# The Evolution of the Rapid Service Sulphur Gun

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This paper will review the use of pressure atomized sulphur nozzles in the sulphuric acid industry and examine the benefits available with a newly designed sulphur gun. Our premise is, that no sulphuric acid plant of any capacity can run at its best if it lacks the proper means of delivering the sulphur to the furnace. We firmly believe that good sulphuric plant operation must begin right where the process starts, in the furnace.

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.

## History

The pressure atomized sulphur gun, or spray burner, was first introduced in 1927 by Chemical Construction Corporation (Chemico) which greatly simplified the sulphuric 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.

The predominant spray burner used by the industry for many years was essentially a steam jacketed pipe with a commercially available spray nozzle screwed on the end. The

sulphur nozzle sticks out into the furnace on the end of a 3/4" pipe with no steam cooling whatsoever. 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.

Improperly cooled sulphur nozzles have caused a number of unfortunate incidents in the sulphuric 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 instrumented, 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. 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 number of reported incidents where the sulphur has gotten into the cooling steam chamber. Down stream equipment becomes contaminated with sulphur, which may have devastating results.

Neither 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.

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.

## Building the Better Sulphur Gun

For the past 40 years Marcos D. Riaño (co-author) has been associated with the phosphate industry holding many positions in the operation and maintenance of sulphuric 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. Riaño built a prototype nozzle that showed remarkable nozzle performance. These results were so 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

The first "trial test" was performed at a Monsanto 2,000 STD design $H_2SO_4$ plant, originally fitted with five sulphur guns fitted with Spraying Systems Whirljet Nozzles, Model 1/2" BA45 with a 3/8" orifice. Sulphur pooling has occurred in the furnace since the start up of this plant. New plants are up and down several times during the few days following the initial start up, but the sulphur pooling in the furnace bottom was always present and became "normal" plant condition. A proposal was made to management to use Marcos' new nozzle to solve the problems of the furnace. After some discussions with upper management the proposal was accepted to modify the existing sulphur gun to try this nozzle.

In October 1980, the decisive moment arrived. The five conventional, originally installed sulphur guns were replaced by not five, but only three of the adapted new nozzles. Sulphur was successfully fired and the plant was smoothly started and came up to full capacity.

The performance of the nozzle was excellent. Within a few hours, sulphur that had been pooling on the furnace floor stopped and the furnace gases were clear. 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 "cooking" in the nozzle during shutdowns.

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. 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 sulphuric acid plant, Marcos introduced the nozzle to the industry. When the Riaño 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 Riaño 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.

At the 1982 AIChE Convention Mr. Riaño presented a paper, entitled, "The Latest Improvement in Sulphur Spray Nozzles" and described a new style of sulphur pressure atomizing nozzle for the production of sulphuric acid, which at that time, had only been in

service for 2 years. That was not enough operating time to properly evaluate a brand new piece of equipment to any extent necessary. Many of the vast chain of benefits associated with its operation can only be evaluated over a long term. Now, after fourteen years of service the benefits we count as extraordinary are its output, atomization, long lasting life, and reduced maintenance.

## Design Refinement

Obviously, at the beginning, the device was not near as efficient or refined as it is today. We definitely have come a long way! However, its performance always was, at any time since the initial installation, far superior than any other nozzles designed for the same function and, now, more than ever before!

Despite the impressive performance of the original nozzle during the first few years, we continued to add engineering improvements to the device and by the end of its first decade, we had accomplished another major goal. A set of four improved "Super Nozzles" were assembled with sulphur guns built around its features and put into operation at a chemical complex in Louisiana in October 1990. The results were positively beyond expectation! Now, after 5 1/2 consecutive years of operation, we were informed that one of the "trial" nozzles is still in service.

The major features of the new design are:

- Improved steam cooling of the Riaño Super Nozzle
- Eliminated the threaded connection between the feedpipe and the nozzle
- Redesigned the 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 to minimize the possibility of sulphur entering the steam chamber

## The Continuing Evolution to Build the Best Sulphur Gun

Today's sulphur guns have much better protection because of the improvements of materials, fabrication, and the steam cooling system. The guns can withstand the furnace's high temperature, suffering no considerable damage in most cases even during a lengthy plant shut down. Nevertheless, the improvements gathered in modern sulphur guns have also brought along an increase in weight which considerably worsen the handling of this equipment, especially when hot. They still have to be removed when the situation arises usually under very undesirable circumstances and normally in a hurry. Because of the nature of this kind of job, occurrences are almost always classified as an emergency and could very well be translated as dangerous. In other words, the equipment life expectancy has greatly been improved, but the personnel bitterness and "safety risks" involved in the sulphur gun's replacement job has worsen.

We are continually listening to our customers and other acid producers to understand their needs and operating problems. Normally, when a sulphur gun must be removed from service it is due to a problem with the nozzle. A tip failure or simple pluggage requires a plant shutdown and removal of a heavy and very hot gun. The main concerns we heard from producers were:

1. The nozzle should be designed not to plug
2. The gun should be easier to handle

Many long hard hours has gone into the development of a "special sulphur gun" that would eliminate or minimize the possibility of pluggages, simplify the maintenance task for gun removal, and improve the overall safety of the task. This "special sulphur gun" has been designed, patented (U.S. Patent No. 5,467,925), and tested. Now, at the end of over six decades, a sulphur gun has been developed that has solved all of the past problems. The "Riaño Sulphur Gun Assembly With Rapid Service Capability" is composed of two separate parts, the Casing and the Insert. The Casing is designed to be permanently installed in the sulphur furnace gun ports and should operate many, many years without needing any maintenance. The Insert consists of the sulphur feedpipe and the Riaño nozzle which only weighs approximately 18 pounds.

Casing The casing is the outer part that projects into the furnace and supports the sulphur feedline. It is composed of two concentric pipes (3" & 4") and connected together by a 4" pipe cap at the casing tip inside the furnace and to the sulphur feedline flange. The space in between the 3" and 4" pipes forms the cooling steam chamber, which protect the whole

assembly, the internal sulphur line, and the attached nozzle. Two rods are attached to the outside diameter of the 3" pipe at the 3 o'clock and the 9 o'clock position. These rods run down the length of the 3" pipe and wrap 360° around. The diameter of the rod is such that when the 4" pipe is placed over the 3" pipe it forms a tight fit. This forms two flow paths for the cooling steam. One path for the cooler steam to travel to the end of the gun and the other for the steam to travel back.

Insert The Riaño nozzle is attached to one end of a 1" 304 stainless pipe. At the other end is the sulphur inlet flange. A locking nut, sealing flange, and a threaded area form the connection between the casing and the insert. The nozzle is supported in a bushing on the inside diameter of the 3" pipe.

The Rapid Service Sulphur Gun was designed, built, and put into service at Occidental's Swift Creek Chemical Complex (now PCS - White Springs Corporation) in one of their Monsanto 2,000 STPD $H_2SO_4$ plants on a trial basis. The gun was installed on 11/14/95 as a complete assembly. (A drawing of the prototype gun assembly installed at Oxy is included on the last page of this paper.) We had Occidental's permission to visually check and monitor the performance of the equipment. We checked it 2 to 3 times per week, 20 to 30 minutes each time from November 14, 1995 through March 13, 1996. At no time was the performance found different from the first day to the last day in operation. In February 8, 1996, almost 3 months into the trial test, the plant went down for a repair day and the Insert (the sulphur line

with the nozzle) was pulled out for two purposes:

1. To inspect the nozzle
2. To test the "Rapid Service Capability".

The Insert was replaced by 2 men in 26 minutes and the nozzle was in excellent condition!

As part of our close monitoring we maintained on the equipment, we asked production and maintenance to pull the whole assembly out for inspection at their earliest convenience during one of the routine repair down days, which they agreed. On March 13, 1996, a cold morning, the plant went down for a repair day and the whole assembly was removed and laid down on the furnace platform. At first glance, a hair crack no longer than 1½" was observed on the gun casing tip at the weld of the 4" pipe cap to the 3" pipe. As the dripping sulphur from the gun caught fire on several spots of the furnace platform, water was used to put them out. Some water was splashed over the assembly tip, which was still dripping burning sulphur. The water hose was momentarily directed over the assembly, evidently accelerating the metal contraction, causing the hair crack to grow lengthwise to almost cover the entire circumference of the 3" pipe. We decided to determine the exact reason for the failed weld.

Two days later (March 15) we personally took the complete assembly to the fabricating shop and had a meeting with the general manager and the shop foreman, who personally performed the welding. We put the assembly on the lathe and cut the pipe cap off the 4" pipe and carefully examined the affected area around the circumference. The finding was an extremely weak weld and insufficient weld penetration. The sudden temperature difference

from 2,000 °F to the outside ambient temperature of approximately 45°F that morning and the dousing of the water caused thermal stresses which lead to the weld failure.

Although we regret that the test wasn't 100% perfect, this undesired incident caused us to conclude that it couldn't have happened at a better time. The incident didn't cause any serious inconveniences to either the operation or maintenance of the plant plus the facts that we learned will accelerate engineering refinement of the gun's design. The conditions that caused the high stress combined with a less than perfect weld would have happened some time sooner or later. If future guns were assembled with less than adequate welding techniques and caused plant problems it may be more difficult to resolve. We decided to eradicate the stresses to make the gun less susceptible to common welding problems with the addition of an expansion joint. With this change the casing will handle the stresses that might be generated, either while operating or out of the furnace. In concluding our study, we proudly reassure that the device "stood the test" for four consecutive months (being as defective as it was), and would have performed for an indefinitely longer period of time in the absence of the evident human error.

Fortunately, although we had no reason for doubting the usefulness of this extraordinary piece of equipment for the Sulphuric industry, we warned Oxy about the unexpected. That is, with any brand new equipment there is the possibility of some kind of failure because of the uncertainty commonly involved in the typical "break in" period.

The test period demonstrated the capabilities of the gun assembly design by:

1. The nozzle can be protected even though it's not directly in contact with the cooling steam
2. The light weight nozzle assembly can be easily replaced in ½ hour
3. Absolutely prevents the possibility of sulphur intrusion into the steam system
4. The future expansion joint never can experience overpressurization

The testing program demonstrated that we could quickly remove a plugged sulphur nozzle. The Riaño nozzle, like most nozzle, will plug if a stone, aggregate, or catalyst pellets enters the nozzle until now.

While the tests were successful we did not stop our development program. We have recently water tested a new nozzle which has equal or better atomization than the original design, but a ¼" diameter stone will not appreciably affect its capacity or performance. With the original nozzle, an internal sulphur flow path was the most restrictive area of the nozzle. Debris could become lodged drastically reducing the capacity and performance. The design modification now places the most restrictive area in a place where debris does not restrict the flow and can be removed from the feed pipe. While the modification makes the nozzle more restrictive it actually increases the available flow area by over 300%.

## Benefits of the Riaño Rapid Service Capability Sulphur Gun Assembly

The primary object of this new development is to provide a sulphur gun assembly to the Sulphuric Acid industry which may be serviced safely and easily by greatly reducing the

removal and installation time as well as the weight, while significantly improving the economics involved.

Personnel safety precaution is not a matter of option, but of utmost importance for this difficult job. By reducing the weight to be handled to approximately eighteen (18) pounds, it provides the handlers a sense of self-confidence and safety about what they are doing. The task required 3 men plus 1 safety monitor and now is easily done with only 1 man plus 1 safety monitor. They feel now positively sure of "being in command", instead of the negative idea of "being the target of eminent danger". As a result, now the same task may be accomplished in 1/3 of the time, safer, and easier. No more handling of a hot, heavy sulphur gun.

The Rapid Service Capability assembly reduces the manhours required to remove and install a sulphur nozzle. This can reduce plant downtime and free up the availability of plant maintenance personnel. Reducing plant downtime improves the economics.

For an example, let's assume that a regular sulphur gun replacement job in a 2,000 T/D $H_2SO_4$ plant takes 1 1/2 hr. The Rapid Service gun replacement takes a ½ hour. The difference in this particular plant alone, is the equivalent of 83 tons of acid production. If the sulphuric acid plants were running at maximum production this loss represents the need for outside purchases of acid or the loss of phosphoric acid production. Assuming fifty dollars ($50) per ton of sulphuric acid would equate to a forty-two hundred dollars ($4,200) savings. In addition, the downtime causes a shortfall of steam production and a reduction of power generation. The shortfall in steam production may cause loss of phosphoric acid production or cause fuel oil or natural gas to be consumed. The drop of power generation causes the

purchase of power which could amount to approximately one thousand dollars ($1,000) for each emergency shutdown to replace a sulphur gun. With this example the Rapid Service gun saves over five thousand dollar for one outage. When these savings are applied to your plant specifics we believe you will find this new design deserves further consideration.

## Conclusion

Now, at the end of over six decades, a sulphur gun has been developed that has solved all of the problems.

The benefits of the Rapid Service Capability Gun assembly are:

- is not prone to pluggage from debris
- is not prone to pluggage caused by cooked sulphur
- cannot contaminate the steam system
- nozzle maintenance cost is reduced
- risk exposure to maintenance personnel is reduced

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

## References Cited

Freeport Sulphur Handbook, Freeport Sulphur Company, pg. 126

The Latest Improvement in Sulphur Spray Nozzles, Marcos D. Riaño, 1982 AIChE Clearwater Convention

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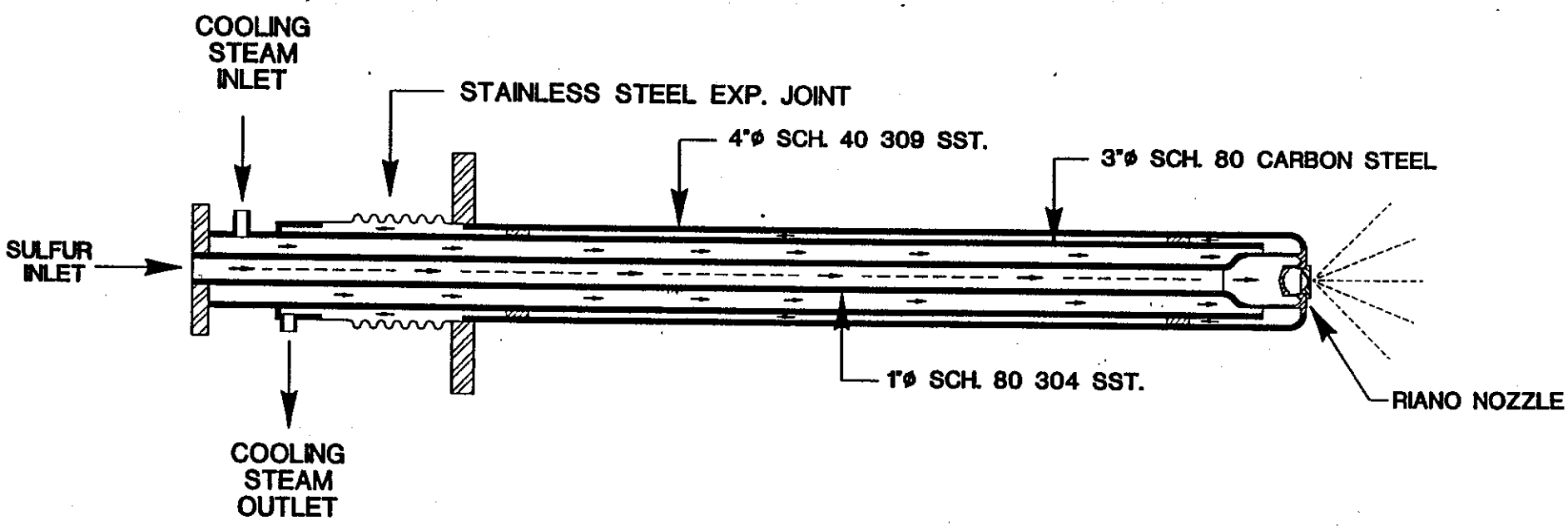
# RIANO SULFUR GUN



# RIANO RAPID SERVICE CAPABILITY

## SULFUR GUN ASSEMBLY