ENVIRONMENTAL ASSESSMENT MANAGEMENT PLAN
FOR
CHEMTECH INC. FOR PLANTATION YORK

Prepared for:

CHEMTECH INC.
Plantation York
On the Demerara river shore at 16 miles from Linden
Lots 52 (117 acres) and/or 54 (375.4 acres), block XLI

Prepared by:

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1.0 INTRODUCTION

1.1 BACKGROUND

CHEMTECH Limited intends to construct and operate a chemical complex consisting of the following plants and facilities:

- Formaldehyde Plant
- Resin Plant
- Paraformaldehyde Plant
- Nitrogen fertilizer Plant
- Oriented Strand Board (OSB) Plant
- Veneer Plant
- Tank Farm
- Detention pond for storm water management
- Evaporation ponds
- Wastewater treatment facility
- Warehouses
- Administrative Center
- Storage Yard
- Green open space

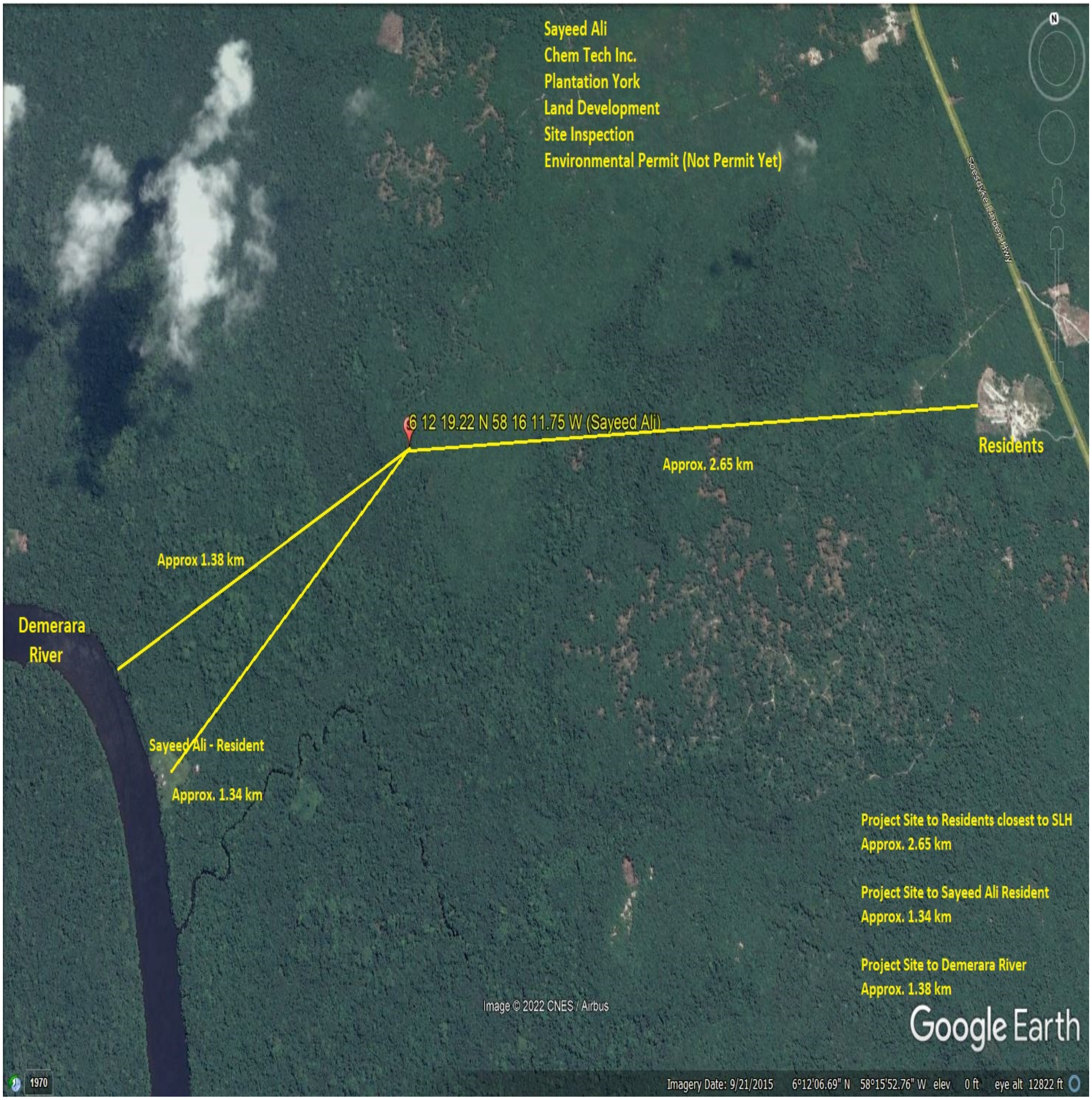
Methanol will be used as the feedstock in the formaldehyde plant to produce 100% formalin which is used along with other chemicals such as melamine, phenol, resorcinol and urea to create the resins which are utilized in the Veneer and OSB Plants and other applications.

Formalin, a product of the formaldehyde plant, will be used for the production of paraformaldehyde which will be exported. A by-product of the resins manufacturing is nitrogen which will be used in the fertilizer plant. The entire process will be aero discharge and all waste products will be recycled within the plant.

Resin, a product of the resin plant, will be used for the production of Oriented Strand Board (OSB). The process is a standard Dynea batch process for production of phenolic resin (PF resin) with caustic soda as an initial catalyst and formalin and phenol as main raw materials.

1.2 Site Location

The proposed CHEMTECH Chemical Complex will be located at Plantation York, 16 miles from Linden. Figure 1-1 and

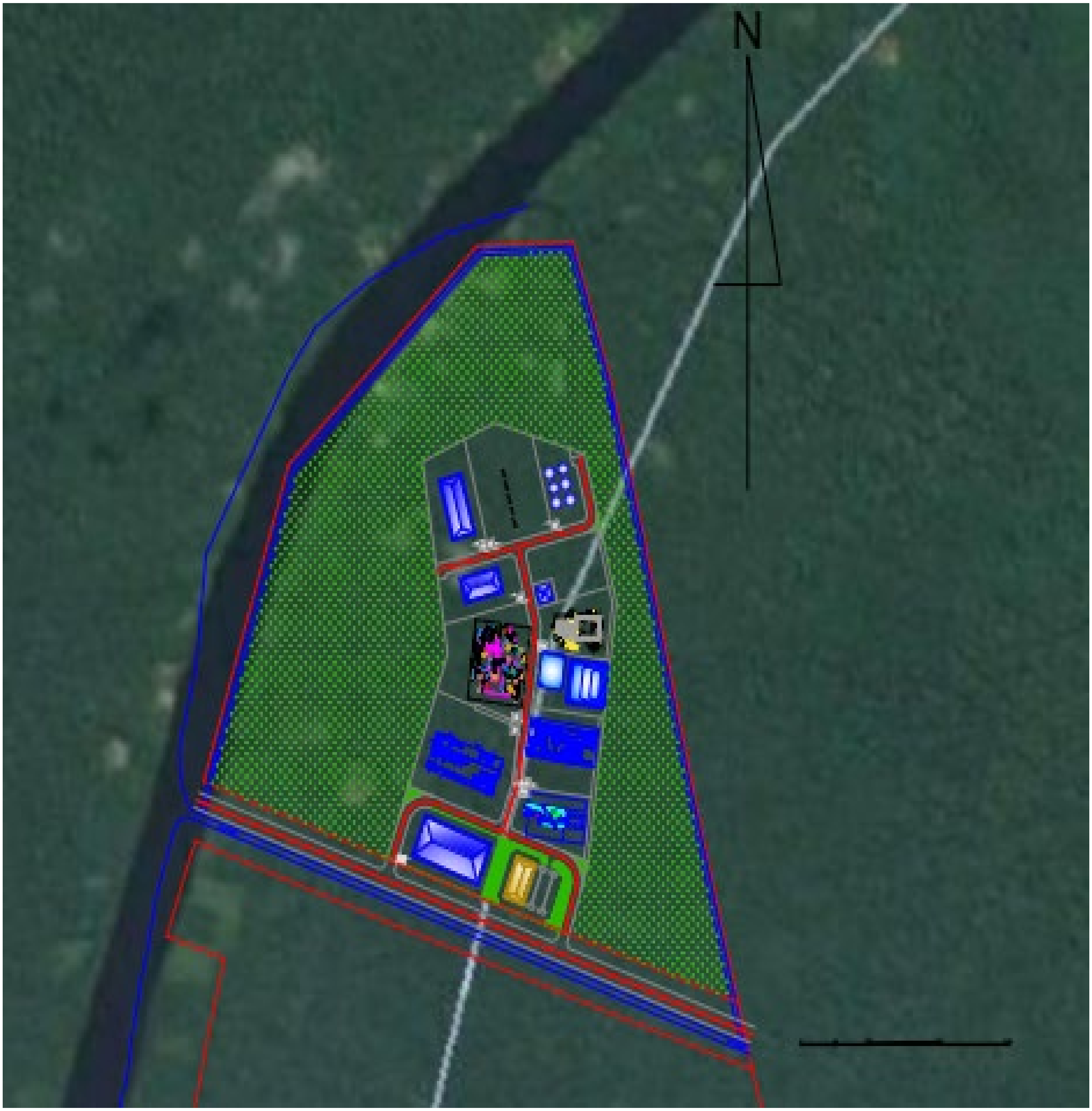



Sayeed Ali
Chem Tech Inc.
Plantation York
Land Development
Site Inspection
Base Camp Seweyo
Soesdyke-Linden Hwy
6 12 19.22 N 58 16 11.75 W (Sayeed Ali)
Residents
Demerara
River
Sayeed - Resident
St. Cuthberth's
Amerindian Village
Net Surf Nature Park
Image © 2022 CNES / Airbus
Google Earth
1970
Imagery Date: 9/21/2015 6°13'04.83" N 58°15'15.84" W elev 0 ft eye alt 37666 ft

Figure 1-2 show the proposed location of the plant. The distance between the proposed location of the formaldehyde and paraformaldehyde plants and the Demerara River is approximately 1.38 KM. The nearest residential areas to the facility is approximately1.34 KM away from the location of the formaldehyde and paraformaldehyde plants. The nearest residential area closest to SLH is approximately 2.65 KM away from the location of the formaldehyde and paraformaldehyde plants.

Figure 1-1 - Site Location

Figure 1-2 - Plant Surrounding Areas



1.3 PROJECT DESCRIPTION

The following subsections describe the key components of the proposed CHEMTECH Chemical Complex.

1.3.1 Formaldehyde Chemical Plant

The formaldehyde plant will operate 8,300 hours per year. The plant will be designed to produce 148 tons/day 100% by weight, in concentration of 37 - 55% formaldehyde by weight in water. The formaldehyde will be produced by catalytic oxidation (silver catalyst) and dehydrogenation of methanol. The process operates above the upper flammability limit of methanol near the atmospheric pressure.

The first step in the continuous process is mixing and vaporization of the raw materials. The process air will be pressurized by a process air blower and will be filtered and scrubbed from contaminants before mixing. The methanol/water mixture will be fed to the vaporizer where it will be heated in a plate heat exchanger to the desired temperature. The gas-mixture leaving the vaporizer will be superheated and passed through a filter and a flame arrestor before entering the converter where methanol is oxidized exothermically to produce formaldehyde and water at a temperature of 650 °C.

The reaction will be controlled by keeping the catalyst bed temperature constant (+/- 5 °C) by means of regulating the amount of oxygen fed to the converter. The hot reaction gas containing nitrogen, formaldehyde, hydrogen, water-vapour, carbon monoxide and carbon dioxide will be cooled in a special designed waste- heat boiler to produce steam at 16 bars. The gas will be fed to an absorption column where formaldehyde, water and un-reacted methanol will be condensed and absorbed. Nitrogen, carbon dioxide, traces of carbon monoxide, and hydrogen will be compressed and recycled back to the vaporizer. Excess gas from the absorber will be purged to a low-NO_x thermal incinerator.

The concentration of formaldehyde in the product may be adjusted between 32 % and 50 % (by weight), with the concentration of methanol in the range of 0.5 to 1.0 % (by weight).

1.3.2 Resin Chemical Plant

The process of producing Phenol-Formaldehyde resins (phenolic resins), resorcinol-formaldehyde resins, or melamine-formaldehyde resins is a batch process. The batch reactor is a 25-m^3 reactor with internal cooling coils. The raw material will be 45-55% Formalin solution, 100 % Phenol, Urea prills and caustic soda solution (10%) as a catalyst. Formalin is produced in the formaldehyde plant and stored in two storage tanks with a capacity of 300m^3 each, Phenol and caustic soda imported will be stored in a heated storage tank.

The phenolic resin production is an exothermic process and takes place mainly in two steps: an addition reaction between Phenol and Formaldehyde and a following condensation reaction. Caustic soda is used as an initial catalyst and vacuum stripping is used to increase the non-volatile components by removing e.g. water if necessary. All vents from the reactor vacuum pump will be directed to the Formalin thermal incinerator.

Because of the exothermic reaction in resin production process, several safety arrangements will be installed to ensure a safe and controlled production. To control the exothermic reaction, special operating procedures have been written and the following emergency systems will be installed:

- Two independent cooling water systems
- Two independent systems for measuring and indicating the reactor temperature
- Cooling water valve will open in the event of instrument air or power failure.
- Electric power back up for all systems
- Air agitation for the reactor
- Installation of a catchment tank to be used in case of emergency, the vent is equipped with a rupture disc.

The resin plant will be the state-of-the-art Dynea design and based upon more 100 reactor years of operational experience.

1.3.3 Para-Formaldehyde Chemical Plant

The raw material will be 40% Formalin solution, produced in the formaldehyde plant and stored in two storage tanks with a capacity of 300m^3 each. The other raw material will be caustic soda solution (10%) and the catalyst for the process will be triethylamine (5%).

1.3.4 Nitrogen Fertilizer Plant

The raw materials will be transferred to separate volumetric hoppers. The raw material will be weighed / measured and sent to the mixing plant along with other raw materials containing phosphorus pento oxide and potash. All the raw materials will be mixed thoroughly and granulated in granulation drums.

The granulated material will be dried in a drum dryer. The dried material will be cooled in a drum cooler. The cooled material will be screened for product of size 1 – 4 mm. The fertilizer plant will have a design capacity of 200 tonnes per day and will operate 300 days per year, and 24 hours per day.

1.3.5 Oriented Strand Board Plant

The OSB Plant will have a design capacity of 257 Cubic Meters per day and will operate 330 days per year, and 22 hours per day.

1.3.6 Veneer Plant

The Wood Veneer Plant will have a design capacity of 55 cubic meters per day, and 18,150 cubic meters per year and will operate 330 days per year.

Figure 1-3 shows the site plan of the chemical complex. Figure 1-3 to Figure 1-8 Show the process flow diagrams for the above plants.

Figure 1-4 – Flow Diagram for Formaldehyde Plant

		1 Feed methanol	2 Water bleed from absorber	3 Liq. feed to vaporizer	4 Process air	5 Boiler feed wat.	6 + 7 Heat-exch. vaporizer	8 Excess steam	9 Feed gas to converter	10 Feed gas to absorber	11 + 12 Heat-exch. process	13 Process air	14 Steam to preheater	15 Steam to superheater
Temperature	°C	20	30	25	20	100	63 + 77	204	79	87	85 + 71	38	204	204
Pressure	barg	4,00	0,26	0,26	0,35	19,00	0,45	20,00	0,24	0,12	0,00	0,26	16	16
Density	kg/m3	791,0	1003,3	871,8	1,65	960,0	909,0	6,1	1,3	1,0	0,0	1,5	6,1	6,1
Total flow	kg/h	7525	4132	11657	13447	7501	269941	4580	31438	31438	218114	14016	461	310
Oxygen	kg/h				3074				3074	0		3074		
Nitrogen	kg/h				10212				16339	16339		10212		
CO2	kg/h				7				626	1658		7		
CO	kg/h								8	21		0		
Hydrogen	kg/h								105	280		0		
Methanol	kg/h	7525	81	7606			67485		7601	168	1374	369		
Formaldehyde	kg/h									6250	80048	0		
Water	kg/h		4051	4051	155	7501	202456	4580	3685	6721	136692	355	461	310
Formic Acid	kg/h									1				

		17 Tail gas to thermal oxidizer	18 Process water	19 Hot water circ.	20 Product FA	21 Recycle gas	22 Formalin/ water	23 Air scrubber liquid	24 Cooling water	25 Cooling water return	26 Blow down	27 Total boiler feed water	30 Total excess steam	33 Boiler feed oxidizer
Temperature	°C	26	20	201	65	25	30	62	25	35	204	100	195	100
Pressure	barg	0,06	1,00	16,00	2,00	0,02	0,39	0,45	2,00	0,00	16,00	4,50	16,00	19,00
Density	kg/m3	1,0	995	850	1058	1,0	1000	909	998	994	850	994	6,1	960,0
Total flow	kg/h	11619	8167	150000	11365	6968	930	1494	1353671	1353671	635	14104	12698	8714
Oxygen	kg/h	0												
Nitrogen	kg/h	10212				6127								
CO2	kg/h	1039				619								
CO	kg/h	13				8								
Hydrogen	kg/h	175				105								
Methanol	kg/h	0			93			374						
Formaldehyde	kg/h	0			6250		10							
Water	kg/h	180	8167	150000	5021	108	920	1121	1353671	1353671	635	14104	12698	8714
Formic Acid	kg/h				1									

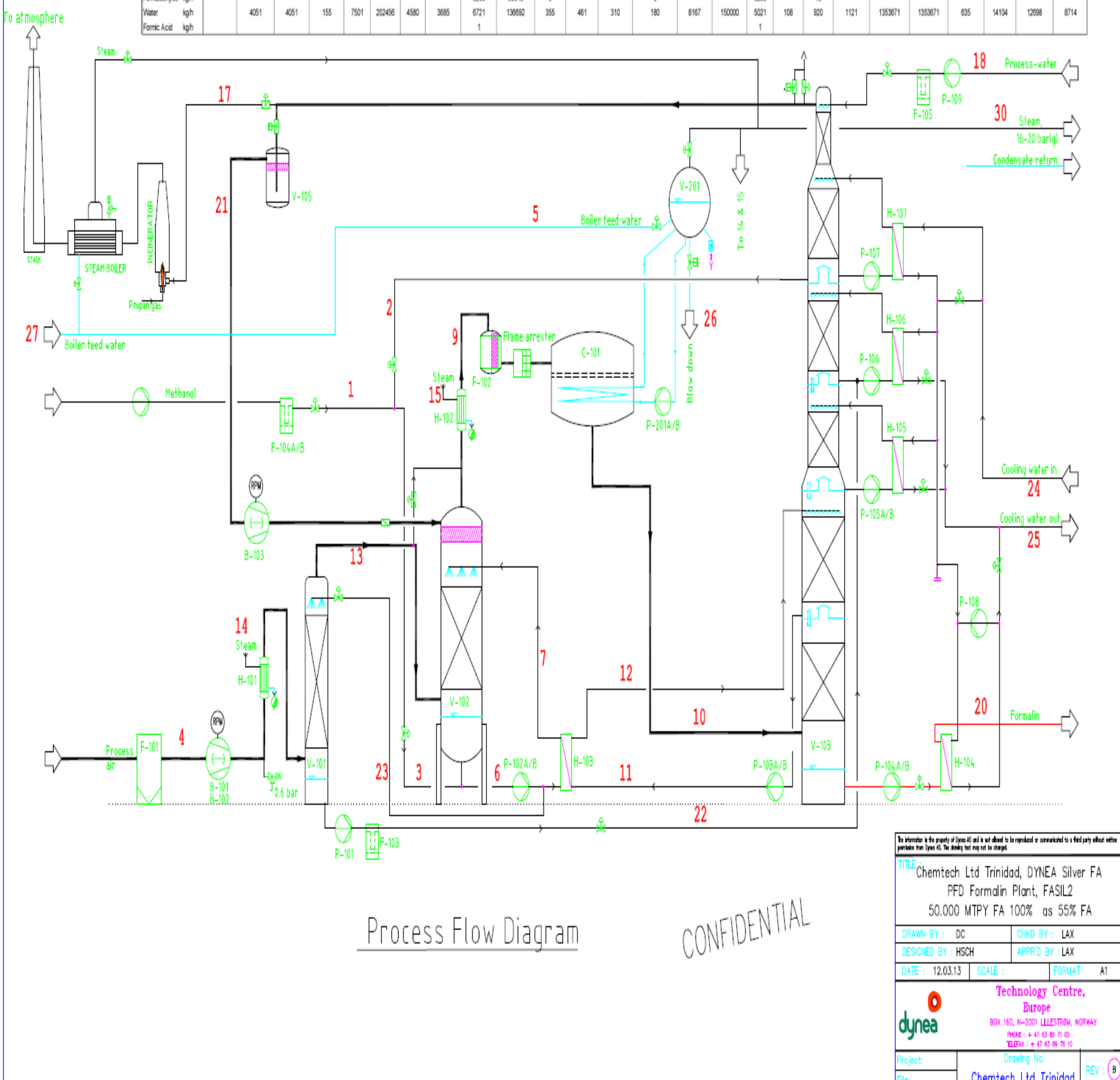
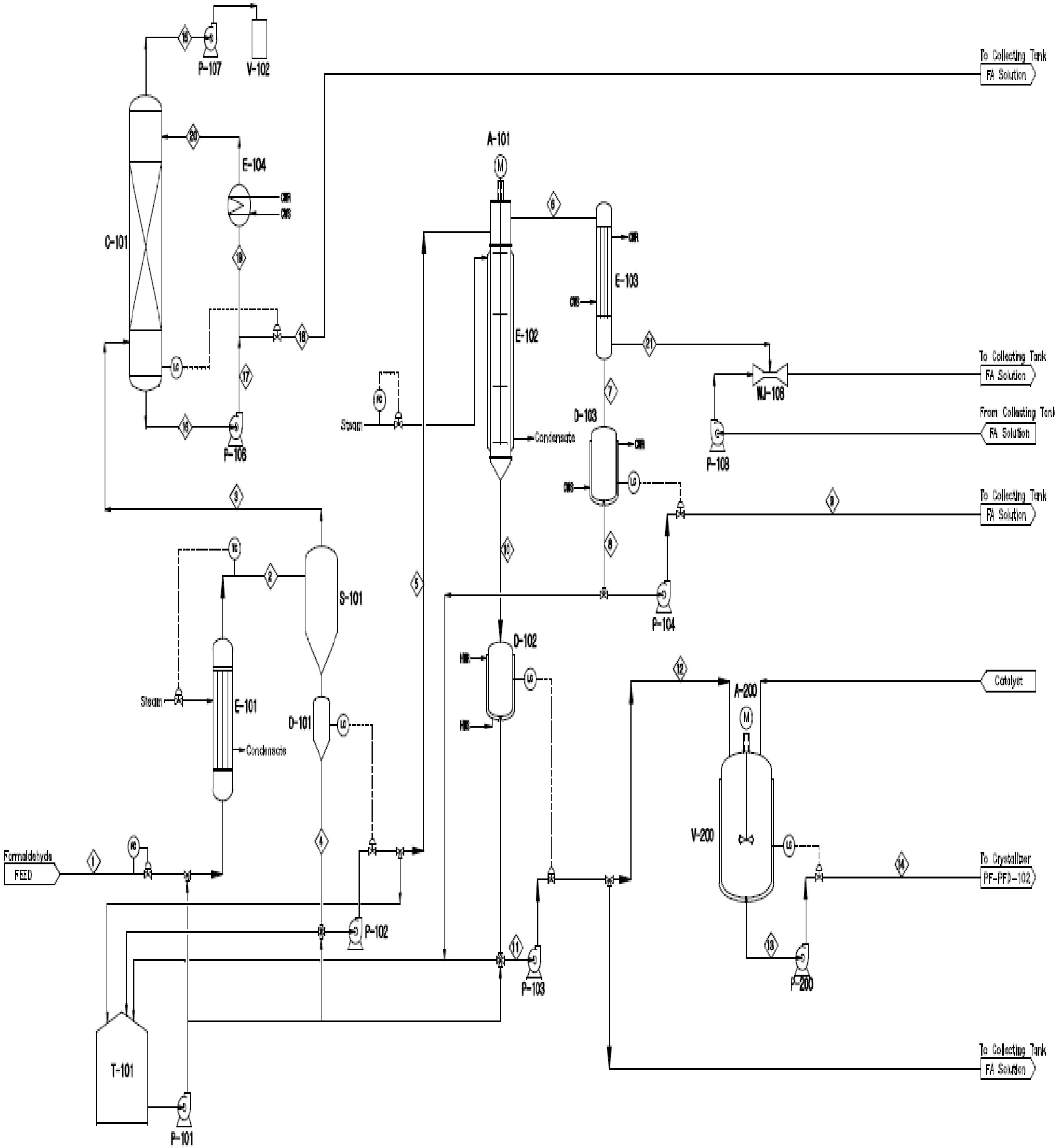


Figure 1-5 - Flow Diagram for Para-Formaldehyde Plant



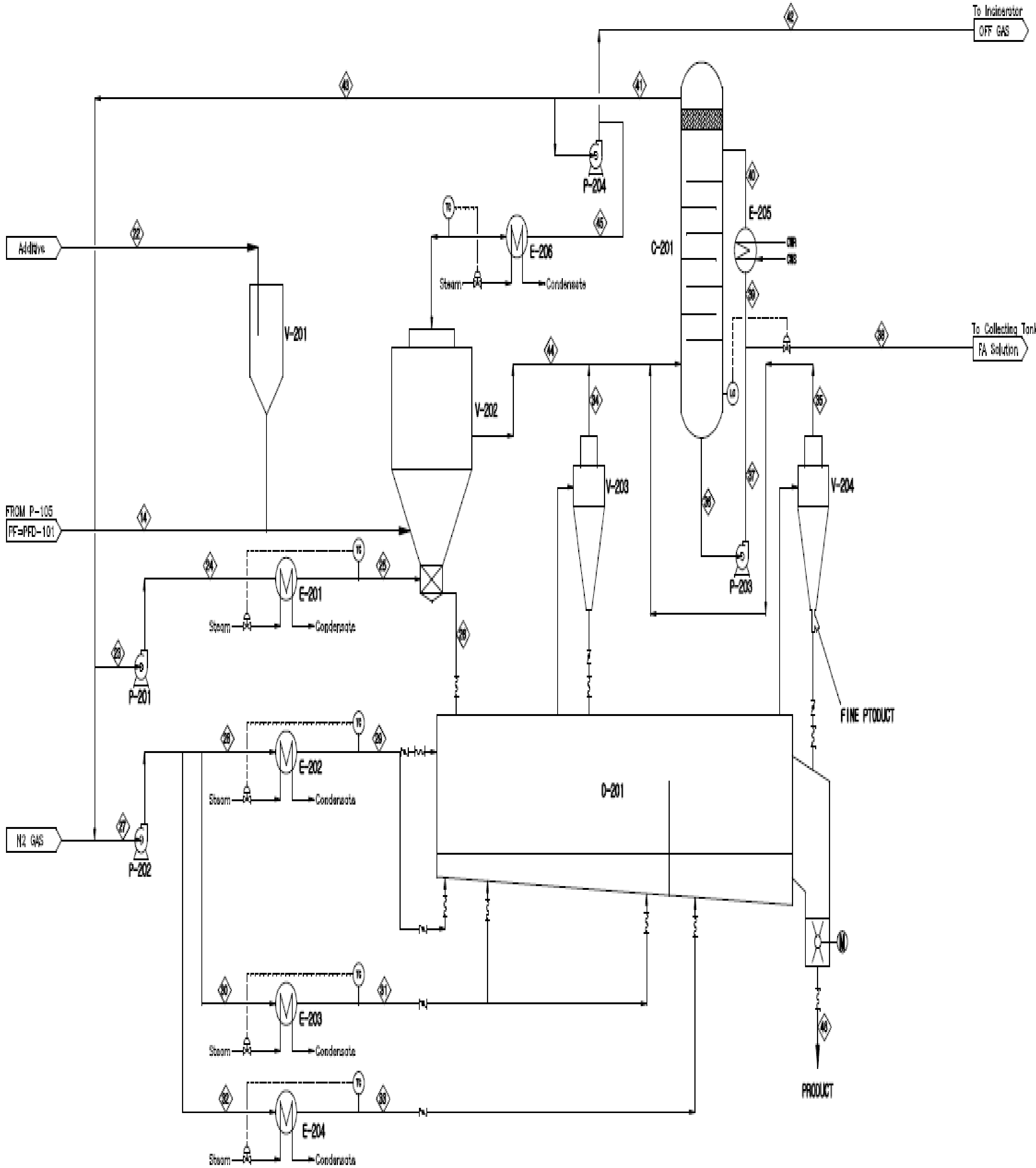

To Incinerator
OFF GAS
Additive
V-201
P-204
E-206
Steam
Condensate
E-205
C-201
To Collecting Tank
FA Solution
V-202
V-203
V-204
FROM P-105
PF=PFD-101
E-201
P-201
P-203
FINE PTODUCT
E-202
D-201
N2 GAS
P-202
E-203
E-204
PRODUCT

Figure 1-6 - Flow Diagram for Nitrogen Fertilizer Plant

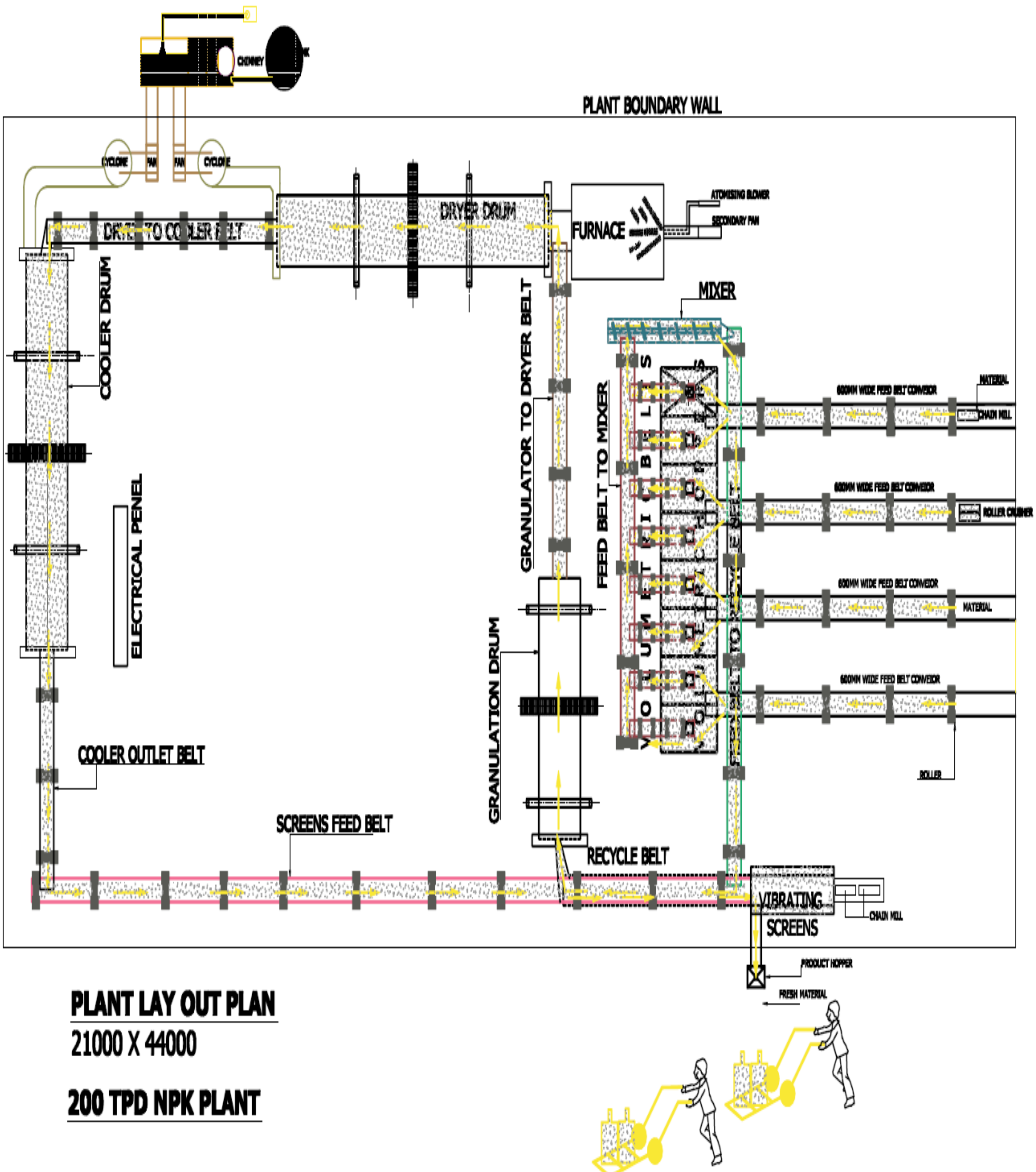


Figure 1-7 - Flow Diagram for the OSB Plant

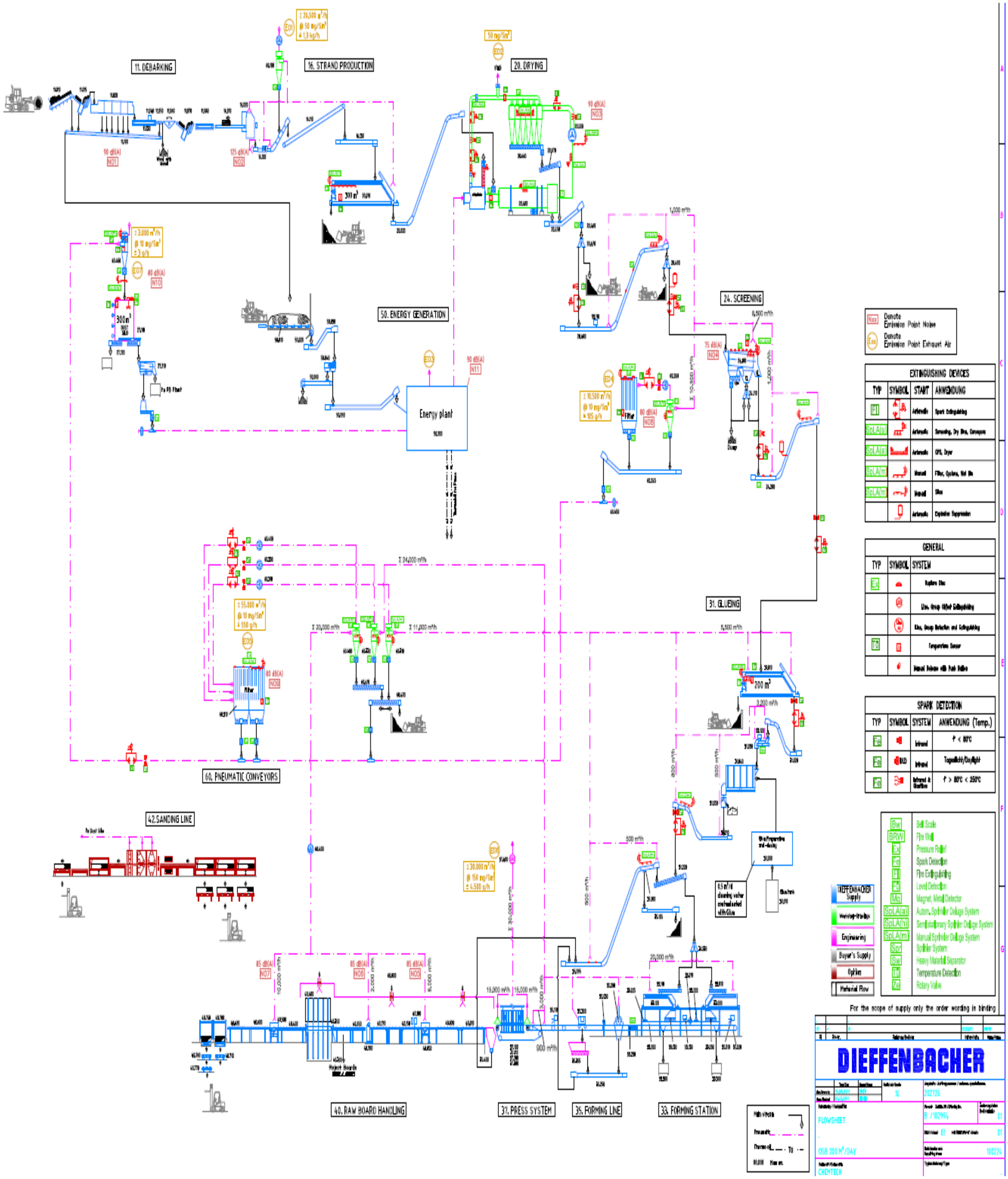


Figure 1-8 - Flow Diagram for Veneer Plant

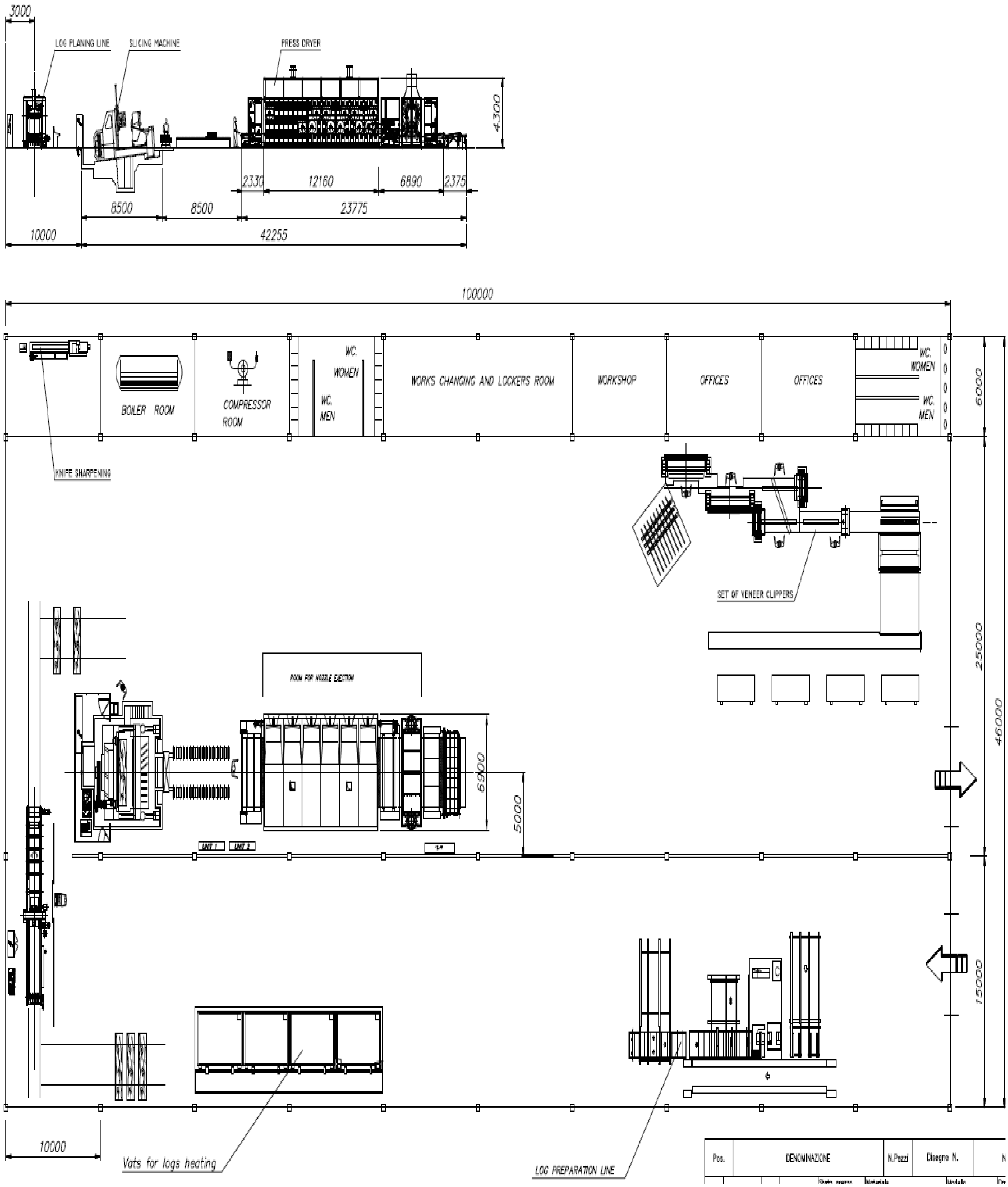


Table 1-1 shows the approximate area of each part of the complex.

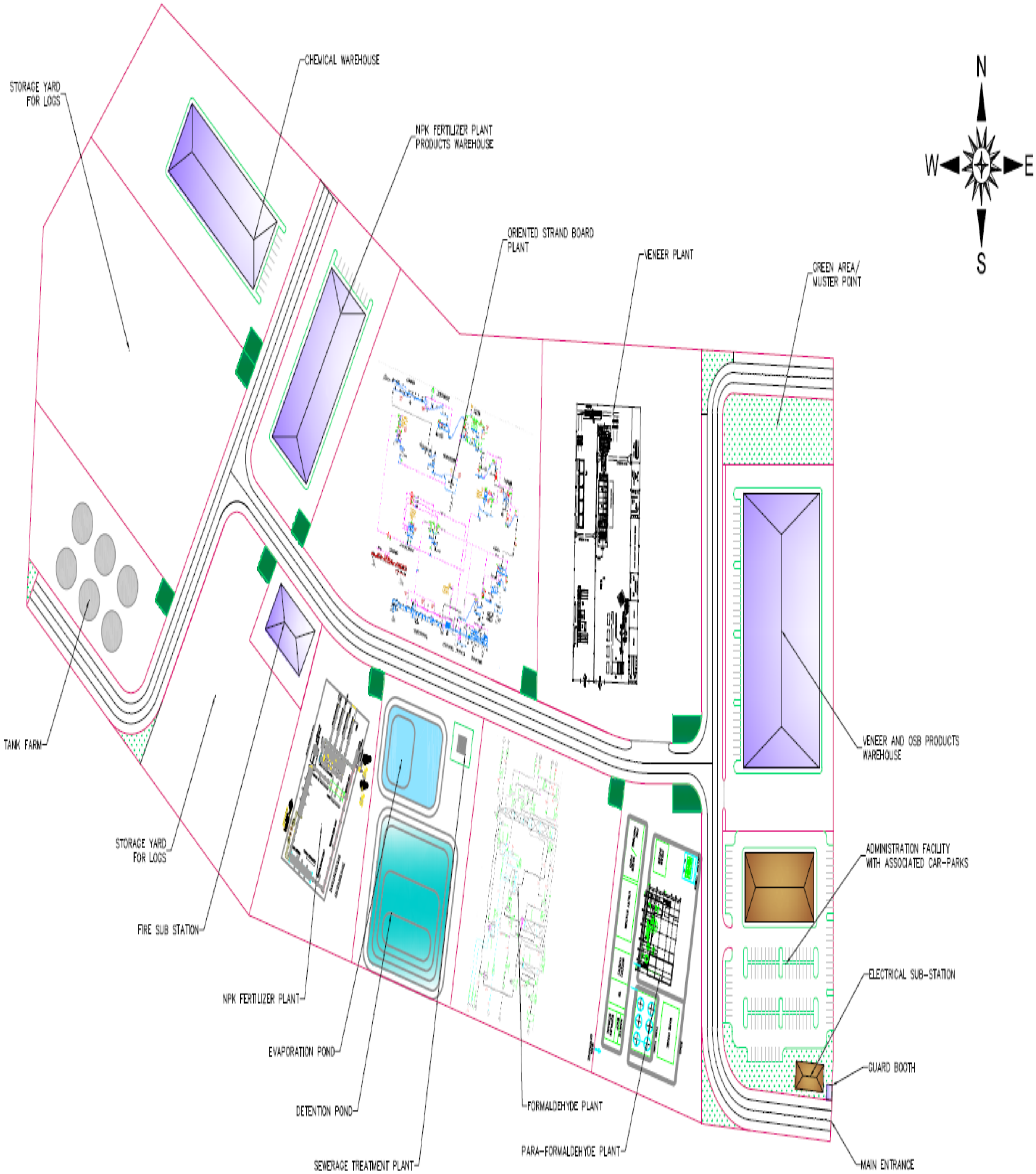
Table 1-1 - Plant Areas

DESCRIPTION	SQUARE METER / m^2
TOTAL SITE AREA	152500.00
AMINSTRATION FACILITY	7775.00
WAREHOUSE	19500.00
TANK FARM	7750.00
PARA-FORMALDEHYDE PLANT	7200.00
FORMALDEHYDE PLANT	12200.00
NITROGEN FERTILIZER	7215.00
FIRE RESPONSE FACILITY	1800.00
VENEER PLANT	16850.00
ORIENTED STRAND BOARD PLANT	18280.00
PONDS	4800.00
WASTE WATER TREATMENT FACILITY	121.00
ROAD NETWORK (15.0m ROW WITH 7.3m WIDE ROAD)	15000.00

The chemicals stored in the tank farm located at Lot #2 include:

- Methanol
- Urea

Figure 1-3 - Plant Layout



2.0 METHODOLOGY FOR RISK ASSESSMENT

There are several quantitative risk assessment (QRA) methods. Two of the most widely accepted QRA guidelines are provided by Center for Chemical Process Safety (CCPS 1989) of the American Institute of Chemical Engineers (AIChE) and Netherlands Organisation for Applied Scientific Research (TNO 2005). In this study, the methodology followed the guidelines recommended by CCPS.

The QRA of accidents and malfunctions involves several steps that follow the industry standard guideline designed to provide a clear definition of the potential problems and to provide a framework for quantifying and mitigating risks from identified hazards (including the screening-out of trivial hazards). A structured risk assessment method adopted in this work is shown in Figure 2-1.

The basic steps in the process of analysis of accidents and malfunctions are as follows:

- **Hazard Identification and Development of Hazard Scenarios:** The identification of physical situations with the potential for harming humans, property or the environment, or a combination of these is carried out and hazard scenarios are developed.

- **Grouping Hazard Scenarios and Identification of Bounding Scenarios:** The identified hazard scenarios are grouped based on the types of accidents (e.g. scenarios specific to construction, spill, fire/explosion, etc.). The bounding scenarios are selected based on the severity of potential consequences in each group.

- **Risk Assessment of Bounding Scenarios:** In general terms, risk is defined as the multiplication of the frequency of occurrence and the severity of the consequence of a hazardous event.

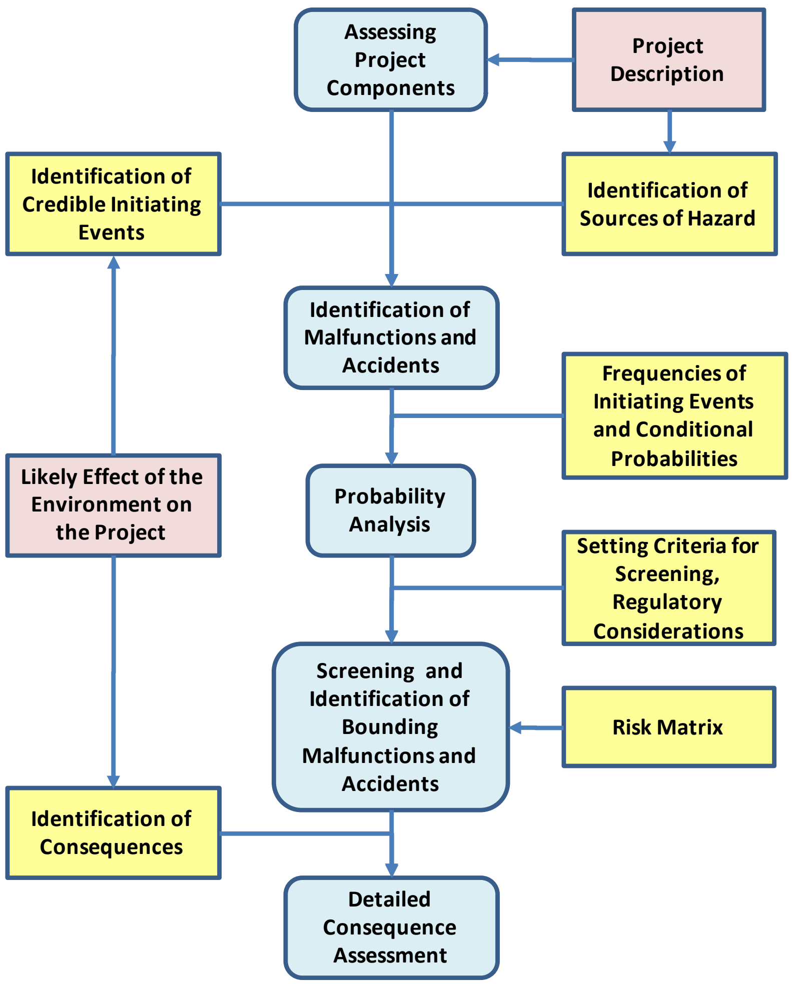
    - **Frequency Analysis:** The estimation of the occurrence frequency of the hazard within a specific time period or in specified circumstances.
    - **Consequence Analysis:** The identification of the effects of a hazard on human, property or the environment.
    - **Risk Estimation:** The estimation of the consequences of a hazard scenario and its frequency.

- **Risk Management:** For scenarios with risk that is unacceptable, risk mitigation and risk reduction plans will be recommended.

This methodology looks at the malfunctions or accidents that would potentially result and not the initiating event that may have caused them. For the purposes of this assessment, it will be assumed that an event would have an equivalent environmental effect regardless of whether it was the result of an internal event, such as human error or equipment failure, or an external event such as extreme weather.

This methodology has been extensively used by SENES in providing risk assessment to numerous industry clients.

Figure 2-1 - Methodology for the Assessment of Malfunctions and Accidents



2.1 HAZARD IDENTIFICATION AND DEVELOPMENT OF HAZARD SCENARIOS

Hazard identification starts with the review of the process description and chemicals involved in the chemical complex. The presence of the sources of hazards, the past industry experience, and professional judgment are used to postulate the hazard scenarios.

To facilitate risk assessment, the identified hazard scenarios are grouped depending on the types of accidents. For example, scenarios specific to construction activities, such as operation of heavy equipment, installation of pipes and devices, cutting and welding, etc, are grouped together. To identify bounding scenarios for each group for illustrating the most (reasonably) severe potential consequences, the following aspects of the identified scenarios are considered:

- quantity of hazardous substances involved;
- duration and potential spatial extent of releases to the environment; and
- magnitude of the effects on human or the environment.

2.2 Risk Assessment of Bounding Scenarios

The risk arising from malfunctions or accidents has two aspects: first, likelihood (or frequency of occurrence) and second the consequences (should the event occur). The use of a risk ranking matrix is a standard and effective method of ranking the risk of hazard scenarios. Likelihood and consequence ranking form two dimensions of the risk ranking matrix.

Figure 2-2 shows the risk-ranking matrix that will be used in this current analysis. Explanations of the "Frequency" dimension and the "Consequence" dimension are given in Section 2.2.1 and Section 2.2.2.

Figure 2-2 - Risk Matrix

Frequency		**Consequences**				
5	**Very Likely**	5	10	15	20	25
4	**Quite Likely**	4	8	12	16	20
3	**Somewhat Likely**	3	6	9	12	15
2	**Unlikely**	2	4	6	8	10
1	**Extremely Unlikely**	1	2	3	4	5
		Minor	**Moderate**	**Major**	**Very Serious**	**Catastrophic**
		1	2	3	4	5

Acceptable Risk (green)	ALARP (yellow)	Unacceptable Risk (red)

2.2.1 Frequency Assessment

The frequency corresponding to each level of likelihood is specific for each facility. Table 2-1 provides the frequency associated with the various levels of likelihood adopted in this analysis.

The frequency of the occurrence of any accident scenario is a combination of the frequency of the initiating events and the conditional probabilities of the hazard scenario occurring.

*Frequency of Hazard Scenario = Frequency of the Initiating Event * Conditional Probabilities*

The conditional probabilities are dependent on the operating conditions and the existing measures to prevent the occurrence of a hazard scenario. For example, in the case of the methanol release to the environment, the frequency of the release is the product of the failure frequency of the storage tank and the conditional failure probability of the secondary containment.

Provisions of preventive measures such as redundancy and diversity will reduce the frequency of a hazard scenario.

Table 2-1 - Definition of Frequency Classes

Frequency Class	Likelihood	Frequency
5	Very Likely	Expected to occur more than once a year (> 1:1 or 100% chances of occurrence/year)
4	Quite Likely	Expected to occur several times during lifetime of facility (1:3 or 10% to 30 % chances of occurrence/year)
3	Somewhat Likely	Expected to occur once during lifetime of facility (<1:10 or 1% to 10% chances of occurrence/year)
2	Unlikely	Not expected to occur once during lifetime of facility (1:1000 or 0.1% to 1% chances of occurrence/year)
1	Extremely Unlikely	Extremely unlikely to occur once during lifetime of facility (<1:1000 or <0.1% chances of occurrence/year)

2.2.2 Consequence Assessment

The consequence ranking was based on two aspects:

- Health and Safety
- Environment.

The description of the consequence classes is given in Table 2-2.

Table 2-2 - Definition of Consequence Classes

Consequence Class	Health and Safety	Environment
1	First aid injury	Negligible effect
2	Medical aid injury	Reversible minor effects
3	Major Injury	Reversible moderate effects
4	Permanent Disability	Reversible major effects
5	Fatality	Irreversible major effect

2.2.3 Risk Assessment

Risk is the product of the frequency of the hazard scenario and its consequence, given as:

Risk = Consequence x Frequency of Occurrence

The risk assessment result can be filled in the risk matrix shown in Figure 2-2. In the risk matrix, risk is classified into three categories:

- Acceptable
- ALARP (As Low As Reasonably Practicable)
- Not acceptable

2.3 Risk Management

No actions are needed to reduce risk for scenarios with acceptable risk. For scenarios with ALARP risk, optimization of preventive/mitigative measures will be determined based on the practice. As to scenarios with unacceptable risk, preventive and mitigative measures, such as redundancy, second containment, safety system, etc., must be implemented to reduce the risk.

3.0 HAZARD IDENTIFICATION AND DEVELOPMENT OF BOUNDING ACCIDENT SCENARIOS

Hazard identification starts with the review of the process description and the chemicals involved in the processes. In addition, historic accidents at similar operations are also reviewed.

3.1 SOURCES OF HAZARD

The identified sources of hazards are as follows:

- Conventional sources of hazard such as working in an industrial installation, machinery, hot surfaces, etc.

- Irritants, toxic and corrosive chemicals
    - Carbon monoxide
    - Ammonium Chloride
    - Ammonium Nitrate
    - Ammonium Sulphate
    - Mono Ammonium Phosphate
    - Potassium Chloride
    - Potassium Sulphate
    - Super Phosphate
    - Urea
    - Phenol
    - Resorcinol
    - Sodium hydroxide

- Combustible material
    - Formaldehyde solution
    - Phenol
    - Resorcinol
    - Wood

- Flammable liquids
    - Methanol

- Flammable/explosive gases
    - Methanol vapour
    - Formaldehyde vapor
    - Carbon monoxide
    - Hydrogen

- Explosive dust
    - Saw dust
    - Ammonium nitrate
    - Melamine

The National Fire Protection Agency (NFPA) 704 (2012) has classifies hazardous materials for three categories of health, flammability, and reactivity for emergency response according to the following tables.

Table 3-1 - Description of Health Rating

Rating	Description
4	May be fatal on short exposure. Specialized protective equipment required
3	Corrosive or toxic. Avoid skin contact or inhalation
2	May be harmful if inhaled or absorbed
1	May be irritating
0	No unusual hazard

Table 3-2 - Description of Flammability Rating

Rating	Description
4	Flammable gas or extremely flammable liquid
3	Flammable liquid flash point below 100°F
2	Combustible liquid flash point of 100° to 200°F
1	Combustible if heated
0	Not combustible

Table 3-3 - Description of Reactivity Rating

Rating	Description
4	Explosive material at room temperature
3	May be explosive if shocked, heated under confinement or mixed with water
2	Unstable or may react violently if mixed with water
1	May react if heated or mixed with water but not violently
0	Not reactive when mixed with water

The properties of the above chemicals are listed in Table 3-4.

Table 3-4 - Properties of Hazardous Chemicals on Site

Chemical	NFPA Classification			LEL*	HEL**	ERPG Levels*** PPM		
	Health	Flammability	Reactivity			1	2	3
Ammonium Chloride	2	0	0	--	-	-	-	-
Ammonium Nitrate	0	0	3	-	-	-	-	-
Ammonium Sulphate	3	0	0	-	-	-	-	-
Ammonium Phosphate	2	0	0	-	-	-	-	-
Potassium Chloride	1	0	0	-	-	-	-	-
Potassium Sulphate	1	0	0	-	-	-	-	-
Super Phosphate	1	0	0	-	-	-	-	-
Phenol	3	2	0	1.7%	8.6%	-	50	200
Resorcinol	3	1	0	1.4%	-	-	-	-
Urea	1	0	0	-	-	-	-	-
Sodium Hydroxide	3	0	1	-	-	-	-	-
Formaldehyde	3	4	0	7%	73%	1	10	40
Melamine	2	1	1	-	-	-	-	-
Wood	0	1	0	-	-	-	-	-
Methanol	2	3	0	6%	36%	200	1000	5000
Transformer Oil	0	2	0	-	-	-	-	-
Carbon Monoxide	3	4	0	12%	75%	200	350	500
Hydrogen	0	4	0	4%	75%	-	-	-
Saw dust	0	1	0	-	-	-	-	

Notes:
* Lower Explosion Level
** Higher Explosion Level
*** ERPG – Emergency Response Planning Guidelines (AIHA 2011)

Beyond typical workplace exposure limits such as the Threshold Limit Value (TLV) and Recommended Exposure Limit (REL), exposure limits for emergency scenarios are defined by a hierarchy of threshold concentrations. These include the Acute Exposure Guideline Level (AEGL) or Emergency Response Planning Guidelines (ERPG). The ERPGs are developed by the American Industrial Hygiene Association (AIHA 2011).

ERPGs are intended to be a planning tool to help anticipate human adverse effects to the general public caused by toxic chemical exposure. These are only available for 1-hour exposure duration, and are not designed for hypersensitive individuals:

ERPG-1 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour

ERPG-2 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects to symptoms which could impair an individual's ability to take protective action

ERPG-3 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

3.2 Initiating Events

The methodology used to develop the potential accident scenarios for this project focuses on the potential scenario(s) that could occur during the process activities regardless of the initiating event that caused it. For example, methanol leaking could be caused by several initiating events, such as pipe rupture, pump/valve failure, human error, the result of extreme weather or some combinations. Regardless of the initiating events, reasonably conservative assumptions are used to ensure that the permutation of the accident scenario with the highest possible environmental consequence was assessed.

3.3 Accident Scenarios

For this assessment, the sources of hazards identified in the previous section for each process section and the locations were used to determine potential accident scenarios. Table 3-5 shows the identified accident scenarios. In addition, the preliminary screening of the accident scenarios is also provided in the table.

Table 3-5 – Potential Accident Scenarios and Preliminary Screening

Process	Possible Accidents	Screening Decision
Entire Site	Conventional accidents involving worker injuries	The operation of this plant is not different from other standard chemical plants. The design and operation of the plant follows internationally accepted codes and standards. Health and safety measures and standard operating procedures are prepared and implemented to reduce the probability and severity of the consequences of potential workplace accidents. Fire safety plan and emergency response plan are prepared to adequately handle the emergency situations. The fire safety systems are designed implemented and tested routinely according to the process needs. The The personnel are adequately trained for working with hazardous materials and equipped with the appropriate personal protection equipment (PPE). This scenario does not need further assessment.
	Traffic accidents (such as collision, roll over, derailment or collision of trains) resulting in potential release of chemicals, human injuries and property damage	Traffic safety measures, such as speed limit, adequate signing, and drivers training are in place to minimize traffic accidents on site. The consequence of onsite traffic accident is expected to be low. The consequence of spill of chemicals during onsite traffic accident is bounded by the spill of chemicals from process operation. This scenario does not need further assessment.
	Transformer fire	The consequences of potential transformer fire are bounded by the chemical fire such as methanol and formaldehyde fires. The quantity of such materials stored on site is much larger. This scenario does not need further assessment.

Process	Possible Accidents	Screening Decision
Formaldehyde Chemical Plant	Release of methanol	The small-scale release of methanol from storage tank can be contained and cleaned easily. In addition, the storage tanks will be of stainless steel construction to prevent corrosion and will be equipped with secondary containment to serve as multiple barriers against release to the environment. The potential consequences will be limited within the site boundary. The site drainage system will be designed to conduct all the surface runoff toward the detention pond in the south side of the facility. There would be no discharge to the environment. The probability of catastrophic failure of large stainless steel storage tank (250 m^3) resulting in release of large amount of methanol is much less than 10^{-5} per year (TNO 2005). Therefore, according to the risk matrix provided in section 2.2, the risk is low. This scenario does not need further assessment.
	Fire involving liquid methanol	The thermal radiation resulting from large scale methanol fire could be high. This scenario was selected as bounding for further analysis.
	Release of formaldehyde solution	The small-scale release formaldehyde from storage tank can be contained and cleaned easily. In addition, the storage tanks will be of stainless-steel construction to prevent corrosion and will be equipped with secondary containment to serve as multiple barriers against release to the environment. The potential consequences will be limited within the site boundary. The site drainage system will be designed to conduct all the surface runoff toward the detention pond in the south side of the facility. There would be no discharge to the environment. The probability of catastrophic failure of large stainless steel storage tank (300 m^3) resulting in release of large amount of formaldehyde is much less than 10^{-5} per year (TNO 2005). Therefore, according to the risk matrix provided in section 2.2, the risk is low. This scenario does not need further assessment.

Process	Possible Accidents	Screening Decision
	Boiler explosion	The explosion of the boiler is a very low probability event (CCPS 19890. The regular and preventive maintenance programs, in addition to regular testing and inspection would prevent unexpected failure of the boiler vessel. Any potential explosion of the boiler may have onsite consequences such as injuries or even fatality. However, given the preventive measures and considering the very low probability of such events, the risk of such event is deemed as low. The adverse consequences offsite is not expected. This scenario does not need further assessment.
	Fire involving formaldehyde solution	The thermal radiation resulting from large scale formaldehyde fire could be high. This scenario was selected as bounding for further analysis.
	Release of hydrogen to air and consequent fire ball	The thermal radiation resulting from large scale hydrogen fire could be high. This scenario was selected as bounding for further analysis.
	Release of carbon monoxide to air with toxic effects	Carbon monoxide is both toxic and flammable. The release of carbon monoxide may have adverse consequences offsite. This scenario was selected as bounding for further analysis.
	Release of carbon monoxide to air and consequence fire ball	Carbon monoxide is both toxic and flammable. The release and fire involving carbon monoxide may have adverse consequences offsite. This scenario was selected as bounding for further analysis.
	Release of methanol vapour and consequent BLEVE	The thermal radiation resulting from large scale methanol fire could be high. This scenario was selected as bounding for further analysis.
	Release of formaldehyde vapour and consequent BLEVE	The thermal radiation resulting from large scale methanol fire could be high. This scenario was selected as bounding for further analysis.
	Offsite vapour cloud explosion from hydrogen release	The blast overpressure resulting from large scale hydrogen explosion could be high. This scenario was selected as bounding for further analysis.

Process	Possible Accidents	Screening Decision
	Offsite vapour cloud explosion from methanol vapour release	The blast overpressure resulting from large scale methanol explosion could be high. This scenario was selected as bounding for further analysis.
	Offsite vapour cloud explosion from formaldehyde vapour release	The blast overpressure resulting from large scale formaldehyde explosion could be high. This scenario was selected as bounding for further analysis.
Para-Formaldehyde Chemical Plant	Release of formaldehyde solution	The small-scale release of formaldehyde from storage tanks can be contained and cleaned easily. In addition, the storage tanks will be of stainless steel construction to prevent corrosion and will be equipped with secondary containment to serve as multiple barriers against release to the environment. The potential consequences will be limited within the site boundary. The site drainage system will be designed to conduct all the surface runoff toward the detention pond in the south side of the facility. There would be no discharge to the environment. The probability of catastrophic failure of large stainless steel storage tank resulting in release of large amount of formaldehyde is much less than 10^{-5} per year (TNO 2005). Therefore, according to the risk matrix provided in section 2.2, the risk is low. This scenario does not need further assessment.
	Fire involving formaldehyde solution	This scenario is bounded by the formaldehyde fire in the formaldehyde plant.
	Release of formaldehyde vapour and consequence fire ball or Boiling Liquid Expanding Vapor Explosion (BLEVE)	This scenario is bounded by the release of formaldehyde vapour from formaldehyde plant and consequence fire ball or BLEVE.
	Offsite vapour cloud explosion from formaldehyde vapour release	This scenario is bounded by the offsite vapour cloud explosion involving formaldehyde vapour released from formaldehyde plant and consequence fire ball or BLEVE.
Nitrogen Fertilizer Plant	Spill of solid chemicals (e.g. urea)	Any spill of solid material on site can be contained and cleaned immediately. The emergency response plan has procedures for handling a chemical spill. Any waste generated during the clean up can be recycled internally of disposed off safely according to the plant procedures. This scenario does not need further assessment.

Process	Possible Accidents	Screening Decision
	Ammonium nitrate explosion	Dust explosion in industry is a rare accident; however, the consequences could be severe. These consequences are mostly onsite. Offsite consequences are not expected. Proper grounding of the process equipment, housekeeping, regular cleaning of the building and equipment (e.g. hoppers, ducts, pipes, vents) that may accumulate the explosive dust, proper design of the process will effectively prevent dust explosion. According to risk matrix provided in Section 2.2, the risk is deemed to be low. This scenario does not need further assessment.
Oriented Strand Board Plant	Wood fire	The magnitude of the consequence of a wood fire is expected to be bounded by a chemical fire. This scenario does not need further assessment.
	Saw dust explosion	Dust explosion in industry is a rare accident; however, the consequences could be severe. These consequences are mostly onsite. Offsite consequences are not expected. Proper grounding of the process equipment, housekeeping, regular cleaning of the building and equipment (e.g. hoppers, ducts, pipes, vents) that may accumulate the explosive dust, proper design of the process will effectively prevent dust explosion. According to risk matrix provided in Section 2.2, the risk is deemed to be low. This scenario does not need further assessment.
	Spill of resins	Any small-scale spill of solid or liquid materials such as resins on site can be contained and cleaned immediately. The emergency response plan has procedures for handling chemical spills. Any waste generated during the clean up can be recycled internally or disposed off safely according to the plant procedures. This scenario does not need further assessment.
Veneer Plant	Wood fire	The magnitude of the consequence of a wood fir is expected to be bounded by a chemical fire. This scenario does not need further assessment.

Process	Possible Accidents	Screening Decision
	Saw dust explosion	Dust explosion in industry is a rare accident; however, the consequences could be severe. These consequences are mostly onsite. Offsite consequences are not expected. Proper grounding of the process equipment, housekeeping, regular cleaning of the building and equipment (e.g. hoppers, ducts, pipes, vents) that may accumulate the explosive dust, proper design of the process will effectively prevent dust explosion. According to risk matrix provided in Section 2.2, the risk is deemed to be low. This scenario does not need further assessment.
Resin Plant	Spill of resins	Any small-scale spill of solid or liquid materials such as resins on site can be contained and cleaned immediately. The emergency response plan has procedures for handling chemical spills. Any waste generated during the clean up can be recycled internally of disposed off safely according to the plant procedures. This scenario does not need further assessment.

Process	Possible Accidents	Screening Decision
	Release of phenol/resorcinol from storage tank	The release of phenol/resorcinol from storage tank can be contained and cleaned easily. The waste generated during the process can be collected and disposed of safely according to the plant procedures. In addition, the storage tanks are equipped with secondary containment to serve as multiple barriers against release to the environment. The potential consequences are limited within the site boundary. The site drainage system is designed to conduct all the surface runoff toward the detention pond in the south side of the facility. There would be no discharge to the environment. The probability of catastrophic failure of large storage tank resulting in release of large amount of phenol/resorcinol is in the order of 10^{-5} per year. Therefore, according to the risk matrix provided in section 2.2, the risk is low. The workers responding to the phenol/resorcinol release will be equipped with the adequate personal protection equipment such as full-face masks to reduce the risk of exposure and human health adverse effects on the workers. This scenario does not need further assessment.
	Release of phenol/resorcinol during a fire	Due to high boiling point (~182ºC) evaporation of phenol and dispersion offsite is very unlikely, however, the thermal radiation resulting from large scale phenol fire could be high. This scenario was selected as bounding for further analysis. Due to higher flash point of resorcinol (127ºC) compared with the flash point of phenol (79ºC), the consequence and probability of a resorcinol fire is bounded by those of a phenol fire.

Process	Possible Accidents	Screening Decision
	Melamine dust explosion	Dust explosion in industry is a rare accident; however, the consequences could be severe. These consequences are mostly onsite. Offsite consequences are not expected. In the plant: • deposition of dust will be prevented; • when excessive dusting is expected, closed system will be used; and • dust explosion-proof electrical equipment and lighting will be used in the area that the dust explosion is probable. In addition, proper grounding of the process equipment, housekeeping, regular cleaning of the building and equipment (e.g. hoppers, ducts, pipes, vents) that may accumulate the explosive dust, proper design of the process will effectively prevent dust explosion. According to risk matrix provided in Section 2.2, the risk is deemed to be low. This scenario does not need further assessment.

3.3.1 Identification of Bounding Hazard Scenarios for Assessment

The following aspects of the identified scenarios for each group were considered to develop the bounding scenarios that would serve to illustrate the most (reasonably) severe potential consequences.

- quantity of hazardous substances involved;
- duration and potential spatial extent of releases to the environment; and
- magnitude of the effects on humans or the environment.

The result of this step was a set of representative accidents scenarios that maximize the effects and bound the consequences of accidents associated with the process operation. The following bounding scenarios were identified and carried through for quantitative assessment of effects as appropriate:

1. Fire involving liquid methanol
2. Fire involving formaldehyde solution
3. Release of methanol vapour and consequent BLEVE
4. Release of formaldehyde vapour and consequent BLEVE
5. Offsite vapour cloud explosion from methanol vapour release
6. Offsite vapour cloud explosion from formaldehyde vapour release
7. Offsite vapour cloud explosion from hydrogen release
8. Fire involving liquid Phenol
9. Release of hydrogen to air and consequent fire ball
10. Release of carbon monoxide to air and consequence fire ball
11. Release of carbon monoxide to air with toxic effects

4.0 CONSIDERATIONS IN THE ASSESSMENT OF MALFUNCTIONS AND ACCIDENTS

4.1 GENERAL

The Health and Safety Officer will develop systems and delineate procedures for the following:

- Health, Safety and Environment Management
- Waste Management Systems for waste reduction, recycling, storage and disposal,
- Detailing of Mitigation Measures
- Emergency Prevention and Response Plan
- Fire Safety Plan

The facility has an Emergency Response Team with coordination with local emergency response organizations

Area classification is consistent with the chemicals being used in each area. Electrical equipment and instruments are selected properly for each area class.

Material of construction is compatible with the services (e.g. stainless steel construction for methanol and formaldehyde storage tanks and process vessels.

Emergency response procedures will be tested routinely. Plant personnel and employees are trained routinely

All necessary safety precautions will be taken within the project area to prevent the occurrence of accidents and to minimize the disturbance to the surrounding community with respect to noise pollution and dust emissions. The following will be used to ensure these risks are controlled:

- Installation of hoarding and the permanent fencing around the perimeter of the project
- Installation of all warning signs
- Installation of proper lighting
- Installation of proper security systems

The entire site is equipped with fire hydrants.

Monitoring and alarms will be provided to detect the fire, smoke, and release of flammable materials and carbon monoxide.

4.2 CHEMICAL STORAGE

All storage tanks for flammable liquid will be equipped with sprinkler and nitrogen blanketing.

All materials will be stored in suitable locations within the site. The large storage tanks are located at the tank farm on the west side of the facility. The location of the tanks conforms to the NFPA Flammable and Combustible Liquids Code (NFPA 2012 and the distance of the tank farm from the nearest process plant is 150 m. No incompatible chemicals are stored in the same area (e.g. flammable and oxidizers). Chemicals will be stored on secure, impervious locations with secondary containment. This will prevent the release of chemicals into the environment should there be any accidents. The secondary containment will have a capacity of 110% of the maximum volume of the storage container. All loading and offloading will occur in contained designated areas. The loading and offloading operations will be supervised all the time.

5.0 ASSESSMENT OF BOUNDING MALFUNCTION AND ACCIDENT SCENARIOS

5.1 FIRE INVOLVING LIQUID METHANOL

5.1.1 Scenario Definition

This scenario involves release of methanol from damaged storage tanks, broken pipe, or faulty valves or pumps.

The maximum flow rate of methanol in the proposed plant is to the heat exchanger/ vaporizer. The flow rate is approximately 230,000 kg/hour of 25% methanol. In this scenario, it was assumed that upon a major pipe break, it would take 5 minutes to shut off the broken pipe segment. During this period, approximately 19,200 kg of 25% methanol will be released. It was assumed that the released methanol will form a pool with an area of 200 m^2. Upon ignition, the pool fire will be 15.6 m in diameter. The area of the pool is based o the approximate exposed surface area of the deemed area around the tank (secondary containment).

5.1.2 Consequence Assessment

The hazard end point for thermal injury is the thermal load equivalent of 5 kW/m^2 for 40 seconds. This is the criterion specified by the U.S. EPA (EPA 2009) for either workers or members of the public. This radiation intensity corresponds to second degree burns to the skin of humans exposed to the fire. The radiation intensity criterion decreases with the duration of exposure time (TNO 1992). The thermal radiation resulting in lethality was generally taken as 12.5 kW/m^2 to 37.5 kW/m^2.

Application of solid flame model (CCPS 1994) for a typical liquid methanol pool of 15.6 m in diameter gives a minimum safe distance of 43 m (based on the criteria of 5 kW/m^2) from the fire. This analysis indicates that the impact of release of methanol is contained locally with no measurable effect away from the site.

5.1.3 Probability Assessment

For a "pipe rupture" and "valve failure" of the methanol supply line, failure data from CCPS (1989) are applicable. This information is provided in Table 5-1.

Table 5-1 Failure Frequency of the Piping system

Component	Frequency of Failure per Hour
Pipe failure	5.97×10^{-7}
Valve failure	1.52×10^{-7}

It was assumed that there are 3 pipe segments and 3 valves in the area next to the vaporizer. This assumption was based on a typical outlet arrangement form the vaporizer. Given that methanol is supplied to the process 24 hours per day, 365 days/year, the failure frequency of pipes is:

$$365 \text{ day/year} * 24 \text{ hour/day} * (5.97 \times 10^{-7})/(\text{hour}) * 3 = 0.016 \text{ per year}$$

For the valves, the frequency of is:

$$365 \text{ day/year} * 24 \text{ hour/day} * (1.52 \times 10^{-7})/\text{hour} * 3 = 0.004 \text{ per year}$$

The overall frequency of the release will be 0.02 per year. Assuming 10% probability of ignition, the frequency of a methanol fire will be 0.002 per year.

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 43 m distance from the fire (during a fire event) is less than 0.001. Therefore, the frequency of public fatality is less than 2×10^{-6} per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 300 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 400 m: 25 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:100 people with the frequency of less than 10^{-8} per year

5.2 FIRE INVOLVING FORMALDEHYDE SOLUTION

5.2.1 Scenario Definition

This scenario involves release of formaldehyde from damaged storage tanks, broken pipe, or faulty valves or pumps.

The maximum flow rate of formaldehyde in plant will be to the heat exchanger/ vaporizer. The flow rate will be approximately 400,000 kg/hour of 37% formaldehyde. In this scenario, it was assumed that upon a major pipe break, it would take 5 minutes to shut off the broken pipe segment. During this period, approximately 33,330 kg of 37% formaldehyde will be released. It was assumed that the released formaldehyde will form a pool with an area of 330 m^2. The area of the pool is based o the approximate entire surface area of the deemed area around the tank for larger liquid volume. Upon ignition, the pool fire will be 20.6 m in diameter.

5.2.2 Consequence Assessment

The same criteria used in Section 5.1 are used for this scenario as well.

Application of solid flame model (CCPS 1994) for a typical liquid formaldehyde pool of 20.6 m in diameter gives a minimum safe distance of 52 m (based on the criteria of 5 kW/m^2) from the fire. This analysis indicates that the impact of release of formaldehyde will be contained locally with no measurable effect beyond the site.

5.2.3 Probability Assessment

The same methodology used to calculate the frequency in Section 5.1 is used here to calculate the frequency of fire in this scenario. For 3 pipe segments and 3 valves (typical piping arrangement for outlet from a tank) and 5% conditional probability of ignition for formaldehyde, the overall frequency of formaldehyde fire will be 0.001 per year. Due to much higher flash point of formaldehyde compared to methanol (80 ºC versus 10 ºC), the conditional probability is lower in this scenario.

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 52 m distance from the fire (during a fire event) is less than 0.001. Therefore, the frequency of public fatality is less than 1×10^{-6} per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 15 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:120 people with the frequency of less than 10^{-8} per year

5.3 Release of Methanol Vapour and Consequent Boiling Liquid Expanding Vapor Explosion (BLEVE)

5.3.1 Scenario Definition

In a circumstance where the fire engulfs another storage tank, and where the tank cannot be cooled, the elevated temperature of the tank may lead to increased internal pressure, and weakening of the storage tank. In this case, a BLEVE may occur. According to the plant information, the maximum amount of methanol involved in the BLEVE can be 250 m^3, however, the probability of such event is very low (see Section 5.3.2).

5.3.2 Consequence Assessment

Catastrophic failure of the methanol storage tank exposed to a large fire may release large quantities of methanol. Subsequently a large explosive vapour cloud may be created. If ignited, a blast from the expanding vapour cloud or a fireball could damage the structures and facilities near the methanol storage and may cause injuries or fatalities.

For modelling methanol explosion hazards, the multi-Energy model developed by TNO in The Netherlands (TNO 2005a) and described in CCPS (1994, Section 7.2.2, pp. 250-256) was used. This model provides information on the overpressure P_s as a function of distance from the blast location.

Table 5-2 shows the blast overpressure versus distance from the explosion for release of large quantities of methanol from a 250 m^3 methanol storage tank.

Table 5-2 - Blast Overpressure versus Distance from the Explosion of Methanol Storage Tank

Distance, m	Blast Overpressure, psi
100	34.6
250	11.2

500	3.8
1000	1.1

The effects of blast overpressure are as follows:

- 5 PSI overpressure: Slight chance of eardrum rupture (without hearing protection);
- 15 PSI overpressure: 50% chance of eardrum rupture;
- 30 to 40 PSI overpressure: Slight chance of lunge damage;
- 10-20 PSI overpressure: damage to concrete structures;
- 5-10 PSI overpressure: damage to steel storage tanks.

These results show that a BLEVE may affect other storage tanks and structures within 250 m of the explosion. Worker injuries may occur at the distance of 200 m from the explosion. Fatalities may occur at distances closer than 100 m. Damage to the residential structures to the north of the facility is expected. Less severe damages are expected to the residential areas in the south. The damage would include broken windows and limited damage to the roofing material. No damage to the house structures is expected. Given that the distance of the storage tank from the nearest regularly occupied building is approximately 150 m, the probability of fatality is extremely low (less than 10^{-6} per year). Damage to the other tanks or injuries may occur at higher probabilities, yet still very low (10^{-6} to 10^{-5} per vessel year).

The risk of a methanol storage tank explosion would be mitigated by standard industrial practice and trained staff. Despite the potential catastrophic consequences of a large methanol explosion, the frequency of such accidents is very low.

5.3.3 Probability Assessment

The frequency of a storage tank BLEVE should be calculated using fault tree analysis, taking account of adjacent fire sources capable of causing this event and other detailed process information which is not currently available for this study. Therefore, information published by appropriate agencies for similar cases are used. Previous such analyses indicate that a frequency in the range 10^{-6} to 10^{-5} per vessel year would be expected for large storage vessels (TNO 2005).

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 100 m distance from the explosion (during an explosion) is less than 0.1. Therefore, the frequency of public fatality is less than 1×10^{-6} per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 300 m: 7 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 400 m: 30 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:120 people with the frequency of less than 10^{-8} per year

5.4 RELEASE OF FORMALDEHYDE VAPOUR AND CONSEQUENT BLEVE

5.4.1 Scenario Definition

In an instance where fire engulfs a formaldehyde storage tank which cannot be cooled, the elevated temperature of the tank may lead to increased internal pressure, and weakening of the storage tank. In this case, a boiling liquid expanding vapor explosion (BLEVE) may occur. According to the plant information, the maximum amount of formaldehyde involved in the BLEVE can be 300 m^3.

5.4.2 Consequence Assessment

Catastrophic failure of the formaldehyde storage tank exposed to a large fire may release large quantities of formaldehyde. Subsequently a large explosive vapour cloud may be created. If ignited, a blast from the expanding vapour cloud or a fireball could damage the structures and facilities near the formaldehyde storage and may cause injuries or fatalities.

For modelling formaldehyde explosion hazards, the Multi-Energy model developed by TNO in The Netherlands (TNO 2005a) and described in CCPS (1994, Section 7.2.2, pp. 250-256) was used. This model provides information on the overpressure P_s as a function of distance from the blast location.

Error! Reference source not found. shows the blast overpressure versus distance from the explosion for release of large quantities of formaldehyde from a 300 m^3 methanol storage tank.

Table 5-3 - Blast Overpressure versus Distance from the Explosion of Formaldehyde Storage Tank

Distance, m	Blast Overpressure, psi
100	37.3
250	12.1
500	4.1
1000	1.3

These results show that a BLEVE may affect other storage tanks and structures within 250 m of the explosion. Worker injuries may occur at the distance of 200 m from the explosion. Fatalities may occur at distances closer than 100 m. Damage to the residential structures to the north of the facility would be expected. Less severe damages are expected to the residential areas in the south. The damage would include broken windows and limited damage to the roofing material. No damage to the house structures is expected

The risk of a formaldehyde storage tank explosion would be mitigated by standard industrial practice and trained staff. These practices involve fire fighting measures, tank breathing system to prevent pressure build-up, leak and spill prevention measures and preventive and routine maintenance programs. Despite the potential catastrophic consequences of a large formaldehyde explosion, the frequency of such accidents is very low.

5.4.3 Probability Assessment

Similar to Section 5.3, the frequency of a formaldehyde storage tank BLEVE is expected to be in the range 10^{-6} to 10^{-5} per vessel year (TNO 2005).

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 100 m distance from the explosion (during an explosion) is less than 0.1. Therefore, the frequency of public fatality is less than 1×10^{-6} per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 8 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 30 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:140 people with the frequency of less than 10^{-8} per year

5.5 OFFSITE VAPOUR CLOUD EXPLOSION FROM METHANOL VAPOUR RELEASE

5.5.1 Scenario Definition

This scenario involves release of methanol from broken pipes or faulty valves.

The maximum flow rate of methanol vapour in the proposed plant will be to the convertor. The flow rate will be 7,500 kg/hour methanol. For this scenario, it was assumed that upon a major pipe break, it would take 5 minutes to shut off the broken pipe segment. During this period, approximately 625 kg of methanol vapour will be released to the atmosphere. The released gas will move offsite and form an explosive vapour mixture. If this mixture is within the explosive limits and encounter an ignition source it may ignite.

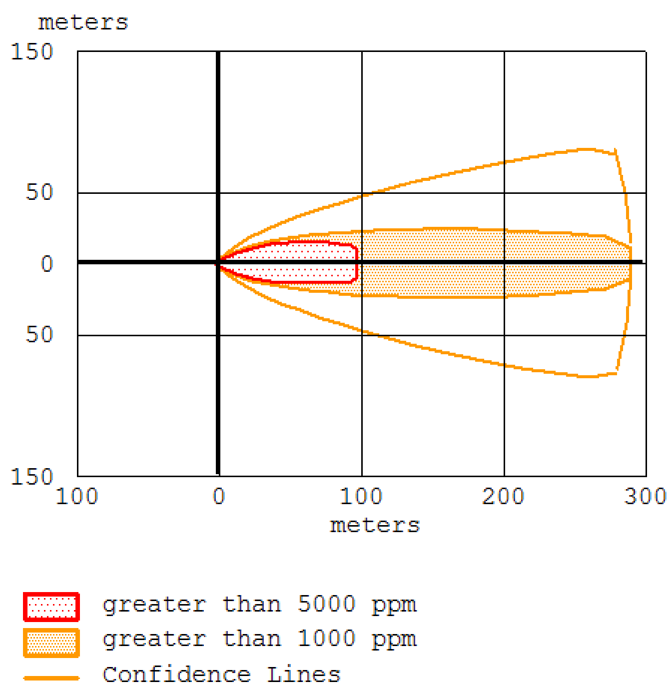
5.5.2 Consequence Assessment

In order to conduct the air dispersion modelling for methanol vapour release, the Areal Locations of Hazardous Atmospheres (ALOHA) model was used. The ALOHA model was jointly developed by EPA office of Emergency Management and the Emergency Response Division of National Ocean and Atmospheric Administration (NOAA 2013).

Figure 5-1 shows the ALOHA model results for this release scenario. The results indicate that the ERPG level 2 is exceeded at residential areas in the north only; however no permanent damage is expected. ERPG level 3 is not exceeded offsite. For affected areas, it is expected that upon discovery of large scale release of methanol, public notification be initiated. As the exposure is short-term the best defence is shelter-in-place. In this case, members of the public are advised to stay inside and to keep all doors and windows closed.

The ALOHA results indicate that the concentration of formaldehyde drops below 50% of LEL within 30 m of the release location. Therefore, no vapour-cloud explosion is expected offsite.

Figure 5-1 - ALOHA Model Results for Methanol Release



The results indicate that the ERPG level 2 is exceeded at residential areas in the north only; however no permanent damage is expected. ERPG level 3 is not exceeded offsite. For affected areas, it is expected that upon discovery of large scale release of methanol, public notification be initiated. As the exposure is short-term the best defence is shelter-in-place. In this case, members of the public are advised to stay inside and to keep all doors and windows closed, and to turn off all ventilation and air conditioning systems.

The ALOHA results indicate that the concentration of formaldehyde drops below 50% of LEL within 30 m of the release location. Therefore, no vapour-cloud explosion is expected for offsite.

5.5.3 Probability Assessment

Similar to Section 5.1 the frequency of the methanol vapour release and ignition offsite is expected to be approximately 0.001 per year. This is based on three broken pipe sections and three faulty valves, and 5% conditional probability of ignition offsite.

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 30 m distance from the explosion (during an explosion) is less than 0.001. Therefore, the frequency of public fatality is less than $1x10^{-6}$ per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 300 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 400 m: 25 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:100 people with the frequency of less than 10^{-8} per year

5.6 OFFSITE VAPOUR CLOUD EXPLOSION FROM FORMALDEHYDE VAPOUR RELEASE

5.6.1 Scenario Definition

This scenario involves release of formaldehyde from broken pipes or faulty valves.

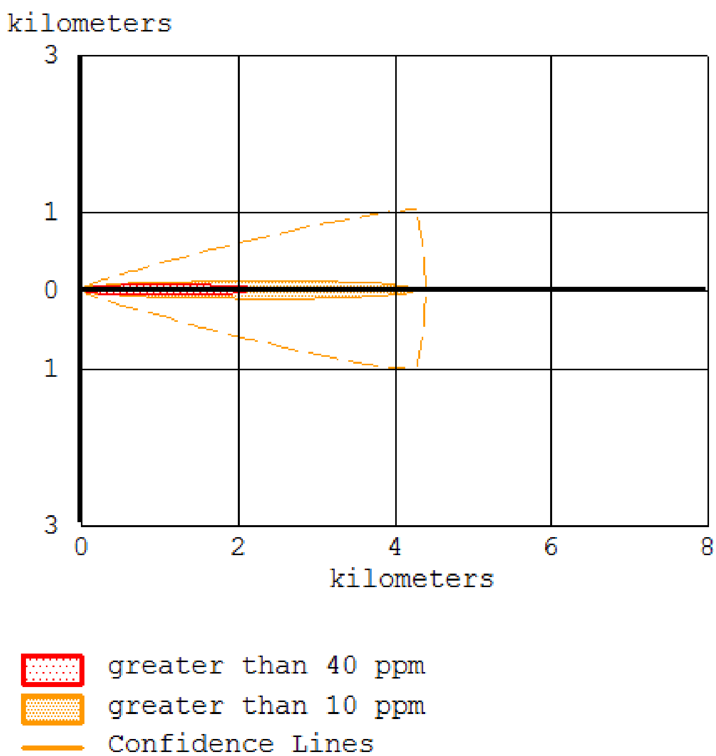
The maximum flow rate of formaldehyde vapour in the proposed plant will be to the absorber. The flow rate will be 6,167 kg/hour formaldehyde. In this scenario, it was assumed that upon a major pipe break, it would take5 minutes to shut off the broken pipe segment. During this period, approximately 514 kg of formaldehyde vapour will be released to the atmosphere. The released gas will move offsite and form an explosive vapour mixture. If this mixture is within the explosive limits and encounter an ignition source it may ignite.

5.6.2 Consequence Assessment

In order to conduct the air dispersion modelling for formaldehyde vapour release, the ALOHA model was used.

Figure 5-2 shows the ALOHA model results for this release scenario.

Figure 5-2 - ALOHA Model Results for Formaldehyde Release



The results indicate that the ERPG levels 2 and 3 are exceeded at residential areas, however no life-threatening damage is expected. At ERPG level 3, it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects. For accidental releases, the indoor air concentrations are much smaller than outdoor air concentrations at the receptor locations immediately following a release. The exposure is short-term, therefore, to minimize the exposure it is advisable that the residence stay inside for a short period following a release and the best defence is shelter-in-place. It is expected that upon discovery of large scale release of formaldehyde, public notification be initiated. In this case, members of the public are advised to stay inside and to keep all doors and windows closed and to turn off all ventilation and air conditioning systems.

The ALOHA results indicate that the concentration of formaldehyde drops below 50% of LEL within 30 m of the release location. Therefore, no vapour-cloud explosion is expected for offsite.

5.6.3 Probability Assessment

Similar to Section 5.2 the frequency of the formaldehyde vapour release and ignition offsite is expected to be approximately 0.0004 per year. This is based on three broken pipe sections and three faulty valves, and 2% conditional probability of ignition offsite (because of higher flash point of formaldehyde).

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 30 m distance from the explosion (during an explosion) is less than 0.001. Therefore, the frequency of public fatality is less than $1x10^{-6}$ per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 15 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:120 people with the frequency of less than 10^{-8} per year

5.7 OFFSITE VAPOUR CLOUD EXPLOSION FROM HYDROGEN RELEASE

5.7.1 Scenario Definition

This scenario involves release of hydrogen from broken pipes or faulty valves.

The maximum flow rate of hydrogen in the proposed plant will be to the absorber. The flow rate is 227 kg/hour hydrogen. In this scenario, it was assumed that upon a major pipe break, it would take 5 minutes to shut off the broken pipe segment. During this period, approximately 19 kg of hydrogen will be released to the atmosphere. The released gas will move offsite and form an explosive vapour mixture. If this mixture is within the explosive limits and encounter an ignition source it may ignite.

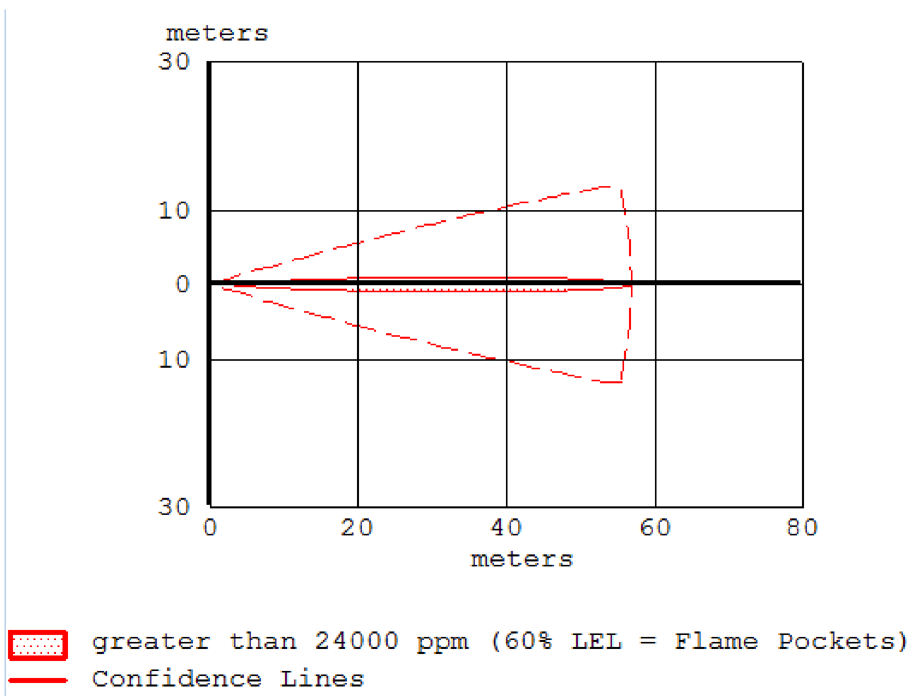
5.7.2 Consequence Assessment

In order to conduct the air dispersion modelling for hydrogen release, the ALOHA model was used.

Figure 5-3 shows the ALOHA model results for this release scenario.

The ALOHA results indicate that the concentration of hydrogen drops below 60% of LEL within 58 m of the release location. Therefore, no vapour-cloud explosion is expected offsite.

Figure 5-3 - ALOHA Model Results for Hydrogen Release



5.7.3 Probability Assessment

Similar to Section 5.1 the frequency of the hydrogen release and ignition offsite is expected to be approximately 0.0002 per year. This is based on three broken pipe sections and three faulty valves, and 1% conditional probability of ignition offsite (note that Hydrogen is very buoyant and it is extremely unlikely that it forms explosive mixture away from the release location).

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 58 m distance from the explosion (during an explosion) is less than 0.01. Therefore, the frequency of public fatality is less than $1x10^{-6}$ per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 15 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:120 people with the frequency of less than 10^{-8} per year

5.8 FIRE INVOLVING LIQUID PHENOL

5.8.1 Scenario Definition

This scenario involves release of phenol from damaged storage tanks or reactor, broken pipe, or faulty valves or pumps.

It is expected that less the maximum release amount would be less than 10,000 kg phenol. It was assumed that the released phenol will form a pool with a depth of 10 cm and area of 95 m^2. Upon ignition, the pool fire will be 12 m in diameter.

5.8.2 Consequence Assessment

The hazard end point for thermal injury is the thermal load equivalent of 5 kW/m^2 for 40 seconds. This is the criterion specified by the U.S. EPA[1] for either workers or members of the public. This radiation intensity corresponds to second degree burns to the skin of humans exposed to the fire. The radiation intensity criterion decreases with the duration of exposure time (TNO 1992). The thermal radiation resulting in lethality was generally taken as 12.5 kW/m^2 to 37.5 kW/m^2.

Application of solid flame model (CCPS 1994) for a typical liquid phenol pool of 12 m in diameter gives a minimum safe distance of 52 m (based on the criteria of 5 kW/m^2) from the fire. This analysis indicates that the impact of release of phenol is contained locally with no measurable effect away from the site.

[1] 12(r) Risk Management Program rule (U.S. EPA, 1999, p. E-13)

5.8.3 Probability Assessment

Analogues the Section 5.1, the overall frequency of the release will be 0.02 per year. Due to considerably higher flash point for phenol (79ºC) compared with methanol flash point (11ºC), the conditional probability of ignition was assumed at 1%. , therefore frequency of a phenol fire will be 0.0002 per year.

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 52 m distance from the fire (during a fire event) is less than 0.001. Therefore, the frequency of public fatality is less than $1x10^{-6}$ per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 10 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 25 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:150 people with the frequency of less than 10^{-8} per year

5.9 RELEASE OF HYDROGEN TO AIR AND CONSEQUENT FIRE BALL

5.9.1 Scenario Definition

This scenario involves release of hydrogen from broken pipes or faulty valves.

The maximum flow rate of hydrogen in the proposed plant will be to the absorber. The flow rate will be 227 kg/hour hydrogen. In this scenario, it was assumed that upon a major pipe break, it would take 5 minutes to shut off the broken pipe segment. During this period, approximately 19 kg of hydrogen will be released to the atmosphere. If the released gas forms an explosive mixture, it may ignite and will create a fire ball.

5.9.2 Consequence Assessment

Catastrophic failure of a pipe may release relatively large quantities of hydrogen gas. Subsequently an explosive vapour may be created in the vicinity of the release location. If the cloud is confined and ignited, a blast from a fireball could damage the structures and facilities near the release area and may cause injuries or fatalities.

For modelling hydrogen fireball hazards, the Multi-Energy model developed by TNO in The Netherlands (TNO 2005a) and described in CCPS (1994) was used. This model provides information on the overpressure P_s as a function of distance from the blast location.

Table 5-4 shows the blast overpressure versus distance from a 19 kg hydrogen fireball.

Table 5-4 - Blast Overpressure versus Distance from the Hydrogen Fireball

Distance, m	Blast Overpressure, psi
50	18.6
100	5.1
250	1.9
500	0.5

These results show that a fireball may affect other storage tanks within 100 m. Therefore, it is expected that other storage tanks within the tank farm may be affected. The release from other tanks has been assessed in other scenarios. Worker injuries may occur at a distance of less than 100 m from the fire ball. Fatalities may occur in very close proximity to the ignition (less than 50). As the closest regularly occupied building is at least 150 m away from the storage tank, no injuries or fatalities are expected, except in rare occasions when workers are at the site for maintenance activities. The probability of such events is extremely low. Damage to the residential structures offsite is not expected.

5.9.3 Probability Assessment

Similar to Section 5.7, the frequency of the hydrogen release and ignition onsite is expected to be approximately 0.002 per year. This is based on three broken pipe sections and three faulty valves, and 10% conditional probability of ignition offsite (note that Hydrogen is very buoyant and it is extremely unlikely that it forms explosive mixture away from the release location).
The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 50 m distance from the fire (during a fire event) is less than 0.001. Therefore, the frequency of public fatality is less than 1×10^{-6} per year. The frequencies at the greater distances are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 5 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 15 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m:120 people with the frequency of less than 10^{-8} per year

5.10 RELEASE OF CARBON MONOXIDE TO AIR AND CONSEQUENT FIRE BALL

5.10.1 Scenario Definition

This scenario involves release of carbon monoxide from broken pipes or faulty valves.

The maximum flow rate of carbon monoxide in the proposed plant will be to the absorber. The flow rate will be 22 kg/hour carbon monoxide. In this scenario, it was assumed that upon a major pipe break, it would take5 minutes to shut off the broken pipe segment. During this period, approximately 1.8 kg of carbon monoxide will be released to the atmosphere. If the released gas forms an explosive mixture, it may ignite and will create a fire ball.

5.10.2 Consequence Assessment

Catastrophic failure of the pipe may release carbon monoxide. Subsequently an explosive vapour may be created in the vicinity of the release location. If the cloud is confined and ignited, a blast from a fireball could damage the structures and facilities near the release area and may cause injuries or fatalities.

For modelling carbon monoxide fireball hazards, the Multi-Energy model developed by TNO in The Netherlands (TNO 2005a) and described in CCPS (1994) was used. This model provides information on the overpressure P_s as a function of distance from the blast location.

Table 5-5 shows the blast overpressure versus distance from a 1.8 kg carbon monoxide fireball.

Table 5-5 - Blast Overpressure versus Distance from the Carbon Monoxide Fireball

Distance, m	Blast Overpressure, psi
50	4.9
100	1.3
250	0.5
500	0.1

Worker injuries may occur at the distance less than 50 m from the fire ball. Damage to the residential structures offsite is not expected. Fatalities may occur within few metres from the incidents.

5.10.3 Probability Assessment

Similar to Section 5.8, the frequency of the carbon monoxide release and ignition onsite is expected to be approximately 0.004 per year. This is based on three broken pipe sections and three faulty valves, and 20% conditional probability of ignition offsite.

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 20 m distance from the fire (during a fire event) is less than 0.001. Therefore, the frequency of public fatality is less than $4x10^{-6}$ per year. The frequencies at the greater distances or at the facility boundary are expected to be lower. Estimating the frequencies and the number of fatalities at the greater distances can be done semi-quantitatively based on the information available in Figure 1-2 and Figure 1-3 with the following conservative assumptions:

- Maximum fatalities within 400 m: 3 people with the frequency of less than 10^{-6} per year
- Maximum fatalities within 500 m: 8 people with the frequency of less than 10^{-7} per year
- Maximum fatalities within 800 m: 60 people with the frequency of less than 10^{-8} per year

5.11 RELEASE OF CARBON MONOXIDE TO AIR WITH TOXIC EFFECTS

5.11.1 Scenario Definition

This scenario involves release of carbon monoxide from broken pipes or faulty valves.

The maximum flow rate of carbon monoxide in the proposed plant is to the absorber. The flow rate will be 22 kg/hour carbon monoxide. In this scenario, it was assumed that upon a major pipe break, it takes 5 minutes to shut off the broken pipe segment. During this period, approximately 1.8 kg of carbon monoxide will be released to the atmosphere. The released gas will move offsite and form a toxic atmosphere.

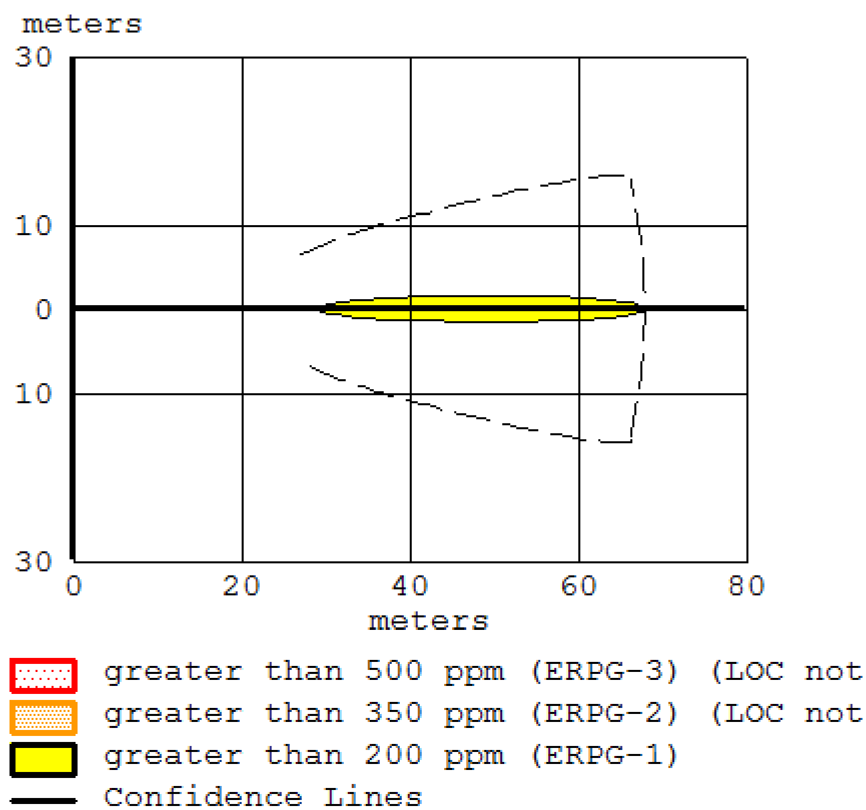
5.11.2 Consequence Assessment

In order to conduct the air dispersion modelling for carbon monoxide release, the ALOHA model was used.

The ALOHA results indicate that the concentration of carbon monoxide drops below ERPG level 2 within 40 m and bellow ERPG level 1 within less than 70 m of the release location. Therefore, no adverse toxic effect is expected offsite. Fatality may only occur at a very close proximity of the incident in case of a long exposure.

Figure 5-4 shows the ALOHA model results for this release scenario.

Figure 5-4 - ALOHA Model Results for Carbon Monoxide Release



5.11.3 Probability Assessment

Similar to Section 5.8 the frequency of the carbon monoxide release and toxic effects offsite is expected to be approximately 0.02 per year. This is based on three broken pipe sections and three faulty valves. Fatality may only occur at a very close proximity of the incident

The safe distance to the source of fire is within the facility boundary and the probability of the presence of members of the public within 40 m distance from the incident is less than 0.001. Therefore, the frequency of public fatality is less than 1×10^{-6} per year. The frequencies at the greater distances are expected to be lower. No fatalities are expected outside the plant boundaries at any conditions.

6.0 SUMMARY AND CONCLUSIONS

The contour plots of isopleths of individual risk for various scenarios are shown in Figure 6.1.

As the plot shows no fatalities are expected outside the facility boundary with the frequency greater than 10^{-6} per year.

The F-N plots of the calculated societal risk for various scenarios are presented in Figure 6-2. Comparing the F-N plots for scenarios with the line through (0.0001, 1) with a slope of -1 shows that the societal risk for all scenarios are less than negligible.

A summary of the quantitative risk assessment results of the selected bounding accident scenarios are also provided in Table 6-1. In this context, the 'Risk' is defined based on the risk matrix provided in Figure 2-2.

It is shown that, the mitigated risk from all accident scenarios is acceptable. This means that the proposed preventive and mitigative measures are adequate to maintain the risk for all proposed accident scenarios at acceptable levels. The only exception is the accident scenario #6 "Offsite vapour cloud explosion from formaldehyde vapour release". In this scenario, the toxic effect of formaldehyde is not dependent on the ignition of the vapour cloud. Therefore, the frequency of exposure for the scenario becomes 0.02 per year and the risk becomes As Low As Reasonably Practicable (ALARP). This is based on the concentrations exceeding the ERPG level 3 at which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

For accidental releases, the indoor air concentrations are much smaller than outdoor air concentrations at the receptor locations immediately following a release. The exposure is short-term, therefore, to minimize the exposure it is advisable that the residence stay inside for a short period following a release and keep all doors and windows closed, and turn off all ventilation and air conditioning systems.

Table 6-1 - Summary of Probabilities and Impacts for Accident Scenarios

Sc No.	Bounding Accident Scenario	Frequency per Year	Consequence	Risk
1	Fire involving liquid methanol	0.002 or rank 2	2 - Moderate	Acceptable
2	Fire involving formaldehyde solution	0.001 or rank 2	2 - Moderate	Acceptable
3	Release of methanol vapour and consequent BLEVE	10^{-6} to 10^{-5} or rank 1	4 - Very Serious	Acceptable
4	Release of formaldehyde vapour and consequent BLEVE	10^{-6} to 10^{-5} or rank 1	4- Very Serious	Acceptable
5	Offsite vapour cloud explosion from methanol vapour release	0.001 or rank 2	1 - Minor	Acceptable
6	Offsite vapour cloud explosion from formaldehyde vapour release	0.0004 or rank 1*	2 - Moderate	Acceptable*
7	Offsite vapour cloud explosion from hydrogen release	0.0002 or rank 1	1 - Minor	Acceptable
8	Fire involving liquid phenol	0.0002 or rank 1	2 - Moderate	Acceptable
9	Release of hydrogen to air and consequent fire ball	0.002 or rank 2	2 - Moderate	Acceptable
10	Release of carbon monoxide to air and consequence fire ball	0.004 or rank 2	2 - Moderate	Acceptable
11	Release of carbon monoxide to air with toxic effects	0.02 or rank 3	1- Minor	Acceptable

Notes
* For toxicity effect the frequency is 0.02 and the risk becomes ALARP

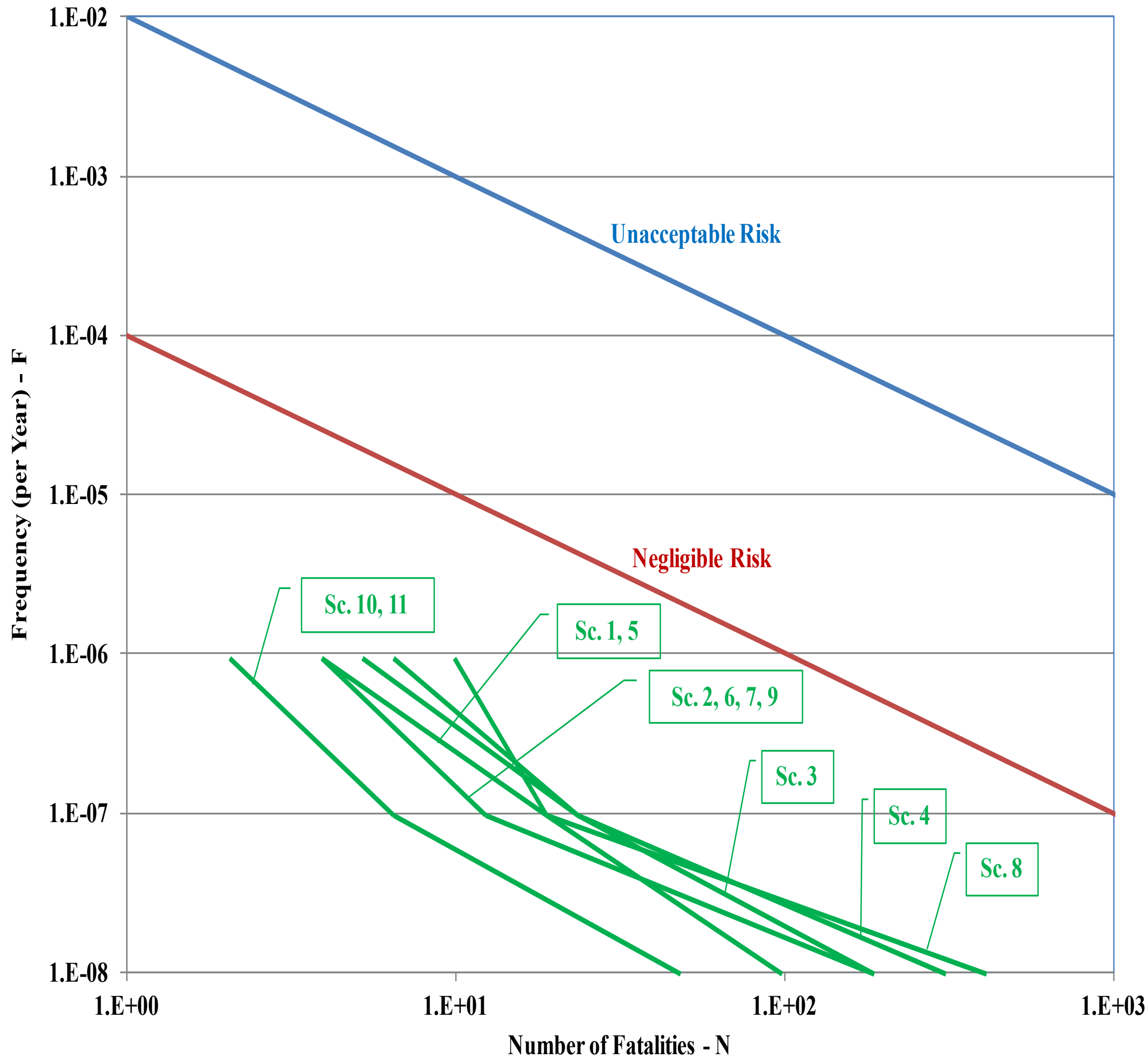
6.1 Cumulative Effects

The results of the QRA indicate that the frequency of the fatality of members of the public is less than 10^{-6} per year for all bounding accidents scenarios. It is possible that an accident scenario would result in a secondary accident. For example, a fire in a storage tank may spread to another storage tank or facility, if the fire fighting measure fails to prevent the spread of the fire. However, given the conditional probability of such event, the cumulative frequency of multiple simultaneous accident scenarios will be less than 10^{-6} per year. In addition, considering the results of consequence assessment, it is not expected that the consequence of multiple scenarios be experiences outside the facility boundary with a frequency greater than 10^{-6} per year.

Figure 6-1 - Contour Plots of Isopleths of Individual Risk of 10^{-6} per Year

INTEGRATED CHEMICAL COMPLEX SITE

Figure 6-2 - F-N Plots of the Calculated Societal Risk for Various Scenarios

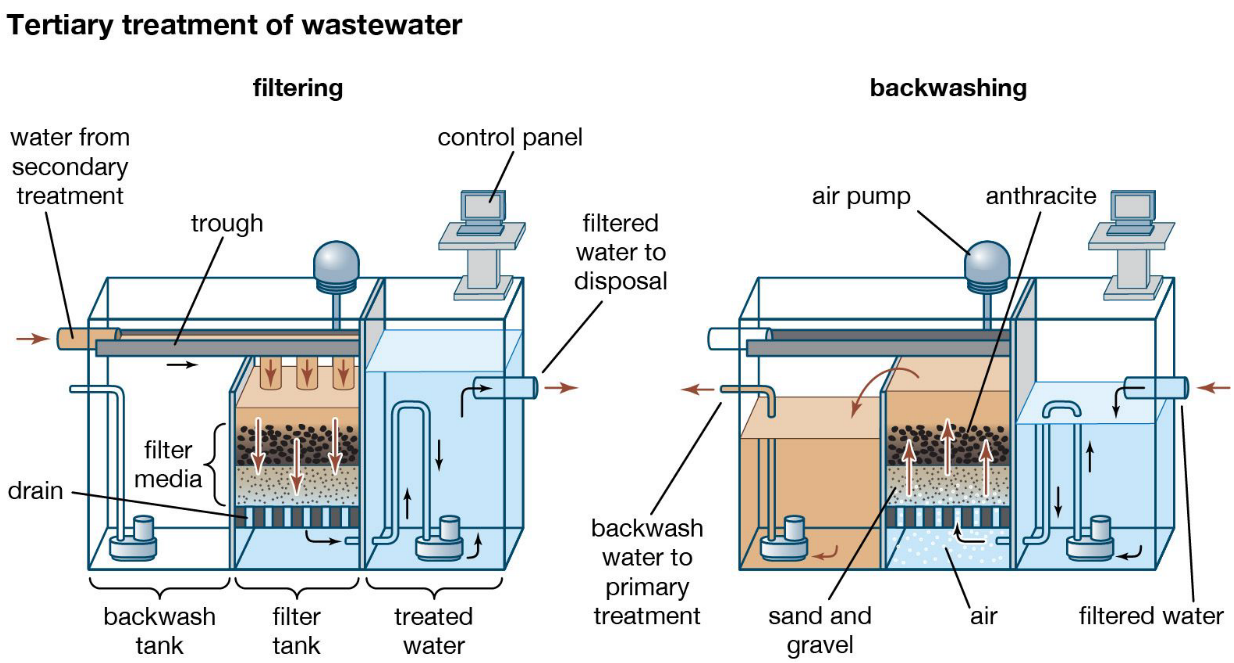


7.0 WASTE WATER

Tertiary Treatment of Wastewater

(Left design) During the filtering step, wastewater from secondary treatment, still containing suspended solids, pours from a trough and percolates through a filter bed made of porous media such as sand, gravel, and anthracite. The filtered water is then piped away for disposal. (Right design) In the backwashing step, entrained solids are periodically flushed from the filter media by pumping filtered water back through the assembly. The backwash water, carrying suspended solids, is returned to the beginning of the wastewater treatment process.

Figure 7-1 – Tertiary Treatment of Wastewater



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