Corrosion in GASCO Habshan CBA Units and its mitigation

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AGENDA

- Introduction
- Process Description for CBA Units
- Damage mechanisms
- Major Corrosion Findings
- Root causes
- Corrosion Mitigation
- Challenges
Introduction

GASCO is operating total 14 Nos Of Sulfur Recovery Units in Habshan Complex:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Unit Nos.</th>
<th>Process Design</th>
<th>Capacity (Tons/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habshan-0</td>
<td>50/51</td>
<td>Claus with Split feed flow</td>
<td>400</td>
</tr>
<tr>
<td>Habshan-1</td>
<td>52/53/54</td>
<td>1\textsuperscript{st} stage Claus with 2 parallel CBA</td>
<td>600</td>
</tr>
<tr>
<td>Habshan-2</td>
<td>57/58/59</td>
<td>1\textsuperscript{st} stage Claus with 2 parallel CBA</td>
<td>634/733</td>
</tr>
<tr>
<td>Habshan-4</td>
<td>152/153</td>
<td>Super Claus</td>
<td>800</td>
</tr>
<tr>
<td>Habshan-5</td>
<td>550/551/552/553</td>
<td>Modified Claus with TGTU</td>
<td>1300</td>
</tr>
</tbody>
</table>
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TYPICAL CLAUS WITH 2 PARALLEL CBA SRU’s

Acid gas

KO(V-101)

Sour water

AIR

Pre-heater E-101

Reaction furnace (H-101)

WHB (B-101)

Claus (V-103)

CBA V-104

CBA V-105

Incinerator H-102

STACK S-101

Pre-heater E-105

Claus Condenser (E-106)

CBA Condenser (E-109)

CBA Condenser (E-108)

CBA Condenser (E-107)

Claus Condenser (E-104)

Claus Condenser (E-107)

Claus Condenser (E-108)

CBA Condenser (E-109)

Liquid Sulphur

Sulphur storage

HSGP
BRIEF PROCESS DESCRIPTION

■ The acid gas received from gas sweetening unit, first water is knocked out in (V-101) gas is preheated in (E-101) and enters the reaction furnace for thermal reaction.

■ The feed gas meets a ratio-controlled supply of air in the main burner, where about 1/3 of the H2S and all other combustibles are burnt under controlled air in the reaction furnace (H-101).

■ The reaction furnace temperature is about 1200° C. A considerable amount of sulphur is formed in this reaction chamber.

■ The gases are subsequently cooled in the waste heat boilers (B-101/102) to about 315° C.

■ The bulk of the sulphur present, sent to Boiler condenser (E-104) condenses as liquid Sulphur and the rest remains in the process as vapor. In (E-104) the gases pass through the tubes and are cooled to 171° C then are sent to preheater (E-105), where it is preheated to 265° C.
BRIEF PROCESS DESCRIPTION

- The outlet from Claus reactor (V-103) at temperature of 325º C is routed through Claus condensers (E-106/107) where liquid sulphur is condensed and separated. Remaining vapor at temperature of 130ºC is routed and enter the CBA reactor (V-104) where further reaction for sulphur formation is completed. The outlet from CBA reactor is passed through CBA condensers (E-108/109) where sulphur is condensed and separated.

- The outlet remaining vapor from CBA condensers at 127ºC enters the second CBA reactor (V-105) for further adsorption. The outlet effluent is routed to incinerator for further disposal through the stack.

- The condensed sulphur vapors from all the condensers in form of liquid sulphur are connected and collected in the liquid Sulphur storage pit drum (V-108). From (V-108) it is pumped to Sulphur storage tanks and from there it is pumped to Sulfur Granulation plant.

- The tail gases are burnt in the Incinerator (H-102) and burnt gases are released to 80 meter stack to atmosphere.
BRIEF PROCESS DESCRIPTION

- CBA reactors operate under cyclic mode with temperature variation from around 127 to 343 ºC.

- CBA reaction is a cyclic process which uses the catalyst in a low temperature range such that sulphur as produced is adsorbed on the catalyst, but the catalyst is then regenerated, before it becomes significantly deactivated, to restore its activity.

- Regeneration is accomplished by flowing hot gas through the reactor to heat the catalyst and desorb (vaporise) the sulphur, then condensing sulphur from the reactor effluent gas. After regeneration, the catalyst is cooled using gas at lower temperature.
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CBA Reactor-1

CS + Alum replaced by SS 347

CBA Reactor-2

Tail gas to incinerator

CS + Alum

CBA REACTOR DESIGN DATA:

Design Pressure: 3.5 Bar G
Design Temp.: 400 Deg C (Thermal cycling 130-343 Deg.C)
Material: Carbon steel, SA516 Gr60 + Internally Aluminized
Thickness: 16mm thick, CA= 5mm
Dimensions: Dia. 3,700mm Length 25,000mm
Surface Area: 320 M²

CONDENSER

Liquid sulphur to seal pot
HIGH TEMPERATURE SULFIDATION:

Sulfidation in CS begins at above 260°C. This temperature is reached during regeneration phase in CBA reactor at around 343°C. Aluminization is a preventive measure for sulfidation.

WATER DEW POINT BASED ACIDIC CORROSION:

The lowest operating temperature of the CBA reactor is 127°C, which is higher than water dew point. Hence, SO2 based corrosion should not be applicable in this situation.

However it is possible that some extent of water vapor may be present to combine with SO2 to form H2SO3.

Drop of temperature may be due to inefficiency of the Claus condensers or flashing of inlet fluid at the catalyst bed and inefficiency of the steam coils and insulation.

THERMAL CYCLIC FATIGUE:

Reactors are working under thermal cyclic conditions. Generally cracks kind of damage mechanisms are caused by thermal or vibration fatigue. So far no such evidences have been reported for this type of failure.
MAJOR CORROSION FINDINGS

Internal corrosion of CBA reactors (V-104/5) with significant metal losses up to 8mm, on carbon steel and aluminization. This is observed not only near inlet nozzles, but also at all upper portion of vessel (9 to 3 O’clock) above the catalyst bed. Corrosion rates of 0.53 to 1.66 mm/year were measured.
MAJOR CORROSION FINDINGS

- The CBA reactor inlet nozzles thermal sleeves were found with severe perforations due to corrosion and found collapsed on the baffle plates or catalyst bed.

- Shell and Heads manway nozzles (M4, M5, M6) of CBA reactors were found internally corroded and perforated.

- Internal corrosion of CBA Reactor Carbon steel Aluminized inlet and outlet piping.
MAJOR CORROSION FINDINGS

- Significant internal corrosion of inlet nozzle & channel head of Claus condenser 1st pass (E-106).
- Minor corrosion in Claus condenser (E107) and CBA condensers (E108/109) outlet channel heads and piping.
- Internal corrosion of Hot gas bypass line made by SS347.
MAJOR CORROSION FINDINGS

■ CBA Switching KVs made of Carbon steel + aluminization were found with significant metal loss in the internal surface of body between the internal jacket and plug body and weld joints.

■ Cracking of Waste heat boiler 1st pass tube sheet ferrules noticed every shutdown.

■ Seal pots external corrosion.

■ Frequent failure of steam traps.
The internal corrosion in CBA reactors is mainly due to acid dew point corrosion in aluminization damaged areas, where temperature drops below 127°C, which may be possible due to inefficiency of the Claus condensers or flashing of incoming fluid causing drop in temperature especially dead zones for entrapped gases in upper portion of the reactor. Inefficiency of the steam heating coils may be another reason for such temperature drop.

- There are no thermowells to measure the actual temperature above the catalyst bed.

- Aluminization can not resist low dew point based acidic corrosion. Failure in control of the water dew point may be the main reason for the initiation of Aluminization damage. Once aluminization is damaged it peels off and the bare Carbon steel material is exposed to cyclic temperature, from 127 to 343°C, leading to FeS scale cracking. This scale re-establishes within each cycle. The cracking and re-establishment of FeS scale increases the corrosion rate significantly comparing with a non-cyclic equivalent temperature application.

Porosity in TSA coatings which gives origin for coating peeling off and formation of underlying scale
ROOT CAUSES

- Similar corrosion mechanism is observed in Carbon steel and alumination equipment/piping/switching KVs subjected to cyclic temperatures as well as where temperatures below 127°C are expected.

- Material selection of Carbon steel + aluminization is found not suitable for this service to meet the design life.

- Hot gas bypass line made of SS347 was found with sulfidation attack resulting in thinning of material with corrosion rate approximately 0.57mm/year. Despite this material can provide significant resistance to sulfidation, the actual corrosion is matching with McConomy curves. The later CBA units in Habshan 2, were designed with Carbon steel + Internal refractory lining.

- Cracking of Waste heat boiler 1st pass tube sheet ferrules may be due to improper cooling process prior to shutting down the units, as no significant sulfidation attack was observed in the tubes and tube sheets.

- Seal pots external corrosion is due to ground water in the underground pits.

- The frequent failure of steam traps may be associated to the installed type.
CORROSION MITIGATION

Corrosion problems resolved:
- CBA reactor inlet piping was partially replaced with SS347.
- Inlet nozzle of Claus condenser 1st pass (E-106) weld overlaid with Inconel 625.
- CBA reactors shell and heads manway nozzles internally corroded and perforated (M4, M5, M6) were replaced and insulation was provided.
- Hot gas bypass lines in Habshan 1 units were replaced by carbon steel with Internal refractory lining, adopting the same design of Habshan 2.
- Proper cooling procedure was developed and implemented to minimize the ferrules cracking.

Corrosion problems leading to every 3 years shutdown:
- CBA reactors internal corrosion.
- Corrosion of the CBA reactor inlet nozzle thermal sleeves CS Aluminized.
- CS aluminized inlet and outlet piping internal corroded spots.
- Internal corrosion of the Claus condenser (E106/107) and CBA condensers (E108/109) CS aluminized outlet channel heads and piping.
- Internal corrosion of the Switching critical KVs, outlet of Claus reactor (V103) and outlet of Claus condenser 2nd pass (E107).

Action plan for resolving other issues:
- Pilot test for new seal pot above ground system is going to be implemented.
- Steam traps with Orifice-Venturi type (without internal movable parts) may be tested to mitigate the current problem.
CHALLENGES

Cost effective solution for mitigation the acidic dew point corrosion problems in CBA reactors, condensers outlet channel heads and piping in order to extend shutdown frequency from 3 to 6 years by:

- Replacing CBA reactors by solid SS material?
- Weld overlay with SS material the full internal surface or only from (9 to 3 O’clock) above the catalyst bed where significant metal losses are observed. Is this task practical, due to the size of the reactors, time required to complete this task and quality assurance constraints of weld overlay process?
- Weld overlay condensers outlet channel heads from 4 to 8 O’clock position?
- Replacement the inlet nozzles thermal sleeves by SS material?

Prevent internal corrosion of CBA reactor inlet switching critical KV valves (2nos) by:
- Upgrading from CS internally aluminized to solid SS?
Thank you!