

Improving Gas Conditioning in Electric Arc Furnaces

Bernie Forster
Lechler, Inc.
445 Kautz Rd
St. Charles, IL 60174
1-800-777-2926

Introduction

A steel producer trying to make a profit in today's often hostile environment has many concerns to deal with, including relationships with the EPA and the residents surrounding the plant facilities. If you operate electric arc furnaces, you know one of the main environmental issues relates to particulate emissions, and the regulations are only getting tighter.

This is nothing new, and the technology for combating these emissions has not changed much for many years. The two main weapons against particulates are bag houses and electrostatic precipitators. You can improve the performance of these devices while increasing the capacity of your overall production with the addition of a small but strategically placed gas conditioning system between the furnace and your particulate capture devices.

Discussion

A typical air handling system incorporates a hood over the furnace connected to a duct, which leads to the precipitator or bag house. An induced draft fan pulls the dust-laden gasses through the filter device and exhausts the gas out the stack. These systems have specific capacities in both the volume of gas and the amount of particulate they can process.

A spray gas conditioning system cools the gas very quickly by injecting finely atomized water into the gas stream as close to the source as possible, where it is the hottest. When the droplets meet the hot gas, they are flashed into steam with a complete evaporation of the water. This has several very beneficial results:

- The temperature of the gas falls off very quickly which can reduce the amount of water cooled ducting.
- The gas volume decreases with the temperature, so the velocity in the duct declines. This reduces the load on the induced draft fan.
- The humidity of the gas increases, boosting the efficiency of an electrostatic precipitator.
- The gas temperature reaching a bag house can now be lower, allowing the use of less expensive bags.

All of these are very helpful from an operational standpoint and have the potential to reduce costs and increase the amount of throughput for an existing system. The only thing a gas conditioning system will not do is reduce the volume of actual particulate material.

Designing and configuring a system

As mentioned before, an effective gas conditioning system uses spray nozzles to atomize water and inject it into the gas stream. The droplets absorb heat as their temperature increases until they evaporate completely. As the vapor superheats, it absorbs additional heat until the vapor temperature equals that of the gas.

Since the amount of heat required to evaporate a specific volume of water is easy to calculate, determining how much water to inject is not difficult. The key of system design is making sure all the liquid evaporates before it has an opportunity to hit a wall or bottom and wet the surface. A wet surface provides an excellent point for dust to collect and robs the system of cooling capacity.

A system should not overcool the gas either. If the temperature goes down too far, acid gasses can condense corroding the ducts and equipment. There has to be a critical balance which the system can maintain using a carefully monitored feedback loop to control the spray.

Achieving these critical results requires two important skills: The ability to create droplets small enough to evaporate before they hit a surface combined with trajectory modeling that determines the directions the droplets will travel. From these calculations, the system designer then chooses the nozzle capable of producing a small enough droplet and determines how they should be positioned in the tower or duct. The liquid will not evaporate effectively if it is not mixed sufficiently in the gas stream to avoid hot and cold areas.

Since the gas temperature and volume changes drastically during a melting cycle, an effective system has to be able to respond to these fluctuations in a way that will stabilize the outlet temperature and keep it steady regardless of what is going on in the furnace. This depends on a well-integrated package of nozzles, pumps and control equipment combined with careful design and tuning to ensure flawless performance across a wide range of operating conditions.

Nozzle selection

Most gas conditioning systems use hydraulic nozzles featuring an internal mechanism that allows a portion of the flow to bypass the orifice or a twin fluid atomizer that uses compressed air to break up the liquid. Each approach has its own advantages related to the turn down ratio, droplet size and energy consumption.

When a system is being initially evaluated, a hydraulic system is usually the preferred method due to its lower operating cost over an air atomizing system. For hydraulic nozzles, pressures in the 200-500 psi range are typically required to generate droplets small enough to attain complete evaporation. Standard hydraulic nozzles' droplet sizes increase when the liquid pressure is decreased to cut back on the water flow. As a result, specially designed hydraulic nozzles are used because they produce constant droplet sizes over a wide range of flow rates, which this application needs.

The degree of fineness needed for a droplet depends on several factors. These can include: a short distance available for the droplet to evaporate or a large amount of cooling needed in a small amount of space. When the droplet size required is extremely small and beyond the realm of a hydraulic nozzle, the air atomizing nozzle becomes the better choice. See **Figure 1**, which shows the comparison between droplet size capabilities of hydraulic and air atomizing nozzles.

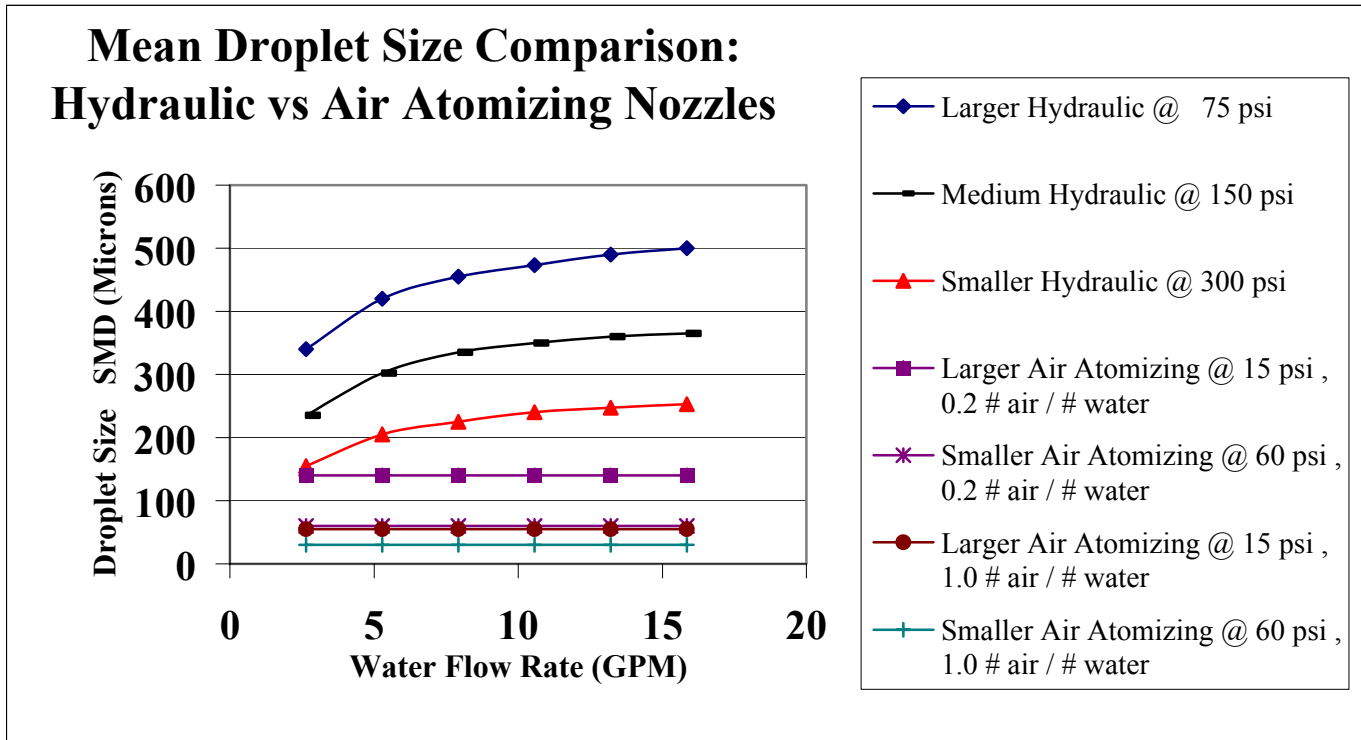


Figure 1. Mean droplet size comparison for various size nozzles at different operating conditions.

An air atomizing nozzle's droplet size is dependent upon the mass ratio of air to water and upon the air pressure. As the process conditions change and the volume of water is changed, it is a good idea to adjust the air flow as well. This will result in a more efficient use of compressed air, thus saving the capital cost of an oversized compressor and operating cost of wasted compressed air.

Like the special hydraulic nozzles, they also have the capability of holding a constant droplet size over a wide range of flow rates. A 10:1 turn down ratio (or larger) is easily accomplished with this nozzle design. Air atomizing nozzles can atomize larger volumes of water to a finer droplet size than hydraulic nozzles, which some systems may demand.

Air atomizing nozzles also boast free passage diameters that are substantially larger than hydraulic nozzles. Large free passages make the nozzle more clog resistant, which is critical to its performance. A nozzle that becomes plugged will not provide the cooling capacity needed, and may also create a disturbed spray pattern, which can mean bigger droplets. In either event, the process is negatively affected. Larger free passages also allow the use of 'dirtier' water because the nozzles aren't as sensitive to impurities. See **Figure 2** for an illustration of how the free passages compare between both styles of nozzles.

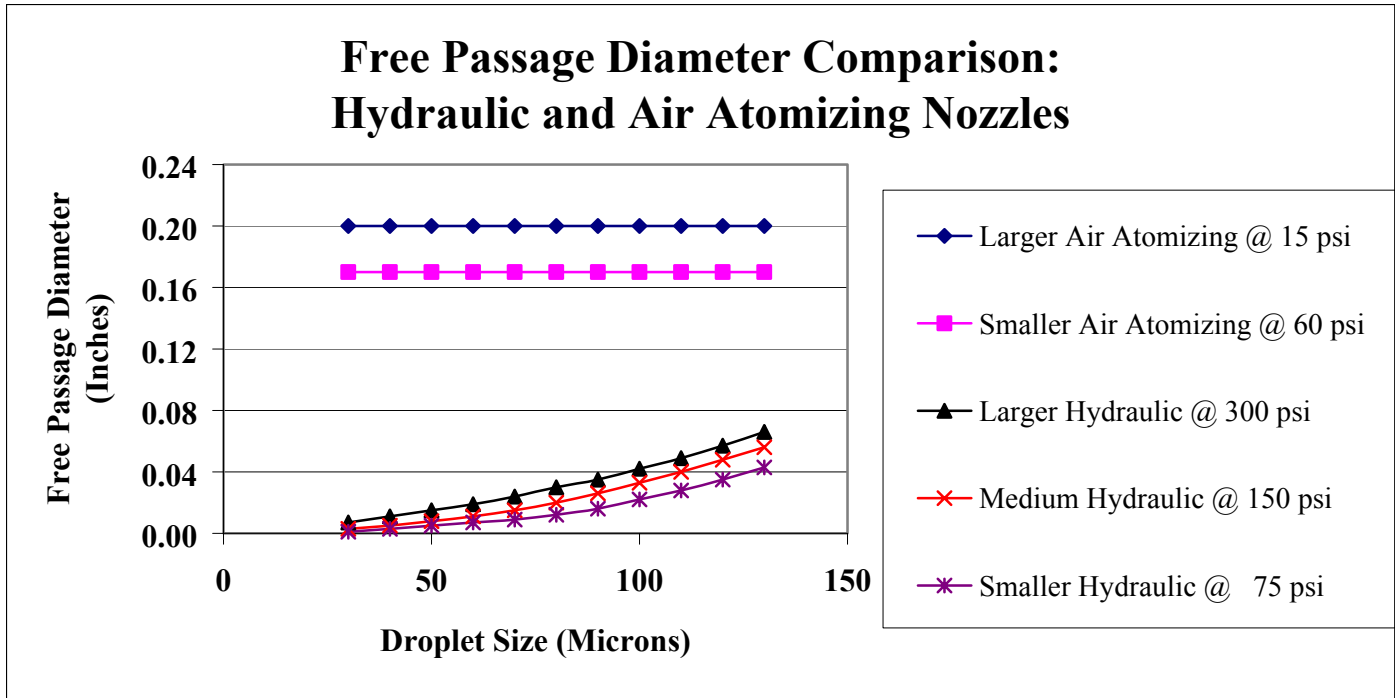


Figure 2. Free passage diameter comparison for various size nozzles.

Distribution is important

Assuring uniform gas flow in the duct or vessel across its cross-section is a critical key factor to successful evaporative gas cooling. Without this, spray cooling can be very problematic. Turbulence tends to sweep the droplets onto the walls and may also produce areas that are hotter than others. If this were the case, then the degree of cooling would be uneven and result in excessively long or incomplete evaporation due to zonal saturation. Upstream diffuser plates can be effective in providing gas flow distribution uniformity.

Further, a uniform distribution of droplets across the section of the duct or vessel is extremely important to achieve proper gas cooling to avoid these similar temperature differentials. Droplet trajectory calculations, cold flow modeling, and computational fluid dynamics (CFD) modeling can be useful tools in assuring that a nozzle array will provide this uniform distribution.

Successful nozzle operation

To assure successful and reliable nozzle operation, several factors need consideration.

First, complete evaporation needs to occur in the straight portion of the duct before any downstream elbows, turns, straightening vanes, or internal structural members. Because of their momentum, droplets will tend to impact on these surfaces rather than follow the changing gas flow direction. Spray orientation is normally co-current with the gas flow, and all nozzles in one cross section. This avoids spray droplets impinging on the nozzle or adjacent nozzles.

To prevent the nozzle from overheating, all nozzles (either hydraulic or air atomizing) need to have air flowing through them if the water flow is shut off. Use of barrier air (low pressure / low flow air that surrounds the nozzle tip) is often used to help cool the nozzles, and can also prevent potential buildup of dust on the outer surfaces of the nozzle. Excessive buildup near the leaving edge of the nozzle orifice can disrupt proper droplet generation, which can lead to downstream wetting.

If the process gas flow rate varies rapidly, an effective control package is a critical component in achieving maximum performance from a spray nozzle system. A feed-forward control scheme can allow for this maximum performance. Feed-forward control is a system that will calculate how much water will be needed at a certain capacity, and use that volume as the starting point for cooling the gas. The normal feedback control loop would then be coupled with the feed-forward control loop to optimize the process. Cascade loop tuning is also useful for smooth transitions from startup to normal operation. It is important to be sure that the gas dew point is not reached at any point in the gas flow. Hot flue gas in contact with a cold duct wall can lead to condensation and subsequent scale buildup from dust plating out on the walls. For this reason, an effective control system needs to be designed to keep the process out of these potentially dangerous situations.

Nozzle wear will result in a decay of a good droplet size spectrum. Typically, a visible streak in the spray pattern is evidence of excessive wear. These streaks tend to have larger droplets, which may not evaporate quickly enough resulting in downstream wetting. Wear resistant materials are available to help solve this problem. Nozzles made out of these materials have a longer service life, which means less maintenance, and fewer performance problems. **Figure 3** shows a comparison between relative wear resistances of various materials. Hastelloy offers improved chemical resistance that may improve wear life since corrosion of the surfaces can result in an accelerated erosive rate. Silicon carbide is the most wear resistant, but is fragile. If the liquid being sprayed is relatively free of erosive particles, alloy nozzles are preferred.

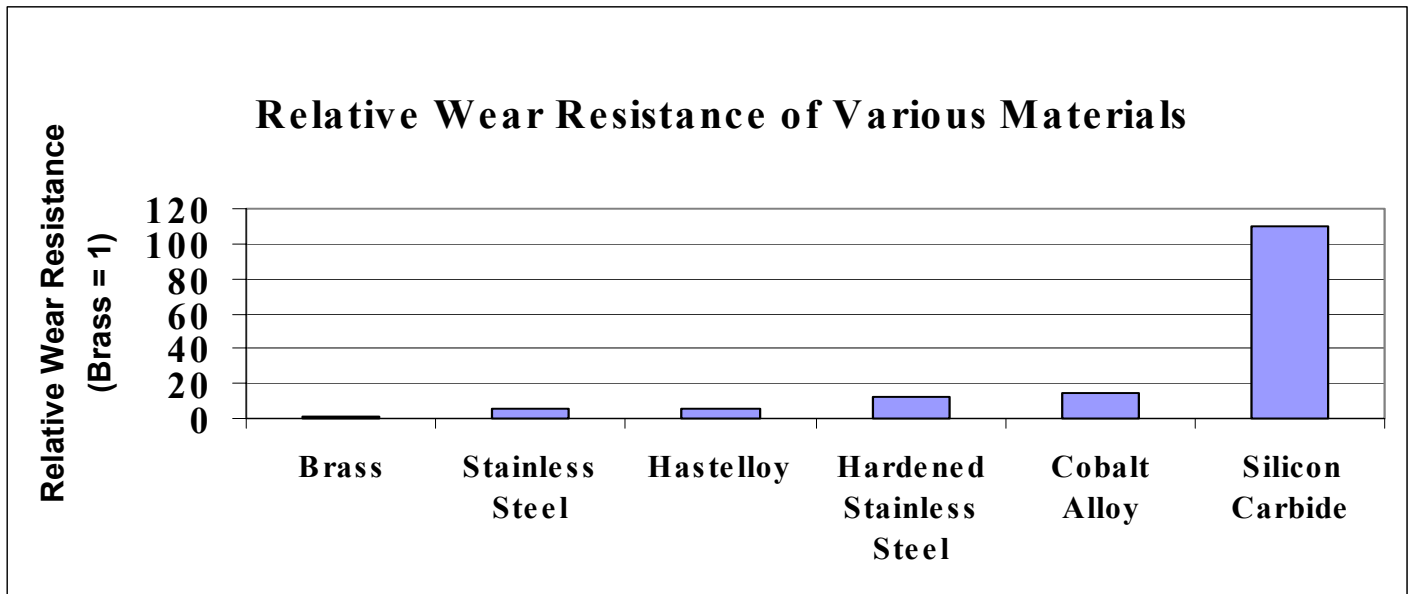


Figure 3. Relative wear resistance of various materials.

The significant factors that contribute to successful evaporative spray gas cooling therefore include:

- Spray droplet size
- Vessel or duct dimensions
- Evaporation time
- Capital costs
- Operating costs
- Energy consumption
- Uniformity of inlet gas distribution
- Uniformity of droplet distribution
- Nozzle clogging potential
- Corrosion resistance
- Erosion resistance

In conclusion, evaporative spray cooling of gases from EAFs has many key benefits that make it an invaluable part of your process. Existing air pollution equipment can handle higher plant capacities because spray cooling reduces gas volumes. A reduced gas volume also saves energy by decreasing the horsepower needed for induced draft fans. Spray cooling also reduces the need for water-cooled duct systems, which are a less efficient mode of heat transfer.

Finally, it can be an effective tool to improve the performance of air pollution equipment. Savings can be seen with the use of lower cost bags in the baghouses, and enhanced ESP performance through humidification.

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References

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