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Sand Binder Systems

Technical Paper

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Part XI: The Phenolic Urethane Amine Cold Box System

Eleventh of a 13-part series filled with useful and up-to-date information about sand binder systems.

Section B

Process Equipment

The success of the Phenolic Urethane Cold Box (PUCB) Process has been, in no small part, due to ingenious process innovations and creative equipment modifications by equipment manufacturers. Equipment used to produce cold box cores and molds includes, a sand coating device, a coreblower, a compressed air system and dryer, a catalyst gas generator, a scrubber system to control and neutralize effluents exiting the tooling and finally, and perhaps most importantly, a properly rigged pattern.

Fig. 1: Laempe batch mixer

Fig. 2: Klein batch mixer

Fig. 3: OMCO batch mixer

Fig. 4: Tinker Omega continous mixer

Fig. 5: Palmer continous mixer

Sand Coaters - A wide variety of sand mixing equipment can be used with the PUCB Process. A sand delivery system that minimizes coated sand aeration is best. Sand mixing system should be selected based on the mixed sand quantities that can be used rapidly and replenished with fresh mixed sand on demand. Vibratory batch mixers, high speed batch mixers, and practically all types of continous mixers have been especially well applied to high production PUCB operations. Computer controlled resin metering for the sand coater helps to ensure a continous supply of high quality sand, lower binder level, and minimize casting defects. In general, the payback period for a computer controlled resin metering package is less than 12 months.

Core Blowers – Although PUCB cores and molds can be made utilizing a gassing hood arrangement, they are almost always produced on core/mold blowers. As shown in Fig. 6-9, core/mold blowers can be small and simple or large and complex. Through the combination of air transported coated sand and properly rigged tooling, PUCB cores/molds can be compacted and cured in rapid blow/gas/purge steps.

Fig. 6: Laempe core blower

Fig. 7: Loramendi core blower

Fig. 8: Gaylord core blower

Fig. 9: Redford Carver core blower

Since any movement of uncured cold box sand can result in sand sticking to the screens in the upper half of the tooling, the ideal coreblower has constant clamping that firmly locks the cope to the drag. It is even more important to minimize, if not eliminate, movement of the corebox between the blow and gassing cycles. Any movement must be accomplished in the smoothest manner possible. This point becomes more important as core weight and thickness increase.

When the tooling is stationary, the chance of producing a "laminated" or "scabby" core is greatly reduced. Vents will remain unplugged and pattern surfaces clean. The ability to provide and maintain sufficient clamping pressure during tooling transfer acceleration/deceleration will, in large part, determine the quality level of the cores/molds produced.

The Sand Magazine – The sand magazine is located between the resin coated sand hopper and the core machine. Once it is filled with the coated sand from the hopper, dry, compressed air fills the magazine and conveys the coated sand into the PUCB tooling. The ideal sand magazine should contain little more than the minimum quantity of sand necessary to blow a set of cores and should be designed to blow nearly all of the sand from the magazine by the conclusion of each blow cycle. There are three basic types of sand magazines: blower, shooter, and extruder.

Catalyst Gassing System – The primary function of the gassing system is to meter out a predetermined quantity of liquid amine, change its physical state from a liquid to gas or vapor, combine it with a carrier gas and finally to deliver it to the corebox for use without allowing the vaporized material to re-condense back into liquid form.

Two successful approaches are used for the catalyst gassing system: individual gassing units for each core machine and a centralized system servicing a group of core machines.

Individual gassing units, also called On Demand Generators, are generally used to supply amine to a single machine. Individual gassing units measure the amine, inject it into a gas carrier stream, then deliver the amine/vapor carrier gas at a controller pressure through temperature controlled and insulated piping to the core/mold machine.

On Demand Generators come in a variety of designs. A stroke injector unit uses a syringe-like pump to measure and mix the amine with the carrier gas stream.

A standard injector unit introduces the amine into the carrier gas stream through a metering orifice. In this type of unit liquid amine flow into the carrier gas stream is controlled by time and pressure. A controlled amount of liquid amine is delivered to and through the injector orifice by way of a diverter valve that utilizes either a pump or some other constant pressure supply device to deliver a constant supply of amine.

A vaporizer generator that heats either the amine and/or the carrier gas stream is considered to be a vaporizing generator. The term "vaporizing generator" denotes that the generator heats the amine and/or the carrier gas in order to improve vaporization of the amine and increase the volume of amine that the carrier gas can hold in the vaporized phase. The heated carrier and heated purge air type of amine generator has proven to be a very effective way to minimize gas consumption, decrease the gas and purge cycle, and minimize residual amine in the core/mold. If, of course, it is used in combination with properly rigged tooling.

On-demand generators generally utilize dry, compressed plant air as their carrier and purge gas. There are obvious economics benefits associated with this type of system compared to units that use an inert gas (generally nitrogen) as their gas carrier. It should be noted that carbon dioxide, although once used as a carrier gas for the amine, is rarely utilized because it can react with the amines in the presence of moisture to form amine carbonates which can plug the equipment and result in productivity losses and excessive maintenance costs.

Amine gas generating units should be as close to the core machines as possible in order to prevent liquid dropout of the amine vapor in the supply lines and mixing of the purge air from the prior cycle with amine from the current cycle. For optimum results all carrier/catalyst supply lines, accumulator tanks, etc., should be heated and insulated. It is advisable to have the insulated line temperature increase 25°F from the generator to the final delivery point to ensure that the amine vapor does not condense back into the liquid state. Caution must be exercised when using a cal-rod as a heat source when heating amine since it might serve as an ignition source in case of some malfunction.

On-demand generators usually draw their amine supply from a small storage tank attached to the mixing unit. This limited supply of liquid amine requires that the tanks be routinely, manually filled with the flammable liquid. Some on-demand injector units can be tied together with a central liquid amine delivery system by way of a manifold system that services all the units in the system, eliminating the inconvenient filling of individual supply containers.

In high volume applications, in order to minimize the cost of multiple individual amine gassing units, a centralized catalyst gassing system can be utilized. A centralized amine generation system can be of several designs. It is often a modified version of the on-demand units discussed above, but it can also be a "bubbler" or "sparger" type generator. In this design, an inert gas, generally nitrogen, is passed through a fritted glass filter that is submersed in liquid amine. The nitrogen emerges from the filter as tiny bubbles and as they pass through the liquid amine they become saturated with the amine. As the amine saturated gas emerges from the tank it is piped to strategically located, heated accumulator tanks for storage and supplying the core/mold machines. From the accumulators it passes through heat-traced and insulated carrier lines, which ensures that the vaporized amine does not re-condense as a liquid. Finally it arrives at the inlet plenum of the core machine where it is directed into the cold box tooling.

An utilization of 2 to 3 lb. amine per ton of sand is considered good. It should be noted that with a correctly designed and configured distribution system, along with properly rigged tooling, vaporizer generators are able to produce cores/molds with as little as 0.8 lbs. of amine per ton of coated sand.

Gas Input Plenum and Piping – The gas input plenum should be the minimal volume that will still insure a quick and uniform distribution of the amine to the input openings in the tooling.

The amine delivery system used to convey catalyst gas and purge air to the pattern must be capable of quickly delivering a large volume of catalyst gas to the cope half of the corebox at a relatively low pressure (2 to 10 psi) during the first 1–5 sec of the cure cycle. Then it must follow quickly with a surge of purge air at 15–35 psi to disperse the catalyst completely throughout the coated sand in the pattern and then flush it out of the coated sand. To do so effectively, the route from the catalyst control valve to the core itself must be as unrestricted and as direct as possible. This requires that the gas transport volume between the catalyst valve at the machine and the point at which the catalyst initially contacts the sand be as little as possible. Otherwise, there will be a curing delay at the beginning of each cycle as excessive un-catalyzed purge air remaining in the pipe and plenum from the last cycle is pushed through the system in front of the new surge of catalyst gas.

Heated Purge Air – One of the most effective and, yet, relatively inexpensive ways to increase the efficiency and productivity of the PUCB Process is through the use of heated purge air. Heating the purge air and passing it through heat-traced and insulated lines so that the plenum inlet temperature of triethylamine (TEA) mixtures is 210°F (TEA vaporization temperature is 198°F) and that of Dimethylamine (DMEA) is 110°F (DMEA vaporization temperature is 98°F) can dramatically reduce sticking and cycle time. In addition, by preheating the tooling prior to start-up the practice of dry cycling or blowing and discarding the first few cores is eliminated. A 9 kW heater is satisfactory for core production under 150 lbs. per blow, a 12 kW heater is used for blow weights greater than 150 lb. Heater sizes of more than 30 kW are available for servicing a multiple core machine installation. Care should be exercised to keep the temperature of the TEA below 300°F since at that temperature it begins to decompose.

Exhaust Plenum and Piping – A properly designed PUCB exhaust system should not allow significant back pressure to develop during the high-pressure purge, nor should a high vacuum develop in the exhaust plenum when suction disposal units are used. Exhaust piping must exceed the flow capacity of the input system by a factor of three. Again, the piping should contain no restriction and a minimum number of elbows and tees.

A -10 to +10 psi gage can, and should, be installed in the exhaust plenum. Pressure from -1 to +1 psi are desirable, and efforts should be made to maintain that range during operation.

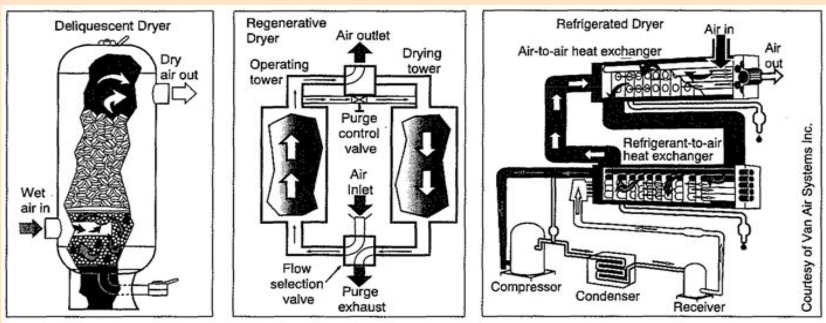
The Exhaust Scrubber System – Once the catalyst has cured the binder it is conveyed through exhaust piping to a wet, packed tower scrubber, such as that shown in Fig. 10-11. The amine is reacted with free sulfuric acid to form an amine sulfate salt in the scrubber's aqueous sulfuric acid atmosphere. The sludge-like material, which accumulates in the bottom of the scrubber's, can be chemically reclaimed, thereby eliminating a waste stream from the foundry. The primary function of the scrubber system is to prevent the discharge of offensive chemical odors from entering into the atmosphere. However, since the scrubber produces a negative pressure in the exhaust plenum of the core box, it can be used to help promote the smooth, uniform flow of gas through the core and assist in the production of quality cores/molds by helping to direct the flow of amine vapor through the tooling cavity.

Fig. 10: Dakota scrubber.

Fig. 11: Gaylord scrubber.

When a corebox venting system is developed, and standard gas and purge times are established, they are based on a constant exhaust plenum pressure. If pressure fluctuations occur because of fan downtime of other system malfunctions, gas flow through the corebox can be altered, possibly resulting in improperly cured sand. For that reason, scrubber consistency is important, and a vacuum/pressure gauge should be installed in the cold box exhaust plenum as a monitoring device.

Fig. 12: Compressed Air Dryers



The function of the compressed air system is to supply dry compressed air that will blow coated sand into the corebox, disperse the catalyst gas throughout the sand, and purge the catalyst from the sand at the cycle's end. It is extremely important to the success of a coldbox operation that the air be dry. Any moisture in the cold box sand or the blow and purge air has a detrimental effect on core/mold quality, as well as shelf life. Because industrial compressed air usually contains moisture and oil, air dryers are required. There are three basic types of industrial air dryers: deliquescent, regenerative desiccant, and refrigated. To be effective, the dryers must be capable of maintaining an atmospheric dew point of -40°F or lower.

The regenerative desiccant dryer system has a relatively low initial cost, very low maintenance and can sustain an atmospheric dew point of well below -65°F. Refrigerant-type air dryers will do the job, but do not attain as low a dew point and are generally more expensive to purchase and maintain than the regenerative desiccant-type. Deliquescent types, although inexpensive, are not satisfactory for the PUCB Process.

It is critical that the dew point be monitored continually and that corrective action be taken at the first sign of an increase, even if the effects cannot be observed at the core machine. Unfortunately, core degradation associated with high dew point compresed air is not generally recognized until the cores and/or mold are removed from storage and are ready to be used.

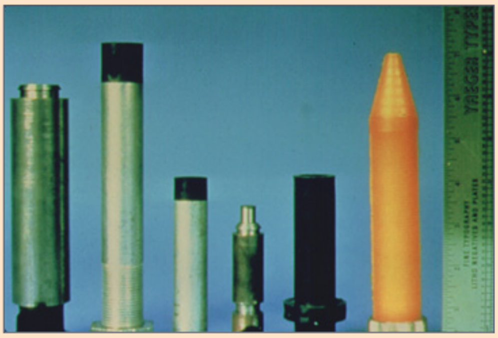
Corebox Tooling Design

Although cast iron is generally used for high production tooling, many other materials can be used in experimental or low-volume situations. These include aluminum alloy, wood, epoxy, urethane, and aluminum frame/plastic lined composites. Plastic tooling offers lower initial cost, simplified repair, and less replacement cost. However, because plastic is attacked by cleaning agents and many release agents, it does not have the longevity of cast iron. Because there is no high-temperature heat expansion and contraction of the pattern, cores without parting line fins can be produced if the parting line match is less than 0.005 in.

Blow Tubes – Traditionally, blow tubes have been made from medium carbon steel, thick-walled tubing, or machined steel bar stock. Metal blow tubes require a resilient blow-tip seal to prevent sand from blowing out between the blow tube and cope blow tube seal.

More recent developments include nylon and cast urethane blow tubes. Their compressibility eliminates the need for a flexible rubber tip seal, thereby reducing cost and improving quality (because the rubber tips suffer from high wear). Fig. 13 shows basic steel and nylon tubes. Proper sizing and placement of blows tubes insure reliable production of high density cores at low blow pressures and low sand velocities.

Fig. 13: PUCB Process blow tubes.



It is almost impossible to have too much blown tube area for producing a quality core/mold, and blow tubes with inside diameters less than 0.5 in. should be avoided. They are prone to plugging, which results in poorly blown cores/molds and causes machine downtime. Blow tubes with inside diameters greater than 1 in. also should be avoided because of their tendency to drop sand into the blow tube seal. Large diameter blow tubes also will leave large scars on the core surface.

Blow tube length should provide for 0.03 in. squeeze when the blow tip contacts the blow tube seat. The blow plate should be equipped with locating pins that engage bushing in the cope before the blow tubes make contact with the blow seats. Blow tubes never should function as locators.

A guideline for determining total blow tube area is to use 0.20 to 0.35 in^2 of blow tube cross-section for each pound of sand to be blown. More blow tube area is required for thinner cores than for chunky ones. Placement of the blow tubes should be in the heavier section of the cores wherever possible.

Maximizing the distance between the blow tube and the point where the sand impinges on the pattern surface reduces resin wipe-off and reduces tooling wear. If possible, avoid placing a blow tube so that it discharges directly into a thin core section or over a sloping wall that will direct the sand into a deep pocket. Otherwise, the sand will erode the tooling surface directly below its entry point.

Vents – A number of pattern vent types are available. Among others, they include woven wire, slotted steel, laser cut, ceramic, and electromesh. The most widely accepted vents for use in high-production applications are 1) woven wire using No. 30 mesh stainless steel and a brass body and 2) perforated brass-plate slotted with 0.02 in. slots. However, the ones that seem to work the best are laser cut and the ceramic-type show promise. Woven wire, laser cut, and ceramic are employed where possible because of their greater vent area and for ease of cleaning. Unfortunately, its application is restricted to fairly flat surfaces. When venting is required on contoured or vertical surfaces, the brass slotted vents are used so that the core will pull past the vent surface.

Size and placement of vents are key factors for achieving core quality, minimum cycle time, and low catalyst consumption. Vent considerations are far more critical in cold box than in the heated pattern processes. They affect not only the ability to blow a dense core, but also the uniform permeation of catalyst gas throughout it. It is good practice to saturate the cope half of the pattern with vents on at least 2 in. centers.

Total open cross sectional open vent area in the cope side should be 0.25–0.40 in^2/lbs. of sand, including the blowing seat areas, if applicable. Total cross sectional open area of box exhaust vents should be approximately 50–80% of the total input vent area. The condition of less exhaust to input open vent area creates the back pressure necessary to force the catalyst gas through all sections of the core, resulting in a uniformly cured piece. To facilitate dispersion of the catalyst gas, vents need to be placed in low pockets, near sharp corners, and in critical areas so as to direct the gas toward those points. Exhaust vents never should be directly beneath input vents, but should be staggered to prevent short circuiting the gas through the sand and out of an opposite vent.

When vents are placed in a pattern where the thickness of the pattern less than 1 in. the vent channel, or the opening behind the vent leading into the plenum, can be slightly less than the diameter of the vent. If, however, box thickness is greater than 1 in., the vent channel should be at least 1/8 in. larger than the diameter of the vent. This practice reduces the tendency of the channel to plug and also simplifies cleaning.

In general, vents less than 1/4 in. in diameter are of minimal value and should be avoided. For best results, vents with 3/8 in. diameter or larger are preferred.

A very important aspect of core /mold quality is tooling cleanliness. Detailed cleanout procedures are essential. They should describe the equipment, and the method, sequence, and frequency of cleaning. Vents require constant attention. It is generally necessary to interrupt production and shut down the machine at regular intervals to clean the vents with a metal cleaner. That cleaner must be allowed to soak into the resin buildup and should not be blown off until the machine is about to be restarted.

Thorough cleaning and maintenance of the vents must take place during down shifts. Ideally, all vents should be cleaned nightly with a wire brush or vent cleaning blade (for the slotted vents), or they should be blasted with aggregate. Worn vents should be removed and replaced regularly.

Pins and Bushings – Corebox locating pins and bushings should be gauged weekly. Normally, 0.005 in. clearance between stripper pin and bushing is desirable. When that clearance reaches 0.010 in. sand will blow by the stripper pin, resulting in poor quality cores. Pins and bushings must be changed before that problem occurs.

Core Box Seals – Proper sealing of all parting surfaces is critical in the PUCB Process for reasons of productivity, ecology, and economics. Proper sealing helps achieve shorter cure time, low catalyst usage, minimal odor, and minimal downtime. Seals should be used between the gassing input plenum and the top of the cope half of the pattern, between the parting lines of the pattern, and between the exhaust plenum and the drag half of the pattern.

Seal compression strength must be low enough to prevent the cope separating from the drag during the purge and the blow operations, yet high enough to produce a positive seal while not being blown out by the gas pressure from the blow, gas and purge parts of the cycle. If box separation occurs after the blow, sand sticking or parting line fins may result.

Plenum seals are generally situated on the lower side of the input plenum and the upper side of the exhaust plenum. Corebox parting seals, generally, are in the lower half of the corebox in horizontally parted tooling. The dovetailed shape is more applicable to upper-half surface installations, but the square or round shape is better suited for locating in the lower half.

Fig. 14: Seals for the PUCB Process.

The compressive force for the seal used for the parting lines should be 2–5 lbs. per linear inch of the seal. The seals which go between the input and exhaust plenums can have a higher compression, but must be capable of being compressed by the mechanism that fastens the surfaces together.

Conclusion

Current Phenolic Urethane Cold Box Process Systems are the result of nearly 60 years of refinement based on innovative equipment developments, environmental necessities, and new foundry applications. Perhaps the most amazing aspect of this mature system is that it is still undergoing dramatic refinements.

This technology has become the overwhelming choice for high-production, precision sand casting operations. Predictable dimensions, automated handling and economical productivity inherent in the process have combined to make it the best-selling binder system worldwide. When castings are needed for heavy construction, high production automotive applications, specialty steel parts, or precision parts in iron, steel, brass/bronze or aluminum, a PUCB system can be and is used to make it.

References

Fig. 1 & 6: LAEMPE+REICH CORP.
Fig. 2: Klein Palmer Inc.
Fig. 3: OMCO Group
Fig. 4: Tinker Omega Manufacturing LLC
Fig. 5: Palmer Manufacturing & Supply Inc.
Fig. 7: Loramendi S.Coop.
Fig. 8: ASK owned picture
Fig. 9: TROMLEY INDUSTRIAL HOLDINGS INC.
Fig. 10: Dakota International Inc.
Fig. 11: Gaylord Foundry Equipment Inc.
Fig. 12: Van Air Systems Inc.
Fig. 13 & 14: ASK owned picture

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