Unit 14 / Sulphur Springs H2S Abatement Process Screening and Stretford Improvements Study—Part 3

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ABSTRACT

Presented in this report are the results of Part 3 of a three-part study performed in 2007. The major goal of the study was to improve the primary H2S abatement system at the Sulphur Springs (Unit 14) Power Plant owned by Calpine Corporation and located at The Geysers. The existing Stretford system is approximately 30 years old and is now under-loaded due to reduced NCG, which was a result of Geysers Recharge water injection. The following three questions were investigated in the 2007 study:

Part 1) Is replacement of the existing Stretford system economically advantageous, given the availability of modern, environmentally-friendly gas treatment technology that could handle the current low sulfur load with a much smaller footprint and less parasitic power load? [An article that was focused on Part 1 was presented at the 2010 GRC Annual Meeting in Sacramento, CA (Benn et al., 2010).]

Part 2) In lieu of replacing the Stretford system, what operational improvements can be made to the existing system to reduce the total cost of treatment? [An article that was focused on Part 2 was presented at the 2011 GRC Annual Meeting in San Diego, CA (Benn et al., 2011).]

Part 3) What physical modifications can be made to the Stretford system to reduce process shutdowns caused by sulfur plugging? [Part 3 is the basis of this article.]

The primary conclusions of the study are: i) every alternative technology considered proved to have a higher total treatment cost than continuing with the existing Stretford unit, even if no improvements are made, and even though it is operating at ~10% of original design loading; and ii) significant reductions in total treatment cost should be possible by implementing several recommended improvements described in Part 2 and Part 3 of this work.

1.0 Scope

The geothermal power production site at The Geysers known as Unit 14 / Sulphur Springs (U14) currently has a Stretford unit for the removal of H2S from the noncondensable tail gas. The Stretford unit has operated since approximately September 1980. Based on compositions and flows from source testing over the last few years and based on the stated original design capacities, the Stretford is currently operating at roughly 10-12% of the original design sulfur loads and gas flows. As a result of the low load on the unit, the operating cost of the unit was considered to be high relative to the amount of sulfur that it removes from the gas. Calpine desired to identify ways to reduce operating costs at the H2S abatement unit.

Calpine contracted Trimeric Corporation, a technical services company with expertise in H2S removal, in general, as well as specific Stretford expertise, to study the situation at U14. Presented in this paper is a high-level overview of a portion of the results discussed in detail in the unpublished ~100 page report that resulted from the work.

2.0 Background, Design and Operation of the U14 Stretford[1]

Figure 1 shows a block flow diagram of a geothermal power station like U14. High pressure geothermal steam passes through a turbine, which drives the electric generator unit. The lower pressure steam exiting the turbine then passes into an indirect ("surface") condenser. Non-condensable gases exit the condenser and pass through one or more steam jet eductors and condensers in the gas removal system and then into the Stretford H2S abatement system. The non-condensable gases, including H2S (about 80% of the total H2S contained in the incoming steam) pass to the Stretford unit. The sweet gas from the Stretford unit is vented to the atmosphere through the cooling towers.

Figure 2 shows an original process flow diagram (PFD) of the Stretford process as implemented at U14 with noted modifications. Similarly, Table 1 shows the material balance with 2007 flow rates of the sour gas and elemental sulfur product.

LINE NO.	1 Approx. 2007 Actual	1 MOL/HR	2 MOL/HR	3 MOL/HR
CO_2	29.54	233.50	233.50	
O_2	2.56	28.70	28.70	22.86
CH_4	4.95	40.74	40.74	
H_2	6.35	77.36	77.36	
N_2	11.82	76.42	76.42	87.05
H_2S	1.98	17.60		
H_2O	8.82	73.07	30.05	2.15
TOTAL	66.04	547.34	486.77	112.06
MW	30.7	29.343	30.171	28.64
LB/HR	2027	16,061	14,686	3,209
SCFM	417	3,462	3,079	709
ACFS		67.14	60.99	9.93
TEMP.°F		124.5	95	170
PRESS. PSIA		14.2	13.2	21.2

Temp and Press assumed same as orig for water content in "Approx. Actual"

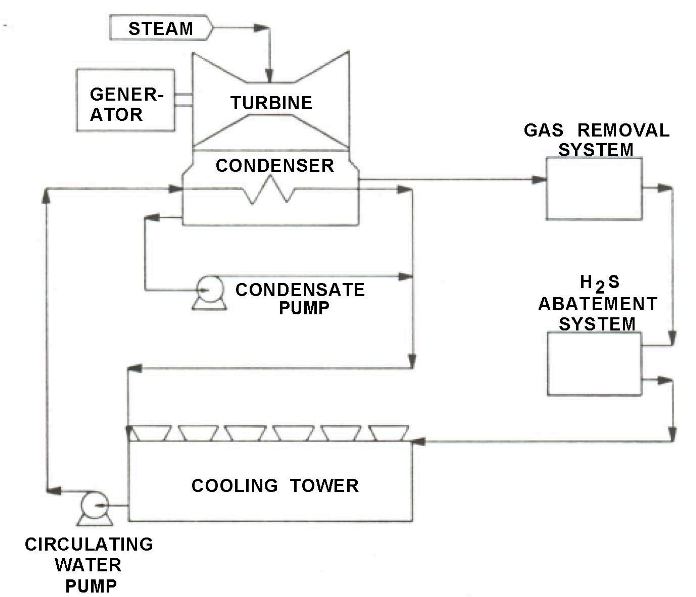
LINE NO.	4 LB/HR	5 LB/HR	6 LB/HR	7 LB/HR	8 LB/HR
SULFUR	2,911	1,456	7,842	564	2,256
STRETFORD	582,208	291,104	1,456,895	5,079	20,316
STEAM					
TOTAL	585,119	292,560	1,464,737	5,643	22,572
SP.GR.	1.04	1.04	1.04	1.09	1.09
GPM	1,120	560	2,818	10.33	41.32
TEMP.°F	95	95	98	98	98
PRESS. PSIA	53	53		65	65

LINE NO.	9 LB/HR	10 LB/HR.	11 Approx. 2007 Actual	11 LB/HR.	12 LB/HR.	13 LB/HR
SULFUR			67.4	564	2,256	2,599
STRETFORD		5,079			25,395	519,829
STEAM	1,034					
TOTAL	1,034	5,079		564	27,651	522,428
SP.GR.	1.0	1.04		1.80	1.08	1.04
GPM		9.77		0.63	5,109	1,000
TEMP.°F	337	280		280	131	95
PRESS. PSIA	113	63				

Table 1. Material Balance for Calpine U14 Stretford with Notations.

The non-condensable gas exported from the gas removal unit first passes into two parallel Venturi scrubbers. Most of the lean Stretford solution passes through the Venturi scrubber(s) as the motive fluid. In the case of U14, with its current very low gas flows, an unusually large fraction of the H2S appears to be removed across the Venturi scrubbers; gas enters the Venturi scrubbers with ~3 vol% H2S and exits the baffle/channel device into the main part of the absorber with only roughly 20-120 ppmv of H2S remaining. The gas then passes upward through a single bed absorber to remove the remainder of the H2S. The absorber contains Flexiring packing, which is a large diameter, open-type, plastic, random packing. H2S is typically removed to less than 1 ppmv, a value well below the 10 ppmv permit limit.

From the sump at the bottom of the absorber, the solution then flows via gravity through a line that enters near the bottom of an open-topped, stirred reaction tank. The purpose of the reaction tank is to allow the sulfide that was dissolved into the liquor in the Venturis and absorber to react to form elemental sulfur particles. From the reaction tank, the solution and suspended sulfur particles flow sequentially



Source: "The Geysers Unit 1, Pacific Gas and Electric Company," National Historic Mechanical Engineering Landmark, The American Society of Mechanical Engineers, October 1985, p. 7. **"(Although the source for Figure 1 mentions Unit 1, Figure 1 does not depict Unit 1 but rather later units.)**

Figure 1. Block Diagram of Geothermal Power Plant.

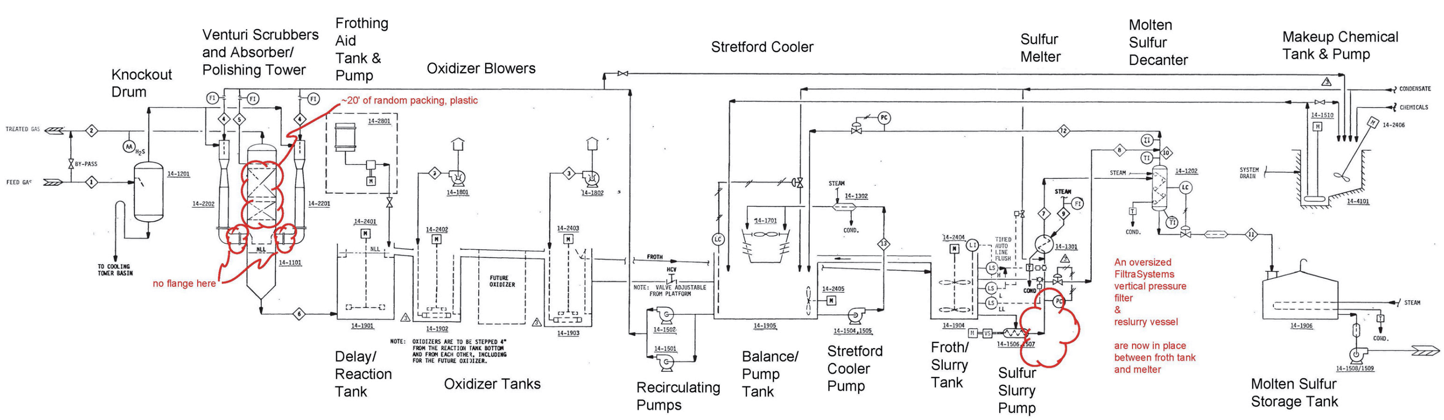


Figure 2. PFD of Calpine U14 Stretford Unit with Notations.

through two equally sized, round, stirred oxidizers. Individual blowers supply air to each oxidizer. The oxidizers serve two primary functions: (1) they separate the sulfur particles from the liquor via froth floatation, and (2) they re-oxidize the vanadium catalyst contained in the Stretford liquor. Diesel or other floatation / frothing aids are not currently used, although equipment is available to do so.

Lean Stretford solution underflows a weir mounted in the second oxidizer and is directed to the balance tank. Dedicated pumps circulate a stream of lean solution from the balance tank to a cooling tower / evaporator located above the balance tank. The purpose of the cooling tower / evaporator is to maintain the water balance of the system. Another set of 3 pumps (two operating and one spare), the Stretford circulating pumps, send lean Stretford solution from the balance tank back to the Venturi scrubbers and to the top of the absorber.

Sulfur-laden froth created in the oxidizers overflows the weir mounted in the second oxidizer and is directed into the stirred froth tank. From the froth tank, the sulfur froth is pumped via a progressive cavity pump through a FiltraSystems vertical pressure filter. The washed cake discharges to a transport bin and is sold for agricultural soil amendment.

2.1 Problems Noted at the U14 Stretford Unit

The following are known or suspected primary problems at the U14 Stretford unit. The first two items listed were the drivers for conducting this project.

- Plugging of the tailpipes of the Venturi scrubber causing forced outages of 3 days duration approximately once per year for cleaning; both Venturi scrubber tailpipes and absorber packing are cleaned when the unit is brought down. If the Stretford unit were not a source of downtime, the U14 power plant would be capable of running continuously for several years between turnarounds.
- High operating costs, dominated by electricity usage (~0.4 to 0.5 MW of the ~60 MW [gross] generated at U14 is consumed by the Stretford unit).
- Plugging of absorber packing, which occurs from the bottom up. The depth to which plugging rises in the packing depends on length of time between cleanouts.
- High thiosulfate concentrations, averaging 300-400 g/l.
- Occurrence of flocculated solid (“floc”) on the reaction tank; this material is stiff in consistency, and, when it occurs in quantity (floc is sometimes up to 2’ tall in elevation above the liquor level), requires the use of a hose and sprayer to herd the floc out of the reaction tank. Floc causes problems with vacuum filters in that it is hard to get the material to come off of the vacuum filter belts, even with a cake knife mounted on the filter.
- Inaccurate or nonexistent measurement of Stretford solution flow, air flow, sour gas flow, and sweet gas flow.
- Process data (e.g., temperatures, flow rates, pressure drops) around the unit are few in number and generally must be collected manually.

3.0 Potential Physical Improvements to the U14 Stretford Unit

This section of the paper discusses physical changes that are being considered to help address several of the bulleted problems listed above. Operational changes were also recommended and summarized in the article covering Part 2 of the study (Benn, et.al., 2011).

3.1 Reducing Consequences of Venturi Scrubber Plugging

The most costly issue at the U14 Stretford unit is plugging of the Venturi tailpipes with solid material. Solids build up over time and harden on the surface of the metal. Plugging is thickest at the bottom of the tailpipe and thinnest at the top. The Venturi nozzle and the converging and diverging sections that make up the body of the Venturi do not plug up. The plugging only occurs in the tailpipe.

As shown in Figure 3, the material has the classic tree-ring layered appearance of scale removed from many other Stretford units in all types of service. The Venturi scrubber tailpipe plugging eventually restricts gas flow and causes back-pressure to build on the upstream generation equipment to the point where the entire U14 facility must be shut down so that the Venturis and tailpipes can either be removed for cleaning or cleaned in place. The frequency of downtime caused by Venturi scrubber plugging is once per year, with 3 days of downtime required for cleaning. Lost power generation and third party cleaning and disposal costs are estimated to be $180,000 per shutdown occurrence.

Part 2 of this publication discussed operational modifications to address the root cause of the scale and plugging via chemistry, and the design of the Venturi scrubber for appropriate velocities and residence times. This section of this Part 3 of the publication discusses the physical changes that could be made to deal effectively with the scale by creating an arrangement where a spare Venturi scrubber is always available and where dirty Venturi scrubbers can be cleaned without a shutdown. Since it is known

Figure 3. Picture of Scale from U14 Stretford Unit.

to be very difficult to completely eliminate plugging in Venturis in Stretford service, and since two Venturi scrubbers with plenty of capacity are in place at U14, it is recommended that modifications be made to arrange for sparing so that on-line Venturi cleaning can be conducted.

3.1.1 Cleaning of Venturi Scrubbers and Tailpipes While Running

Two Venturi scrubbers were installed at U14 with the sour NCG flow split equally between the two units. Because the NCG flow rate decreased over time at U14, the velocity in the Venturi scrubbers is now much lower than the design velocity. Based on the original U14 design information, it was believed that all of the sour NCG could be processed by one of the two Venturi scrubbers and still be well within the Venturi design limits. In fact, testing showed that a single Venturi scrubber could handle the entire current gas flow without excessive backpressure on the sour gas inlet line. Although the H2S content after the Venturi scrubber rose from ~20 ppmv to ~120 ppmv, the H2S content of the sweet gas after the packed absorber section remained at 1 ppmv or less. Thus, it appears that the unit could operate successfully with a single Venturi scrubber in operation. These single Venturi scrubber test results seem reasonable because each of the two Venturi scrubbers was originally designed to handle a gas flow ~5 times as large as current gas flows.

Since it should be possible to run the U14 Stretford with a single Venturi scrubber in operation, it should also be possible to make modifications that allow the second Venturi scrubber and tailpipe to be cleaned without a unit shutdown, thus eliminating downtime associated with Venturi scrubber plugging. Multiple approaches are possible, one of which is discussed in this section.

Figure 4 shows an example of how the absorber and Venturi scrubbers could be modified to allow one Venturi scrubber and tailpipe to be cleaned without requiring a unit shutdown. The Venturi scrubber tailpipes currently terminate onto a flanged connection on the top of a tee that is welded to the absorber shell. In this example, the tee connection is cut from the absorber. A short piece of the tee is left protruding from the absorber wall and is referred to below as the "new absorber nozzle". Avoiding a modification to the vessel shell may dictate the length of the piece that is left connected to the absorber. Otherwise, the piece should be as short as possible and still allow room for a welded flange.

A 20" full-bore, sleeved, knife-gate valve is installed onto this new absorber nozzle. The remainder of the tee, or a new flanged tee, is bolted to the knife-gate valve to serve as the new termination for the Venturi scrubber tailpipes. A full-bore, sleeved, knife-gate valve is recommended for this location because solids are highly likely to accumulate over time. This type of valve, which is used in paper manufacturing and other high-solids applications, is meant for use where high solids and scale accumulation are likely.

The sour gas piping, lean solution piping, and other connections and supports are modified as necessary to achieve 'double block and bleed' isolation of the sour gas line and the lean solution line. Finally, a pipe spool with flange is made up with a connection for a sealed retractable lance with two clear view ports, one through which to view and the other through which to shine a light.

When dirty, the Venturi scrubber would be isolated from lean liquor and sour gas feeds and the absorber via the downstream knife-gate valve and the upstream lean liquor and sour gas valving. Then, the Venturi, tailpipe, and tee would be hoisted down to grade and cleaned. The flanged pipe spool with retractable lance would be bolted to the knife-gate valve. Then, the portion of the port on the absorber side of the knife-gate valve would be cleaned by opening the knife-gate, inserting the retractable lance (with appropriate nozzle on the end), and using a high-pressure water jet to clean the inside of the new absorber nozzle and the back side of the knife-gate valve.

The scale from the Venturis scrubbers and tailpipes would be collected upon cleaning at grade level and not enter the absorber vessel. However, any material on the interior side of the knife-gate (e.g., material inside the new absorber nozzle) as well as any material dislodged from the chute/diverter inside the absorber would end up falling to the bottom of the absorber along with the water used in the cleaning. Keeping the absorber nozzle as short as possible will help limit the amount of material that has to be cleaned with the lance into the absorber. As long as any dislodged solids were not so large as to plug the piping from the bottom of the absorber to the reaction tank, there would likely be no harm with this material passing through the absorber outlet piping and into the stirred reaction tank as the unit continues to operating using the second Venturi. Surging the liquid flow through the absorber liquid outlet piping may also allow any larger-sized particles or chunks to be flushed into the reaction tank.

Double block and bleed isolation is likely not possible for the vessel port fitted with the knife-gate valve. Although the pressure in the absorber is low and the

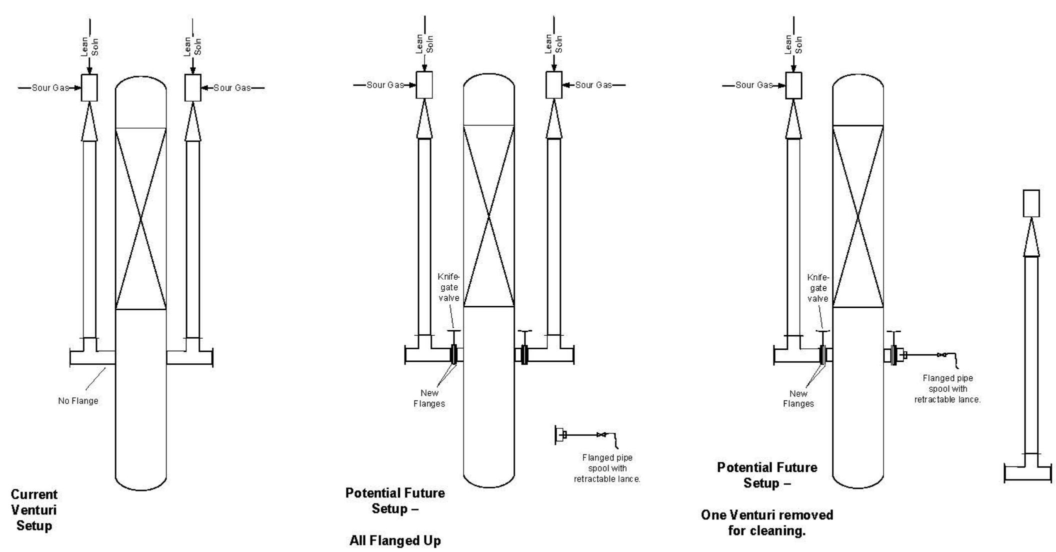


Figure 4. Example Absorber and Venturi Setup to Allow Removal of One Venturi and Tailpipe for Cleaning.

concentration of H2S inside the absorber is much lower than that in the sour gas, precautions (breathing apparatus, or H2S monitors and escape plans, or other means) would be necessary to ensure safety when breaking the tee loose from the knife-gate, inspecting the knife gate, and installing the retractable lance apparatus.

Another variation of the concept in Figure 4 would be to use two knife-gate valves, one vertically on the new short absorber port and one horizontally between the tee and Venturi scrubber tailpipe. A bleeder valve would be installed in the tee, possibly in the blind flange. This would allow for double block and bleed between the Venturi scrubber tailpipe and absorber. However, the large knife-gate valves with their long stems and handles/actuators present on both Venturi scrubber/absorber connections might require an extensive rebuild of the platform in the area; a larger quantity of scale, from the interior of the tee, would fall in the absorber, increasing the potential problems that larger particles and chunks could cause in the absorber.

3.2 Reducing Absorber Packing Plugging

3.2.1 Description of Packing Plugging

The single bed absorber is packed with plastic Flexiring packing. The plastic packing tends to plug with a mud-like material that is relatively easy to remove, in comparison with the layered scale material that is found in the Venturi scrubber tailpipes. This mud-like material is found at the bottom of the bed only and decreases in amount with increasing elevation through the bed. Plugging has not been observed to start at the top of the packing. This is important because it indicates that the cause of packing plugging probably originates from below the bed rather than from above; therefore, the lean solution total suspended solids (TSS) is probably not the key factor in packing plugging.

The longer the Stretford unit runs between packing cleanings, the more of the packing that is plugged. For example, when the packing was cleaned in February 2006 after a longer than usual run of ~514 days, the plugging was said to extend more than halfway up the ~20' bed of packing. Yet, when the site went down in late March 2007 (for reasons unrelated to the Stretford unit) and the absorber was cleaned again, the plugging only extended about 1' to 1.5' up into the packing.

3.2.2 Likely Causes of Packing Plugging from Below

A key cause of plugging of packing from below is foaming or frothing at the surface of the liquor in the collection basin of the absorber and inside the disengaging section of the tower. The inlet gas picks up this froth and carries it into the bottom of the packing. Once in the packing, the sulfur particles find areas of low velocity to settle and accumulate.

Abundant floating material on the surface of the liquid in the downstream Stretford reaction tank is believed to be indicative of foaming in the collection basin of the Stretford absorbers. As described previously, the U14 Stretford and some of the other Stretford units at The Geysers are known to exhibit floc on the surface of the liquor resident in the reaction tank from time to time. Taken together, the observation of floc on the reaction tank and the observed pattern of packing plugging from below likely indicate that there is foaming in the U14 absorber, at least part of the time.

An additional possible cause of plugging of the packing is the direct formation of sulfur particles on the packing. As H2S is absorbed into the solution on the packing, a fraction of it may react to elemental solid sulfur prior to the liquid draining off the packing into the sump.

3.2.3 Mitigating Packing Plugging

Part 2 of this study described operational changes to mitigate packing plugging by addressing the cause of the foaming and maintaining plenty of packing irrigation. There are also several different physical changes that could be made to the equipment at U14 to minimize the effects of foaming and minimize plugging. These are discussed below in the order of their likelihood for possible implementation at U14. Relative cost, ease of implementation, and complexity of equipment modifications are key factors in selecting which of the options might be implemented. In this case, since the operational changes could significantly minimize absorber packing plugging, it is recommended that these be applied first, followed by the equipment changes discussed below.

Remove the lowest section of packing – Since plugging is only observed at the bottom portion of the packing in the absorber, removing the lowest section of packing will provide more disengaging height for the foam and sulfur particles to settle back into the absorber sump and not on the packing itself. At the U14 Stretford, there is only a single bed of random packing. Thus, removing the lowest part of the packing involves raising the packing support and shortening the overall depth of the packing. Problems with H2S removal are not expected to result. The U14 absorber is achieving very good H2S removal, and removing 2'-5' of the packing would not likely result in much change in outlet H2S content.

Modifying the packing to be more plugging resistant – Another way to minimize plugging in the absorber packing is to change the packing type and material from which the packing is made. Other Stretford plants have used packing designs wherein the packing at the bottom has an especially large amount of open space. The Flexiring packing used at the U14 Stretford is of a large, open style. However, this Flexiring packing has higher liquid holdup and residence time than some other packings. Higher liquid holdup and residence time may allow more of the absorbed H2S to convert into elemental sulfur while on the packing, thus increasing the potential for plugging. Other styles of packing (e.g., CMR packing) have better fouling resistance and more open space than Flexiring packing (98% void space for 3A CMR packing as compared to 96% for 4” high performance Flexiring packing). Changing to CMR packing (or other similar open-style packing) should reduce absorber plugging with little risk in unit performance. Minor modifications to the vessel may be required, with moderate capital cost for the packing.

The packing material could also be changed from the plastic currently used to a Teflon (or similar) material (e.g., E-CTFE, ETFE, glass reinforced ETFE). The sulfur may not stick as easily to Teflon packing. If the packing efficiency is as good as it is for plastics, then there will be little risk in trying the Teflon packing. The cost of the Teflon packing will need to be evaluated to determine its potential for use at U14. If the cost is prohibitive, then just a change in the packing type, not material, could be made.

Use sprays below the packing to control foam in the absorber – In addition to removing the lower part of the packing and creating more open space in the packing, many Stretford units use sprays of solution in the space between the bottom of the packing and the liquid surface in the absorber sump. The flow rate of lean solution to the sprays may be on the order of 50-60% of the flow rate to the top of the absorber. The flow to the U14 Stretford absorber is ~600 gpm, so an additional ~300 gpm may be needed to the spray headers. This plugging mitigation technique may require the most modification to the absorber vessel to install the spray header and nozzles. Additional pump capacity with increased parasitic load and controls will also be required.

3.3 Improving Flow Measurement

Stream flow measurement on the U14 Stretford is less than ideal. There are inaccurate or nonexistent measurements of Stretford solution flow, air flow, sour gas flow, and sweet gas flow. It is important to know these flow rates to evaluate and optimize the performance of the process when operational or physical changes are made to it. Thus, improvements to the flow measurements in these key areas are discussed below.

Sour and sweet gas flow measurement – Conventional concentric orifice meters are used at U14 for gas flow service and have performed poorly due to plugging of the meters. However, eccentric orifice meters worked well for this service at other sites in The Geysers and are strongly being considered for use at U14 in the future. Eccentric orifices are designs where the orifice hole is located near the pipe wall instead of being centered. For a horizontal pipe measuring a gas stream containing some liquid, the hole is located at the bottom of the pipe cross section to allow liquid to pass through the orifice without accumulating. Other designs for dirty gas service, such as Venturi flow meters (which have a smoother transition in diameter and low permanent pressure drop) and wedge flow meters, could also be used. Figure 5 illustrates some of these designs.

Stretford solution flow measurement – Of the three types of flow elements shown in Figure 5, the Venturi meter and wedge meter could be used on the solution flow to the Venturi scrubbers or the solution flow to the top of the absorber. Wedge meters have been used reliably in sulfur slurry service in other types of liquid redox plants.

Other options to measure the Stretford solution flows include Coriolis meters of the straight-through variety (e.g., Krohne Optimass 7000 series) and magnetic flow meters. Coriolis meters could be used on the individual streams after they have split to go to the Venturi scrubber(s) or to the top of the absorber, but they may not be available in large enough sizes to measure the entire flow from the solution pumps. In addition, Stretford operators at other sites have used magnetic meters for solution flow successfully but some have reported problems related to corrosion or deposits at wire terminations.

Oxidizer air stream flow measurement – The flow meters in the oxidizer air lines at U14 were removed several years ago due to suspected restrictions causing lower than desired air flow. It is important to know the air flow to the oxidizers, so the original orifice meters will be re-installed or Venturi meters put in place. If the cost of retrofitting is not too high, then Venturi air flow meters are preferred because the total permanent pressure drop is relatively low.

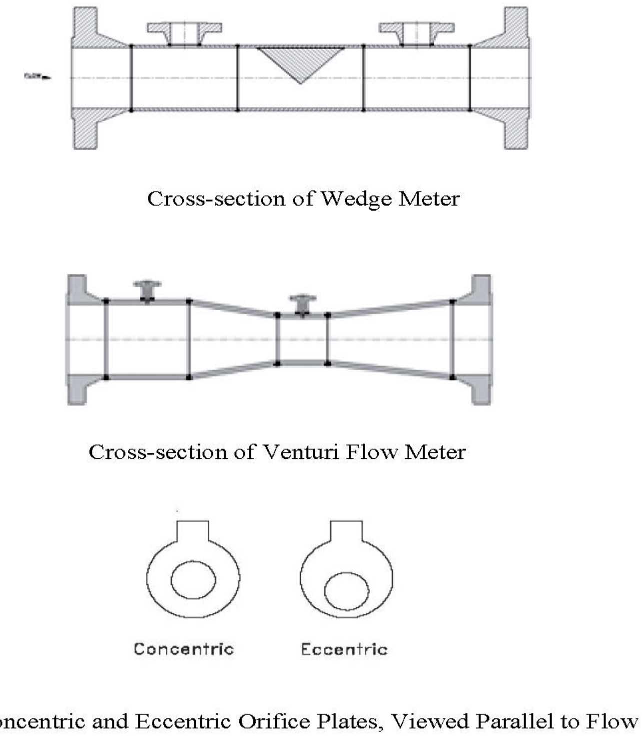


Figure 5. Types of Flow Meters for Wet Gases.

Pressure sensing line maintenance – A key issue with the flow meter types shown in Figure 5 is measuring the differential pressure of the meter accurately without plugging or filling of the pressure sensing lines. There are several techniques that eliminate the concern with condensation and/or collection of solids in the pressure sensing tubing. U14 has had good success by locating the taps on the top of a horizontal meter run and using oversized sloping pressure transmission tubing so that liquids drain back into the pipe. However, some alternative techniques used at other Stretford sites include: (1) purging the tubing with a small flow of inert gas to keep the pressure sensing lines free of liquids or solids, or (2) using a remote diaphragm differential pressure sensor. The remote diaphragm differential pressure sensor could be used with one of the devices in Figure 5 to measure any of the inlet gas, outlet gas, solution, or oxidizer air flows.

3.4 Analytical Requirements

Analytical data are also important for troubleshooting U14. The following data are gathered on a weekly basis: thiosulfate, ADA and total vanadium concentrations, total alkalinity, TSS in lean solution, pH, boron, color, and specific gravity. Sulfate concentrations are measured on request. Pentavalent vanadium (V^{5+}) data are not collected, but it is possible to measure pentavalent vanadium on site. Thus, it is recommended that the pentavalent vanadium concentration at the outlet of the main Stretford circulating pumps be routinely measured to aid in optimization of oxidizer performance at the plant. Monthly source testing is currently done for total gas flow to the Stretford unit, air inleakage, and gas composition is adequate. H2S sampling below the absorber packing is also possible, and may be useful to collect in future troubleshooting efforts.

4.0 Summary

This study presented operational (Part 2, previously) and physical (Part 3, this article) changes that could be made to the Stretford unit to improve performance and minimize plugging issues in key areas of the process. Because it is difficult to completely eliminate the plugging and scaling that occurs in the Venturi scrubbers, and because there are two scrubbers, either of which are more than large enough to process all the gas by itself, it is recommended that U14 be converted to operate with a single Venturi scrubber unit. This would allow for cleaning of the Venturi scrubbers and tailpipes while running. Plugging of the absorber packing could be significantly minimized by eliminating the foaming issue or providing plenty of packing irrigation as described in Part 2. Therefore, it is recommended that these operational changes be implemented first, followed by the equipment modifications described in this publication, if needed. Improvements to flow measurements and analytical data collection are necessary for monitoring and controlling the U14 Stretford process. Overall, these changes will allow U14 to run more efficiently, thereby minimizing downtime and costly equipment cleanouts, and increasing power production at the plant.

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[1] Note: Section 2 contains general background information about the Unit 14 Stretford system that is applicable to all three parts of the study. Thus, much of the material in this section 2.0 was presented at previous GRC Annual Meetings in Parts 1 and 2 of this topic (Benn et al., 2010 and 2011).