



Research Paper on Comparison on Extent of Zone 2 Hazardous Area specified in IS 5572 using Dispersion Modelling software DNV Phast 8.71

Anil Kumar Bhana Department of Chemical Engineering, Ujjain Engineering College, Ujjain, 456010, Madhya Pradesh, India

Rini Mathew, Department of Environment Studies, The Maharaja Sayajirao University of Baroda, Pratapgunj, Vadodara, Gujarat-390002

Dr. Kanjan Upadhyay, Department of Chemical Engineering, Ujjain Engineering College, Ujjain, 456010, Madhya Pradesh, India

Mahesh Patidar, Department of Chemical Engineering, Ujjain Engineering College, Ujjain, 456010, Madhya Pradesh, India

Abstract:

Any leakage from process equipment (process vessels, storage tanks, pumps pipelines etc) may lead to formation of flammable gas cloud in surrounding area. If any ignition sources is present in the area where flammable gas cloud can reach will result into flash fire or vapor cloud explosion and fatalities. Hazardous area classification study aims to eliminate electrical ignition sources from the area where there is a possibility of flammable atmosphere is present during normal or abnormal operations or during accidental leakages. Several standards (6,7,8) has described methods to be used for hazardous area classification. However, these methods are generic in nature and may not be suitable considering extreme operating conditions and numerous flammable chemicals present in chemical manufacturing plants.

This research paper aims to compare and validate the extent of hazardous area defined in Indian Standard IS 5572: 2009 (reaffirmed in 2018), Classification of hazardous areas (Other Than Mines) having flammable gases and vapours for electrical installation (Third Revision) by use of dispersion modelling using DNV PHAST 8.71.

Keywords:

HAC; Hazardous Area Classification, Electrical Area Classification, IS: 5572, ATEX; CFD, PHAST 8.71

Abbreviations:

HAC: Hazard Area Classification,

CFD : Computational Fluid Dynamics

LEL- Lower Explosive Limit

1. Introduction (6,7,8)

Hazardous Area Classification (HAC) standards gives guidance on the classification of areas around equipment handling or storing flammable liquid or gases and explosive dusts, and provides a basis for both the correct selection of fixed electrical equipment and the location of other fixed sources of ignition in those areas. An 'area' in context of HAC is always taken to be three-dimensional.

Hazardous Area Classification Study is determination of the extent of hazardous zone in the vicinity of the source of release where flammable vapour cloud can reach. Hazardous (Classified) Locations are the locations where fire or explosion hazards may exist due to the presence of flammable gases or vapours or flammable liquids. Hazardous Area Classification is the process of determining the existence and extent of Hazardous (Classified) Locations in a facility handling any flammable liquids or gases.

In manufacturing plants and storage locations several hazardous streams containing mixtures of chemicals are present, their handling volume, flow rates, temperature and pressure conditions etc are always variable. These properties of the chemicals can behave differently when released to the atmosphere. Highly volatile compounds will flash into the gaseous phase and less volatile compounds will rainout and form a pool on the ground. These changes in chemical properties and handling conditions can significantly affect the dispersion modelling and extent of damage caused by chemical release.

The aim of the paper is to compare and validate the extent of hazardous areas as defined in IS:5572; 2009 in 3-dimensional context by using dispersion modelling of DNV PHAST-8.71

2. Definitions

Classification of Zone as per IS-5572:2009 (8)

Zone 0: Place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is present continuously or for long periods or frequently. Examples of Zone 0 area are inside storage tank, inside process vessels and piping handling flammable liquids and gases.

Zone 1: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is likely to occur in normal operation occasionally. Example of Zone-1 area are sampling points, drum filling points, vent of atmospheric storage tanks handling flammable chemicals.

Zone 2: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is not likely to occur in normal operation, but if does occur, will persist for a short period only (means the total time for which the flammable atmosphere will exist).

Extent of the Zone: It is the distance starting from the source of the release to the point where the material is diluted below its lower explosive limit. This can be determined by using various standards stated above.

3. Method

DNV PHAST 8.71 atmospheric dispersion modelling software was used for dispersion modelling of LEL clouds. This software enables accurate and rigorous modelling of various chemicals at various parameters and release location/ direction providing us with more detailed and accurate consequence results. Our focus of study is to evaluate dispersion of flammable cloud for various sources of release, at various location of release and under various handling and leakage conditions.

Assumption made during dispersion modelling**Weather conditions** considered for dispersion modelling

	Wind Velocity	Stability Class	Remarks
1.0 F	1.0 m/s	F- Stable – Night with Moderate Clouds and Light / Moderate Wind	In stable atmospheric conditions the dispersion of flammable cloud is very slow and extent of hazardous area is highest
3 D	3 m/s	D- Neutral – Little Sun and High Wind or Overcast / Windy Night	In sun light the vaporization of liquid chemical is relatively more and dispersion of flammable cloud is fast therefore extent of hazardous area is relatively low

Leakage size: Only Small and medium leakage are considered for the dispersion modelling. As per IS-5572 clause 1.2 (d) Catastrophic failures are not considered in HAC. As per TNO guidelines following leak sizes are used for various process equipment

Process Equipment	Small leak size	Release Duration	Remarks
Process vessels, pressure vessels and atmospheric storage tanks	10 mm	3600 seconds	TNO Guideline for quantitative risk assessment (purple Book)
Pump and associated pipelines	10 % of pipe diameter	1800 seconds	TNO Guideline for quantitative risk assessment (purple Book)

Direction of release- For heavier than air direction of release is considered in horizontal and vertical direction both. For lighter than air gases the direction of release is considered in horizontal, vertical and downgrade impingement towards ground

Atmospheric temperature- 30 °C

Land Temperature-30 °C

Surface Roughness- 5 mm with negligible obstructions for proper dispersion for LEL cloud

Type of surface for pool- Concrete

Chemicals

Following chemicals are used for dispersion modelling and validation of extent of HAC as they are commonly used in chemical plant

Name of Chemical	CAS No	Flash Point	Boiling Point	LEL % in Air	Relative Vapour density
Hexane	110-54-3	-23 °C	68.73 °C	1.2 % (12,000) PPM	2.97
N Pentane	109-66-0	-49 °C	36.07	1.4 % (14000 ppm)	2.48
Iso butylene	115-11-7	-75.15	-6.24	1.6 % (16000 ppm)	1.9
Propylene	108-32-7	-104.15	-104.15	2.15% (21500 ppm)	1.46
Hydrogen	1333-74-0	-259.15	-252.76	4% (40000 ppm)	0.069

Extent of Hazardous area as per IS-5572 reference fig H-1 (for heavier than air gas/ vapour and leak sources located within 8 m height from ground level)

As per fig H1 of IS-5572 the extent of hazardous area for leakage source located within 8 m height from ground for heavier than air gases is

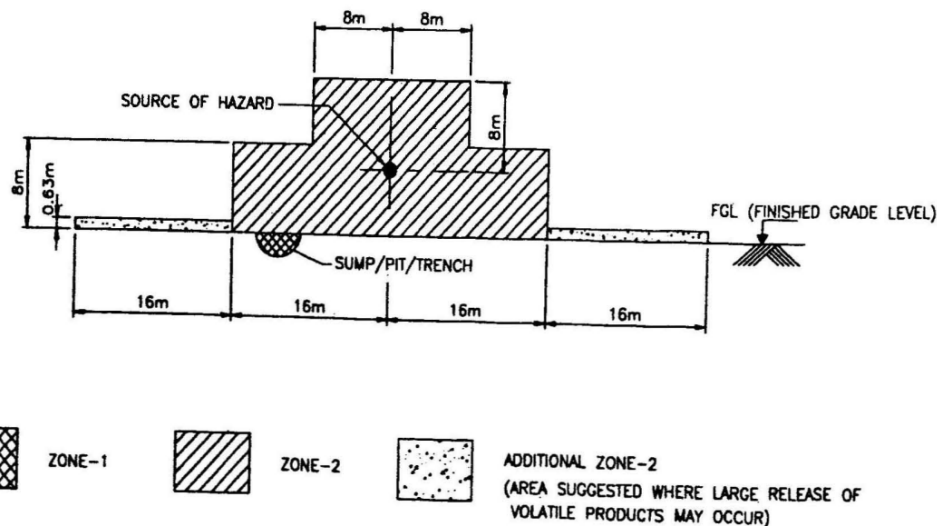


FIG. H1 FREELY VENTILATED PROCESS AREA (HEAVIER-THAN-AIR GASES OR VAPOURS)
(SOURCE OF HAZARD LOCATED NEAR GROUND LEVEL)

Zone 2- Zone 2 hazardous area is 16 m radius from the source of leakage in all direction and up to 8 m high. Zone is also within 8 m high from the source of leakage. The extent of hazardous area above 8 m height is a radius of 8 m in all directions

Extended zone 2- Extended zone 2 hazardous area is from 16 to 32 m from the source of leakage in all direction up to height of 0.63 m

Following scenarios are considered for evaluation of IS 5572 ref fig H1

IS #	Process Equipment	Name of chemical	Quantity / Flow Rate	Temperature	Pressure Kg/cm ²	height from ground
IS-1	Atmospheric storage	Hexane	5000 kg	30 °C	Atm	1 m
IS-3	Process Vessel	Hexane	5000 kg	65 °C	Atm	1 m
IS-5	Atmospheric storage	Hexane	10000 Kg	30 °C	Atm	1 m
IS-7	Process Vessel	Hexane	10000 Kg	65 °C	Atm	1 m
IS-9	Pump and transfer line 100 NB	Hexane	5000 kg/hr	30 °C	3	5 m
IS-10	Pump and transfer line 100 NB	Hexane	15000 Kg/hr	30 °C	3	1 m
IS-11	Atmospheric storage	N- Pentane	5000 kg	34 °C	Atm	1 m
IS-13	Atmospheric storage	N- Pentane	10000 kg	34 °C	Atm	1 m
IS-15	Pump and transfer line 100 NB	N- Pentane	5000 kg/hr	30 °C	3	1 m
IS-16	Pump and transfer line 100 NB	N- Pentane	15000 Kg/hr	30 °C	3	5 m
IS-17	iso butylene Bullet	iso butylene	10000 kg	30 °C	2.5	1 m
IS-19	Propylene Bullet	Propylene	10000 kg	30 °C	12.8	1 m

Extent of Hazardous area as per IS-5572 reference fig H-2 (for heavier than air gas/ vapour and leak sources located above 8 m height from ground level)

As per fig H2 of IS-5572 the extent of hazardous area for leakage source located above 8 m height from ground for heavier than air gases is

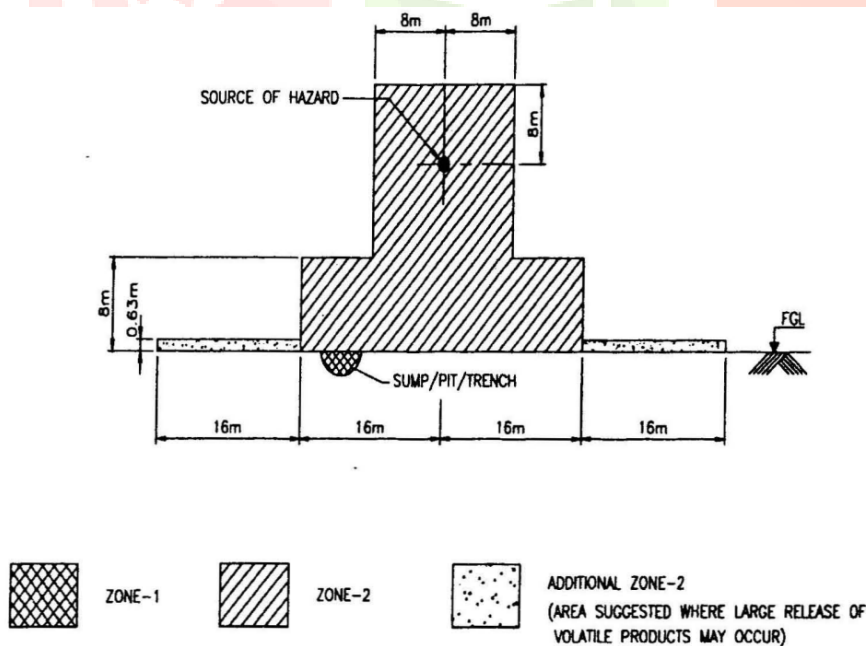


FIG. H2 FREELY VENTILATED PROCESS AREA (HEAVIER-THAN-AIR GASES OR VAPOURS)
(SOURCE OF HAZARD LOCATED ABOVE GROUND LEVEL)

Zone 2- Zone 2 hazardous area is 16 m radius from the ground below source of leakage in all direction and up to 8 m high. Zone is also within 8 m high from the source of leakage. The extent of hazardous area above 8 m height is a radius of 8 m in all directions

Extended zone 2- Extended zone 2 hazardous area is from 16 to 32 m from the source of leakage in all direction up to height of 0.63 m

Following scenarios are considered for evaluation of IS 5572 ref fig H2

IS #	Process Equipment	Name of chemical	Quantity/ Flow Rate	Temperature	Pressure Kg/cm ²	Leakage height from ground (m)
IS-2	Atmospheric storage	Hexane	5000 kg	30 °C	Atm	11 m
IS-4	Process Vessel	Hexane	5000 kg	65 °C	Atm	11 m
IS-6	Atmospheric storage	Hexane	10000 Kg	30 °C	Atm	11 m
IS-8	Process Vessel	Hexane	10000 Kg	65 °C	Atm	11 m
IS-12	Atmospheric storage	N- Pentane	5000 kg	34 °C	Atm	11 m
IS-14	Atmospheric storage	N- Pentane	10000 kg	34 °C	Atm	11 m
IS-18	iso butylene Bullet	iso butylene	10000 kg	30 °C	2.5	11 m
IS-20	Propylene Bullet	Propylene	10000 kg	30 °C	12.8	11 m

Extent of Hazardous area as per IS-5572 reference fig L-1 (for lighter than air gas/ vapour and leak sources)

As per fig L1 of IS-5572 the extent of hazardous area for lighter than air gas/ vapour leakage

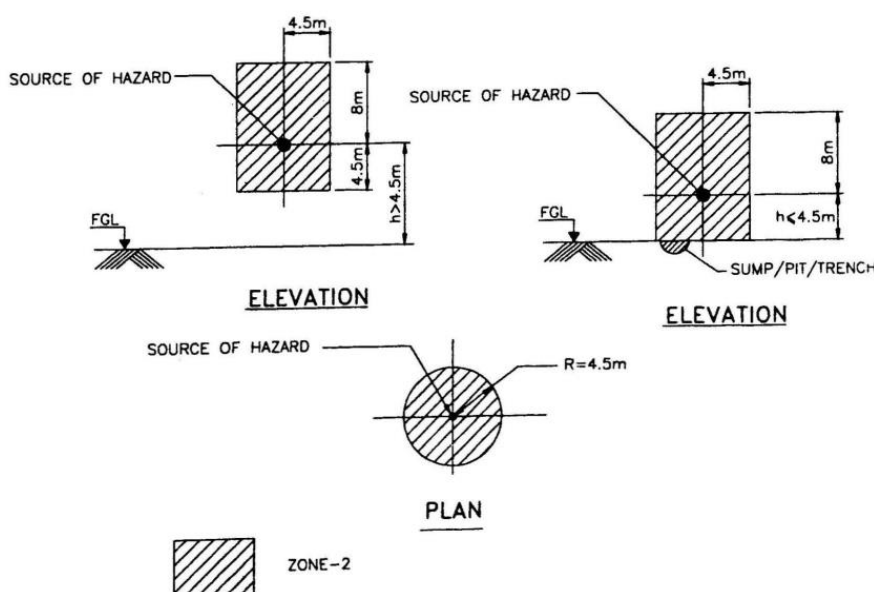


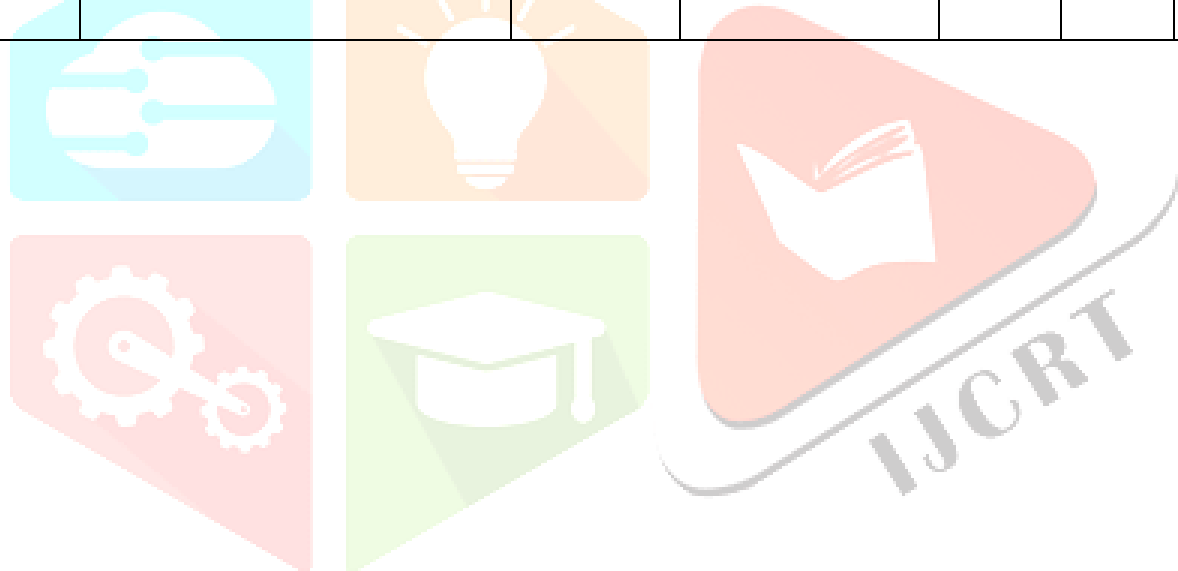
FIG. L1 FREELY VENTILATED PROCESS AREA (FOR LIGHTER-THAN-AIR GASES OR VAPOURS)

Zone 2- Zone 2 hazardous area is 4.5 m radius from the from source of leakage in all direction and up to 8 m high and 4.5 m depth.

Extended zone 2- there is no extended zone 2 for lighter than air gasses

Following scenarios are considered for evaluation of IS 5572 ref fig L-1

IS #	Process Equipment	Name of chemical	Quantity	Temperature	Pressure Kg/cm ²	Leakage height from ground (m)
IS-21	Hydrogen Pressure vessel	Hydrogen	10 m3 (4.79 Kg)	30 °C	5	1 m
IS-22	Hydrogen Pressure vessel	Hydrogen	10 m3 (4.79 Kg)	30 °C	5	11 m
IS-23	Hydrogen Pressure vessel	Hydrogen	10 m3 (39.4 Kg)	30 °C	50	1 m
IS-24	Hydrogen Pressure vessel	Hydrogen	10 m3 (39.4 Kg)	30 °C	50	11 m



4. Results and Discussion

Table -4.1 comparison between IS-5572 ref fig H1 and DNV PHAST 8.71 LEL cloud dispersion results for the heavier than air gas/ vapours and leak sources located below 8 m height

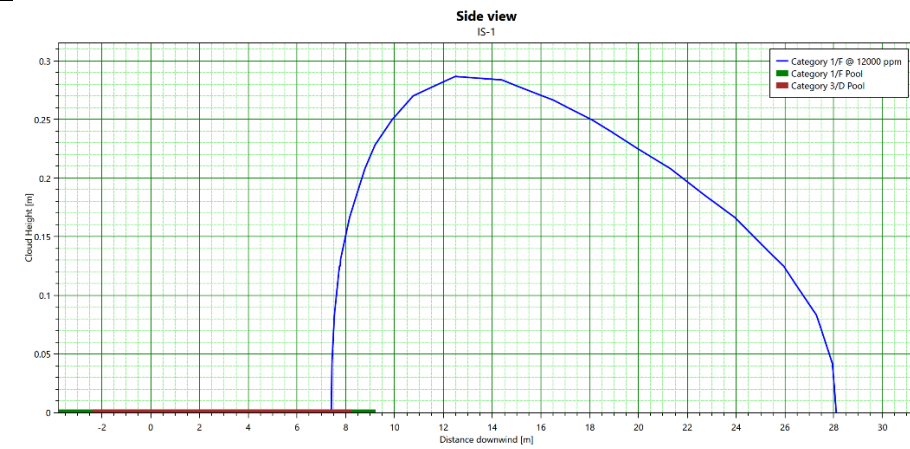
IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
IS-1	Horizontal	Zone 2 - 16 m (8 m high) Extended	28.22	9	0.29	-	8	0.29	-	0.63	0.28	-	For IS-1 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	11.96	9	1.2	-	8	1	-	0.63	0	-	For IS-1 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-3	Horizontal	Zone 2 - 16 m (8 m high) Extended	28.48	9	0.303	-	8	0.303	-	0.63	0.3	-	For IS-3 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	9.86	9	2.87	-	8	0.21	-	0.63	0	-	For IS-3 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-5	Horizontal	Zone 2 - 16 m (8 m high) Extended	28.22	9	0.29	-	8	0.29	-	0.63	0.28	-	For IS-5 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	11.97	9	2.01	-	8	0.1	-	0.63	0	-	For IS-5 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-7	Horizontal	Zone 2 - 16 m (8 m high) Extended	28.48	9	0.303	-	8	0.303	-	0.63	0.29	-	For IS-7 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	9.37	9	2.85	-	8	0.21	-	0.63	0	-	For IS-7 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-9	Horizontal	Zone 2 - 16 m (8 m high) Extended	14.78	13	5.43	-	8	5.4	-	0.63	0	-	For IS-9 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1

IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
	Vertical	Zone 2- 16-32 m (0.63 m high)	4.70	13	14.24	-9.54	8	0	-	0.63	0	-	For IS-9 (1) the vertical release point is at 5 m height. Height of LEL cloud in 0-8 m distance is 1.24 m (9.54%) more than the height specified in IS 5572 Ref fig H1 and LEL cloud does not extend beyond 4.7 m horizontally
IS-10	Horizontal	Zone 2 - 16 m (8 m high) Extended	29.22	9	1.33	-	8	1.2	-	0.63	0.63	-	For IS-10 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	3.93	9	10.67	-18.56	8	0	-	0.63	0	-	For IS10 (1) the vertical release point is at 1 m height. Height of LEL cloud in 0-8 m distance is 1.67 m (18.56%) more than the height specified in IS 5572 Ref fig H-1 and LEL cloud does not extend beyond 3.93 m horizontally
IS-11	Horizontal	Zone 2 - 16 m (8 m high) Extended	32.57	9	0.33	-	8	0.33	-	0.63	0.29	-	For IS-11 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	15.63	9	2.83	-	8	0.09	-	0.63	0	-	For IS-11 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-13	Horizontal	Zone 2 - 16 m (8 m high) Extended	32.57	9	0.295	-	8		-	0.63	0.29	-	For IS-13 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	15.63	9	2.83	-	8	0.34	-	0.63	0	-	For IS-13 (1) vertical release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
IS-15	Horizontal	Zone 2 - 16 m (8 m high) Extended Zone 2- 16-32 m (0.63 m high)	29.79	9	1.35	-	8	1.35	-	0.63	0.754	-19.68	For IS-15 the horizontal release point is at 1 m height. Height of LEL cloud in 0-8 m and 8-16 m is below 1.35 m which is in line with I-5572. The height of LEL cloud in extended zone is 0.12 m (19.69 %) more than the height specified in IS 5572 Ref fig H1
	Vertical		4.53	9	10.52	-16.89	8	0	-	0.63	0	-	For IS15 (1) the vertical release point is at 1 m

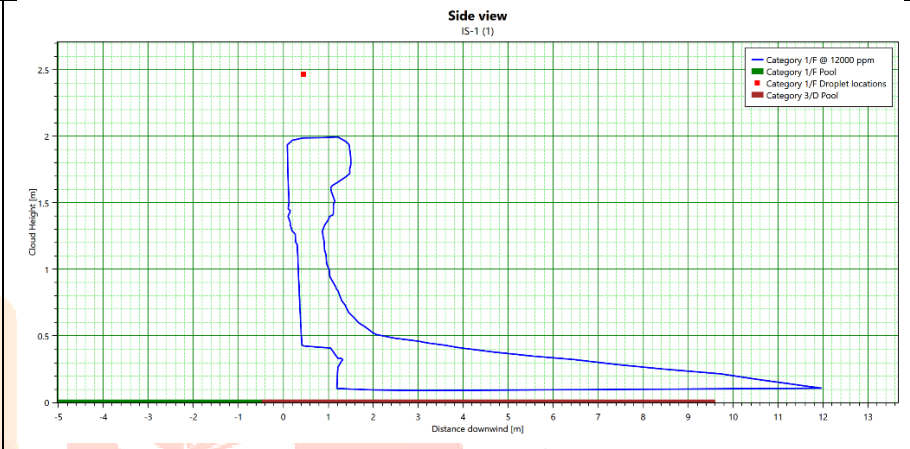
IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
													height. Height of LEL cloud in 0-8 m distance is 1.52 m (16.89%) more than the height specified in IS 5572 Ref fig H1 and LEL cloud does not extend beyond 4.53 m horizontally
IS-16	Horizontal	Zone 2 - 16 m (8 m high) Extended	14.36	13	5.32	-	8	5.25	-	0.63	0	-	For IS-16 horizontal release the LEL cloud distance and height are within the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	4.65	13	14.07	-8.23	8		-	0.63	0	-	For IS16 (1) the vertical release point is at 1 m height. Height of LEL cloud in 0-8 m distance is 1.44 m (16%) more than the height specified in IS 5572 Ref fig H1 and LEL cloud does not extend beyond 4.65 m horizontally
IS-17	Horizontal	Zone 2 - 16 m (8 m high) Extended	15.20	9	1.45	-	8	1.45	-	0.63	0	-	For IS-17 horizontal release the LEL cloud distance and height are within the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	1.57	9	10.44	-16.00	8	0	-	0.63	0	-	For IS17 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is 1.44 m (16%) more and LEL cloud does not extend beyond 1.57 m horizontally
IS-19	Horizontal	Zone 2 - 16 m (8 m high) Extended	14.60	9	1.56	-	8	1.56	-	0.63	0	-	For IS-19 horizontal release the LEL cloud distance and height are within the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Zone 2- 16-32 m (0.63 m high)	1.21	9	11.76	-30.67	8	0	-	0.63	0	-	For IS-19 (1) the vertical release point is at 1 m height. Height of LEL cloud in 0-8 m distance is 2.76 m (30.67%) more than the height specified in IS 5572 Ref fig H1 and LEL cloud does not extend beyond 1.21 m horizontally

Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

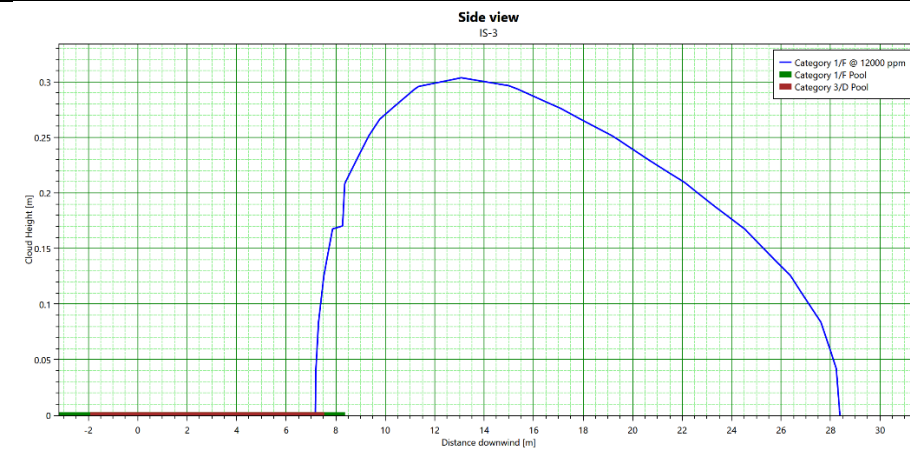
IS-1 Horizontal Release



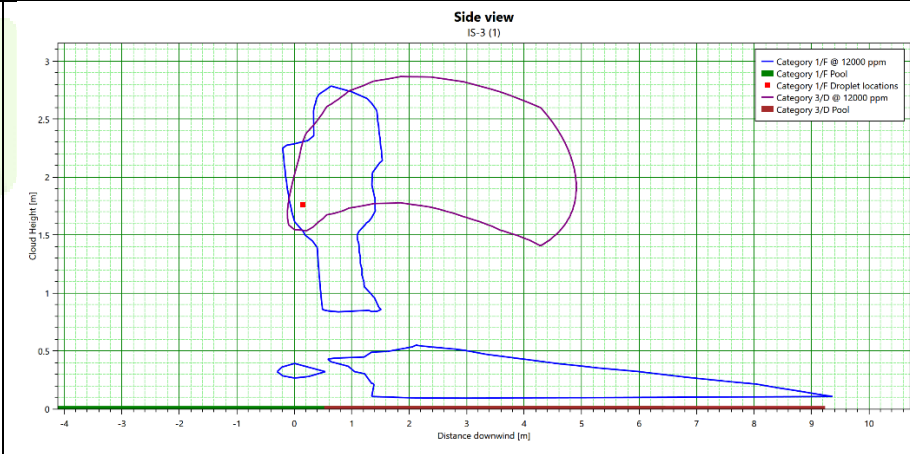
IS-1 (1) Vertical Release



IS-3 Horizontal Release

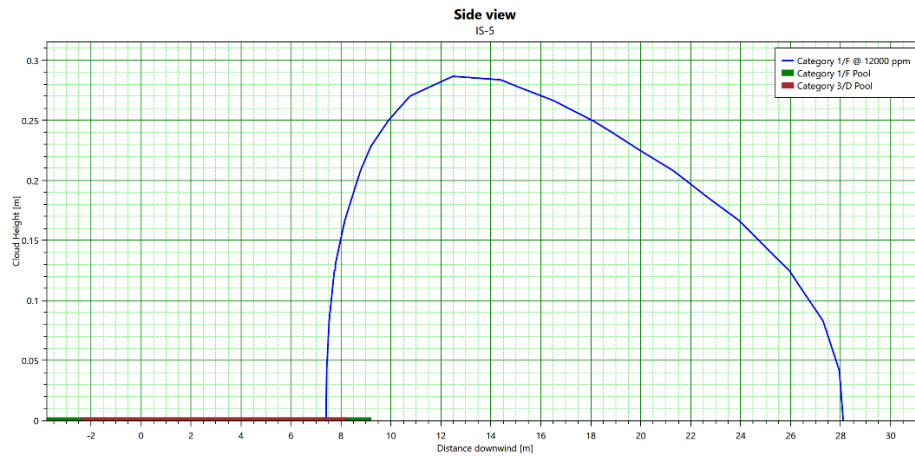


IS-3 (1) Vertical Release

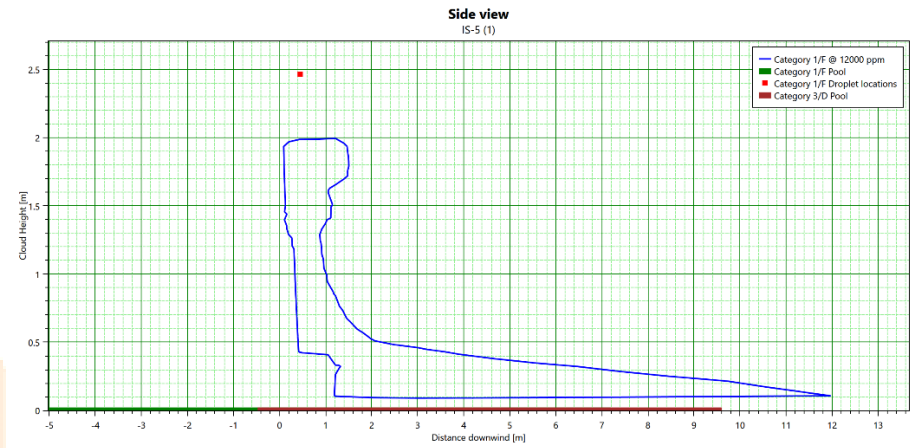


Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

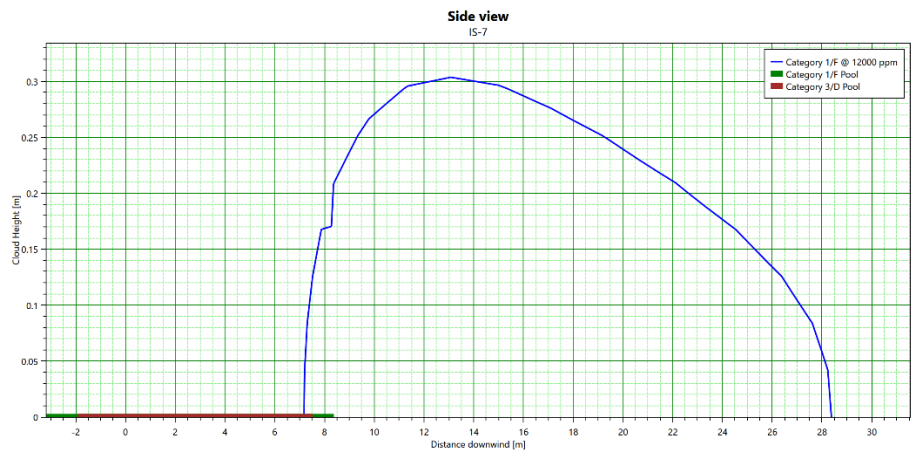
IS-5 Horizontal Release



IS-5 (1) Vertical Release



IS-7 Horizontal Release

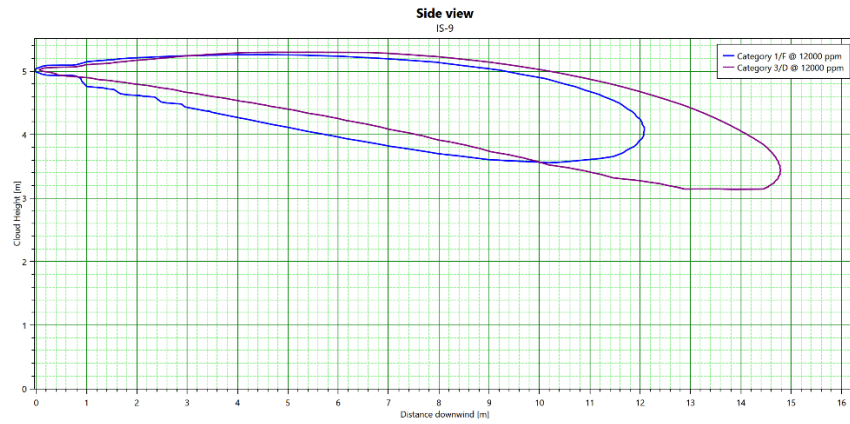


IS-7 (1) Vertical Release

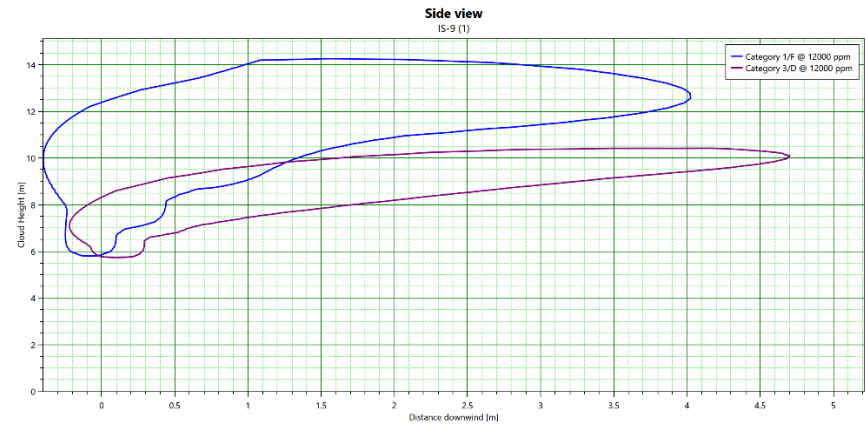


Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

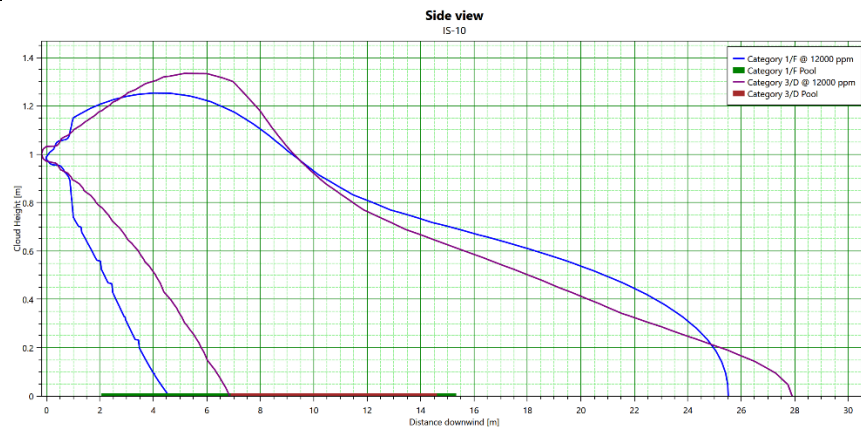
IS-9 Horizontal Release



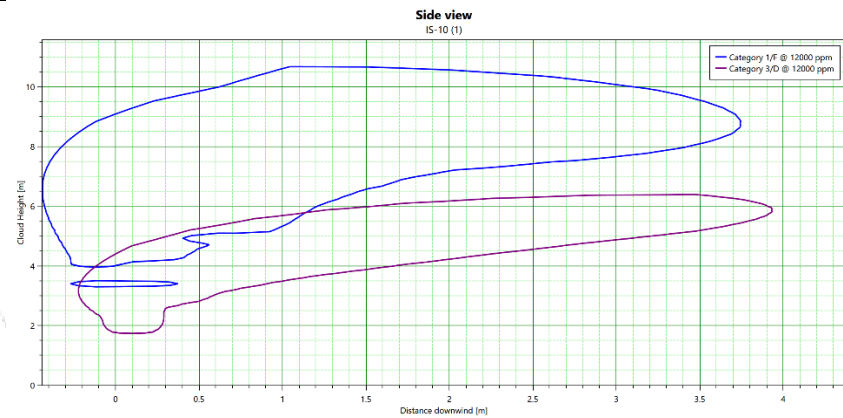
IS-9 (1) Vertical Release



IS-10 Horizontal Release

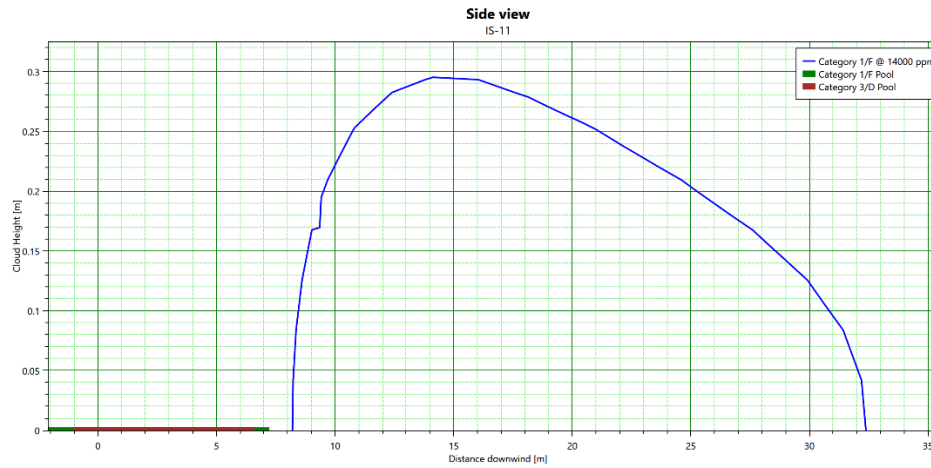


IS-10 (1) Vertical Release

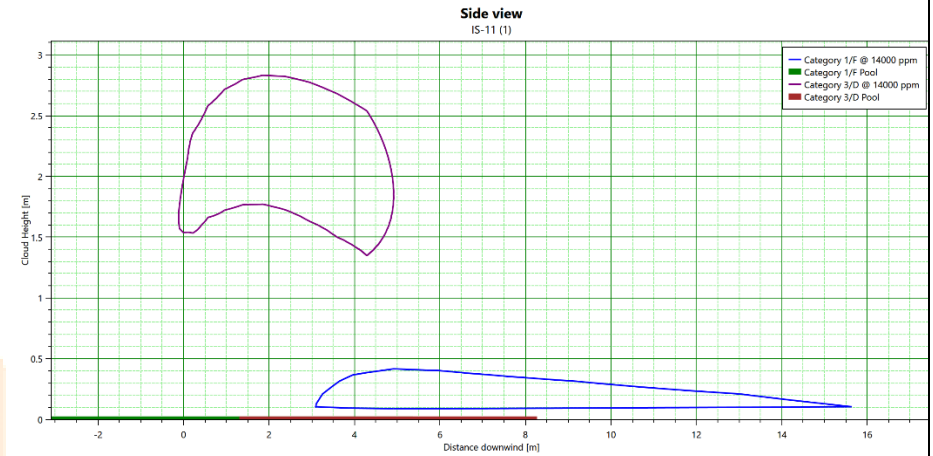


Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

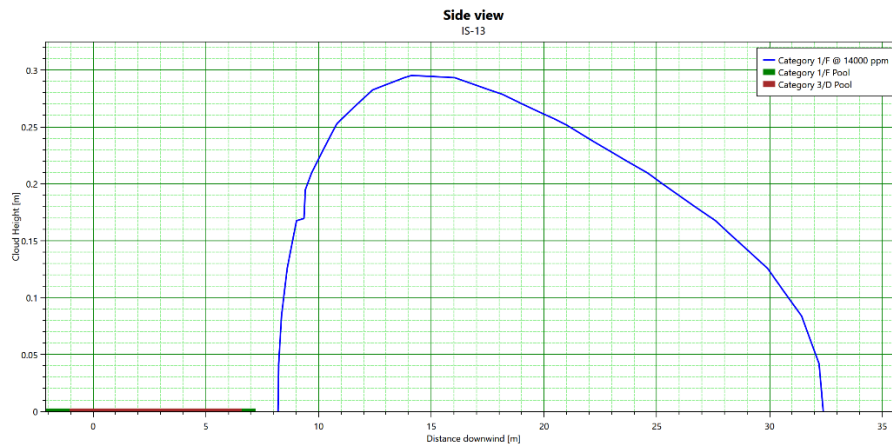
IS-11 Horizontal Release



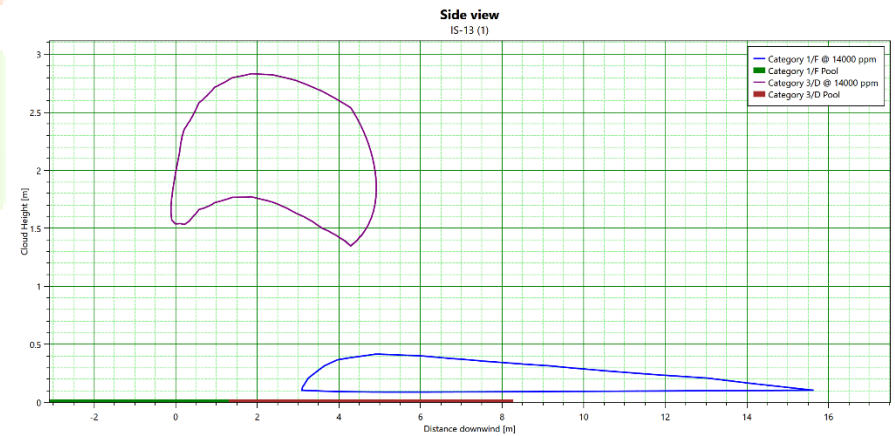
IS-11 (1) Vertical Release



IS-13 Horizontal Release

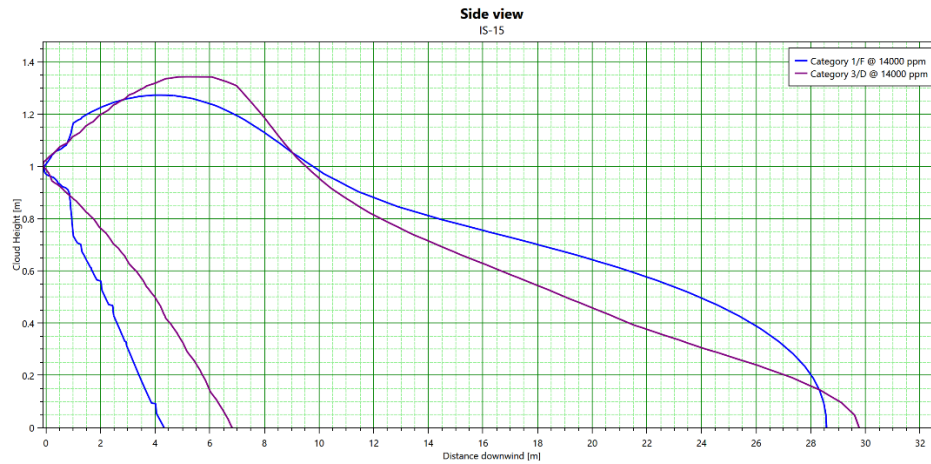


IS-13 (1) Vertical Release

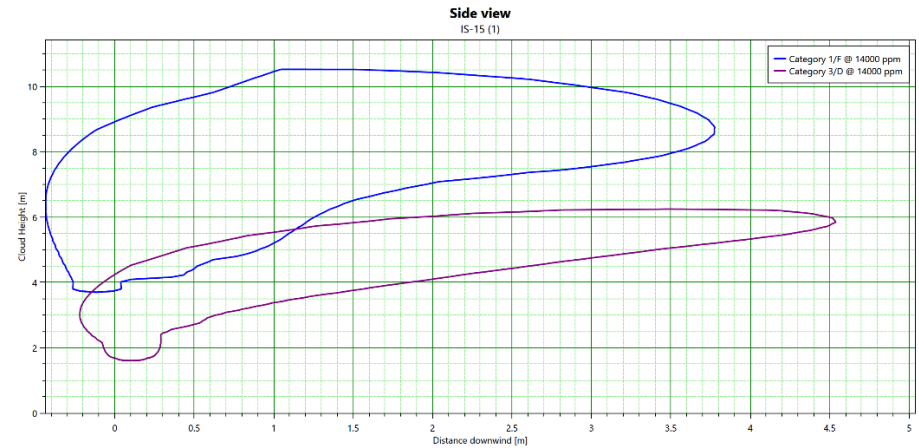


Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

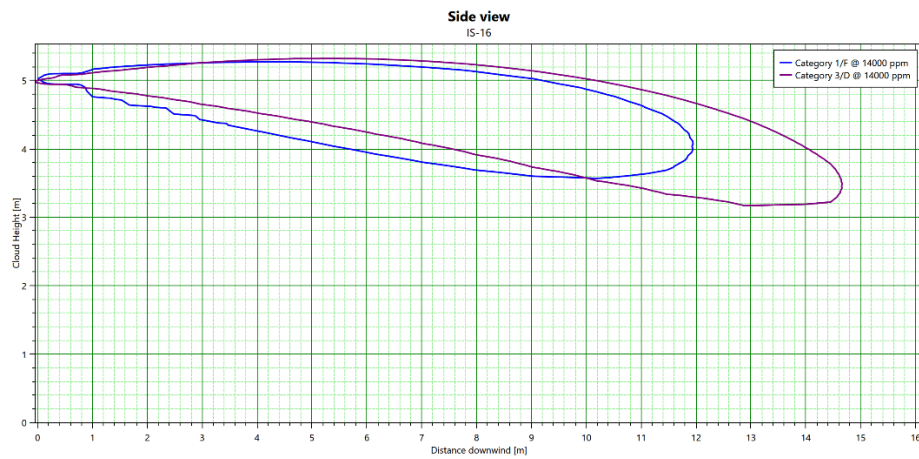
IS-15 Horizontal Release



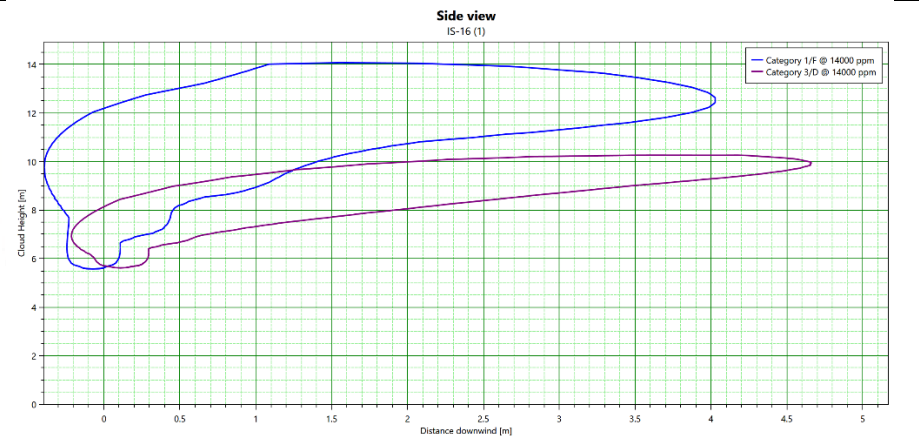
IS-15 (1) Vertical Release



IS-16 Horizontal Release

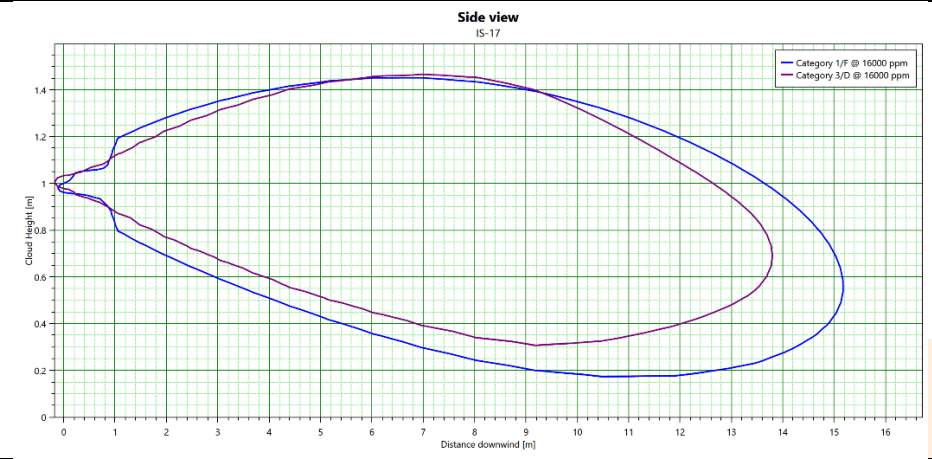


IS-16 (1) Vertical Release

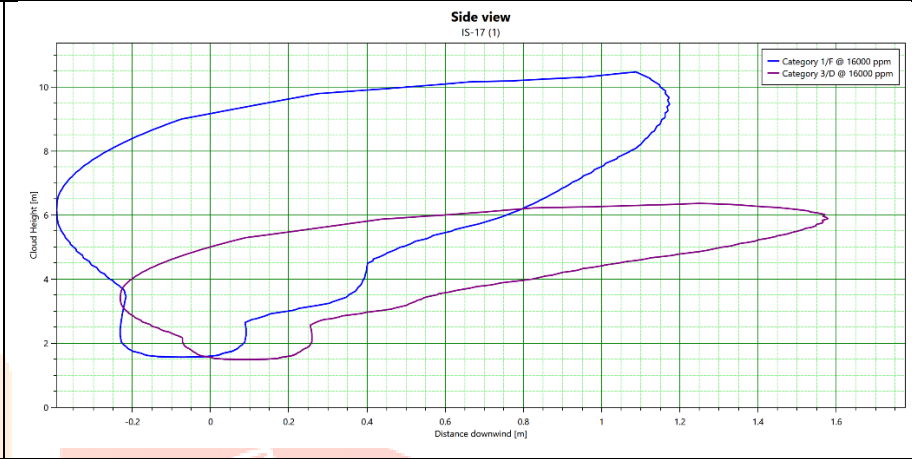


Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the heavier than air gas/ vapours and leak source located below 8 m height

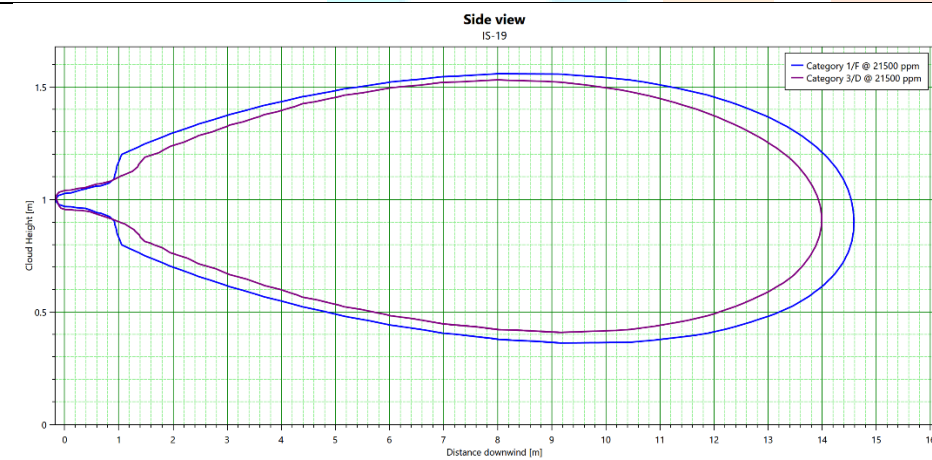
IS-17 Horizontal Release



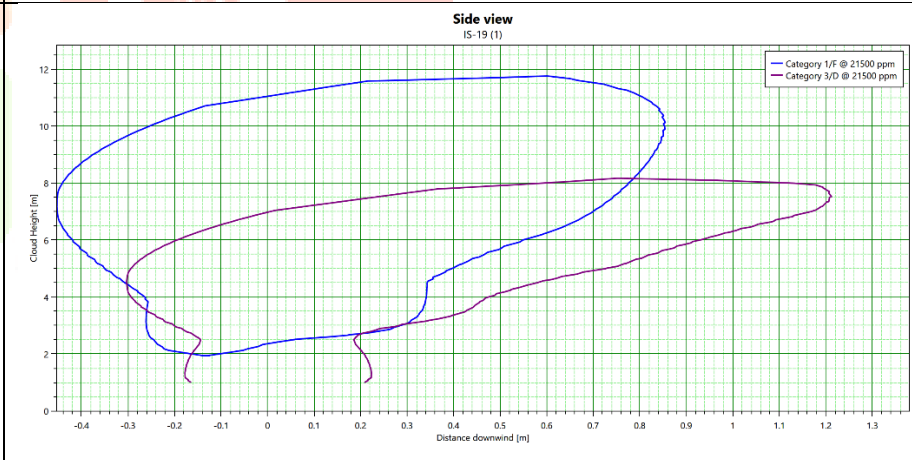
IS-17 (1) Vertical Release



IS-19 Horizontal Release



IS-19 (1) Vertical Release



4.1. Results and discussion on comparison between IS-5572 ref fig H1 and DNV PHAST 8.71 LEL cloud dispersion results for the heavier than air gas/ vapour and leak sources located below 8 m height from ground level

The height and horizontal distance of LEL cloud modelled considering horizontal and vertical leakage from IS-1, IS-3, IS-5, IS-7, IS-9, IS-10, IS-11, IS-13, IS-15, IS-16, IS-17 and IS-19 were compared with the distances and height specified in IS 5572 ref figure H-1. As IS:5572 has safety consideration while specifying extent of hazardous area therefore the results of dispersion modelling which were less than the extent defined in IS-5572 ref fig H-1 were not considered during comparison between IS-5572 and dispersion modelling results. Only the results exceeding the distances specified in IS-5572 ref figure H-1 were considered. Following observations are made

1. Based on dispersion data of LEL cloud of IS-1, IS-3, IS-5, IS-7, IS-11 and IS-13 the atmospheric storage tanks of flammable chemicals having a leak location below 8 m are having their LEL cloud within the distance and height specified in reference figure H-1 of IS 5572:2009 in all quantities and up to respective boiling temperature.
2. Based on dispersion data of LEL cloud of IS- 9, IS-10, IS-15 and IS-16 the transfer pump/ pipeline of flammable chemicals having a leakage location below 8 m height and horizontal leak direction are having their LEL cloud within the distance and height specified in reference figure H-1 of IS 5572:2009 in all flow rates. For vertical leak direction the vertical height in 0-8 m distance from source is having an exceedance of 9.54%, 18.56%, 16.89 % and 8.23 % for IS- 9, IS-10, IS-15 and IS-16 respectively.
3. Based on dispersion data of LEL cloud of IS- 17 and IS-19 pressurized storage of flammable gases having a leakage location below 8 m height and horizontal leak direction are having their LEL cloud within the distance and height specified in reference figure H-1 of IS 5572:2009. For vertical leak direction the vertical height in 0-8 m distance from source is having an exceedance of 16% and 30.67%, for IS 17 and IS-19 respectively

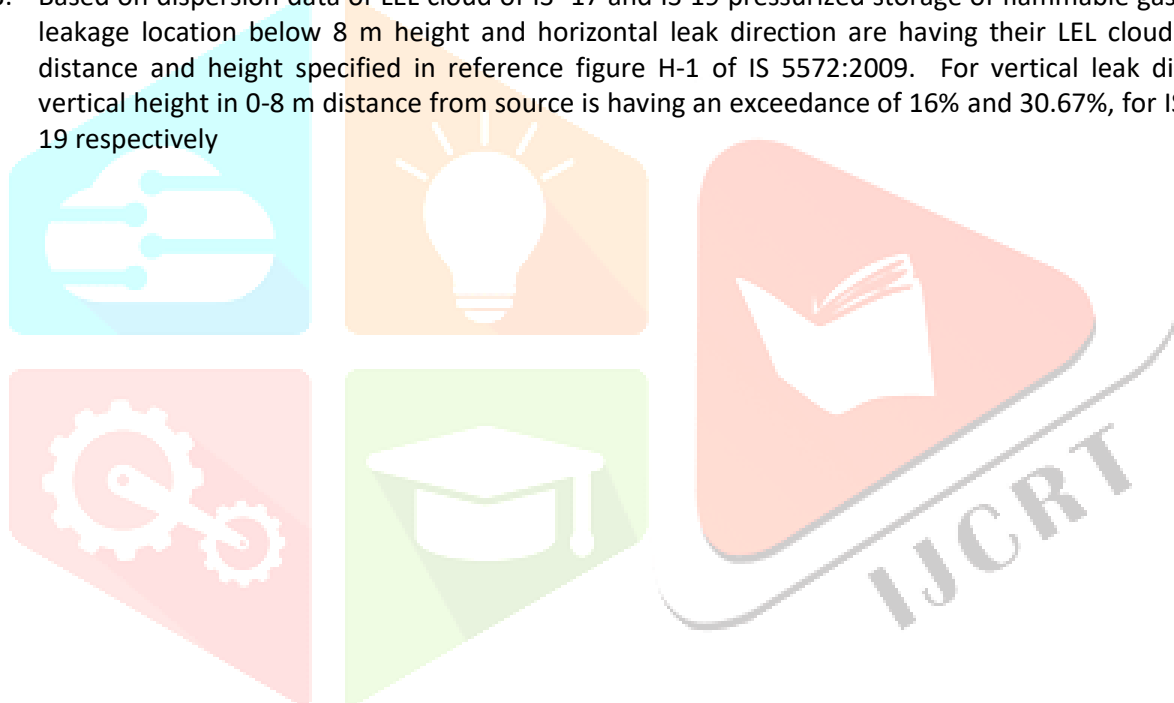


Table -4.2 comparison between IS-5572 ref fig H1 and DNV PHAST 8.71 LEL cloud dispersion results for the heavier than air gas/ vapour and leak sources located above 8 m height

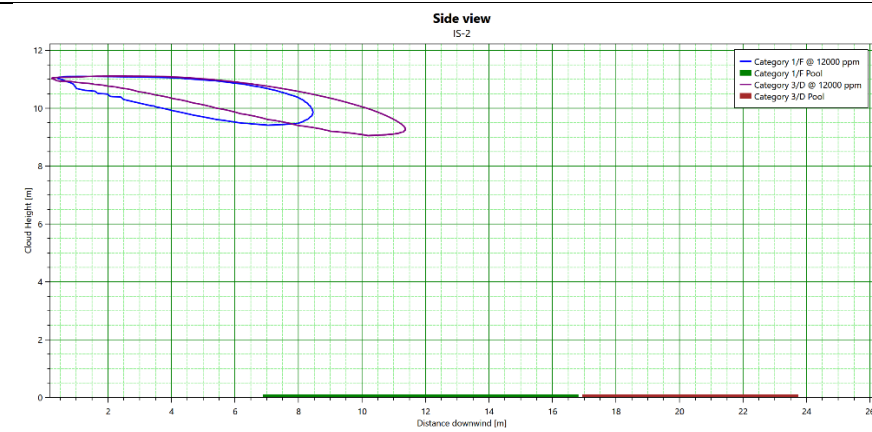
IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572 (m)	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
IS-2	Horizontal	Zone 2 - 16 m (8 m high) Extended Zone 2- 16-32 m (0.63 m high)	10.95	19	11.3	-	8	10.3	-28.75	0.63	0	-	For IS-2 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is 2.3 m (25.56%) more and between 8-16 m distance is 2.3 m (28.75%) more than the height specified in IS 5572 Ref fig H2
	Vertical	Zone 2 - 16-32 m (0.63 m high)	8.27	19	13.22	-	8	13.1	-63.75	0.63	0	-	For IS-2 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is 4.22 m (46.89%) more and between 8-16 m distance is 5.1 m (63.75%) more than the height specified in IS 5572 Ref fig H2
IS-4	Horizontal	Zone 2 - 16 m (8 m high) Extended Zone 2- 16-32 m (0.63 m high)	11.12	19	11	-	8	10.3	-28.75	0.63	0	-	For IS-4 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 2.3 m (28.75%) more than the height specified in IS 5572 Ref fig H2
	Vertical	Zone 2 - 16-32 m (0.63 m high)	8.28	19	15.815	-	8	13.02	-62.75	0.63	0	-	For IS-4 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 5.1 m (63.75%) more than the height specified in IS 5572 Ref fig H2
IS-6	Horizontal	Zone 2 - 16 m (8 m high) Extended Zone 2- 16-	11.36	19	11.03	-	8	10.57	-32.13	0.63	0	-	For IS-6 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 2.57 m (32.13 %) more than the height specified in IS 5572 Ref fig H2

IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572 (m)	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
	Vertical	32 m (0.63 m high)	8.27	19	15.98	-	8	13.25	-65.63	0.63	0	-	For IS-6 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 5.25 m (65.63%) more than the height specified in IS 5572 Ref fig H2
IS-8	Horizontal	Zone 2 - 16 m (8 m high)	11.12	19	11.13	-	8	10.3	-28.75	0.63	0	-	For IS-8 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 2.3 m (28.75 %) more than the height specified in IS 5572 Ref fig H2
	Vertical	Extended Zone 2- 16-32 m (0.63 m high)	8.27	19	15.82	-	8	13.42	-67.75	0.63	0	-	For IS-8 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 5.42 m (67.75%) more than the height specified in IS 5572 Ref fig H2
IS-12	Horizontal	Zone 2 - 16 m (8 m high)	11.02	19	11.13	-	8	10.25	-28.13	0.63	0	-	For IS-12 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 2.25 m (28.13 %) more than the height specified in IS 5572 Ref fig H2
	Vertical	Extended Zone 2- 16-32 m (0.63 m high)	8.28	19	15.75	-	8	13.07	-63.38	0.63	0	-	For IS-12 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 5.07 m (63.38%) more than the height specified in IS 5572 Ref fig H2
IS-14	Horizontal	Zone 2 - 16 m (8 m high) Extended Zone 2- 16-	11.02	19	11.13	-	8	10.25	-28.13	0.63	0	-	For IS-14 the horizontal release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 2.25 m (28.13 %) more than the height specified in IS 5572 Ref fig H2

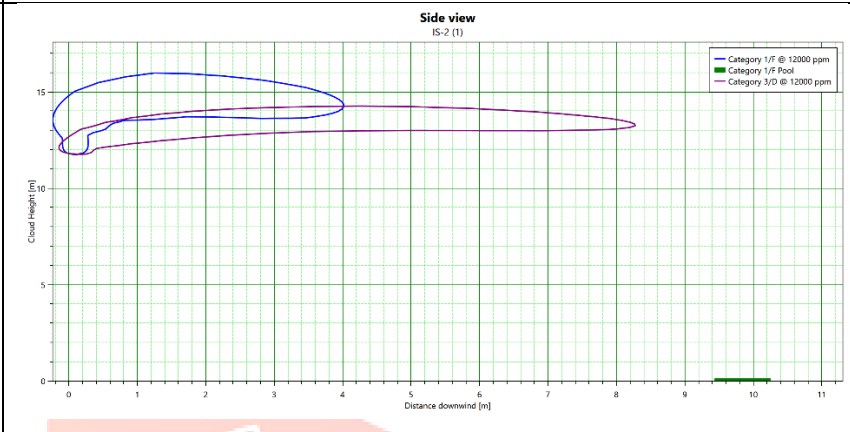
IS #	Release Direction	Horizontal distance of LEL cloud as per IS 5572 (m)	Horizontal distance of LEL cloud (m) from DNV PHAST	Height of cloud between 0-8 m as per IS 5572 (m)	Maximum Height of cloud between 0-8 m distance (m) from PHAST	% Error	Height of cloud between 8-16 m as per IS 5572 (m)	Maximum Height of cloud between 8-16 m distance (m) from PHAST	Error %	Height of cloud between 16-32 m as per IS 5572 (m)	Maximum Height of cloud between 16-32 m distance (m) PHAST	Error %	Conclusion/ Remarks
	Vertical	32 m (0.63 m high)	8.31	19	15.74	-	8	13.04	-63.00	0.63	0	-	For IS-14 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 5.04 m (63.0%) more than the height specified in IS 5572 Ref fig H2
IS-18	Horizontal	Zone 2 - 16 m (8 m high)	15.10	19	11.43	-	8	11.43	-42.88	0.63	0	-	For IS-18 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is below 19 m and between 8-16 m distance is 3.43 m (42.88%) more than the height specified in IS 5572 Ref fig H2
	Vertical	Extended Zone 2- 16-32 m (0.63 m high)	1.77	19	19.57	-3.00	8	0	-	0.63	0	-	For IS18 (1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is 0.57 m (3%) more than the height specified in IS 5572 Ref fig H2 and LEL cloud does extend beyond 1.77 m horizontally
IS-20	Horizontal	Zone 2 - 16 m (8 m high)	14.87	19	11.51	-	8	11.51	-43.88	0.63	0	-	For IS-20 horizontal release the LEL could distance and height are with in the distances and height specified in IS-5572 ref Fig H-1
	Vertical	Extended Zone 2- 16-32 m (0.63 m high)	1.26	19	20.86	-9.79	8	0	-	0.63	0	-	For IS-20(1) the vertical release point is at 11 m height. Height of LEL cloud in 0-8 m distance is 1.86 m (9.79%) more than the height specified in IS 5572 Ref fig H2 and LEL cloud does extend beyond 1.26 m horizontally

Graphical Results from DNV PHAST 8.71 LEL Cloud dispersion modelling for the heavier than air gas/ vapour, leak sources located above 8 m height

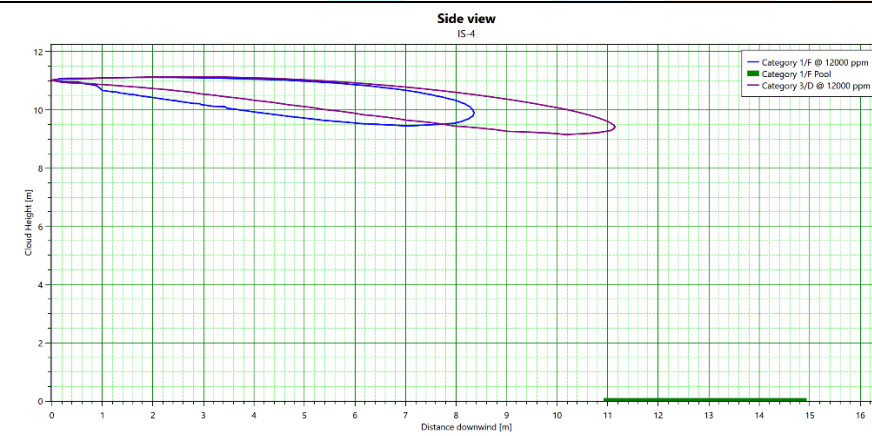
IS-2 Horizontal Release



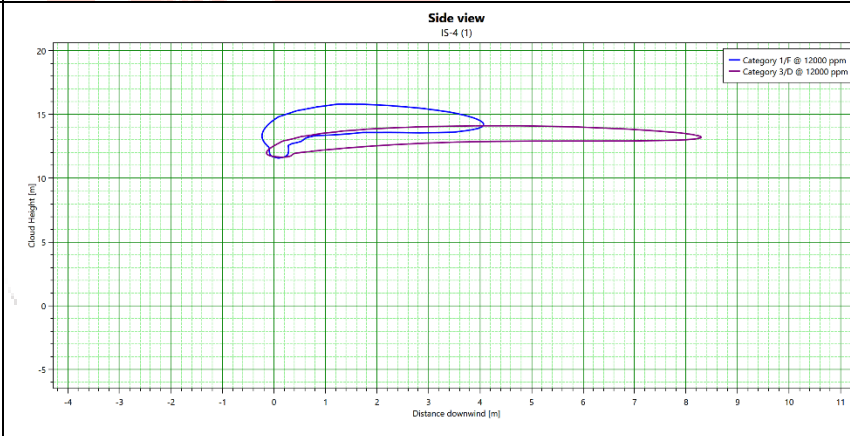
IS-2 (1) Vertical Release



IS-4 Horizontal Release

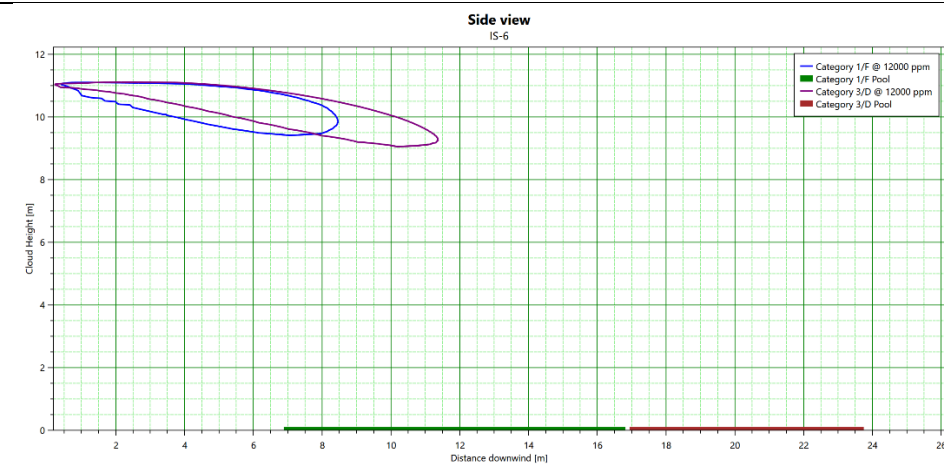


IS-4 (1) Vertical Release

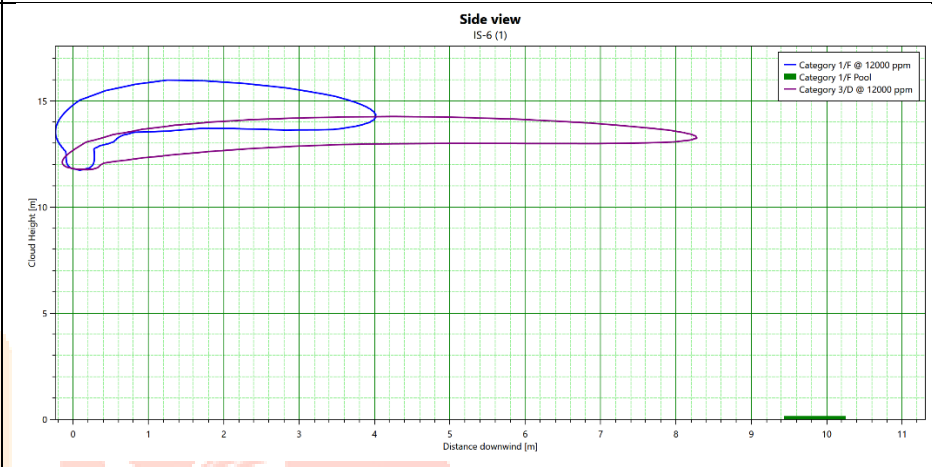


Graphical Results from DNV PHAST 8.71 LEL Cloud dispersion modelling for the heavier than air gas/ vapour, leak sources located above 8 m height

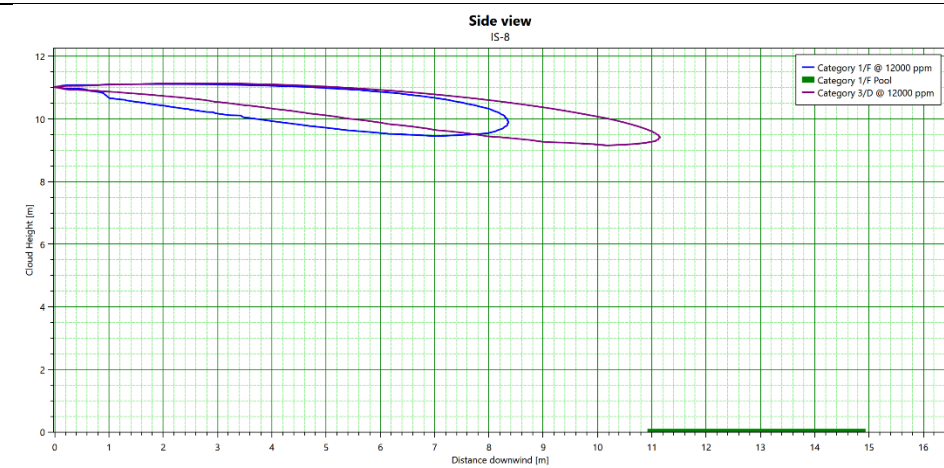
IS-6 Horizontal Release



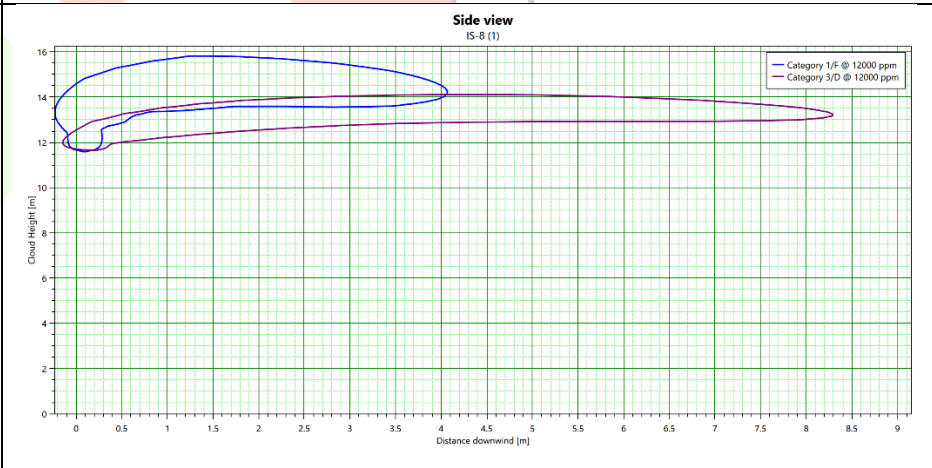
IS-6 (1) Vertical Release



IS-8 Horizontal Release

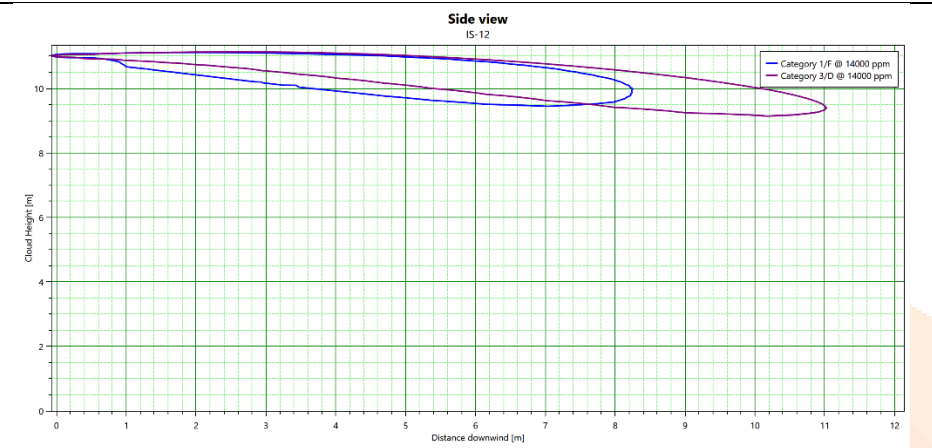


IS-8 (1) Vertical Release

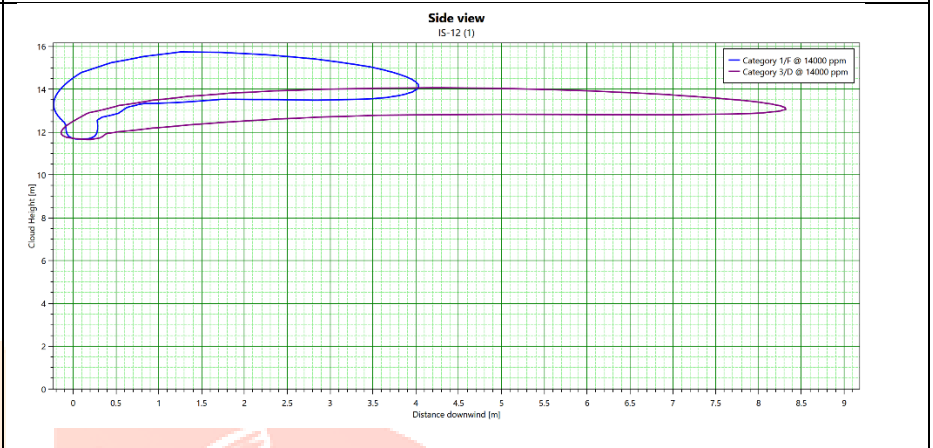


Graphical Results from DNV PHAST 8.71 LEL Cloud dispersion modelling for the heavier than air gas/ vapour, leak sources located above 8 m height

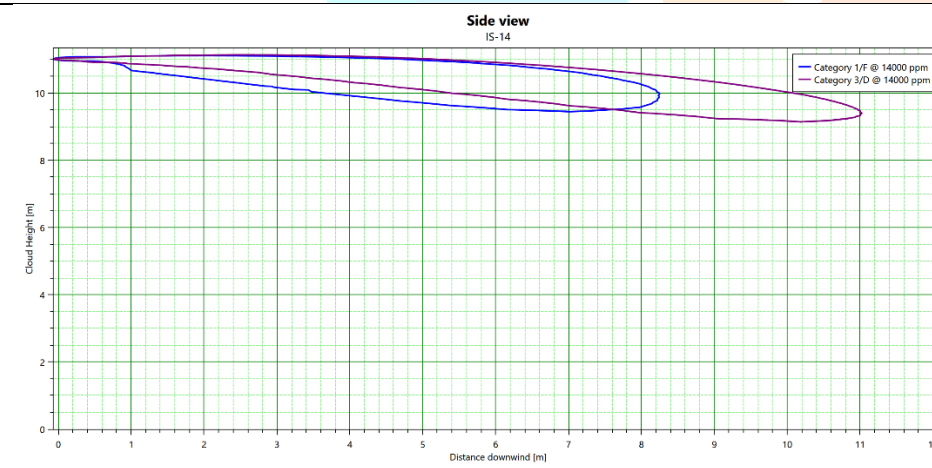
IS-12 Horizontal Release



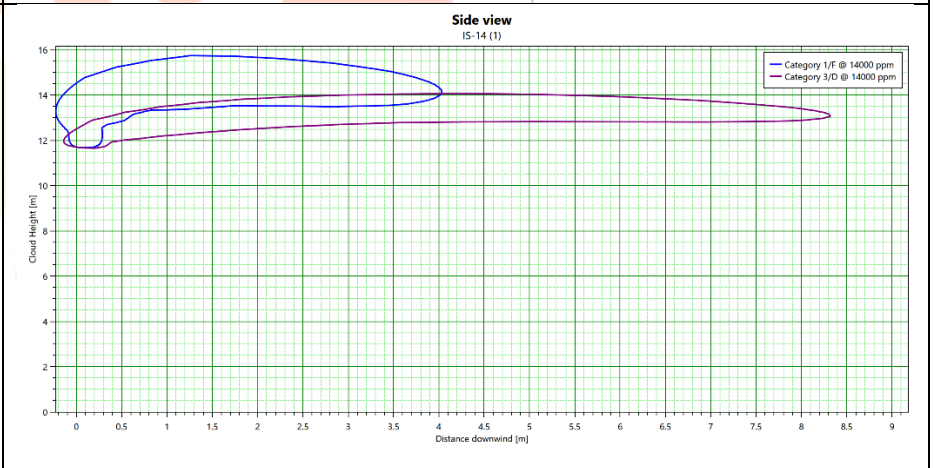
IS-12 (1) Vertical Release



IS-14 Horizontal Release

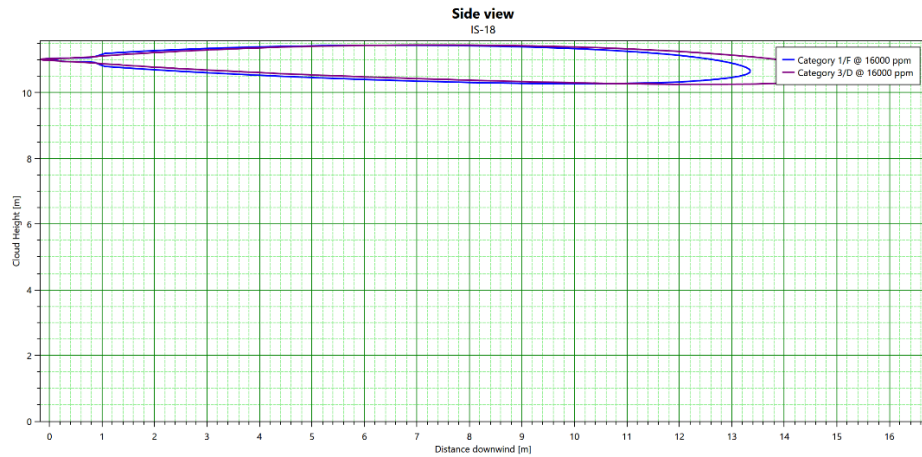


IS-14 (1) Vertical Release

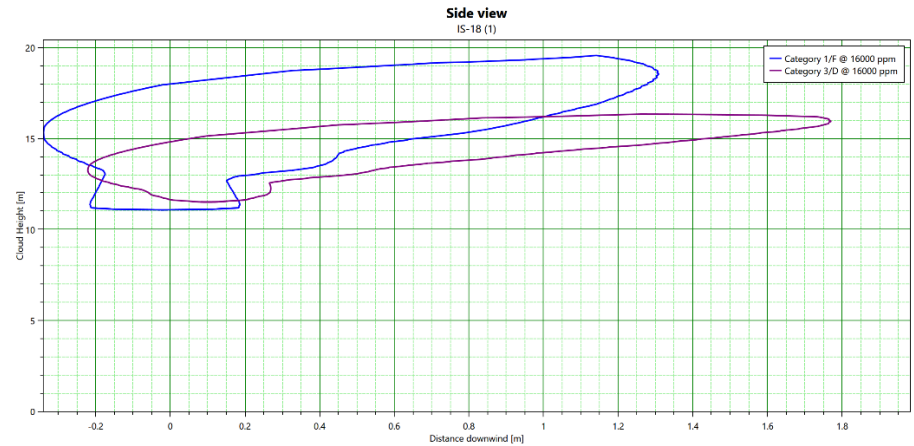


Graphical Results from DNV PHAST 8.71 LEL Cloud dispersion modelling for the heavier than air gas/ vapour, leak sources located above 8 m height

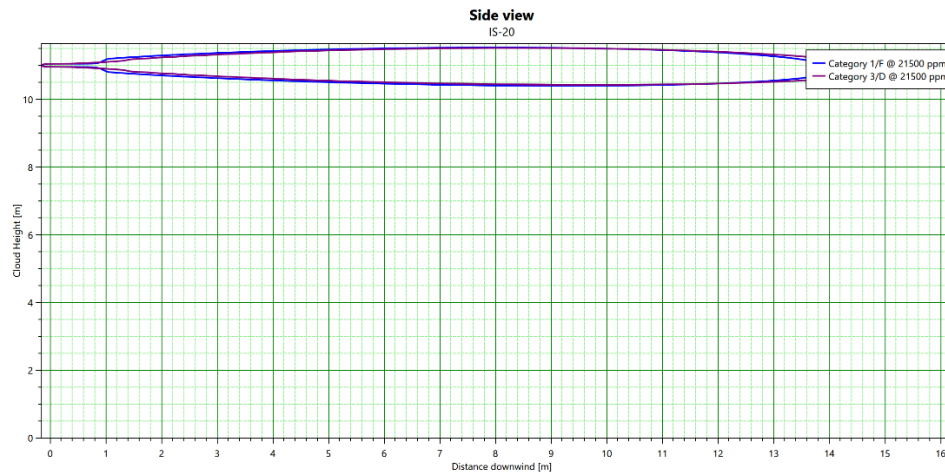
IS-18 Horizontal Release



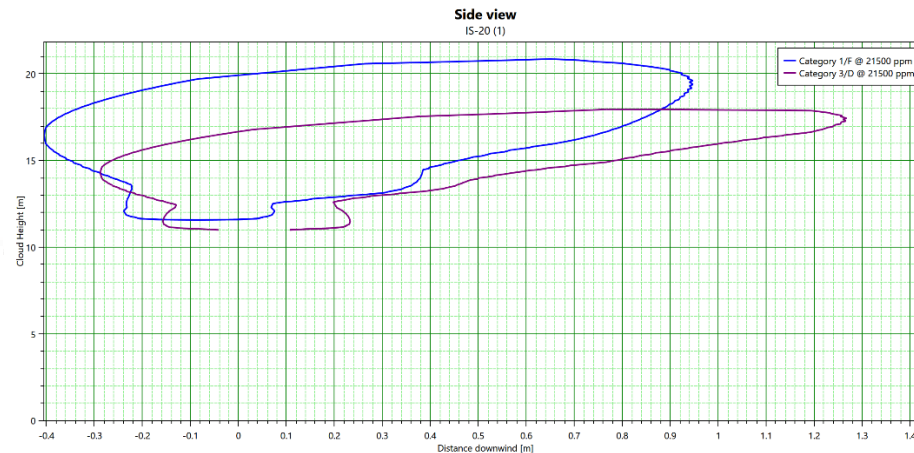
IS-18 (1) Vertical Release



IS-20 Horizontal Release



IS-20 (1) Vertical Release



4.2 Results and discussion on comparison between IS-5572 ref fig H2 and DNV PHAST 8.71 LEL Cloud dispersion results for the heavier than air gas/ vapour and leak sources located above 8 m height from ground

The horizontal distance and height of LEL cloud formed during modelling of horizontal and vertical leakage from IS-2, IS-4, IS-6, IS-8, IS-12, IS-14, IS-18 and IS-20 were compared with the distances specified in IS 5572 ref figure H-2. As IS:5572 has safety consideration while specifying extent of hazardous area therefore the results of dispersion modelling which were less than the extent defined in IS-5572 ref fig H-2 were not considered during comparison between IS-5572 and dispersion modelling results. Only the results exceeding the distances specified in IS-5572 ref figure H-2 were considered. Following observations are made

1. Based on dispersion data of LEL cloud IS-2, IS-4, IS-6, IS-8, IS-12, IS-14, IS-18 and IS-20 of flammable chemicals having a leak location above 8 m height are having their LEL cloud within 16 m horizontal distance from the leak source for both horizontal and vertical leakage direction irrespective of quantity of temperature of material. There is no extended zone 2.
2. Based on dispersion data of LEL cloud of IS-2, IS-4, IS-6, IS-8, IS-12, IS-14 of flammable liquids having a leakage location above 8 m height, the height of LEL cloud within 0-8 m is within the height specified in IS-5572 ref Fig H2 for all temperature, quantities and leak direction modelled. For IS- 18 and IS-20 the leak height within 0-8 m distance is exceeds with error of 3% and 9.79% respectively from vertical leakage direction.
3. Based on dispersion data of LEL cloud of IS-2, IS-4, IS-6, IS-8, IS-12, IS-14 IS-18 and IS-20 of flammable liquids and gases having a leakage location above 8 m height, the height of LEL cloud within 8-16 m is having and excess height with error ranging from 28.63% to 67.65% and there is a high probability of error if IS 5572 ref fig H2 is used for hazardous area classification

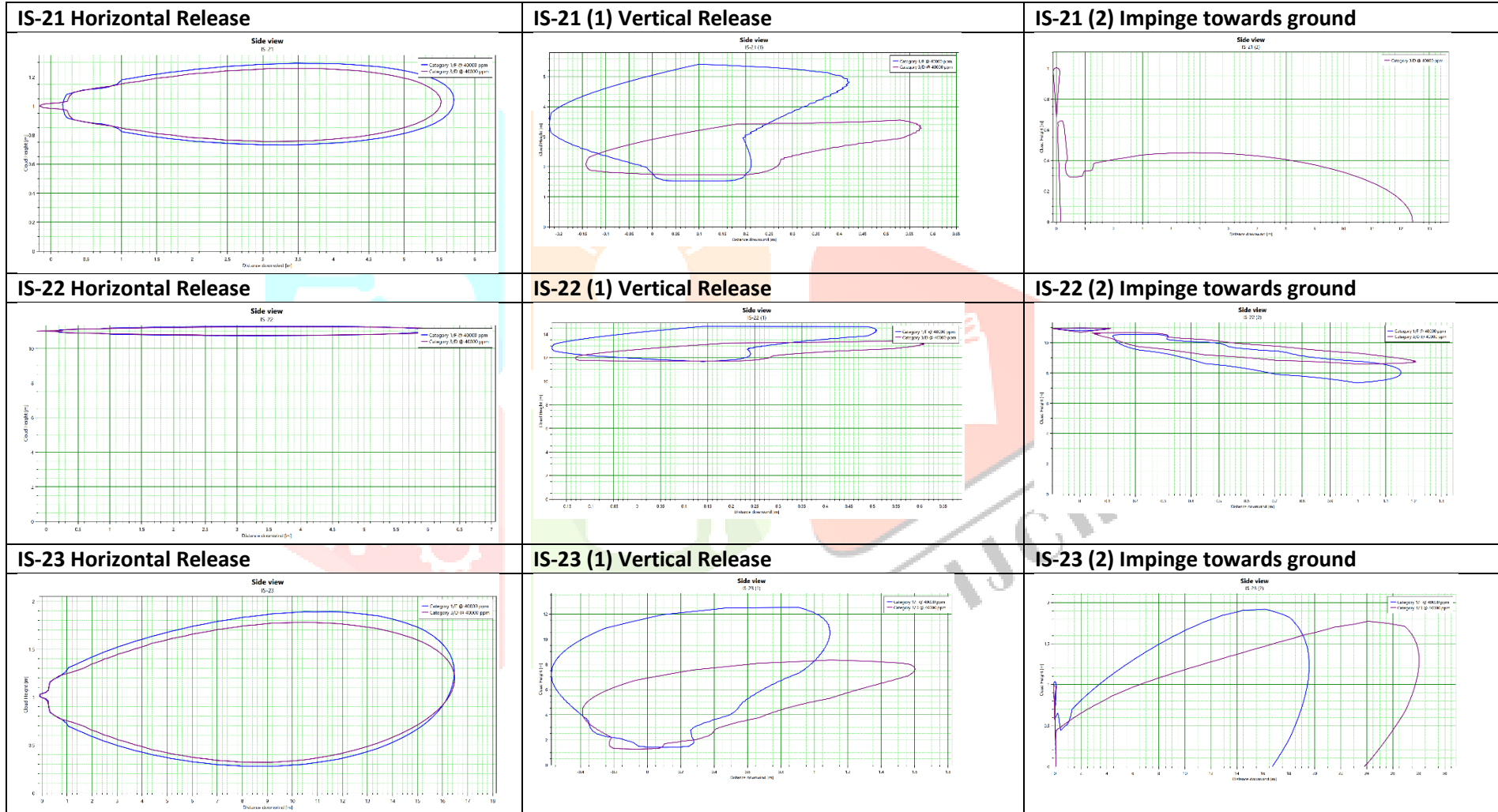


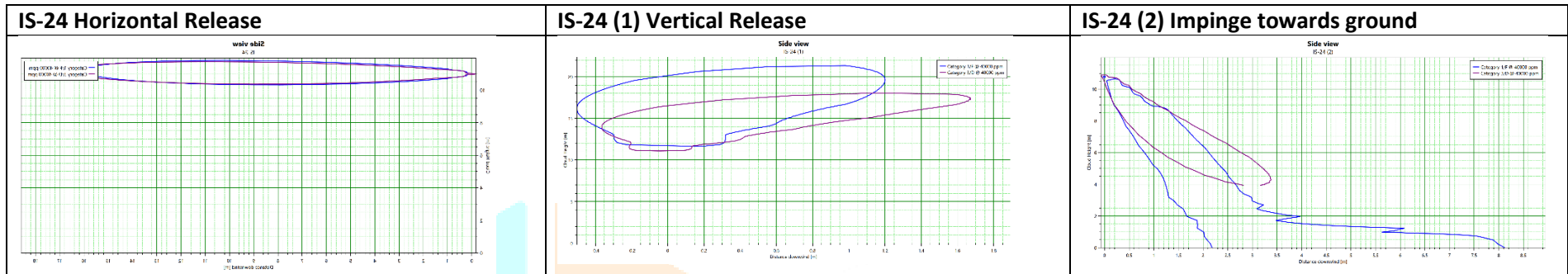
Table -4.3comparison between IS-5572 ref fig L-1 and DNV PHAST 8.71 LEL cloud dispersion results for lighter than airgas/ vapour leak sources

IS #	Leakage height from ground	Direction of release	Horizontal distance of LEL cloud (m) from PHAST	Horizontal distance of cloud from source as per IS 5572 Ref Fig L-1 (m)	Error %	Maximum Height of cloud between 0-4.5m distance (m) from leak source (PHAST) (m)	Height of cloud between 0-4.5 m as per IS 5572 Ref Fig L-1 (m)	% Error	Maximum Height of cloud up after 4.5 m distance from leak source PHAST) (m)	Conclusion/ Remarks
21	1 m	Horizontal release	5.70	4.5	-26.67	3.7	9	-	4.61	For IS-21 Horizontal release LEL cloud extends up to 5.70 m (Error- 26.67 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572 . Height of cloud is within limits specified
		Vertical release	0.57	4.5	-	5.4	9	-	0	For IS-21 (1) Vertical release LEL cloud is within the height and distance specified in ref Fig L-1 of IS-5572
		Angled 75 ° from horizontal towards ground Downwards impinging the ground	12.41	4.5	-175.78	0.45	4.5 towards ground	-		For IS-21 (2) Angled release towards ground the LEL cloud extends up to 12.4 m (Error-175.78 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572. Vertical height is within the height specified in IS-5572 ref fig L-1
22	11 m	Horizontal release	6.40	4.5	-42.22	11.29	19	-	11.29	For IS-22 Horizontal release LEL cloud extends up to 6.4 m (error 42.22 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572
		Vertical release	0.61	4.5	-	14.64	19	-	0	For IS-21 (1) Vertical release LEL cloud is within the height and distance specified in ref Fig L-1 of IS-5572
		Angled 75 ° from horizontal towards ground Downwards impinging the ground	1.15	4.5	-	3.5	4.5 towards ground	-	0.45	For IS-21 (2) Angled release towards ground LEL cloud is within the height and distance specified in ref Fig L-1 of IS-5572

IS #	Leakage height from ground	Direction of release	Horizontal distance of LEL cloud (m) from PHAST	Horizontal distance of cloud from source as per IS 5572 Ref Fig L-1 (m)	Error %	Maximum Height of cloud between 0-4.5m distance (m) from leak source (PHAST) (m)	Height of cloud between 0-4.5 m as per IS 5572 Ref Fig L-1 (m)	% Error	Maximum Height of cloud up after 4.5 m distance from leak source PHAST) (m)	Conclusion/ Remarks
23	1 m	Horizontal release	16.45	4.5	-265.56	1.64	9	-	1.89	For IS-23 Horizontal release LEL cloud extends up to 16.45 m (Error- 26265.56 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572. Height of cloud is 1.64 m which is acceptable
		Vertical release	1.60	4.5	-	12.37	9	-37.44	0	For IS-23 Vertical release LEL cloud extends up to 1.6 m horizontally and 12.37 m (error 37.44) high as against 9 m defined in fig L-1 of IS 5572. width of cloud is 1.60 m which is acceptable
		Angled 75 ° from horizontal towards ground Downwards impinging the ground	28.00	4.5	-522.22	1.92	4.5 towards ground	-	1.92	For IS-21 (2) Angled release towards ground the LEL cloud extends up to 28 m (Error-522 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572.
24	11 m	Horizontal release	16.85	4.5	-274.44	11.62	19	-	11.82	For IS-24 Horizontal release LEL cloud extends up to 16.85 m (Error- 277.44 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572. Height of cloud is 11.62 m which is acceptable
		Vertical release	1.67	4.5	-	21.34	19	-12.32	0	For IS-24 Vertical release LEL cloud extends up to 1.67 m horizontally and 21.34 m (error 12.32 %) high as against 19 m defined in fig L-1 of IS 5572.
		Angled 75 ° from horizontal towards ground Downwards impinging the ground	8.12	4.5	-80.44	11	4.5	-144.44	1.41	For IS-23 (2) Angled release towards ground the LEL cloud extends up to 8.12 m (Error-80.44 %) horizontally as against 4.5 m defined in fig L-1 of IS 5572. Similarly the cloud touches ground level which is 11 m below the source of leak where as per fig L-1 the downward distance from source of leakage is only 4.5 m .

Graphical Results from DNV PHAST 8.71 LEL cloud dispersion modelling for the lighter than air gas/ vapour leak sources





4.3 Results and Discussion on comparison between IS-5572 ref fig L-1 and DNV PHAST 8.71 LEL cloud dispersion results for lighter than air gas/ vapour leak sources

As IS:5572 has safety consideration while specifying extent of hazardous area therefore the results of dispersion modelling which were less than the extent defined in IS-5572 ref fig L-1 were not considered during comparison between IS-5572 and dispersion modelling results, Only the results exceeding the distances specified in IS-5572 ref figure L-1 were considered. Following observations are made

1. Based on dispersion data of LEL cloud of IS-21, IS-22, IS-23 and IS-24 of Hydrogen gas at 5 bar and 50 bar pressure there is an error of 80% to 522 % in horizontal distance for LEL cloud and error of 12 % to 144% in height of LEL cloud in various release

5. Conclusion

Hazardous area classification design is required to reduce the explosion risk in process plants(5). In the era of technological development and popularity of computer software, as well as increasing computing power of computers, the introduction of CFD methodology as an effective tool, helpful also in classifying explosive hazardous areas / zones, should be considered (1). Nowadays, no one is surprised by the use of simulations based on ALOHA, PHAST, RIZEX and other programs. Properly performed simulations of vapour cloud dispersion become useful in classifying extent of Hazardous area. This makes it all the more important to improve the knowledge base on the phenomena associated with the emission of flammable liquids/ fumes /dusts /gases for the purposes of classifying explosive hazardous areas / zones(1).

IS:5572 which is most conservative standard for hazardous area classification across the world. It accurately predicts extent of hazardous area for atmospheric storage of liquids located below 8 m from ground level however there is chances of considerable error when leakage source are located above 8 m or when pump or pipeline leaks are considered or for vertical release of pressurized flammable gases. Also there is considerable error in determining extent of hazardous area for lighter than air gases at various pressure and as gas pressure increases the error margin also increases. Based on above study it is concluded that hazardous area classification is not simply a copy paste exercise (2) in which HAC is marked based on distances given in various standards.

The forward note of IS-5572:2009 rightly says (8)

“This standard includes generalized statements and recommendations on matters on which there are diverse opinions. It is, therefore, important that sound engineering judgement take precedence over a literal interpretation of text. Good judgement should be exercised without jeopardizing the requirements laid down in this standard.”

Use of modern dispersion modelling software and CFD can accurately predict extent of hazardous area in all directions and HAC standards like IS-5572 should be considered as a minimum requirement of hazardous area classification.

6. References

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2. Estellito Rangel Junior, Aurélio Moreira Luiz, Hilton Leão de P. M. Filho, Area Classification Is Not A Copy and Paste Process, IEEE Industry Applications Magazine 22(1):381-388
3. Vlad Mihai Păsculescu* , Nicolae-Ioan Vlasin, Emilian Ghicioi, Gheorghe Daniel Florea, Marius Cornel Şuvar NEW TOOLS FOR ESTIMATING THE EXTENT OF HAZARDOUS AREAS GENERATED BY GAS LEAK EXPLOSIONS, Environmental Engineering and Management Journal, April 2019, Vol. 18, No. 4, 889-900
4. H. Zohdirad , T. Ebadi, S. Givehchi, Optimization of the calculation of hazardous zones boundaries for classification of hazardous area using riskbased approach, Optimization of the calculation of hazardous zones boundaries for classification of hazardous area using riskbased approach. Journal of Health and Safety at Work Vol. 6; No. 1; Spring 2016

5. Jae-Young Choi, Sang-HoonByeon, Specific Process Conditions for Non-Hazardous Classification of Hydrogen Handling Facilities. Journal of Health and Safety at Work Vol. 6; No. 1; Spring 2016

6.NFPA 497: 2017 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

7. IEC 60079-10-1:2015, Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres

8. IS 5572: 2009 (reaffirmed in 2018), Classification of hazardous areas (Other Than Mines) having flammable gases and vapours for electrical installation (Third Revision)

