Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project: Long Baseline Neutrino Experiment

Title: LBNE Vapor Dispersion

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Introduction / Abstract

Due to the large scale of LBNE, a vast quantity of liquid argon will be stored in the cavern at DUSEL. It will be on the order of 20 kton of liquid argon and 0.04 kton of liquid nitrogen. Since there is a trail nearby, the hazards of a catastrophic spill are examined using the ALOHA program.

Description

LBNE is a large-scale argon neutrino experiment that requires 20 kton of argon and 0.04 kton of nitrogen both of which displace oxygen when released into the air. An ODH analysis was done to determine spill rates and likely release scenarios. There major cases were considered: the LN2 cooling system shuts down and argon boils, a large break in the main argon line connected to the four 150 gpm pumps, and lastly a 30 psig LN2 line develops a large leak. Each case has a low probability of happening, but in the event one does occur, ALOHA can help predict what will happen.

ALOHA, Areal Locations Of HAzardous materials, is a widely-recognized dispersion model program. It uses both the Gaussian and DEGADIS (dense gas dispersion) models so it can account for lighter-than-air gases like nitrogen and heavier-than-air gases like argon. EPA recommends this program and it is used in federal standards like 49 CFR 193 (LNG transportation).

Analysis

The program was setup to run each different case using specific inputs such as chemical, atmospheric, and source data. Table listed below summarizes all of the inputs placed for Case 1. Case 1 looks at the situation where LN2 cooling is down and all of the argon is being boiled off through the vent pipe. It is the one scenario that is most realistic to consider since all it takes is operational maintenance on the cooling system to cause it.

Case 1: Argon boil-off with no LN2 cooling

SITE DATA:
Location: HOMESTAKE MINE, SOUTH DAKOTA

CHEMICAL DATA:
Chemical Name: ARGON Molecular Weight: 39.95 g/mol
Ambient Boiling Point: -305.7° F
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 5 miles/hour from E at 3 meters
Ground Roughness: urban or forest Cloud Cover: 0 tenths
Air Temperature: 72° F Stability Class: C
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:
Direct Source: 2500 pounds/hr Source Height: 0 feet
Release Duration: 60 minutes
Release Rate: 41.7 pounds/min (403 scfm)
Total Amount Released: 2,500 pounds
Note: This chemical may flash boil and/or result in two phase flow.

Case 2 looks at four 150 gpm LAr pumps discharging argon into the vent shaft. Flow rate used was increased by 20% to include any extra flow occurring due to no back pressure. With a 200-fold increase in flow rate from case 1, this is a more drastic event but also much more improbable.

Case 2: Four 150 gpm LAr discharging to vent

SITE DATA:

Location: HOMESTAKE MINE, SOUTH DAKOTA

CHEMICAL DATA:

Chemical Name: ARGON Molecular Weight: 39.95 g/mol
Ambient Boiling Point: -305.7° F
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 5 miles/hour from E at 3 meters
Ground Roughness: urban or forest Cloud Cover: 0 tenths
Air Temperature: 72° F Stability Class: C
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 720 gallons/min Source Height: 0
Source State: Liquid
Source Temperature: -305° F
Release Duration: 60 minutes
Release Rate: 8,440 pounds/min (80,000 scfm)
Total Amount Released: 506,349 pounds
Note: This chemical may flash boil and/or result in two phase flow.

Lastly, the third case delves into a large break in the LN2 piping. Since the piping is designed for 30 psig, it can deliver high flow rates if a large leak occurred. Its flow rate is not as high as case 2 but still 125 times case 1's.

Case 3: Large leak in 30 psig LN2 piping

CHEMICAL DATA:

Chemical Name: NITROGEN Molecular Weight: 28.01 g/mol

TEEL-1: 65000 ppm TEEL-2: 230000 ppm TEEL-3: 400000 ppm
Ambient Boiling Point: -323.3° F
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 5 miles/hour from E at 3 meters
Ground Roughness: urban or forest Cloud Cover: 0 tenths
Air Temperature: 72° F Stability Class: C
No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:

Direct Source: 222000 pounds/hr Source Height: 0
Release Duration: 24 minutes
Release Rate: 3700 pounds/min (50,000 scfm)
Total Amount Released: 89,000 pounds
Note: This chemical may flash boil and/or result in two phase flow.
Use both dispersion modules to investigate its potential behavior.

Results

Because the affected zones are small in size compared to most catastrophic spills, ALOHA does not generate plots due to near-field patchiness. So in order to interpret the data, concentration values were calculated at various downwind distances along the centerline of the plumes. That generates the highest concentration values and presents a conservative estimate. Tables below show at which distances the TEEL values are.

TEEL stands for Temporary Emergency Exposure Limit. TEEL-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m^3 [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure. TEEL-2 is where a person could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape. The most

serious one is TEEL-3 and that is where a person experiences life-threatening issues and death. These values correspond to Fermilab's FESHM 5064 values.

Table 1: Case 1 Results Summary

TEEL	Distance (yards)	Argon Concentration	Oxygen Concentration
	0	31.0%	14.5%
	1	28.7%	15.0%
	2	26.3%	15.5%
-2	3	24.0%	16.0%
	4	21.6%	16.5%
	5	19.3%	16.9%
	6	16.9%	17.5%
	7	14.6%	17.9%
	8	12.2%	18.4%
	9	9.9%	18.9%
-1	10	7.5%	19.4%
	11	5.2%	19.9%
	12	2.8%	20.4%

Table 2: Case 2 Results Summary

TEEL	Distance (yards)	Argon Concentration	Oxygen Concentration
	0	100.0%	0.0%
	10	100.0%	0.0%
	17	100.0%	0.0%
-3	20	75.0%	5.3%
-2	30	33.3%	14.0%
	40	18.8%	17.1%
	50	12.0%	18.5%
	60	9.3%	19.0%
-1	70	7.8%	19.4%
	80	6.6%	19.6%
	90	5.7%	19.8%
	100	5.0%	20.0%
	110	4.4%	20.1%

Table 3: Case 3 Results Summary

TEEL	Distance (yards)	Nitrogen Concentration	Oxygen Concentration
	0	100.0%	0.0%
	5	100.0%	0.0%
	10	100.0%	0.0%
	20	46.9%	11.2%
-3	22	38.7%	12.9%
-2	28	23.9%	16.0%
	30	20.8%	16.6%
	40	11.7%	18.5%
	50	7.5%	19.4%
-1	54	6.4%	19.6%
	60	5.2%	19.9%

Conclusion

Overall, 70 yards downwind from the vent exiting to atmosphere seems to be where oxygen-deficiency issues begin to arise. At 30 yards is where health issues can become serious because that is where TEEL-2's limit is. Life-threatening situations could occur anywhere in the 20-30 yard range in the case of a catastrophic event.

Case 2 ends up as the worst case scenario due to extremely high flow rate compared to the other cases. It ends up driving the distances of the various TEELs. However, it is also the unlikeliest situation. Other emergency spills can still be considered, but the three cases analyzed already give a good idea of the disaster areas possible. All three of them do not pose a risk to the homes and trails nearby but since case 1 can be down for operational reasons, a fence, barricade, and/or signs should be put up in a 10 yard radius around the vent pipe exit as a safety barrier.