Alternate Methodology for De-Plugging of Sulphur in the Run down Lines of SRU Plant

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Abstract—The frequent shut down of Sulphur Recovery Unit (SRU) in any manufacturing or process industries leads to loss of production, loss of money, additional labour cost and wastage of utilities. Sulphur recovery unit being the downstream plant designed for meeting environmental legislation requires special attention. The main reason for the shutdown of SRU is identified as plugging of sulphur. A study was conducted to identify the reasons for sulphur plugging and the possible remedies in the SRU of Kochi Refineries, Kerala. This report covers the root cause analysis of sulphur plugging its locations, probable reasons, suitable remedial measures and technical and economic feasibility for the suggested method. Approximately around eight lacks of money can be saved using this method, also the productivity of the company increases and shut down of the plant also can be avoided using this method.

Keywords—Sulphur, RCA.

I. INTRODUCTION

The sulphur recovery systems remove hydrogen sulphide from the fuel gas streams generated by the process units of the petroleum refinery. This desulphurised fuel gas is used in the fired heaters thereby reducing the sulphide dioxide emissions from the stacks of fired heaters. The system is liquid oxidation process, which removes hydrogen sulphide from the fuel streams by converting it to elemental sulphur. The system is designed to process fuel gas with a removal efficiency of 99.8%.

A. Sulphur

Sulphur is multivalent abundant, non-metal, tasteless and odourless. In its native form sulphur is a yellow crystalline solid. In nature it occurs as the pure element or as sulphide and sulphate minerals. Although sulphur is infamous for its smell, frequently compared to rotten eggs, that odour is actually characteristic of hydrogen sulphide (H\textsubscript{2}S). Sulphur can be found in the air in many different forms. It can cause irritations of the eyes and the throat with animals, when the intake takes place through inhalation of sulphur in the gaseous phase. The damaging effects of sulphur with animals are mostly brain damage, through malfunctioning of the hypothalamus, and damage to the nervous system. Laboratory tests with test animals have indicated that sulphur can cause serious vascular damage in veins of the brains, the heart and the kidneys. Mothers can even carry sulphur poisoning over to their children through breast feeding. Finally, sulphur can damage the internal enzyme systems of animals.

B. Sulphur in Crude Oil

Sulphur in crude oil is very important because it causes difficulties, such as corrosion of metals, difficulties in processing the oil and air pollution resulting from the burning of high-sulphur fuels processed from crude oils having high sulphur content. Sulphur is a by-product produced in various refineries, processing high Sulphur crude. Hydro treating is one way of removing many of the contaminants from many of the intermediate or final products. In the hydro treating process, the entering feedstock is mixed with hydrogen and heated to 300°C - 380°C. The oil combined with the hydrogen then enters a reactor loaded with a catalyst which promotes several reactions:

- hydrogen combines with sulphur to form hydrogen sulphide (H\textsubscript{2}S),
- nitrogen compounds are converted to ammonia
- Any metals contained in the oil are deposited on the catalyst due to which some of the olefins, aromatics or naphthenes become saturated with hydrogen to become paraffins and partial cracking takes place, resulting in the creation of a mixture of methane, ethane, propane and butane.

C. Sulphur Recovery Plants

The hydrogen sulphide created from hydro treating is a toxic gas that needs further treatment. The usual process involves two steps:

- the removal of the hydrogen sulphide gas from the hydrocarbon stream
The conversion of hydrogen sulphide to elemental sulphur, a non-toxic and useful chemical.

**D. Process Description of SRU**

The schematic layout of sulphur recovery unit is given in figure 1. The sulphur recovery plant consisting of one thermal reactor (main reaction furnace) and four catalytic reactors is a Claus converter while the last three are MCRC converters that alternate between sub-dew point mode and regeneration mode. With such a four converter MCRC configuration sulphur recovery of over 99% is achievable. The salient feature of MCRC process is that the regeneration takes place online. The acid from amine regeneration unit (ARU), H2S gas from the first stage sour water stripper unit (SWS) and ammonia rich gas from second stage sour water stripper unit are the feed to the sulphur recovery unit (SRU). The SRU consists of Claus and MCRC section, feed KO drum, combustion air blowers, fuel gas facilities, tail gas facilities, tail gas incineration facility, ammonia reaction furnace, sulphur collection pit and sulphur solidification facility. MCRC process adopted for SRU is an extension of conventional Claus process. Features of the process are applied to achieve bulk of the recovery with one thermal reactor and one Claus reactor in the first section of MCRC process. This section is called Claus section. The next section which is usually called as MCRC section consists of three MCRC reactors operating at temperature lower than the sulphur dew point. First of the three MCRC reactors operate at the temperature higher than sulphur dew point so that the vaporization of the bed sulphur absorbed on the catalyst surface takes place. Product sulphur condensation and adsorption of the catalyst is allowed in the two succeeding reactors. Operating the second and third MCRC reactors at a lower temperature is the key parameter for enhanced sulphur recovery. Each reactor of MCRC section switches from one mode of operation to another mode on a programmed cycle or manual switch over. MCRC section is followed by incineration section for burning the tail gas leaving MCRC section. All sulphur species present in the tail gas is incinerated to sulphur dioxide. Refinery fuel gas or LPG is used as fuel for incinerator.

**Fig 1. Schematic Layout of SRU**

**II. MAIN EQUIPMENTS IN SRU**

**A. Seal Pot**

Seal pots are provided for sulphur lines at the outlet of waste heat re-boiler, all sulphur condensers and one common spare seal pot. There are totally seven seal pots for each train. The seal pots are column in pipe construction which stands a column of liquid sulphur inside a pipe. The feed liquid sulphur flows through the inner pipe, fills up the column pipe and flows through the outlet nozzle at the top side of the column pipe thus standing a permanent column of liquid sulphur forming liquid sulphur seal. The seal is necessary for the following reasons:

- To provide necessary back pressure in the respective heat exchanger to facilitate flow of gases in process flow direction.
- To prevent uncondensed acid gases containing unconverted H2S in the exchanger to escape from the product sulphur equipment

All the seal pots are identical in design, construction and operation. The seal pots are steam jacketed at 2.5 kg/cm² pressure. The jacketing is necessary to maintain the liquid sulphur in molten condition for gravity flow. The correct LP steam operating pressure is necessary as the viscosity of liquid sulphur increases with increase in temperature beyond 155°C -160°C. But below 135°C, the viscosity increases with decrease in temperature. The optimum temperature of liquid sulphur for smooth flow is around 145°C. The saturated LP steam at 24.5 N/m² – 29.5 N/m² is the optimum steam pressure for the jacket. Separate steam header is provided to meet this requirement. The seal pot is provided integrally with a lock at the exit of the seal pot. Inspection door and outlet/rodding connections are provided to facilitate de-chocking of the seal pot and look pots. The seal pots are sunk in underground concrete casings. The material adopted for the construction of seal pot is cast steel.
B. Sulphur Pit
The liquid sulphur from various seal pots are connected to a jacketed piping header and routed to sulphur pit. The liquid sulphur flows by gravity into the pit. H₂S is dissolved in liquid sulphur to its equilibrium solubility at the separating temperature. The H₂S is removed by circulating liquid sulphur by pumping and discharging through a flash plate and displacing it by sweep air from atmosphere. An ejector system is provided to suck the air- H₂S mixture from the pit and discharge into incinerator. The liquid sulphur is stored at about 138°C, suitable no of heating coils, with LP steam heating are provided to maintain the temperature of the sulphur. The sulphur pit is provided in two compartments with equalizing provision. The sulphur from condenser may have dissolved H₂S up to 300 ppm. This is an unacceptable quantity for direct disposal to solidification yard for atmospheric solidification of sulphur, as threshold limit for H₂S for continuous exposure is only 10ppm. The H₂S removal is carried out by recirculation of liquid from bottom side by sulphur pump and discharging into vapour space through spray nozzle. The dissolved H₂S is released from the liquid and scavenged out of the pit by the deep air drawn into pit through air intake pit provided on the pit. The sweep air along with H₂S is sucked by an ejector system and the liquid sulphur- H₂S contamination is controlled to 10ppm. The sulphur pit is provided with number rupture disc provision for venting during process/operation upset condition such as ejector malfunction or steam failure. The inside walls and the bottom of the pit are lined with acid proof lining and acid resistant fire brick, as the sulphur is acidic due to H₂S presence and the temperature is about 132°C -140°C . The pit bottom is provided with a slope towards the sump for the location for two sulphur pumps. The pit is provided with the following facilities
- Inspection opening cover
- Dipstick inspection
- Temperature indication connection
- Level Connection

C. Steam Jacketed Pipe
The temperature of molten sulphur is to be maintained between 155°C-160°C to maintain the required viscosity. In order to maintain this temperature a steam jacket is supplied around the pipe at a pressure of 24.5 N/cm²-29.4 N/cm². It is a concentric pipe in which molten sulphur flows to the innermost side of the pump and the low pressure steam flows through the outer pipe, the whole pipe being covered with thermal insulators to prevent the loss of heat. Steam traps are fixed in the outer pipe to remove the condensed steam from the pipe.

D. Sulphur Pump
Sulphur pump is a centrifugal pump used for the recirculation of molten sulphur in the sulphur pit. In BPCL-KRL the sulphur recovery unit under consideration has two sulphur pumps in action. One pump is always online throughout the process and the other one is reserved as standby. The sulphur pumps are steam jacketed for prevention of solidification of sulphur inside the pumps. The technical description of the sulphur pumps used in sulphur pit is given in table 1, below.

<table>
<thead>
<tr>
<th>Table 1. Technical Description of the Sulphur Pumps</th>
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<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Casing</td>
</tr>
<tr>
<td>Seal</td>
</tr>
<tr>
<td>Power</td>
</tr>
<tr>
<td>Rpm</td>
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<tr>
<td>Flow</td>
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<td>Discharge Pressure</td>
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III. HISTORY OF SHUTDOWN OF SRU
One of the main problems associated with any industry is the shutdown of the plant during operation. Shutdown of a plant in an industry is because of many reasons, the probable reasons for shut down of a plant are
- Critical Component/process (bottleneck) failure
- Break down maintenance
- Shut down maintenance
- Very high inventory
- Accidents
- Seasonal Industry
IV. REASONS FOR SULPHUR PLUGGING

The possible reasons for sulphur plugging in SRU are found out by using cause and effect diagram (Ishikawa diagram). Figure 3 shows the root cause analysis of sulphur plugging in SRU found out by brain storming with engineers of KRL. Accordingly, the probable factors are mainly classified into five. They are

- Man
- Material
- Method
- Equipment
- Environment

The main reasons for sulphur plugging are mentioned below.

- Ineffective temperature monitoring: - Due to the lack of attention from operator like tiredness, loss of concentration etc. If the reduction in temperature is not monitored properly, it will lead to the sulphur plugging.
- Presence of hydrocarbons (HC) in the molten sulphur: - Since SRU is a downstream plant in Kochi refineries Ltd, any malfunction in the upstream processing plant will lead to the presence of hydrocarbons in the molten sulphur, which ultimately lead to the plugging of sulphur in rundown lines and seal pots.
- Steam trap not working properly: – Steam traps are equipments used to remove the condensed steam inside a pipe. The condensed steam (water) will be removed by differential pressure between atmosphere and pipe. Steam traps may fail due to rust in metal parts.
Rain: – Sudden rain causes loss of heat from steam which leads to the formation of more condensate in the pipe, which cannot be removed by steam traps. This leads to reduction in temperature for the molten sulphur which ultimately results in the plugging of sulphur.

The above mentioned problems arise due to chance causes which cannot be eliminated completely, although periodic replacements of steam traps are effective. Therefore complete elimination of reasons for sulphur plugging is not possible.

V. METHODOLOGY

A. Existing Methodology to remove Plugged Sulphur

The plugging of sulphur mostly occurs in rundown lines and seal pots. The existing method is to shut down the plant and remove the solid sulphur by nitrogen flushing (at approx 49 N/cm² - 58.8 N/cm²) followed by rodding. The pressurized nitrogen pushes out the plugged sulphur from the rundown lines and seal pots. This is a tedious process and consumes long time to clean (approx 8 hours) the seal pots. The H2S gas present in the rundown lines and seal pots are hazardous to the operating personnel. The H2S gas affects the nervous system and ultimately leads to the death of the person. So roding and flushing is not an effective solution because it is time consuming, labour oriented and hazardous to the operating personnel.

B. Suggestion to Remove Plugged Sulphur

A flow chart of the alternative suggestion to this problem is given in figure 4. A bye pass line may be provided and it may be connected to the nitrogen flushing pot. When the sulphur plugging occurs the flow of molten sulphur will be reduced, which can be noticed by operator. When the flow reduces the pump which is connected in series to the sulphur pit by valve arrangement starts pumping and the combined pressure will push out the plugged sulphur from rundown lines and seal pots. This will enable the smooth flow of molten sulphur. When the plugged sulphur is removed the pumps can be switched off and the connection will be back in previous mode.

Inlet pressure after losses = 13137.36 – 226.58 = 12910.78 kPa
Nitrogen flushing pressure (max) = 7 kg/cm² = 6862.8 kPa
Since the discharge pressure is higher than the nitrogen flushing pressure (almost double) the choked sulphur in seal pots and rundown lines can be removed

C. Cost Benefit Analysis

Daily Production of SRU = 80 TPD
Loss of production during shut down = 3.33 TPH
Loss of money during shut down/hr = 3.33 X 5000* = Rs 16650
*Sulphur price approx Rs. 5000/tonnes
Loss of money during one shut down = 16650 X 8* = Rs 133200
*average shutdown duration in hours

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
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<tbody>
<tr>
<td>2 operator (2 X 1000)</td>
<td>Rs 2000</td>
</tr>
<tr>
<td>4 labour (4 x 500)</td>
<td>Rs 2000</td>
</tr>
<tr>
<td>Cost of N2 and instruments</td>
<td>Rs 1000</td>
</tr>
<tr>
<td>Total</td>
<td>Rs 5000</td>
</tr>
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Total Loss in a year = 138200 X 6* = Rs 829200
D. Investment Cost Of Suggested Method

- Cost of 15m pipe = Rs. 450 x 15 = Rs 6750
- Cost of jacketing = Rs. 500 x 15 = Rs 7500
- Cost of 7 three way valves = 7 x Rs 2500 = Rs 17500
- Erection Cost = Rs 5000
- Total Cost = Rs 36,750
- Savings per Annum = 829200 - 36750 = Rs 792,450

After this investment plugged sulphur can be removed without shut down of the plant. So the processes like rodding, flushing, blinding and blasting can be avoided which will ultimately save the time and money.

VI. CONCLUSION

The frequent shut down in sulphur recovery unit was noticed. The main reason for shutdown is identified as sulphur plugging. In order to reduce the frequency of shut down, n bye pass line is suggested for the removal of plugged sulphur. The financial and technical feasibility analysis is carried out to ensure the scope of suggested alternation in the company.

REFERENCES


AUTHOR BIOGRAPHY

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