RISK ASSESSMENT STUDY

Bharat Petroleum

BHARAT PETROLEUM CORPORATION LTD
MUMBAI REFINERY

Submitted by:

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Rev No	Date	Purpose	Prepared By	Reviewed By	Approved By
0	14/02/2019	Issued as Final	MG	DK	DK

PREFACE

M/s Bharat Petroleum Corporation Limited (BPCL) has awarded the job of carrying out Environmental Impact Analysis and Risk Analysis of Petro Resid Fluidized Catalyst Cracker Unit (PRFCC) to M/s Engineers India Limited (EIL).

Risk Assessment study identifies the hazards associated with the facility, analyses the consequences, draws suitable conclusions and provides necessary recommendations to mitigate the hazard/ risk.

This Risk Assessment study is based on the information made available at the time of this study and EIL's own data source for similar plants. EIL has exercised all reasonable skill, care and diligence in carrying out the study. However, this report is not deemed to be any undertaking, warrantee or certificate.

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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Mumbai Refinery (MR) of Bharat Petroleum Corporation Limited (BPCL), is located at Mahul, Mumbai, Maharashtra, India. The refinery was commissioned in 1955 with a crude oil processing capacity of 2.2 MMTPA in a plot area of 450 acres. The refining capacity has subsequently been augmented through progressive revamps, addition of various process units and incorporating advanced refining technologies.

BPCL intends to diversify into Petrochemical products with major focus on Ethylene/ Propylene based petrochemical products to further improve refinery profitability. BPCL has recently carried out a Bottoms upgrading Study which recommended the setting up of a Petrochemical Resid FCC (PRFCC) complex with the intent of maximizing Polymer Grade Propylene production which will feed a Polypropylene complex being planned at Rasayani, 50 km from MR.

The 3 MMTPA PRFCC complex will include the following units:

- PRFCC Reactor and Regeneration
- Main Fractionator and Unsaturated Gas Plant
- PRFCC Regenerator Flue Gas Scrubber
- Unsaturated LPG Treating Unit
- Propylene Recovery Unit (PRU)
- Sulfur Recovery Unit (SRU)

This executive summary covers major findings arising out of the Risk Assessment study and recommendations for the safe operation.

1.2 APPROACH METHODOLOGY

Risk analysis study evaluates the consequences of potential failure scenarios, assess extent of damages, based on damage criteria's and suggest suitable measures for mitigating the Hazard.

Risk Analysis involves identification of various potential hazards & credible failure scenarios for various units and other facilities including off-site storages & pumping, etc., based on their frequency of occurrence & resulting consequence. Basically two types of scenarios are identified spanning across various process facilities; Cases with high chance of occurrence but having low consequence, e.g., Instrument Tapping Failure (20mm) or Flange Leakage (10mm) or Seal Failure (6mm) and cases with low chance of occurrence but having high consequence, e.g., Catastrophic Rupture of Pressure Vessels or large hole. Effect zones for various outcomes of failure scenarios (Flash Fire, Jet Fire, Pool Fire, Blast overpressure, etc.) are studied and identified in terms of distances on plot plan. Based on effect zones, measures for mitigation of the hazard/risk are suggested.

1.3 MAJOR FINDINGS AND RECOMMENDATIONS

The detailed consequence analysis of release of hydrocarbon in case of major credible scenarios are modeled in terms of release rate, dispersion, flammability and toxic characteristics, which have been discussed in detail in the report. The major findings and recommendations arising out of the Risk Assessment study are summarized below (*directions based on plant north*):

High Frequency & Low Severity Cases

a) Flammable Gas Modelling

1. **Instrument Tapping Failure at Main Fractionator Overhead Liquid Pump Discharge in PRFCC** (Figures 1.2): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone covers the road on the western & eastern side of the unit and Central Control Room on the western side of the unit. Blast over pressure effect of 5 psi extends beyond the unit covering the Central Control Room of the western side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the western and eastern side (roads on both sides of pipe track no.7) of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*
   - *Ensure that the Central Control Room on the western side of the unit is blast proof for protection of individuals from explosion effects.*

2. **Instrument Tapping Failure at LCO Product Pump Discharge in PRFCC** (Figures 1.3): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone covers the road on the western & eastern side of the unit and Central Control Room on the western side of the unit. Blast over pressure effect of 5 psi extends beyond the unit covering the Central Control Room of the western side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the western and eastern side of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*
   - *Ensure that the Central Control Room on the western side of the unit is blast proof and positively pressured for protection of individuals from explosion effects.*

3. **Instrument Tapping Failure at Debutanizer Overhead Reflux Pump Discharge in Unsat Gas Plant / LPGTU** (Figures 2.7): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone is mostly restricted within the unit covering a portion of road on the western and eastern side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the western and eastern side of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*

4. **Instrument Tapping Failure at Depropanizer Feed Pump Discharge in PRU** (Figures 3.1): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone covers a portion of the road on the eastern side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the eastern side of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*

5. **Instrument Tapping Failure at Propylene Product Pump Discharge in PRU** (Figures 3.5): A 20 mm leak scenario corresponding to instrument tapping failure is analyzed under this case. This results in a flash fire zone which covers a portion of the road on the eastern side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the eastern side of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*

6. **Instrument Tapping Failure at Propylene / LPG (Future) Booster Pump Discharge in Offsites** (Figures 5.1): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone covers a portion of road on the northern and western side of the unit.

   It is recommended to

   - *Restrict vehicle movements on the road on the northern and western side of the LPG bullet area through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*

7. **Instrument Tapping Failure at Propylene / LPG (Future) Mainline Pump Discharge in Offsites** (Figures 5.2): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone covers a portion of road on the northern and western side of the unit. The Jet fire thermal radiation intensity of 8 kW/m^2 covers a portion of Kerosene Tank (T-412) on the western side of LPG Bullet area. Blast over pressure effect of 5 psi covers a portion of Naphtha Tank (T-423) on the north-western side of LPG Bullet Area.

It is recommended to

- *Restrict vehicle movements on the road on the northern and western side of the LPG bullet area through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*
- *Relocate the Propylene / LPG (Future) Mainline Pump such that the Naphtha Tank (T-423) falls outside the blast overpressure effect of 3 psi.*
- *Relocate the Propylene / LPG (Future) Mainline Pump such that the Kerosene Tank (T-412) falls outside the jet fire thermal radiation intensity of 8 kW/m^2.*

b) Toxic Gas Modelling

1. **Instrument Tapping Failure at Primary Absorber Top PA Pump Discharge in Unsat Gas Plant / LPGTU** (Figures 2.3): A 20 mm leak scenario corresponding to instrument tapping failure is analyzed under this case. This results in a flash fire zone which covers the road on the western, southern and eastern side of the unit. Blast over pressure effect of 5 psi extends beyond the unit covering a portion of Central Control Room on the western side of the unit. IDLH concentration (100 pm Hydrogen Sulfide) effects extend beyond the unit covering the Central Control Room on the western side of the unit and CPP Control Room on the south-western side of the unit.

It is recommended to

- *Restrict vehicle movements on the road on the western, southern and eastern side (roads on both sides of pipe track no. 7) of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*
- *Ensure that the Central Control Room on the western side of the unit is blast proof for protection of individuals from explosion effects.*
- *Ensure that the Central Control Room on the western side of the unit and CPP Control Room on the south-western side of the unit is positively pressured for protection of individuals from toxic effects.*
- *Ensure that adequate numbers of detectors are provided in the inlet air duct of HVAC of the Central Control Room on the western side of the unit and CPP Control Room on*

the south-western side of the unit for detecting toxic gases and actuating interlock for tripping HVAC.

- *Ensure that adequate numbers of breathing masks are provided in the Central Control Room on the western side of the unit and CPP Control Room on the south-western side of the unit for emergency escape during toxic gas release scenario.*

2. **Instrument Tapping Failure at Stripper Feed Pump Discharge in Unsat Gas Plant / LPGTU** (Figures 2.4): An analysis of instrument tapping failure (20 mm) shows that the flash fire zone extends beyond the unit covering the road on the western and eastern side of the unit. Blast over pressure effect of 5 psi extends beyond the unit covering a small portion of the Central Control Room of the western side of the unit. IDLH concentration (100 pm Hydrogen Sulfide) effects extend beyond the unit covering the Central Control Room, a potion of Chemical Store, Cement Godown, a portion of Warehouse & Porta Cabin on the western side of the unit; CPP Control Room & a major portion of Admin building on the south-western side of the unit; Central Control Room DM Plant on the southern side of the unit and BBU Control Room on the eastern side of the unit.

It is recommended to

- *Restrict vehicle movements on the road on the western and eastern side of the unit through suitable means. Only emergency vehicles or authorized vehicles shall be allowed on this road.*
- *Ensure that the Central Control Room on the western side of the unit is blast proof for protection of individuals from explosion effects.*
- *Ensure that the Central Control Room on the western side of the unit; CPP Control Room on the south-western side of the unit; Central Control Room DM Plant on the southern side of the unit and BBU Control Room on the eastern side of the unit is positively pressured for protection of individuals from toxic effects.*
- *Ensure that adequate numbers of detectors are provided in the inlet air duct of HVAC of the Central Control Room on the western side of the unit; CPP Control Room on the south-western side of the unit; Central Control Room DM Plant on the southern side of the unit and BBU Control Room on the eastern side of the unit for detecting toxic gases and actuating interlock for tripping HVAC.*
- *Ensure that adequate numbers of breathing masks are provided in the Central Control Room on the western side of the unit; CPP Control Room on the south-western side of the unit; Central Control Room DM Plant on the southern side of the unit and BBU Control Room on the eastern side of the unit for emergency escape during toxic gas release scenario.*

- *Ensure that there is no permanent sitting arrangement in the affected portion of Chemical Store, Cement Godown, Warehouse & Porta Cabin on the western side of the unit.*
- *Locate Stripper Feed Pump in such a way that the Admin building on the south-western side of the unit falls outside the IDLH Concentration Effect Zone. Also, based on the finalized location & process parameters of Stripper Feed Pump, evaluate the risk on Admin building (on the south-western side of the unit) and ensure that the same is within acceptable limits.*

3. **Instrument Tapping Failure at Acid Gas KOD Inlet in SRU** (Figures 4.1): A 20 mm leak scenario corresponding to instrument tapping failure is analyzed under this case. IDLH concentration (100 ppm Hydrogen Sulfide) effects extend beyond the unit covering the DHDS Control Room on the northern side of the unit; Scrap Yard, Chemical Store, Cement Godown, a major portion of Warehouse & Porta Cabin on the western side of the unit and Central Control Room on the southern side of the unit.

   It is recommended to

   - *Ensure that the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit is positively pressured for protection of individuals from toxic effects.*
   - *Ensure that adequate numbers of detectors are provided in the inlet air duct of HVAC of the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit for detecting toxic gases and actuating interlock for tripping HVAC.*
   - *Ensure that adequate numbers of breathing masks are provided in the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit for emergency escape during toxic gas release scenario.*
   - *Ensure that there is no permanent sitting arrangement in the affected portion of Scrape Yard, Chemical Store, Cement Godown, Porta Cabin and the affected portion of Warehouse on the western side of the unit.*

4. **Instrument Tapping Failure at SWS Acid Gas HP Stage KOD Inlet in SRU** (Figures 4.2): An analysis of instrument tapping failure (20 mm) shows that the IDLH concentration (100 ppm Hydrogen Sulfide) effects extend beyond the unit covering DHDS Control Room on the northern side of the unit; Scrap Yard, Chemical Store, Cement Godown, Porta Cabin and a major portion of Warehouse on the western side of the unit and Central Control Room on the southern side of the unit.

It is recommended to

- *Ensure that the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit is positively pressured for protection of individuals from toxic effects.*
- *Ensure that adequate numbers of detectors are provided in the inlet air duct of HVAC of the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit for detecting toxic gases and actuating interlock for tripping HVAC.*
- *Ensure that adequate numbers of breathing masks are provided in the DHDS Control Room on the northern side of the unit and Central Control Room on the southern side of the unit for emergency escape during toxic gas release scenario.*
- *Ensure that there is no permanent sitting arrangement in the affected portion of Scrape Yard, Chemical Store, Cement Godown, Porta Cabin and the affected portion of Warehouse on the western side of the unit.*

Low Frequency & High Severity Cases

a) Flammable Gas Modelling

1. **Large Hole at Main Fractionator Bottom in PRFCC** (Figures 1.5): A large hole (50 mm) is analyzed at Main Fractionator Bottom line. This results in a flash fire which extends beyond the unit covering the Central Control Room on the western side of the unit. Blast over pressure effect of 5 psi extends beyond the unit covering the Central Control Room of the western side of the unit.
   It is recommended to *utilize the results of this scenario while formulation / updation of Emergency Response Disaster Management Plan (ERDMP).*

2. **Large Hole at Debutanizer Bottom in Unsat Gas Plant / LPGTU** (Figures 2.5): An analysis of large hole (50 mm) shows that the blast over pressure zone of 3 psi extends beyond the unit covering Ammonia Storage Shed (has already been dismantled as informed by BPCL) on the eastern side of the unit.

   It is recommended to *utilize the results of this scenario while formulation / updation of Emergency Response Disaster Management Plan (ERDMP).*

3. **Catastrophic Rupture of Depropanizer Reflux Drum in PRU** (Figures 3.3): A catastrophic rupture scenario is analyzed for Depropanizer Reflux Drum. This results in a flash fire zone which covers the road on the eastern side of the unit. The effect zone of fireball thermal

radiation intensity of 37.5 kW/m^2 extends beyond the unit. Blast overpressure effects of 5 psi extend beyond the unit covering the Central Control Room on the western side of the unit.

It is recommended to *utilize the results of this scenario while formulation / updation of Emergency Response Disaster Management Plan (ERDMP).*

b) Toxic Gas Modelling

1. **Catastrophic Rupture of HP Separator Drum in Unsat Gas Plant / LPGTU** (Figures 2.2): An analysis of catastrophic rupture shows that the generated flash fire extends beyond the unit covering the road on western side of the unit. Blast over pressure zone of 5 psi extends beyond the unit covering existing CDU / VDU on the eastern side of the unit; NSU & Proposed GTU Plant on the northern side of the unit; Central Control Room on the western side of the unit and CPP Control Room on the south-western side of the unit. IDLH concentration (100 pm Hydrogen Sulfide) effects extend beyond the unit and the refinery on the western and eastern side of the unit.

   It is recommended to *utilize the results of this scenario while formulation / updation of Emergency Response Disaster Management Plan (ERDMP).*

2. **Catastrophic Rupture of Debutanizer Reflux Drum in Unsat Gas Plant / LPGTU** (Figures 2.6): A catastrophic rupture scenario is analyzed for Debutanizer Reflux Drum. This results in a flash fire which extends beyond the unit. The Fireball thermal radiation intensity of 37.5 kW/m^2 extends beyond the unit on the eastern and southern side. Blast overpressure effects of 5 psi extend beyond the unit but restricted within the refinery. IDLH concentration (100 pm Hydrogen Sulfide) effects are restricted within the unit.

   It is recommended to *utilize the results of this scenario while formulation / updation of Emergency Response Disaster Management Plan (ERDMP).*

3. **Large Hole at LPG Amine Absorber Bottom in Unsat Gas Plant / LPGTU** (Figures 2.8): An analysis of large hole (50 mm) shows that the IDLH concentration (100 pm Hydrogen Sulfide) effects extend beyond the unit but are restricted within the refinery.

   It is recommended to *utilize the results of this scenario while formulation / updation of Emergency*

General Recommendations

- ✓ Quantitative Risk analysis needs to be carried out for entire facility for overall risk assessment.
- ✓ Low frequency failure scenario (Refer large hole and catastrophic rupture scenarios) discussed in this report shall be considered in updating of existing disaster management plan of whole facility.
- ✓ To enable rapid detection of leak/ fire, flammable gas detector shall be located in strategic location in the facility.
- ✓ For positively pressurized building, both Hydrocarbon & Toxic detectors need to be placed at suction duct of HVAC. HVAC to be tripped automatically in event of the detection of any Hydrocarbon / toxic material by detector.
- ✓ In order to prevent secondary incident arising from any failure scenario, it is recommended that sprinklers and other protective devices provided on the tanks to be regularly checked to ensure that they are functional.
- ✓ Proper checking of contract people for Smoking or Inflammable materials to be ensured at entry gates to avoid presence of any unidentified source of ignition.
- ✓ It shall be ensured that all the vehicles entering the plant shall be provided with spark arrestors at the exhaust.
- ✓ Employees and Truck drivers must be well trained and must be aware of the hazards involved in the loading operation.
- ✓ The critical operating steps shall be displayed on the board near the location where applicable.
- ✓ Loading operations shall be immediately suspended in the event of leak, a fire in the vicinity, lightning and thunder storm.
- ✓ Clearly marked escape routes shall be provided in the gantry for ease of escape.
- ✓ Mock drills to be organized at organization level to ensure preparation of the personnel's working in premises for handling any hazardous situation.
- ✓ Active fire protection system shall be provided throughout the plant for preventing escalation of fire.
- ✓ Recommended to use portable HC detector during sampling and maintenance etc.

(A) Mitigating Measures

Mitigating measures are those measures in place to minimize the loss of containment event and hazards arising out of Loss of containment. These include:

- ✓ Early detection of an undesirable event (HC/ toxic leak, Flame etc.) and development of subsequent quick isolation mechanism.
- ✓ Measures for controlling / minimization of Ignition sources inside the operating area.
- ✓ Active and Passive Fire Protection for critical equipment's and major structures

- ✓ Effective Emergency Response plans to be in place

(B) Ignition Control

- ✓ Ignition control will reduce the likelihood of fire events. This is the key for reducing the risk within facilities processing flammable materials. As part of mitigation measure it is strongly recommended to consider minimization of the traffic movement in the vicinity of operating area.

(C) Escape Routes

- ✓ Ensure sufficient escape routes from the site are available to allow redundancy in escape from all areas.
- ✓ Ensure sufficient number of windsocks throughout the site to ensure visibility from all locations. This will enable people to escape upwind or crosswind from flammable / toxic releases.
- ✓ Provide sign boards marking emergency/safe roads to be taken during any exigencies.

(D) Preventive Maintenance for Critical Equipment's

- ✓ In order to reduce the failure frequency of critical equipment's, the following are recommended:

    a. High head pumps and Compressors, which are in flammable/ toxic services, are needed to be identified.
        i. Their seals, instruments and accessories are to be monitored closely
        ii. A detailed preventive maintenance plan to be prepared and followed.
    b. High inventory vessels whose rupture may lead to massive consequences are needed to be identified and following to be ensured:
        i. Monitoring of vessel internals during shut down.
        ii. A detailed preventive maintenance plan to be prepared and followed.
        iii. Emergency inventory isolation valves shall be provided for vessel/column having large inventory and containing flammable/ toxic compound.

(E) Recommendations for Construction Safety during execution

- ✓ Adequate barricading of the proposed unit to be done from existing running process units during construction phase. Hydrocarbon / toxic detectors to be placed along the barricading suitably to detect any hydrocarbon / toxic gas in vicinity of construction area.
- ✓ Adequate firefighting & toxic gas handling arrangement are to be ensured in the construction area. Ensure training of persons associated with construction activities for response during fire & toxic gas release.

- ✓ Proper material movement path within the Refinery shall be identified during the construction phase of the project.
- ✓ Detailed HSE Plan & HSE Philosophy to be developed by contractors during construction phase of the project, in line with client's safety requirements.