

Thinning of Inlet Piping to Reactor Effluent Air Condenser [REAC] Of Gas Oil Hydrotreating Unit - Case Study

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ABSTRACT

During a turnaround inspection of a Gasoil Hydrotreater, severe metal loss was observed in the Reactor Effluent Product Condenser Inlet piping. The thickness loss was on the straight horizontal piping portion downstream of continuous wash water injection point. Metal loss is confined to top portion i.e., 10 to 2 o'clock position of the piping only. Corrosion rates in excess of 1mm/year were noticed. The unusual observation was that there was no significant thickness loss at point of water injection or immediate downstream piping, but loss was predominantly on straight portion after 5 directional change. Process simulation, Ionic Equilibria modelling and Computational Fluid Dynamics (CFD) study of the REAC inlet system was performed. This paper explains how the location of wash water injection and type of injection device has influenced the corrosion in the REAC inlet piping. Based on the study, it was identified that stratification of flow and inadequate scrubbing of reactor effluent vapor by wash water has led to HCl/NH₄Cl corrosion. Subsequently it was recommended to shift the wash-water injection location to vertical section of the piping and to change the injection type from quill to spray nozzle

Key words: REAC, Hydrochloric Acid, Ammonium chloride, Wash water injection, Hydro processing,

INTRODUCTION

Gas Oil Hydrotreating Unit uses a catalytic hydrotreating process employing a selective catalyst and a hydrogen-rich gas stream to decompose organic sulfur, oxygen and nitrogen compounds contained in the feed. The products of these reactions are the contaminant free hydrocarbon, along with H₂S and NH₃. Other Treating reactions include halide removal and aromatic saturation. Reactor effluent is cooled in series of Combined Feed Exchangers followed by REAC for product separation. The reactor effluent system is prone for corrosion and fouling due to salting of NH₄HS and NH₄Cl. Most of the failure analysis studies and literature available in public domain regarding reactor effluent corrosion deals with the corrosion in the REAC and its outlet piping. Even though unusual failure in the form top-half pipe corrosion was reported in few instances of REFINCOR¹ forums, not much has been written on this subject. This paper discusses the methodology and analysis carried out to understand the factors influencing such corrosion in the inlet piping of REAC.

Process Description:

In this Gasoil Hydrotreater unit, the feed is a blend of Gasoil from Crude/Vacuum Distillation unit and Condensate splitting unit. The feed is mixed with hydrogen and it is preheated in series of Combined Feed Exchangers (CFE) followed by a Charge Heater and fed into Reactor, where denitrification and desulfurization reaction occur. The hydrotreated gasoil is cooled in CFEs to recover the heat for preheating and the final cooling of the reactor effluent is obtained in air fin coolers i.e., REAC. Water is injected into the stream before it enters the coolers in order to prevent the deposition of salts. In the stripper section, Sour gas and the Naphtha is separated from the Gasoil product. Refer Figure 1 for process flow of the Reactor effluent section.

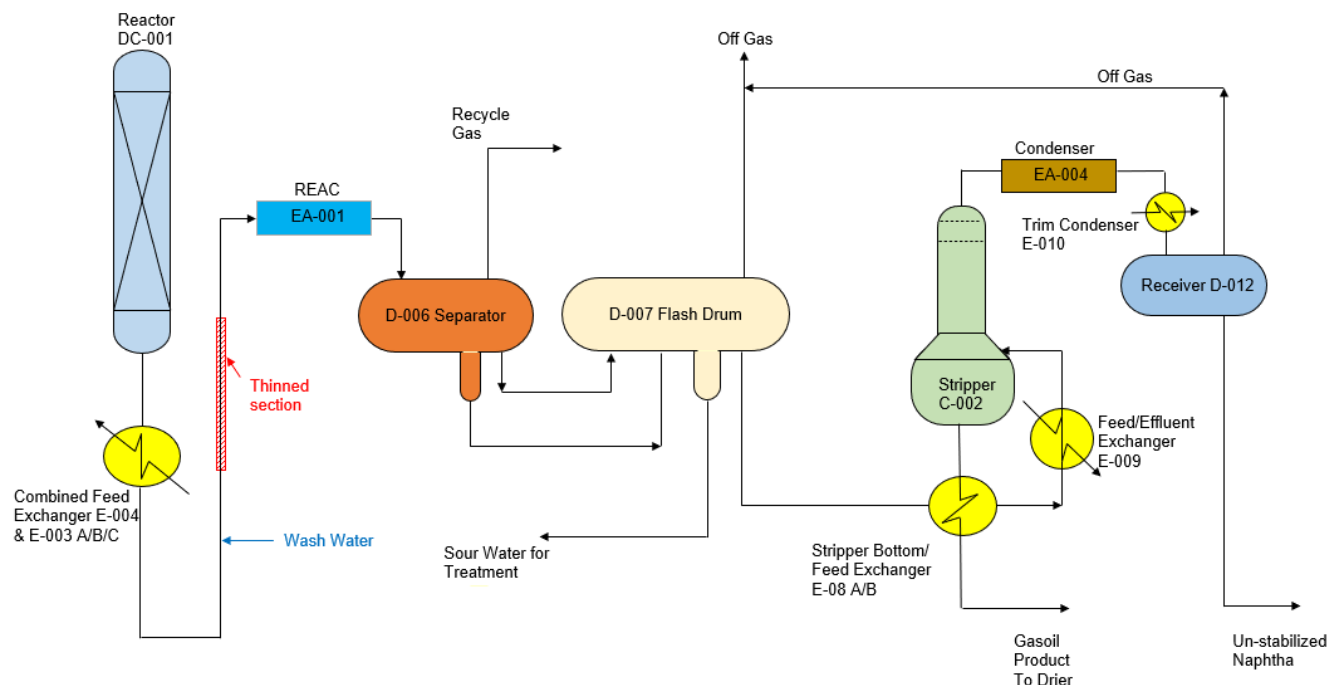


Figure: 1 Process Flow Diagram of Reactor Effluent and Product separation system

During a turnaround inspection, as a part critical piping system, an extensive Ultrasonic Thickness (UT) survey was carried out on inlet piping to REAC. The metallurgy of the piping is ASTM⁽¹⁾ A 335² Gr P11 i.e., 1.25Cr-0.5Mo. The diameter and thickness of the pipe is DN200 (NPS 8") and 15.09mm (0.594"). The operating pressure & temperature of the pipe is around 60kg/cm² (865 Psi) & 150°C (275°F) respectively. The inspection coverage was over and above of recommendations for injection point inspection in API⁽²⁾ 570³. Severe metal loss was observed on the piping downstream of wash injection. Thinned location is highlighted in Figure 1. The unusual observation was that there was no significant thickness loss at point of water injection or immediate downstream piping, but loss was predominantly on straight portions after 5 directional change, Refer Figure 2. The thickness loss was on the horizontal

⁽¹⁾ American Society for Testing and Materials (ASTM)

⁽²⁾ American Petroleum Institute (API), 1220 L St. N.W. Washington DC 20005-4070

piping portion downstream of continuous wash water injection point. Corrosion rates in excess of 1mm/year was noticed. However, no metal loss was observed on the subsequent vertical portion of piping up to REAC. All the thinned piping was replaced with same metallurgy. The removed pipe sample was split opened, and it was observed that metal loss is confined to top portion i.e., 10 to 2 o'clock position of the pipe only. Refer Figure 3 & 4 for photographs of the split opened pipe section. The morphology of failure is similar to that of acidic under deposit corrosion. Internal deposit from top section of the pipe was analyzed using Wavelength Dispersive X-ray Fluorescence method (WD XRF). The analysis revealed the deposit is predominantly an iron (Fe) based corrosion product with Sulfur (S), Chlorine (Cl) and Oxygen being the other contributing elements. The results are tabulated in Table-I.

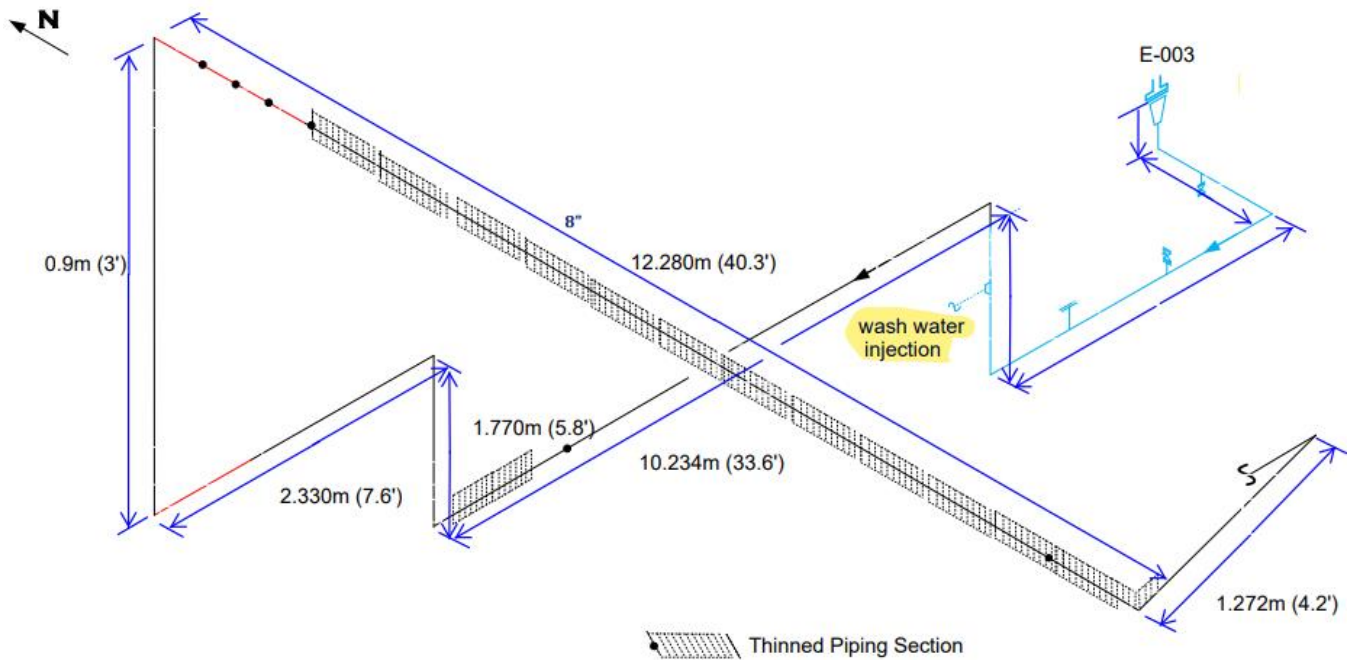


Figure: 2 Isometric drawing of the E-03 outlet piping highlighted with thinned section



Figure 3: Top Half of the Pipe



Figure 4: Bottom Half of the pipe

Table-I
Composition of Internal Process Deposit from the thinned pipe

Analysis	Method	Unit	Internal Pipe Deposit
O	WD XRF	Weight %	12.963
Al			0.276
Si			0.481
Cl			4.201
Fe			54.152
S			16.835
Cr			0.788
Mn			0.085
Co			0.111
Ni			0.072
Cu			0.094
Mo			0.228
Loss of Ignition at 100°C			Weight %
Loss of Ignition at 550°C		Weight %	6.4

Table-II
Corrosive Species Analysis of Feed

Date	Feed Sample	Sulphur ASTM D2622 ⁴ %wt	Nitrogen ASTM D4629 ⁵ ppm wt.	Chloride ASTM D4929 ⁶ ppm wt.
Day 1	Gasoil Blend	0.67	70	<0.5
Day 2	Gasoil Blend	0.6704	70	0.7
Day 3	Gasoil Blend	0.575	54	<0.5

EXPERIMENTAL PROCEDURE

To study the tendency for Ammonium salts depositions and HCl corrosion in the piping, Ionic equilibria model of the Reactor effluent circuit was developed. The Gas oil feed to unit was analyzed for Chloride, Sulfur & Nitrogen for three different days to capture the variation in the blend composition, Refer Table-II. Average operating parameters like pressure, temperature and flow of that particular day was used in the calculation.

Since no significant thinning was observed on the elbows, stratification of flow and erosion due to higher vapor velocity was also considered as possible damage mechanism. To evaluate the same, Computational Fluid Dynamics (CFD) study of the piping system was carried out.

Process Simulation/ Ionic Equilibria modelling:

The process calculation to estimate the stream composition of reactor effluent was carried as per guidelines in Annex A3 of API 932B⁷. The reactor effluent is separated into Diesel Product, Unstabilized Naphtha, Recycle Hydrogen and Off gas. These streams were back blended to simulate the reactor effluent stream and the chemistry was analysed using Mixed Solvent Electrolyte (MSE) model of OLI[†] Systems. As per simulation, the quantity of injected water that remains in the aqueous phase after equilibrium flash is 76%. The estimated ammonium chloride (NH_4Cl) precipitation temperature is 180°C (356°F) and there is no precipitation of ammonium bisulfide salts (NH_4HS). The temperature survey of stream S-4, refer Figure 6, revealed that conditions are not favorable for precipitation of salts and pH is above 6.2 at the region of interest.

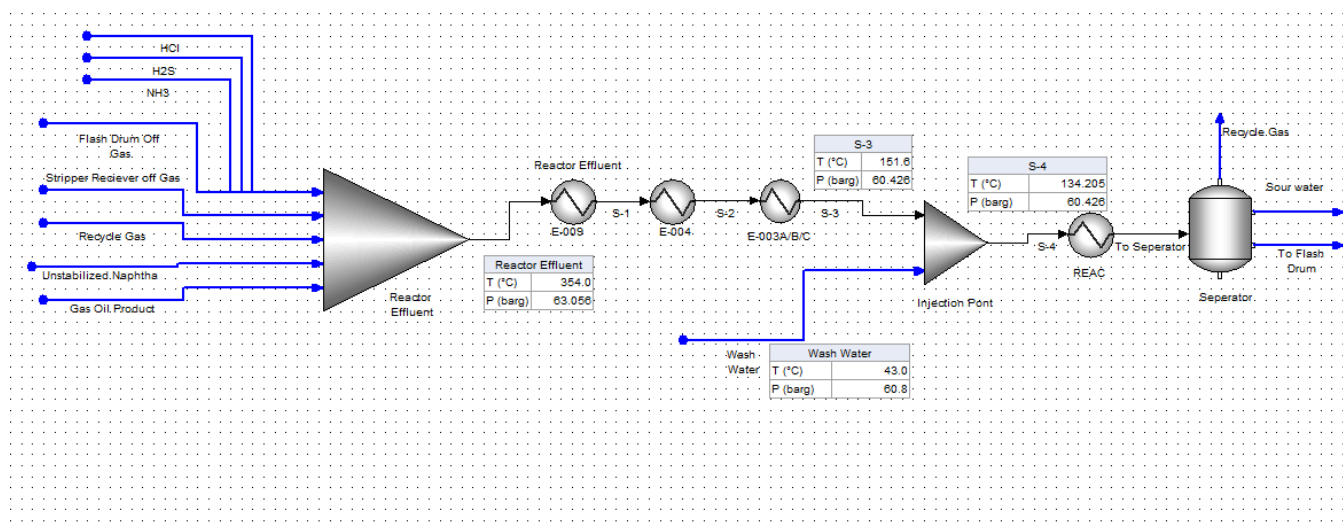


Figure: 5 Process Simulation Model

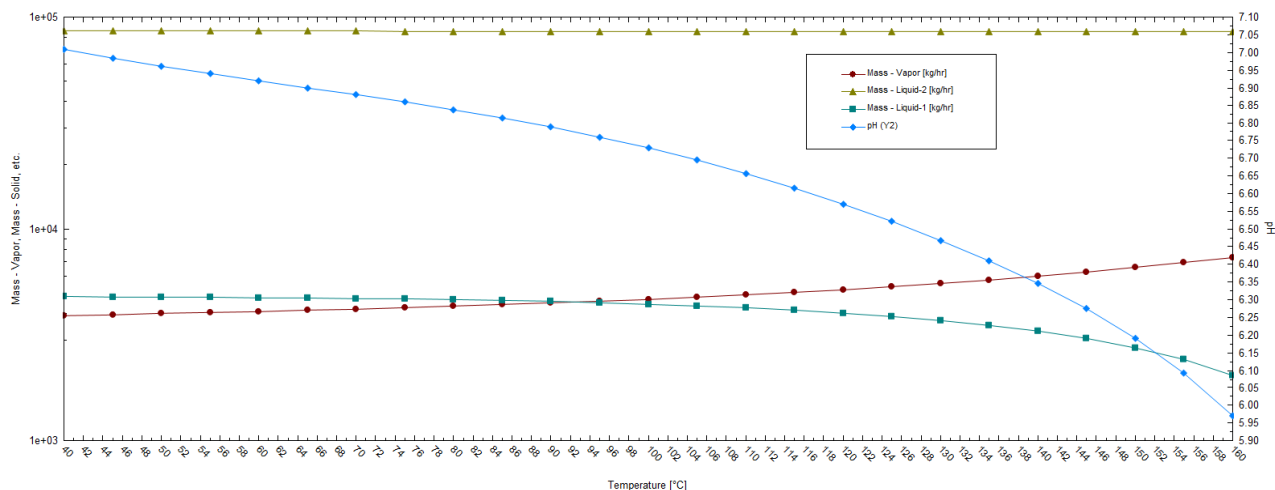


Figure: 6 Plot of Temperature survey

[†] Trade name