New Innovations of Sulphur Guns

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This paper will review the use of pressure atomized sulphur nozzles in the sulfuric acid industry and examine the benefits available with a newly designed sulphur gun. This review will include a brief history of pressure atomized sulphur guns and the operating and maintenance problems associated with these guns. A detailed examination of the newly designed gun will demonstrate how the new design eliminates many of the problems of previous designs. The initial plant performance indicates that the new design is successful providing excellent performance, which the paper will review.

History

The pressure atomized sulphur gun, or spray burner, was first introduced in 1927 by Chemical Construction Corporation (Chemico) which greatly simplified the sulfuric acid process by eliminating the need to burn solid sulphur. Pressure atomized burners have dominated the industry for over 50 years because of their low capital cost, low operating cost and ease of operation. Problems occurred with the burners, but they were manageable and the performance was acceptable. History shows that the guns would plug causing plant shutdowns, the burners had relatively poor sulphur atomization, the guns had limited turn down capabilities, and sometimes were the cause of mishaps.

The patented Chemico gun included a replaceable orifice burner tip, spiral, and clean-out rod. The clean-out rod or poke rod permitted the operator to clear the nozzle periodically with the plant on-line. The gun was completely steam jacketed to prevent the sulphur in the section outside the burner from freezing and to cool the gun parts inside the burner, otherwise, the temperature of the gun could cause sulphur to become viscous. Maintaining the sulphur temperature as low as possible in the gun also prevents the excess formation of tarry or solid carbonaceous compounds that might plug the tip.

The clean-out rod ran the entire length of the sulphur gun. One end was a handle for the operator to poke the pointed tip located on the other end of the rod through the orifice of the burner tip. The pointed end of the clean-out rod would remove the tarry or other deposits from the orifice. The rod went through a stuffing box that was often subject to either leaking or freezing in place. While the clean-out rod was a unique feature, it also became a major problem causing frequent gun replacements.

The predominant spray burner being used by the industry today is essentially a steam jacketed pipe with a commercially available spray nozzle screwed on the end. The steam jacketed section consists of two separate sections. The first section heats the sulphur while it's outside the furnace and the second section inside the furnace cools the sulphur and the gun components. The sulphur nozzle sticks out into the furnace on the end of a 3/4" pipe with no steam cooling whatsoever. This design overcomes many of the maintenance problems associated with the Chemico gun because of its simplicity of design having no stuffing box to maintain. A problem associated with this gun is that once the gun is shut off the sulphur remaining in the gun overheats, which leads to the formation of deposits plugging the gun. The flow of sulphur through the nozzle is the only cooling the nozzle receives. Once the flow stops, the sulphur remaining in the spray nozzle will overheat. The equipment supplier recommends that the remaining sulphur be purged from the gun with compressed air. Many plants do not follow this procedure, which leads to problems. If the gun cannot be turned off and on without causing plugged guns, then the only way to reduce the plant rate is to throttle sulphur, which in turn decreases the effective atomization of the nozzle.

The uncooled sulphur nozzle has caused a number of unfortunate incidents in the sulfuric industry. Nozzle caps have blown off nozzles from time to time causing an excessive amount of sulphur to pour into the furnace. If the operator can quickly react or if the plant is sufficiently instrumentated, the affects of sulphur sublimation can be minimized. If not, condensing sulphur will deposit on the colder downstream equipment, such as the mist eliminators of the intermediate absorption tower. As the sulphur vapor cools, solid deposits form as the sulphur condenses on cold equipment surfaces. The plant usually must shut down to remove the sulphur causing many days of downtime and lost power generation revenues.

In both of these designs low pressure steam cools the portion of the gun that protrudes into the furnace. This steam jacket surrounds the high pressure sulphur feedline with cooling steam. Inside the feedline the sulphur pressure is much greater than the steam pressure with a normal operating pressure range of 75 psig to 175 psig and it can be as high as 250 psig. There have been a high number of reported incidents where the induction of wet steam into the cooling jacket has caused erosion damage to the sulphur feedpipe. Once the feedpipe begins to leak sulphur, the sulphur flow will continue to flow with the cooling steam until the sulphur cools enough to freeze. All down stream equipment becomes contaminated with sulphur, which may have devastating results. Sulphur can contaminate steam systems, condensate systems, cause personnel injury from sulphur splashes, and can even cause the gun to self destruct.

Either of the nozzles had good atomization causing unburnt sulphur to exit the intended combustion zone. Many sulphur furnace designs include flow obstructions, such as brick arches, baffles, or checkered walls, to try to capture the sulphur droplets to prevent them from entering the down stream waste heat boiler. Once the captured droplet stops, the sulphur burns off the brick. Often the quantity of unburnt sulphur is so large that sulphur would pool on the bottom of the furnace causing the deterioration of the furnace brick. The gas stream entrains the brick particles caused by the deterioration of the refractory, which can lead to fouling of the boiler and the catalyst. The problems caused by poor atomization are slow to develop and routine inspections may totally overlook the signs of deterioration, but the long term results reduce refractory life, reduce heat transfer, and increase catalyst fouling.

The boiler fouling tendencies of the old design sulphur nozzle became apparent when some plants were built with water tube boilers. With a water tube boiler the hot process gas from the furnace is on the outside of the boiler tube. The heat transfer coefficient on the gas side is normally lower with a water tube boiler than with a fire tube boiler. Fouling on the gas side will become more apparent than the same amount of fouling on the tube side of a fire tube boiler because of the lower initial heat transfer coefficient. There were three plants built in the phosphate industry with water tube boilers and two out of the three have experienced fireside fouling of their boilers. The one plant that did not experience a decline in boiler performance uses a Riano Super Nozzle, which provides anecdotal evidence that sulphur atomization is connected with fireside fouling. The differences between the plants and their performance have not been thoroughly investigated but poor sulphur atomization may explain why one plant doesn't have boiler fouling. Unburnt sulphur, dirt, brick particles, and sulfate carry-over from the drying tower could be the cause of this fouling. The sulphur will burn in the boiler combining with the other particulate to form an insulating barrier in the tubes.

One reason why poor atomization can go undetected is because many plants do not monitor the day to day changes of their sulphur guns. Maintenance priority placed on the clarity of furnace sight glasses is very low at some plants. Without the ability to view the flame pattern, operators could not evaluate the atomization efficiency. They can't see the sulphur burning off the floor or view the clarity of the furnace gases, which indicates good gun performance.

Building the Better Nozzle

For the past 40 years Marcos D. Riano (co-author) has been associated with the phosphate industry holding many positions in the operation and maintenance of sulfuric acid and phosphoric acid plants. Over the years Marcos developed a special interest in sulphur and sulphur handling equipment. After finding that many plants were operating with similar furnace problems, Marcos committed himself to build a better sulphur nozzle. In the early months of 1977, Mr. Riano built a prototype nozzle that showed remarkable nozzle performance. These results were so very encouraging that Marcos went to the expense to apply for a patent, which was granted in early 1979 (U. S. Patent Number 4,154,399).

Commercial Development

When Mr. Riano received the patent he was working for Occidental Chemical with the operation of two newly commissioned Monsanto 2000 STPD sulfuric acid plants. After demonstrating his nozzle to management, Oxy agreed to develop the nozzle at their expense and for the right to use the nozzle royalty free.

Oxy ran side by side tests using the prototype Super Nozzle and the Spraying Systems nozzle originally supplied with the plant. The test showed that the Super Nozzle produced a finer spray than the Spraying Systems nozzle at the same supply pressure. Further testing provided pressure drop versus flow data, which served as a basis for the first commercial nozzle. Process calculations determined the hydraulic performance of the prototype nozzle, which established the size of the internal flow ports and the nozzle tip of the commercial nozzles.

The existing 3" diameter sulphur gun was modified by expanding the nozzle end of the barrel to a 5" diameter forming a steam cooled enclosure for the nozzle. The 5" diameter section created a steam jacket that provided adequate steam flow area to get cooling steam to the end of the gun. The nozzle body, surrounded by a steam jacketed pipe on three sides, was threaded to the feedpipe, which allowed for the nozzle removal.

The performance of the nozzle was excellent. Sulphur that had been pooling on the furnace floor stopped and the furnace gases were clearer. With the improved cooling of the nozzle, the sulphur gun can be shut off in the hot furnace and relit when needed. The improved cooling of the nozzle eliminated the problem of guns plugging caused by the sulphur in the nozzle "cooking".

The sulphur furnace has five guns which are all required for 100% production with the original nozzles. With the new nozzle three sulphur guns could meet the sulphur requirements of 100% of the plant capacity leaving two sulphur guns as installed spares. The two "extra" guns had smaller sized nozzle tips installed in them for reduced production. By mixing the combinations of the guns, most production rates were possible with only a minimum amount of sulphur throttling, which minimizes the pressure lost across a control valve, in this way, sulphur feed pressure is available for atomization. Reducing the pressure to a pressure atomized nozzle causes the atomization efficiency to drop off quickly. Using different size orifices in the spare guns allows plant turn down control without sacrificing atomization efficiency. The plant can successfully operate in the range from 2200 to 400 STPD.

Original Applications

Once the nozzle proved successful in a large sulfuric acid plant, Marcos introduced the nozzle to the industry. Since its initial commercial availability over twelve sulfuric acid producers have installed the Super Nozzle producing over 40 million tons of sulfuric acid. When the Riano Super Nozzle was first introduced to the market, the nozzle was sold separately, which left the customer to modify their existing sulphur gun to accept the Super Nozzle. The different users applied the nozzle in many different ways, modifying their existing sulphur guns.

The majority of the guns use a 3" diameter gun barrel in which the Riano nozzle easily fits into, greatly improving the cooling of the nozzle versus the previous design that had no steam cooling. The performance was much better than the previous guns, but the steam path arrangement did not allow for good steam circulation to the entire nozzle body.

Design Refinement

After many years of successful operation the nozzle and the 3" diameter gun design went through an extensive engineering review. The results of this review served as the basis for a newly designed nozzle and gun assembly. The new Riano designed gun enhances the inherent superiority of the Riano Super Nozzle and improves the reliability of the sulphur gun assembly. The demonstration set of Riano sulphur guns went into operation in October 1990 and have performed extremely well. Riano Equipment Company began to offer the complete sulphur gun assembly designed around the Riano Super nozzle in early 1991.

The major features of the new design are:

- Improved steam cooling of the Riano Super Nozzle
- Eliminated the threaded connection between the feedpipe and the nozzle
- Redesigned nozzle to reduce regions of potential high stress
- Easier inspection and maintenance of the sulphur feedpipe and nozzle
- Added protection to the high pressure sulphur feedline

The components exposed to the furnace conditions use 309 stainless steel, which includes the outer gun barrel, made of 4" schedule 40 pipe, and the nozzle. Using 4" pipe allows for a sufficient cross sectional area for the steam to circulate enveloping the nozzle body, which greatly improves the cooling of the nozzle.

The new design eliminates the threaded connection at the nozzle body and feedpipe by fabricating a reducer that is butt welded to the redesigned nozzle body and feedpipe. The length of the nozzle body is shorter due to the elimination of the threaded connection, which also improves the cooling of the body.

The improved nozzle reduces the number of points of potential high stress created by square cuts and replaces them with radius cuts or eliminates them altogether. The new design reduces stress generated at the nozzle body and the gun barrel weld by changing the welding configuration and revising the expansion joint design specification.

The high pressure sulphur feedpipe, constructed of 304 stainless steel, can experience wear due to steam erosion at the cooling steam inlet connection. This important component of the gun assembly is often forgotten, and with some designs cost more to inspect than the cost of replacing the entire gun. The new design protects the feedpipe by shielding it with an erosion plate that is sacrificial. In addition, the new design allows for the removal of the feedpipe and welded nozzle body for maintenance with two cuts. To remove the feedpipe, the weld at the sulphur inlet flange is cut separating the feedpipe from the inlet flange. Then the outer gun barrel is cut at the nozzle end that allows the nozzle body, a piece of the outer gun barrel, and the feedpipe to be withdrawn from the gun in one piece. The feedpipe near the steam inlet connection can then be inspected for steam erosion damage.

Operational History

The first set of Riano sulphur guns was installed in a 1800 STPD Monsanto designed sulfuric acid plant in October 1990. Plant personnel have repeatedly reported that the gun assemblies are performing extremely well. After 18 months of operation the nozzles have the same apparent atomization performance as they did on the first day. The only reported problem occurred when one gun became plugged with debris, which was suspected to be a piece of Claus plant catalyst. To evaluate the new design, the plugged gun will be dissected to determine if the gun assembly shows any signs of wear, stress, or corrosion. The guns are performing so well that the examination of this gun has been receiving a low priority and has not been internally inspected yet.

Two new installations have recently been commissioned using the new Riano guns and both locations are reporting very satisfactory results. One of the plants selected the Riano gun because the plant required a 5 to 1 turn down ratio. This is no problem for the Riano gun because a gun can be turned off and on without plugging due to its superior design that keeps the nozzle cool. Selecting the number of guns required allows the plant to run at reduced rates without sacrificing the nozzle atomization efficiency with little need to throttle sulphur. The second location, in Central Florida, decided to use the Riano gun with a major revamp and expansion being made to their existing sulfuric acid plants. The existing sulphur nozzles would not be adequate for the new production rate. The Riano guns were selected because the nozzles could delivery the desired throughput at the current available sulphur pressure without sulphur feed pump modifications. The guns are performing very well without any problems since March.

Conclusions

Many plants live with the associated problems of poor sulphur atomization and don't realize it. If your sulphur furnace operates with sulphur burning off the brick, this usually indicates poor atomization. A thorough inspection of the sulphur furnace, boiler bypass damper and waste heat boiler may reveal other tell tale signs of poor atomization. The Riano Super Nozzle, which has been in commercial service for the last 12 years, has been proven to improve sulphur atomization. Now this proven nozzle is available with a sulphur gun assembly to provide reliability and safer operation than previous designs.

If you are experiencing unexplained plugged sulphur guns or if the guns require replacement in between turnaround cycles the superior design of Riano sulphur guns may help improve your plant operation and reliability. The continued acceptance of the new gun design is a testimonial of the superior design and plant performance available with the Riano gun.

References Cited

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The Latest Improvement in Sulfur Spray Nozzles, Marcos D. Riano, 1982 AIChE Clearwater Convention