CASE STUDY ON FIRE INCIDENT AT VGO-HDT UNIT

1.0 THE INCIDENT:

An incident of major fire occurred in VGO- HDT unit of a petroleum refinery leading to shutdown of the unit. Fire continued for about 4 hours. Due to the incident, the unit suffered major damages (shown below) and is under shutdown pending major repairs.

The explosion took place at the outlet line of VGO Feed/Reactor effluent heat exchanger, shown in Fig.1.

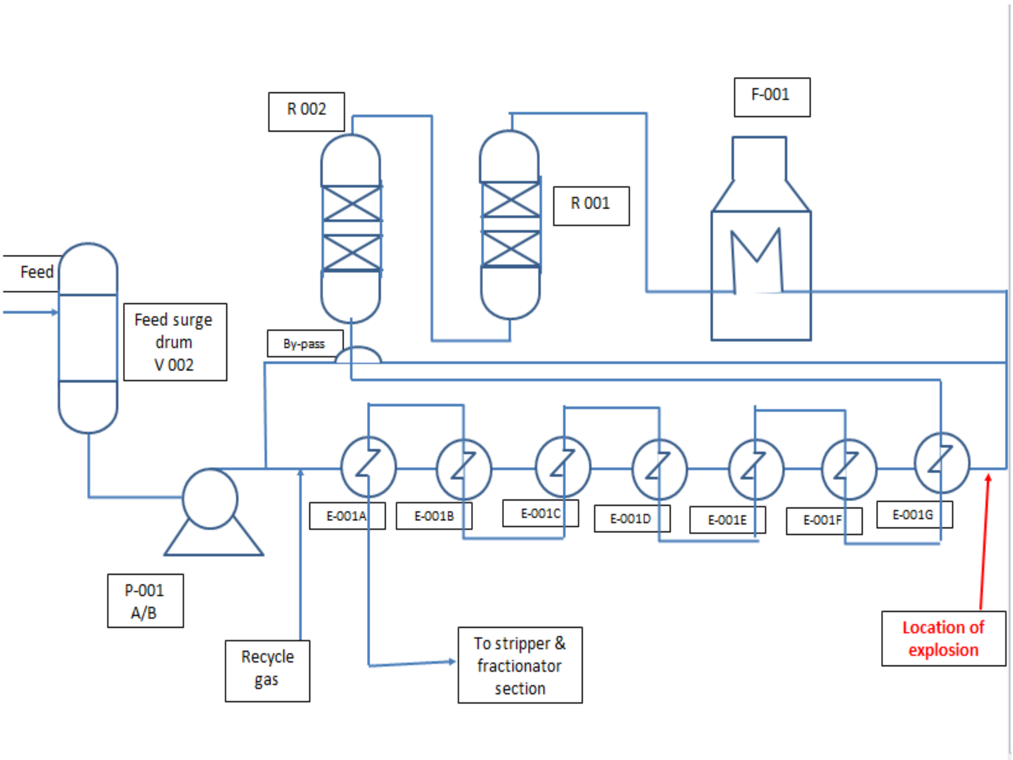

Fig. 1

Due to this major explosion, about 40 inch portion of the exchanger outlet line along with part of elbow got detached from it’s parent piping which flew to a distance of about 20 M. Due to the rupture of the line, there was enormous spillage of VGO and Hydrogen which resulted in a major fire. Also a support (20”NB SS-321 pipe, approx. 1M long) holding this portion of the pipe got detached and was found lying at a distance of about 40M westward. The mainline which got detached is made of stainless steel (SS-321) of 23.8 mm thickness.

Operating personnel, after getting the information of fire in control panel, activated emergency shutdown system. VGO feed pump, lean amine pump, wash water pump, hydrocarbon washing pump, MUG compressor got shutdown and furnace trip operated and dump valve opened. Recycle gas compressor continued to run as per the normal procedure to cool the reactor bed. The hydrocarbon as well as hydrogen in the system, which were at high pressure and temperature continued to burn in the vicinity of exchanger, reactor, furnace, technological platform etc. The recycle gas compressor was stopped after about 6 minutes since the discharge was contributing to fire. The sketch of pipeline of the affected portion, its interconnection with exchanger bypass line with Quill provision is shown below as Fig.2:

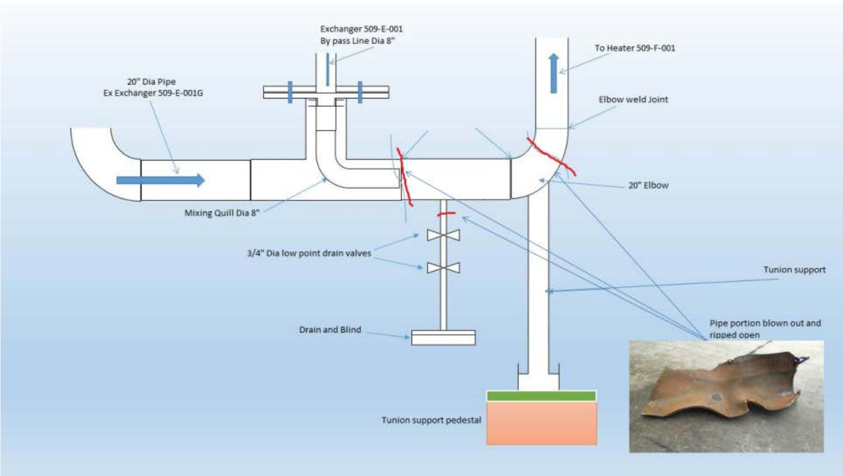

Fig. 2

The fire continued for almost 4hrs and there was substantial damage of structure, pipeline, instrument & electrical cables etc. in the vicinity of Exchangers, Furnace and Reactors. At the time of incident, there were no personnel near the affected area due to shift change over. There was no casualty/injury of persons due to the incident.

2.0 OBSERVATIONS:

- The unit was commissioned in the year 2012. Post commissioning, the unit experienced several interruptions causing frequent shutdown and start up prior to current major shutdown due to explosion and fire. However, there was no M&I shutdown of the unit since commissioning. The frequent shutdown and start up of the unit caused significant thermal shock and stress in the high pressure - high temperature piping circuit.

- Prior to the fire incident, the unit was running at a throughput of 453 M^3 / hr. vis-à-vis design throughput of 416 M^3 /hr. (around 109% of design). About 265 M^3/hr. feed was routed through feed/reactor effluent heat exchanger and balance quantity of feed 188 M^3/hr. (which is as high as 41.5% of the Feed) was bypassed the exchanger train and joining with the hot feed at the downstream of the exchanger.

- The temperature of the hot feed downstream of exchanger was recorded 402^oC and the temperature of bypass cold feed was about 200^oC. The bypassed cold feed i.e 188 M^3/hr joined the hot feed through a Quill and the combined feed was routed to reactor after heating in the furnace.

- The quantity of cold feed (exchanger bypass) was much higher (188 M^3/hr.) compared to design (106 M^3/hr), due to which the coil inlet temperature of the furnace was less at 312^oC compared to design of 344^oC causing higher heat load in the furnace.

- Due to substantial higher bypass of cold feed through the Quill and it's mixing with the hot feed at exchanger outlet there must be a rapid turbulence and two phase flow at the mixing point. This is a high severity zone in piping system and the above phenomenon led to extraordinary stress in the downstream piping. The eddy produced due to high turbulence, if not allowed to travel sufficient straight length, upon encountering bend on it's path could have severely damage the pipe structure.

- Thus immediately after the mixing point (i.e. Quill in this case), no restriction zone is provided, by way of adequate straight length of pipeline. It has been observed that the straight length of the line, downstream of Quill was much shorter than the design requirement of 10*D, where D is the outer diameter of the main pipe. Actual straight length was about 40 inch compared to the recommended length of 200 inch (should be 10*D stipulated in the design) causing much higher stress at the elbow downstream to the mixing Quill.

- Due to continuous exposure to this high stress, a portion of the pipe (from Quill to part of the elbow) got sheared from both the sides, and got completely detached from its location. The impact was such that ruptured cylindrical pipe was observed flat and was found at a distance of about 20 M near the reactor. The support at the downstream elbow was found detached & blown away to a distance of about 40 Meter due to impact of the explosion.

- There was a ¾ inch low point drain (LPD) in this portion of the line prior to the elbow. It has been observed that the pipe adjacent to this LPD also sheared. It was noted that the LPD has been bent and there was a crack in the joint of LPD. This crack might have developed because of explosion. The two nos. of valves with end flange on the LPD were detached and couldn't be traced at site.

- The main piping support at the elbow (about 1 M length SS pipe) was detached from its location was found at a distance of about 40 M away.

- The downstream portion of the failed pipeline (Shell side) and tube side outlet piping of the exchanger were found buckled.

- In the Process Flow Diagram, it is observed that there are 6 Nos. of exchangers, which was confirmed in the operating manual also, whereas at the site there were 7 exchangers. It is not clear at which stage the 7th exchanger was added. The Management of Change (MOC) of the same was not available. In fact the PFD and operating manual were found not updated although the addition of one more exchanger is an important process change.

- The fire continued for about 4 hrs. due to burning of hold up hydrocarbon and hydrogen in the system. There was no isolation valve between exchanger, furnace and reactor section.

3.0 DISCUSSIONS AND ANALYSIS:

- The portion of affected pipes and its support got detached and blown away to a distance of 20M to 40 M, which is possible only in case of an explosion. Since there was no hot job or any source of spark in the vicinity, this phenomenon occurred due to auto ignition of the leaky hydrocarbon at high temperature, which was above the auto ignition temperature of VGO. The Jet fire from the leakage led to explosion inside the pipe containing hydrogen gas along with hot feed.

- From DCS records prior to the incident, it is observed that the unit condition was normal. The graph showing operating parameters like flow rate, pressure, temperature etc. were steady. There was no sudden increase in pressure / temperature in the circuit.

- The abnormality noted in process was bypass of huge quantity (about 41.5%) of VGO by passing feed / reactor effluent exchanger. It is understood that the bypass is kept high since last more than a year. Such higher amount of feed bypass created higher turbulence & stress in the vicinity of mixing points, resulting in a higher degree of thermal shock due to sudden temperature difference between the hot feed and cold feed.

- To ensure better mixing of hot and cold feed downstream of exchanger, the cold feed is passed through a Quill. As per the design of the Quill, there has to be a minimum length of 10*D (D= OD of the main pipe) without elbow or Tee. **However, it was observed that the straight length up to the next elbow is only 40 inch compared to requirement of 200 inch.** Not providing adequate length between the Quill and the elbow caused tremendous stress on the main pipe particularly the elbow section which ultimately gave away.

- Other likelihood for initial leakage can also be attributed to drain point valve(s) gland leakage. The Jet fire from the leakage might have led to explosion inside the pipe which was having hydrogen gas along with hot VGO.

- The support of the pipe at the elbow was a pipe of about 1M length. The support pipe was welded with the elbow at one side while the other firmly anchored to the ground – on plate on a concrete base locked on all four sides by angles. Since this portion was firmly anchored and there was no room for lateral movement, the eddy that formed inside the pipe due to mixing of huge quantity of cold feed with hot feed resulted in tremendous stress on the welded joint at the pipe with the support leading to crack at the joint. This might also lead to leakage followed by fire and explosion. Flexibility analysis of support should have been checked.

- The other possible reasons which might have contributed to the failure could be:

  - Weakening of joint due to exposure to continuous high vibration
  - Chloride attack of SS tube due to presence of high chloride in insulation material.
  - High Temperature Hydrogen Attack (HTHA) weakening the metal.
  - Use of inferior metallurgy / welding material (designed metallurgy SS-321)

- Damage of pipe may be possible in case of continuous vibration of the pipe due to turbulence caused by mixing of more than designed quantity of cold feed with hot feed in a two phase flow..

- Chloride content of the insulation material should be analyzed which might have contributed in chloride attack on SS pipe.

- Though the process parameters like temperature, pressure, flow etc. were steady as per the chart obtained from DCS, the pressure & temperature variation during explosion was not captured in DCS.

4.0 ROOT CAUSE OF THE INCIDENT:

The root cause of the incident could be due to multiple factors as described below either one of the same or all put together:

- Continuous exposure to internal turbulence and thermal shock at the elbow due to bypass of cold feed much higher than the design. The mixing of more quantity of cold feed with hot feed leads to change in two-phase flow regime and thermal shock.

- Inadequate distance between the Quill and the elbow joint. As per design, the straight distance between the Quill and the elbow should be 10 times pipe diameter. At site, the straight length was only 40 inches against 200 inches requirement. Deviation from standard engineering practice of maintaining a clear straight distance (10*D in this case) after the mixing point (Quill) resulted in continuous stress and erosion at the elbow section which finally gave away.

- The locked anchor of the elbow, as mentioned above might have prevented lateral movement of the pipe which caused tremendous continuous stress at the elbow section and failure of the pipe due to weakening of the subject section.

- The failure could also be attributed to leakage from the ¾ inch LPD through valve gland / end flange or from weak joint of the high pressure / temperature system in the vicinity of the failure.

5.0 RECOMMENDATIONS AND LEARNING:

1. Bypassing such huge quantity of VGO (around 41.5 % which is much more than design) should be stopped. Instead, HMEL must conduct a detailed study to identify the exact reason that forced the Operator to

bypass such quantity of cold feed and take adequate measures to resolve this technical issue. Bypassing so much cold VGO led to thermal shock and stress at the exchanger outlet at the location where cold feed meets the hot feed.

2. As per P&ID, a minimum straight distance prescribed should be 10D i.e. 200 inch is to be maintained after the Quill. The actual straight distance is only about 40 inch which is far less than the prescribed limit. Inadequate straight length caused the turbulence created in the pipe to exert additional stress (erosion) on the elbow of the pipeline and thus weakening of the section. This deficiency must be corrected upon discussion with Licensor.

3. The provision of LPD may be reviewed in view of possibility of leakage through the drain pipe particularly since the line is handling hydrocarbon and hydrogen at high pressure and temperature.

4. The inflexible support of the elbow must be checked with Detailed Engineering Consultant. It is felt that due to locked anchor of the elbow, lateral expansion was prohibited that led to stress and subsequent weakening of the section. Flexibility analysis of the piping system and it's supporting should be ensured.

5. Lot of discrepancies has been found in PFD, P&ID and operating manual with respect to number of exchangers. In PFD and Operating Manual 6 nos. of exchangers have been shown whereas at site there are 7 nos. of exchangers. LPD & HPV at the heat exchanger outlet are not shown in as built P&ID / PFD. Since these are very important documents for operation, proper MOC and documentation w.r.t PFD, P&ID, Operating Manual, Design Manual etc. must be ensured.

6. The insulation provided at the exchanger outlet must be checked with respect to chloride content. It must be ensured that proper insulating materials are used and chloride content of the insulating material must be less than 10 ppm to avoid chloride corrosion.

7. OISD-STD-128 must be followed for inspection of unfired pressure vessels.

8. Regular Internal Audit, ESA must be carried & encouraged to identify the gaps and action taken to liquidate the same.

9. It is recommended that refinery must carry out detail chemical and metallurgical analysis of the failed portion of the pipe and fittings.

At the time of preparation of this case study, it has been gathered that the company has made necessary engineering corrections including other modifications prior to re-starting of the unit.

OISD Investigation Team comprised –

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