Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters
PEC

Deliverable D.A.4

Anthropogenic Hazard

ECHO/SUB/2015-713844-PREV11 - PEC: Post-Emergency, multi-hazard health risk assessment in Chemical disasters
Project co-funded by ECHO - Humanitarian Aid and Civil Protection

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1. INTRODUCTION

When assessing loss of containment events from a process plant, scenarios of leakage derived by causes related to human action have to be taken into account. Human action plays a crucial role in this evaluation since usually most likely causes of loss of containment are the ones related to human action.
The causes of loss of containment related to human action/presence can be divided in four main categories:

a) **Errors in design, construction, maintenance**
Potential errors in design, construction and other phases, such as normal operation, maintenance, etc., leading to hazardous scenarios as loss of containment are related to the human action since the cause of the loss of containment is related to wrong human action (error of operator during the design, wrong action during the construction or during maintenance, etc.).

b) **Not voluntary errors by plant operators**
One of the most likely causes of loss of containment in industrial plant is the operator error during an action that requires operator intervention: in fact manned operations with respect to unmanned operations have largest probability of failure and need to be analyzed in order to prevent potential severe damages.

c) **Sabotage**
Sabotage is defined as a deliberate action aimed at weakening a polity or corporation through subversion, obstruction, disruption or destruction. Regarding industrial plants, usually sabotage events are voluntary actions planned and acted in order to cause loss of containment, fire or explosion.

d) **Terrorism**
In the last years the terrorist attacks phenomenon is increased due to the general world situation. Accidents in industrial plant caused by terroristic attack have to be taken into account when assessing all the potential causes of loss of containment.

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2. ERRORS IN DESIGN, CONSTRUCTION, MAINTENANCE (A)

In order to evaluate the frequency of events of loss of containment from process items, the statistical database OGP Risk Assessment Data Directory has been taken into account. The frequency with which hydrocarbon releases may potentially occur item has been calculated through the "parts count" exercise: the method involves counting items (valves, flanges, instrument connections, vessels and other equipment) for each representative section and multiplying the number of equipment parts with generic release frequency for each component, provided by the OGP Directory, to obtain the total release frequency.

Since the objective of the study is to provide the frequency of loss of containment of toxic substances (namely, Benzene and Acrylonitrile for Plant A and Cadmium and Arsenic for Plant B), the attention has been focused on plant items that contains the larger volumes of these substances, and each of these identified items has been selected as representative section. 2

In the following the details of calculation and relevant assumption and hypothesis are provided.

2.1 Methodology and assumptions

The activity has been performed through the following steps:

1) Identification of representative section of each Plant;
2) Calculation of items quantity in each section;
3) Calculation of frequency of release.

As already described, the identification of representative section has been performed considering main equipment (e.g., the equipment with largest hold-up) of each plant that contains the toxic substance of interest.

The calculation of item inside each representative section has been performed adopting a qualitative approach: since the main typologies of items of interest in the two plants are very few (namely, storage tanks, pressure vessels, filters, furnaces), for each typology a "standard model" in terms of item composition (number of valves, flanges, etc.) has been built and applied.

In the end, the calculation of frequency of release has been performed multiplying the number of equipment parts with generic release frequency for each component, provided by the OGP Directory.

The main assumptions adopted during this task are listed in the following:

- Piping contribution to the total leak frequency has been estimated as 20% of the calculated leak frequency of each section, therefore the final leak frequency of each section is 1.2 times the calculated one;
- OGP Report 434-1 does not provide any leak data about storage tanks, therefore the OGP Report 434-3 "Storage incidents frequency" has been considered, since it is specifically developed for storage tanks; particularly, for each storage tanks the "tank rupture" frequency provided in the report has been considered and applied, assuming the total rupture of the tank (and the consequent release of contained inventory) as the worst possible event.

2.2 Results

In the following the results obtained applying the methodology described above are provided. Particularly, the following Table details the number of items assigned to each “typical” that is used to describe the representative sections of the Plant and that are described in the following list.

- TYP01: Representative of static equipment such as distillation columns, scrubbers, buffer tanks, reactors;
- TYP02: Representative of filtering units;
- TYP03: Representative of furnaces;
- TYP04: Representative of pumps;
- TYP05: Representative of storage tanks.

Parts Count Elements(1)	Typical				
	TYP01	TYP02	TYP03	TYP04	TYP05
Valve	10	6	6	2	
Flange	15	2	2	6	
Instrumented connection	10	4	4	2	
Pressure Vessel	1				
Pump				1	
Filter		1			
Piping(2)			150		
Tank					1

(1) The number provided for each element refers to element numbers

(2) The number provided for piping refers to meter of piping

Considering available documentation of the two Plants (such as PFD, P&ID, etc.) it has been possible to identify the representative sections that are plant items that contains the largest volumes of toxic substances analyzed in this work, and to each of them the corresponding typical (from previous table) has been assigned in order to characterize the loss of containment frequency.

PLANT A		
Cracking Unit		
ID	Item	Typical
CR-1	VN Storage Tank	TYP05
CR-2	VN Storage Tank Pump	TYP04
CR-3	Primary Fractionator	TYP01
CR-4	Primary Fractionator Pump	TYP04
CR-5	Heavy Gasoline Stripper	TYP01
CR-6	Heavy Gasoline Stripper Pump	TYP04
CR-7	Quench Column	TYP01
CR-8	Quench Column Pump	TYP04
CR-9	Debutanizer	TYP01

PLANT A		
Cracking Unit		
ID	**Item**	**Typical**
CR-10	Debutanizer Pump	TYP04
CR-11	Cracking Gasoline Unit Buffer Tank	TYP05
CR-12	Cracking Gasoline Unit Buffer Tank Pump	TYP04
CR-13	Cracking Gasoline Tank	TYP05
CR-14	Cracking Gasoline Tank	TYP05
Polymerization Unit		
ID	**Item**	**Typical**
EL-1	ACN Storage Tank	TYP05
EL-2	ACN Storage Tank Pump	TYP04
EL-3	Unit Buffer Vessel (horiz)	TYP01
EL-4	Unit Buffer Vessel (horiz) Pump	TYP04
EL-5	Elastomer Production Reactor	TYP01
EL-6	Stripping Column	TYP01

PLANT B		
Cadmium		
ID	**Item**	**Typical**
CD-1	Leaching Tank	TYP01
CD-2	Leaching Tank	TYP01
CD-3	Leaching Tank	TYP01
CD-4	Filter Press (IN)	TYP02
CD-5	Precipitation Tank	TYP05
CD-6	Filter Press (OUT)	TYP02
CD-7	Melting furnace	TYP03
CD-8	Refining Furnace	TYP03
CD-9	Vacuum Distillation	TYP01
CD-10	Refined Cadmium Furnace	TYP03
Arsenic		
ID	**Item**	**Typical**
AR-1	CC-2 Distillation	TYP01
AR-2	Pregant Solution Tank	TYP05
AR-3	Leach Thickener	TYP03
AR-4	High Shear Pre-oxidation	TYP03
AR-5	Cyanide Leach Circuit	TYP03
AR-6	Strip Circuit	TYP02
AR-7	Large Rotary Vacuum Filters	TYP02
AR-8	Smelting and Crystalline of Arsenic	TYP01

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Considering available OGP data it has been possible to calculate, for each defined typical element, the loss of containment frequencies depending on the rupture size diameter.
The results are provided in the following Table detailing, for each typical, the total frequency of loss containment and the probability associated to each rupture size; in addition also exceedance curve probability vs diameter are provided.

Typical	Frequency of loss of containment [ev/y]	Probability [-]				
		2 mm	5 mm	25 mm	100 mm	250mm
TYP01	9.25E-03	0.67	0.23	0.08	0.01	0.01
TYP02	6.13E-03	0.67	0.23	0.08	0.01	0.01
TYP03	9.70E-03	0.69	0.23	0.07	0.01	0.01
TYP04	7.66E-03	0.71	0.21	0.06	0.01	0.01
TYP05(1)	3.60E-06	0.00	0.00	0.00	0.00	1.00

(1) Data derived from OGP Report 434-3 "Process Storage Frequencies" and associated to the catastrophic rupture of the tank (i.e., immediately release of the whole inventory contained)

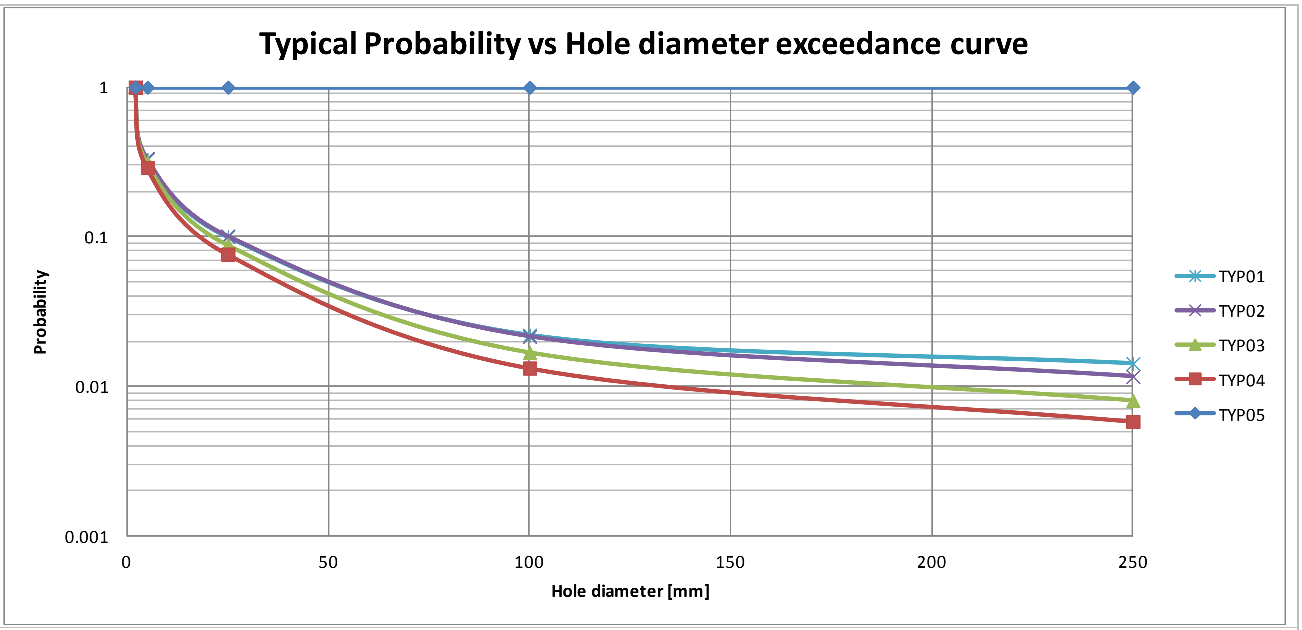

Figure 2-1: Probability vs Hole diameter exceedance curve

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3. NOT VOLUNTARY ERRORS BY PLANT OPERATORS (B)

One of the most likely causes of loss of containment in industrial plant is the operator error during an action that requires operator intervention.
In order to assess this possible source of loss of containment for Plant A and B, tasks that require operator intervention have to be defined and analyzed.
With respect to Plant A, operations of unloading of reactants from road tankers to storage tanks and loading of products from storage tanks to road tankers are the ones in which operators are manly involved.
In the following a brief description of procedures are provided.

3.1 Procedures – Plant A

Procedure description: Reactants unloading from road tankers to storage tanks (Procedure 1)
The refilling of reactants storage tanks (Virgin Naphtha and Acrylonitrile in Plant A) is required when the field operators detect that the liquid level in the tanks is below the reference value. When the truck arrives in the plant the field operator verifies the accompanying documents, prepare the required modules and carry out the weight operation. Once all these actions are performed the unloading procedure can start.

Procedure 1	
Task	**Description**
1	Field operator tells to truck driver to park the truck close to the tank that requires refilling
2	Field operator verify that the truck driver put wedges below the truck
3	Field operator goes in Unit Control Room and switch on the signal related to the Reactant Storage Tanks refilling
4	Field operator from Control Room opens the on-off valve located on the top of the tank
5	Field operator activate the earthling connection to the truck and verify that related lamps switch on
6	Field operator connects the flexible hose and verify that it is well connected
7	Field operator connects the balancing line to the tanker and opens manual valve
8	Field operator starts the unloading of reactants from tanker
9	Field operator attends the unloading operation for the complete duration of the task; during this time he verifies the hose (via visual inspection to prevent potential liquid leakages) and tanker pressure (via field pressure gauge, located at the end of balancing line)
10	Field operator verify the level in the tank; once the tank is filled he closes the valve on unloading pump, the valve on the hose and the valve on balancing line
11	Field operator disconnect the hose and he flushes it with water, discharging the water in the closed drain pit
12	Field operator disconnect balancing line
13	Truck driver remove wedges from the truck

Procedure description: Products loading from storage tanks to road tankers (Procedure 2)
The loading of products from storage tanks (Gasoline BK in Plant A) is required when the field operators detect that the liquid level in the tanks is above the reference value. When the truck arrives in the plant the field operator verifies the accompanying documents, prepare the required

modules and carry out the weight operation. Once all these actions are performed the unloading procedure can start.

Procedure 2	
Task	**Description**
1	Field operator tells to truck driver to park the truck close to the tank that requires refilling
2	Field operator verify that the truck driver put wedges below the truck
3	Field operator goes in Unit Control Room and switch on the signal related to the Product Storage Tanks loading
4	Field operator from Control Room opens the on-off valve of nitrogen blanketing ok tank
5	Field operator activate the earthling connection to the truck and verify that related lamps switch on
6	Field operator connects the flexible hose and verify that it is well connected
7	Field operator connects the balancing line to the tanker and opens manual valve
8	Field operator starts the loading of products to tank
9	Field operator attends the loading operation for the complete duration of the task; during this time he verifies the hose (via visual inspection to prevent potential liquid leakages) and tanker pressure (via field pressure gauge, located at the end of balancing line)
10	Field operator verify the level in the tanker; once the tanker is filled he closes the valve on unloading pump, the valve on the hose and the valve on balancing line
11	Field operator disconnect the hose and he flushes it with water, discharging the water in the closed drain pit
12	Field operator disconnect balancing line
13	Truck driver remove wedges from the truck

3.2 Procedures – Plant B

Procedure Description: Metal Refining and Melting Furnace

Metal-refining melters, furnace operators, blowers and keepers monitor and control vessels and furnaces that melt and purify metal so that it can be poured into a mold to make a product (cadmium and arsenic production (smelting stage) in Plant B). The furnace operator, using computerized charge models, watches over the amounts of scrap, hot metal, and additive used and makes adjustments as necessary. He or she is responsible for ensuring that the proper ratio of raw materials is maintained, and for adjusting the furnace temperature.

Procedure 1	
Task	**Description**
1	Furnace operator weighs materials to be charged into furnaces, using scales
2	Furnace operator regulates supplies of fuel and air, or controls flow of electric current and water coolant to heat furnaces and adjust temperatures
3	Furnace operator inspects furnaces and equipment to locate defects and wear
4	Furnace operator observes air and temperature gauges or metal color and fluidity, and turns fuel valves or adjusts controls to maintain required temperatures
5	Furnace operator operates controls to move or discharge metal workpieces from furnaces
6	Furnace operator draws smelted metal samples from furnaces or kettles for analysis, and calculates types and amounts of materials needed to ensure that materials meet specifications

7	Furnace operator drains, transfers, or removes molten metal from furnaces, and places it into molds, using hoists, pumps, or ladles
8	Furnace operator records production data, and maintains production logs

Procedure Description: Production

This operator position is responsible for correctly and safely operating various machines and production equipment to produce high quality manufactured parts (Plant B).

Procedure 2	
Task	**Description**
1	Production operator correctly setups and operates various machines
2	Production operator follows the production and quality procedures by following prints and checking materials for defects
3	Production operator maintains production materials and inspects product to ensure high quality
4	Production operator performs adjustments and daily maintenance to equipment
5	Production operator verifies measurements to ensure product quality and accuracy
6	Production operator transports the product to the correct location when completed
7	Production operator makes sure materials are readily available for the job
8	Production operator updates all completed work in the correct system per the schedule
9	Production operator assists with other duties within the department and/or other work stations/departments when necessary
10	Production operator completes clean-up responsibilities and maintains work station
11	Production operator performs work at or above pre-established performance objectives
12	Production operator understands workplace hazards and takes steps to proactively prevent and report hazards or injuries in the workplace

3.3 What-If Analysis

Procedures described above have been analyzed by means of “What-If Analysis” technique, a brainstorming approach in which a group of experienced people familiar with the subject process ask questions or voice concerns about possible undesired events. The purpose of a What-If Analysis is to identify hazards, hazardous situations, or specific event sequences that could produce undesirable consequences. During the analysis possible abnormal situations are identified, together with their consequences, and existing safeguards, and then alternatives for risk reduction, where obvious improvement opportunities are identified or where Safeguards are judged to be inadequate, are suggested. The method can involve examination of possible deviations from the design, construction, modification, or operating intent. It requires a basic understanding of the process intention, along with the ability to mentally combine possible deviations from the design intent that could result in an incident.

Results of the analysis are provided in tabular form, and in addition to What-If Analysis also Top Event identification and definition has been performed. Top Event is the undesired event related to the identified hazard: depending on the results of What-If Analysis it is evaluated if the consequence (the answer to the question) can result in a undesired/hazardous event; if so, the event is listed as Top Event and it will be analyzed by means of Fault Tree Analysis in order to quantify the frequency of occurrence.

The procedures have been analyzed and results are provided in the following Tables. The Tables provides:

- Task: the task number;
- Description: description of the task;
- What if..: question that allows to reflect on potential hazards related to the selected action/operation;
- Answer: answer to the question;
- Safeguards: existing safeguards that can avoid or protect from the identified hazard;
- TOP: the number of Top Event identified;
- TOP Description: the description of Top Event.

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Task	Description	What if…	Answer	Safeguards	TOP	TOP Description
			Plant A - Procedure 1			
1	Field operator tells to truck driver to park the truck close to the tank that requires refilling	Truck driver park the truck too far from the tank?	Need to move the truck otherwise the flexible hose cannot be connected. No safety issue	-	-	-
2	Field operator verify that the truck driver put wedges below the truck	Truck driver does not put the wedges and the field operator does not notice it?	Potential truck movement during unloading operation with consequent disconnection/rupture of flexible hose and release of liquid	Flat soil Handbrake Not immediate consequence (time to intervene)	TOP01	Release of virgin Naphtha/acrylonitrile during unloading operation
3	Field operator goes in Unit Control Room and switch on the signal related to the Reactant Storage Tanks refilling	Field operator does not switch on signal?	No safety issue	-	-	-
4	Field operator from Control Room opens the on-off valve located on the top of the Storage Tank	Field operator does not open the on-off valve?	Potential overpressurization of Tank during truck unloading operation	Procedure High Pressure alarm High high pressure interlock to stop loading pump PSV	TOP02	Virgin Naphtha/acrylonitrile tanks overpressurization
5	Field operator activate the earthing connection to the truck and verify that related lamps switch on	Field operator does not activate earthing connection?	Potential fire in case of air ingress in tanker due to electrostatic energy	Procedure	TOP03	Virgin Naphtha/acrylonitrile tanker trucks fire
6	Field operator connects the flexible hose and verify that it is well connected	Field operator does not connect properly hose connection?	Potential liquid leak during unloading operation	Procedure Visual inspection Not immediate consequence (time to intervene)	TOP01	Release of virgin Naphtha/acrylonitrile during unloading operation
7	Field operator connects the balancing line to the tanker and opens manual valve	Field operator does not connect properly the balancing line?	Potential damages to tanker for low pressure	Low pressure alarm on tanker Vacuum breaker	TOP04	Virgin Naphtha/acrylonitrile tanker damages for low pressure
		Field operator does not open manual valve on balancing line?	Potential damages to tanker for low pressure	Low pressure alarm on tanker Vacuum breaker	TOP04	Virgin Naphtha/acrylonitrile tanker damages for low pressure
8	Field operator starts the unloading of reactants from tanker	-	-		-	-
9	Field operator attends the unloading operation for the complete duration of the task; during this time he verifies the hose (via visual inspection to prevent potential liquid leakages) and tanker pressure (via field pressure gauge, located at the end of balancing line)	Field operator does not notice liquid leakages?	Potential liquid leak during unloading operation	Procedure Visual inspection Not immediate consequence (time to intervene)	TOP01	Release of virgin Naphtha/acrylonitrile during unloading operation
		Field operator does not notice low pressure in tanker?	Potential damages to tanker for low pressure	Balancing line Low pressure alarm on tanker Vacuum breaker	TOP04	Virgin Naphtha/acrylonitrile tanker damages for low pressure
10	Field operator verify the level in the tank; once the tank is filled he closes the valve on unloading pump, the valve on the hose and the valve on balancing line	Field operator does not stop unloading when the maximum level is reached?	Potential overfilling of Storage Tank	Procedure High level alarm High high level to stop loading pump	TOP05	Virgin Naphtha/acrylonitrile tanks overfilling
11	Field operator disconnect the hose and he flushes it with water, discharging the water in the closed drain pit	Field operator does not flush hose with water	Potential spread of small liquid quantity (volume contained in the hose) in the area. No safety issue	-	-	-

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12	Field operator disconnect balancing line	Field operator does not disconnect balancing line	Potential line rupture during truck movement. No safety issue	-	-	-
13	Truck driver remove wedges from the truck	-	-	-	-	-

Plant A - Procedure 2						
Task	**Description**	**What if…**	**Answer**	**Safeguards**	**TOP**	**TOP Description**
1	Field operator tells to truck driver to park the truck close to the tank that requires refilling	Truck driver park the truck too far from the tank?	Need to move the truck otherwise the flexible hose cannot be connected. No safety issue	-	-	-
2	Field operator verify that the truck driver put wedges below the truck	Truck driver does not put the wedges and the field operator does not notice it?	Potential truck movement during unloading operation with consequent disconnection/rupture of flexible hose and release of liquid	Flat soil Handbrake Not immediate consequence (time to intervene)	TOP01	Release of gasoline BK during loading operation
3	Field operator goes in Unit Control Room and switch on the signal related to the Product Storage Tanks loading	Field operator does not switch on signal?	No safety issue	-	-	-
4	Field operator from Control Room opens the on-off valve of nitrogen blanketing on tank	Field operator does not open the nitrogen blanketing valve?	Potential vacuum in the tank during loading operation	Balancing line Low pressure alarm on tank Low low pressure trip to stop pump Vacuum breaker	TOP08	-
5	Field operator activate the earthling connection to the truck and verify that related lamps switch on	Field operator does not activate earthing connection?	Potential fire in case of air ingress in tanker due to electrostatic energy	Procedure	TOP03	BK gasoline tanker trucks fire
6	Field operator connects the flexible hose and verify that it is well connected	Field operator does not connect properly hose connection?	Potential liquid leak during unloading operation	Procedure Visual inspection Not immediate consequence (time to intervene)	TOP01	Release of gasoline BK during loading operation
7	Field operator connects the balancing line to the tanker and opens manual valve	Field operator does not connect properly the balancing line?	Potential overpressurization of tanker during unloading operation	Procedure High Pressure alarm PSV	TOP06	Gasoline BK tanker overpressurization
		Field operator does not open manual valve on balancing line?	Potential overpressurization of tanker during unloading operation	Procedure High Pressure alarm PSV	TOP06	Gasoline BK tanker overpressurization
8	Field operator starts the loading of products to tanker	-	-	-	-	-
9	Field operator attends the loading operation for the complete duration of the task; during this time he verifies the hose (via visual inspection to prevent potential liquid leakages) and tanker pressure (via field pressure gauge, located at the end of balancing line)	Field operator does not notice liquid leakages?	Potential liquid leak during unloading operation	Procedure Visual inspection Not immediate consequence (time to intervene)	TOP01	Release of gasoline BK during loading operation
		Field operator does not notice high pressure in tanker?	-	-	-	-
10	Field operator verify the level in the tanker; once the tanker is filled he closes the valve on unloading pump, the valve on the hose and the valve on balancing line	Field operator does not stop loading when the maximum level is reached?	Potential overfilling of tanker	Procedure High level alarm	TOP07	Gasoline BK tanker overfilling
11	Field operator disconnect the hose and he flushes it with water, discharging the water in the closed drain pit	Field operator does not flush hose with water	Potential spread of small liquid quantity (volume contained in the hose) in the area. No safety issue	-	-	-
12	Field operator disconnect balancing line	Field operator does not disconnect balancing line	Potential rupture during truck movement. No safety issue	-	-	-
13	Truck driver remove wedges from the truck	-	-	-	-	-

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Task	Description	What if…	Answer	Safeguards	TOP	TOP Description
Plant B - Procedure 1						
1	Furnace operator weighs materials to be charged into furnaces, using scales	Furnace operator does not weigh materials?	Higher quantity of the melt product than required leading to waste of raw materials and energy	Operating procedure	-	
			Lower quantity of the melt product than required leading to waste of raw materials and energy	Operating procedure		
			Low quality of the service and raw material consumption is not traced	Operating procedure		
2	Furnace operator regulates supplies of fuel and air, or controls flow of electric current and water coolant to heat furnaces and adjust temperatures	Furnace operator does not regulate correctly supplies of fuel and air or does not control flow of electric current and water coolant?	Higher temperature with potential unexpected/undesired reactions leading to formation of flammable atmosphere and consequent explosion affecting people and equipment present in involved area	Operating procedure High Temperature Alarm Explosion vent	TOP09	Furnace Explosion
			Lower temperature with loss of efficiency in melting process leading to time delay in the process and potential contamination of raw materials with low quality of the product	Operating procedure Low Temperature Alarm		
3	Furnace operator inspects furnaces and equipment to locate defects and wear	Furnace operator does not inspect furnaces and relevant equipment?	Potential lower efficiency in melting process leading to product off-spec and waste of energy	Operating procedure		
			Potential loss of containment leading to waste of raw materials or melting product	Operating procedure		
4	Furnace operator observes air and temperature gauges or metal color and fluidity, and turns fuel valves or adjusts controls to maintain required temperatures	Furnace operator does not observe air and temperature gauges or metal color and fluidity, and turns fuel valves or adjusts controls?	Higher temperature with potential unexpected/undesired reactions leading to formation of flammable atmosphere and consequent explosion affecting people and equipment present in involved area	Visual inspection High Temperature Alarm Explosion vent	TOP09	Furnace Explosion
			Lower temperature with loss of efficiency in melting process leading to time delay in the process and potential contamination of raw materials with low quality of the product	Operating procedure Low Temperature Alarm		
5	Furnace operator operates controls to move or discharge metal workpieces from furnaces	Furnace operator does not operate controls to move or discharge metal workpieces from furnaces	Accumulation of molten metal in furnaces leading to potential overfilling or discharge outside the furnace from other holes with potential hazard to operators if present in the area	Operating procedure	TOP10	Furnace Overfilling
6	Furnace operator draws smelted metal samples from furnaces or kettles for analysis, and calculates types and amounts of materials needed to ensure that materials meet specifications	Furnace operator does not draw smelted metal samples from furnace for analysis?	Potential product off-spec leading to waste of materials and energy	Operating procedure		
7	Furnace operator drains, transfers, or removes molten metal from furnaces, and places it into molds, using hoists, pumps, or ladles	Furnace operator does not remove molten metal from furnaces and places it into molds?	Accumulation of molten metal in furnaces leading to potential overfilling or discharge outside the furnace from other holes with potential hazard to operators if present in the area	Operating procedure	TOP10	Furnace Overfilling
8	Furnace operator records production data, and maintains production logs	Furnace operator does not record production data?	Low quality of the service and the product remains non-traced/classified	Operating procedure		

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Plant B - Procedure 2						
Task	**Description**	**What if…**	**Answer**	**Safeguards**	**TOP**	**TOP Description**
1	Production operator correctly setups and operates various machines	Production operator does not correctly setup various machines?	Even if production operator operates correctly the involved machines, potential manufactured parts off-spec caused by incorrect set-up of machines affecting the quality of the production and the production plan	Operating procedure		
		Production operator does not correctly operate various machines?	Potential manufactured parts off-spec due to incorrect machines operation affecting the quality of the production and the production plan	Operating procedure		
2	Production operator follows the production and quality procedures by following prints and checking materials for defects	Production operator does not follow the production and quality procedures?	Defected material pass to next production step without check. It potentially leads to material off-spec affecting the quality of the production and the production plan	Operating procedure		
3	Production operator maintains production materials and inspects product to ensure high quality	Production operator does not maintain production materials and does not inspect product?	Potential manufactured parts off-spec affecting the quality of the production and the production plan with claims from the client	Operating procedure		
4	Production operator performs adjustments and daily maintenance to equipment	Production operator does not perform adjustments and daily maintenance to equipment?	Potential damage to equipment involved due to no maintenance leading to production disruption	Operating procedure		
			Potential manufactured parts off-spec affecting the quality of the production and the production plan with claims from the client	Operating procedure		
5	Production operator verifies measurements to ensure product quality and accuracy	Production operator does not verify measurements to ensure product quality and accuracy?	Defected material pass to next production step without check. It potentially leads to material off-spec affecting the quality of the production and the production plan	Operating procedure		
6	Production operator transports the product to the correct location when completed	Production operator does not move the product when completed?	Potential product damage due to ambient conditions affecting the quality of the production and the production plan with claims from the client	Operating procedure		
		Production operator does not transport the product to the correct location?	Product can be classified not completed potentially leading to production disruption	Operating procedure		
7	Production operator makes sure materials are readily available for the job	Production operator does not make sure materials are readily available for the job?	Potential manufactured parts off-spec affecting the quality of the production and the production plan with claims from the client	Operating procedure		
				Operating procedure		
8	Production operator updates all completed work in the correct system per the schedule	Production operator does not update all completed work in the system per the schedule?	Potential delay in the schedule leading to claims from the client	Operating procedure		
9	Production operator assists with other duties within the department and/or other work stations/departments when necessary	Production operator does not assist with other duties within the department and/or other work stations/departments when	Potential inefficient and ineffective communication among departments leading to materials off-spec, production disruption affecting the quality of the production with	Training		
				Training		

Plant B - Procedure 2						
Task	**Description**	**What if…**	**Answer**	**Safeguards**	**TOP**	**TOP Description**
		necessary?	claims from the client			
10	Production operator completes clean-up responsibilities and maintains work station	Production operator does not complete clean-up responsibilities and maintains work station?	A dirty work station may affect the availability of the machines, the product integrity and/or may affect the health of the operator leading to potential product off-spec, production disruption and injury on operator	Operating procedure		
11	Production operator performs work at or above pre-established performance objectives	Production operator does not perform work at or above pre-established performance objectives?	Potential increase of product off-spec, production disruption or delays, claims from client and injuries on operator.	Training Operating procedure		
12	Production operator understands workplace hazards and takes steps to proactively prevent and report hazards or injuries in the workplace	Production operator does not understand workplace hazards?	Increase of potential injuries on operators working in the area due to leave out PPE or the incorrect use of PPE	Training PPE Operating procedure		
		Production operator does not take steps to proactively prevent and report hazards or injuries in the workplace	The improvement of near misses and accidents avoidance study is stuck due to data shortage	Training PPE Operating procedure		

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As shown in previous Table, eight Top Events have been identified considering What-If Analysis results. The following Table provides the list of Top Evens and relevant description and involved substances.

ID	Sub-ID	Substances involved	TOP	Description
TOP01	TOP01a	Virgin Naphtha	Release of liquid from flexible hose	The liquid release from flexible hose is caused by two independent events: the first is related to the truck movement resulting in hose disconnection (flat soil that avoid unplanned truck movements and truck handbrake are considered as protections), while second is related to the wrong hose connection (time to intervene to mitigate consequences and check of second operator as protection)
	TOP01b	Acrylonitrile		
	TOP01c	BK Gasoline		
TOP02	TOP02a	Virgin Naphtha	Tank overpressurization and potential rupture	The overpressurization of the tank can be caused in case operator does not open the on/off valve on the top of the tank before starting the unloading procedure. Protections provided are the balancing line (that is connected before starting the unloading procedure), the high pressure alarm, the high high pressure interlock to stop the pump and the PSV provided on the tank.
	TOP02b	Acrylonitrile		
TOP03	TOP03a	Virgin Naphtha	Tanker fire due to electrostatic energy	Virgin Naphtha/acrylonitrile tanker trucks fire due to electrostatic energy (only in case of air ingress)
	TOP03b	Acrylonitrile		
	TOP03c	BK Gasoline		
TOP04	TOP04a	Virgin Naphtha	Tanker damages for low pressure	The low pressure in the tanker can occur during unloading operation in case operator does not connect properly the balancing line; an additional protection is provided by the low pressure alarm provided on tanker
	TOP04b	Acrylonitrile		
TOP05	TOP05a	Virgin Naphtha	Tank overfilling	Overfilling of the tank can happen during liquid loading in case operator forgets to check the level inside the tank to stop the loading operation. Other protections provided are the high level alarm on the tank and the high high level interlock to stop loading pump
	TOP05b	Acrylonitrile		
TOP06	-	BK Gasoline	Tank overpressurization and potential rupture	The overpressurization of the tanker can be caused in case operator does not open connect the balancing line before starting the unloading procedure. Protections provided are the high pressure alarm and the PSV provided on the tank.
TOP07	-	BK Gasoline	Tank overfilling	The overpressurization of the tanker can be caused in case operator forgets to check the level inside the tank to stop the loading operation. Additional protection provided is the high pressure alarm on the tank.
TOP08	-	BK Gasoline	Tank damages for low pressure	The low pressure in the tank can occur during tanker loading operation in case operator does not open nitrogen blanketing valve to the tank; an additional protection is provided by the low pressure alarm provided on tanker
TOP09	TOP09a	Undefined flammable mixture	Furnace Explosion	Furnace explosion is caused by two independent events: the first is related to operator error not adjusting the temperature in the furnace by regulating supplies of fuel and air, or controlling flow of electric current and water coolant; the second one is related to operator error not maintaining the required temperature and not monitoring air and temperature gauges or metal color and fluidity during operation
	TOP09b	Undefined flammable mixture		
TOP10	-	Molten metal	Furnace Overfilling	Furnace overfilling is caused by two independent events: operator error not checking if the furnace is empty and operator error not removing molten metal from the furnace

3.4 Frequencies of operations

In order to analyze the potential errors related to manned operation of loading/unloading, the numbers of loading/unloading operations per year are required. These frequencies are provided in the following Table depending on the selected material.

Material	Operation	Frequency of operation [ev/y]
Virgin Naphtha	Unloading (from road tanker to storage tank)	165 (1 op/2 day)
Acrylonitrile	Unloading (from road tanker to storage tank)	52 (1 op/month)
BK Gasoline	Loading (from storage tank to road tanker)	110 (1 op/3 days)

In order to analyse the potential errors related to melting process, the total duration of a melting cycle with the combustion system is 6-8 hours; it is possible to assume 1 cycle per day as shown in the following Table.

Material	Operation	Frequency of operation [ev/y]
Metal raw materials / molten metal / final products	Melting Process	240 (1 op/working day) (Note 1)
Note 1: it is assumed 5 working days per week and it results in 240 operations per year		

3.5 Fault Tree Analysis

In order to quantify the frequency of occurrence of each identified Top Event, the Fault Tree Analysis has been applied. This methodology is a top down, deductive failure analysis in which the undesired event (Top Event) is analyzed using Boolean Logic to combine a series of lower level events. The approach is used to understand how systems can fail and to quantify the probability of occurrence of the undesired event.

The quantification of failure rate has been performed considering available literature data; particularly failure rates of process items and components has been taken from reliability databases (Exida 2007, Sintef 2010, Oreda 2009), while the quantification of operator error probability has been performed by means of Human Error Assessment & Reduction Technique (HEART), developed in 1986 by Williams (HEART, 1986); HEART is a Human Reliability Assessment method based on human performance literature that allows to estimate the probability of error for a specific operator task once some parameters (such as Generic Task Unreliability, Error Producing Condition&Multiplier, Assessed Proportion of Effect) are defined selecting them from provided lists.

In case of failure rates of process items the databases provide failure rates in ev/h; if the evaluation of unavailability is required, the following equation is applied:

$$q = \frac{\lambda \cdot \tau}{2}$$

where:

- λ: is the failure rate of the component;

- τ: is the test interval (conservatively selected equal to 1 year for each component);
- q: is the unavailability of the component.

The reliability data used in the Fault Trees are provided in the following Table, providing for each of them a description, the literature reference and the events reference numbers; for probability evaluated by means of HEART methodology, relevant worksheets are provided in Attachment B.

Event	Description	Reference	Failure rate [ev/h]	Unavailability [-]	Fault Tree Event Reference
Unloading operation	Unloading operation of Virgin Naphtha from road tanker to storage tank	-	165 ev/y	-	1.1a, 2.1a, 3.1a, 4.1a, 5.1a
Unloading operation	Unloading operation of Acrylonitrile from road tanker to storage tank	-	52 ev/y	-	1.1b, 2.1b, 3.1b, 4.1b, 5.1b
Loading operation	Loading operation of BK Gasoline from storage tank to road tanker	-	110 ev/y	-	1.1c, 3.1c, 6.1, 7.1, 8.1
Melting operation	Furnaces that melt and purify metal so that it can be poured into a mold to make a product	-	240 ev/y	-	9.1, 10.1
Flat soil	The park area for truck stop is flat, therefore even in case of handbrake not activated the truck will not move	-	-	1.00E-05	1.2
HE – Handbrake	The probability that the truck driver does not activate the handbrake after parking the truck	HEART	-	2.11E-02	1.3
Wrong connection	The operators does not connect properly the flexible hose for loading/unloading operations	HEART	-	3.05E-03	1.4
Time to intervene	The operator does not detect a leakage during transferring operations and therefore he cannot intervene stopping the transferring	HEART	-	1.80E-02	1.5
Missing check of second operator	The probability that truck driver, even if he is present during transferring and he could help the field operator to follow the procedures and to detect potential liquid spillage	HEART	-	1.80E-02	1.6, 3.3, 4.3, 5.7, 6.5, 7.4
Procedure (balancing line)	The field operator has to connect balancing line between tank and tanker before starting the transferring operation.	HEART	-	3.05E-03	2.2, 3.4, 4.2, 6.2, 8.2
Operator response on alarm	The probability that the operator does not perform the correct action in case of alarm (high/low pressure, high/low level)	HEART	-	1.05E-02	2.3, 4.4, 6.3, 7.3, 8.6, 9.4
Failure of PT	Failure of Pressure Transmitter	Sintef 2010	3.00E-07	1.31E-03	2.4, 8.3
Failure of control logic	It is assumed a control logic ranked SIL2 level	-	5.00E-03	-	2.5, 5.5, 8.4
Failure of pump	The failure of pump that does not stop when required	Exida 2007	7.20E-07	3.15E-03	2.6, 5.6, 8.5
PSV on tank	The failure of PSV that does not open when required	Sintef 2010	2.20E-06	9.64E-03	2.7, 6.4
No earthing connection	The field operator does not connect truck earthing connection before starting loading/unloading activities	HEART	-	3.04E-03	3.2

Event	Description	Reference	Failure rate [ev/h]	Unavailability [-]	Fault Tree Event Reference
Procedure (check of the level)	The field operator checks the tanker/truck level during the transferring operation in order to stop the pump when the maximum allowable level is reached	HEART	-	8.00E-04	2.8, 5.2, 7.2
Failure of LT	Failure of Level Transmitter	Sintef 2010	6.00E-07	2.63E-03	5.4
Wrong setting of Temperature	Furnace operator does not regulate / adjust correctly the temperature of the furnace	HEART	-	2.40E-05	9.2
Missing checks on melting operation	Furnace operator does not observe air and temperature gauges or metal color and fluidity, and adjust temperature	HEART	-	2.40E-05	9.3
Explosion vent	Failure of explosion vent (assumed equivalent to bursting disk)	Lees	2.30 E-05/h	-	9.5
Missing check on furnace filling level	Furnace operator does not operate controls to move or discharge metal workpieces from furnaces	HEART	-	2.40E-05	10.2
Missing removal of molten metal	Furnace operator does not operate controls to move or discharge metal workpieces from furnaces	HEART	-	9.60E-05	10.3

The detail of the Fault Tree Analysis are provided in Attachment A, while in the following Table a summary of the results, in terms of frequency of occurrence, is provided.

ID	Substances involved	TOP	Frequency of occurrence [ev/y]
TOP01a	Virgin Naphtha	Release of liquid from flexible hose	1.98E-04
TOP01b	Acrylonitrile		6.24E-05
TOP01c	BK Gasoline		1.32E-04
TOP02a	Virgin Naphtha	Tank overpressurization and potential rupture	3.16E-10
TOP02b	Acrylonitrile		5.01E-11
TOP03a	Virgin Naphtha	Tanker fire due to electrostatic energy	2.75E-05
TOP03b	Acrylonitrile		8.68E-06
TOP03c	BK Gasoline		1.84E-05
TOP04a	Virgin Naphtha	Tanker damages for low pressure	9.51E-05
TOP04b	Acrylonitrile		3.00E-05
TOP05a	Virgin Naphtha	Tank overfilling	2.69E-07
TOP05b	Acrylonitrile		8.48E-08
TOP06	BK Gasoline	Tank overpressurization and potential rupture	6.11E-07

ID	Substances involved	TOP	Frequency of occurrence [ev/y]
TOP07	BK Gasoline	Tank overfilling	1.66E-05
TOP08	BK Gasoline	Tanker damages for low pressure	5.00E-05
TOP09	Metal raw materials / molten metal (Cadmium)	Furnace Explosion	6.40E-07
TOP10	Metal raw materials / molten metal (Cadmium)	Furnace Overfilling	2.42E-03

4. SABOTAGE AND TERRORISM (C)

4.1 General Overview

In order to develop an analysis that takes into account potential hazards deriving by terrorism and sabotage, a general overview of the historical and political Italian situation is required.
In Italy there is a general threat from terrorism, meaning that the alert is significant but aligned to the same levels of other European Countries. There have been isolated cases of domestic terrorism, and they are carried out by the extreme left-wing and secessionist groups have generally been aimed at official Italian targets, mainly in the form of small bombs and incendiary devices.
Attacks could be indiscriminate, including in places frequented by foreigners, and usually the targets are public places like squares, railway stations, trains, airports. No terroristic attack has been carried out up to now in a chemical/industrial plant or facility.

Considering the explanation reported in the previous paragraphs, the characteristics of the site and the minimum security required for the facility, a list of threats has been identified:

- Electrical Power System Sabotage;
- Internal Communication System Sabotage;
- External Communication System Sabotage;
- Water System Sabotage;
- Bomb Attack;
- Discovery of an Improvised Explosive Device (IEDs);
- Vandalism;
- Theft;
- Intruders;
- Suicide Attacks;
- Hostage/Kidnapping;
- Armed/ Terrorist attack.

Each threat of previous list have been described and analyzed in the following paragraph.

4.1.1 Electrical Power System Sabotage

From its earliest days, the electric power industry has been able to provide, or rapidly restore, essential services during various types of natural emergencies. Recent international developments have created a heightened threat to the nation's infrastructure from terrorist attack, including the electric power supply system. It is also evident from the various attacks carried out by terrorists groups against power systems elsewhere in the world that many such groups consider electric power systems to be on their list of potential targets. Potential terrorist attacks against electric power systems may include:

- Sabotage;
- Physical assault;
- Disruption of sensors.
- Information systems and computer networks;
- Tampering with process safety;

- Disruption of fail-safe systems;
- Indirect attacks such as disruption of water, fuel, or key personnel.

Electric power transmission and distribution systems are susceptible to attack by saboteurs and terrorists. The electrical power is generated inside the perimeter of the Plant. Selecting points for attack and estimating the consequences are within the capability of technically trained individuals in the terrorist community.

4.1.2 Internal/External Communication System Sabotage

Attackers have a variety of options for breaking into an industrial facility's operations: a sabotage of the Communication System is one of the most diffused. Often, communication systems are connected to corporate systems, so commonly known Windows or server vulnerabilities can open a back door into the control rooms. Internal communication is protected by the station perimeter that is a restricted area. External communication is through buried cables and satellite dishes located inside the station perimeters that is a restricted area of the Plant. Moreover, external communications to corporate systems are firewalled.

4.1.3 Bomb Attack

A bomb is basically some type of casing or shell that contains explosive material. The casing can be anything from a steel-walled artillery shell to a glass bottle or a sealed-shut length of lead pipe. It can even be as ordinary as a coffee tin or an automobile. Once the casing is penetrated by the force of the explosion, it will fragment outward, each piece of the shell serving as a deadly projectile. The explosive material inside the shell could be any type of high explosive.
A bomb causes damage in several different ways, depending on the point at which the explosion impacts. These different points include:

- Blast wave: When a bomb explodes, the area around the explosion becomes over-pressurized, resulting in highly compressed air particles that travel faster than the speed of sound. This wave will dissipate over time and distance and will exist only for a matter of milliseconds. This initial blast wave inflicts the most damage. When this blast wave reaches a structure or person, two things will initially happen. First, the person will feel the force of the blast, which is the primary and initial impact of the shockwave. This will damage a structure or body on impact.
- Shockwaves: After a blast wave strikes a surface or body, high-velocity shockwaves, or stress waves, will continue to pass through in the body, they travel through the organs and tissues. Shockwaves carry energy through the medium they pass through; they're supersonic and transport more energy than sound waves. Currently, there are no effective ways to prevent shockwaves from passing through protective clothing, and in some cases protective measures may even amplify the destructive effects?
- Fragmentation: When the bomb explodes, the bomb casing, as well as any additional shrapnel (nails, screws or other items included in the bomb), will be violently thrown outward and away from the explosion. When these fragments strike buildings, concrete, masonry, glass and even people, they may fragment even further and cause even more damage. This is known as secondary fragmentation.
- Fire and heat: The explosion may also create a fireball and high temperatures, which will result in burns on a human body or even cause secondary fires or explosions, depending on whether any other fuel sources or flammable materials are located near the blast.

- Blast wind: At the explosion site, a vacuum is created by the rapid outward movement of the blast. This vacuum will almost immediately refill itself with the surrounding atmosphere. This creates a very strong pull on any nearby person or structural surface after the initial push effect of the blast has been delivered. As this void is refilled, it creates a high-intensity wind that causes fragmented objects, glass and debris to be drawn back in toward the source of the explosion.

4.1.4 Discovery of an Improvised Explosive Device (IEDs)

An improvised explosive device (IED) attack is the use of a “homemade” bomb and/or destructive device to destroy, incapacitate, harass, or distract. IEDs are used by criminals, vandals, terrorists, suicide bombers, and insurgents. Because they are improvised, IEDs can come in many forms, ranging from a small pipe bomb to a sophisticated device capable of causing massive damage and loss of life. IEDs can be carried or delivered in a vehicle; carried, placed, or thrown by a person; delivered in a package; or concealed on the roadside.

4.1.5 Vandalism

The intentional destruction of property is popularly referred to as vandalism. It includes behavior such as breaking windows, slashing tires, spray painting a wall with graffiti, and destroying a computer system through the use of a computer virus.
In this environment, vandalism is a malicious act aimed to cause damages or destruction of critical components, devices or infrastructures of the facility, and may reflect personal. The recklessness of the act imputes both intent and malice.

4.1.6 Theft

A “thief” is person who dishonestly appropriates property belonging to another with the intention of permanently depriving the other of it; and “thief” and “steal” shall be construed accordingly. In this case, act of robbery and theft are intended as intentional actions aimed to the robbery of critical devices inside the facility.
Infiltrators can enter the facility only by land, with the aim of stealing material and/or damaging apparatus, compromising operability of the entire plant.

4.1.7 Intruders

The term “intruder” is referred to a person who is present in the system and that is doing business without any documents or identification device exposed or at least clearly visible.
The reason for the lack of identification can be due to various causes: loss of recognition device (ID badge or document legally recognized), lack of board staff, unauthorized access to restricted areas, and intrusion for the purpose of sabotage or criminal act).

4.1.8 Suicide Attacks

Terrorist organizations may organize acts aimed to reach the highest level of destruction and injuries in the facility proximities. Subversive groups can carry out attacks with explosives, possibly from portable missile launchers or transported by local drivers, on parts of the gas pipeline or against the company, with the result of causing fires, interrupting operations of the facility or the gas pipeline, interrupting any maintenance operations underway.

4.1.9 Hostage/Kidnapping

Possible threats can derive from terrorist action or protests, aimed at creating a significant psychological impact on public opinion in order to receive satisfaction for any claims/requests made or in order to raise awareness in society at large of the damage that man, globalization and in particular multinational companies cause to the environment; action could also be aimed at striking at symbols of capitalism and the western lifestyle in general.
Nationally based subversive groups could use action against sites to protest against current energy policies or against major projects undertaken by the current government or, more in general, the candidates chosen by a political party.
Finally, the intense media coverage given a significant incident at a site could also provide a kick-start to launch new subversive groups in search of publicity and support in non-parliamentary environments.

4.1.10 Armed / Terrorist Attack

Armed attacks are terrorist acts aimed to reach the highest level of destruction and injuries in the facility proximities. Activist/Local Groups occupy facility zones and/or block access to it, in order to block operations, obtain publicity and a response to any claims made.

4.2 Risk Assessment

In the following chapters the main steps of the security risk analysis are explained. It has been performed in two stages.

- A facility based assessment that calculates the Security Risk Level as an overall high-level risk screen;
- A scenario based assessment that goes into much more detail and that will be described and analyzed in another part of the document. The scenario-based assessments may cause a re-evaluation of the overall facility based high level risk screen.

The risk level is only valid at the time of the assessment. Threat levels do vary and it would be prudent to include a severity factor to cover foreseeable variations in level of risk.
The Security Risk List level (SRL) is defined as the sum of the following numerical values:

- Severity Factor (S);
- Difficulty of Attack Factor (D);
- Attractiveness of Target Factor (At).

Different risk levels are defined in the first column of the following Table.

No	Risk	Description
3	Low	Common sense security practices to be implemented – typically, follow best practice by other oil and gas companies in the same location. Second stage scenario risk assessment may not be required
4	Low	
5	Medium	Review and introduce additional security measures to reduce risk. Second stage scenario based risk assessment to be carried out for the more obvious threats
6	Medium	
7	Medium	

No	Risk	Description
8	High	Second stage scenario risk assessment to be carried out for all possible threats. Expert security advisor to review SRL assessment, conduct facility survey and make recommendations to reduce risk
9	High	
10	Extreme	As for "high"; also consider evacuation of vulnerable personnel and possible cessation of activities until risk reduction recommendations are fully implemented
11	Extreme	

In the second column the description of the security risk level defined by the range is provided. It can assume the Low, Medium, High or Extreme value.
The third column is a color code associated to the security risk level. (Green as Low, Yellow as Medium, Orange as High and Red as Extreme)
The last column defines the general actions/countermeasure which should be taken in order to reduce the security risk level.
The parameters that define the SRL are described more deeply in the following paragraphs.

4.2.1 Severity Factor (S)

Severity is a parameter that defines the predicted consequences resulting from a security incident. The values and examples are defined in the following Table**Errore. L'origine riferimento non è stata trovata.**. The monetary criteria showed in the following table are generally replacement cost insured values and does not cover consequential losses.

Factor	Generic consequence severities	Examples
1	Injuries Theft or damage of low value items (up to 10k€) Minimal disruption of activities, possible local media coverage	• Theft of laptop PC from office • Security guard concussed and weapons/ammunition stolen
2	Fatalities Theft or damage of high value items (up to 500 k€) Theft of hazardous or dangerous items Significant but short term disruption to activities National media coverage	• Radioactive source stolen from construction site • Bomb ruptures well flow line – repaired and production back online in one weeks
3	Fatalities including third parties Theft or damage to very high value items (over 500k€) Theft of hazardous or dangerous items Major and long term disruption to activities International media coverage	• Armed terrorist attack on drilling site – two fatalities • Rocket attack on production plant – 5M€ asset damage and loss of full production for 6 months

4.2.2 Difficulty of Attack Factor (D)

The Difficulty of Attack Factor is as shown in Table below. This factor is to be estimated based on the type(s) of scenario(s) expected at the facility. It is influenced by the site layout, existing risk reduction measures and other considerations.

Factor	Description and Factors which influence the likelihood of attack	Examples
1	The scenario could be caused by a successful attack, which would require a well-planned and coordinated series of events involving several individuals with special general knowledge/training and breaching several independent security barriers	• Hijacking an aircraft • Organised paramilitary attack on a facility
2	The scenario could be caused by a successful attack, which could be accomplished by a small group of individuals with equipment or materials available to terrorist (or criminal) organisations (or an insider with special knowledge of the facility), and does require access to restricted areas	• Use of explosive materials within the facility boundaries • Sabotage of central communications and IT infrastructure • Theft of cash or valuables
3	The scenario could be caused by a successful attack, which could be accomplished by a small group of individuals with equipment or materials available to terrorist (or criminal) organisations, but does not require access to restricted access areas	• Use of explosives from outside the facility boundaries, e.g. truck bomb • Kidnap/ransom of senior executive • Damage to remote wellhead
4	The scenario could be caused by a successful attack accomplished by a single individual with readily available equipment or materials	• Rifle shot from outside a fence • Assault and robbery • Theft of or from vehicle

4.2.3 Attractiveness Factor (At)

Not all targets are of equal value to adversaries. Attractiveness of target (At) is an estimate of the real or perceived value of a target to an adversary based on such factors as shown in the Table below:

Possible Target Attractiveness Factor (A_T)
Poor community relations
Extreme rich/poor polarisation
Association with human rights abuses
High value items e.g. laptops, cash, jewellery, precious metals
Drugs in weapons, ammunition
Hazardous inventories e.g. explosives, radioactive sources
Potential for large casualties/fatalities
Extensive property/asset damage
Partnership with unpopular government
Facilities shared or adjacent to “attractive” target
Proximity to national asset or landmark
Disruption or damage to company critical infrastructure
Disruption of the national, regional, local economy infrastructure
Ease of access to the target
Extent of media interest
Company reputation and brand exposure
Iconic or symbolic target

Attractiveness Factor is related to the facility and its value is fixed for all the considered threats. It has a value between “1” and “4”. There are no specific criteria for deciding the exact value.
The reference provided in the following Table has been used for the At evaluation method.

A_T	**Number of factors that apply to facility**
1	~ 20%
2	~ 30%
3	~ 50%
4	~ 50% to 100%

Taking into account what is described in this paragraph and applying it to the current geopolitical and social situation of the nation in which the facility will be built (in accordance with the Threats

Identification detailed in previous paragraph), the value of the parameter Attractiveness of Target is found to be equal to “4”.
The details of the calculation are shown in the following Table.

Possible Target Attractiveness Factor (A_T)	
Poor community relations	No
Extreme rich/poor polarisation	No
Association with human rights abuses	No
High value items e.g. laptops, cash, jewellery, precious metals	No
Drugs in weapons, ammunition	No
Hazardous inventories e.g. explosives, radioactive sources	Yes
Potential for large casualties/fatalities	Yes
Extensive property/asset damage	Yes
Partnership with unpopular government	No
Facilities shared or adjacent to “attractive” target	No
Proximity to national asset or landmark	No
Disruption or damage to company critical infrastructure	Yes
Disruption of the national, regional, local economy infrastructure	Yes
Ease of access to the target	No
Extent of media interest	No
Company reputation and brand exposure	Yes
Iconic or symbolic target	No
Final Percentage	**35%**
A_T	**3**

4.2.4 Risk results

The following Table provides the results of risk calculation of the Security Risk Level.

Threats		**SRL (Security Risk Level)**		**SRL (Calculation Parameters)**		
No	**Description**	**Level**	**Definition**	**S (Severity Factor)**	**D (Difficulty Factor)**	**AT (Attractiveness Factor)**
1	Electrical Power System Sabotage	7	Medium	2	2	3
2	Internal Communication System Sabotage	7	Medium	2	2	3

Threats		SRL (Security Risk Level)		SRL (Calculation Parameters)		
No	Description	Level	Definition	S (Severity Factor)	D (Difficulty Factor)	AT (Attractiveness Factor)
3	External Communication System Sabotage	7	Medium	2	2	3
4	Water System Sabotage	6	Medium	1	2	3
5	Bomb Attack	10	Extreme	3	4	3
6	Discovery of an improvised explosive device (IED)	9	High	3	3	3
7	Vandalism	6	Medium	1	2	3
8	Theft	7	Medium	1	3	3
9	Intruders	8	High	1	4	3
10	Suicide Attacks	9	High	3	3	3
11	Hostage / Kidnapping	9	High	2	4	3
12	Armed / Terroristic Attack	10	Extreme	3	4	3

Considering above results, only the two threats classified as "Extreme" risk level are selected for further analysis, since they are the worst possible cases. Particularly, in the following a more detailed description of the events are provided in order to clarify how these events can evolve and results in loss of containment.

- Bomb attack: in case of bomb attack the worst possible scenario in terms of loss of containment is assigned. Considering the characteristics of the Plants, it has been associated to the instantaneous release of the inventory contained in the storage tanks for Plant A (item with largest inventories and located in area where plant operators are less present), while for Plant B it has been associated to the instantaneous release of the inventory contained in the pregant solution tanks (item which the largest inventory);
- Armed/Terroristic Attack: with respect to this case a lower severity has been assigned since an armed attack could be less impacting with respect to bomb attack, and the consequences have been associated to a 250 mm rupture from storage tanks (item with largest inventories and located in area where plant operators are less present) while for Plant B the

consequences have been associated to a 250 mm rupture from pregant solution tanks (item which the largest inventory).

After the identification of the scenarios, a frequency of occurrence has to be assigned to each of them; the evaluation of the likelihood of this kind of events is quite difficult due to the uncertainty and the lack of literature information about. Some databases are available online, but they provide only a record of the number of terroristic attack per Country without any addition information about the targets and the development of the attack. A terroristic attack involving a chemical/industrial plant is never happened in Italy: worst attacks have been directed to crowded places as city squares, railway stations, airports, etc.
Considering this, to the identified scenarios lower credible frequency of occurrence has been applied; this frequency is equal to 1.00E-06 ev/y and represents the usual credibility threshold for events occurrence in risk assessment and it is the lowest frequency value used in risk assessment matrixes.

5. CONCLUSIONS

This report details the methodology, results and findings of the anthropogenic hazard assessment carried out for the Plant A and B.
Particularly, the following aspects have been covered within this report:

a) Errors in design, construction, maintenance
b) Not voluntary errors by plant operators
c) Sabotage and terrorism

The point a) has been developed by means of the statistical databases OGP Report 434-1 and 434-3 through the parts count method. Typical items have been identified on Plants PFDs and, for each of them, a leak frequency and an exceedance probability (for the diameters identification) has been worked out.

Typical	Frequency of loss of containment [ev/y]	Probability [-]				
		2 mm	5 mm	25 mm	100 mm	250mm
TYP01	9.25E-03	0.67	0.23	0.08	0.01	0.01
TYP02	6.13E-03	0.67	0.23	0.08	0.01	0.01
TYP03	9.70E-03	0.69	0.23	0.07	0.01	0.01
TYP04	7.66E-03	0.71	0.21	0.06	0.01	0.01
TYP05(1)	3.60E-06	0.00	0.00	0.00	0.00	1.00

(1) Data derived from OGP Report 434-3 "Process Storage Frequencies" and associated to the catastrophic rupture of the tank (i.e., immediately release of the whole inventory contained)

Point b) has been analyzed starting from the procedures developed for tasks that require a significant operator action. For each task a dedicated "What-if Analysis" has been developed and from the results potential hazardous scenario (called Top Event) have been identified, analyzed and quantified in terms of frequency of occurrence by means of Fault Tree Analysis; the following Tables provides the summary of the results of point b).

ID	Substances involved	TOP	Frequency of occurrence [ev/y]
TOP01a	Virgin Naphtha	Release of liquid from flexible hose	1.98E-04
TOP01b	Acrylonitrile		6.24E-05
TOP01c	BK Gasoline		1.32E-04
TOP02a	Virgin Naphtha	Tank overpressurization and potential rupture	3.16E-10
TOP02b	Acrylonitrile		5.01E-11
TOP03a	Virgin Naphtha	Tanker fire due to electrostatic energy	2.75E-05
TOP03b	Acrylonitrile		8.68E-06
TOP03c	BK Gasoline		1.84E-05

ID	Substances involved	TOP	Frequency of occurrence [ev/y]
TOP04a	Virgin Naphtha	Tanker damages for low pressure	9.51E-05
TOP04b	Acrylonitrile		3.00E-05
TOP05a	Virgin Naphtha	Tank overfilling	2.69E-07
TOP05b	Acrylonitrile		8.48E-08
TOP06	BK Gasoline	Tank overpressurization and potential rupture	6.11E-07
TOP07	BK Gasoline	Tank overfilling	1.66E-05
TOP08	BK Gasoline	Tanker damages for low pressure	5.00E-05
TOP09	Metal raw materials / molten metal	Furnace Explosion	6.40E-07
TOP10	Metal raw materials / molten metal	Furnace Overfilling	2.42E-03

Point c) have been developed considering a qualitative approach that allow to analyze main possibile threaths derived by a terrorist attack or a sabotage and to identify the worst in order to consider them in next phases.
In the following Table a summary of the results of point c) is provided.

Threat	Substances involved	Description	Frequency of occurrence [ev/y]
Bomb attack	Virgin Naphtha	A bomb placed close to the storage tanks that results in instantaneous release/fire of virgin Naphtha	1.00E-06
Bomb attack	BK Gasoline	A bomb placed close to the storage tanks that results in instantaneous release/fire of BK Gasoline	1.00E-06
Bomb attack	Acrylonitrile	A bomb placed close to the storage tanks that results in instantaneous release/fire of Acrylonitrile	1.00E-06
Bomb attack	Arsenic	A bomb placed close to the pregant solution tank that results in instantaneous release of Arsenic	1.00E-06
Terroristic attack	Virgin Naphtha	A terroristic attack that results in a 250 mm release from storage tank	1.00E-06
Terroristic attack	BK Gasoline	A terroristic attack that results in a 250 mm release from storage tank	1.00E-06
Terroristic attack	Acrylonitrile	A terroristic attack that results in a 250 mm release from storage tank	1.00E-06
Terroristic attack	Arsenic	A terroristic attack that results in a 250 mm release from pregant solution tank	1.00E-06

6. REFERENCES

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