# BOW-TIE ANALYSIS FOR PROPYLENE RECOVERY UNIT IN HINDUSTAN ORGANIC CHEMICALS LIMITED (HOCL), COCHIN

**Final Year Project Report**

***Submitted by***


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## BONAFIDE CERTIFICATE

Certified this titled "Bow – Tie analysis for Propylene Recovery Unit in Hindustan Organic Chemicals Limited, Cochin" is the bonafide work of **MOHAMMED MUSTHAFA HASSAN FAROOK (R080213023)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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# Abstract

Bowtie analysis are a simple and effective tool for communicating risk assessment results to employees at all levels. The diagram clearly displays the linksbetween the potential causes, preventive and mitigative control and consequences of major accident. Bow tie diagrams may be used to display the results of various types of risk assessments. Bow tie diagrams are also integrated with semi- quantitative analysis techniques such as LOPA depending on the level of complexity The benefits of using bow-tie diagrams for risk management have been realized by organizations world-wide across a variety of business sectors. Also known as barrier diagrams, they provide a readily understandable visualization of the relationships between the causes of business upsets, the escalation of such events to a range of possible outcomes, the controls preventing the event from occurring and the preparedness measures in place to limit the consequences.

More importantly, the preventive and mitigating measures are linked to tasks, procedures, responsible individuals and competencies. This demonstrates the crucial connection between risk controls (whether hardware or human intervention) and the management system for assuring their ongoing effectiveness.

The main use of bow-tie analysis is for the visualization of the links between the hazard model and the safety management system and the workforce, once the hazard model (threats, barriers, top event, barriers and consequences) is assembled. The sequence of procedures to be followed is HEMP (Hazard Effective Management Programme) which led to bow-tie assessment.

**Keywords:** *Bow-Tie Analysis, Risk Assessment, HEMP, Health & Safety, Risk Matrix*

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# List of Abbreviations

| | | |
|---|---|---|
| HOCL | - | Hindustan Organic Chemicals Limited |
| PRU | - | Propylene Recovery Unit |
| HSE | - | Health, Safety & Environment |
| HEMP | - | Hazard Effective Management Programme |
| MAH | - | Major Accident Hazard |
| PTFE | - | Poly Tetra Fluro Ethylene |
| BVQI | - | Bureau Veritas Quality International |
| FUV | - | Fuzzy Utility Valve |
| TBL | - | Triple Bottom Line |
| MEA | - | Mono Ethanol Amine |
| SPA | - | Solid Phosphoric Acid |
| DNET | - | Direct Neutralization & Effluent Treatment |
| CHP | - | Cumene Hydro Peroxide |
| CCWC | - | Cumene Caustic Wash Column |
| PTP | - | Pre Treatment Plant |
| DMP | - | Demineralized Water Treatment Plant |
| ETP | - | Effluent Treatment Plant |
| KWA | - | Kerala Water Authority |
| KRL | - | Kochi Refineries Limited |
| REET | - | Raw Effluent & Equalization Tank |
| RAM | - | Risk Assessment Matrix |
| ALARP | - | As Low As Reasonably Practicable |

| | | |
|---|---|---|
| VCE | - | Vapour Cloud Expansion |
| EOCSC | - | Extraction Oil Caustic Scrubbing Column |
| CGP | - | Chemical Grade Propylene |
| CAC | - | Crude Acetone Column |
| FAC | - | Finished Acetone Column |
| TC | - | Tar Column |
| AMSC | - | Alpha Methyl Styrene Column |
| PC | - | Phenol Column |
| PRC | - | Phenol Rectifier Column |
| SAC | - | Strong Acid Cation |
| SBA | - | Strong Basic Anion |
| MB | - | Mixed Bed |
| ISO | - | International Organization for Standardization |
| BT | - | Bow Tie |
| LPG | - | Liquefied Petroleum Gas |

# CHAPTER 1

# INTRODUCTION

For any industry to be successful, it has become essential to identify the Hazards, to assess the associated risks and to bring the risks to tolerable level. Recognizing this, the objective is to study all potentially hazardous events associated with Hindustan Organic Chemicals Limited (HOCL) which is a gas processing plant, handling hydrocarbon gas and condensate and the necessary preventive measures for each scenario. This study identifies the necessary tasks, activity, and recovery preparedness and mitigation methods from escalation of top event scenarios. This study determines the requirement of Bow Tie analysis based on risk assessment of identified hazards addressing various threats, consequences, respective barriers and control measures from all identified resources. The overall objective is to learn safety systems for on- and off-site personnel, equipment and the environment.

In Propylene Recovery Unit, hydrocarbon gas and associated condensate liquids are handled and processed by these facilities. Hydrocarbon gas is a fuel source that burns when ignited in air and condensate is a key feedstock for oil refineries and chemical industries. However, these products are also major hazards that require to be managed with extreme care. Any loss of containment of hydrocarbons from the pipelines and/or processing facilities could result in exposing personnel and the assets to consequences of jet fires and vapour cloud explosions leading to injury, death and significant impact on the reputation of the business.

In such plants, hazards and risk are identified time to time by using modern techniques. Hindustan Organic Chemicals Limited, Cochin is OHSAS 18001 certified company. So in all departments /section risk and hazards are finding out by proper risk assessments. During this severity at various levels matched with probability level. And find out the case of intolerable, substantial, moderate and tolerable risk. Accordingly control measures at the place checked. Documentation done and records are maintained. Thus the risk is assessed and mitigated by the bow-tie analysis for this respective unit.

## 1.1 PROJECT AIM

To provide understandable visualization of the relationships between the causes of business upsets, the escalation of such events, the controls preventing the event from occurring and the preparedness measures in place to limit the consequences to reduce the risks of injury and ill health in Propylene Recovery Unit of Hindustan Organic Chemicals Limited, Cochin.

## 1.2 PROJECT OBJECTIVES

- To understand the concept of Bow-Tie analysis in Propylene Recovery Unit of Hindustan Organic Chemicals Limited.
- To provide understandable visualization of the relationships between the causes of the business upsets and the escalation of such events.
- To control and prevent the hazardous event from occurring and preparedness measures in place to limit the consequences.
- To demonstrate control of health, safety and environmental (HSE) hazards.
- To provide the link between the risk controls and the management system.
- To be able to recommend practical control measures for hazards identified.

## 1.3 PROJECT SCOPE

Scope is for the application of Bow-Tie analysis to all Activities & Sub Activities in Propylene Recovery Unit of Hindustan Organic Chemicals Limited, Cochin. The main use of Bow Tie analysis is for the visualization of the links between the hazard model and the safety management system and the workforce, once the hazard model (threats, barriers, top event, barriers and consequences) is assembled. The sequences of procedures followed by Hindustan Organic Chemicals Limited encompass HEMP (Hazard Effective Management Programme) which led to Bow-Tie assessment.

## 1.4 COMPANY PROFILE

Hindustan Organic Chemicals Ltd. (HOCL), a Govt. of India enterprise, incorporated in the year 1960 set up its plants at Rasayani, Maharashtra state for the manufacture of bulk basic organic chemicals. HOCL set up its second unit at Ambalmughal, Kochi in 1983 for the manufacture of Phenol and Acetone based on the technology of Universal Oil Products (UOP), USA. As a part of diversification, HOCL Kochi installed hydrogen peroxide plant using technology of UDHE. HOCL has got subsidiary unit at Medak Hyderabad for manufacturing of poly tetra fluro ethylene (PTFE).

HOCL, Ambalmughal is situated in the Ernakulam district, Kunnathunadu Taluk of Kerala state. The factory has a total area of 100 acres out of which 70 acres is occupied by plant building, road, etc. and 30 acres is free land. Our works is situated on Tripunithura to Karimugal road and is adjacent to Kochi refineries ltd. The factory is located about 7km from Tripunithura.

HOCL, Kochi unit bagged the best productivity award instituted by the Kerala state productivity council for major industries during the year 1989-90, 1990-91, 1991-92, 1994-95, 1996-97, 1997-98 and 2000-2001. HOCL Kochi was adjudged best in outstanding performance in industrial safety by safety council for the four consecutive years from 1988-1990 and eleven consecutive years from 1993-2003 and got Kerala State Pollution Control award in 1988-89, 1994, 1996 and 1997.

ISO 9002:1994 certification was done by Bureau Veritas Quality International (BVQI) in the year 1996. Recertification of ISO 9001:2000 was done in 1999. Based on ISO 9002 foundation on quality management system, Kochi unit established environmental management system as per the requirements of ISO 14001 and received certification form BVQI in the year 1999.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Risk analysis for oil & gas pipelines: A sustainability assessment approach using fuzzy based bow-tie analysis by Anjuman Shahriar & Rehan Sadiq (2012):

‘Bow-tie’ is an approach that integrates a fault tree (on the left side) and an event tree (on the right side) to represent causes, threat (hazards) and consequences in a common platform. Traditional ‘bow-tie’ approach is not able to characterize model uncertainty that arises due to assumption of independence among different risk events. In this paper, in order to deal with vagueness of the data, the fuzzy logic is employed to derive fuzzy probabilities (*likelihood*) of basic events in fault tree and to estimate fuzzy probabilities (*likelihood*) of output event consequences. The study also explores how interdependencies among various factors might influence analysis results and introduces *fuzzy utility value* (FUV) to perform risk assessment for natural gas pipelines using triple bottom line (TBL) sustainability criteria, namely, social, environmental and economic consequences. The present study aims to help owners of transmission and distribution pipeline companies in risk management and decision-making to consider multi-dimensional consequences that may arise from pipeline failures. The research results can help professionals to decide whether and where to take preventive or corrective actions and help informed decision-making in the risk management process. A simple example is used to demonstrate the proposed approach.

## 2.2 Dynamic risk analysis using bow-tie approach by Nima Khakzad, Faisal Khan & Paul Amyotte (2012):

Accident probability estimation is a common and central step to all quantitative risk assessment methods. Among many techniques available, bow-tie model (BT) is very popular because it represent the accident scenario altogether including causes and consequences. However, it suffers a static structure limiting its application in real-time monitoring and probability updating which are key factors in dynamic risk analysis. The present work is focused on using BT approach in a dynamic environment in which the occurrence probability of accident consequences changes. In this method, on one hand, failure probability of primary events of BT, leading to the top event, are developed using physical reliability models, and constantly revised as physical parameters (e.g., pressure, velocity, dimension, etc.) change. And, on the other hand, the failure probabilities of safety barriers of the BT are periodically updated using Bayes’ theorem as new information becomes available over time. Finally, the resulting, updated BT is used to estimate the posterior probability of the consequences which in turn results in an updated risk profile.

### 2.3 A new multi-objectives approach to implement preventive and protective barriers in bow tie diagram by Ahmed Badreddine, Taieb Ben Romdhane, Mohamed Aymen, Ben HajKacem & Nahla Ben Amor (2014):

Bow tie diagram has become a popular method to implement safety barriers. It defines several preventive and protective barriers to reduce respectively the frequency and severity of a given risk. These barriers are often defined by experts that ignore the real aspect of the system. However, the definition of barriers based on expert's experiences limits this method because it seems unrealistic to use static recommendations in real dynamic systems. This paper proposes a new multi-objectives approach to implement preventive and protective barriers. The proposed approach is mainly based on three phases namely; a parameters learning phase, a simulation phase and a selection phase.

### 2.4 Handling and updating uncertain information in bow-tie analysis by Refaul Ferdous, Faisal Khan, Rehan Sadiq, Paul Amyotte & Brian Veitch (2009):

Bow-tie analysis is a fairly new concept in risk assessment that can describe the relationships among different risk control parameters, such as causes, hazards and consequences to mitigate the likelihood of occurrence of unwanted events in an industrial system. It also facilitates the performance of quantitative risk analysis for an unwanted event providing a detailed investigation starting from basic causes to final consequences. The credibility of quantitative evaluation of the bow-tie is still a major concern since uncertainty, due to limited or missing data, often restricts the performance of analysis. The utilization of expert knowledge often provides an alternative for such a situation. However, it comes at the cost of possible uncertainties related to incompleteness (partial ignorance), imprecision (subjectivity), and lack of consensus (if multiple expert judgments are used). Further, if the bow-tie analysis is not flexible enough to incorporate new knowledge or evidence, it may undermine the purpose of risk assessment.

# CHAPTER 3

# METHODOLOGY

## 3.1 BOW TIE METHODOLOGY

The Main use of Bow Tie analysis is for the visualization of the links between the hazard model and the safety management system and the workforce, once the hazard model (threats, barriers, top event, barriers and consequences) is assembled. The sequence of procedures to be followed is HEMP (Hazard Effective Management Programme) which led to Bow-Tie assessment.

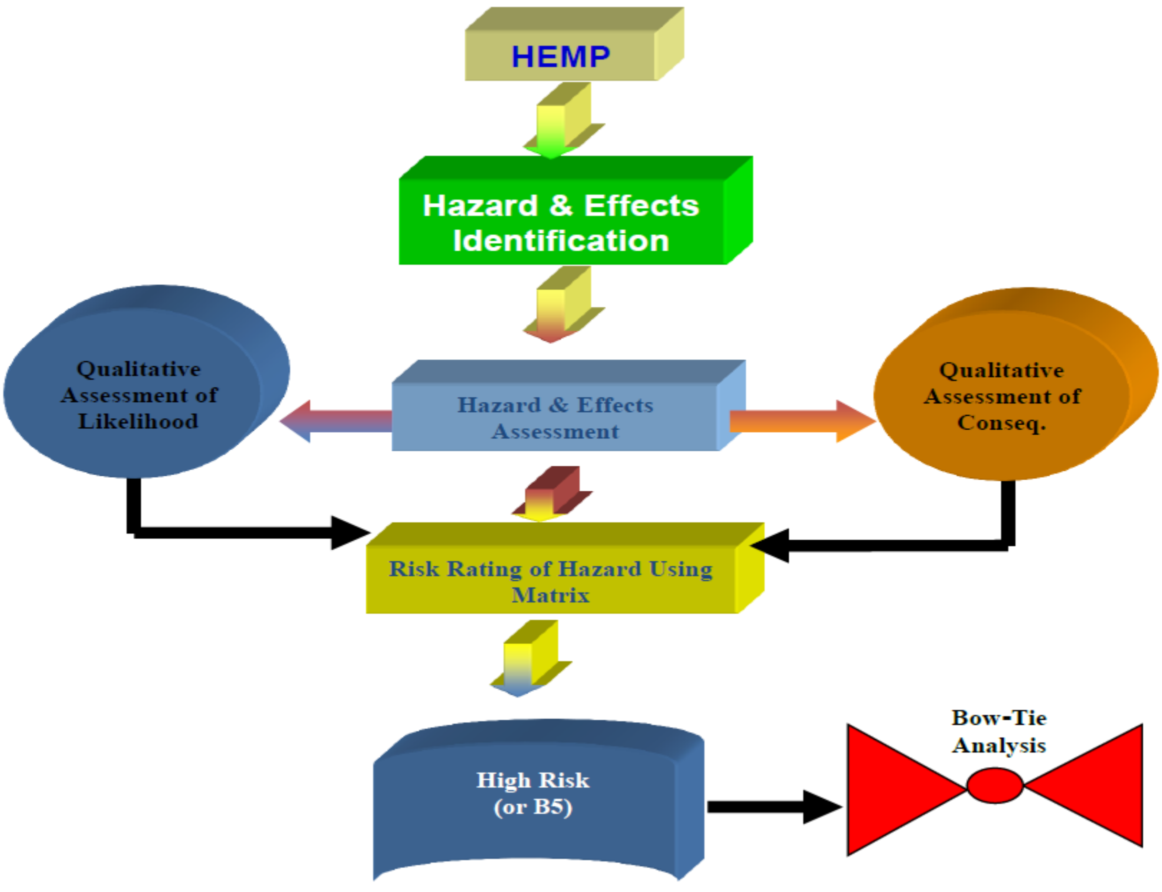



Fig: HEMP FLOW CHART

**Figure 3.1: HEMP Flowchart**

## 3.2 HEMP (Hazards and Effects Management Process) IDENTIFICATION

The Hazards and Effects Management Process (HEMP) is the process by which identifies and assesses the hazards, implements measures to manage them, and demonstrates that the risks have been reduced to a level that is ALARP.

HEMP is summarized in the four key steps as follows:

| | |
|---|---|
| **Step 1: IDENTIFY** | Identify all hazards associated with facility through a comprehensive and structured process. |
| **Step 2: ASSESS** | Assess the likelihood (how often the hazardous event could occur), the size of the consequences (e.g. how big is the fire), and the severity of the outcome (what sort of damage/harm would occur). |
| **Step 3: CONTROL** | Determine what needs to be in place to remove the hazard from the business, or reduce the likelihood of it occurring, or mitigate the consequences and severity. |
| **Step 4: RECOVER** | Provide measures that allow people to get safely away from the location of the hazard (e.g. source of escape from the scenario) or re-establish normal operations after an incident. |

**Table 3.1: Steps for the HEMP procedure**

The structured application of the HEMP process with regards to major accident hazards has been through the application of the process presented.

*Hazard Identification:* A hazard is anything that has the potential to cause:

- Harm to people such as ill health or injury
- Harm to the environment
- Damage to assets
- Adverse impact on the Company's reputation

Hazards with the potential having adverse impact upon personnel, damage to assets, or affect the environment were noted, compared with the HOCL Hazard sheets from which relevant hazards were identified. Hence, these hazards are fully evaluated As Low As Reasonably Practicable (ALARP).

### 3.3 MAH (Major Accident Hazard) IDENTIFICATION

Hazards identified in the facility were determined and the ones that fall under Major Accident Hazards (MAHs) were identified with reference to HOCL Risk Assessment Matrix (RAM) – The hazards that fall in the RED AREA or Severity 5 are classified as MAH as shown in the below table.

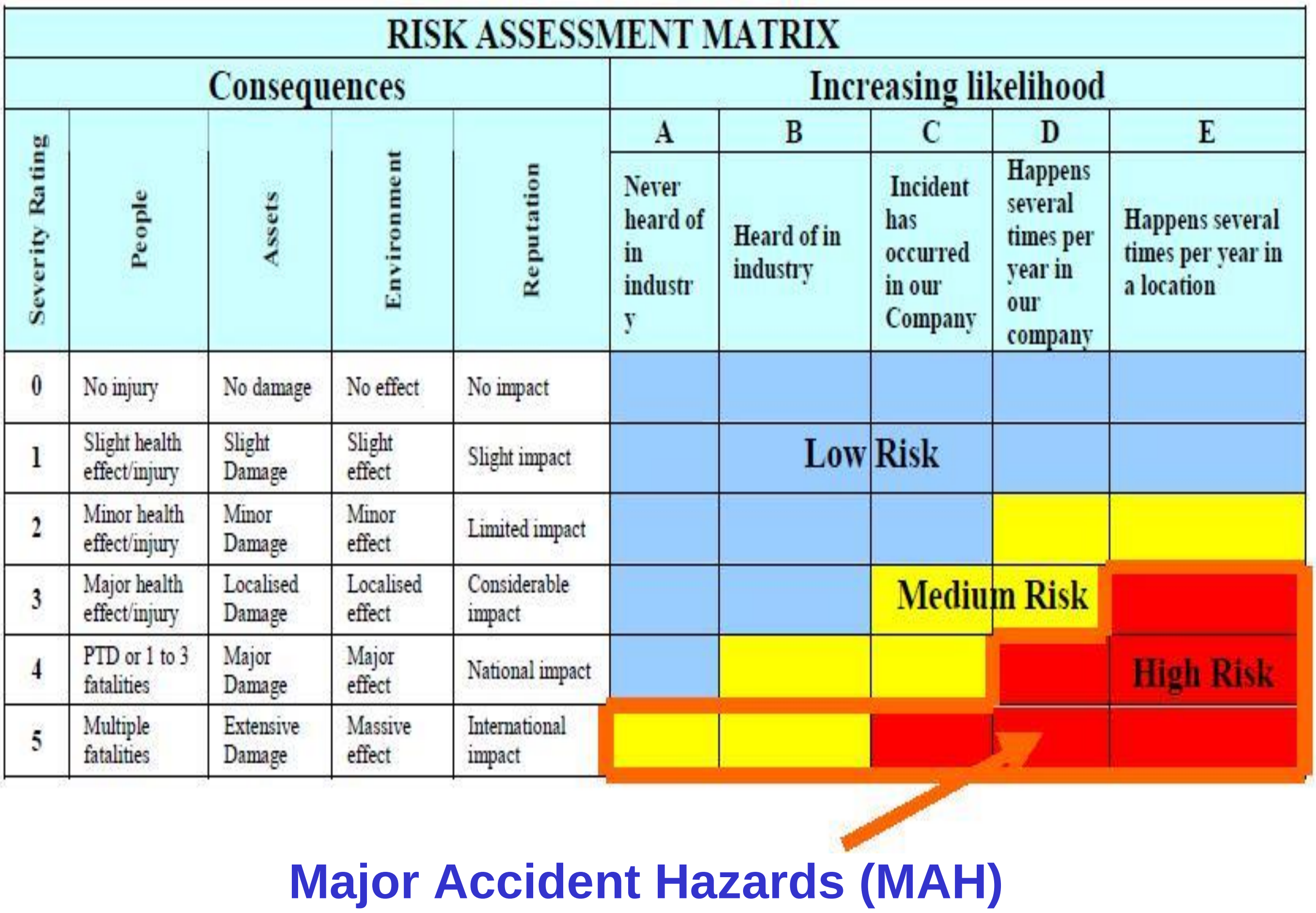
Hazards are primarily identified with participation of personnel from a wide range of experience within the Organization and also Operators involvement.

The HAZID is based on the "hazard inventory", which covers a complete range of hazardous events, ranging from loss of hydrocarbon containment to general slips, trips and falls. A summary of the inventory is presented.

Each major accident hazard was reviewed and assessed to identify the risk controls (equipment, systems and procedures) in place to prevent the hazard occurring or to mitigate the consequences if it does occur and the additional controls required to reduce the risks to ALARP.

### 3.4 RISK RANKING & MAJOR ACCIDENT HAZARDS

Hazards classified as "Major Accident Hazards" require assessment and are demonstrated to ALARP through an HSE Case. The classification of hazards as MAHs is determined by risk ranking using the Risk Assessment Matrix.



| RISK ASSESSMENT MATRIX | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Consequences | | | | | Increasing likelihood | | | | |
| | | | | | A | B | C | D | E |
| Severity Rating | People | Assets | Environment | Reputation | Never heard of in industry | Heard of in industry | Incident has occurred in our Company | Happens several times per year in our company | Happens several times per year in a location |
| 0 | No injury | No damage | No effect | No impact | | | | | |
| 1 | Slight health effect/injury | Slight Damage | Slight effect | Slight impact | | | | | |
| 2 | Minor health effect/injury | Minor Damage | Minor effect | Limited impact | | | | | |
| 3 | Major health effect/injury | Localised Damage | Localised effect | Considerable impact | | | | | |
| 4 | PTD or 1 to 3 fatalities | Major Damage | Major effect | National impact | | | | | |
| 5 | Multiple fatalities | Extensive Damage | Massive effect | International impact | | | | | |



**Table 3.2: Risk assessment matrix**

### 3.5 RISK ASSESSMENT MATRIX

A specific hazard is classified as MAH if it is assessed as "High" risk (RED area in RAM) or if it has a SEVERITY 5 consequence. For MAHs, ALARP has to be demonstrated through this case by using the Bow-Tie model and through the Technical HSE Assessments.

The hazards within the YELLOW area with consequence severity of 4 or lower needs to be controlled to ALARP as well. Hazard Control Sheet may be developed for these hazards through documented and structured assessments and specific procedures, which are referenced in the hazard register.

Hazards within the BLUE area need to be managed for continuous improvement in accordance with the HOCL HSE-MS and HOCL EP Policies. Through the application of HSE and Standard Work/Operating Procedures, the risks from these hazards are managed adequately and shall be verified through audits.

### 3.6 BOW TIE MODEL

Once MAHs have been identified, the Bow-Tie methodology is applied. This methodology specifies the required mandatory barriers and controls for each threat and consequences.

Bow-Ties are developed for each MAH that has been identified and reviewed, specifying the Barriers and Controls that needs to be in place to manage the hazards which PRU facilities must comply.


**Figure 3.2: Bow Tie model**

Controls shall be identified for each Threat (i.e. a possible cause that will potentially release the Hazard and produce an incident), which effectively prevent the occurrence of an undesirable Top Event. The Effective Recovery Measures shall be documented which are in place to lessen the severity of each identified Consequence. For each Threat and Consequence, an Escalation Factor and associated Escalation Factor Control shall be conceived for at least one of the identified Controls and Recovery Measures.

Risk control acceptance criteria are defined as:

- The level of risk that can be tolerated; and
- The minimum level of control and recovery preparedness required.

In order for a Barrier to be considered valid it shall be:

- ***Effective*** -The Barrier prevents the consequence when it functions as designed (i.e. big enough, fast enough and strong enough).
- ***Auditable*** -The Barrier can be evaluated to assure that it can operate correctly when it is called upon.
- ***Independent*** -The Barrier is independent of the initiating event (threat) and the components of any other Barrier already validated for the same condition. The Barriers cannot be considered independent from one another if there is a Common Cause Failure.

### 3.6.1 Primary and Secondary Barriers

While the function of the primary barrier is to eliminate, prevent, reduce, mitigate or control threat transmission and escalation of the realized hazard, the function of the secondary barrier (control of barrier decay mode) is to prevent the barrier decay, erosion or failure: the primary means of preventing and controlling hazards are primary barriers, while secondary barriers are fortifying the primary barriers. The following rule set can now be established:

- Primary barriers are: Technical active barriers (e.g. shut-down valves, deluge system, etc.), Technical passive barriers (e.g. fire wall, blast wall, containment, separation, etc.), Technical control barriers (e.g. fire and gas detection, alarms, etc.), Organizational (procedural) barriers (e.g. inspection and monitoring, etc.), Human (operator) barriers (e.g. process control operator, etc.).
- Secondary barriers are: Human (operator) barriers (e.g. supervision, etc.), Fundamental (procedural) barriers (e.g. design reviews, operational reviews, Competence assurance, etc.), Fundamental human barriers (e.g. good health, etc.)

Table specifies the minimum number of barriers considered necessary to reduce the risk to ***ALARP level***.

| Barriers | **"Red" Risk Hazards** | **Yellow Risk Hazards with potential fatalities** | **Other Yellow Risk Hazards** |
|---|---|---|---|
| Total Number of barriers from Threat to Consequence | **5** Controls + Recovery Measures | **4** Controls + Recovery Measures | **3** Controls + Recovery Measures |
| Controls (Threat) | **3** controls to be in place for each identified threat. Alternative: **4** controls | **2** controls to be in place for each identified threat. Alternative: **3** controls | **2** controls to be in place for each identified threat. |
| Recovery Measures (Consequence) | **2** Recovery Measures required for each identified consequence. Alternative: **1** Recovery Measure | **2** Recovery Measures required for each identified consequence. Alternative: **1** Recovery Measure | **1** Recovery Measures required for each identified consequence. |

**Table 3.3: Number of barriers required to reduce the risk**

# CHAPTER 4

# PROCESS DETAIL

## 4.1 BRIEF DESCRIPTION OF PHENOL AND ACETONE PRODUCTION

4.1.1 Propylene Recovery Unit PRU:

There are two number of LPG storage spheres, one sphere receives LPG from Kochi Refineries Ltd(KRL) and other, supplies LPG to C3-C4 column. The top product of the column having 75% propylene purity (Lean Propylene) goes to Mono Ethanol Amine (MEA) Caustic system where sulphur is removed. Then the lean propylene either goes to C3-C3 column or collected in lean propylene bullets. The top product of the C3-C3 column having 95% propylene purity (Chemical Grade Propylene) is stored in chemical grade propylene bullet. The bottom product of C3-C4 and C3-C3 columns are collected in our return LPG spheres. From the other return LPG sphere, LPG is sent back to KRL.

4.1.2 Cumene Plant:

A mixture of propylene, propane and benzene (1:2:8ratio) having 150 ppm of water enters cumene reactor containing solid phosphoric acid (SPA) catalyst. Propylene and benzene react in the presence of SPA catalyst to form cumene and heavy aromatics. Thus the reactor outlet contains cumene, heavy aromatics, unreacted benzene and propane. By multistage fractionation technique, cumene and heavy aromatics are separated and send to respective storage tanks. Unreacted benzene and part of propane are recycled back to cumene reactor. Excess propane is sent back to return LPG sphere. Benzene is removed as drag benzene to keep the non-aromatics below 10% in recycle benzene.

4.1.3 Synthesis Section:

It has four sections namely

- Oxidation
- Evaporation
- Cleavage
- Direct neutralization and Effluent Treatment (DNET).

In oxidation section, there are two oxidizers where cumene and oxygen (from air) react under controlled condition and in an alkaline environment to form Cumene Hydro Peroxide (CHP). In oxidizer no.1 average CHP concentration is 14% and in oxidizer no.2 average CHP concentration is 24%. Oxidizer no.2 outlet is send to evaporation section where CHP is concentrated in two stages. In preflash evaporator CHP concentration goes up to 40%

and in the no.2 stage in Thin Film Evaporators, the CHP concentration goes up to 80%. Evaporators and preflash drum overhead cumene is recycled back to oxidizers. From thin film evaporators, 80% CHP is fed to cleavage section loops 2 nos. where it is cleaved (hydrolyzed) to Phenol and Acetone in the presence of sulphuric acid (acidity is 0.08%-0.10%). Cleavage product then fed to DNET section. This section performs four main functions

- Neutralization of the excess acid used in cleavage section
- Washing of salts from the organic phase which results from neutralization
- Recovery of phenol and acetone from several effluent streams of the fractionation and DNET sections
- Recovery of phenol from sodium phenate which is obtained from cumene caustic wash column (CCWC), extraction oil caustic scrubbing column (EOCSC), and phenol column overhead receiver
- Remove traces of water carry over from the DNET product, with the help of coalescer.

4.1.4 Fractionation Section:

DNET product stored in fractionation section feed tank. This section has number of columns Crude Acetone Column (CAC), Finished Acetone Column (FAC), Tar Column (TC), Alpha Methyl Styrene Column (AMSC), Phenol Column (PC), Phenol Rectifier Column (PRC) and in between AMSC and PC, there is a Phenol Treating Reactor (PTR) to remove the impurities and improve color of phenol. Here by multistage fractionation methods, Phenol and Acetone are separated and stored in respective tanks. Heavies tar is stored in tart tank and AMSC overhead organic goes to CCWC to remove phenol before entering hydrogenation section as phenol in cumene will retard oxidation rate in oxidizer, if which recycling cumene from hydrogenation section.

4.1.5 Hydrogenation Section:

AMS as such cannot be used in the process. But we can convert AMS to usable Cumene by reacting AMS with Hydrogen (supplied by hydrogen plant) in the presence of Palladium catalyst. The converted cumene from hydrogenation section is fed back to the oxidizers.

4.1.6 Hot Oil Section:

Hot oil circulating pump takes hot oil from surge drum and supplies hot oil to hot oil furnace; where it is heated by burners using LSHS. The hot oil furnace outlet temperature is maintained at 320 degree C. a side stream is taken from hot oil furnace discharge loop through a temperature control valve (TC 6019) and enters the suction of tempered hot oil circulating pump (P6002 A/B). P6002 A/B discharge goes to different reboilers (CAC

REBOILER, PRC reboiler, hydrogenation charge heater and tar tank) and the return from above reboiler join back to suction of P6002 A/B. TC6019 (located on the side stream taken from hot oil loop to suction of P6002 A/B) operates as per the supply tempered hot oil temperature of above mentioned reboilers. The pressure of tempered hot oil loop is maintained by PDIC 6018. The hot oil supplies heat to other reboilers (TC, AMSC, CC, RC, and PC), PTR pre heater and combined feed heater. Hot oil/tempered hot oil enters the hot oil surge drum at 265 degree C.

4.1.7 Utilities Section:

The utility plant under production dept. consists of Pre-Treatment Plant (PTP), Demineralized Water Treatment Plant (DM plant), Effluent Treatment Plant (ETP), Flare Stack, Nitrogen receipt/Distribution and Benzene/Cumene Tanker unloading.

4.1.7.1 Pre Treatment Plant :

Water from Kerala Water Authority (KWA) is stored in reservoir having capacity of 20,000 $m^3$ (10,000 $m^3$ of water for process use and 10,000 $m^3$ of water reserved for fire-fighting purpose). Here water is treated with chlorine, alum and lime, filtered (using pressure sand filter) and supplied to DM plant, cooling tower, process use and drinking water purpose.

4.1.7.2 Demineralized Water Treatment Plant :

The process water from PTP goes to Activated Carbon Filter for the removal of chlorine and then to Strong Acid Cation (SAC), Strong Basic Anion (SBA) and Mixed Bed (MB) units for the removal of Cations (Calcium, Magnesium, Sodium, etc.) and Anions (Sulphates, Chlorides, Silica, etc.) demineralized water from MB outlet can be used in Boiler, $H_2O_2$ plants and Hydrogen plant 1&2.

4.1.7.3 Effluent Treatment Plant :

The effluents from PRU, Cumene Plant, Fractionation Section, Cumox Section, $H_2O_2$ Plant, Tank Farm, CPP and Boiler are stored in Raw Effluent And Equalization Tank (REET), Mixing Tank And Mea-Caustic Sump and treated in the plant using Primary, Secondary treatment and activated sludge process so that ETP effluent meets Kerala State Pollution Control Board (KSPCB) norms. Then only the effluent is disposed to Chitrapuzha River.

4.1.7.4 $H_2$ Plant 1 :

Produces gaseous hydrogen which is used in hydrogenation section and oxygen produced is vented to atmosphere. It has 24 cells filled with 20% sodium hydroxide which is used as electrolyte. Mild steel plate is used as cathode and nickel coated on mild plate steel is used as anode. By electrolysis method water splits to hydrogen and oxygen. Oxygen is vented to atmosphere. Hydrogen produced is collected in cathode and then washed with DM water in gas washer to remove caustic and DM water with traces of caustic is returned to cells. Caustic free hydrogen gas enters hydrogen holders (2 numbers). The hydrogen gas is compressed and stored at high pressure (35-40 kg/cm$^2$g) in bullets (4 numbers). Then hydrogen pressure is reduced (15kg/cm$^2$g) and sent to hydrogenation section.

4.1.7.5 $H_2$ Plant 2 :

By electrolysis method hydrogen produced is used in hydrogen peroxide plant. Here 25% potassium hydroxide solution is used as electrolyte. 2 electrolysers are used which are more compact with 139 cells in each electrolyser. Oxygen gas is vented to atmosphere. Hydrogen gas is scrubbed with DM water in a scrubber to remove caustic and DM water with traces of caustic is returned to electrolysers, caustic free hydrogen gas is compressed and supplied to $H_2O_2$ plant at 4 kg/cm$^2$g pressure.

4.1.7.6 Flare Stack :

From the vents of vessels, columns, pressure safety valve outlet, etc. hydrocarbon vapour/liquid enters knock out pot at flare stack bottom. Hydrocarbon liquid collected at knock out bottom and drained to flare pit. Flare pit material is pumped either to heavy aromatics tank or drag benzene tank depending on its analysis. Hydrocarbon vapour from knock out pot goes up to flare stack top. 3 pilot burners are continuously burning using LPG. Flare stack top which is 70m high from ground level. Hydrocarbon vapour from knock out pot is burnt using the above pilot flame.

4.1.7.7 Benzene/Cumene Tanker Unloading :

Benzene required for the cumene plant is received in tankers. After ensuring specification then tankers are unloaded into main benzene tank 9401 A/B using a pump. Similarly, imported cumene is unloaded to cumene main tank 6518 A/B/C.

4.1.7.8 $N_2$ Receipt and Distribution :

HOCL have 5 numbers of $N_2$ storage bullets having capacity of 60 m$^3$. Four nitrogen bullets meant for phenol section and one nitrogen bullet is meant for $H_2O_2$ section. $N_2$ from sterling gas limited is received in first two bullets and later three $N_2$ bullets are used for the distribution of $N_2$ to plants. Normally $N_2$ bullet pressure is 30-35 kg/cm$^2$g and distribution $N_2$ pressure is 3-4 kg/cm$^2$g.

## 4.2 DETAILED DESCRIPTION OF PROPYLENE RECOVERY UNIT (PRU)

Propylene Recovery Unit is designed to produce Lean Propylene of 75% purity suitable for the production of Cumene Lean Propylene: 21840 TPA (100% Basis). The Propylene Recovery Unit is designed to recover Propylene from the cracked LPG received from BPCL. The cracked LPG is a mixture of Propane, Propylene, Butane, Isobutene and Butylenes. The plant is designed to produce to Propylene by fractionation (lean propylene of 75% purity minimum). The process scheme consists of a fractionating column with the auxiliaries and equipment.

Cracked LPG from KRL is received in the LPG storage spheres 102-S-003 A/B through the cross country pipeline and stored at 5-10 kg/cm$^2$ g pressure. At a time one sphere receives LPG and the other one is supplied to the plant. From the supply sphere, LPG is pumped by LPG feed pumps (102-P-001) A/B to the C3-C4 splitter column (101-C-001) through the feed/bottom exchanger (101-E-001). The distillation column (C3-C4) consists of 44 valve trays. Feed enters 20$^{th}$ tray of the column at around 60 degree C. The column operates at a pressure of 15.5 kg/cm$^2$ g (PC-101). Column bottom temperature is maintained at 87.5 degree C (TE-108) by steam (5.5kg/cm$^2$ g) flow to the reboiler (101-E-003). The steam flow (FC-108) is cascaded with the level control valve (LC-105) on the drain line of the condensate pot. (As the steam flow setting is raised, condensate pot level setting will be reduced automatically). The control tray is the 34$^{th}$ tray. [This temperature is maintained at 44 degree C by adjusting the reflux flow (FC-102) on cascade control]. The column pressure is maintained by top product draw off from the reflux drum (101-V-001) through PC-101 (pressure control valve). In this column propylene and propane vapour are lifted up and condensed in overhead condenser 101-E-002. The condensed liquid is collected in the reflux drum (101-V 101). When the reflux drum boot level comes more than 20% water is drained off.

The C3-C4 column bottom enters the bottom feed exchanger (101-E-001) where its heat is recovered by the column feed. C3-C4 bottom stream flow varies as per C3-C4 bottom level control (101-LIC-101) and flows to bottom cooler (101-E-006). C3-C3 column bottom stream joins the C3-C4 column bottom between the above control valve and cooler (101-E-006). The combined bottom streams flow to return LPG spheres (102-S 002A/B). At a time one return sphere receives column bottom streams and from the other one, LPG is returned to KRL using pump (102-P-003A/B). We can also send the return LPG to KRL directly from the column bottom on column pressure head.

MEA-caustic solution is drawn from COS-settler by the circulation pump P101-P003 A/B. The flow rate is controlled by FC103. The combined stream of MEA caustic (FC 103) and lean propylene through PC 101 goes through the HC 101 and returns to COS settler. The mixture is allowed to settle in the COS settler. Lean propylene comes out from the top of the COS settler and enters water wash drum and gets water washed for removing the traces of MEA caustic. If MEA-caustic traces in water wash drum reach more than 2%, the content is drained partially and made up with DM water.

From the top of the water wash drum, lean propylene enters the coalescer (101-V-006) for removing the water droplets carryover. The water collected is drained out from the coalescer boot periodically. From the coalescer, propylene product either goes to the lean propylene storage bullets 102-S-004 A/B or enters C3-C3 column 101-C-002 at tray 27. This has 80 valve trays and the column operates at a pressure of 16.6 kg/cm$^2$ g and heated by steam 5.5 kg/cm$^2$g. Column top and bottom temperatures are maintained at 41 and 47 degree c respectively. The propylene goes up and gets condensed in condenser 101-E-004 which is cooled by cooling water and propylene 95% purity collects in reflux drum 101-V-007. Reflux pump 101-P-005 A/B takes suction from reflux drum 101-V-007 to C3-C3 column (C3-C3 column top temperature is controlled by reflux flow FC-105). The C3-C3 column pressure is

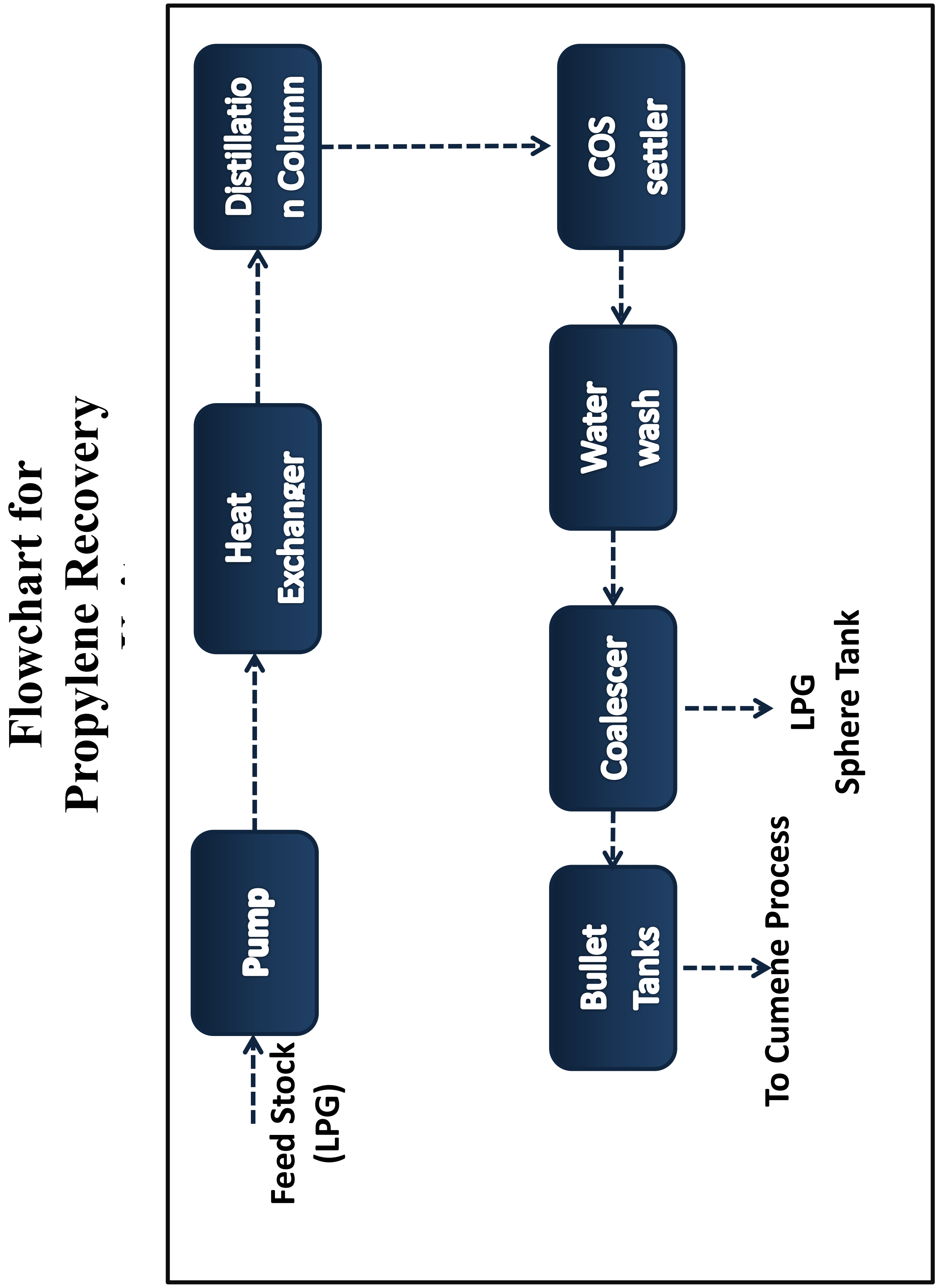



**Figure 4.1: Flowchart for Propylene Recovery Unit**

maintained by drawing overhead product through PC-102 and flows to chemical grade propylene 95% bullet 102-S-001 A/B.

### 4.3 EXPECTED PROBLEMS IN PROPYLENE RECOVERY UNIT

The process control and expected problems in PRU are following:

- During initial startup, if the column is heated with higher heat rate, there is a possibility of heavies carrying to the top and collecting in the reflux drum. It takes longer period for reducing the heavies in the column top product. There is also a possibility of heavies carrying to the top during normal operation.
- If the circulating MEA-caustic concentration is low 2.5%, sulphur may carry over along with the lean propylene product, there by poisoning the solid phosphoric acid catalyst in the cumene plant.
- When reflux temperature becomes high, reflux flow fails. This may be due to insufficient flow of cooling water through the condenser tubes because of fouling or due to high cooling water temperature.
- Specification of lean propylene purity is >75%. In normal operation, there is a possibility of purity coming down below 75%.
- Propylene slippage through C3-C4 bottom should be below 3%. In normal operation there is a possibility of more propylene slippage in the C3-C4 bottom.

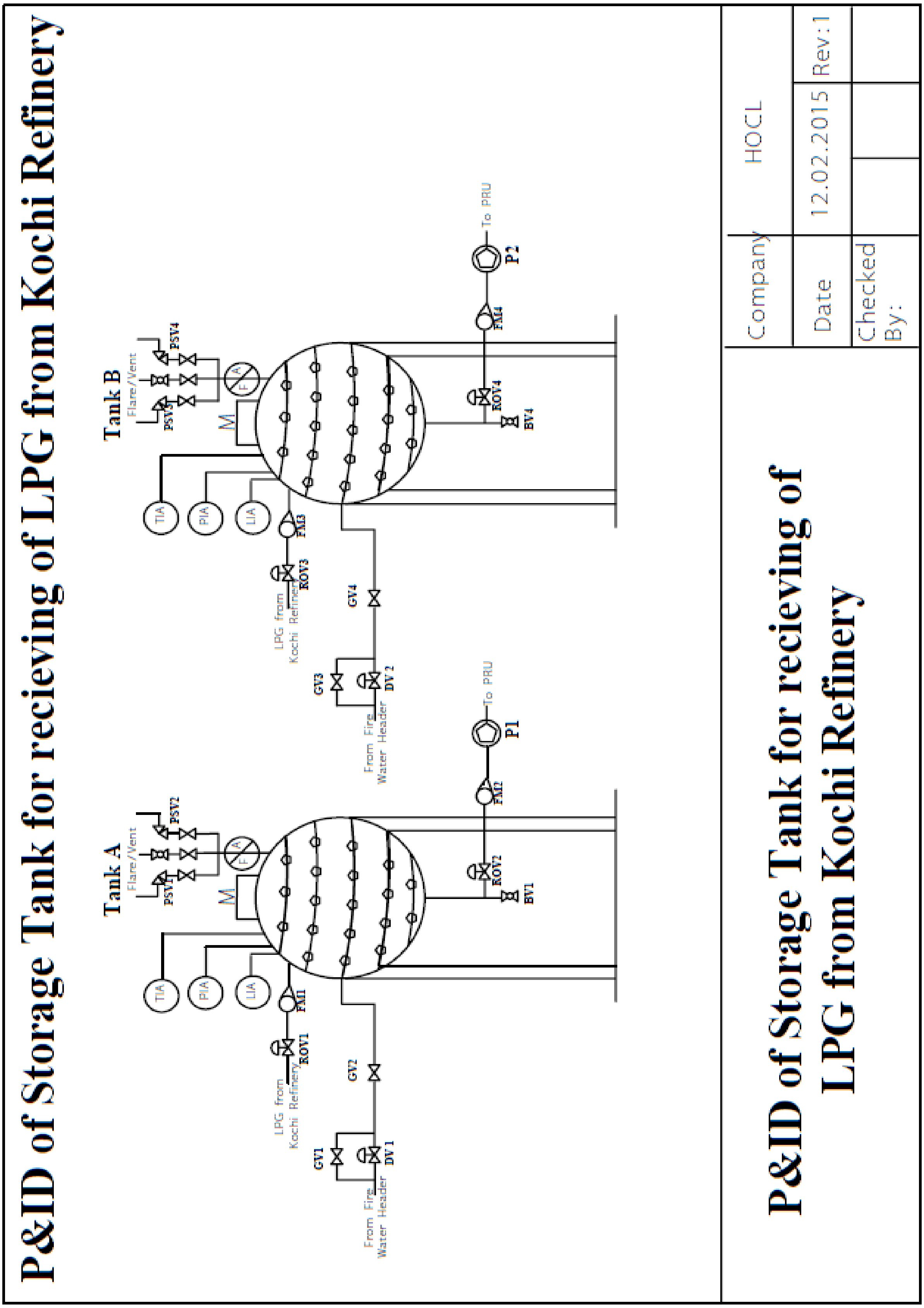



**Figure 4.2: P & ID of Storage Tank for receiving LPG from Kochi refinery**

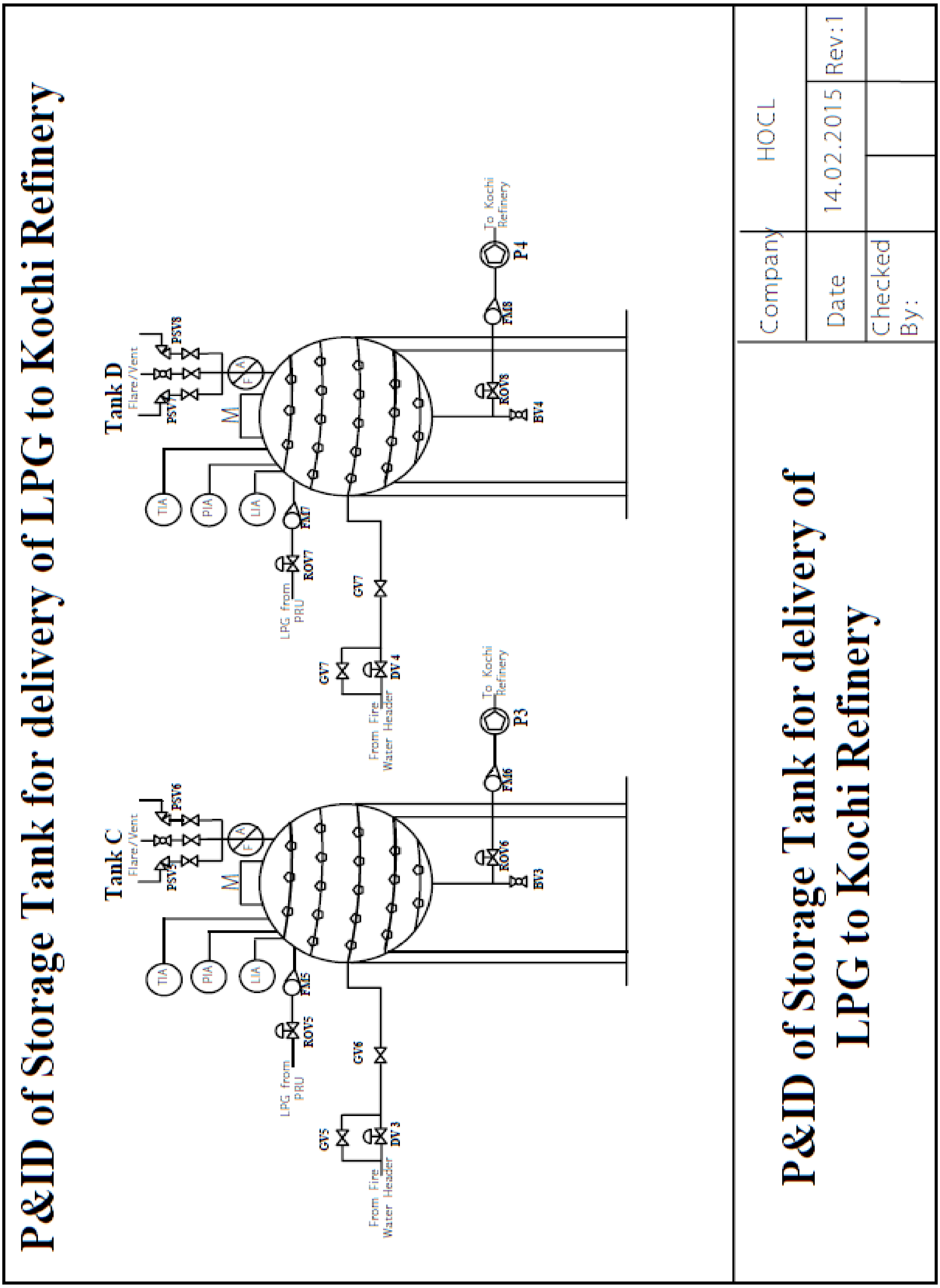



**Figure 4.3: P & ID of Storage Tank for delivering LPG to Kochi refinery**

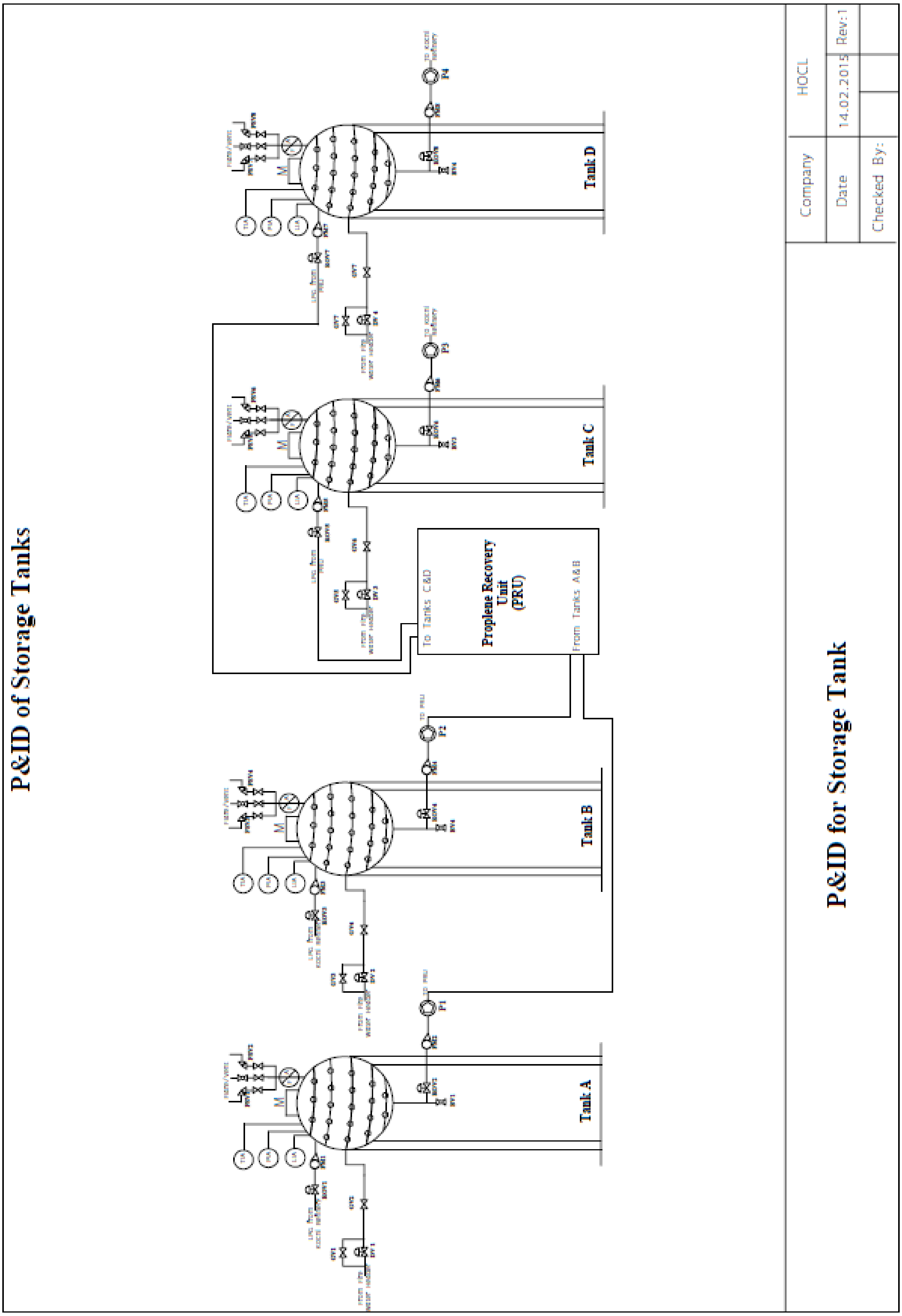



Figure 4.4: P& ID of Storage Tank

## CHAPTER 5

## BOW TIE PROCESS

### 5.1 GENERAL:

The bow-tie method provides a readily understood visualization of the relationships between the causes of business upsets, the escalation of such events, the controls preventing the event from occurring and the preparedness measures in place to limit the business impact.

In its most common use, the ultimate aim is to demonstrate control of health, safety and environmental (HSE) hazards; it is therefore necessary, firstly, to identify those hazards requiring bow-tie analysis. Hindustan Organic Chemicals Limited, Cochin involved in hazardous activities have an HSE management system within which there will be formal procedures and/or guidance for identification of potential hazards and assessment of risks. Similarly, other companies have systems and standards for management of commercial, security, business continuity and corporate governance issues, to which the bow-tie method is equally applicable.

Once hazards have been identified, the bow-tie method can be applied to further assess risks and provide a framework for demonstrating their effective control. Typically bow-ties are developed by asking a structured set of questions which build up the diagram step-by-step.


**Figure 5.1 General BOW TIE**

### 5.2 BOWTIE PROCEDURE:

Developing the bow-tie diagrams and critical tasks should be carried out in a structured manner in order to obtain quality information and best represent the actual risk control arrangements. The figure below summarizes an effective bow-tie building process, which has been developed and refined through experience with a variety of companies, industries and work groups.

Facilitated workshops involving people who are regularly confronted with the risks have proven to be the most effective way of identifying real controls and capturing past incidents and current practice. Openness is an essential ingredient during these sessions if any weaknesses in controls are going to be uncovered. To encourage free discussion, the workshop needs to be run in an honest and engaging fashion, and, like HAZOP study for example, an independent facilitator can often help to create such an environment.

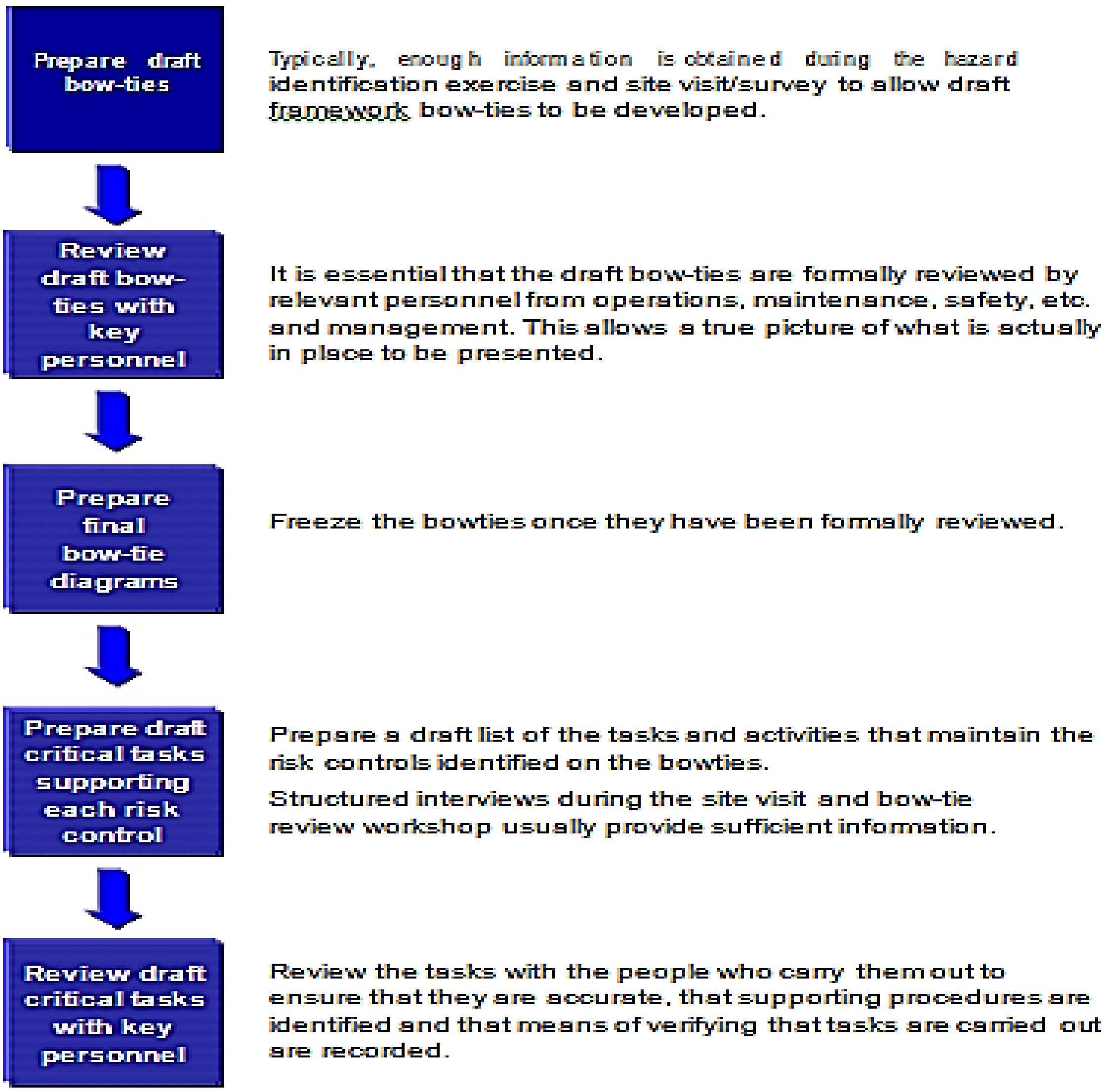



**Figure 5.2: Flowchart for BOW TIE**

## 5.3 STEPS FOR AN EFFECTIVE BOW-TIE

- Avoid working in a vacuum - Operational experience or bow-tie experience alone gives sub-standard results; a combination of the two is essential.
- Involve people – Use people in building bow-ties, reviewing tasks and identifying areas for improvement. Whilst a first pass bow-tie can be developed as a desk top study, quality can only be assured by involving competent people who know how activities are in reality carried out in the workplace and have an in-depth understanding of the plant, the operation or design. This ensures that risk controls and supporting tasks accurately reflect actual practice rather than the preconceptions of senior management or the risk department. However, to arrive quickly at a truly representative bow-tie structure and avoid getting stuck in the detail, it is accepted best practice to use independent facilitation to solicit the input from the workforce. The facilitator should have practical experience of building bow-ties. The subjective nature of the method means that different groups of people may produce different bow-ties for the same event. However, this is of secondary importance; the main point is that the assessment should be complete and the key risk controls and tasks captured.
- Pitch at the correct level of detail - Too high and the bow-tie is meaningless; too low and the exercise is labor intensive.
- Make sure the control responsibilities don’t all finish up at the manager level - Care needs to be taken when setting the level of detail. Controls should be independent and self-explanatory. Tasks need to be meaningful and assigned at a level where their completion can be verified. Typically when building bow-ties for assessing major hazards (e.g. multiple fatalities, massive environmental impact, extensive asset loss, international reputation damage), tasks supporting the controls should be pitched at the supervisor or team leader level.
- Balance the information between the bow-ties and the tasks - Depending on the intended use of the bow-ties, it may be appropriate to keep the diagrams simple, with few words, and present any detailed information in the tasks. This approach can be appropriate when using bow-ties to represent the management of major business risks across the company. Alternatively, it is sometimes beneficial to keep the detail in the diagram, e.g. where a bow-tie is to be used for training purposes during a pre-job safety meeting.
- Prioritize effort - Don’t get carried away. The bow-tie method is a flexible, generic tool that can be applied to any type of risk at any level. It can equally be used for assessing lower consequence ‘workplace’ hazards (e.g. slips, trips, and falls) as well as for assessing major business risks. It provides useful information for pre-job safety meetings. When using the technique at this level, it may be prudent to select representative workplace hazards with care and prioritize resources at those which are most common, are of greatest concern or are unique, otherwise significant resources could be demanded and the method called into question.

- ALARP demonstration - Bow-ties are an appropriate tool for qualitative demonstration that risk is managed to a level which is As Low As Reasonably Practicable (ALARP). However, avoid barrier counting where possible. Instead, in addition to the controls currently in place, the team must ask "what additional, practical controls can we implement?" There is one school of thought that advocates setting numerical risk acceptance criteria for bow-ties, (e.g. there must be at least three independent controls for every threat). The danger with this approach is that the assessment becomes a 'control counting' exercise, with dependent controls artificially represented as separate control measures in order to meet the criteria and with the assessment stopping once the requisite number of controls has been confirmed. It is better to use the cumulative experience of the bow-tie building team to review the completeness of the assessment as a whole and confirm the number, suitability, quality and effectiveness of the controls and supporting critical tasks. The important question must always be asked "is there anything more we can reasonably do?"
- Verify control measures and tasks - Follow-up with an audit. Depending on the make-up of the group who develop the bow-tie and the expertise of the facilitation, there can be a danger that the diagram represents only a single opinion, has serious omissions or does not represent what actually happens in the 'real life' situation. A follow up audit or inspection helps to ensure the credibility of the bow-tie and the completeness of the management arrangements. It verifies that the controls are actually in place and the critical tasks ensuring control effectiveness are being carried out. This is particularly useful when bow-ties have been developed for a new project, when there may be limited information available, when procedures are still to be developed and roles are not yet assigned. The verification audit can be carried out as part of pre-start up activities.
- Software helps but don't get hung up on it - The true benefits from the bow-tie process are largely independent of the means by which the bow-tie is constructed, e.g. by hand or electronically. A number of software tools are available to construct bow-ties and manage the information behind the diagram. It should not be forgotten however that many of the benefits of the approach are associated with the actual implementation of the process and involvement of the workforce, which is often easiest to achieve using hand drawn bow-ties in a brainstorming, workshop setting. Software is ideal for speeding up the reproduction of bow-tie diagrams and organizing the information for future interrogation, retrieval and update.
- Use the method to its full potential - As use of bow-ties has become more widespread, partial assessment has become more common, with the analysis ceasing once the diagram is constructed. While this gives a graphical demonstration of risk control, it provides no more information than other risk assessment tools which illustrate the controls in place at that moment in time, e.g. HAZOP, What-If. In other words the bow-tie diagram on its own is just a 'snap shot' of the current risk control arrangements. What is missing is the direct and visible link between the controls as they are today and the procedures and people responsible for ensuring they will continue to be effective tomorrow. This understanding is only achieved by identifying

and documenting the critical tasks and/or critical procedures which are crucial for ongoing functioning of the controls.

- Keep the end objective in mind - It can be easy to get carried away when using the bow-tie method. For example, for an operating plant the key controls are in making sure that the installed equipment keeps working properly, not in assessing the quality control of the design process from many years before. Similarly, there may be little point in reproducing the large number of individual steps taken to control an event if they are already well documented in a work instruction or manual. Reference to the external document is usually sufficient.
- Quantification - use the right tool for the job - The bow-tie is sometimes described as "like a fault-tree on the left hand side with an event-tree on the right". Some risk assessors interpret this as an opportunity to try to quantify the risk level, but the bow-tie is wholly qualitative, without any of the complex logic of fault and event trees. While a well -constructed bow-tie can be used to support a quantitative LOPA approach, most attempts to quantify the risk tend to miss the main point of the bow-tie, which is to identify how the management system provides assurance that risks will continue to be properly managed in the future.

## 5.4 BENEFITS

The bow-tie method has three main benefits:

- Clear communication and improved understanding - Visually illustrating the hazard, its causes and consequences, and the controls to minimize the risk, the bow-tie can be readily understood at all levels, from senior managers and operations personnel, to regulators and members of the public. Bow-ties keep sight of the big picture and can capture the sequence of events as well as previous incidents.
- Greater ownership - Recognizing that effective risk management is only possible if people are assigned responsibilities for controls. Bow-tie workshops encourage participation and stimulate communication between key stakeholders, whether from the company, contractors or external parties, who all have a role to play in managing risk and yet may not be involved in more traditional techniques. When people feel involved they tend to 'buy-in' to the process. When action is taken based on what they say, people will take ownership. Bow-ties should especially be considered where lack of ownership of process safety by all levels of operations personnel may be an issue.
- Efficiency gains - Realizing efficiency improvements through a number of different ways, for example: the method is less labor intensive than many other traditional techniques; it identifies where resources should be focused for risk reduction (i.e. prevention or mitigation); it can reduce the volume of safety analysis – it is true that a picture paints a thousand words; it can lead to a potential reduction in unnecessary/lower importance barriers (where fully justified); it helps to target maintenance, inspection and testing activities on critical hardware barriers; and it provides a 'corporate memory' to avoid reinventing the wheel every few years.

- ‘Future proof’ risk management - Illustrating not only what controls are currently in place today, but, through the use of critical tasks, why they will still be there tomorrow.
- Fit-for-purpose management system - Linking the elements of the organization’s management system to specific controls to show how it ensures the ongoing management of risk. This avoids the development of over-burdensome management systems and unnecessary procedures, by focusing on those procedures required to support risk control.
- Practical approach - Focusing on risk management by people on a day-to-day basis, rather than analytical studies by technical risk specialists. All too often, risk analysis can become progressively more complex leading to ‘analysis paralysis’ which overwhelms the need to take positive action.
- Workforce involvement - Risk management is the responsibility of line managers and their people; all staff can see why what they do is critical for risk control.
- Logical structured approach - Considering all aspects of the management of risk, from initial cause to final consequence in a sequential manner. This logical approach often identifies gaps and issues that are missed by other techniques.
- Auditable trail - The diagrams and critical task lists provide a protocol around which auditing by internal departments or regulators can focus on what people are actually doing rather than the condition of physical systems.
- International application – The graphical-based approach is easy to implement with multi-national teams where language difficulties may otherwise hinder progress.
- All risks – The technique is not limited to assessment of HSE risks. Bow-ties have been developed for demonstrating management of security, information technology, business interruption and project risks. The possibilities are endless.
- ‘Living case for safety’ – Comprehensive bow-tie assessments can be captured in a relational database which supports ready and wide access across an organization, and enables easier periodic updating. Links to current safety-critical procedures help to maintain any case for safety as a live tool rather than a document for risk practitioners that sits on the shelf

**5.5 LIMITATIONS**

Of course, bow-ties are not the panacea for all risk management problems. If you want to quantify your level of risk in absolute terms then the bow-tie method will not help directly. If you want to model complex inter-relationships between your risk controls, there are better ways than using bow-ties. If you want to identify individual safeguards for every line of every section of every unit of your process facility, then HAZOP study is the solution. But if you want to remove the mystique of risk management and obtain insights into your risk controls that are easy to understand and easy to communicate, and at the same time realize some efficiency gains, there is no better method than bow-ties.

# CHAPTER 6

# RESULTS & DISCUSSION

In PRU hydrocarbon gas and associated condensate liquids are handled and processed by these facilities. Hydrocarbon gas is a fuel source that burns when ignited in air and condensate is a key feedstock for oil refineries. However, these products are also major hazards that require to be managed with extreme care. Any loss of containment of hydrocarbons from the pipelines and/or processing facilities could result in exposing personnel and the assets to consequences of jet fires and vapour cloud explosions leading to injury, death and significant impact on the reputation of the business.

## 6.1 HAZARD DESCRIPTION

- Hydrocarbon Gas (LPG-PRU)

Major sources of hydrocarbon hazards in the PRU were LPG process systems were hydrocarbons from the incoming gas/condensate pipeline coming from KRL go through separation, dehydration and treatment stages to the PRU.

The normal hydrocarbon operating pressures of PRU are facilities ranges from 5-20kg/cm2. Table below illustrates the range of pressure regimes at the various points of the processing facilities.

| **Element** | **Operating Pressure** |
|---|---|
| LPG storage spheres | 5-10kg/cm$^2$ g |
| C3-C4 Distillation column | 15.5kg/cm$^2$ g |
| C3-C3 Chemical Grade Propylene column | 16.5kg/cm$^2$ g |

**Table 6.1: Elements & operating pressure in propylene recovery unit**

The key locations where a hydrocarbon release and subsequently resulting in potential fire or explosion are as follows:

- LPG Storage Spheres (102-S-003 A/B)
- C3-C4 Distillation Column (101-C-001) and C3-C3 CGP Column (101-C-002)
- Propylene Storage Bullets (102-S-004)

## 6.2 BOW TIE ANALYSIS ON HYDROCARBON GAS

### 6.2.1 Threats & Causes are:

- Internal corrosion
- External corrosion
- Flange leak/small bore fittings
- High pressure downstream of pressure up to gas export compressor inlet
- Structural support failure
- High temperature downstream of inlet gas heater

Threats that are common with other oil and gas industry such as corrosion, operating outside the design limits (too much/little pressure, temperature, vibration, fatigue etc.), flange/seal leaks etc. are also the threats that are experienced with operating the PRU facilities. These threats need to be managed through comprehensive design processes, and robust technical integrity management during operations.

### 6.2.2 Consequences & Controls are:

The consequences as a result of the top event are identified in the LPG Hydrocarbon Gas Bow-Tie are as follows:

✓ Outcome – Vapour Cloud Expansion VCE Fire
  - Asphyxiation of the personnel enveloped by the cloud
  - Personnel injuries during escape and evacuation
  - Environmental impact

✓ Outcome – Jet Fire
  - Jet fire of gas
  - Fire on facility or surrounding ground area generating smoke (depending upon the volumes of gas ignited and whether it is wet or dry gas)
  - Asphyxiation of personnel enveloped by the smoke / gas cloud
  - Impairment of escape and evacuation systems
  - Structural loss / damage

### 6.2.3 Immediate Consequences:

The Condensate release can result in on-land spill at PRU causing soil/ground contamination. The primary measure to reduce the leak inventory is via emergency isolation in the form of SDVs closure whilst containing the spill from PRU areas within the contained area and draining it to the catchments area via the drain system. Detection and shutdown systems generally offers little protection to personnel in the vicinity of the incident for these types of events and the most effective way to reduce the risks to personnel are via:

- Sound technical integrity management to eliminate/stop gas leakage, which is the most effective means of reducing/minimizing the risks associated with loss of containment.
- Minimization of ignition sources on the facility by ensuring that all electrical equipment are specified based on IS5572 or IP15 ("Ex" rated equipment) and are in good working condition and the enforcement of strict controls over temporary ignition sources (e.g. hot work, vehicles).

Ignited condensate releases produces pool fires with thick smoke. The fatality risk due to immediate ignition may be insignificant but it is essential to control and mitigate the fire consequences in order to prevent escalation towards severe asset damage/loss. The magnitude of the fire can be minimized by emergency isolation by the closing actions the SDVs. To mitigate the fire consequences, PRU relies on the emergency response action and firewater system, using manual fire-fighting equipment i.e. firefighting services, hydrants/monitors and foam generators.

### 6.2.4 Escalation likelihood and control:

Condensate pool fires at PRU, if not effectively controlled and mitigated, could result in severe escalation consequences due to the condensate inventory present. The MAH management strategies have been assessed for the following type of escalation scenarios. Escalation occurs when the consequences spread from the area where the event started to other areas of the facility or when the incident increases in size considerably.

There are two main areas where escalation requires to be given attention are:

- Escalation to other areas of the plant facilities.
- Escalation to the on-site buildings/central control room and affecting the personnel evacuation routes.

The strategies for managing the escalation within and between process areas in the PRU are summarized as follows:

- Emergency shutdown and isolation is the primary action, with draining of spills via open drain system to a safe area will prevent or minimize size/duration of condensate pool fires.

- Bund walls around process area and tanks and drain into the safe containment area.
- Passive fire protection system built into the design of the facilities.
- Separation distance between equipment (heat radiation from fire decreases) prevents fire escalating.
- Control of ignition source (EX rated equipment and controls for hot work)
- Effective and timely emergency response by the fire brigade team is critical for preventing escalations between process areas and between tanks. The fire service team relies on the firewater system and manual firefighting equipment such as fire tenders, hydrants, monitors and foam generators/pourers. The strategy is to provide firewater cooling of the area and adjacent facilities or smother condensate pool fires using foam.

## 6.3 RECOMMENDATIONS

### 6.3.1 Leading Indicators

During the observation the leading indicators found were:

- Usage of PPE
- Display of Sign Boards and Health Safety and Environment policy at every point
- Employee Safety Trainings
- Standard Operating Procedures were updated
- Permit to Work System
- Management of Change
- Waste Management plan

### 6.3.2 Lagging Indicators

During the observation the lagging indicators found were:

- Employee involvement should be increased by various programmes which can increase the motivation towards the work.
- Contractor's safety management can be improved.

## 6.4. HSE CRITICAL TASKS

- Developing a Corrosion management strategy and monitoring corrosion for Propylene Recovery Unit facilities including pipelines and condensate storage Tanks.
- Developing and following SOPs for all intervention activities [Ensure risk assessment with respect to impact on adjacent unit is covered in job specific SOP].
- Carrying out JSAs for all critical lifts (which have potential to fall upon hydrocarbon facility) as part of PTW system.

- Developing and following Standard maintenance procedures (SMPs) for Propylene Recovery Unit facilities.
- Developing and following SOP for condensate loading including tanker check list (Ensure presence of operator on loading platform all the time during condensate loading operations).
- Carrying out periodic Fire drills.
- Ensure ERP addresses actions to be taken in case of any danger.
- Carrying out ERP awareness campaign [Ensure action in case of gas ingress into the buildings is known to people].
- Establish a Policy of 'No Smoking' in Propylene Recovery Unit and carry out random checks.
- Developing and implementing a QC procedure at receiving end particularly for the material which is inspected on random sample basis at dispatch end.

### 6.5 SAFETY CRITICAL ELEMENTS

- Periodic Test and maintenance of Fire & Gas system
- Periodic testing of Emergency Shut Down valves ESD's
- Testing and calibration of Pressure Safety Valves PSV's at the time of first installation
- Periodic check of earthling of condensate storage tanks
- Periodic testing of high level trip on propylene bullet storage tanks
- Periodic testing of high level trip on condensate storage Tanks
- Periodic testing of low pressure alarm condensate storage Tanks
- Inspection and maintenance of water deluge system condensate storage Tanks
- Inspection and maintenance of foam spray system condensate storage Tanks
- Inspection and maintenance of water deluge system in condensate loading area
- Inspection and maintenance of foam spray system in condensate loading area
- Provide gas detectors in air suction of each HVAC in utility building which shall automatically close the dampers.
- Ensure fire hydrants / monitors are located at least on two opposite sides in utility building area.

# Chapter 7

# CONCLUSION

All potentially hazardous events associated with Hindustan Organic Chemicals Limited which is a gas processing plant, handling hydrocarbon gas were identified and condensate and the necessary preventive measures for each scenario was done. This study identified the necessary tasks, activity, and recovery preparedness and mitigation methods from escalation of top event scenarios. This study determined the requirement of Bow Tie analysis based on risk assessment of identified hazards addressing various threats, consequences, respective barriers and control measures from all identified resources. The overall objective to learn safety systems for on- and off-site personnel, equipment and the environment were done.

Thus my experience has shown that the Bow-Tie is ideal for structured assessment and communication of risks, clearly demonstrates the link between control measures and management system arrangements and can be used to qualitatively assess and demonstrate control of all types of risk. Bowtie Analysis helps the organization in the following ways:-

- Helps in determination of mitigation measures for top priority risk found in the HIRA.
- Helps in formulating the barrier to prevent an cause being an event and further to be an hazards outcome.
- Helps in controlling and preventing the hazardous event from occurring and preparedness measures in place to limit the consequences.

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# ANNEXURE