PERFORMANCE EVALUATION OF
ENI GELA
SULPHUR RECOVERY FACILITY

November, 2007

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Attention: Ing. Mauro MOCCIA
Reference: Sulphur Plant Evaluation at Gela

Sulphur Experts Inc. conducted a full performance evaluation of the sulphur recovery facility at the ENI Gela Refinery between 08 and 09 November, 2007. The testing program was completed on the 3-stage Claus plus SuperClaus sulphur recovery unit (SRU).

The primary purpose of the test was to determine the overall and interstage recovery efficiency of the SRU. The on site analytical data was used to evaluate each piece of equipment and to determine if there were any problem areas which may be limiting the plant efficiency, and to recommend operating changes which will be required to achieve optimal efficiency. The November 2007 test was part of a routine annual testing program to give ENI the plant performance data as well as stack emission data for the government authorities.

The results of this performance evaluation are contained in this report. If you have any questions about the information contained in this report, please contact us by phone at +1-403-215-8400, by fax at +1-403-215-8419 or by email at *pseville@sulphurexperts.com*.

Yours truly,
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Summary

ENI operate a single SRU at the Raffineria di Gela. This SRU consists of three Claus stages followed by a SuperClaus® reactor and a thermal incinerator. Catalyst was last changed in all reactors in March 2005.

During the period from 08 to 09 November 2007, Sulphur Experts conducted a full performance investigation. This report summarises the results of the evaluation. The previous test on this SRU was completed by Sulphur Experts in October of 2006.

The average measured conversion efficiency through the 3-stage Claus section was 97.5 percent. This is lower than measured in 2006 but meets expectations for this Claus section The first two Claus reactors were achieving equilibrium conversion, which indicated good catalyst activity in these beds. The third bed appeared to be partially deactivated–this is not yet affecting the overall performance with the SuperClaus in service. In the event of a SuperClaus bypass, the emissions from the three stages of Claus will, however, be higher than the optimum value.

The sulphur recovery efficiency to the outlet of the SuperClaus stage averaged 98.78 percent. This was poorer than the October 2006 results. This was due primarily to a un-optimised SuperClaus reactor. However, the best on-site performance was 99.15 percent (at the stack outlet) which indicates only a slight decline in activity from 2006. These results were achieved after optimising the SRU on site. There may be room for further optimisation of the SuperClaus.

The stack test also confirmed minimal potential for sulphur entrainment from the coalescer, or for process gas leakage around the SuperClaus bypass valves. Pollutant emissions from the SRU to the atmosphere are summarised in this report.

There remain a lack of proper sample points inside the SRU. It is highly recommended that proper sample valves be installed so a more complete evaluation can be done in the future (reference PFD diagram Figure 1.1-1).

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1.0 Introduction

1.1 Background

A comprehensive plant performance test and engineering evaluation was carried out by Sulphur Experts Inc. of Heerhugowaard, The Netherlands, at the Gela Refinery between 08-09 November, 2007.

The Gela sulphur recovery unit is a 3-stage modified Claus plant followed by a SuperClaus stage. When the SuperClaus is in service, the tail gas from the third Claus stage is fed directly to the SuperClaus *stage (i.e., without a condensing stage)*. The tail gas is processed in a forced-draft thermal incinerator. The oxygen content in the stack is measured continuously. There is no measurement of SO_2 concentration in the stack.

The primary purpose of the test was to provide a performance review of the complete SRU.

The plant load was about 6.5 t/h of amine acid gas and about 1.5 t/h of SWS off-gas. This compares to a design total feed gas load of 12 t/d. The plant was operating in SuperClaus mode for the entire test period. Both the Superclaus and the incinerator stack oxygen analysers were off-line during the testing.

Table 1.1-1 gives a description of the major SRU equipment and the respective equipment numbers. A schematic flow diagram of the entire sulphur recovery facility is presented in Figure 1.1-1.

Table 1.1-1 - SRU Major Equipment List

Equipment	Equipment Number	Description
Reaction Furnace	B-1	straight through configuration
Waste Heat Exchanger	E-1	two pass / 37 bar steam production
Condensers 1, 2	E-2	shell and tube exchanger/ common shell / 6 bar steam
Condenser 3	E-16	shell and tube exchanger / 6 bar steam
Reheater 1	HGBP	hot gas from B-1
Reheater 2, 3, 4	E-6, E-8, E-10	indirect steam reheater
Reheater 5	E-11	electric booster heater (SuperClaus)
Converter(s) 1, 2, 3	R-1, R-2, R-3, R-4	horizontal; separate shell *(R4 with dual inlets)*
Condenser 4	E-3	shell and tube exchanger (closed-loop, air cooled water-side)
Thermal Incinerator	B-2	Forced-draft with steam super-heater heat recovery section (37 bar steam)

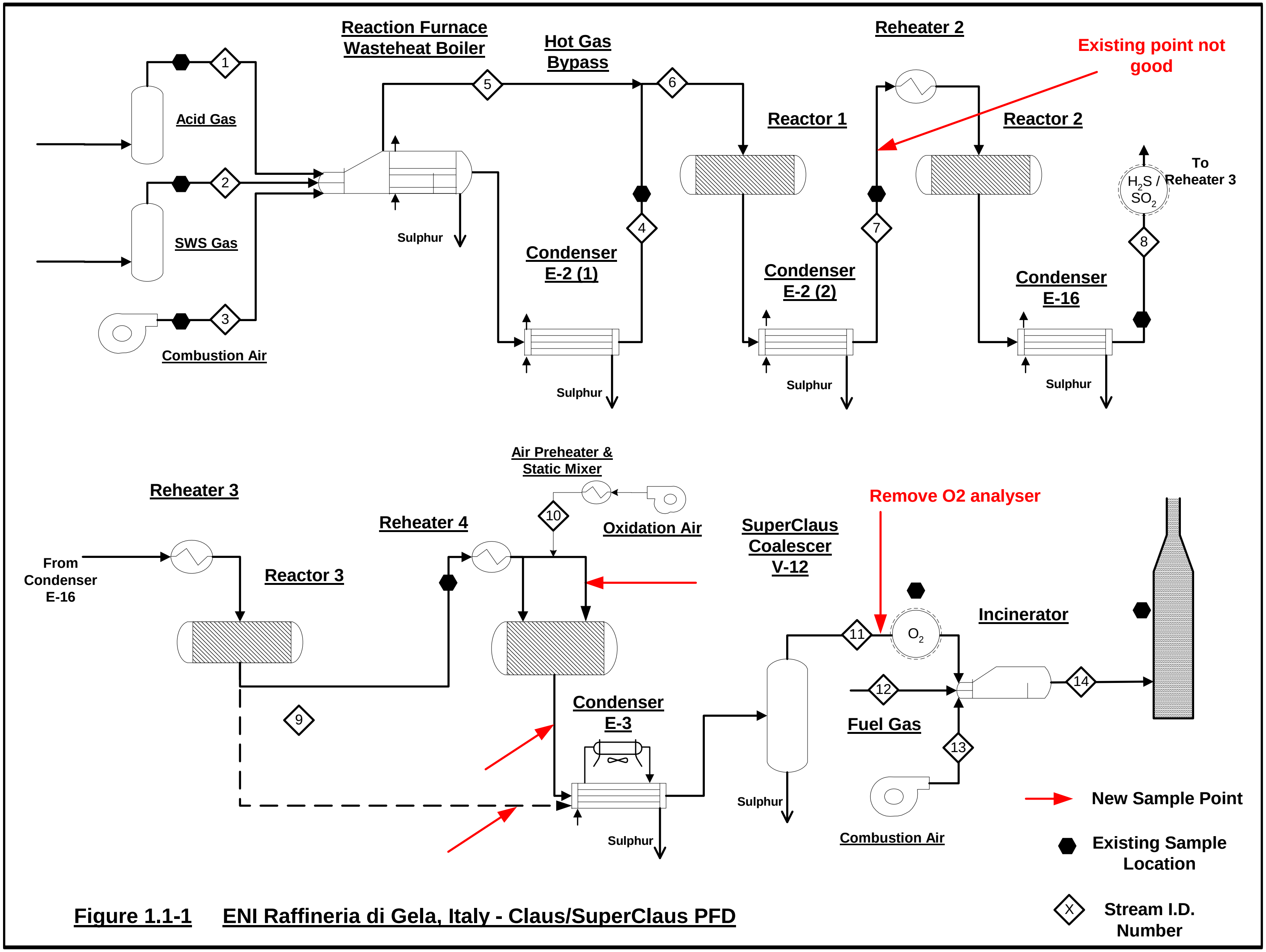


Figure 1.1-1 - Claus / SuperClaus Process Flow Diagram

1.2 Project Scope

The specific objectives of the testing were to provide the following information:

Claus Plant
- overall and interstage efficiencies;
- overall and interstage material and heat balances;
- process stream compositions;
- evaluation of catalyst activity in all Claus reactors;
- evaluation of the COS and CS_2 formation rates in the Claus reaction furnace;
- evaluation of the COS and CS_2 hydrolysis rates in the first Claus reactor;
- evaluation of the tail gas analyser and air flow control system.

SuperClaus Plant
- performance of the SuperClaus reactor (conversion, selectivity and yield).

Incinerator
- overall material and heat balances;
- process stream compositions;

1.3 Future Project Requirements: Laboratory and Process Preparations

These recommendations should be passed to the appropriate department to simplify the logistics for the next schedule sulphur plant performance test.

Sample Connections

The following connections remain **to be installed by Gela** (*refer to arrows on Figure 1.1-1 for reference*):

1. SuperClaus reactor inlet (after the E10 heater at one of the two physical inlets to the reactor);
2. SuperClaus coalescer outlet (remove the existing oxygen analyser connection);
3. Reactor 1 outlet (at the E2-2nd pass outlet, before the inlet to E-6; or at the inlet to the Reactor R2);
4. Two new sample points: one before and one after the SuperClaus bypass line exit and re-entry (at E-3 inlet).

The first two points will permit a complete evaluation of the SuperClaus (inlet including the oxidation air). The third point will allow a more reliable evaluation of the 1st reactor. The last two sample points will allow a check on the potential of bypass valve leakage.

To ensure that proper samples can be obtained, the following criteria should be used to prepare the sample points:

- samples must be collected through a valve which is in a straight line directly into the flowing process line;
- there should be no additional piping or valving after the initial sample valve;
- the sample valve outlet should end in a minimum 3/4" NPT threaded connection;
- the sample valve should allow for the insertion of a 10mm sample line into the flowing process gas.

We recommend a piston-type sample valve designed specifically for this application. Sulphur Experts can assist Gela with these preparations. See details in the *Appendix B.*

Laboratory

In addition to the sample point preparation noted above, the following additional recommendations should also be implemented prior to the next plant test:

1. 500 g of **new** P_2O_5 powder should be ordered immediately prior to each test;
2. A **calibration standard** gas containing 5 volume percent hydrogen (H_2, balance Nitrogen) should be available in the lab.

Process Area

1. Plant **nitrogen or instrument air** should be permanently piped to the stack sample level (2nd platform) to be used to operate Sulphur Experts' stack sampling apparatus.
2. Engineering should prepare an **XL spreadsheet of the ALL of the process data** screens from the DCS (SWS, amine regenerators, Claus, SuperClaus, Incinerator). This should include all pressure, temperature, flow and analyser data. Arrangements should be made to save the data for each test period. The process variable AR101 (R2 outlet SO_2) should be added to the off-line data storage.

2.0 Performance Test Results

Test Schedule and Sample Locations

The schedule of the November tests completed on the ENI Gela sulphur recovery facility is summarized in Table 2.0-1.

Table 2.0-1 - Test Schedule

Date	Time	Test	Plant	Test Description
Thursday 08-Dec	12h30 - 13h30	1	SRU	Full Claus & SuperClaus
Thursday 08-Dec	15h50 - 16h10	2	SRU	Full Claus & SuperClaus
Friday 09-Dec	09h15 - 10h50	3	SRU	SuperClaus + Stack
Friday 09-Dec	12h40 - 14h10	Other	Stack	Stack test (SO_2; SO_2 +SO_3) [1]

[1] - Series of two high-volume wet chemical absorptions on the stack effluent.

Each performance test involved sampling at locations in the plant where a change occurred in the process. The sample locations and analysis methods are summarized in Table A.1-1 in *Appendix A*. It should be noted that a sample could not be obtained from the outlet of the first reactor (R1, or E-6 inlet) due to the sample connection.

Detailed analysis of all of the pertinent process gas streams was completed during the on-site tests. Tables A.1-2 through A.1-4 in *Appendix A* summarize the analytical results for all of the test runs. Table A.1-5 is a comparison of the SuperClaus performance over the test period. These results are presented on a water- and sulphur-free basis as analysed in the field.

A full set of plant operating data was collected in each plant for each test run. The actual plant data sheets are included in *Appendix B*. There is also a reference given for the recommended sampling valve to be installed in the required locations (per Figure 1.1-1)

The process gas analyses and the plant operating data were used to complete heat and material balances for each test run. These material balances were then used to evaluate the required SRU process units. A selected material balance is presented in Table C.1-1 *(Claus & SuperClaus sections–Test 3)* and C.1-2 *(Incinerator section–Stack testing)* in *Appendix C*. The stream numbers correspond to the process flow diagram presented in Figure 1.1-1.

2.1 Overall Conversion and Recovery Efficiency

The material balance calculations were used to determine the overall conversion and recovery efficiencies for each plant. The results for each plant and test are presented in Table 2.1-1.

Table 2.1-1 - Overall Plant Recovery Performance

Performance Parameter	Rated	*Oct. 2006 Average*	Test 1	Test 2	Test 3	Stack Testing	Average
Total Inlet Sulphur (t/d)	200-250	*130.1*	140.8	139.8	143.1	143.1	**141.2**
Claus Conversion [1] (%)	*98.2*	*97.91*	97.79	97.15	97.49	---	**97.48**
Claus Recovery [1] (%)	*98.0*	---	*no final Claus sulphur condenser*				
Overall Conversion [2] (%)	*99.2*	*99.40*	98.96	99.00	99.23	---	**99.06**
Overall Recovery [2] (%)	*99.0*	*99.19*	98.68	98.73	99.00	---	**98.78**
Overall Recovery [3] (%)	*99.0*	*99.18*	---	---	99.10	99.25 (99.00 / 99.30)[4]	**99.15 (99.15)**[4]
Sulphur Produced (t/d)	*n/a*	*136.1*	138.9	138.0	141.7	n/a	**n/a**

[1] Based on the Claus tail gas analyses (assuming zero sulphur entrainment). There is no condenser after the 3rd Claus stage, thus no recovery value.
[2] Based on the SuperClaus reactor outlet analyses.
[3] Based on the Incinerator stack effluent analyses.
[4] The calculated recovery using the SO_2 values from the two stack absorption tests (in brackets).
Note: Due to normal the expected accuracy of the analysis and calculation techniques, the overall recovery efficiency values are accurate to ±0.05% to the SuperClaus.

The initial tests indicated that the **SuperClaus reactor operation was not optimised**. Following partial optimisation on site of the plant parameters, the results from Test 3 and the later stack gas and chemical absorption tests indicated better performance.

The overall recovery efficiency averaged 99.15 percent to the incinerator outlet with the SuperClaus in near-optimised operation. Note that these samples were taken at the end of the test period when the SuperClaus was performing at its best. The expected recovery efficiency is between 99.0 and 99.2 percent. The recovery efficiency measurements to the incinerator outlet (by GC and by high-volume absorption) supported the calculations using the SuperClaus outlet analyses. This was similar to the previous October 2006 tests and indicated no change in the capability of the SuperClaus unit. ***However, given the initial recovery efficiency values ENI will need to operate the unit much more tightly controlled than in the past in order to to achieve the optimum results on a continuous basis.***

For the SRU 3-Stage Claus section, the measured conversion efficiency averaged 97.5 percent. Although there was no gas sample available after the first reactor, the results suggested that the catalyst in Reactors 1 and 2 were fully active. However, the third Reactor was not performing as expected, indicating some deactivation of the catalyst. Fortunately, this was not yet affecting the overall plant efficiency.

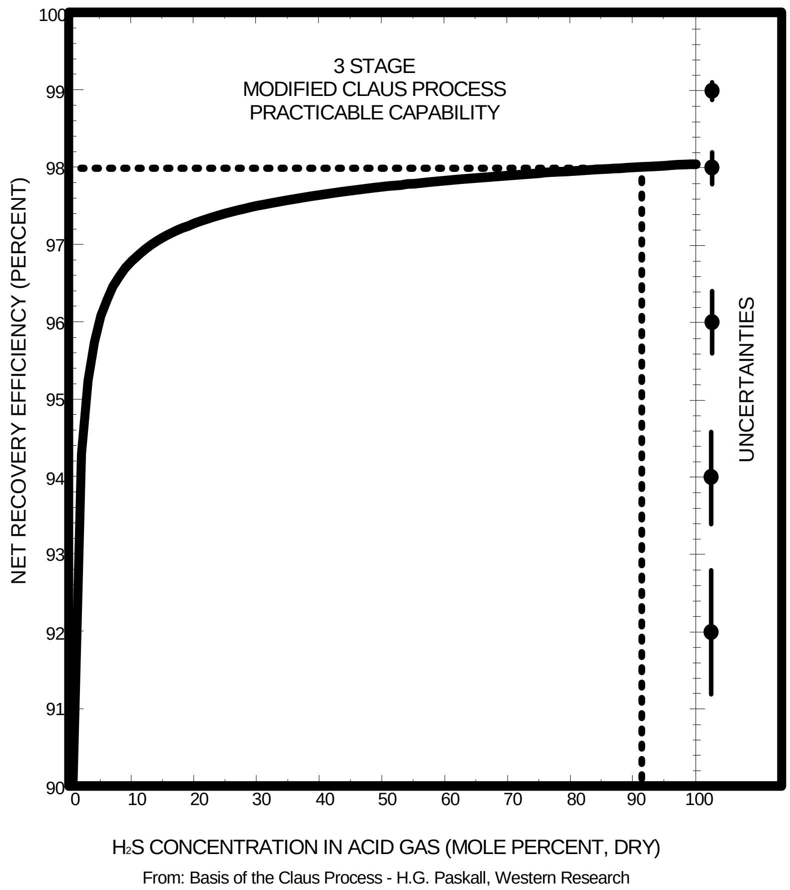


Figure 2.1-1 - Three-Stage Modified Claus Process Practicable Capability

The Gela plant was also simulated using **Sulsim®** to determine the theoretical maximum optimized recovery efficiency. The results showed a maximum optimized recovery efficiency of 99.3 percent with the SuperClaus in operation. (*In Claus mode, the expected ideal 3-stage recovery was 98.5 percent. In SuperClaus mode, this drops to about 97%, where it is now performing*) This value represents the maximum instantaneous recovery efficiency which could be attained under the optimum operating conditions recommended in this report and is usually higher than the rated value described above. With smooth operation and full optimization, the plant recovery efficiency could approach this value.

2.2 Claus Unit Operations

The following sections include specific discussions on the performance of the individual units in the Claus units.

Feed Gas Quality

The amine acid gas was very clean, with minimal hydrocarbon contamination. The sample of the sour water stripper gas was inconclusive due to problems with the sample point. In comparing the operation of the three stripper towers from 2005 and 2006 to this year, it was presumed that the average gas analysis from these combined towers was unchanged. This is normally a valid assumption for these unit operations. The material balance from the inlet streams across the reaction furnace was a good match to the measured gas composition, thereby confirming this assumption.

At the next turnaround/shutdown, the SWS sample point should be completely cleaned and all valves serviced.

Reaction Furnace

The reaction furnace is responsible for initiating the Claus reaction in a free-flame reaction and also generates a significant portion of the overall recovery efficiency in the unit. The reaction furnace is also responsible for destroying many of the contaminants (hydrocarbons, ammonia etc.) in the acid gas feed. The Gela SRU has a straight-through type of reaction furnace where both the SWS off-gas and amine acid gases are processed together in the main burner.

Table 2.2-1 on the following page summarizes the reaction furnace variables from the October tests.

The measured furnace temperature was in the correct range for good ammonia destruction. The calculated temperature using the measured gas composition after the furnace agreed well with the average measured value. The measured residual ammonia after the wasteheat exchanger was relatively low (<40 ppmv, wet) which indicated good destruction of the ammonia in the reaction furnace.

The production of COS in the reaction furnace was significant (~ 1.7 percent of the total inlet sulphur). Therefore, if the COS is not converted in the downstream Claus reactors, it would directly contribute to sulphur emissions. There was no CS_2 detected in the reaction furnace effluent.

The measured total combustion air flow rate was in very good agreement with the calculated value based on the flow and composition of the acid gas feed streams. This indicated good flow metering of the three inlet gases. This is an improvement over past years.

Table 2.2-1 - Reaction Furnace Performance Summary		
Performance Parameter		**Test 1**
Amine Acid Gas flow rate	(t/h)	6.37
Sour Water Stripper flow rate	(kg/h)	1592
Measured combustion air flow rate	(t/h)	18.67
Calculated combustion air flow rate	(t/h)	18.08
Measured Furnace Temperature	(ºC)	1286/1284/1274
Calculated Adiabatic Furnace Temperature	Front (ºC)	1400
Recommended Front Chamber Temperature	*(ºC)*	***1250***
Unit Conversion Efficiency [1]	(%)	61
COS Formation	(%)[1]	1.69
CS_2 Formation	(%)[1]	0.00
Hydrocarbon	Total Content in Acid Gas Feed (mole %) [2] Content in furnace outlet (ppm wet)	6.2 n/d
NH_3	Total Content in Acid Gas Feed (mole %, wet) Content in furnace outlet (ppmv, wet) Destruction efficiency (%)	10.0 40 99.9

[1] Percentage of total inlet sulphur. n/d - not detected
[2] Expressed as methane

Claus Reactors

The primary function of the Claus reactor is to catalyse the H_2S and SO_2 reaction. The first converter is also normally required to promote the reaction of COS and CS_2 in order to minimize the impact of those components on the overall recovery efficiency.

The Gela SRU has three reactors in the Claus section. All of the catalyst in these reactors was changed in May 2005. Reactor 1 is equipped with a mixed catalyst of standard activated alumina and a bottom layer of titania (~ 40% by mass). Reactors 2 and 3 are equipped with standard activated alumina catalyst. Table 2.2-2 summarizes the performance of the Claus reactors from Test 1.

Table 2.2-2 - Claus Reactor Performance Summary

Performance Parameter		**Test 1**		
		Reactor 1 (R1)	**Reactor 2 (R2)**	**Reactor 3 (R3)**
Inlet temperature	(°C) *Oct 2006 (ºC)*	259 *251*	207 *209*	195 *195*
Maximum bed temperature	(°C) *Oct 2006 (ºC)*	329 *325*	229 *229*	192 *192*
Delta T (observed)	(degree C) *Oct 2006 (ºC)*	70 *74*	22 *20*	-3 *-3*
Delta T (thermodynamic)	(degree C)	-no sample-	-no sample-	n/a
Outlet sulphur dewpoint temperature	(°C)	-no sample-	-no sample-	177
Outlet dewpoint margin	Measured (ºC) *Target (ºC)*	--- *n/a*	--- *10 - 15*	15 *10 - 15*
Target catalyst bed temperature	(°C)	**300-320**	**225**	**195**
Unit conversion				
All species	(%) *Oct 2006 (%)*	93 (combined) *81 / 60 (versus 92)*		23 (*estimated*)
COS	(%) *Oct 2005 (%)*	99.0 *99.5*		-- --
CS_2	(%) *Oct 2005 (%)*	100 *100*	-- --	-- --
COS and CS_2 Losses	(%) *Oct 2006 (%)*	<0.02 *<0.01*		
Cumulative plant conversion	(%)	97.13		97.79
Approach to equilibrium reaction [1]	Measured(%) *Oct 2006 (%)* *Target*	n/a *>100* *100*	n/a *100* *100*	80 *n/a* *100*
Catalyst History	Last Changed Type	May 2005 Axens CR+ CRS31	May 2005 Axens CR	May 2005 Axens CR

[1] Measured sulphur conversion as a percentage of the theoretical Claus reaction equilibrium at process conditions.

There was no sample available between the first and second reactors. Therefore, the analysis of the combined reactions in **Reactor 1** and **Reactor 2** showed that they were attaining Claus equilibrium and the COS and CS_2 hydrolysis was very high. This indicated good catalyst activity in the combined reactors. ***Continue to operate Reactor 1 with a maximum bed temperature of 320ºC.***

Operate Reactor 2 with a maximum bed temperature of 225ºC.

Reactor 3 was showing a similar performance to that in the 2005 & 2006 tests with respect to the conversion. However, the approach to equilibrium was somewhat lower, indicating early signs of deactivation in this bed. This was not yet lowering the Claus efficiency nor affecting the overall plant performance (with the SuperClaus in operation). ***Operate Reactor 3 with a maximum bed temperature of 195ºC.***

Conduct a rejuvenation on this bed while monitoring the tail gas analyser in the outlet of this reactor. If the bed has recovered some activity as a result of the rejuvenation, the total sulphur in the feed to the SuperClaus should decline (i.e., at the same H_2S inlet concentration, the SO_2 concentration should be lower). If it does not respond, then schedule this bed for replacement in the next two to three years. Since the majority of SuperClaus operate with only two upstream Claus reactors, it provides added conversion security for the Claus section but is not critical to the overall plant performance. If the reactor is opened in the coming months, it is recommended that ENI collect a sample of this to send to the manufacturer for analysis and interpretation.

Gela needs to put the SO_2 value output from the analyser (AR-101) on the DCS to monitor the 2-stage Claus performance.

Figures 2.2-1 and 2.2-2 show the temperature profiles for the first and second reactors in the Gela train. There is no useful information associated with the profile of the third reactor due to the minor temperature rise in this vessel.

The excellent temperature profiles in both reactors support the positive findings of the catalyst performance indicators.

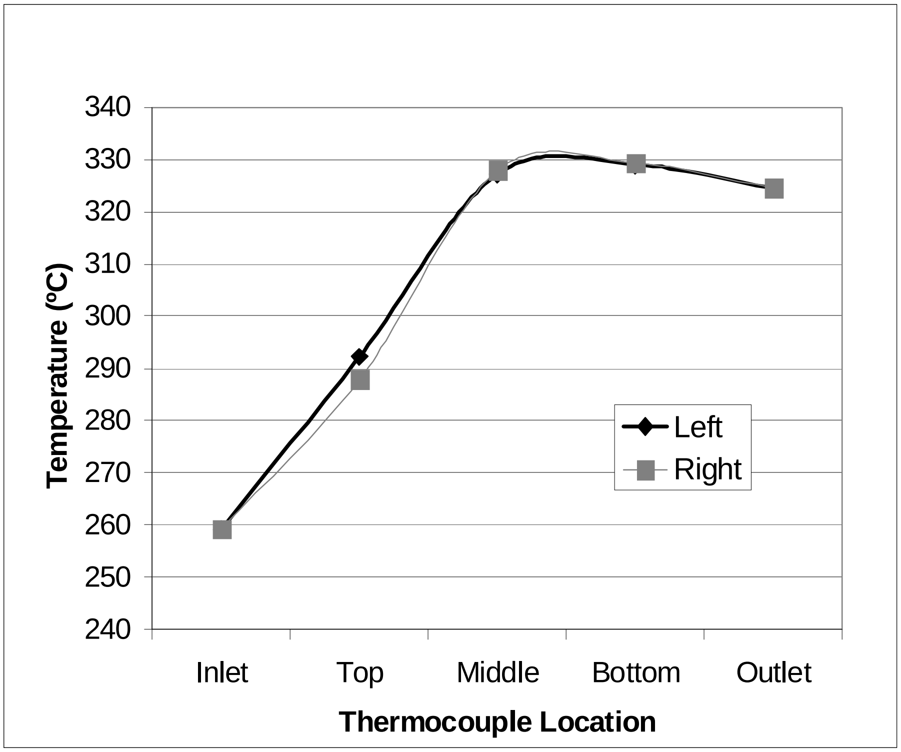


Figure 2.2-1 - ENI Gela Reactor 1 Temperature Profile

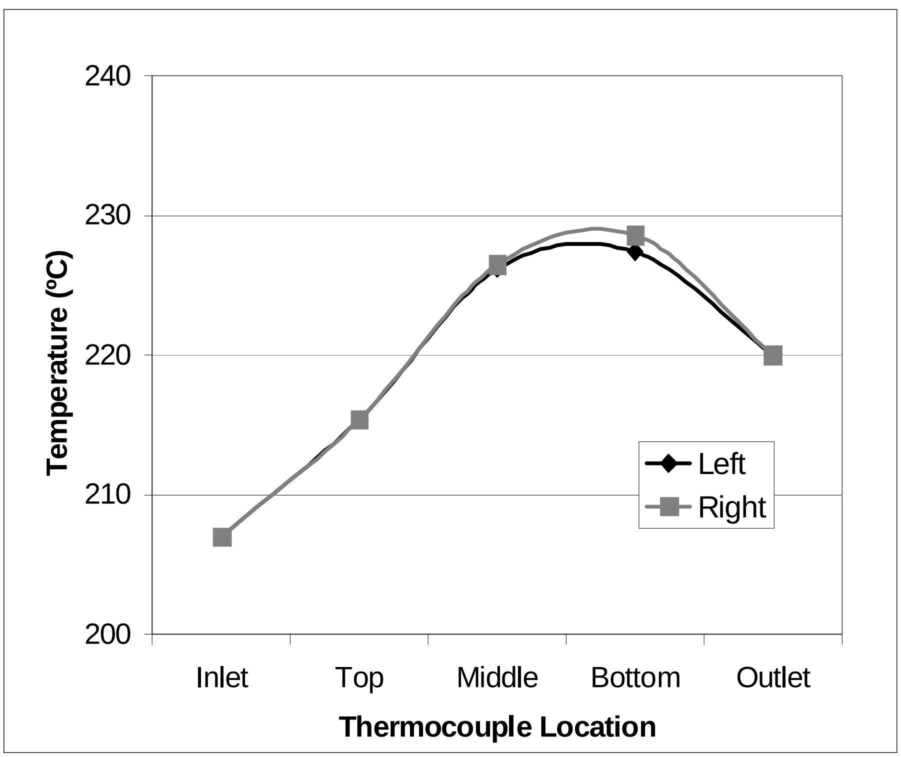


Figure 2.2-2 - ENI Gela Reactor 2 Temperature Profile

SuperClaus® Reactor

In the SuperClaus Reactor, the catalyst promotes the oxidation of H_2S directly to sulphur while inhibiting the further oxidation of H_2S and sulphur vapour to SO_2. However, other sulphur components (SO_2, COS, CS_2) are not converted to sulphur in this reactor, and should therefore be minimized at the reactor inlet for the highest unit sulphur conversions. For more discussion of the operation of a SuperClaus unit refer to the discussion paper in *Appendix* E.

At the Gela gas plant, the SuperClaus stage was preceded by three stages of Claus reaction. The air demand analyser is situated after the second Claus stage and acts on the trim air valve using the H_2S concentration. Table 2.2-3 summarizes the test results for the SuperClaus Reactor.

Table 2.2-3 - SuperClaus® Reactor Performance Summary

		Oct 2006 Test 1	**Nov 2007 Test 1**	**Nov 2007 Test 3**
Reactor Temperature	Inlet (°C)	*220*	210	210
	Maximum (°C)	*241*	248	260
Reported Temperature Rise	(degrees C)	*21*	38	50
SuperClaus Inlet	H_2S (mole % wet)	*0.37*	0.49	0.56
	SO_2 (mole % wet)	*0.068*	0.024	0.00
Predicted Temperature Rise [a]	*Theory (degrees C)*	*13*	*28*	*40*
	Rule of Thumb (degrees C)	*24*	*32*	*36*
Reactor Performance	Activity [1] (%)	***81***	**70**	**85**
	Selectivity [2] (%)	***93***	**80**	**83**
	Yield [3] (%)	***75***	**56**	**70**
Outlet Composition	H_2S (mole % wet)	*0.073*	0.130	0.085
	SO_2 (mole % wet)	*0.09*	0.082	0.083
	O_2 (mole % wet)	*1.4*	1.7	1.4
	O_2 Target (mole % wet)	*0.5 - 1.0*	*0.5 - 1.0*	*0.5 - 1.0*
	O_2 analyser (mole % wet)	*out of service*	out of service	out of service
Oxidation Air	Measured (kg/h)	*2018*	2032	1500
	Calculated (kg/h) [4]	*n/d*	2310	2100
	Required (kg/h) [5]	*n/d*	*1080*	*1200*
Pressure Drop	(mbar)	*n/d*	50-100	n/d

[a] Theory delta T is based on the simulation with the known composition. The rule of thumb assumes 65C rise for every 1% inlet H_2S.
[1] SuperClaus® Activity = moles H_2S reacted / moles H_2S in reactor inlet.
[2] SuperClaus® Selectivity = moles S_1 formed / mole H_2S reacted.
[3] SuperClaus® Yield = moles S_1 formed / moles H_2S in reactor inlet (or Yield = Activity *x* Selectivity).
[4] Calculated oxidation air flow rate to match the oxygen content in the outlet of the SuperClaus reactor.
[5] Required (calculated) oxidation air flow rate to leave 0.7% excess oxygen after the SuperClaus reactor.

Catalyst Performance

The performance of the SuperClaus Reactor has further declined since 2006, although some performance improvement was made on site by operating the reactor with a slightly higher inlet concentration of H_2S (and consequently a higher delta T in the reactor). The improvement is evident in the difference between Test 1 and Test 3 in the Table 2.2-3.

In the initial tests the poor H_2S conversion resulted in a low sulphur yield and a 0.5% loss in overall recovery efficiency as compared to 2006. The recovery efficiency was increased by 0.3% with a slightly higher inlet H_2S target. This performance in general, however, suggests a further reduction in catalyst activity from 2006. The activity can be assessed through the reactor temperature profiles and the SuperClaus tail gas H_2S and SO_2 values (Draeger stain tubes).

The inlet temperature is another variable used to control the SuperClaus reaction rate and thus the H_2S conversion. Before deciding to replace the catalyst, ENI should consider increasing the inlet temperature from 210˚C to 220˚C ***in 5 ˚C increments*** over several weeks to judge the effect on the performance of the SuperClaus catalyst.

If the recovery efficiency cannot be maintained at the levels achieved during this test, ENI should consider changing the SuperClaus catalyst at the next turnaround.

Reactor Inlet H_2S

The inlet H_2S concentration was slightly lower than the recommended value in the first two tests. The corresponding SO_2 concentration in the Claus section tail gas was relatively low in all tests, and in line with expectations. There is not much room to increase the inlet concentration more without adversely affecting the Claus reaction upstream, thus it is a balance between low SO_2 to the SuperClaus and good Claus conversion. However, it must also be remembered that the ADA setting is before the final stage of Claus. ***Maintain the target set point on the tail gas analyser at 0.8% H_2S*** (while in SuperClaus mode). The higher H_2S content will partially compensate for minor losses in catalyst activity by ensuring the bed reaches the minimum activation temperatures without affecting the Claus recovery.

Oxidation Air

The outlet (or excess) oxygen content was higher than recommended by the designer. However, this did not affect the performance of the SuperClaus catalyst measurably. Since the oxygen analyser was out of service, the oxidation air has been set to a fixed rate. ***The existing oxygen analyser can be removed, leaving the connection point steam traced and available for tail gas sampling.*** While conservative, the fixed flow rate was shown to result in more than 50% more than the maximum required residual amount of oxygen. As the catalyst ages, this excess air condition may promote increased formation of SO_2. ***It is recommended that the oxidation air flow rate be set according to the formula (to get 0.7% excess O_2):***

Oxidation Air (kg/h) = 0,15 × {**Acid Gas + SWS Off-gas**} (kg/h)

A similar equation can be obtained directly from the licensor (Jacobs). In addition, it appears that the measurement of the oxidation air flow rate is inaccurate. This flow meter should be reviewed and calibrated.

Temperature Profile

Figure 2.2-3 presents the temperature profile results for the SuperClaus (see Figure E.1-1 in *Appendix E* for the ideal profile).

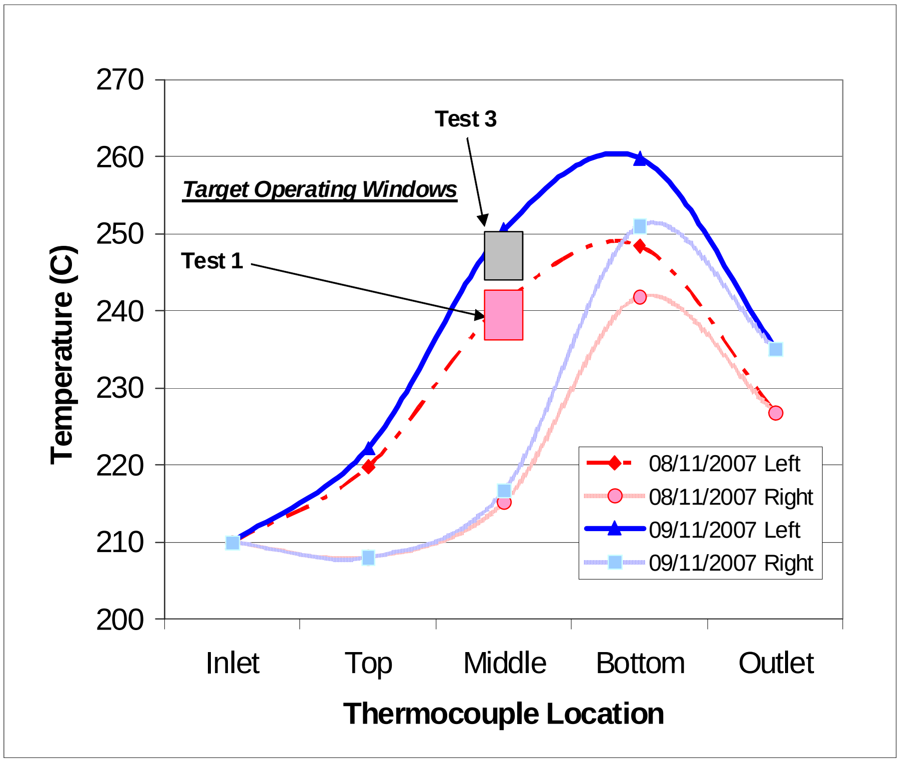


Figure 2.2-3 - SuperClaus Temperature Profile

Test 1 was made with the current inlet H_2S target of 0.65%. Test 3 was made with a target value of 0.80%. The overall delta T can be seen to have risen as a result of the higher exothermic activity. Both temperature profile curves are also following the ideal distribution in the bed to maximise the oxidation reaction and minimise SO_2 formation. This series of tests confirms that the activity of the SuperClaus is still reasonable since it responds appropriately to changes in the operating parameters.

As in previous years, one vertical line of thermocouples *(right side of DCS screen)* consistently reports a lower temperature in the top and middle sections of the reactor. The process gas inlet divides into two entry lines at the top of the reactor. There may be some partial blockage in one line which forces more gas through the other to account for the higher temperatures (channelling). It may also be related to poor temperature measurement, or problems with the catalyst bed itself (physical shifting or surface layer crusting). If the problem disappears at higher throughput, then it was likely due to flow distribution within the bed. ***If the problem persists, investigate the thermocouple***

placement, the two inlet lines, and the catalyst layer in the SuperClaus.

Reheaters

The purpose of the reheaters in the Claus plant is to control the inlet temperature to each Claus reactor and thus control the reaction (bed) temperature in each reactor.

The Gela SRU is equipped with two different styles of reheaters: the first reactor stage has a hot gas bypass (HGBP) from the first pass of the WHE. The second and third reactor stages have indirect steam reheaters. There is also an electric booster heater at the inlet to the SuperClaus, which is normally off. Table 2.2-4 summarizes the performance of the reheaters in the Gela SRU.

Table 2.2-4 - Claus Reheater Performance Summary

Performance Parameter		**Test 1**			
		Reheater 1	**Reheater 2**	**Reheater 3**	**Reheater 4**
Inlet temperature	(°C)	199	177	172	192
Outlet temperature	(°C)	260	207	195	210
Delta T (observed)	(degree C)	61	30	23	18
Hot gas bypass	(%)	9.7	-	-	-
Indirect Reheaters					
Heat duty	(kW)	419	219	149	128

No issues were reported or observed related to the operation of the reheaters.

Wasteheat Exchanger and Condensers

The purpose of the wasteheat exchanger and condensers is to remove energy from the process gas, condense the sulphur product to the liquid phase and remove the sulphur product from the process gas stream at each intermediate point.

The Gela SRU is equipped with a 40-bar steam generator on the wasteheat boiler. The common-shell first and second condensers produce 6-bar steam. The separate third condenser also produces 6-bar steam. The final condenser, following the SuperClaus, uses a closed-loop condensing system to control the outlet process temperature as low as practicable. Table 2.2-4 summarizes the performance of the exchangers in the Gela SRU.

Table 2.2-5 - Claus WHE and Condenser Performance Summary

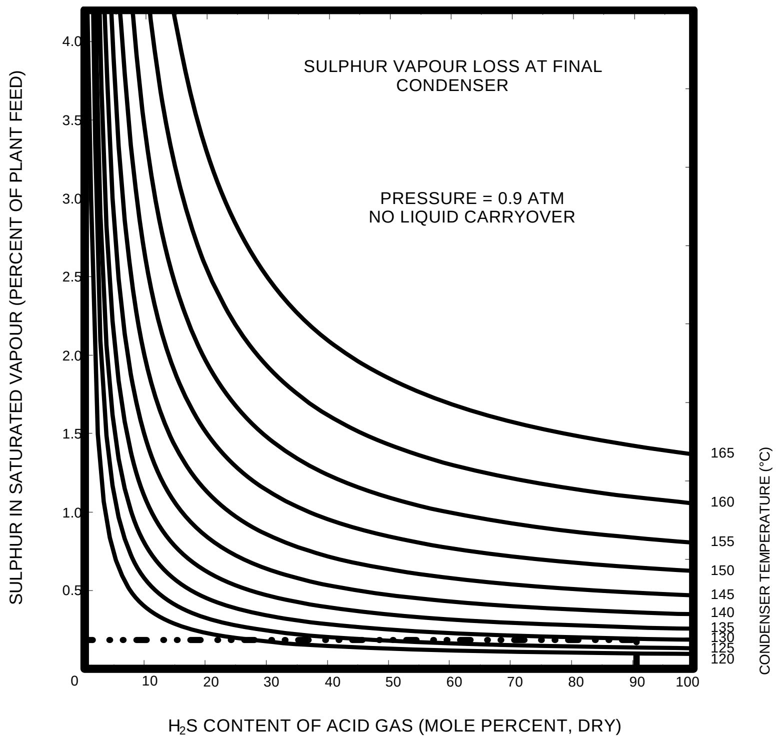
Performance Parameter	Test 1					
	WHE Pass 1 (E-1)	**WHE Pass 2 (E-1)**	**Cond 1 (E-2: 1st Pass)**	**Cond 2 (E-2 2nd Pass)**	**Cond 3 (E-16)**	**Cond 4 (E-3)**
Inlet temperature (°C)	1284	605	351	325	220	227
Outlet temperature (°C)	605	351	199	177	172	130
Delta T (degree C)	679	254	152	148	48	97
Recovered sulphur (%) (t/d)	0 0	0 0	50 69	35 49	11 15	4 6
Residual sulphur vapour [2] (%)	-	-	6.12	2.69	2.43	0.28
Heat duty (kW/)	8125	3174	1442	1403	471	856
Steam Production (barg) Measured (t/h)	37.6 9.7		6 4.9		6 1.5	0 1.8

[1] Measured from rundown sulphur production.
[2] As a percentage of the total inlet sulphur.

During the November tests, the final Condenser E-3 was operating with an outlet temperature of approximately 130ºC which was consistent with the recommended value. As illustrated in Figure 2.2-4, this resulted in a sulphur vapour loss of approximately 0.3 percent to the incinerator. Since the condenser operation can be controlled using the utility-side back-pressure, this outlet temperature can be adjusted to minimise the sulphur vapour going to the incinerator. It was operating correctly. If Gela are confident in the accuracy of this number, the back-pressure can be lowered slightly to target a process outlet temperature of 125˚C, the ideal value.

The interstage condenser temperatures are slightly higher than the typical values, but this is due to the steam pressure on the utility side (6 bar). There was minimal impact of this operation on the overall performance of the SRU.

No other issues were reported or observed with the condensers.



From : Condenser Function and Operation
H.G. Paskall, Amsterdam, 1982

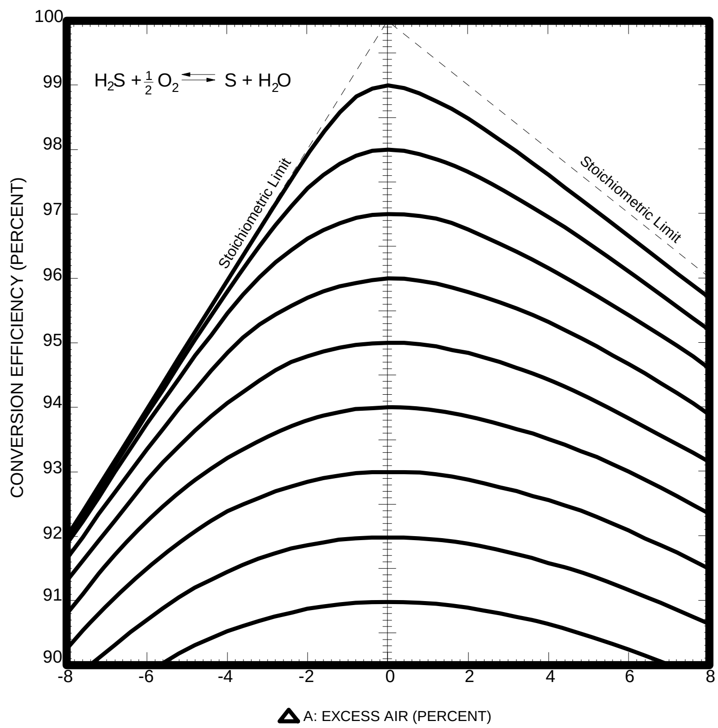
Figure 2.2-4 - Sulphur Vapour Loss At Final Condenser

Claus Air Flow Control

In order to maximize the conversion efficiency from a Modified Claus plant, the reaction stoichiometry of H_2S and SO_2 must be controlled precisely. The Gela SRU employs a combined feed forward/feed back control scheme for the combustion air flow control. This system consists of feed forward control based on the individual acid gas and SWS off-gas flow rates and an appropriate air-to-acid-gas flow ratio for each feed stream combined into one signal to the main air valve. The feed back system consists of a tail gas analyser which controls the trim air control valve. At Gela, this analyser is located after the condenser of the 2nd Claus stage (Dupont), before the 3rd stage Claus reactor.

<u>Claus Mode Operation</u>

When operating the SRU in the <u>conventional Claus mode</u>, the desired reaction stoichiometry requires an H_2S to SO_2 ratio of 2 : 1 at the Claus tail gas (excess air or air demand is zero). Under these conditions the Claus conversion is maximized. In practical terms, the desired air demand is typically ±0.5% which ensures that the conversion losses due to incorrect reaction stoichiometry are essentially zero (Figure 2.2-5).



From: Sulphur Plant Methods - H.G. Paskall, Western Research Seminar "Optimizing Sulphur Recovery" 1980 - 1983

Figure 2.2-5 - Effect of Claus Air Control on Recovery Efficiency

SuperClaus Mode Operation

When operating in SuperClaus mode, it is critical that the feed gas to the SuperClaus reactor be controlled to provide an optimum concentration of H_2S, while minimizing the SO_2 content. This results in the best operation of the SuperClaus reactor. An excess of H_2S, however, can result in runaway temperatures in this catalyst.

The typical design target is between 0.7 and 0.9 percent H_2S inlet to the SuperClaus reactor with two stages upstream. At the Gela plant, the ADA is located after the 2nd stage so the process gas must also pass through the 3rd Claus reactor. Therefore the ADA set-point could be set slightly higher to account for the conversion across this extra stage without affecting the Claus performance.

When operating in SuperClaus mode during the test period in October, the feed back control loop was operated with an H_2S set point of approximately 0.65 percent. In later testing this was increased to 0.8 percent with good results. Since the 3rd Claus reactor is not contributing much conversion, ***it is recommended that ENI change the H_2S set-point to 0.80 percent. Monitor the SuperClaus temperature trends against the H_2S set-point.***

As the catalyst activity further declines, the inlet temperature can be increased to provide better H_2S conversion (as discussed in a previous section) .

Table 2.2-6 summarizes a comparison between the measured gas composition by GC with the values measured by the tail gas analyser.

Table 2.2-6 - Tail Gas Analyser Comparison

Parameter		**Test 1**	**Test 2**	**Test 3**
Tail Gas Analyser	*H_2S set point (mole % wet)*	*0.65*	*0.65*	*0.80*
	H_2S (mole % wet)	0.57	0.54	0.71
	SO_2 (mole % wet) [1]	---	---	---
Gas Analysis [2]	H_2S (mole % wet)	0.50	n/a	n/a
	SO_2 (mole % wet)	0.13		

[1] SO_2 is not reported by ADA to the DCS.
[2] As measured at the outlet of the 2nd reactor near the analyser measurement.

The tail gas analyser was reporting H_2S values similar to those measured on site by GC indicating reasonable operation of the analyser–the accuracy should be better to improve control over the process. ***The analyser should be serviced and calibrated to improve the accuracy***.

The SO_2 value from the tail gas analyser was not available through the DCS history. ***The SO_2 data point (AR-101) needs to be added to the DCS historical storage system.***

Incinerator Performance and Emissions

The purpose of the incinerator is to oxidise all of the sulphur compounds (H_2S, COS, CS_2 and elemental sulphur) to SO_2. This ensures that these compounds are not emitted to the atmosphere in significant quantities. The incinerator also provides substantial heat to the tail gas stream so that it disperses well after exiting the top of the stack. At Gela, oxygen is measured in the outlet from Incinerator B-2, but not SO_2 concentration. In Gela, much of the heat of incineration is recovered through a wasteheat boiler/super-heater. This equipment produces 40-bar steam.

In addition to the standard gas sampling, a duplicate absorption-style sample was also completed on the stack effluent to determine the water content, the SO_2 emission, and the SO_3 emission. These values were determined over a two-hour period. Table 2.2-7 on the following page summarizes the results from the B-2 incinerator evaluation.

The destruction of TRS (Total Reduced Sulphur) species was good with no detection of these components.

The stack oxygen analyser was providing a value to the DCS but, according to Gela Operations, it is out of service as it was in 2005 and 2006. The results in the table indicate that the measured excess air was much higher than necessary. Considerable fuel could be conserved if the air were properly controlled down to between 2 and 3 percent excess oxygen. ***The oxygen analyser (AR144) should be repaired and put back into service.*** Since there is also measurable H_2S in this fuel gas, the sulphur emissions are increased slightly by using excessive fuel.

As in previous tests at Gela, the concentration of H_2O, SO_2, and SO_3 in the incinerator effluent were determined. The full sample and testing details are given in *Appendix A*. During the October tests, the average emission of SO_3 was calculated to be 184 kg/day *(an average of two tests)*, with SO_2 emissions ranging from 2250 kg/d to 4000 kg/d. The following Table 2.2-7 summarises the performance of the incinerator and the emissions to atmosphere.

Table 2.2-7 - Thermal Incinerator Performance Summary			
		October 2006 ***Tests 3, 4***	**09-Nov-2007 [1]**
Incinerator/Stack Temperature	Bottom (°C) Mid (°C) Top (°C)	*n/a* *600* *480*	434 600 518
Fuel Gas Flow rate	(kg/h)	*515*	513
Air Flow rate	Primary + Secondary (t/h)	*12.5*	12.8
Calculated Adiabatic Temperature	(ºC)	-	-
Excess oxygen	Analyser (mole % wet) Gas Analysis (mole % wet) *Target (mole % wet)*	*out of service* *5.3 / 6.3* *2 - 3*	out of service 4.6 / 6.0 *2 - 3*
Stack Flow	Stack Analyser (t/h) Calculated (t/h)	*n/a* *34.2 / 37.9*	n/a 30.7 / 33.3
Stack Sulphur Residuals (*GC values*)	H_2S (ppmv, wet) COS (ppmv, wet) CS_2 (ppmv, wet)	*0* *0* *0*	0 0 0
Water content	Measured (%) Calculated (%)	*22 / 17* *27 / 25*	19 / 19 27 / 26
Pollutant Emission Rates (at actual effluent conditions)			
H_2S	(ppmv, wet) (mg/Nm^3)	*0* *0*	0 0
COS	(ppmv, wet) (mg/Nm^3)	*0* *0*	0 0
CS_2	(ppmv, wet) (mg/Nm^3)	*0* *0*	0 0
SO_3 Concentration	(ppmv, wet)	*74 / 89*	143 / 8
SO_3 Emission	**(mg/Nm^3)** **(kg/d)** **Average Emission (kg/d)**	***264 / 318*** ***187 /224*** ***206***	**511 / 30** **348 / 20** **184**
SO_2 Concentration	GC Gas Analysis (ppmv, wet) Absorption Method (ppmv, wet)	*930 / 865* *1394 / 1563*	1480 / 1140 2060 / 1156
SO_2 Emission	**(mg/Nm^3)** **Calculated (kg/d)** **Average Emission (kg/d)**	***2655 / 2469*** ***1876 / 1744*** ***1810***	**5887 / 3303** **4005 / 2247** **3126**

[1] Based on the stack effluent absorption tests (2 tests) and the GC analyses.

3.0 Conclusions and Recommendations

Claus Section

- For the SRU Claus section, the measured conversion efficiency average 97.5 percent which confirms good overall operation.

- Reactor 1 and Reactor 2 combined were achieving a Claus conversion efficiency consistent with the equilibrium values which indicated fully activated catalyst.

  Recommendation: No changes are required to the Reactor 1 catalyst.

  Recommendation: No changes are required to the Reactor 2 catalyst.

- Reactor 1 was achieving excellent COS conversion rates (100 percent) which further confirmed the good catalyst activity in R1. The CS_2 content in the process gas was minimal.

  Recommendation: Continue to operate Reactor 1 with a maximum bottom-bed temperature between 300°C and 320°C.

- Based on past testing, Reactor 2 was operating with an outlet dewpoint margin consistent with the recommended range.

  Recommendation: Operate the Reactor 2 with a bottom-bed temperature of 225°C for the best conversion.

- Reactor 3 was also operating with an outlet dewpoint margin consistent with the recommended value. While the conversion in this reactor was consistent with expectations, the evaluation indicated early signs of deactivation in this catalyst.

  Recommendation: Perform a rejuvenation on Reactor 3 catalyst while monitoring the tail gas H_2S and SO_2 concentrations.

- In order to avert the potential for sulphur condensation in Reactor 3, the recommended bottom-bed temperature should be increased slightly.

  Recommendation: Operate the Reactor 3 with a bottom-bed temperature of 195°C.

- The acid gas analyses indicated a very clean feed gas stream during the test period. The level of hydrocarbon contamination was negligible.

- The measured ammonia breakthrough after the reaction furnace was consistent with good destruction (<40 ppmv).

- The measured and calculated combustion air flow were in good agreement.

- All reheaters were performing to expectations.

- All condensers were performing to expectations.

- The tail gas analyser was performing adequately. However, the H_2S accuracy could be improved. The SO_2 data point was not available on the DCS historical system and could not be assessed.

  Recommendation: Service and calibrate the tail gas analyser. Add the SO_2 data point (AR101) to the DCS historical (off-line storage) system.

SuperClaus Section

- The average recovery efficiency to the outlet of the SuperClaus reactor was 98.78 percent (un-optimised). After partial site optimisation, this was increased to 99.00. This was still lower than expectations and lower than the previous October 2006 tests and indicated a slight decline in the performance of the SuperClaus catalyst.

- The average recovery efficiency to the incinerator was 99.15 percent (optimised). This indicated minimal sulphur entrainment from the coalescer and no SuperClaus bypass valve leakage.

- The performance parameters for the SuperClaus reactor was initially 70 percent activity; 80 percent selectivity, for a combined yield of 56 percent. Partial optimisation brought these values to 85, 83, and 70 percent, respectively. This was also lower than the previous test indicating a further decline in the performance of the SuperClaus catalyst.

  Recommendation: If the recovery efficiency continues to decline, ENI should consider increasing the inlet temperature. Move from the current 210 ℃ to 220 ℃ in 5 ℃ steps. If this fails to improve the conversion, change the SuperClaus catalyst at the next turnaround.

- The temperature profile in the reactor was meeting the design target on only one side of the reactor. The other side was significantly cooler, suggesting poor inlet distribution, gas channelling, or poor temperature measurement.

  Recommendation: Review the reactor temperature distribution (left-right) to determine the cause of the uneven horizontal profile. Correct this at the next opportunity.

- The excess oxygen in the outlet of the SuperClaus was 50% higher than required by design. This could lead to excessive SO_2 formation, particularly at higher reactor temperatures.

  Recommendation: Adjust the oxidation air flow to match the load on the SRU according to the formula given in this report. Consult the designer in order to implement an oxidation air flow calculation into the DCS.

- When operating in SuperClaus mode during the test period in October, the feed back control loop was operated with an H_2S set point of approximately 0.65%.

  Recommendation: Increase the H_2S set-point to 0.8 percent. Monitor the SuperClaus temperature trends against the H_2S set-point.

- The final condenser E-3 was operating with an outlet temperature of 130°C which resulted in sulphur vapour losses of 0.3 percent of the total inlet sulphur. This was consistent with optimized conditions, but could be improved.

  Recommendation: Operate Condenser B-3 with an outlet temperature of 125°C if ENI are confident in this process temperature measurement.

Incinerator Section

- The incinerator outlet excess oxygen was much higher than necessary for this configuration. It could be optimised to reduce fuel consumption. The oxygen analyser was not working during the test period.

  Recommendation: Repair the oxygen analyser (AR-144) and put it back in service. Control the excess air to result in an outlet oxygen between 2 and 3 percent.

- No reduced sulphur species were found in the outlet of the incinerator which indicated good combustion.

  Recommendation: Continue to operate the incinerator with a bottom temperature of 220°C.

Appendix A

Analytical Results

Table A.1-1 - Sample Locations and Analysis Methods			
	SAS[1]	**High Level NH_3[2]**	**Trace Level NH_3[3]**
Acid Gas	✔		
Sour Water Stripper Gas	✔	✔	
Condenser 1 outlet 1st pass	✔		✔
Condenser 1 outlet 2nd pass	✔		
Condenser 2 outlet	not available		
Condenser 3 outlet			
SuperClaus reactor inlet (before Oxidation air)	✔		
SuperClaus coalescer outlet	✔		
Stack Gas	✔		
Fuel Gas	✔		

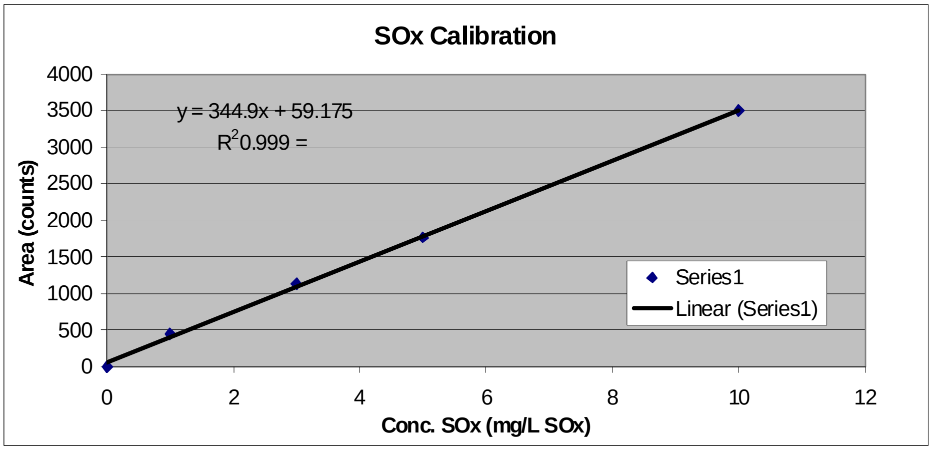
1 Sulphur Analytical System™ - Sulphur Experts proprietary analysis for bulk sour gas process samples.
2 High level NH_3 - Analysis for high levels of ammonia (up to 100% NH_3).
3 Trace level NH_3 - Sulphur Experts proprietary Analysis for trace levels of ammonia (to less than 5 ppm NH_3).

Calibration Data

Company: ENI
Locaiton: Gela
Job #: SE739

Analyst: MAF
Date: 13-Nov-07

Component: SOx



Calibration:

Std Conc. Mg/L SOx	Area (counts)
0	0
1.00	449.5
3.00	1130.5
5.00	1769
10.00	3500

Calculated:

Slope:	344.9013
Intercept:	59.17516
R^2	0.999039

Raw Data:

Sample #	Dillution Aliquot (ml)	Dillution Vol (ml)	Area Counts	Conc. (mg/L SOx)	Ave. Conc. (mg/L SOx)	Comment
1-IPA	1	500	1023	1397.25		
2-H2O2	1	5000	801	10754.16		
3-IPA-SO2	1	25	698	46.30		
3-IPA-SO3	1	25	1022.5	69.83		
4-H2O2	1	1000	1625	4539.92		
3ppm	1	1	1144	3.15		

SO2 / SO3 ABSORPTION DATA WORK SHEET

Company: **ENI**
Location: **Gela, Sicily**
Job No. **SE739**

Date: Nov 8 2007
Created By: DJD
Checked By: PRD

Unit		Stack	Stack		
Test No.		1	2		
Time:		12:40-13:15	13:30-14:08		
Meter Fact.		1.00	1.00		
B.P.	(mm Hg)	761.24	761.24		
Gas Vol.	(Litres)	300	225		
T. meter	(deg.C)	25	25		
P.meter	(mm Hg)	-61.5	-61.5		
P.Impinger	(mm Hg)	-61.5	-61.5		
H2O Cond.	(ml)	47	35		
Soln. Vol.	H2O2 (ml)	258	254		
	IPA (ml)	138	120		
Analysis	SO2 (mg/L)	10754.162	4586.225		
	SO3 (mg/L)	1397.247	69.826		
				AVERAGE	
SO2	(ppm,v/v,wet)	2060	1156	**1608**	
SO3	(ppm,v/v,wet)	143	8	**76**	
SO2	(mg/wscm)*	5886.86	3303.25	**4595**	
SO3	(mg/wscm)*	511.28	29.69	**270**	
SO2	(kg/d)	4005.1	2247.4	**3126**	*at stack conditions 09Nov*
SO3	(kg/d)	347.8	20.2	**184**	*filename gela-stk.s40 (ISUL8)*
H2O	(mole %)	19.28	19.19	**19**	

* at 0degC.&760 mm Hg.

Table A.1-2 TEST 1

Gas Chromatographic Analyses
(Mole Percent)

ENI | Nov 08, 2007
Gela, Sicily | Job Number: SE739

Sample No:	2	3	5	6	7	8
Site:	Acid Gas	Sour Water Strip.	Cond.1 Outlet	Cond.3 Outlet	Super Claus Inlet	Tail Gas
Time:	12:37	12:30	13:20	13:42	13:30	13:35
H2:	0.000	19.782	2.971	2.706	2.965	2.534
Ar:	0.000	0.000	0.971	1.085	1.078	1.071
O2:	0.000	0.000	0.000	0.000	0.000	2.404
N2:	0.083	3.937	81.221	90.708	90.161	89.545
CH4:	0.085	17.923	0.000	0.000	0.000	0.000
CO:	0.000	0.177	0.718	0.638	0.718	0.582
CO2:	5.438	0.613	2.855	3.939	4.300	3.557
C2H4:	0.014	0.768	0.000	0.000	0.000	0.000
C2H6:	0.045	7.200	0.000	0.000	0.000	0.000
H2S:	93.809	34.589	6.546	0.745	0.736	0.186
COS:	0.002	0.002	0.542	0.006	0.006	0.005
C3H8:	0.177	7.449	0.000	0.000	0.000	0.000
SO2:	0.000	0.000	4.172	0.173	0.036	0.117
CS2:	0.000	0.000	0.000	0.000	0.000	0.000
iC4H10:	0.019	1.321	0.000	0.000	0.000	0.000
C4H10:	0.086	4.225	0.000	0.000	0.000	0.000
iC5H12:	0.005	0.554	0.000	0.000	0.000	0.000
C5H12:	0.018	0.708	0.000	0.000	0.000	0.000
C6H14+:	0.015	0.642	0.000	0.000	0.000	0.000
NH3:	**	**	0.003	**	**	**
RxSH:	0.127	0.000	**	**	**	**
BTEX:	0.076	0.110	**	**	**	**
	100.000	100.000	100.000	100.000	100.000	100.000
H2S/SO2:	---	---	1.569	4.313	20.265	1.589
C/S Ratio:	0.072	2.583	0.365	4.961	6.461	13.475

Zero means not detected | Trace means less than 0.0005
Sampled water and sulphur free | ** = Not Analysed

Sulphur Experts Inc. | Heerhugowaard, The Netherlands

Table A.1-3 TEST 2

Gas Chromatographic Analyses
(Mole Percent)

ENI
Gela, Sicily

Nov 08, 2007
Job Number: SE739

Sample No:	9	10	4	11
Site:	Super Claus Inlet	Tail Gas	Fuel Gas	Stack Gas
Time:	15:50	15:53	13:50	16:08
H2:	2.751	2.356	39.958	0.000
Ar:	1.073	1.075	0.000	1.048
O2:	0.000	2.173	0.000	6.473
N2:	90.695	89.875	3.392	87.579
CH4:	0.000	0.000	32.613	0.000
CO:	0.632	0.580	1.523	0.162
CO2:	3.934	3.635	0.260	4.531
C2H4:	0.000	0.000	2.297	0.000
C2H6:	0.000	0.000	7.602	0.000
H2S:	0.893	0.172	0.379	0.000
COS:	0.005	0.005	0.004	0.003
C3H8:	0.000	0.000	5.771	0.000
SO2:	0.018	0.130	0.000	0.204
CS2:	0.000	0.000	0.000	0.000
iC4H10:	0.000	0.000	1.050	0.000
C4H10:	0.000	0.000	2.346	0.000
iC5H12:	0.000	0.000	0.770	0.000
C5H12:	0.000	0.000	1.008	0.000
C6H14+:	0.000	0.000	0.869	0.000
NH3:	**	**	**	**
RxSH:	**	**	0.000	**
BTEX:	**	**	0.158	**
	100.000	100.000	100.000	100.000
H2S/SO2:	50.081	1.324	---	0.000
C/S Ratio:	4.994	13.764	258.923	22.694

Zero means not detected
Sampled water and sulphur free

Trace means less than 0.0005
** = Not Analysed

Sulphur Experts Inc. Heerhugowaard, The Netherlands

Table A.1-4 TEST 3

Gas Chromatographic Analyses
(Mole Percent)

ENI
Gela, Sicily

Nov 09, 2007
Job Number: SE739

Sample No:	12	13	14	4	15	17
Site:	Acid Gas	Super Claus Inlet	Tail Gas	Fuel Gas	Stack Gas	Stack Gas
Time:	09:15	10:32	10:32	13:50	10:50	12:35
H2:	0.000	2.713	2.339	39.958	0.000	0.000
Ar:	0.000	1.087	1.080	0.000	1.048	1.039
O2:	0.000	0.000	2.073	0.000	6.404	7.878
N2:	0.050	90.904	90.311	3.392	87.630	86.881
CH4:	0.076	0.000	0.000	32.613	0.000	0.000
CO:	0.000	0.606	0.537	1.523	0.155	0.130
CO2:	5.089	3.863	3.416	0.260	4.558	3.917
C2H4:	0.010	0.000	0.000	2.297	0.000	0.000
C2H6:	0.050	0.000	0.000	7.602	0.000	0.000
H2S:	94.194	0.823	0.121	0.379	0.000	0.000
COS:	0.003	0.004	0.005	0.004	0.000	0.000
C3H8:	0.183	0.000	0.000	5.771	0.000	0.000
SO2:	0.000	0.000	0.118	0.000	0.205	0.154
CS2:	0.000	0.000	0.000	0.000	0.000	0.000
iC4H10:	0.017	0.000	0.000	1.050	0.000	0.000
C4H10:	0.074	0.000	0.000	2.346	0.000	0.000
iC5H12:	0.001	0.000	0.000	0.770	0.000	0.000
C5H12:	0.008	0.000	0.000	1.008	0.000	0.000
C6H14+:	0.021	0.000	0.000	0.869	0.000	0.000
NH3:	**	**	**	**	**	**
RxSH:	0.140	**	**	0.000	**	**
BTEX:	0.085	**	**	0.158	**	**
	100.000	100.000	100.000	100.000	100.000	100.000
H2S/SO2:	---	---	1.021	---	0.000	0.000
C/S Ratio:	0.068	5.409	16.166	258.923	22.943	26.264

Zero means not detected
Sampled water and sulphur free

Trace means less than 0.0005
** = Not Analysed

Sulphur Experts Inc. Heerhugowaard, The Netherlands

Table A.1-5
SuperClaus Performance Trends

Gas Chromatographic Analyses
(Mole Percent)

ENI Nov 08, 2007
Gela, Sicily Job Number: SE739

Sample No:	8	10	14	15	17
Site:	Tail Gas	Tail Gas	Tail Gas	Stack Gas	Stack Gas
Date:	08-11	08-11	09-11	09-11	09-11
Time:	13:35	15:53	10:32	10:50	12:35
H2:	2.534	2.356	2.339	0.000	0.000
Ar:	1.071	1.075	1.080	1.048	1.039
O2:	2.404	2.173	2.073	6.404	7.878
N2:	89.545	89.875	90.311	87.630	86.881
CH4:	0.000	0.000	0.000	0.000	0.000
CO:	0.582	0.580	0.537	0.155	0.130
CO2:	3.557	3.635	3.416	4.558	3.917
C2H4:	0.000	0.000	0.000	0.000	0.000
C2H6:	0.000	0.000	0.000	0.000	0.000
H2S:	***0.186***	***0.172 ->***	***0.121***	0.000	0.000
COS:	0.005	0.005	0.005	0.000	0.000
C3H8:	0.000	0.000	0.000	0.000	0.000
SO2:	***0.117***	***0.130 ->***	***0.118***	***0.205 ->***	***0.154***
CS2:	0.000	0.000	0.000	0.000	0.000
iC4H10:	0.000	0.000	0.000	0.000	0.000
C4H10:	0.000	0.000	0.000	0.000	0.000
iC5H12:	0.000	0.000	0.000	0.000	0.000
C5H12:	0.000	0.000	0.000	0.000	0.000
C6H14+:	0.000	0.000	0.000	0.000	0.000
NH3:	**	**	**	**	**
RxSH:	**	**	**	**	**
BTEX:	**	**	**	**	**
	100.000	100.000	100.000	100.000	100.000
H2S/SO2:	1.589	1.324	1.021	0.000	0.000
C/S Ratio:	13.475	***13.764 ->***	***16.166***	22.943	26.264

Zero means not detected Trace means less than 0.0005
Sampled water and sulphur free ** = Not Analysed

Sulphur Experts Inc. Heerhugowaard, The Netherlands

Appendix B

Plant Data

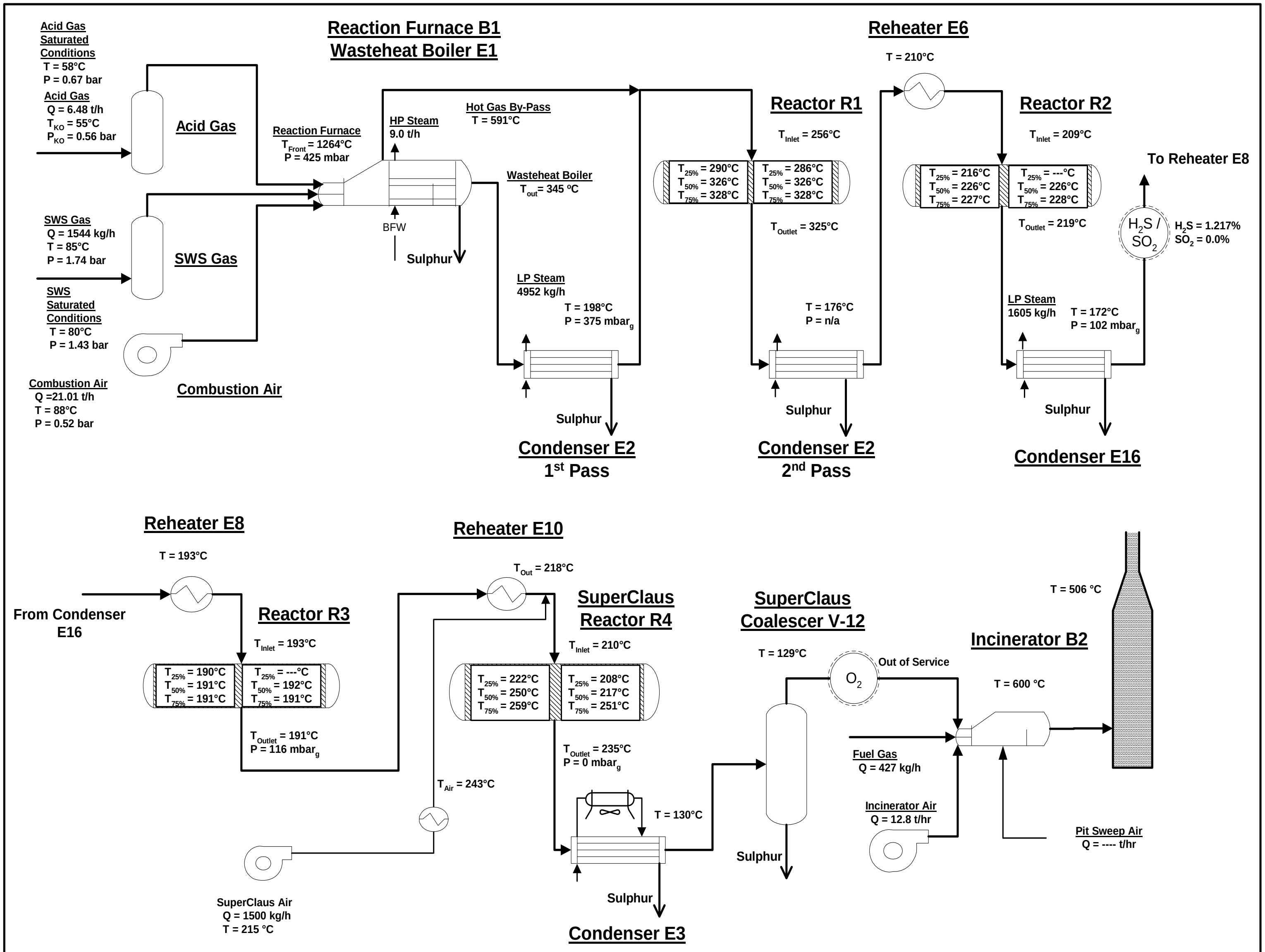


Figure B.1-1 ENI Raffineria di Gela - Plant Process Data for Test 3

Figure B.1-1 - Plant Process Data - Test 3

Cannot Clog – Does Not Leak

Since 1921, Strahman Valves Inc. has been a Pioneer and Leader in the Sampling Valve Industry by first developing the Piston-Type Sampling Valve series. The unique design of dual sealing rings at the time was truly innovative and set Strahman apart from other valve companies. The quality and integrity of manufacturing excellence has provided Strahman customers with a long lasting, reliable product that work for years with trouble free performance.

Visit our website at www.strahmanvalves.com and learn more about the Strahman product line that differentiates us from other manufacturers of Sampling Valves.

- Piston moves through the valve clearing out any material that may harden
- Piston extension breaks through any crust or scale that forms
- Dual sealing ring arrangement keeps the valve from leaking to the atmosphere
- No dead spot – piston completely fills the valve interior
- Always gives a live sample – new product is introduced into the sampling area when the piston retracts
- Opening indicator provides operators clear and simple indication of the valve position
- 316 stainless steel body is standard – available in the following materials:
  - ◆ Alloy 20 ◆ Hastelloy B or C
  - ◆ Titanium ◆ Nickel
  - ◆ Monel ◆ Inconel
  - ◆ Other stainless steels and materials available on request
- Body extensions can be customized for special applications and installations
- Couplings, tees, adapters and inserts allow a wide variety of installation possibilities
- Standard and custom piston extensions are available to unclog almost any depth of piping dead space
- Strahman offers a wide range of product options that provide great flexibility of choice to the user. These options are:
  - ◆ Inlet and outlet connections can be threaded, flanged, or socket welded
  - ◆ Connections can be US Standard, DIN, BSP, JIS or other
  - ◆ Actuation can be hand crank, handwheel, gear operator, electric actuator or cylinder actuator (air or hydraulic)
  - ◆ Local and remote position indication available
  - ◆ Positioners available
  - ◆ Sampling bottles, flushing connection and other accessories are available upon request

Pressure and temperature ratings are in accordance with ASME B16.34 pressure class 600. See below for 316 & 316L stainless steel material. For Pressure/Temperature ratings in other materials consult Strahman Valves.

NOTE: Maximum temperature allowable for 316L

Pressure/Temperature Ratings Table

													316L MAX
	Pressure	psig	275	235	215	195	170	140	110	80	50	35	65
316	**CL 150**	(barg)	(19.0)	(16.2)	(14.8)	(13.4)	(11.7)	(9.7)	(7.6)	(5.5)	(3.4)	(2.4)	(4.5)
& 316L	**Temperature**	Deg. F	100	200	300	400	500	600	700	800	900	950	**850**
		(Deg. C)	(37.8)	(93.3)	(148.9)	(204.4)	(260.0)	(315.6)	(371.1)	(426.7)	(482.2)	(510.0)	(454.4)
	Pressure	psig	720	620	560	515	480	450	430	420	400	385	420
316	**CL 300**	(barg)	(49.7)	(42.8)	(38.6)	(35.5)	(33.1)	(31.0)	(29.7)	(29.0)	(27.6)	(26.6)	(29.0)
& 316L	**Temperature**	Deg. F	100	200	300	400	500	600	700	800	900	950	**850**
		(Deg. C)	(37.8)	(93.3)	(148.9)	(204.4)	(260.0)	(315.6)	(371.1)	(426.7)	(482.2)	(510.0)	(454.4)
	Pressure	psig	1440	1240	1120	1025	955	900	870	845	830	775	835
316	**CL 600**	(barg)	(99.3)	(85.5)	(77.2)	(70.7)	(65.9)	(62.1)	(60.0)	(58.3)	(57.2)	(53.4)	(57.6)
& 316L	**Temperature**	Deg. F	100	200	300	400	500	600	700	800	900	950	**850**
		(Deg. C)	(37.8)	(93.3)	(148.9)	(204.4)	(260.0)	(315.6)	(371.1)	(426.7)	(482.2)	(510.0)	(454.4)

MAX. TEMP

LAM/TFE, TFM	450°
MR (medium range) rings	650°
Graphite rings	1000°

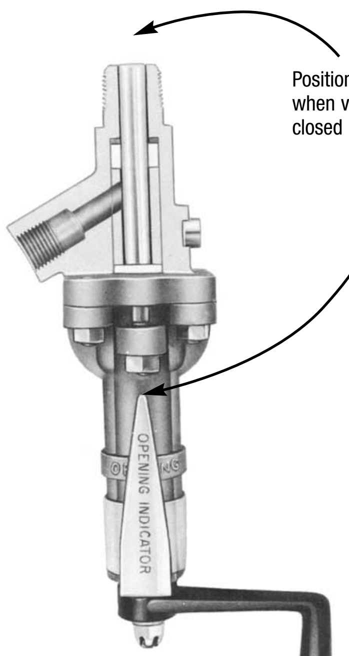
PED Compliant

To keep abreast of our customers' requirements, Strahman Valves, Inc. includes an OPENING INDICATOR on its line of hand operated Piston-Type Sampling Valves (on all models up to 6" piston extensions*). The indicator shows the operator of the valve that the product, which is normally under pressure, is in position to start flowing through the valve and tells him to be cautious and open the valve slowly so there will not be a sudden surge of product.

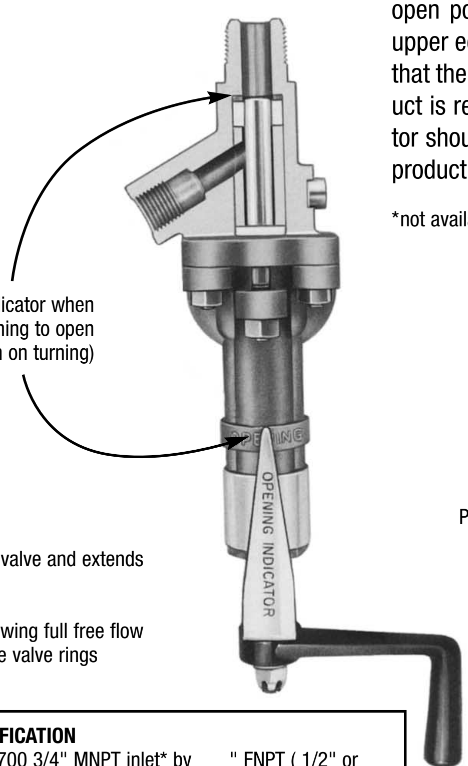
The INDICATOR is attached to the valve directly under the valve handle and extends up the side of the bonnet. When the valve is in the fully closed (extended) position the indicator extends beyond the upper edge of a raised ring on the bonnet, which is marked "OPENING."

As the operator turns the valve handle counter-clockwise, the indicator lowers as the piston is being retracted to the fully open position. When the tip of the indicator is flush with the upper edge of the "OPENING" ring on the bonnet it is indicating that the piston is moving through the sealing ring and the product is ready to flow through the valve. At this point, the operator should turn the handle slowly to avoid any sudden burst of product which would be under pressure.

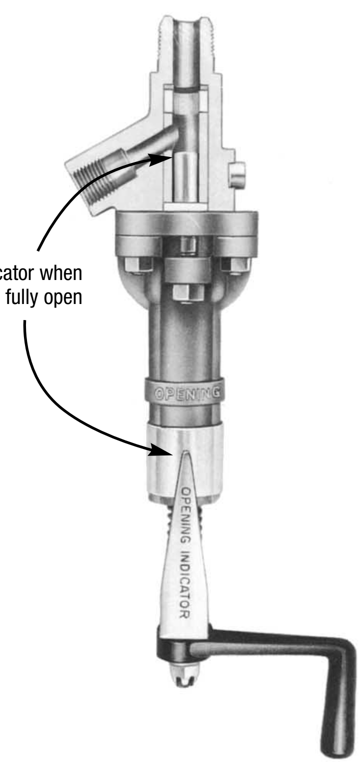
*not available on valves above 6" piston extensions.



Position of indicator when valve is fully closed



Position of indicator when valve is beginning to open (slow down on turning)



Position of indicator when valve is fully open

AVAILABLE ON MODELS

SV-500 ⅜" x ¼"	SV-700 ¾" x ½"
SV-600 ½" x ⅜"	SV-800 1" x ¾"
SV-700 FLG	SV-800 FLG
SV-900	SV-1000

1. No dead spot – piston completely fills valve and extends to inner surface of pipe
2. Always gives a live sample
3. Open-piston is retracted into body allowing full free flow
4. Valve is kept tight by two compressible valve rings

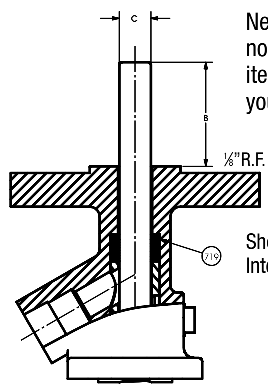
PISTON-TYPE SAMPLING VALVE SPECIFICATION

The Sampling Valve shall be a Model SV700 3/4" MNPT inlet* by ___" FNPT (1/2" or 3/4") outlet*. The body shall be investment cast 316 stainless steel and internals of 316 SS fabricated wetted parts. The valve shall be a soft seat design of Teflon that shall meet ANSI Class VI, bubble tight shut off. The piston shall have linear travel with a rising stem with multi-turn handle for manual operation, or a pneumatic or hydraulic cylinder for automatic operation. The piston shall completely fill the valve interior allowing for no cavities (dead space), the valve will be self-pigging and will not clog. The Sampling Valve will insure new product samples are always taken with no prior sample material remaining. The piston shall have a ____" extension that shall extend beyond the threaded inlet to break through any product crust insuring proper sample flow.

*Also available with Flanged, or SW inlet and outlet connection. For other Sampling Valve Models refer to the size tables.

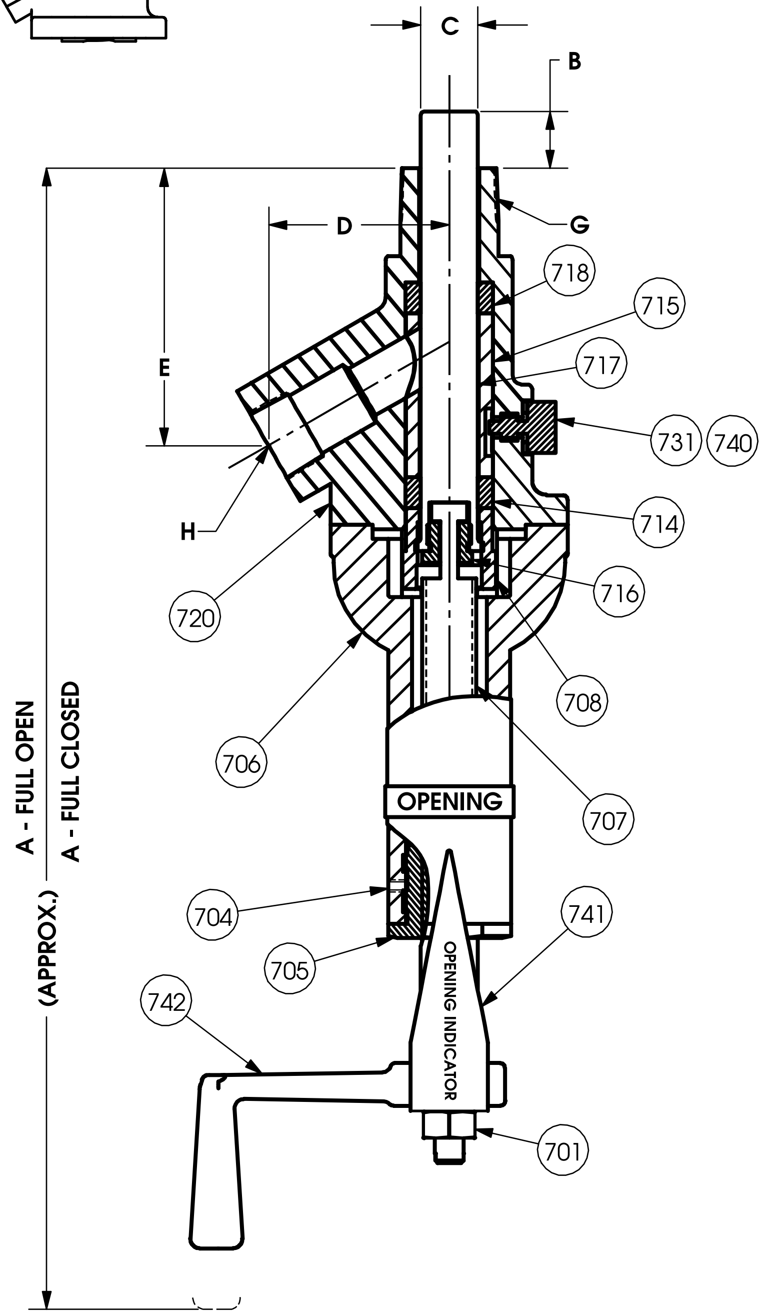
PED Compliant

Hand Operated Sampling Valves SV-500, SV-600, SV-700 and SV-800



New Sampling Valves SV-500, SV-600 and SV-700 body no longer require a base ring. For older valves base rings, item #719 may be required as spare parts. Please consult your Strahman representative for verification.

Shown with
Integral Flange Option



Item	Name	Standard Material
701	Lock Nut	Stainless Steel Type 304
704	Bushing Lock Screw	Stainless Steel Type 304
*705	Bushing	Bronze
706	Bonnet	Stainless Steel Type 304
*707	Stem	Stainless Steel Type 416
708	Gland	Stainless Steel Type 304
712	Bonnet Nuts	Stainless Steel Type 303
713	Bonnet Studs	Stainless Steel Type 304
*714	Gland Ring	TFE
715	Cage	Stainless Steel Type 316
*716	Split Nut	Stainless Steel Type 316
*717	Piston	Stainless Steel Type 316
*718	Inlet Ring	TFE
719	Base Ring	
720	Body	Stainless Steel Type 316
724	Gland Nuts	Stainless Steel Type 303
725	Gland Studs	Stainless Steel Type 304
731	Cage Lock	Stainless Steel Type 316
*740	Cage Lock Gasket	RTFE
741	Opening Indicator	Stainless Steel Type 304
742	Crank Handle	Malleable Iron

*Denotes recommended spare parts
Wetted parts underlined

SV-500 3/8" x 1/4" ANSI 600

A Closed	A Open	B	C	D	E	G NPT	H NPT
11 3/8"	13 3/4"	0"	.243"	1 7/8"	3 1/32"	3/8"	1/4"
13 3/8"	17 3/4"	2"	.243"	1 7/8"	3 1/32"	3/8"	1/4"
15 3/8"	21 3/4"	4"	.243"	1 7/8"	3 1/32"	3/8"	1/4"
17 3/8"	25 3/4"	6"	.243"	1 7/8"	3 1/32"	3/8"	1/4"

SV-600 1/2" x 3/8" ANSI 600

A Closed	A Open	B	C	D	E	G NPT	H NPT
11 3/8"	13 3/4"	0"	.368"	1 7/8"	3 1/32"	1/2"	3/8"
13 3/8"	17 3/4"	2"	.368"	1 7/8"	3 1/32"	1/2"	3/8"
15 3/8"	21 3/4"	4"	.368"	1 7/8"	3 1/32"	1/2"	3/8"
17 3/8"	25 3/4"	6"	.368"	1 7/8"	3 1/32"	1/2"	3/8"

SV-700 3/4" x 1/2" & 3/4" x 3/4" ANSI 600

A Closed	A Open	B	C	D	E	G NPT	H NPT
11 3/8"	13 7/8"	0"	.590"	1 7/8"	3 1/32"	3/4"	1/2", 3/4"
13 3/8"	17 7/8"	2"	.590"	1 7/8"	3 1/32"	3/4"	1/2", 3/4"
15 3/8"	21 7/8"	4"	.590"	1 7/8"	3 1/32"	3/4"	1/2", 3/4"
17 3/8"	25 7/8"	6"	.590"	1 7/8"	3 1/32"	3/4"	1/2", 3/4"

SV-800 1" x 3/4" & 1"x 1" ANSI 600

A Closed	A Open	B	C	D	E	G NPT	H NPT
12 5/8"	15 1/2"	0"	.787"	2 3/8"	3 5/8"	1"	3/4", 1"
14 5/8"	19 1/2"	2"	.787"	2 3/8"	3 5/8"	1"	3/4", 1"
16 5/8"	23 1/2"	4"	.787"	2 3/8"	3 5/8"	1"	3/4", 1"
18 5/8"	27 1/2"	6"	.787"	2 3/8"	3 5/8"	1"	3/4", 1"

"B" DIM ± 1/16"
"C" DIM ± .002"

Forward Deck details see page 7, Item #712, #713, #724, #725

PED Compliant

Appendix C

Material Balances

Table C.1-1

Material Balance

Claus-SuperClaus Test 1

ENI									**Date :**		**08-Nov-07**
Raffineria di Gela									**File :**		**SE739**
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Composition (kmol/h)	Acid Gas	SWS	Combustion Air to B-1	E2-1st Pass Condenser	HGBP to R1	Reactor 1 Inlet	E2-2nd Pass Condenser	E16 Condenser	Reactor 3 Outlet	Oxidation Air	SuperClaus Coalescer
H2	0.000	0.000	0.000	17.005	1.827	18.832	18.832	15.398	15.390	0.000	15.390
Ar	0.000	0.000	5.787	5.225	0.561	5.787	5.787	5.656	5.628	0.739	6.367
O2	0.000	0.000	129.777	0.000	0.000	0.000	0.000	0.000	0.000	16.580	14.708
N2	0.143	1.053	483.811	449.591	48.306	497.896	497.896	486.941	484.589	61.809	546.398
C1	0.145	0.047	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO	0.000	0.047	0.000	4.110	0.442	4.551	4.551	3.630	3.727	0.000	3.727
CO2	9.392	0.164	0.204	16.341	1.756	18.097	21.461	22.414	22.319	0.026	22.346
C2	0.102	0.505	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H2S	162.012	20.723	0.000	37.467	4.026	41.492	13.474	4.239	3.820	0.000	1.146
COS	0.003	0.001	0.000	3.102	0.333	3.435	0.071	0.034	0.031	0.000	0.031
SO2	0.000	0.000	0.000	23.879	2.566	26.444	10.753	0.984	0.187	0.000	0.722
CS2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H2O	20.600	12.300	7.516	200.888	21.584	222.473	250.491	263.018	263.408	0.960	267.042
NH3	0.000	25.777	0.000	0.017	0.002	0.019	0.019	0.000	0.000	0.000	0.000
HCN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C3	0.306	1.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
iC4	0.033	0.353	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
nC4	0.149	1.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
iC5	0.009	0.149	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
nC5	0.031	0.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C6	0.157	0.201	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CH4S	0.219	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C2H6S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	193.300	63.650	627.096	757.624	81.402	839.026	823.335	802.314	799.099	80.114	877.876
Stream S as S1	162.234	20.724	0.000	75.650	17.751	93.400	29.212	9.711	9.711	0.000	2.406
S vapour as Sx	NA	NA	NA	1.502	4.908	3.072	0.656	0.594	0.766	NA	0.067
S vapour as S1	NA	NA	NA	11.202	10.826	22.028	4.915	4.453	5.672	NA	0.507
Mass Flow (kg/h)	6366.730	1592.930	18082.880	20644.820	2526.710	23171.530	21113.310	20078.140	19990.230	2310.170	22066.190
Temperature (C)	75.000	85.000	88.000	199.000	605.000	259.700	177.000	172.000	192.000	240.000	130.300
Pressure (kPa (g))	65.000	171.000	52.000	37.500	40.000	40.000	30.000	10.200	10.000	52.000	5.000
Molecular Weight	32.940	25.030	28.840	27.200	29.270	27.520	25.620	25.010	24.990	28.840	25.130
Sulphur Production (t/d)				68.9			49.4	15.0			5.6
Cumulative Production (t/d)				**68.9**			**118.3**	**133.3**			**138.9**

CANADA -USA - NETHERLANDS

Sulphur Experts Inc. **Calgary, Canada ++1 403-215-8400**

Table C.1-2
Material Balance
Stack Testing

ENI — Date : **09-Nov-07**
Raffineria di Gela — File : **SE739**

Stream Number	**1**	**2**	**3**	**12**	**13**	**14**
Composition (kmol/h)	Acid Gas	SWS	Combustion Air to B-1	Fuel Gas to B-2	Combustion Air to B-2	B-2 Outlet
H2	0.000	0.000	0.000	7.992	0.000	0.000
Ar	0.000	0.000	5.623	0.000	4.921	9.479
O2	0.000	0.000	126.113	0.000	110.352	73.990
N2	0.088	1.021	470.152	0.678	411.392	806.750
C1	0.134	0.046	0.000	6.523	0.000	0.000
CO	0.000	0.046	0.000	0.305	0.000	1.301
CO2	8.949	0.159	0.199	0.052	0.174	44.140
C2	0.106	0.490	0.000	1.980	0.000	0.000
H2S	165.634	20.088	0.000	0.076	0.000	0.000
COS	0.005	0.000	0.000	0.001	0.000	0.000
SO2	0.000	0.000	0.000	0.000	0.000	1.470
CS2	0.000	0.000	0.000	0.000	0.000	0.000
H2O	20.975	11.923	7.304	0.000	6.391	327.612
NH3	0.000	24.988	0.000	0.000	0.000	0.000
HCN	0.000	0.000	0.000	0.000	0.000	0.000
C3	0.322	0.980	0.000	1.154	0.000	0.000
iC4	0.030	0.342	0.000	0.210	0.000	0.000
nC4	0.130	1.095	0.000	0.469	0.000	0.000
iC5	0.002	0.144	0.000	0.154	0.000	0.000
nC5	0.014	0.184	0.000	0.202	0.000	0.000
C6	0.186	0.195	0.000	0.205	0.000	0.000
CH4S	0.246	0.000	0.000	0.000	0.000	0.000
C2H6S	0.000	0.000	0.000	0.000	0.000	0.000
------------------------------------	---------	---------	---------	---------	---------	---------
TOTAL	196.820	61.700	609.392	20.000	533.230	1264.742
Stream S as S1	165.885	20.089	0.000	0.077	0.000	1.470
S vapour as Sx	NA	NA	NA	NA	NA	NA
S vapour as S1	NA	NA	NA	NA	NA	NA
Mass Flow (kg/h)	6477.49	1544.13	17572.36	346.47	15376.17	33323.72
Temperature (C)	75	85	88	20	70	605
Pressure (kPa (g))	65.0	171.0	52.0	150.0	10.0	5.0
Molecular Weight	32.91	25.03	28.84	17.32	28.84	26.35
Sulphur Production (t/d)			136.1			
Cumulative Production (t/d)			**136.1**			

Appendix D

Sulsim Optimized Case

SULSIM CASE: GELA-OPT 07/11/28

ENI Gela - Optimised Case

SULPHUR PLANT PERFORMANCE

EFFICIENCY

Unit: Efficiency (Percent)	Thermal Stage	Catalytic Stage 1	Catalytic Stage 2	Catalytic Stage 3	Catalytic Stage 4
Conversion:					
Unit	61.01	66.31	69.57	25.59	82.29
Cumulative	61.01	86.86	96.00	97.03	**99.47**
Recovery:					
Unit	80.70	93.11	79.61	0.00	96.81
Cumulative	49.23	84.27	93.61	93.61	**99.29**
Unit Hydrolysis:					
COS	NA	98.92	0.00	0.00	0.00
CS2	NA	0.00	0.00	0.00	0.00

Overall Recovery Efficiency **99.29**

PRODUCTION

Unit: Production (t/d)	Thermal Stage	Catalytic Stage 1	Catalytic Stage 2	Catalytic Stage 3	Catalytic Stage 4
Conversion:					
Unit	85.89	36.40	12.87	1.44	3.45
Cumulative	85.89	122.29	135.16	136.60	140.05
Recovery:					
Unit	69.31	49.33	13.15	0.00	7.99
Cumulative	69.31	118.65	131.80	131.80	139.79

Total Inlet Sulphur 140.79

MATERIAL BALANCE

Stream:	AAG STREAM	SWS STREAM	AIR STREAM	WH1 STREAM	PIPE STREAM
Component (kmol/h)					
H2:	0.000	0.000	0.000	18.824	1.807
Ar:	0.000	0.000	5.499	5.499	0.528
O2:	0.000	0.000	123.317	0.000	0.000
N2:	0.143	1.053	459.729	473.814	45.484
C1:	0.145	0.047	0.000	0.000	0.000
CO:	0.000	0.047	0.000	4.549	0.437
CO2:	9.392	0.164	0.194	18.089	1.737
C2:	0.102	0.505	0.000	0.000	0.000
H2S:	162.012	20.723	0.000	45.784	4.395
COS:	0.003	0.001	0.000	3.434	0.330
SO2:	0.000	0.000	0.000	22.126	2.124
CS2:	0.000	0.000	0.000	0.000	0.000
H2O:	20.600	12.300	7.142	217.813	20.909
NH3:	0.000	25.777	0.000	0.019	0.002
HCN:	0.000	0.000	0.000	0.000	0.000
C3:	0.306	1.011	0.000	0.000	0.000
iC4:	0.033	0.353	0.000	0.000	0.000
nC4:	0.149	1.130	0.000	0.000	0.000
iC5:	0.009	0.149	0.000	0.000	0.000
nC5:	0.031	0.190	0.000	0.000	0.000
C6:	0.157	0.201	0.000	0.000	0.000
CH4S:	0.219	0.000	0.000	0.000	0.000
C2H6S:	0.000	0.000	0.000	0.000	0.000
TOTAL	193.300	63.650	595.881	809.952	77.753
Stream S as S1	162.234	20.724	0.000	182.958	17.563
S vapour as Sx	NA	NA	NA	50.436	4.842
S vapour as S1	NA	NA	NA	111.614	10.715
S liquid as S1	NA	NA	NA	0.000	0.000
S Product as S1:					
Unit	NA	NA	NA	0.000	--
Cumulative	NA	NA	NA	0.000	--
Sulphur Production (t/d)					
Unit	NA	NA	NA	0.00	--
Cumulative	NA	NA	NA	0.00	--
Mass Flow (kg/h)	6366.73	1592.93	17182.79	25142.99	2413.64
Temperature (C)	75.0	85.0	88.0	605.0	605.0
Pressure (kPa (g))	65.00	171.00	52.00	40.00	40.00
Molecular Weight	32.94	25.03	28.84	29.22	29.22

Total Inlet Sulphur (t/d) 140.79
Total Mixed Feed (kmol/h) 256.950
Total Process Air (kmol/h) 595.881
Total Fuel Gas (kmol/h) 0.000

MATERIAL BALANCE

Stream:	HGB SRC STREAM	WHE STREAM	E-2-1 STREAM	PIPE STREAM	RH1 STREAM
Component (kmol/h)					
H2:	17.017	17.017	17.017	1.807	18.824
Ar:	4.971	4.971	4.971	0.528	5.499
O2:	0.000	0.000	0.000	0.000	0.000
N2:	428.329	428.329	428.329	45.484	473.814
C1:	0.000	0.000	0.000	0.000	0.000
CO:	4.113	4.113	4.113	0.437	4.549
CO2:	16.353	16.353	16.353	1.737	18.089
C2:	0.000	0.000	0.000	0.000	0.000
H2S:	41.389	41.389	41.389	4.395	45.784
COS:	3.104	3.104	3.104	0.330	3.434
SO2:	20.002	20.002	20.002	2.124	22.126
CS2:	0.000	0.000	0.000	0.000	0.000
H2O:	196.904	196.904	196.904	20.909	217.813
NH3:	0.017	0.017	0.017	0.002	0.019
HCN:	0.000	0.000	0.000	0.000	0.000
C3:	0.000	0.000	0.000	0.000	0.000
iC4:	0.000	0.000	0.000	0.000	0.000
nC4:	0.000	0.000	0.000	0.000	0.000
iC5:	0.000	0.000	0.000	0.000	0.000
nC5:	0.000	0.000	0.000	0.000	0.000
C6:	0.000	0.000	0.000	0.000	0.000
CH4S:	0.000	0.000	0.000	0.000	0.000
C2H6S:	0.000	0.000	0.000	0.000	0.000
TOTAL	732.200	732.200	732.200	77.752	809.952
Stream S as S1	165.395	165.395	75.321	17.563	92.885
S vapour as Sx	45.594	14.828	1.452	4.842	3.003
S vapour as S1	100.899	100.899	10.826	10.715	21.541
S liquid as S1	0.000	0.000	0.000	0.000	0.000
S Product as S1:					
Unit	--	0.000	90.073	--	--
Cumulative	--	0.000	90.073	--	--
Sulphur Production (t/d)					
Unit	--	0.00	69.31	--	--
Cumulative	--	0.00	69.31	--	--
Mass Flow (kg/h)	22729.36	22729.36	19841.25	2413.63	22254.88
Temperature (C)	605.0	351.0	199.0	605.0	259.7
Pressure (kPa (g))	40.00	40.00	37.50	40.00	40.00
Molecular Weight	29.22	30.43	27.04	29.22	27.38

Total Inlet Sulphur (t/d) 140.79
Total Mixed Feed (kmol/h) 256.950
Total Process Air (kmol/h) 595.881
Total Fuel Gas (kmol/h) 0.000

MATERIAL BALANCE

Stream:	E-2-2 STREAM	RH2 STREAM	E-16 STREAM	RH3 STREAM	fake STREAM
Component (kmol/h)					
H2:	18.824	18.824	18.824	18.824	18.824
Ar:	5.499	5.499	5.499	5.499	5.499
O2:	0.000	0.000	0.000	0.000	0.000
N2:	473.814	473.814	473.814	473.814	473.814
C1:	0.000	0.000	0.000	0.000	0.000
CO:	4.549	4.549	4.549	4.549	4.549
CO2:	21.487	21.487	21.487	21.487	21.487
C2:	0.000	0.000	0.000	0.000	0.000
H2S:	17.645	17.645	6.496	6.496	5.247
COS:	0.037	0.037	0.037	0.037	0.037
SO2:	6.357	6.357	0.783	0.783	0.158
CS2:	0.000	0.000	0.000	0.000	0.000
H2O:	245.953	245.953	257.102	257.102	258.350
NH3:	0.019	0.019	0.019	0.019	0.019
HCN:	0.000	0.000	0.000	0.000	0.000
C3:	0.000	0.000	0.000	0.000	0.000
iC4:	0.000	0.000	0.000	0.000	0.000
nC4:	0.000	0.000	0.000	0.000	0.000
iC5:	0.000	0.000	0.000	0.000	0.000
nC5:	0.000	0.000	0.000	0.000	0.000
C6:	0.000	0.000	0.000	0.000	0.000
CH4S:	0.000	0.000	0.000	0.000	0.000
C2H6S:	0.000	0.000	0.000	0.000	0.000
TOTAL	794.184	794.184	788.609	788.609	787.985
Stream S as S1	28.780	28.780	11.692	11.692	11.692
S vapour as Sx	0.633	0.647	0.583	0.593	0.843
S vapour as S1	4.741	4.741	4.377	4.377	6.249
S liquid as S1	0.000	0.000	0.000	0.000	0.000
S Product as S1:					
Unit	64.105	--	17.088	--	0.000
Cumulative	154.178	--	171.266	--	171.266
Sulphur Production (t/d)					
Unit	49.33	--	13.15	--	0.00
Cumulative	118.65	--	131.80	--	131.80
Mass Flow (kg/h)	20199.32	20199.32	19651.40	19651.40	19651.39
Temperature (C)	177.0	203.0	172.0	192.0	192.0
Pressure (kPa (g))	30.00	25.00	10.20	10.00	10.00
Molecular Weight	25.41	25.41	24.90	24.90	24.91

Total Inlet Sulphur (t/d) 140.79
Total Mixed Feed (kmol/h) 256.950
Total Process Air (kmol/h) 595.881
Total Fuel Gas (kmol/h) 0.000

MATERIAL BALANCE

Stream:	RH4 STREAM	Selox STREAM	E-3 STREAM	FG STREAM	IAIR STREAM
Component (kmol/h)					
H2:	18.824	0.000	18.824	9.634	0.000
Ar:	5.499	0.401	5.900	0.000	4.936
O2:	0.000	8.989	5.833	0.000	110.685
N2:	473.814	33.510	507.324	0.818	412.637
C1:	0.000	0.000	0.000	7.863	0.000
CO:	4.549	0.000	4.549	0.367	0.000
CO2:	21.487	0.014	21.501	0.063	0.174
C2:	0.000	0.000	0.000	2.387	0.000
H2S:	5.247	0.000	0.157	0.091	0.000
COS:	0.037	0.000	0.037	0.001	0.000
SO2:	0.158	0.000	0.769	0.000	0.000
CS2:	0.000	0.000	0.000	0.000	0.000
H2O:	258.350	0.521	263.961	0.000	6.411
NH3:	0.019	0.000	0.019	0.000	0.000
HCN:	0.000	0.000	0.000	0.000	0.000
C3:	0.000	0.000	0.000	1.391	0.000
iC4:	0.000	0.000	0.000	0.253	0.000
nC4:	0.000	0.000	0.000	0.566	0.000
iC5:	0.000	0.000	0.000	0.186	0.000
nC5:	0.000	0.000	0.000	0.243	0.000
C6:	0.000	0.000	0.000	0.248	0.000
CH4S:	0.000	0.000	0.000	0.000	0.000
C2H6S:	0.000	0.000	0.000	0.000	0.000
TOTAL	787.985	43.435	828.875	24.110	534.843
Stream S as S1	11.692	0.000	1.306	0.092	0.000
S vapour as Sx	0.855	NA	0.045	NA	NA
S vapour as S1	6.249	NA	0.342	NA	NA
S liquid as S1	0.000	NA	0.000	NA	NA
S Product as S1:					
Unit	--	NA	10.386	NA	NA
Cumulative	--	NA	181.652	NA	NA
Sulphur Production (t/d)					
Unit	--	NA	7.99	NA	NA
Cumulative	--	NA	139.79	NA	NA
Mass Flow (kg/h)	19651.39	1252.48	20570.85	417.67	15422.68
Temperature (C)	210.0	240.0	125.0	20.0	70.0
Pressure (kPa (g))	10.00	52.00	5.00	150.00	10.00
Molecular Weight	24.91	28.84	24.82	17.32	28.84

Total Inlet Sulphur (t/d) 140.79
Total Mixed Feed (kmol/h) 256.950
Total Process Air (kmol/h) 595.881
Total Fuel Gas (kmol/h) 0.000

MATERIAL BALANCE

Stream:	B-2 STREAM	STREAM
Component (kmol/h)		
H2:	0.000	0.000
Ar:	8.727	8.727
O2:	58.023	58.023
N2:	744.529	744.529
C1:	0.000	0.000
CO:	2.275	2.275
CO2:	48.058	48.058
C2:	0.000	0.000
H2S:	0.000	0.000
COS:	0.000	0.000
SO2:	1.398	1.398
CS2:	0.000	0.000
H2O:	333.219	333.219
NH3:	0.000	0.000
HCN:	0.000	0.000
C3:	0.000	0.000
iC4:	0.000	0.000
nC4:	0.000	0.000
iC5:	0.000	0.000
nC5:	0.000	0.000
C6:	0.000	0.000
CH4S:	0.000	0.000
C2H6S:	0.000	0.000
TOTAL	1196.229	1196.229
Stream S as S1	1.398	1.398
S vapour as Sx	NA	NA
S vapour as S1	NA	NA
S liquid as S1	NA	NA
S Product as S1:		
Unit	--	--
Cumulative	--	--
Sulphur Production (t/d)		
Unit	--	--
Cumulative	--	--
Mass Flow (kg/h)	31335.71	31335.71
Temperature (C)	721.5	721.5
Pressure (kPa (g))	5.00	5.00
Molecular Weight	26.20	26.20

Total Inlet Sulphur (t/d) 140.79
Total Sulphur Emission (t/d) 1.08
Total Mixed Feed (kmol/h) 256.950
Total Process Air (kmol/h) 595.881
Total Fuel Gas (kmol/h) 0.000

Appendix E

SuperClaus® Operations Discussion Paper

The SuperClaus Process

The SuperClaus process normally includes a conventional two- or three-stage Claus process followed by a catalytic reactor (SuperClaus reactor) that promotes the oxidation of H_2S directly to sulphur. Other sulphur components (SO_2, COS, CS_2) are not converted to sulphur in this reactor, and should therefore need to be minimized at the reactor inlet for the highest unit sulphur conversions.

The process variables that affect the performance of the Superclaus Reactor and need to be controlled are:

1. H_2S *(and SO_2)* concentration in the inlet
2. Inlet temperature
3. Oxidation air

1. The inlet H_2S concentration is normally set to 0.8 to 1.5 mol%, depending on the number of preceding Claus catalytic stages. This should result in a minimal SO_2 concentration in the inlet gas to the SuperClaus reactor. It is important to control the inlet gas close to the design H_2S concentration to minimize the amount of SO_2 in the inlet and to prevent temperature excursions due to high H_2S. Higher concentrations of H_2S will result in increased bed temperature due to the exothermic reaction. This can result in poorer selectivity. Excessive quantities of SO_2 may also temporarily deactivate the catalyst. The normal inlet target is between 0.8 to 0.9 mol% (wet) H_2S. With fully active catalyst in the two or more upstream Claus reactors, the expected SO_2 concentration should be in the 500-600 ppmv range.

2. The inlet temperature to the reactor is controlled by the upstream reheater. The recommended inlet temperature normally ranges from 190 to 220ºC (375 to 430ºF), however this is highly dependent on the inlet H_2S concentration and the plant load (which affects the residence time in the reactor). The typical inlet temperature for most installations is 210˚C. The temperature must be controlled at an optimal level as excessive temperature will promote the production of SO_2.

3. The air required for the oxidation reaction is added after the reheater and is normally controlled by a excess oxygen analyser situated at the outlet of the reactor. It can also be controlled with a simple calculation internal to the DCS, using the feed and air flow rates. The air flow rate should be set to achieve between 0.5 to 1.0 mol% at the outlet of the reactor. This ensures sufficient oxygen for the direct oxidation reaction and protection of the catalyst. Excessive oxygen concentrations in the reactor will promote the production of SO_2, and therefore it must be controlled within the licensor’s recommended range.

Care should also be taken to ensure that when a fired reheater is employed upstream of the SuperClaus reactor that its burn stoichiometry is kept below 100%. Modern high-intensity burners have the potential to combust some of the sulphur vapour (or H_2S) in the Claus tail gas to SO_2 if there is excessive free oxygen present at the outlet of the burner section.

SuperClaus Reactor Performance Evaluation

The SuperClaus reactor is evaluated in terms of:

1. *Activity* (percentage of inlet H_2S reacted), also known as 'conversion';
2. *Selectivity* (percentage of reacted H_2S which forms sulphur product);
3. *Yield* (percentage of inlet H_2S which forms sulphur product).

These performance values are controlled by the various operating parameters described in the previous section and are limited by the activity of the SuperClaus catalyst. Ideally, the performance of a SuperClaus reactor is optimized by minimizing the SO_2 inlet, maximizing the H_2S conversion, and maintaining the highest selectivity possible.

With SuperClaus catalyst in good condition, a conversion rate of 97 percent, a selectivity of 88 percent, and a yield of over 85 percent should be attainable. Newer generation SuperClaus catalysts may provide even higher conversion, selectivity and yields. Another indicator of good <u>catalyst performance</u> is that for every 1.0 percent (wet) of H_2S at the inlet to the reactor, the temperature is expected to rise between 60-65ºC.

A final process variable that affects the SuperClaus performance is the catalyst bed <u>temperature profile</u>. The reactor bed temperature profile should be controlled so that two-thirds of the total temperature rise is achieved in the top half of the catalyst. For example, if the total ΔT is 47ºC, then the bed temperature at the midpoint of the catalyst bed should be at about 30-35ºC above the inlet temperature *(Figure E.1-1)*. This type of profile ensures the best H_2S conversion and helps to minimise the formation of SO_2. This profile can be controlled by manipulating the inlet temperature, either manually according to the plant load or with an appropriate control algorithm.

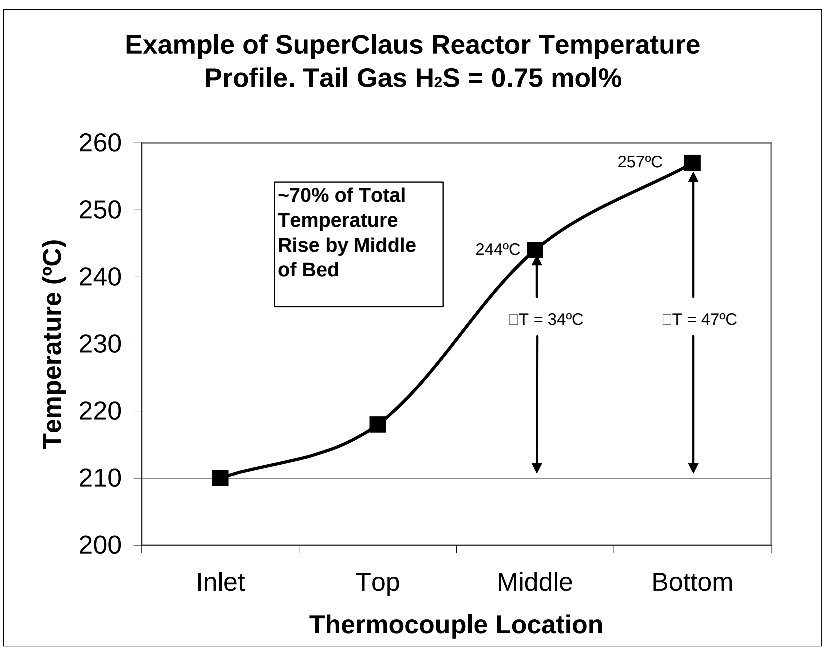


Figure E.1-1 - Ideal SuperClaus Reactor Temperature Profile