KOREA OCCUPATIONAL SAFETY & HEALTH AGENCY

INVESTIGATION REPORT

REBOILER HEATER TUBE FIRE

Ulsan, Korea

October , 2003

KEY ISSUES:

- **Tube rupture by high temperature H_2S- H_2 Corrosion**
- **Reassurance of Convection tube inspection period & inspection method**

ABSTRACT

This report explains the fire that occurred on October, 2003 in a HOU(Heavy Oil Upgrading) Plant, Ulsan, Korea. The fire was arisen due to corrosion of fire heater tube, which was the convection heater tube of pre-fractionator reboiler and released VGO(Vacuum Gas Oil) that ignited. No employee was injured, but potentially polluted material was released into the air. The key safety issues covered in this report were how to inspect the convection heater tube and to select proper tube material of construction at the stage of design. Recommendations concerning this issue were delivered to said Plant.

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SUMMARY

1. INTRODUCTION

On October, 2003, a pre-fractionator reboiler fired in a HOU (Heavy Oil Upgrading) Plant, Ulsan, Korea. The fire continued for 2 hours and damaged reboiler itself. No employees were injured, potentially polluted vent gas was released into the air. Because of the serious nature of the incident, the Korea Occupational Safety and Health Agency initiated an incident investigation. The purpose of the investigation was to identify the root causes of the incident and make recommendations to prevent similar incidents.

The company who owns HOU plant is mainly composed of oil refinery, petrochemical plant, and other facilities for shipping, storing, and so on. It is one of the big refinery and petrochemical complex in the world, with the up-to-date automation process on area of 2000 acres (8.26 million m2). There are about 40 plants in the Complex. About 1/3 of them is for petroleum. Another 1/3 is for petrochemical factories. And the last 1/3 is for PE/PP plants, lubricants, and other facilities like a power plant.

2. IINITIATING EVENT

The investigation team determined that the fire occurred in the convection section of the reboiler heater. There were no other physical damages except convection part of the heater itself. The investigation team decided to dismantle the heater. 5 days later, the damaged heater was took to pieces. The investigation team found out that the upper side (‘E” pass ; the eighth row of convection section in prefractionator reboiler heater) had ruptured and it was split into 2 part with the length of about 2.1m.

3. KEY FINDINGS

The cause of the fire that occurred at the reboiler heater of the UC Unit is high temperature sulfidic corrosion. The report, *Overview of Sulfidic Corrosion in Petroleum Refining* which was proposed by NACE technical committee in 2003, provides the following descriptions of corrosion

1) Steel with 5% or even 9% Cr has been observed to corrode at rates as high as CS
2) Corrosion can be locally aggressive, such as in areas of higher velocity or turbulent flow, or on the topside of horizontally oriented furnace tubes

3) Corrosion rates can be high, even if total sulfur content is low (several parts per million)

In this incident, the upper side of the convection had corroded and ruptured so that it caused fire and made damages around the heater and facilities.

4. Root Cause

- Tube rupture by high temperature H_2S - H_2 Corrosion

1.0 INTRODUCTION

Figure 1: UC(Unicracking) Unit after fire

1.1 BACKGROUND

On October, 2003, a pre-fractionator reboiler fired in a UC(Unicracking) Unit of HOU (Heavy Oil Upgrading)Plant, Ulsan, Korea. The fire broke out on the eighth row tube on the convection part of the heater. It continued for 2 hours and damaged reboiler itself. No employees were injured. However, potentially polluted vent gas was released into the air. Because of the serious nature of the incident, the Korea Occupational Safety and Health Agency initiated an incident investigation. The purpose of the investigation was to identify the root causes of the incident and make recommendations to prevent similar incidents.

1.2 INVESTIGATION PROCESS

The KOSHA investigation team conducted an on-site investigation until November 6, 2003. The scope of the investigation team was to examine and analyze the circumstances of the fire to learn what happened, and to attempt to determine the cause of the fire. The team evaluated the process design and safety management systems to determine their adequacy in controlling the cause of this

fire. The ultimate objective of this investigation was to develop recommendations to help prevent similar incidents.

The team used the following investigation methodology adapted to address overlapping roles and responsibilities of other agencies investigating this incident. Facts were compiled by examining evidence at the incident site, conducting interviews, and reviewing documentation. To minimize duplication of effort, the team used the information collected by other agency to the maximum extent practical.

2.0 SYSTEM ANALYSIS

2.1 HOU(Heavy Oil Upgrading) PROCESS

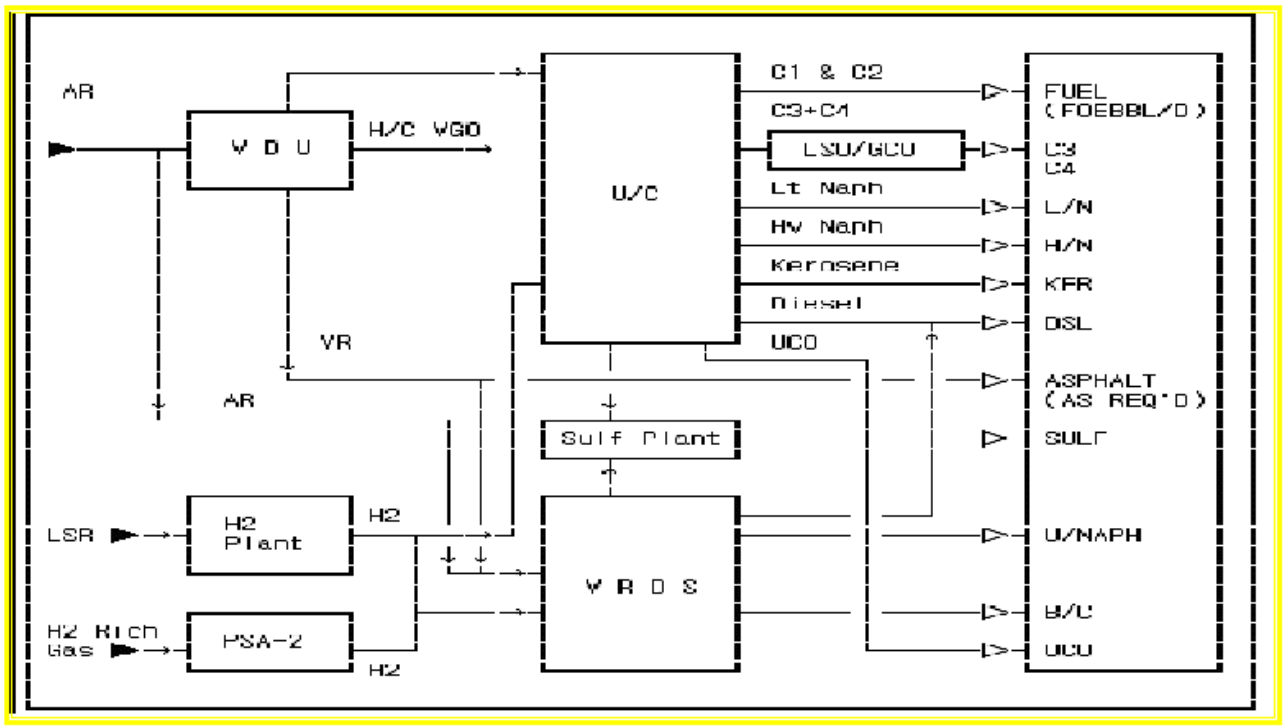

Fig.2 : HOU Process Flow Diagram

The plant, No.1 Hydro-cracker, called HOU(Heavy Oil Upgrading) was built in 1992. This is mainly composed of Vacuum Distillation Unit (VDU), Unicracking Unit(UC), Vacuum Residue Desulfurization Unit (VRDS), and Hydrogen Plant(HP). The Plant can handle maximum 120,000 barrel of high sulfur bunker-C oil per day and produce naphtha, light oil products, such as kerosene, gasoline, ultra-low sulfur bunker-C oil and sulfur products. The HOU plant is mainly operated under high temperature and high pressure. Fig. 2 shows HOU Process Flow Diagram.

2.2 UC UNIT

UC (Unicracking) unit produces LPG, naphtha, light oil, and gasoline which use 30,000 BPSD(Barrel Per Stream Day) of VGO(Vacuum Gas Oil) from Vacuum Distillation Unit as feed through hydro-cracking process as shown in fig. 3.

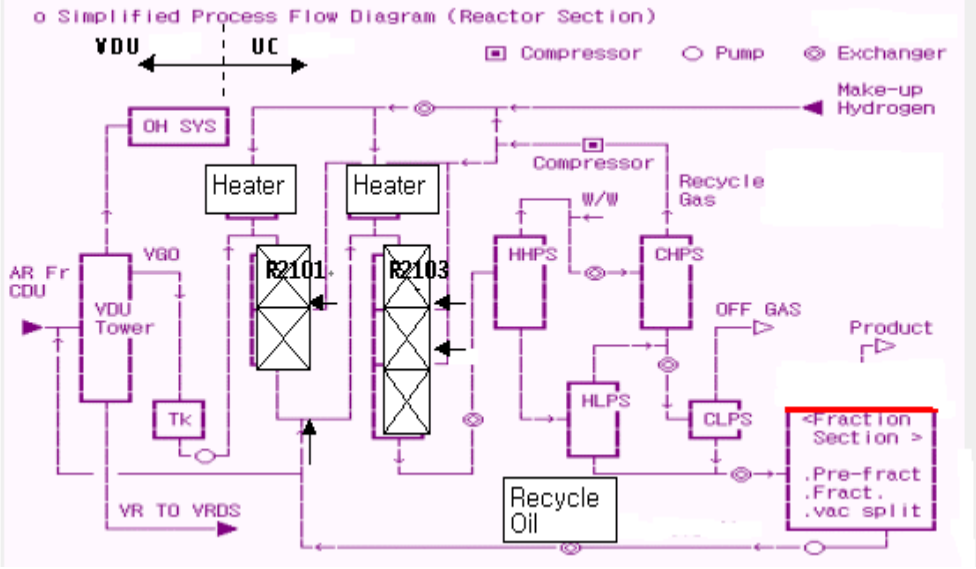

Fig.3 : UC Process Flow Diagram

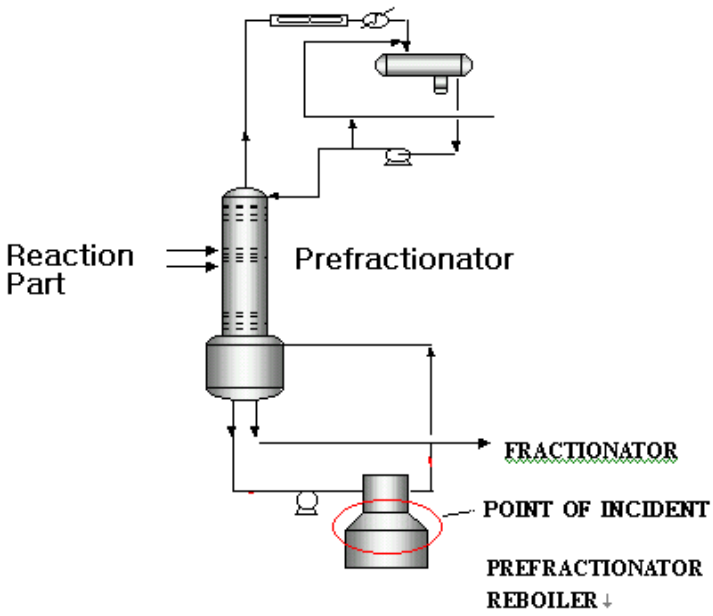

Fig. 4 : Point of Incident of UC Unit

3.0 INCIDENT ANALYSIS

3.1 Description

In the midnight of October, 2003 a pre-fractionator reboiler fired in a UC(Unicracking) Unit of HOU (Heavy Oil Upgrading)Plant, Ulsan, Korea. The fire broke out on the eighth row tube on the convection part of the heater. It continued for 2 hours and damaged reboiler itself and facilities. The upper side of the convection tube (pass 'E' ; row 8 in Pre-fractionator reboiler heater) had ruptured that it caused fire,

Fig. 5: Ruptured Tube

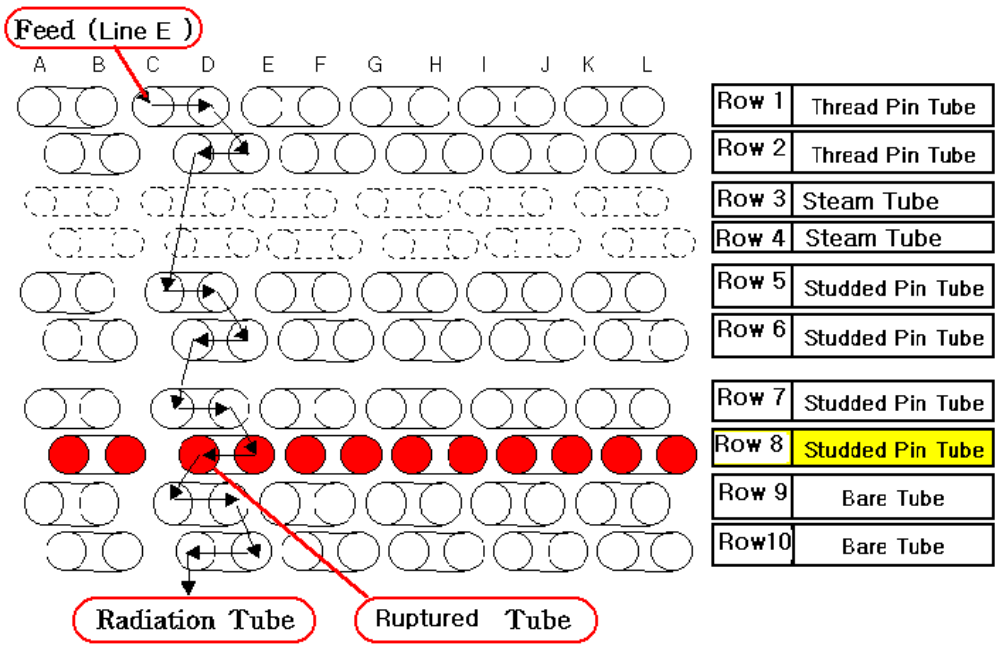

Fig. 6 : Heater Tube Arrangement

Fig. 7 : Appearance of the Reboiler Heater after Fire

Fig. 8 : Ruptured Tube Detached from the Heater Convection Box

4.0 Result of Investigation

4.1 Convection Tube Inspection Result

- Generally it has a kind of high temperature H_2S- H_2 Corrosion trend and especially the corrosion of middle row is more serious than that of lower row tube walls in the convection section under high temperature. The rows 7 and 8 showed more serious corrosion.

4.2 Convection Tube Scaling Analysis Result

- In the view of external inspection and component analysis, most of contents were FeS which was corrosion residue of tube metal from typical Sulfur.

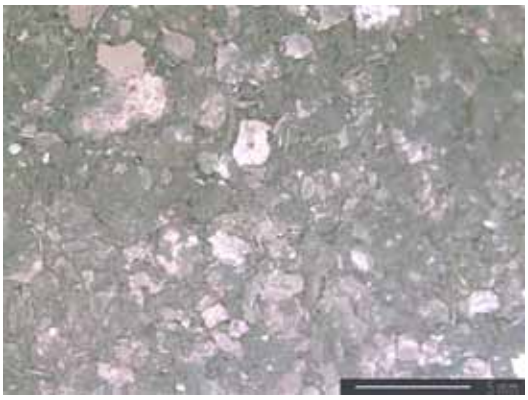

Fig. 9 : View of Scale in the Tube Inside -EDX(Energy Dispersive X-Ray)Analysis

4.3 Vapor/Liquid Pattern and Flow Regime Analysis inside Convection Tube

- Slug flow existed cause of vaporization in the convection tube, and this part was not much affected under real operation fluctuation range condition .
- In addition to rupture pass, other passes were also detected serious thin condition in 7,8 rows. From this result, the section of ventilation was supposed to be limited, therefore the cause of accident was not short term corrosion but long term one.
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4.4 Corrosion Mechanism

As flow temperature was going up in the convection tube, the vaporization was occurred, initial bubble type vapor components were crashed each other and after all converted into slug flow type flow regime. In the slug flow zone, high concentration H_2S vapor was driven to upper tube side, therefore H_2S concentration and tube metal temperature was getting higher and higher in this spot, as time goes by, high temperature H_2S - H_2 corrosion broke out very seriously. This corrosion rates was very high, even if total sulfur content is low (several parts per million [ppm]).

5.0 ROOT CAUSE

5.1 Tube rupture by high temperature H_2S- H_2 Corrosion

The general corrosion of whole tube and local corrosion of slug flow inside tube from material vaporization made the thickness of tube to be thin therefore it became of tube rupture.

6.0 RECOMMENDATIONS

6.1 Material of Construction of Reboiler Heater Tube Upgrade

Reboiler heater tube and subsidiary tube material of construction need to be upgraded. In addition, the scope of material selection and replacement policy shall be rechecked and revised.

6.2. Reassurance of Convection Heater Tube Inspection Period and Method

Convection tube inspection period & inspection method shall be revised considering operation condition of heater convection section, material and corrosion status, and then the inspection period and method to be decided clearly.

7.0 REFERENCE

National Association of Corrosion Engineers, *Overview of Sulfidic Corrosion in Petroleum Refining*; Proposed NACE Technical Committee Report: NACE International, Houston, Texas, 2003.