PHAST is the world's most comprehensive ammonia refrigerant (NH_3) hazard analysis software system for safety management operation of industrial buildings

PHAST hazard analysis software examines the progress of a potential Ammonia (NH_3) leak from its initial release to far-field dispersion analysis including modelling of pool spreading, evaporation, flammable and toxic effects.

DNV

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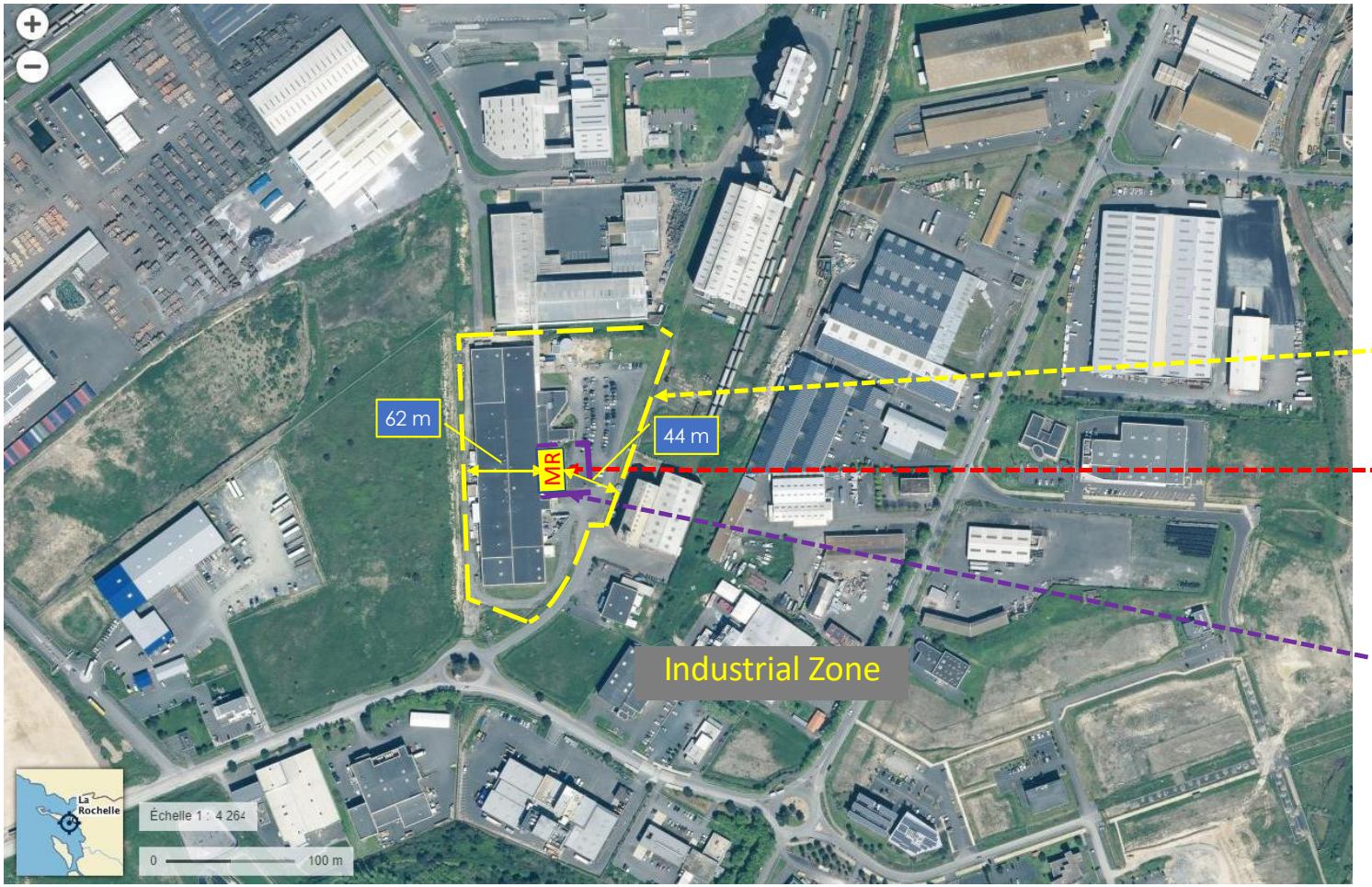
1 – Risk Area Localization related to Ammonia Refrigerant usage



The different scenarios studied with the measures that will be put in place do not have effects outside the property limits of the Atlantique Alimentaire - La Rochelle site (France)

Potential Hazardous Areas:

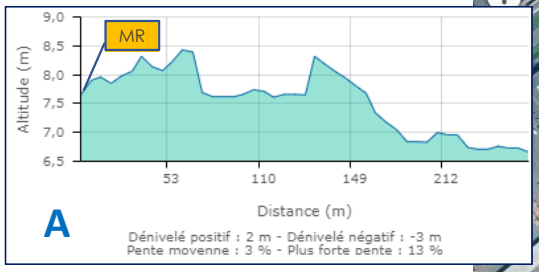
- **Machine Room (compressors & vessels)**
- **Rooftop (condensers)**
- **Attic (valves stations)**

Access to the site is strictly prohibited for any foreign person

Machine Room
(scenario results 10, 11, 12, 13, 14, 15, 16 et 17)
Z1 (au sol) DEL < 10 m
Z2 (au sol) DEI < 10 m

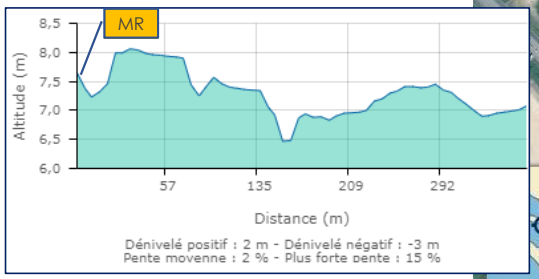
This exterior safety distance of 10 m around buildings corresponds to a minimum safety zone to be set up, on the ground and on nearby roofs, in the event of an NH3 leak (2nd threshold) in and outside the machine room. The machine room extractor is 100 and 140 m from the nearest site boundary.

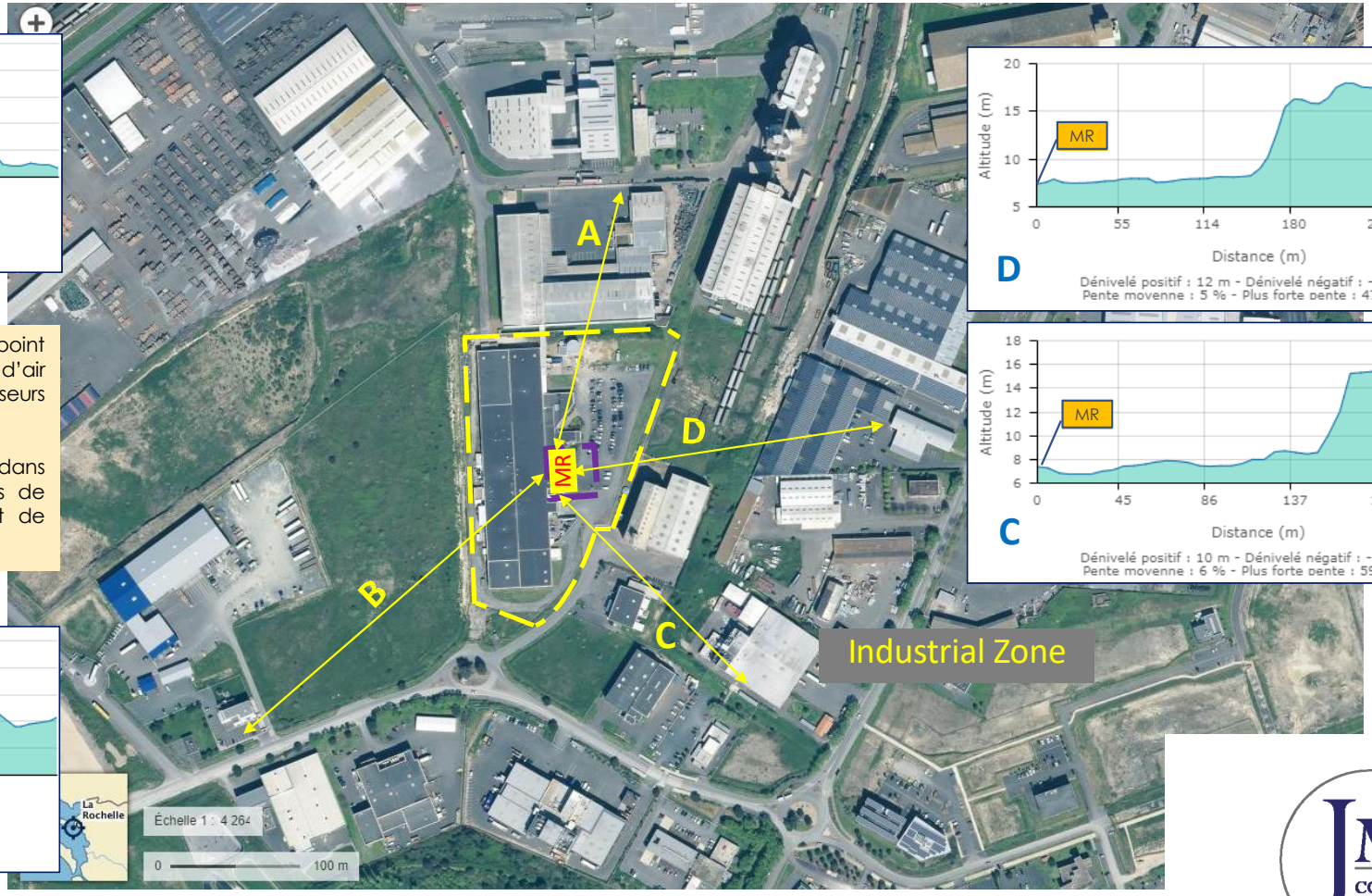
2 – Altimetry study around the site



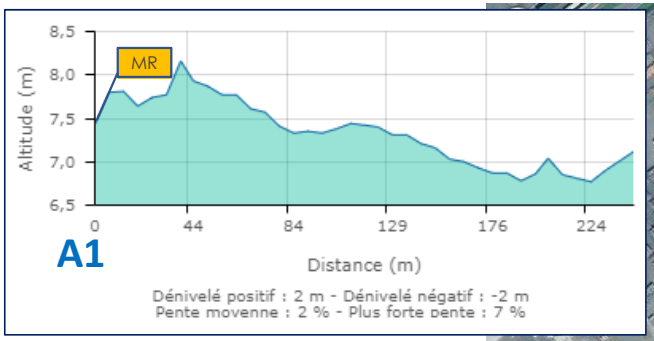
Le point 0 en abscisse correspond au point de rejet (extracteur de sécurité d'air ammoniaqué et à la zone des condenseurs extérieur).

L'étude de l'altimétrie est nécessaire dans l'analyse des résultats de modélisations de fuites pour valider la hauteur du point de rejet.



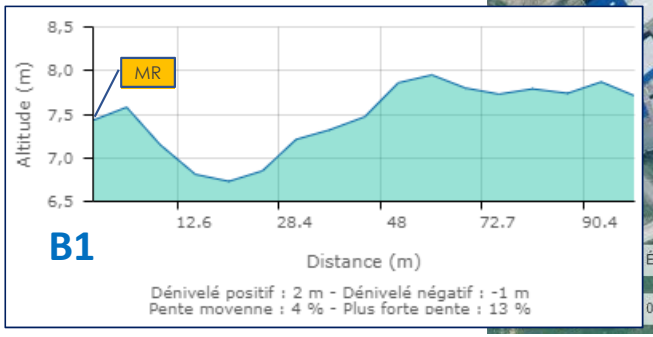


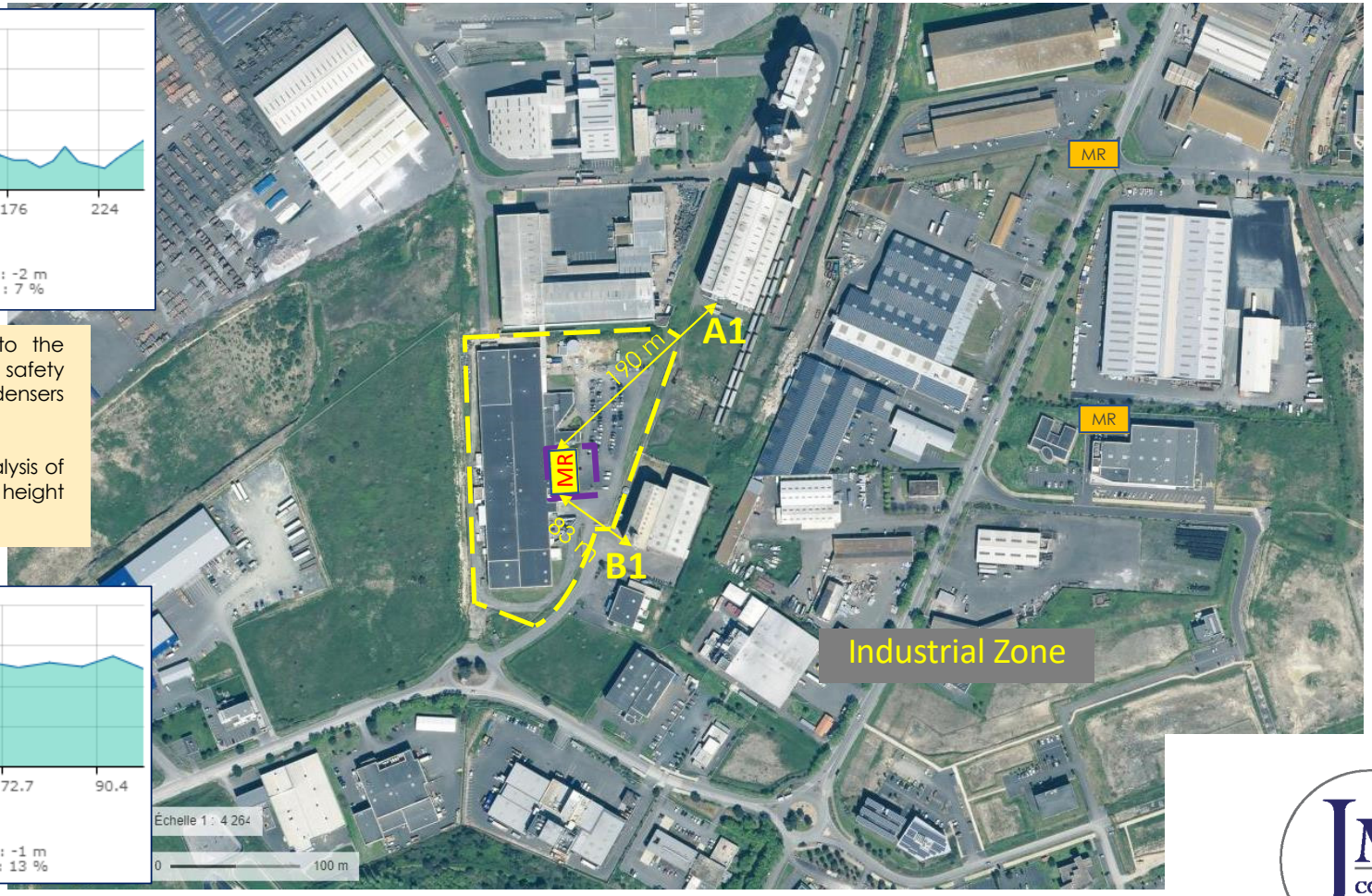
3 – Altimetry study near the site



Point 0 on the abscissa corresponds to the discharge point (ammonia-containing air safety extractor and the area of the condensers outside).

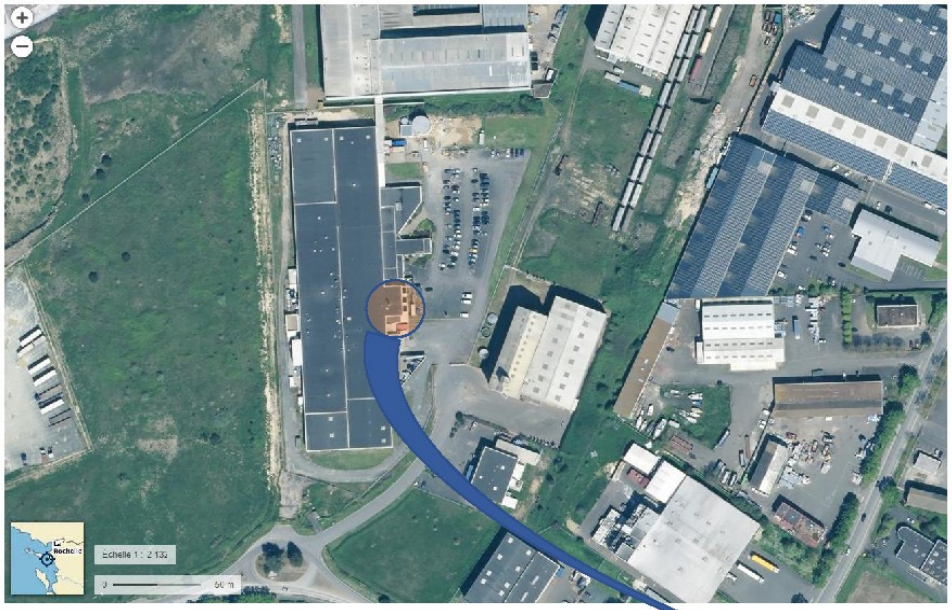
The altimetry study is necessary in the analysis of the leaks modeling results to validate the height of the discharge point.





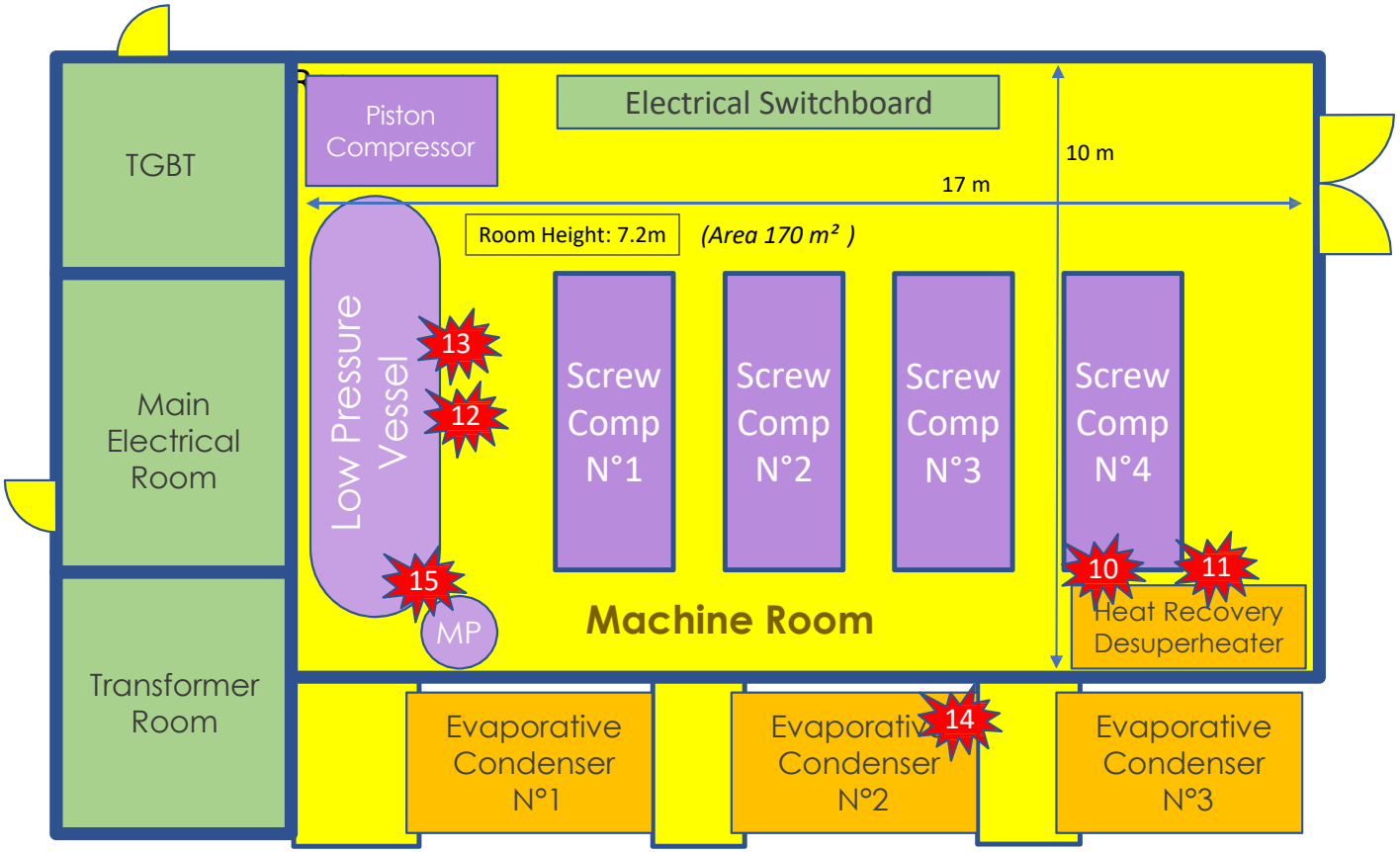
4 – Sectional details - Proximity

5 – Refrigeration Plant Localisation on site



6 – Machine Room – Refrigeration equipment layout

NH3 Ammonia Charge = 6,650 Kg



Scenario 10 : High Pressure Vapor)
Scenario 11 : High Pressure Liquid)
Scenario 12 : Low Pressure Receiver in operation)
Scenario 13 : Low Pressure Receiver on stand-by with vessel pressure increasing)
Scenario 14 : Evaporative Condenser Liquid Pipe)
Scenario 15 : Safety Valve
Scenario 16 : Low Pressure Liquid in the Attic
Scenario 17 : Hot Gas Defrost in the Attic

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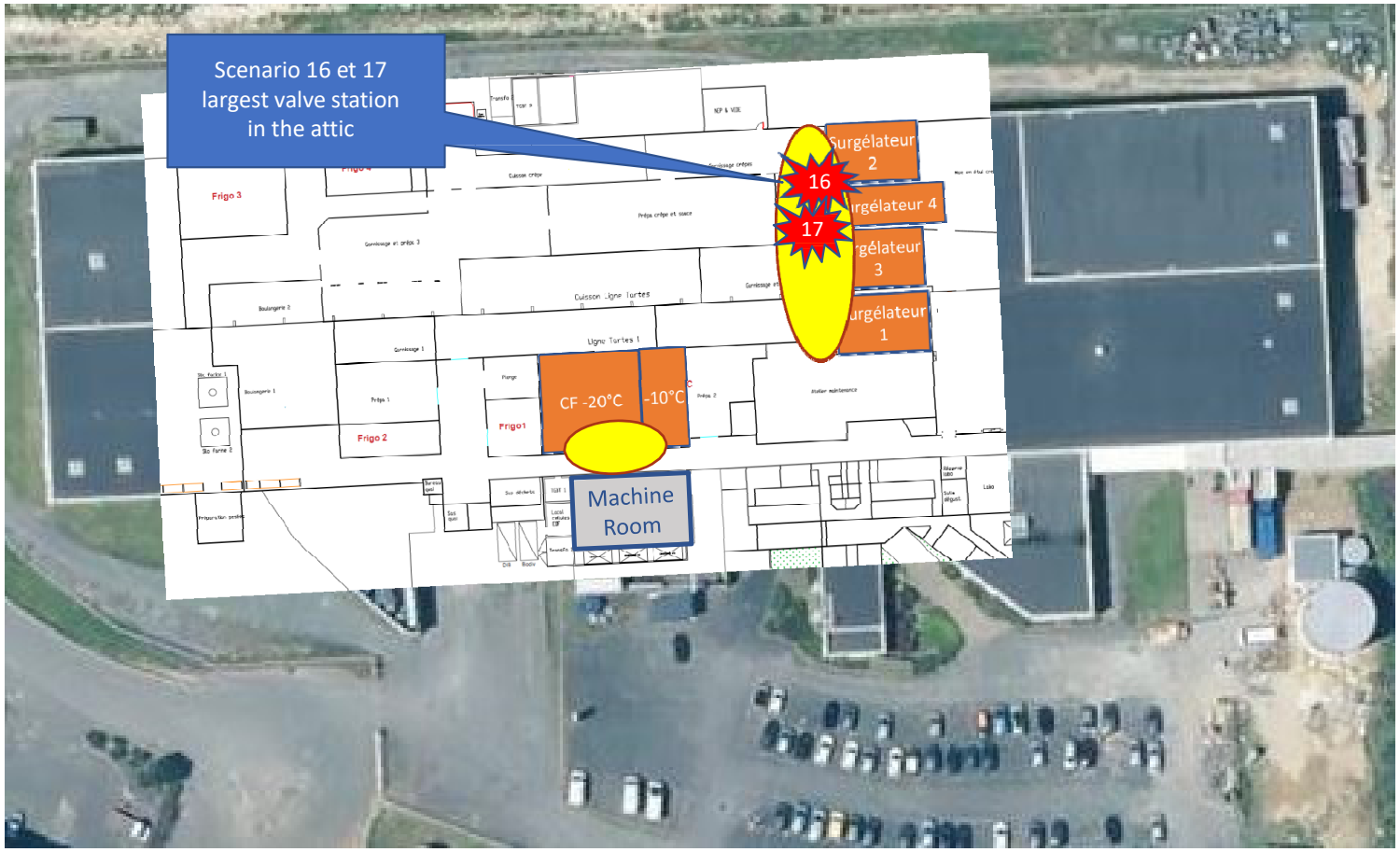
7 – Implantation of NH3 user areas



Scenario 16 : Liquid leak in the attic

Scénario 17 : Hot gas leak in the attic

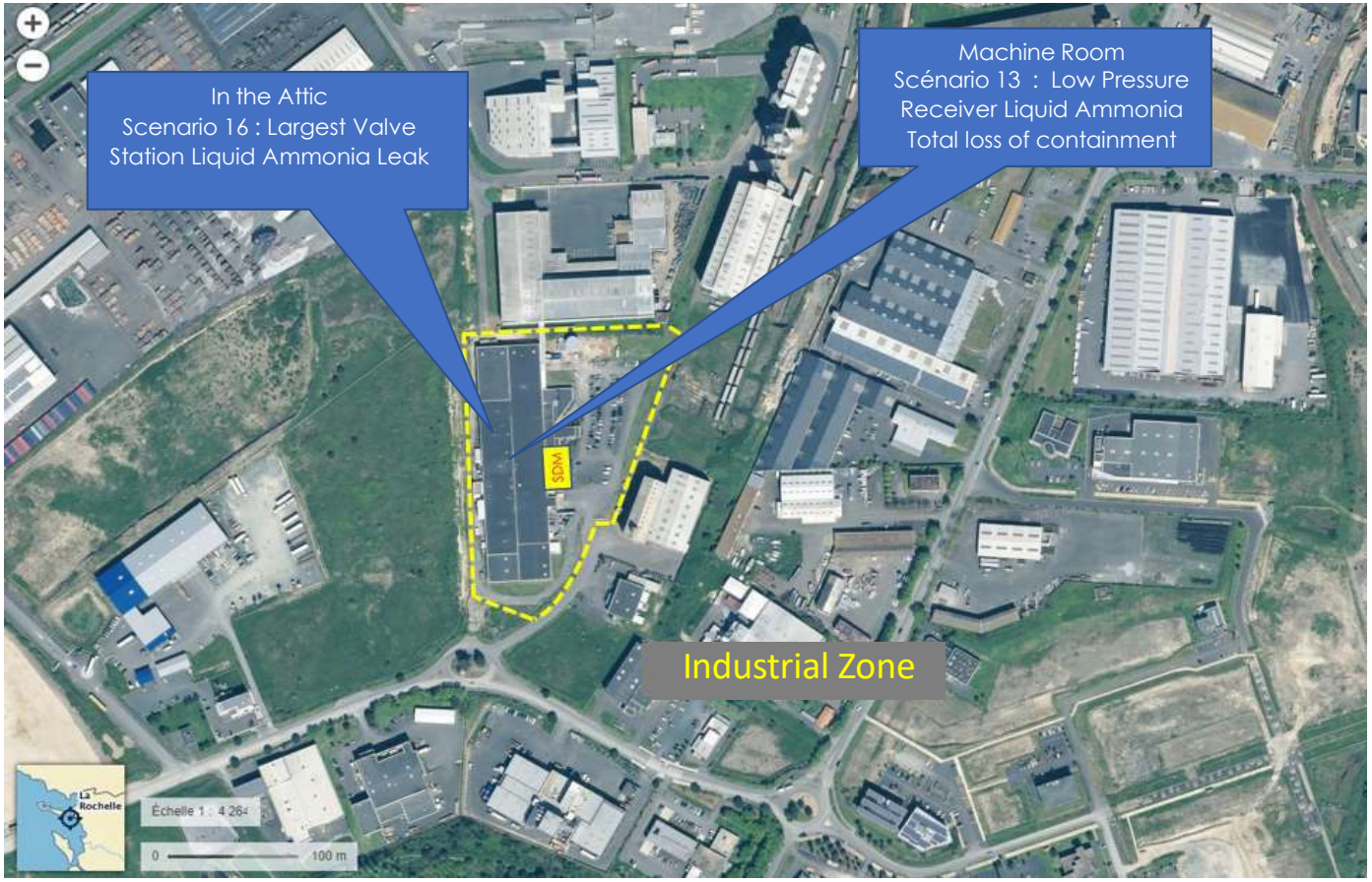
Z1 (au sol) DEL = NR
Z2 (au sol) DEI = NR

NR = «Not Reached» in horizontal distance means that the doses of Lethal Effects (SEL) or Irreversible Effects (SEI) are not perceived on the ground.

X **Ammonia presence**

Valve station zones In the Attic

8 – Scenarios Localization



The site map is downloaded into the PHAST software for positioning of the selected scenarios.

The modeled scenarios are the most hazardous scenarios at the point of NH_3 rejection considered.

9 – Scenario 13 : Low Pressure Vessel Total Loss of Containment – Machine Room

Calculation input data:

The installation is assumed to be stopped. The LP capacity contains 6,000 kg of ammonia at saturation at +10°C under 6.15 bars absolute. Assumed to have a pipe line break of 88.9 mm outside diameter and 78 mm inside diameter in the liquid phase. The ammonia then spills out into a 30 m2 containment inside the machine room.

Scenario Description:

Upon ammonia leak detection, the ammonia air safety extractor is activated. The extracted flow rate is 17,500 m3/h. The discharge point is at 12.5m high (see attached result). The speed of the gases at the outlet of the pipe is set at 9.67 m/s.

Source Modeling:

The characteristics of discharge are as follows:

Phase	Diphasic	
Rejection Flow Rate	82	*Kg/s*
Rejection Duration	73	*Sec*
Rejection Temperature	-33,4	*°C*
Rejection Speed	187	*m/s*
Liquid Drop Diameter	124	*µm*
Liquid Fraction	86	*%*

The values are given by a first "leak" calculation on the "pressure vessel", the load considered is the maximum load contained in the largest 6,000 kg container. During this leak there is an expansion of the liquid, the discharge lasts 73 seconds at a flow rate (liquid with vapor fraction due to the expansion) of 82 Kg/s. The final temperature corresponds to the boiling point of ammonia at atmospheric pressure, i.e. -33.4 ° C. The fraction forming a liquid sheet on the "rain-out" ground is 88%, therefore 840 kg are directly emitted in the gas phase and evacuated by the safety extractor.

Subsequently, the slick covering the machine room floor slowly evaporates at a steam rate of 1.89 kg / s.

The remote effects are predominant during the rejection phase, that is to say during the initial 510 seconds (duration calculated according to the flow rate of the ammonia air extractor). The evaporation phase of the water table is not taken into account subsequently (descending phase of the cloud).

9 – Scenario 13 : Low Pressure Vessel Total Loss of Containment

Modeling of the final scenario:

In the room, it is therefore assumed that, following the release, an air / ammonia mixture is created inside the room. The mass fraction of ammonia at Y_{NH3} equilibrium is given by: $Y_{NH3} = m_{NH3} / (m_{AIR} + m_{NH3})$

The air mass in the room is 645 kg taking into account a density of 1.2 kg / m3. As a result, $Y_{NH3} = 0.328$

The final temperature Tf (in K) of the mixture is such that $T_f = [Y_{NH3}\, C_{p,NH3}\, T_{NH3} + (1-Y_{NH3})\, C_{p,AIR}\, T_{AIR}] / [Y_{NH3}\, C_{p,NH3} + (1-Y_{NH3})\, C_{p,AIR}]$

$C_{p,NH3}$	Ammonia Vapor Specific heat at constant pressure (2 KJ/Kg.K)
T_{NH3}	Ammonia boiling point temperature (239.6 K)
T_{air}	Ambient air temperature (293 K)
$C_{p,air}$	Air Specific heat at constant pressure (1.004 KJ/Kg.K)

Therefore, Tf = -6,52°C

The molar mass M_f of the mixture is deduced from the relation:

$M_f = 1 / [Y_{NH3} / M_{NH3} + (1- Y_{NH3})/M_{AIR}]$

Where M_{NH3} is the molar mass of ammonia (0.017 Kg/mol) and M_{AIR} is the molar mass of air (0.0288 Kg/mol). Thus: Mf = 0.0234 kg / mol. The average density of the mixture at -6.52°C is therefore 1.03 Kg/m^3. Assuming that the volume flow rate of the extractor remains constant, the mass flow rate of the gas mixture discharged to the stack is 5.01 Kg/s. At this rate the total extraction time of the vaporized ammonia during the release phase is: 840 / (0.328 x 5.01) = 510 seconds (9 minutes). Finally, the scenario is defined using the "user defined" model with the following imposed values:

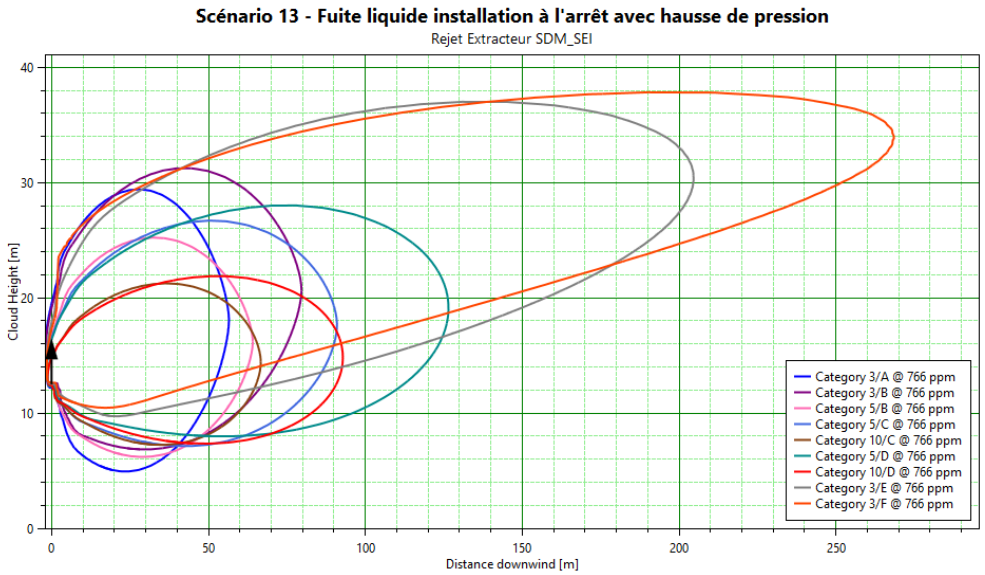
Phase	Vapor (69 % ammonia, 31 % air)
Discharge flowrate (extractor)	5,01 Kg/s
Rejection Duration	510 sec
Rejection Temperature	-6,52 °C
Rejection Speed	9.67 m/s (diameter 800 mm)
Rejection Altitude	12.5 m

With regard to a vertical gas discharge at altitude, all the atmospheric conditions specified in the paragraph are considered. Finally, on the basis of the ammonia effect thresholds indicated in paragraph, the concentrations to be sought over the exposure time (564 sec) are the following:

- SEI : 766 ppm
- SPEL : 8,854 ppm
- SELS : 9,628 ppm

9 – Scenario 13 : Side view - Irreversible Effects Thresholds (IET)

Audit Number	24150
Averaging time	Toxic (600 s)
Equipment	Local SDM
Spacing parameter for the grid in the x dimension	0,1
Material	Mélange AIR/ AMMONIA_SDM
Offset from Centerline	0 m
Program	Phast 8,22
Scenario	Rejet Extracteur SDM_SEI
View Time	509,999 s
Weather	Multiple Weather
Workspace	PhastConsequence



La hauteur de 12,5 m correspond à la hauteur du rejet (sortie de conduit). **Avec ce point de rejet à 12,5 m, on constate un risque des effets irréversible sur le bâtiment voisin situé à 83 m et avec un escalier à une hauteur de 20 m, mais pas d'effets au sol pour les hauteurs correspondant à l'activité humaine (de 1,5 m à 2 m)**.

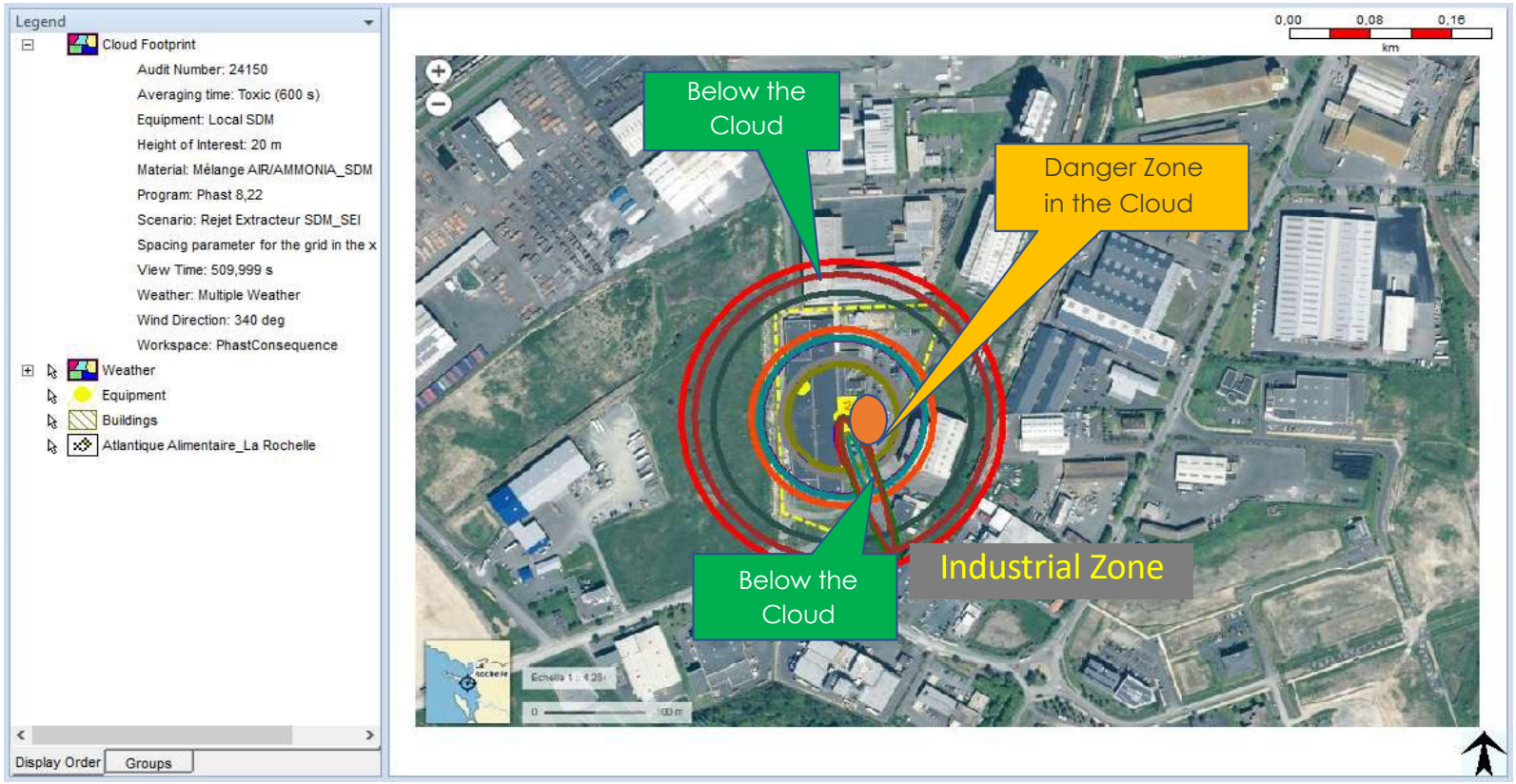
Résultats de calcul :

Le graphique ci-dessus illustre la forme du panache (concentration des effets irréversibles). Les distances d'effets calculées à hauteur d'homme (1,5 m voir ci-dessus) sont les suivantes, en fonctions des différentes conditions de stabilité atmosphérique (Circulaire du 10 mai 2010) :

	3A	3B	5B	5C	10C	5D	10D	3E	3F
SEI	NA	NA	NA	NA	NA	NA	NA	NA	NA
SPEL	NA	NA	NA	NA	NA	NA	NA	NA	NA
SELS	NA	NA	NA	NA	NA	NA	NA	NA	NA

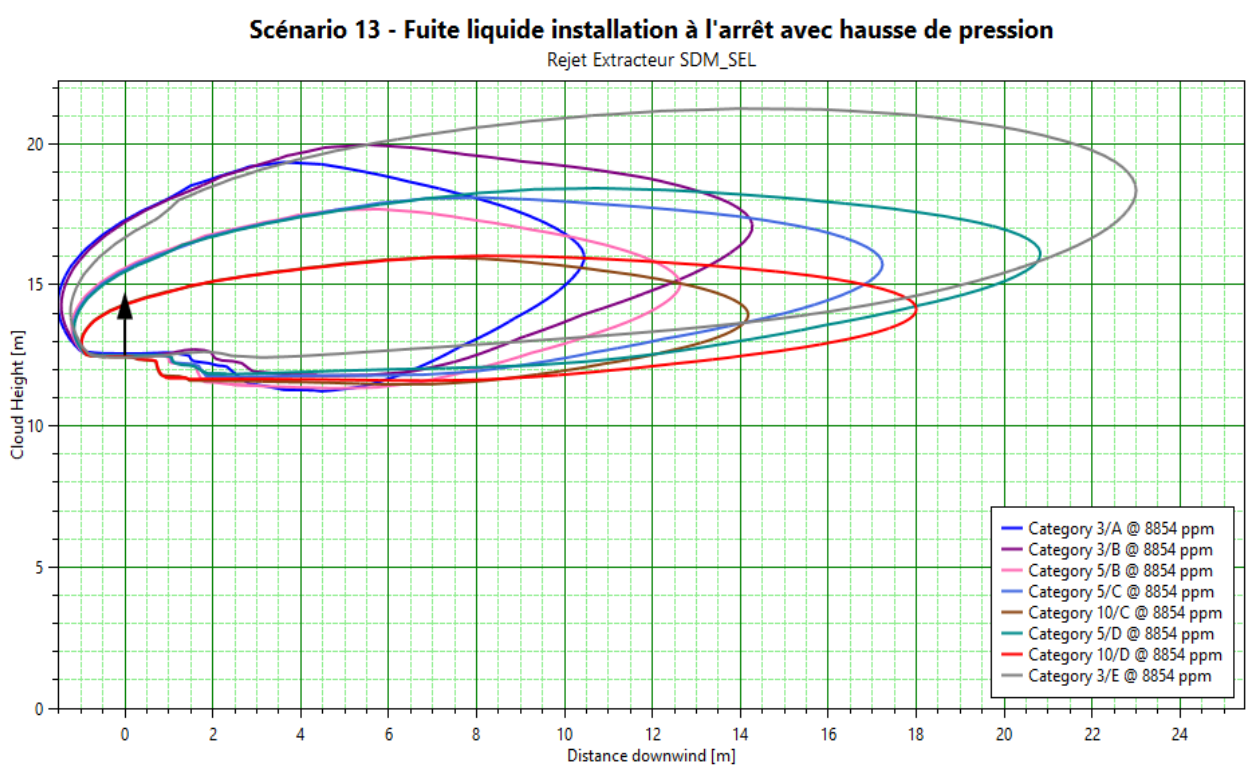
9 – Scenario 13 : Top view - Irreversible Effects Thresholds (IET)

Cross-section of the NH_3 cloud for 20m height corresponding to the staircase of the neighboring building:



9 – Scenario 13 : Side view - Lethal Effects Thresholds (LET)

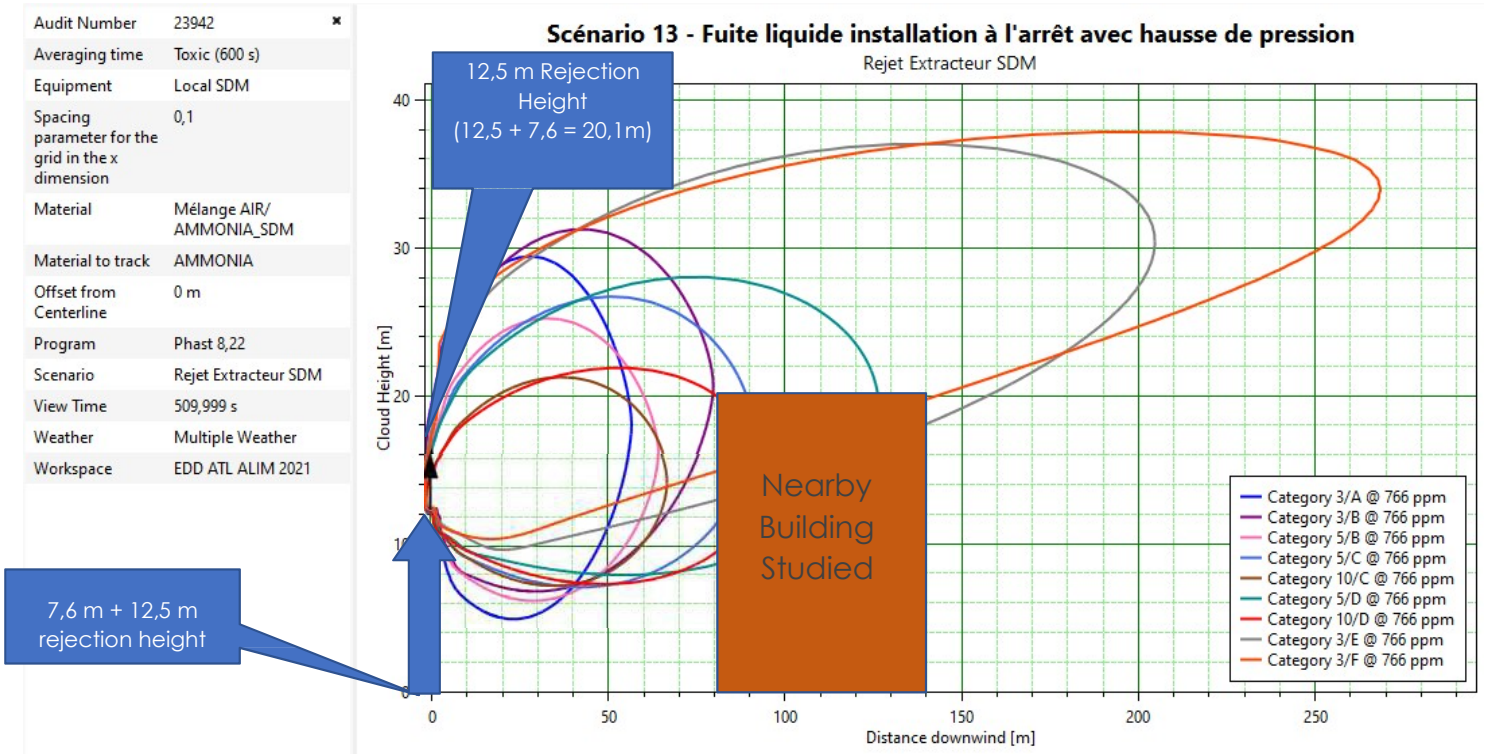
Audit Number	24150
Averaging time	Toxic (600 s)
Equipment	Local SDM
Spacing parameter for the grid in the x dimension	0,1
Material	Mélange AIR/ AMMONIA_SDM
Offset from Centerline	0 m
Program	Phast 8,22
Scenario	Rejet Extracteur SDM_SEL
View Time	509,999 s
Weather	Multiple Weather
Workspace	PhastConsequence



The 12.5m height corresponds to the height of the discharge (duct outlet). With this release point at 12.5 m, we see that there are no lethal effects outside the property lines and no longer on the ground (the LET remains at a sufficient height, without impact).

9 – Scenario 13 : Side view - Lethal Effects Thresholds (LET)

Audit Number	23942
Averaging time	Toxic (600 s)
Equipment	Local SDM
Spacing parameter for the grid in the x dimension	0,1
Material	Mélange AIR/ AMMONIA_SDM
Material to track	AMMONIA
Offset from Centerline	0 m
Program	Phast 8,22
Scenario	Rejet Extracteur SDM
View Time	509,999 s
Weather	Multiple Weather
Workspace	EDD ATL ALIM 2021



Overlaying the site altimetry and the cloud, be careful here, the 0 in the PHAST software corresponds to 7.6m
Be careful when reading (Geoportal scales are different from PHAST due to the different origin of 7.6m)

10 – Scenario 16 : NH3 Rejection from Valve Station - Attic

Calculation input data:

The installation is assumed to be in operation. The quantity of ammonia considered corresponds to the quantity necessary for the operation of the evaporator associated with the flow rate of the ammonia pumps. Here the quantity of ammonia involved is 318 Kg in a battery emitted by the pumps for 45 sec. Ammonia at saturation, at -40 ° C under a pressure of 3 bars absolute (pressure generated by the ammonia distribution pumps). It is assumed that the liquid line of 48.3 mm outside diameter, 41 mm inside diameter in the liquid phase is broken. The ammonia then spreads into a retention of 10 m2 (valve station in retention inside technical attic).

Upon detection of ammonia, the ammonia air safety extractor is activated. The extracted flow rate is 5,000 m3/h. The discharge point is at 8 m high (see attached result). The gas velocity at the outlet of the pipe is set at 11.0 m/s (pipe diameter 400 mm).

Modeling of the source (inside the attic):

We will take the full amount of ammonia from the evaporator connected to the valve station, therefore 80 Kg are directly emitted in the gaseous phase and evacuated by the air safety extractor. Subsequently, the spill covering the attic slowly evaporates at a vapor flow rate of 1.2 Kg/s.

Modeling of the final scenario:

Finally, the scenario is defined using the "user defined" model with the following imposed values:

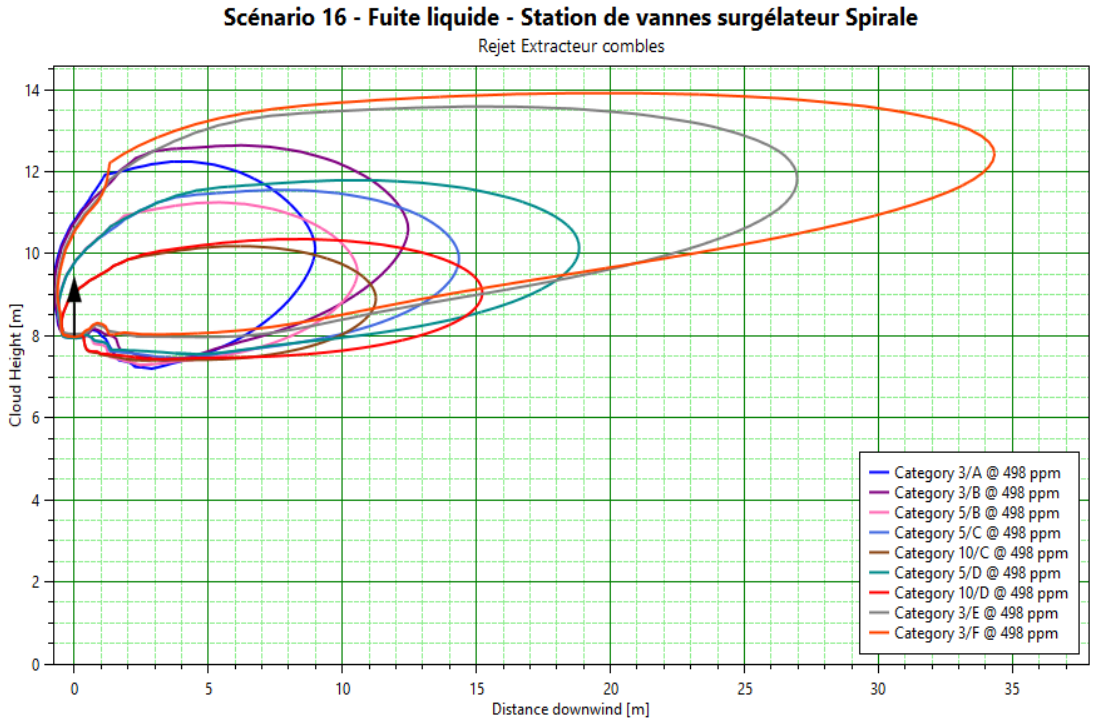
Phase	Vapor (17% ammoniac, 83% air)
Rejection Flowrate (extractor)	1,20 Kg/s
Rejection Duration	1,863 sec (31 mins)
Rejection Temperature	+15.5°C
Rejection Speed	11 m/s (diameter 400 mm)
Rejection Altitude	8 m

As it is a vertical vapor discharge at a high altitude, all the atmospheric conditions specified in the paragraph are considered. Finally, on the basis of the ammonia effect thresholds indicated in paragraph, the concentrations to be sought over the exposure time (31 minutes) are as follows:

- SEI : 498 ppm
- SPEL : 4 690 ppm
- SELS : 5 041 ppm

10 – Scenario 16 : NH3 Rejection from Valve Station - Attic

Audit Number	24146
Averaging time	Toxic (600 s)
Equipment	Local combles techniques surgélateurs
Spacing parameter for the grid in the x dimension	0,1
Material	Mélange AIR/ AMMONIA_St V Surgélateur
Material to track	AMMONIA
Offset from Centerline	0 m
Program	Phast 8,22
Scenario	Rejet Extracteur combles
View Time	1863 s
Weather	Multiple Weather
Workspace	EDD ATL ALIM 2021



The 8m height ocorresponds to the height of the building (freezer cold room zone, above the valve station).

With this discharge point at 8 m, it is confirmed that the current height is compliant and does not cause any adverse effect outside the property lines site at a ground height of 1.5 m.

This graph illustrates the shape of the plume (concentration of irreversible effects). The effective distances calculated at breast height of 1.5m are as follows, depending on the different conditions of atmospheric stability:

	3A	3B	5B	5C	10C	5D	10D	3E	3F
SEI	NA	NA	NA	NA	NA	NA	NA	NA	NA
SPEL	NA	NA	NA	NA	NA	NA	NA	NA	NA
SELS	NA	NA	NA	NA	NA	NA	NA	NA	NA