Fire Hazard Mitigation and Prevention Plan

Nighthawk Energy Storage

SEPTEMBER 2023

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition [Table Heading (RGB: 15, 43,77)]
AHJ	Authority Having Jurisdiction
BESS	Battery Energy Storage System
CAL FIRE	California Department of Forestry and Fire Protection
FHMPP	Fire Hazard Mitigation and Prevention Plan
Hot Works	Any potential ignition producing equipment or activity
NFPA	National Fire Protection Association
NWS	National Weather Service
OSHA	Occupational Safety and Health Administration
PFD	Poway Fire Department
SCADA	Supervisory Control and Data Acquisition
SSO	Site Safety Officer

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1 Introduction

This Fire Hazard Mitigation and Prevention Plan (FHMPP) focuses on the Project's fire protection and measures to prevent vegetative ignitions. The Nighthawk Energy Storage project (Project) site is located in Poway, California south of Kirkham Way, east of Paine Street (Figure 1) and north of Beeler Canyon Road. The project includes approximately 15 acres and will include up to 300 MW of battery energy storage capacity. The site will include up to 329 battery container units (Figure 2) along with necessary transformers, access roads, and gen-tie transmission line.

The Project site would be located at the corner of Kirkham Way and Paine Street in the City of Poway, CA on parcel APN: 3200310300. The proposed Project location would be immediately south of Kirkham Way and associated industrial areas located north of Kirkham Way (such as HiTec Multiplex and Disguise Inc), immediately east of Paine Street, and north of Beeler Canyon Road. The site is currently undeveloped. Appendix A includes photographs of the site.

The Project would involve the installation of 329 self-contained energy storage and management cabinets (most recent version called a Megapack-2 XL) containing battery modules designed and manufactured by Tesla. Each cabinet would hold 24 modules of batteries. The Megapack XL cabinets would be placed at the site outdoors. The Megapack XLs will have no walk-in or occupied facilities in the proposed Project design, and the Project will not otherwise include any buildings.

Battery energy storage systems convert electrical energy into a chemically stored form that can later be converted back into electrical energy when needed. The first U.S. battery storage system listed in the Federal Energy Information Administration (EIA) database was a 40 MW system in Alaska in 2003. As of October 2020, the United States has 1,363 MW of total battery storage capacity (EIA 2020) at 188 installations. California leads the U.S. in battery energy storage with 528 MW at 55 installations, with an additional 2,712 MW of battery storage capacity projected to be placed in service by 2024.

The Project would be equipped with inverters to convert the DC electricity of the battery systems into AC current used by the electrical grid and AC to DC to charge the batteries as required. There would also be a liquid thermal cooling system integrated into the cabinets to provide cooling to the batteries and power electronics.

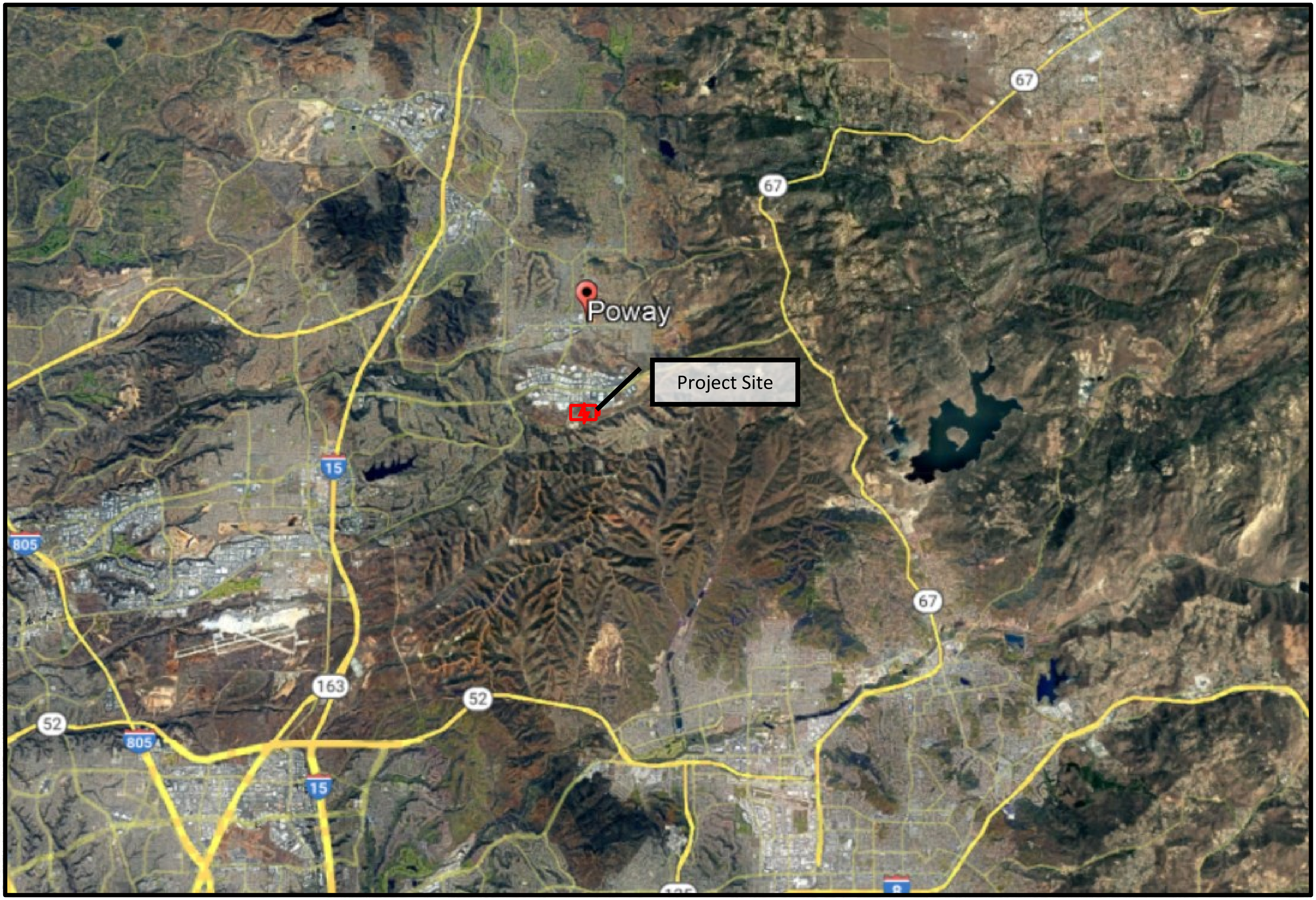
The project is located within an area statutorily designated a very high fire hazard severity zone by CAL FIRE and Poway Fire Department (PFD). The site and its surroundings include sloping terrain with native and non-native vegetative fuels. PFD provides initial response for fire and other emergencies.

This Fire Hazard Mitigation and Prevention Plan (FHMPP) augments the facility's Emergency Action Plan and focuses on fire safety and prevention. The activities anticipated during construction, operation and maintenance, and decommissioning include potential ignition sources and fire hazards normally encountered on construction sites. Because the Project is located within a fire hazard severity zone, there is the potential for fire to threaten the site and absent suitable mitigations, for an accidental on-site fire to result in a vegetation fire. This project-specific FHMPP is intended to assist the project developers and their contractors and maintenance staff with identification of fire risk and implementation of important fire prevention measures. This FHMPP is also intended to provide a training guide as well as a quick reference for all site staff for recognizing fire hazards, reporting them, and managing them during construction, operation/maintenance, and decommissioning.

1.1 Purpose

The primary purpose of this FHMPP is to address the identified ignition sources and risks so that the Nighthawk BESS Project, from the construction phase to the final decommissioning phase, has clearly defined protocols and procedures for reducing wildfire risk and maintaining a fire safe worksite. Among the goals developed for the Project site are:

- Prevent/minimize fires during construction, operation, and decommissioning
- Provide a safe worksite for all employees, contractors, visitors and emergency personnel
- Minimize the potential for on-site ignitions to escape the site and create a vegetation fire
- Prevent shock to emergency responders, workers, and unauthorized trespassers
- Prevent arcing or sparking
- Employ materials which will not be readily ignited by airborne burning embers or exposure to off-site wildland fires or on-site equipment fires
- Employ materials which will not emit toxic fumes during a fire and spread off site
- Prevent or minimize dollar loss to the equipment
- Prevent or minimize potential for a fire starting on site to spread off site
- Provide water, appropriate fire extinguishers and access for firefighters
- Provide adequate signage and shut off devices
- Provide the ability to report a fire or other emergency to emergency dispatch center without delay



SOURCE: USGS 7.5-Minute Series Del Mar Quadrangle

DUDEK 0 1,000 2,000 Feet

FIGURE 1
Project Location
Nighthawk Battery Energy Storage Project

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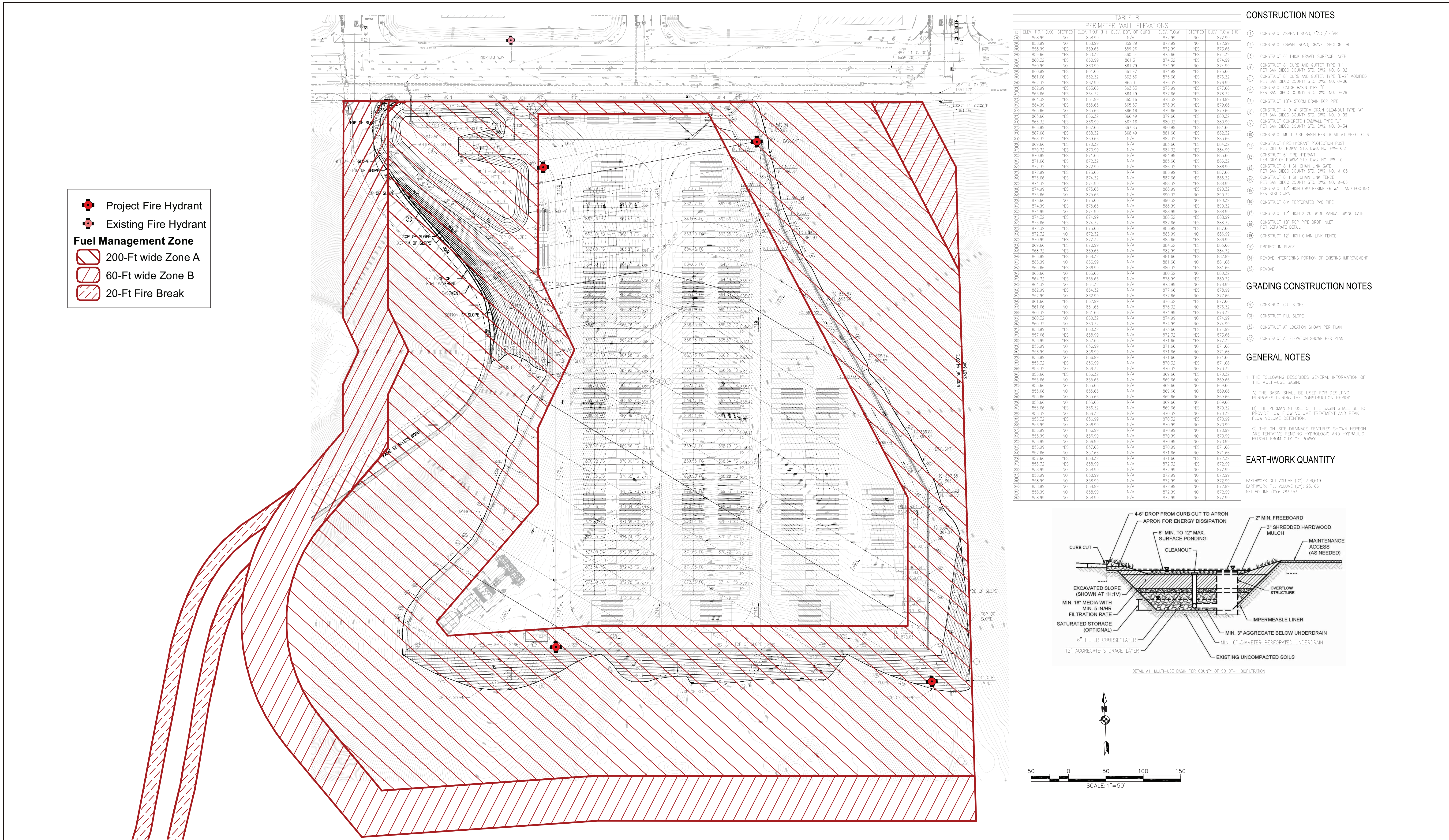

SOURCE: PACRIM ENGINEERING 2023

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FIGURE 2

Nighthawk Site Plan

Nighthawk Energy Storage Project

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2 Construction Emergency Notification Procedures

Any fire event at or near the site will trigger the emergency notification procedures identified in this section. Fire reporting is critical for tracking where, when, how, and why fire ignitions occur and will help the PFD develop protocols for reducing their occurrence.

2.1 First Call = 9-1-1

Reporting Fires and other emergencies: The first call should be to 9-1-1 so that appropriate apparatus can be dispatched.

The personnel in Table 1 are the primary site contacts to be notified during a fire emergency.

Table 1. Emergency Notification Primary Contacts

Name	Position	Telephone Number
TBD	Site Safety Officer	TBD
TBD	Site Manager	TBD
TBD	Project Manager	TBD
TBD	Project Engineer	TBD
TBD	Construction Supervisor	TBD

The first call should be to 911 so that emergency responders can be dispatched. Travel times to the site require notification of 911 as early as possible after the fire or other emergency has been observed.

Emergency related contacts near the site include:

- Fire/Emergency Medical Poway Fire Department -760.921.7822
- Ambulance 911
- Poway Police Department 760.921.7900
- Hospital Pomerado Hospital - 760.922.4115
- California OSHA Region 6 office - 909.383.4567

To facilitate the arrival of fire services during construction, an emergency response meeting point will be established with the PFD. The Site Safety Officer (SSO), or designee will meet the emergency response team at the meeting point to lead them into the site. The meeting point will be selected with fire agency input.

2.2 Evacuation Procedures

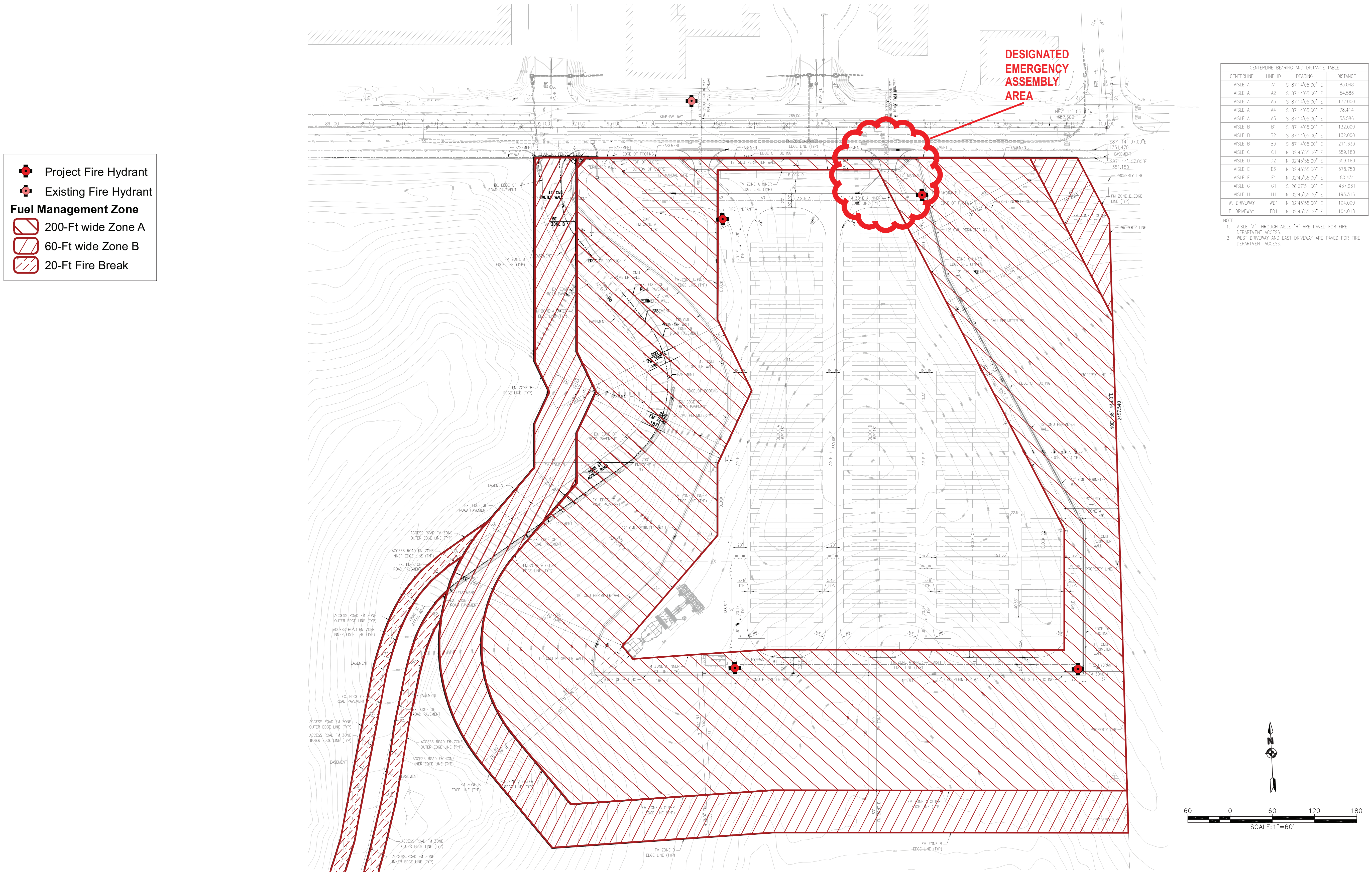
During significant emergency situations at, or near the Project site, the site manager and/or SSO, in consultation with law or fire authorities, as possible, may issue an evacuation notice. When an evacuation has been called, all on-site personnel will gather at the designated assembly area (site entrance at Kirkham Way) and the SSO will account for all personnel. Once all employees are accounted for, the vehicles will safely leave the area. Should there still be persons within the site after the evacuation has been called, the SSO will send convened personnel off site and the SSO and supervisors will perform a sweep of the facility to locate persons and reconvene at the assembly area. Once all personnel are accounted for, they will exit the site. The Primary Designated Assembly Area is designated as the area just inside the site entrance per Figure 3. Figure 4 provides an evacuation route map depicting the major evacuation corridors that may be available to site personnel/visitors.

Should a structure or wildland fire (or other emergency) occur that threatens the primary assembly area; other locations may be designated as secondary assembly areas by the SSO or supervisors, as dictated by the situation. The SSO and/or Site Supervisors should be prepared to be available to the Incident Commander throughout the Incident to facilitate information exchange.

2.2.1 Evacuation Routes

Depending on the type and severity of the emergency, along with weather and/or localized site conditions, roadways designated on Figure 4 will be used for evacuating the area. The primary site access and evacuation route is off Kirkham Way. There are several potential evacuation routes from the site that lead to one of three primary roadways and eventually to Interstate 15 and/or SR-56.

The SSO and site managers are primarily responsible for evacuations and will follow evacuation orders provided by Poway Police Department, PFD, and/or other local emergency managers. They will employ procedures to determine the emergency, talk with fire officials, as possible, and declare the emergency status. Foreman level supervisors shall assist in accounting for personnel. The SSO or his/her designee, shall be assigned to meet and guide firefighting resources to the scene



CENTERLINE BEARING AND DISTANCE TABLE			
CENTERLINE	LINE ID	BEARING	DISTANCE
AISLE A	A1	S 87°14'05.00" E	85.048
AISLE A	A2	S 87°14'05.00" E	54.586
AISLE A	A3	S 87°14'05.00" E	132.000
AISLE A	A4	S 87°14'05.00" E	78.414
AISLE A	A5	S 87°14'05.00" E	53.586
AISLE B	B1	S 87°14'05.00" E	132.000
AISLE B	B2	S 87°14'05.00" E	132.000
AISLE B	B3	S 87°14'05.00" E	211.633
AISLE C	C1	N 02°45'55.00" E	659.180
AISLE D	D2	N 02°45'55.00" E	659.180
AISLE E	E3	N 02°45'55.00" E	578.750
AISLE F	F1	N 02°45'55.00" E	80.431
AISLE G	G1	S 26°07'51.00" E	437.961
AISLE H	H1	N 02°45'55.00" E	195.316
W. DRIVEWAY	WD1	N 02°45'55.00" E	104.000
E. DRIVEWAY	ED1	N 02°45'55.00" E	104.018

NOTE:
1. AISLE "A" THROUGH AISLE "H" ARE PAVED FOR FIRE DEPARTMENT ACCESS.
2. WEST DRIVEWAY AND EAST DRIVEWAY ARE PAVED FOR FIRE DEPARTMENT ACCESS.

SOURCE: PACRIM ENGINEERING 2023

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FIGURE 3
Nighthawk Safety Plan
Nighthawk Energy Storage Project

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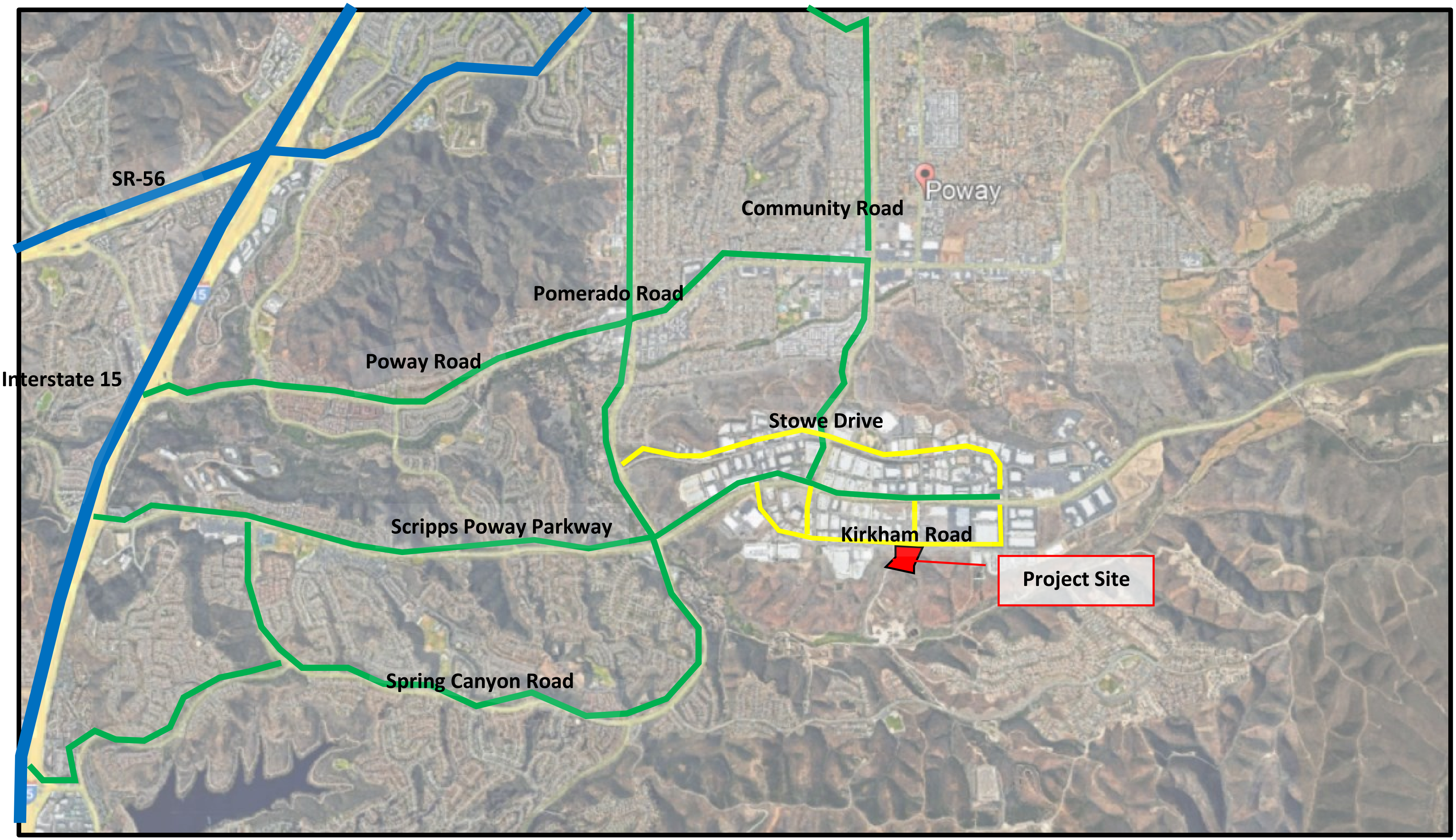
Nighthawk Battery Energy Storage
Potential Evacuation Routes



Major Transportation Corridor

Surface street options

Primary road options

Nighthawk Battery Energy Storage
Potential Evacuation Routes

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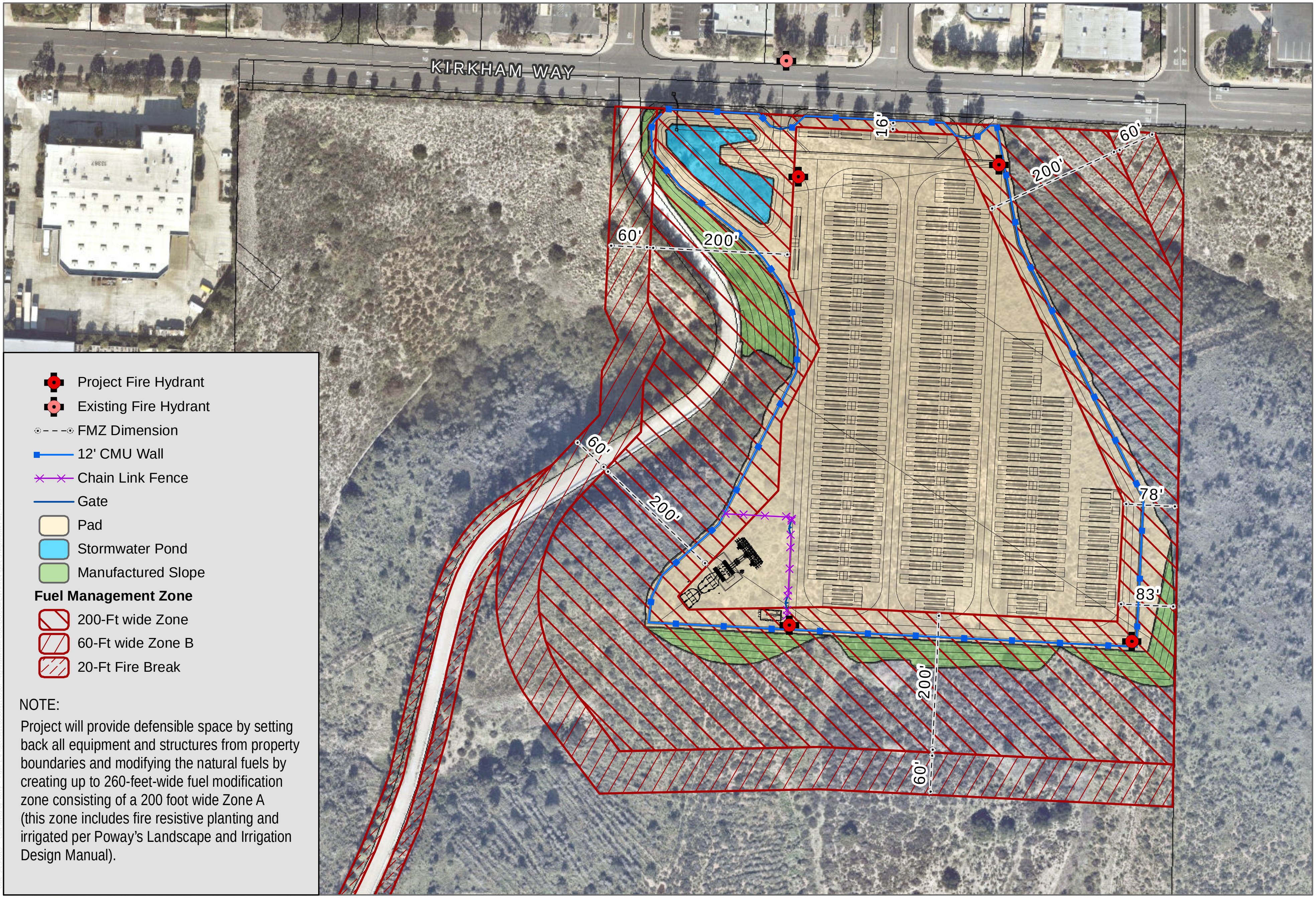
3 Project Provided Fire Safety Standards

1. **Roads: Fire Apparatus Access Roads (Fire):** fire access roads are provided according to local fire agency requirements which typically include an all-weather surface and ability to support the imposed loads of fire apparatus. At minimum, fire access roads should be provided around the perimeter of the property and to within 150 feet of any on-site structures.
   a. Service Roads: paved roads (Figure 5) for servicing and maintenance of batteries. Service roads will be capable of supporting typical maintenance vehicles and fire apparatus.
   b. Secondary Access: Because this project will not include an on-site population (once construction is completed), the need for secondary access, which is designed to enable responding fire engine access and citizen egress during an emergency is not applicable. Primary access is provided off Kirkham Way via an approximately 30-foot-wide entrance leading to 20-foot-wide onsite roads providing access through the site in a looped road system.
   c. Vertical clearance: Minimum vertical clearance of 13 feet 6 inches shall be provided throughout the roadway unless the fire agency determines it is not required due to provided mitigations.
   d. Turning radii: site fire apparatus access roads will be consistent with the PFD's requirements of 28' inside turning radius to enable fire engines to navigate the site.
   e. Surface: All internal fire access road surfaces will be considered "all-weather" and capable of supporting the imposed load of responding firefighting and emergency apparatus (75,000 pound minimum).
   f. Gates/Fences: Gates will be in compliance with FAHJ requirements (Fire Code D103.5). The entrance gate will be provided a Knox key switch for fire and law enforcement access. The facility will be completely enclosed with a 10-feet tall, pre-cast concrete wall. Fences: shall not limit access to fire roads, fire hydrants, or fire protection systems, such limitations shall be mitigated with gates to allow immediate access.
   g. Identification: Identification of roads and structures will comply with California Fire Code requirements. Below surface pipelines, electrical and communications lines Shall be "signed" at an interval appropriate to alert firefighting fire engine operations to advise firefighters of depth and location. Appropriate signage to be reviewed with the PFD prior to installing.
2. **Water:** The Project is not anticipated to require the use of water for operations activities. There are fire hydrants located along Kirkham Way with one (1) existing fire hydrant as close as approximately 200 feet to the Project's entrance. Site plan design will include four (4) fire hydrants. Water availability would be anticipated to be suitable for fire fighting operations at the Project site.
3. **Ignition-Resistant Construction and Fire Protection Systems:** There are no habitable structures on the site. Battery containers, transformers, and other equipment will be of ignition resistant materials. Battery technology and its redundant fire prevention measures are summarized in Section 8.
4. **Substations:** Substation and panel transformers will use biodegradable low flammability FR3 to minimize environmental effects should a leak occur.
5. **Fire/Heat Wall:** the entire developed area where battery cabinets are located will be encompassed by a 12 foot tall, decorative, pre-cast concrete wall. These walls have been shown to provide an effective fire and heat barrier.

6. **Defensible Space and Vegetation Management:** The Project will provide defensible space by setting back all equipment and structures from property boundaries and modifying the natural fuels by creating up to 260-feet-wide fuel modification zone consisting of a 200 foot wide Zone A (this zone includes fire resistive planting and irrigated per Poway's Landscape and Irrigation Design Manual). The FMZ to the east extends to the property line, providing up to 78 feet of FMZ), and a 60 foot Zone B except to the east where all FMZ will be bare ground or Zone A. Additionally, the site's roads will include 20 feet of Zone B thinning wherever they are not already within a fuel modification zone. For example, the site's secondary access road would receive 20 feet of roadside thinning (Zone B) on its western edge, per Figure 5.

   Defensible Space will be maintained on at least an annual basis or more often, as needed, by the applicant or current Project owner
7. **Remote Monitoring:** Remote monitoring of the facility and its system features will be incorporated into the facility design. For example, the supervisory control and data acquisition (SCADA) system utilized by the Proposed Project will provide notification to technical staff of system faults, battery abnormalities or potential issues.
8. **Technical Staff Contact:** Project contact information will be provided to local fire agencies/stations to assist responding firefighters during an emergency. A copy of this FHMPP will be submitted to PFD.
9. **Funded and Enforced Maintenance:** Committed on-going maintenance of all facility components to fire safe levels for the life of the project.
10. **Battery Testing Requirements and Regulations:** Batteries are subject to several codes and standards. Some of the relevant ones are summarized in Appendix D.



SOURCE: AERIAL - SANGIS IMAGERY 2020; DEVELOPMENT - POWER ENGINEERS 2023

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FIGURE 5

Fuel Management Plan

Nighthawk Energy Storage Project

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4 Fire Environment Evaluation and Fire Behavior Modeling

The Project site is situated on a hilltop and includes sloped terrain to the east, west and south. North of the site is flat and developed – converted to ignition resistant landscapes. South of the site includes open space, a gravel operation, with a graded pad used as a heavy equipment storage area, a semi-disturbed canyon (Beeler Canyon) and a residential community, with Naval Air Station Miramar beyond that.

The Project area is comprised of chaparral with pockets of disturbance dominated by non-native grasses. These fuel types are fire adapted vegetation which historically experience occasional wildfire and can burn in an extreme manner under the occasional severe fire weather (dry and windy) conditions that occur in the area.

Vegetative fuels directly adjacent the site are primarily non-native grassland, chaparral, coastal sage scrub, and ornamental vegetation types. Site-adjacent vegetation is important relative to wildfire as some vegetation, such as grassland habitats, are highly flammable while other vegetation, such as chaparral and oak riparian forest, may be less flammable, but would burn under certain, more intense fire conditions.

Fire environment: Fuels – combination of coastal sage scrub, chaparral, non-native grasses. Terrain – sloped and will facilitate fire spread toward the project. Fire spread away from the project would generally be slower due to the terrain. Climate – intense fire weather is possible during Red Flag Warning conditions.

Existing ignition sources in the Project area are numerous – developed industrial areas, treatment plant, roadways, Miramar MCAS, and residential development. Ignitions have been minimal in this area. Dry fuels are susceptible to ignition from sparks and heat sources that may occur as part of the normal operations of the site.

4.1 Fire Behavior Modeling

Following field data collection efforts and available data analysis, fire behavior modeling was conducted to document the type and intensity of the fire that would be expected adjacent to the Project site given characteristic site features such as topography, vegetation, and weather. Dudek utilized BehavePlus software package version 6 (Andrews, Bevins, and Seli 2008) to analyze potential fire behavior[1] for the wildland fuels to the west/southwest, south, and east/southeast of the Project site. As is customary for this type of analysis, three fire scenarios were evaluated, including one summer, on-shore weather condition (south/southwest of the Project site) and two extreme fall, off-shore weather conditions (south and east/southeast of the Project site). Results are provided below and a more detailed presentation of the BehavePlus analysis, including fuel moisture and weather input variables, is provided in Appendix B.

1 A discussion of fire behavior modeling is presented in Appendix B, Fire Behavior Modeling Summary.

4.2 Fire Behavior Modeling Analysis Effort

An analysis utilizing the BehavePlus software package was conducted to evaluate fire behavior variables and to objectively predict flame lengths (feet), fireline intensities (BTU/feet/second), spotting distance (miles), and spread rates (feet/minute) for three modeling scenarios for the Nighthawk Battery Energy Storage System Project; these three fire scenarios incorporated observed fuel types representing the dominant on- and- off-site vegetation on vacant land adjacent to the proposed development, in addition to measured slope gradients, wind, and fuel moisture values derived from Remote Automated Weather Stations (RAWS) weather data sets (San Pasqual RAWS) for both the 50th percentile weather (on-shore winds) and the 97th percentile weather (off-shore winds). Modeling scenario locations were selected to better understand different fire behavior that may be experienced on or adjacent to the site.

To support the fire behavior modeling efforts conducted for this Fire Hazard Mitigation and Prevention Plan, the different vegetation types observed on and adjacent to the Project site were classified into the aforementioned numeric fuel models. Dudek analyzed fire behavior for the fuels adjacent to/in close proximity to the property to the north and east. As is customary for this type of analysis, the terrain and fuels within and adjacent to the Project area were used for determining flame lengths and fire spread. It is these fuels that would have the potential to affect the Project's structures from a radiant and convective heat perspective as well as from direct flame impingement. Fuel beds, including the intermix of non-native grasslands, coast sage scrub and mixed chaparral fuels (Fuel Models Gs2, Sh2, and Sh5) found throughout the adjacent areas east, west, and south of the Project site. Table 2 provides a description of the four existing fuel models observed in the vicinity of the site that were subsequently used in the analysis for this project. The three scenario locations were selected based on the strong likelihood of fire approaching from these directions during a Santa Ana wind-driven fire event (fire scenarios 2 and 3) and an on-shore weather pattern (fire scenario 1).

Table 2. Fuel Models Used for Fire Behavior Modeling

Fuel Model	Description	Location of Fuel Models	Fuel Bed Depth (Feet)
Existing Conditions			
Gs2	Moderate Load, Dry Climate Grass-Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh2	Moderate Load, Dry Climate Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh5	High Load Dry Climate Shrub	Represented throughout the adjacent areas west and east of the Project site.	>4.0 ft.

Table 3 summarizes the weather and wind input variables used in the BehavePlus modeling process.

Table 3. Fuel Moisture and Wind Inputs

Model Variable	Summer Weather Condition (50th Percentile)	Peak Fall Weather Condition (97th Percentile)
Fuel Models	Sh2 and Sh5	Gs2, Sh2, and Sh5
1 h fuel moisture	6%	1%
10 h fuel moisture	7%	4%

Table 3. Fuel Moisture and Wind Inputs

Model Variable	Summer Weather Condition (50th Percentile)	Peak Fall Weather Condition (97th Percentile)
100 h fuel moisture	15%	11%
Live herbaceous moisture	58%	30%
Live woody moisture	117%	60%
20 ft. wind speed	12 mph (sustained winds)	16 mph (sustained winds); wind gusts of 50 mph
Wind Directions from north (degrees)	240	90 and 180
Wind adjustment factor	0.4	0.4
Slope (uphill)	31%	19 to 21%

4.3 Fire Behavior Modeling Results

The results of fire behavior modeling analysis for pre-Project conditions are presented in Table 3. Identification of modeling runs (fire scenarios) locations is presented graphically in Figure 6, BehavePlus Fire Behavior Analysis Map.

As presented, in the Fire Behavior Analysis Summary (Appendix B), wildfire behavior on the Project site is expected to be primarily of moderate to high intensity throughout the non-maintained intermix of non-native grasslands, coast sage scrub and mixed chaparral fuels throughout the perimeter areas of the Project site. As mentioned, the BehavePlus fire behavior modeling software package was utilized in evaluating anticipated fire behavior adjacent to the Proposed Project site. Three focused analyses were completed for the existing Project site conditions, assuming worst-case fire weather conditions for a fire approaching the Project site from the west/southwest, south, and east/southeast. The results of the modeling effort included anticipated values for surface fires flame length (feet), rate of spread (mph), fireline intensity (Btu/ft/s), and spotting distance (miles). The aforementioned fire behavior variables are an important component in understanding fire risk and fire agency response capabilities. Flame length, the length of the flame of a spreading surface fire within the flaming front, is measured from midway in the active flaming combustion zone to the average tip of the flames (Andrews, Bevins, and Seli 2008). Fireline intensity is a measure of heat output from the flaming front, and also affects the potential for a surface fire to transition to a crown fire. Fire spread rate represents the speed at which the fire progresses through surface fuels and is another important variable in initial attack and fire suppression efforts (Rothermel and Rinehart 1983). Spotting distance is the distance a firebrand or ember can travel down wind and ignite receptive fuel beds. Three fire modeling scenario locations were selected to better understand the different fire behavior that may be experienced on or adjacent the site based on slope and fuel conditions; these three fire scenarios are explained in more detail below:

Fire Scenario Locations and Descriptions:

- **Scenario 1:** A summer, on-shore fire (50th percentile weather condition) burning in moderate- to high-load intermix of shrubs and chaparral dominated vegetation located in the hillsides west/southwest of the Project site, below Kirkham Way and west of Paine Street. The terrain is moderately steep (approximately 31% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or

Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southwestern portion of the development.

- Scenario 2: A fall, off-shore fire (97th percentile weather condition) burning in low- to moderate-load intermix of non-native grasses and shrubs/chaparral dominated vegetation located in the hillsides south of the Project site, below Kirkham Way and north of Beeler Canyon Road. The terrain is moderately steep (approximately 19% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southern portion of the development.
- Scenario 3: A fall, off-shore fire (97^{th} percentile weather condition) burning in moderate- to high-load intermix of shrubs and chaparral dominated vegetation located in the hillsides east/southeast of the Project site, below Kirkham Way and east of Paine Street. The terrain is moderately steep (approximately 21% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southeastern portion of the development.

The results presented in Table 3 depict values based on inputs to the BehavePlus software and are not intended to capture changing fire behavior as it moves across a landscape. Changes in slope, weather, or pockets of different fuel types are not accounted for in this analysis. For planning purposes, the averaged worst-case fire behavior is the most useful information for conservative fuel modification design. Model results should be used as a basis for planning only, as actual fire behavior for a given location will be affected by many factors, including unique weather patterns, small-scale topographic variations, or changing vegetation patterns.

Table 1. Existing Fuel Model Characteristics

Fuel Model	Description	Location of Fuel Models	Fuel Bed Depth (Feet)
Existing Conditions			
Gs2	Moderate Load, Dry Climate Grass-Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh2	Moderate Load, Dry Climate Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh5	High Load Dry Climate Shrub	Represented throughout the adjacent areas west and east of the Project site.	>4.0 ft.

Table 2: Variables Used for Fire Behavior Modeling

Model Variable	Summer Weather (50th Percentile)	Peak Weather (97th Percentile)
Fuel Models	Sh2 and Sh5	Gs2, Sh2, and Sh5
1 h fuel moisture	6%	1%
10 h fuel moisture	7%	4%
100 h fuel moisture	15%	11%
Live herbaceous moisture	58%	30%
Live woody moisture	117%	60%
20 ft. wind speed	12 mph (sustained winds)	16 mph (sustained winds); wind gusts of 50 mph
Wind Directions from north (degrees)	240	90 and 180
Wind adjustment factor	0.4	0.4
Slope (uphill)	31%	19 to 21%

Table 3: RAWS BehavePlus Fire Behavior Model Results – Existing Conditions

Fire Scenario	Flame Length (feet)	Spread Rate (mph)[6]	Fireline Intensity (Btu/ft./sec)	Spot Fire (Miles)[6]
Scenario 1: 31% slope, Summer, On-shore wind from the S/SW, 12 mph sustained winds (Current conditions)				
High-load, dry climate shrubs (Sh5)	11.4	0.5	1,121	0.4
Moderate-load, dry climate shrubs (Sh2)	1.3	0.0	10	0.1
Scenario 2: 19% slope, Fall, Off-shore wind from the S, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
Moderate-load, dry climate grass-shrubs (Gs2)	9.8 (20.5)	0.8 (4.2)	808 (4,016)	0.4 (1.4)
Moderate-load, dry climate shrubs (Sh2)	7.9 (15.7)	0.2 (1.0)	506 (2,272)	0.3 (1.2)
Scenario 3: 21% slope, Fall, Off-shore wind from the E/SE, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
High-load, dry climate shrubs (Sh5)	23.4 (43.8)	1.7 (6.6)	5,374 (21,047)	0.7 (2.4)

SOURCE: AERIAL-BING MAPPING SERVICE

DUDEK 0 250 500 1,000 Feet

FIGURE 6

BehavePlus Analysis Map

The Nighthawk Battery Energy Storage System Fire Hazard Mitigation and Prevention Plant

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4.3.1 Existing Conditions

Based on the BehavePlus analysis result presented below and in Table 4, worst-case fire behavior is expected in the non-maintained shrub and chaparral dominated fuels throughout the hillsides around the perimeter areas of the Project site. Worst-case fire behavior is expected in untreated, shrub and chaparral vegetation under peak weather conditions (represented by Fall Weather, Scenario 3). The fire is anticipated to be a wind-driven fire from the east/southeast during the fall. Under such conditions, expected surface flame length are expected to reach approximately 44 feet with wind speeds of 50+ mph. Under this scenario, fireline intensities reach 21,047 BTU/feet/second with moderate spread rates of 6.6 mph and could have a spotting distance up to 2.4 miles away.

Wildfire behavior in non-maintained chaparral in the hillsides south/southwest of the Project site, modeled as Sh2 and Sh5 fuels being fanned by 12 mph sustained, on-shore winds. Fires burning from the west and pushed by ocean breezes typically exhibit less severe fire behavior due to lower wind speeds and higher humidity. Under typical onshore weather conditions, a moderate- to- high-load chaparral dominated vegetation fire could have flame lengths approximately 12 feet in height and spread rates of approximately 0.5 mph. Spotting distances, where airborne embers can ignite new fires downwind of the initial fire are approximately 0.4 miles.

Table 4. RAWS BehavePlus Fire Behavior Model Results – Existing Conditions

Fire Scenario	Flame Length (feet)	Spread Rate (mph)[2]	Fireline Intensity (Btu/ft./sec)	Spot Fire (Miles) [3]
Scenario 1: 31% slope, Summer, On-shore wind from the S/SW, 12 mph sustained winds (Current conditions)				
High-load, dry climate shrubs (Sh5)	11.4	0.5	1,121	0.4
Moderate-load, dry climate shrubs (Sh2)	1.3	0.0	10	0.1
Scenario 2: 19% slope, Fall, Off-shore wind from the S, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
Moderate-load, dry climate grass-shrubs (Gs2)	9.8 (20.5)	0.8 (4.2)	808 (4,016)	0.4 (1.4)
Moderate-load, dry climate shrubs (Sh2)	7.9 (15.7)	0.2 (1.0)	506 (2,272)	0.3 (1.2)
Scenario 3: 21% slope, Fall, Off-shore wind from the E/SE, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
High-load, dry climate shrubs (Sh5)	23.4 (43.8)	1.7 (6.6)	5,374 (21,047)	0.7 (2.4)

Surface Fire:

- **Flame Length (feet):** The flame length of a spreading surface fire within the flaming front is measured from midway in the active flaming combustion zone to the average tip of the flames.
- **Fireline Intensity (Btu/ft/s):** Fireline intensity is the heat energy release per unit time from a one-foot wide section of the fuel bed extending from the front to the rear of the flaming zone. Fireline intensity is a function

2 mph = miles per hour
3 Spotting distance from a wind driven surface fire; it should be noted that the wind mph in parenthesis represent peak gusts of 50 mph.

of rate of spread and heat per unit area, and is directly related to flame length. Fireline intensity and the flame length are related to the heat felt by a person standing next to the flames.

- Surface Rate of Spread (mph): Surface rate of spread is the "speed" the fire travels through the surface fuels. Surface fuels include the litter, grass, brush and other dead and live vegetation within about 6 feet of the ground.

The information in Table 5 presents an interpretation of the outputs for five fire behavior variables as related to fire suppression efforts. The results of fire behavior modeling efforts are presented in Table 3. Identification of modeling run locations is presented graphically in Figure 6 of this report.

Table 5. Fire Suppression Interpretation

Flame Length (ft)	Fireline Intensity (Btu/ft/s)	Interpretations
Under 4 feet	Under 100 BTU/ft/s	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
4 to 8 feet	100-500 BTU/ft/s	Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 to 11 feet	500-1000 BTU/ft/s	Fires may present serious control problems -- torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
Over 11 feet	Over 1000 BTU/ft/s	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

Based on these fire behavior results, it is evident that the natural fuels in the area can facilitate fire spread, particularly under extreme fire weather conditions. Fire behavior modeling predicts fire spread toward the facility. Fire originating at the facility and spreading off-site would be expected to behave differently due primarily to terrain influence. Fire typically moves slower downslope than up slope due to the lack of vegetation preheating in the former.

Therefore, in the unforeseen event where a fire originating on the Project site escapes into the adjacent fuels, the fire flame lengths and intensity may be similar to the modeled outputs, but the spread rates would be expected to be significantly lower. This results in a greater ability for responding firefighters to control the fire in its insipient stage, where fire control is a much greater probability.

5 Project Specific Risk Summary

5.1 Fire Risk

Fire risks must be assessed based upon the potential frequency (probability of an incident occurring) and consequence (potential damage should an event occur). The evaluation of fire risks must take into account the frequency and severity of fires and other significant incidents.

The Project Area includes common risk types as well as heightened sources of risk. Common risks that result in emergency calls include accidental injuries (residential, vehicle, other), medical related incidents including heart attacks, strokes and other serious conditions and illnesses, accidental vegetation fires, and occasional structure fires.

Among the listed potential causes of fire incidents involving electrical related facilities that are relevant for this study are:

- Explosion/Arcs, arc flashing, electrical shorts, sparking, motor or other machinery fire, wiring and harnessing fire, overheated junction boxes, rodents chewing on wires and causing arcing, etc.
- Collapse of supporting structure causing electrical shorts and fire
- Equipment and supplies stored within the site
- Tables, trash cans, smoking areas and other combustible storage
- Fire in an inverter or transformer
- Short circuit and fire of components in or on a panel
- Lubricating and control oil fire
- Switchgear and cable fire

The Project's fire risks are associated with the following:

5.1.1 Construction and Decommissioning Phase Risks

- Earth-moving equipment – create sparks, heat sources, fuel or hydraulic leaks, etc.
- Chainsaws – may result in vegetation ignition from overheating, spark, fuel leak, etc.
- Vehicles – heated exhausts/catalytic converters in contact with vegetation may result in ignition
- Welders – open heat source may result in metallic spark coming into contact with vegetation
- Wood chippers – include flammable fuels and hydraulic fluid that may overheat and spray onto vegetation with a hose failure
- Compost piles – large piles that are allowed to dry and are left on-site for extended periods may result in combustion and potential for embers landing in adjacent vegetation
- Grinders – sparks from grinding metal components may land on a receptive fuel bed
- Torches – heat source, open flame, and resulting heated metal shards may come in contact with vegetation
- Dynamite/blasting – if necessary, blasting may cause vegetation ignition from open flame, excessive heat or contact of heated material on dry vegetation
- Other human-caused accidental ignitions – ignitions related to discarded cigarettes, matches, temporary electrical connections, inappropriately placed generators, poor maintenance of equipment, and others.

5.1.2 Operation and Maintenance Phase Risks

Ignition risks are anticipated to drop considerably following the Project's active construction phase. Operation and maintenance activities occur within a defined project footprint where the adjacent fuels have been removed or converted to fuel modification-consistent vegetation.

- Transformers – are subject to occasional failure, sending sparks, hot materials out in any direction; fire in a transformer may result in ignition of the oil therein
- Electrical transmission lines – Nighthawk Energy Storage design will include underground/buried transmission line (at least 3 feet beneath ground level) to completely eliminate this risk)
- Substations – include various electrical components that may explode, fail, or ignite and include oil-cooled transformers, low flammability bio-degradable FR3 will be used in the transformer systems.
- Vehicles – heated exhausts in contact with vegetation may result in ignition
- Hot Works Equipment – all small hand tools either gas or electric powered that may result in sparks, flames, or excessive heat may result in vegetation ignition.

5.1.3 Power Line Risks

Electrical transmission and collection lines can start fires in a number of ways, including the following. However Nighthawk Energy Storage project design will include underground /buried transmission line (at least 3 feet beneath ground level) and hence above power line risks are completely eliminated.

- Uncleared vegetation, especially trees, coming into contact with conductors
- Sparks (from exploding hardware such as transformers and capacitors) coming into contact with vegetation
- Wind-blown debris coming into contact with hardware such as transformers and conductors
- Conductor-to-conductor contact
- Dust or dirt buildup on power line hardware
- Aircraft or helicopter, or attached features such as fire-fighting water buckets, coming into contact with power line hardware and support structures Wildlife coming into contact with power line hardware or transmission line Vandals shooting or throwing rocks at panels

5.1.4 Overall Project Risk

The estimated risk associated with the Nighthawk Energy Storage site is considered to be low during construction, decommissioning and operation. The risk of fires associated with the latest battery technology that meets UL 9540A testing requirements is low. Newer technology battery modules and processes result in even lower risk of ignitions due to safer battery chemistries and the redundancy of fire safety measures. The Project's battery related safety and technical analysis UL 9540A Test Report is provided in Appendix C.

The Project will be equipped with monitoring and control systems that will prevent and/or control battery cell malfunctions. However, to determine an unlikely, but reasonable worst-case public health impacts for this analysis, it is assumed that these control systems fail and do not control the battery cell malfunction. For this unlikely scenario, it is assumed that the battery cell malfunction continues until third-party or municipal fire suppression services arrive at the Project site. Please refer to Hazard Analysis Report prepared by MRS Environmental and enclosed under Appendix D.

The active construction phase results in higher potential for fires. Hot works, vegetation clearing, and other activities that may result in flame or heat sources can ignite vegetation, especially if non-native grasses have established and cured. Although there will be a potential for structural/equipment fires and wildfires, the risk is considered manageable as indicated by the low historic fire occurrence in existing battery facilities.

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6 Off-site Fire Hazard Potential

The incidence of battery fires is extremely low. The latest battery technology includes built in safety measures to minimize the potential for a thermal runaway and if it does occur, compartmentalization so that it is minimal in scale and does not spread to adjacent battery enclosures. Further, the heat generated by a battery container fire dissipates rapidly with distance from the event. Based on calculated low probabilities for battery technology fires and the modeled heat flux reduction experienced over distance (discussed in Section 8), it is considered to be a low probability for an on-site ignition to escape into the off-site native vegetation, especially given the property-wide conversion of vegetation to rock/gravel surface, which provides up to 30 feet of setback from the nearest battery container, and 12-feet tall, pre-cast concrete walls enclosing the facility.

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7 Fire Prevention Measures

7.1 Construction Daily Fire Prevention Measures

To limit the risk of fires, all site staff, employees, and contractors shall take the following precautions:

- Fire safety shall be a component of daily tailgate meetings. Foremen will remind employees of fire safety, prevention, and emergency protocols on a daily basis.
- No smoking will be allowed on site. Smoking inside closed vehicles at the site may be allowed in designated areas away from vegetation, at the discretion of the SSO.
- Combustible materials will be stored in areas away from native vegetation. Whenever combustibles are being stored in the open air, the SSO shall be informed of the situation.
- Maintain all evacuation routes free of obstructions. Coordinate unavoidable evacuation route blockages such that a secondary route is identified and available.
- Dispose of combustible waste in accordance with all applicable laws and regulations.
- Use and store flammable materials in areas away from ignition sources.
- Properly store chemicals such that incompatible (i.e., chemically reactive) substances are separated appropriately.
- Perform "hot work" (i.e., welding or working with an open flame or other ignition sources) in controlled areas under the supervision of a fire watch. Hot work permits are required and will be reviewed and granted by the SSO for all hot work.
- Keep equipment in good working order by inspecting electrical wiring and appliances regularly and maintaining motors and tools free of excessive dust and grease.
- Ensure that heating units are safeguarded.
- Report all fuel or petroleum leaks immediately. The Site Mechanic shall ensure that all leaks are repaired immediately upon notification.
- Repair and clean up flammable liquid leaks immediately.
- Keep work areas free of combustible materials.
- Do not rely on extension cords if wiring improvements are needed and take care not to overload circuits with multiple pieces of equipment.
- Turn off and unplug electrical equipment when not in use.

7.2 Red Flag Warning Protocol

Red Flag Warnings are issued by the National Weather Service (NWS) and indicate that conditions are such (low humidity, high winds) that wildfire ignitions and spread may be facilitated. During Red Flag Warning or Watch periods, no Hot Works (any activity that can result in heat, flame, sparks) will be performed until consultation with the local fire agency to discuss the type of hot works activity and what precautions will be provided. Other construction, operation and maintenance, and decommissioning activities may proceed during these periods under heightened awareness conditions. The SSO, in consultation with the PFD, will determine what activities are appropriate and which should not be conducted until the Red Flag Warning has been lifted.

In order to ensure compliance with Red Flag Warning restrictions, the NWS Web site will be monitored.

Upon announcement of a Red Flag Warning, red flags will be prominently displayed at the entrance gate and main office indicating to employees and contractors that restrictions are in place.

7.3 Fire Prevention/Protection System Maintenance

The site Operations and Maintenance team (or trained specialist, when necessary) will ensure that fire suppression and related equipment is maintained according to manufacturers' specifications. National Fire Protection Association (NFPA) guidelines shall be implemented for specific equipment.

The following equipment is subject to ongoing maintenance, inspection, and testing procedures:

- Infrared camera fire detection system – Yearly testing
- Battery and system monitoring systems – continuous monitoring, with monthly inspections
- Transformers – continuous monitoring, monthly inspections

8 Summary of Battery Fire Safety Details

This section summarizes a Project Hazards Analysis (MRS Environmental May 2022) that is provided in its entirety in Appendix D.

Results from the analysis indicate that the reasonable worst-case battery cell malfunction scenarios would result in manageable hazards, with ground-level toxic, thermal and deflagration hazards remaining onsite. Therefore, the maximum potential public health impacts for the battery facility are considered less than significant. See section 6, Fire Protection Measures, Isolation and Protective Action Distances in Hazard Analysis Report by MRS Environmental

8.1 Recommendation

To manage potential for off-site vegetation ignition, the site plan design will exceed Poway's required 100 feet of defensible space (including 40 feet wide Zone A and 60 feet wide Zone B) from the edge of equipment (Figure 5), by providing 260 feet of FMZ (200 feet Zone A and 60 feet Zone B, except to the east where FMZ will be provided to the property line that is a minimum 78 feet and up to approximately 83 feet. This FMZ along with placement of a 12-feet tall, pre-cast concrete wall around the entire site, provides significant protection for the facility and prevention of an onsite ignition migrating off-site. This approach to minimizing the likelihood of off-site vegetation ignitions is considered appropriate given the low probability of a fire event at the Project site and even lower probability of heated material ejection reaching the flammable vegetation areas.

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9 Emergency Access/Egress

Emergency Access is provided off a public road, Kirkham Way. Emergency access will be consistent with PFD's requirements for road width, grade, and load capacity.

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10 Fire Department Response

Emergency fire response will be provided by Poway Fire Department Station 1 at 13080 Community Road. Station 1 is approximately 1.9 miles from the Project site. Using the Insurance Service Office's travel time formula that accounts for intersection decelerations and accelerations (delays) – T (time) = 0.6 * 1.7D (distance). This distance results in a travel time of 0.6 + 1.7*1.9, which equals 3.83 minutes. This is a fast response travel time and meets the PFD's response time standards.

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11 Vegetation Management and Defensible Space

All vegetation on the site will be removed within the perimeter fence and/or wall and two fuel modification zones will be provided, a Zone A that is 200 feet wide (this zone includes fire resistive planting and irrigated per Poway's Landscape and Irrigation Design Manual) and a Zone B that is 60 feet wide (except to the north where the FMZ is 16 feet and the east where FMZ varies between 78 feet and approximately 83 feet wide – all bare ground (pad and/or manufactured scope) or Zone A along with placement of the 12-feet tall, precast concrete wall around the site.   Annual maintenance will be provided to remove weeds and other established vegetation within these no-fuel areas.

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12 Customized Measures/Features to Reduce Potential for Vegetation Ignition

The following measures will be employed, as appropriate, during each phase of the project (construction, operation and maintenance and decommissioning) to reduce the risk of ignitions. These measures will be enforced through the SSO or designated manager and ongoing worker safety training.

- All internal combustion engines used at the Project site shall be equipped with spark arrestors that are in good working order.
- Once initial two-track roads have been cut and initial fencing and walls completed, light trucks and cars shall be used only on roads where the roadway is cleared of vegetation. Mufflers on all cars and light trucks shall be maintained in good working order.
- Precast concrete walls will be used on all sides of the facility to reduce the likelihood of an on-site fire ignition from escaping the facility, or an approaching wildland fire from impacting the facility.
- The project will be equipped with water truck as needed during grubbing and initial grading activities.
- Additionally, on-site pickup trucks will be equipped with first-aid kits, fire extinguishers and shovels. Contractor vehicles will be required to include the same basic equipment.
- Equipment parking areas and small stationary engine sites shall be cleared of all extraneous flammable materials.
- The Applicant shall make an effort to restrict use of chainsaws, chippers, vegetation masticators, grinders, drill rigs, tractors, torches, and explosives to outside of the official fire season. When the above tools are used, water tanks equipped with hoses, fire rakes and axes shall be easily accessible to personnel.
- A fire watch (person responsible for monitoring for ignitions) will be provided during hot works as needed.
- Smoking shall be prohibited on site.
- The project construction site shall be equipped with fire extinguishers and firefighting equipment sufficient to extinguish small fires.
- The Applicant shall coordinate with the PFD to create a training component for emergency first responders to prepare for specialized emergency incidents that may occur at the Project site.
  - The Project will conduct annual fire department training for the three Poway FD Divisions. This training will be conducted in-service, i.e., in Poway, and will encompass the battery technology, the site, and operational items.
- All construction workers, Plant personnel, and maintenance workers visiting the plant and/or transmission lines to perform maintenance activities shall receive training on the proper use of firefighting equipment and procedures to be followed in the event of a fire.
- Vegetation within the perimeter fence/wall shall be controlled through periodic cutting and spraying of weeds, in accordance with PFD requirements.
- Vegetation within the Zone A FMZ will be fire resistive planting and irrigated per Poway's Landscape and Irrigation Design Manual.
- Vegetation within Zone B FMZ areas will be treated by thinning the fuels to remove 50% of the ground cover.

- Maintenance shall be performed on a seasonal basis. Maintenance shall include removal of dead plants and vegetation, weeding, pruning, and inspection and repair of irrigation systems. Invasive exotic plant species listed by the California Invasive Plant Council (Cal-IPC) latest edition, shall not be planted in this zone, and shall be removed if present. Highly combustible native plant species noted in Poway's Landscape and Irrigation Design Manual's Table 4-1, Undesirable and Non-Fire Resistive Plants, shall not be planted and shall be removed if present in Zone B. Highly combustible native plant species noted in Table 4-1 along with annual weeds, shall be removed if present.
- A Site Safety Officer(s) will perform routine patrols of the site during construction activities occurring within fire weather (Red Flag Watch and Warning days) equipped with a portable fire extinguisher and communications equipment.
- Remote monitoring of all major electrical equipment (transformers and inverters) and batteries will screen for unusual operating conditions. Higher than nominal temperatures, for example, can be compared with other operational factors to indicate the potential for overheating which, under certain conditions, could precipitate a fire. Units could then be shut down or generation curtailed remotely until corrective actions are taken.
- Fires ignited on site shall be immediately reported to PFD.
- The engineering, procurement, and construction contracts for the project shall clearly state the fire safety requirements that are the responsibility of any person who enters the site, as described in this FHMPP.

Appendix A
Site Photograph Log

View Facing South

View Facing South

View Facing North

View Facing North

View Facing East

View Facing East

View Facing West

View Facing West

Appendix B

Fire Behavior Modeling Analysis

1 BehavePlus Fire Behavior Modeling History

Fire behavior modeling has been used by researchers for approximately 50+ years to predict how a fire will move through a given landscape (Linn 2003). The models have had varied complexities and applications throughout the years. One model has become the most widely used as the industry standard for predicting fire behavior on a given landscape. That model, known as "BEHAVE", was developed by the U. S. Government (USDA Forest Service, Rocky Mountain Research Station) and has been in use since 1984. Since that time, it has undergone continued research, improvements, and refinement. The current version, BehavePlus 6.0, includes the latest updates incorporating years of research and testing. Numerous studies have been completed testing the validity of the fire behavior models' ability to predict fire behavior given site specific inputs. One of the most successful ways the model has been improved has been through post-wildfire modeling (Brown 1972, Lawson 1972, Sneeuwjagt and Frandsen 1977, Andrews 1980, Brown 1982, Rothermel and Rinehart 1983, Bushey 1985, McAlpine and Xanthopoulos 1989, Grabner, et. al. 1994, Marsden-Smedley and Catchpole 1995, Grabner 1996, Alexander 1998, Grabner et al. 2001, Arca et al. 2005). In this type of study, Behave is used to model fire behavior based on pre-fire conditions in an area that recently burned. Real-world fire behavior, documented during the wildfire, can then be compared to the prediction results of Behave and refinements to the fuel models incorporated, retested, and so on.

Fire behavior modeling conducted on this site includes a relatively high-level of detail and analysis which results in reasonably accurate representations of how wildfire may move through available fuels on and adjacent the property. Fire behavior calculations are based on site-specific fuel characteristics supported by fire science research that analyzes heat transfer related to specific fire behavior. To objectively predict flame lengths, spread rates, and fireline intensities, this analysis incorporated predominant fuel characteristics, slope percentages, and representative fuel models observed on site. The BehavePlus fire behavior modeling system was used to analyze anticipated fire behavior within and adjacent to key areas just outside of the proposed lots. Predicting wildland fire behavior is not an exact science. As such, the movement of a fire will likely never be fully predictable, especially considering the variations in weather and the limits of weather forecasting. Nevertheless, practiced and experienced judgment, coupled with a validated fire behavior modeling system, results in useful and accurate fire prevention planning information. To be used effectively, the basic assumptions and limitations of BehavePlus must be understood.

- First, it must be realized that the fire model describes fire behavior only in the flaming front. The primary driving force in the predictive calculations is dead fuels less than one-quarter inch in diameter. These are the fine fuels that carry fire. Fuels greater than one inch have little effect while fuels greater than three inches have no effect on fire behavior.
- Second, the model bases calculations and descriptions on a wildfire spreading through surface fuels that are within six feet of the ground and contiguous to the ground. Surface fuels are often classified as grass, brush, litter, or slash.
- Third, the software assumes that weather and topography are uniform. However, because wildfires almost always burn under non-uniform conditions, length of projection period and choice of fuel model must be carefully considered to obtain useful predictions.

- Fourth, the BehavePlus fire behavior computer modeling system was not intended for determining sufficient fuel modification zone/defensible space widths. However, it does provide the average length of the flames, which is a key element for determining "defensible space" distances for minimizing structure ignition.

Although BehavePlus has some limitations, it can still provide valuable fire behavior predictions which can be used as a tool in the decision-making process. In order to make reliable estimates of fire behavior, one must understand the relationship of fuels to the fire environment and be able to recognize the variations in these fuels. Natural fuels are made up of the various components of vegetation, both live and dead, that occur on a site. The type and quantity will depend upon the soil, climate, geographic features, and the fire history of the site. The major fuel groups of grass, shrub, trees, and slash are defined by their constituent types and quantities of litter and duff layers, dead woody material, grasses and forbs, shrubs, regeneration, and trees. Fire behavior can be predicted largely by analyzing the characteristics of these fuels. Fire behavior is affected by seven principal fuel characteristics: fuel loading, size and shape, compactness, horizontal continuity, vertical arrangement, moisture content, and chemical properties.

The seven fuel characteristics help define the 13 standard fire behavior fuel models[1] and the five custom fuel models developed for Southern California[2]. According to the model classifications, fuel models used in BehavePlus have been classified into four groups, based upon fuel loading (tons/acre), fuel height, and surface to volume ratio. Observation of the fuels in the field (on site) determines which fuel models should be applied in BehavePlus. The following describes the distribution of fuel models among general vegetation types for the standard 13 fuel models and the custom Southern California fuel models:

- Grasses Fuel Models 1 through 3
- Brush Fuel Models 4 through 7, SCAL 14 through 18
- Timber Fuel Models 8 through 10
- Logging Slash Fuel Models 11 through 13

In addition, the aforementioned fuel characteristics were utilized in the recent development of 40 new fire behavior fuel models[3] developed for use in BehavePlus modeling efforts. These new models attempt to improve the accuracy of the standard 13 fuel models outside of severe fire season conditions, and to allow for the simulation of fuel treatment prescriptions. The following describes the distribution of fuel models among general vegetation types for the new 40 fuel models:

- Grass Models GR1 through GR9
- Grass-shrub Models GS1 through GS4

1 Anderson, Hal E. 1982. Aids to Determining Fuel Models for Estimating Fire Behavior. USDA Forest Service Gen. Tech. Report INT-122. Intermountain Forest and Range Experiment Station, Ogden, UT.

2 Weise, D.R. and J. Regelbrugge. 1997. Recent chaparral fuel modeling efforts. Prescribed Fire and Effects Research Unit, Riverside Fire Laboratory, Pacific Southwest Research Station. 5p.

3 Scott, Joe H. and Robert E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

- Shrub Models SH1 through SH9
- Timber-understory Models TU1 through TU5
- Timber litter Models TL1 through TL9
- Slash blowdown Models SB1 through SB4

BehavePlus software was used in the development of the Nighthawk Battery Storage System Project (Proposed Project) Fire Hazard Mitigation and Prevention Plan in order to evaluate potential fire behavior for the Project site. Existing site conditions were evaluated, and local weather data was incorporated into the BehavePlus modeling runs.

2 Fuel Models

Dudek utilized the BehavePlus software package to analyze fire behavior potential for the Proposed Project site in northern San Diego County. As is customary for this type of analysis, three fire scenarios were evaluated, including one summer, onshore weather condition (west/south of the Project Site) and two extreme fall, offshore weather condition (south and east/southeast of the Project Site). The Project site is surrounded by existing commercial and industrial developments to the north, residential communities to the south, and open space to the west, east and south. With that said, fuels and terrain within and adjacent to the Project development area could produce flying embers that may affect the Project. It is the fuels directly adjacent to and within fuel modification zones that would have the potential to affect the Project's main components from a radiant and convective heat perspective as well as from direct flame impingement. BehavePlus software requires site-specific variables for surface fire spread analysis, including fuel type, fuel moisture, wind speed, and slope data. The output variables used in this analysis include flame length (feet), rate of spread (feet/minute), fireline intensity (BTU/feet/second), and spotting distance (miles). The following provides a description of the input variables used in processing the BehavePlus models for the Proposed Project site. In addition, data sources are cited and any assumptions made during the modeling process are described.

2.1 Vegetation (Fuels)

To support the fire behavior modeling efforts conducted for the Nighthawk Battery Energy Storage System Project Hazard Mitigation and Prevention Plan, the different vegetation types observed within the Project areas and adjacent to the Project site were classified into the aforementioned numeric fuel models. As is customary for this type of analysis, the terrain and fuels within and adjacent to the project area were used for determining flame lengths and fire spread. It is these fuels that would have the potential to affect the project's main components from a radiant and convective heat perspective as well as from direct flame impingement. Fuel beds, including the intermix of non-native grasslands, coast sage scrub and mixed chaparral fuels (Fuel Models FM4, Gs2, Sh2, and Sh5) found throughout the adjacent areas west, south, and east of the Project site. These fuel types can produce flying embers that may affect the project, but defenses have been built into the structure(s) to prevent ember penetration. Table 1 provides a description of the two existing fuel models observed in the vicinity of the site that were subsequently used in the analysis for this project. These sites were selected based on the strong likelihood of fire approaching from these directions during a Santa Ana wind-driven fire event (fire scenarios 2 and 3) and an on-shore weather pattern (fire scenario 1).

Table 1. Existing Fuel Model Characteristics

Fuel Model	Description	Location of Fuel Models	Fuel Bed Depth (Feet)
Existing Conditions			
Gs2	Moderate Load, Dry Climate Grass-Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh2	Moderate Load, Dry Climate Shrub	Represented throughout the adjacent areas south, west and east of the Project site	<2.0 ft.
Sh5	High Load Dry Climate Shrub	Represented throughout the adjacent areas west and east of the Project site.	>4.0 ft.

2.2 Topography

Slope is a measure of angle in degrees from horizontal and can be presented in units of degrees or percent. Slope is important in fire behavior analysis as it affects the exposure of fuel beds. Additionally, fire burning uphill spreads faster than those burning on flat terrain or downhill as uphill vegetation is pre-heated and dried in advance of the flaming front, resulting in faster ignition rates. Natural slope values ranging from 19% to 33% were measured in the foothills north of the Project site and around the eastern perimeter of the Project site from U.S. Geological Survey (USGS) topographic maps.

2.3 Weather Analysis

Historical weather data for the Poway region was utilized in determining appropriate fire behavior modeling inputs for the Project area. 50th and 97th percentile moisture values were derived from Remote Automated Weather Station (RAWS) and utilized in the fire behavior modeling efforts conducted in support of this report. Weather data sets from the San Pasqual RAWS (ID number 045746)[4] were utilized in the fire modeling runs.

RAWS fuel moisture and wind speed data were processed utilizing the Fire Family Plus software package to determine atypical (97th percentile) and typical (50th percentile) weather conditions. Data from the RAWS was evaluated from August 1 through November 30 for each year between 2002 and 2020 (extent of available data record) for 97th percentile weather conditions and from June 1 through September 30 for each year between 2015 and 2021 for 50th percentile weather conditions.

Following analysis in Fire Family Plus, fuel moisture information was incorporated into the Initial Fuel Moisture file used as an input in BehavePlus. Wind speed data resulting from the Fire Family Plus analysis was also determined. Initial wind direction and wind speed values for the five BehavePlus runs were manually entered during the data input phase. The input wind speed and direction is roughly an average surface wind at 20 feet above the vegetation over the analysis area. Table 2 summarizes the wind and weather input variables used in the Fire BehavePlus modeling efforts.

[4] San Pasqual RAWS Station Latitude and Longitude: 33.090954, -117.011979

Table 2: Variables Used for Fire Behavior Modeling

Model Variable	Summer Weather (50th Percentile)	Peak Weather (97th Percentile)
Fuel Models	Sh2 and Sh5	Gs2, Sh2, and Sh5
1 h fuel moisture	6%	1%
10 h fuel moisture	7%	4%
100 h fuel moisture	15%	11%
Live herbaceous moisture	58%	30%
Live woody moisture	117%	60%
20 ft. wind speed	12 mph (sustained winds)	16 mph (sustained winds); wind gusts of 50 mph
Wind Directions from north (degrees)	240	90 and 180
Wind adjustment factor	0.4	0.4
Slope (uphill)	31%	19 to 21%

3 Fire Behavior Modeling Efforts

As mentioned, the BehavePlus fire behavior modeling software package was utilized in evaluating anticipated fire behavior adjacent to the Proposed Project site. Three focused analyses were completed for the existing Project site conditions, assuming worst-case fire weather conditions for a fire approaching the Project site from the west/southwest, south, and east/southeast. The results of the modeling effort included anticipated values for surface fires flame length (feet), rate of spread (mph), fireline intensity (Btu/ft/s), and spotting distance (miles). The aforementioned fire behavior variables are an important component in understanding fire risk and fire agency response capabilities. Flame length, the length of the flame of a spreading surface fire within the flaming front, is measured from midway in the active flaming combustion zone to the average tip of the flames (Andrews, Bevins, and Seli 2008). Fireline intensity is a measure of heat output from the flaming front, and also affects the potential for a surface fire to transition to a crown fire. Fire spread rate represents the speed at which the fire progresses through surface fuels and is another important variable in initial attack and fire suppression efforts (Rothermel and Rinehart 1983). Spotting distance is the distance a firebrand or ember can travel down wind and ignite receptive fuel beds. Three fire modeling scenario locations were selected to better understand the different fire behavior that may be experienced on or adjacent the site based on slope and fuel conditions; these three fire scenarios are explained in more detail below:

Fire Scenario Locations and Descriptions:

- Scenario 1: A summer, on-shore fire (50th percentile weather condition) burning in moderate- to high-load intermix of shrubs and chaparral dominated vegetation located in the hillsides west/southwest of the Project site, below Kirkham Way and west of Paine Street. The terrain is moderately steep (approximately 31% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southwestern portion of the development.

- **Scenario 2:** A fall, off-shore fire (97th percentile weather condition) burning in low- to moderate-load intermix of non-native grasses and shrubs/chaparral dominated vegetation located in the hillsides south of the Project site, below Kirkham Way and north of Beeler Canyon Road. The terrain is moderately steep (approximately 19% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southern portion of the development.
- **Scenario 3:** A fall, off-shore fire (97th percentile weather condition) burning in moderate- to high-load intermix of shrubs and chaparral dominated vegetation located in the hillsides east/southeast of the Project site, below Kirkham Way and east of Paine Street. The terrain is moderately steep (approximately 21% slope) with potential ignition sources from a car fire originating along Kirkham Way, Paine Street, or Beeler Canyon Road to the south, a home or commercial structure fire, or a wildfire originating west, south, or east of the proposed Project site. This type of fire would typically spread up slope relatively slow towards the southeastern portion of the development.

4 Fire Behavior Modeling Results

The results presented in Table 3 depict values based on inputs to the BehavePlus software and are not intended to capture changing fire behavior as it moves across a landscape. Changes in slope, weather, or pockets of different fuel types are not accounted for in this analysis. For planning purposes, the averaged worst-case fire behavior is the most useful information for conservative fuel modification design. Model results should be used as a basis for planning only, as actual fire behavior for a given location will be affected by many factors, including unique weather patterns, small-scale topographic variations, or changing vegetation patterns.

As presented in Table 4, worst-case fire behavior is expected in the non-maintained shrub and chaparral dominated fuels throughout the hillsides around the perimeter areas of the Project site. Worst-case fire behavior is expected in untreated, shrub and chaparral vegetation under peak weather conditions (represented by Fall Weather, Scenario 3). The fire is anticipated to be a wind-driven fire from the east/southeast during the fall. Under such conditions, expected surface flame length are expected to reach approximately 44 feet with wind speeds of 50+ mph. Under this scenario, fireline intensities reach 21,047 BTU/feet/second with moderate spread rates of 6.6 mph and could have a spotting distance up to 2.4 miles away.

Wildfire behavior in non-maintained chaparrals in the hillsides south/southwest of the Project site, modeled as Sh2 and Sh5 fuel models being fanned by 12 mph sustained, on-shore winds Fires burning from the west and pushed by ocean breezes typically exhibit less severe fire behavior due to lower wind speeds and higher humidity. Under typical onshore weather conditions, a moderate- to- high-load chaparral dominated vegetation fire could have flame lengths approximately 12 feet in height and spread rates of approximately 0.5 mph. Spotting distances, where airborne embers can ignite new fires downwind of the initial fire are approximately 0.4 miles.

Table 3: RAWS BehavePlus Fire Behavior Model Results – Existing Conditions

Fire Scenario	Flame Length (feet)	Spread Rate (mph)[5]	Fireline Intensity (Btu/ft./sec)	Spot Fire (Miles) [6]
Scenario 1: 31% slope, Summer, On-shore wind from the S/SW, 12 mph sustained winds (Current conditions)				
High-load, dry climate shrubs (Sh5)	11.4	0.5	1,121	0.4
Moderate-load, dry climate shrubs (Sh2)	1.3	0.0	10	0.1
Scenario 2: 19% slope, Fall, Off-shore wind from the S, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
Moderate-load, dry climate grass-shrubs (Gs2)	9.8 (20.5)	0.8 (4.2)	808 (4,016)	0.4 (1.4)
Moderate-load, dry climate shrubs (Sh2)	7.9 (15.7)	0.2 (1.0)	506 (2,272)	0.3 (1.2)
Scenario 3: 21% slope, Fall, Off-shore wind from the E/SE, 16 mph sustained winds with 50 mph wind gusts (Current conditions)				
High-load, dry climate shrubs (Sh5)	23.4 (43.8)	1.7 (6.6)	5,374 (21,047)	0.7 (2.4)

The following describes the fire behavior variables (Heisch and Andrews 2010) as presented in Tables 4 and 5:

Surface Fire:

- Flame Length (feet): The flame length of a spreading surface fire within the flaming front is measured from midway in the active flaming combustion zone to the average tip of the flames.
- Fireline Intensity (Btu/ft/s): Fireline intensity is the heat energy release per unit time from a one-foot wide section of the fuel bed extending from the front to the rear of the flaming zone. Fireline intensity is a function of rate of spread and heat per unit area, and is directly related to flame length. Fireline intensity and the flame length are related to the heat felt by a person standing next to the flames.
- Surface Rate of Spread (mph): Surface rate of spread is the "speed" the fire travels through the surface fuels. Surface fuels include the litter, grass, brush and other dead and live vegetation within about 6 feet of the ground.

The information in Table 4 presents an interpretation of the outputs for five fire behavior variables as related to fire suppression efforts. The results of fire behavior modeling efforts are presented in Table 3. Identification of modeling run locations is presented graphically in Figure 5 of this report.

[5] mph = miles per hour
[6] Spotting distance from a wind driven surface fire; it should be noted that the wind mph in parenthesis represent peak gusts of 50 mph.

Table 4: Fire Suppression Interpretation

Flame Length (ft)	Fireline Intensity (Btu/ft/s)	Interpretations
Under 4 feet	Under 100 BTU/ft/s	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
4 to 8 feet	100-500 BTU/ft/s	Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 to 11 feet	500-1000 BTU/ft/s	Fires may present serious control problems -- torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
Over 11 feet	Over 1000 BTU/ft/s	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

Appendix C

UL 9540A Test Report

(Please refer to enclosed UL 9540 A Test Report from Tesla)

TEST REPORT

ANSI/CAN/UL 9540A:2019
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Number.............................:	NN22GLCI.003
Date of issue ....:	08/05/2022
Total number of pages.................:	28
Name of Testing Laboratory preparing the Report....................:	**TÜV Rheinland of North America, Inc.** 1279 Quarry Lane, Suite A, Pleasanton, CA 94566
Applicant's name ....:	**Tesla, Inc.**
Address ....:	3500 Deer Creek Road, Palo Alto, CA 94304
Test specification:	
Standard.......................................:	ANSI/CAN/UL 9540A:2019
Test procedure.............................:	Report
Non-standard test method...........:	N/A
Test Report Form No. ....:	N/A
Test Report Form(s) Originator....:	N/A
Master TRF ....:	Dated 2019-01-17

General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the CB, responsible for this Test Report.

Other / Scope:

1. Update Lower Apparent power ratings from 367.5 kVA and 735 kVA to 300 kVA for Megapack 2 as per safety evaluation report 32195843.005.
2. Update Lower Apparent power ratings from 504 kVA and 1008 kVA to 400 kVA for Megapack 2 as per safety evaluation report US22K5PS.002.
3. Removed Nominal Battery power kW ratings.
4. Added 3 hr rating for Megapack 2 and Megapack 2 XL.

Test item description .... :	Battery Energy Storage System
Trade Mark .... :	Tesla
Manufacturer .... :	Tesla, Inc, (new # 1210368) 3500 Deer Creek Rd, Palo Alto, CA 94304
Model/Type reference .... :	1748844-XX-Y, 1848844-XX-Y XX – can be any number from 00 to 99. XX – represents style codes used for different variants of the same part, having no impact on the safety and functionality of the entire product. Y – Can be any upper case letter from A to Z. Y – represents pedigree and is used for tracking changes to parts that have already been released to suppliers or production, having no impact on the safety and functionality of the entire product.
Ratings .... :	**<u>Megapack 2 - 1748844-XX-Y</u>** 480Vac, 50/60 Hz, 3P3W, Apparent power rating 4hr: 300 kVA to 997.5 kVA; 3hr: 300 kVA to 1008 kVA; 2hr: 300 kVA to 1890 kVA Nominal Battery capacity 4hr: 1142.4 kWh to 3100.8 kWh; 3hr: 1122.1 kWh to 2564.8 kWh; 2hr: 1124.2 kWh to 2890.8 kWh **<u>Megapack 2 XL- 1848844-XX-Y</u>** 480Vac, 50/60 Hz, 3P3W, Apparent power rating 4 hr: 400 kVA to 1512 kVA; 3 hr: 400 kVA to 1512 kVA; 2 hr: 400 kVA to 2400 kVA Nominal Battery capacity 4 hr: 1305.6 kWh to 3916.8 kWh; 3 hr: 1282.4 kWh to 3847.2 kWh; 2 hr: 1284.8 kWh to 3854.4 kWh

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):

☒	**Testing Laboratory:**	**TÜV Rheinland of North America, Inc.** 1279 Quarry Lane, Suite A, Pleasanton, CA 94566	
Testing location/ address .... :			
Tested by (name, function, signature) .... :			
Approved by (name, function, signature) .. :			
☐	**Testing procedure: CTF Stage 1/TMP:**		
Testing location/ address .... :			
Tested by (name, function, signature) .... :			
Approved by (name, function, signature) .. :			
☒	**Tesla, Inc.**	**Tesla, Inc.**	

Testing location/ address............................ :		Tesla Battery Test Facility Fernley, Nevada	
Tested by (name + signature)..................... :		Kiran Krishnan Kutty	[signature]
Witnessed by (name, function, signature). :		Himanshu Vaidya	[signature]
Approved by (name, function, signature) .. :		Howard Liu	[signature]
☐	**Testing procedure: CTF Stage 3/SMT:**		
☐	**Testing procedure: CTF Stage 4:**		
Testing location/ address............................ :			
Tested by (name, function, signature) .... :			
Witnessed by (name, function, signature). :			
Approved by (name, function, signature) .. :			
Supervised by (name, function, signature) :			

List of Attachments (including a total number of pages in each attachment):

N/A

Summary of testing:

Tests performed (name of test and test clause):	**Testing location:**
NN22GLCI.001 UL 9540A clause 9 – Unit Level Round 2 **NN22GLCI.002** N/A **NN22GLCI.003** N/A	Tesla, Inc. Tesla Battery Test Facility Fernley, Nevada

Summary of compliance with National Differences (List of countries addressed): N/A

☐ **The product fulfils the requirements of _________ (insert standard number and edition and delete the text in parenthesis, leave it blank or delete the whole sentence, if not applicable)**

Possible test case verdicts:	
- test case does not apply to the test object ... :	N/A
- test object does meet the requirement .... :	P (Pass)
- test object does not meet the requirement ... :	F (Fail)
Testing:	
Date of receipt of test item .... :	February 22, 2022
Date (s) of performance of tests...................... :	March 09, 2022

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a ☐ comma / ☒ point is used as the decimal separator.

Name and address of factory (ies) .... :

Copy of marking plate: Use – "Only for use with Tesla Products"

"The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCB' s that own these marks"

General product information and other remarks:

Megapack is bi-directional, supporting charge and discharge. It converts power for storage in rechargeable lithium-ion battery packs (battery modules) and is designed in a modular fashion in order to support a range of AC power.

Each Megapack contains up to 19 battery modules with inverters (24 for Megapack 2 XL), a thermal bay and associated thermal roof components, an AC circuit breaker, and a set of customer interface terminals and internal controls circuit boards. An external auxiliary power supply is not required for Megapack; Megapack pulls auxiliary power for the control power and thermal management from the local AC.

Depending on the system configuration (2-hour or 4-hour), each Megapack can be configured with different quantities of battery modules which, together with the site's grid voltage, determine Megapack's nominal power rating.

Report History:

NN22EDSI.001: UL 9540A clause 9 – Unit Level Round 1 for Megapack 2

NN22GLCI.001: UL 9540A clause 9 – Unit Level Round 2 for Megapack 2

NN22GLCI.002: Add Megapack 2 XL model number

"MP2XL(1848844-XX-Y) uses the same batteries, converters, vents and sparker system used in MP2 (1748844-XX-Y). The enclosure is of similar construction to that of MP2. Key difference in the 2 models is that MP2XL contains 24 AC battery modules instead of 19 in MP2. Based on the limited module propagation observed during MP2 testing (7 cells in runaway) the behavior would be the same with MP2XL. With the increase in volume and sparker count, the deflagration risk is minimized. The testing performed on MP2 is considered harsher with higher gas concentrations, and fundamental engineering analysis for MP2XL shows comparable behavior as worst case"

NN22GLCI.003:

1. Update Lower Apparent power ratings from 367.5 kVA and 735 kVA to 300 kVA for Megapack 2 as per safety evaluation report 32195843.005.
2. Update Lower Apparent power ratings from 504 kVA and 1008 kVA to 400 kVA for Megapack 2 as per safety evaluation report US22K5PS.002.
3. Removed Nominal Battery power kW ratings.
4. Added 3 hr rating for Megapack 2 and Megapack 2 XL.

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict

CONSTRUCTION			--
5	**General**		--
5.1	**Cell**		
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report	CATL Lithium Iron Phosphate Rated Capacity (Ah): 157.2Ah Nominal Voltage: 3.22V Nominal mass: 2991 ± 60 g Dimension: 50.75±0.5mm*166±0.5mm*169.3±0.5mm	
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973	Battery module and cell is certified to UL 1973	P
5.1.3	Refer to 7.6.1 for further details	See 7.6.1	N/A
5.2	**Module**		
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report	Battery module (3 modules in series, 336S1P)	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973	Battery module is compliant with UL 1973	P
5.2.3	Refer to 8.3 for further details	See 8.3	N/A
5.3	**Battery energy storage system unit**		P
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540	UL 9540 compliant and certified	P
5.3.2	For BESS units for which UL 9540 compliance cannot be determined,	See above	N/A
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report	No fire detection and suppression systems used	N/A
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details	See 9.7	N/A
5.4	**Flow Batteries**		N/A
5.4.1	For flow batteries, the report will cover the chemistry, as well as the electrical rating in capacity and nominal voltage of the cell stack	Not flow Batteries	N/A
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973		N/A
5.4.3	See 7.6.2 for further details		N/A
PERFORMANCE			--
6	**General**		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires		N/A
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications		N/A
9	**Unit Level**		
9.1	**Sample and test configuration**		P
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:		P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; and i) Rooftop and open garage non-residential use BESS installations.	Outdoor ground mounted non-residential use BESS	P
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation	One initiating BESS and three target adjacent BESS	P
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:	Testing can be conducted outdoors for outdoor only installations See Figure 1	P
	a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph; b) The temperature range is within 10°C to 40°C (50°F to 104°F); c) The humidity is < 90% RH; d) There is sufficient light to observe the testing; e) There is no precipitation during the testing; f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.	This was an outdoor installation test. The ambient temperature was varied between 10°C and 15°C and humidity less than 90% RH, and wind was under 10 mph.	P
9.1.3	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level	Testing performed at BESS level	N/A
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.	Complete unit in the testing	P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components		P
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC),	100% SOC	P
9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT	No integral fire suppression system	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.		P
9.2	**Test method – Indoor floor mounted BESS units**	Outdoor ground mounted units. Used the test method described in the Section 9.2 except conflicted with Section 9.3.	-
9.2.1	Samples and test configurations are in accordance with 9.1.	Testing conducted outdoor	N/A
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed,	Doors closed	P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections	Wall construction per 9.3.3	N/A
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.	Wall construction per 9.3.3	N/A
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height	Wall construction per 9.3.3	N/A
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black	Wall construction per 9.3.3	N/A
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter	Testing conducted outdoor	N/A
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test	Testing conducted outdoor	N/A
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively	Testing conducted outdoor	N/A
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated	Testing conducted outdoor	N/A
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile	Testing conducted outdoor	N/A
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$	Testing conducted outdoor	N/A
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation	Wall construction per 9.3.3	N/A
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
	a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	a) 5 ft from Initiator to the left b) 6 inches from ISO knuckle of Initiating unit to Target unit. 4 inches from surface of initiating unit to target unit surface.	P
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction.	Wall construction per 9.3.3	N/A
9.2.16	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller,	Wall construction per 9.3.3	N/A
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires	Wall construction per 9.3.3	N/A
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:	Wall construction per 9.3.3	N/A
	a) Both are collinear with the vertical thermocouple array;		N/A
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		N/A
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		N/A
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		P
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		P
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge	Testing conducted outdoor	N/A
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface	No. 24-gauge, Type-K used	P
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth	Non-residential	N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:	See Figure 2 Megapack can consist up to 19 Battery Module assemblies. Each module assembly contains 3 battery Modules each which is a total of 112 cell modules. Two sections of heaters for 2 cells was setup to force thermal runaway.	P
	a) The position of the module shall be selected to present the greatest thermal exposure		P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test		P
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct	Testing conducted outdoor	N/A
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection	Testing conducted outdoor	N/A
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	Applicable	P
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation		N/A
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation	Non-residential	N/A
9.3	**Test method – Outdoor ground mounted units**		
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings shall use the test method described in Section 9.2	See 9.2	P
9.3.2	except as noted in 9.3.3 and 9.3.4. Heat flux measurements for the accessible means of egress shall be measured in accordance with 9.2.20.	See 9.2	P
9.3.3	Test samples shall be installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit		P
	Exception: If the manufacturer requires installation against non-flammable material, the test setup may include manufacturer recommended backing material between the unit and plywood wall		N/A
9.3.4	Target BESS shall be installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications	Target unit on the front, side and back of the initiating BESS	P
9.4	**Test Method – Indoor wall mounted units**	Outdoor	N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
9.4.1	Testing of indoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.3.		N/A
9.4.2	The test shall be conducted in a standard NFPA 286 fire test room, 3.66 × 2.44 × 2.44-m (12 × 8 × 8-ft) high, with a 0.76 × 2.13-m (2-1/2 × 7-ft) high opening.		N/A
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening		N/A
9.4.4	Target BESS shall be installed on the wall on each side of the initiating BESS		N/A
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.4.6	The gas collection methods shall be in accordance with 9.2		N/A
9.4.7	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		N/A
9.5	**Test Method – Outdoor wall mounted units**	Outdoor and ground mounted	N/A
9.5.1	Testing of outdoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.4.		N/A
9.5.2	Test samples shall be mounted on an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.4).		N/A
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 1.22-m (4-ft) above the floor,		N/A
9.5.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height		N/A
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.5.6	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth		N/A
9.6	**Rooftop and open garage installations**	Outdoor and ground mounted	N/A
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations shall be in accordance with 9.2.		N/A
9.6.2	If intended for rooftop and open garage use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured		N/A
9.7	**Unit level test report**		
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; i) Rooftop installed non-residential use BESS; or j) Open garage installed non-residential use BESS.	Outdoor ground mounted non-residential use BESS;	P
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report	One installation type only	P
9.7.3	The report shall include the following, as applicable:	See table 1	P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
	a) Unit manufacturer name and model number (and whether UL 9540 compliant); b) Number of modules in the initiating BESS unit; c) The construction of the initiating BESS unit per 5.3; d) Fire protection features/detection/suppression systems within unit; e) Module voltage(s) corresponding to the tested SOC; f) The thermal runaway initiation method used; g) Location of the initiating module within the BESS unit; h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits; i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension; j) Chemical and convective heat release rate versus time data; k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1); l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1); m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple; n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple; o) The maximum incident heat flux on target wall surfaces and target BESS units; p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test; q) Gas generation and composition data; r) Peak smoke release rate and total smoke release data; at which activation occurred; t) Observation of flying debris or explosive discharge of gases; u) Observation of re-ignition(s) from thermal runaway events; v) Observation(s) of sparks, electrical arcs, or other electrical events; w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits; and x) Photos and video of the test.		
9.8	**Performance at unit level testing**		

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	Conditions in table 9.1 met	P
10	**Installation Level**	Unit level testing only	N/A
10.1	General		N/A
10.1.1	The installation level test method assesses the effectiveness of the fire and explosion mitigation methods for the BESS in its intended installation		N/A
	a) Test Method 1 – "Effectiveness of sprinklers" is used		N/A
	b) Test Method 2 – "Effectiveness of fire protection plan" is used		N/A
10.1.2	Installation level testing is not appropriate for units only intended for outdoor use or residential use.	Outdoor only	P
10.2	Sample		N/A
10.2.1	The samples (initiating BESS and target BESS) and their preparation for testing		N/A
10.2.2	A flame indicator consisting of a cable tray with fire rated cables that complies with UL 1685 and representative of the installation per the anufacturer's specifications		N/A
10.3	Test method 1 – Effectiveness of sprinklers		N/A
10.3.1	For BESS units with a height of 2.44 m (8 ft) or less, the test shall be conducted in a 6.10 × 6.10 × 3.05-m (20 × 20 × 10-ft) high test room		N/A
10.3.2	The test room shall be fitted with four sprinklers at 3.05-m (10-ft) spacing in the center		N/A
10.3.3	Walls shall be constructed with 16-mm (5/8-in) gypsum wall board		N/A
10.3.4	The initiating BESS unit shall be positioned at manufacturer specified distances		N/A
10.3.5	Temperature measurements at the ceiling locations directly above the initiating and target BESS unit shall be collected by an array of thermocouples		N/A
10.3.6	Instrumented wall surface temperature measurements shall be collected in a vertical array at 152-mm (6-in) intervals		N/A
10.3.7	Thermocouples for wall surface temperature measurements shall be secured to gypsum surfaces by the use of staples		N/A
10.3.8	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:		N/A
	a) Both are collinear with the vertical thermocouple array;		N/A
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		N/A
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
10.3.9	Heat flux shall be measured with at least two sensing water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		N/A
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		N/A
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		N/A
10.3.10	The heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge		N/A
10.3.11	No. 24-gauge or smaller Type-K exposed junction thermocouples shall be installed		N/A
10.3.12	An internal fire condition in accordance with the module level test shall be created		N/A
	a) The position of the module shall be selected to present the greatest thermal exposure		N/A
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same		N/A
10.3.13	The composition of BESS unit vent gases shall be measured		N/A
10.3.14	The test shall be terminated if:		N/A
	a) Temperatures measured inside each module of the initiating BESS return to below the cell vent temperature;		N/A
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation.		N/A
10.3.15	The initiating unit shall be under observation for 24 h after conclusion of the installation test		N/A
10.4	**Installation level test report – Test method 1 – Effectiveness of sprinklers**	No sprinkler system	N/A
10.4.1	The report on installation level testing shall include the following:		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict
	a) Unit manufacturer name and model number (and whether compliant with UL 9540); b) Number of modules in the initiating BESS unit; c) The construction of the initiating BESS unit per 5.3; d) Module voltage(s) of initiating BESS corresponding to the tested SOC; e) The thermal runaway initiation method used; f) Diagram and dimensions of the test setup including location of the initiating and target BESS units, and the locations of walls and ceilings; g) Location of initiating module within the BESS unit; h) Separation distances from the initiating BESS unit to (e.g. distances A and C in Figure 10.1); i) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and E in Figure 10.1); j) Distances of the flame indicator (if used) with respect to the BESS (e. g. distances A and B in Figure 10.2); k) Maximum temperature at the ceiling; l) Distance of fire spread within the flame indicator; m) The maximum wall surface and target BESS unit temperatures achieved during the test and the location of the measuring thermocouple; n) The maximum incident heat flux on target wall surfaces and target BESS units; o) Voltages of initiating BESS; p) Total number of sprinklers that operated and length of time the sprinklers operated during the test; q) Gas generation and composition data, if measured; r) Observation of flaming outside of the test room s) Observation of flying debris or explosive discharge of gases; t) Observation of re-ignition(s) from thermal runaway events; u) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; and 3) Adjacent walls; v) Photos and video of the test; w) Fire protection features/detection/suppression systems within unit; and x) Sprinkler K-factor, RTI, manufacturer and model, number of sprinklers and layout		N/A
10.5	**Performance – Test method 1 – Effectiveness of sprinklers**		N/A
10.5.1	For BESS units intended for installation in locations with combustible construction, surface temperature measurements along instrumented wall surfaces shall not exceed a temperature rise of 97°C		N/A
10.5.2	The surface temperature of modules within the BESS units adjacent to the initiating BESS unit shall not exceed the temperature at which thermally initiated cell venting occurs		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement – Test	Result – Remark	Verdict

10.5.3	The fire spread on the cables in the flame indicator shall not extend horizontally beyond the initiating BESS enclosure dimensions		N/A
10.5.4	There shall be no flaming outside the test room.		N/A
10.5.5	There is no observation of detonation.		N/A
10.5.6	Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		N/A
10.5.7	There shall be no observation of re-ignition within the initiating unit after the installation test		N/A
10.5.8	An installation level test that does not meet the applicable performance criteria noted above is considered noncompliant and would need to be revised and retested		N/A
10.6	**Test method 2 – Effectiveness of fire protection plan**	Refer 10.3	N/A
10.6.1	The test method 2 test set-up and test procedures are identical to that in 10.3, except instead of the sprinkler system set up of 10.3.2, the room shall be fitted with the specified fire protection		N/A
10.7	**Installation level test report – Test method 2 – Effectiveness of fire protection plan**	Refer 10.4	N/A
10.7.1	The report on installation level testing shall include the following:		N/A
	a) The report information in 10.4.1 items (a) – (u), and (v) if applicable; b) Fire protection features/detection/suppression systems within installation; and c) Length of time of operation of the clean agent, or other suppression system in addition to any sprinklers used.		N/A
10.8	**Performance – Test method 2 – Effectiveness of fire protection plan**	Refer 10.5	N/A
10.8.1	See 10.5 for performance criteria		N/A

ANNEX A	**Test Concepts And Application Of Test Results To Installations**	INFORMATIVE	
A2.1	**General**		N/A
A2.2	**Cell level testing**	CATL UL9540a certified by UL project no. 4789956341	P
A2.3	**Module level testing**	CATL UL9540a certified by TUV Sud project no. 64.290.21.30597.01	P
A2.4	**Unit level testing**	Refer Table 1 below for results	P

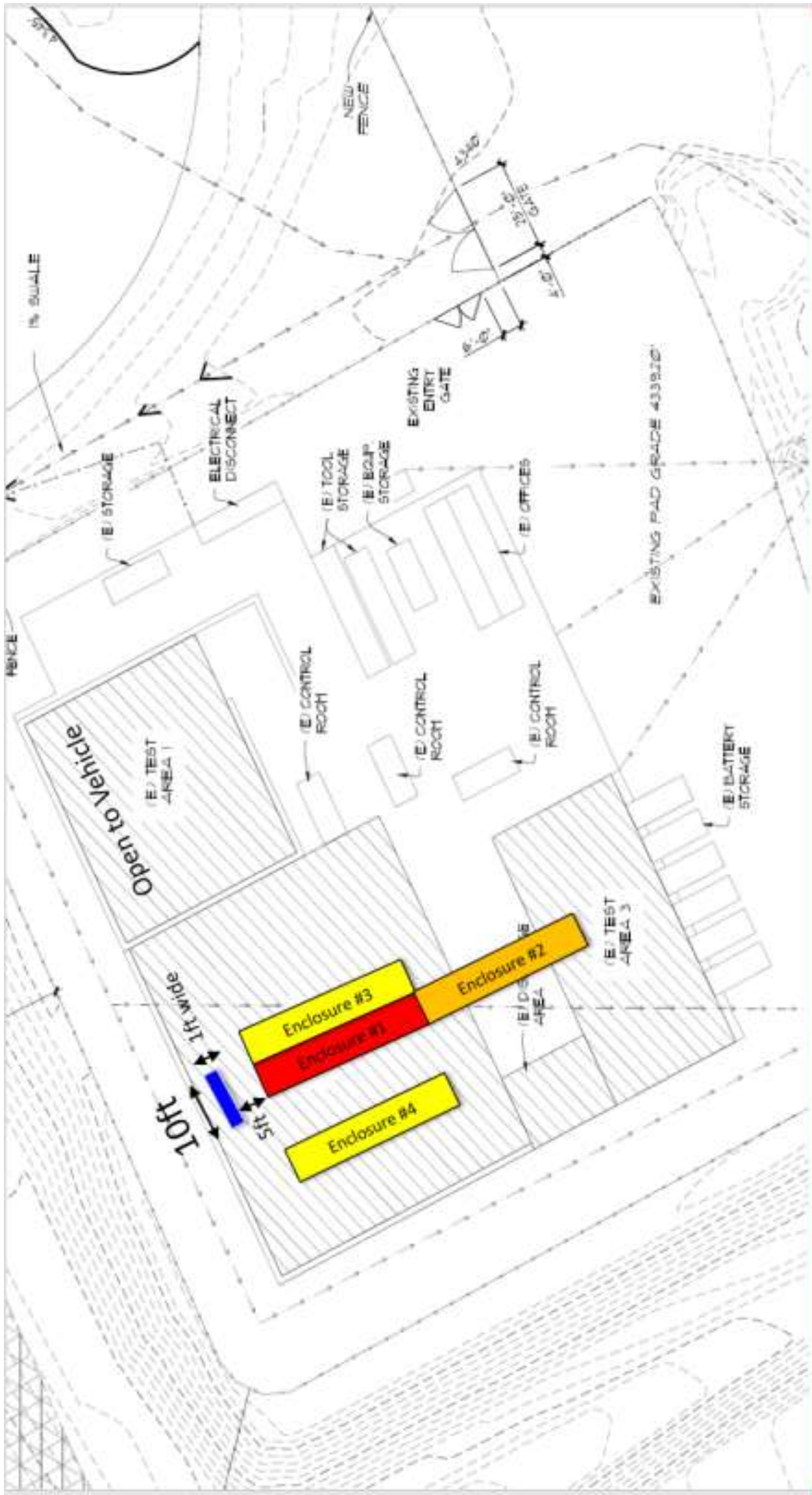

Fig 1. Site Layout

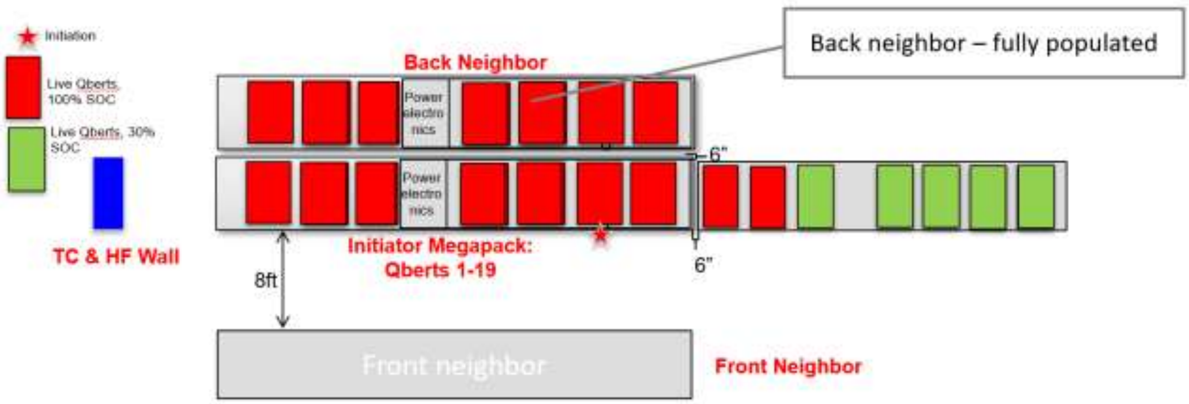

Fig 2. Test area Layout

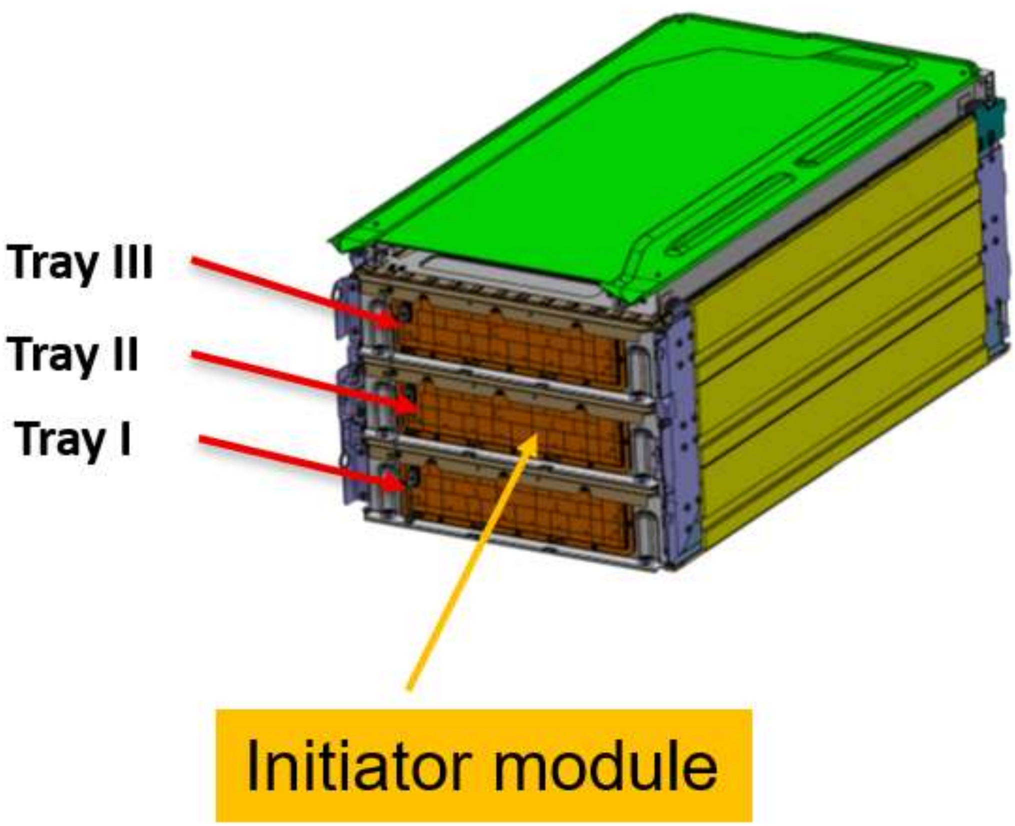

Fig 3. Initiator module location

Fig 4. Initiator AC Battery module location

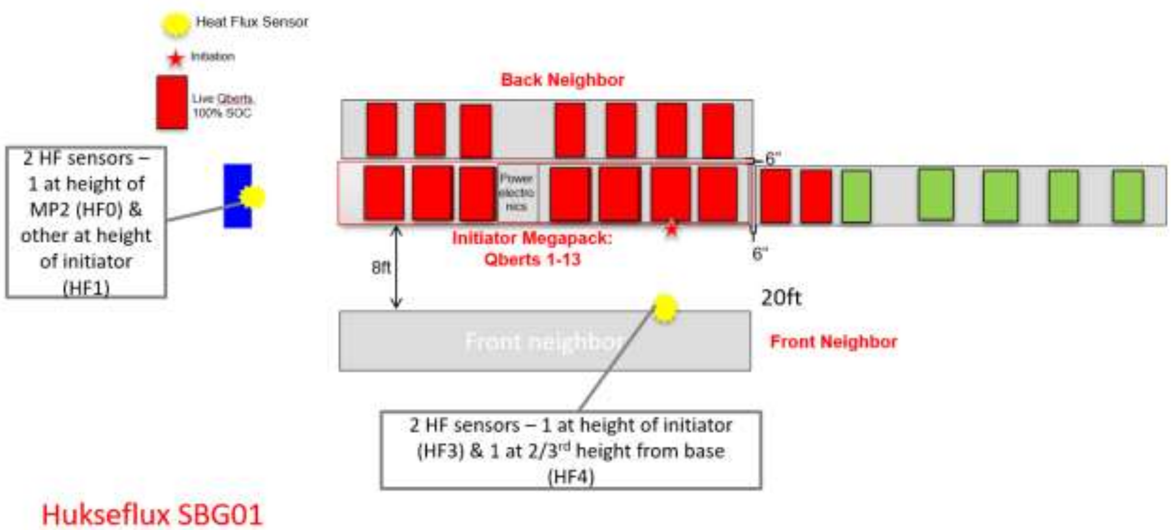

Fig 5. Heat Flux locations

Fig 6. Camera Layout

Fig 7. Pre test photos

Fig 8. Post-test photo of Initiator location

Fig 9. Internal view, post test photo

Fig 10. Initiator Qbert module, Rear view – Post test

Fig 11. Front view – Post test

Fig 12. Side view

Fig 13.– Initiator Battery module – Post test

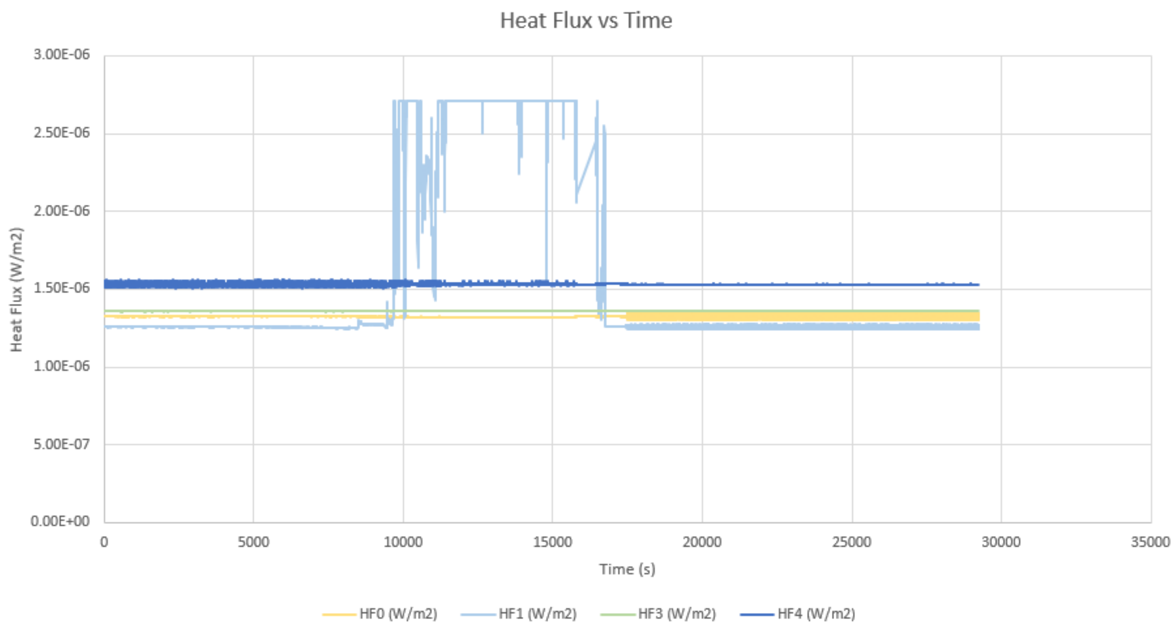

Fig 14.- Heat Flux graph

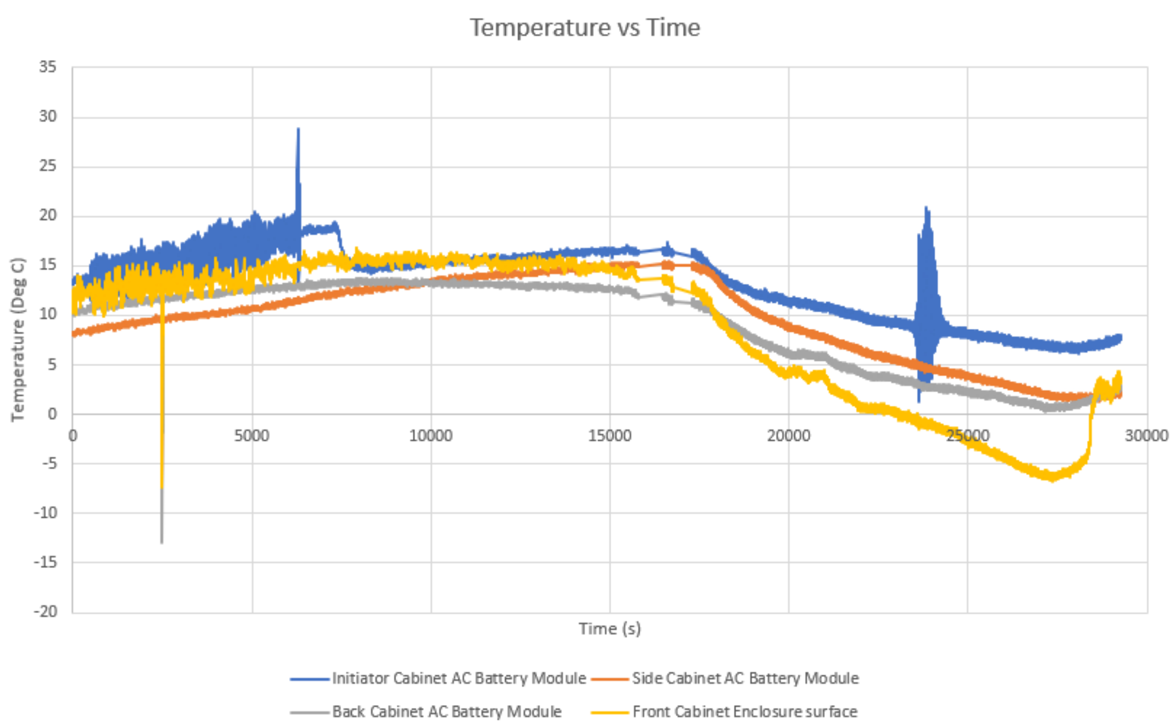

Fig 15.- Temperature graph – Target BESS and Initiator BESS non-initiating AC Battery modules

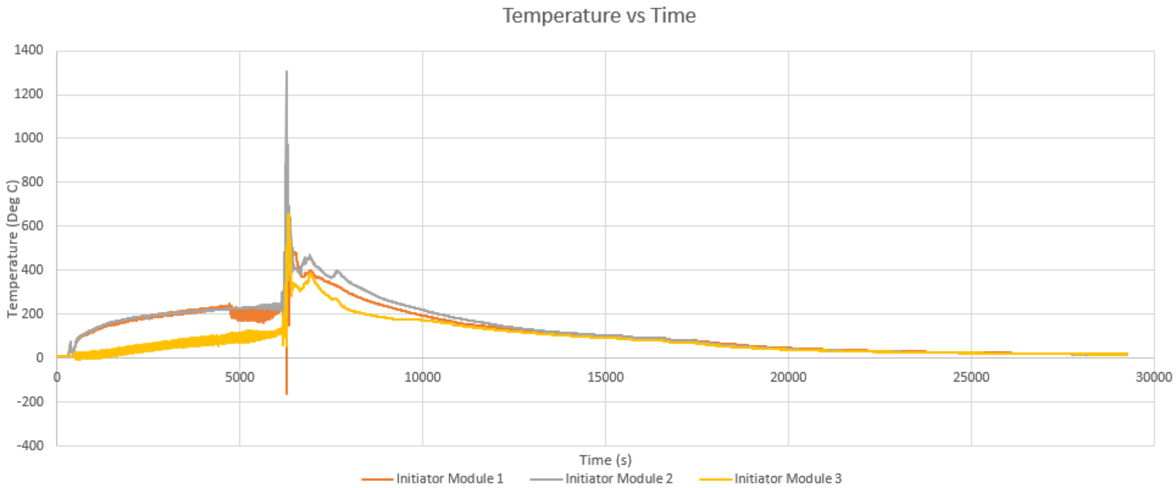

Fig 16.- Temperature graph – Initator module tray

Table 1. Test results per Clause 9.7

#	Items	Description	Comment
a)	Unit manufacturer name and model number (and whether UL 9540 compliant);	Tesla, Megapack 2, 174884-XX-Y, UL9540 compliant	Pass
b)	Number of modules in the initiating BESS unit;	3 module forming AC Battery and 19 AC Batteries in Megapack	Pass
c)	The critical construction of the initiating BESS unit per 5.3;	UL 9540 compliant.	Pass
d)	Fire protection features/detection/suppression systems within unit;	Optional Detection Signal	Pass
e)	Module voltage(s) corresponding to the tested SOC;	100%SOC measured. 373.5V Module voltage	Pass
f)	The thermal runaway initiation method used;	4 film heaters heating 6 cells simultaneously	Pass
g)	Location of the initiating module within the BESS unit;	Initiator Megapack AC Battery 7-3	Pass
h)	Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	6 inches from ISO knuckle of Initiating unit to side and back Target unit. 8 ft from front Target.; wall – 5 ft from Initiator	Pass
i)	Observation of any flaming outside the initiating BESS enclosure;	No	Pass
j)	Chemical and convective heat release rate versus time data;	N/A	N/A
k)	Separation distances from the initiating BESS unit to target walls (e.g. distances A and C in Figure 9.1);	5 ft	Pass
l)	Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	6 inches from ISO knuckle	Pass
m)	The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Wall – 30.75 deg C Front Target surface- 16.8C	Pass
n)	The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	N/A	N/A
o)	The maximum incident heat flux on target wall surfaces and target BESS units;	Wall-2.71 X 10^-6 W/m2 Front Target – 1.54 X 10^-6 W/m2	Pass
p)	The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;	N/A	N/A
q)	Gas generation and composition data;	N/A	N/A
r)	Peak smoke release rate and total smoke release data;	N/A	N/A
s)	Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	N/A	N/A
t)	Observation of flying debris or explosive discharge of gases;	None observed	Pass
u)	Observation of re-ignition(s) from thermal runaway events;	None observed	Pass
v)	Observation(s) of sparks, electrical arcs, or other electrical events;	None observed	Pass
w)	Observations of the damage to: 1) The initiating BESS unit;	1. No external damage. Initiating AC battery	Pass

	2) Target BESS units; and 3) Adjacent walls	module had burn marks. Other 2 modules of AC Battery intact. Balance 18 AC AC Battery intact. 2. None observed 3. None observed	
x)	Photos and video of the test	Attached	Pass
Note:			

- End of Report -

Appendix D

Nighthawk Energy Storage Hazards Analysis

(Please refer to enclosed Nighthawk Hazards Analysis Report by MRS Environmental)

Hazards Analysis
Final Report

Nighthawk Energy Storage, LLC Project
City of Poway, California

Prepared for:
Nighthawk Energy Storage, LLC
14302 FNB Parkway
Omaha, NE 68154

Prepared by:
MRS Environmental
1306 Santa Barbara Street
Santa Barbara, CA 93101

Date:

May 9, 2022

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Attachments

List of Acronyms and Definitions

Acronym	Definition
Ah	Amp hour
AHJ	Authority Having Jurisdiction
BMS	Battery Management System
BSS	Battery Storage System
CFC	California Fire Code
CGA	Compressed Gas Association
CPUC	California Public Utilities Commission
EPA	Environmental Protection Agency
ESS	Energy Storage Systems
GWh	Gigawatt hour (equal to 1,000 MWhs)
HVAC	Heating Ventilation and Air Conditioning
IDLH	Immediately Dangerous to Life and Health: developed by National Institute for Occupational Safety and Health (NIOSH)
IEEE	Institute of Electrical and Electronics Engineers
kWh	Kilowatt hour
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
MWhr	Megawatt hour (equal to 1,000 kWh)
NCA	Lithium Nickel Cobalt Aluminum
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NRTL	OSHAs Nationally Recognized Testing Laboratory
OEHHA	Office of Environmental Health Hazard Assessment
ppm	Parts Per Million
REL	Reference Exposure Level
SCADA	Supervisory Control and Data Acquisition
SDS	Safety Data Sheet
SOC	State of Charge
TCP	Transmission Control Protocol
Thermal Runaway	During the thermal runaway, the battery temperature increases due to exothermic reactions. In turn, the increased temperature accelerates those degradation reactions and the system destabilizes, potentially releasing flammable and toxic gases.
SFPE	Society of Fire Protection Engineers
UL	Underwriters Laboratory
USDOT	U.S. Department of Transportation
Whr	Watt hour

1.0 Introduction

Nighthawk Energy Storage, LLC proposes to install a battery storage system with a capacity of 300 MW in the City of Poway, CA (Project). The Project would provide additional capacity to the electrical grid during periods when electrical sources are not generating power or when there is a need for additional power. The Project would provide increased electrical reliability and stability to the local grid, thereby reducing the need to operate fossil-fuel generation systems and reducing the consumption of fossil fuels and associated emissions of greenhouse gases.

This report examines the potential upset and malfunction scenarios for the Project that could result in impacts to nearby receptors from toxic and flammable gas releases. The Project would not cause any impacts from toxic gas or flammable gas releases during normal operations (operations include battery storage and planned and unplanned maintenance activities).

Battery energy storage systems convert electrical energy into a chemically stored form that can later be converted back into electrical energy when needed. The first U.S. battery storage system listed in the Federal Energy Information Administration (EIA) database was a 40 MW system in Alaska in 2003. As of October 2020, the United States has 1,363 MW of total battery storage capacity (EIA 2020) at 188 installations. California leads the U.S. in battery energy storage with 528 MW at 55 installations, with an additional 2,712 MW of battery storage capacity projected to be placed in service by 2024.

Lithium-ion batteries were introduced commercially by Sony in 1991 for use primarily in consumer products, and they since have become the most widely used battery technology for grid-scale energy storage. Lithium-ion batteries are scalable. About 92% of U.S. grid-storage installations utilize lithium-ion batteries (EIA 2020).

2.0 Project Description

The Project site would be located at the corner of Kirkham Way and Paine Street in the City of Poway, CA on parcel APN: 3200310300. The proposed Project location would be immediately south of Kirkham Way and associated industrial areas located north of Kirkham Way (such as HiTec Multiplex and Disguise Inc), immediately east of Paine Street, and north of Beeler Canyon Road. The site is currently undeveloped. See Figure 1.

The Project would involve the installation of about 332 self-contained energy storage and management cabinets (most recent versions called Megapack 2 and the XL versions) containing battery modules designed and manufactured by Tesla. Each cabinet would hold approximately 24 modules of batteries. An operations and maintenance (O&M) control enclosure would also be located on the Project site. The Megapack cabinets would be placed at the site outdoors. The Megapacks will have no walk-in or occupied facilities in the proposed Project design, and the Project will not otherwise include any buildings.

Figure 1 Project Location

Source: Google Maps imagery date 3/23/2019

The Megapack 2 and the XL are the most recent design of the Megapack series. The Megapack 2 has undergone 9540A and UL testing at this time. The results of the UL9540A testing for the unit demonstrate that with heating, the LFP battery modules do not undergo thermal runaway and that there was no resulting off gassing or fire, resulting in minimal radiation. Cell level testing was not available from Tesla.

As the intent of a hazard mitigation analysis is to examine a reasonable worst-case failure, other manufacturers information on cell level testing was utilized to estimate worst case impacts. These other cell levels tests indicate that thermal runaway is possible and that off gassing and fires could occur, even though they are harder to generate as evidenced by the UL9540A unit level testing for the Megapack 2. Therefore, this report is based on other manufacturers tests and the previous Megapack design, which is considered to be a worst-case scenario.

The O&M control enclosure would be a physically small footprint (i.e., similar to a desktop computer) and is typically located within or adjacent to the Megapacks, along with the rest of the Project communications equipment. Access to the O&M control enclosure would be external only; it would not be a walk-in enclosure. The O&M control enclosure houses the external communication interface over TCP (Modbus, DNP3.0 or REST) to the utility and network operator or customer SCADA systems. The Controller communicates to each Megapack over a private TCP network. Each Megapack is controlled by the inverter: based on the signal received from the controller, the Megapack will trigger the charge or discharge of each battery module. The Controller aggregates real-time information from all the Megapacks and leverages the information to optimize the commands sent to each Megapack.

The Project will be monitored remotely by the Tesla Operations Center. Daily inspections of the Project would also be conducted. The Project would not be manned on-site.

The proposed battery cell type for the project Megapacks would be Lithium-iron Phosphate (LFP) (associated with the Megapack 2 and XL versions).

The Project would be equipped with inverters to convert the DC electricity of the battery systems into AC current used by the electrical grid and AC to DC to charge the batteries as required. There would also be a liquid thermal cooling system integrated into the cabinets to provide cooling to the batteries and power electronics.

Fire prevention systems would include proposed cabinets designed to limit or eliminate the potential for fire to spread from one cabinet to another, infrared camera monitoring at the site for external fire detection, and access to fire hydrants. Additional items include video monitoring of the site, site lighting, site security, training, fire access planning and fire water flow design.

The Battery Management System (BMS) would monitor all cell voltages, currents and temperatures and shut down equipment if unsafe conditions are detected with monitoring and control by the Tesla Operations Center.

The Megapacks are equipped with ventilation systems which allow for the removal and combustion of off-gassed emissions. The design of Megapack includes 33 pressure-sensitive vents (over-pressure vents) and a sparker system. The sparker system utilizes an igniter to produce a spark on a periodic basis sufficient to ensure ignition of any flammable gases. The over-pressure vents and sparker system work in combination with each other to mitigate the risks of deflagration and overpressure events by combusting flammable off-gassed emissions before they reach the Project enclosure's lower flammability limit (LFL). This design essentially ignites the gases very early in a thermal runaway scenario, before there is time for the gas volume to build up within the enclosure and become an explosion hazard. Eight sparkers in total are installed at the top of the Megapack bays, just below the over-pressure vents installed within the roof. The sparkers enable a rapid combustion of the hot gases and opening of the closest over-pressure vents. This ensures products of combustion and flames will exit through the roof, without creating a pressure scenario within the Megapack large enough to blow open doors or expel projectiles from the unit. By keeping all the doors shut during the fire, this also helps ensure that the fire will not propagate to adjacent Megapacks.

Thermal management of a Megapack is achieved via liquid cooling using a 50/50 mixture of ethylene glycol and water. A typical Megapack includes about 540 liters of coolant. Mechanical damage of a Tesla Energy Product could result in leakage of the coolant.

The Megapack thermal management system also includes 7.6 kg of R134a refrigerant in a sealed system. Mechanical damage of a Megapack could result in a release of the refrigerant. R134a is non-flammable.

The electrolyte within Megapack cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of lithium ions). The electrolyte in a Megapack cell is absorbed in electrodes within individual sealed cells. The electrolyte reacts with those materials and is consumed during normal operation of the batteries. As such, the Megapack does not contain free liquid electrolyte.

The potential for an electrolyte spill from a Megapack is very unlikely. Electrolyte can be extracted from a single cell using a centrifuge, or under some extreme abuse conditions such as a severe crush. However, it is very difficult to mechanically damage cells in such a way as would be required for an electrolyte leak to occur. Even if a single cell was damaged in a manner that could cause electrolyte leakage, it is highly improbable that any incident would result in leak from more than a few cells.

3.0 Environmental and Regulatory Setting

There are a number of different lithium battery types including the following:

- Lithium Nickel Cobalt Aluminum (NCA)
- Lithium Nickel Manganese Cobalt (NMC)
- Lithium Manganese Oxide (LMO)
- Lithium Titanate Oxide (LTO)
- Lithium-Iron Phosphate (LFP, proposed for this project)

This study assumed the use of the Lithium-Iron Phosphate (LFP) battery type.

Battery Testing Requirements and Regulations

Batteries are subject to several codes and standards. Some of the relevant ones are discussed below.

UL9540: Safety for Energy Storage Systems. The requirement addresses the inherent design and performance, as well as the interface of the energy storage system with the infrastructure. Addresses construction, performance, electrical, mechanical, environmental, manufacturing and markings.

UL9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems – this test methodology evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. The data generated can be used to determine the fire and explosion protection required for an installation of a battery energy storage system. UL9540A requires examining three separate tests: testing on the cell level, testing on the module level and testing on the entire unit level.

UL1973: Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications - These requirements cover battery systems as defined by this standard for use as energy storage for stationary applications such as for PV, wind turbine storage or for UPS, etc. applications. This standard evaluates the battery system's ability to safely withstand simulated abuse conditions. This standard evaluates the system based upon the manufacturer's specified charge and discharge parameters. Requires that an Energy Storage System (ESS) is not allowed to be an explosion hazard when exposed to an external fire source and that a single cell failure will not result in a cascading thermal runaway of cells.

IEEE C2: This Code covers basic provisions for safeguarding of persons from hazards arising from the installation, O&M of (1) conductors and equipment in electric supply stations, and (2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment. The Code is applicable to the systems and equipment operated by utilities, or similar systems and equipment, of an industrial establishment or complex under the control of qualified persons.

California Fire Code 1206 and International Fire Code: Specifies minimum size requiring permits (Lithium, all types, 20 kWh), specifies maximum limits on sizing for battery systems (Lithium all type, 50 kWh each array), seismic and structural design, spacing (minimum 3 feet separation of arrays), vehicle impact protection, testing, maintenance and repairs, maximum quantities within a building (Lithium of 600 kWh), BMS monitoring, shutdown and notification requirements, automatic smoke detector requirements, automatic fire sprinkler systems and ventilation specifications. Section 1210 of the California Fire Code also requires that the battery systems be “listed”, which is achieved through testing by an OSHA certified NRTL laboratory.

NFPA 1: The General NFPA Fire Code addressing extracts from other NFPA codes.

NFPA 13: Standard for the Installation of Sprinkler Systems, addresses sprinkler system design approaches, installation, and component options.

NFPA 70: National Electrical Code, addresses electrical design, installation, and inspection.

NFPA 550: Guide to Fire Safety Concepts Tree for Protecting Energy Systems - addresses issues such as utilizing BMS and compatible equipment, ventilation as needed, fire resistive separation, array spacing, signage.

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems - establishes criteria for minimizing the hazards associated with ESS. NFPA 855 addresses issues including ventilation, smoke and fire detection, fire control and suppression, explosion control, water supply, O&M, battery energy storage systems hazards and firefighting considerations.

OSHA NRTL: The OSHA Nationally Recognized Testing Laboratory (NRTL) program recognizes private sector organizations to perform certification for certain products to ensure that they meet the requirements of both the construction and general industry OSHA electrical standards. Each NRTL has a scope of test standards that they are recognized for, and each NRTL uses its own registered certification mark(s) to designate product conformance to the applicable product safety test standards, thereby “listing” the product. After certifying a product, the NRTL authorizes the manufacturer to apply a registered certification mark to the product. If the certification is done under the NRTL program, this mark signifies that the NRTL tested and certified the product, and that the product complies with the requirements of one or more appropriate product safety test standards. Two testing laboratories certified for the electrical components discussed in this analysis are Underwriters Laboratory (UL) and TUV Rheinland.

Health Protective Regulations

The National Institute for Occupational Safety and Health (NIOSH) has established standards or concentrations at which certain pollutants are defined as immediately dangerous to life and health (IDLH).

In 2016, a technical working group comprised of utility and industry representatives worked with the California Public Utilities Commission Safety & Enforcement Division's Risk Assessment and Safety Advisory (RASA) section to develop a set of guidelines for documentation and safe practices at ESS collocated at electric utility substations, power plants or other facilities (CPUC 2017). The guidelines require a safety plan and inspection procedures.

Receptors

There are receptors located near the Project site. These receptors are listed in Table 1 along with the respective distances to the closest Project Megapack.

Table 1 Distance to Receptors

Receptor	Distance to Battery Megapack Cabinet, feet
Sidewalk along north side of Kirkham Way	127
Closest building along Kirkham Way	148
Closest Residence (along Green Valley Ct)	2,470
Closest Park (SportsPlex USA)	2,800
School (Pacific Coast Academy)	2,800
Park (Sycamore Canyon Park)	3,600

4.0 Assessment Methodology

There will be no emissions from the battery systems associated with the Project during normal operations (battery storage and planned and unplanned maintenance). However, in the unlikely event of a battery cell malfunction, such as a thermal runaway reaction or external impact scenario, the Project could emit air pollutants to the atmosphere. For these types of battery cell malfunctions, air pollutant emissions could be generated due to elevated temperatures within a single storage cell or group of storage cells caused by a runaway reaction. When Li-ion batteries are mistreated with high over-temperature, a strong overcharge or suffer damage, they can transit into a so-called "thermal runaway". During the thermal runaway, the battery temperature increases due to exothermic reactions. In turn, the increased temperature accelerates those degradation reactions, and the system destabilizes. At the end of the thermal runaway, battery temperatures higher than 1,000 °C can be reached and flammable and toxic gases can be released (Golubkov 2015). A thermal runaway event would be considered a worst-case event and is addressed in further detail below. Tesla has experienced only a single thermal runaway event with any of their installed base of battery systems to date and only during the installation phase of a system in Australia. The event causes have been addressed and revisions incorporated into their current Megapack designs in order to prevent future similar scenarios.

This analysis is limited to a reasonable worst-case scenario. A catastrophic scenario, such as an airplane impact, runaway vehicle impact, runaway train impact, terrorist incident or nearby construction equipment collapse causing impact, could cause multiple Megapacks to be destroyed, causing substantial emissions associated with a large-scale fire. A reasonable worst-case scenario is more limited in scope, defined as a control system failure or a puncture of a module, similar to that conducted as part of the UL 1973 testing, which could cause a runaway reaction in a group of cells. Generally, a reasonable worst-case scenario is more appropriate for a planning scenario as any development project could produce substantial fires and cause impacts to neighboring facilities under a catastrophic scenario.

The Project will be equipped with monitoring and control systems that will prevent and/or control battery cell malfunctions. However, to determine an unlikely, but reasonable worst-case public health impacts for this analysis, it is assumed that these control systems fail and do not control the battery cell malfunction. For this unlikely scenario, it is assumed that the battery cell malfunction continues until third-party or municipal fire suppression services arrive at the Project site.

Different manufacturers have developed various studies examining the potential scenarios related to battery malfunctions, although most of these studies are proprietary. Some studies have been independently performed for agencies, including by Det Norske Veritas (DNVGL 2017) conducted for the New York State Energy Research & Development Authority (NYSERDA) and Consolidated Edison. Other studies include Anderson 2013, Blum 2016, Larsson 2017 and LG Chem (another battery manufacturer) where batteries were exposed to heat sources and off-gases were measured. In addition, the battery manufacturer, Tesla, has performed testing on a representative system by DNVGL (DNVGL 2019) where heat was added and forced a burn of the entire enclosure (Megapack previous version).

Different battery cell malfunctions could produce emissions. These include:

- An elevated temperature situation due to a runaway reaction with no combustion (venting with no combustion or off gassing phase); or
- Combustion of the battery due to an elevated temperature situation from a runaway (combustion phase).

Studies have shown (Rincon 2017, and proprietary UL9540A testing) that a localized runaway reaction with combustion produces the greatest flow of emissions. Emissions would occur both during the pre-combustion off-gassing phase and during the combustion phase.

During the off-gassing phase, the off-gassed materials would contain flammable and toxic materials. Although the flow of materials during the off-gassing phase would be lower than the combustion phase, the off-gassing phase would still present impacts as the temperature of the off-gassed materials would be lower than combustion, thereby producing less lift and buoyancy, resulting in potentially higher levels of toxic gases at ground level. In addition, during the off-gassing phase, there would be more flammable materials that could give rise to a vapor cloud with subsequent deflagration or explosion.

During the combustion phase, most of the off-gassed materials would be combusted and hence would contain only low levels of flammable gases. During combustion, the off-gassed toxics would also be combusted, but a different array of toxic combustion products, mostly from the combustion of the plastics used in the Megapacks, would be produced. In addition, during combustion, the heat of combustion would produce substantial plume buoyancy, thereby causing the materials to rise into the air. As the downwind, ground-level impacts could be greater during the pre-combustion off-gassing phase, both phases are examined in this analysis.

The Megapacks are enclosed in cabinets that have venting. It is assumed that the air emissions caused by these malfunction scenarios will be vented during the malfunction scenarios. As per the

UL9540A testing on previous iterations of the Megapack systems, emissions occurred from the Megapack over a 3.5-hour period. Two reasonable worst-case scenarios are addressed in this analysis:

- The loss of 10 percent of the cells within a Megapack module (multicell scenario), and
- The loss of an entire Megapack.

For the multicell scenario, it is assumed that the release of pollutants to the atmosphere would occur all within one hour as a reasonable worst case. While emissions could occur over a longer period of time, a worst-case analysis is produced if the same quantity of pollutants are released over a shorter period of time, thereby increasing the emission rates and increasing the downwind distance and potential impacts. In addition, as part of the UL1973 design requirements, battery malfunctions and punctures have limited cascading capabilities. Therefore, it is highly unlikely that an entire module or groups of modules would be involved in a single scenario. Accordingly, a reasonable worst-case for the multicell scenario is assumed to involve only 10 percent of the cells in a single module if a battery malfunction were to occur.

For the Megapack scenario, it is assumed that the entire Megapack is consumed similar to the large-scale fire testing conducted under UL9540A unit testing and pollutants are released over a 3.5-hour duration, which was the duration of the off-gassing observed during the UL9540A large-scale fire test on a previous version of the Megapack.

Battery malfunctions can result in the release of toxic materials and/or the release of a flammable gas mixture and subsequent flammable gas vapor cloud with subsequent fire or explosion. The pollutants released are discussed below.

4.1 Toxic Pollutants

Toxic pollutants emitted from battery malfunctions are partially dependent on the battery type. For lithium-ion batteries, studies indicate that the primary toxic pollutants could be any of the following:

Table 2 Potential Toxic Pollutants from Battery Malfunctions

Pollutant	OEHHA Reference Exposure Level (REL), µg/m3 / (ppm)	IDLH (Immediately Dangerous to Life and Health)	ERPG-3 (Emergency Response Planning Guidelines)	ERPG-2 (Emergency Response Planning Guidelines)
Carbon monoxide (CO)	23,000/26.7	1,200 ppm	500 ppm	350 ppm
Hydrogen Chloride (HCL)	2100/3.2	50 ppm	150 ppm	20 ppm
Hydrogen Cyanide (HCN)	340/0.4	50 ppm	25 ppm	10 ppm
Hydrogen Fluoride (HF)	240/0.2	30 ppm	50 ppm	20 ppm
Methanol (CH_3OH)	28,000/37	6,000 ppm	5,000 ppm	1,000 ppm
Nitrogen Oxide (NO_x)	470/0.9	13 ppm	30 ppm	15 ppm
Phosphine (PH_3)**	400/0.6	50 ppm	5 ppm	0.5 ppm

Table 2 Potential Toxic Pollutants from Battery Malfunctions

Pollutant	OEHHA Reference Exposure Level (REL), µg/m3 / (ppm)	IDLH (Immediately Dangerous to Life and Health)	ERPG-3 (Emergency Response Planning Guidelines)	ERPG-2 (Emergency Response Planning Guidelines)
Phosphorous Pentafluoride (PF_5)	240/0.2*	50 ppm***	-	-
Phosphoryl Fluoride (POF_3)	240/1.0*	50 ppm	-	-
Styrene	21,000/90	700 ppm	1000 ppm	250 ppm
Sulfur Dioxide (SO_2)	660/1.8	100 ppm	25 ppm	3 ppm
Toluene	37,000/140	500 ppm	1,000 ppm	300 ppm

* Utilized the acute REL for hydrogen fluoride as per OEHHA REL tables for Fluorides chronic are very similar.
** OEHHA does not have REL for acute PH3. Estimated based on NIOSH values.
*** The National Institute for Occupational Safety and Health (NIOSH) does not have a listing for PF_5. PF_5 and POF_3 estimated based on general fluorides.
Sources: See Table 3.

Generally, the battery cell will start to off-gas if the internal temperature exceeds 120 °C (DNVGL 2017).

A range of available studies of emissions from a thermal runaway scenario associated with the Tesla battery cells, together with the Megapack-specific UL9540A testing, has been reviewed in connection with this hazard analysis. Several studies have examined the emissions of toxic pollutants from battery off-gassing situations, with some studies examining only the concentration of toxic pollutants and others also examining emission rates. By addressing a range of studies and utilizing the worst-case emissions, the estimates of impacts are conservative as the emissions from a range of tests on the same battery type could produce a range of pollutant concentrations.

The relevant studies are listed in Table 3.

Some of the key findings from a review of these studies include the following:

- HF was found to be produced by all battery types.
- Toxic gases common across chemistries were CO, HCl, HF, and HCN (Fireway 2017).
- PH_3 was only identified by LG Chem for the NMC battery type. No other studies identified PH_3 as an issue for the non-NMC battery.
- PF_5 rapidly decomposes to HF and was therefore generally not detected (Anderson 2013).
- POF_3 was only produced by LCO battery type (Larsson 2017).

It was also found that the average emission rate of HF in a plastics fire can be higher than that for a battery fire (DNVGL 2017), indicating that potentially a majority of the toxic emissions from a battery fire are a result of the combustion of the plastic components.

The battery type proposed for this project, LFP, has demonstrated superior performance in terms of preventing thermal runaway, because the Oxygen bond is harder to break and thus lower flammability (NFPA 2017). This is demonstrated in the relatively low thermal activity shown in the UL9540A testing unit level results associated with the Megapacks 2.

This analysis reviewed the studies listed in Table 3, including the UL9540A large-scale fire testing conducted on the previous version of the Megapacks, and utilized the highest toxic and flammable concentrations identified in any of these studies. As a battery off-gassing scenario could have a range of characteristics, utilizing the maximum levels seen in a range of studies ensures a conservative analysis.

4.2 Flammable Components and Flammability

Flammable components are also emitted from a battery malfunction. Based upon the studies listed in Table 3, the flammable components could include the following:

Table 4 Potential Flammable Components from Battery Off-gassing

Component	Lower Flammability Limit (LFL), vol%
Acetylene (C_2H_2)	2.5
Butanes (C_4)	1.8
Carbon monoxide (CO)	12.5
Ethane (C_2H_6)	3.0
Ethylene (C_2H_4)	2.7
Hydrogen (H_2)	4.0
Methane (CH_4)	5.0
Pentanes (C_5)	1.4
Propane (C_3H_8)	2.1
Propene (C_3H_6)	2.0

Depending on the combination of these flammable materials, the off-gases could have varying degrees of flammability.

Table 3 Studies on Emissions from Battery Malfunctions

Study	Description	Results
Anderson 2013	Exposure of battery to heat source, off-gases tested. LFP battery, 1.2 kg, 35 Ah	HF: 30-50 ppm peak POF_3: 1-2 ppm peak HF Rate: 0.01 g/s
Blum 2016	Modules tested with heat exposure until thermal runaways. 100 kWh unit by Tesla.	HF: 100 ppm peak
CATL	UL 9540A testing, LFP	Composition of off-gassing: primary pollutants only. Up to 153.5 L off-gas per cell
Larsson 2017	External propane burner used to heat batteries, measured toxic gases. Examined different battery types	HF: up to 145 ppm peak HF rate: 50 mg/s peak HF rate: 200 mg/Whr peak POF_3 rate: 22 mg/Whr peak
LG Chem	Proprietary data on polymer battery tests. NMC battery type.	HF-0.2 ppm PH_3-1.0 ppm HF rate: 4.7e-7 g/hr PH_3 rate: 2.4e-4 g/hr Up to 244 L off-gas per cell
DNVGL 2017	Measured characteristics of a wide range of battery types and failures	release rates per kg of battery weight: HF rate: 1.7e-7 kg/s-kg
DNVGL 2019	Measure characteristics of a Tesla powerpack thermal runaway scenario	Maximum Values: HCL: 538 ppm HF: 183 ppm HCN: 67 ppm
Tesla	Proprietary studies	HF: 500 ppm HCL: 1,000 ppm HCN: 1,600 ppm Methanol: 32 ppm Styrene: 1 ppm Toluene: 3,500 ppm
	UL 9540A cell, module and unit level tests	HF: 0.5 ppm CO: 83 ppm CO: 51% of off-gassed materials

Tesla provided information on the composition of battery off-gassing as part of battery testing UL9540A tests on previous versions of the Megapack. These are shown below:

Table 5 Tesla Manufacturer Battery Off-gassing Primary Flammable Components

Component	Mole Percent
Hydrogen (H_2)	26
Carbon monoxide (CO)	51
Methane (CH_4)	10
Ethylene (C_2H_4)	4
Propane (C_3H_8) +	9

Note: based on Tesla UL9540A cell and module testing, previous Megapack version.

The Compressed Gas Association (CGA) Publication P-23 provides algorithms for estimating the level of flammability of gas mixtures. The application of this technique to the off-gassed materials as provided by the manufacturer as part of the testing (shown in Table 5) indicates that the released vapor/gas would be flammable, with a Q value of over 9.0 (This exceeds the Q value flammability limit of 1.0, established by the CGA, indicating the materials is flammable. See Attachment G (CGA 2015) with an estimated lower flammability limit of over 5.5 percent. The 9540A testing indicated a LFL of 6.0 percent.

4.3 Modeling

In order to estimate the impacts of the off-gassing from toxic and flammable emissions, a modeling approach was used. The Canary© model was run to examine the downwind distance to the toxic IDLH and the flammable and explosive levels that could occur under the release scenario situations. The IDLH is the level specified as a concern in NFPA 855 and was therefore used in this analysis to assess toxic impacts.

The Canary© model is a computerized model developed by Quest Consulting to estimate the thermodynamic properties of gas mixtures and estimate impact distances of thermal exposure, explosions, vapor clouds and toxic effects.

For flammable impacts, the Canary© model was used to determine the distances that flammable vapor clouds (assessed to the LFL level) could travel with a resulting battery malfunction scenario under different meteorological conditions. The Canary© model was also used to examine explosion impacts to 1 psi overpressure.

For thermal impacts due to a fire, the UL9540A testing results were utilized to estimate the distances to different heat flux values.

4.4 UL 9540A Large Scale Fire Tests

As per the requirements of NFPA 855, large scale fire testing was conducted for the Megapack cells, the module and the entire Megapack (unit test) for the previous iteration of the Megapack systems. The results of this testing are more conservative than the results for the Megapack 2 model recently conducted for Tesla as they show a higher off gassing and fire potential. However, these are considered representative of a worst-case scenario. This testing provides for assessing a number of characteristics applicable to this analysis, including:

- Temperatures of the cells during off-gassing;
- Thermal flux experienced at nearby areas;
- Chemical composition of off-gassed materials;
- Chemical composition of combustion products;
- Smoke production rates; and
- The impacts on adjacent Megapacks.

The UL9540A tests require that the battery arrangements are forced into thermal runaway by inserting heaters into the batteries and forcing the temperature of the system to be elevated, thereby producing thermal runaway. In the cell and module level tests, the chemical compositions are measured both during the off-gassing and the combustion phases. For the Megapacks, as they are designed to be installed outside and not inside buildings or near buildings, the unit level test is primarily performed to examine the ability of the Megapack to maintain containment and prevent the spread of a fire or thermal runaway scenario to adjacent Megapacks.

Table 6 shows a summary of the test results.

Table 6 Megapack UL9540A Tests Results Summary

Component	Value
Surface temperature at which gases are first vented	282 °F
Gas composition off-gassing	CO (51.0%), H_2(26.0%), CH_4(10.6%), C_3H_8(9.4%), Others
Gas composition combustion gas	C_3H_8 2ppm, CH_4 2.8 ppm, CO 83 ppm, CO_2 650 ppm, C_2H_4 2.5 ppm, HF 0.5 ppm, H_2 Maximum 35% of LEL.
Average smoke release rate	0.68 m^2/s
Unit level test flame size	Peak flame extension was observed to be at about 10-12 ft upwards and 8-10 ft in front of the unit.
Unit level test heat flux	Maximum incident heat flux was 17.5 kW/m^2 at 3 ft
Unit level test neighbor module peak temperature	113 °F

Note: based on Tesla UL9540A cell, module and unit testing, previous Megapack version.

The fire testing indicated that the Megapack fire is not a high energy fire like a flame jet or an explosion. During the testing, no projectiles, explosions or flying debris were observed. The fire also develops relatively slowly, as listed below, allowing for effective fire department response and presence during the peak flame period:

- 38 seconds after initial heating: Hot gases detected by flame detection system;
- 2 minutes 40 seconds: Megapack temperature alarms to Tesla Operations Center;
- 8 minutes 25 seconds into test: hot gases coming from top of Megapack;
- 14 minutes 40 seconds: first flames observed;
- 38 minutes: peak flame intensity;
- 38 – 43 minutes: peak flame thermal flux levels above 5 kW/m^2 at 30 feet;
- 3 hours 30 minutes duration of off-gassing and flames.

5.0 Consequences

The consequences associated with battery malfunctions are discussed below based on the methodology presented above.

5.1 Exposure Assessment

Project emissions to the air would consist of off-gassed and combustion products due to a battery cell malfunction under the reasonable worst-case scenario. Inhalation is the main pathway by which toxic air pollutants could potentially cause public health impacts.

Flammable material impacts could be produced by vapor cloud deflagrations or explosions for the reasonable worst-case scenario, or from thermal exposure to fires.

5.2 Significance Criteria

For toxic impacts, limiting IDLH to areas onsite or away from high density areas offsite would produce less than significant hazards, as indicated in NFPA 855 4.1.4.3 and B.3.2. High density areas are defined as residential, commercial areas or schools. For toxic impacts, impacts offsite into high density populated areas may require additional analysis in order to determine significance utilizing a quantitative risk assessment (QRA).

Flammable impacts are less than significant if vapor cloud fires, explosions or thermal impacts do not impact high density areas.

5.3 Toxic Impacts

Potential human health impacts associated with the Project stem from exposure to air emissions from the battery cell malfunction reasonable worst-case scenario discussed above. The reasonable worst-case scenario would involve the battery malfunctions associated with off-gassing or combustion. The battery manufacturer provided information on primary and toxic pollutants from the battery malfunction, and that information was utilized for the analysis.

Detailed calculations are provided in Attachment C. The compounds and the associated mass emission rates were determined by UL9540A testing performed by the battery vendor as well as historical studies on toxic emissions.

Because the emissions would occur over a short period of time, only the public health impacts associated with acute exposure to short term releases were analyzed for the reasonable worst-case battery cell malfunction. No longer-term chronic or carcinogenic impacts are produced as no emissions are associated with normal, long term operations.

Modeling conducted utilizing the Canary© software indicated that the plume centerline rises due to the elevated temperature of the off-gassed materials. However, as the exact elevations of the plume could vary with varying meteorological conditions and the influence of structures causing downwash, the plume centerline concentrations were used to determine impacts.

As the emissions would occur over a short period of time, only the public health impacts associated with acute exposure to short term releases were analyzed for the reasonable worst-case battery cell malfunction. The acute impact distances for the reasonable worst-case battery cell malfunction scenarios are provided in Table 7, and detailed calculations can be found in Attachment C. Public health impacts from toxic pollutants associated with the reasonable worst-case battery cell malfunction would not impact populated areas and would be less than significant.

Table 7 Modeling Toxic Materials Results

Pollutant	IDLH Downwind Distance, feet
Multicell Scenario	
Carbon monoxide (CO)	99
Hydrogen Chloride (HCL)	5
Hydrogen Cyanide (HCN)	16
Hydrogen Fluoride (HF)	7
Toluene	3
Megapack Scenario	
Carbon monoxide (CO)	166
Hydrogen Chloride (HCL)	5
Hydrogen Cyanide (HCN)	16
Hydrogen Fluoride (HF)	12
Toluene	5

Notes: based on Canary© modeling, assuming meteorology of F stability and 1.5 m/s wind speeds. See Attachment G.

5.4 Combustion Smoke Impacts

Combustion products can include a number of components that can be toxic: particles, vapors, toxic gases including carbon monoxide (CO), hydrogen cyanide from the burning of plastics, phosgene from vinyl materials. Fire can also reduce oxygen levels, either by consuming the oxygen, or by displacing it with other gases.

The UL9540A testing describes some of the combustion products as part of the fire testing. Monitoring indicated low levels of carbon monoxide and carbon dioxide (83 – 680 ppm) and low levels of toxins (HF less than 1.0 ppm).

The dispersion and downwind impacts of smoke are highly complex due to the influence of the flame and fire-induced turbulence as well as the effect of structures and meteorological parameters. Impacts during the combustion phase are estimated based on the smoke release rate for the UL9540A module level testing, scaled up to an entire Megapack. Smoke generation during a fire is complex, as a wide range of materials in the Megapack would be consumed by the fire, including electronic components and plastics. During the UL9540A unit fire test, there was a wide range of fire conditions, flame lengths, wind effects producing a wide range of ground level exposures near the Megapack.

In order to address a range of potential smoke impacts, both a high fire case and a lower fire case were modeled. The high fire case assumed a high level of smoke flow based on the UL9540A module testing smoke generation rates. The lower fire case was assumed to be 10% of the high fire case in terms of smoke flow. Both a high wind (10 mph) which constitutes about 9% of the wind conditions at the site (see meteorological conditions discussion below) and a low wind case were modeled, with the low wind speed at 3.3 mph. The higher wind generally produced higher ground level impacts, but with additional dispersion and air mixing, reduces the downwind distances to impacts.

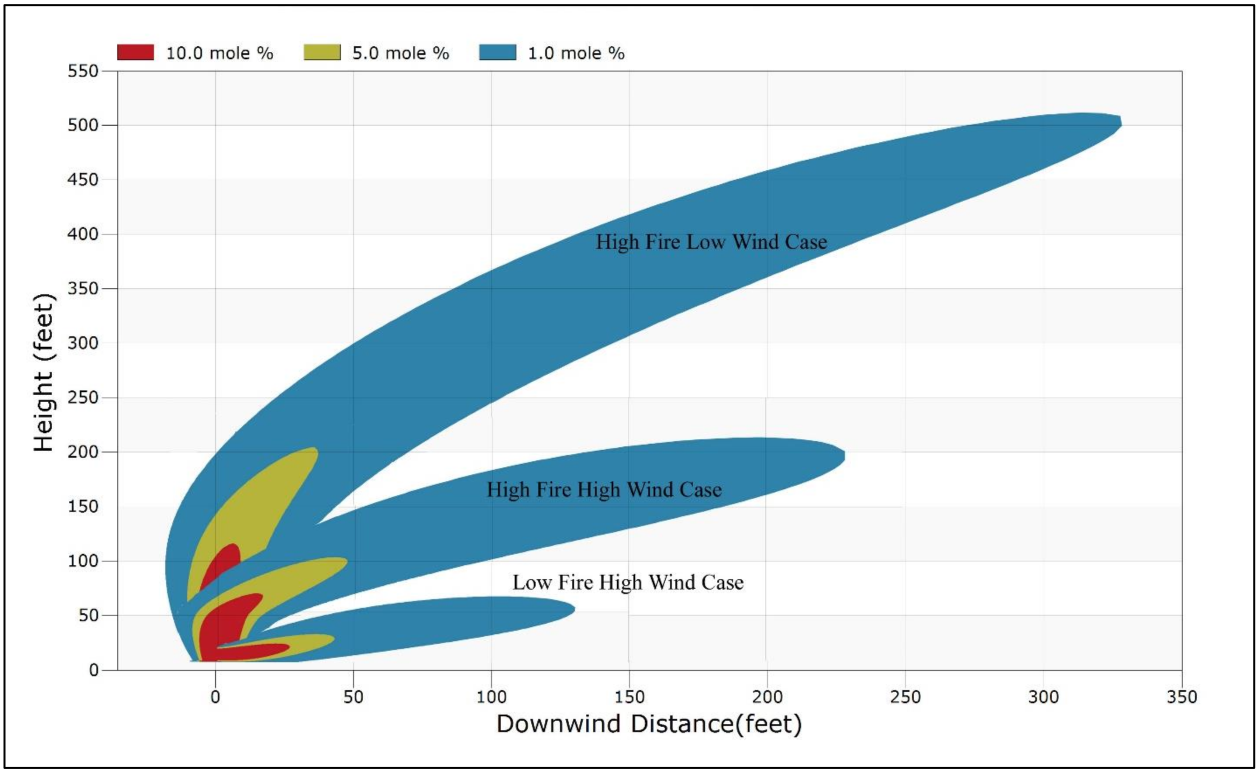
During the combustion phase, substantial temperature and buoyancy effect are produced by the open flame. During the module level UL9540A testing, smoke generation rates were estimated. Based on studies that involve the testing of a range of materials (Heskested 1994), in combination with smoke release rates and smoke generation rates, the flow of combustion products was estimated and then used in the CANARY© model to estimate the downwind impacts due to dispersion. Fire temperatures were assumed to be 1650 °F as per temperatures measured during testing.

Smoke levels above 1 - 10% in the air would displace oxygen and could produce impacts, as well as increased toxicity of the smoke could cause impacts. CANARY modeling estimated that the smoke concentrations would be as high as 1% concentrations as far as 325 feet from the fire, although this plume would be substantially elevated. Peak near-ground-level impacts could be realized as far as 60 feet from the Megapack. Figure 2 shows the horizontal profile of the combustion products plume for both the high fire case and lower fire case along with the range of wind speeds. The ground-level distance would not extend outside of the Project site boundaries and would not impact any off-site receptors. Therefore, impacts would be less than significant.

5.5 Flammable Vapor Impacts

The off-gassed materials could generate a flammable vapor cloud and may produce a flammable gas mixture (see above). The CANARY© computer model was utilized to estimate the distance that the flammable vapor cloud could reach (see Attachment C for the CANARY© model outputs and assumptions). The lower flammability limit (LFL) and the ½ LFL were used as an estimate of the potential impacts from flammable vapors. Distances for the LFL and the ½ LFL were estimated to be 15 and 18 feet for the multicell scenario, respectively, with a Megapack scenario extending to 18-30 feet. This distance would not extend outside of the Project site boundaries and would not impact any offsite receptors. Therefore, impacts would be less than significant.

Figure 2 Combustion Products Downwind Impacts



Notes: Analysis using the Canary© model windy (10 mph) meteorological conditions.

Explosion distances to a 1 psi overpressure assumed a high level of material reactivity (due to the presence of hydrogen) and a high obstacle density (due to the location of multiple cabinets together), thereby increasing the potential for an explosion, under a conservative scenario. The 1 psi overpressure levels are those at which building glass would shatter or light injuries occur due to fragments (NFPA 2014). Vapor cloud explosion impacts were estimated to be between 18-69 feet for the multicell and Megapack scenarios, respectively. This distance would not extend outside of the Project site boundaries and would not impact any offsite receptors. Therefore, impacts would be less than significant.

5.6 Thermal Impacts

Impacts from a fire could produce thermal radiation which could affect areas near the fire and areas offsite. During the UL9540A testing, thermal radiation impacts were measured at both 20 and 30 feet from the Megapack. The UL9540A testing indicated that the Megapack produced a fire for a peak period of about 10 minutes (from minutes 38-43 and minutes 53-58 of the test). Peak levels at 20 feet during that period were 28.8 kW/m^2 and averaged 19.1 kW/m^2. Peak levels at 30 feet during that period were 9.8 kW/m^2 and averaged 4.9 kW/m^2.

In order to estimate the thermal radiation at different distances from the Megapack during a fire scenario, a point source model for thermal radiation was utilized (CCPS 2003). The point source model uses the following equation:

$$q = \frac{x\,Q}{4\,\pi\,R}$$

Where

q = heat flux in kW/m^2

Q = heat release rate, kW

R = distance from the flame center, meters

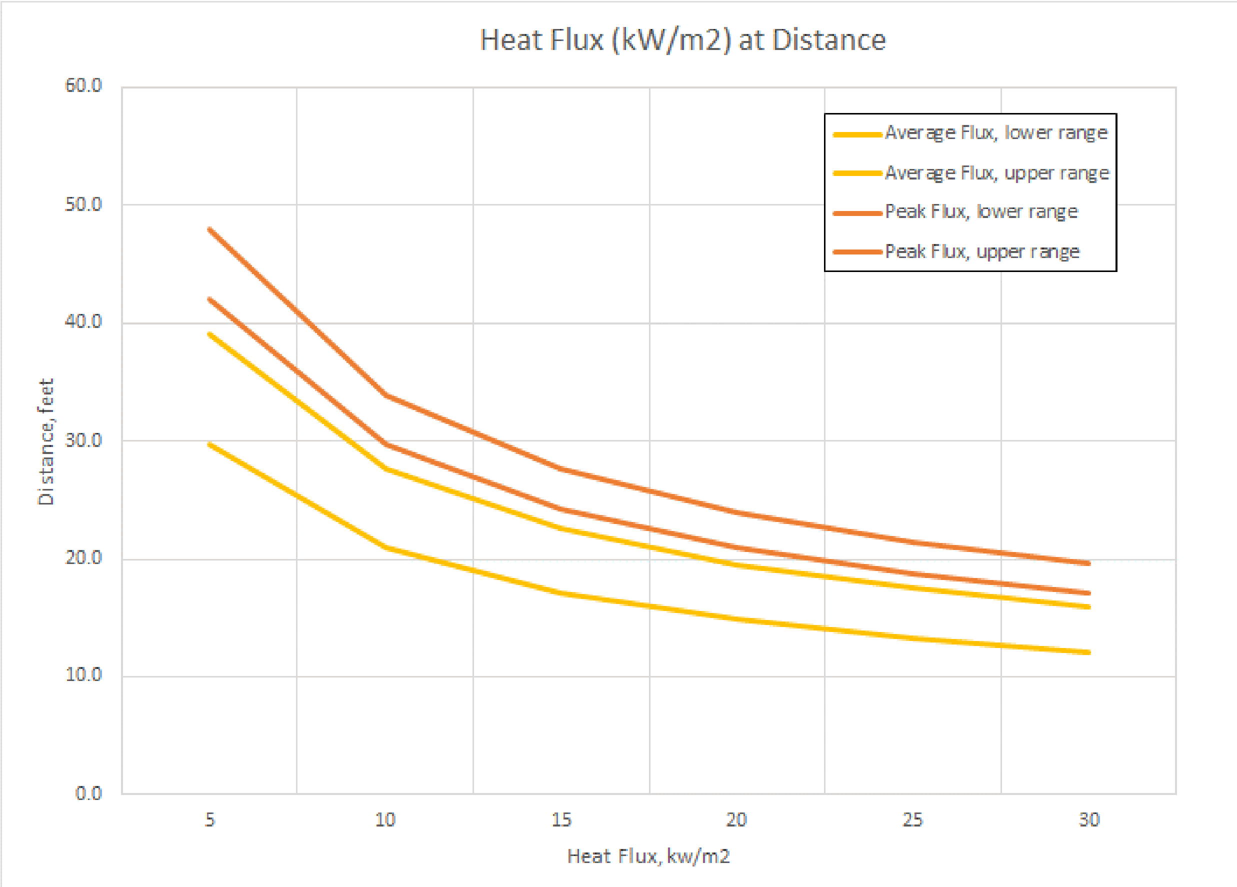
x = radiative fraction, energy fraction released as thermal radiation, with the fraction of energy released as radiation between 0.10 and 0.40 with a value of 0.35 conservatively assumed (as per SFPE 1999 and FMGlobal 2019).

Using the above point source approach, Figure 3 was produced showing the thermal flux at different distances from a Megapack fire. Note this is a conservative assumption as no impacts due to the atmosphere or smoke effects are assumed and a high fraction of heat to radiation is also assumed. The UL9540A testing examined heat flux at two different distances, which provide an estimate of the range of heat release rate generated from the fire. The figure shows the range of peak heat flux and the range of average heat flux for different heat flux levels and distance.

In general, when estimating the potential impacts of thermal radiation, both the level of heat flux and the duration are used to estimate the thermal dose or amount of heat transferred or the “thermal load”. Probit equations demonstrate this effect, as higher heat flux impacts to humans and materials can be tolerated at shorter durations (Lees 2014). Table 8 below shows different heat flux levels and associated impacts on humans and materials.

Note that heat flux impacts to humans can generally be tolerated below 5 kW/m^2 and below 10 kW/m^2 if sufficient time to escape is feasible. Heat flux levels that can produce spontaneous ignition in building materials generally do not occur below 12.5 – 20 kW/m^2.

Figure 3 UL9540 Analysis Estimated Heat Flux at Distance



Notes: using the point source model and the UL9540A results for peak and average heat flux at 20 and 30 feet, to define the ranges of impacts.

Table 8 Potential Thermal Impacts from Heat Flux Exposure and Duration

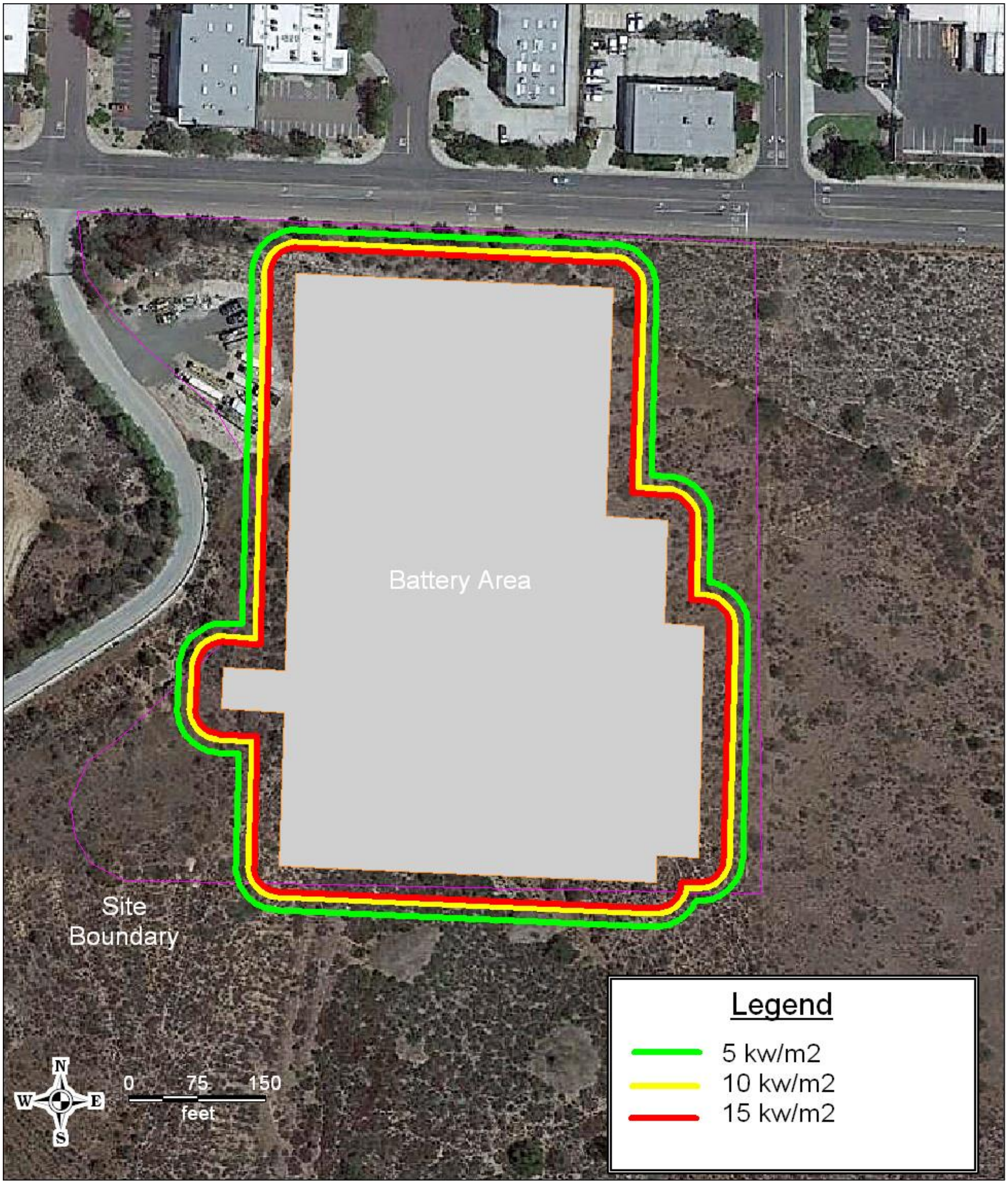
Incident Flux, kW/m^2	Duration	Impact
Impacts on Humans		
4.7	Multiple minutes	Emergency actions lasting several minutes can be performed without shielding
6.3	Several minutes	Emergency actions lasting several minutes can be performed without shielding
10.0	20 seconds	Time to threshold of pain for bare skin Threshold for thermal Class IV
12.5	1 minute 10 seconds	1% fatalities First degree burns
15.8	1 minute 10 seconds	100% fatalities Significant injury from burns
25.0	10 seconds	1% fatality
Impacts on Materials		
12.5	Long exposure	Threshold for ignition of combustible materials (plastics and wood).
12.5 - 25	Long exposure	Wood ignites
20	< 30 seconds	Paper spontaneously ignites
20	250 seconds	Wood particle board ignites
27	Long exposure	Threshold for damage to non-combustible materials
35.0	1 minute	Cellulosic material will spontaneously ignite
35.0	< 30 seconds	Cloth spontaneously ignites
37.5	13 minutes	7mm steel plate failure
40.0	< 30 seconds	Wood spontaneously ignites

Notes: from CCPS 2003, NRC 2004, NIOSH 2017, SFPE 1999 and 2020, FMGlobal 2019

Heat flux levels would not extend outside of the Project site boundaries if a thermal scenario were to occur at one of the Megapacks located at the closest area to the site boundary. See Figure 4 for a site map showing the heat flux values.

The battery installation would comply with the NFPA 855 Section 4.4.3.3, setback requirement of 10 feet from lot lines and public ways (see recommendations section below). In addition, the battery fire in the UL9540A tests took 38 minutes to develop, which, along with the detection systems proposed for the site, would allow for ample time to notify the fire department and evacuate persons from the areas near the Megapack installations. In addition, the intense fire period was of short duration (10 minutes) during the UL9540A tests during a 3.5 hour test. The thermal heat flux distance would not extend outside of the Project site boundaries and would not impact any offsite receptors. Therefore, impacts would be less than significant.

Figure 4 Site Map with Potential Worst-Case Thermal Flux Estimates

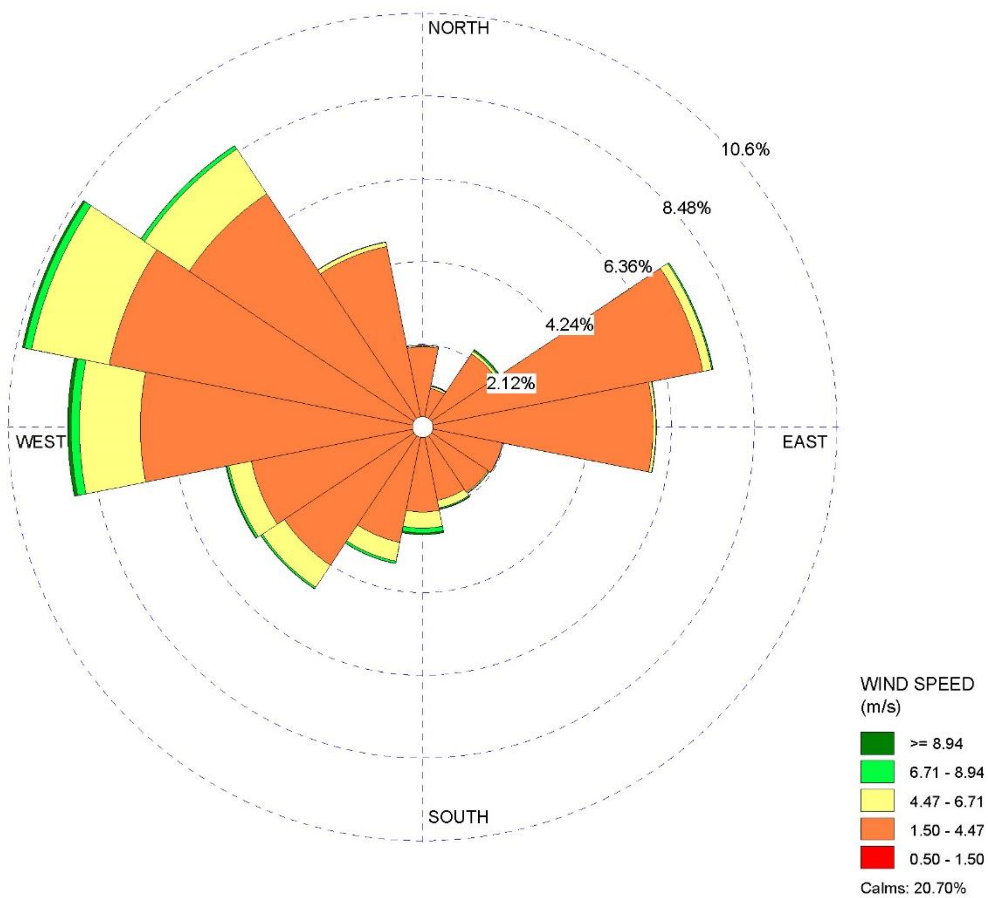


Notes: using the point source model and the UL9540A results for average and peak heat flux at 20 and 30 feet, to define the ranges of impacts.

5.7 Meteorological Data

The meteorological data shown in Figure 5 represents the meteorological conditions at the closest site (Marine Corps Air Station) for the years 2010-2014. The wind rose shows the predominant wind is from the west.

Figure 5 Meteorological Wind Rose



Note: For the Marine Corps Air Station Monitoring Station 2010-2014. Wind Rose shows the wind based on the direction the wind is from.

6.0 Fire Protection Measures, Isolation and Protective Action Distances

An effective fire response can mitigate many hazards. As discussed in Section 4.4, a fire at a Megapack is a relatively slow evolving scenario that does not produce a high energy flame jet or produce projectiles, explosions or flying debris, thereby allowing for firefighters to be on scene during an escalating scenario.

Tesla provides an Emergency Response Guide (Attachment B) for the Megapack detailing hazards, firefighting measures, shutting down and disposal of materials. The Emergency Response Guide recommends the following related to firefighting measures:

- If a fire develops and visible flames appear, it is recommended to apply water spray to neighboring battery enclosures and exposures rather than directly onto the burning unit.
- Applying water directly to the affected enclosure will not stop the thermal runaway scenario, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit.
- The cabinet door(s) should not be opened in such a scenario. Testing has shown that a thermal runaway scenario in a single Megapack does not propagate to a neighboring Megapack, even without the application of water or other suppression sources, but water can be used to further mitigate the hazard spread to exposures and surrounding.
- Water is considered the preferred agent for suppressing lithium-ion battery fires.
- If water is used directly on the enclosure that is burning, electrolysis of water (splitting of water into hydrogen and oxygen) may contribute to the flammable gas mixture formed by venting cells, burning plastic, and burning of other combustibles.
- A battery fire may continue for several hours and it may take 24 hours or longer for the battery pack to cool after it has been fully consumed by a thermal runaway scenario. A lithium-ion battery fire that has been seemingly extinguished can flare up again if all cells have not been consumed.
- Allow the battery pack to fully consume itself and then cool the burned mass by flooding with water. After all fire and smoke has visibly subsided, a thermal imaging camera can be used to actively measure the temperature of the unit.
- Tesla’s recommendation is to fight a Megapack fire defensively. The fire crew should maintain a safe distance and allow the battery to burn itself out. Fire crews should utilize a fog pattern to protect neighboring units or exposures or control the path of smoke. A single one-and-three-quarter inch (~5cm) hand line has shown to be sufficient.
- Firefighters should wear self-contained breathing apparatus (SCBA) and fire protective turnout gear.

In addition, a site-specific Fire Protection Plan will be developed for the facility and will address the following issues:

- State and Local requirements;
- Code Requirements;
- Battery OEM-provided Fire Protection Features;

- Fire Hydrant Placement;
- Water Design Flows;
- Fire Truck Access;
- Hazard Mitigation Analysis Approach;
- Permits;
- First Responder Training; and
- Variance and Approvals from Fire Official.

NFPA 855 and studies by DNVGL (2017) contain a number of recommendations related to fire department response. NFPA 855 Annex C provides fire-fighting considerations, summarized below:

- Identifying the location of all electrical disconnects in the building and understanding that electrical energy stored in ESS equipment cannot always be removed or isolated.
- Understanding the procedures for shutting down and deenergizing or isolating equipment to reduce the risk of fire, electric shock, and personal injury hazards.
- Understanding the procedures for dealing with damaged ESS equipment in a post-fire incident.
- Fires involving lithium-ion cells must be cooled to terminate the thermal runaway process and water is the agent of choice.
- Response should include commonly accepted practices with any hazmat response, including isolating the area to all personnel, confirming location and type of alarm, performing air monitoring, managing ventilation/exhaust, and suppressing fires.
- The response of a qualified and trained individual in ESS should be made available.
- A user interface to access the state of operating parameters or a method to interface to monitored alarm systems would enhance the effectiveness of the response.
- Response procedures and steps:
    - Isolate area of all nonessential personnel.
    - Review status of both building and ESS alarm system with available data.
    - Review status of any fire protection system activation.
    - Perform air monitoring of all connected spaces.

  - Identify location of overheated battery.
  - Isolate affected battery, string, or entire system based on the extent of damage by opening battery disconnect switches, where provided.
  - Contact person or company responsible for O&M of system.
  - Continue temperature monitoring to ensure mitigation of overheating condition.

- Responding fire companies should use gas detection equipment to determine toxic gas levels.
- Full PPE and SCBA should be used during a fire and post-fire scenario.
- Fire fighters should never use piercing nozzles and long penetrating irons. Mechanically damaged cells or puncturing unburned or undamaged cells can result in the immediate ignition of those cells.
- Li-ion batteries might continue to generate flammable gases during and after extinguishing.
- Batteries should be monitored for residual heat and temperature, as reignition is a possibility in cells that are not sufficiently cooled.
- Though trace amounts of heavy metals such as nickel and cobalt can be deposited from combustion of the batteries, these elements are not expected to be present in large quantities or in quantities larger than any other similar fire. In most instances, water exposed to the batteries shows very mild acidity, with an approximate pH of 6. Runoff water pH can be monitored during fire-fighting operations but should not pose a greater risk than normal fire-fighting run-off.

DNVGL Studies (2017) also recommends the following:

- Fire scene considerations include:
  - Has on-site extinguishing already been triggered?
  - Is the system gassing?
  - Is the temperature of the system rising?
  - Are flames visible?
  - Is there a site representative available?
- An information display panel, or other form of emergency contact, will greatly aid in assessing the risk.

- Battery fires, even once extinguished, continue to emit CO as long as the batteries remain hot and CO monitoring should be performed.
- Partially burned systems may continue to emit flammable gas even after the fire is extinguished as long as the cells remain hot. Proper cooling of the system is key to remove prolonged fire risks.
- If flames are visible and temperature is rising, the system may have more than one battery cell or module engulfed.
- If temperatures are rising rapidly (>1 °F per minute) and temperatures on the battery are approaching anywhere near 100 °C (212 °F), cooling will be required with water.
- Monitoring with handheld infrared (IR) thermometers, if available, should provide an assessment of risk.
- Cooling the battery once flames are knocked down is the most important aspect of containing battery fires. Water was found to be the most effective at cooling. Shock during water suppression (via conduction into the water spray) was not observed.
- Water should be used to provide indirect cooling on the outside of the system to prevent spreading.

In the event of a fire and/or off-gassing at the facility, the USDOT Emergency Response Guide (2020) provides estimates of the initial isolation and protective action distances recommended for small and large spills (defined as less than or more than 55 gallons). The isolation and protective action distances for lithium-ion batteries (Guide 147) is as follows:

- Isolate spill or leak area for at least 25 meters (82 feet) in all directions.
- Large Spill: Consider initial downwind evacuation for at least 100 meters (328 feet).
- Fire: If rail car or trailer is involved in a fire, isolate for 500 meters (1/3 mile) in all directions; also initiate evacuation including emergency responders for 500 meters (1/3 mile) in all directions.

7.0 NFPA 855 Hazard Mitigation Analysis Requirements

NFPA 855 Section 4.1.4 and the California Fire Code Section 1206.1.4 requires a hazard mitigation analysis under the following circumstances:

1. *When technologies are specifically not addressed in NFPA 855 Table 1.3 or CFC Table 1206.1.*
2. *More than one ESS technology is provided in a room or indoor area where adverse interaction between the technologies is possible.*

3. *When allowed as a basis for increasing the maximum stored energy as specified in NFPA 855 section 4.8.1 and 4.8.2 of CFC 1206.5.2.*

The lithium technology is specifically listed in NFPA 855 Table 1.3 and the technology is not located inside of a room. Therefore, numbers 1 and 2 are not applicable.

NFPA 855 Section 4.8.1 is applicable to areas in non-dedicated use buildings and is not applicable to this Project as this Project would be located entirely outside with no buildings.

NFPA 855 Section 4.8.2 allows for approval of an outdoor ESS installation that exceed 600 kWh if a hazard mitigation analysis in accordance with Section 4.1.4 and large scale fire testing as per 4.1.5.

NFPA 855 Section 4.8 (2) indicates that "*Outdoor ESS installations in locations near exposures as described in 4.4.3.1(2) [within 100 feet of buildings] shall not exceed the maximum stored energy values in Table 4.8 [600 kWh] except as permitted by 4.8.3."*

NFPA 855 Section 4.1.4 and CFC Section 1206.1.4 addresses the requirements for a hazard mitigation analysis. Section 4.1.4.2 specifies:

NFPA 855 Section 4.1.4.2 and CFC Section 1206.4.1 The analysis shall evaluate the consequences of the following failure modes and other deemed necessary:

1. *Thermal runaway condition in a single module, array or unit.*
2. *Failure of an energy storage management system.*
3. *Failure of a required ventilation or exhaust system.*
4. *Failure of a required smoke detection, fire detection, fire suppression or gas detection system.*
5. *Voltage Surges on the primary electrical supply (CFC 1206.1.4).*
6. *Short circuits on the load side of the ESS (CFC 1206.1.4).*
7. *Required spill neutralization not being provided or failure of a required secondary containment system (CFC 1206.1.4).*

In addition, NFPA 855 Section 4.1.4.3 and CFC Section 1206.1.4 indicates that a hazard mitigation analysis should demonstrate the following:

1. *Fire will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rate specified in NFPA 855 Section 4.3.6 or CFC Section 1206.7.4.*
2. *Suitable deflagration protection is provided where required (NFPA 855).*
3. *ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.*

4. Toxic and highly toxic gases released during normal charging, discharging, and operation with not exceed the permissible exposure limit in the area where the ESS is contained.

5. Toxic and highly toxic gases released during fires and other fault conditions will not reach IDLH concentrations in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area

6. Flammable gases released during charging, discharging and normal operations will not exceed 25 percent of the LFL

This report documents the reasonable worst-case failure that could lead to a release of toxic and flammable materials, and documents that the levels of toxic and flammable materials do not produce impacts offsite in high density areas, such as residential areas. This report indicates that the primary focus is on the worst-case reasonable scenario which could produce the largest impacts. This report also indicates that it is assumed that the control systems fail and do not control the battery cell malfunction in line with the requirements for a hazard mitigation analysis under NFPA 855, Section 4.1.4.2.

The analysis in this report demonstrates, in response to the above listings from NFPA 855 Section 4.1.4.3, that:

1. The process would be located outside, so containment of fire within rooms is not applicable.

2. Deflagration protection is provided in the form of over-pressure ventilation and sparkers to ensure combustion of gases as well as the facilities would be installed outside, thereby reducing the potential for deflagration. As per the UL9540A unit level testing, the detection system alarmed from the off-gassing within 38 seconds that, with local alarms, allowing for rapid detection of any potential deflagration scenario.

3. There would not be any occupied work centers as all cabinets would be located outside.

4. During normal charging, discharging, and operations, no discharges of toxic materials would occur.

5. Reasonable worst-case fault conditions would release flammable and toxic materials, but the hazard levels are determined to be acceptable as they do not impact areas with high density areas or expected regular populations. Multiple egress routes (to the east and to the south) are available and detection systems, including the flame detection and high temperature monitoring and alarms, would allow for egress routes to be utilized during the time necessary to evacuate from the area. As per the UL9540A unit level testing, the detection system alarmed from the off-gassing within 38 seconds that, with local alarms, allow sufficient time for egress efforts.

6. During normal charging, discharging operations, no discharges of flammable materials would occur and therefore the 25 percent of the LFL levels would not be exceeded.

NFPA 855 Section 4.1.5 and CFC Section 1206.1.5 requires large scale fire testing, which was conducted by Tesla and TUV.

Therefore, this report satisfies the NFPA 855 and CFC 1206 requirements for a hazard mitigation analysis.

NFPA 855 Section 4.2.1 and CLC Section 1206.3 requires that battery systems be listed in accordance with UL 9540. The Tesla battery systems have been tested and certified to comply with UL 1973 and UL 9540.

8.0 Recommendations

Recommendations related to siting and Megapack installation would help to ensure that the potential for significant hazards are minimized. These would include the following:

1. All batteries shall be discharged to below 30% state of charge (SOC) during the construction/installation phases.
2. Any replacement or maintenance of batteries requiring the use of heavy construction equipment, such as cranes or forklifts, shall be conducted only on batteries discharged to below 30% SOC and nearby batteries that could be affected shall also be discharged to below 30% SOC.
3. Vehicle impact bollards or equivalent shall be installed to reduce the potential for vehicle impacts (as per NFPA 855 Section 4.3.7).
4. Install detection systems for flame detection, being equal to or similar to the Det-Tronics x3302 flame detector.
5. Detection systems shall alarm locally and both visually and audibly, shall be monitored by a 24-hour system and shall notify the local Fire Department.
6. Indication shall be provided to responders at the site indicating which Megapack is experiencing issues in the form of a user-friendly user interface system.
7. Develop an Emergency Operations Plan in compliance with sections of NFPA 855 Section 4.1.3.2.1, including:
    a. Procedures for safe shutdown, de-energizing and isolation of equipment under emergency situations;
    b. Procedures for inspection and testing of alarms, interlocks, detection systems and controls including recordkeeping;
    c. Procedures to be followed in response to notification from the storage systems that could signify dangerous situations, including shutting down equipment and notification to the local fire department;

   d. Emergency procedures to be followed in case of fire, explosion, release of liquids or vapors, damage to critical moving parts, or other potentially dangerous conditions;

   e. Response considerations similar to a safety data sheet (SDS) that will address response safety concerns and extinguishment when an SDS is not required;

   f. Procedures for dealing with ESS equipment damaged in a fire or other emergency scenario, including contact information for personnel qualified to safely remove damaged ESS equipment from the facility;

   g. Other procedures as determined necessary by the AHJ to provide for the safety of occupants and emergency responders; and

   h. Procedures and schedules for conducting drills of the procedures.

8. Develop a Fire Protection Plan prior to startup, that identifies and summarizes the design safety features identified in the Project description and measures required pursuant to the measures above. Measures required by the Fire Department shall be included in the Fire Protection Plan. The Plan shall include a graphic depiction of Project safety features and equipment onsite, including but not limited to, the following:

   a. Fire prevention, detection, and suppression features, including:

      i. a description of the BMS and the monitoring of alarms and battery cell conditions and thresholds for alarms;

      ii. flame detection systems, including the location of detection, type of detection and the monitoring of alarms (NFPA 855 Section 4.10);

      iii. availability of water for firefighting and compliance with Fire Department requirements for flow and availability (NFPA 855 Section 4.13);

   b. Emergency response procedures, including notification of local responders (NFPA 855 Section 4.1.3.2.1 and A.4.1.3.2);

   c. Personnel safety training (NFPA 855 Section 4.1.3.2.2 and 7.2.5);

   d. Fire suppression and other safety features/equipment located at the site;

   e. Type and placement of warning signs (NFPA 855 Section 4.3.5);

   f. Emergency ingress and egress routes (NFPA 855 Section 4.3.10);

   g. Special safety measures to be implemented for battery installation and replacement, including disposal of replaced (discarded) equipment;

h. Provisions and timing for updating the Plan to incorporate new or changed requirements;

i. Control of vegetation (NFPA 855 Section 4.4.3.6);

j. Security of installations (NFPA 855 Section 4.3.8);

k. Access roads design (NFPA Section 4.3.8);

l. Signage (NFPA Section 4.3.5); and

m. Remediation measures (NFPA 855 Section 4.5.4 and 4.16) including authorized service personnel and fire mitigation personnel.

9. Provide a copy of an NFPA 855 compliance audit report to verify that the system is designed and built to comply with the NFPA 855 requirements prior to system startup.

Studies have shown (Golubkov 2015) that the potential for thermal runaway is a strong function of the level of charge of the batteries, with batteries that are charged below 50% having a lower potential for runaway and lower levels of off-gassed volume given an external accident scenario. Therefore, when construction equipment is operating onsite, batteries that could be affected should be discharged to less than 30% SOC in order to reduce the potential for thermal-runaway accidents.

In addition, ensuring all batteries are protected from vehicle impacts would reduce the potential for accident scenarios associated with vehicle impacts.

Detection systems allow for efficient response coordination and rapid detection of potential issues of concern. Flame detection are recommended to ensure detection of a range of scenarios, with local and remote notifications, and to alert onsite personnel of potential issues and allowing for rapid egress if needed.

An Emergency Operations Plan ensures procedures are in place to respond to emergency scenarios including notification to the local responders.

9.0 Summary of Impacts and Conclusions

Results from the analysis indicate that the reasonable worst-case battery cell malfunction scenarios would result in manageable hazards, with ground-level toxic, thermal and deflagration hazards remaining onsite. Therefore, the maximum potential public health impacts for the battery facility are considered less than significant.

10.0 References

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USDOT, 2020 Emergency Response Guidebook

Attachment A Megapack XL Design Specification

Megapack 2 XL Specification - Rev. 1.6.4

PRE-PRODUCTION SPECIFICATION: SUBJECT TO CHANGE.
APPLICABLE TO MEGAPACK 2 XL SYSTEMS TO WHICH THIS SPECIFICATION IS EXPRESSED TO APPLY

PRODUCT SPECIFICATIONS

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1 System Description

Tesla Megapack 2 XL (Megapack) is an all-in-one utility-scale energy storage system optimized for cost and performance. It scales to the space, power, and energy requirements of any site from 1 MWh to 1 GWh+. The product is a complete energy storage solution including batteries, bi-directional inverter, thermal system, and a Tesla Site Controller with intelligent software.

This turnkey system is designed to maximize savings and prolong battery life. Megapacks have the most advanced battery technology and dispatch optimization software to quickly learn and predict a facility's energy patterns. Tesla's proprietary storage dispatch software can charge and discharge autonomously to maximize customer value.

Megapack's architecture consists of battery cells aggregated into modules, and power electronics modules. Both are thermally managed by an integrated liquid cooling and heating system for thermal safety, enhanced performance, and reliability. The architecture also includes sensors supporting embedded monitoring and controls as well as electrical interface equipment including an industry standard breaker for AC protection.

1.1 Application

Megapack is capable of various on-grid applications such as tariff optimization, peak load shaving, energy shifting, and demand response. In addition, the system can operate as a microgrid to support backup and islanded systems.

1.2 Capacity Maintenance

Megapack can be provided with a Capacity Maintenance Agreement (CMA), which guarantees power and energy capacity over the life of the product. A capacity-maintained system requires the addition of battery modules over time to maintain power and energy. The product is designed to accommodate these additions over time without impact to site design. This specification describes up to a 10-year capacity-maintained system operated up to one full cycle per day. Upon request, Tesla can also provide specifications for CMA lengths of 15 or 20 years. Technical details and characteristics differ between a product with Capacity Maintenance Agreement and a product without. These differences are highlighted in the relevant sections within this specification. Capacity maintenance is offered for projects with a minimum size of 10 MWh.

1.3 Constituent Parts

Each Megapack enclosure includes the following components provided by Tesla:

- Smart inverter
- AC main breaker
- Battery modules
- Thermal system
- Tesla Site Controller
- Low voltage interface panel

1.4 Definitions

Battery Cell: The smallest non-divisible energy component of the Megapack, assembled into a battery module in series and parallel arrays.

Battery Module: A field-replaceable unit that integrates battery cells, fusing, and battery management system functions. The battery module interfaces are output electrical connections, thermal interface, and communication connections.

CMA: Capacity Maintenance Agreement, used to define a system that guarantees power and energy over the life of the system.

Communication cable harness: A pre-manufactured cable with locking connectors on both ends to connect Megapacks to the site-level control interface of the Tesla Site Controller.

Efficiency Degradation (%): Represented with a stated efficiency value at the beginning of life and the minimum seen over 10 years and 365 cycles/year.

Fully Operational: The operating condition where the system is capable of discharging or charging at full power.

kWp: Nameplate AC power rating of the system, or kilowatt peak.

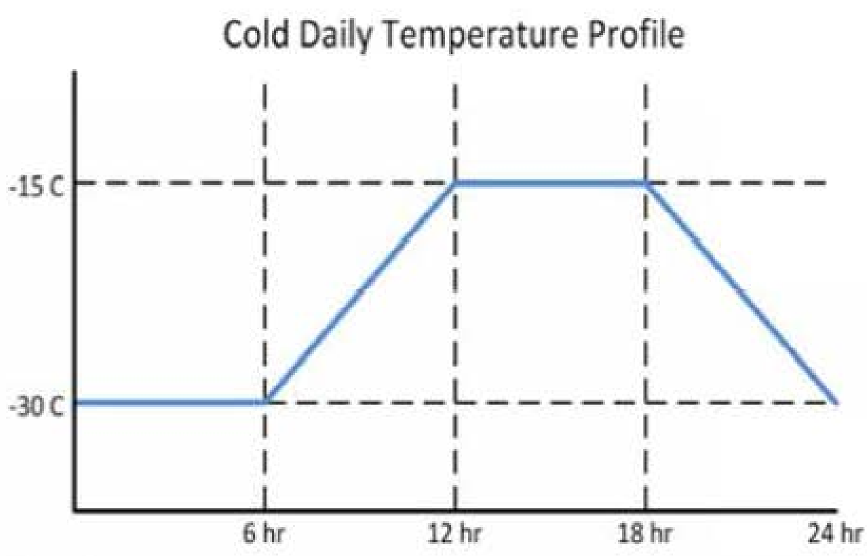
PCS or **Inverter:** Bi-directional power conversion system that couples each Megapack with the power grid (AC power).

Megapack: The complete AC-coupled system, inclusive of battery modules, inverter, thermal system, and Tesla Site Controller.

PCC: Point of Common Coupling.

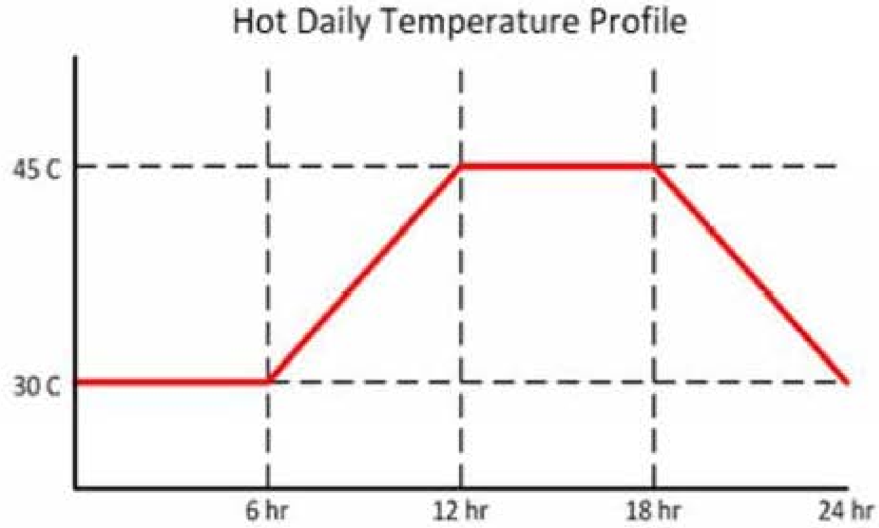
Profile$_{COLD}$: The ambient temperature daily profile for cold weather standby use, indicative of winter in Grand Forks, ND, is defined below:

Figure 1. Cold Daily Temperature Profile



Profile$_{HOT}$: The ambient temperature daily profile for hot weather standby use, indicative of summer in Palm Springs, CA, is defined below:

Figure 2. Hot Daily Temperature Profile



Roundtrip Efficiency (%): Defined as discharge of the system from 100% SOE to 0% SOE at kWp immediately followed by charging the system from 0% SOE to 100% SOE at kWp. The roundtrip AC-AC energy efficiency shall be measured at the AC terminals of the inverter and shall include parasitic loads.

SOE with CMA: Battery State of Energy: Available energy / Rated energy (0-100%).

SOE without CMA: Battery State of Energy: Available energy / Full Megapack energy (0-100%).

STC: Standard Test Conditions, defined as the system soaked at 25°C and 1 atmosphere (101.3 kPa) of pressure.

System Duration: The amount of time the Megapack can continuously charge or discharge power at kWp when new.

$T_{AMBCOLD}$: The ambient temperature for cold weather performance is defined as the system soaked at -20°C. This temperature definition is used to define the system performance in a nominally cold temperature climate. This temperature does not define the operating limitation or temperature rating of the system.

T_{AMBHOT}: The ambient temperature for hot weather performance is defined as the system soaked at 45°C. This temperature definition is used to define the system performance in a nominally hot temperature climate. This temperature does not define the operating limitation or temperature rating of the system.

Tesla Site Controller: Site-level control interface that is the single point of feedback and control for a physical installation. It is also responsible for collecting feedback data from each individual Megapack, running algorithms to optimize the system operation, and providing commands to inverters.

1.5 Standards and Regulations

The system and components are compliant with the standards and directives listed in the *Megapack 2 XL Compliance Packet*, found on the Tesla Partner Portal web site at https://partners.tesla.com/.

2 Electrical Specifications

Megapack is rated in terms of net-delivered power and minimum energy at its AC output terminals. Loads and losses, including power conversion, thermal system losses, auxiliary loads, and chemical/ionic losses are considered internal to the system and ratings are net of these loads. Losses between the AC output terminals and the point of interconnection with the customer/utility are site-dependent and excluded from the rated power and energy.

2.1 Power and Energy

System ratings are defined in kWp and kWh as measured at the AC terminals of the Megapack. The given energy ratings (kWh) in this document are minimum initial energy ratings.

Megapack is capable of providing nameplate kWh energy at nameplate kW when discharged from 100% SOE at STC. Megapack is capable of charging or discharging at the rated power for the life of the system. The maximum duration of charge/discharge will decrease over the life of the system. The kW is net of thermal loads and can be achieved throughout life.

A fully populated Megapack has the following nominal ratings at 480 V AC:

Table 1. Nominal Fully Populated Ratings

System Duration	Max. Configurable AC Power (kVA)	AC Power (kWp)	AC Minimum Initial Energy (kWh)
2-hour	2400.0	1927.2	3854.4
4-hour	1632.0	969.6	3878.4

2.1.1 Scaling Power and Energy

Megapack can be requested with lower factory-configured inverter ratings. See *Inverter Configurations* on page 9 for more details.

Megapack can be requested with fewer battery modules. See *Battery Module Configurations* on page 10 for more details.

2.2 Roundtrip Efficiency and Energy Consumption

Roundtrip efficiency (RTE) is defined as the relative difference in energy charged to the system from 0% SOE to 100% SOE at kWp immediately followed by energy discharged of the system from 100% SOE to 0% SOE at kWp. The quotient of energy discharged over energy charged is the RTE. This RTE includes all thermal system energy consumption and all internal Megapack control power consumption during the cycle.

The roundtrip efficiency and auxiliary energy consumption is specified in the table below:

Table 2. Roundtrip Efficiency and Energy Consumption

Parameter	2-Hour System	4-Hour System
Roundtrip Efficiency (Year 0) inclusive of thermal management loads	STC: 92.5% T_{AMBHOT}: 91.0% $T_{AMBCOLD}$: 92.5%	STC: 94.0% T_{AMBHOT}: 93.0% $T_{AMBCOLD}$: 93.5%
Minimum Roundtrip Efficiency (non-CMA) over 15 years*	STC: 90.0% T_{AMBHOT}: 88.0% $T_{AMBCOLD}$: 90.0%	STC: 92.0% T_{AMBHOT}: 91.5% $T_{AMBCOLD}$: 92.0%

** Indicative figures. Exact value will depend on battery utilization and climate over the 15 years.*

2.3 Charge and Discharge Limitations

Megapack's thermal management system is used to maintain the battery's charge and discharge capabilities across the system's rated temperature range. In cold ambient conditions, operating in this state results in lower overall efficiency due to increased parasitic loads.

By activating heat mode, the 2-hour or 4-hour Megapack can be preconditioned to allow rated charge/ discharge power. Heating will be required to maintain full power capability if Megapack battery temperature drops below 20C.

2.4 Inverter Specifications

Table 3. Inverter Specifications

Max Continuous Output Current	Factory-configurable (See *Inverter Configurations* on page 9)
Overload Capability	120% of rated current (10 sec max)
Output Voltage Range	432-552 V AC (480 V AC nominal)
Nominal Frequency (configurable)	50 or 60 Hz
Frequency Range	45-66 Hz
Phases	3
System Configuration	3-wire, Wye **Note:** Grounded Wye required at transformer secondary
Full Load Efficiency	98.3%
CEC Weighted Efficiency	98.5%
Power Factor at Full Load	> 99%
Adjustable Power Factor (Controller Feature)	-1 to +1

Total Current Harmonic Distortion (THD)	< 5%
Power Regulation Accuracy	< 2%
Overvoltage Category	Category III up to 3000 m
Maximum Short Circuit Current Withstand	85 kAIC

2.4.1 AC Interface

2.4.1.1 Medium Voltage Transformer Connection

If Megapack is connected to a medium-voltage transformer, the transformer must be a grounded wye transformer and the connection must be made via a 3-wire circuit (3 phases, ground) connection.

It is possible to parallel multiple Megapacks on the low-voltage side of a transformer without providing additional galvanic isolation.

2.4.1.2 AC Breaker

Each Megapack includes an AC breaker with the following features:

- 85 kAIC interrupting capacity (2-hour and 4-hour Megapacks)
- GND fault detection
- Shunt trip
- Pad lockable

2.4.1.3 Voltage Ride-Through

The maximum HVRT the Megapack system can allow is 1.3 per unit at POI. This HVRT capability can be achieved so long as Megapack is connected to the grid via a transformer of at least 5.75% impedance.

Table 4. Setting Ranges

Parameter	Setting Range	Resolution
Voltages	0.00-Maximum HVRT Allowed	0.01 per unit
Times	0.00-60.00 sec*	0.01 sec

** Time allowed a specific per-unit voltage depends on the nominal voltage rating. Typically, default settings and acceptable ranges are tested as part of a specific certification. For deviations from certified settings in a region, please contact a Tesla Sales Engineer.*

Megapack has five voltage and time setpoints for low voltage ride-through (LVRT), configurable to the following ranges:

Table 5. Megapack LVRT Settings

Parameter	Default Values for 480 V
LVRT Point 5	88% @ 2.00 sec
LVRT Point 4	60% @ 1.00 sec
LVRT Point 3	45% @ 0.13 sec
LVRT Point 2	45% @ 0.13 sec

Parameter	Default Values for 480 V
LVRT Point 1	45% @ 0.13 sec

Megapack has four high voltage ride-through (HVRT) setpoints, with one instantaneous trip voltage setting, configurable to the following ranges:

Table 6. Megapack HVRT Settings

Parameter	Default Values for 480 V
HVRT Point 3	120% @ 0.13 sec
HVRT Point 2	120% @ 0.13 sec
HVRT Point 1	110% @ 1.00 sec
HVRT max trip	121%

The table below represents the maximum per-unit voltage value that can be set for a given nominal system voltage. If site-specific ride-through requirements at the Point of Common Coupling are required, contact a Tesla Sales Engineer.

Table 7. Maximum HVRT Values

Nominal System Voltage	480 V AC
Maximum HVRT Allowed	130% @ 0.2 sec

Table 8. Trip Accuracy

Trip Setting	Accuracy
Voltage	+/- 2% of nominal voltage
Frequency	+/- 0.01 Hz
Reconnection Time	1% of set point
Trip Time	+/- 100 mS

2.4.1.4 Frequency Ride-Through

The Megapack inverter is capable of staying connected to the distribution provider's distribution or transmission system while the grid is within the frequency-time range indicated in the table below and will disconnect from the electric grid during a high or low frequency event that is outside that frequency-time range.

The Megapack inverter allows for a minimum of 3 under-frequency and 3 over-frequency trip points and times, as well as 1 under-frequency instantaneous trip and 1 over-frequency instantaneous trip.

Table 9. Frequency Ride-Through

Trip Point	Frequency Range	Time (sec)	Notes
Instantaneous UF Trip	40 Hz-70 Hz	Instantaneous	0.1 Hz resolution, filtering as necessary
UF Trip Time 3	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
UF Trip Time 2	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
UF Trip Time 1	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
OF Trip Time 1	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
OF Trip Time 2	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution

Trip Point	Frequency Range	Time (sec)	Notes
OF Trip Time 3	40 Hz-70 Hz	0-600	0.1 Hz and 0.01 second resolution
Instantaneous OF Trip	40 Hz-70 Hz	Instantaneous	0.1 Hz resolution, filtering as necessary

2.4.1.5 Anti-Islanding Features

The Megapack inverter includes these anti-islanding features:

- Reconnection delay timer
- Active anti-islanding: Sandia Frequency Shift implemented on all systems
- Passive anti-islanding: Configurable Rate of Change of Frequency (ROCOF) preferences

The reconnection delay timer is configurable with the following settings:

Table 10. Reconnection Delay Timer Default Settings

Feature Name	Effect	Setting Range	Default
Reconnect Time Delay	The amount of time Megapack waits before reconnection, after the grid returns within the frequency and voltage ride-through windows defined above	0-600 sec	300 sec
Reconnect Min. Voltage	The minimum voltage at which Megapack interprets the grid is within tolerable conditions	0-150%	88.33%
Reconnect Max. Voltage	The maximum voltage at which Megapack interprets the grid is within tolerable conditions	0-150%	105.83%
Reconnect Min. Frequency	The minimum frequency at which Megapack interprets the grid is within tolerable conditions	40-70 Hz	59.3 Hz
Reconnect Max. Frequency	The maximum frequency at which Megapack interprets the grid is within tolerable conditions	40-70 Hz	60.5 Hz

Sandia Frequency Shift is enabled by default, but can be disabled if required for the application. ROCOF is configurable with the following settings:

Table 11. ROCOF Settings

Feature Name	Effect	Setting Range	Default
ROCOF Enable	Turns ROCOF on or off	n/a	Off
ROCOF Fault Limit	Sets the rate of change required for a trip	0.1-100.0 Hz/sec	1 Hz/sec
ROCOF Time Delay	Sets how long the rate of change has to be present for the inverter to trip	0-1 second	1 second

2.4.1.6 Inverter Configurations

The configurations listed below are example inverter configurations. Megapack can be requested to be factory-configured with other current limits lower than the maximum below to de-rate to meet particular project needs. Any multiple of 100 kVA over and including 300kVA is available as a factory configuration.

The Megapack inverter should be configured with a kVA rating at least 60 kVA (2-hour systems) or 25 kVA (4-hour systems) higher than the site requirement, to ensure the Megapack can supply enough AC current to simultaneously run the thermal system and discharge in accordance with commands.

Megapacks with fewer battery modules will have a lower absolute maximum, as indicated in *Battery Module Configurations* on page 10.

Table 12. Example Inverter Configurations

Power Configuration Factory Product Code	Configured Inverter Power Rating [kVA]	Maximum Continuous Output Current [A]	Applicable Megapack Type
P240	2400.0	2886.8	2-Hour Maximum
P230	2300.0	2766.5	2-Hour
P220	2200.0	2646.2	2-Hour
P210	2100.0	2525.9	2-Hour
P200	2000.0	2405.6	2-Hour
P163	1632.0	1963.0	4-Hour Maximum and 2-Hour
P140	1400.0	1683.9	4-Hour and 2-Hour
P136	1363.2	1639.4	4-Hour and 2-Hour
P130	1300.0	1563.7	4-Hour and 2-Hour
P120	1200.0	1443.4	4-Hour and 2-Hour
P110	1100.0	1323.1	4-Hour and 2-Hour
P100	1000.0	1202.8	4-Hour and 2-Hour
P030	300.0	360.8	4-Hour and 2-Hour Minimum

2.4.1.7 Battery Module Configurations

Table 13. Available Battery Configurations

Battery Module Count (Code)	2-Hour Megapack Rating (kW / kWh)	4-Hour Megapack Rating (kW / kWh)	Maximum Allowable Inverter Configuration for 2hr / 4hr
8 (EC08)	642.4 kW / 1284.8 kWh	323.2 kW / 1292.8 kWh	1088 kVA (2hr) / 544 kVA (4hr)
9 (EC09)	722.7 kW / 1445.4 kWh	363.6 kW / 1454.4 kWh	1224 kVA (2hr) / 612 kVA (4hr)
10 (EC10)	803.0 kW / 1606.0 kWh	404.0 kW / 1616.0 kWh	1360 kVA (2hr) / 680 kVA (4hr)
11 (EC11)	883.3 kW / 1766.6 kWh	444.4 kW / 1777.6 kWh	1496 kVA (2hr) / 748 kVA (4hr)
12 (EC12)	963.6 kW / 1927.2 kWh	484.8 kW / 1939.2 kWh	1632 kVA (2hr) / 816 kVA (4hr)
13 (EC13)	1043.9 kW / 2087.8 kWh	525.2 kW / 2100.8 kWh	1768 kVA (2hr) / 884 kVA (4hr)
14 (EC14)	1124.2 kW / 2248.4 kWh	565.6 kW / 2262.4 kWh	1904 kVA (2hr) / 952 kVA (4hr)
15 (EC15)	1204.5 kW / 2409.0 kWh	606.0 kW / 2424.0 kWh	2040 kVA (2hr) / 1020 kVA (4hr)
16 (EC16)	1284.8 kW / 2569.6 kWh	646.4 kW / 2585.6 kWh	2176 kVA (2hr) / 1088 kVA (4hr)
17 (EC17)	1365.1 kW / 2730.2 kWh	686.8 kW / 2747.2 kWh	2312 kVA (2hr) / 1156 kVA (4hr)
18 (EC18)	1445.4 kW / 2890.8 kWh	727.2 kW / 2908.8 kWh	2400 kVA (2hr) / 1224 kVA (4hr)
19 (EC19)	1525.7 kW / 3051.4 kWh	767.6 kW / 3070.4 kWh	2400 kVA (2hr) / 1292 kVA (4hr)
20 (EC20)	1606.0 kW / 3212.0 kWh	808.0 kW / 3232.0 kWh	2400 kVA (2hr) / 1360 kVA (4hr)
21 (EC21)	1686.3 kW / 3372.6 kWh	848.4 kW / 3393.6 kWh	2400 kVA (2hr) / 1428 kVA (4hr)
22 (EC22)	1766.6 kW / 3533.2 kWh	888.8 kW / 3555.2 kWh	2400 kVA (2hr) / 1496 kVA (4hr)
23 (EC23)	1846.9 kW / 3693.8 kWh	929.2 kW / 3716.8 kWh	2400 kVA (2hr) / 1564 kVA (4hr)

Battery Module Count (Code)	2-Hour Megapack Rating (kW / kWh)	4-Hour Megapack Rating (kW / kWh)	Maximum Allowable Inverter Configuration for 2hr / 4hr
24 (EC24)	1927.2 kW / 3854.4 kWh	969.6 kW / 3878.4 kWh	2400 kVA (2hr) / 1632 kVA (4hr)

3 Environmental Specifications

3.1 Ambient Temperature

Megapack is capable of meeting rated power in ambient temperatures between -30°C and 50°C, and in relative humidity of up to 100% condensing.

In high altitudes, at low air pressure, the cooling capability of Megapack may be reduced, but is no worse than standard altitude-temperature de-rate as specified by standard atmosphere conditions as indicated below:

Table 14. Ambient Temperature

Altitude [m]	Maximum Ambient Temperature During Operation [°C]
0	50
1000	48.5
2000	42
3000	35.5

At no time, including during shipping, may storage conditions exceed the ranges indicated below.

NOTE: The system must be at a specified level of charge prior to 12-month storage. Contact your Tesla representative for information on long-term storage.

Table 15. Storage Conditions

Duration	Temperature Range During Storage [°C]	Maximum Humidity
Up to 12 months (365 days)	-30 to 50	Up to 100% relative humidity, condensing

3.2 Elevation

Megapack provides rated power up to 3000 m elevation above sea level in ambient temperature conditions per *Ambient Temperature* on page 12.

3.3 Shock and Vibration

A fully populated Megapack passes the ASTM D4169-2016 "Table 2 Truck unit level shipping and vibration test".

3.4 Seismic

Megapack meets the high seismic performance levels per the following standards:

- Qualification Level - IEEE 693-2018 High PL: *ZPA*=1.0 g 5% damping
- Certification Level - ICC-ES AC 156-2018 S_{DS}=2.50 g z/h=0 I_p=1.5

3.5 Wind

If installed as a standalone enclosure, Megapack is able to withstand Category 5 hurricane sustained wind speeds of up to 157 mph (252 km/h).

3.6 Precipitation Resistance

Megapack is able to withstand a snow load limit of no less than 150 pounds/sqft on its roof or other surface.

3.7 Solar Loading

Megapack provides full rated power in all ambient temperature conditions (*Ambient Temperature* on page 12), and at maximum elevation (*Elevation* on page 12) under up to 1000 W/m^2 solar loading, in any direction.

4 Mechanical Specifications

4.1 Dimensions and Mass

NOTE: Disclaimer: Dimension specification subject to change.

NOTE: Megapack can be configured for lighter shipping mass based on project-specific requirements.

NOTE: Mass as listed is maximum mass. The final product mass as configured may be lower.

Table 16. Megapack Dimensions and Mass (Weight)

Width	Depth	Height	Max. Shipping Mass
9118 mm (359 in)	1659 mm (65 ¼ in)	2800 mm (110 ¼ in)	38,100 kg (84,000 lb)

4.2 Transportation

Megapack is a non-divisible structure. No disassembly for transport is required.

Megapack is over-height on a normal flat rack, so for ocean shipping use of an adjustable-height flat rack ("Super Rack") is recommended if available.

4.3 Enclosure

4.3.1 Ingress Protection

Megapack has an IP rating of IP66.

The thermal system shall have a rating of IP20.

Megapack (main enclosure) is classified as NEMA 3R certification including rain and sprinkler test immunity.

4.3.2 Impact Protection

Megapack (main enclosure) has a minimum IK rating of IK09 for impact protection.

4.3.3 Salt and Fog

Megapack (main enclosure) is able to withstand over 1,000 hours of salt fog application per a C5M system.

4.3.4 Corrosion Resistance and Paint

The paint system of the Megapack enclosure is compliant with ISO 12944: C5I (industrial) and C5M (coastal) standards.

4.4 Audible Noise

The audible noise of Megapack, measured 10 meters from any side surface of the enclosure, is less than 85 dBA (SPL sound pressure) at full thermal system performance.

5 Communication and Control

The Tesla Site Controller is the main data concentrator for a Megapack site and is the single node through which the system can communicate with Tesla servers and other third-party interfaces. When connected to an external network (either over GSM or Internet), the Tesla Site Controller can be used for monitoring and controlling the system.

The Tesla Site Controller is capable of collecting data from all equipment installed onsite, including meters. The Tesla Site Controller communicates to external interfaces via Modbus TCP, DNP3, or REST API.

The Tesla Site Controller has the following interfaces:

- (1) 10/100/1000 Ethernet port for customer third-party interface connection
- (1) 10/100/1000 Ethernet port for the Tesla battery network

Refer to the *Tesla Energy Controls and Communications Manual* for details.

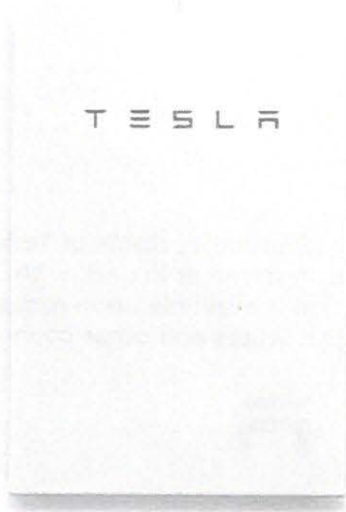
Revision History

Revision	Date	Description
1.6.4	November 9, 2021	• Real power / energy ratings update • RTE update (Roundtrip Efficiency and Energy Consumption on page 5) • Audible noise spec update (Audible Noise on page 15)
1.6.3	July 21, 2021	• Updated unit height
1.6.2	07-14-2021	• Ratings & RTE update
1.6.1	05-04-2021	• Ratings update • New language in inverter section • Battery modules depopulation
1.6	04-15-2021	• Ratings update to reflect additional battery modules
1.51	04-06-2021	• Product name is now officially Megapack 2
1.5	03-30-2021	• Slightly increased unit width • 2hr and 4hr ratings update
1.4.1	03-05-2021	• Updated product long-term RTE
1.4	02-23-2021	• Updated product mass projection • Updated product RTE
1.3	02-02-2021	• Rating update
1.2	11-25-2020	• Rating update
1.1.1	10-02-2020	• Fixed a broken cross-reference link
1.1	09-30-2020	• First version of specification for limited external release
1.0	09-14-2020	• Initial release candidate for external version of next-generation Megapack specification

TESLA

Megapack 2 XL Specification - Revision 1.6.4 - Published November 9, 2021

Attachment B 2020 Emergency Response Guide



Lithium-Ion Battery Emergency Response Guide

For Tesla Energy Products including Powerwall, Powerpack, and Megapack – TS-00004027 – REV 2.1

PRODUCT SPECIFICATIONS

All specifications and descriptions contained in this document are verified to be accurate at the time of printing. However, because continuous improvement is a goal at Tesla, we reserve the right to make product or documentation modifications at any time, with or without notice.

The images provided in this document are for demonstration purposes only. Depending on product version and market region, details may appear slightly different.

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CONTENTS

1.1 Scope

This guide serves as a resource for emergency responders and Authorities Having Jurisdiction (AHJs) with regards to safety surrounding Tesla Energy Products. Tesla Energy Products are defined as rechargeable lithium-ion battery energy storage products designed, manufactured, and sold by Tesla, and include products such as Megapack, Powerpack, and Powerwall. The information and recommendations set forth are made in good faith and believed to be accurate as of the date of preparation. TESLA, INC. makes no warranty, expressed or implied, with respect to this information.

2.1 Identification of Company and Contact Information

Table 1. Company and Contact Information

Products	Tesla Energy Products, designed for residential, commercial, and industrial/utility energy applications, and modules and sub-assemblies that can be installed in such products. Specific part numbers are listed below.	
Locations	Headquarters (USA)	3500 Deer Creek Road Palo Alto, CA 94304 USA Tel. No. +1 650-681-5000 (do not use for emergencies, see below)
	Europe and Africa	Burgemeester Stramanweg 122 1101EN Amsterdam, The Netherlands Tel. No. +31 20 258 3916 (do not use for emergencies, see below)
	Australia and Asia	Eastern Aoyama Building 4F 8-5-41 Akasaka, Minato-ku, Tokyo, Japan 107-0052 Tel: +81 3 6890 7700 (do not use for emergencies, see below)
	Manufacturer (USA)	3500 Deer Creek Road Palo Alto, CA 94304 USA Tel. No. +1 650-681-5000 (do not use for emergencies, see below)
Emergency Contacts	CHEMTREC	For Hazardous Materials (or Dangerous Goods) Incidents: Spill, Leak, Fire, Exposure, or Accident Call CHEMTREC Day or Night Within USA and Canada: 1-800-424-9300 Contract Number: CCN204273 Outside USA and Canada: +1 703-741-5970 (collect calls accepted)
	Tesla Service Support Contacts	Powerpack & Megapack: • Hotline numbers (24h / 7 coverage): ∘ North America: +1 (650) 681-6060 ∘ Australia: +1800 294 431 ∘ New Zealand: +0800 995 020 ∘ Japan: +0120 975 214

- Asia/Pacific: +61 2 432 802 81
- Email support: *IndustrialStorageSupport@tesla.com*

Powerwall:

- Hotline numbers (24h / 7 coverage):
  - North America: +(877) 798-3752
  - United Kingdom: +44 8000988064
  - Germany: +49 800 724 4529
  - Italy: +39 800596849
  - South Africa: +27 87 550 3480
- Email support:
  - North America: *PowerwallSupportNA@tesla.com*
  - Australia/New Zealand: *PowerwallSupportNA@tesla.com*
  - Japan: *EnergyCustomerSupportJP@tesla.com*
  - Europe/Middle East/Africa: *EnergySupportEmea@tesla.com*

2.2 SDS and Product Information

Safety Data Sheets (SDS) are a sub-requirement of the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR Subpart 1910.1200. This Hazard Communication Standard does not apply to various subcategories including anything defined by OSHA as an "article." OSHA has defined "article" as a manufactured item other than a fluid or particle; (i) which is formed to a specific shape or design during manufacture; (ii) which has end use function(s) dependent in whole or in part upon its shape or design during end use; and (iii) which under normal conditions of use does not release more than very small quantities (e.g., minute or trace amounts) of a hazardous chemical, and does not pose a physical hazard or health risk to employees.

Tesla Energy Products referenced herein meet the OSHA definition of "article." Thus, they are exempt from the requirements of the Hazard Communication Standard and do not require an SDS. However, SDS are available for non-cell materials found inside these products.

Tesla Energy Products contain sealed lithium-ion battery cells (cells) that are similar to rechargeable batteries in many consumer electronic products. Cells are individually hermetically sealed cylinders approximately 21 mm in diameter and 70 mm in length.

Cells each contain lithium ion electrodes, which can be composed of either:

- Lithium Nickel Cobalt Aluminum Oxide (NCA material), $LiNi_xCo_yAl_zO_2$;
- Lithium Nickel, Manganese, Cobalt Oxide (NMC material) $LiNi_xMn_yCo_zO_2$;
- Lithium Nickel, Manganese Oxide (NMO material), $LiNi_xMn_yO_2$
- Lithium Cobalt Oxide, $LiCoO_2$;
- or a mixture of these compounds

THE CELLS AND BATTERIES DO NOT CONTAIN METALLIC LITHIUM. Individual cells have nominal voltages of approximately 3.6 V.

Tesla Energy Products also include sealed thermal management systems containing coolants and/or refrigerants. Safety Data Sheets (SDS) are available for these liquid materials.

Table 2. Thermal Contents

Non-Cell Materials with SDS found in Tesla Energy Products	Approximate Quantity
Ethylene glycol 50/50 mixture with water	Powerwall 1: 1.6 L of 50/50 mixture Powerwall 2: 2.3 L of 50/50 mixture Powerpack 1: 22 L of 50/50 mixture Powerpack 2: 26 L of 50/50 mixture Powerpack Inverter: 11 L of 50/50 mixture Megapack: 540 L of 50/50 mixture Powerpack Pod Module: none Megapack Battery Module: none
R134a: 1,1,1,2-Tetrafluoroethane refrigerant	Powerwall 1, 2: none Powerpack 1, 2: 400 g Megapack: 7.6 kg Powerpack Pod Module: none Megapack Battery Module: none

Individual lithium-ion cells are connected to form modules. Modules are battery sub-assemblies. These modules are installed in Tesla Energy Products. Approximate specifications of Tesla Energy Products are listed below.

Table 3. Approximate Tesla Energy Product Specifications

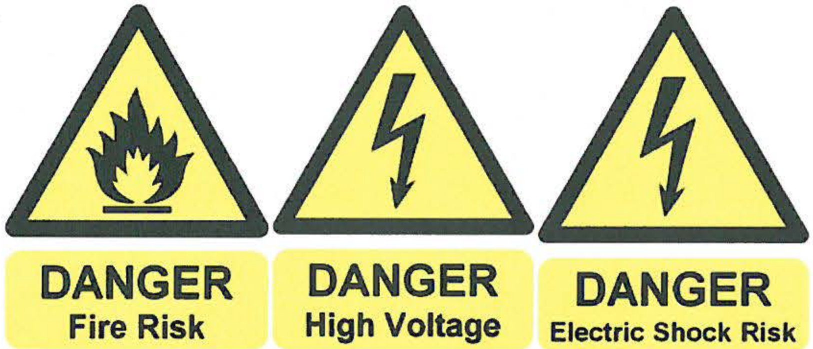
Part Number (Reman Number if available)	Description	Module Voltage - as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
Powerwall 1 Versions								
1050100-x*y*-z*	POWERWALL, 2KW, 7KWH	<30 (DC)	450 (DC)	-	95 (210 lb)	130 (51 in)	86 (34 in)	18 (7 in)
1067000-x*y*-z*	POWERWALL, 3.3KW, 7KWH	<30 (DC)	450 (DC)	-	95 (210 lb)	130 (51 in)	86 (34 in)	18 (7 in)

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
1068000-x*y*-z*	POWERWALL, 6.6KW, 10KWH	<30 (DC)	450 (DC)	-	101 (223 lb)	130 (51 in)	86 (34 in)	18 (7 in)
Powerwall 2 Versions								
1092170-x*y*-z*	AC POWERWALL	<30 (DC)	450 (DC)	300 (AC)	114 (251.3 lb)	115 (45.3 in)	75 (29.6 in)	14 (5.75 in)
1112170-x*y*-z*	DC POWERWALL	<30 (DC)	450 (DC)	-	115 (254 lb)	112 (44 in)	74 (29 in)	14 (5.5 in)
Powerpack 1 Versions								
1047404-x*y*-z*	POWERPACK (2hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1680 (3700 lb)	219 (86 in)	97 (38 in)	132 (52 in)
1060119-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1665 (3670 lb)	219 (86 in)	97 (38 in)	132 (52 in)
1121229-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	97 (38 in)	132 (52 in)
Powerpack 1.5 Version								
1089288-x*y*-z*	POWERPACK 1.5 C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	1622 (3575 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
Powerpack 2 / 2.5 Versions								
1083931-x*y*-z* (1130518-x*y*-z*)	POWERPACK 2,C/4 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160	219 (86 in)	131 (51.5 in)	82 (32.5 in)

Part Number (Reman Number if available)	Description	Module Voltage - as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight (kg)	Height (cm)	Width (cm)	Depth (cm)
					(4765 lb)			
1083932-x*y*-z*	POWERPACK 2,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490025-x*y*-z*	POWERPACK 2.5,C/4 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490026-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
1490027-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 (4765 lb)	219 (86 in)	131 (51.5 in)	82 (32.5 in)
Megapack (all versions - dimensions as measured for enclosure envelope for 1462965-x*y*-z*)								
1462965-x*y*-z*	MEGAPACK	<450 (DC)	960 (DC)	505 (AC)	25,400 (56,000 lb) (max)	252.2 (99 ¼ in)	716.8 (282 ¼ in) (length)	165.9 (65 ¼ in)
Spare Parts								
N/A	POWERPACK POD MODULE	<30 (DC)	960 (DC)	N/A	98 (215 lb)	12 (5 in)	100 (39 ½ in)	75 (29 ½ in)
N/A	MEGAPACK BATTERY MODULE	<450 (DC)	960 (DC)	N/A	1,085 (2,400 lb)	66 (26 in)	81 (32 in)	149 (59 ½ in)

** Note that the 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*

3.1 General Precautions



The products described by this document are dangerous if mishandled. Injury to property or person, including loss of life is possible if mishandled.

Tesla Energy Products contain lithium-ion batteries. A battery is a source of energy. Do not short circuit, puncture, incinerate, crush, immerse, force discharge or expose to temperatures above the declared operating temperature range of the product. An internal or external short circuit can cause significant overheating and provide an ignition source resulting in fire, including surrounding materials or materials within the cell or battery. Under normal conditions of use, the electrode materials and electrolyte they contain are not exposed, provided the battery integrity is maintained and seals remain intact. Risk of exposure may occur only in cases of abuse (mechanical, thermal, electrical).

3.2 High-Voltage Hazards

Under normal conditions of use, provided that a Tesla Energy Product enclosure remains closed, handling the product does not pose an electrical hazard. Numerous safeguards have been designed into Tesla Energy Products to help ensure that the high voltage battery is kept safe and secure as a result of a number of expected abuse conditions. All of the constituent component battery cells are sealed within the product as sub-groups within enclosures (Pods for Powerpack or battery modules for Megapack).

In Powerpack and Megapack, the exterior of each Pod/battery module is isolated from internal components and connectors are touch-safe. Pods are then installed in a rigid metal enclosure, which is isolated from high voltage. Megapack battery modules are similarly sealed and cannot be accessed from the exterior. In the Powerwall, the module is contained within the unit and not accessible to non-Tesla personnel. Access to these components is limited to Tesla-authorized personnel only.

A Tesla Energy Product may pose a significant high voltage and electrocution risk if the outer enclosure, Pod / battery module enclosures and/or safety circuits have been compromised or have been significantly damaged. A battery pack, even in a normally discharged condition, is likely to contain substantial electrical charge and can cause injury or death if mishandled. If a Tesla Energy Product has been significantly visibly damaged or its enclosure compromised, practice appropriate high-voltage preventative measures until the danger has been assessed (and dissipated if necessary).

⚠ **WARNING:** NEVER CUT INTO A SEALED TESLA ENERGY PRODUCT ENCLOSURE due to the high voltage and electrocution risks.

For proper installation / removal instructions please contact the Tesla Service Support team.

3.3 Hazards Associated with Mechanical Damage

Mechanical damage to Tesla Energy Products can result in a number of hazardous conditions (discussed below) including:

- Leaked battery pack coolant (see *Hazards Associated with Leaked Coolant* on page 9)
- Leaked refrigerant (Powerpack System and Megapack only, see *Hazards Associated with Leaked Refrigerant (Powerpack and Megapack Only)* on page 9)
- Leaked cell electrolyte (see *Hazards Associated with Leaked Electrolyte* on page 10)
- Rapid heating of individual cells due to exothermic reaction of constituent materials (cell thermal runaway), venting of cells, and propagation of self-heating and thermal runaway reactions to neighboring cells.
- Fire

To prevent mechanical damage to Tesla Energy Products, these items should be stored in their original packaging when not in use or prior to being installed (see *Storage Precautions* on page 16).

3.4 Hazards Associated with Elevated Temperature Exposure

Tesla Energy Products are designed to withstand operating ambient temperatures up to 50°C (122°F), with up to 100% operating humidity (condensing), and storage temperatures up to 60°C (140°F) and <95% relative humidity (non-condensing) for up to 24 hours without affecting the health of the unit.

Prolonged exposure of Tesla Energy Products to temperatures beyond that can drive battery cells into thermal runaway and result in a fire. Exposure of battery packs to localized heat sources such as flames could result in cell thermal runaway reactions and should be avoided.

3.5 Hazards Associated with Leaked Coolant

Thermal management of Tesla Energy Products is achieved via liquid cooling using a 50/50 mixture of ethylene glycol and water. A typical Powerpack battery unit includes about 26 L of coolant (Powerpack 2/2.5) or about 22 L of coolant (Powerpack 1). A typical Powerwall unit includes about 1.6 L of coolant (Powerwall 1) or about 2.3 L of coolant (Powerwall 2). The Powerpack Inverter (fully populated) includes about 11 L of coolant. A typical Megapack includes about 540 L of coolant. Mechanical damage of a Tesla Energy Product that has been installed could result in leakage of the coolant. The fluid is blue in color and does not emit a strong odor.

For information regarding the toxicological hazards associated with ethylene glycol, as well as ecological effects and disposal considerations, refer to the specific Safety Data Sheet (SDS) for battery coolant.

Extended exposure of a Tesla Energy Product to leaked coolant could cause additional damage to the product such as corrosion and compromise of protection electronics.

3.6 Hazards Associated with Leaked Refrigerant (Powerpack and Megapack Only)

The Powerpack and Megapack thermal management system includes 400 g and 7.6 kg respectively of R134a: 1,1,1,2-Tetrafluoroethane refrigerant in a sealed system. Mechanical damage of a Powerpack or Megapack could result in a release of the refrigerant. Such a release would appear similar to the emission of smoke.

For information regarding the toxicological hazards associated with R134a, as well as ecological effects and disposal considerations, refer to the specific Safety Data Sheet (SDS) for R134a.

3.7 Hazards Associated with Leaked Electrolyte

The electrolyte within constituent cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of lithium ions) such as lithium hexafluorophosphate. The electrolyte in Tesla Energy Products' cells is largely absorbed in electrodes within individual sealed cells. The electrolyte reacts with those materials and is consumed during normal operation of the batteries. As such, the absence of free liquid electrolyte makes it impractical to report the volume of electrolyte within Tesla Energy Products.

The possibility of a spill of electrolyte from Tesla Energy Products is very remote. Electrolyte can be extracted from a single cell using a centrifuge, or under some extreme abuse conditions such as a severe crush. However, it is very difficult to mechanically damage cells in such a way as to cause leakage of electrolyte. Even if a single cell were damaged in a manner that could cause electrolyte leakage, it is extremely difficult to cause a leak from more than a few cells due to any incident. Furthermore, cells are connected into modules which are placed within a sealed steel compartmentalized enclosure. Each compartment has the capacity to contain liquid from a large number of individual cells. For the electrolyte liquid to come into contact with a user of a Tesla Energy Product, the external enclosure, the Pod/battery module enclosure, and the cell would have to be severely mechanically damaged. As such, Tesla Energy Products are deemed not to pose a liquid electrolyte release hazard.

Any released electrolyte liquid is likely to evaporate rapidly, leaving a white salt residue. Evaporated electrolyte is flammable and will contain alkyl-carbonate compounds. Leaked electrolyte is colorless and characterized by a sweet odor. If an odor is obvious, evacuate or clear the surrounding area and ventilate the area.

WARNING: AVOID CONTACT WITH ELECTROLYTE.

Leaked electrolyte solution is flammable and corrosive / irritating to the eyes and skin. If a liquid is observed that is suspected electrolyte, ventilate the area and avoid contact with the liquid until a positive identification can be made and sufficient protective equipment can be obtained (eye, skin, and respiratory protection). Chemical classifier strips can be used to identify the spilled liquid (electrolyte will contain petroleum/organic solvent and fluoride compounds).

In case of an electrolyte leak, the following protective equipment is recommended: an air purifying respirator with organic vapor/acid gas cartridges, safety goggles or a full-face respirator, and safety gloves (Butyl rubber or laminated film (e.g., Silver Shield)). Protective clothing should be worn. Use a dry absorbent material to clean up a spill.

NOTE: An acceptable exposure concentration of electrolyte has not been identified by the American Council of Governmental Industrial Hygienists (ACGIH). In case of electrolyte leakage from the battery, the oral (rat) LD50 is greater than 2 g/kg (estimated).

3.8 Hazards Associated with Vented Electrolyte

Lithium-ion cells are sealed units, and thus under normal usage conditions, venting of electrolyte should not occur. If subjected to abnormal heating or other abuse conditions, electrolyte and electrolyte decomposition products can vaporize and be vented from cells. Accumulation of liquid electrolyte is unlikely in the case of abnormal heating. Vented gases are a common early indicator of a thermal runaway reaction - an abnormal and hazardous condition.

If gases or smoke are observed escaping from a Tesla Energy Product, evacuate the area and notify a first responder team and/or the local fire department. Gases or smoke exiting a lithium-ion battery pack are likely flammable and could ignite unexpectedly as the condition that led to cell venting may also cause ignition of the vent gases. A venting Tesla Energy Product should only be approached with extreme caution by trained first responders equipped with appropriate personal protective equipment (PPE), as discussed in *Firefighter PPE* on page 13.

Cell vent gas composition will depend upon a number of factors, including cell composition, cell state of charge, and the cause of cell venting. Vent gases may include volatile organic compounds (VOCs) such as alkyl-carbonates, methane, ethylene, and ethane; hydrogen gas; carbon dioxide; carbon monoxide; soot; and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF3, and HF vapors may form.

WARNING: AVOID CONTACT WITH VENTED GASES.

Vented gases may irritate the eyes, skin, and throat. Cell vent gases are typically hot; upon exit from a cell, vent gas temperatures can exceed 600°C (1,110°F). Contact with hot gases can cause thermal burns. Vented electrolyte is flammable and may ignite on contact with a competent ignition source such as an open flame, spark, or a sufficiently heated surface. Vented electrolyte may also ignite on contact with cells undergoing a thermal runaway reaction.

4.1 Firefighting Measures

CAUTION: In the event of a response to a Tesla product fire or hazardous event, contact Tesla immediately for technical guidance. Response should only be performed by trained professionals.

To create a significant fire in Tesla Energy Products, the enclosure of the battery unit needs to be subject to an extreme external event, such as direct exposure to a large prolonged fire or severe physical impact. A single cell thermal runaway does not propagate to neighboring cells as demonstrated in testing per UL and IEC standards. In the event of a fire, rigorous full-scale fire testing has shown that Tesla Energy Products perform in a safe and controlled manner, consuming themselves slowly without explosive bursts, deflagrations, or unexpected hazards, and without propagating to neighboring enclosure units. These claims have been validated through large-scale fire testing, with available third-party reports.

4.1.1 Responding to a Venting Tesla Energy Product

Smoke emanating from a Tesla Energy Product can be an indication of an abnormal and hazardous condition. Battery thermal runaway fires are preceded by a period of smoke. The smoke is likely flammable and may ignite at any time. If fire or smoke is observed emanating from a Tesla Energy Product at any time, the following should be performed:

1. If possible, shut off the unit/system (see *Shutting Down in an Emergency* on page 14)
2. Evacuate the area
3. Notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available

WARNING: When responding to a fire event with the **Powerpack System**, do not approach the Powerpack units from the front (door-side). Perform all incident response from the sides or rear of the unit. Do not attempt to open the enclosure door or come in contact with the unit. Per testing results, a Powerpack fire will not propagate to neighboring Powerpacks.

WARNING: When responding to a fire event with **Megapack**, do not approach the unit and attempt to open any doors. The doors are designed to remain shut, and built-in deflagration vents in the roof of the unit will vent any smoke and flame out of the top of the unit and front thermal system intake louvers. Per testing results, a Megapack fire will not propagate to neighboring Megapacks.

The Tesla Energy Product should then be monitored for evidence of continued smoke venting. If a fire develops and visible flames appear, it is recommended to apply water spray to neighboring battery enclosures and exposures (see *Defensive Firefighting* on page 13), rather than directly onto the burning unit. Applying water directly to the affected enclosure will not stop the thermal runaway event, as the fire will be located behind several layers of steel material, and direct application of water has shown to only delay the eventual combustion of the entire unit. The door(s) should not be opened in such an event. Testing has shown that a thermal runaway event in a single Powerpack or Megapack does not propagate to a neighboring enclosure, even without the application of water or other suppression sources, but water can be used to further mitigate the hazard spread to exposures and surroundings.

Water spray has been deemed safe as an agent for use on exposed Tesla Energy Products. Water is considered the preferred agent for suppressing lithium-ion battery fires. Water has superior cooling capacity, is plentiful (in many areas), and is easy to transport to the seat of the fire. Gaseous agents such as CO2, Halon, or dry chemical suppressants may temporarily suppress flaming of lithium-ion battery packs, but they will not cool lithium-ion batteries and will not limit the propagation of cell thermal runaway reactions. Metal fire suppressants such as LITH-X, graphite powder, or copper powder are not appropriate agents for suppressing fires involving lithium-ion battery packs as they are unlikely to be effective.

If water is used directly on the enclosure that is burning, electrolysis of water (splitting of water into hydrogen and oxygen) may contribute to the flammable gas mixture formed by venting cells, burning plastic, and burning of other combustibles.

A battery fire may continue for several hours and it may take 24 hours or longer for the battery pack to cool after it has been fully consumed by a thermal runaway event. A lithium-ion battery fire that has been seemingly extinguished can flare up again if all cells have not been consumed due to the exothermic reaction of constituent materials from broken or damaged cells, or unburnt cells. Allow the battery pack to fully consume itself and then cool the burned mass by flooding with water. After all fire and smoke has visibly subsided, a thermal imaging camera can be used to actively measure the temperature of the unit.

4.1.2 Defensive Firefighting

Tesla's recommendation is to fight a Tesla Energy Product fire defensively. The fire crew should maintain a safe distance and allow the battery to burn itself out. Fire crews should utilize a fog pattern to protect neighboring units or exposures or control the path of smoke. A single one-and-three-quarter inch (~5cm) hand line has shown to be sufficient. Applying water directly on the burning unit will only delay the burn and not suppress it. A battery fire may continue for several hours and may result in multiple flare-up events due to the way thermal runaway propagates throughout the enclosure. It may take 24 hours or longer for the battery pack to cool once completely consumed.

4.1.3 Firefighter PPE

Firefighters should wear self-contained breathing apparatus (SCBA) and fire protective turnout gear. Cells or batteries may flame or leak potentially hazardous organic vapors if exposed to excessive heat, fire or over voltage conditions. These vapors may include volatile organic compounds (VOCs), hydrogen gas, carbon dioxide, carbon monoxide, soot, and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF3 and HF vapors may form.

WARNING: Shutting off power to a Tesla Energy Product does not de-energize the battery, and a shock hazard may still be present.

WARNING: If smoke or fire is visible, do not approach the product or open any of its doors.

To shut off the Powerpack System, Megapack, or Powerwall in an emergency:

5.1 Powerpack System

1. If an external E-stop button or remote shutdown contact to Powerpack is present, engage it.
2. If Powerpack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.
3. Only if safe to do so, open the DC disconnect switch on the inverter door.

5.2 Megapack

1. If an external E-stop button or remote shutdown contact to Megapack is present, engage it.
2. If Megapack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.
3. Only if safe to do so, open the customer interface bay door to access the AC breaker, remove the DC lockout key, and apply Lock Out, Tag Out (LOTO) if needed.

5.3 Powerwall

1. If an E-Stop button is present, engage the E-Stop.
2. Open the AC disconnect installed upstream of the system.

6.1 First Aid Measures

6.1.1 Electric Shock / Electrocution

Seek immediate medical assistance if an electrical shock or electrocution has occurred (or is suspected).

6.1.2 Contact with Leaked Electrolyte

The constituent battery cells are sealed. Contents of an open (broken) constituent battery cell can cause skin irritation and/or chemical burns. If materials from a ruptured or otherwise damaged cell or battery contact skin, flush immediately with water and wash affected area with soap and water. If a chemical burn occurs or if irritation persists, seek medical assistance.

For eye contact, flush with significant amounts of water for 15 minutes without rubbing and see a physician at once.

6.1.3 Inhalation of Electrolyte Vapors

If inhalation of electrolyte vapors occurs, move person into fresh air. If not breathing give artificial respiration and seek immediate medical assistance.

6.1.4 Vent Gas Inhalation

The constituent battery cells are sealed and venting of cells should not occur during normal use. If inhalation of vent gases occurs, move person into fresh air. If not breathing give artificial respiration. Seek immediate medical assistance.

7.1 Storage Precautions

Powerpack systems, Powerwalls, and sub-assemblies should be stored in approved packaging prior to installation. Megapack does not include packaging and can be stored as-shipped with a tarp.

Do not store Tesla Energy Products in a manner that allows terminals to short circuit (do not allow the formation of an electrically-conductive path).

Elevated temperatures can result in reduced battery service life. Tesla Energy Products can withstand ambient temperatures of -40°C to 60°C for up to 24 hours. However, Tesla Energy Products stored for longer than one month should be stored at ambient temperatures between -20°C and 30°C (-4°F and 86°F), at humidity <95%, and protected from condensation. Storing at temperatures outside the recommended range can result in degradation of product lifetime. Do not store Tesla Energy Products near heating equipment.

Ideally, a Tesla Energy Product should be stored at 50% state of charge (SOC) or less. Tesla Energy Products should not be stored for extended periods either at a full SOC or completely discharged since both conditions adversely impact battery life. Tesla Energy Products should not be stored untended for longer than twelve months since battery service life likely will be adversely impacted.

The storage area should be protected from flooding.

Long-term storage areas should be compliant with the appropriate local fire code requirements.

Acceptable storage density of battery packs and storage height of battery packs will be defined by the local authority having jurisdiction (AHJ). Requirements and limits will be based upon a number of factors including the structural and fire protection characteristics of the storage area and recommendations for fire protection promulgated by the National Fire Protection Association (NFPA) and similar organizations. At the time of this writing, no standard Commodity Classification has been defined for lithium-ion cells or battery packs (see 2016 NFPA 13: Standard for the Installation of Sprinkler Systems). Tesla products only have a 30-40 % state of charge (SOC) while in storage which reduces the energy impact on fire occurrences. As an example of the reduced energy, the 30% level has been determined to be acceptable for air flight shipping based upon extensive testing and analysis in conjunction with the FAA. Tesla recommends treating lithium-ion cells and batteries in packaging as equivalent to a Group A Plastic Commodity.

8.1 Handling, Storage, and Transportation of Damaged Tesla Energy Products

If the event of damage to a Tesla Energy Product, contact Tesla immediately.

If a Tesla Energy Product has been damaged (battery enclosure has been dented or compromised), it is possible that heating is occurring that may eventually lead to a fire. Damaged or opened cells/batteries can result in rapid heating (due to exothermic reaction of constituent materials), the release of flammable vapors, and propagation of self-heating and thermal runaway reactions to neighboring cells.

Before handling or transporting a damaged Tesla Energy Product, wait at least 24 hours. Smoke may be an indication that a thermal reaction is in progress. If no smoke, flame, sign of coolant leakage, or signs of heat has been observed for 24 hours, the Tesla Energy Product may be disconnected and moved to a safe location. To obtain specific instructions for evaluating, disconnecting, and preparing a damaged Tesla Energy Product for transport, please contact the Tesla Service team.

A damaged Tesla Energy Product should be monitored during storage for evidence of smoke, flame, sign of coolant leakage, or signs of heat. If full-time monitoring of the Product is not possible (for example during extended storage), the Product should be moved to a safe storage location.

A safe storage location for a damaged battery will be free of flammable materials, accessible only by trained professionals, and 50 feet (15m) downwind of occupied structures. For example, a fenced, open yard may be an appropriate safe location. DO NOT STORE DAMAGED TESLA ENERGY PRODUCTS ADJACENT TO UNDAMAGED TESLA ENERGY PRODUCTS. It is possible that a damaged battery may sustain further damage during transportation and may lead to a fire. To further reduce this risk, handle the damaged battery with extreme caution.

9.1 Disposal Procedures

Tesla Energy lithium-ion batteries do not contain heavy metals such as lead, cadmium, or mercury.

The procedures below apply to Tesla Energy Products at the end of their life (EOL). For disposal after a fire or thermal event, please contact Tesla for guidance.

Tesla Energy Products should be disposed of or recycled in accordance with local, state, and federal regulations. Note that regulations regarding disposal of batteries vary by jurisdiction. In the United States, batteries are classified as Universal Waste, and in addition, many individual states have specific regulations regarding disposal of battery packs. For example, in California, all batteries must be taken to a Universal Waste handler or authorized recycling facility.

Tesla Energy Products contain recyclable materials. Tesla strongly encourages recycling. At this time, when a Tesla product must be decommissioned, we request that it be returned to a Tesla facility for disassembly and further processing.

If disposing without return to Tesla, please consult with local, state and/or federal authorities on the appropriate methods for disposal and recycling. Tesla has confirmed that at least two recycling processors are capable of recycling Tesla battery products in North America and three in the Europe, the Middle East and Africa (EMEA) region.

10.1 Maintenance or Repair

Tesla requests all maintenance, service, and repairs of Tesla Energy Products be performed by Tesla-approved service personnel or Tesla authorized repair facilities. This includes all proactive and corrective maintenance over the lifetime of a Tesla Energy Product. Improper service or repair by personnel not approved nor authorized by Tesla could void the product's Limited Warranty, lead to failure of the Tesla Energy product, and potentially result in development of an unsafe condition and unexpected electrical events.

11.1 Transport Information

Lithium-ion batteries are regulated as Class 9 Miscellaneous dangerous goods (also known as "hazardous materials") pursuant to the International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air, International Air Transport Association (IATA) Dangerous Goods Regulations, the International Maritime Dangerous Goods (IMDG) Code, European Agreements concerning the International Carriage of Dangerous Goods by Rail (RID) and Road (ADR), and applicable national regulations such as the USA's hazardous materials regulations (see 49 CFR 173.185). These regulations contain very specific packaging, labeling, marking, and documentation requirements. The regulations also require that individuals involved in the preparation of dangerous goods for transport be trained on how to properly package, label, mark and prepare shipping documents.

UN Number	3480
Proper Shipping Name	Lithium Ion Batteries
Hazard Classification	Class 9 Miscellaneous
Packing Group	N/A

NOTE: The information and recommendations set forth are made in good faith and believed to be accurate as of the date of preparation. TESLA, INC. makes no warranty, expressed or implied, with respect to this information.

Revision #	Date	Description
01	14-July-2015	ERG for Tesla Powerpack systems, Powerwalls, and Sub-assemblies
02	3-Sept-2015	Added part numbers, updated weights, voltages, and temperatures, clarified hazards associated with spilled electrolyte, updated storage requirements, updated warning label icons, updated packing group.
03	3-Oct-2016	Added part numbers, minor edits
04	30-June-2017	Added fire ground operations response for Powerpack 2, including approach; exhaust gases; and safety. Updated general product information and contacts, as well as part numbers and reman numbers
05	22-Oct 2018	Reformatted for ease of use and translation; removed Confidential status; corrected phone number for CHEMTREC
06	27-Feb-2019	Updated storage conditions and firefighting measures section to provide further context on response tactics to Tesla Energy Product fires. Adjusted formatting, included graphics for warnings and notices.
07	17-Dec-2019	Updates to contact information (Tesla contact), product specs section, leaked electrolyte section, and inclusion of Megapack throughout the document.
1.8	March 11, 2020	Fixed footer; fixed styles.
2.0	July 8, 2020	• Updated formatting • Updated product specs • Updated contact info • Corrected elevated temperature topic to include Megapack • Corrected name of Tesla Inverter to Powerpack Inverter • Separated information on shutting down into its own topic for visibility • Reorganized the Firefighting section for clarity • Updated language on re-ignition risks
2.1	August 28, 2020	• Added spare parts specifications: o Megapack battery module o Powerpack Pod module

Attachment C Calculations

Thermal Calculations point source model

UL9540 Report Summary

Peak	**Peak**	**Avg**	**Avg**	
20 ft	**30 ft**	**20 ft**	**30 ft**	
28.8	9.8	19.1	4.9	**q, heat flux, KW/m2**
6.096	9.144	6.096	9.144	**R, distance, meters**
0.35	0.35	0.35	0.35	**Pr, energy fraction released as radiation, value conservative as per SFPE 1999**
38,426	29,420	25,484	14,710	**P, peak heat release rate, KW, calculated**

Distance to estimates				
5	5	5	5	**Heat Flux, kw/m2**
14.6	12.8	11.9	9.1	**Distance, m**
48.0	42.0	39.1	29.7	**Distance, ft**
10	10	10	10	**Heat Flux, kw/m2**
10.3	9.1	8.4	6.4	**Distance, m**
33.9	29.7	27.6	21.0	**Distance, ft**
12.5	12.5	12.5	12.5	**Heat Flux, kw/m2**
9.3	8.1	7.5	5.7	**Distance, m**
30.4	26.6	24.7	18.8	**Distance, ft**
15	15	15	15	**Heat Flux, kw/m2**
8.4	7.4	6.9	5.2	**Distance, m**
27.7	24.2	22.6	17.1	**Distance, ft**
20	20	20	20	**Heat Flux, kw/m2**
7.3	6.4	6.0	4.5	**Distance, m**
24.0	21.0	19.5	14.8	**Distance, ft**
25	25	25	25	**Heat Flux, kw/m2**
6.5	5.7	5.3	4.0	**Distance, m**
21.5	18.8	17.5	13.3	**Distance, ft**
30	30	30	30	**Heat Flux, kw/m2**
6.0	5.2	4.9	3.7	**Distance, m**
19.6	17.1	16.0	12.1	**Distance, ft**

Battery Malfunction Flammability Analysis: Cell/Module UL9540A Testing

CGA P-23 Method

Component	**Mole %**	**MW**	**Wt %**	**LEL**	**NFN2: Non-Flamm in Nitrogen***	**Mole% x NFN2**	**Mole Frac/LFL**	HHV , btu/scf
H2	26	2	2.41	4.0	5.7	4.56	6.50	343
N2	0	28	0.00	-			0.00	0
CO2	0	44	0.00	-			0.00	0
CO	51	28	66.23	12.5	20	2.55	4.08	0
Ch4	10	16	7.42	5	14.3	0.70	2.00	1089
C2	4	30	5.57	3	12	0.33	1.33	1783
C3	9	44	18.37	2.1	6.5	1.38	4.29	1783
C4	0	58	0.00	1.8	5.6	0.00	0.00	1783
C5+	0	72	0.00	1.4	4.4	0.00	0.00	1783
Total	100	21.6	100		Q factor =	9.53		429.9
Frac flamm	100.00		100.00		LFL - >		5.49	

* From CGA P-23 Table 1

LFL estimated based on Le Chatelier’s formula

Tesla Battery System: Based on 9540A Cell and Module Level test by TUV
NCA Toxic Emission Calcs: during offgassing prior to combustion

Pollutant	Vol %	Volume (Liter)	MW (g/mol)	Single Cell Emissions (grams)	Single Cell Rate (g/s)	Single Cell Rate (lbs/hr)	Multicell Rate (g/s)	Multicell Rate (lbs/hr)	MegaPack Rate (g/s)	MegaPack Rate (lbs/hr)
Primary Compounds										
H2	26	1.9	2.0	0.2	0.0000	0.0003	0.0549	0.4359	2.6675	21.1710
CO	51	3.8	28.0	4.7	0.0013	0.0103	1.6462	13.0653	79.9594	634.5986
CO2	0	0.0	44.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4	10	0.7	16.0	0.5	0.0001	0.0012	0.1845	1.4639	8.9590	71.1035
C2H4	4	0.3	28.1	0.4	0.0001	0.0008	0.1296	1.0284	6.2937	49.9502
C2H6	0	0.0	30.1	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C3H6	9	0.7	42.1	1.2	0.0003	0.0027	0.4368	3.4667	21.2161	168.3819
C3H8	0	0.0	44.1	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C4	0	0.0	58.1	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C5	0	0.0	72.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0	0.0	28.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	100.0	7.4	21.3	7.0	0.0019	0.0154	2.4570	19.5000	119.3400	947.1429
Trace compounds	**ppm**	**MW**								
HF	500	20.0		3.3E-03	9.1E-07	7.2E-06	1.2E-03	9.1E-03	0.0560	0.4444
HCL	1,000	36.4		1.2E-02	3.3E-06	2.6E-05	4.2E-03	3.3E-02	0.2038	1.6176
HCN	1,600	27.0		1.4E-02	3.9E-06	3.1E-05	5.0E-03	4.0E-02	0.2419	1.9198
Methanol	210	27.0		1.9E-03	5.2E-07	4.1E-06	6.5E-04	5.2E-03	0.0317	0.2520
Styrene	1	104.0		3.4E-05	9.5E-09	7.5E-08	1.2E-05	9.5E-05	0.0006	0.0046
Toluene	3,500	92.0		1.1E-01	2.9E-05	2.3E-04	3.7E-02	2.9E-01	1.8030	14.3096

Flammable concentrations based on cell level 9540A testing
Trace Toxic compounds based on highest range encounted by Tesla in cell and cabinet level testing
Loss of 7g per cell based on Tesla cell level thermal offgassing studies - only offgassing period prior to combustion
Assumes: Atmospheric Normal Temperature and Pressure (298.15K and 100.3 kpa)
Vol % and single cell emissions total provided by manufacturer
Standard temperature and pressure (STP) is defined as 0°C (273.15 K) and 1 atm of pressure

Number of cells in multicell event	1264	10% of a module
Time of event, minutes	60	1 hour
Number of cells in Megapack event	214,812	Entire Megapack
Time of event, minutes	210	3.5 hours
Temperature of release, C	50	

Temperature based on DNV testing prior to ignition, estimated value based on graphs of 50C

Combustion Components
as per UL9540 Reports

Component	PPM	Notes
Propane	2.2	
Methane	2.9	
CO	83	
CO2	680	
ethylene	2.5	
HF	0.5	
H2	14000	35% LEL, 4% is the LEL
NO2	0.7 mole fr	Estimated based on stoichiometric H2
Water	0.3 mole fr	Estimated based on stoichiometric H2

Smoke Generation From 9540A testing: Smoke Opacity Basis

9540A test results avg Smoke rate	0.68	m2/s
RV/RSP ratio	5.8	average of testing, Hekestad 1994
estimated smoke production, module	3.9	m3/s
Module flow rate, using NO2 density	7.4	kg/s
estimated production, per cell	0.0037	m3/s
Megapack smoke production	805	m3/s
Fraction	0.19	based on timing of thermal activity module/megapack
Assume fraction at any one time	153	m3/s
Assume NO2 density, g/L	1.88	
Flow rate of fraction, kg/s	287	
Low Rate, kg/s, assume 10%	29	
Duration of test, min, module	40	
Duration of MegaPack test, min	210	
Fraction at one time	0.19	
Area of smoke release, assumed size of megapack		
Area of megapack, top, ft2	122.9	
Equivelent dia, ft	12.5	
Fraction average coverage	0.5	
Equivelent dia, ft	8.8	
Equivelent dia, inches	106	

Use 900C as per testing low end temp

From 9540A testing: Smoke Yield estimated basis

Module Weight Loss		
Weight loss, kg	69.7	
Number of cells	1053	
Weight loss per cell, g	66	
Weight loss, Megapack, kg	14219	
Smoke Yield ratio	7.4	Based on NIST Technical Note 1453, high end of range
Total Smoke Yield Megapack, kg	105219	
Test duration, minutes	210	
Smoke rate, kg/s	8.35	

Case Inputs

Case Type	: Vapor Dispersion
Case Name	: B-1vert
User ID	: GC
Project Number	:
Type of Units	: English Units

NOTES:

MATERIAL MENU

Materials Released	: Number	Formula	Name	Fraction
Component 1	: 51 =	H2	Hydrogen(equilibrium)	0.258295
Component 2	: 43 =	CO	Carbon Monoxide	0.506656
Component 3	: 1 =	CH4	Methane	0.099344
Component 4	: 2 =	C2H6	Ethane	0.039738
Component 5	: 3 =	C3H8	Propane	0.089410
Component 6	: 50 =	HF	Hydrogen Fluoride	0.000497
Component 7	: 26 =	HCl	Hydrogen Chloride	0.000993
Component 8	: 103 =	HCN	Hydrogen Cyanide	0.001590
Component 9	: 281 =	C7H8	Toluene	0.003477
Component 10	:			

Temperature	: 122.00 °F
Pressure	: 15.00 psia

The material is Indeterminate

NOTES:

ENVIRONMENT MENU

Wind speed	3.36 mph
Wind speed measurement height	32.8 feet
Stability class <A-F>	F
Relative humidity	70 %
Air temperature	77.0 °F
Spill surface temperature	77.0 °F

Substrate name	Soil
Substrate thermal conductivity	1.0000 Btu/hr-ft-F
Substrate density	100 lb/cu.ft
Substrate heat Capacity	0.24 Btu/lb-F
Substrate delay time	60 sec
Surrounding terrain	Long grass or crops > 15 cm (6 in)

NOTES:

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate              << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation, dispersion and cloud explosion - Flammable calculation
Concentration endpoint 1                         LFL mol%
Concentration endpoint 2                     1/2 LFL mol%
Concentration endpoint 3                     1/2 LFL mol%

Dispersion coefficient averaging time              1 min

Baker-Strehlow-Tang parameters

Fuel reactivity                                 High
Obstacle density                                High
Flame expansion                                  3-D

Overpressure values

Overpressure endpoint 1                         3.00 psi
Overpressure endpoint 2                         1.00 psi
Overpressure endpoint 3                         1.00 psi

  NOTES:
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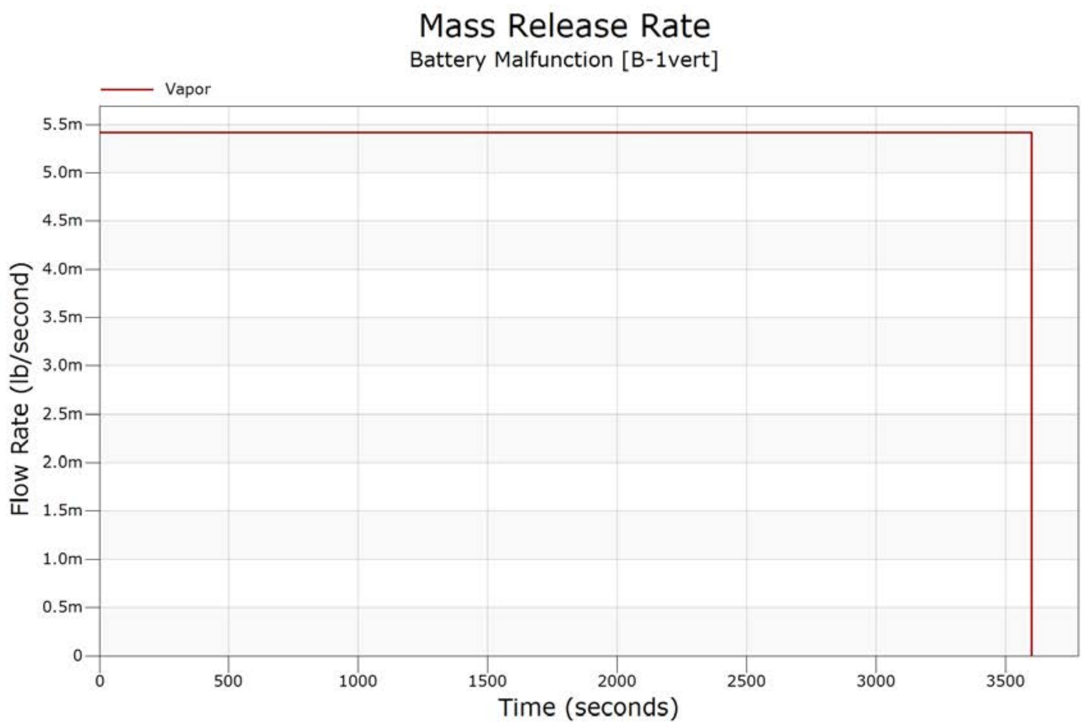
Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Flowrate for Jet Fire [immediate ignition] = 0.5417999E-02 lb/sec.
Jet Fire [delayed ignition] = 0.5417999E-02 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1vert]
Vapor
Flow Rate (lb/second)
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Flammable Limits (Mole %) of Fluid Streams

Limit	Feed Stream	Momentum Jet Stream	Liquid Pool Stream
LFL	5.43	5.43	
UFL	33.27	33.27	
LBV		0.39 m/s	

Momentum Jet Dispersion

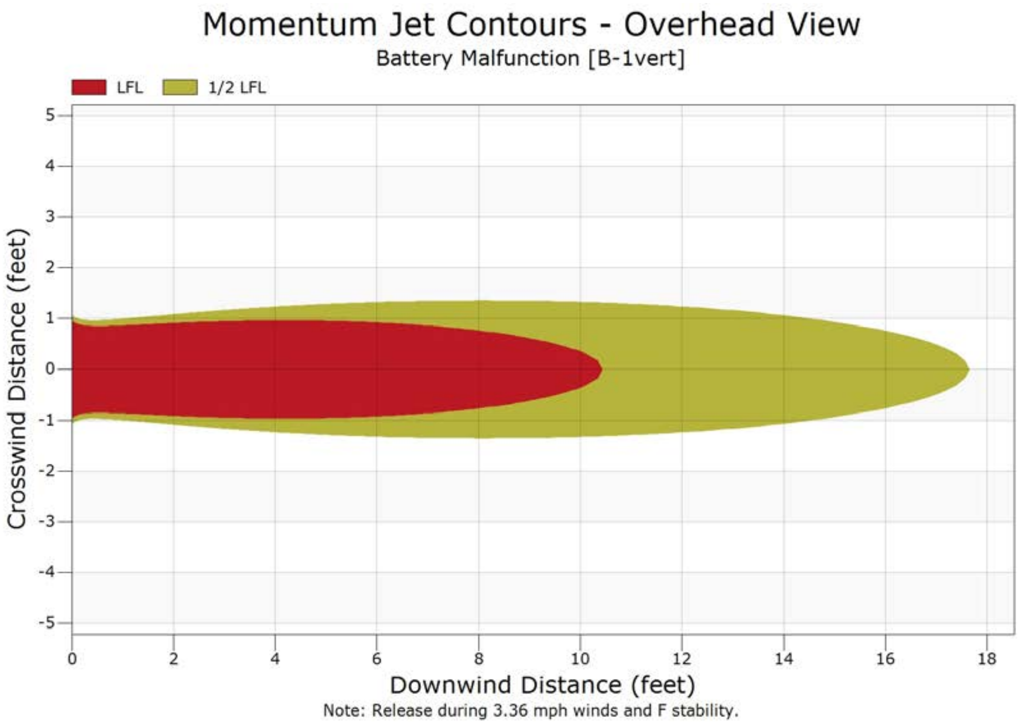
concentration limits

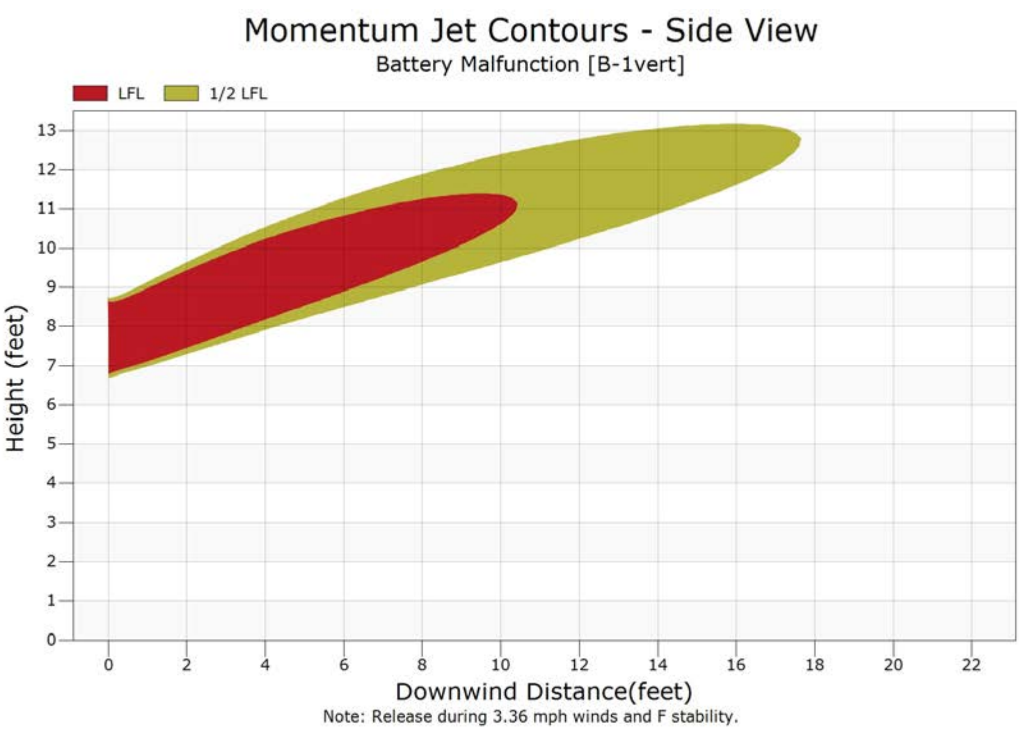
Endpoint 1 (highest) = 0.054276 mole fraction
Endpoint 2 (middle) = 0.027138 mole fraction
Endpoint 3 (lowest) = 0.027138 mole fraction

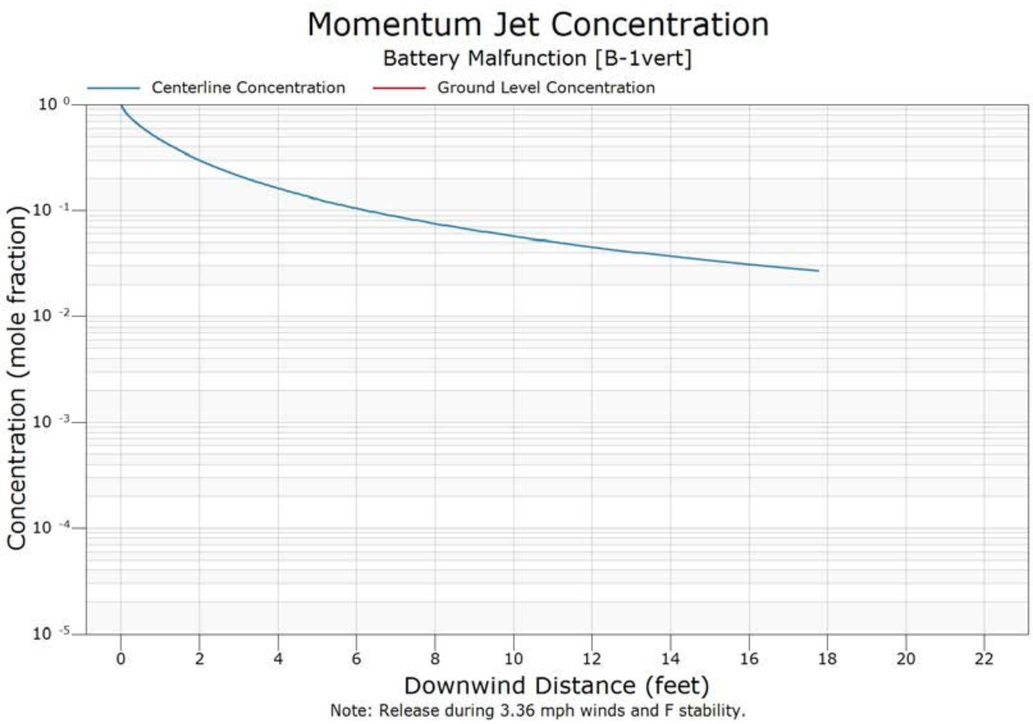
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	1.1	1.1	1.0	7.7
0.3	0.752273	0.000000	1.0	1.0	0.9	7.8
0.5	0.626005	0.000000	1.0	1.0	0.9	7.8
0.8	0.535606	0.000000	1.0	1.0	0.9	7.9
1.0	0.466592	0.000000	1.0	1.0	0.9	8.0
1.3	0.412142	0.000000	1.0	1.0	0.9	8.1
1.5	0.367693	0.000000	1.0	1.0	0.9	8.2
1.7	0.330699	0.000000	1.1	1.1	0.9	8.3
2.0	0.299584	0.000000	1.1	1.1	0.9	8.4
2.3	0.273057	0.000000	1.1	1.1	0.9	8.5
2.5	0.250294	0.000000	1.1	1.1	0.9	8.6
2.8	0.230566	0.000000	1.2	1.2	0.9	8.7
3.0	0.213360	0.000000	1.2	1.2	1.0	8.8
3.3	0.198131	0.000000	1.2	1.2	1.0	8.9
3.5	0.184698	0.000000	1.2	1.2	1.0	9.0
3.7	0.172729	0.000000	1.2	1.2	1.0	9.1
4.0	0.162003	0.000000	1.2	1.2	1.0	9.2
4.3	0.152309	0.000000	1.3	1.3	1.0	9.3
4.5	0.143674	0.000000	1.3	1.3	1.0	9.4
4.8	0.135714	0.000000	1.3	1.3	1.0	9.5
5.0	0.128455	0.000000	1.3	1.3	1.0	9.5
5.3	0.121922	0.000000	1.3	1.3	1.0	9.6
5.5	0.115893	0.000000	1.3	1.3	0.9	9.7
5.8	0.110404	0.000000	1.3	1.3	0.9	9.8
6.0	0.105263	0.000000	1.3	1.3	0.9	9.9
6.3	0.100460	0.000000	1.3	1.3	0.9	10.0
6.5	0.096089	0.000000	1.3	1.3	0.9	10.0
6.8	0.092000	0.000000	1.3	1.3	0.9	10.1
7.0	0.088189	0.000000	1.3	1.3	0.9	10.2
7.3	0.084652	0.000000	1.4	1.4	0.8	10.3
7.5	0.081311	0.000000	1.4	1.4	0.8	10.3
7.8	0.078198	0.000000	1.4	1.4	0.8	10.4
8.0	0.075310	0.000000	1.4	1.4	0.8	10.5
8.3	0.072575	0.000000	1.4	1.4	0.7	10.6
8.5	0.070010	0.000000	1.4	1.4	0.7	10.6

downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
8.8	0.067560	0.000000	1.4	1.4	0.7	10.7
9.0	0.065288	0.000000	1.4	1.4	0.6	10.8
9.3	0.063109	0.000000	1.3	1.3	0.6	10.8
9.5	0.061054	0.000000	1.3	1.3	0.5	10.9
9.8	0.059111	0.000000	1.3	1.3	0.4	11.0
10.0	0.057272	0.000000	1.3	1.3	0.4	11.0
10.3	0.055498	0.000000	1.3	1.3	0.2	11.1
10.5	0.053834	0.000000	1.3	1.3	0.0	11.2
10.8	0.052255	0.000000	1.3	1.3	0.0	11.2
11.0	0.050747	0.000000	1.3	1.3	0.0	11.3
11.3	0.049314	0.000000	1.3	1.3	0.0	11.3
11.5	0.047951	0.000000	1.3	1.3	0.0	11.4
11.8	0.046639	0.000000	1.3	1.3	0.0	11.5
12.0	0.045382	0.000000	1.2	1.2	0.0	11.5
12.3	0.044195	0.000000	1.2	1.2	0.0	11.6
12.5	0.043053	0.000000	1.2	1.2	0.0	11.6
12.8	0.041943	0.000000	1.2	1.2	0.0	11.7
13.0	0.040894	0.000000	1.2	1.2	0.0	11.8
13.2	0.039891	0.000000	1.1	1.1	0.0	11.8
13.5	0.038917	0.000000	1.1	1.1	0.0	11.9
13.8	0.037982	0.000000	1.1	1.1	0.0	11.9
14.0	0.037076	0.000000	1.1	1.1	0.0	12.0
14.3	0.036227	0.000000	1.0	1.0	0.0	12.1
14.5	0.035387	0.000000	1.0	1.0	0.0	12.1
14.8	0.034600	0.000000	1.0	1.0	0.0	12.2
15.0	0.033824	0.000000	0.9	0.9	0.0	12.2
15.3	0.033088	0.000000	0.9	0.9	0.0	12.3
15.5	0.032374	0.000000	0.9	0.9	0.0	12.3
15.7	0.031674	0.000000	0.8	0.8	0.0	12.4
16.0	0.031009	0.000000	0.8	0.8	0.0	12.4
16.3	0.030367	0.000000	0.7	0.7	0.0	12.5
16.5	0.029748	0.000000	0.6	0.6	0.0	12.5
16.8	0.029145	0.000000	0.6	0.6	0.0	12.6
17.0	0.028556	0.000000	0.5	0.5	0.0	12.6
17.3	0.027993	0.000000	0.4	0.4	0.0	12.7
17.5	0.027451	0.000000	0.2	0.2	0.0	12.7
17.8	0.026929	0.000000	0.0	0.0	0.0	12.8

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.054276 (LFL)	10.4	3
2 0.027138 (1/2 LFL)	17.6	5
3 0.027138 (1/2 LFL)	17.6	5


Momentum Jet Contours - Overhead View
Battery Malfunction [B-1vert]
LFL
1/2 LFL
Crosswind Distance (feet)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
2
4
6
8
10
12
14
16
18
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction [B-1vert]
LFL
1/2 LFL
Height (feet)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
16
18
20
22
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1vert]
Centerline Concentration
Ground Level Concentration
10 0
10 -1
10 -2
10 -3
10 -4
10 -5
Concentration (mole fraction)
0
2
4
6
8
10
12
14
16
18
20
22
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

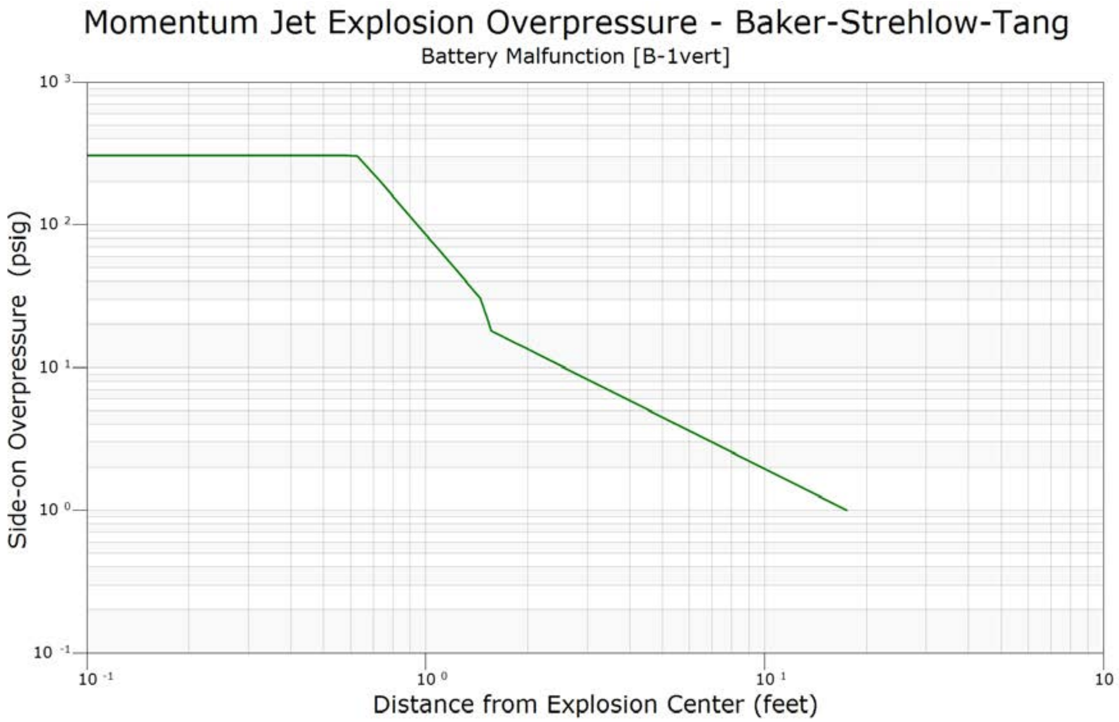
Momentum Jet Explosion

Fuel Reactivity: High   Obstacle Density: High
Flame Expansion: 3-D   Flame Speed: 5.20

Mass of released material involved in explosion: 0.0162488 lbs.

Distance from Center of Flammable Cloud (feet)	Overpressure (psi gauge)	Impulse (psi-s)
0.0	308.61	0.0152
0.4	308.61	0.0152
0.4	308.61	0.0141
0.5	308.61	0.0131
0.5	308.61	0.0122
0.5	308.61	0.0113
0.6	308.61	0.0105
0.6	305.51	0.0097
0.7	247.89	0.0090
0.7	201.14	0.0084
0.8	163.21	0.0078
0.9	132.43	0.0072
0.9	107.45	0.0067
1.0	87.19	0.0062
1.1	70.75	0.0058
1.2	57.40	0.0054
1.2	46.58	0.0050
1.3	37.79	0.0046
1.5	30.67	0.0043
1.6	18.05	0.0040
1.7	16.47	0.0037
1.8	15.04	0.0034
2.0	13.73	0.0032
2.1	12.53	0.0030
17.4	1.00	0.0004

The downwind distance to 3.00 psi is 14.8 feet
The downwind distance to 1.00 psi is 17.4 feet
The downwind distance to 1.00 psi is 17.4 feet


Momentum Jet Explosion Overpressure - Baker-Strehlow-Tang
Battery Malfunction [B-1vert]
Side-on Overpressure (psig)
10 3
10 2
10 1
10 0
10 -1
10 -1
10 0
10 1
10 2
Distance from Explosion Center (feet)

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : B-1toxicCO
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                         Fraction
Component  1         :    51 = H2        Hydrogen(equilibrium)        0.258295
Component  2         :    43 = CO        Carbon Monoxide              0.506656
Component  3         :     1 = CH4       Methane                      0.099344
Component  4         :     2 = C2H6      Ethane                       0.039738
Component  5         :     3 = C3H8      Propane                      0.089410
Component  6         :    50 = HF        Hydrogen Fluoride            0.000497
Component  7         :    26 = HCl       Hydrogen Chloride            0.000993
Component  8         :   103 = HCN       Hydrogen Cyanide             0.001590
Component  9         :   281 = C7H8      Toluene                      0.003477
Component 10         :

Temperature          :       122.00 °F
Pressure             :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate              << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   43 = CO        Carbon Monoxide
Concentration endpoint 1                     1200.0 ppm
Concentration endpoint 2                      500.0 ppm
Concentration endpoint 3                      350.0 ppm

Dispersion coefficient averaging time            1 min

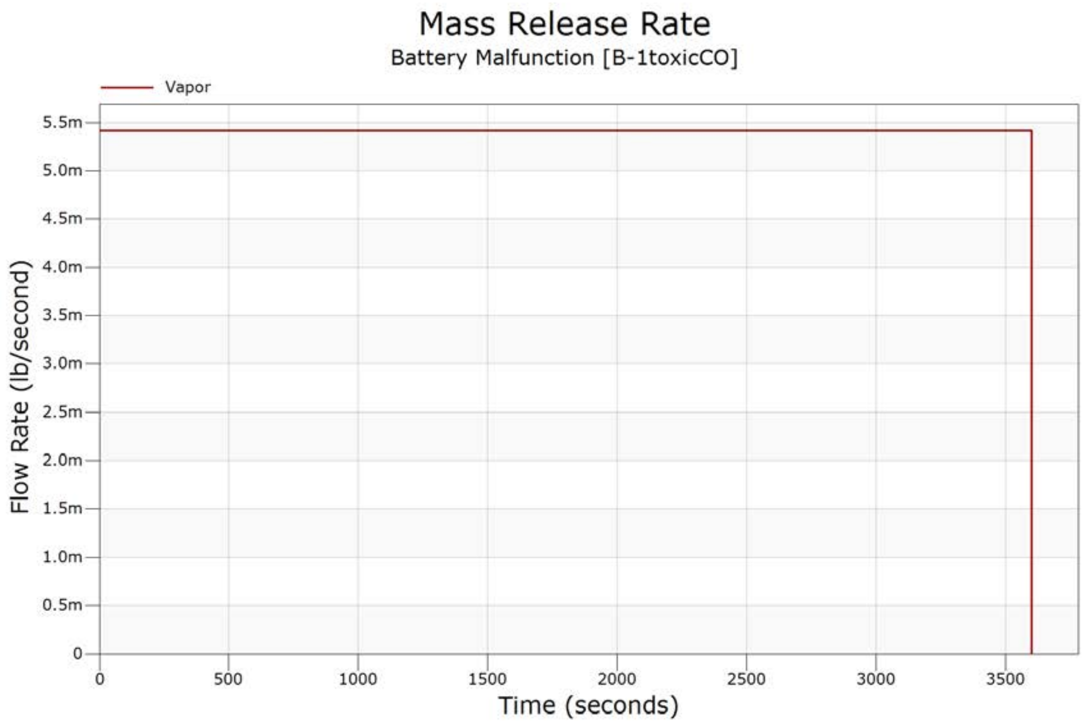

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1toxicCO]
Vapor
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
Flow Rate (lb/second)
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

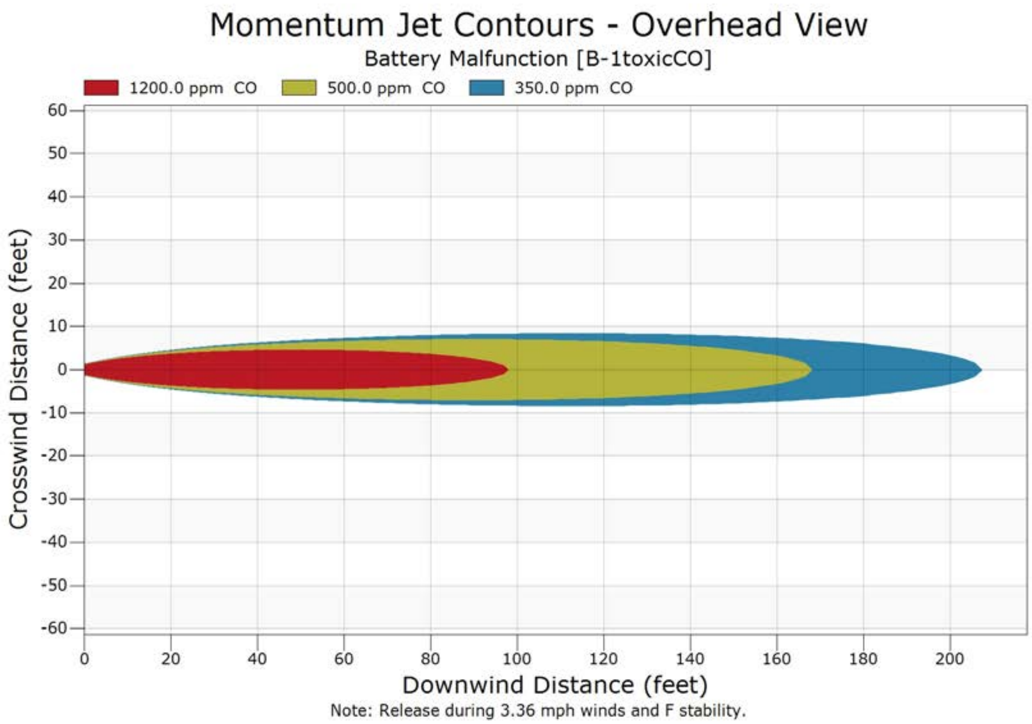
concentration limits

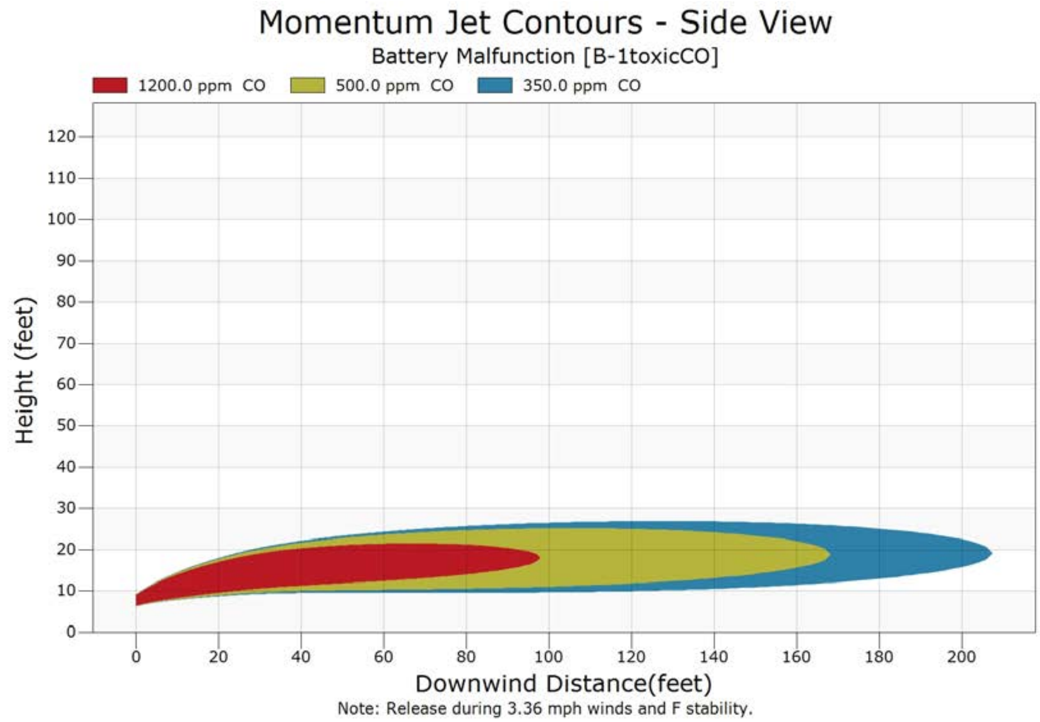
Endpoint 1 (highest) = 1200.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 350.0 ppm

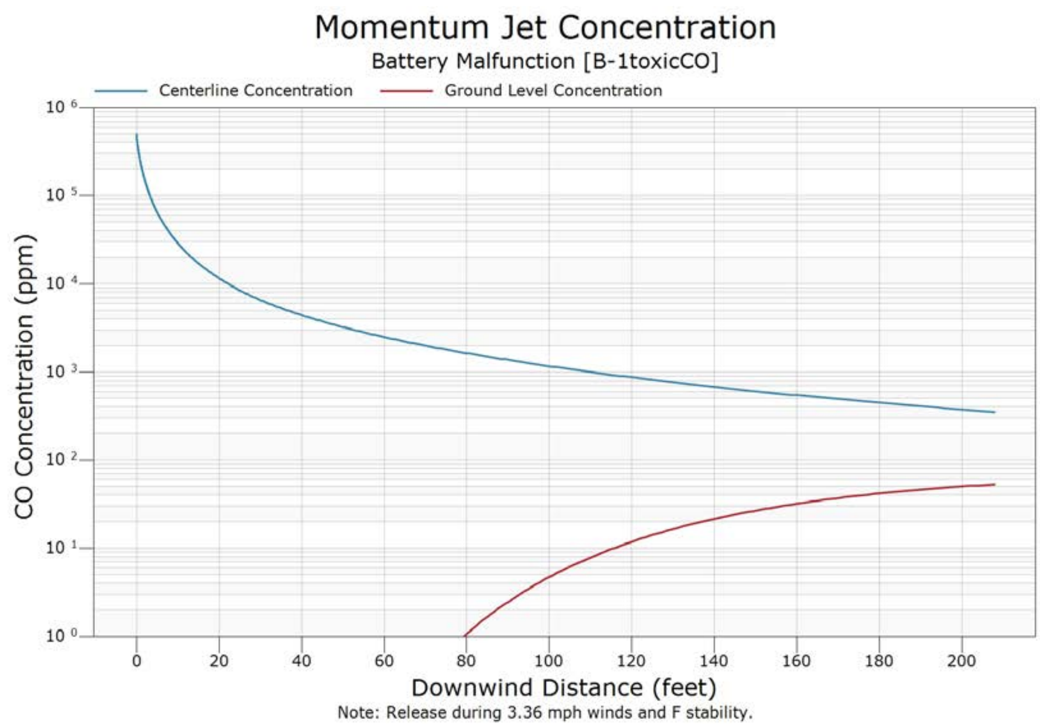
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	506656.000	0.000	1.5	1.5	1.4	7.7
5	65106.411	0.000	2.4	2.3	2.1	9.5
10	29013.440	0.000	3.2	3.1	2.8	11.0
15	17136.398	0.000	4.0	3.8	3.3	12.2
20	11570.560	0.000	4.6	4.3	3.7	13.2
25	8465.761	0.000	5.1	4.8	4.0	14.1
30	6565.454	0.000	5.6	5.2	4.2	14.8
35	5306.888	0.000	6.0	5.6	4.4	15.3
40	4415.335	0.001	6.3	5.9	4.5	15.8
45	3750.826	0.003	6.6	6.1	4.6	16.1
50	3233.824	0.011	6.9	6.3	4.6	16.4
55	2827.669	0.032	7.2	6.5	4.6	16.7
60	2494.633	0.082	7.4	6.7	4.5	16.9
65	2220.465	0.180	7.6	6.8	4.4	17.1
70	1993.080	0.355	7.8	6.9	4.2	17.3
75	1799.711	0.634	7.9	7.0	3.9	17.5
80	1633.699	1.057	8.1	7.1	3.6	17.6
85	1490.549	1.654	8.2	7.1	3.2	17.7
90	1365.964	2.451	8.3	7.1	2.6	17.9
95	1257.383	3.453	8.4	7.1	1.6	18.0
100	1160.509	4.690	8.4	7.1	0.0	18.1
105	1075.839	6.176	8.5	7.0	0.0	18.2
110	999.565	7.833	8.5	6.9	0.0	18.2
115	931.613	9.744	8.5	6.8	0.0	18.3
120	870.839	11.843	8.5	6.6	0.0	18.4
125	815.435	14.091	8.4	6.4	0.0	18.5
130	765.409	16.478	8.4	6.2	0.0	18.5
135	720.037	18.981	8.3	5.9	0.0	18.6
140	678.445	21.527	8.2	5.5	0.0	18.6
145	640.295	24.170	8.0	5.1	0.0	18.7
150	605.601	26.782	7.9	4.6	0.0	18.8
155	573.409	29.416	7.7	4.0	0.0	18.8
160	543.789	32.027	7.4	3.2	0.0	18.8
165	516.536	34.575	7.2	2.1	0.0	18.9
170	491.286	37.030	6.9	0.0	0.0	18.9

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
175	467.721	39.463	6.5	0.0	0.0	19.0
180	445.900	41.741	6.1	0.0	0.0	19.0
185	425.650	43.985	5.6	0.0	0.0	19.0
190	406.732	46.067	5.0	0.0	0.0	19.1
195	388.967	48.042	4.3	0.0	0.0	19.1
200	372.400	49.886	3.4	0.0	0.0	19.1
205	356.921	51.654	1.9	0.0	0.0	19.2

Endpoint (ppm, CO)		Downwind Distance (feet)	Approximate Time (seconds)
1	1200.0	97.9	26
2	500.0	168.2	43
3	350.0	207.3	53




Momentum Jet Contours - Side View
Battery Malfunction [B-1toxicCO]
1200.0 ppm CO
500.0 ppm CO
350.0 ppm CO
Height (feet)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
20
40
60
80
100
120
140
160
180
200
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1toxicCO]
Centerline Concentration
Ground Level Concentration
CO Concentration (ppm)
10 0
10 1
10 2
10 3
10 4
10 5
10 6
0
20
40
60
80
100
120
140
160
180
200
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type              : Vapor Dispersion
Case Name              : B-1toxicHCL
User ID                : GC
Project Number         :
Type of Units          : English Units

  NOTES:

MATERIAL MENU
Materials Released     : Number  Formula   Name                         Fraction
Component  1           :    51 = H2        Hydrogen(equilibrium)        0.258295
Component  2           :    43 = CO        Carbon Monoxide              0.506656
Component  3           :     1 = CH4       Methane                      0.099344
Component  4           :     2 = C2H6      Ethane                       0.039738
Component  5           :     3 = C3H8      Propane                      0.089410
Component  6           :    50 = HF        Hydrogen Fluoride            0.000497
Component  7           :    26 = HCl       Hydrogen Chloride            0.000993
Component  8           :   103 = HCN       Hydrogen Cyanide             0.001590
Component  9           :   281 = C7H8      Toluene                      0.003477
Component 10           :

Temperature            :       122.00 °F
Pressure               :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate               << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component    26 = HCl       Hydrogen Chloride
Concentration endpoint 1                       150.0 ppm
Concentration endpoint 2                        50.0 ppm
Concentration endpoint 3                        20.0 ppm

Dispersion coefficient averaging time              1 min

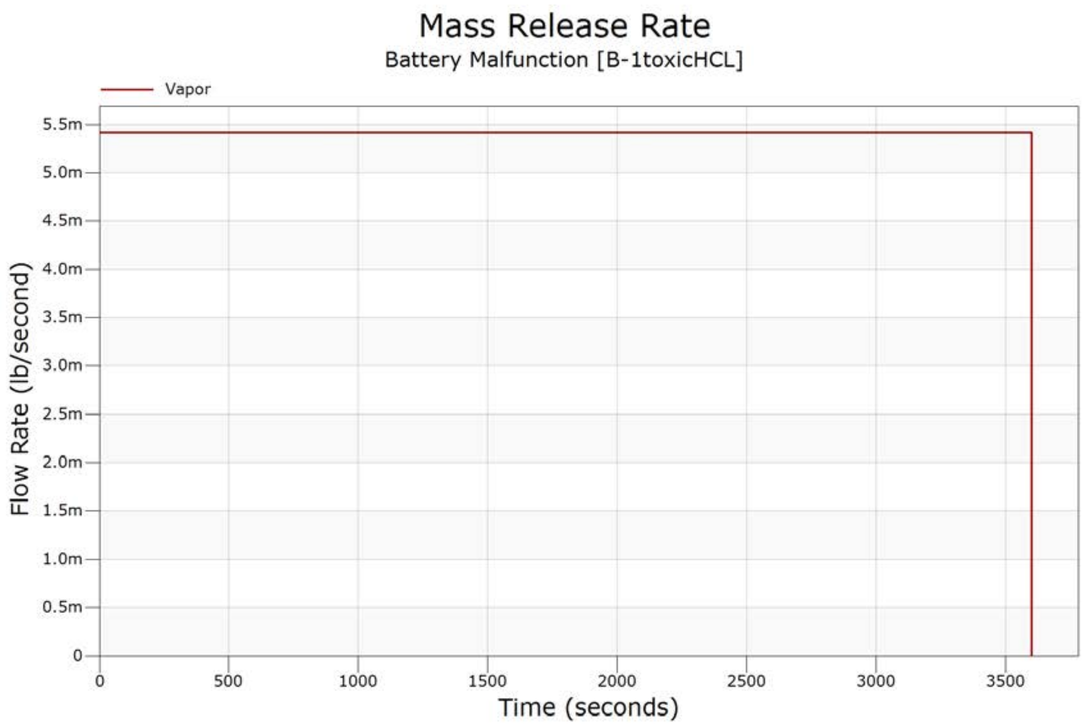

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1toxicHCL]
Vapor
Flow Rate (lb/second)
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H_2
43	Carbon Monoxide, CO
1	Methane, CH_4
2	Ethane, C_2H_6
3	Propane, C_3H_8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C_7H_8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

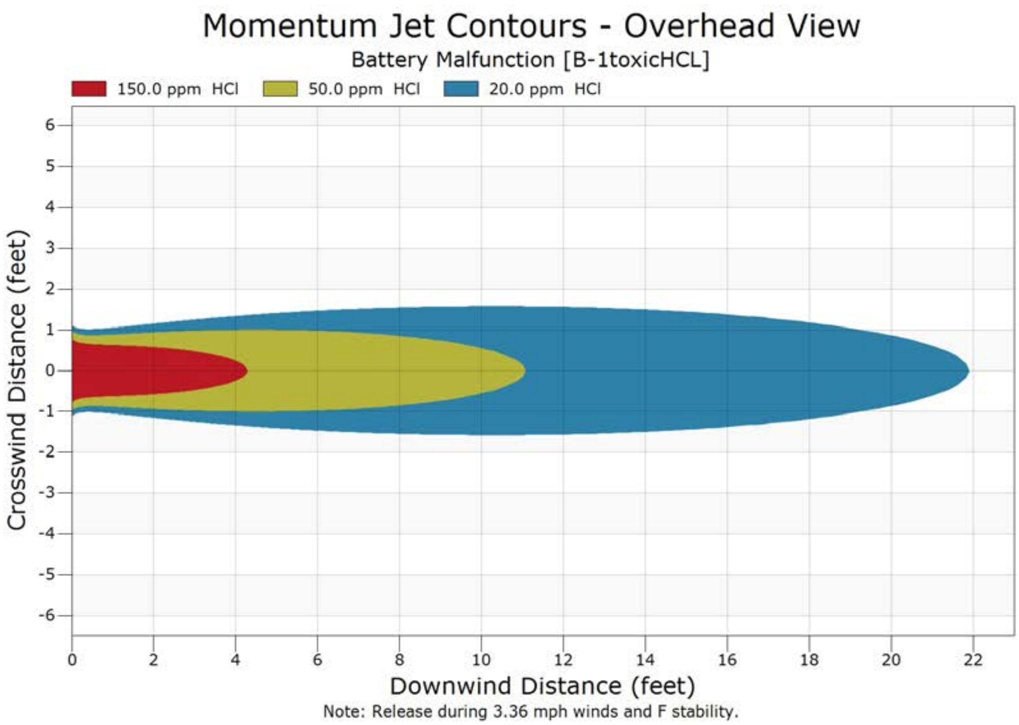
concentration limits

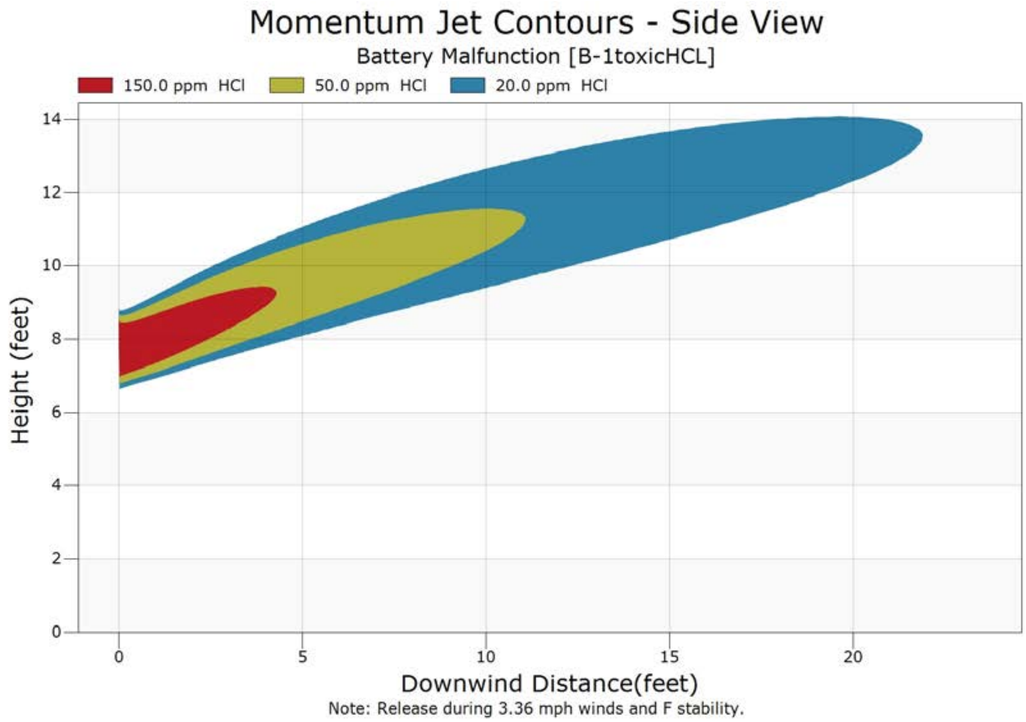
Endpoint 1 (highest) = 150.0 ppm
Endpoint 2 (middle) = 50.0 ppm
Endpoint 3 (lowest) = 20.0 ppm

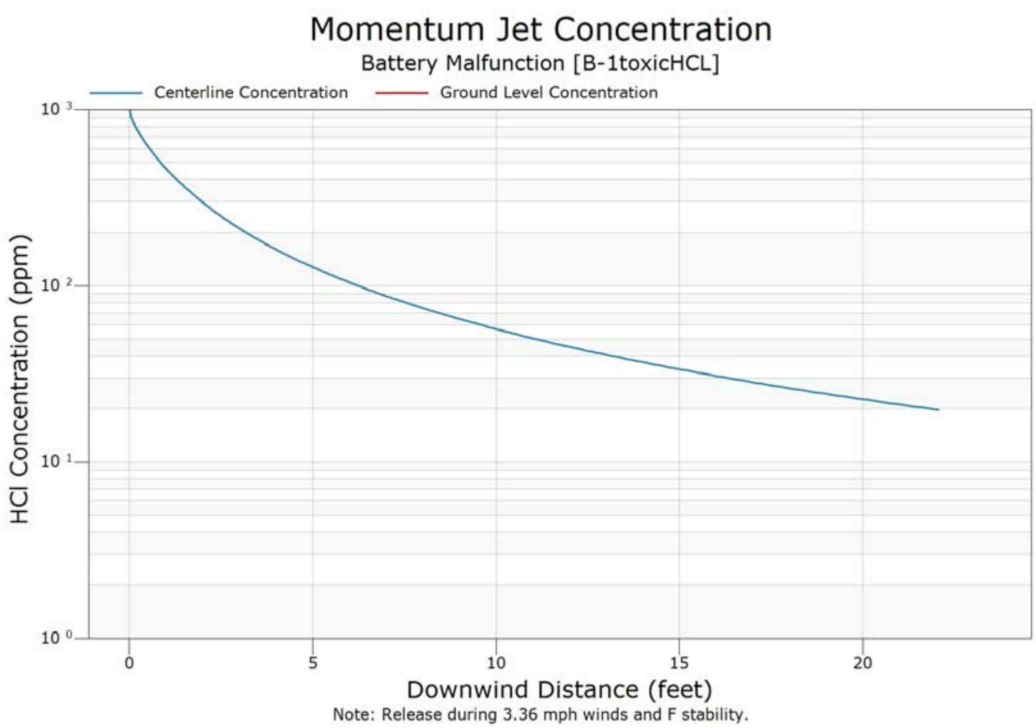
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	993.440	0.000	1.1	1.0	0.8	7.7
0.5	621.845	0.000	1.0	0.9	0.6	7.8
1.0	463.613	0.000	1.1	0.9	0.6	8.0
1.5	365.263	0.000	1.1	0.9	0.6	8.2
2.0	297.645	0.000	1.2	0.9	0.6	8.4
2.5	248.636	0.000	1.2	1.0	0.5	8.6
3.0	211.849	0.000	1.3	1.0	0.5	8.8
3.5	183.402	0.000	1.3	1.0	0.4	9.0
4.0	160.968	0.000	1.3	1.0	0.2	9.2
4.5	142.785	0.000	1.4	1.0	0.0	9.4
5.0	127.689	0.000	1.4	1.0	0.0	9.5
5.5	115.155	0.000	1.4	1.0	0.0	9.7
6.0	104.505	0.000	1.5	1.0	0.0	9.9
6.5	95.455	0.000	1.5	1.0	0.0	10.0
7.0	87.613	0.000	1.5	0.9	0.0	10.2
7.5	80.775	0.000	1.5	0.9	0.0	10.3
8.0	74.826	0.000	1.5	0.9	0.0	10.5
8.5	69.556	0.000	1.6	0.8	0.0	10.6
9.0	64.861	0.000	1.6	0.7	0.0	10.8
9.5	60.659	0.000	1.6	0.7	0.0	10.9
10.0	56.895	0.000	1.6	0.6	0.0	11.0
10.5	53.483	0.000	1.6	0.4	0.0	11.2
11.0	50.431	0.000	1.6	0.1	0.0	11.3
11.5	47.640	0.000	1.6	0.0	0.0	11.4
12.0	45.096	0.000	1.6	0.0	0.0	11.5
12.5	42.769	0.000	1.5	0.0	0.0	11.6
13.0	40.635	0.000	1.5	0.0	0.0	11.8
13.5	38.662	0.000	1.5	0.0	0.0	11.9
14.0	36.840	0.000	1.5	0.0	0.0	12.0
14.5	35.158	0.000	1.5	0.0	0.0	12.1
15.0	33.601	0.000	1.4	0.0	0.0	12.2
15.5	32.157	0.000	1.4	0.0	0.0	12.3
16.0	30.802	0.000	1.4	0.0	0.0	12.4
16.5	29.551	0.000	1.3	0.0	0.0	12.5
17.0	28.370	0.000	1.3	0.0	0.0	12.6

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
17.5	27.270	0.000	1.2	0.0	0.0	12.7
18.0	26.237	0.000	1.2	0.0	0.0	12.8
18.5	25.270	0.000	1.1	0.0	0.0	12.9
19.0	24.359	0.000	1.0	0.0	0.0	13.0
19.5	23.503	0.000	1.0	0.0	0.0	13.1
20.0	22.694	0.000	0.9	0.0	0.0	13.2
20.5	21.927	0.000	0.8	0.0	0.0	13.3
21.0	21.203	0.000	0.6	0.0	0.0	13.4
21.5	20.517	0.000	0.4	0.0	0.0	13.5
22.0	19.868	0.000	0.0	0.0	0.0	13.6

Endpoint (ppm, HCl)		Downwind Distance (feet)	Approximate Time (seconds)
1	150.0	4.3	2
2	50.0	11.1	4
3	20.0	21.9	7




Momentum Jet Contours - Side View
Battery Malfunction [B-1toxicHCL]
150.0 ppm HCl
50.0 ppm HCl
20.0 ppm HCl
Height (feet)
14
12
10
8
6
4
2
0
0
5
10
15
20
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1toxicHCL]
Centerline Concentration
Ground Level Concentration
HCl Concentration (ppm)
10 3
10 2
10 1
10 0
0
5
10
15
20
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type              : Vapor Dispersion
Case Name              : B-1toxicHCN
User ID                : GC
Project Number         :
Type of Units          : English Units

  NOTES:

MATERIAL MENU
Materials Released     : Number  Formula   Name                          Fraction
Component  1           :    51 = H2        Hydrogen(equilibrium)         0.258295
Component  2           :    43 = CO        Carbon Monoxide               0.506656
Component  3           :     1 = CH4       Methane                       0.099344
Component  4           :     2 = C2H6      Ethane                        0.039738
Component  5           :     3 = C3H8      Propane                       0.089410
Component  6           :    50 = HF        Hydrogen Fluoride             0.000497
Component  7           :    26 = HCl       Hydrogen Chloride             0.000993
Component  8           :   103 = HCN       Hydrogen Cyanide              0.001590
Component  9           :   281 = C7H8      Toluene                       0.003477
Component 10           :

Temperature            :       122.00 °F
Pressure               :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate              << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component  103 = HCN       Hydrogen Cyanide
Concentration endpoint 1                        50.0 ppm
Concentration endpoint 2                        25.0 ppm
Concentration endpoint 3                        10.0 ppm

Dispersion coefficient averaging time              1 min

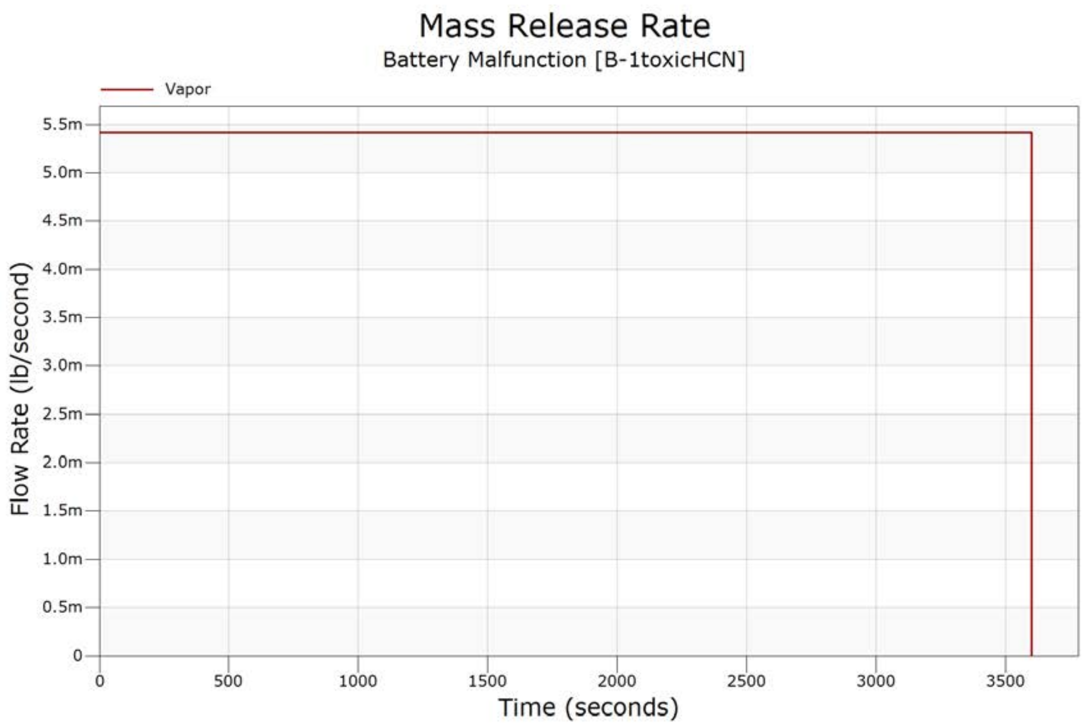

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1toxicHCN]
Vapor
Flow Rate (lb/second)
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

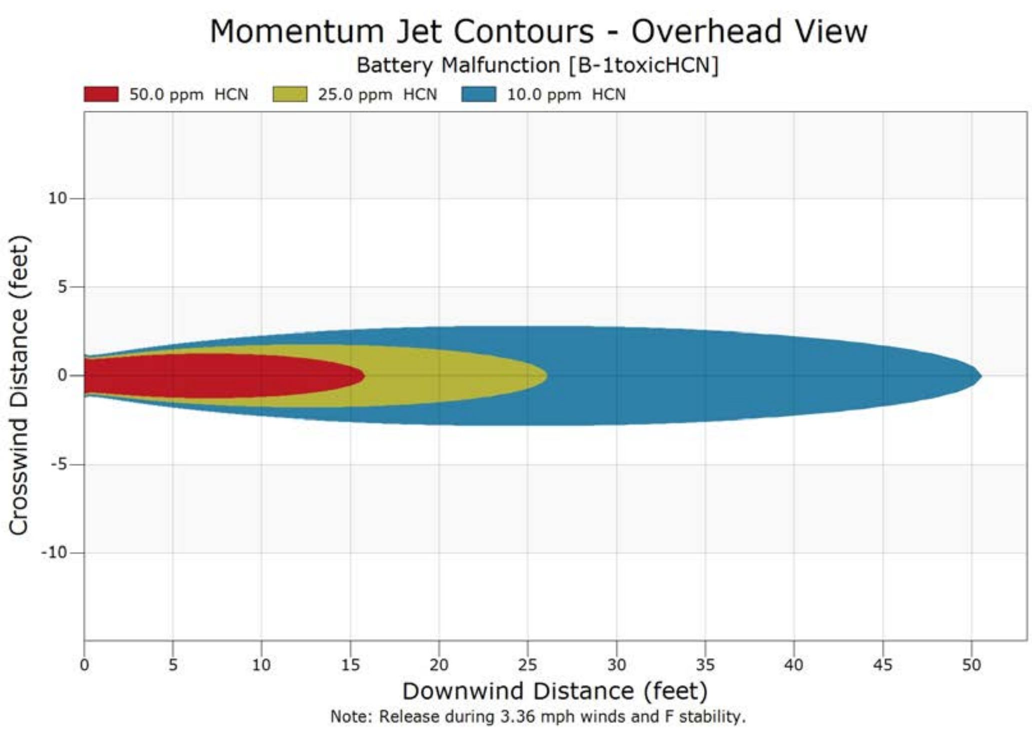
concentration limits

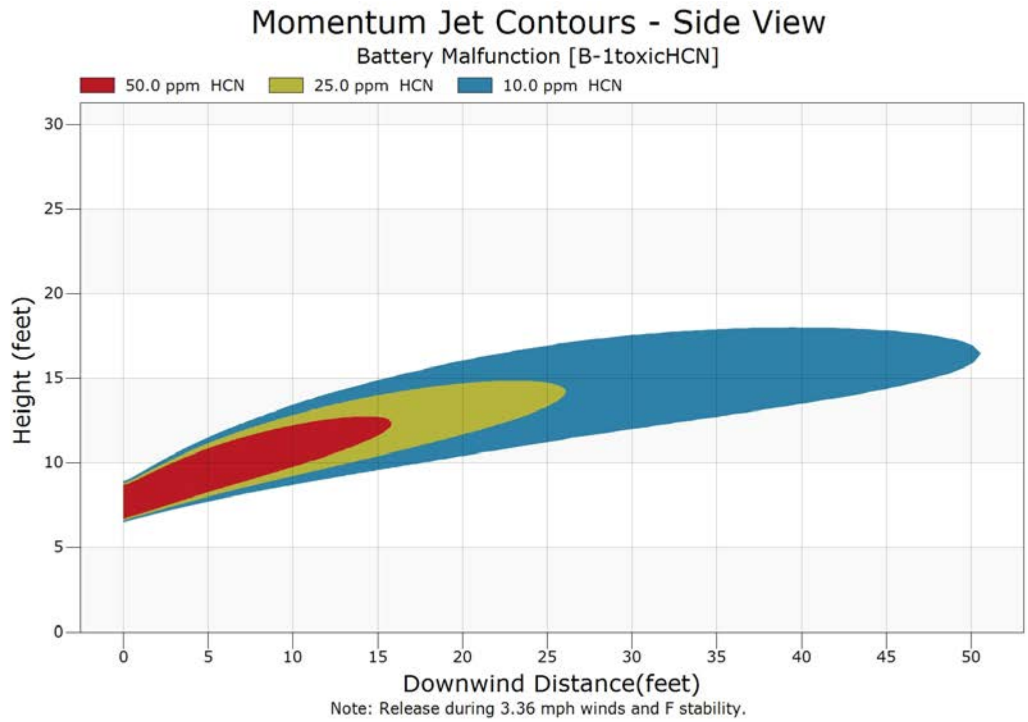
Endpoint 1 (highest) = 50.0 ppm
Endpoint 2 (middle) = 25.0 ppm
Endpoint 3 (lowest) = 10.0 ppm

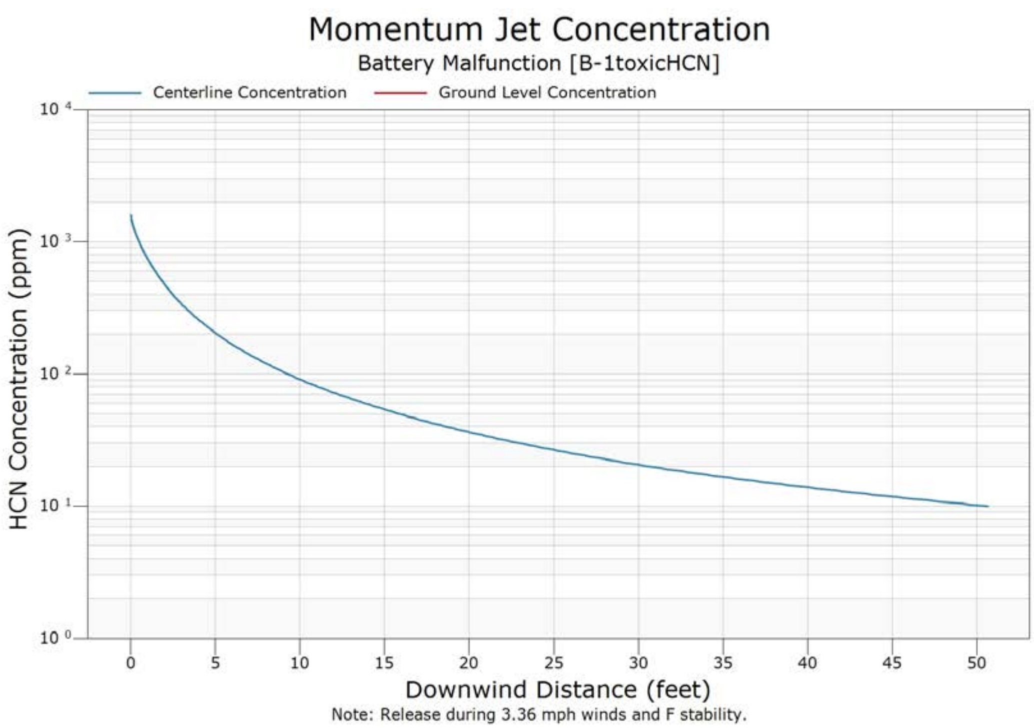
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1589.510	0.000	1.3	1.1	1.0	7.7
1	741.728	0.000	1.2	1.1	1.0	8.0
2	476.104	0.000	1.4	1.2	1.1	8.4
3	338.895	0.000	1.5	1.3	1.1	8.8
4	257.414	0.000	1.7	1.4	1.2	9.2
5	204.233	0.000	1.8	1.5	1.2	9.5
6	167.235	0.000	1.9	1.6	1.3	9.9
7	140.125	0.000	2.0	1.6	1.3	10.2
8	119.705	0.000	2.1	1.7	1.3	10.5
9	103.761	0.000	2.2	1.7	1.2	10.8
10	91.038	0.000	2.3	1.8	1.2	11.0
11	80.687	0.000	2.4	1.8	1.1	11.3
12	72.142	0.000	2.4	1.8	1.0	11.5
13	64.994	0.000	2.5	1.8	0.9	11.8
14	58.937	0.000	2.6	1.8	0.8	12.0
15	53.768	0.000	2.6	1.8	0.5	12.2
16	49.293	0.000	2.6	1.7	0.0	12.4
17	45.389	0.000	2.7	1.7	0.0	12.6
18	41.981	0.000	2.7	1.6	0.0	12.8
19	38.972	0.000	2.7	1.6	0.0	13.0
20	36.303	0.000	2.8	1.5	0.0	13.2
21	33.932	0.000	2.8	1.4	0.0	13.4
22	31.791	0.000	2.8	1.3	0.0	13.6
23	29.874	0.000	2.8	1.1	0.0	13.8
24	28.133	0.000	2.8	1.0	0.0	13.9
25	26.554	0.000	2.8	0.7	0.0	14.1
26	25.126	0.000	2.8	0.2	0.0	14.3
27	23.842	0.000	2.8	0.0	0.0	14.4
28	22.663	0.000	2.8	0.0	0.0	14.5
29	21.586	0.000	2.8	0.0	0.0	14.7
30	20.594	0.000	2.8	0.0	0.0	14.8
31	19.679	0.000	2.7	0.0	0.0	14.9
32	18.830	0.000	2.7	0.0	0.0	15.0
33	18.033	0.000	2.7	0.0	0.0	15.1
34	17.328	0.000	2.6	0.0	0.0	15.2

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
35	16.635	0.000	2.6	0.0	0.0	15.3
36	16.007	0.000	2.5	0.0	0.0	15.4
37	15.419	0.000	2.5	0.0	0.0	15.5
38	14.866	0.000	2.4	0.0	0.0	15.6
39	14.343	0.000	2.3	0.0	0.0	15.7
40	13.853	0.000	2.3	0.0	0.0	15.8
41	13.383	0.000	2.2	0.0	0.0	15.9
42	12.933	0.000	2.1	0.0	0.0	15.9
43	12.530	0.000	2.0	0.0	0.0	16.0
44	12.136	0.000	1.9	0.0	0.0	16.1
45	11.764	0.000	1.7	0.0	0.0	16.1
46	11.405	0.000	1.6	0.0	0.0	16.2
47	11.070	0.000	1.4	0.0	0.0	16.3
48	10.750	0.000	1.2	0.0	0.0	16.3
49	10.445	0.000	1.0	0.0	0.0	16.4
50	10.152	0.000	0.6	0.0	0.0	16.4

Endpoint	(ppm, HCN)	Downwind Distance (feet)	Approximate Time (seconds)
1	50.0	15.8	5
2	25.0	26.1	8
3	10.0	50.6	14




Momentum Jet Contours - Side View
Battery Malfunction [B-1toxicHCN]
50.0 ppm HCN
25.0 ppm HCN
10.0 ppm HCN
Height (feet)
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45
50
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1toxicHCN]
Centerline Concentration
Ground Level Concentration
HCN Concentration (ppm)
10 4
10 3
10 2
10 1
10 0
0
5
10
15
20
25
30
35
40
45
50
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

Case Type : Vapor Dispersion
Case Name : B-1toxicHF
User ID : GC
Project Number :
Type of Units : English Units

NOTES:

MATERIAL MENU

Materials Released	Number	Formula	Name	Fraction
Component 1	51	= H2	Hydrogen(equilibrium)	0.258295
Component 2	43	= CO	Carbon Monoxide	0.506656
Component 3	1	= CH4	Methane	0.099344
Component 4	2	= C2H6	Ethane	0.039738
Component 5	3	= C3H8	Propane	0.089410
Component 6	50	= HF	Hydrogen Fluoride	0.000497
Component 7	26	= HCl	Hydrogen Chloride	0.000993
Component 8	103	= HCN	Hydrogen Cyanide	0.001590
Component 9	281	= C7H8	Toluene	0.003477
Component 10				

Temperature : 122.00 °F
Pressure : 15.00 psia
The material is Indeterminate

NOTES:

ENVIRONMENT MENU

Wind speed	3.36 mph
Wind speed measurement height	32.8 feet
Stability class <A-F>	F
Relative humidity	70 %
Air temperature	77.0 °F
Spill surface temperature	77.0 °F

Substrate name	Soil
Substrate thermal conductivity	1.0000 Btu/hr-ft-F
Substrate density	100 lb/cu.ft
Substrate heat Capacity	0.24 Btu/lb-F
Substrate delay time	60 sec
Surrounding terrain	Long grass or crops > 15 cm (6 in)

NOTES:

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate              << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   50 = HF        Hydrogen Fluoride
Concentration endpoint 1                        50.0 ppm
Concentration endpoint 2                        30.0 ppm
Concentration endpoint 3                        20.0 ppm

Dispersion coefficient averaging time              1 min

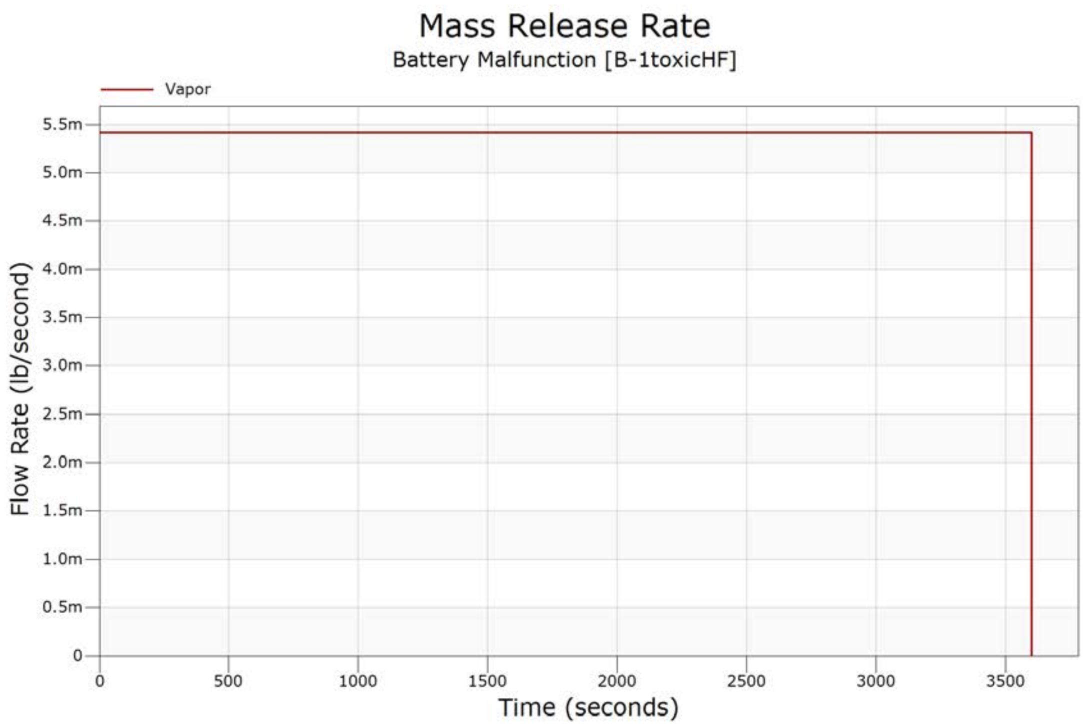

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1toxicHF]
Vapor
Flow Rate (lb/second)
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H_2
43	Carbon Monoxide, CO
1	Methane, CH_4
2	Ethane, C_2H_6
3	Propane, C_3H_8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C_7H_8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

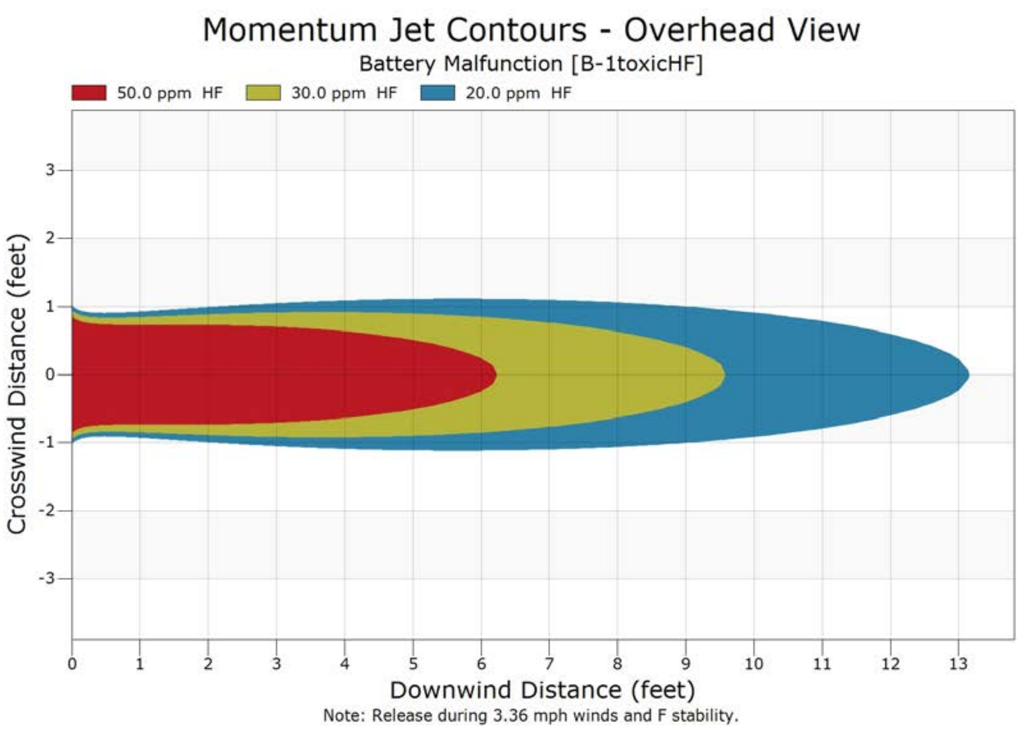
concentration limits

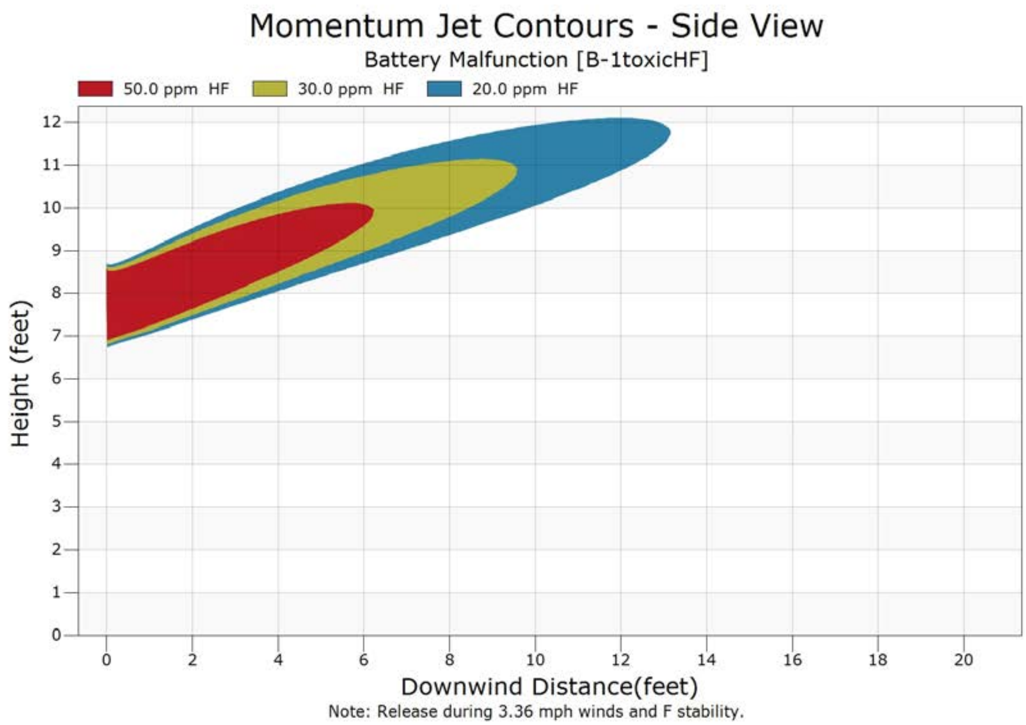
Endpoint 1 (highest) = 50.0 ppm
Endpoint 2 (middle) = 30.0 ppm
Endpoint 3 (lowest) = 20.0 ppm

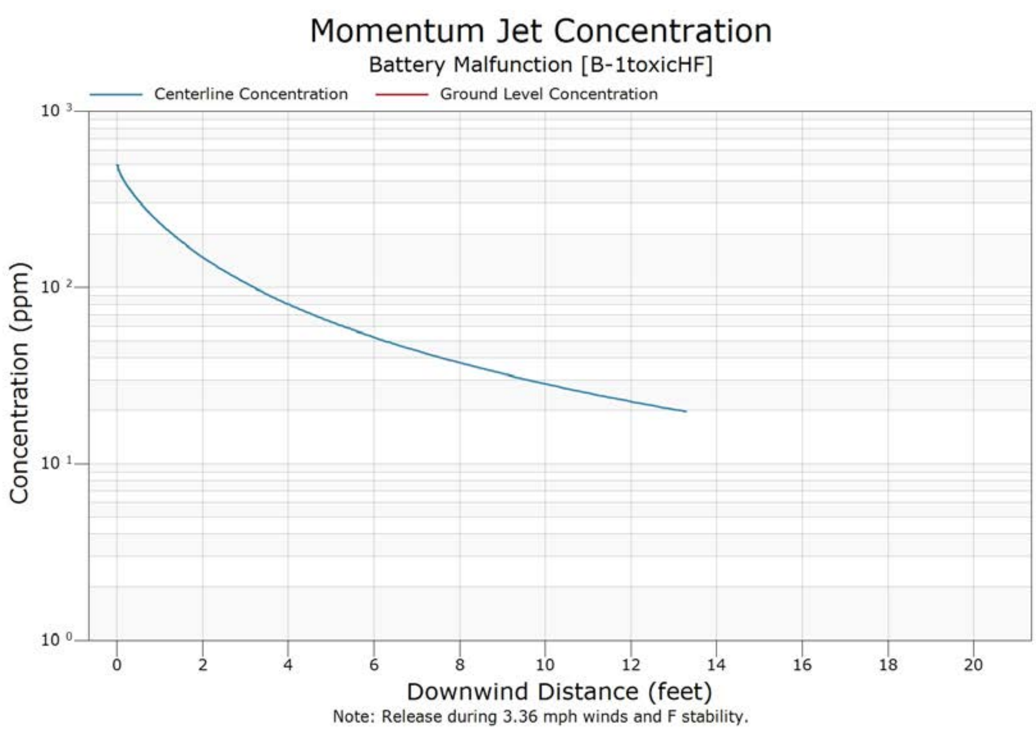
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	496.720	0.000	1.0	0.9	0.8	7.7
0.3	373.700	0.000	0.9	0.9	0.8	7.8
0.5	310.963	0.000	0.9	0.8	0.7	7.8
0.8	266.053	0.000	0.9	0.8	0.7	7.9
1.0	231.767	0.000	0.9	0.8	0.7	8.0
1.3	204.719	0.000	0.9	0.9	0.7	8.1
1.5	182.655	0.000	1.0	0.9	0.7	8.2
1.7	164.296	0.000	1.0	0.9	0.7	8.3
2.0	148.804	0.000	1.0	0.9	0.7	8.4
2.3	135.628	0.000	1.0	0.9	0.7	8.5
2.5	124.338	0.000	1.0	0.9	0.7	8.6
2.8	114.533	0.000	1.0	0.9	0.7	8.7
3.0	105.978	0.000	1.1	0.9	0.7	8.8
3.3	98.436	0.000	1.1	0.9	0.7	8.9
3.5	91.769	0.000	1.1	0.9	0.7	9.0
3.7	85.794	0.000	1.1	0.9	0.7	9.1
4.0	80.454	0.000	1.1	0.9	0.6	9.2
4.3	75.649	0.000	1.1	0.9	0.6	9.3
4.5	71.377	0.000	1.1	0.9	0.6	9.4
4.8	67.438	0.000	1.1	0.9	0.5	9.5
5.0	63.822	0.000	1.1	0.9	0.5	9.5
5.3	60.573	0.000	1.1	0.9	0.5	9.6
5.5	57.576	0.000	1.1	0.9	0.4	9.7
5.8	54.832	0.000	1.1	0.9	0.3	9.8
6.0	52.270	0.000	1.1	0.8	0.2	9.9
6.3	49.894	0.000	1.1	0.8	0.0	10.0
6.5	47.728	0.000	1.1	0.8	0.0	10.0
6.8	45.699	0.000	1.1	0.8	0.0	10.1
7.0	43.806	0.000	1.1	0.8	0.0	10.2
7.3	42.050	0.000	1.1	0.7	0.0	10.3
7.5	40.391	0.000	1.1	0.7	0.0	10.3
7.8	38.846	0.000	1.1	0.7	0.0	10.4
8.0	37.411	0.000	1.1	0.6	0.0	10.5
8.3	36.053	0.000	1.1	0.6	0.0	10.6
8.5	34.778	0.000	1.0	0.5	0.0	10.6

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
8.8	33.559	0.000	1.0	0.5	0.0	10.7
9.0	32.429	0.000	1.0	0.4	0.0	10.8
9.3	31.346	0.000	1.0	0.3	0.0	10.8
9.5	30.328	0.000	1.0	0.2	0.0	10.9
9.8	29.365	0.000	0.9	0.0	0.0	11.0
10.0	28.453	0.000	0.9	0.0	0.0	11.0
10.3	27.571	0.000	0.9	0.0	0.0	11.1
10.5	26.744	0.000	0.9	0.0	0.0	11.2
10.8	25.959	0.000	0.8	0.0	0.0	11.2
11.0	25.208	0.000	0.8	0.0	0.0	11.3
11.3	24.494	0.000	0.7	0.0	0.0	11.3
11.5	23.816	0.000	0.7	0.0	0.0	11.4
11.8	23.166	0.000	0.7	0.0	0.0	11.5
12.0	22.543	0.000	0.6	0.0	0.0	11.5
12.3	21.955	0.000	0.5	0.0	0.0	11.6
12.5	21.387	0.000	0.5	0.0	0.0	11.6
12.8	20.833	0.000	0.4	0.0	0.0	11.7
13.0	20.311	0.000	0.2	0.0	0.0	11.8
13.2	19.810	0.000	0.0	0.0	0.0	11.8

Endpoint (ppm, HF)		Downwind Distance (feet)	Approximate Time (seconds)
1	50.0	6.2	2
2	30.0	9.6	3
3	20.0	13.2	4




Momentum Jet Contours - Side View
Battery Malfunction [B-1toxicHF]
50.0 ppm HF
30.0 ppm HF
20.0 ppm HF
Height (feet)
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1toxicHF]
Centerline Concentration
Ground Level Concentration
Concentration (ppm)
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : B-1toxicTol
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                        Fraction
Component  1         :    51 = H2        Hydrogen(equilibrium)       0.258295
Component  2         :    43 = CO        Carbon Monoxide             0.506656
Component  3         :     1 = CH4       Methane                     0.099344
Component  4         :     2 = C2H6      Ethane                      0.039738
Component  5         :     3 = C3H8      Propane                     0.089410
Component  6         :    50 = HF        Hydrogen Fluoride           0.000497
Component  7         :    26 = HCl       Hydrogen Chloride           0.000993
Component  8         :   103 = HCN       Hydrogen Cyanide            0.001590
Component  9         :   281 = C7H8      Toluene                     0.003477
Component 10         :

Temperature          :       122.00 °F
Pressure             :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
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RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate               << trace amount >> lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component  281 = C7H8      Toluene
Concentration endpoint 1                     1000.0 ppm
Concentration endpoint 2                      500.0 ppm
Concentration endpoint 3                      300.0 ppm

Dispersion coefficient averaging time             1 min

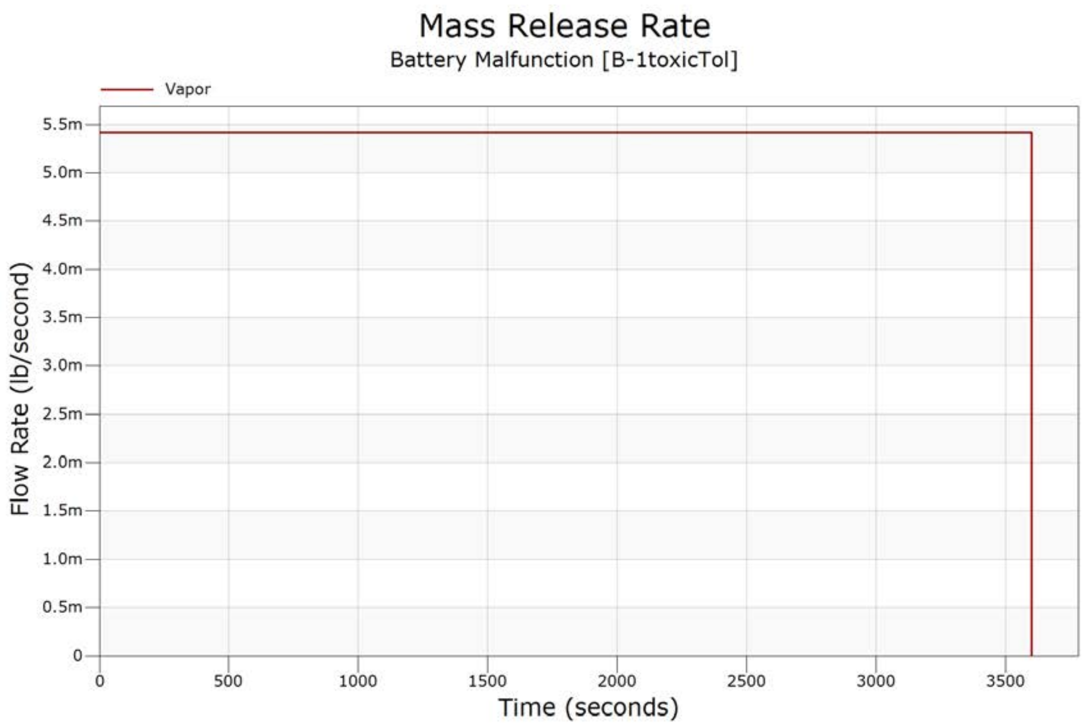

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.1000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.3000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.5000000	.5417999E-02	0.000000	0.000000	.5417999E-02
0.7000000	.5417999E-02	0.000000	0.000000	.5417999E-02
1.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
3.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
5.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
7.000000	.5417999E-02	0.000000	0.000000	.5417999E-02
10.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
20.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
30.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
40.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
50.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
60.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
70.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
85.00000	.5417999E-02	0.000000	0.000000	.5417999E-02
100.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
200.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
300.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
400.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
500.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
600.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
700.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
850.0000	.5417999E-02	0.000000	0.000000	.5417999E-02
1000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
2000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3000.000	.5417999E-02	0.000000	0.000000	.5417999E-02
3600.000	.5417999E-02	0.000000	0.000000	.5417999E-02
Totals (lb)	19.50480	0.000000	0.000000	19.50480

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [B-1toxicTol]
Vapor
Flow Rate (lb/second)
5.5m
5.0m
4.5m
4.0m
3.5m
3.0m
2.5m
2.0m
1.5m
1.0m
0.5m
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

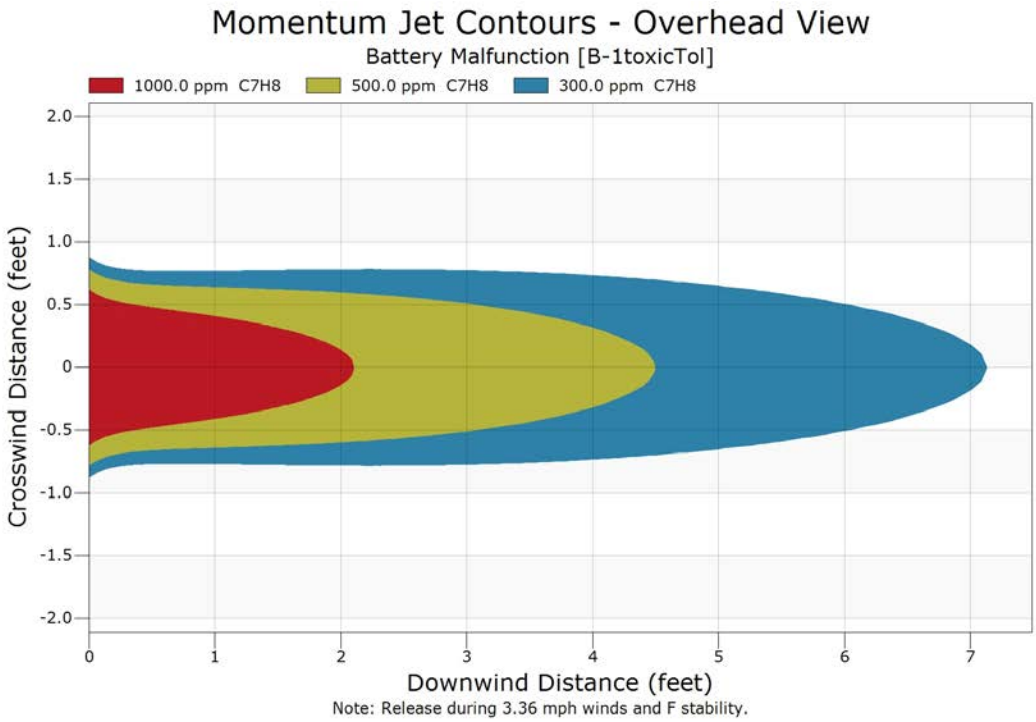
concentration limits

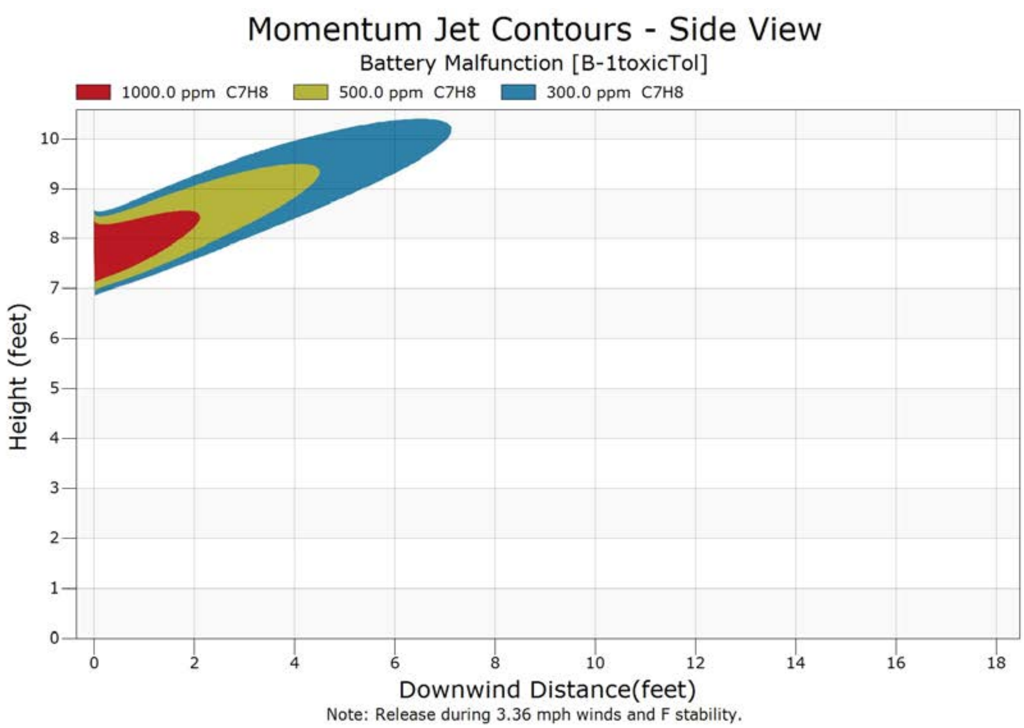
Endpoint 1 (highest) = 1000.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 300.0 ppm

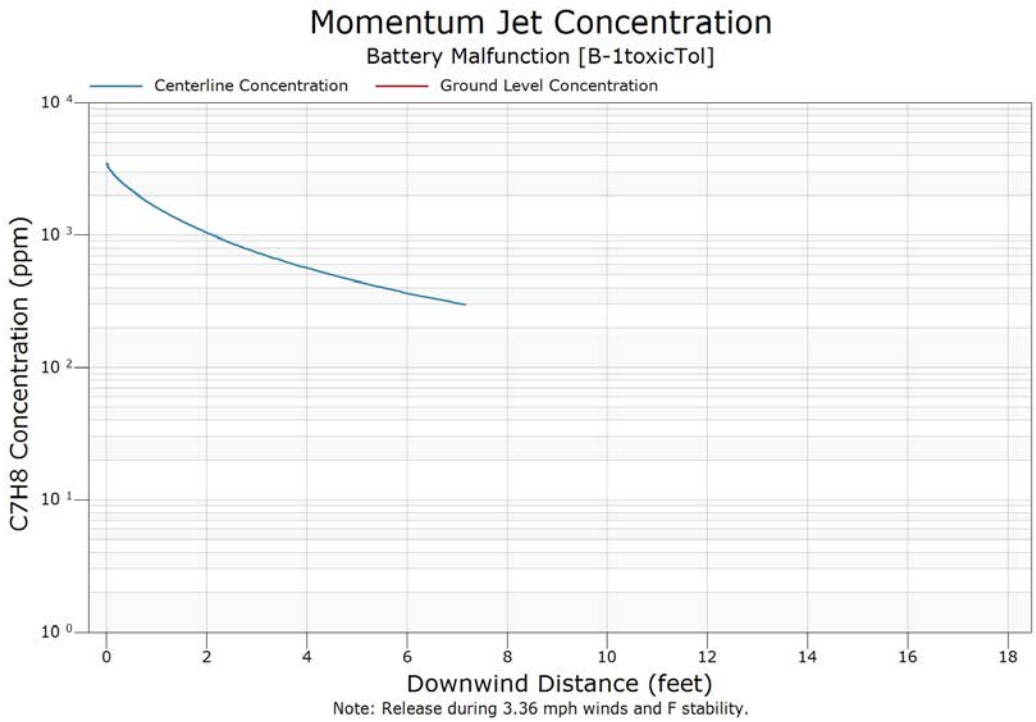
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	3477.050	0.000	0.9	0.8	0.6	7.7
0.1	3015.230	0.000	0.8	0.7	0.6	7.8
0.2	2729.769	0.000	0.8	0.7	0.5	7.8
0.3	2512.129	0.000	0.8	0.7	0.5	7.8
0.4	2332.043	0.000	0.8	0.7	0.5	7.8
0.5	2176.619	0.000	0.8	0.7	0.5	7.8
0.6	2040.429	0.000	0.8	0.7	0.5	7.9
0.7	1918.495	0.000	0.8	0.7	0.5	7.9
0.8	1809.839	0.000	0.8	0.6	0.4	7.9
0.9	1711.794	0.000	0.8	0.6	0.4	8.0
1.0	1622.524	0.000	0.8	0.6	0.4	8.0
1.1	1541.512	0.000	0.8	0.6	0.4	8.1
1.2	1467.498	0.000	0.8	0.6	0.4	8.1
1.3	1399.708	0.000	0.8	0.6	0.4	8.1
1.4	1336.492	0.000	0.8	0.6	0.3	8.2
1.5	1278.414	0.000	0.8	0.6	0.3	8.2
1.6	1224.085	0.000	0.8	0.6	0.3	8.3
1.7	1173.435	0.000	0.8	0.6	0.3	8.3
1.8	1126.535	0.000	0.8	0.6	0.2	8.3
1.9	1082.949	0.000	0.8	0.6	0.2	8.4
2.0	1041.380	0.000	0.8	0.6	0.1	8.4
2.1	1002.701	0.000	0.8	0.6	0.0	8.5
2.2	966.963	0.000	0.8	0.6	0.0	8.5
2.3	932.729	0.000	0.8	0.6	0.0	8.6
2.4	900.822	0.000	0.8	0.6	0.0	8.6
2.5	870.300	0.000	0.8	0.6	0.0	8.6
2.6	841.794	0.000	0.8	0.6	0.0	8.7
2.7	814.553	0.000	0.8	0.5	0.0	8.7
2.8	789.036	0.000	0.8	0.5	0.0	8.8
2.9	764.642	0.000	0.8	0.5	0.0	8.8
3.0	741.845	0.000	0.8	0.5	0.0	8.8
3.1	719.853	0.000	0.8	0.5	0.0	8.9
3.2	698.929	0.000	0.8	0.5	0.0	8.9
3.3	678.915	0.000	0.8	0.5	0.0	8.9
3.4	660.538	0.000	0.8	0.5	0.0	9.0

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
3.5	642.389	0.000	0.8	0.4	0.0	9.0
3.6	624.965	0.000	0.8	0.4	0.0	9.1
3.7	608.469	0.000	0.7	0.4	0.0	9.1
3.8	593.037	0.000	0.7	0.4	0.0	9.1
3.9	578.088	0.000	0.7	0.3	0.0	9.2
4.0	563.215	0.000	0.7	0.3	0.0	9.2
4.1	549.579	0.000	0.7	0.3	0.0	9.2
4.2	536.063	0.000	0.7	0.2	0.0	9.3
4.3	523.219	0.000	0.7	0.2	0.0	9.3
4.4	511.343	0.000	0.7	0.1	0.0	9.3
4.5	499.623	0.000	0.7	0.0	0.0	9.4
4.6	487.913	0.000	0.7	0.0	0.0	9.4
4.7	477.108	0.000	0.7	0.0	0.0	9.4
4.8	466.726	0.000	0.7	0.0	0.0	9.5
4.9	456.589	0.000	0.7	0.0	0.0	9.5
5.0	446.739	0.000	0.7	0.0	0.0	9.5
5.1	437.647	0.000	0.6	0.0	0.0	9.6
5.2	428.410	0.000	0.6	0.0	0.0	9.6
5.3	419.640	0.000	0.6	0.0	0.0	9.7
5.4	411.176	0.000	0.6	0.0	0.0	9.7
5.5	403.025	0.000	0.6	0.0	0.0	9.7
5.6	395.034	0.000	0.6	0.0	0.0	9.7
5.7	387.446	0.000	0.6	0.0	0.0	9.8
5.8	379.934	0.000	0.5	0.0	0.0	9.8
5.9	372.799	0.000	0.5	0.0	0.0	9.8
6.0	365.846	0.000	0.5	0.0	0.0	9.9
6.1	359.016	0.000	0.5	0.0	0.0	9.9
6.2	352.429	0.000	0.5	0.0	0.0	9.9
6.3	346.271	0.000	0.4	0.0	0.0	10.0
6.4	340.141	0.000	0.4	0.0	0.0	10.0
6.5	334.114	0.000	0.4	0.0	0.0	10.0
6.6	328.282	0.000	0.4	0.0	0.0	10.1
6.7	322.642	0.000	0.3	0.0	0.0	10.1
6.8	317.177	0.000	0.3	0.0	0.0	10.1
6.9	311.778	0.000	0.2	0.0	0.0	10.2
7.0	306.646	0.000	0.2	0.0	0.0	10.2
7.1	301.608	0.000	0.1	0.0	0.0	10.2

Endpoint	(ppm, C7H8)	Downwind Distance (feet)	Approximate Time (seconds)
1	1000.0	2.1	1
2	500.0	4.5	2
3	300.0	7.1	3


Momentum Jet Contours - Overhead View
Battery Malfunction [B-1toxicTol]
1000.0 ppm C7H8
500.0 ppm C7H8
300.0 ppm C7H8
Crosswind Distance (feet)
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
0
1
2
3
4
5
6
7
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction [B-1toxicTol]
1000.0 ppm C7H8
500.0 ppm C7H8
300.0 ppm C7H8
Height (feet)
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
16
18
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [B-1toxicTol]
Centerline Concentration
Ground Level Concentration
C7H8 Concentration (ppm)
10 4
10 3
10 2
10 1
10 0
0
2
4
6
8
10
12
14
16
18
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

Case Type : Vapor Dispersion
Case Name : B-1vertCombustionHighCase
User ID : GC
Project Number :
Type of Units : English Units

NOTES:

MATERIAL MENU

Materials Released	: Number	Formula	Name	Fraction
Component 1	: 51 =	H2	Hydrogen(equilibrium)	0.013905
Component 2	: 43 =	CO	Carbon Monoxide	0.000099
Component 3	: 17 =	CO2	Carbon Dioxide	0.000671
Component 4	: 1 =	CH4	Methane	0.000099
Component 5	: 89 =	NO2	Nitrogen Dioxide	0.689369
Component 6	: 52 =	H2O	Water	0.295858
Component 7	:			
Component 8	:			
Component 9	:			
Component 10	:			

Temperature : 1652.00 °F
Pressure : 15.00 psia
The material is Indeterminate

NOTES:

ENVIRONMENT MENU

Wind speed	3.36 mph
Wind speed measurement height	32.8 feet
Stability class <A-F>	F
Relative humidity	70 %
Air temperature	77.0 °F
Spill surface temperature	77.0 °F

Substrate name	Soil
Substrate thermal conductivity	1.0000 Btu/hr-ft-F
Substrate density	100 lb/cu.ft
Substrate heat Capacity	0.24 Btu/lb-F
Substrate delay time	60 sec
Surrounding terrain	Long grass or crops > 15 cm (6 in)

NOTES:

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RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                           632.70 lb/sec
Pipe inner diameter                           106.00 inches
Equivalent release diameter                   106.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Flammable calculation
Concentration endpoint 1                   10.000000 mol%
Concentration endpoint 2                    5.000000 mol%
Concentration endpoint 3                    1.000000 mol%

Dispersion coefficient averaging time              1 min


  NOTES:
```

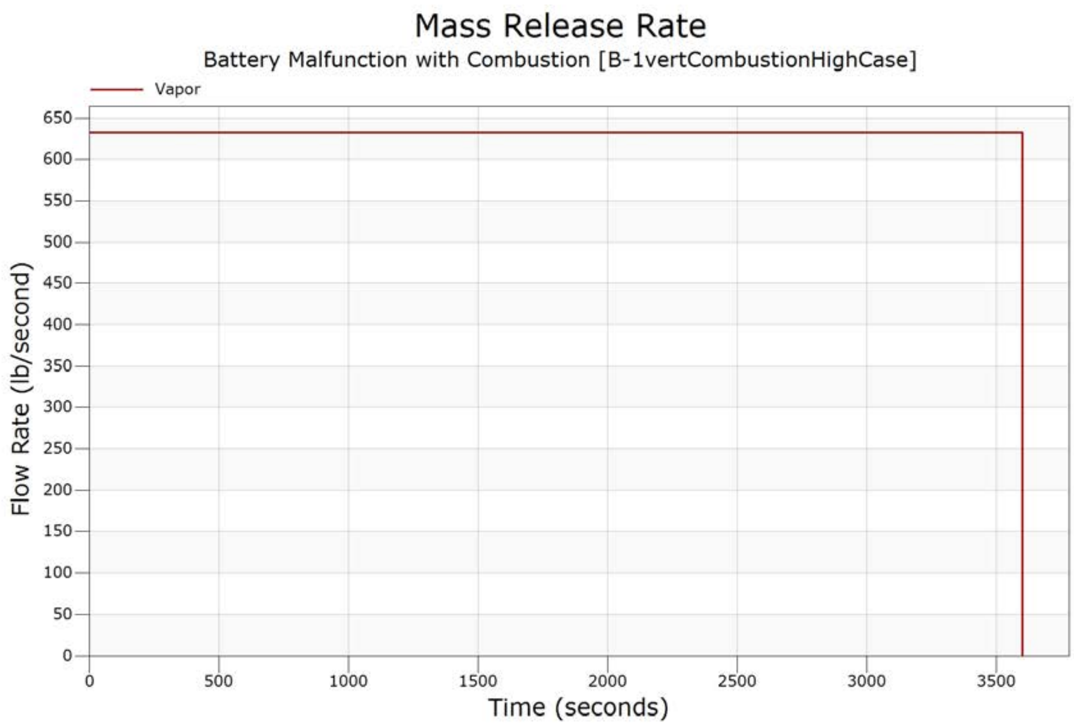
Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	632.7001	0.000000	0.000000	632.7001
0.1000000	632.7001	0.000000	0.000000	632.7001
0.3000000	632.7001	0.000000	0.000000	632.7001
0.5000000	632.7001	0.000000	0.000000	632.7001
0.7000000	632.7001	0.000000	0.000000	632.7001
1.000000	632.7001	0.000000	0.000000	632.7001
3.000000	632.7001	0.000000	0.000000	632.7001
5.000000	632.7001	0.000000	0.000000	632.7001
7.000000	632.7001	0.000000	0.000000	632.7001
10.00000	632.7001	0.000000	0.000000	632.7001
20.00000	632.7001	0.000000	0.000000	632.7001
30.00000	632.7001	0.000000	0.000000	632.7001
40.00000	632.7001	0.000000	0.000000	632.7001
50.00000	632.7001	0.000000	0.000000	632.7001
60.00000	632.7001	0.000000	0.000000	632.7001
70.00000	632.7001	0.000000	0.000000	632.7001
85.00000	632.7001	0.000000	0.000000	632.7001
100.0000	632.7001	0.000000	0.000000	632.7001
200.0000	632.7001	0.000000	0.000000	632.7001
300.0000	632.7001	0.000000	0.000000	632.7001
400.0000	632.7001	0.000000	0.000000	632.7001
500.0000	632.7001	0.000000	0.000000	632.7001
600.0000	632.7001	0.000000	0.000000	632.7001
700.0000	632.7001	0.000000	0.000000	632.7001
850.0000	632.7001	0.000000	0.000000	632.7001
1000.000	632.7001	0.000000	0.000000	632.7001
2000.000	632.7001	0.000000	0.000000	632.7001
3000.000	632.7001	0.000000	0.000000	632.7001
3600.000	632.7001	0.000000	0.000000	632.7001
Totals (lb)	2277720.	0.000000	0.000000	2277720.

Flowrate for Jet Fire [immediate ignition] = 632.7001 lb/sec.
Jet Fire [delayed ignition] = 632.7001 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction with Combustion [B-1vertCombustionHighCase]
Vapor
Flow Rate (lb/second)
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
17	Carbon Dioxide, CO2
1	Methane, CH4
89	Nitrogen Dioxide, NO2
52	Water, H2O

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.013905	0.013905	0.000000	0.000000	0.013905	0.000000
43	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
17	0.000671	0.000671	0.000000	0.000000	0.000671	0.000000
1	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
89	0.689369	0.689369	0.000000	0.000000	0.689369	0.000000
52	0.295858	0.295858	0.000000	0.000000	0.295858	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Flammable Limits (Mole %) of Fluid Streams

Limit	Feed Stream	Momentum Jet Stream	Liquid Pool Stream
LFL	100.00	100.00	
UFL	100.00	100.00	
LBV		0.00 m/s	

Momentum Jet Dispersion

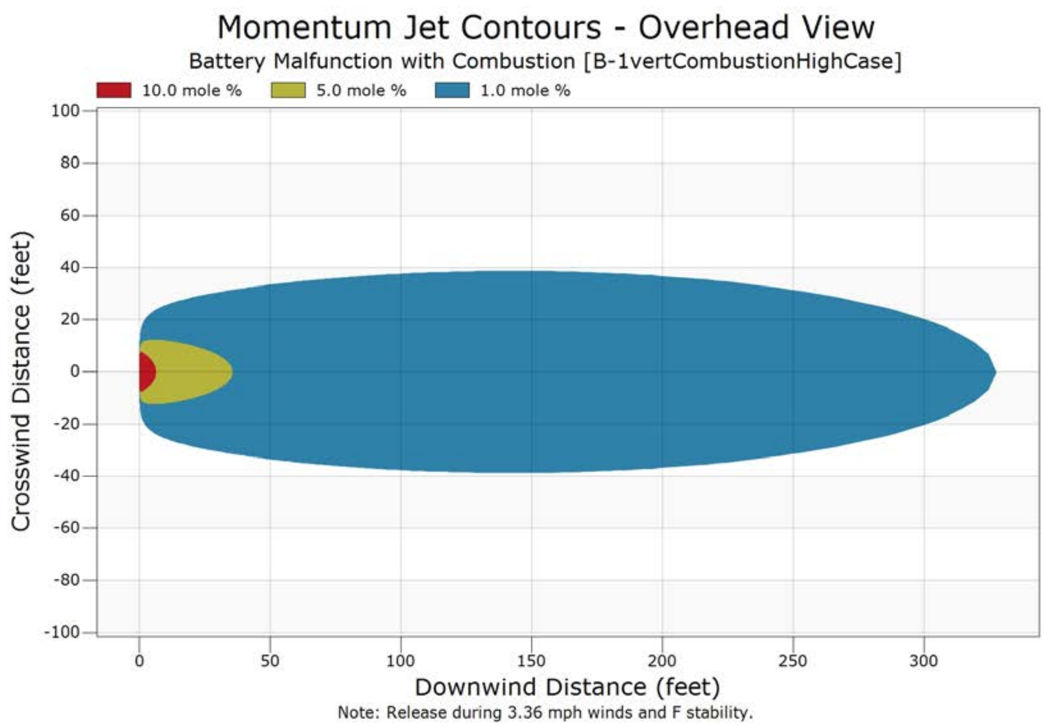
concentration limits

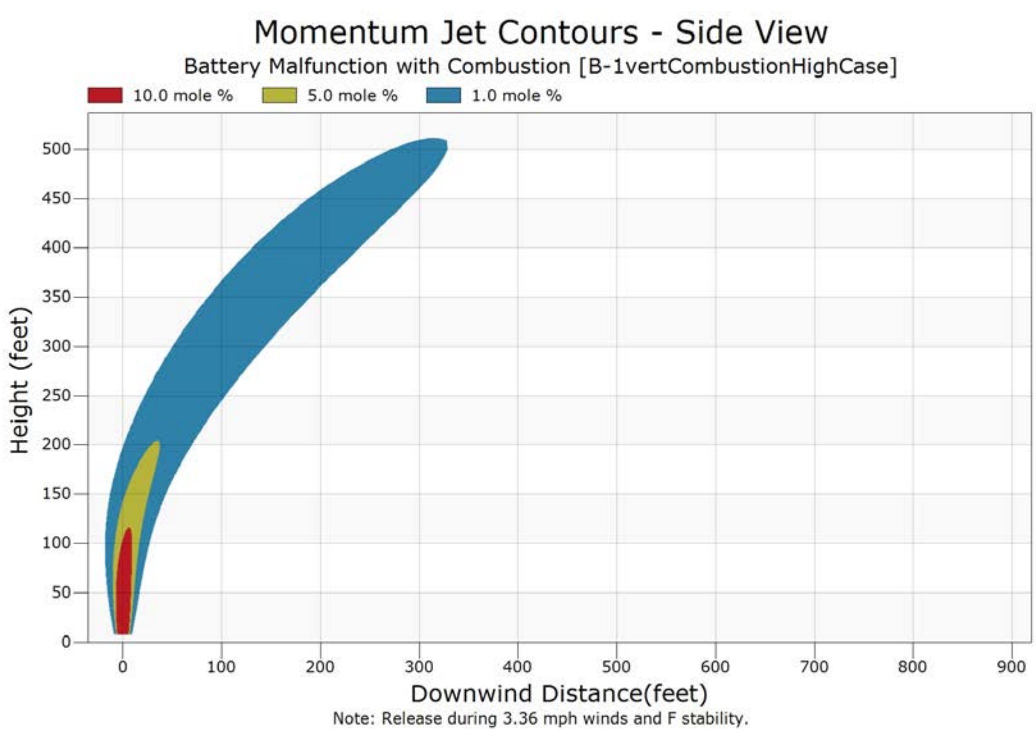
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

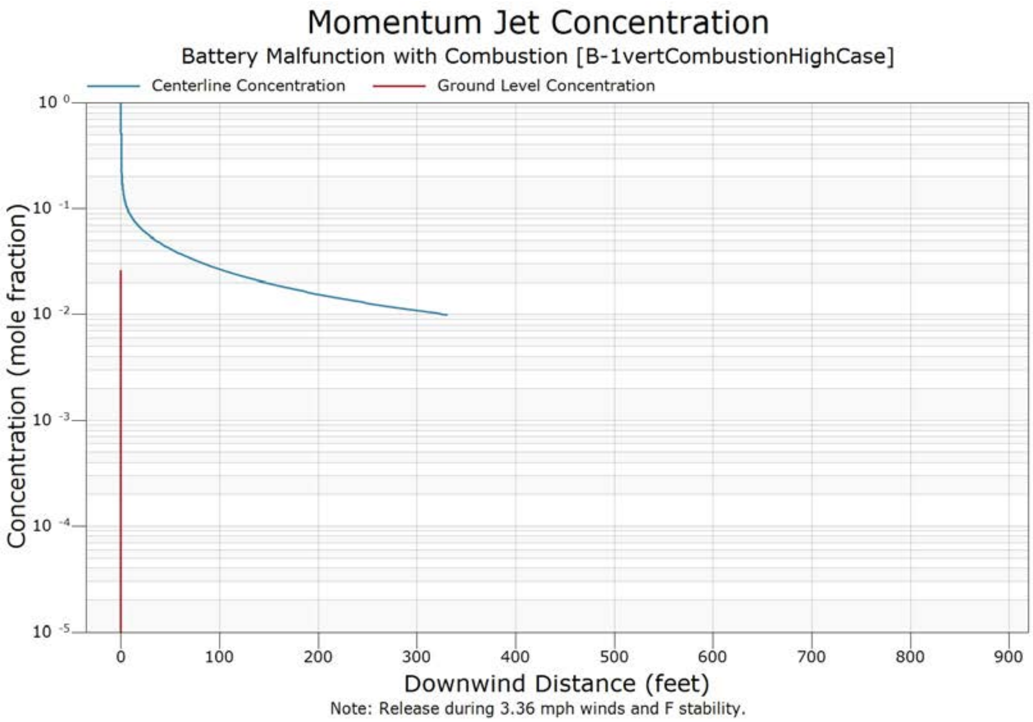
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
5	0.108710	0.000000	23.1	12.4	3.9	107.7
10	0.085169	0.000000	25.6	12.1	0.0	133.8
15	0.073108	0.000000	27.3	11.3	0.0	152.2
20	0.065083	0.000000	28.6	10.2	0.0	167.2
25	0.059069	0.000000	29.6	8.6	0.0	180.3
30	0.054358	0.000000	30.6	6.5	0.0	192.1
35	0.050401	0.000000	31.4	2.0	0.0	202.9
40	0.047118	0.000000	32.2	0.0	0.0	213.1
45	0.044223	0.000000	32.9	0.0	0.0	222.7
50	0.041727	0.000000	33.5	0.0	0.0	231.8
55	0.039541	0.000000	34.1	0.0	0.0	240.5
60	0.037543	0.000000	34.6	0.0	0.0	248.8
65	0.035748	0.000000	35.1	0.0	0.0	256.8
70	0.034139	0.000000	35.6	0.0	0.0	264.6
75	0.032667	0.000000	36.0	0.0	0.0	272.1
80	0.031298	0.000000	36.4	0.0	0.0	279.4
85	0.030051	0.000000	36.8	0.0	0.0	286.5
90	0.028910	0.000000	37.1	0.0	0.0	293.4
95	0.027854	0.000000	37.4	0.0	0.0	300.1
100	0.026848	0.000000	37.7	0.0	0.0	306.6
105	0.025906	0.000000	37.9	0.0	0.0	313.0
110	0.025053	0.000000	38.1	0.0	0.0	319.2
115	0.024246	0.000000	38.3	0.0	0.0	325.3
120	0.023496	0.000000	38.4	0.0	0.0	331.2
125	0.022773	0.000000	38.5	0.0	0.0	337.2
130	0.022094	0.000000	38.6	0.0	0.0	342.9
135	0.021460	0.000000	38.7	0.0	0.0	348.4
140	0.020853	0.000000	38.7	0.0	0.0	354.0
145	0.020304	0.000000	38.7	0.0	0.0	359.4
150	0.019764	0.000000	38.7	0.0	0.0	364.6
155	0.019248	0.000000	38.6	0.0	0.0	369.9
160	0.018755	0.000000	38.6	0.0	0.0	375.0
165	0.018278	0.000000	38.4	0.0	0.0	380.1
170	0.017838	0.000000	38.3	0.0	0.0	385.0

downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
175	0.017399	0.000000	38.1	0.0	0.0	389.8
180	0.016997	0.000000	37.9	0.0	0.0	394.5
185	0.016608	0.000000	37.7	0.0	0.0	399.3
190	0.016236	0.000000	37.4	0.0	0.0	403.8
195	0.015891	0.000000	37.2	0.0	0.0	408.4
200	0.015536	0.000000	36.8	0.0	0.0	412.8
205	0.015216	0.000000	36.4	0.0	0.0	417.3
210	0.014899	0.000000	36.0	0.0	0.0	421.7
215	0.014598	0.000000	35.6	0.0	0.0	425.8
220	0.014316	0.000000	35.2	0.0	0.0	430.2
225	0.014027	0.000000	34.6	0.0	0.0	434.2
230	0.013764	0.000000	34.1	0.0	0.0	438.4
235	0.013507	0.000000	33.5	0.0	0.0	442.3
240	0.013255	0.000000	32.9	0.0	0.0	446.2
245	0.013014	0.000000	32.2	0.0	0.0	450.2
250	0.012783	0.000000	31.5	0.0	0.0	454.1
255	0.012562	0.000000	30.7	0.0	0.0	457.9
260	0.012345	0.000000	29.9	0.0	0.0	461.5
265	0.012131	0.000000	29.0	0.0	0.0	465.2
270	0.011926	0.000000	28.0	0.0	0.0	468.9
275	0.011730	0.000000	27.0	0.0	0.0	472.5
280	0.011543	0.000000	25.9	0.0	0.0	476.0
285	0.011362	0.000000	24.7	0.0	0.0	479.5
290	0.011180	0.000000	23.3	0.0	0.0	483.0
295	0.011004	0.000000	21.8	0.0	0.0	486.3
300	0.010836	0.000000	20.2	0.0	0.0	489.7
305	0.010674	0.000000	18.4	0.0	0.0	493.0
310	0.010518	0.000000	16.3	0.0	0.0	496.3
315	0.010362	0.000000	13.9	0.0	0.0	499.5
320	0.010219	0.000000	10.9	0.0	0.0	502.6
325	0.010073	0.000000	6.1	0.0	0.0	505.7
330	0.009933	0.000000	0.0	0.0	0.0	508.8

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.100000	6.4	1
2 0.050000	35.6	1
3 0.010000	327.6	9


Momentum Jet Contours - Overhead View
Battery Malfunction with Combustion [B-1vertCombustionHighCase]
10.0 mole %
5.0 mole %
1.0 mole %
Crosswind Distance (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
50
100
150
200
250
300
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction with Combustion [B-1vertCombustionHighCase]
10.0 mole %
5.0 mole %
1.0 mole %
Height (feet)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction with Combustion [B-1vertCombustionHighCase]
Centerline Concentration
Ground Level Concentration
Concentration (mole fraction)
10 0
10 -1
10 -2
10 -3
10 -4
10 -5
0
100
200
300
400
500
600
700
800
900
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type             : Vapor Dispersion
Case Name             : B-1vertCombustionHighCaseWind
User ID               : GC
Project Number        :
Type of Units         : English Units

  NOTES:

MATERIAL MENU
Materials Released    : Number  Formula   Name                         Fraction
Component  1          :    51 = H2        Hydrogen(equilibrium)        0.013905
Component  2          :    43 = CO        Carbon Monoxide              0.000099
Component  3          :    17 = CO2       Carbon Dioxide               0.000671
Component  4          :     1 = CH4       Methane                      0.000099
Component  5          :    89 = NO2       Nitrogen Dioxide             0.689369
Component  6          :    52 = H2O       Water                        0.295858
Component  7          :
Component  8          :
Component  9          :
Component 10          :

Temperature           :      1652.00 °F
Pressure              :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                       10.00 mph
Wind speed measurement height                     32.8 feet
Stability class <A-F>                                D
Relative humidity                                   70 %
Air temperature                                   77.0 °F
Spill surface temperature                         77.0 °F

Substrate name                           Soil
  Substrate thermal conductivity             1.0000 Btu/hr-ft-F
  Substrate density                             100 lb/cu.ft
  Substrate heat Capacity                      0.24 Btu/lb-F
  Substrate delay time                           60 sec
Surrounding terrain                      Long grass or crops > 15 cm (6 in)

  NOTES:
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```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                           632.70 lb/sec
Pipe inner diameter                           106.00 inches
Equivalent release diameter                   106.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Flammable calculation
Concentration endpoint 1                   10.000000 mol%
Concentration endpoint 2                    5.000000 mol%
Concentration endpoint 3                    1.000000 mol%

Dispersion coefficient averaging time             1 min


  NOTES:
```

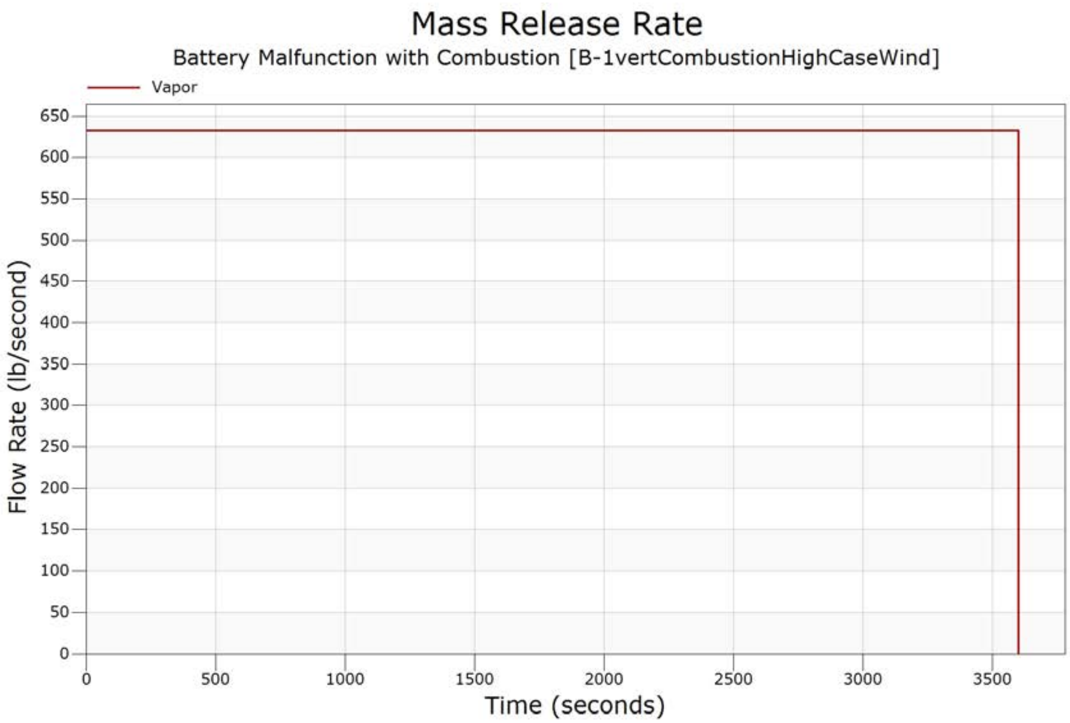
Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	632.7001	0.000000	0.000000	632.7001
0.1000000	632.7001	0.000000	0.000000	632.7001
0.3000000	632.7001	0.000000	0.000000	632.7001
0.5000000	632.7001	0.000000	0.000000	632.7001
0.7000000	632.7001	0.000000	0.000000	632.7001
1.000000	632.7001	0.000000	0.000000	632.7001
3.000000	632.7001	0.000000	0.000000	632.7001
5.000000	632.7001	0.000000	0.000000	632.7001
7.000000	632.7001	0.000000	0.000000	632.7001
10.00000	632.7001	0.000000	0.000000	632.7001
20.00000	632.7001	0.000000	0.000000	632.7001
30.00000	632.7001	0.000000	0.000000	632.7001
40.00000	632.7001	0.000000	0.000000	632.7001
50.00000	632.7001	0.000000	0.000000	632.7001
60.00000	632.7001	0.000000	0.000000	632.7001
70.00000	632.7001	0.000000	0.000000	632.7001
85.00000	632.7001	0.000000	0.000000	632.7001
100.0000	632.7001	0.000000	0.000000	632.7001
200.0000	632.7001	0.000000	0.000000	632.7001
300.0000	632.7001	0.000000	0.000000	632.7001
400.0000	632.7001	0.000000	0.000000	632.7001
500.0000	632.7001	0.000000	0.000000	632.7001
600.0000	632.7001	0.000000	0.000000	632.7001
700.0000	632.7001	0.000000	0.000000	632.7001
850.0000	632.7001	0.000000	0.000000	632.7001
1000.000	632.7001	0.000000	0.000000	632.7001
2000.000	632.7001	0.000000	0.000000	632.7001
3000.000	632.7001	0.000000	0.000000	632.7001
3600.000	632.7001	0.000000	0.000000	632.7001
Totals (lb)	2277720.	0.000000	0.000000	2277720.

Flowrate for Jet Fire [immediate ignition] = 632.7001 lb/sec.
Jet Fire [delayed ignition] = 632.7001 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction with Combustion [B-1vertCombustionHighCaseWind]
Vapor
Flow Rate (lb/second)
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
17	Carbon Dioxide, CO2
1	Methane, CH4
89	Nitrogen Dioxide, NO2
52	Water, H2O

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.013905	0.013905	0.000000	0.000000	0.013905	0.000000
43	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
17	0.000671	0.000671	0.000000	0.000000	0.000671	0.000000
1	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
89	0.689369	0.689369	0.000000	0.000000	0.689369	0.000000
52	0.295858	0.295858	0.000000	0.000000	0.295858	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Flammable Limits (Mole %) of Fluid Streams

Limit	Feed Stream	Momentum Jet Stream	Liquid Pool Stream
LFL	100.00	100.00	
UFL	100.00	100.00	
LBV		0.00 m/s	

Momentum Jet Dispersion

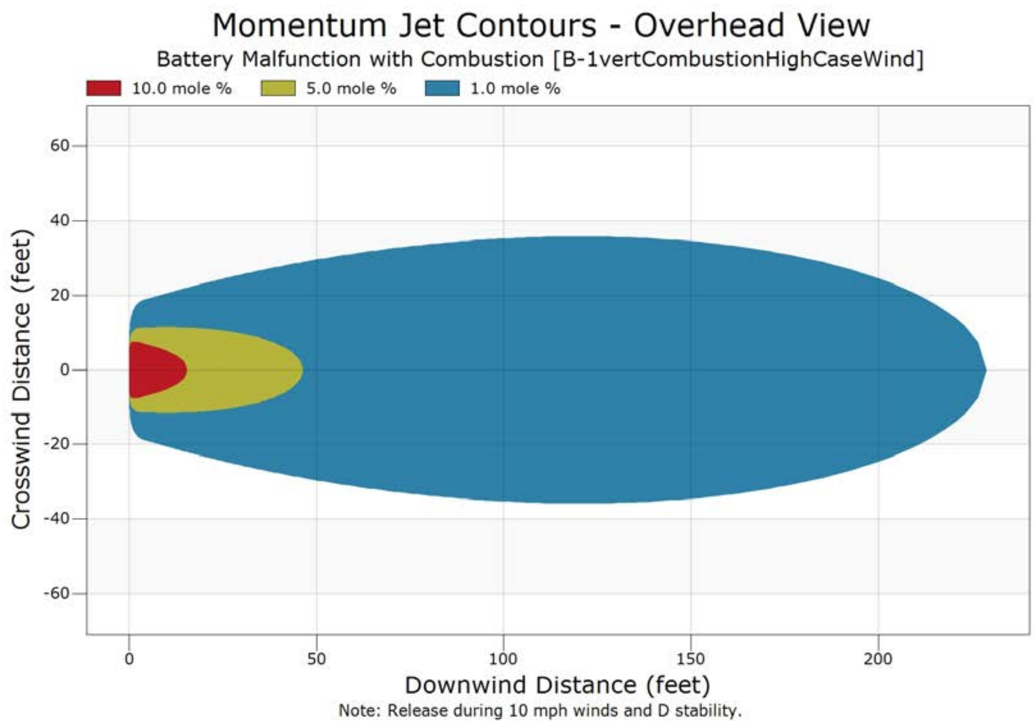
concentration limits

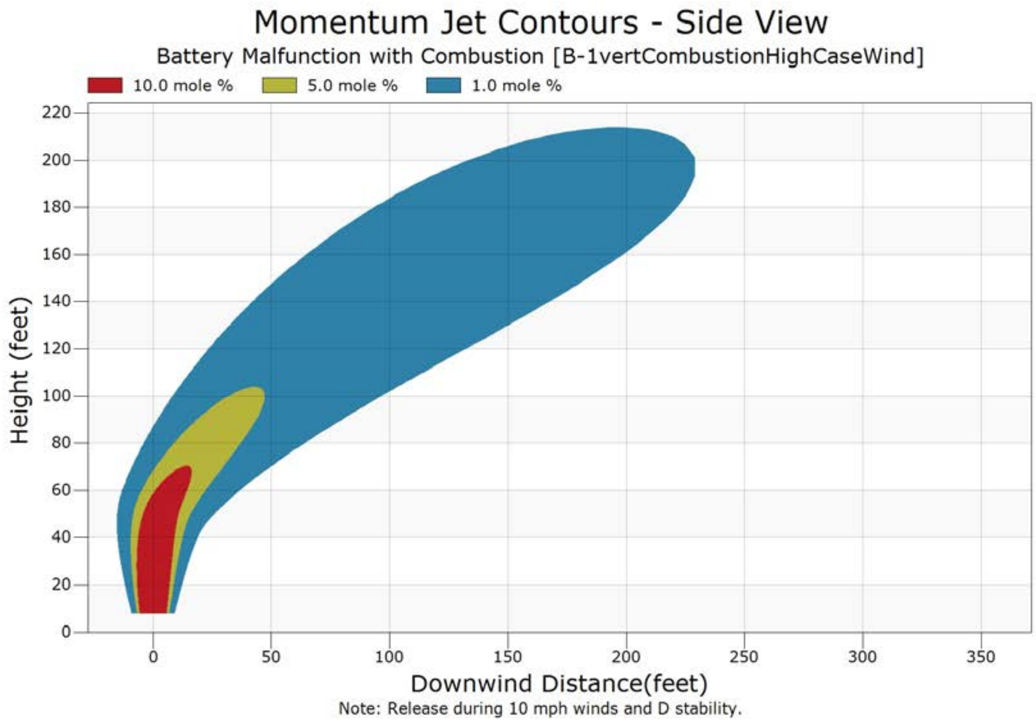
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

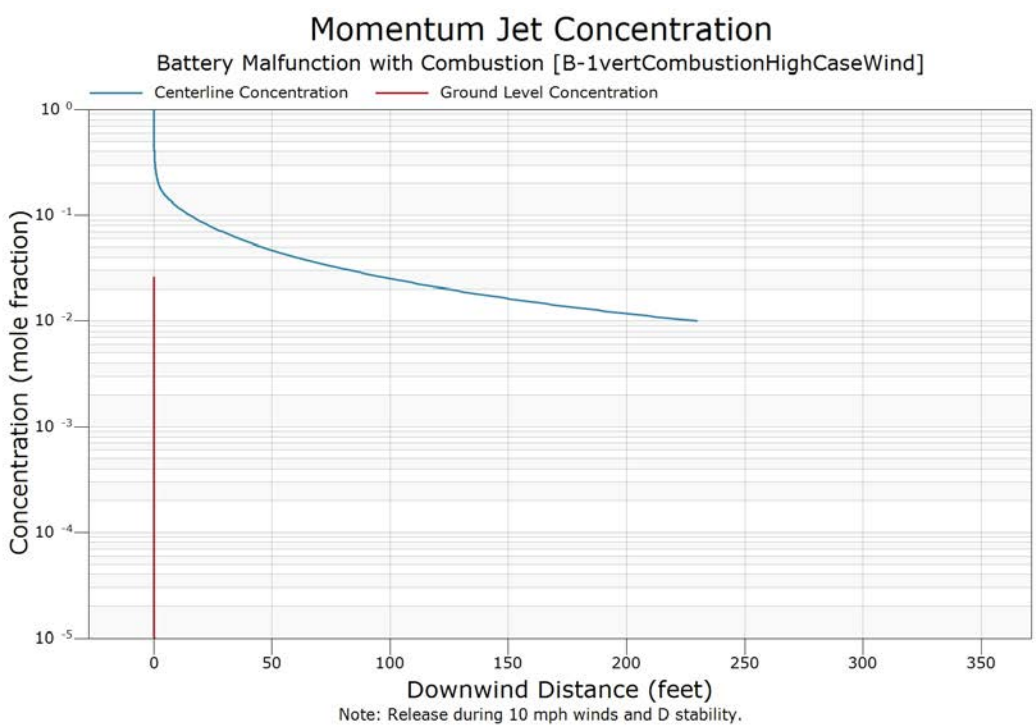
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
5	0.152590	0.000000	19.1	11.5	6.8	54.1
10	0.121143	0.000000	20.5	11.5	5.1	62.7
15	0.101440	0.000000	21.9	11.4	1.5	69.6
20	0.087403	0.000000	23.2	11.2	0.0	75.9
25	0.076783	0.000000	24.5	10.6	0.0	81.6
30	0.068379	0.000000	25.6	9.8	0.0	87.0
35	0.061574	0.000000	26.7	8.6	0.0	92.1
40	0.055932	0.000000	27.7	6.7	0.0	96.9
45	0.051150	0.000000	28.7	3.2	0.0	101.5
50	0.047075	0.000000	29.6	0.0	0.0	105.9
55	0.043538	0.000000	30.4	0.0	0.0	110.1
60	0.040462	0.000000	31.2	0.0	0.0	114.2
65	0.037733	0.000000	31.9	0.0	0.0	118.2
70	0.035339	0.000000	32.6	0.0	0.0	122.0
75	0.033181	0.000000	33.2	0.0	0.0	125.6
80	0.031229	0.000000	33.7	0.0	0.0	129.2
85	0.029484	0.000000	34.2	0.0	0.0	132.7
90	0.027906	0.000000	34.6	0.0	0.0	136.0
95	0.026454	0.000000	34.9	0.0	0.0	139.2
100	0.025132	0.000000	35.2	0.0	0.0	142.4
105	0.023923	0.000000	35.5	0.0	0.0	145.5
110	0.022815	0.000000	35.6	0.0	0.0	148.5
115	0.021784	0.000000	35.7	0.0	0.0	151.3
120	0.020834	0.000000	35.8	0.0	0.0	154.2
125	0.019963	0.000000	35.8	0.0	0.0	156.9
130	0.019140	0.000000	35.7	0.0	0.0	159.6
135	0.018367	0.000000	35.5	0.0	0.0	162.2
140	0.017648	0.000000	35.2	0.0	0.0	164.7
145	0.016977	0.000000	34.9	0.0	0.0	167.2
150	0.016349	0.000000	34.5	0.0	0.0	169.6
155	0.015761	0.000000	34.0	0.0	0.0	172.0
160	0.015205	0.000000	33.4	0.0	0.0	174.3
165	0.014685	0.000000	32.8	0.0	0.0	176.5
170	0.014193	0.000000	32.0	0.0	0.0	178.7

downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
175	0.013729	0.000001	31.1	0.0	0.0	180.8
180	0.013291	0.000001	30.1	0.0	0.0	182.9
185	0.012873	0.000001	29.0	0.0	0.0	184.9
190	0.012480	0.000001	27.7	0.0	0.0	186.9
195	0.012105	0.000001	26.2	0.0	0.0	188.9
200	0.011749	0.000001	24.6	0.0	0.0	190.8
205	0.011412	0.000001	22.7	0.0	0.0	192.6
210	0.011091	0.000001	20.4	0.0	0.0	194.4
215	0.010783	0.000002	17.8	0.0	0.0	196.2
220	0.010490	0.000002	14.4	0.0	0.0	198.0
225	0.010210	0.000002	9.5	0.0	0.0	199.6

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.100000	15.4	0
2 0.050000	46.3	1
3 0.010000	228.9	4




Momentum Jet Contours - Side View
Battery Malfunction with Combustion [B-1vertCombustionHighCaseWind]
10.0 mole %
5.0 mole %
1.0 mole %
Height (feet)
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
Downwind Distance(feet)
Note: Release during 10 mph winds and D stability.


Momentum Jet Concentration
Battery Malfunction with Combustion [B-1vertCombustionHighCaseWind]
Centerline Concentration
Ground Level Concentration
Concentration (mole fraction)
10 0
10 -1
10 -2
10 -3
10 -4
10 -5
0
50
100
150
200
250
300
350
Downwind Distance (feet)
Note: Release during 10 mph winds and D stability.

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : B-1vertCombustionLowCase
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                        Fraction
Component  1         :    51 = H2        Hydrogen(equilibrium)       0.013905
Component  2         :    43 = CO        Carbon Monoxide             0.000099
Component  3         :    17 = CO2       Carbon Dioxide              0.000671
Component  4         :     1 = CH4       Methane                     0.000099
Component  5         :    89 = NO2       Nitrogen Dioxide            0.689369
Component  6         :    52 = H2O       Water                       0.295858
Component  7         :
Component  8         :
Component  9         :
Component 10         :

Temperature          :      1652.00 °F
Pressure             :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                     10.00 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              D
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                           Soil
  Substrate thermal conductivity             1.0000 Btu/hr-ft-F
  Substrate density                             100 lb/cu.ft
  Substrate heat Capacity                      0.24 Btu/lb-F
  Substrate delay time                           60 sec
Surrounding terrain                      Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                            63.93 lb/sec
Pipe inner diameter                           106.00 inches
Equivalent release diameter                   106.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Flammable calculation
Concentration endpoint 1                 10.000000 mol%
Concentration endpoint 2                  5.000000 mol%
Concentration endpoint 3                  1.000000 mol%

Dispersion coefficient averaging time             1 min


  NOTES:
```

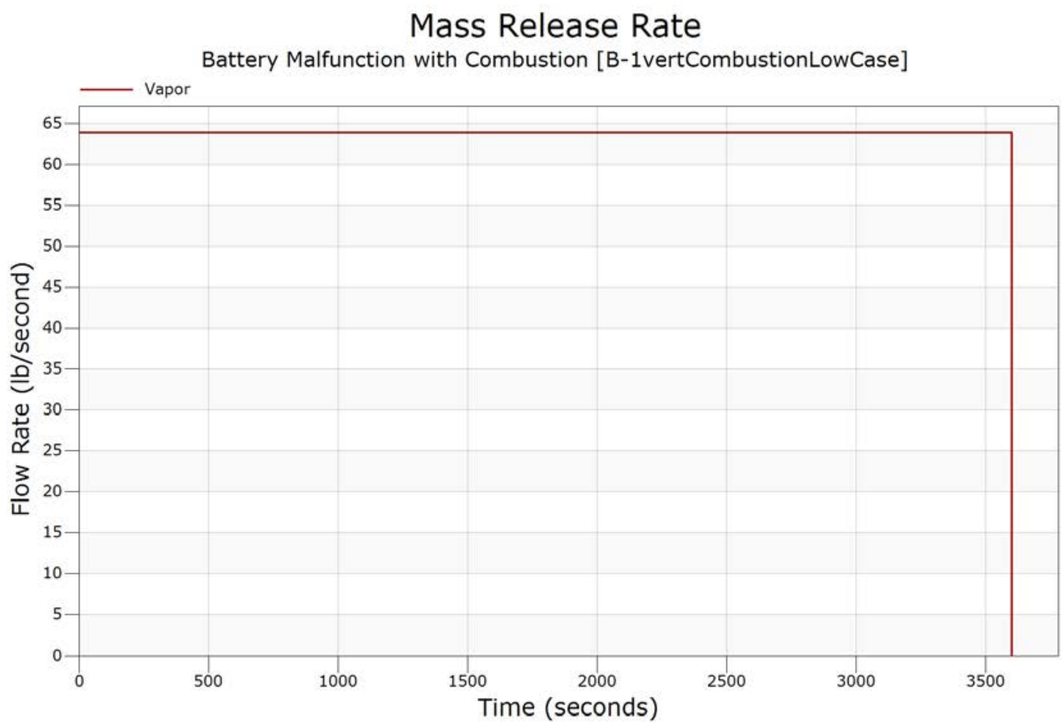
Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	63.93000	0.000000	0.000000	63.93000
0.1000000	63.93000	0.000000	0.000000	63.93000
0.3000000	63.93000	0.000000	0.000000	63.93000
0.5000000	63.93000	0.000000	0.000000	63.93000
0.7000000	63.93000	0.000000	0.000000	63.93000
1.000000	63.93000	0.000000	0.000000	63.93000
3.000000	63.93000	0.000000	0.000000	63.93000
5.000000	63.93000	0.000000	0.000000	63.93000
7.000000	63.93000	0.000000	0.000000	63.93000
10.00000	63.93000	0.000000	0.000000	63.93000
20.00000	63.93000	0.000000	0.000000	63.93000
30.00000	63.93000	0.000000	0.000000	63.93000
40.00000	63.93000	0.000000	0.000000	63.93000
50.00000	63.93000	0.000000	0.000000	63.93000
60.00000	63.93000	0.000000	0.000000	63.93000
70.00000	63.93000	0.000000	0.000000	63.93000
85.00000	63.93000	0.000000	0.000000	63.93000
100.0000	63.93000	0.000000	0.000000	63.93000
200.0000	63.93000	0.000000	0.000000	63.93000
300.0000	63.93000	0.000000	0.000000	63.93000
400.0000	63.93000	0.000000	0.000000	63.93000
500.0000	63.93000	0.000000	0.000000	63.93000
600.0000	63.93000	0.000000	0.000000	63.93000
700.0000	63.93000	0.000000	0.000000	63.93000
850.0000	63.93000	0.000000	0.000000	63.93000
1000.000	63.93000	0.000000	0.000000	63.93000
2000.000	63.93000	0.000000	0.000000	63.93000
3000.000	63.93000	0.000000	0.000000	63.93000
3600.000	63.93000	0.000000	0.000000	63.93000
Totals (lb)	230148.0	0.000000	0.000000	230148.0

Flowrate for Jet Fire [immediate ignition] = 63.93000 lb/sec.
Jet Fire [delayed ignition] = 63.93000 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction with Combustion [B-1vertCombustionLowCase]
Vapor
Flow Rate (lb/second)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
17	Carbon Dioxide, CO2
1	Methane, CH4
89	Nitrogen Dioxide, NO2
52	Water, H2O

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.013905	0.013905	0.000000	0.000000	0.013905	0.000000
43	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
17	0.000671	0.000671	0.000000	0.000000	0.000671	0.000000
1	0.000099	0.000099	0.000000	0.000000	0.000099	0.000000
89	0.689369	0.689369	0.000000	0.000000	0.689369	0.000000
52	0.295858	0.295858	0.000000	0.000000	0.295858	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Flammable Limits (Mole %) of Fluid Streams

Limit	Feed Stream	Momentum Jet Stream	Liquid Pool Stream
LFL	100.00	100.00	
UFL	100.00	100.00	
LBV		0.00 m/s	

Momentum Jet Dispersion

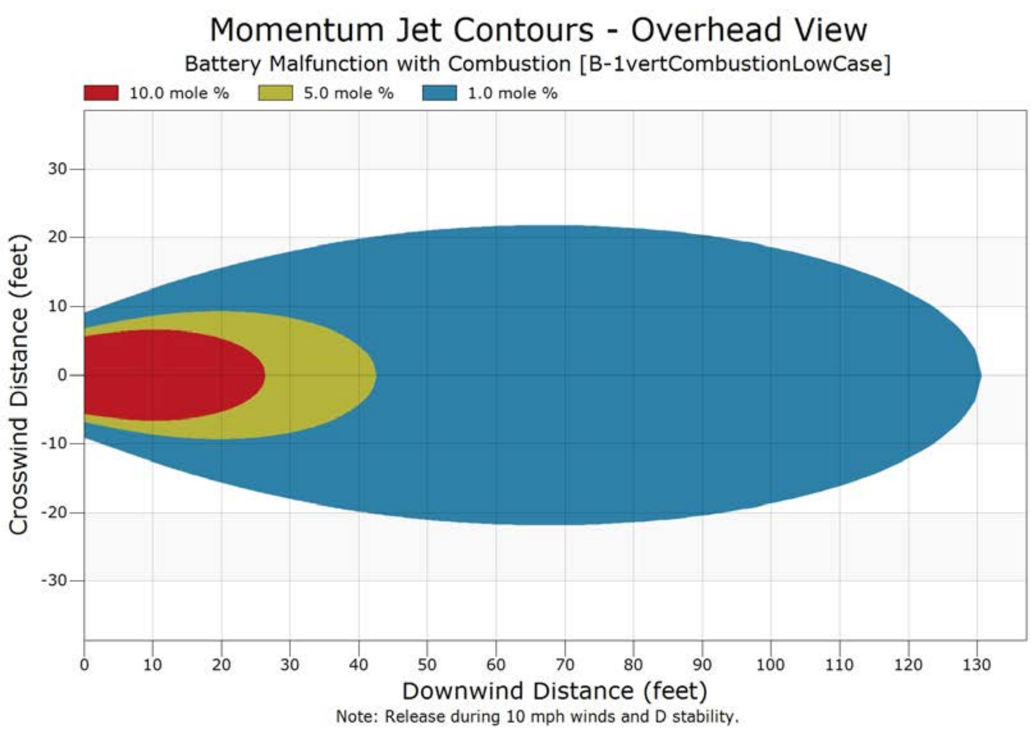
concentration limits

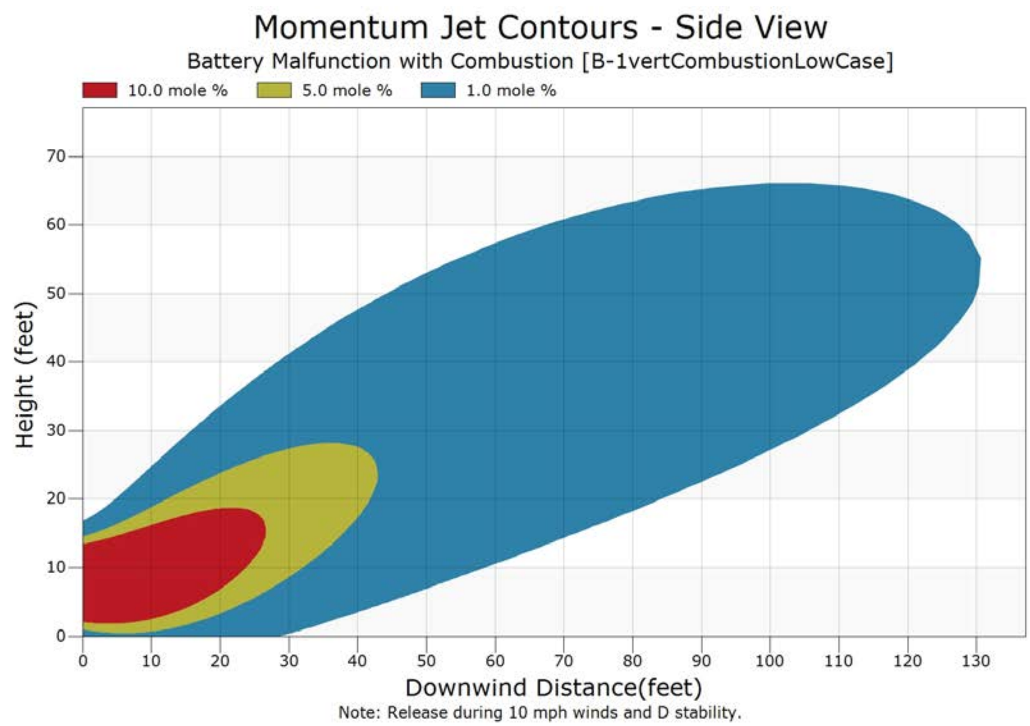
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

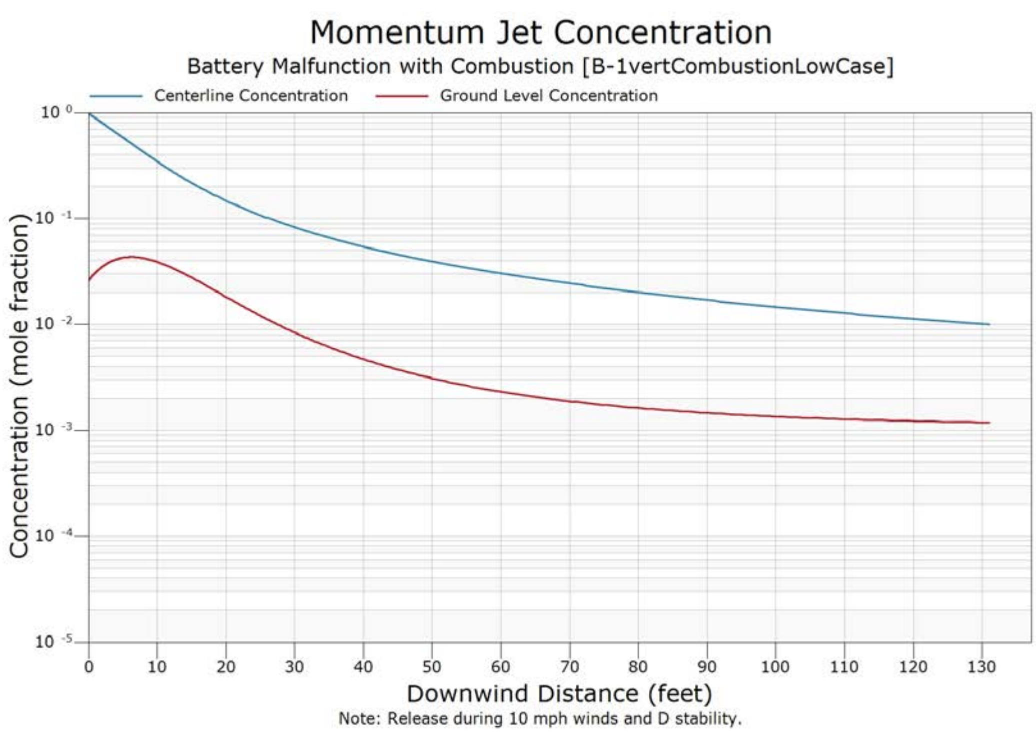
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
3	0.760889	0.037002	10.0	7.3	6.0	7.8
5	0.584698	0.042718	10.9	7.8	6.3	8.1
7	0.449199	0.042792	11.8	8.3	6.5	8.6
10	0.346711	0.039003	12.6	8.6	6.6	9.3
13	0.272026	0.033436	13.4	8.9	6.5	10.2
15	0.217595	0.027760	14.2	9.1	6.4	11.2
18	0.177672	0.022592	15.0	9.3	6.0	12.3
20	0.147962	0.018284	15.7	9.3	5.4	13.5
23	0.125401	0.014818	16.3	9.2	4.4	14.8
25	0.107950	0.012120	16.9	9.1	2.7	16.2
28	0.094095	0.010003	17.5	8.8	0.0	17.5
30	0.082968	0.008380	18.0	8.4	0.0	18.9
33	0.073884	0.007133	18.6	7.8	0.0	20.2
35	0.066365	0.006133	19.0	7.0	0.0	21.6
38	0.060083	0.005342	19.4	5.9	0.0	22.9
40	0.054650	0.004694	19.8	4.3	0.0	24.2
43	0.050077	0.004174	20.2	0.2	0.0	25.5
45	0.046089	0.003746	20.5	0.0	0.0	26.8
48	0.042647	0.003396	20.8	0.0	0.0	28.0
50	0.039616	0.003102	21.1	0.0	0.0	29.2
53	0.036935	0.002855	21.3	0.0	0.0	30.4
55	0.034524	0.002645	21.5	0.0	0.0	31.5
58	0.032393	0.002470	21.6	0.0	0.0	32.7
60	0.030473	0.002313	21.7	0.0	0.0	33.8
62	0.028735	0.002181	21.8	0.0	0.0	34.8
65	0.027167	0.002071	21.8	0.0	0.0	35.8
68	0.025744	0.001973	21.9	0.0	0.0	36.8
70	0.024441	0.001882	21.8	0.0	0.0	37.8
73	0.023231	0.001806	21.8	0.0	0.0	38.8
75	0.022144	0.001737	21.7	0.0	0.0	39.7
78	0.021136	0.001679	21.6	0.0	0.0	40.6
80	0.020196	0.001626	21.4	0.0	0.0	41.5
83	0.019320	0.001576	21.2	0.0	0.0	42.3
85	0.018508	0.001533	21.0	0.0	0.0	43.2

downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
88	0.017752	0.001497	20.7	0.0	0.0	44.0
90	0.017047	0.001460	20.4	0.0	0.0	44.8
93	0.016392	0.001426	20.1	0.0	0.0	45.6
95	0.015773	0.001401	19.7	0.0	0.0	46.3
98	0.015202	0.001375	19.2	0.0	0.0	47.0
100	0.014659	0.001350	18.7	0.0	0.0	47.7
103	0.014147	0.001328	18.2	0.0	0.0	48.4
105	0.013671	0.001311	17.6	0.0	0.0	49.1
108	0.013221	0.001293	16.9	0.0	0.0	49.8
110	0.012795	0.001277	16.1	0.0	0.0	50.4
112	0.012387	0.001262	15.3	0.0	0.0	51.0
115	0.012003	0.001249	14.4	0.0	0.0	51.6
118	0.011638	0.001237	13.3	0.0	0.0	52.2
120	0.011291	0.001226	12.1	0.0	0.0	52.8
123	0.010963	0.001217	10.7	0.0	0.0	53.3
125	0.010647	0.001207	8.9	0.0	0.0	53.9
128	0.010349	0.001199	6.7	0.0	0.0	54.4
130	0.010066	0.001191	2.4	0.0	0.0	55.0

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.100000	26.4	1
2 0.050000	42.5	2
3 0.010000	130.6	6




Momentum Jet Contours - Side View
Battery Malfunction with Combustion [B-1vertCombustionLowCase]
10.0 mole %
5.0 mole %
1.0 mole %
Height (feet)
Downwind Distance(feet)
Note: Release during 10 mph winds and D stability.


Momentum Jet Concentration
Battery Malfunction with Combustion [B-1vertCombustionLowCase]
Centerline Concentration
Ground Level Concentration
Concentration (mole fraction)
Downwind Distance (feet)
Note: Release during 10 mph winds and D stability.

Case Inputs

```
Case Type             : Vapor Dispersion
Case Name             : MegaPack-B-1vert
User ID               : GC
Project Number        :
Type of Units         : English Units

  NOTES:

MATERIAL MENU
Materials Released    : Number  Formula   Name                         Fraction
Component  1          :    51 = H2        Hydrogen(equilibrium)        0.258295
Component  2          :    43 = CO        Carbon Monoxide              0.506656
Component  3          :     1 = CH4       Methane                      0.099344
Component  4          :     2 = C2H6      Ethane                       0.039738
Component  5          :     3 = C3H8      Propane                      0.089410
Component  6          :    50 = HF        Hydrogen Fluoride            0.000497
Component  7          :    26 = HCl       Hydrogen Chloride            0.000993
Component  8          :   103 = HCN       Hydrogen Cyanide             0.001590
Component  9          :   281 = C7H8      Toluene                      0.003477
Component 10          :

Temperature           :       122.00 °F
Pressure              :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                   60 min
Regulated flow rate                              0.26 lb/sec
Pipe inner diameter                             12.00 inches
Equivalent release diameter                     12.00 inches
Height of release point                           7.8 feet
Angle of release from horizontal                 90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation, dispersion and cloud explosion - Flammable calculation
Concentration endpoint 1                          LFL mol%
Concentration endpoint 2                      1/2 LFL mol%
Concentration endpoint 3                      1/2 LFL mol%

Dispersion coefficient averaging time               1 min

Baker-Strehlow-Tang parameters

Fuel reactivity                                  High
Obstacle density                                 High
Flame expansion                                   3-D

Overpressure values

Overpressure endpoint 1                          3.00 psi
Overpressure endpoint 2                          1.00 psi
Overpressure endpoint 3                          1.00 psi

  NOTES:
```

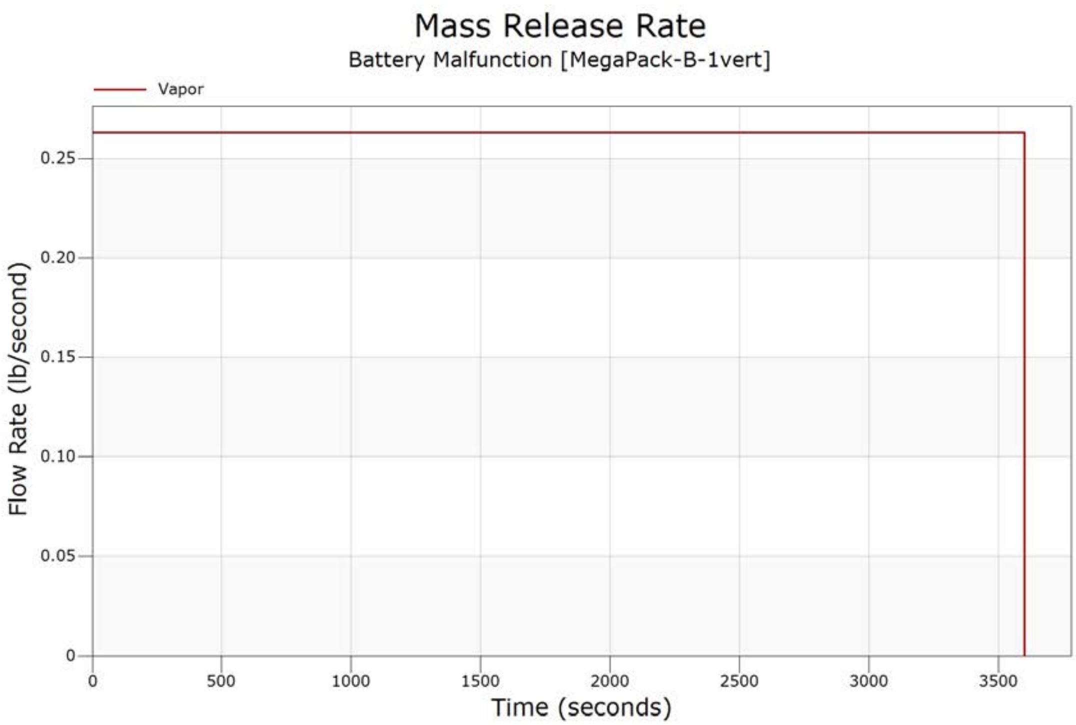
Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Flowrate for Jet Fire [immediate ignition] = 0.2631001 lb/sec.
Jet Fire [delayed ignition] = 0.2631001 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1vert]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Flammable Limits (Mole %) of Fluid Streams

Limit	Feed Stream	Momentum Jet Stream	Liquid Pool Stream
LFL	5.43	5.43	
UFL	33.27	33.27	
LBV		0.39 m/s	

Momentum Jet Dispersion

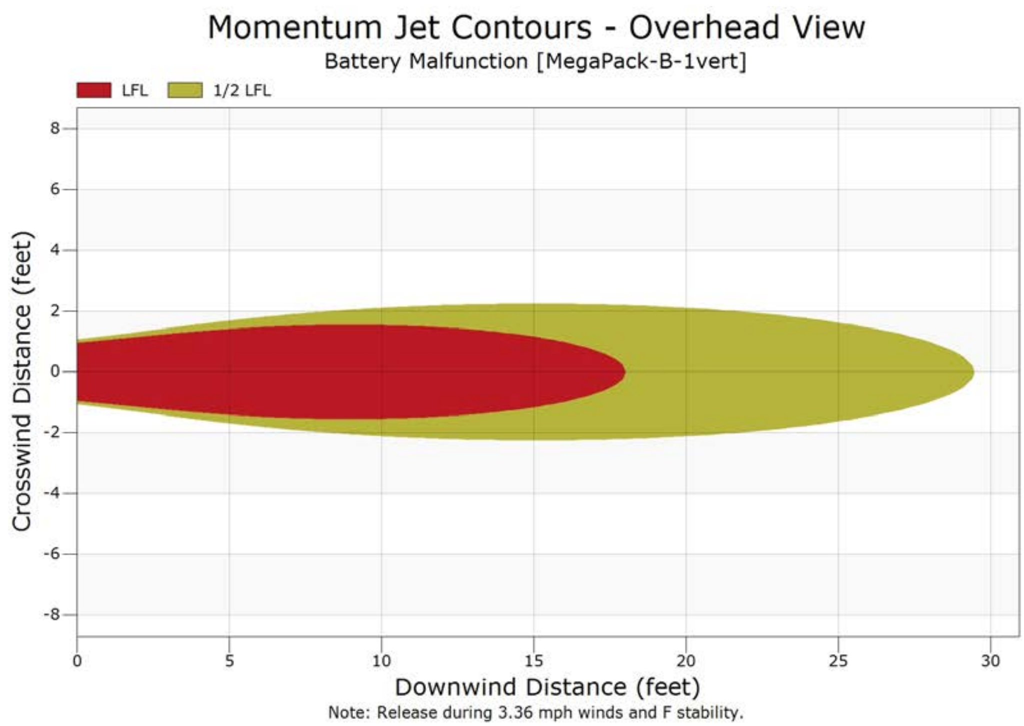
concentration limits

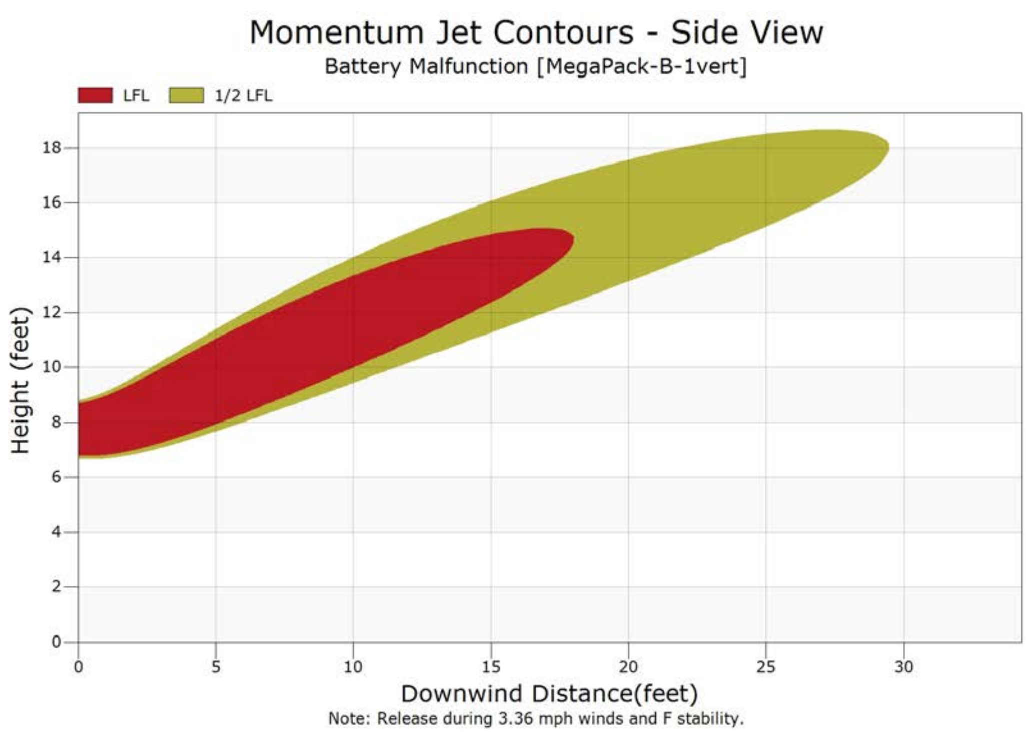
Endpoint 1 (highest) = 0.054276 mole fraction
Endpoint 2 (middle) = 0.027138 mole fraction
Endpoint 3 (lowest) = 0.027138 mole fraction

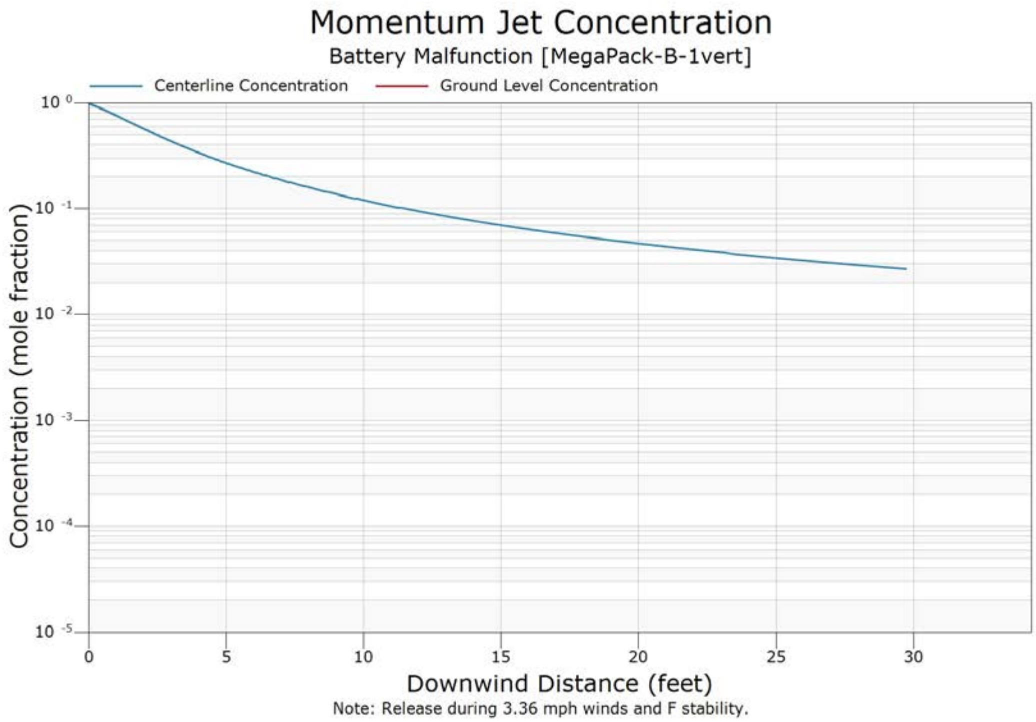
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	1.1	1.1	1.0	7.7
0.5	0.873278	0.000000	1.1	1.1	1.0	7.8
1.0	0.760914	0.000000	1.2	1.2	1.1	7.9
1.5	0.658185	0.000000	1.2	1.2	1.1	8.0
2.0	0.569624	0.000000	1.3	1.3	1.2	8.2
2.5	0.494998	0.000000	1.4	1.4	1.2	8.3
3.0	0.432882	0.000000	1.4	1.4	1.2	8.6
3.5	0.381287	0.000000	1.5	1.5	1.3	8.8
4.0	0.338129	0.000000	1.6	1.6	1.3	9.0
4.5	0.301985	0.000000	1.6	1.6	1.4	9.2
5.0	0.271111	0.000000	1.7	1.7	1.4	9.4
5.5	0.245067	0.000000	1.7	1.7	1.4	9.7
6.0	0.222817	0.000000	1.8	1.8	1.5	9.9
6.5	0.203370	0.000000	1.8	1.8	1.5	10.1
7.0	0.186506	0.000000	1.9	1.9	1.5	10.4
7.5	0.171836	0.000000	1.9	1.9	1.5	10.6
8.0	0.158859	0.000000	2.0	2.0	1.5	10.8
8.5	0.147408	0.000000	2.0	2.0	1.5	11.0
9.0	0.137303	0.000000	2.1	2.1	1.6	11.3
9.5	0.128144	0.000000	2.1	2.1	1.5	11.5
10.0	0.119931	0.000000	2.1	2.1	1.5	11.7
10.5	0.112618	0.000000	2.1	2.1	1.5	11.9
11.0	0.106009	0.000000	2.2	2.2	1.5	12.1
11.5	0.100040	0.000000	2.2	2.2	1.5	12.3
12.0	0.094536	0.000000	2.2	2.2	1.5	12.5
12.5	0.089555	0.000000	2.2	2.2	1.4	12.7
13.0	0.084913	0.000000	2.2	2.2	1.4	12.9
13.5	0.080692	0.000000	2.2	2.2	1.4	13.1
14.0	0.076797	0.000000	2.2	2.2	1.3	13.3
14.5	0.073224	0.000000	2.3	2.3	1.2	13.5
15.0	0.069927	0.000000	2.3	2.3	1.2	13.7
15.5	0.066836	0.000000	2.3	2.3	1.1	13.9
16.0	0.063996	0.000000	2.2	2.2	1.0	14.0
16.5	0.061321	0.000000	2.2	2.2	0.9	14.2
17.0	0.058840	0.000000	2.2	2.2	0.7	14.4

downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
17.5	0.056515	0.000000	2.2	2.2	0.5	14.6
18.0	0.054350	0.000000	2.2	2.2	0.0	14.7
18.5	0.052310	0.000000	2.2	2.2	0.0	14.9
19.0	0.050398	0.000000	2.2	2.2	0.0	15.1
19.5	0.048603	0.000000	2.1	2.1	0.0	15.2
20.0	0.046907	0.000000	2.1	2.1	0.0	15.4
20.5	0.045316	0.000000	2.1	2.1	0.0	15.6
21.0	0.043808	0.000000	2.1	2.1	0.0	15.7
21.5	0.042381	0.000000	2.0	2.0	0.0	15.9
22.0	0.041037	0.000000	2.0	2.0	0.0	16.0
22.5	0.039764	0.000000	1.9	1.9	0.0	16.2
23.0	0.038550	0.000000	1.9	1.9	0.0	16.3
23.5	0.037394	0.000000	1.8	1.8	0.0	16.5
24.0	0.036301	0.000000	1.8	1.8	0.0	16.6
24.5	0.035261	0.000000	1.7	1.7	0.0	16.8
25.0	0.034266	0.000000	1.6	1.6	0.0	16.9
25.5	0.033321	0.000000	1.6	1.6	0.0	17.0
26.0	0.032419	0.000000	1.5	1.5	0.0	17.2
26.5	0.031552	0.000000	1.4	1.4	0.0	17.3
27.0	0.030725	0.000000	1.3	1.3	0.0	17.4
27.5	0.029937	0.000000	1.1	1.1	0.0	17.6
28.0	0.029182	0.000000	1.0	1.0	0.0	17.7
28.5	0.028457	0.000000	0.8	0.8	0.0	17.8
29.0	0.027762	0.000000	0.6	0.6	0.0	18.0
29.5	0.027095	0.000000	0.0	0.0	0.0	18.1

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.054276 (LFL)	18.0	4
2 0.027138 (1/2 LFL)	29.5	6
3 0.027138 (1/2 LFL)	29.5	6


Momentum Jet Contours - Overhead View
Battery Malfunction [MegaPack-B-1vert]
LFL
1/2 LFL
Crosswind Distance (feet)
8
6
4
2
0
-2
-4
-6
-8
0
5
10
15
20
25
30
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1vert]
LFL
1/2 LFL
Height (feet)
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1vert]
Centerline Concentration
Ground Level Concentration
Concentration (mole fraction)
10 0
10 -1
10 -2
10 -3
10 -4
10 -5
0
5
10
15
20
25
30
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

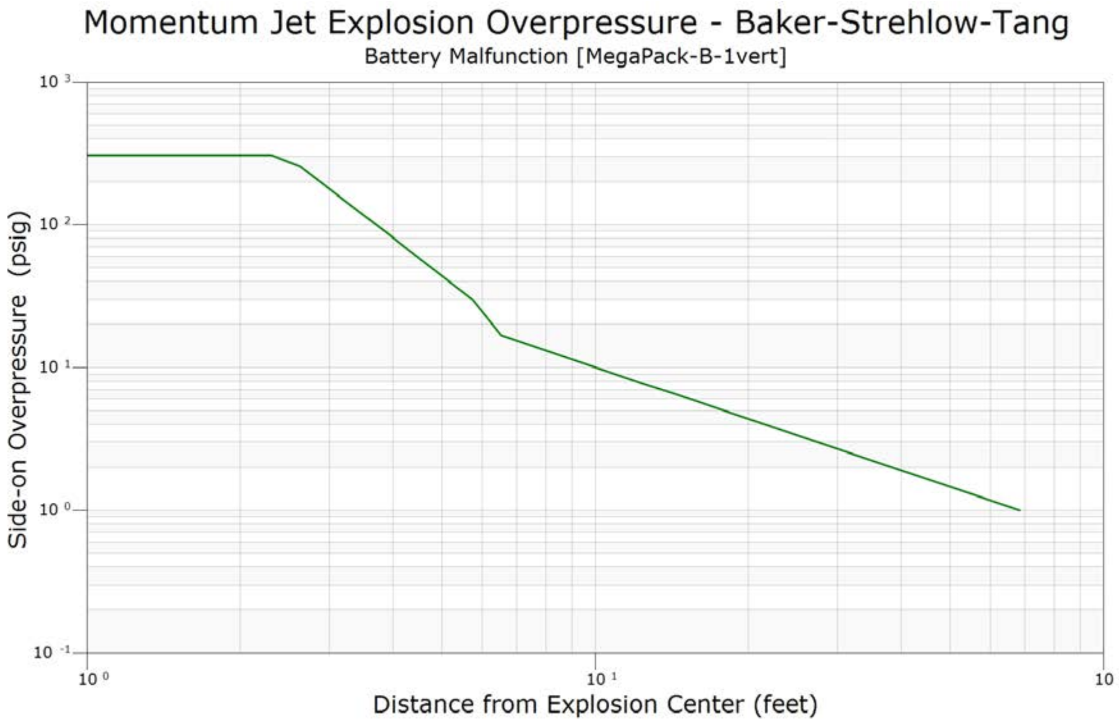
Momentum Jet Explosion

Fuel Reactivity: High Obstacle Density: High
Flame Expansion: 3-D Flame Speed: 5.20

Mass of released material involved in explosion: 0.980046 lbs.

Distance from Center of Flammable Cloud (feet)	Overpressure (psi gauge)	Impulse (psi-s)
0.0	308.61	0.0596
1.6	308.61	0.0596
1.8	308.61	0.0525
2.0	308.61	0.0462
2.3	308.61	0.0407
2.6	256.33	0.0358
3.0	179.31	0.0315
3.4	125.43	0.0278
3.9	87.74	0.0244
4.4	61.37	0.0215
5.0	42.93	0.0189
5.7	30.03	0.0167
6.5	16.76	0.0147
7.4	14.34	0.0129
8.5	12.27	0.0114
9.6	10.50	0.0100
11.0	8.98	0.0088
12.5	7.69	0.0078
14.2	6.58	0.0068
16.2	5.63	0.0060
18.5	4.81	0.0053
21.0	4.12	0.0047
23.9	3.52	0.0041
27.3	3.02	0.0036
68.4	1.00	0.0015

The downwind distance to 3.00 psi is 27.6 feet
The downwind distance to 1.00 psi is 68.4 feet
The downwind distance to 1.00 psi is 68.4 feet


Momentum Jet Explosion Overpressure - Baker-Strehlow-Tang
Battery Malfunction [MegaPack-B-1vert]
Side-on Overpressure (psig)
10 3
10 2
10 1
10 0
10 -1
10 0
10 1
10 2
Distance from Explosion Center (feet)

Case Inputs

```
Case Type           : Vapor Dispersion
Case Name           : MegaPack-B-1toxicCO
User ID             : GC
Project Number      :
Type of Units       : English Units

  NOTES:

MATERIAL MENU
Materials Released  : Number  Formula   Name                         Fraction
Component  1        :    51 = H2        Hydrogen(equilibrium)        0.258295
Component  2        :    43 = CO        Carbon Monoxide              0.506656
Component  3        :     1 = CH4       Methane                      0.099344
Component  4        :     2 = C2H6      Ethane                       0.039738
Component  5        :     3 = C3H8      Propane                      0.089410
Component  6        :    50 = HF        Hydrogen Fluoride            0.000497
Component  7        :    26 = HCl       Hydrogen Chloride            0.000993
Component  8        :   103 = HCN       Hydrogen Cyanide             0.001590
Component  9        :   281 = C7H8      Toluene                      0.003477
Component 10        :

Temperature         :       122.00 °F
Pressure            :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                     3.36 mph
Wind speed measurement height                  32.8 feet
Stability class <A-F>                            F
Relative humidity                                70 %
Air temperature                                77.0 °F
Spill surface temperature                      77.0 °F

Substrate name                           Soil
  Substrate thermal conductivity             1.0000 Btu/hr-ft-F
  Substrate density                             100 lb/cu.ft
  Substrate heat Capacity                      0.24 Btu/lb-F
  Substrate delay time                           60 sec
Surrounding terrain                      Long grass or crops > 15 cm (6 in)

  NOTES:
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RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   43 = CO        Carbon Monoxide
Concentration endpoint 1                      1200.0 ppm
Concentration endpoint 2                       500.0 ppm
Concentration endpoint 3                       350.0 ppm

Dispersion coefficient averaging time              1 min

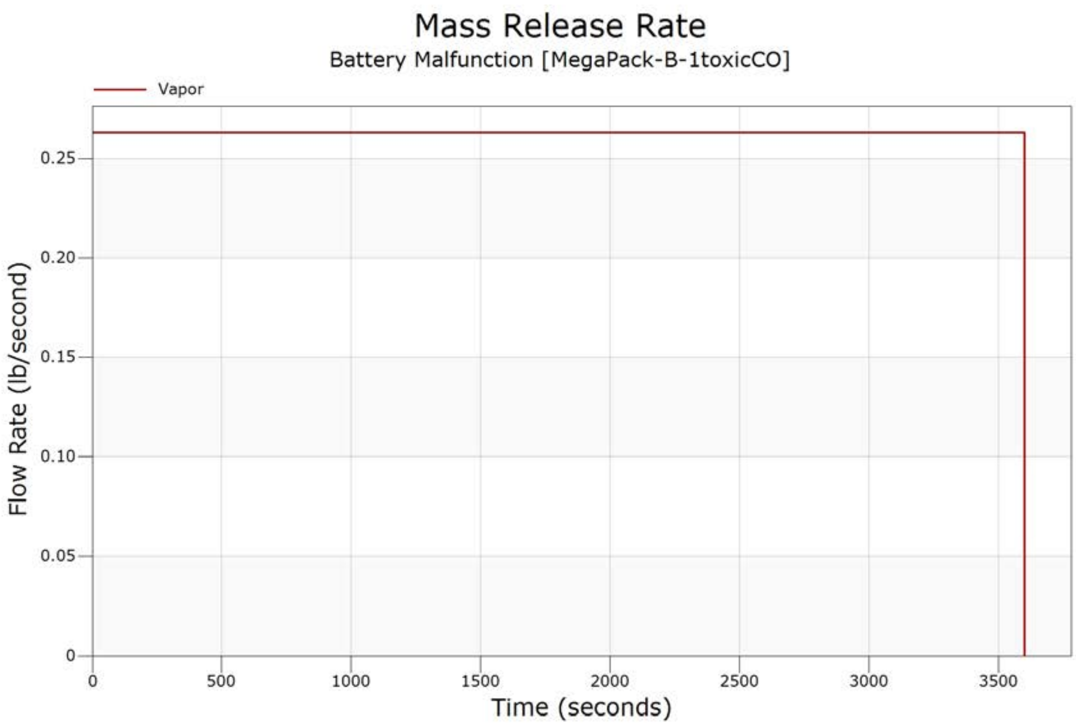

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicCO]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

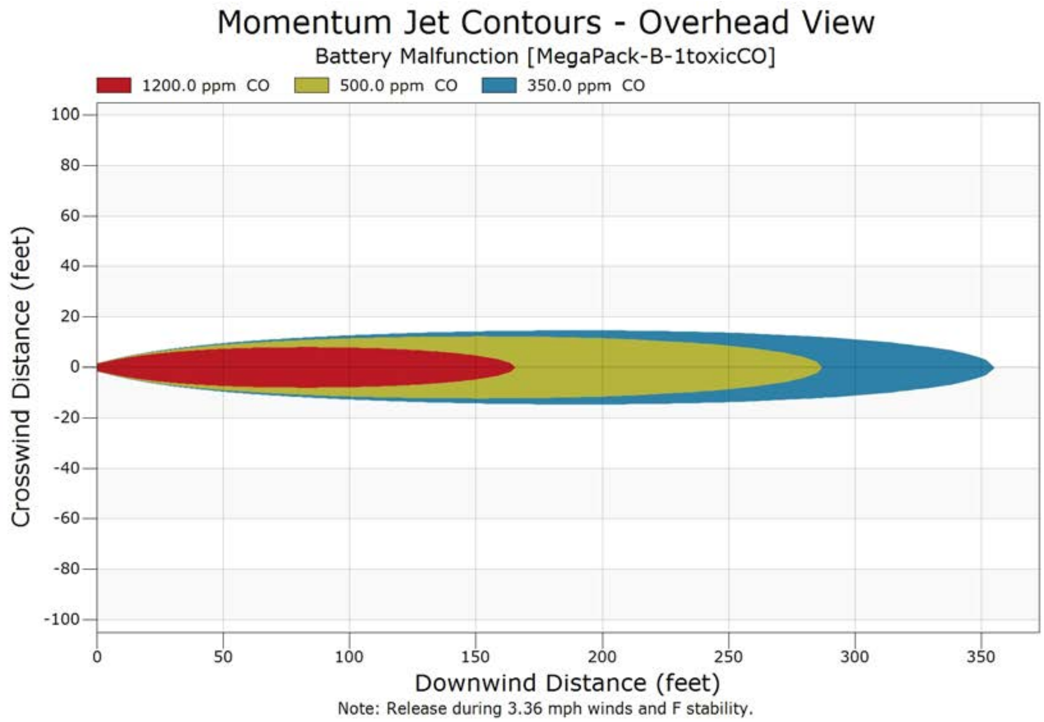
concentration limits

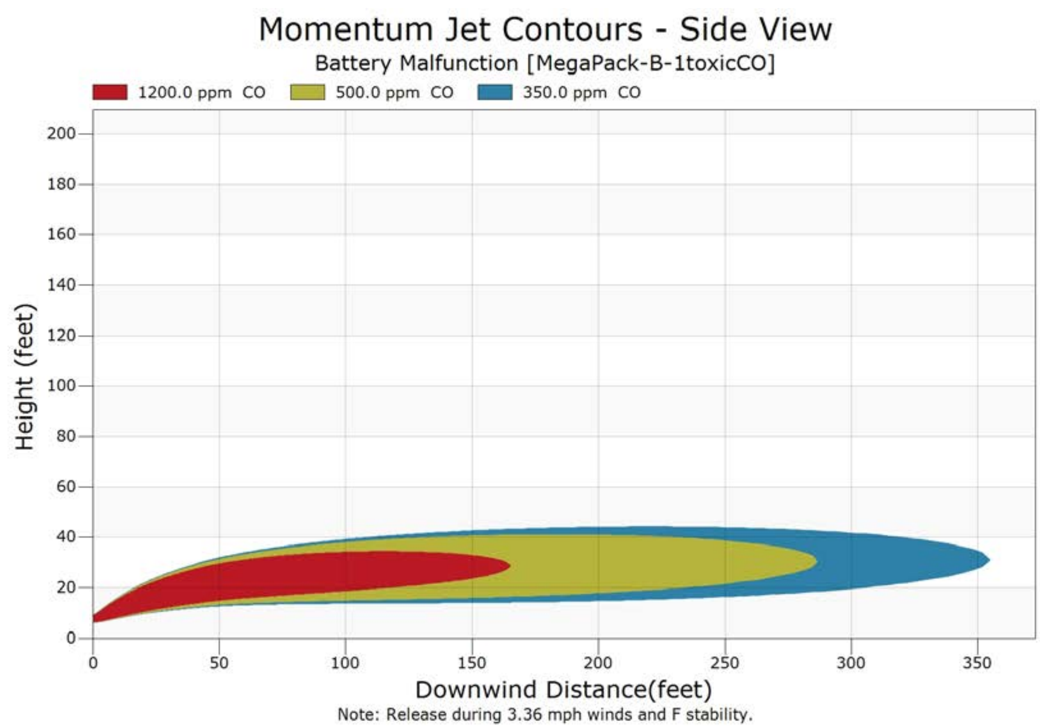
Endpoint 1 (highest) = 1200.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 350.0 ppm

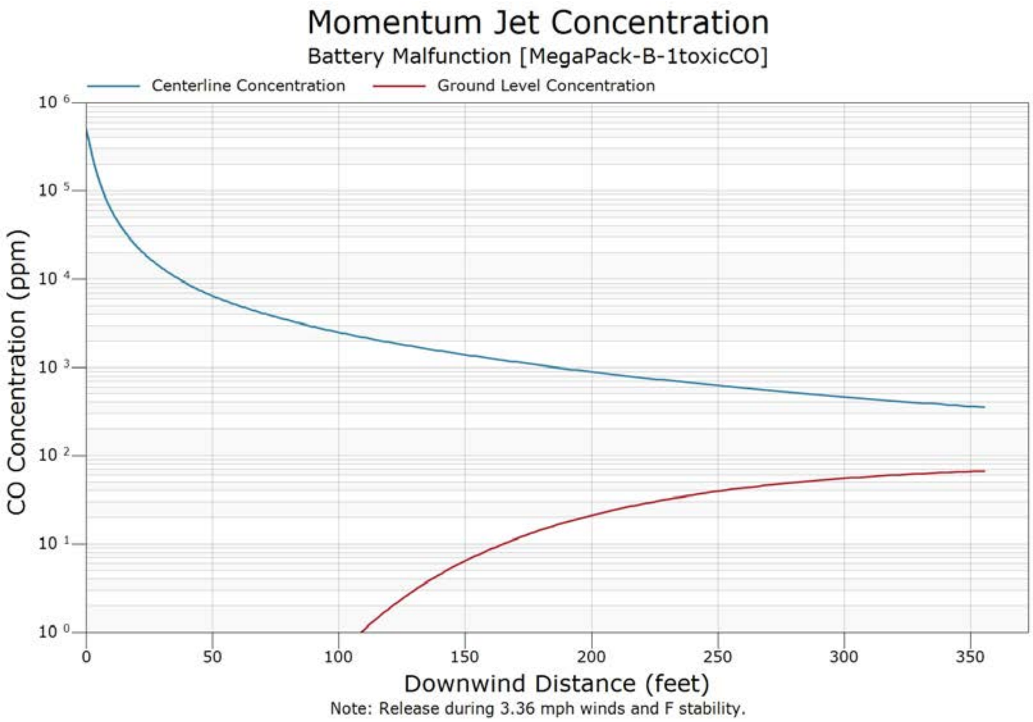
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	506656.000	0.000	1.5	1.5	1.4	7.7
5	137308.239	0.000	2.7	2.6	2.4	9.4
10	60760.707	0.000	3.9	3.8	3.4	11.7
15	35426.246	0.000	5.0	4.8	4.3	13.7
20	23767.614	0.000	5.9	5.6	5.0	15.4
25	17354.285	0.000	6.7	6.4	5.5	16.9
30	13393.549	0.000	7.4	7.0	6.0	18.2
35	10752.091	0.000	8.0	7.6	6.4	19.4
40	8883.918	0.000	8.6	8.1	6.8	20.5
45	7527.030	0.000	9.1	8.6	7.1	21.4
50	6502.521	0.001	9.6	9.0	7.3	22.2
55	5705.038	0.003	10.1	9.4	7.5	22.9
60	5061.222	0.007	10.5	9.7	7.7	23.5
65	4539.876	0.015	10.8	10.0	7.8	24.0
70	4101.976	0.030	11.2	10.3	7.9	24.5
75	3732.426	0.056	11.5	10.6	8.0	24.9
80	3415.790	0.097	11.8	10.8	8.0	25.3
85	3141.463	0.159	12.1	11.0	8.0	25.6
90	2900.717	0.251	12.3	11.2	8.0	25.9
95	2690.091	0.377	12.6	11.4	7.9	26.2
100	2503.831	0.550	12.8	11.6	7.8	26.5
105	2335.373	0.777	13.0	11.7	7.7	26.7
110	2185.421	1.065	13.2	11.9	7.6	27.0
115	2051.339	1.425	13.4	12.0	7.4	27.2
120	1928.338	1.863	13.6	12.1	7.2	27.4
125	1817.921	2.391	13.7	12.2	6.9	27.6
130	1717.183	3.004	13.9	12.2	6.6	27.7
135	1624.107	3.709	14.0	12.3	6.2	27.9
140	1539.503	4.517	14.1	12.3	5.8	28.1
145	1461.542	5.422	14.3	12.4	5.3	28.2
150	1388.766	6.436	14.4	12.4	4.7	28.4
155	1322.264	7.537	14.4	12.4	3.9	28.5
160	1260.656	8.743	14.5	12.3	2.8	28.6
165	1202.743	10.022	14.6	12.3	0.4	28.7
170	1149.250	11.391	14.6	12.3	0.0	28.9

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
175	1099.196	12.861	14.7	12.2	0.0	29.0
180	1052.833	14.390	14.7	12.1	0.0	29.1
185	1009.354	15.993	14.7	12.0	0.0	29.2
190	968.234	17.630	14.8	11.9	0.0	29.3
195	929.536	19.351	14.7	11.8	0.0	29.4
200	893.531	21.099	14.7	11.6	0.0	29.5
205	859.962	22.873	14.7	11.4	0.0	29.5
210	827.760	24.691	14.7	11.2	0.0	29.6
215	797.424	26.555	14.6	11.0	0.0	29.7
220	768.706	28.375	14.5	10.8	0.0	29.8
225	741.671	30.258	14.5	10.5	0.0	29.9
230	716.240	32.100	14.4	10.2	0.0	29.9
235	691.938	33.957	14.3	9.8	0.0	30.0
240	668.740	35.753	14.1	9.5	0.0	30.1
245	646.902	37.582	14.0	9.1	0.0	30.1
250	626.068	39.359	13.8	8.6	0.0	30.2
255	606.163	41.166	13.7	8.1	0.0	30.2
260	587.378	42.907	13.5	7.5	0.0	30.3
265	569.391	44.625	13.3	6.9	0.0	30.4
270	552.127	46.263	13.0	6.1	0.0	30.4
275	535.687	47.863	12.8	5.1	0.0	30.5
280	520.086	49.428	12.5	3.9	0.0	30.5
285	505.067	50.954	12.2	1.9	0.0	30.6
290	490.795	52.449	11.9	0.0	0.0	30.6
295	477.157	53.856	11.6	0.0	0.0	30.7
300	463.979	55.263	11.2	0.0	0.0	30.7
305	451.363	56.580	10.8	0.0	0.0	30.7
310	439.221	57.845	10.3	0.0	0.0	30.8
315	427.515	59.028	9.8	0.0	0.0	30.8
320	416.370	60.216	9.2	0.0	0.0	30.9
325	405.660	61.324	8.6	0.0	0.0	30.9
330	395.244	62.359	7.9	0.0	0.0	31.0
335	385.486	63.443	7.2	0.0	0.0	31.0
340	376.038	64.334	6.2	0.0	0.0	31.0
345	366.627	65.296	5.1	0.0	0.0	31.1
350	358.094	66.106	3.6	0.0	0.0	31.1
355	349.842	66.948	0.0	0.0	0.0	31.1

Endpoint (ppm, CO)		Downwind Distance (feet)	Approximate Time (seconds)
1	1200.0	165.2	36
2	500.0	286.7	61
3	350.0	354.9	75


Momentum Jet Contours - Overhead View
Battery Malfunction [MegaPack-B-1toxicCO]
1200.0 ppm CO
500.0 ppm CO
350.0 ppm CO
Crosswind Distance (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
50
100
150
200
250
300
350
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicCO]
1200.0 ppm CO
500.0 ppm CO
350.0 ppm CO
Height (feet)
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicCO]
Centerline Concentration
Ground Level Concentration
CO Concentration (ppm)
10 6
10 5
10 4
10 3
10 2
10 1
10 0
0
50
100
150
200
250
300
350
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type           : Vapor Dispersion
Case Name           : MegaPack-B-1toxicCOHighWind
User ID             : GC
Project Number      :
Type of Units       : English Units

  NOTES:

MATERIAL MENU
Materials Released  : Number  Formula   Name                        Fraction
Component  1        :    51 = H2        Hydrogen(equilibrium)       0.258295
Component  2        :    43 = CO        Carbon Monoxide             0.506656
Component  3        :     1 = CH4       Methane                     0.099344
Component  4        :     2 = C2H6      Ethane                      0.039738
Component  5        :     3 = C3H8      Propane                     0.089410
Component  6        :    50 = HF        Hydrogen Fluoride           0.000497
Component  7        :    26 = HCl       Hydrogen Chloride           0.000993
Component  8        :   103 = HCN       Hydrogen Cyanide            0.001590
Component  9        :   281 = C7H8      Toluene                     0.003477
Component 10        :

Temperature         :       122.00 °F
Pressure            :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                 10.00 mph
Wind speed measurement height               32.8 feet
Stability class <A-F>                          D
Relative humidity                             70 %
Air temperature                             77.0 °F
Spill surface temperature                   77.0 °F

Substrate name                          Soil
  Substrate thermal conductivity          1.0000 Btu/hr-ft-F
  Substrate density                          100 lb/cu.ft
  Substrate heat Capacity                   0.24 Btu/lb-F
  Substrate delay time                        60 sec
Surrounding terrain                     Long grass or crops > 15 cm (6 in)

  NOTES:
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```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   43 = CO       Carbon Monoxide
Concentration endpoint 1                      1200.0 ppm
Concentration endpoint 2                       500.0 ppm
Concentration endpoint 3                       350.0 ppm

Dispersion coefficient averaging time             1 min

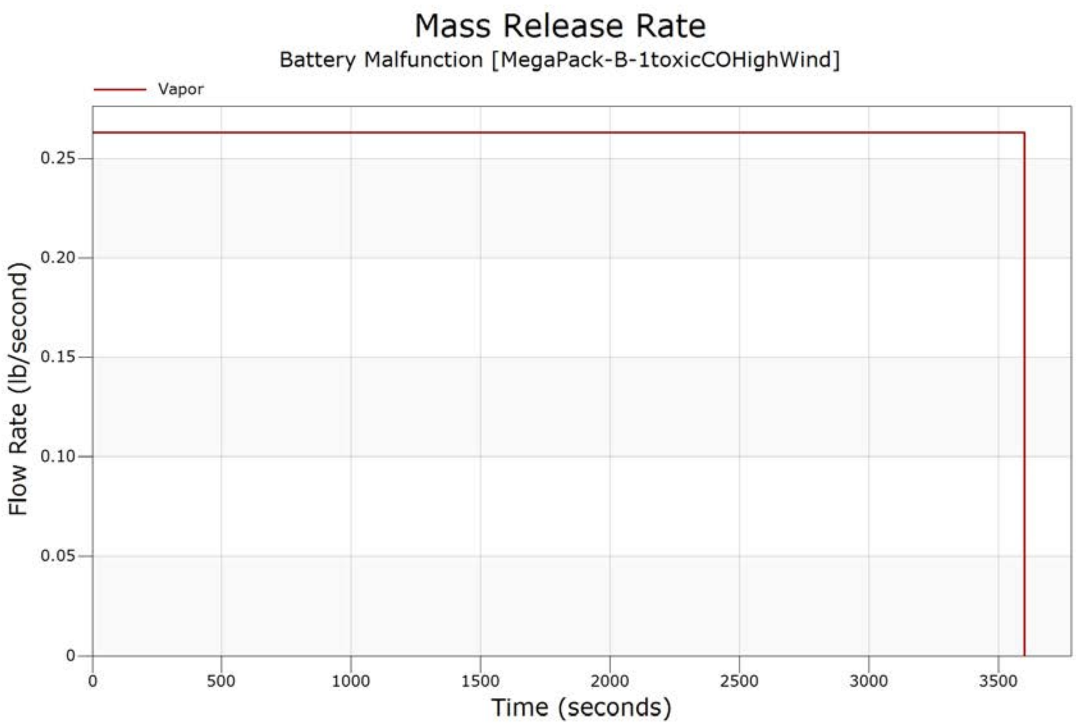

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicCOHighWind]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

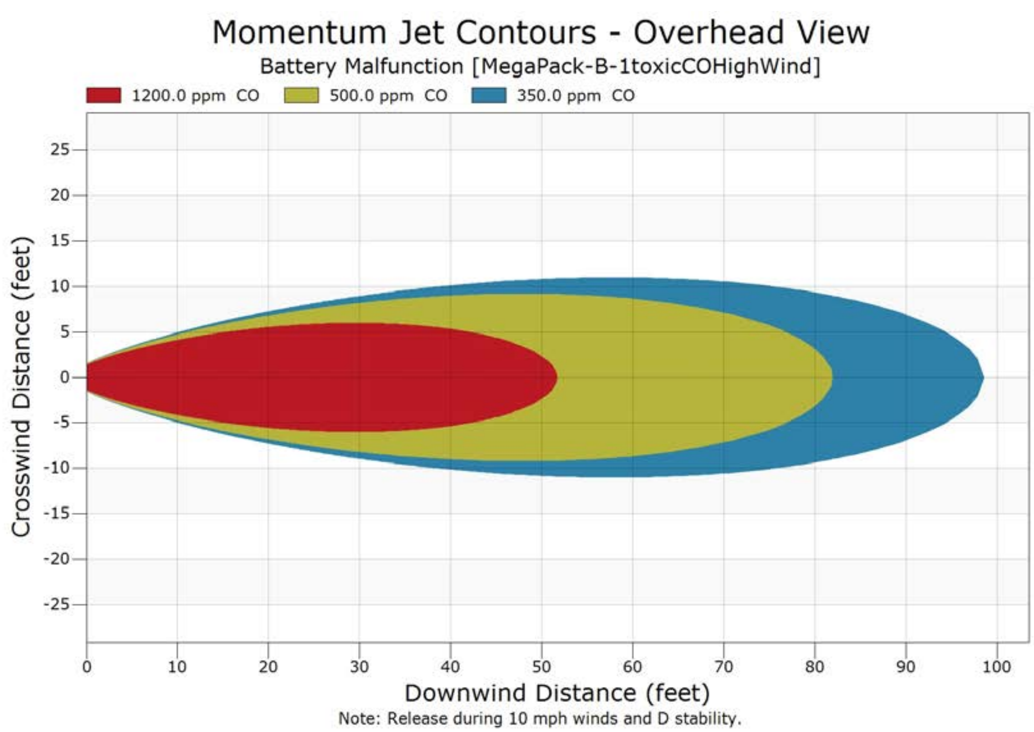
concentration limits

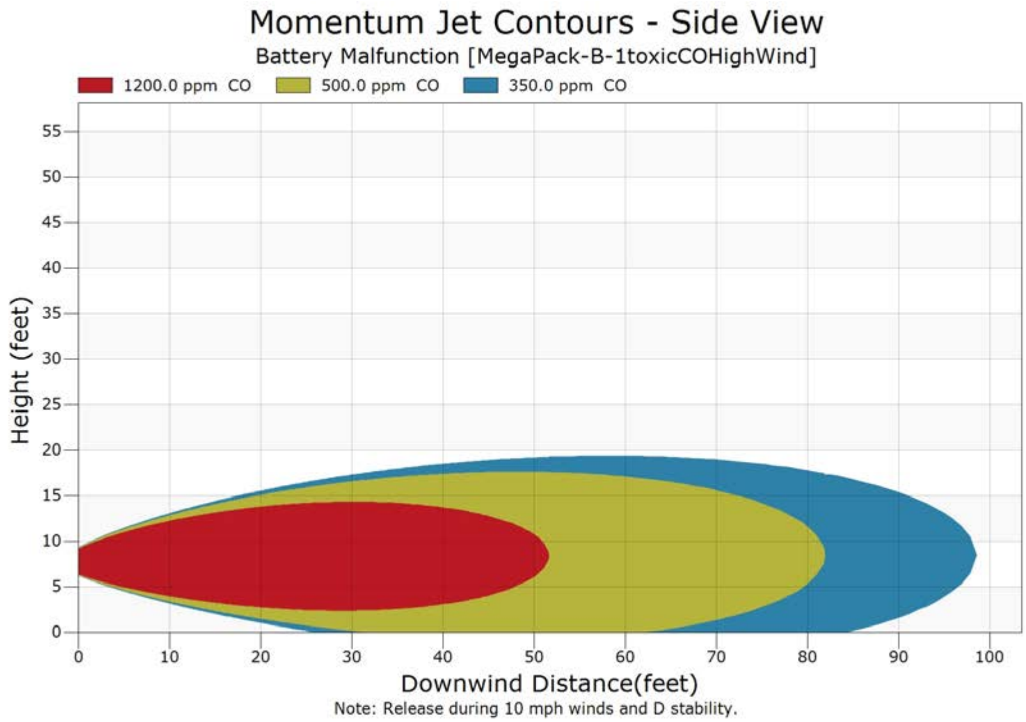
Endpoint 1 (highest) = 1200.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 350.0 ppm

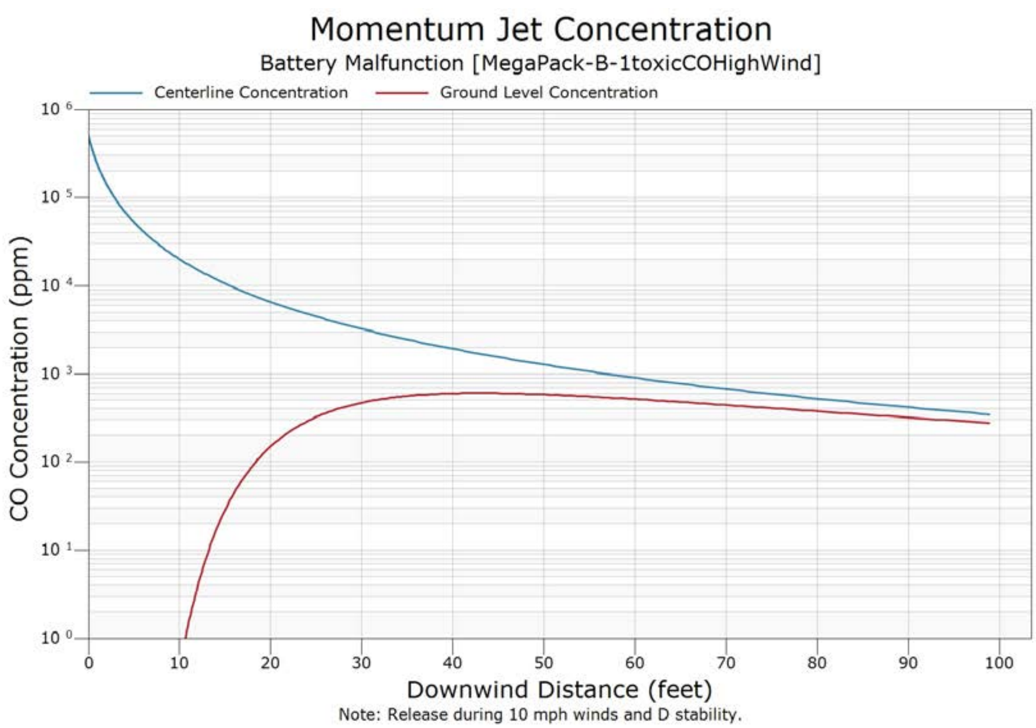
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	506656.000	0.000	1.5	1.5	1.4	7.7
2	140961.756	0.000	2.4	2.3	2.1	7.8
4	69008.638	0.000	3.1	3.0	2.8	7.9
6	41510.280	0.000	3.8	3.7	3.3	8.0
8	27865.466	0.014	4.4	4.2	3.7	8.0
10	20060.989	0.453	5.0	4.7	4.1	8.1
12	15156.137	3.986	5.5	5.2	4.5	8.1
14	11860.789	16.788	6.0	5.7	4.8	8.2
16	9546.501	45.156	6.4	6.1	5.1	8.2
18	7849.517	90.751	6.9	6.5	5.3	8.2
20	6570.735	151.095	7.3	6.8	5.5	8.3
22	5583.131	219.568	7.7	7.1	5.7	8.3
24	4803.644	290.691	8.0	7.5	5.8	8.3
26	4176.731	358.803	8.4	7.7	5.9	8.3
28	3665.496	418.964	8.7	8.0	6.0	8.3
30	3242.243	471.259	9.0	8.2	6.0	8.3
32	2889.907	513.876	9.2	8.4	6.0	8.4
34	2589.776	546.638	9.5	8.6	5.9	8.4
36	2333.599	571.617	9.7	8.8	5.8	8.4
38	2115.524	587.739	9.9	8.9	5.6	8.4
40	1925.758	598.242	10.1	9.0	5.3	8.4
42	1760.564	602.310	10.3	9.1	5.0	8.4
44	1618.114	603.067	10.5	9.2	4.6	8.4
46	1489.869	598.381	10.6	9.2	4.1	8.4
48	1375.022	591.053	10.7	9.2	3.4	8.4
50	1273.903	581.528	10.8	9.2	2.3	8.4
52	1185.461	570.748	10.9	9.2	0.0	8.4
54	1103.881	557.900	10.9	9.1	0.0	8.4
56	1030.383	544.146	11.0	9.0	0.0	8.4
58	965.687	530.495	11.0	8.8	0.0	8.4
60	905.761	515.810	11.0	8.7	0.0	8.4
62	851.389	501.032	10.9	8.5	0.0	8.4
64	801.423	486.272	10.9	8.2	0.0	8.4
66	755.773	471.405	10.8	7.9	0.0	8.5
68	714.344	456.982	10.7	7.6	0.0	8.5

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
70	675.926	442.717	10.5	7.1	0.0	8.5
72	639.965	428.351	10.4	6.6	0.0	8.5
74	607.813	414.958	10.2	6.1	0.0	8.5
76	577.581	401.709	9.9	5.3	0.0	8.5
78	549.456	388.750	9.7	4.4	0.0	8.5
80	523.365	376.293	9.4	3.1	0.0	8.5
82	499.088	364.283	9.0	0.0	0.0	8.5
84	476.308	352.465	8.6	0.0	0.0	8.5
86	455.269	341.343	8.1	0.0	0.0	8.5
88	435.370	330.431	7.5	0.0	0.0	8.5
90	416.948	320.120	6.9	0.0	0.0	8.5
92	399.359	309.910	6.1	0.0	0.0	8.5
94	383.295	300.482	5.2	0.0	0.0	8.5
96	367.974	291.198	3.9	0.0	0.0	8.5
98	353.591	282.340	1.6	0.0	0.0	8.5

Endpoint (ppm, CO)		Downwind Distance (feet)	Approximate Time (seconds)
1	1200.0	51.7	5
2	500.0	81.9	8
3	350.0	98.5	10




Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicCOHighWind]
1200.0 ppm CO
500.0 ppm CO
350.0 ppm CO
Height (feet)
Downwind Distance(feet)
Note: Release during 10 mph winds and D stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicCOHighWind]
Centerline Concentration
Ground Level Concentration
CO Concentration (ppm)
Downwind Distance (feet)
Note: Release during 10 mph winds and D stability.

Case Inputs

Case Type : Vapor Dispersion
Case Name : MegaPack-B-1toxicHCL
User ID : GC
Project Number :
Type of Units : English Units

NOTES:

MATERIAL MENU

Materials Released	Number	Formula	Name	Fraction
Component 1	51	= H2	Hydrogen(equilibrium)	0.258295
Component 2	43	= CO	Carbon Monoxide	0.506656
Component 3	1	= CH4	Methane	0.099344
Component 4	2	= C2H6	Ethane	0.039738
Component 5	3	= C3H8	Propane	0.089410
Component 6	50	= HF	Hydrogen Fluoride	0.000497
Component 7	26	= HCl	Hydrogen Chloride	0.000993
Component 8	103	= HCN	Hydrogen Cyanide	0.001590
Component 9	281	= C7H8	Toluene	0.003477
Component 10				

Temperature : 122.00 °F
Pressure : 15.00 psia
The material is Indeterminate

NOTES:

ENVIRONMENT MENU

Wind speed	3.36 mph
Wind speed measurement height	32.8 feet
Stability class <A-F>	F
Relative humidity	70 %
Air temperature	77.0 °F
Spill surface temperature	77.0 °F

Substrate name	Soil
Substrate thermal conductivity	1.0000 Btu/hr-ft-F
Substrate density	100 lb/cu.ft
Substrate heat Capacity	0.24 Btu/lb-F
Substrate delay time	60 sec
Surrounding terrain	Long grass or crops > 15 cm (6 in)

NOTES:

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RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   26 = HCl       Hydrogen Chloride
Concentration endpoint 1                       150.0 ppm
Concentration endpoint 2                        50.0 ppm
Concentration endpoint 3                        20.0 ppm

Dispersion coefficient averaging time              1 min

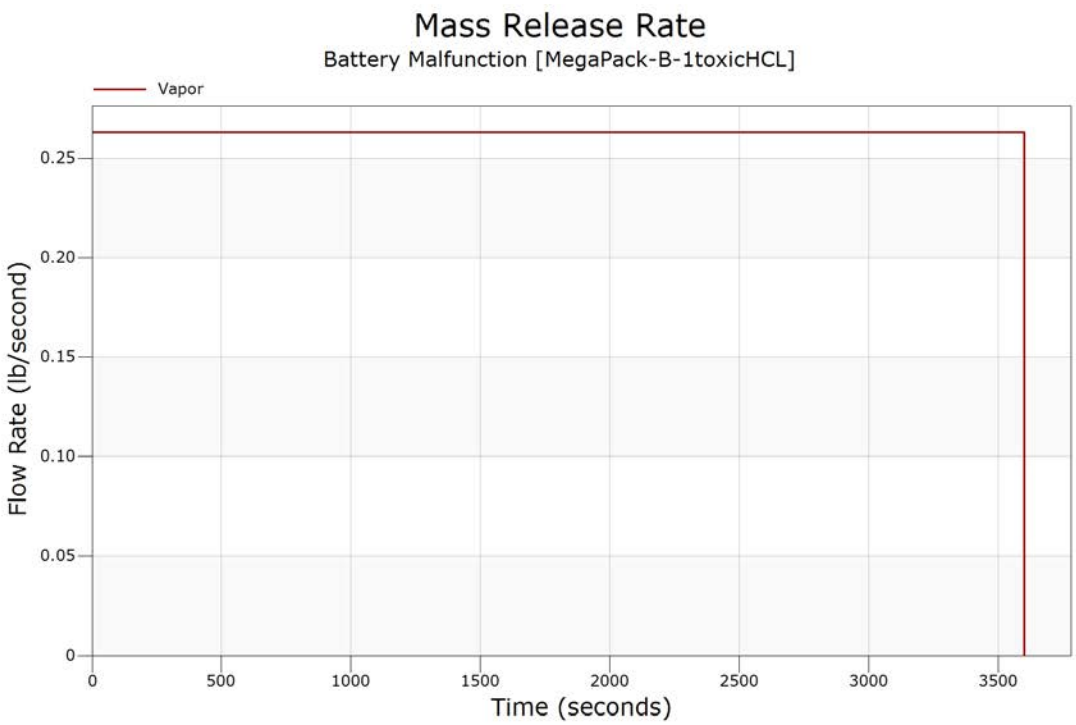

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicHCL]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

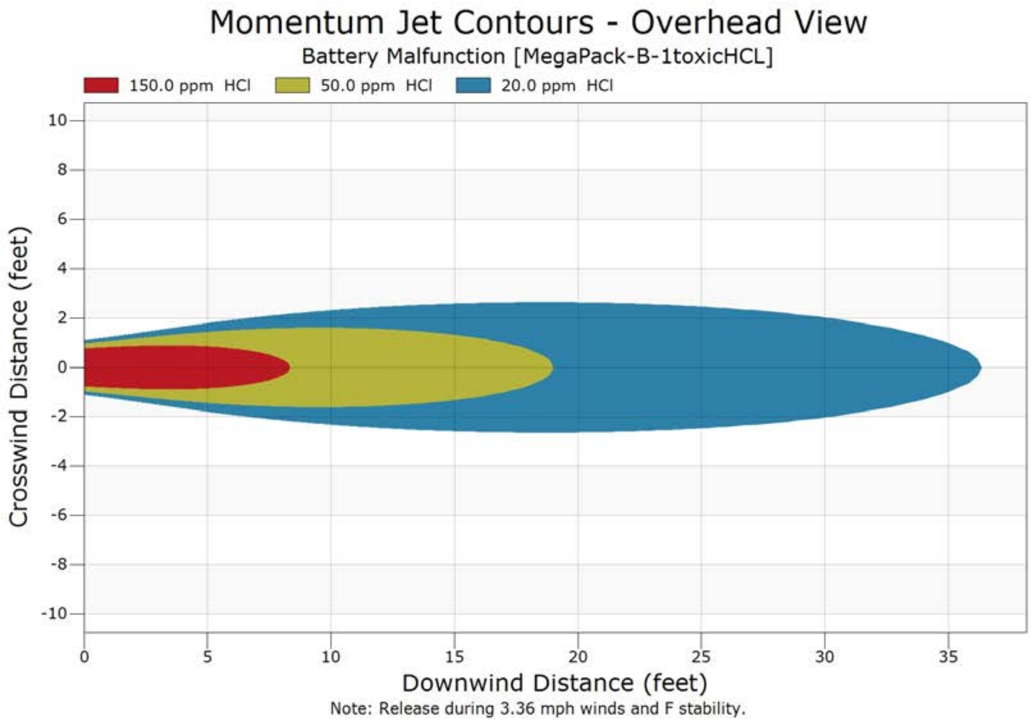
concentration limits

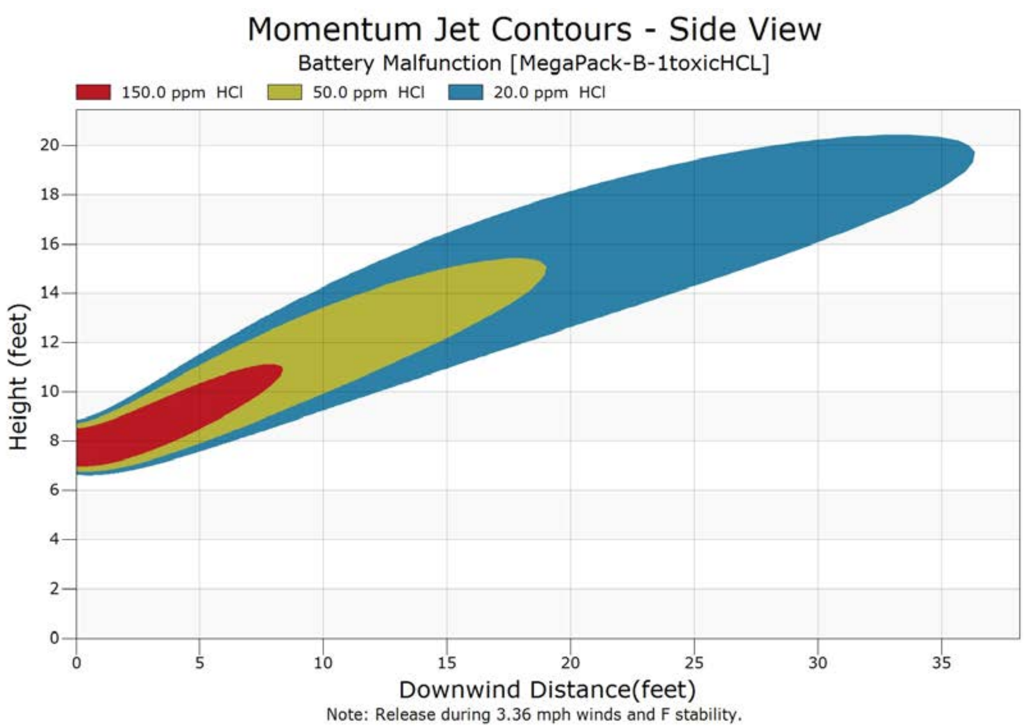
Endpoint 1 (highest) = 150.0 ppm
Endpoint 2 (middle) = 50.0 ppm
Endpoint 3 (lowest) = 20.0 ppm

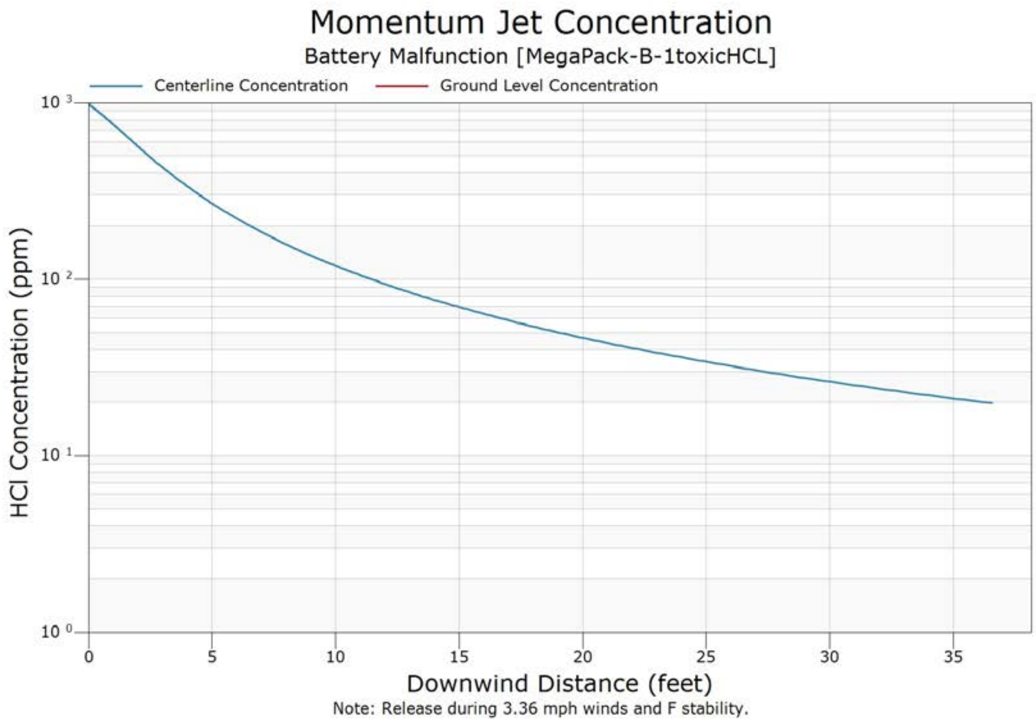
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	993.440	0.000	1.1	1.0	0.8	7.7
0.5	867.586	0.000	1.2	1.0	0.8	7.8
1.0	755.784	0.000	1.2	1.1	0.8	7.9
1.5	653.892	0.000	1.3	1.1	0.8	8.0
2.0	566.010	0.000	1.4	1.2	0.9	8.2
2.5	491.708	0.000	1.4	1.2	0.9	8.3
3.0	430.079	0.000	1.5	1.3	0.9	8.6
3.5	378.920	0.000	1.6	1.3	0.9	8.8
4.0	335.901	0.000	1.7	1.4	0.9	9.0
4.5	299.951	0.000	1.7	1.4	0.9	9.2
5.0	269.346	0.000	1.8	1.4	0.8	9.4
5.5	243.425	0.000	1.9	1.5	0.8	9.7
6.0	221.308	0.000	1.9	1.5	0.8	9.9
6.5	201.967	0.000	2.0	1.5	0.7	10.1
7.0	185.177	0.000	2.0	1.6	0.6	10.4
7.5	170.679	0.000	2.1	1.6	0.5	10.6
8.0	157.789	0.000	2.1	1.6	0.3	10.8
8.5	146.417	0.000	2.2	1.6	0.0	11.0
9.0	136.358	0.000	2.2	1.6	0.0	11.3
9.5	127.276	0.000	2.3	1.6	0.0	11.5
10.0	119.150	0.000	2.3	1.6	0.0	11.7
10.5	111.894	0.000	2.4	1.6	0.0	11.9
11.0	105.318	0.000	2.4	1.6	0.0	12.1
11.5	99.365	0.000	2.4	1.6	0.0	12.3
12.0	93.907	0.000	2.5	1.6	0.0	12.5
12.5	88.940	0.000	2.5	1.5	0.0	12.7
13.0	84.362	0.000	2.5	1.5	0.0	12.9
13.5	80.168	0.000	2.5	1.5	0.0	13.1
14.0	76.313	0.000	2.6	1.4	0.0	13.3
14.5	72.752	0.000	2.6	1.4	0.0	13.5
15.0	69.464	0.000	2.6	1.3	0.0	13.7
15.5	66.411	0.000	2.6	1.3	0.0	13.9
16.0	63.568	0.000	2.6	1.2	0.0	14.0
16.5	60.916	0.000	2.6	1.1	0.0	14.2
17.0	58.467	0.000	2.6	1.0	0.0	14.4

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
17.5	56.142	0.000	2.6	0.9	0.0	14.6
18.0	53.994	0.000	2.6	0.7	0.0	14.7
18.5	51.970	0.000	2.6	0.5	0.0	14.9
19.0	50.066	0.000	2.6	0.0	0.0	15.1
19.5	48.285	0.000	2.6	0.0	0.0	15.2
20.0	46.603	0.000	2.6	0.0	0.0	15.4
20.5	45.025	0.000	2.6	0.0	0.0	15.6
21.0	43.522	0.000	2.6	0.0	0.0	15.7
21.5	42.105	0.000	2.6	0.0	0.0	15.9
22.0	40.769	0.000	2.6	0.0	0.0	16.0
22.5	39.505	0.000	2.6	0.0	0.0	16.2
23.0	38.297	0.000	2.6	0.0	0.0	16.3
23.5	37.148	0.000	2.5	0.0	0.0	16.5
24.0	36.063	0.000	2.5	0.0	0.0	16.6
24.5	35.030	0.000	2.5	0.0	0.0	16.8
25.0	34.041	0.000	2.5	0.0	0.0	16.9
25.5	33.100	0.000	2.4	0.0	0.0	17.0
26.0	32.201	0.000	2.4	0.0	0.0	17.2
26.5	31.337	0.000	2.4	0.0	0.0	17.3
27.0	30.517	0.000	2.3	0.0	0.0	17.4
27.5	29.735	0.000	2.3	0.0	0.0	17.6
28.0	28.985	0.000	2.2	0.0	0.0	17.7
28.5	28.265	0.000	2.2	0.0	0.0	17.8
29.0	27.576	0.000	2.1	0.0	0.0	18.0
29.5	26.914	0.000	2.1	0.0	0.0	18.1
30.0	26.276	0.000	2.0	0.0	0.0	18.2
30.5	25.665	0.000	2.0	0.0	0.0	18.3
31.0	25.066	0.000	1.9	0.0	0.0	18.5
31.5	24.508	0.000	1.8	0.0	0.0	18.6
32.0	23.943	0.000	1.7	0.0	0.0	18.7
32.5	23.442	0.000	1.6	0.0	0.0	18.8
33.0	22.939	0.000	1.5	0.0	0.0	18.9
33.5	22.439	0.000	1.4	0.0	0.0	19.1
34.0	21.954	0.000	1.3	0.0	0.0	19.2
34.5	21.515	0.000	1.2	0.0	0.0	19.3
35.0	21.091	0.000	1.0	0.0	0.0	19.4
35.5	20.659	0.000	0.8	0.0	0.0	19.5
36.0	20.272	0.000	0.5	0.0	0.0	19.6
36.5	19.875	0.000	0.0	0.0	0.0	19.7

Endpoint (ppm, HCl)		Downwind Distance (feet)	Approximate Time (seconds)
1	150.0	8.3	2
2	50.0	19.0	4
3	20.0	36.3	8


Momentum Jet Contours - Overhead View
Battery Malfunction [MegaPack-B-1toxicHCL]
150.0 ppm HCl
50.0 ppm HCl
20.0 ppm HCl
Crosswind Distance (feet)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
5
10
15
20
25
30
35
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicHCL]
150.0 ppm HCl
50.0 ppm HCl
20.0 ppm HCl
Height (feet)
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicHCL]
Centerline Concentration
Ground Level Concentration
HCl Concentration (ppm)
10 3
10 2
10 1
10 0
0
5
10
15
20
25
30
35
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : MegaPack-B-1toxicHCN
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                        Fraction
Component  1         :    51 = H2        Hydrogen(equilibrium)       0.258295
Component  2         :    43 = CO        Carbon Monoxide             0.506656
Component  3         :     1 = CH4       Methane                     0.099344
Component  4         :     2 = C2H6      Ethane                      0.039738
Component  5         :     3 = C3H8      Propane                     0.089410
Component  6         :    50 = HF        Hydrogen Fluoride           0.000497
Component  7         :    26 = HCl       Hydrogen Chloride           0.000993
Component  8         :   103 = HCN       Hydrogen Cyanide            0.001590
Component  9         :   281 = C7H8      Toluene                     0.003477
Component 10         :

Temperature          :       122.00 °F
Pressure             :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                      3.36 mph
Wind speed measurement height                   32.8 feet
Stability class <A-F>                              F
Relative humidity                                 70 %
Air temperature                                 77.0 °F
Spill surface temperature                       77.0 °F

Substrate name                            Soil
  Substrate thermal conductivity              1.0000 Btu/hr-ft-F
  Substrate density                              100 lb/cu.ft
  Substrate heat Capacity                       0.24 Btu/lb-F
  Substrate delay time                            60 sec
Surrounding terrain                       Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component  103 = HCN       Hydrogen Cyanide
Concentration endpoint 1                        50.0 ppm
Concentration endpoint 2                        25.0 ppm
Concentration endpoint 3                        10.0 ppm

Dispersion coefficient averaging time              1 min

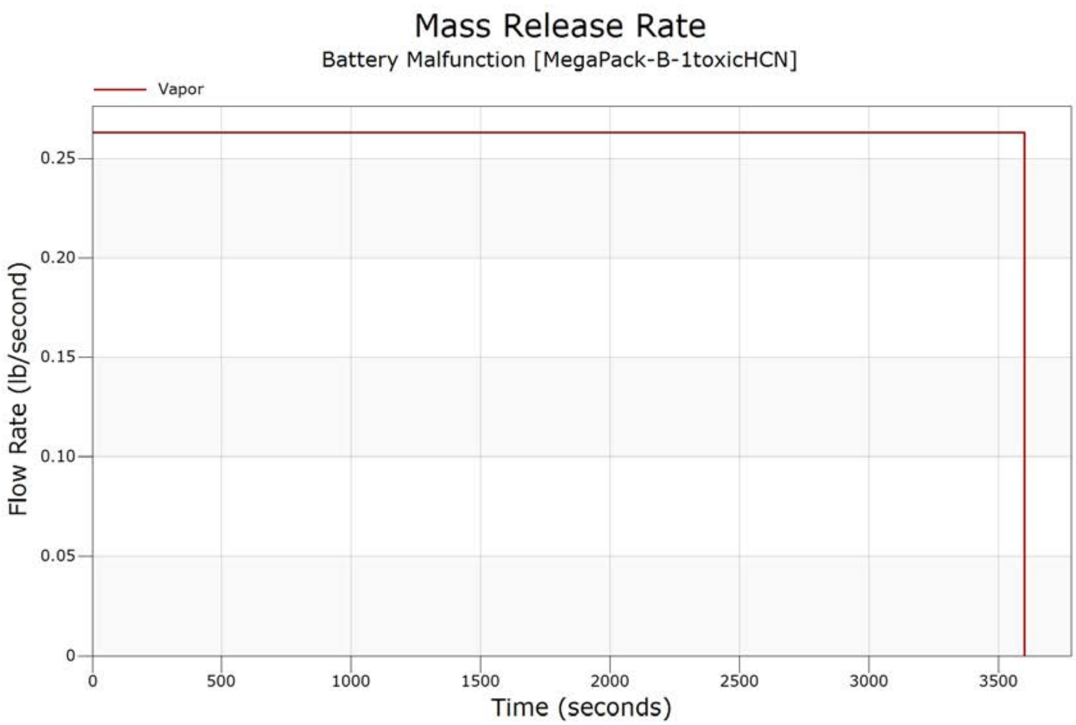

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicHCN]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

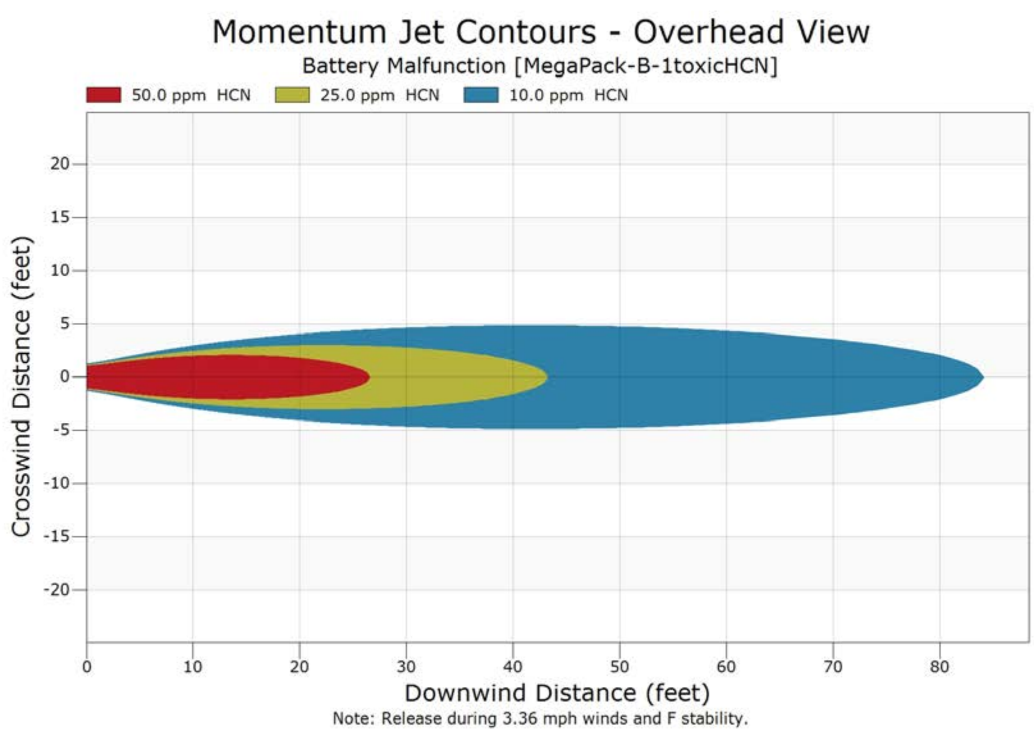
concentration limits

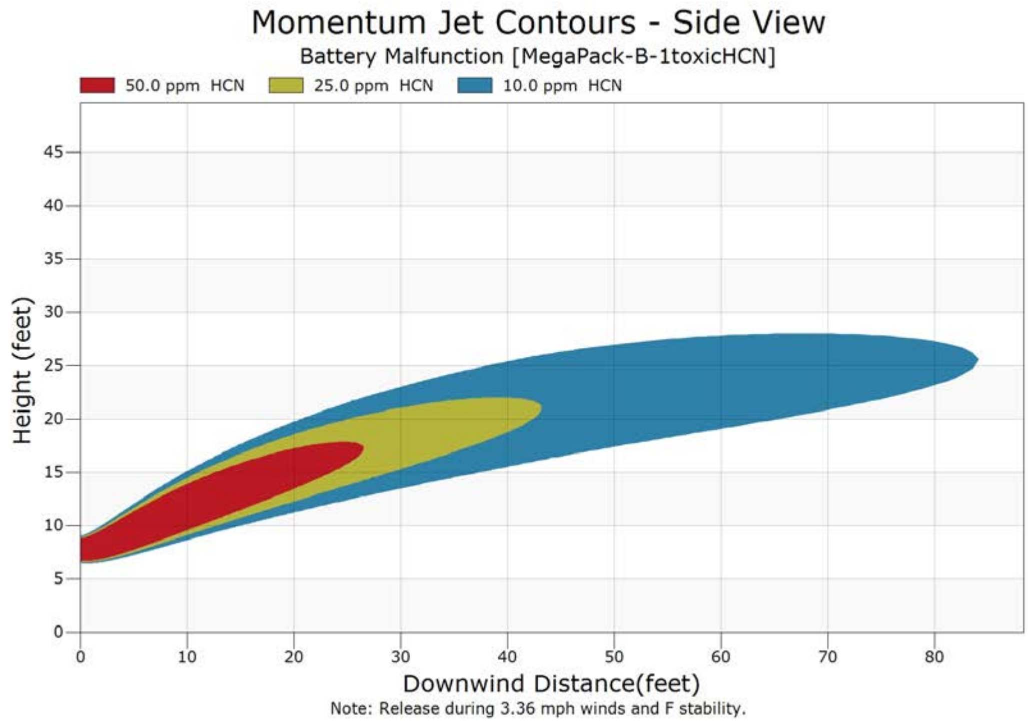
Endpoint 1 (highest) = 50.0 ppm
Endpoint 2 (middle) = 25.0 ppm
Endpoint 3 (lowest) = 10.0 ppm

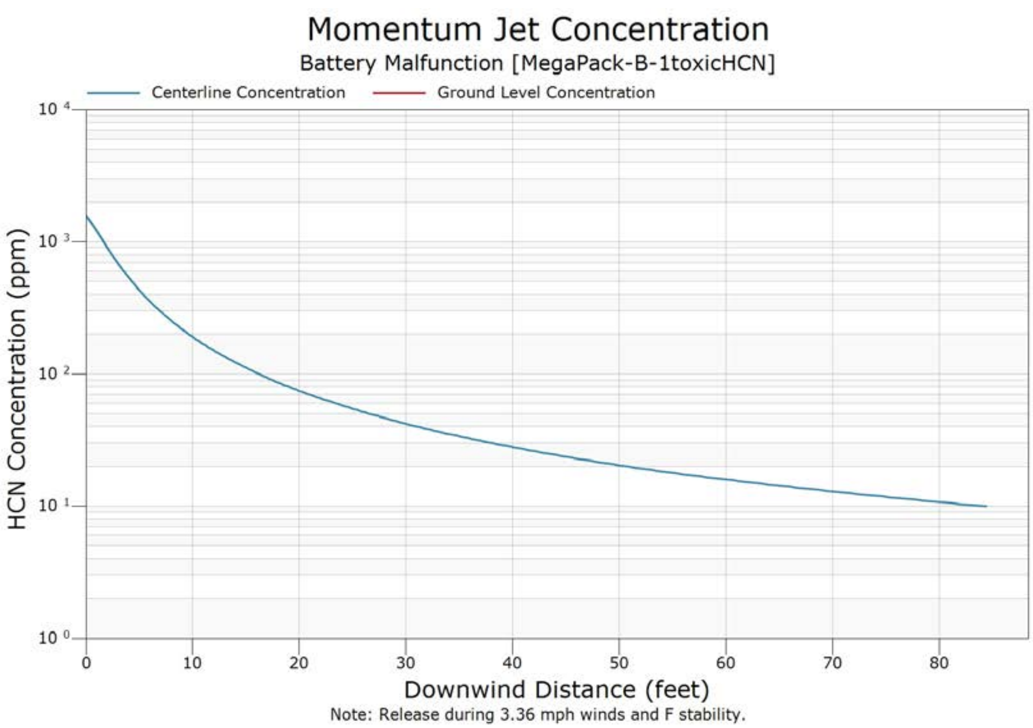
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1589.510	0.000	1.3	1.1	1.0	7.7
2	905.371	0.000	1.6	1.4	1.3	8.2
4	537.140	0.000	2.0	1.7	1.5	9.0
6	353.983	0.000	2.3	2.0	1.7	9.9
8	252.500	0.000	2.7	2.3	1.9	10.8
10	190.676	0.000	3.0	2.5	2.0	11.7
12	150.295	0.000	3.2	2.6	2.1	12.5
14	122.097	0.000	3.5	2.8	2.1	13.3
16	101.728	0.000	3.7	2.9	2.0	14.0
18	86.382	0.000	3.9	3.0	2.0	14.7
20	74.569	0.000	4.1	3.0	1.8	15.4
22	65.236	0.000	4.2	3.0	1.6	16.0
24	57.707	0.000	4.3	3.0	1.2	16.6
26	51.528	0.000	4.5	3.0	0.6	17.2
28	46.380	0.000	4.6	2.9	0.0	17.7
30	42.039	0.000	4.6	2.8	0.0	18.2
32	38.334	0.000	4.7	2.7	0.0	18.7
34	35.147	0.000	4.8	2.5	0.0	19.2
36	32.431	0.000	4.8	2.3	0.0	19.6
38	30.027	0.000	4.8	2.0	0.0	20.0
40	27.885	0.000	4.8	1.6	0.0	20.5
42	26.028	0.000	4.9	1.0	0.0	20.9
44	24.376	0.000	4.8	0.0	0.0	21.2
46	22.871	0.000	4.8	0.0	0.0	21.6
48	21.579	0.000	4.8	0.0	0.0	21.9
50	20.388	0.000	4.8	0.0	0.0	22.2
52	19.312	0.000	4.7	0.0	0.0	22.5
54	18.331	0.000	4.6	0.0	0.0	22.8
56	17.446	0.000	4.6	0.0	0.0	23.0
58	16.631	0.000	4.5	0.0	0.0	23.3
60	15.883	0.000	4.4	0.0	0.0	23.5
62	15.192	0.000	4.2	0.0	0.0	23.7
64	14.540	0.000	4.1	0.0	0.0	23.9
66	13.951	0.000	3.9	0.0	0.0	24.1
68	13.395	0.000	3.8	0.0	0.0	24.3

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
70	12.869	0.000	3.6	0.0	0.0	24.5
72	12.385	0.000	3.4	0.0	0.0	24.7
74	11.932	0.000	3.1	0.0	0.0	24.8
76	11.500	0.000	2.8	0.0	0.0	25.0
78	11.096	0.000	2.5	0.0	0.0	25.1
80	10.717	0.000	2.1	0.0	0.0	25.3
82	10.357	0.000	1.5	0.0	0.0	25.4
84	10.018	0.000	0.1	0.0	0.0	25.5

Endpoint (ppm, HCN)		Downwind Distance (feet)	Approximate Time (seconds)
1	50.0	26.6	6
2	25.0	43.2	9
3	10.0	84.1	18




Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicHCN]
50.0 ppm HCN
25.0 ppm HCN
10.0 ppm HCN
Height (feet)
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicHCN]
Centerline Concentration
Ground Level Concentration
HCN Concentration (ppm)
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

Case Type : Vapor Dispersion
Case Name : MegaPack-B-1toxicHF
User ID : GC
Project Number :
Type of Units : English Units

NOTES:

MATERIAL MENU

Materials Released	: Number	Formula	Name	Fraction
Component 1	: 51 =	H2	Hydrogen(equilibrium)	0.258295
Component 2	: 43 =	CO	Carbon Monoxide	0.506656
Component 3	: 1 =	CH4	Methane	0.099344
Component 4	: 2 =	C2H6	Ethane	0.039738
Component 5	: 3 =	C3H8	Propane	0.089410
Component 6	: 50 =	HF	Hydrogen Fluoride	0.000497
Component 7	: 26 =	HCl	Hydrogen Chloride	0.000993
Component 8	: 103 =	HCN	Hydrogen Cyanide	0.001590
Component 9	: 281 =	C7H8	Toluene	0.003477
Component 10	:			

Temperature : 122.00 °F
Pressure : 15.00 psia
The material is Indeterminate

NOTES:

ENVIRONMENT MENU

Wind speed	3.36 mph
Wind speed measurement height	32.8 feet
Stability class <A-F>	F
Relative humidity	70 %
Air temperature	77.0 °F
Spill surface temperature	77.0 °F

Substrate name	Soil
Substrate thermal conductivity	1.0000 Btu/hr-ft-F
Substrate density	100 lb/cu.ft
Substrate heat Capacity	0.24 Btu/lb-F
Substrate delay time	60 sec
Surrounding terrain	Long grass or crops > 15 cm (6 in)

NOTES:

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component   50 = HF       Hydrogen Fluoride
Concentration endpoint 1                        50.0 ppm
Concentration endpoint 2                        30.0 ppm
Concentration endpoint 3                        20.0 ppm

Dispersion coefficient averaging time              1 min

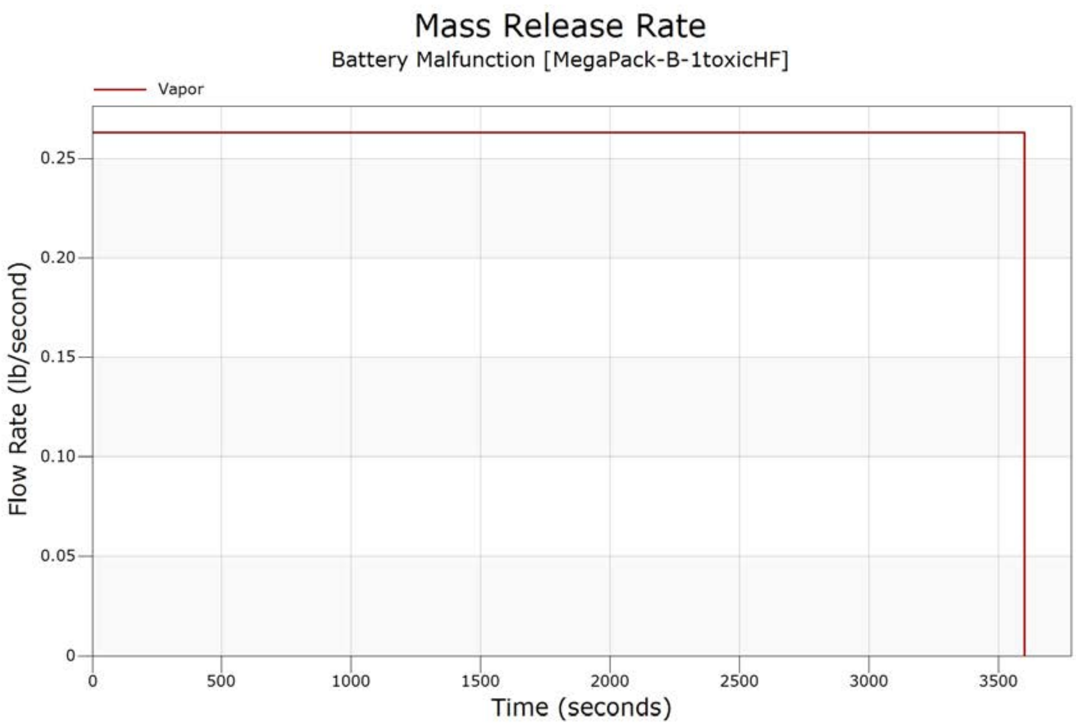

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicHF]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

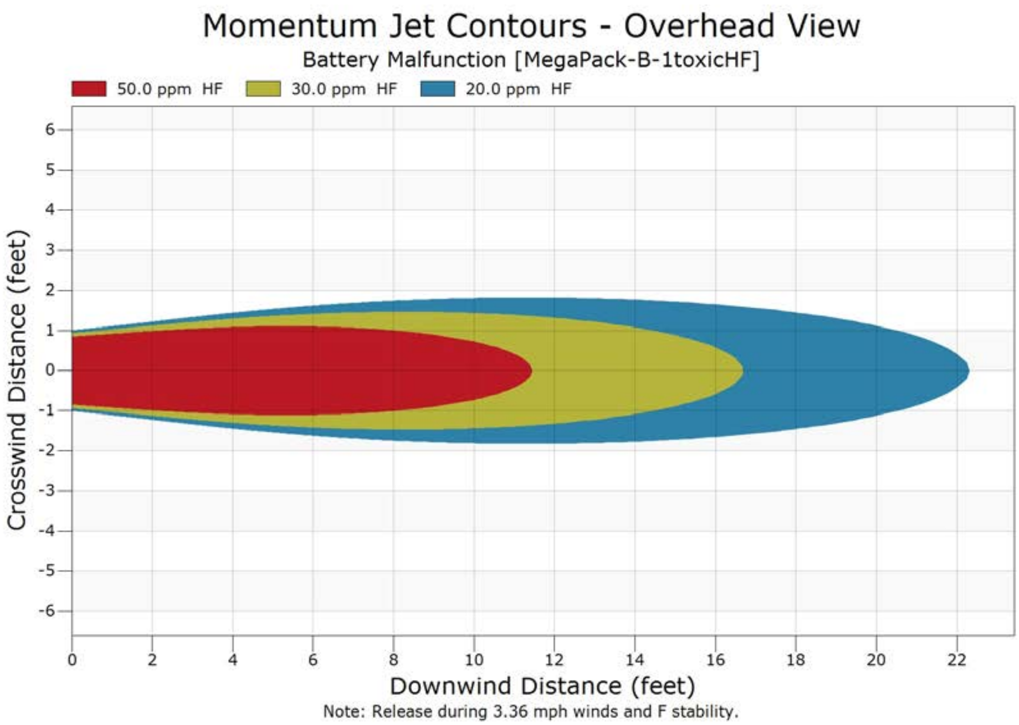
concentration limits

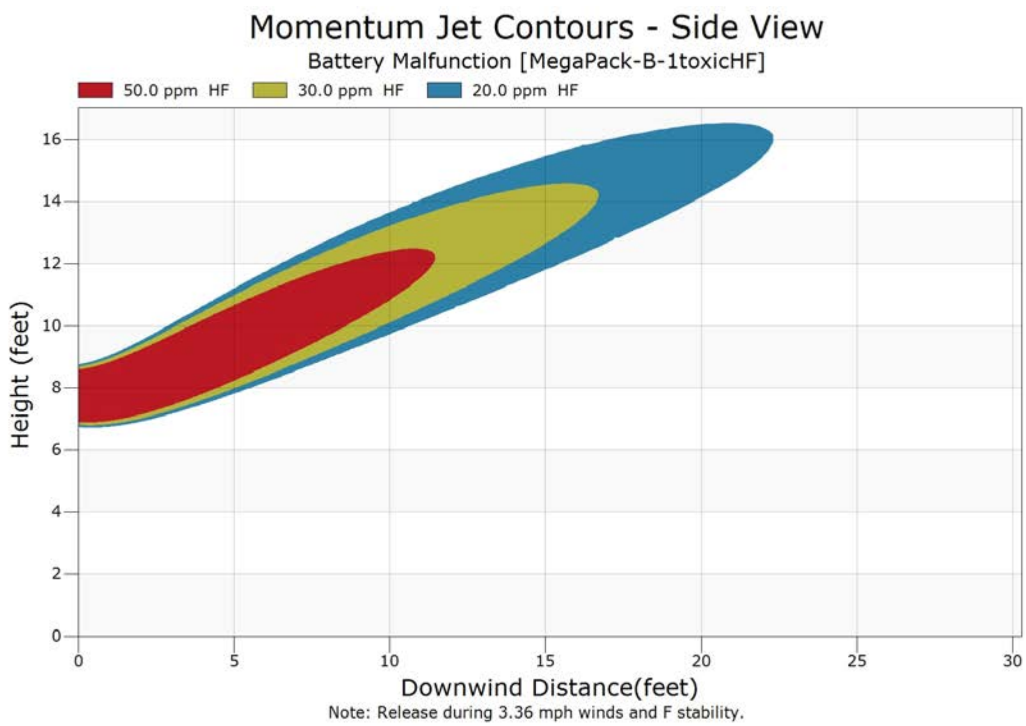
Endpoint 1 (highest) = 50.0 ppm
Endpoint 2 (middle) = 30.0 ppm
Endpoint 3 (lowest) = 20.0 ppm

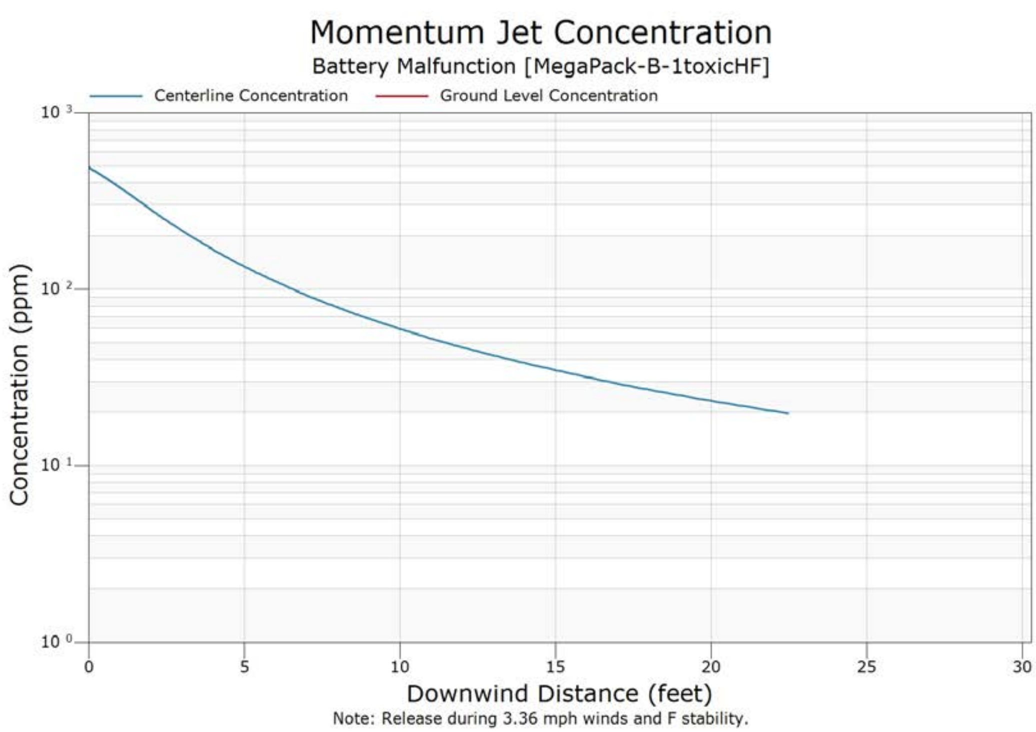
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	496.720	0.000	1.0	0.9	0.8	7.7
0.5	433.768	0.000	1.1	1.0	0.9	7.8
1.0	377.913	0.000	1.1	1.0	0.9	7.9
1.5	326.959	0.000	1.2	1.1	1.0	8.0
2.0	282.971	0.000	1.2	1.1	1.0	8.2
2.5	245.832	0.000	1.3	1.2	1.0	8.3
3.0	215.014	0.000	1.3	1.2	1.0	8.6
3.5	189.408	0.000	1.4	1.3	1.1	8.8
4.0	168.001	0.000	1.4	1.3	1.1	9.0
4.5	149.977	0.000	1.5	1.3	1.1	9.2
5.0	134.669	0.000	1.5	1.4	1.1	9.4
5.5	121.764	0.000	1.6	1.4	1.1	9.7
6.0	110.701	0.000	1.6	1.4	1.1	9.9
6.5	101.019	0.000	1.7	1.4	1.1	10.1
7.0	92.631	0.000	1.7	1.4	1.1	10.4
7.5	85.339	0.000	1.7	1.5	1.0	10.6
8.0	78.908	0.000	1.7	1.5	1.0	10.8
8.5	73.237	0.000	1.8	1.5	1.0	11.0
9.0	68.198	0.000	1.8	1.5	0.9	11.3
9.5	63.659	0.000	1.8	1.5	0.8	11.5
10.0	59.591	0.000	1.8	1.4	0.7	11.7
10.5	55.959	0.000	1.8	1.4	0.6	11.9
11.0	52.670	0.000	1.8	1.4	0.4	12.1
11.5	49.697	0.000	1.8	1.4	0.0	12.3
12.0	46.960	0.000	1.8	1.3	0.0	12.5
12.5	44.484	0.000	1.8	1.3	0.0	12.7
13.0	42.178	0.000	1.8	1.2	0.0	12.9
13.5	40.081	0.000	1.8	1.2	0.0	13.1
14.0	38.148	0.000	1.8	1.1	0.0	13.3
14.5	36.376	0.000	1.7	1.0	0.0	13.5
15.0	34.740	0.000	1.7	0.9	0.0	13.7
15.5	33.201	0.000	1.7	0.8	0.0	13.9
16.0	31.786	0.000	1.7	0.6	0.0	14.0
16.5	30.459	0.000	1.6	0.3	0.0	14.2
17.0	29.229	0.000	1.6	0.0	0.0	14.4

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
17.5	28.077	0.000	1.5	0.0	0.0	14.6
18.0	27.002	0.000	1.5	0.0	0.0	14.7
18.5	25.988	0.000	1.4	0.0	0.0	14.9
19.0	25.038	0.000	1.3	0.0	0.0	15.1
19.5	24.147	0.000	1.2	0.0	0.0	15.2
20.0	23.306	0.000	1.1	0.0	0.0	15.4
20.5	22.516	0.000	1.0	0.0	0.0	15.6
21.0	21.767	0.000	0.9	0.0	0.0	15.7
21.5	21.058	0.000	0.7	0.0	0.0	15.9
22.0	20.390	0.000	0.4	0.0	0.0	16.0

Endpoint (ppm, HF)		Downwind Distance (feet)	Approximate Time (seconds)
1	50.0	11.4	2
2	30.0	16.7	3
3	20.0	22.3	5




Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicHF]
50.0 ppm HF
30.0 ppm HF
20.0 ppm HF
Height (feet)
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
30
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicHF]
Centerline Concentration
Ground Level Concentration
Concentration (ppm)
10 3
10 2
10 1
10 0
0
5
10
15
20
25
30
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : MegaPack-B-1toxicTol
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                         Fraction
Component  1         :     51 = H2       Hydrogen(equilibrium)        0.258295
Component  2         :     43 = CO       Carbon Monoxide              0.506656
Component  3         :      1 = CH4      Methane                      0.099344
Component  4         :      2 = C2H6     Ethane                       0.039738
Component  5         :      3 = C3H8     Propane                      0.089410
Component  6         :     50 = HF       Hydrogen Fluoride            0.000497
Component  7         :     26 = HCl      Hydrogen Chloride            0.000993
Component  8         :    103 = HCN      Hydrogen Cyanide             0.001590
Component  9         :    281 = C7H8     Toluene                      0.003477
Component 10         :

Temperature          :       122.00 °F
Pressure             :        15.00 psia
The material is Indeterminate


  NOTES:

ENVIRONMENT MENU
Wind speed                                     3.36 mph
Wind speed measurement height                  32.8 feet
Stability class <A-F>                            F
Relative humidity                                70 %
Air temperature                                77.0 °F
Spill surface temperature                      77.0 °F

Substrate name                           Soil
  Substrate thermal conductivity             1.0000 Btu/hr-ft-F
  Substrate density                             100 lb/cu.ft
  Substrate heat Capacity                      0.24 Btu/lb-F
  Substrate delay time                           60 sec
Surrounding terrain                      Long grass or crops > 15 cm (6 in)

  NOTES:
```

```
RELEASE MENU
Type of release:   Regulated, Continuous release
Release duration                                  60 min
Regulated flow rate                             0.26 lb/sec
Pipe inner diameter                            12.00 inches
Equivalent release diameter                    12.00 inches
Height of release point                          7.8 feet
Angle of release from horizontal                90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic calculation
Tracking component  281 = C7H8      Toluene
Concentration endpoint 1                      1000.0 ppm
Concentration endpoint 2                       500.0 ppm
Concentration endpoint 3                       300.0 ppm

Dispersion coefficient averaging time              1 min

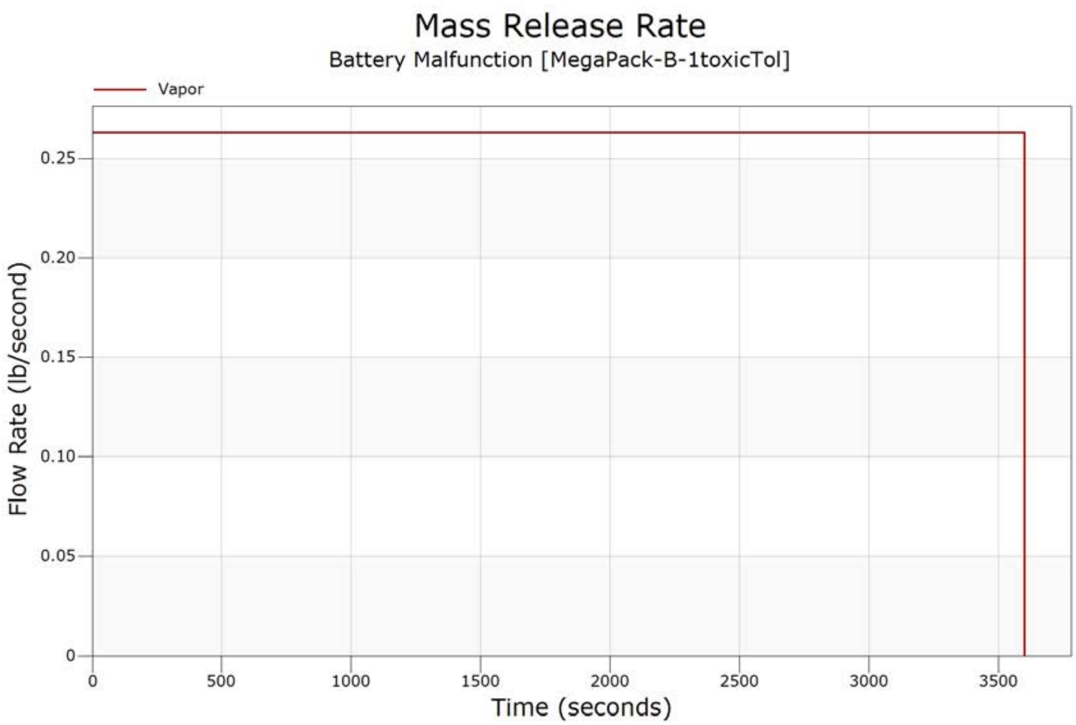

  NOTES:
```

Release Model

WARNING USER ASSUMES RESPONSIBLIITY FOR INPUT CONSISTENCY IN REGULATED RELEASE CASE

Time (sec)	Vapor (lb/sec)	Aerosol Rate (lb/sec)	Liquid Rate (lb/sec)	Total Rate (lb/sec)
0.000000	.2631001	0.000000	0.000000	.2631001
0.1000000	.2631001	0.000000	0.000000	.2631001
0.3000000	.2631001	0.000000	0.000000	.2631001
0.5000000	.2631001	0.000000	0.000000	.2631001
0.7000000	.2631001	0.000000	0.000000	.2631001
1.000000	.2631001	0.000000	0.000000	.2631001
3.000000	.2631001	0.000000	0.000000	.2631001
5.000000	.2631001	0.000000	0.000000	.2631001
7.000000	.2631001	0.000000	0.000000	.2631001
10.00000	.2631001	0.000000	0.000000	.2631001
20.00000	.2631001	0.000000	0.000000	.2631001
30.00000	.2631001	0.000000	0.000000	.2631001
40.00000	.2631001	0.000000	0.000000	.2631001
50.00000	.2631001	0.000000	0.000000	.2631001
60.00000	.2631001	0.000000	0.000000	.2631001
70.00000	.2631001	0.000000	0.000000	.2631001
85.00000	.2631001	0.000000	0.000000	.2631001
100.0000	.2631001	0.000000	0.000000	.2631001
200.0000	.2631001	0.000000	0.000000	.2631001
300.0000	.2631001	0.000000	0.000000	.2631001
400.0000	.2631001	0.000000	0.000000	.2631001
500.0000	.2631001	0.000000	0.000000	.2631001
600.0000	.2631001	0.000000	0.000000	.2631001
700.0000	.2631001	0.000000	0.000000	.2631001
850.0000	.2631001	0.000000	0.000000	.2631001
1000.000	.2631001	0.000000	0.000000	.2631001
2000.000	.2631001	0.000000	0.000000	.2631001
3000.000	.2631001	0.000000	0.000000	.2631001
3600.000	.2631001	0.000000	0.000000	.2631001
Totals (lb)	947.1604	0.000000	0.000000	947.1604

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction [MegaPack-B-1toxicTol]
Vapor
Flow Rate (lb/second)
0.25
0.20
0.15
0.10
0.05
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen(equilibrium), H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
50	Hydrogen Fluoride, HF
26	Hydrogen Chloride, HCl
103	Hydrogen Cyanide, HCN
281	Toluene, C7H8

Composition (Mole Fraction) of Fluid Streams

Comp. No.	Feed Stream	Momentum Jet Stream				Liquid Pool Stream
		Flashed Vapor	Evaporated Vapor	Aerosol Liquid	Total Stream	Liquid to Ground
51	0.258295	0.258295	0.000000	0.000000	0.258295	0.000000
43	0.506656	0.506656	0.000000	0.000000	0.506656	0.000000
1	0.099344	0.099344	0.000000	0.000000	0.099344	0.000000
2	0.039738	0.039738	0.000000	0.000000	0.039738	0.000000
3	0.089410	0.089410	0.000000	0.000000	0.089410	0.000000
50	0.000497	0.000497	0.000000	0.000000	0.000497	0.000000
26	0.000993	0.000993	0.000000	0.000000	0.000993	0.000000
103	0.001590	0.001590	0.000000	0.000000	0.001590	0.000000
281	0.003477	0.003477	0.000000	0.000000	0.003477	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Dispersion

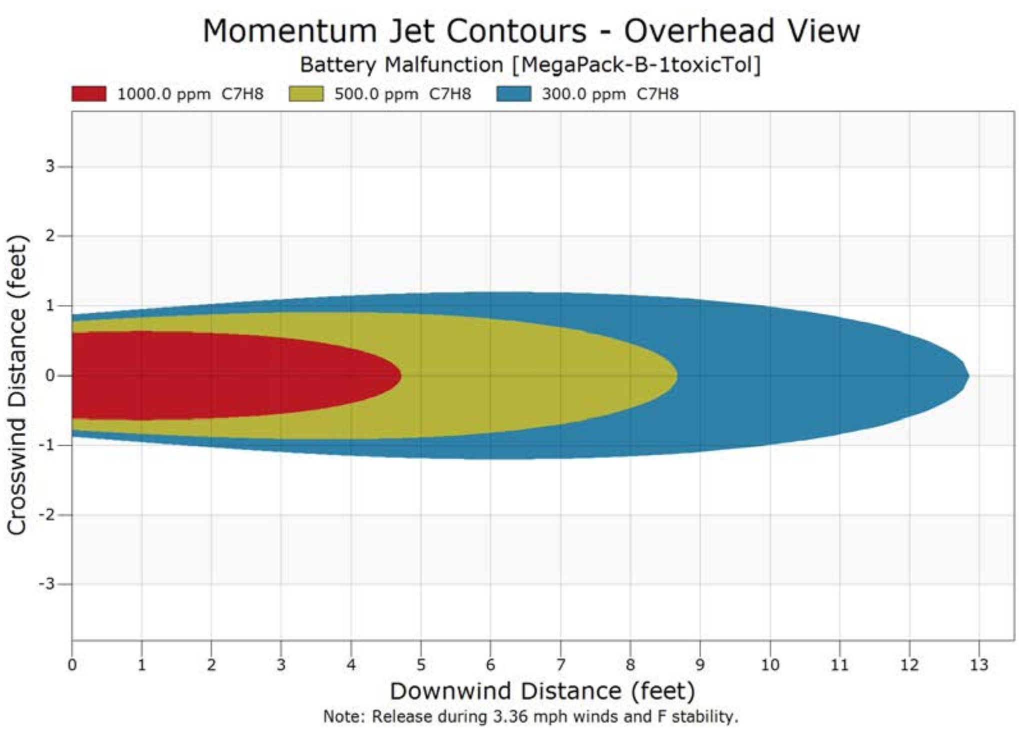
concentration limits

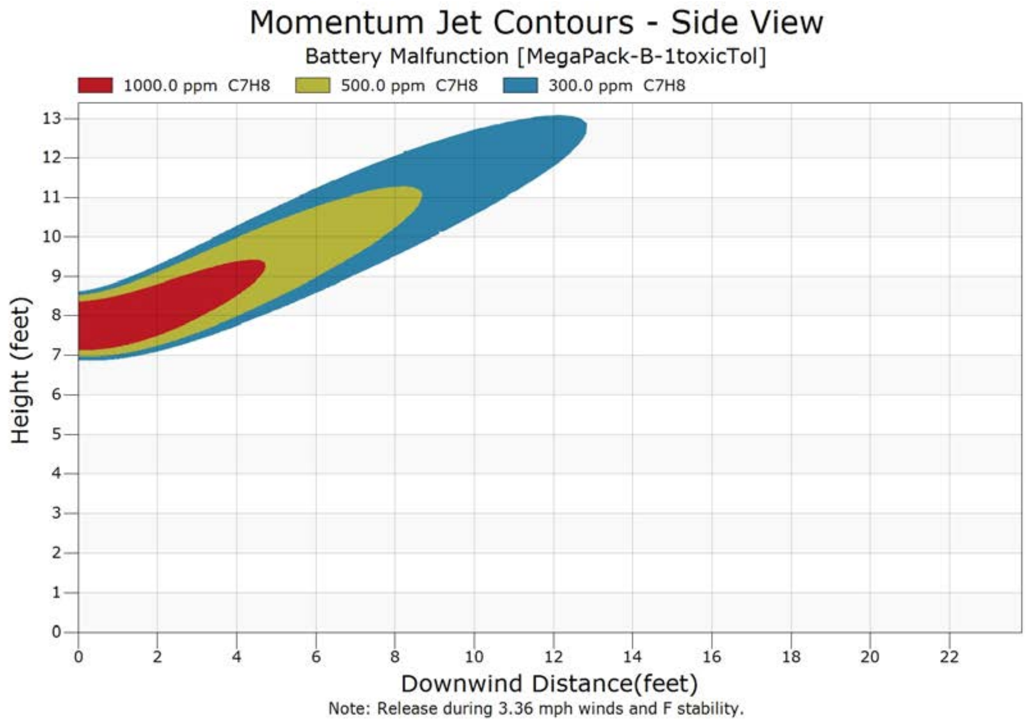
Endpoint 1 (highest) = 1000.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 300.0 ppm

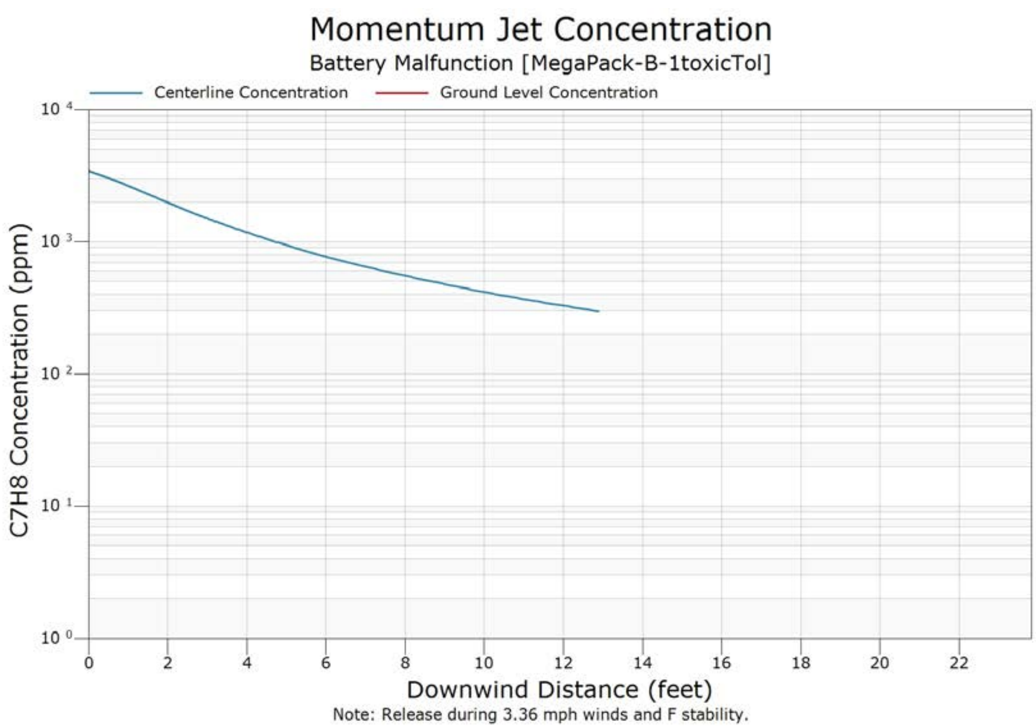
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	3477.050	0.000	0.9	0.8	0.6	7.7
0.3	3234.423	0.000	0.9	0.8	0.6	7.8
0.5	3037.018	0.000	0.9	0.8	0.6	7.8
0.8	2839.863	0.000	0.9	0.8	0.6	7.8
1.0	2646.355	0.000	1.0	0.8	0.6	7.9
1.3	2461.649	0.000	1.0	0.8	0.6	7.9
1.5	2289.478	0.000	1.0	0.9	0.6	8.0
1.7	2128.320	0.000	1.0	0.9	0.6	8.1
2.0	1980.617	0.000	1.0	0.9	0.6	8.2
2.3	1845.573	0.000	1.0	0.9	0.6	8.3
2.5	1721.141	0.000	1.1	0.9	0.6	8.3
2.8	1608.097	0.000	1.1	0.9	0.6	8.4
3.0	1505.462	0.000	1.1	0.9	0.6	8.6
3.3	1411.967	0.000	1.1	0.9	0.5	8.7
3.5	1326.015	0.000	1.1	0.9	0.5	8.8
3.7	1246.785	0.000	1.1	0.9	0.4	8.9
4.0	1175.388	0.000	1.2	0.9	0.4	9.0
4.3	1110.273	0.000	1.2	0.9	0.3	9.1
4.5	1050.037	0.000	1.2	0.9	0.2	9.2
4.8	994.230	0.000	1.2	0.9	0.0	9.3
5.0	942.715	0.000	1.2	0.9	0.0	9.4
5.3	896.213	0.000	1.2	0.9	0.0	9.6
5.5	852.259	0.000	1.2	0.9	0.0	9.7
5.8	812.000	0.000	1.2	0.8	0.0	9.8
6.0	774.559	0.000	1.2	0.8	0.0	9.9
6.3	739.492	0.000	1.2	0.8	0.0	10.0
6.5	706.908	0.000	1.2	0.8	0.0	10.1
6.8	676.786	0.000	1.2	0.7	0.0	10.3
7.0	648.326	0.000	1.2	0.7	0.0	10.4
7.3	622.167	0.000	1.2	0.7	0.0	10.5
7.5	597.368	0.000	1.2	0.6	0.0	10.6
7.8	574.154	0.000	1.2	0.5	0.0	10.7
8.0	552.315	0.000	1.2	0.5	0.0	10.8
8.3	531.886	0.000	1.1	0.4	0.0	10.9
8.5	512.646	0.000	1.1	0.2	0.0	11.0

downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
8.8	494.311	0.000	1.1	0.0	0.0	11.1
9.0	477.372	0.000	1.1	0.0	0.0	11.3
9.3	460.996	0.000	1.1	0.0	0.0	11.4
9.5	445.642	0.000	1.1	0.0	0.0	11.5
9.8	431.118	0.000	1.0	0.0	0.0	11.6
10.0	417.148	0.000	1.0	0.0	0.0	11.7
10.3	404.197	0.000	1.0	0.0	0.0	11.8
10.5	391.738	0.000	0.9	0.0	0.0	11.9
10.8	379.840	0.000	0.9	0.0	0.0	12.0
11.0	368.656	0.000	0.8	0.0	0.0	12.1
11.3	358.047	0.000	0.8	0.0	0.0	12.2
11.5	347.763	0.000	0.7	0.0	0.0	12.3
11.8	338.001	0.000	0.7	0.0	0.0	12.4
12.0	328.729	0.000	0.6	0.0	0.0	12.5
12.3	319.872	0.000	0.5	0.0	0.0	12.6
12.5	311.336	0.000	0.4	0.0	0.0	12.7
12.8	303.196	0.000	0.2	0.0	0.0	12.8

	Endpoint (ppm, C7H8)	Downwind Distance (feet)	Approximate Time (seconds)
1	1000.0	4.7	1
2	500.0	8.7	2
3	300.0	12.9	3




Momentum Jet Contours - Side View
Battery Malfunction [MegaPack-B-1toxicTol]
1000.0 ppm C7H8
500.0 ppm C7H8
300.0 ppm C7H8
Height (feet)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
2
4
6
8
10
12
14
16
18
20
22
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction [MegaPack-B-1toxicTol]
Centerline Concentration
Ground Level Concentration
C7H8 Concentration (ppm)
10 0
10 1
10 2
10 3
10 4
0
2
4
6
8
10
12
14
16
18
20
22
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.