PLANT RISK ASSESSMENT DOCUMENT

In accordance to Legal notice 114 of 2007 "Environmental Impact Assessment Regulations, 2007 Arrangement of Regulations"

Branch: **Industrial Estate**

Hal Far HF 51

Malta

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1. INTRODUCTION AND PURPOSE

The identification of risks in an industrial plant consists in identifying the hazards and assess them on the basis of the consequences they may have on the people involved and on the environment, in addition to economic damages for loss of production. The risk identifying aims to find what might happen or what situations may occur and what effect could have on the plant and on the organization. The process of the risk identifying includes the assessment of the causes and origins of the risk, the events, conditions or dangerous circumstances. This is a fundamental activity in the design of a plant and it starts from the very preliminary stages of the project, taking into account the fact that the decisions taken from the beginning may have an effect on the reliability and safety of the plant. However, it is important to carry out activities for the identification and assessment of risks throughout the life cycle of the plant, monitoring the changes introduced not only in the case of major interventions, but also in the case of ordinary operations such as replacement of devices or components.

Therefore the purpose of this document is to assess the risks, the possible major accidents and the consequences that can occur both within the plant of the Sterling Chemical Malta LTD, and on the surrounding environment.

The normative reference for the assessment of risk from a major accident is the Legal Notice 36 of 2003 “Control of Major Accident Hazard Regulation", as amended by Legal Notice 6 of 2005.

In fact, the plant of the Sterling Chemical Malta LTD, based on the verification, does not fall within the scope of this Regulation because there are no substances listed in the Annexes in the expected quantities.

The document (Plant Risk Assessment) instead comply to the requirements of art. 16 of Legal Notice 114 of 2007 "Environmental Impact Assessment Regulations, 2007 Arrangement of Regulations" and the requirements of the clause 4.3 of the Terms of Reference issued by MEPA (Malta Environment & Planning Authority) for the preparation of the Environmental Impact Statement (EIS) that obliges the employer to determine the risks of the use, handling, transportation and storage of hazardous substances. This document is necessary for the application of the European IPPC (Integrated Pollution Prevention & Control 2010/75/EU) on the containment of the industrial emissions within the member countries of the European community.

The assessment of the major hazards in this document was made from Sterling Chemical Malta Ltd in collaboration with Trecon Srl.

2. ASSESSMENT METHODOLOGY

The techniques used for the identification and assessment of the risks are several. In general there is a better technique than the others, but each has different characteristics that must be taken into account before choosing which one to consider. They use different types of information and can be applied at various stages of the life cycle of the plant. Some of them require only the general aspects of the process and therefore they result more suitable for the conceptual stages of the project, while others require the detailed description of the plant and are used in the operational phase and operation of the plant.

In this report are used techniques of the reliability study as:

- Index method
- Analysis of operability
- Fault tree and probabilistic calculation
- Event tree
- Assessment of the consequences through the spreadsheets use

These are all techniques born in the chemical and oil industry, but applicable in all productive activities in a continuous process, including food, pharmaceutical, energy, metallurgy and the cement.

3. RELIABILITY ANALYSIS

3.1. THE INDEX METHOD

This method has been developed at the time by the Institute for Prevention and Safety at Work in collaboration with the Italian Institute of Health and IT was an important moment of original synthesis of the most popular methods, tailored to the specific needs of techniques and regulations. The method does not require considerable detailed information on the operation of the plant and represents a very good guide for the decisions relating to the installation choices.

The index method is an attempt to estimate the risk due to the occurrence of certain events, through the calculation of a series of conventional indexes, in order to limit the risk analysis to specific areas of the plant (critical areas).

Precursors of this method were other methods used in the international area as the Dow-AicheEi, of U.S. origin used in insurance and refining, and the Mond-Ici, of Anglosaxon origin used for the chemical plants.

All index methods operate on an assignment policy of set scores negative or positive; negatives are the elements that worsen the risk, positive the ones that improve safety. The final balance between the various factors leads to numerical risk index for the facility in question.

Nowadays, the Italian legislation, have planned 3 applications of the method to index through procedures reported in many decrees:

1. D.P.C.M. 31/03/1989 "Applicazione dell'art.12 del decreto del Presidente della Repubblica 17 maggio 1988, n.175, concernente rischi rilevanti connessi a determinate attività industriali" (Application of Article 12 of the Decree of the President of the Republic 17 May 1988 175, concerning significant risks associated with certain industrial activities) that applies to the plants in general;
2. D.M. 20/10/1998 "Criteri di analisi e valutazione dei rapporti di sicurezza relativi ai depositi di liquidi facilmente infiammabili e/o tossici" (Policy analysis and evaluation of safety reports related to deposits of highly flammable and/or toxics);
3. D.M. 15/05/1996 "Criteri di analisi e valutazione dei rapporti di sicurezza relativi ai depositi di gas e petrolio liquefatto (GPL)" (Policy analysis and evaluation of safety reports related to deposits of gas and liquefied petroleum gas LPG);

The method begins with the division of the plant into logical units, each of them corresponding to a single processing of the production process. For each unit, based on the hazard characteristics of the substance, it it necessary to identify the substance subject to a predominant risk, ie the compound or mixture present in the unit that for their intrinsic characteristics and the quantities present, in case of fire or explosion, provide the higher potential energy, and a "material factor" must be assessed. The material factor is a measure of the energy content per unit of weight of the substance present, and provides a data base for numerical indices. The material factor of many substances are already calculated and recorded. Where not recorded, the reactivity characteristics and flammability of the predominant substance are taken into account, as well as the temperature at which the processing is carried out.

After that, there is the exam of the unit using a checklist of more than 40 points reviewing in detail all the aspects that could affect the security grouping them according to a logical path that involves:

- <u>the specific risks of the "M" substances</u>: into account are taken particular properties of the predominant substance that may affect the nature of an accident or on the possibility that it will occur, such as oxidizing power, the reactivity with the water, the polymerization etc.. and the substance is considered in the conditions in which it normally is within the unit;
- <u>the general risks of the "P" process</u>: into account are taken the common risks associated with the basic process or with other operations performed within the units, such as manipulation, reactions, transfer, pouring in containers, etc..;
- <u>the particular risks of the "S" process</u>: for the determination of this parameter, there are some factors of penalty depending on the specific operating conditions suitable for the

conduct of the process, such as temperature, pressure, flammable range, electrostatic problems, difficulty on the controlling reaction, etc..;

- risks due to the "Q" quantities involved: there is the attribution of one factor for the additional risks associated with the use of large quantities of combustible, flammable, explosive and decomposable;
- the risks associated with peculiarities arising from the "L, H, N" "layout" of the plant: there is the study of the physical structure of the unit and the plant relative to the ground plan and the vertical surfaces of the equipments containing flammable liquids, ventilation systems and surface drainage, the possible domino effects and the placement of the rooms permanently occupied by people;
- the health risks in case of "s" accident: this parameter takes into account the toxicity of the substances on the overall assessment of the unit, assessing the effects of delay caused by the toxicity of the material while dealing with an accident or a risk of an accident. In fact, since an accident involves the release of a substance, where the operators, to approach the point of the release, must wear the protective equipments, there will be a delay in dealing with the accident and a higher likelihood of a relevant fire or explosion.

Each of the sections is further subdivided to take account of individual issues in order to assign penalty factors and in each case, there are elements, provided in the recommended range, for the factors to assume. For each of these groups, there is a corresponding numerical factor. From a complex combination of factors, derived from the checklist and from the "material factor", it is calculated an overall risk index and the inherent indices for the fire, confined explosion, unconfined explosion (in air), toxic release. The numerical values of the indices are converted, according to a system of categories, to a gradation of qualitative values ranging from light to serious, according to the summary table, page 40.

In this case, the index method was applied to the following units:

A - Raw materials and waste storage area (External Inflammable Warehouse)
B - Production Area (lines L1 and L2[1])
C - Storage area and offloading gas (LPG Tanks)

In cases A it was applied the D.M. specified in step 2., in case B the DPCM specified in step 1. and in case C, the DM specified in step 3.

[1] As for the unit B it is not known the production capacity of L3 because it is strongly linked to the developments in the market, therefore it will not be taken into account in the assessment step.

A - RAW MATERIALS AND WASTE STORAGE AREA (EXTERNAL Inflammable WAREHOUSE)

In this area as a reference were taken the following work phases:

1. Storage and handling of raw materials

   The raw materials to be sent to the production are stored in this area bounded by a steel cover with iron support with a maximum height of 5.35 m at the center where are allocated the not conveyed chimneys serving as natural escape routes for any vapors that can accumulate under cover in case of spills or leaks from the containers. The materials contained in IBC (Intermediate Bulk Container) from 1m3 each, are here allocated on two of the three rectangular tanks, identified as Zone 2 and Zone 3. The IBC's stand on platforms, typically made of wood, and on fasteners tracing the longitudinal wall of the shed and moved by forklifts.

2. Fractionation and weighing of the raw materials

   In this phase, the weighing of the raw materials to be sent to the production with a steel platform scale placed on a basin with grid surface and a support surface as a support for tanks or drums. The transfer of the liquids from a tank to another occurs through closed circuit in order to prevent the contact with the liquids free air and their gases (volatile organic compounds) to avoid the formation of flammable mixtures and the vapor dispersion. This area is completely separated from the storage warehouse through a concrete wall that allows to isolate the area in case of a possible fire. At the end, the affected area is freed from any residue of the previous product.

3. Waste disposal

   The tanks of waste sent for disposal (mainly waste water used for the cleaning of reactors, centrifuges, filters and heat exchangers or balls of collection) are placed on a storage basin consisting of a reinforced concrete tank with a certain volumetric capacity collection of eventual spilled liquids, identified as Zone 1. The basin is not unique but it is divided into two areas by a vertical intermediate septum that allows to keep separate the waste with the incompatible EWC codes. The IBC containing liquid wastes lean on platforms, typically made of wood, and are allocated on the docks directly leaning on locks that trace longitudinally the wall of the shed.

The IBC's, shall be stored on three vertical rows in bulk from 1 m^3 each. These zones have independent access via a ramp with which, by forklift, the operators can fix the tanks of raw materials/waste. Hazardous waste is sent for recycling or disposal at least every 20 days regardless of the amount and they are loaded onto trucks of external specialized companies, who will bring them to appropriate destinations.

Based on the quantity of the substances and their hazardous properties assessed by the relevant safety data sheets, they result key substances for the application of the index method:

- **Methanol** (as raw material for the production phase)
- **Acetone** (as raw material for the production phase)
- **Waste EWC code 070701 *** (refusal to be allocated for disposal at a licensed installation)

The choice of the substances was carried out taking into account se those flammable substances that are usually more present as quantity within the area of External Inflammable Warehouse (although the involved quantities are closely linked to the production schedule and the customer demand).

The chosen substances simulate in a proper way the presence of additional substances, mainly flammable, in the storage but with quantities much lower than those of the key substances. In the case of waste EWC code 070701*, as a reference there is the type with higher risk phrases and lower flame temperature (aqueous washing liquids and mother liquors - fluticasone - code sample 1200685-002).

For The index method application, forasmuch as the storage amount in according to the production program, has been evaluated different scenarios by taking into account the following assumptions:

- For raw material like methanol and acetone it has been considered a limit quantity value assuming that they fully occupied their bund present in zone 2 of External flammable warehouse (about amount 19 tons). HYPOTHESIS 1.1 (for methanol) and 2.1 (for acetone)
- The substance behavior (methanol and acetone) it has been evaluated considering both a single IBC (amount 0.79 tons) and medium/yearly amount storage (about 15 tons of methanol and 7 tons of acetone). Hypothesis 1.2 and 1.3 (for methanol) and 2.2 and 2.3 (for acetone)
- For the waste shipment to disposal it has considerated the unloading on van of n.o 10 IBC (max volume 1 m^3), for amount about 10 tons. HYPOTHESIS 3.1

KEY SUBSTANCE 1: METHANOL

HYPOTHESIS 1.1: 19 tons substances storage (volume max storage bund-containment basin)

NOT-COMPENSATED RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A – Raw material and waste storage area** **(EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipments	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of $1m^3$. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance	**METHANOL**	
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	19,000

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks	**0**

PROCESS GENERAL RISKS: (P)	GRADE
Penalizations (Σ)	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (fattore 0-100)	25
3.4.2.3. Transportable containers (fattore 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS: (S)	GRADE
Penalizations(Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

Risks analysis for plant placement: (L),(H),(N)	GRADE
Penalizzations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	30
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**391.8**

Risks analysis for dangerous substances*(s):*	**GRADE**
3.4.6. Health risk from incident case(***s***)	**46**

Summary for the risks calculation	
SUBSTANCE FACTOR*(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS*(P)*	75
PROCESS SPECIFIC RISKS*(S)*	216
QUALITY RISKS*(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	391.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	46
AMOUNT SUBSTANCE*(K)*	19,000
HIGH PRESSURE FACTOR*(p)*	1
HEIGHT*(H)*	0.35
NORMAL WORKABLE AREA*(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 9.68

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 3.36

EQUIVALENT INDEX

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 215.25

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 651.60

HYPOTHESIS 1.2: Substance storage (0.79 tons into IBC)

NOT-COMPENSATED RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A - Raw material and waste storage area** **(EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance	**METHANOL**	
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	790

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS*(P)*	**GRADE**
Penalizations (Σ):	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (fattore 0-100)	25
3.4.2.3. Transportable containers (fattore 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS *(S):*	**GRADE**
Penalizations(Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

Risks analysis for plant placement: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	-20
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**341.8**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s):*	**GRADE**
3.4.6. Health risk from incident case (***s***)	**46**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR*(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE*(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	341.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	46
AMOUNT SUBSTANCE*(K)*	790
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT*(H)*	0.35
NORMAL WORKABLE AREA *(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 0.40

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 3.36

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 201.25

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 284.44

HYPOTHESIS 1.3: n.15 tons substance storage (yearly medium volume into n.1 bund-containment basin)

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A - Raw material and waste storage area** **(EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance		**METHANOL**
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	15,000

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS*(P):*	**GRADE**
Penalizzations (Σ):	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (fattore 0-100)	25
3.4.2.3. Transportable containers (fattore 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS *(S):*	**GRADE**
Penalizations(Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	30
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**391.8**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s):*	**GRADE**
3.4.6. Health risk from incident case (***s***)	**46**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE *(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	391.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	46
AMOUNT SUBSTANCE *(K)*	15,000
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT *(H)*	0.35
NORMAL WORKABLE AREA *(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 7.64

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 3.36

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 215.25

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 602.96

KEY SUBSTANCE N.o 2: ACETONE

HYPOTHESIS 2.1: n.o 19 tons substance storage (max volume for storage into the bund)

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A – Raw material and waste storage area** **(EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance	**ACETONE**	
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	19,000

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS: *(P)*	**GRADE**
Penalizations (Σ):	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (fattore 0-100)	25
3.4.2.3. Transportable containers (fattore 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS: *(S)*	**GRADE**
Penalizations(Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	30
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**391.8**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*:	GRADE
3.4.6. Health risk from incident case (***s***)	**14**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE *(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	391.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	14
AMOUNT SUBSTANCE *(K)*	19,000
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT *(H)*	0,35
NORMAL WORKABLE AREA *(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 9.68

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 12.39

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 206.29

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 624.48

HYPOTHESIS 2.2: Substance storage (0.79 tonns into IBC)

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A - Raw material and waste storage area (EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance	**ACETONE**	
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	790

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerizzation (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS: *(P)*	**GRADE**
Penalizations(Σ)	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (fattore 0-100)	25
3.4.2.3. Transportable containers (fattore 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS: *(S)*	**GRADE**
Penalizations (Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	-20
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**341.8**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*:	**GRADE**
3.4.6. Health risk from incident case (**s**)	**14**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE *(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	341.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	14
AMOUNT SUBSTANCE *(K)*	790
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT *(H)*	0.35
NORMAL WORKABLE AREA *(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 0.40

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 12.39

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 192.29

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 271.77

HYPOTESYS 2.3: n.o 7 tons substance storage (yearly medium volume into n.o 1 bund)

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICAL MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A - Raw material and waste storage area** **(EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage liquid and in particular methanol. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid.

Key substance	**ACETONE**	16
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	7,000

SUBSTANCES SPECIFIC RISKS: (M)	**GRADE**
Penalizations (Σ)	
3.4.1.1. Substances reacting with the water forming a fuel gas (factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS: (P)	**GRADE**
Penalizations (Σ)	
3.4.2.1. Handlings (factor from 10 to 50)	10
3.4.2.2. Substances transfer (Range factor 0-100)	25
3.4.2.3. Transportable containers (Range factor 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS: *(S)*	**GRADE**
Penalizations (Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.35
3.4.5.2. Normal workable area: (**N**) (units: square meter)	31.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	30
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**391.8**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*:	**GRADE**
3.4.6. Health risk from incident case (***s***)	**14**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE *(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	391.75
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	14
AMOUNT SUBSTANCE *(K)*	7,000
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT *(H)*	0.35
NORMAL WORKABLE AREA *(N)*	31.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) — F= 3.57

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 0.69

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 12.39

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 206.29

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 460.12

KEY SUBSTANCE 3: EUROPEAN WASTE CODE 070701* - aqueous washing liquids and mother liquors

IPOTESI 3.1: Shipment and disposal Waste of n°10 IBC

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**A - Raw material and waste storage area (EXTERNAL INFLAMMABLE WAREHOUSE)**
Equipment	Intermediate Bulk Container used for transport and storage hazardous waste liquid and in particular aqueous washing liquids and mother liquors. These IBCs have a volume of 1 m^3. Bund is an embankment which forms the perimeter and floor of a compound and provides a barrier to retain liquid. The capacity volume of bund Is 12 m^3

Key substance	**EUROPEAN WASTE CODE 070701***	
Factor substance	***(B)***	16
Quantity factor substance	***(Q)***	15
Amount substance	***(K)***	10,000

SUBSTANCES SPECIFIC RISKS: *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Contact with water liberates extremely flammable gases (range factor 0-30)	0
3.4.1.2. Natural warming (factor from 30 to 250)	0
3.4.1.3. Natural polymerization (factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (factor from -75 to 150)	0
3.4.1.5. Other unusual behaviors (factor from 0 to 150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS: (P)	**GRADE**
Penalizations (Σ)	
3.4.2.1. Handlings (Range factor from 10 to 50)	10
3.4.2.2. Substances transfer (Range factor 0-100)	25
3.4.2.3. Transportable containers (Range factor 10-100)	40
Total factor of process general risks (P)	**75**

PROCESS SPECIFIC RISKS: *(S)*	**GRADE**
Penalizations (Σ)	
3.4.3.1. High pressure: (**p**) (factor from 0 to 160)	1
3.4.3.2. High temperature	25
3.4.3.3. Corrosion and Erosion Risks	
3.4.3.3.1. Inside corrosion (factor 0-100)	0
3.4.3.3.2. Outside corrosion (factor 20-100)	20
3.4.3.4. Leaks joints and seals (factor 0-100)	10
3.4.3.5. Vibrations, Equipment cycle loading and natural causes RISKS	
Vibrations and cycle loading of equipments	0
3.4.3.6. Operation within the flammable range (factor 0-100)	100
3.4.3.7. Electrostatic risks	60
3.4.3.8. Intensive use risks	0
Total factor process specific risks (S)	**216**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	0.30
3.4.5.2. Normal workable area: (**N**) (units: square meter)	15.4
3.4.5.3. “lay-out” penalization factor (**L**)	
3.4.5.3.1. Structural design	30
3.4.5.3.2. Domino effects (factor 0-250)	150
3.4.5.3.3. Underground structure	80
3.4.5.3.4. Surface drainage	50
3.4.5.3.5. Other characteristics	50
Total factor of risks analysis for plant placement (L)	**375.7**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*:	**GRADE**
3.4.6. Health risk from incident case (***s***)	**8**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	75
PROCESS SPECIFIC RISKS *(S)*	216
QUANTITY FACTOR SUBSTANCE *(Q)*	15
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	375.7
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	8
AMOUNT SUBSTANCE *(K)*	10,000
HIGH PRESSURE FACTOR *(p)*	1
HEIGHT *(H)*	0.3
NORMAL WORKABLE AREA *(N)*	15.4
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/(N*1000) | F= 10.39

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 | C= 3.91

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 | A= 0.59

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 | T= 3.98

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 | D= 200.12

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) | G= 589.19

B – PRODUCTION AREA (L1 and L2 lines)

The production area consists in a multipurpose facility divided into three work areas:

1. The *Steroids Production Area* contains reactors, centrifuges and filters. This equipment handlings raw material turn into intermediate or finished products;
2. The *Steroid Finishing Area*, contains dryer, centrifuges and filters for intermediate dry-up and wrap products too;
3. The *Utilities Area* where are located the machine manage working fluids.

There is a fourth area also, the auxiliary equipment's area that includes all equipment not covered in other areas.
This equipment are all mobile machine necessary for still system, just like:
- filters,
- reactors,
- pumps,
- scales,

equipment for logistic and transport, just like
- transpallet,
- forklift truck.

The Steroid Production Area is divided into three production line with different reactors used . The reactors may vary for numbers, volume capacity, building materials, but the operative method, the scope e purpose and utilities employed are same as. After IPPC and EIA permit, the Steroid Production Area consists in two active production lines. For the risk analysis will be considered the line L1 only.

For the risk assessment, in this report are taken into account "Steroids Production Area" and the "auxiliary equipment area" sections because this areas may cause major environmental problems both for the safety workers in the event of accident.
The Steroid finishing area is controlled by air handling unit dedicated than consists of an input s, distribution and expulsion section, then definitely lower risk.

On the strength of amount substances and their dangerousness is believed key substance in the production area:

- **Methanol**

The choice of this key substance was made taking into consideration, among all flammable / toxic substances, that for intrinsic characteristics and quantities handled, may lead to higher risk.
For the index method calculation by DPCM 31/03/1989 (Italy low reference), the event has been considered to use methanol into greater reactor of the L1 production line.

KEY SUBSTANCE 3: METHANOL

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd	
Place	MALTA - HAL FAR 51	
Plant	API Manufacturing Plant	
Unit	**B – Production area (L1 line)**	
Equipment	Reactors, shell-and-tube-condensers, centrifuges/filters	
Key substance	**METHANOL**	
Substance factor	***(B)***	16
Quantity substance factor	***(Q)***	37
Amount substance	***(K)***	8

SUBSTANCE SPECIFIC RISKS *(M)*	**GRADE**
Penalizations (Σ)	
2.4.1.1. Oxidizing agent (range factor 0-20)	0
2.4.1.2. Contact with water liberates extremely flammable gases (range factor 0-30)	0
2.4.1.3. Miscibility and dispersion: *(m)*	
2.4.1.3.1. Flammable gases of low density (range factor da -60 a 0)	0
2.4.1.3.2. Liquefied flammable gas (range factor 30)	0
2.4.1.3.3. Cryogenic storage (range factor 0-60)	0
2.4.1.3.4. High viscosity substance (range factor - 20 to 0)	0
2.4.1.3.5. Fuel and inflammable powders (range factor 0-100)	0
Total factor m	***0***
2.4.1.4. Natural heating (range factor from 30 to 250)	0
3.4.1.3. Natural polymerization (range factor 25 - 75)	0
3.4.1.4. Susceptibility of ignition (range factor -75 to 150)	0
2.4.1.7. Trend to explosive decomposition in the gas phase (range factor 75- 125)	0
2.4.1.8. Susceptibility to detonation in the gas phase (range factor 0-150)	0
2.4.1.9. Explosive properties in the condensed phase (range factor 200-1500)	0
2.4.1.10. Other unusual behaviors (range factor 0-150)	0
Total factor of substances specific risks (M)	**0**

PROCESS GENERAL RISKS: *(P)*	**GRADE**
Penalizations (Σ)	
2.4.2.1. Handling and change the physical state only (range factor 10-50)	30
2.4.2.2. Reactions phase	
2.4.2.2.1. Features of Chemical Reaction. (Range factor 25-50)	50
2.4.2.2.2. Discontinuous reaction process (Range factor 10-60)	60
2.4.2.2.3. Equipment-Multipurpose operations and reactions (range factor 25-75)	65
2.4.2.3. Transfer substances (Range factor 0-150)	50
2.4.2.4. Transportable containers (Range factor 10-100)	0
Total factor of process general risks (P)	**255**

PROCESS SPECIFIC RISK: *(S)*	**GRADE**
Penalizations (Σ)	
2.4.3.1. Low pressure (range factor 50-150)	50
2.4.3.2. High pressure: ***(p)*** (range factor 0-160)	0
2.4.3.3. Low temperature (range factor 0-100)	0
2.4.3.4. High temperature	
2.4.3.4.1. Inflammable substances (range factor 0-35)	25
2.4.3.4.2. Strength of Materials. (range factor 0-25)	0
2.4.3.5. Corrosion and Erosion Risks	
2.4.3.5.1. Inside corrosion (Range factor 0-150)	0
2.4.3.5.2. Outside corrosion (Range factor 0-250)	0
2.4.3.6. Leaks joints and seals (factor 0-60)	0
2.4.3.7. Vibrations, Equipment cycle loading and natural causes risks (Range factor 0-100)	0
2.4.3.8. Process or reaction difficult to control (Range factor 20-300)	0
2.4.3.9. Operation within or closeness of flammable range (Range factor 25-450)	150
2.4.3.10. Greater average explosion risk (Range factor 40-100)	40
2.4.3.11. Dust or mist explosion risk (Range factor 30-70)	0
2.4.3.12. Processes using oxidizing gases (Range factor 0- 400)	0
2.4.3.13. The suceptibility process to ignition (Range factor 0-100)	0
2.4.3.14. Electrostatic risks (Range factor 10-200)	75
Total factor of process specific risks (S)	**340**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
2.4.5.1 . Height: (**H**) (unit: meter)	6.0
2.4.5.2. Normal workable area: (**N**) (units: square meter)	30
2.4.5.3. “lay-out” penalization factor (**L**) (range factor 0-200)	25
2.4.5.4. Domino effects (range factor 0-250)	0
2.4.5.5. Underground structure (range factor 50 - 150)	0
2.4.5.6. Surface dreinage (range factor 0-100)	0
2.4.5.7. Other characteristics (range factor 50-250)	50
Total factor of risks analysis for plant placement (L)	**111**

RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s):*	**GRADE**
3.4.6. Health risk from incident case (***s***)	**16**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	16
SUBSTANCES SPECIFIC RISKS *(M)*	0
PROCESS GENERAL RISKS *(P)*	255
PROCESS SPECIFIC RISKS *(S)*	340
QUANTITY FACTOR SUBSTANCE *(Q)*	37
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	111
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	16
AMOUNT SUBSTANCE *(K)*	8
HIGH PRESSURE FACTOR *(p)*	0
HEIGHT *(H)*	0
NORMAL WORKABLE AREA*(N)*	6
TEMPERATURE *(t)*	30
SUBSTANCE FACTOR *(B)*	44

FIRE INDEX

F=B*K/N — F= 4.27

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 6.95

AIR EXPLOSION INDEX

A=B*(1+p)*(Q*H*C/1000)*(t+273)/300 — A= 26.09

TOXIC INDEX

T=1500*(AQ/IDLH)1/2 — T= 2.15

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 343.07

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 5,373.93

C – LPG Storage and loading area (LPG Tanks)

The steam production is delegated to a steam generator that burns LPG stored into 3 vertical tanks of 2,250 liters capacity each. The steam is used in the reactors heating coil.
This area that host 3 tanks is located on the ground floor, outdoor, and is easily accessible from the truck to the gas supply and the eventual maintenance.

The tanks are equipped with all the instruments with the Pressure Equipment Directive complies, including safety valves and pressure gauges. Near them is present a vaporizer of hot water and the first stage pressure regulating valve with relative shut-off OPSO.

The LPG pressure from first regulation stage to steam generator is 700 mbar, Before go into steam generator, a second regulation stage is able to lower pressure until 35 mbar.

In this case, for risk index evaluation, the Italian Legal Notice "DM 15/05/96" was applied, and for equipment intended to contain propane and butane in variable mixture (Types A, AO, A1, B and C), the key substance choice is:

- **Propane**

Considering tankage up to 80% of their volumetric capacity will use as reference quantity 5,400 liters.

KEY SUBSTANCE 3: PROPANE

NO COMPENSATION RISK INDEX CALCULATION

Operator	STERLING CHEMICALS MALTA Ltd
Place	MALTA - HAL FAR 51
Plant	API Manufacturing Plant
Unit	**C – Storage and loading area (LPG Tanks)**
Equipment	n.o 3 LPG tank of 2,250 litres

Key substance	**PROPANE**	
Substance factor	***(B)***	21
Quantity substance factor	***(Q)***	18
Amount substance	***(K)***	2.8

SUBSTANCE SPECIFIC RISKS *(M)*	**GRADE**
Penalizations (Σ)	
3.4.1.1. Miscibility and dispersion: *(m)*	30
Total factor of substances specific risks (M)	**30**

SUBSTANCE GENERAL RISKS: *(P)*	**GRADE**
Penalizations (Σ)	
3.4.2.1. Handling	10
3.4.2.2. Substance transfer	25
3.4.2.3. Transportable containers	0
Total factor of process general risks (P)	**35**

PROCESS SPECIFIC RISKS: *(S)*	**GRADE**
Penalizations (Σ)	
3.4.3.1. High pressure: ***(p)***	46
3.4.3.2. Low temperature	15
3.4.3.3. High temperature	25
3.4.3.4. Corrosion and Erosion Risks	0
3.4.3.5. Leaks joints and seals (factor 0-60)	0
3.4.3.6. Vibrations, Equipment cycle loading and natural causes RISKS	50
3.4.3.7. Operation within or closeness of flammable range	0
3.4.3.8. Greater average explosion risk	40
3.4.3.9. Electrostatic risks	30
3.4.3.10. Risk resulting from intensive use	-0.5
Total factor of process specific risks (S)	**205.5**

RISKS ANALYSIS FOR PLANT PLACEMENT: (L),(H),(N):	**GRADE**
Penalizations (Σ)	
3.4.5.1. Height: (**H**) (unit: meter)	1.1
3.4.5.2. Normal workable area: (**N**) (units: square meter)	6.75
3.4.5.3. Lay out plant	0
3.4.5.4. Domino effects	0
3.4.5.5. Underground structure	0
3.4.5.6. Surface dreinage	0
3.4.5.7 Other characteristics (fattore 50-250)	50
Total factor of risks analysis for plant placement (L)	**58**

SUMMARY FOR THE RISKS CALCULATION	
SUBSTANCE FACTOR *(B)*	21
SUBSTANCES SPECIFIC RISKS *(M)*	30
PROCESS GENERAL RISKS *(P)*	35
PROCESS SPECIFIC RISKS *(S)*	205.5
QUANTITY FACTOR SUBSTANCE *(Q)*	18
RISKS ANALYSIS FOR PLANT PLACEMENT *(L)*	58
RISKS ANALYSIS FOR DANGEROUS SUBSTANCES *(s)*	2.8
AMOUNT SUBSTANCE *(K)*	30
HIGH PRESSURE FACTOR *(p)*	46
HEIGHT *(H)*	1.1
NORMAL WORKABLE AREA *(N)*	6.75
TEMPERATURE *(t)*	44

FIRE INDEX

F=B*K/N — F= 8.71

PENT-UP EXPLOSION INDEX

C=1+(M+P+S)/100 — C= 3.71

AIR EXPLOSION INDEX

A=B*(1+M/100)*(1+p)*Q*H*C/1000*(T+273)/300 — A= 102.17

EQUIVALENT INDEX dow

D=B*(1+M/100)*(1+P/100)*(1+(S+Q+L+s)/100 — D= 140.56

GENERAL RISK INDEX

G=D*(1+(0,2*C*(A*F)^0,5)) — G= 3,247.82

To be more precautionary we prefer not to apply the compensation of factor risks and refer directly to incidental analysis the results that are shown in table 3.2.

SUMMARY TABLE FOR RISK RATING

The summary table identifies the categories of hazard risk rating, obtained from the index method application, as defined by italian law:

DANGEROUS CATEGORIES OF RISK RATING					
	F Fire index	**C** Pent-up explosion index	**A** Air explosion index	**T** Toxic index	**G** General risk index
Light	**0-2**	**0-1,5**	**0-10**	**0-5**	**0-20**
Low	**2-5**	**1,5-2,5**	**10-30**	**5-10**	**20-200**
Moderate	**5-10**	**2,5-4**	**30-100**	**10-15**	**200-500**
High I	**10-20**	**4-6**	**100-400**	**15-20**	**500-1100**
High II	**20-50**	**-**	**-**	**-**	**1100-2500**
Very high	**50-100**	**> 6**	**400-1700**	**> 20**	**2500-12500**
Serious	**100-250**	**-**	**> 1700**	**-**	**12500-65000**
Very serious	**> 250**	**-**	**-**	**-**	**> 65000**

- **Table 3.1** – Summary table hazard categories of risk ratings.

Index / Area/Key substance	F Fire index	C Pent-up explosion index	A Air explosion index	T Toxic index	G General risk index
Raw material and waste storage (Ext. Infl. WH) **Key substance: METHANOL** **Amount: 19 t**	**9.68 (Moderate)**	**3.91 (Moderate)**	**0.69 (Light)**	**3.36 (Light)**	**651.60 (High I)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: ACETONE** **Amount: 19 t**	**9.68 (Moderate)**	**3.91 (Moderate)**	**0.69 (Light)**	**12.39 (Moderate)**	**624.48 (High I)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: METHANOL** **Amount: 0,79 t**	**0.40 (Light)**	**3.91 (Moderate)**	**0.69 (Light)**	**3.36 (Light)**	**284.44 (Moderate)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: ACETONE** **Amount: 0,79 t**	**0.40 (Light)**	**3.91 (Moderate)**	**0.69 (Light)**	**12.39 (Moderate)**	**271.77 (Moderate)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: METHANOL** **Amount: 15 t**	**7.64 (Moderate)**	**3.91 (Moderate)**	**0.69 (Light)**	**3.36 (Light)**	**602.96 (High I)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: ACETONE** **Amount: 7 t**	**3.57 (Low)**	**3.91 (Moderate)**	**0.69 (Light)**	**12.39 (Moderate)**	**460.12 (Moderate)**
Raw material and waste storage (Ext. Infl. WH) **Key substance: Waste EWC 070701*** **Amount: 10 t**	**10.39 (High I)**	**3.91 (Moderate)**	**0.59 (Light)**	**3.98 (Light)**	**589.19 (High I)**
Production Area (L1 and L2 lines) **Key substance: METHANOL** **Amount : 8 t**	**4.27 (Low)**	**6.95 (High I)**	**26.09 (Low)**	**2.15 (Light)**	**5,373.93 (Very High)**
Loading / unloading and storage LPG area (LPG Tanks) **Key substance: PROPANE** **Amount: 2,8 t**	**8.71 (Moderate)**	**3.71 (Moderate)**	**102.71 (High I)**	**N.A.**	**3,247.82 (Very high)**

- **Table 3.2** – Summary index method results

3.2. HAZARD AND OPERABILITY ANALYSIS (HAZOP)

The hazard and operability analysis called HAZOP, or "Key words" technique, is currently the technique of identification of risk most known and used. It can also be applied to manufacturing processes, equipment and systems for pharmaceutical products, such as the present, to facilitate regular monitoring of critical points in the production process.

This technique is a highly structured process, headed by a group of experts who systematically check (brainstorms) the manufacturing process by applying key words to the operating parameters. The group is composed of technical experts representing different disciplines and / or specialty and is driven by a "team leader" who will ensure the application of the methodology and the effectiveness of group work.

Through the analysis of the possible deviations of the main variables of the system (temperature, pressure, composition, flow, level, ...) from their values system, it researches the causes and identifies the consequences, in terms of accidents (TOP EVENT[2]) by creating a "cause and effect" logical connection, suitable for the accident sequences that from the failure or malfunction of simple elements can lead to the malfunction of more complex systems and thus the occurrence of the accident.

This method also provides a logical subdivision of the installation (functional subsets) that is characterized by a project, for example a process line.

In general, an HAZOP research, is articulated in the following way:

- subdivision of the test system into functional subsets (usually the identification of the subsets is related to the main receptacles of the process to which are associated the lines that enclose and/or that branch off from it, and also the secondary equipment to them connected);
- identification of the process parameters characteristic of each subsystem;
- in each subsystem, variance analysis of the process parameters guided by the type of guide words expressing the deviation of these parameters from their nominal value (eg, major, minor, void, etc..) and its effects on the system, the role of the words guide is to stimulate imagination and discussion within the group, but in a systematic and organized way.
- detection of any alteration of the parameters that may be critical to the operability of the system, its determinants, the protections that intervene to face such alteration and the states of the determined system.

[2] Definition of *TOP EVENT: The incident which occurs as a result of the hazard being released*

The plant system under consideration is divided as follows:

- A – Raw material and waste storage area (External Inflammable Warehouse)
- B – Production area (Lines L1 and L2)
- C – LPG Storage and Loading area (LPG Tanks)

The study of the conformation of the unit A has led to the identification of the following activities:

- Raw material/waste storage and handling
- Raw material Splitting/Pouring/Weighing
- Waste IBC/Drums/tank loading into a VAN

These activities will be investigated through the operability's analysis. The details of the analysis are shown in **Annex 1**.

The analysis led to the identification of the following probable accident events:

✓	Uncontrolled spill out of the containment basin	(**Top event 1**)
✓	Uncontrolled liquid spill in the containment basin	(**Top event 2**)
✓	A different quantity of raw materials out of specification sent in production area	(**Top event 3**)
✓	A different quantity of raw materials out of specification sent in facility results in a higher risk of hazardous uncontrolled chemical reactions	(**Top event 4**)
✓	A different type of waste sent in disposal facility results in higher risk of hazardous uncontrolled chemical reactions	(**Top event 5**)
✓	Vapors escaping during splitting/pouring of liquids	(**Top event 6**)
✓	Breakage the liquid transfer pipe with spill/overflow inside or outside containment basin	(**Top event 7**)

The study of the unit B has led to the identification of the following activities:

- Loading/unloading of the reactor
- Condensation
- Fuel gas abatement

The operability analysis led to the identification of the following probable accident events:

- ✓ Production of API's out of specification (**Top event 8**)
- ✓ Uncontrolled chemical reactions (**Top event 9**)
- ✓ Opening safety rupture disk (**Top event 10**)
- ✓ Uncontrolled spilling (**Top event 11**)
- ✓ Explosion mixture caused per insufficient neutralization of the reactor (**Top event 12**)
- ✓ Lack neutralization of the reactor with generation of mixture explosive gas (**Top event 13**)
- ✓ Opening safety rupture disk of condensator (**Top event 14**)
- ✓ Vapours to escape as they rotate from the reactor space (**Top event 15**)
- ✓ Possible inlet air flow to the condenser and resulting development o a inflammable mixture (**Top event 16**)
- ✓ Spillage of liquid from the recirculation line (**Top event 17**)
- ✓ Less pollution abatement (**Top event 18**)
- ✓ Possible leakage of small amounts of flue gas from flanges and nozzles (**Top event 19**)
- ✓ Possible breakage with leaking gas and vapor with washing solution (**Top event 20**)
- ✓ Leakage washing solution (**Top event 21**)
- ✓ Leakage hot flue gas from low-rise (**Top event 22**)

The study of the unit B has led to the identification of the following activities:

- Storage and loading LPG into tank.

The operability analysis led to the identification of the following probable accident events:

- ✓ LPG vapors leakage/emission (**Top event 23**)

3.3. FAULT TREE AND PROBABILISTIC CALCULATION

METHOD DESCRIPTION

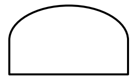
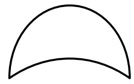
The technique of the fault tree was used to analyze in detail the mode of failure of the most critical systems for the operability of the overall system.

The fault tree is used to evaluate the frequency of the incidents identified through the analysis of the operability on the system. This method, based on the experience, provides feedback of qualitative and quantitative type, in the case that failure rates would be known. Basically, the fault tree is a graphical representation by which the incident is interpreted, according to logical relationships, such as a sequence of events, starting from the failure of an elementary component to the occurrence of the accident.

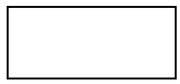
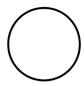
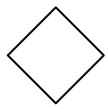
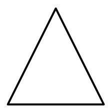
Among the top event emerged from the analysis of the operability, it was considered appropriate to address the following:

EVENT	NAME	PHASE
Uncontrolled spill out of the containment basin	**TOP EVENT 1**	Storage and handling
		Splitting/pouring/ weighing
		Waste load
Uncontrolled liquid spill out of the containment basin	**TOP EVENT 2**	Storage and handling
		Splitting/pouring/ weighing
Vapors escaping	**TOP EVENT 6**	Splitting/pouring weighing
Opening of the safety rupture disk	**TOP EVENT 14**	Reactor
		Condenser
Minor pollution abatement	**TOP EVENT 18**	Abatement unit
Vapors escaping/spillage	**TOP EVENT 23**	LPG storage and loading

These events have been developed in order to highlight the logical connections and sequences of occurrence generating them from the primary events. The connections between events are expressed through logic gates, as shown:

AND: the output event occurs only if all the input conditions are simultaneously verified.	
OR: the output event occurs if at least one of the input conditions are verified.	

The events are represented according to the following symbols:

INTERMEDIATE OR TOP EVENT *event occurring as a result of the interaction of other basic events (intermediate event) or adverse event for which it is request to determine the causes and to give a measure of the probability of the occurrence (top event).*	
BASIC OR PRIMARY EVENT *event of failure of a component or a subsystem that does not require further in-depth investigations.*	
NOT DEVELOPED EVENT *Those failure events that are not developed in their basic events for two main reasons: the available information are not sufficient, or the event, leaves the boundaries prescribed in the survey.*	
IN – OUT TRANSFER *the triangle with the word IN, shows that the event of a fault is elsewhere developed (in this case it assumes the function of top event for the related tree). The triangle with OUT only has a recall function.*	

For the probability calculus of the top events it have been used the reliability data present in the literature; where it has not been possible to find any data it has been hypothesized a value.

To each primary event it has been associated the failure rate λ (t) defined as the probability that the concerned component fails between time t and t + dt, influenced by the fact that it properly worked up to the t time.

For the calculation it was assumed a constant value of λ (t): in addition, provided that the system operates in discontinuous, it was not taken into account the rate of repair μ (t).

The **annex 2** shows the calculations for determining the probability of occurrence of the considered events.

TOP EVENT 1: Uncontrolled spill out of the containment basin

A: Valve opened;

B: Lack of valve for wear;

C: Tank (or IBC/drum) accidental breakage;

D: Tank deterioration.

TOP-DOWN METHOD

TOP=G1

G1= A + B + G2

G2 = C + D

G1= A + B + C + D = TOP

TOP = A + B + C + D

Fault rates of single events: $\lambda=\begin{pmatrix} 5\cdot 10^{-7} \\ 1{,}141\cdot 10^{-6} \\ 2\cdot 10^{-7} \\ 5\cdot 10^{-5} \end{pmatrix}$ events/hr

Probability of occurrence of an event MCS: P= λ then P = $\begin{pmatrix} 5\cdot 10^{-7} \\ 1{,}141\cdot 10^{-6} \\ 2\cdot 10^{-7} \\ 5\cdot 10^{-5} \end{pmatrix}$

Range of probability of top event:

supremum

$$P_{sup} = \sum_{i=0}^{3} P_i \qquad P_{sup} = 5{,}184\cdot 10^{-5}\,\frac{events}{hr} p_{sup} = P_{sup}\cdot 8760 \qquad p_{sup} = 0{,}454127\,\frac{events}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{3}\sum_{j=i}^{3} P_i P_j\; P_{inf} = 5{,}184\cdot 10^{-5}\,\frac{events}{hr} P_{inf} = p_{inf}\cdot 8760 \quad p_{inf} = 0{,}454104\,\frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760\ \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 \cdot \int_0^\tau e^{-\lambda_0 t} dt \\ \lambda_1 \cdot \int_0^\tau e^{-\lambda_1 t} dt \\ \lambda_2 \cdot \int_0^\tau e^{-\lambda_2 t} dt \\ \lambda_3 \cdot \int_0^\tau e^{-\lambda_3 t} dt \end{pmatrix} \text{then} W = \begin{pmatrix} 4{,}37 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 1{,}75 \cdot 10^{-3} \\ 0{,}335 \end{pmatrix}$$

Faults number expected per year:

$$W_{TOP} = \sum_{i=0}^{3} W_i$$

Then W_{TOP} = 0,37074

TOP EVENT 2: Uncontrolled liquid spill out of the containment basin

A: Opened valve;

B: Lack from valve for wear;

C: Tank accidental breakage;

D: Tank deterioration.

TOP-DOWN method

TOP=G1

G1= A + B + G2

G2 = C + D

G1= A + B + C + D = TOP

TOP = A + B + C + D

Fault rates of single events: $\lambda = \begin{pmatrix} 5 \cdot 10^{-7} \\ 1{,}141 \cdot 10^{-6} \\ 2 \cdot 10^{-7} \\ 5 \cdot 10^{-5} \end{pmatrix}$ events/hr

Probability of occurrence of an event MCS: P= λ then $P = \begin{pmatrix} 5 \cdot 10^{-7} \\ 1{,}141 \cdot 10^{-6} \\ 2 \cdot 10^{-7} \\ 5 \cdot 10^{-5} \end{pmatrix}$

Range of probability of top event:

supremum

$$P_{sup} = \sum_{i=0}^{3} P_i \qquad P_{sup} = 5{,}184 \cdot 10^{-5} \frac{events}{hr} p_{sup} = P_{sup} \cdot 8760 \qquad p_{sup} = 0{,}454127 \frac{events}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{3} \sum_{j=i}^{3} P_i P_j \; P_{inf} = 5{,}184 \cdot 10^{-5} \frac{events}{hr} P_{inf} = p_{inf} \cdot 8760 \quad p_{inf} = 0{,}454104 \frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760\ \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 \cdot \int_0^\tau e^{-\lambda_0 t} dt \\ \lambda_1 \cdot \int_0^\tau e^{-\lambda_1 t} dt \\ \lambda_2 \cdot \int_0^\tau e^{-\lambda_2 t} dt \\ \lambda_3 \cdot \int_0^\tau e^{-\lambda_3 t} dt \end{pmatrix} \text{then} W = \begin{pmatrix} 4{,}37 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 1{,}75 \cdot 10^{-3} \\ 0{,}335 \end{pmatrix}$$

Faults number expected per year:

$$W_{TOP} = \sum_{i=0}^{3} W_i$$

Then W_{TOP} = 0,37074

TOP EVENT 7: Spilling/overflowing liquid inside or outside containment basin

A: clogged pipe;

B: Wear/worsening/damage pipe.

TOP-DOWN method

TOP=G1

G1= A + B

TOP = A + B

Fault rates of single events: $\lambda=\begin{pmatrix} 1{,}15 \cdot 10^{-5} \\ 1{,}7 \cdot 10^{-5} \end{pmatrix}$ events/hr

Probability of occurrence of an event MCS: P= λ then $P = \begin{pmatrix} 1{,}15 \cdot 10^{-5} \\ 1{,}7 \cdot 10^{-5} \end{pmatrix}$

Range of probability of top event:

supremum

$$P_{sup} = \sum_{i=0}^{1} P_i \qquad P_{sup} = 2{,}7 \cdot 10^{-5} \frac{eventi}{hr} p_{sup} = P_{sup} \cdot 8760 \qquad p_{sup} = 0{,}23 \frac{eventi}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{1} \sum_{j=i}^{1} P_i P_j \; P_{inf} = 2{,}7 \cdot 10^{-5} \frac{events}{hr} P_{inf} = p_{inf} \cdot 8760 \quad p_{inf} = 0{,}23 \frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760 \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 \cdot \int_0^{\tau} e^{-\lambda_0 t} dt \\ \lambda_1 \cdot \int_0^{\tau} e^{-\lambda_1 t} dt \end{pmatrix} \quad \text{then} W = \begin{pmatrix} 0{,}084 \\ 0{,}138 \end{pmatrix}$$

Faults number expected per year:

$$W_{TOP} = \sum_{i=0}^{1} W_i$$

Then $W_{TOP} = 0{,}222$

TOP EVENT 10/14: Opening of the safety rupture disk

A: Malfunction of pressure reducing system;

B: Setting of the reducing valve (employee wrong);

C: Temperature ride for the exothermic reaction;

D: Absence endothermic reaction;

E: Error substance identification (employee wrong);

F: Drain valve malfunction;

G: Tank overflowed;

H: Closed drain valve (operator’s wrong);

I: Rupture of reactor’s agitator;

J: Lack of electricity;

K: Lack of starting (operator’s wrong);

L: Lack of electricity;

M: Rupture pump/motor;

N: will not boot (operator’s wrong);

O: Valve opening error (operator’s wrong);

P: Malfunctioning system control valve opening;

Q: automatic valve malfunctioning;

R: Closed manual valve (operator’s wrong);

S: Lack of utilities;

T: Line clogged;

U: Automatic valve malfunctioning;

V: Closed manual valve (operator’s wrong);

W: Line clogged;

X: Opening/closing manual valve (operator’s wrong);

Y: Rupture line;

Z: Opened drain valve (operator’s wrong);

A’: Rupture sensor probe;

B': Lack of calibration/maintenance (operator's wrong);

C': Lack of electricity;

D': Pump/motor rupture;

E': Will not boot (operator's wrong);

F': Failure valve opening (operator's wrong);

G': Malfunctioning system control valve opening;

H': Malfunctioning automatic valve;

I': Manual valve closed (operator's wrong);

J': Clogged line;

K': Opening/closing manual valve (operator's wrong);

L': Rupture line;

M': Drain valve opened (operator's wrong);

N': Sensor probe rupture;

O': Lack of calibration/maintenance (operator's wrong).

TOP-DOWN method

TOP=G1= G2+G3

G2= A+B

G3= G4+G5

G4= G6+G7+G8+E

G5=F+G+H

G6= C*G9

G7= D*G10

G8= I+J+K

G9= G11+G12+G13+G14+X+G15

G10= G16+G17+G18+K'+G19

G11= L+M+N

G12= O+G20+P

G13= Q+R+S+T

G14= U+V+W

G15= Y+Z

G16= C'+D'+E'

G17= F'+G21+G'

G18= H'+I'+J'

G19= L'+M'

G20= A'+B'

G21= N'+O'

G17= F'+N'+O'+G'

G12= O+A'+B'+P

G10= C'+D'+E'+F'+N'+O'+G'+H'+I'+J'+K'+L'+M'

G9= L+M+N+O+A'+B'+P+Q+R+S+T+U+V+W+X+Y+Z

G7= D*(C'+D'+E'+F'+N'+O'+G'+H'+I'+J'+K'+L'+M')

G6= C*(L+M+N+O+A'+B'+P+Q+R+S+T+U+V+W+X+Y+Z)

G4=(C*(L+M+N+O+A'+B'+P+Q+R+S+T+U+V+W+X+Y+Z))+(D*(C'+D'+E'+F'+N'+O'+G'+H'+I'+J'+K'+L'+M')
)+I+J+K+E

G3=(C*(L+M+N+O+A'+B'+P+Q+R+S+T+U+V+W+X+Y+Z))+(D*(C'+D'+E'+F'+N'+O'+G'+H'+I'+J'+K'+L'+M'))+I+J+K
+E+F+G+H

G1=A+B+C*(L+M+N+O+A'+B'+P+Q+R+S+T+U+V+W+X+Y+Z))+(D*(C'+D'+E'+F'+N'+O'+G'+H'+I'+J'+K'+L'+M'))+I+J+K+E+F+G+H

G1=A+B+CL+CM+CN+CO+CA'+CB'+CP+CQ+CR+CS+CT+CU+CV+CW+CX+CY+CZ+DC'+DD'+DE'+DF'+DN'+DO'+DG'+DH'+DI'+DJ'+DK'+DL'+DM'+I+J+K+E+F+G+H

Neglecting the minimal cut set higher order, we obtain:

G1=A+B+I+J+K+E+F+G+H=TOP

TOP= A+B+E+F+G+H+I+J+K

Fault rates of single events: $\lambda=\begin{pmatrix} 3\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \\ 3\cdot 10^{-6} \\ 1{,}15\cdot 10^{-5} \\ 1{,}141\cdot 10^{-6} \\ 1\cdot 10^{-5} \\ 4\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \end{pmatrix}$ events/hr

Probability of occurrence of an event MCS: $P = \begin{pmatrix} \lambda_0 \\ \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \\ \lambda_8 \end{pmatrix}$ then P = $\begin{pmatrix} 3\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \\ 3\cdot 10^{-6} \\ 1{,}15\cdot 10^{-5} \\ 1{,}141\cdot 10^{-6} \\ 1\cdot 10^{-5} \\ 4\cdot 10^{-6} \\ 1{,}141\cdot 10^{-6} \end{pmatrix}$

Range of probability of top event:

supremum

$$P_{sup} = \sum_{i=0}^{8} P_i \qquad P_{sup} = 3{,}606\cdot 10^{-5}\,\frac{events}{hr}\, p_{sup} = P_{sup}\cdot 8760 \qquad p_{sup} = 0{,}315921\,\frac{events}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{8}\sum_{j=i}^{8} P_i P_j\; P_{inf} = 3{,}606\cdot 10^{-5}\,\frac{events}{hr}\, P_{inf} = p_{inf}\cdot 8760 \quad p_{inf} = 0{,}315914\,\frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760\ \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 \cdot \int_0^\tau e^{-\lambda_0 t}\,dt \\ \lambda_1 \cdot \int_0^\tau e^{-\lambda_1 t}\,dt \\ \lambda_2 \cdot \int_0^\tau e^{-\lambda_2 t}\,dt \\ \lambda_3 \cdot \int_0^\tau e^{-\lambda_3 t}\,dt \\ \lambda_4 \cdot \int_0^\tau e^{-\lambda_4 t}\,dt \\ \lambda_5 \cdot \int_0^\tau e^{-\lambda_5 t}\,dt \\ \lambda_6 \cdot \int_0^\tau e^{-\lambda_6 t}\,dt \\ \lambda_7 \cdot \int_0^\tau e^{-\lambda_7 t}\,dt \\ \lambda_8 \cdot \int_0^\tau e^{-\lambda_8 t}\,dt \end{pmatrix} \quad \text{then} W = \begin{pmatrix} 0{,}026 \\ 9{,}945 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 0{,}026 \\ 0{,}026 \\ 9{,}945 \cdot 10^{-3} \\ 0{,}084 \\ 0{,}084 \\ 9{,}945 \cdot 10^{-3} \end{pmatrix}$$

Faults number expected per year: $W_{TOP} = \sum_{i=0}^{8} W_i$

Then W_{TOP} = 0,30579

TOP EVENT 18: Minor pollution abatement

A: Activated carbons choice (worker mistake);

B: Incorrect loading (worker mistake);

C: Failure to replace fluid losses;

D: Drain valve of column opened (worker mistake);

E: Liquid losses;

F: Pump malfunction;

G: Pipe clogged;

H: Pipe rupture;

I: Environmental temperature rise;

J: Higher temperature reactor and/or condenser system;

K: Condensate system failure;

L: Lack of loading (worker mistake);

M: Lack to replace (worker mistake);

N: Higher temperature reactor and/or condenser system;

O: Environment temperature rise.

TOP-DOWN method

TOP= G1

G1= G2+A+G3+B+G4+G5

G2= C+D+E+F+G+H

G3= I+G6

G4= L+M

G5= N+O

G6= J+K

G3= I+J+K

G1= C+D+E+F+G+H+A+I+J+K+B+L+M+N+O

TOP= A+B+C+D+E+F+G+H+I+J+K+L+M+N+O

Fault rates of single events: $\lambda = \begin{pmatrix} 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 4 \cdot 10^{-6} \\ 1 \cdot 10^{-4} \\ 1{,}15 \cdot 10^{-5} \\ 2 \cdot 10^{-7} \\ 5{,}7 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 5{,}7 \cdot 10^{-6} \end{pmatrix}$ events/hr

Probability of occurrence of an event MCS: $P = \begin{pmatrix} \lambda_0 \\ \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \\ \lambda_8 \\ \lambda_9 \\ \lambda_{10} \\ \lambda_{11} \\ \lambda_{12} \\ \lambda_{13} \\ \lambda_{14} \end{pmatrix}$ then P = $\begin{pmatrix} 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 4 \cdot 10^{-6} \\ 1 \cdot 10^{-4} \\ 1{,}15 \cdot 10^{-5} \\ 2 \cdot 10^{-7} \\ 5{,}7 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1{,}141 \cdot 10^{-6} \\ 1 \cdot 10^{-6} \\ 5{,}7 \cdot 10^{-6} \end{pmatrix}$

Range of probability of top event:

supremum

$$P_{sup} = \sum_{i=0}^{14} P_i \qquad P_{sup} = 1{,}369 \cdot 10^{-4} \frac{eventi}{hr} p_{sup} = P_{sup} \cdot 8760 \qquad p_{sup} = -1{,}199647 \frac{eventi}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{14} \sum_{j=i}^{14} P_i P_j \, P_{inf} = 1{,}369 \cdot 10^{-4} \frac{events}{hr} P_{inf} = p_{inf} \cdot 8760 \quad p_{inf} = 1{,}19952 \frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760 \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 \cdot \int_0^\tau e^{-\lambda_0 t}\, dt \\ \lambda_1 \cdot \int_0^\tau e^{-\lambda_1 t}\, dt \\ \lambda_2 \cdot \int_0^\tau e^{-\lambda_2 t}\, dt \\ \lambda_3 \cdot \int_0^\tau e^{-\lambda_3 t}\, dt \\ \lambda_4 \cdot \int_0^\tau e^{-\lambda_4 t}\, dt \\ \lambda_5 \cdot \int_0^\tau e^{-\lambda_5 t}\, dt \\ \lambda_6 \cdot \int_0^\tau e^{-\lambda_6 t}\, dt \\ \lambda_7 \cdot \int_0^\tau e^{-\lambda_7 t}\, dt \\ \lambda_8 \cdot \int_0^\tau e^{-\lambda_8 t}\, dt \\ \lambda_9 \cdot \int_0^\tau e^{-\lambda_9 t}\, dt \\ \lambda_{10} \cdot \int_0^\tau e^{-\lambda_{10} t}\, dt \\ \lambda_{11} \cdot \int_0^\tau e^{-\lambda_{11} t}\, dt \\ \lambda_{12} \cdot \int_0^\tau e^{-\lambda_{12} t}\, dt \\ \lambda_{13} \cdot \int_0^\tau e^{-\lambda_{13} t}\, dt \\ \lambda_{14} \cdot \int_0^\tau e^{-\lambda_{14} t}\, dt \end{pmatrix} \quad \text{then } W = \begin{pmatrix} 9{,}945 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 0{,}034 \\ 0{,}584 \\ 0{,}096 \\ 1{,}75 \cdot 10^{-3} \\ 0{,}049 \\ 8{,}722 \cdot 10^{-3} \\ 8{,}722 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 9{,}945 \cdot 10^{-3} \\ 8{,}722 \cdot 10^{-3} \\ 0{,}049 \end{pmatrix}$$

Faults number expected per year:

$$W_{TOP} = \sum_{i=0}^{14} W_i$$

Then $W_{TOP} = 0{,}89882$

TOP EVENT 23: Vapor emission in air

A: Environmental temperature rise;

B: Loading error;

C: Wear of valve;

D: Accidental rupture of tank;

E: Damage of tank.

TOP-DOWN method

TOP=G1

G1= G2 + C + G3

G2 = A + B

G3 = D + E

G1= A + B + C + D + E = TOP

TOP = A + B + C + D + E

Fault rates of single events: $\lambda=\begin{pmatrix} 5{,}7\cdot 10^{-5} \\ 1{,}141\cdot 10^{-6} \\ 1{,}7\cdot 10^{-5} \\ 5\cdot 10^{-7} \\ 5\cdot 10^{-5} \end{pmatrix}$ events/hr

Probability of occurance of an event MCS: P= λ then $P=\begin{pmatrix} 5{,}7\cdot 10^{-5} \\ 1{,}141\cdot 10^{-6} \\ 1{,}7\cdot 10^{-5} \\ 5\cdot 10^{-7} \\ 5\cdot 10^{-5} \end{pmatrix}$

<u>Range of probability of top event:</u>

supremum

$$P_{sup} = \sum_{i=0}^{4} P_i \qquad P_{sup} = 1{,}256\cdot 10^{-4}\,\frac{events}{hr}\; p_{sup} = P_{sup}\cdot 8760 \qquad p_{sup} = 1{,}101\,\frac{events}{hr}$$

infimum

$$P_{inf} = P_{sup} - \sum_{i=0}^{4}\sum_{j=i}^{4} P_i P_j \; P_{inf} = 1{,}256 \cdot 10^{-4} \frac{events}{hr} P_{inf} = p_{inf} \cdot 8760 \quad p_{inf} = 1{,}101 \frac{events}{hr}$$

Calculation of the expected faults number per year:

Mission time: $\tau = 8760 \, \frac{hr}{yr}$

$$W = \begin{pmatrix} \lambda_0 . \int_0^\tau e^{-\lambda_0 t} dt \\ \lambda_1 . \int_0^\tau e^{-\lambda_1 t} dt \\ \lambda_2 . \int_0^\tau e^{-\lambda_2 t} dt \\ \lambda_3 . \int_0^\tau e^{-\lambda_3 t} dt \\ \lambda_4 . \int_0^\tau e^{-\lambda_4 t} dt \end{pmatrix} \text{then} W = \begin{pmatrix} 0{,}393 \\ 9{,}945 \cdot 10^{-3} \\ 0{,}138 \\ 4{,}37 \cdot 10^{-3} \\ 0{,}335 \end{pmatrix}$$

Faults number expected per year:

$$W_{TOP} = \sum_{i=0}^{4} W_i$$

Then W_{TOP}= 0,9

3.4. EVENTS TREE

The events tree were constructed related to the following top-event:

STORAGE, HANDLING and MOVEMENTS, SPLITTING/POORING/WEIGHING and WASTE LOADING

- **Uncontrolled spill out of the containment basin (TOP EVENT 1)**

This event tree analysis displays the possible accident scenarios following:

- **Pool fire (an accidental event that involves the initiation of a liquid substance spilled in an enclosed area or less);**
- **Release of gas and vapors in air;**
- **Emission in soil;**
- **Flash fire (is a sudden, intense fire caused by ignition of a mixture of air and a dispersed flammable substance such as a solid (including dust));**
- **Unconfined vapors cloud explosion (UVCE).**

STORAGE, HANDLING and SPLITTING/POORING/WEIGHING:

- **Uncontrolled liquid spill into the containment basin (TOP EVENT 2)**

This event tree analysis displays the possible accident scenarios following:

- **Pool fire;**
- **Release of gas and vapors in air;**
- **Flash fire;**
- **Unconfined vapors cloud explosion (UVCE).**

SPLITTING/POORING/WEIGHING:

- **Spilled/overflowed uncontrolled inside or outside the containment basin (TOP EVENT 7)**

This event tree analysis displays the possible accident scenarios following:

- **Pool fire;**
- **Release of gas and vapors in air;**
- **Flash fire;**
- **Unconfined vapors cloud explosion (UVCE).**

REACTOR AND CONDENSER (CAPACITOR)

- **Opening safety rupture disk (TOP EVENT 10/14)**

This event tree analysis displays the possible accident scenarios following:

- **Jet fire (A jet or spray fire is a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions. Jet fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories);**
- **Release of gas and vapors in air;**
- **Flash fire;**
- **Unconfined vapors cloud explosion (UVCE).**

ABATEMENT POLLUNTANT UNIT

- **Minor pollution abatement (TOP EVENT 18)**

This event tree analysis displays the possible accident scenarios following:

- **Jet fire;**
- **Release of gas and vapors in air;**
- **Flash fire;**
- **Unconfined vapors cloud explosion (UVCE).**

STORAGE AND LOADING LPG

- **Release of gas and vapors in air (TOP EVENT 23)**

This event tree analysis displays the possible accident scenarios following:

- **Jet fire;**
- **Release of gas and vapors in air;**
- **Flash fire;**
- **Unconfined vapors cloud explosion (UVCE).**

In **Annex 3** is provided the graphs of the event trees. In red-highlighted were applied correction factors to the probability of occurrence of the various scenarios, taking into account the measures of prevention and protection in the company, the operational procedures/instructions implemented, and the training/information for workers for the various operational phases taken into consideration.

3.5. ASSESSMENT OF IMPACT BY CALCULATIONS MODEL

METHOD DESCRIPTION

With the mathematical method PHAST 6.0 have been studied the consequences related to the accident scenarios identified by the event trees constructed.

Has been considered two particular atmospheric conditions, as such as:

- Stability class D with wind speed of 5 m/sec;
- Stability class F with wind speed of 2 m/sec.

The scientific approach to the problem has been to make choices based on precautionary conditions like most difficult cloud dispersion.

The calculations on effects can be found in Annex 4 of this report

TYPE OF EFFECT FOR THE POPULATION AND THE ENVIRONMENT

The following table show the reference values for the each effect assessment

The table shows the distances of damage (contours) for areas for emergency planning.

ZONE	EFFECT
ZONE 1	Impact sure, portion of the land in which they may be exceeded threshold values relative to the band of high lethality
ZONE 2	Damage area, is that between the outer limit of the area of "impact sure" and that beyond which there are conceivable serious and irreversible damage
ZONE 3	Focus area, portion of the land in which they are external to the previous only minor and reversible damage

Accident scenarious	Reference parameter	Thresholds of damage to people and structures				
		High lethality	Beginning lethality	Irreversibile lesions	Reversible lesions	damage to structures Domino effect
Fire (Pool-fire e Jet-fire)	Thermal radiation stationary	**12.5 kW/m²**	**7 kW/m²**	**5 kW/m²**	**3 kW/m²**	**12.5 kW/m²**
Fire (Flash-fire)	Thermal radiation instantaneous	**LFL**	**½ LFL**			
Explosion (UVCE/CVE)	Overpressure of peak	**0.6 bar (0.3)**	**0.14 bar**	**0.07 bar**	**0.03 bar**	
Toxic release (Dispersion)	Concentration in air	**LC50 30min**		**IDLH**	**LOC**	
Area emergency planning		**ZONE 1**		**ZONE 2**	**ZONE 3**	

4. ASSESSMENT REPORTS

Evaluating all the incidental hypotheses occurred during this study, below are some of the consequences of the major events examined.

Other accident scenarios that may involve the use of flammable and/or toxic substances were not considered in the analysis, since the appropriate choice of materials for containment and management precautions generally adopted allow to reduce the frequency of occurrence of an accident and its consequences below the foreseen limits of danger.

- **Uncontrolled spill out of the containment basin (TOP EVENT 1)**

The probabilistic calculation evaluates approximately **0.37074** incidents per year about the uncontrolled spill out of the containment basin event. From the simulations carried out by the calculation software is significant the **Pool-fire** event with the following thresholds:

ZONE 1 overcoming of the lethality threshold (7 kW/m^2 - beginning lethality limit) for a radius of 15 meters from the point of release (Stability class F with wind speed of 2 m/sec).

ZONE 2 overcoming of the damage threshold for people and structures (5 kW/m^2 - Irreversible lesions limit) for a radius between 15 and 17 metres from the point of release (Stability class F with wind speed of 2 m/sec).

- **Uncontrolled liquid spill into the containment basin (TOP EVENT 2)**

The probabilistic calculation evaluates approximately **0.37074** incidents per year about the uncontrolled spill into the containment basin event. From the simulations carried out by the calculation software is significant the **Pool-fire** event with the following thresholds:

ZONE 1 overcoming of the lethality threshold (7 kW/m^2 - beginning lethality limit) for a radius of 15 meters from the point of release (Stability class F with wind speed of 2 m/sec).

ZONE 2 overcoming of the damage threshold for people and structures (5 kW/m^2 - Irreversible lesions limit) for a radius between 15 and 17 metres from the point of release (Stability class F with wind speed of 2 m/sec).

- **Opening safety rupture disk (TOP EVENT 10/14)**

The probabilistic calculation evaluates approximately **0.30579** incidents per year about the safety rupture disk opening event. From the simulations carried out by the calculation software is not significant any event.

- **Release of gas and vapors in air (TOP EVENT 23)**

The probabilistic calculation evaluates approximately **0.9** incidents per year about the release of gas and LPG vapors in air event. From the simulations carried out by the calculation software are significant the **Jet-fire**, **Pool-fire** and **Bleve** events with the following thresholds (presumed in the case of release in the external environment):

ZONE 1 overcoming of the lethality threshold (7 kW/m^2 - beginning lethality limit) in close proximity of the release point.

5. OUTWARDS CONSEQUENCES ASSESSMENT

ZONE 1

The area in which it can be reached or exceeded the threshold values of high lethality is always contained within the plant.

High mortality effects due to radiation (stationary thermal radiation) are limited in close proximity of the release point.

ZONE 2

The area in which are foreseen effects of a certain severity (non-fatal) on the exposed subjects and in which damages of a certain size on the structures or equipments are expected, is generally contained within the company perimeter.

The radiation effects are always contained in the plant area and may reach maximum distances of approximately 20 metres from the release point.

ZONE 3

The focus area with minor and/or reversible effects, in which are predictable effects of radiation, are always contained within the plant. The effects are not responsible for domino effects.

6. PRECAUTION AND/OR PREVENT MEASURES

In order to reduce the risks for accidents previously evaluated, the following table shows some of the measures of prevention and/or precaution, as the factors used for integrating the measures, systems, and procedures already adopted by the company risks management:

- From a planning and management point of view the adoptable systems for the prevention and control of accidental releases are multiple and may be carried out at different levels, also according to the characteristics of the substances used. Simplest preventive actions consist in the adoption of appropriate procedures on the handling and storage of products, checking procedures for the tanks adequacy to corporate standards and storage and maintenance procedures.
- During the use, storage, transfer of flammable and/or toxic substances must not be used closer open flames, sparks, and of course you should not smoke. To avoid explosive phenomena must adequately ventilate the area, also the lighting and electrical equipments must be explosion-proof and maintained in full working order. In case of release the danger area must be evacuated, ventilated (if necessary) and all sources of ignition has to be removed. Below are some operational rules to be observed to prevent hazards to human health related to the use of flammable substances:
    - smoking and the use of lighters and systems that can generate sparks must be prevented;
    - "No Smoking" signs must be properly positioned in the plant areas;
    - pipelines and systems containing flammable substances should be characterized and identified by colors, signs or both;
    - must ensure that flammable liquids containers are connected to the system ground to prevent static electricity and creating sparks. During the filling operation, a cable connection between the container to be filled and the storage container must be present and connected to the ground system;
    - the management of the system grounding must be included in a preventive maintenance system to ensure that equipments are inspected with a regular frequency from a continuity point of view. Besides the visible part of the ground system must be visually inspected by the workers prior to begin the transfer of liquids;
    - the transfer of flammable substances by means of pressurized air must be prohibited;

- the tanker carrying substances/refusals must be electrically connected with the network grounding;
- only non-sparking tools should be used where flammable gases or vapors could be triggered by sparks;
- adeguati corridoi o passaggi devono essere garantititi per accessi non ostruiti tra cui movimento dei mezzi antincendio, personale e equipaggiamenti. La larghezza del corridoio deve essere almeno di 1,5 m. Per aree interne di stoccaggio i principali passaggi devono avere una larghezza di almeno 2,4 m; adequate corridors or passages must be unobstructed for the fire-fighting personnel and equipment. The width of the corridor should be at least 1.5 m. Internal storage areas should have a width of at least 2.4 m;
- flammable substances must not be stored in open containers. In addition, the containers should not be stored near hot pipes or other heat sources or exposed to direct sunlight;
- gasoline and carbon tetrachloride must not be used for cleaning operations. Only approved fluids for cleaning at open air are allowed;
- all flammable liquids containers filling areas shall be in designated areas and away from buildings;
- avoid carrying out any welding and metal cutting in the storage area;
- the storage tanks of flammable and/or toxic substances must be designed, built and installed in accordance with international recognized standards. The tanks must be made of steel or of a non-combustible material approved compatible with the liquid to contain;
- PPEs are to be used and made quickly available, including devices for respiratory protection, gloves and protective clothing resistant to chemicals;
- Preventive and periodic maintenance must be ensured in particular to check the structural integrity of the storages, the electrical continuity of the ground system and the adequacy of ventilation systems in the production department.

➲ More training/information for the personnel responsible for handling/storage of raw materials/waste.

➲ More training/information to contractors that carry out activities of collection and transport of waste out of the plant.

- Training and information to all employees about the procedures to be implemented in the event of an accident (all the workers in the plant have to read the safety plan).
- Discussion of procedures/operating instructions already present in the plant.

ANNEX 1 – HAZOP WORKSHEETS

ANNEX 2 – FAULT TREE DIAGRAMS

ANNEX 3 – EVENT TREE DIAGRAMS

ANNEX 4 – SOFTWARE SPREADSHEETS

FOR CONSEQUENCES ASSESSMENT