during this process. The height and length of each vein is measured in the void where the core was placed. To rate the surface finish, a wire brush is used to clean the outside wall of the cavity. The outside wall is used to minimize the effect from the thermal shock of the molten gray iron on the inside of the casting. The surface finish is then rated using a casting finish comparator standard.

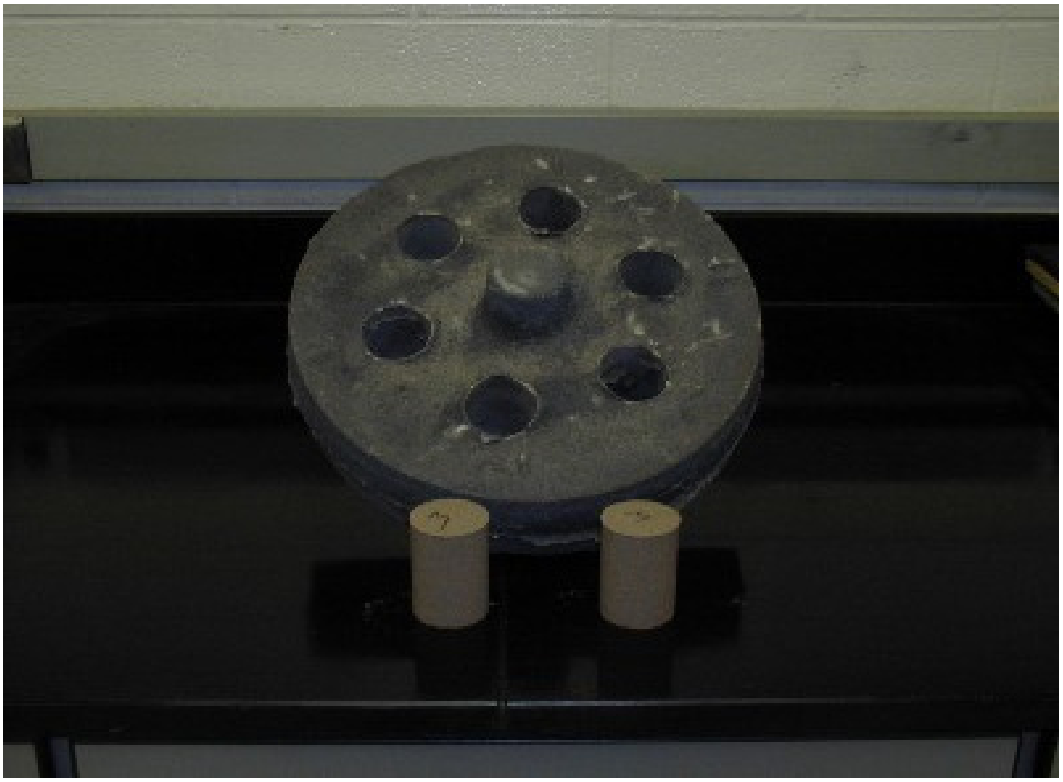

Figure 8
Test Casting for evaluating veins and casting surface finish.

SUMMARY

All of the tests outlined in this paper are used for evaluating new sand systems at our foundry. These tests are relatively easy to perform but are invaluable in showing the strengths and weaknesses of sand systems. After performing these tests, if a new sand system shows a benefit over the current system, production cores and castings will be made and evaluated.

REFERENCES

1. Reference –book: See procedure 102-87-S, American Foundry Society, *Mold and Core Test Handbook* 2nd Ed, Des Planes, IL (1989).
2 Reference –book: See procedure 105-87-S, American Foundry Society, *Mold and Core Test Handbook* 2nd Ed, Des Planes, IL (1989).
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4 Reference –book: See procedure 113-87-S, American Foundry Society, *Mold and Core Test Handbook* 2nd Ed, Des Planes, IL (1989).
5 Reference –book: See procedure 114-87-S, American Foundry Society, *Mold and Core Test Handbook* 2nd Ed, Des Planes, IL (1989).
6 Reference –book: See procedure 327-87-S, American Foundry Society, *Mold and Core Test Handbook* 2nd Ed, Des Planes, IL (1989).