HAZOP & JOB SAFETY ANALYSIS

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UNIVERSITY OF PETROLEUM & ENERGY STUDIES

ENERGY ACRES, DEHRADUN.

MAY 2008

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A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
[Health, Safety & Environment]

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Approved

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CERTIFICATE

This is to certify that work contained in this thesis titled "HAZOP & Job Safety Analysis" has been carried out by Mr. M.Ragunathan under my supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

Chemical Industry has number of special hazards and risks. The hazard and operability study(HAZOP) & job safety analysis(JSA) attempts to define the possible hazards and to eliminate or contain hazardous situations which would be encountered in a working plant. This is achieved by recognizing hazards from the initial stage onwards right through construction, commissioning, and operation stage.

In many chemical industries manufacturing of chemicals involves various unit process and unit operations. While performing the operations various safety requirements have to be adhered and followed for higher productivity without any accidents. This project mainly focuses on HAZOP study for hydrogen generation unit, flammable storage tank and also JSA for the production for gabapentin in pharmaceutical industry.

The main aim and objective of the project are:

1. To study the safety aspects in the design and operation of hydrogen generation unit

2. To identify the drawbacks in the design affecting safety and basic operation of the plant with the aid of Hazard & operability study and Job safety analysis.

3. To suggest recommendations based on study.

ACKNOWLEDGEMENT

It gives me immense pleasure to express my deep sense of gratitude to my guide Dr.Nihal Anwar Siddique, Assistant Professor, College of Engineering, UPES, Dehradun for his inspiring guidance and Constant encouragement. It would have been impossible to accomplish this work, without his able guidance and unabated perseverance in the quest for success.

I would like to express my special thanks to Dr.B.P.Pandey, Dean, College of Engineering, UPES, Dehradun for his kind support in carrying out the project and also provided me facility whenever required. Working under him was great pleasure and learning experience.

It is indeed a privilege to associate myself with Mr.M.Rajkumar,Safety Engineer, Shasun Chemicals and Drugs Limited (SCDL),Cuddalore, he deserves much more than a mere thanks for his support throughout my Project period. I am highly indebted for his valuable suggestions and timely help.

I am thankful to all my class mates and friends who helped me a lot to do this project.
Finally I dedicate this project work to my parents, to whom I love a lot.

M.Ragunathan
M.Tech [Health, Safety & Environment]

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1. INTRODUCTION

Hazard

Any operation that could possibly cause a catastrophic release of toxic, flammable or explosive chemicals or any action that could result in injury to personnel.

Operability

Any operation inside the design envelope that would cause a shutdown that could possibly lead to a violation of environmental, health or safety regulations or negatively impact profitability.

1. A Hazard and Operability (HAZOP) study is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation.
2. The HAZOP technique was initially developed to analyze chemical process systems, but has later been extended to other types of systems and also to complex operations and to software systems.
3. A HAZOP is a qualitative technique based on guide-words and is carried out by a multi-disciplinary team (HAZOP team) during a set of meetings.

Concept

The HAZOP concept is to review the plant in a series of meetings, during which a multidisciplinary team methodically "brainstorms" the plant design, following the structure provided by the guide words and the team leader's experience.

The primary advantage of this brainstorming is that it stimulates creativity and generates ideas. This creativity results from the interaction of the team and their diverse backgrounds. Consequently the process requires that all team members participate (quantity breeds quality in this case), and team members must refrain from criticizing each other to the point that members hesitate to suggest Ideas.

The team focuses on specific points of the design (called "study nodes"), one at a time. At each of these study nodes, deviations in the process parameters are examined using the guide words. The guide words are used to ensure that the design is explored in every conceivable way. Thus the team must identify a fairly large number of deviations, each of which must then be considered so that their potential causes and consequences can be identified.

The HAZOP study should preferably be carried out as early in the design phase as possible - to have influence on the design. On the other hand to carry out a HAZOP we need a rather complete design.

HAZOP studies may also be used for

- At the initial concept stage when design drawings are available
- When the final piping and instrumentation diagrams (P&ID) are available
- During construction and installation to ensure that recommendations are implemented
- During commissioning
- During operation to ensure that plant emergency and operating procedures are regularly reviewed and updated as required

The success or failure of the HAZOP depends on several factors

- The completeness and accuracy of drawings and other data used as a basis for the study
- The technical skills and insights of the team
- The ability of the team to use the approach as an aid to their Imagination in visualizing
- deviations, causes, and consequences
- The ability of the team to concentrate on the more serious hazards which are identified

Job Safety Analysis (JSA)

Definition

A Job Safety Analysis (JSA) is a method that can be used to identify, analyze and record

1) The steps involved in performing a specific job,

2) The existing or potential safety and health hazards associated with each step, and

3) The recommended action(s)/procedure(s) that will eliminate or reduce these hazards and the risk of a workplace injury or illness.

JSA must be done before doing the operation.

A "Job Safety Analysis" is a task oriented risk assessment that can be applied by a work team prior to undertaking potentially hazardous activities. The technique is particularly useful for developing "Safe Work Methods Statements" or Safe Work Procedures (SWP) where the likely level of competence of people involved in carrying out the task must be supplemented with a "set of rules" that will protect them from their competence limitations.

2. LITERATURE REVIEW

In the 1960s, an improved form of what-if analysis emerged within Imperial Chemical Industries (ICI), and its application first became known as operability and hazard studies. Later, to emphasize the importance of process safety, the name HAZOP (Hazard and Operability) was formed. From the literature CIA (Chemical Industries Association, 1977) and discussions with ICI, Rohm and Haas discovered the HAZOP technique and decided to run a pilot study on an agricultural chemical manufacturing plant.

The pilot study was a great success, with the HAZOP logic process re-discovering the mechanism of several incidents that had actually occurred, as well as identifying other credible incident scenarios that had not yet happened. The pilot study also identified many process, equipment, and procedural improvements, which benefited safety, product quality, and plant operations. Accounts of work in heavy organic chemical division of ICI (Binsted 1960) and in Mond division (Elliott and Owen 1968) describe the development of HAZOP and job safety analysis. Accounts of development of HAZOP have been given by kletz (1986).

The advent of the OSHA PSM regulation in May 1992 (OSHA, 1992) introduced a new consideration - possible audit of the HAZOP results by a potentially hostile government agency. Since OSHA's authority only covers safety hazards to workers, companies naturally limited the mandated PHAs to the mandated consequences of interest - hazards that posed a "serious danger" to workers.

3. PROCESS HAZOP

Prerequisites

As a basis for the HAZOP study the following information should be available

1. Process flow diagrams (PFD)
2. Piping and instrumentation diagrams (P&ID)
3. Layout diagrams
4. Material safety data sheets
5. Provisional operating instructions
6. Heat and material balances
7. Equipment data sheets Start-up and emergency shut-down procedures

3.1 HAZOP Procedural Methodology

HAZOP procedure may be illustrated as follows

1. Divide the system into sections (i.e., reactor, storage)
2. Choose a study node (i.e., line, vessel, pump, operating instruction)
3. Describe the design intent
4. Select a process parameter
5. Apply a guide-word
6. Determine cause(s)
7. Evaluate consequences/problems
8. Recommend action: What? When? Who?
9. Record information
10. Repeat procedure (from step 2)

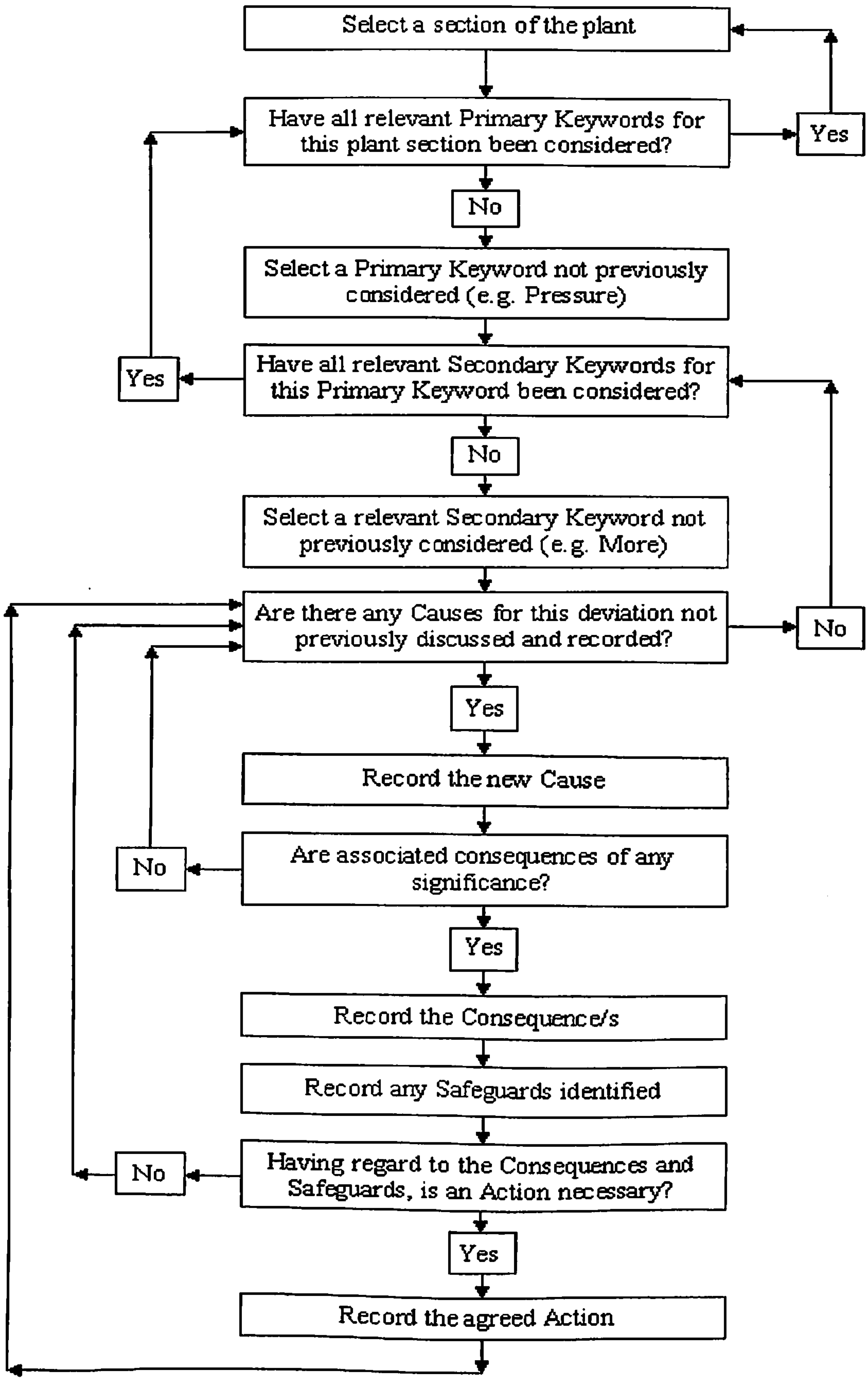


Figure -1 Procedure Methodology for HAZOP

3.2 Worksheet Entries

Node

A node is a specific location in the process in which (the deviations of) the design/process intent are evaluated.

Examples might be: separators, heat exchangers, scrubbers, pumps, compressors, and interconnecting pipes with equipment.

Design Intent

The design intent is a description of how the process is expected to behave at the node. This is qualitatively described as an activity (e.g., feed, reaction, sedimentation) and/or quantitatively in the process parameters, like temperature, flow rate, pressure, composition, etc.

Deviation

A deviation is a way in which the process conditions may depart from their design/process intent.

Parameter

The relevant parameter for the condition(s) of the process (e.g. pressure, temperature, composition).

Guideword

A short word to create the imagination of a deviation of the design/process intent. The most commonly used set of guide-words are no, more, less, as well as, part of, other than, and reverse. In addition, guidewords like too early, too late, instead of, are used; the latter mainly for batch-like processes.

The guidewords are applied, in turn, to all the parameters, in order to identify unexpected and yet credible deviations from the design/process intent.

Guide-word + Parameter = Deviation

Cause

The reason(s) why the deviation could occur. Several causes may be identified for one deviation. It is often recommended to start with the causes that may result in the worst possible consequence.

Consequence

The results of the deviation, in case it occurs. Consequences may both comprise process hazards and operability problems, like plant shut-down or reduced quality of the product. Several consequences may follow from one cause and in turn, one consequence can have several causes.

Safeguard

Facilities that help to reduce the occurrence frequency of the deviation or to mitigate its consequences. There are five types of safeguards that are

1. Identify the deviation (e.g., detectors and alarms, and human operator detection)

2. Compensate for the deviation (e.g., an automatic control system that reduces the feed to a vessel in case of overfilling it. These are usually an integrated part of the process control)

3. Prevent the deviation from occurring (e.g., an inert gas blancket in storages of flammable substances)

4. Prevent further escalation of the deviation (e.g., by (total) trip of the activity. These facilities are often interlocked with several units in the process, often controlled by computers)

5. Relieve the process from the hazardous deviation (e.g., pressure safety valves (PSV) and vent systems)

Process Parameters

Process parameters may generally be classified into the following groups

- Physical parameters related to input medium properties
- Physical parameters related to input medium conditions
- Physical parameters related to system dynamics
- Non-physical tangible parameters related to batch type processes
- Parameters related to system operations

Examples for Process Parameters

3.3 Primary guidewords

These reflect both the process design intent and operational aspects of the plant being studied. Typical process oriented words might be as follows.

Flow	Composition	pH
Pressure	Addition	Sequence
Temperature	Separation	Signal
Mixing	Time	Start/stop
Stirring	Phase	Operate
Transfer	Speed	Maintain
Level	Particle size	Services
Viscosity	Measure	Reaction

Table 1- primary guidewords

3.3 Secondary Keywords

As mentioned above, when applied in conjunction with a Primary Keyword, these suggest potential deviations or problems.

Word	Meaning
No	The design intent does not occur (e.g. Flow/No), or the operational aspect is not achievable (Isolate/No)
Less	A quantitative decrease in the design intent occurs (e.g. Pressure/Less)
More	A quantitative increase in the design intent occurs (e.g. Temperature/More)
Reverse	The opposite of the design intent occurs (e.g. Flow/Reverse)
Fluctuation	The design intent is completely fulfilled, but in addition some other related activity occurs (e.g. Flow/Also indicating contamination in a product stream, or Level/Also meaning material in a tank or vessel which should not be there)
Also	The activity occurs, but not in the way intended (e.g. Flow/Other could indicate a leak or product flowing where it should not, or Composition/Other might suggest unexpected proportions in a feedstock)
Other	The design intention is achieved only part of the time (e.g. an air-lock in a pipeline might result in Flow/Fluctuation)
Early	Usually used when studying sequential operations, this would indicate that a step is started at the wrong time or done out of sequence

Table 2- secondary guidewords

It should be noted that not all combinations of Primary/Secondary words are appropriate. There are other useful modifications to guide words such as

- SOONER or LATER for OTHER THAN when considering time
- WHERE ELSE for OTHER THAN when considering position, sources, or destination
- HIGHER and LOWER for MORE and LESS when considering elevations, temperatures, or pressures.

3.4 HAZOP Team Members and Responsibilities

HAZOP Team Members

The basic team for a process plant will be:

- Process engineer
- Project engineer
- Commissioning manager
- Instrument & design/electrical engineer
- Safety engineer

The team leader should be independent (i.e., no responsibility for the process and/or the performance of operations)

Depending on the actual process the team may be enhanced by

- Operating team leader
- Maintenance engineer
- Suppliers representative
- Other specialists as appropriate

Responsibilities

Define the scope for the analysis

- Select HAZOP team members
- Plan and prepare the study
- Chair the HAZOP meetings
- Trigger the discussion using guide-words and parameters
- Follow up progress according to schedule/agenda
- Ensure completeness of the analysis
- Prepare HAZOP worksheets

- Record the discussion in the HAZOP meetings
- Prepare draft report

To be a good HAZOP participant

- Be active. Everybody's contribution is important
- Be to the point. Avoid endless discussion of details
- Be critical in a positive way - not negative, but constructive
- Be responsible. He who knows should let the others know

3.5 HAZOP Meeting & Recording

HAZOP Meeting

1. Introduction and presentation of participants
2. Overall presentation of the system/operation to be analyzed
3. Description of the HAZOP approach
4. Presentation of the first node or logical part of the operation
5. Analyze the first node/part using the guide-words and Parameters
6. Continue presentation and analysis (steps 4 and 5)
7. Coarse summary of findings

Focus should be on potential hazards as well as potential operational problems

Each session of the HAZOP meeting should not exceed two hours.

HAZOP Recording

The findings are recorded during the meeting using a HAZOP work-sheet, either by filling in paper copies, or by using a computer connected to a projector (recommended).

The HAZOP work-sheets may be different depending on the scope of the study - generally the following entries (columns) are included

1. Ref. no.
2. Guide-word
3. Deviation
4. Possible causes
5. Consequences
6. Safeguards
7. Actions required (or, recommendations)
8. Actions allocated to (follow-up responsibility)

The concepts presented above are put into practice in the following steps

1. Define the purpose, objectives, and scope of the study
2. Select the team
3. Prepare for the study
4. Carry out the team review
5. Record the results.

1. Define the Purpose, Objectives, and Scope of the Study

The purpose, objectives, and scope of the study should be made as explicit as possible. These objectives are normally set by the person responsible for the plant or project, assisted by the HAZOP study leader (perhaps the plant or corporate safety officer). It is important that this interaction take place to provide the proper authority to the study and to ensure that the study is focused. Also, even though the general objective is to identify hazards and operability problems, the team should focus on the underlying purpose or reason for the study.

Examples of reasons for a study might be to:

- Check the safety of a design
- Decide whether and where to build
- Develop a list of questions to ask a supplier
- Check operating/safety procedures
- Improve the safety of an existing facility
- Verify that safety instrumentation is reacting to best parameters.

It is also important to define what specific consequences are to be considered:

- Employee safety (in plant or neighboring research center)
- Loss of plant or equipment
- Loss of production (lose competitive edge in market)
- Liability
- Insurability
- Public safety
- Environmental impacts.

2. Select the Team

HAZOP the team consists of five to seven members, although a smaller team could be sufficient for a smaller plant. If the team is too large, the group approach fails. On the other hand, if the group is too small, it may lack the breadth of knowledge needed to assure completeness. The team leader should have experience in leading a HAZOP. The rest of the team should be experts in areas relevant to the plant operation.

The team leader's most important job is to keep the team focused on the key task: to identify problems, not necessarily to solve them. There is a strong tendency for engineers to launch into a design or problem-solving mode as soon as a new problem comes to light. Unless obvious solutions are apparent, this mode should be avoided or it will detract from the primary purpose of HAZOP, which is hazard identification.

3. Prepare for the Study

The amount of preparation depends upon the size and complexity of the plant. The preparative work consists of three stages

Obtaining the necessary data

Converting the data to a suitable form and planning the study sequence

Arranging the meetings

3- i. Obtain the necessary data

Data consist of various drawings in the form of line diagrams, flow sheets, plant layouts, isometrics, and fabrication drawings. Additionally, there can be operating instructions, instrument sequence control charts, logic diagrams, and computer programs. Occasionally, there are plant manuals and equipment manufacturer's manuals. The data must be inspected to make sure they pertain to the defined area of study and contain no discrepancies or ambiguities.

3-ii. Convert the data into a suitable form and plan the study sequence

The amount of work required in this stage depends on the type of plant. With continuous plants, the preparative work is minimal. The existing, up-to-date flow sheets or pipe and instrument drawings usually contain enough information for the study, and the only preparation necessary is to make sure that enough copies of each drawing are available. Likewise, the sequence for the study is straightforward. The study team starts at the beginning of the process and progressively works downstream, applying the guide words at specific study nodes. These nodes are established by the team leader prior to any meetings. The team leader will generally define the study nodes in pipe sections. These nodes are points where the process parameters (pressure, temperature, flow, etc.) have identified design intent. Between these nodes are found the plant components (pumps, vessels, heat exchangers, etc.) that cause changes in the parameters between nodes. While the study nodes should be identified before the meetings, it is to be expected that some changes will be made as the study progresses due to the learning process that accompanies the study.

3-iii. Arrange the necessary meetings

Once the data have been assembled and the equipment representations made (if necessary), the team leader is in a position to plan meetings. The first requirement is to estimate the team-hours needed for the study. As a general rule, each individual part to be studied, e.g., each main pipeline into a vessel, will take an average of fifteen minutes of team time. For example, a vessel with two inlets, two exits, and a vent should take one and a half hours for those elements and the vessel itself. Thus, an estimate can be made by considering the number of pipelines and vessels. Another way to make a rough estimate is to allow about three hours for each major piece of equipment. Fifteen minutes should also be allowed for each simple verbal statement such as "switch on pump", "motor starts", or "pump starts".

After estimating the team-hours required, the team leader can arrange meetings. Ideally, each session should last no more than three hours (preferably in the morning). Longer sessions are undesirable because their effectiveness usually begins to fall off. Under extreme time-pressures, sessions have been held for two consecutive days, but such a program should be attempted only in very exceptional circumstances, (for example, when the team is from out of town and travel every day is not acceptable.)

With large projects, it has been found that often one team cannot carry out all the studies within the allotted time. It may therefore be necessary to use several teams and team leaders. One of the team leaders should act as a coordinator to allocate sections of the design to different teams and to prepare time schedules for the study as a whole

4. Carry out the Team Review

The HAZOP study requires that the plant schematic be divided into study nodes and that the process at these points is addressed with the guide words. The method applies all of the guide words in turn and either of two outcomes is recorded: (1) more information is needed, or (2) the deviation with its causes and consequences.

As hazards are detected, the team leader should make sure that everyone understands them. As mentioned earlier, the degree of problem-solving during the examination sessions can vary. There are two extreme positions:

- A suggested action is found for each hazard as it is detected before looking for the next hazard.
- No search for suggested actions is started until all hazards have been detected.

5. Record the Results

The recording process is an important part of the HAZOP. It is impossible to record manually all that is said, yet it is very important that all ideas are kept. It is very useful to have the team members review the final report and then come together for a report review meeting. The process of reviewing key findings will often fine-tune these findings and uncover others. The success of this process demands a good recording scheme.

Guide Word	Deviation	Example
Flow	More	Increased pumping capacity - increased suction pressure - reduced delivery head - greater fluid density - exchanger tube leaks - restriction orifice plates deleted - cross connection of systems - control faults - control valve trim changed - running two pumps
	No	Wrong routing - blockage - incorrect slip plate - incorrectly fitted check valve - burst pipe - large leak - equipment failure (isolation valve, pump vessel , etc.) - incorrect pressure differential - isolation in error – etc
	Less	Line restrictions - filter blockage - defective pumps - fouling of vessels, valves, orifice plates - density or viscosity changes - etc.
	Reverse	Defective check valve - siphon effect - incorrect pressure differential - two way flow -emergency venting - incorrect operation - in line spare equipment – etc.
Pressure	More	Surge problems – connection to high pressure system - gas breakthrough (inadequate venting) - defective isothermal overpressure - positive displacement pumps - failed open PCV's design pressures, specifications of pipes, vessels, fittings, instruments - etc.
	Less	Generation of vacuum condition - condensation - gas dissolving in liquid - restricted pump / compressor suction line - undetected leakage - vessel drainage - blockage of blanket gas reducing valve etc.
Level	More	Outlet isolated or blocked - inflow greater than outflow - control failure - faulty level measurement - gravity liquid balancing - etc.
	Less	Inlet flow stops - leak - outflow greater than inflow - control failure - faulty level measurement - draining of vessel - etc.
Temperature	More	Ambient conditions - fouled or failed exchanger tubes - fire situation - cooling water failure - defective control - heater control failure - internal fires - reaction control failures - heating medium leak into process - escalation procedures for relief valves
	Less	Ambient conditions – reducing pressure - fouled or failed exchanger tubes - loss of heating - depressurization of liquefied gas - Joule / Thompson effect - etc.
Viscosity	More	Incorrect material or composition - incorrect temperature – high solids' concentration - setting of slurries - etc.
	Less	Incorrect material or composition - incorrect temperature - solvent flushing -etc.
Relief	Other	Relief philosophy (process / fire etc) - type of relief device and reliability - relief valve discharge location - pollution implications - two phase flow - effect of de-bottlenecking on relief capacity - inlet and outlet piping -etc.
Samples	Other	Sampling procedure and operator safety -time for analysis result - calibration of automatic samplers - reliability / accuracy of representative sample - diagnosis of result - loss of sample flow - etc.
Corrosion/ Erosion	Other	Cathodic protection arrangements - internal / external corrosion protection - engineering specifications - zinc

Guide Word	Deviation	Example
Composition change		Leaking isolation valves - leaking exchanger tubes - phase change - incorrect feedstock / specification - inadequate quality control - process control upset - reaction intermediates / by-products - settling of slurries - etc.
Contamination		Leaking exchanger tubes - leaking isolation valves - incorrect operation of system - interconnected systems (especially services, blanket systems) - effect of corrosion - wrong additives - ingress of air – shutdown and start up conditions - grade change - etc.
Abnormal operation		Purging - flushing - start-up - normal shutdown - emergency shutdown - emergency operations - inspection of operating machines - guarding of machinery – etc.
Maintenance		Isolation philosophy -drainage - purging - cleaning - drying - slip plates - access -rescue plan - training - pressure testing - work permit
Ignition		Grounding arrangements - insulated vessels / equipment - low conductance fluids - splash filling of vessels - insulated strainers and valve components - dust generation - powder handling equipment - electrical classification - flame arrestors - hot work - hot surfaces - auto ignition - pyrophoric materials - etc.
Spare equipment		Installed / non-installed spare equipment - availability of spares - modified specifications - storage of spares - catalogue of spares - test running of spare equipment - etc.
Safety		Toxic properties of process materials - fire and gas detection system - alarms - emergency shutdown arrangements - fire fighting response time - emergency and major emergency training - contingency plans - T.L.V of process materials - first aid / medical resources - effluent disposal - hazards created by others (adjacent storage areas / process plant etc.) - testing of emergency equipment - compliance with local / national regulations - etc.

Table 3- Examples for guidewords

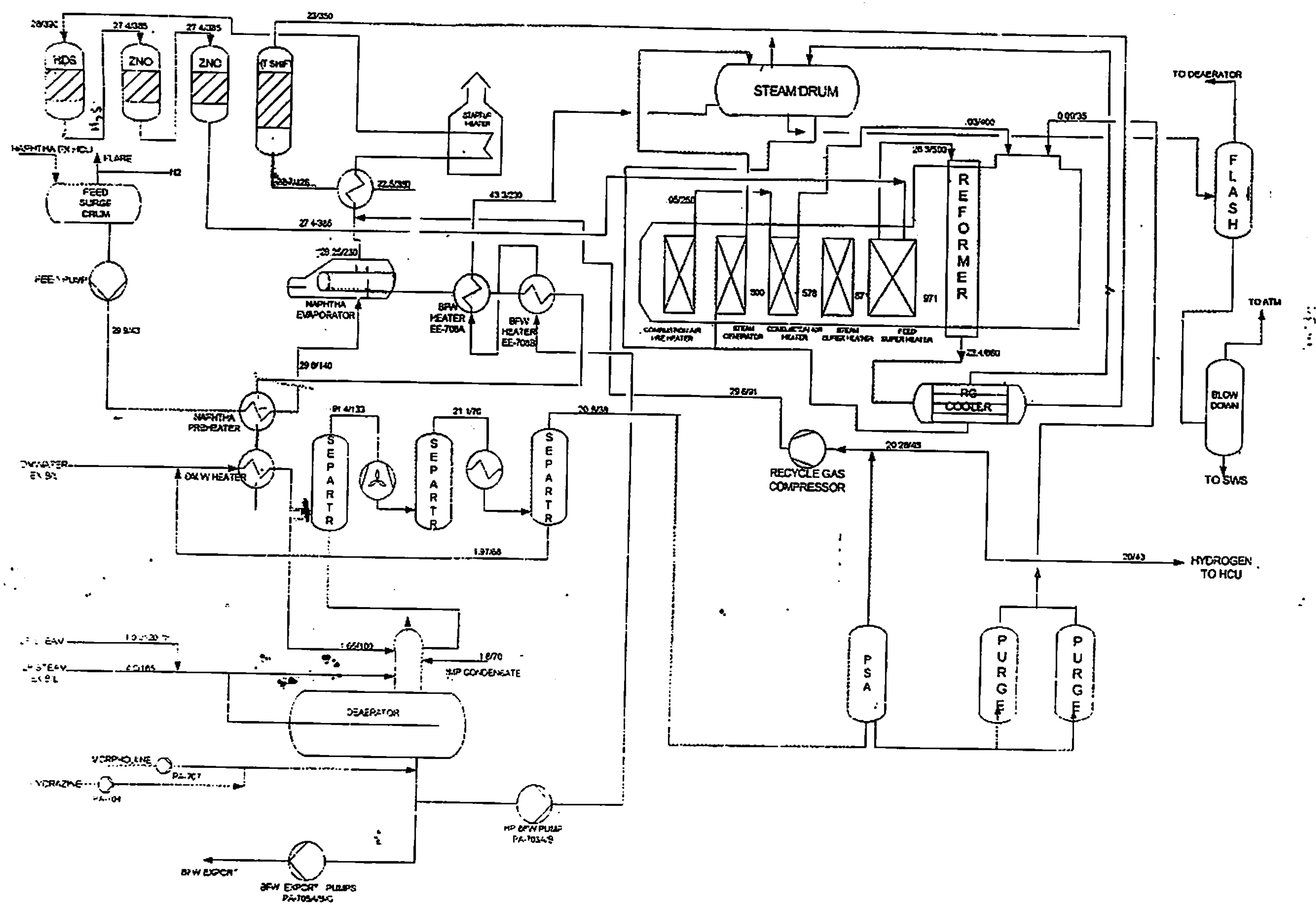
3.6 HYDROGEN GENERATION UNIT

Hydrogen generation unit producing 99.99% has come up as a part of hydrocracker project. Hydrogen is generated in this unit by steam reforming of naphtha employing LINDE's technology. Hydrogen generated in the plant is consumed in hydrocracker unit for various chemical reactions. These reactions need very high purity hydrogen to maintain required partial pressure of hydrogen in the hydrocracker reactor. The fall purity results in the lowering of hydrogen partial pressure which adversely affects the quality of products from hydrocracker unit.

The process for hydrogen generation involves the following four steps:

1. Sulphur removal
2. Steam reforming
3. High temperature shift conversion
4. Pressure swing adsorption purification

Different types of catalysts are used in each of the above sections. As the process involves high temperature condition in steam reforming and high temperature shift conversion, waste heat is utilized generation of large quantity steam. The steam generated in the unit satisfies the requirement in the unit and surplus steam is offered to other units for consumption.



HDS
ZNO
ZNO
HT SHIFT
STARTUP HEATER
FLARE
FEED SURGE DRUM
FEED PUMP
NAPHTHA EVAPORATOR
BFW HEATER EE-708A
BFW HEATER EE-708B
NAPHTHA PREHEATER
DM W HEATER
STEAM DRUM
REFORMER
STEAM GENERATOR
FEED SUPERHEATER
RG COOLER
FLASH
TO DEAERATOR
BLOW DOWN
TO ATM
TO SWS
RECYCLE GAS COMPRESSOR
HYDROGEN TO HCU
SEPARATOR
PSA
PURGE
PURGE
DEAERATOR
HP CONDENSATE
MORPHOLINE
HYDRAZINE
HP BFW PUMP
BFW EXPORT
BFW EXPORT PUMPS

3.7 HAZOP WORKSHEET FOR HYDROGEN GENERATION UNIT (TABLE 4)

Naphtha surge drum (Table 4.1)

Guideword	Deviation	Causes	Consequences	Recommendations
High	High level	High flow of naphtha	Potential release of naphtha into work area	Review naphtha flow process to the vessel
	High pressure	Pump failure Back pressure in line	Rupture of vessel, which leads to fire and explosion Reverse flow	Periodic maintenance of relief system and indicators etc.
	High temperature	Naphtha feed has undergone large preheated residence time (high feed pump)	Result in fire	High temperature alarm and Automatic preheater reduction for feed line.
Low	Low level	Low flow of naphtha. Leak/rupture	Pump cavitation Leads to fire Leads to poor Net positive suction head (NPSH)	Review naphtha flow process to vessel Low level alarm to be installed
Low	Low pressure	Low suction head Low level in tank Operator error	Poor NPSH Leads to fire	Provide downstream pump trip system

	Low temperature	Low feed temperature		Low temperature alarm.

Naphtha line from surge drum to pump at 4 kg/cm2 & 70 c

Table-4.2

Guideword	Deviation	Causes	Consequences	Recommendations
High	High flow	Naphtha flow line block valve fails open	Pump failure	High flow detector & alarm and periodic maintenance of control valve and block valve
	High pressure	High level in surge tank	Pump leak/rupture	Pressure indicator alarm
	High temperature	High feed temperature. High flow of naphtha from vessel	High pressure build up. Line rupture/leak Could result in fire	High temperature alarm
Low/No	Low/No flow	Pipeline plugged. Leak/ rupture. Block valve fails. Operator error.	Low suction. Pump failure. Fire & explosion.	Periodic maintenance of control valve and block valves. Low flow detector & alarm
	Low pressure	Low level in surge vessel	Leads to pump cavitation, leak and in turns fire. Pump failure	Pressure indicator alarm
Reverse	Reverse flow	High pressure in surge vessel.	No safety consequences of interest.	Check valve to be installed.

Naphtha Preheater (Table-4.3)

Guideword	Deviation	Causes	Consequences	Recommendations
Reverse	Tube leak/rupture	Low flow level of naphtha through the exchanger. High pressure naphtha line. High temperature and pressure	Small, large release of naphtha with fire. Potential major equipment damage	Fire monitors in the equipment area, Emergency response team.

Naphtha line to naphtha evaporator from pump at 33.5 kg/cm2 & 18.5 c input: (Table-4.4)

Guideword	Deviation	Causes	Consequences	Recommendations
High	High flow	Naphtha line control valve fails open. High pressure in naphtha surge vessel. High pump output.	High carry over of naphtha to evaporator with potential naphtha release to the work area. Pressure build up in the product stream.	Check valve, block valve
	High pressure	High pump output. Isolation valve closed in error	Leak/rupture of line	Pressure relief safety valve
	High temperature	High flow of naphtha	High pressure in evaporator line	High temperature alarm at evaporator feed end and on the

				line.
Low	Low flow	Low pump output.	Low carry over of naphtha to evaporator.	Provide flow analyzer.
		Less naphtha in vessel.	Incomplete evaporation process.	Proper maintenance of detection and alarm system.
		Low vessel pressure. Leak/rupture in the line	Low level of naphtha in evaporator may cause low pressure in product stream.	
	Low pressure	Pump failure	Low level in evaporator	Block valve and pressure indicator alarm
	Low temperature	Preheater fails to operate	Low pressure in evaporator as well as in line	Temperature alarm
Reverse	Reverse flow	High pressure in surge vessel.	High level of naphtha in surge vessel	Check valve to be installed.
		Pump failure.	Potential release of naphtha.	
		Bad welding, Fouling, corrosion.	Potential major equipment damage.	Line weld should be periodically inspected.
		High flow	Spillage of liquid into enclosed work area.	Emergency response team

Naphtha evaporator

Guideword	Deviation	Causes	Consequences	Recommendations
high	High level	High level of superheated naphtha. High pump output. Naphtha level indicator fails low	Potential release of naphtha into work area. High product flow	Review naphtha flow process to the vessel. Consider an independent high level alarm. Proper maintenance of control systems.
Low	Low level	Low flow of superheated naphtha. Naphtha level indicator fails.		Proper maintenance of control systems
	Leak	High pressure naphtha line Corrosion, fouling	Small, large release of naphtha with fire. Potential major equipment damage	Emergency response team Tube material for construction must be adequate for the material serviced through.

3.8 HAZOP Study for a Flammable Liquid Storage Tank

Assume a HAZOP study on a new flammable liquid storage tank (t-1) and a feed pump (p-1).

Description of plant

The liquid is unloaded from a road tanker and stored under slight positive pressure with nitrogen. The pump feeds liquid to an existing reactor(r-1) where it reacts with another reagent. The scope of the study is to identify hazards in the new facility.

Divide the facility as

1. Tank (T-1)
2. pump (p-1)

Abbreviations

FICA - Flow Indication Control Alarm
TIA - Temperature Indicator Alarm
LIA - Level Indicator Alarm

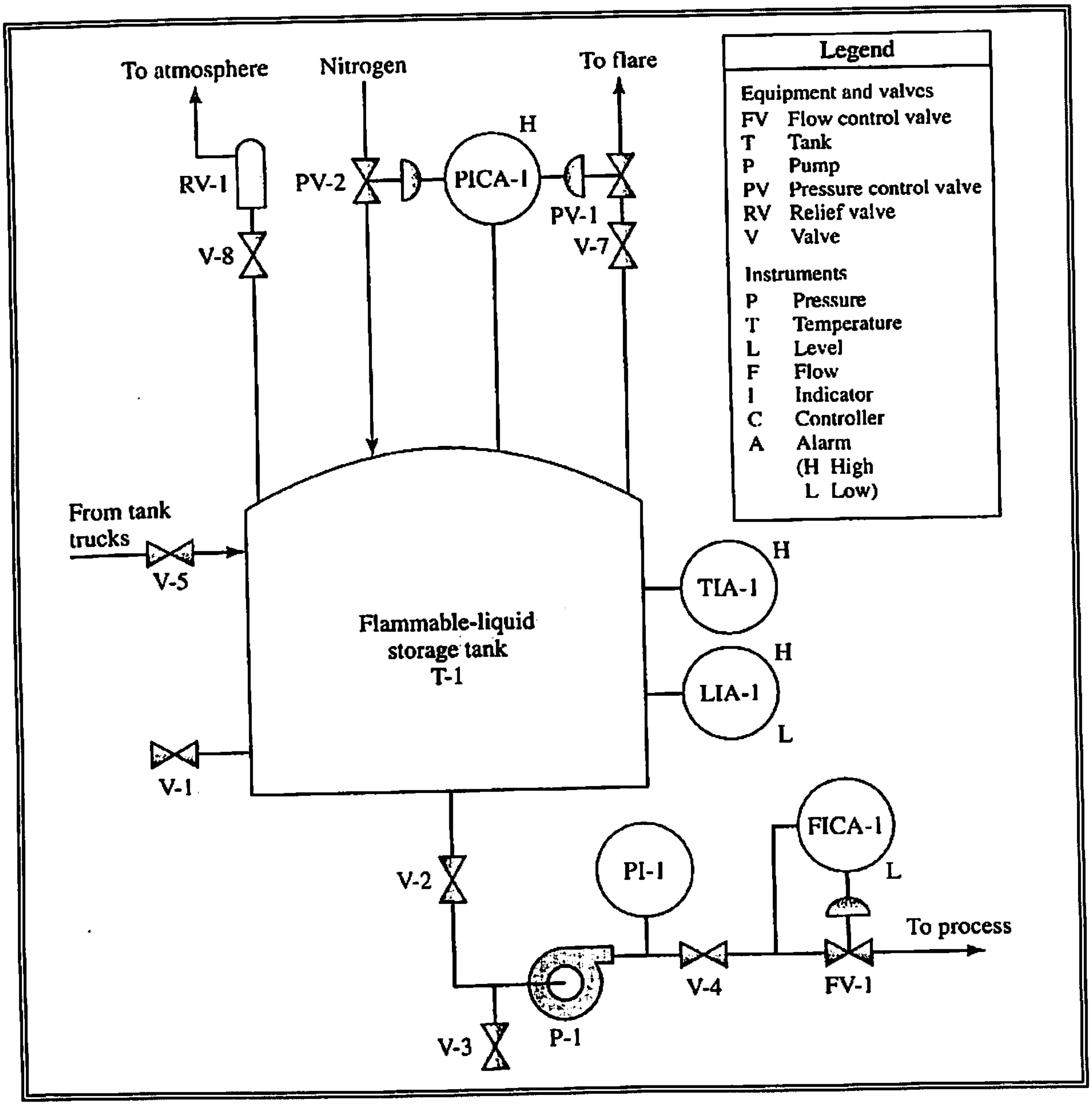


Figure -3 P&I Diagram for flammable storage tank

Table 5- HAZOP Work Sheet

Guide word	Possible cause	Consequences	Process indication	Action / recommendation
Level Less(low) Or No	1.Tank under dry	Pump cavitates damage to pump	LIA-1 FICA-1	Can reagent react explode if overheated in pump-Estimate release quantity
	2.Rupture discharge line	Reagent released potential fire	LIA-1 FICA-1	Consider second LAL Shutdown on pump. Estimate release quantity
	3.V-3 open or broken	Reagent released potential fire	LIA-1	Consider V-1 protection What external events can cause rupture
	4.V-1 open or broken	Reagent released potential fire	LIA-1	Is RV-1 designed to relieve liquid at loading rate
	5.Tank rupture	Reagent released potential fire	LIA-1	Consider second high level shut off
More	6.Unload too much from road tanker	Tank overfills reagent released via RV-1	LIA-1	Consider check valve in pump discharge line.
	7.Reverse flow from Process reactor	Tank overfills reagent released via RV-1	LIA-1	Consider second LAH Shut down on feed lines
Composition other than	8.Wrong reagent	Possible reaction possible tank rupture		Consider sampling before unloading Are other materials delivered in truck
As well as	9. Impurity in reagent	If volatile, possible overpressure possible problem in reactor		Are unloading connections different What are the possible impurities
Pressure less	10. Break in line to flare or to nitrogen line	Reagent released potential fire	PICA-1	Consider PAL to PICA-1
	11.Lose nitrogen	Tank implodes reagent released	PICA-1	Consider independent PAL Consider vacuum break valve

3.9 HAZOP RESULTS AND RECOMMENDATIONS

Results

Improvement of system or operations

- Reduced risk and better contingency
- More efficient operations

Improvement of procedures

- Logical order
- Completeness

General awareness among involved parties

Team building

Advantages

- Systematic examination
- Multidisciplinary study
- Utilizes operational experience
- Covers safety as well as operational aspects
- Solutions to the problems identified may be indicated
- Considers operational procedures
- Covers human errors
- Study led by independent person
- Results are recorded

Success Factors

- Accuracy of drawings and data used as a basis for the study
- Experience and skills of the HAZOP team leader
- Technical skills and insights of the team
- Ability of the team to use the HAZOP approach as an aid to identify - deviations, causes, and consequences
- Ability of the team to maintain a sense of proportion, especially when assessing the severity of the potential consequences.

RECOMMENDATIONS

Hazop exercise for the hydrogen generation unit yielded information on the causes and prevention of accidents. Recommendations arising from the study are given below:

1. Proper periodic maintenance of vessels, pumps, relief valves, temperature control systems, level monitoring systems, close & check valves, interlocking systems, flow analyzing devices.
2. Line welds should be checked periodically.
3. Consider an emergency shut down system in case of abnormal situations.
4. Check the functioning of interlocking and automatic start/stop system of the pumps.
5. Install thermal expansion relief on valve section and an automatic preheater reduction for the feed line.
6. A check valve, one way stop valve to be installed and provide downstream pump trip system.
7. Review naphtha flow process to the vessel and consider adding an independent high level alarm.
8. Consider high-high, low-low naphtha flow detector and alarm.
9. High pressure alarm which can actuates pneumatically the system to shutdown and a positive shut off valve to help prevent fuel leaking.
10. Ensure existence of adequate material handling and receiving procedures, experienced workforce.
11. Ensure proper start up procedure and prior inspection for each and every units.
12. Automatic pump shut off system should be considered which has found not considered in some areas.

4. JOB SAFETY ANALYSIS [JSA]

4.1 About the company

Shasun Chemicals and Drugs Limited (SCDL) was incorporated in 1976 and is headquartered in Chennai, India. It manufactures active pharmaceutical ingredients (APIs), their intermediates and enteric coating excipients with a significant presence in some key generics. Shasun has created a strong product portfolio, building on its R & D Expertise, regulatory capabilities and multi scale production capacities. Shasun has also emerged as a key player in various service segments in the pharmaceutical field besides APIs and intermediaries, and is strengthening its offer of contract research, custom synthesis, contract manufacturing and contract formulation services to clients.

Today, Shasun is one of the largest producers of Ibuprofen worldwide. The company offers derivatives of Ibuprofen like Ibuprofen Sodium, Ibuprofen Lysinate. It is also one of the major producers of Ranitidine and Nizatidine in the world. The company offers other products such as Isradipine, Gabapentine, Olanzapine, and Meprobamate. Its products are exported to countries across North America, Europe, Asia and Latin America.

EHS Policy

Shasun Chemicals and Drugs Limited (Shasun) are committed to protecting the health and safety of their employees and protecting the environment. Shasun is committed to providing a safe working environment for all its employees, independent contractors, vendors, and customers, and will operate its facilities in a manner that prevents harm to public health and the environment. Shasun will seek to conserve energy, water, raw materials and other resources, use recycling and reduce waste generation where appropriate. Shasun shall be good neighbors in their communities by insuring that the facilities do not pose unreasonable risks, and by participating in community activities related to Environment, Health & Safety (EHS). In all its activities, Shasun will comply with all applicable laws. The Shasun will design its products in a manner that eliminates unreasonable risks from the manufacture, use and disposal of the product. This policy applies to all Shasun units and locations.

4.2 Steps of Analysis

1. Select jobs with the highest risk for a workplace injury or illness.
2. Select an experienced employee who is willing to be observed. Involve the employee and his/her immediate supervisor in the process.
3. Identify and record each step necessary to accomplish the task. Use an action verb (i.e. pick up, turn on) to describe each step.
4. Identify all actual or potential safety and health hazards associated with each task.
5. Determine and record the recommended action(s) or procedure(s) for performing each step that will eliminate or reduce the hazard (i.e. engineering changes, job rotation, PPE, etc.).

Hazard Types

The following hazards should be considered when completing a JSA

- Impact with a falling or flying object.
- Penetration of sharp objects.
- Caught in or between a stationary/moving object.
- Falls from an elevated work platform, ladders or stairs.
- Excessive lifting, twisting, pushing, pulling, reaching, or bending.
- Exposure to vibrating power tools, excessive noise, cold or heat, or harmful levels of gases, vapors, liquids, fumes, or dusts.
- Repetitive motion.
- Electrical hazards.
- Light (optical) radiation (i.e. welding operations, etc.).
- Water (potential for drowning or fungal infections caused by wetness).

There are eight steps in reviewing a job using the Job Safety Analysis technique. The steps are essentially the same whether the guideline is informal or formal. The amount of time to complete a JSA may be several seconds to several hours based on the complexity of the job.

The eight steps are as follows

Step 1 - Defining the Scope of the Job to be Analyzed

Defining the scope of the analysis involves determining where the job to be reviewed starts and where it ends. A JSA can be very broad and cover pre- and post-job tasks like: selecting tools, spotting equipment, lockout/tagout, checking MSDS, determining process variables (temperature, pressure, composition, etc), and cleaning up. Or it can be very specific and focus only on the part of the total job that is of concern or isn't covered by other procedures and work practices. The scope will be defined by the individual, Lead Tech, and crew involved.

Step 2 - Determine if an informal or formal JSA is more appropriate for the Task

This determination is based on the complexity of the task, the risk potential of the job, the experience level of the work group, and the amount of uncertainty involved. An informal or formal JSA can be conducted for most tasks.

Informal JSAs may take the form of a crew toolbox safety meeting with the Supervisor or Lead Technician acting as Team Leader. It may also be two employees discussing what they are about to do at the job site. An informal JSA might be as simple as a single employee going through the process mentally before starting a task.

A formal JSA should be performed for the types of jobs listed in the scope section of this guideline. It will provide a written procedure that can be used as a template for future jobs of similar nature.

Step 3 - Finding a place to meet, assembling the people involved, and appointing a team leader/scribe

Performing a formal JSA requires assembling everyone involved in the job (where practical), as well as, anyone who has input into how to perform the job safely. The typical formal JSA meeting is held in a suitable meeting area with the Team Leader being the Supervisor/Lead Technician responsible for the work. A scribe will be necessary and should be appointed by the team leader. The scribe should complete the header portion of the JSA form and use the main portion to record the meeting as it progresses.

JSA team should consist of

Core JSA Team

- Craft personnel involved
- Contractor craft personnel involved
- Owning Area Representative from where the work is taking place
- Valero Contractor Representative and contractor Foreman
- Supervisor/Lead Tech responsible for the job

Optional Support Personnel – (to be contacted by the Team Leader)

- Safety Department Representative
- Inspection, Tech Services Representative, etc.
- Environmental Department Representative

Step 4 - Breaking the job down chronologically by tasks

Breaking the job down into a chronological listing of tasks is what makes the JSA process useful as a step-by-step work procedure. Existing procedures (Operating, Maintenance, etc.) should be reviewed in conjunction with the JSA. If this can be done in advance, the JSA study will proceed more smoothly. The job steps can be discussed verbally, reasoned through mentally or written out in the left-hand column of the JSA form (attached).

Start with the first task of the job as identified in Step 1, and continue going through the tasks chronologically until the job is completed. Whether developing an informal or formal JSA, having a person experienced in doing the job present at the meeting is important.

Step 5 - Identifying the hazards involved with each task

Identifying the hazards involved in each task is one of the main purposes for conducting a JSA. The hazards can be discussed verbally, reasoned through mentally or can be written in the center column of the JSA form. The checklist located on the backside of the JSA Form can be used to help identify the hazards associated with the job. Getting the right people involved in the meeting should ensure diverse points of view on what the hazards might be. Discuss or list all the credible hazards pointed out by the group, even those posed by associated work.

Step 6 - Developing Safeguards to Eliminate or Control the Hazards Identified

This step involves controlling the hazards so the job will be performed safely. The safeguards can be discussed verbally, reasoned through mentally or written in the right hand column of the JSA form. The process of controlling hazards should be carried out in this order:

- Eliminate or remove the hazard from the work area.
- Guard against the hazard by physical barriers or distance.
- Assign appropriate PPE.

If none of these options will eliminate or control the hazard so that the task can be performed safely, that specific task should not be performed. At this point the JSA Team Leader and group should assess other options to performing the job safely without doing that particular task.

Step 7 - Review what was just discussed or written with all personnel involved

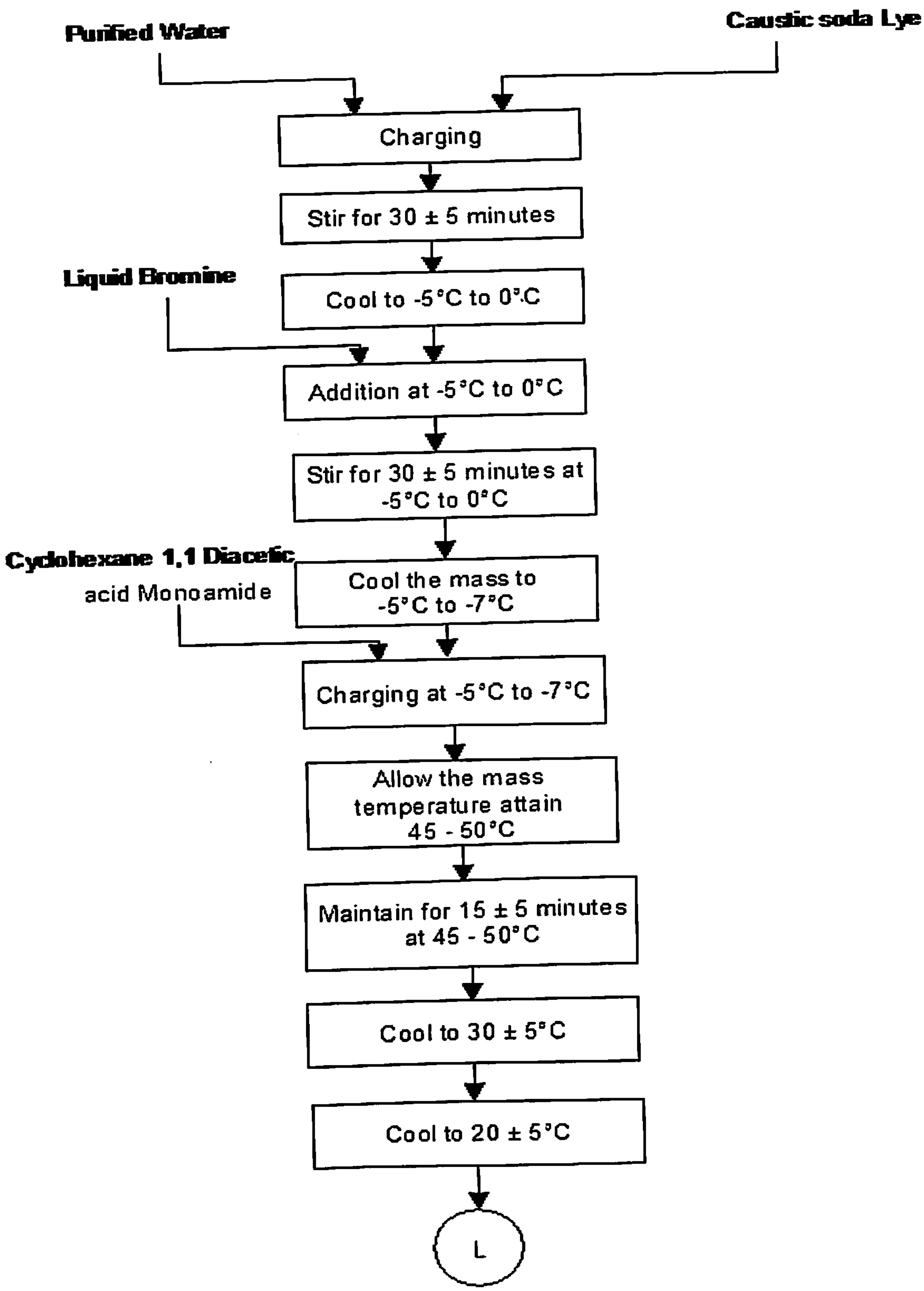
All personnel involved in the job who were not able to attend the meeting need to review and understand the JSA. The Supervisor/Lead Technician responsible for the work will review the JSA with all personnel involved.

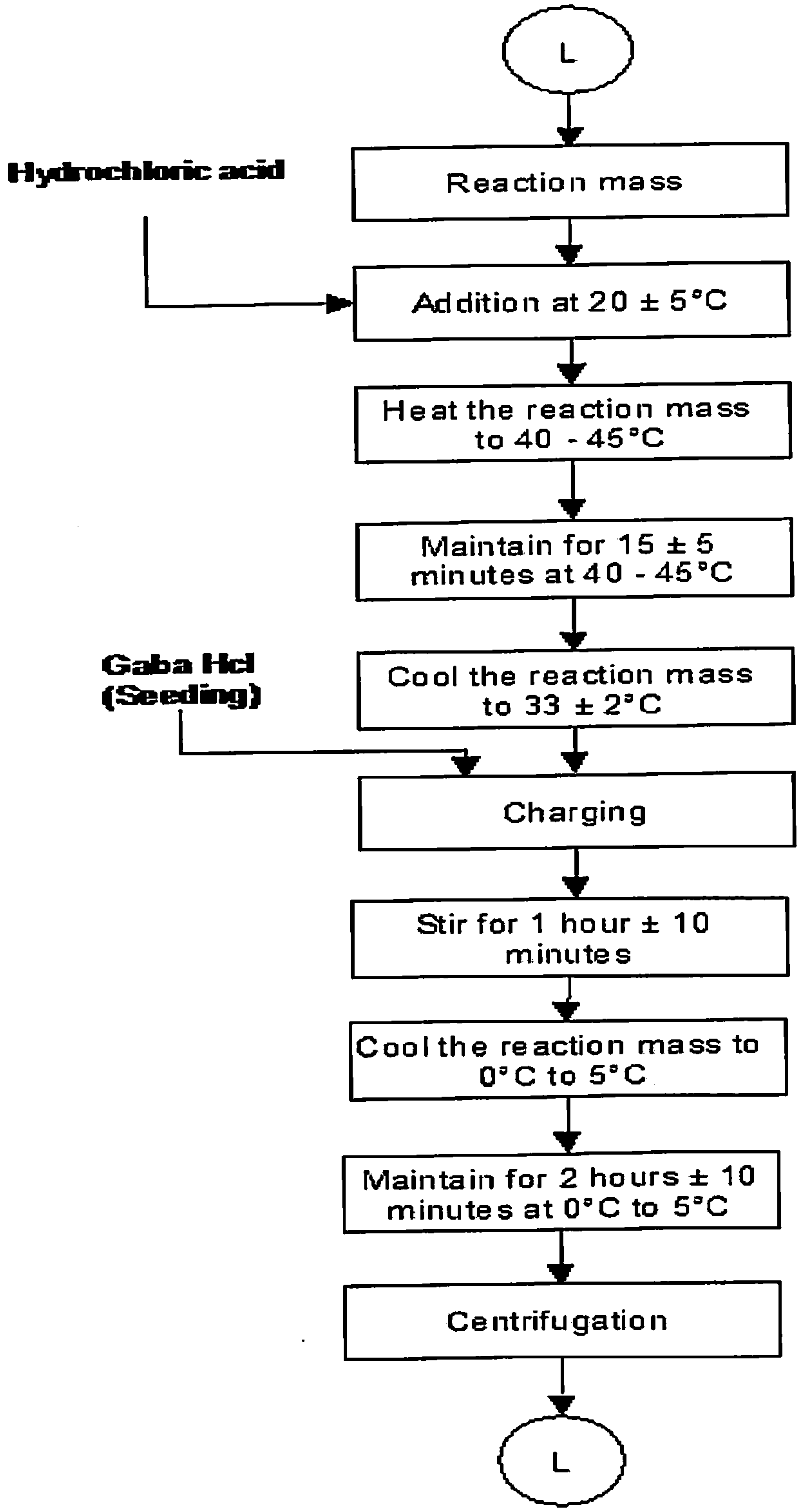
Step 8 – After the job is completed, review the jsa for completeness and accuracy

Note any steps which may have been omitted or were in the incorrect order. Note any hazards which weren't anticipated and any safeguards which didn't work as well as intended. If a formal JSA was prepared, revise the document per the observations noted.

4.3 Process flow diagram of Gabapentin

Figure 4-Production of Gabapentin Hydrochloride




L
Hydrochloric acid
Reaction mass
Addition at 20 ± 5°C
Heat the reaction mass to 40 - 45°C
Maintain for 15 ± 5 minutes at 40 - 45°C
Gaba Hcl (Seeding)
Cool the reaction mass to 33 ± 2°C
Charging
Stir for 1 hour ± 10 minutes
Cool the reaction mass to 0°C to 5°C
Maintain for 2 hours ± 10 minutes at 0°C to 5°C
Centrifugation
L

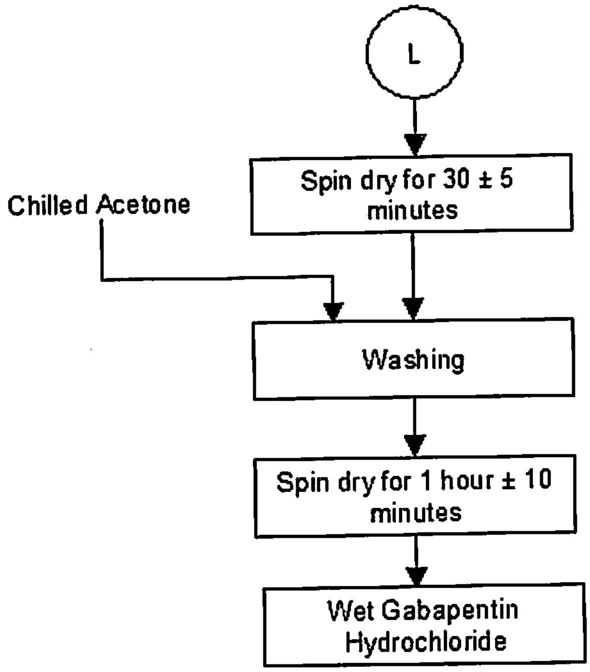
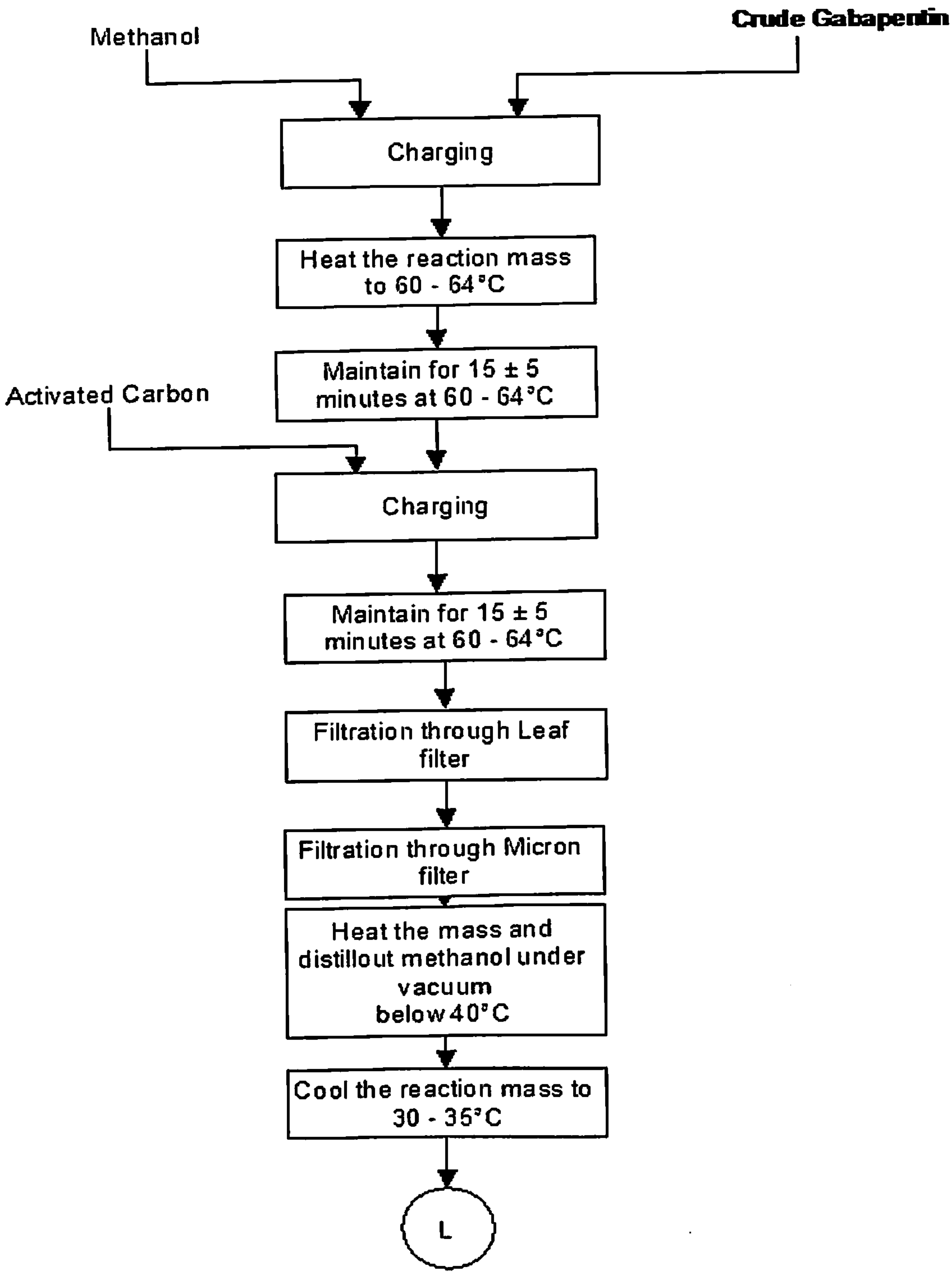

L
Chilled Acetone
Spin dry for 30 ± 5 minutes
Washing
Spin dry for 1 hour ± 10 minutes
Wet Gabapentin Hydrochloride

Figure 5-Purification of Crude Gabapentin



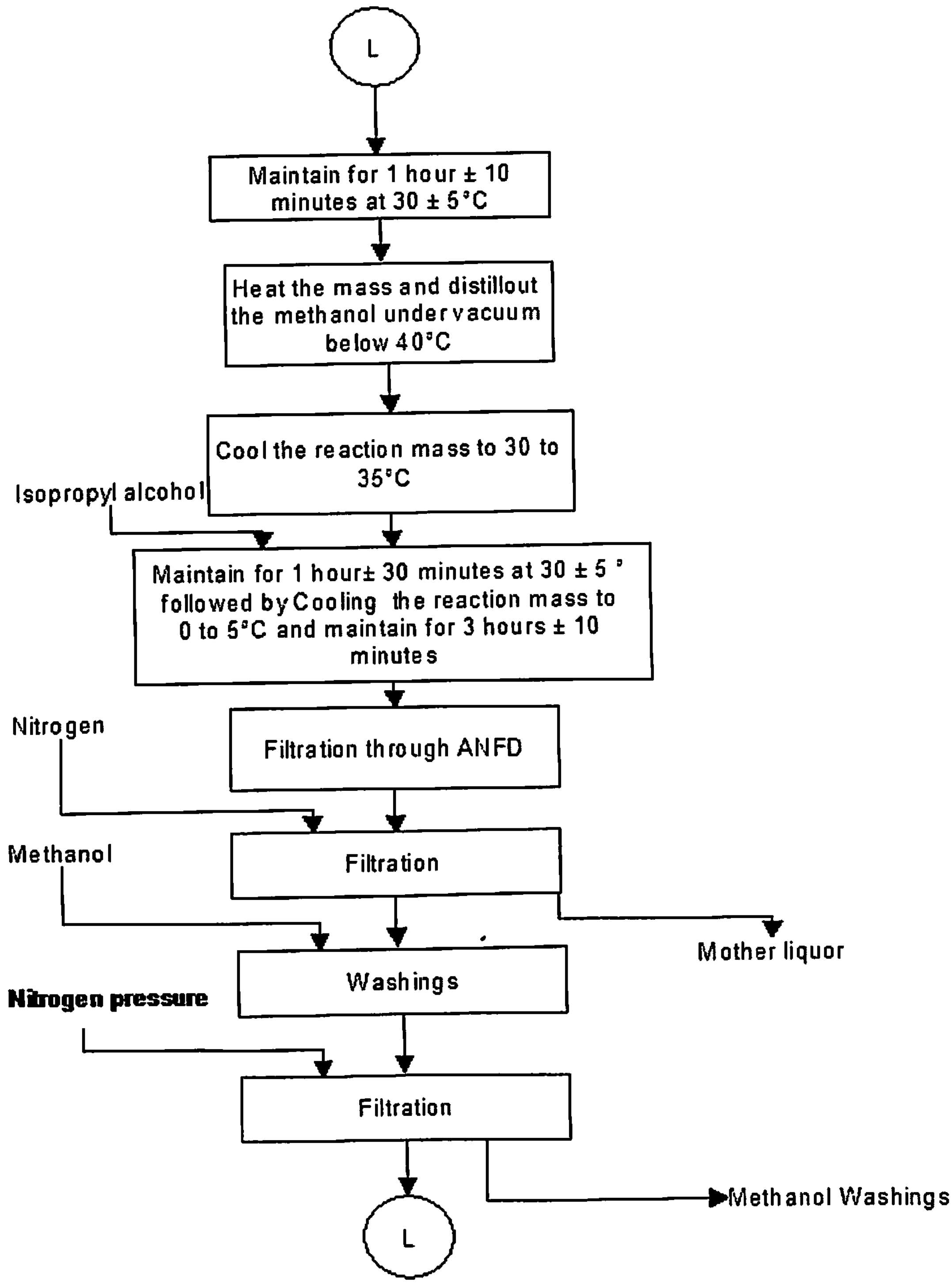
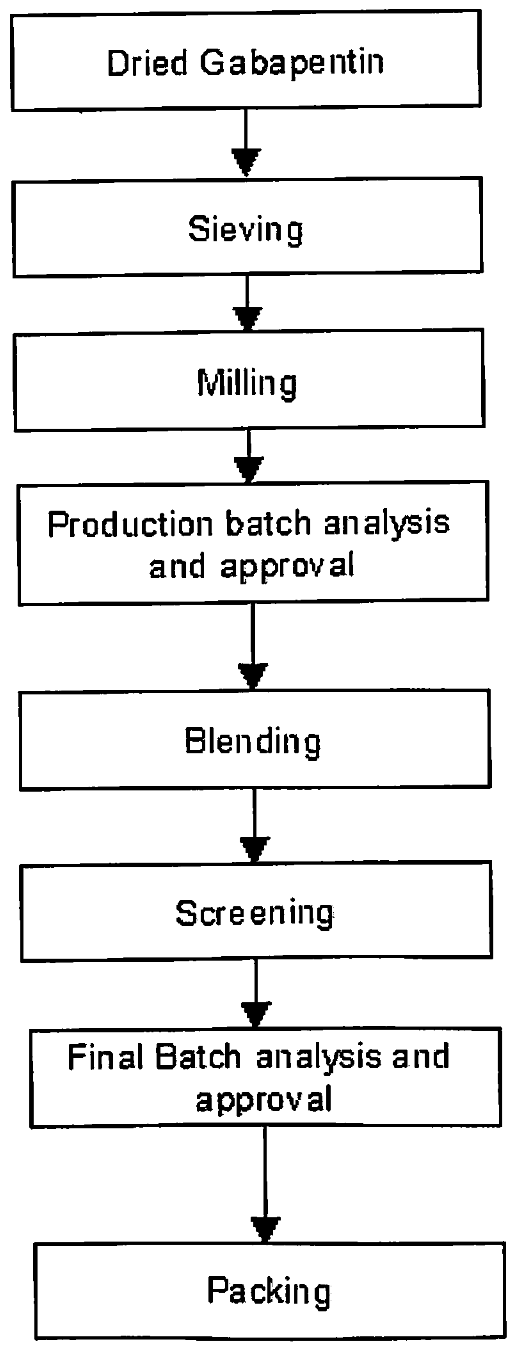

L
Maintain for 1 hour ± 10 minutes at 30 ± 5°C
Heat the mass and distillout the methanol under vacuum below 40°C
Cool the reaction mass to 30 to 35°C
Isopropyl alcohol
Maintain for 1 hour± 30 minutes at 30 ± 5° followed by Cooling the reaction mass to 0 to 5°C and maintain for 3 hours ± 10 minutes
Nitrogen
Filtration through ANFD
Methanol
Filtration
Mother liquor
Nitrogen pressure
Washings
Filtration
Methanol Washings
L

Figure 6-Seiving, Milling, Blending, Screening and packing of gabapentin



4.4 JOB SAFETY ANALYSIS WORKSHEET FOR GABAPENTIN [Table 6]

Sequence of Basic Job Steps	Potential Hazards	Recommended Action/Procedures
Micron Filter Cleaning		
• Removing filter cartridge from housing	Struck Against, exposure to agents	Wear Gloves, face mask with org. vapour respirator
• Cleaning of filter cartridge in methanol	Contact with, exposure to agents	Wear goggles, face mask with org. vapour respirator
• Refixing of filter cartridge	Struck against, caught between	Wear gloves, goggles
Receiving mass		
• Opening of mass receiving Valve & vent valve	Struck against, caught between	Wear Gloves
• Closing of reactor bottom Valve	Struck by	Wear gloves
• Removing air lock when Mass (Gaba) is received	Exposure to Agents Contact with	Wear goggles, face mask with org. vapour respirator
Methanol distillation		
• Opening of receiver drain valve & air line valve	Struck by, Exposure to agents	Wear Gloves, goggles, face mask with org. vap.respirator
• Opening of chilled water circulation valve for ejector cooling coil	No chance for hazard	--
• Opening & closing of fresh water for ejector tank.		
• Closing of reactor & receiver vent valve	No chance for hazard	--
• Applying vacuum to receiver & condenser	Struck by	Wear Gloves
• Opening of brine circulation valve for condenser	Struck by	Wear Gloves, goggles
• Applying vacuum to reactor	No chance for hazard	--
• Charging of fresh water into hot water tank	Struck against	Wear Gloves
• Opening of steam to hot water tank	Struck against	Wear gloves
• Applying hot water by opening hot water inlet & outlet valves	Struck against, thermal radiation	Wear gloves, goggles
• Opening of nitrogen line for breaking vacuum.	No chance for hazard	--
• Breaking of receiver vacuum by opening air line valve	Struck by	Wear Gloves
• Opening of reactor vent & receiver vent.	Struck by	Wear Gloves
• Closing of brine circulation		

valve to condenser • Closing of chilled water circulation valve for ejector cooling coil	Struck by No chance for hazard No chance for hazard	Wear Gloves -- --
Tower cooling & maintenance • Opening the tower inlet & outlet valve • Closing the tower inlet & outlet valve	No chance for hazard No chance for hazard	-- --
Brine cooling & maintenance • Opening the brine inlet & outlet valve • Closing the brine inlet & outlet valve	No chance for hazard No chance for hazard	-- --
ANFD cleaning • Opening the ANFD manhole • Flush ANFD with water • Opening the discharge port • Drain water • Rinse with methanol **Applying brine circulation to ANFD & transfer slurry** • Open brine inlet & outlet valve • Close brine inlet & outlet valve • Open slurry transfer line to ANFD and also pressure balancing line • Open ANFD vent • Open slurry transfer line from reactor	Struck by, caught between Struck by Struck by Fall Contact with, Exposure to Agents No chance for hazard No chance for hazard Struck by Struck by Struck by, Exposure to agents	Wear gloves Wear gloves Wear gloves Wear gum boots/shoes Wear gloves, goggles, face mask with org.vap.respirator -- -- Wear gloves Wear gloves Wear gloves, goggles, face mask with org.vap respirator
Methanol washing • Opening of solvent charging line valve to reactor • Opening solvent flow valve to respective reactor • Switch on solvent pump and switch off after use • Closing of solvent charging line valve	Struck by, Exposure to agents Struck by, Exposure to agents Caught between Struck by	Wear Gloves, goggles, and facemask with org.vap respirator. Wear Gloves, goggles, and facemask with org.vap respirator. Wear gloves Wear gloves, goggles

Methanol transfer to ANFD • Transfer ethyl acetate to ANFD	Struck by, Exposure to agents	Wear gloves, face mask with org.vap respirator
Acetone charging & transfer to ANFD • Opening of solvent charging line valve to reactor and receive acetone(from plant) • Transfer acetone to ANFD	Struck by, Exposure to agents Struck by, Exposure to agents	Wear Gloves, goggles, and facemask with org.vap respirator. Wear Gloves, goggles, and facemask with org.vap respirator.
Filtration • Close the ANFD vent valve • Open the ML tank drain line valve	Struck by Struck by	Wear gloves Wear gloves
N2 filtration • Close ANFD vent valve and open Nitrogen line valve	Struck by	Wear gloves, goggles
Drying (Applying hot water & vacuum) • Drain the receiver by applying air pressure • Closing receiver drain valve & vent valve • Closing ANFD vent valve • Applying vacuum to receiver and condenser • Opening of brine circulation valve • Applying vacuum to receiver & condenser. • Opening steam valve for ejector • Opening steam valve for hot water circulation • Opening of hot water inlet & outlet valve	Struck by Struck by Struck by Struck by No chance for hazard Struck by Struck by, Thermal radiation Struck by, Thermal radiation No chance for hazard	Wear gloves Wear gloves Wear gloves Wear gloves -- Wear gloves Wear gloves, goggles Wear gloves, goggles --
Sampling for LOD • Opening of nitrogen valve to break vacuum • Opening of vent valve • Opening of manhole • Taking sample for LOD	Struck by Struck by Struck by Struck against, Exposure to agents, contact with	Wear gloves Wear gloves Wear gloves Wear gloves, goggles, face mask with dust respirator

Unloading • Unloading of material in HDPE drum Weigh the material	Struck against, caught between, contact with, Exposure to agents Struck against	Wear gloves, goggles, face mask with dust respirator Wear gloves
Sieving • Cleaning of drums for sieving • Charging of material into shifter • Transferring sieved material • Collection of oversize material from mesh	Struck by Struck against, Exposure to agents, Contact with Caught in Exposure to agents, contact with	Wear gloves Wear gloves, goggles, face mask with dust respirator Wear gloves Wear gloves, goggles, face mask with dust respirator
Milling • Cleaning of drums for milling • Charging of material into hopper for milling • Transferring sieved material • Collection of oversize material from mesh	Struck by Struck against, Exposure to agents, Contact with Caught in Exposure to agents, contact with	Wear gloves Wear gloves, goggles, face mask with dust respirator Wear gloves Wear gloves, goggles, face mask with dust respirator
Packing • Weight adjustment of material	Exposure to agents, contact with	Wear goggles, face mask with dust respirator
General Activities • Cleaning of packing section **AHU return filter cleaning** • Removing of filters from return duct • Cleaning using air • Refixing of filters into return duct **Cleaning of filters in AHU & Maintenance** • Cleaning of AHU filters • Maintenance of AHU **Drum cleaning** • Transfer of drums from drum storage to drum cleaning room • Transferred of cleaned drums to respective operating area	Struck against Struck against, Exposure to agents Struck by Struck against Struck against, Caught between Caught between, struck against Struck against Struck against	Wear gloves Wear gloves, face mask with Dust respirator Wear gloves Wear gloves Wear gloves, helmet Wear gloves, helmet Wear gloves, helmet Wear gloves

5. CONCLUSION

In this project, the significance of conducting a hazard & operability study at hydrogen generation unit was studied using the "Guideword" approach. HAZOP study for the flammable storage tank has been performed.

We have performed the Job Safety Analysis for the manufacture of Gabapentin, considering various possible risks and hazards exists in the manufacturing process and the result has been furnished.

From the results of HAZOP Study and Job Safety analysis, various recommended procedures and actions has been found out for the safer operation. It is also recommended to use this tool in all process industry to avoid accidents and for loss prevention.

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