Guide to Solving Hot Sand Problems

Hot sand has been described by metal casting industry researchers as the number one sand related problem facing today's metal casters. Most metal casters can show a direct relationship between reduced casting quality, increased process variation and other inefficiencies in molding that result from using hot molding sands. Studies have shown that hot sand can effect virtually every major operation within the foundry production line. In today's competitive environment foundries can no longer afford to sacrifice the efficiency and lost profits that result from uncontrollable, hot molding hand.

Hot Sand – What Is It?

A system sand returned to the muller for reconditioning with a temperature of 160°F (approximately 70°C) or greater is considered to be excessively hot sand. Return sand in the temperature range of 120°F to 160°F (approximately 49°C to 70°C) is considered to be hot enough to demonstrate inconsistent properties during mixing and to be very difficult to control. Studies have shown that hot sand can effect virtually every major operation within the foundry production line. To best understand the full impact of this problem requires a careful study of what causes hot sand, what happens in a foundry with hot system sand, how can sand be effectively cooled and what benefits can be expected by controlling sand temperatures to 120°F (49°C) or below.

Where Does Hot Sand Come From?

In a regenerative green sand system the composition of the sand mixture is formulated to meet the requirements of the molding method being utilized and the type of casting to be produced. The typical system sand consists of varying percentages of sand, clay, organic additives and water. The system muller and molding machine process this mixture into a finished mold. To form a casting, molten metal is then introduced to the mold, and in the process extensive damage occurs to the mold material (the green sand mixture). The damage that occurs (heat is the primary concern for the purposes of this discussion) will vary according to the location of the material in the mold.

As molten metal is poured into the mold the sand grains expand in size – some by more than 10%. During this time of expansion some of the sand grains will experience thermal shock and crack apart. The effect of this shock is the most severe at the mold/metal interface and diminishes as you move away from the mold face. As the sand grains at the mold/metal interface are maintained at a high temperature for a period of time, they can go through a physical modification. The clay additives in the green sand mold lose their combined water and structure. At this point the clay has lost its plasticity and it cannot be regained by subsequent new water addition. Calcium bentonite is destroyed at a temperature of 850°F (455°C) and sodium bentonite at 1150°F (620°C). The water in the mold evaporates as the temperature in the sand mixture exceeds 212°F (100°C), until all the free water has evaporated. Some of the water that has evaporated is carried through the mold with hot air and condenses in a layer behind the mold face. As a result of this overall process, the green sand mold now consists of many layers of sand with properties ranging from the very hot, hard and brittle layer of sand at the mold face to the relatively cool, wet and plastic layer at the mold back. At the completion of the casting cooling cycle the sand is separated from the casting at shakeout and re-enter the sand system. Typically the hot dry sand is the first part of the mold to re-enter the system followed by the colder, wetter backing sand. Sand in the return sand system is segregated in surges of sand with vastly different properties in terms of temperature, moisture content and clay level. In addition to this basic explanation of heat generation, a sand system can also gain heat from rapid sand system turnover, low sand to metal ratios, or simply high ambient temperatures. Combinations of all of these factors can be found in many metal casting plants.

Where Does Hot Sand Affect The Foundry?

Hot sand will effect every aspect of a green sand molding operation. Depending on the foundry's ability to control the sand temperature, the results can range from higher scrap rates and casting costs to a complete loss of system control. The area of most concern is, naturally, the effects on the product of the foundry itself: the castings.

Casting defects commonly influenced by hot sand are:

Pin Holes:	Cavities in the casting surface, either spherical, flattened, or elongated.
Dirt Inclusions:	Surface or sub-surface particles of sand, slag, dross, or oxides which are embedded in the metal.
Washes:	Rough spots and areas of excess metal caused by erosion of the mold.
Rough Surface:	A casting surface that lacks the required degree of smoothness.
Sand Stickiness:	Excess metal on the surface of the casting caused by a portion of the mold face remaining on the pattern.
Broken Molds:	Molds that are not strong enough to withstand pouring stresses.
Crushes:	Indentations in the castings.

Besides the effects hot sand has on casting quality, there are also many adverse effects on the proper operation of the sand system. For the purpose of this discussion only the most notable or destructive effects will be discussed.

1. The process of shakeout begins sand system segregation. When molds are broken open at shakeout, the hot, loose, dry sand immediately adjacent to the casting tends to pass through the shakeout grating first. This is followed by the wetter, cooler, unburned sand and, finally, by the breakdown of the hard baked, but unburned sand and core lumps. Passing this sand along belt conveyors, up elevators, and through screens does not blend out the variations in temperature, moisture and additive burnout in the sand returning through the system. Sand entering the bulk or batch storage bin is "layered" in such a way that seldom does a uniform cross-section of sand enter the system from one moment to the next.

In fact, one test conducted using multiple thermocouples in a mixer batch hopper showed the sand in one batch varied from 90 to 380°, depending on where in the hopper the reading was taken. This variation makes it extremely difficult for a thermocouple in the batch hopper to accurately predict the cooling water required for the muller. For this reason most sophisticated muller control technologies will take multiple temperature and moisture readings in the batch hopper of a batch type mixer or from the inlet belt of a continuous mixer. For example, the popular 18Mk2/2502 or 18Mk2/2552 on-line compactability controllers from Hartley Controls Corporation each provide for up to nine (9) temperature measuring points and six (6) moisture sensing points for a typical batch hopper. For the same reason, a fixed bond addition or fixed batch mixing cycle cannot compensate for the wide fluctuations in sand properties found in most sand systems.

Handling sand of different consistencies in terms of temperature, grain size, moisture, and other critical physical properties is one of the greatest problems facing sand preparation equipment and controls. This problem is especially evident in the foundries operating batch equipment or continuous mixers which do not have the ability to back-blend the incoming sand. Foundries which strive to automate sand preparation while maintaining a high level of system efficiency will find that formal preconditioning of the sand is absolutely essential to achieve world-class performance in sand control and casting quality.

2. When hot sand, water, and other additives are introduced to the muller for regeneration a variety of problems are created. The most immediate reaction is the creation of steam from the intimate contact of cool water with the heated sand grain. Steam causes the muller to become dirty due to water condensation on the interior surfaces of the machine. This wet area will attract fines and clay that should either have remained in the sand or be on the way to the dust collector. The sand that builds up on the machine interior must be cleaned regularly or the foundry has the risk of the material discharging as a hard agglomerate to the sand system and causing a defect in a mold and/or casting.

   The second problem caused by the evaporation of additive water is the loss of the intended measure of moisture addition to the sand mixture. If this loss is not compensated for in the batch preparation sequence, the resulting sand quality will be less than sufficient for molding operations. At best, if the muller has sophisticated automatic moisture addition controls, the sand system capacity will be reduced due to longer mulling cycles, and consistently high quality sand control will be sacrificed.

   The major problem created by hot sand in the muller is the proven difficulty of efficiently combining hot sand and bentonite clay. Sand with a temperature in excess of 160°F (70°C) cannot be effectively combined with bentonite. The typical "solution" for this problem is the excessive use of clay additives, which is expensive and creates an entirely new classification of sand problems and casting flaws.

   The Volkmar Study (1979) illustrates the compactability results achieved at various temperatures (see graph). In this study, a large sample of sand was split into 13 plastic bags, with a thermocouple in each bag. At each temperature indicated, a bag was removed, and a compactability test was run on the sand with minimum delay. The chart illustrates the loss of compactability at temperatures beginning at 120°F (49°C).

It has been attempted to cool the sand in the muller itself through the use of blowers or vacuum, but this is a technical compromise and is generally considered undesirable. As sand temperatures increase, more cooling is necessary in the muller. As more cooling becomes necessary, more time in the muller is required to accomplish the cooling, thus reducing the system's sand preparation capacity.

3. When the hot sand mixture exits the sand preparation equipment it is commonly transferred to a storage bin. When a combination of hot and wet sand enters a bin, free water vapor is always present. The small percentage of vapor which is above the sand in the bin can be removed by venting the bin, but a good amount of vapor is trapped down inside the bin in the spaces between sand grains. If the bin walls are cooler than the dew point of the hot water vapor (and most are), condensation takes place at the bin wall. Special paints and thin plastic or stainless steel linings do not stop this condensation. As the vapor adjacent to the bin wall condenses, vapor pressure in this area is reduced and vapor from adjacent sand expands to replace that which has condensed. When condensation becomes heavy enough the sand will stick to the bin walls. The result is an overly wet, gummy layer of sand at the bin wall which can rapidly build up to several feet in thickness unless frequently removed. This build-up can cause a variety of problems: A) very wet chunks of sand periodically drop off the walls of the bin and enter the system, further complicating sand control and molding operations, and/or B) perhaps the most serious effect of bin sidewall build-up is the phenomenon of "bin funneling" or "rat holing". Hot sand entering the top of this bin feeds directly down a tube or funnel through the center of the wet sand built up around the bin walls. This means more frequent usage of a smaller portion of the total sand in the system (higher system turnover). With less total sand to absorb heat entering the system from the molten metal, excessive temperatures build up in the sand at an increasing rate. As more of the sand in the system is put out of circulation through bin build-up, hot sand problems increase.

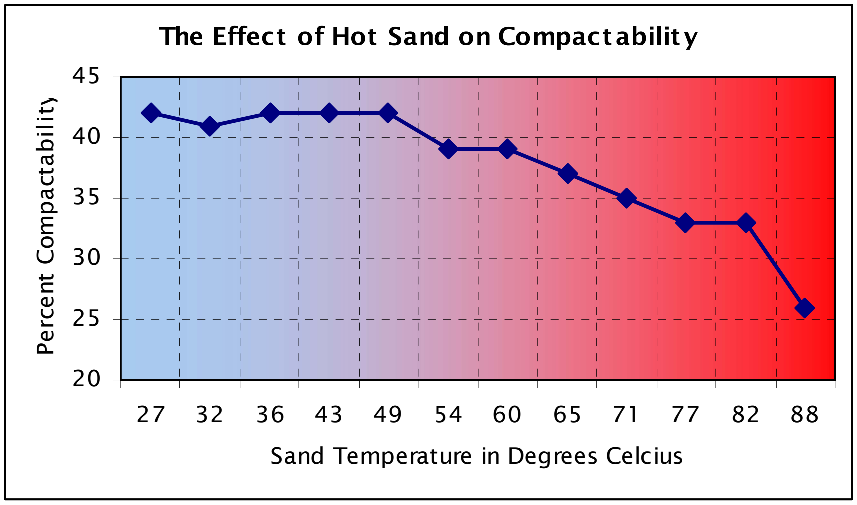


Figure 1 - Volkmar Study

4. Hot sand in the molding operation presents problems that will directly be tied to the production of scrap castings. Because the hot sand is not uniform in green properties, the molding machine cannot produce a uniformly compacted mold, nor guarantee that the mold will remain intact if correctly formed. Variations in mold hardness are known to cause a wide variety of casting defects, especially in molds with critical dimensional tolerances or deep-draw pockets.

5. In operations where chemically bonded cores are set into the hot green sand mold, it is common for the cores to pick up moisture from the condensation between the cool core sand and the hot

molding sand. The increased moisture in the core will weaken it and cause yet another source for major casting defects (scrap).

6. An often overlooked area where hot sand can affect the efficient operation of the foundry is in the sand control laboratory. Hot sand will cause the results of most lab tests to vary greatly from the actual. This is due to the fact that as sand gets hotter it has a direct effect on the sand properties being tested. The three properties most effected are green strength, dry strength, and 2 x 2 specimen weight. If the sand temperature is high and not noted in the testing procedure, the results will be misleading. The results may show a need for more bond or a need for longer mulling, where the actual and final solution to the problem is to cool the sand down under the 120°F (49°C) threshold.

It is universally accepted that sand quality contributes directly to casting quality. Hot sand can be expensive, at best, in the successful operation of a green sand molding line. The increased demands for system efficiency required to operate high pressure molding equipment at minimum scrap levels will make formal cooling/preconditioning even more necessary to sustain a consistently high level of sand quality and equipment productivity. In green sand molding lines there are several types of equipment used to deliver cool prepared sand to the molding system. All, however, employ the principle of introducing water into the hot sand, and subtracting heat from the sand through vaporization of the water. The success of this process is completely reliant on the natural laws of physics.

Common Equipment For Cooling Shakeout Sand

Many types of equipment have been devised in past years to accomplish this task. Following is a brief description of the most prevalent types:

1. **Rotating Cooling Drums.** The cooling drum has great appeal to the foundry industry because of its relative simplicity. However, the inefficiencies of the equipment far outweigh the apparent benefits. In the cooling drum sand is fed into one end of a rather large, inclined rotating drum. Often the downhill side of this drum incorporates a rotary screen. Air is pulled through the drum from end to end by an exhaust fan. Due to the slow movement of sand through the equipment, a major requirement for effective sand cooling is totally ignored; the constant exposure of fresh surface area to the air stream in order to achieve the highest degree of cooling. Furthermore, due to the slow movement, the sand really moves through the drum as a 'slug' and interblending of sand variations is not achieved. The intermixing of sand from various zones of the mold as well as mixing sand from unpoured molds into hot sand originating from the sand/metal interface is performed considerably less than satisfactorily. Sand leaving cooling drums exhibits inconsistent properties in terms of temperature, moisture content, etc.

2. **Stationary Cooling Drums with Rotating Paddles.** Like the rotary drum, sand enters at one end of an inclined stationary drum and is advanced through the unit by lifting paddles or shelves rotating around a central shaft. Air is pulled through side openings in this type drum cooler and exhausted out the top. This equipment has similar performance to the rotating drums.

3. **Sand Cascades.** Hot sand is elevated to the top of cascade towers, from which point it either falls by gravity through a series of baffles or is plowed off stacked shelves, dropping from one shelf to the next lower one. Air is pulled up through both types of units, counterflow to the direction of sand travel. Sand Cascades are not an effective solution to the cooling problems of modern foundries.

4. **Vibrating Fluid Bed Coolers.** Fluid bed coolers also enjoy a degree of popularity in the foundry industry. However, a number of factors limit the effectiveness of a fluid bed cooler. In a fluid bed cooler sand is fed onto the inlet end of a double-deck vibrating conveyor. The upper deck consists of a plate perforated with many small holes or a small opening screen mesh. The sides and lower deck of the conveyor form an air plenum under the upper deck. Air is blown under pressure into the air plenum and passes up through the upper deck as many small high-velocity jets. These air jets keep the sand from falling through to the lower deck and act as cooling and fluidizing air in the sand.

   In practice, a number of technical and practical problems frequently occur. A fluid bed, by definition, is designed for the processing of particulate matter where the particles have identical (or close to identical) diameters. Basic physics explains a critical weakness; if not suspended, each particle in the bed would fall down due to its own weight. The weight of the particles is proportional to the diameter cubed. In order to have a fluid bed, air is pressed from under the bed through the sand mass and the pressure of the air acting upon the sand grains keeps these grains in suspension. This upward directed force of the air, however, is acting on differing areas. All foundries know that molding sand does not consist of identically sized particles but consists of a range of sizes distributed over a wide range. Generally, foundry sand has a grain size range from the smallest to the largest grains of 1:10. An 80 mesh silica particle will be in suspension at an air velocity of approx. 10.5 ft./sec. (3.2 meter / second). However, the speed of the air will have to be quite higher because material in the 70 and 50 mesh range also has to be in suspension in order not to settle out at the bottom of the equipment. On the other hand, bentonite (clay less than 20 micron diameter) is already in suspension at air speeds of approx. 1 ft./sec. (0.3 meter / second). The result is that the fluid bed systems tend to act as segregation devices and remove a lot of fines and clay which, if foundry economics and process needs are considered, must be retrieved and reintroduced into the system. In reaching a compromise to this situation, engineers typically select a lower air velocity, which then results in the small air inlet holes becoming clogged with sand with an associated loss of capacity and cooling effect.

   Research by Buderus AG, Wetzlar, in Germany suggests that in fluid bed systems the discharged air "contains considerable quantities of dust (approximately 15% of the dust from the foundry sand)…the high discharge of dust is due to the requirement that the floor sand moisture must be lower than 1.5%, which does not have to be the case with coolers with mixing arms," (the Simpson Multi-Cooler). This same study documented a 15% greater cooling effect by a Multi-Cooler. The segregation tendencies of fluid bed coolers are further aggravated by their inability to inter-blend the variations of the return sand.

   As the sand cooling effect desired becomes greater it becomes necessary to increase the length and overall size of the fluid bed cooler. In new and old foundries alike, it is difficult to justify the required floor space. The resulting mass and vibration effect makes installation of the fluid bed cooler into basement or tower mezzanine areas impractical.

5. **Cooling in the Muller.** Although providing a degree of relief in some systems, cooling in the muller is widely recognized by most modern foundry engineers as an undesirable technical compromise. Simpson engineers designed and installed systems such as this for Simpson mullers prior to the development of the high technology Multi-Cooler. The process of adding cooling air and fluidizing the sand mass for effective cooling is a direct contradiction to the activities necessary for effective final mixing. At best, mulling cycles will be lengthened and the system mixing capacity reduced.

Some of the mentioned equipment can effectively cool when carefully applied to sand systems where the sand properties are well in control and unusually consistent. However, *none of these units can blend out the minute-to-minute fluctuations in sand temperature, moisture or degree of additive burnout which are prevalent in a significant majority of automated molding systems. None of the above units can effectively back-blend the sand leaving the discharge end with incoming sand; therefore, none can guarantee the control of the moisture, temperature, and the physical characteristics of the sand being discharged to provide a uniform product entering the storage bin ahead of the mullers*.

The Ideal System of Cooling and Pre-Conditioning Return Sand

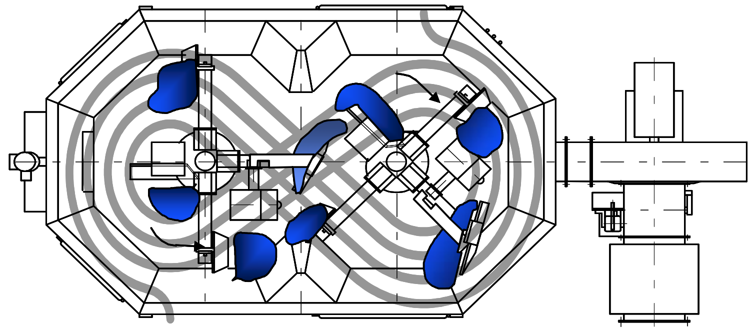
In August of 1964, Simpson Technologies Corporation conceived the idea of developing a continuous cooler (the Simpson Multi-Cooler®) using many of the same principles as the successful Simpson Multi-Mull® continuous muller. Prototypes were developed and the first production Multi-Cooler was offered to the general industry at the 1966 American Foundrymen's Society Castexpo held in Cleveland, Ohio USA. In this concept, the Multi-Cooler is equipped with controls to add a measured amount of cooling and tempering water to insure discharging cool sand within a controlled moisture range on a continuous basis. Recent advancements of this technology have included a method of making the bond (bentonite) addition in the Multi-Cooler to increase the benefit capability of the premixing affect. In this system, the muller group accepts the sand from the Multi-Cooler and makes the necessary final moisture and bentonite addition to build the sand mixture to optimal strengths. Since the Multi-Cooler averages out wide variations in temperature, moisture and degree of additive burnout, the mixer group following it is fed uniformly cool sand with closely controlled moisture content and physical properties. The mixer group, also equipped with sophisticated automatic controls, can be fully utilized to develop the maximum potential of the green sand mixture without the inefficiency of adjusting to inconsistent charge materials. The physical properties of the sand can be continuously and automatically controlled to quality levels not otherwise possible while using a minimum of power, time, labor, and capital investment.

Figure 2 – First Generation Simpson Multi-Cooler

The Simpson Multi-Cooler in the Field

Since the first Multi-Coolers began appearing in North American foundries in the early sixties, they have gained rapid acceptance. Simpson Multi-Coolers are now installed on six continents. Over 300 successful installations in more than 150 foundries have been completed both in relatively small jobbing foundries and in very large automotive foundries. The largest single installation is the giant Kama River Truck Plant in Russia. There, twelve of the big 300+ TPH MC-300 Simpson Multi-Coolers handle all the sand cooling prior to precision mixing in continuous 26G Simpson Multi-Mulls. In the 1990's the design of the smallest model, the 25 tph MC-25 Simpson Multi-Cooler (the seventh model in the series) was completed and immediately began to gain acceptance in small jobbing foundries from Turkey to Sweden to Brazil.

Perhaps the greatest enthusiasm for the unique control capabilities of the Simpson Multi-Cooler in recent years has been in the technically advanced, and highly competitive, automotive foundries. With development of high speed, automatic, high-pressure molding systems (Disa, Seiatsu, etc.), it rapidly became apparent that there was an urgent need for extreme uniformity in prepared molding sand. High speed, high production meant high scrap and high profit loss if the metal casting prodcess was out of control. Competition and foundry economics demand a continuous reduction in sand related scrap. Sand mixtures required by modern foundries have to be controlled within limits far narrower than those to which the average foundry was accustomed. The main problem in achieving the desired degree of control lay in the inability of automatic moisture and bond control equipment to compensate quickly enough for the wide fluctuations in sand temperature, moisture and degree of additive burnout in the sand being returned to the sand preparation equipment (coolers and mixers).



Development of sophisticated on-line mixer group controls provided a degree of relief to this problem not possible with conventional mixing systems. Using sophisticated sensors and control logic, modern on-line controls, such as the Hartley Compactability controller, could quickly and automatically adjust to many return sand variations and sand related casting scrap was reduced. Even the best controllers, however, cannot adjust to the wide variation in return sand conditions found in most foundries. To further minimize sand related casting scrap and optimize the green sand molding process it became necessary to add cooling and pre-mixing technology to the sand plant. The addition of a Multi-Cooler into the system allows the sand preparation plant to develop sand qualities to optimum levels.

Figure 3 - Modern Simpson Multi-Cooler

The Multi-Cooler makes it possible to place sand of a uniform moisture and temperature level into the sand system ahead of the critical mixing stage. Sand cooled to approx. 10-15°C above ambient can discharge from the cooler at 1.5% to 2.0% moisture and can be maintained at this level. In addition, minute-to-minute variations in degree of additive burnout are averaged out and a pre-mixing of the variations in sand properties is achieved. Now, sand delivered to the mixer group is so uniform and that on-line controls in the mixer group can attain a degree of prepared sand uniformity and strength not possible with conventional sand systems.

A complete sand preparation plant integrated with the Simpson Multi-Cooler and a modern muller (such as the Simpson Mix-Muller, Simpson Multi-Mull or Beardsley & Piper Speedmullor) equipped with automated controls (such as the Hartley 18Mk2/2502 Compactability controller or 18Mk2/2552 compactability controller with bond determination feature) as the heart of the system can operate on an automatic, continuous basis with a minimum of labor, power, downtime, and initial capital investment.

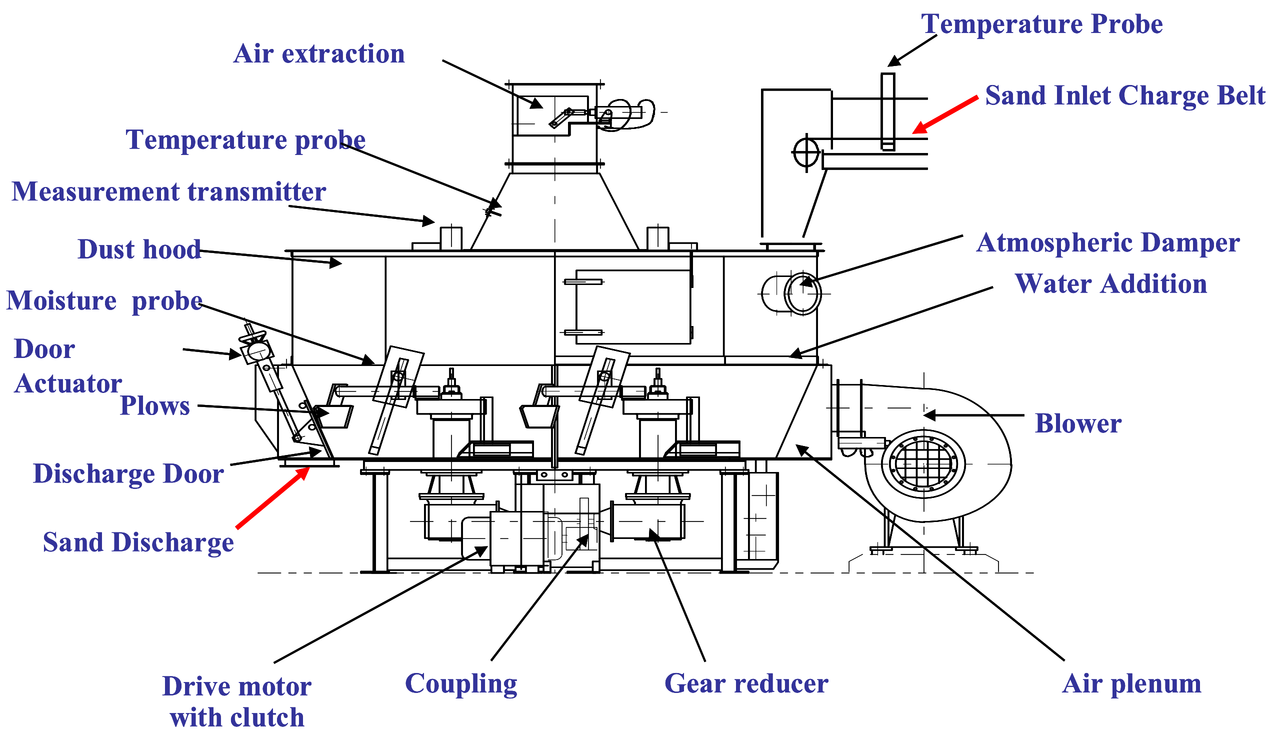


Figure 4 – Simpson Multi-Cooler

For a presentation on this system, or a detailed discussion of the other technology mentioned in this paper, please do not hesitate to contact your Simpson Technologies Corporation representative or visit us on the internet at www.simpsongroup.com.

SIMPSON GROUP

Founded in 1912, Simpson Technologies is a world leader in foundry and process industry technologies. Within the Simpson Group are some of the world's largest and most innovative brands of metal casting technologies including the companies Simpson Technologies, Beardsley & Piper LLC, Hartley Controls Corp. as well as the brands of Dietert Automation and Simpson+Gerosa. In the metal casting industries our products include technologies in the following areas:

- Molding Sand Cooling
- Molding Sand Preparation (batch & continuous)
- On-line Controls for Sand Preparation Systems
- Flaskless, Matchplate Mold Making Equipment
- Core Sand Preparation Equipment
- Core Making Equipment
- Sand Reclamation Equipment
- Pollution Control Equipment
- Sand Laboratory Testing Instrumentation
- OEM Spare Parts and Field Service
- Laboratory Testing and Rental Equipment

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