Hazards Analysis
Final Report

Cormorant Energy Project
Daley City, California

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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 2019)
IEEE	Institute of Electrical and Electronics Engineers
kWh	Kilowatt hour
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LFP	Lithium-Iron Phosphate
MWhr	Megawatt hour (equal to 1,000 kWh)
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

Arevon Energy proposes to install a battery storage system with a capacity of 200 MW in Daly City, 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 release, and thereby cause any impacts from, toxic gas or flammable gas 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 August 2022, the United States has 6,911 MW of total battery storage capacity (EIA 2022) at 394 installations. California leads the U.S. in battery energy storage with 3,732 MW at 116 installations, with an additional 7,825 MW of battery storage capacity projected to be placed in service.

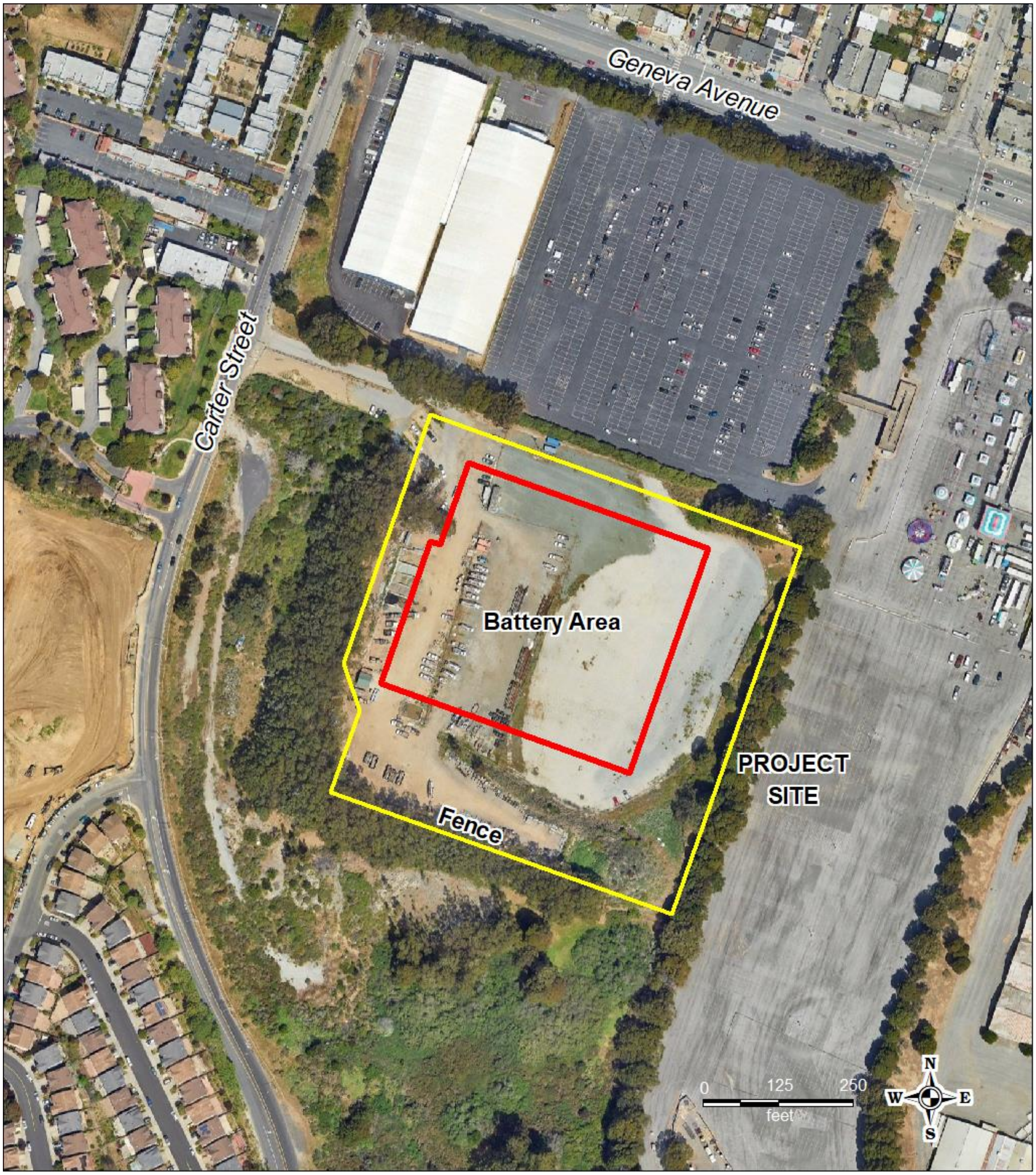
Lithium-ion batteries were introduced commercially by Sony in 1991 for use primarily in consumer products, and they since have become the most widely used battery technology for grid-scale energy storage. Lithium-ion batteries are scalable. About 92% of U.S. grid-storage installations utilize lithium-ion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

2.0 Project Description

The Project site would be located along Geneva Avenue and Carter Street in Daley City, CA. The proposed Project location would be south of Geneva Avenue and east of Carter Street. The site is located south of Bay Club along Carter Street, southwest of the Cow Palace and is currently empty except for some storage use. See Figure 1.

The Project would involve the installation of about 275 self-contained energy storage and management cabinets (the Tesla most recent versions called Megapack 2 XL version or MP2XL) containing battery modules designed and manufactured by Tesla. Each cabinet would hold approximately 24 modules of batteries. The Megapack cabinets would be placed at the site outdoors. The Megapacks would have no walk-in or occupied facilities in the proposed Project design, and the Project would not otherwise include any buildings. The MP2XL are the most recent design of the Tesla Megapack series.

Figure 1 Project Location



Note: red lines are the battery area, yellow lines are the fence line.
Source: Google Maps imagery date 4/4/2022

An operations and maintenance (O&M) control enclosure would also be located on the Project site. 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 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 MP2XL versions).

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 materials. The design of Megapack includes pressure-sensitive vents (over-pressure vents) and a sparker system. 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-gases, if there is an issue with the cells that produce off gassing, before they reach the enclosure's lower flammability limit (LFL). This design essentially ignites the gases very early in a thermal runaway event, before there is time for the gases to build up within the enclosure and become an explosion hazard. Sparkers are installed at the top of all Megapack battery module 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 event 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 400 liters of coolant. Mechanical damage of a Tesla Energy Product could result in leakage of the coolant.

The Megapack thermal management system also includes 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.

The LFP battery type has a lower "specific energy" than other types of lithium-ion batteries, meaning that during thermal runaway scenarios, less heat is produced. Studies show (BU 2019) that the heat given off per kilogram of battery for an LFP battery during thermal runaway is less than half the amount given off by other lithium-ion type batteries. This characteristic makes it more resistant to having a thermal runaway in a single cell or group of cells that could propagate to other cells in the system.

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. CFC 1206 compliance is discussed more below.

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 (2023 version) 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
Bay Club parking Lot	110
Cow Palace Parking Lot	190
Bay Club Building	180
Carter Street	360
Closest Resident (Saddleback Homes)	400
Cow Palace building	500

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 or thermal radiation impacts. 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.

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 and that any gasses are not "ignited" as discussed above. 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 as per UL9540A requirements where heat was added and forced a thermal runaway in a group of cells to determine the potential for a cascading effect. Tesla also conducted a "destructive" test which forces a larger group of cells in to thermal runaway and produced flames and larger impacts than the UL testing procedure. The results of this "destructive" test are used to estimate the impacts of thermal exposure below.

Different battery cell malfunctions could produce toxic and flammable material emissions. These include: (1) an elevated temperature situation due to a runaway reaction with no combustion (venting with no combustion); (2) combustion of the battery due to an elevated temperature situation from a runaway. Emissions would occur both during the pre-combustion phase and during the combustion phase. During the pre-combustion phase, the off gassed materials would contain flammable and toxic materials. During the combustion phase, most of the off gassed materials would be combusted and hence would contain only low levels of flammable gasses. 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 phase, both phases are examined in this analysis.

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 battery testing and potential pollutants released are discussed below.

4.1 UL 9540A Testing

UL9540A requires testing of the individual cells, groups of cells (modules) and the entire Megapack unit. The LFP cells have undergone UL9540A cell level testing, where an individual cell is subject to external heating until it undergoes thermal runaway. The flammable and toxic compounds are measured, and the total volume of materials released are also measured. This allows for an estimate of the total material released and the associated flammable and toxic compounds if an entire module or Megapack were to experience thermal runaway. The cell level testing produced thermal runaway in the cell and generated toxic and flammable gases. The results of the cell level testing are used to estimate the flammable and toxic impacts of the Megapack scenario where it is assumed as a worst case that all cells in the unit thermal off gas at the same time.

The entire Megapack unit was also tested as part of the UL9540A unit testing. Under this unit level UL9540A testing, a group of cells in a module was forced into thermal runaway in a

Megapack and the resulting tendency for the thermal runaway to spread to the entire Megapack was assessed.

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. For the Megapack, 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.

The unit level UL9540A testing indicated that only a subset of the cells within the module area heated went into thermal runaway and the thermal runaway did not spread to neighboring cells and modules. Some toxic and flammable gasses were observed but no flames were produced during the UL9540A unit level testing. This is similar to UL9540A testing on other manufacturers that used LFP-type batteries. As discussed above, the amount of heat given off by an LFP battery during thermal runaway is substantially less than that produced by other lithium-ion battery types, and therefore it is harder to generate a full Megapack unit thermal runaway scenario, as was produced with the earlier Megapack 1 design using a different cell type.

The difficulty in generating a full unit-level thermal runaway is a benefit in using the LFP battery type.

4.2 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)
Benzene	27/0.10	500 ppm	1,000 ppm	150 ppm
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
Phosphorous Pentafluoride (PF_5)	240/0.2*	50 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)
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.

Table 3 Studies on Emissions from Battery Malfunctions

Study	Description	Results
Anderson 2015	Exposure of battery to heat source, off gasses tested. LFP battery, 1.2 kg, 35 Ah	HF: 30-50ppm peak POF_3: 1-2ppm peak HF Rate: 0.01 g/s
Blum 2016	Modules tested with heat exposure until thermal runaways. 100kwh unit by Tesla.	HF: 100 ppm peak
CATL	UL 9540A testing	Composition of off gassing: primary pollutants only. Up to 153.5 L off gas per cell

Table 3 Studies on Emissions from Battery Malfunctions

Study	Description	Results
Larsson 2017	External propane burner used to heat batteries, measured toxic gasses. Examined different battery types	HF: up to 145 ppm peak HF rate: 50 mg/s peak HF rate: 200mg/whr peak POF_3 rate: 22 mg/whr peak
LG Chem	Proprietary data on LFP battery tests. NMC battery type.	HF-0.2ppm PH_3-1.0ppm 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 (not LFP)	Maximum Values: HCL: 538 ppm HF: 183 ppm HCN: 67 ppm
Tesla	Fisher Engineering, 9540A cell test Results, Megapack 2, January 2023	Benzene: 2000 ppm Toluene: 2000 ppm

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 are common across all 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 LFP 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 and utilized the highest toxic and flammable concentrations identified in any of these studies. Primarily, the cell level testing indicated the presence of toxic materials benzene and toluene. Additional studies (Larsson 2017) indicated LFP batteries could also produce HF, and therefore HF emissions were included as well. 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.

4.3 Flammable Components and Flammability

Flammable components can also be 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.

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

Table 5 Tesla Manufacturer Battery Off-gassing Primary Flammable Components

Component	Mole Percent
Hydrogen (H_2)	50.1
Carbon monoxide (CO)	10.9
Methane (CH_4)	6.4
Ethylene (C_2H_4) and other C_2	4.6
Propane (C_3H_8) and other C_3	0.5
C_4 +	0.2

Note: based on Tesla proprietary testing for single cell level testing. Other components, such as nitrogen and carbon dioxide, are also produced but are not shown due to not being flammable. These are the components in the UL9540A Cell Level Testing and are estimates of the pre-combustion off gassed materials.

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 10.3 (this exceeds the Q value flammability limit of 1.0, established by the CGA, indicating the materials is flammable (CGA 2015) with an estimated lower flammability limit of about 6 percent.

4.4 "Destructive" Fire Tests Thermal Impacts

Tesla also conducted more "destructive" unit-level testing than the UL tests required which produced greater thermal runaway and caused thermal runaway in about half of the Megapack modules and cells. This "destructive" testing produced flames out the top of the Megapack and generated thermal impacts to surrounding areas. The results of this testing are discussed below and used in the thermal assessment below to estimate the worst-case thermal radiation impacts.

Note that the UL9540A testing discussed above did not produced a fire.

Table 6 shows a summary of the test results related to thermal impacts from the "destructive" testing.

Table 6 Megapack 2 "Destructive" Test, Thermal Results

Component	Value
Unit level test flame size	Peak flame extension was observed to be at about 11.5 ft upwards from the ground and 3.3ft in front of the unit.
Fire spread	Fire spread from battery bay to battery bay was a slow progressing event
Debris	No hazardous pressure waves, debris, shrapnel, or pieces of the cabinet were ejected.
Unit level test neighbor module peak temperature	113 °F
Unit level test duration	Flame start at 1 hour and 24 minutes. Flames ceased at 8 hours and 4 minutes

Note: based on Tesla "destructive" test (non-UL), conducted with higher heat input rates and more broadly propagated than the UL procedure.

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, allowing for effective fire department response and presence during the peak flame period.

4.5 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 if a full MP2XL were to experience thermal runaway of all cells simultaneously. 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 and ½ LFL levels) could travel with a resulting battery malfunction scenario under favorable meteorological conditions (low wind speeds and high stability). The Canary© model was also used to examine explosion impacts to 1 psi overpressure.

For thermal impacts due to a fire, the Tesla testing using the “destructive” test are utilized to estimate the worst-case distances to different heat flux values.

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 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 of Off Gassing

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 producing toxic chemicals 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 and modeling results are provided in Attachments. 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 relatively short period of time (hours and not days), 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, for non-combustion off gassing, 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 for the non-combustion off gassing.

The acute impact distances for the reasonable worst-case battery cell malfunction off gassing scenarios are provided in Table 7, and detailed calculations can be found in Attachments. Public health impacts from toxic pollutants associated with the reasonable worst-case battery cell malfunction off gassing scenario would remain onsite and would be less than significant.

Table 7 Modeling Toxic Materials Results

Pollutant	IDLH Downwind Distance, feet
Benzene	4
Carbon Monoxide (CO)	43
Hydrogen Fluoride (HF)	5
Toluene	4

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

5.4 Toxic Impacts of Combustion

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 module level testing. Monitoring indicated low levels of carbon monoxide (240 ppm) and low levels of toxins (benzene less than 10 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. Also, a wide range of materials in the Megapack would be consumed by the fire, including electronic components and plastics. Smoke opacity testing was not conducted for the MP2XL UL testing. Therefore, during the UL9540A tests on the Megapack 1, pollutants and smoke levels were monitored, and there was a wide range of fire conditions, flame lengths, wind effects producing a wide range of ground level exposures near the Megapack. 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 associated with a Megapack 1 thermal event 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 1 full thermal runaway scenario encountered in the UL9540A testing for the Megapack 1. This would be considered a worst-case for the MP2XL as the MP2XL produces less heat during a thermal runaway scenario than the Megapack 1. As the MP2XL “destructive” test fire case (as was examined in the Megapack 1 analysis as well) the fire was slowly developing, allowing for appropriate emergency response and control of the area, and the low propensity for the LFP battery-type to produce a full thermal runaway, impacts to nearby receptors 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 Attachments for the Canary© model outputs and assumptions). The lower flammability limit (LFL) and the ½ LFL are used as an estimate of the potential impacts from flammable vapors. Distances for the LFL and the ½ LFL are estimated to be 12 and 21 feet, respectively, for the MP2XL scenario. 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 are estimated to be 41 feet for the Megapack scenario. The distance would remain onsite and not extend to any off-site receptors. Therefore, the 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 Tesla “destructive” testing for the MP2XL, thermal radiation impacts were estimated based on observed flame temperatures and fire radiation models.

In order to estimate the thermal radiation at different distances from the MP2XL 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

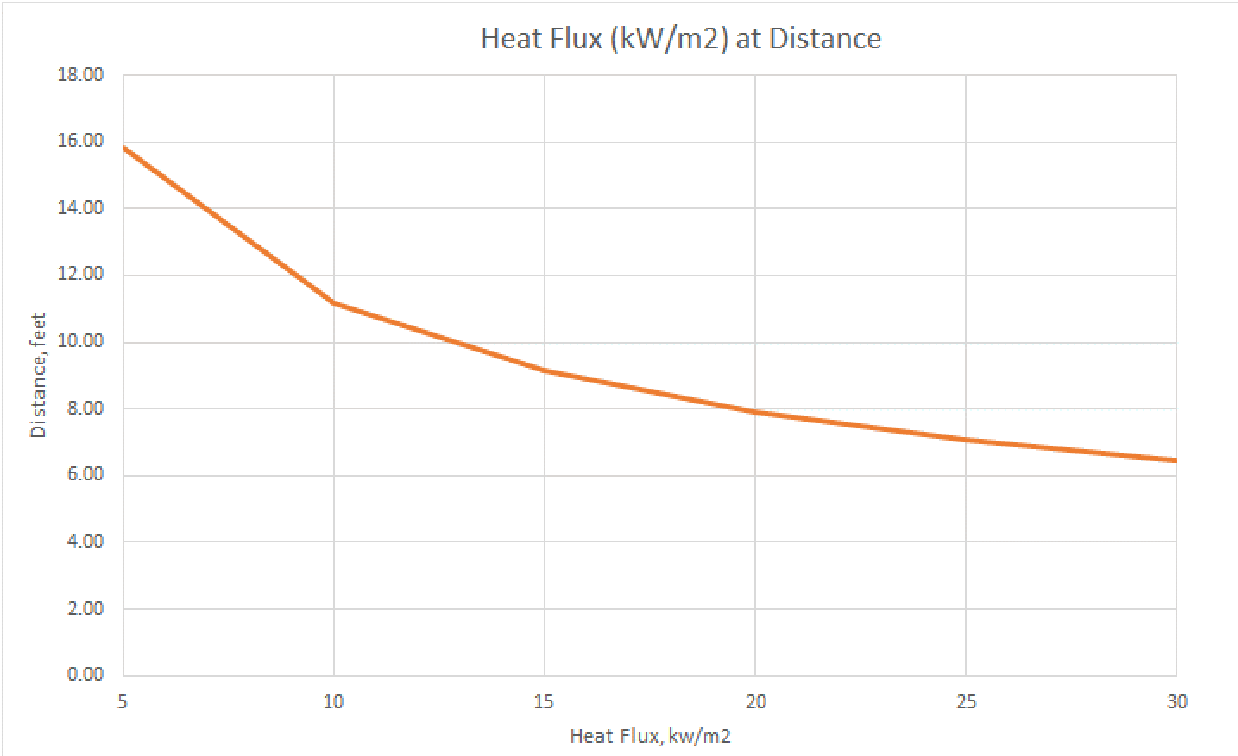
x = radiative fraction, energy fraction released as thermal radiation, with the fraction of energy released as radiation between 0.10 and 0.40 with a value of 0.35 conservatively assumed (as per SFPE 1999 and FMGlobal 2019).

Using the above point source approach, Figure 2 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.

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 2 Tesla "Destructive" Test Modeling and Estimated Heat Flux at Distance



Notes: using the point source model and the Tesla "destructive" test results and modeling for peak heat flux s.

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

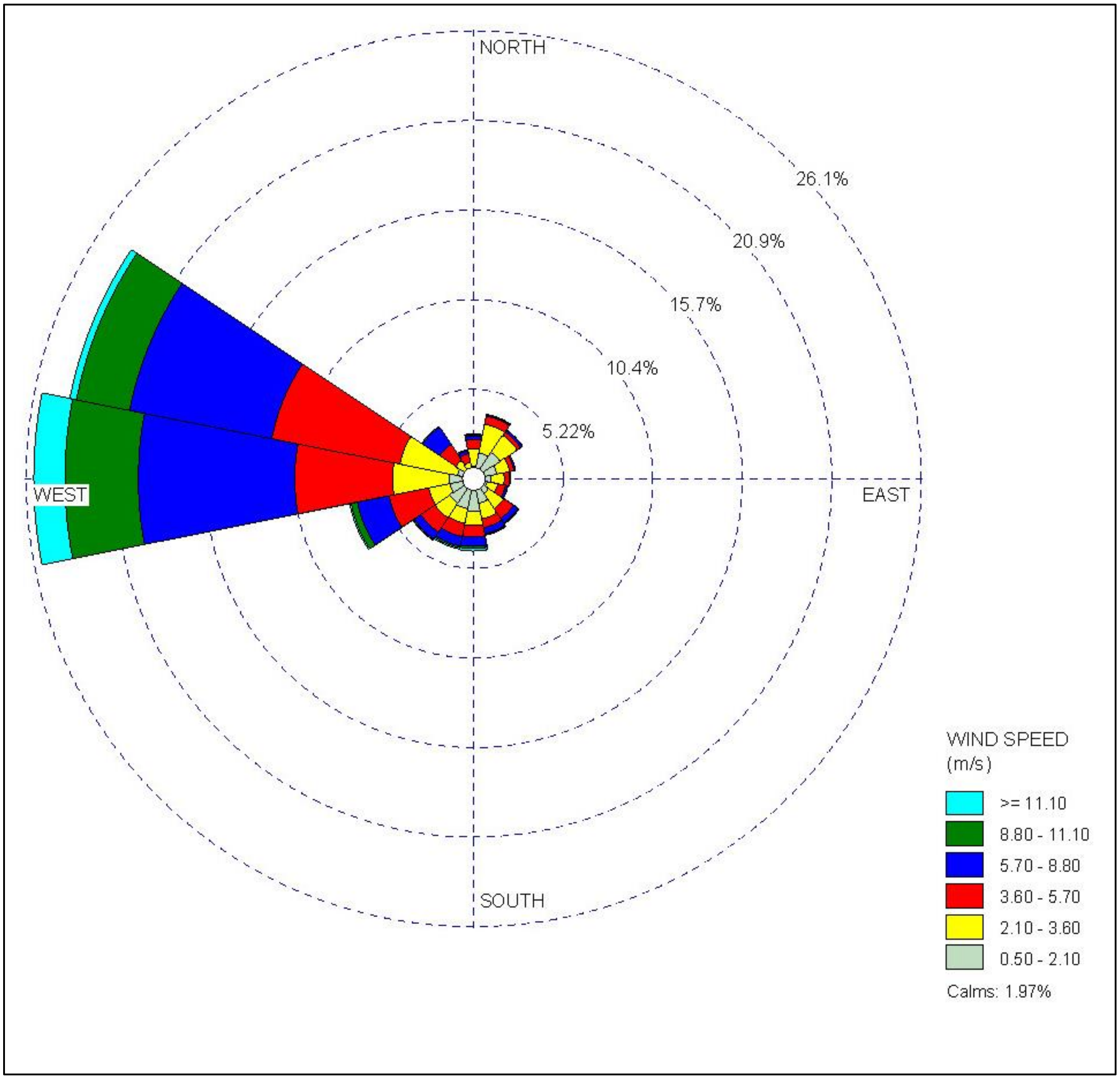
Heat flux levels would not extend outside of the Project site boundaries if a thermal scenario were to occur at one of the Megapacks located at the closest area to the site boundary.

The battery installation would comply with the NFPA 855 Section 9.5.2.6.1, setback requirement of 10 feet from lot lines and public ways (see recommendations section below). In addition, the battery fire in the UL9540A tests developed slowly, 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. Also although the thermal heat flux distance would not extend outside of the Project site boundaries and impact any offsite receptors, the slow scenario development time would also allow for response activities to occur before peak impacts are realized. Impacts would be less than significant.

5.7 Meteorological Data

The meteorological data shown in Figure 3 represents the meteorological conditions at the closest site (San Francisco Airport Air Station). The wind rose shows the predominant wind is from the west.

Figure 3 Meteorological Wind Rose – San Francisco Airport



Note: For the San Francisco Airport Air Station Monitoring Station 2013-2017 as per BAAQMD. Wind Rose shows the wind based on the direction the wind is from.

5.8 Fire Water and Contamination

In the event of a fire and/or off gassing at the facility, the fire department may apply water to the Megapacks both to knock down smoke and/or off gassed materials and also to cool the surrounding Megapacks.

The application of water directly on the Megapack would not allow for direct contact of the water with the lithium-ion battery cells. The cells are protected by the Megapack enclosure and their module shells. This protection effectively limits the extent to which the water could become contaminated with battery elements. Changes to water quality or pH will therefore be limited under the scenarios associated with Megapack fire response activities.

NFPA 855 Annex C.7 also indicates that:

> "*Though trace amounts of heavy metals such as nickel and cobalt [depending on battery type] 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*".

Therefore, water pH would not be expected to exceed a range of 6 – 7 and trace levels of contaminants are expected to be similar to fires associated with other industries and fires.

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 and CFC 1206 Hazard Mitigation Analysis Requirements

NFPA 855 Section 4.4 (2023 edition) 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 9.4.1.1/2 and CFC 1206.5.2.*
4. *Where required by the AHJ to address a potential hazard.*
5. *Where required for systems that are not UL listed.*
6. *Where required for outdoor systems in accordance with 9.5.2.1.*

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 9.4 allows for approval of an outdoor ESS installation that exceed 600 kWh if a hazard mitigation analysis and large scale fire testing as per 9.1.5.

NFPA 855 Section 9.4 indicates that "*Outdoor ESS installations in locations near exposures [within 100 feet of buildings] shall not exceed the maximum stored energy values in Table 9.4-1 [600 kWh] except as permitted by 9.4.1.2.*"

NFPA 855 Section 4.4 and CFC Section 1206.1.4 addresses the requirements for a hazard mitigation analysis. Section 4.4.2 specifies:

NFPA 855 Section 4.4.2.1 and CFC Section 1206.4.1 The analysis shall evaluate the consequences of the following failure modes and other deemed necessary:

1. Thermal runaway or mechanical failure conditions in a single ESS unit.

2. Failure of an energy storage management system or protection system that is not covered by the product listing failure modes and effects analysis (FMEA).

3. Failure of a required protection system including, but not limited to, ventilation HVAC, exhaust ventilation, smoke detection, fire detection fire suppression or gas detection.

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 4.4.3 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 9.6.4 or CFC Section 1206.7.4.*

2. Fires and products of combustion will not prevent occupants from evacuating to a safe location.

3. Deflagration hazards will be addressed by an explosion control or other system.

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.

The analysis in this report demonstrates in Table 9 in response to the above listings from NFPA 855 Section 4.4 and CFC Section 1206.1.4.

Table 9 CFC and NFPA Requirements

CFC and NFPA Requirements	Report Analysis Conclusions
NFPA 855 Section 4.4.2 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.	This report analyzes the results of a potential thermal runaway that involves all cells in a unit utilizing the result of the UL9540A testing.
2. Failure of an energy storage management system or protection system that is not covered by the product listing failure modes and effects analysis (FMEA).	The full thermal runaway of the unit, as analyzed in this analysis, would require the failure of the management system.
3. Failure of a required protection system including, but not limited to, ventilation HVAC, exhaust ventilation, smoke detection, fire detection fire suppression or gas detection.	The units would be located outside, so ventilation systems are not utilized. The off gassed materials would exit the units through the top vents, and this scenario was analyzed in this report. This report analyzed a full thermal runaway of all cells with a unit. No detection or suppression systems were included in the analysis.
5. Voltage Surges on the primary electrical supply (CFC 1206.1.4).	Multiple scenarios could produce a thermal runaway, and the full unit thermal runaway was addressed, regardless of cause, which could include voltage surges.
6. Short circuits on the load side of the ESS (CFC 1206.1.4).	Multiple scenarios could produce a thermal runaway, and the full unit thermal runaway was addressed, regardless of cause, which could include voltage surges.
7. Required spill neutralization not being provided or failure of a required secondary containment system (CFC 1206.1.4).	The LFP batteries would not spill electrolyte materials as other battery types might. Information from NFPA 855 on fire fighting water impacts was included.
NFPA 855 Section 4.4.3 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 9.6.4 or CFC Section 1206.7.4.	The process would be located outside, so containment of fire within rooms is not applicable.

Table 9 CFC and NFPA Requirements

CFC and NFPA Requirements	Report Analysis Conclusions
2. *Fires and products of combustion will not prevent occupants from evacuating to a safe location.*	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. Multiple egress routes 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 that, with local alarms, allow sufficient time for egress efforts.
3. *Deflagration hazards will be addressed by an explosion control or other system*	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 that, with local alarms, allowing for rapid detection of any potential deflagration scenario. Flammable materials impacts were examined if the sparkers fail.

NFPA 855 Section 9.1.5 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 4.6.1 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 4.7.5).
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 4.3.2.1, 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 4.2.1);

        iii. availability of water for firefighting and compliance with Fire Department requirements for flow and availability (NFPA 855 Section 4.9.4);

    b. Emergency response procedures, including notification of local responders (NFPA 855 Section 4.3.2.1 and A.4.3.2);

    c. Personnel safety training (NFPA 855 Section 4.3.2.2 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 4.7.4);

    f. Emergency ingress and egress routes (NFPA 855 Section 4.7.8);

    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 4.5);

    j. Security of installations (NFPA 855 Section 4.7.6);

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 is 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 and away from high density areas. 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 2 XL Design Specification

Megapack 2 XL Specification

Revision 2.5

CONFIDENTIAL INFORMATION - SHARED UNDER NDA ONLY

PRODUCT SPECIFICATIONS

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Reference Documents

Visit the Tesla Partner Portal at *https://partners.tesla.com/* to find reference material referred to within this publication, including:

- Megapack 2 XL Compliance Packet - *https://partners.tesla.com/home/en-US/content/download/Megapack_2_XL_Compliance_Packet.zip*
- Megapack 2 XL Compliance Summary - *https://partners.tesla.com/home/en-US/content/download/Megapack_2_XL_Compliance_Summary.pdf*
- Megapack 2 XL Design and Installation Manual - *https://partners.tesla.com/home/en-US/content/download/Megapack_2_XL_Design_and_Installation_Manual.pdf*
- Megapack 2 XL Drawings - *https://partners.tesla.com/home/en-us/content/download/megapack_2_xl_drawings.zip*
- Powerhub User Manual - *https://partners.tesla.com/home/en-US/content/download/Powerhub_User_Manual.pdf*
- SCADA Design Manual - *https://partners.tesla.com/home/en-us/content/download/scada_design_manual.pdf*
- Controls and Communications Manual - Tesla System Controller - *https://partners.tesla.com/home/en-us/content/view/controls_and_communications/*
- Application Note: Powerhub for Megapack and Powerpack - *https://partners.tesla.com/home/en-US/content/download/Powerhub_for_Megapack_Powerpack_Appnote.pdf*
- Megapack 2 XL Option Codes Quick Reference Guide - *https://partners.tesla.com/home/en-US/content/download/Megapack_2_XL_Option_Codes_Quick_Reference_Guide.pdf*

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+. Megapack is a fully integrated enclosure that contains:

- Battery cells aggregated into battery modules
- Bi-directional inverter modules
- Thermal system
- Customer interface panel including the built-in Megapack AC circuit breaker

The Tesla System Controller, which hosts the Tesla Controls Suite, uses intelligent software to control and monitor Megapacks across the entire energy storage site.

A Megapack System consists of one or more Megapacks and the Tesla System Controller, and can support various applications, including:

- **Renewable Smoothing** – Balance the power output of renewables to the grid by storing and discharging energy
- **Demand Support** – Discharge energy during peak demand to support distribution infrastructure
- **Infrastructure Investment** – Postpone costly grid infrastructure upgrades by storing power at a single location
- **Voltage & Frequency Regulation** – Stabilize voltage and frequency levels by absorbing and injecting reactive and real power
- **Market Participation** – Provide energy support to the grid in response to system operator alerts
- **Microgrid** – Build a localized grid that can disconnect from the main power grid

1.1 Definitions

apparent power capability – Rated AC apparent power capability of Megapack in kVA, factory-configurable by Tesla. Displayed as Maximum Continuous Power on the product nameplate.

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.

beginning of life – The start date of the Megapack warranty.

energy capacity – Rated AC energy capacity of Megapack in kWh. Displayed as Nominal Battery Energy (AC) on the product nameplate.

fully operational – The operating condition in which the Megapack is capable of discharging or charging at real power capability.

Heat Mode – A Megapack control mode that is used to regulate battery cell temperature in order to maintain the real power capability and/or to maximize the discharge energy capacity of Megapack at low ambient temperatures.

high voltage ride through (HVRT) – The capability of Megapack to stay connected over short periods of time despite local voltage exceeding the grid's nominal voltage, while maintaining control of the current output at its AC output terminals.

inverter – Bi-directional power conversion system that couples each Megapack with the power grid (AC power).

Megapack – Modular AC-coupled energy storage system, including an enclosure, battery modules, inverters, and a thermal system.

Megapack energy consumption – Loads and losses internal to the Megapack, including internal controls loads, thermal system losses, and chemical or ionic losses.

Megapack System – A Megapack System consists of one or more Megapacks and the Tesla System Controller.

nameplate – Label attached to a Megapack that indicates its electrical and mechanical specifications.

nominal – Standard value, as used for example in nominal voltage or nominal frequency, to which the Megapack is designed to operate under normal conditions.

overvoltage (OV) withstand – The capability of Megapack to stay connected over short periods of time despite local voltage exceeding the grid's nominal voltage.

peak apparent power capability – Rated peak AC apparent power capability of Megapack in kVA. Only available if Megapack is configured with Peak Power Mode by Tesla.

peak real power capability – Rated peak AC real power capability of Megapack in kW. Only available if Megapack is configured with Peak Power Mode by Tesla.

ratings – Energy capacity or power capability that the Megapack is designed to meet given certain nominal conditions. Nominal ratings are displayed on the product nameplate.

real power capability – Rated AC real power rating of Megapack in kW. Throughout Megapack documentation, the term *real power* may be used synonymously with the term *active power*.

round-trip efficiency (RTE, %) – The quotient of total energy discharged over the total energy charged. The energy charged and discharged are measured during a cycle of 0%-100%-0% SOE, where the Megapack is charged from 0% to 100% at real power capability, then discharged to 0% at real power capability. The round-trip AC-AC energy efficiency shall be measured at the AC terminals of the Megapack and shall include Megapack energy consumption during the cycle as defined above.

Standard Test Conditions (STC) – Defined as the Megapack soaked at 25°C and 1 atmosphere (101.3 kPa) of pressure.

state of charge (SOC) – The amount of energy left in the Megapack System measured as a percentage of energy available when fully charged. This is measured as energy remaining divided by the full pack energy, in units of percent.

state of energy (SOE) – State of charge, measured in energy capacity (kWh).

supervisory control and data acquisition (SCADA) – Additional hardware and software that may be required to control and monitor a Megapack site.

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

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

Tesla Controls Suite - Software and control algorithms hosted on the Tesla System Controller that manage charge and discharge functions of the battery system units, aggregating real-time information and using it to optimize commands sent to each individual battery unit.

Tesla System Controller - The single point of interface for plant operators to monitor and control the entire energy storage system using the Tesla Controls Suite. There are two physical variations of the Tesla System Controller: The Standard Tesla System Controller, deployed in the Standard Tesla System Controller Enclosure, for sites up to 18 MW, and the Large Tesla System Controller for larger sites.

1.2 Standards and Regulations

Refer to the *Megapack 2 XL Compliance Packet* for a full compliance packet of completed certifications in all regions.

2 Electrical Specifications

2.1 Power and Energy

Megapack's apparent power capability, real power capability, and energy capacity are defined at its AC output terminals and include Megapack energy consumption (loads and losses internal to the Megapack, including internal controls loads, thermal system losses, and chemical or ionic losses). Losses between the AC output terminals and the point of interconnection with the customer or utility are site-dependent and excluded from the Megapack ratings.

At beginning of life, Megapack is capable of providing energy capacity (kWh) at real power capability (kW) when discharged from 100% SOE at STC. Megapack is also capable of storing energy capacity (kWh) at real power capability (kW) when charged from 0% SOE at STC.

Megapack is capable of charging or discharging at real power capability for the life of the Megapack. The amount of energy Megapack can store will decrease over time.

NOTE: The Megapack System can be augmented to maintain power and energy capacity over the life of the product if arranged for at the time of contracting. Contact Tesla for more information.

Megapack standard configurations have the following ratings at 480 V AC:

Table 1. Megapack Standard Configuration Ratings

Megapack Configuration	Apparent Power Capability (kVA)	Real Power Capability (kW)	Energy Capacity (kWh)
2-Hour	2400.0	1927.2	3854.4
4-Hour	1320.0	979.2	3916.8

2.1.1 Scaling Power and Energy

Megapack can be requested with lower factory-configured apparent power capability. See *Power Configurations on page 15* for more details.

Megapack can be requested with fewer battery modules. See *Battery Module Configurations on page 16* for more details.

2.2 Round-Trip Efficiency and Energy Consumption

2.2.1 Round-Trip Efficiency

The round-trip efficiency (RTE), which includes Megapack energy consumption during the cycle (*Definitions on page 3*), is specified in the table below:

Table 2. Round-Trip Efficiency

Parameter	2-Hour	4-Hour
Round-Trip Efficiency at Beginning of Life*	STC: 91.7% T_{AMBHOT}: 90.2%	STC: 93.7% T_{AMBHOT}: 92.7% $T_{AMBCOLD}$: 93.2%

Parameter	2-Hour	4-Hour
	$T_{AMBCOLD}$: 91.6%	
Round-Trip Efficiency at Year 15**	STC: 89.5% T_{AMBHOT}: 88.2% $T_{AMBCOLD}$: 89.4%	STC: 92.0% T_{AMBHOT}: 90.7% $T_{AMBCOLD}$: 91.5%

* *Indicative figures.*

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

Indicative round-trip efficiency (beginning of life and year 15) under STC for a single Megapack at different power levels is shown in the graphs below.

Figure 1. Round-Trip Efficiency: 2-Hour

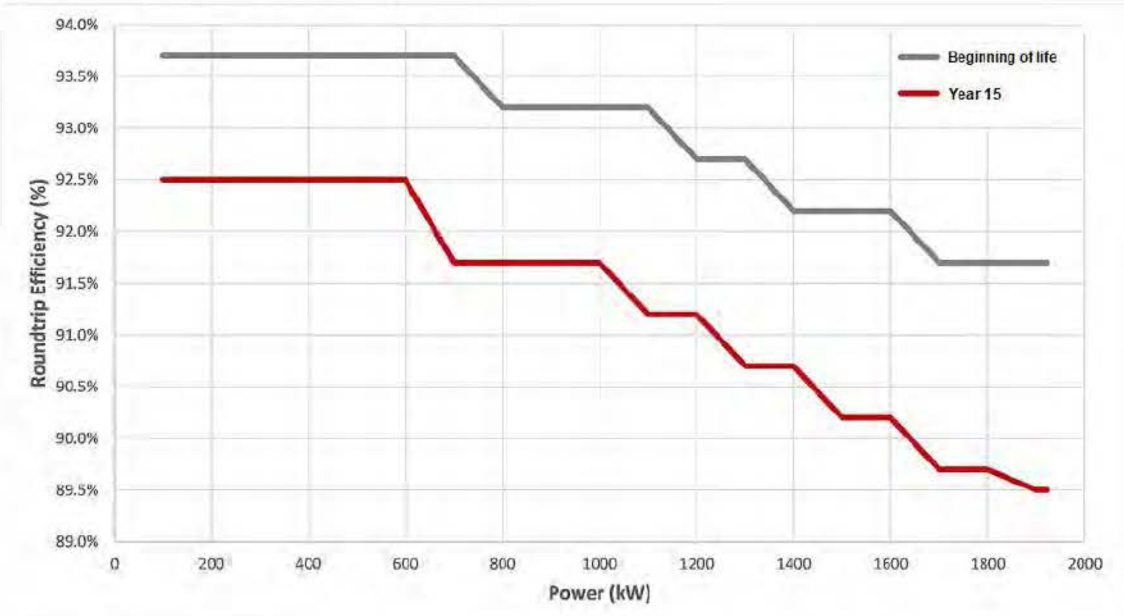
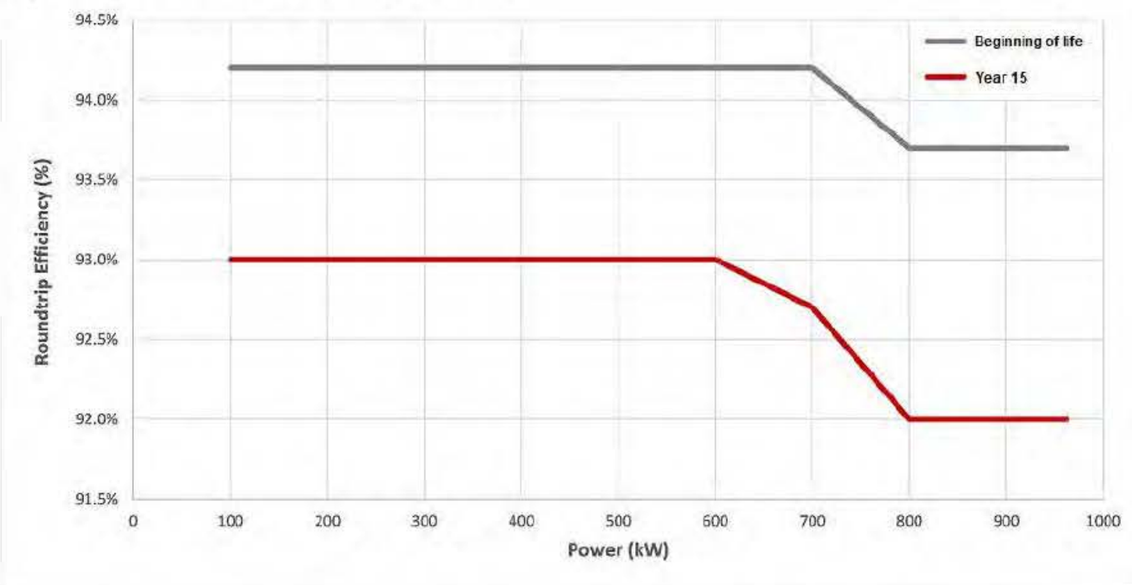


Figure 2. Round-Trip Efficiency: 4-Hour



2.2.2 Energy Consumption

> **NOTE:** All specifications below assume Heat Mode is not enabled by the user. Additional energy consumption due to Heat Mode is detailed in *Charge and Discharge Limitations on page 10*.

When Megapack is not actively charging or discharging, it may still self-discharge and consume energy, which is referred to as Megapack energy consumption (kWh).

Megapack energy consumption (kWh) was evaluated for the following two states:

- **On**: Command Megapack to go active and enables operation. Megapack will consume additional energy to remain active.
- **Off**: Megapack will not be allowed to operate. In this state, contactors may still close and Megapack may draw a small amount of power from the grid to support vital functionality, but they will not respond to Control Elements.

> **NOTE:** There is a third available state, Emergency Off, in which it is not desirable to leave Megapack. Refer to the *Controls and Communications Manual – Tesla System Controller* for more information.

The following cycles are defined as how Megapack was operated immediately before the 24-hour period during which Megapack energy consumption is calculated:

- **No cycle**: Megapack was not charging or discharging power.
- **One full cycle**: Megapack was charged from 0% SOE to 100% SOE at real power capability (kW) and was immediately discharged from 100% SOE to 0% at real power capability (kW).

Megapack energy consumption over a 24-hour period is detailed in the tables for various scenarios below.

Table 3. Megapack Energy Consumption, Off, No Cycle

Megapack Configuration	Ambient Conditions	Megapack Energy Consumption (kWh/Day)
4-Hour	STC	23
4-Hour	$T_{AMBCOLD}$	17

Megapack Configuration	Ambient Conditions	Megapack Energy Consumption (kWh/Day)
4-Hour	T_{AMBHOT}	77
2-Hour	STC	25
2-Hour	$T_{AMBCOLD}$	17
2-Hour	T_{AMBHOT}	81

Table 4. Megapack Energy Consumption, Off, One Full Cycle

Megapack Configuration	Ambient Conditions	Megapack Energy Consumption (kWh/Day)
4-Hour	STC	63
4-Hour	$T_{AMBCOLD}$	21
4-Hour	T_{AMBHOT}	122
2-Hour	STC	67
2-Hour	$T_{AMBCOLD}$	19
2-Hour	T_{AMBHOT}	173

Table 5. Megapack Energy Consumption, On, No Cycle

Megapack Configuration	Ambient Conditions	Megapack Energy Consumption (kWh/Day)
4-Hour	STC	154
4-Hour	$T_{AMBCOLD}$	153
4-Hour	T_{AMBHOT}	208
2-Hour	STC	287
2-Hour	$T_{AMBCOLD}$	287
2-Hour	T_{AMBHOT}	343

Table 6. Megapack Energy Consumption, On, One Full Cycle

Megapack Configuration	Ambient Conditions	Megapack Energy Consumption (kWh/Day)
4-Hour	STC	197
4-Hour	$T_{AMBCOLD}$	192
4-Hour	T_{AMBHOT}	256
2-Hour	STC	338
2-Hour	$T_{AMBCOLD}$	327
2-Hour	T_{AMBHOT}	443

Finally, in addition to Megapack's energy consumption, the Tesla System Controller has the following energy consumption per unit over a 24-hour period:

Table 7. Tesla System Controller Energy Consumption

Parameter	All Megapack Configurations (2-Hour, 4-Hour)
Tesla System Controller Energy Consumption (kWh/day)	0.5

2.3 Charge and Discharge Limitations

Megapack's thermal management system may be used to maintain the battery's charge and discharge capabilities across the Megapack's rated ambient temperature range. Operating in cold ambient temperatures results in lower overall efficiency due to increased Megapack energy consumption.

By raising the battery module temperature using Megapack's thermal management system, Megapack can be preconditioned from the starting temperatures indicated below to allow charge at real power capability. The preconditioning time and energy consumption below are dependent on temperature, product configuration, command, and state of charge.

Table 8. Preconditioning to Charge at Real Power Capability

Starting Temperature	Preconditioning Duration	Preconditioning Energy Consumption	Sustaining Energy Consumption (over 24 Hours)
-30°C	9 hours	328 kWh	445 kWh
-20°C	6 hours	218 kWh	334 kWh
-10°C	3 hours	115 kWh	222 kWh
0°C	0 hours	0 kWh	0 kWh
10°C	0 hours	0 kWh	0 kWh
20°C	0 hours	0 kWh	0 kWh
30°C	0 hours	0 kWh	0 kWh

Similarly, Megapack can be preconditioned to allow discharge at real power capability:

Table 9. Preconditioning to Discharge at Real Power Capability

Starting Temperature	Preconditioning Duration	Preconditioning Energy Consumption	Sustaining Energy Consumption (over 24 Hours)
-30°C	4 hours	152 kWh	269 kWh
-20°C	2 hours	66 kWh	173 kWh
-10°C	0 hours	0 kWh	0 kWh
0°C	0 hours	0 kWh	0 kWh
10°C	0 hours	0 kWh	0 kWh
20°C	0 hours	0 kWh	0 kWh
30°C	0 hours	0 kWh	0 kWh

Finally, Megapack can be preconditioned from the following starting temperatures to maximize Remaining Battery Energy (*Telemetry on page 25*):

Table 10. Preconditioning to Maximize Remaining Battery Energy

Starting Temperature	Preconditioning Duration	Preconditioning Energy Consumption	Sustaining Energy Consumption (over 24 Hours)
-30°C	19 hours	730 kWh	768 kWh
-20°C	15 hours	563 kWh	639 kWh
-10°C	11 hours	420 kWh	541 kWh

Starting Temperature	Preconditioning Duration	Preconditioning Energy Consumption	Sustaining Energy Consumption (over 24 Hours)
0°C	8 hours	294 kWh	409 kWh
10°C	5 hours	180 kWh	302 kWh
20°C	2 hours	70 kWh	169 kWh
30°C	0 hours	0 kWh	0 kWh

2.4 Interconnection Data

Table 11. Interconnection Data

Max Continuous Output Current	Factory-configurable (See *Power Configurations on page 15*)
Overload Capability	120% of rated current (10 sec max)
Nominal Voltage	480 V AC (configurable)
Output Voltage Range	422-552 V AC
Nominal Frequency	50 or 60 Hz (configurable)
Frequency Range	45-66 Hz
Phases	3
Configuration	3-wire, Wye **Note:** Grounded Wye required at transformer secondary
Power Factor Range	-1 to +1
Total Current Harmonic Distortion (THD)	< 5%
Power Regulation Accuracy	< 2% (See *Response Time on page 28*)
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 Megapack AC Circuit Breaker

Each Megapack includes an AC circuit breaker with the following features:

- 85 kAIC interrupting capacity
- GND fault detection
- Shunt trip
- Pad lockable

2.4.1.3 Voltage Ride-Through

Megapack's high-voltage ride-through (HVRT) and low-voltage ride-through (LVRT) settings are adjustable and programmed during the commissioning process to meet IEEE 1547-2018 requirements and/or comply with applicable grid code. All per-unit (pu) voltages are defined with respect to 480 V AC L-L.*

Table 12. Default HVRT Settings

Voltage Range (% of Base Value)	Response Time
Category II	
117.5<V<=120	0.2s
115<V<=117.5	0.5s
110<V<=115	1s
Category III	
110<V<=120	0.083s-12s

Table 13. Default LVRT Settings

Voltage Range (% of Base Value)	Response Time
Category II	
65<=V<88	Linear slope of 8.7s/1 p.u voltage starting at 3s @0.65 p.u
45<=V<65	0.32s
30<=V<45	0.16s
Category III	
70<=V<88	20s
50<=V<70	10s
V<50	0.083s - 1s

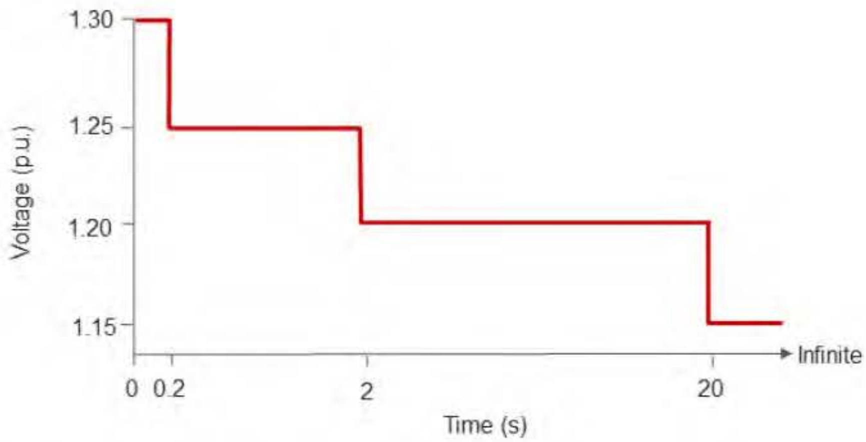
Table 14. Setting Ranges

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 at 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, contact your Tesla sales engineer for more information.*

The curve below specifies the per-unit HVRT non-cumulative capability of Megapack if installed per Tesla's recommendations in the *Megapack 2 XL Design and Installation Manual*. All per-unit voltages are defined with respect to 480 V AC L-L, and are RMS-based.

Figure 3. HVRT Non-Cumulative & RMS-Based Capabilities



The table below specifies the maximum per-unit overvoltage (OV) withstand non-cumulative capability of Megapack if installed per Tesla's recommendations in the *Megapack 2 XL Design and Installation Manual*.

Table 15. Maximum HVRT and Overvoltage Withstand Values

Parameter	Per-Unit Maximum Value, Nominal Voltage of 480 V AC, Non-Cumulative and RMS-Based
Maximum OV withstand allowed	130% @ 0.2 sec

Table 16. Trip Accuracy

Trip Setting	**Accuracy**
Voltage	+/- 1% of nominal voltage
Frequency	+/- 0.01 Hz
Reconnection time	1% of set point
Trip time	.16 seconds for <5 seconds 1% of set point for >5 seconds
Active power	+/- 5% of apparent power capability
Reactive power	+/- 5% of apparent power capability

2.4.1.4 Frequency Ride-Through

The Megapack inverter is capable of staying connected to the 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 17. 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
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 18. 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 19. 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 Power Configurations

Megapack can be requested with lower factory-configured apparent power capability.

The configurations listed below are example power configurations. Megapack can be requested to be factory-configured with lower apparent power capability to meet specific project needs. Starting at the minimum factory configuration of 400 kVA, Megapack is available in 50 kVA increments up to the maximum configuration of 2400 kVA.

Megapack should be configured with a kVA rating that considers and includes at least 40 kVA (2-Hour) or 35 kVA (4-Hour) to ensure that Megapack can supply enough AC current to simultaneously run the thermal system and charge in accordance with commands.

Megapacks with fewer battery modules will have a lower maximum power configuration option code, as indicated in *Battery Module Configurations on page 16*. Refer to the *Megapack 2 XL Option Codes Quick Reference Guide* for more information.

Table 20. Example Inverter Configurations

Power Configuration Option Code	Apparent Power Capability (kVA)	Maximum Continuous Output Current (A)	Applicable Configuration
P240	2400	2886.8	2-Hour Maximum
P230	2300	2766.5	2-Hour
P220	2200	2646.2	2-Hour
P210	2100	2525.9	2-Hour
P200	2000	2405.6	2-Hour
P132	1320	1587.7	4-Hour Maximum and 2-Hour
P130	1300	1563.7	4-Hour and 2-Hour
P120	1200	1443.4	4-Hour and 2-Hour
P110	1100	1323.1	4-Hour and 2-Hour
P100	1000	1202.8	4-Hour and 2-Hour
P040	400	481.1	4-Hour and 2-Hour Minimum

2.4.1.7 Battery Module Configurations

Megapack can be requested with fewer battery modules.

Table 21. Battery Module Configurations

Battery Module Option Code	Battery Module Count	2-Hour			4-Hour		
		Real Power Capability (kW)	Energy Capacity (kWh)	Max. Power Configuration Option Code	Real Power Capability (kW)	Energy Capacity (kWh)	Max. Power Configuration Option Code
EC08	8	642.4	1284.8	P085	326.4	1305.6	P040
EC09	9	722.7	1445.4	P095	367.2	1468.8	P045
EC10	10	803	1606	P110	408	1632	P055
EC11	11	883.3	1766.6	P120	448.8	1795.2	P060
EC12	12	963.6	1927.2	P132	489.6	1958.4	P065
EC13	13	1043.9	2087.8	P140	530.4	2121.6	P070
EC14	14	1124.2	2248.4	P150	571.2	2284.8	P075
EC15	15	1204.5	2409	P165	612	2448	P080
EC16	16	1284.8	2569.6	P175	652.8	2611.2	P085
EC17	17	1365.1	2730.2	P185	693.6	2774.4	P090
EC18	18	1445.4	2890.8	P195	734.4	2937.6	P095
EC19	19	1525.7	3051.4	P205	775.2	3100.8	P100
EC20	20	1606	3212	P220	816	3264	P110
EC21	21	1686.3	3372.6	P230	856.8	3427.2	P115
EC22	22	1766.6	3533.2	P240	897.6	3590.4	P120
EC23	23	1846.9	3693.8	P240	938.4	3753.6	P125
EC24	24	1927.2	3854.4	P240	979.2	3916.8	P132

2.4.1.8 Peak Power

The 2-Hour Megapack can be requested to be configured by Tesla to discharge for up to one hour at higher power than its real power capability (kW) and apparent power capability (kVA) by enabling Peak Power Mode. Megapack's real power capability and apparent power capability revert back to respective values in *Battery Module Configurations on page 16* after one hour at peak power. Megapack must be configured by Tesla for Peak Power Mode to be available.

Table 22. Peak Power Mode Battery Module Configurations

Battery Module Option Code	Battery Module Count	2-hour Megapack Rating	
		Peak Real Power Capability (kW)	Max. Power Configuration Option Code
EC08	8	864	P100
EC09	9	972	P110
EC10	10	1080	P125
EC11	11	1188	P135
EC12	12	1296	P150
EC13	13	1404	P160
EC14	14	1512	P175
EC15	15	1620	P185
EC16	16	1728	P200
EC17	17	1836	P210
EC18	18	1944	P225
EC19	19	2052	P235
EC20	20	N/A	N/A
EC21	21	N/A	N/A
EC22	22	N/A	N/A
EC23	23	N/A	N/A
EC24	24	N/A	N/A

3 Environmental Specifications

3.1 Ambient Temperature

Megapack is capable of meeting apparent power capability and real power capability 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 23. Ambient Temperature

Altitude (M)	Maximum Ambient Temperature During Operation (°C)
0-999	50.0
1000-1999	48.5
2000-2999	42.0
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 24. 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 apparent power capability and real power capability up to 3000 m elevation above sea level in ambient temperature conditions per *Ambient Temperature on page 18*.

3.3 Seismic, Shock, and Vibration

Megapack meets the high seismic, shock, and vibration 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

3.4 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).

3.5 Roof Loading

Megapack is able to withstand a snow load of up to 732.3 kilograms per square meter (150 pounds per square foot, or 7.18 kN_{Earth}/m^2) on its roof or other surface.

Megapack is designed to ensure that its roof can withstand a person of up to 300 lbs (136 kg) gross weight in clearly designated areas.

3.6 Solar Loading

Megapack provides apparent power capability and real power capability in all ambient temperature conditions (*Ambient Temperature on page 18*), and at maximum elevation (*Elevation on page 18*) under up to 1200 W/m^2 solar loading, in any direction.

4 Mechanical Specifications

4.1 Dimensions and Mass

NOTE: Mass as listed is maximum mass. Megapack can be configured for lighter shipping mass based on project-specific requirements.

NOTE: Enclosure dimensions are provided for nominal design guidance only. For precise dimensions, see *Megapack 2 XL Drawings* on the Partner Portal.

Table 25. Megapack Dimensions and Mass (Weight)

Width	Depth	Height	Max. Shipping Mass
8800 mm (346 ½ in)	1650 mm (65 in)	2785 mm (110 in)	38,100 kg (84,000 lb)

4.2 Transportation Considerations

Megapack can be transported by land and sea. Megapack is designed for easy and convenient shipping through a consolidated design with simple, accessible lifting points.

Megapack has six compliant ISO 1161-type lifting points called ISO fittings for effective rigging and to aid transportation and logistics. Megapack, fitted with a protective shipping cover, arrives at the delivery point on a trailer pulled by a truck and can be offloaded by lifting from these six ISO fittings. Depending on site constraints and lifting equipment, additional rigging (such as spreader bars and shackles) may be required.

Because of its pre-assembled and pre-tested nature, Megapack is considered a non-divisible entity, which means it cannot and should not be disassembled during any portion of its transportation. Doors should not be opened and parts should not be removed under any circumstance.

Megapack is a large, overweight load. In order to prepare for successful delivery, access roads must be capable of supporting the loaded delivery vehicle. The site shall provide and maintain a clear access route from the public right-of-way to the on-site maintenance infrastructure, and from the on-site maintenance infrastructure to the front of each Megapack for delivery, installation, replacement, and removal of Megapack and its components. The access route must support Megapack and its transportation equipment, including crane and forklift as required.

4.2.1 Ocean Shipping Guidance

Megapack cannot be shipped using standard (ISO-668 40-ft High Cube dry) container types due the height of the overall product. Tesla's recommendation for ocean transit is via a trailer on roll-on/roll-off (ro-ro) vessels. Based on the applicable Incoterms® Rules, should a ro-ro vessel option not be available, Tesla can work with customers to determine what specialized equipment will be necessary on a case-by-case basis.

4.3 Installation

NOTE: For comprehensive site design and installation guidance, refer to the *Megapack 2 XL Design and Installation Manual*.

4.3.1 Anchoring

Megapacks may be anchored to their foundations using their anchor brackets, which are steel flanges welded to the base of Megapack. Megapack's anchor brackets are to be structurally affixed to a foundation. The use, quantity, and location of anchors is determined by the engineer of record and must conform to the laws, regulations, codes, and standards applicable in the jurisdiction of installation. In general, there are four types of foundations to which a Megapack may be anchored:

1. Concrete slab
2. Steel I-Beam
3. Concrete or steel pile
4. Grade beam

The number of anchors that will be used should be defined by a project's Structural Engineer of Record through the site S_{DS} value and AHJ requirements.

4.3.2 Electrical Termination

Megapack is designed with two above-ground wireways through which to route AC cabling to LV transformer termination and communications cabling. The wireways do not require any site trenching construction. Each wireway runs from each side of the Megapack into the conduit opening in the Customer Interface Bay. Circuits using wireways must be designed and installed in accordance with local code.

4.4 Enclosure

4.4.1 Ingress Protection

The Megapack thermal system has an ingress protection rating of IP20, while the enclosure has an ingress protection rating of IP66 and is classified to NEMA 3R certification (including rain and sprinkler test immunity).

4.4.2 Impact Protection

The Megapack enclosure has a minimum IK rating of IK09 for impact protection.

4.4.3 Salt and Fog

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

4.4.4 Corrosion Resistance and Paint

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

4.5 Audible Noise

The audible noise of Megapack, measured 10 meters from any side surface of the enclosure, is less than 75 dBA (SPL sound pressure) at full thermal system performance.

5 Communication and Control

The Tesla System Controller hosts advanced software that provides the single point of interface through which plant operators control and communicate with a Tesla battery storage system. It supports a comprehensive set of telemetry reported at the system- and Megapack-level, and includes a flexible set of controls to manage real power, reactive power, islanding behaviors and more.

The Tesla System Controller requires one or more supported SEL-735 meters to perform control functions. The meter provides frequency, voltage, real power, and reactive power information required for various controls functions and closed-loop control.

This section defines the functional performance capabilities of Megapack that are available via the Tesla System Controller.

NOTE: Megapack is tested and certified to support IEEE 1547-2018 communication and controls capabilities.

NOTE: Tesla does not guarantee that the telemetry or controls will be implemented exactly as written in this specification. Communication protocols, profiles, and control mode APIs are subject to change but will ultimately address the functional behaviors herein.

5.1 Controls

The controls software that runs on the Tesla System Controller is modular and adaptable to meet project-specific needs, which are primarily driven by site-specific electrical topology, interconnection requirements, and regional regulations. To satisfy these needs, the controls platform supports a fixed set of *Control Templates* that consist of many *Control Elements*.

Control Templates serve different segments of the global battery energy storage market based on geographic region and interconnection type (for example, Utility Scale Battery Only System – North America). Templates decrease project commissioning risk and time by defining, up front, the required set of individual Control Elements, their settings, and how they interact and behave as a system of controls. Depending on project-specific needs, one or more Control Templates will be selected and deployed for a given project by Tesla.

In this specification, Control Elements have been summarized and grouped into functional categories below.

Table 26. Control Elements

Category	Name	Description
Interface	External Interface	Provides a customer-facing Modbus interface to interact with the system. Rejects writes that are outside of acceptable values.
Real Power	Battery Direct Real Power	Battery Real Power command.
	Ramp Rate	Limits the rate of change of Battery Direct Real Power commands.
	Site Control	Site real power control point. Battery charges/discharges autonomously to meet site-level export or demand requirement.

Category	Name	Description
	Maintain Energy	Commands the system to reach and maintain a specific energy value.
	Frequency Droop	Allows to inject Real Power in response to changes in Frequency according to a Droop curve. Both 4- and 6-point frequency-droop are supported.
	Frequency Integral	Provides integral regulation of the Frequency. **NOTE:** Using Frequency Integral in conjunction with Frequency Droop is the equivalent of Isochronous Control.
	Fast Frequency Response (Low Frequency)	Allows to immediately dispatch a given Real Power discharge command for a given duration when Frequency drops below a threshold.
	Fast Frequency Response (High Frequency)	Allows to immediately dispatch a given Real Power charge command for a given duration when Frequency exceeds a threshold.
Reactive Power	Battery Direct Reactive Power	Battery Reactive Power command.
	Ramp Rate	Limits the rate of change of Battery Direct Reactive Power commands.
	Power Factor	Allows to maintain a specific Power Factor value at the Meter.
	Voltage Control	Allows to maintain a Voltage Reference by injecting or absorbing Reactive Power In response to Voltage fluctuations.
Battery Switches	State Request	Commands the state of batteries: On, Off, Emergency Off. **WARNING:** Commanding the system to Off or Emergency Off is not a replacement for performing proper de-energization procedures in order to perform work, as described in the *Megapack 2 XL Design and Installation Manual*.
	Heat Mode Enable	Enables Heat Mode, which preconditions batteries to maintain rated charge and discharge power and energy specifications at low ambient temperatures.
	Peak Power Enable	Enables Peak Power, which enables the Megapack to temporarily discharge at a higher than nominal rated power. **NOTE:** Supported Peak Power product configuration must be selected at contracting. The use of Peak Power may carry special warranty considerations.
	Mode Request	Commands the mode of batteries: Grid-Following or Grid-Forming.

Category	Name	Description
		NOTE: The battery system can be configured to emulate a virtual synchronous machine and provide grids with inertia, which can help stabilize system frequency and provide system strength.
	Black Start Request	Commands the batteries to black start the grid: No Black Start, Black Start Now. **NOTE:** Black start is only available on systems that are designed to grid-form and must be enabled by Tesla at commissioning.
Performance	Closed Loop Control	Regulates Real or Reactive Power output, as measured at the Meter, to accurately meet the total power commands.
	Enable Manager	Enables or disables behaviors based on specific system conditions, such as validity of meter data or connection to RTU.
	Transformer Losses	Allows feed-forward compensation of both real and reactive transformer and conductor losses between the Battery Meter and the Megapacks.
	Battery Group	Intelligently manages system dispatch commands across Megapacks taking into account energy balancing and hardware availability.
	Redundancy	Allows for an automatic failover for redundant Tesla System Controllers. **NOTE:** Automatic Failover is a paid SCADA adder must be selected at contracting to ensure proper SCADA system design.
Islanding **NOTE:** Only available to sites designed for islanding with approved islanding controller.	Transition Manager	Manages islanding transition preferences, including automatic or user-triggered synchronization.
	Isochronous Controller	Provides automatic frequency control as well as automatic voltage regulation leveraging static voltage and frequency targets.
	State of Energy Frequency Shift	System can be configured to shift frequency reference as a function of the system's state of energy, which is used to trigger frequency-dependent control functionality of other components of the microgrid (for example, with active power reduction of solar inverters).
	Black Start Retry	System can be configured to either automatically retry or wait for user-initiated black start.
	Wait for Behaviors	Battery system will operate using specific state of energy thresholds designed to prevent full depletion of batteries (Wait for Solar, Waiting for User, Waiting for AC).
	Solar Retry	Allows the user to configure the system to automatically attempt a black start once per hour during daylight hours.

Category	Name	Description
	Reference Generator	Enables automatic synchronization and seamless transfer back to utility power.
	Islanding Enable Manager	Ensures there is enough energy to island, manages when to island or black start, and determines when isochronous controls should be enabled.
	Islanding Controller	Handles islanding controller driver information and communications.
	Islanded Mode Manager	Automates the battery mode, anti-islanding enable, and black start request of the battery while islanded.
	Spinning Reserve	Manages active battery and generation assets in the microgrid with objective of maintaining sufficient reserve capacity upward and downward to serve sudden changes in net load.
Microgrid **NOTE:** Only available to sites designed for islanding with approved islanding controller or off-grid only microgrids managed by the Tesla System Controller.	Battery Energy Manager	Operates battery between state of energy setpoints to ensure sufficient space is allowed for intended behavior at low and high state of energy, which ensures stable and reliable operation for the overall microgrid.
	Renewable Manager	Manages renewable power contribution to Spinning Reserve from renewable resources including solar and wind.

5.2 Telemetry

This section provides a summary of system-level and Megapack-level telemetry points and alerts reported by the Tesla System Controller over supported communications interfaces. Supported interfaces include Modbus and DNP3. The Modbus interface supports system-level monitoring and control. The DNP3 interface supports Megapack-level monitoring and control.

Table 27. System-Level Telemetry and Alerts

Data Source	Name	Description	SI Units
Tesla System Controller	Tesla System Controller Firmware Version	Tesla System Controller software version number.	N/A
	Dispatchable Charge Power	Negative value. Power that is immediately available to charge the system, taking into account system conditions and excluding power from faulted components. This value applies to Megapack terminals and is not limited by Real Power Charge or Operator Limits.	W
	Dispatchable Discharge Power	Power that is immediately available to discharge the system, taking into account system conditions and excluding the power from faulted components. This value applies at Megapack terminals and is not limited by Real Power Discharge and Operator Limits.	W
	Dispatchable Apparent Power	Immediately available apparent power.	VA

Data Source	Name	Description	SI Units
	Full Battery Energy	Energy capacity of the system when fully charged.	Wh
	Remaining Battery Energy	Energy currently available to discharge.	Wh
	Auxiliary Load	Aggregate power supplied to internal auxiliary loads of all Megapacks.	W
	Number of Available Megapacks	Count of Megapacks available for operation.	N/A
	Not Substantially Available	Asserts when the battery system's dispatchable apparent power is below a threshold (80% by default) of the Nominal Apparent Power.	N/A
	Real Power Available Limited	The battery system is not able to meet the total real power setpoint because the requested power exceeds the Nominal Real Power or the Real Operator Limits.	N/A
	Reactive Power Available Limited	The battery system is not able to meet the total reactive power setpoint because the requested power exceeds the Nominal Reactive Power or the Reactive Operator Limits.	N/A
	Customer Command Timed Out	The Tesla System Controller has not received any commands from a Modbus client for a duration greater than the command timeout configured, and the last command has timed out. The battery system will stop operating.	N/A
Meter	Meter Real Power	Total 3-phase Real Power, as read from the Meter.	W
	Meter Reactive Power	Total 3-phase Reactive Power, as read from the Meter.	var
	Meter Voltage	Average line-to-line RMS voltage, as read from the Meter.	V
	Meter Frequency	Frequency, as read from the Meter. Frequency is filtered and can be overwritten by Tesla for specific tests.	Hz
	Meter Energy Import	Energy Accumulator - lifetime energy imported (charged) by the battery, as read from the Meter.	Wh
	Meter Energy Export	Energy Accumulator - lifetime cumulative energy exported (discharged) by the battery, as read from the Meter.	Wh
	Meter Invalid	Meter data is currently invalid: Readings are out of bounds, meter has lost communication, or a PT/CT failure has occurred (if applicable).	

Table 28. Megapack-Level Telemetry and Alerts

Name	Description	SI Units
Megapack Real Power Target	Real power target sent by the Tesla System Controller to Megapack.	W
Megapack Real Power	Real power measured by Megapack.	W
Megapack Reactive Power Target	Reactive power target sent by the Tesla System Controller to Megapack.	var
Megapack Reactive Power	Reactive power measured by Megapack.	var

Name	Description	SI Units
Megapack State of Energy	State of energy of Megapack.	%
Megapack Energy Remaining	Energy available from Megapack to discharge at nominal operating conditions.	Wh
Megapack Full Pack Energy	Usable energy capacity when Megapack is fully charged and at nominal operating conditions.	Wh
Megapack AC Voltage	Phase-to-ground RMS voltage, average of all three phases.	V rms
Megapack Phase (A/B/C) Voltage	Phase-to-ground RMS voltage (A/B/C).	V rms
Megapack Phase (A/B/C) Current	Phase current (A/B/C).	A rms
Maximum Battery Temperature	Maximum cell temperature across all battery modules within Megapack.	C
Ambient Temperature	Ambient temperature measured inside Megapack enclosure.	C
Megapack Available Charge Power	Real power capability of Megapack for charging.	W
Megapack Available Discharge Power	Real power capability of Megapack for discharging.	W
Megapack Isolation Failure	Megapack has reported an isolation measurement below its acceptable threshold.	N/A
Megapack Inverter Fault	All inverters in the Megapack are faulted.	N/A
Enable Circuit Open	Megapack enable circuit is open.	N/A
Enable Switch Off	Megapack enable switch is in off position, preventing operation.	N/A
AC Breaker Status	Megapack AC circuit breaker status (open/closed).	N/A
Bus Controller Prolonged Fault	Megapack has experienced several consecutive faults and has entered a prolonged fault state, which will stop operation temporarily.	N/A
Coolant Low	Coolant level is low as reported by the coolant sensor.	N/A
Extreme Temperature Warning	Battery cells have reached a temperature above the cell temperature warning threshold.	N/A
Extreme Temperature Fault	Battery cells have reached a temperature above the cell temperature fault threshold.	N/A
Power Electronics Over Temperature	Megapack power electronics are experiencing an overtemperature.	N/A
Low State of Energy	Megapack is at very low state of energy and must be charged as soon as possible to avoid cell damage.	N/A
Megapack Disabled	Megapack is disabled, meaning battery modules and thermal system are disabled.	N/A

5.3 Configurable Parameters

Megapack will support the configurable limits as outlined in this section. Static limits are established during the site commissioning phase and require support from Tesla technical support teams to update. Static limits often represent physical constraints of the site (for example, transformer or conductor sizing) and should not change often. Dynamic limits can be updated in operation by the operator via supported communications interfaces.

Table 29. Configurable Limits

Name	Type	Description
Nominal Real Power Discharge	Static	Nominal discharge power of the site. The maximum power that can be discharged.
Nominal Real Power Charge	Static	Nominal charge power of the site. The maximum power that can be charged.
Nominal Reactive Power	Static	Nominal reactive power of the site. The maximum reactive power that can be injected or absorbed.
Nominal Frequency	Static	Nominal grid frequency (60 Hz or 50 Hz).
Nominal Energy	Static	Nominal energy capacity. The contractual energy capacity of the system.
Voltage Ride-Through	Static	Site-level voltage ride-through.
Frequency Ride-Through	Static	Site-level frequency ride-through.
Export Limits	Static	Set allowed grid export limits (none, solar only, battery and solar).
Charge from Solar	Static	Limit battery system to only charge from solar generation.
Bus Export Limit	Static	Limit combined solar and storage dispatch on a shared bus to remain below ampacity limits. **NOTE:** Requires a supported meter on the bus to regulate.
Reference Frequency	Dynamic	The reference frequency for Frequency Droop, Frequency Integral and Grid-Forming applications.
Reference Voltage	Dynamic	The reference voltage for Voltage Control and Grid-Forming applications.
Real Operator Limit Maximum	Dynamic	The maximum real power limit allowed at the specified measurement point.
Real Operator Limit Minimum	Dynamic	The minimum real power limit allowed at the specified measurement point.
Reactive Operator Limit Maximum	Dynamic	The maximum reactive power limit allowed at the specified measurement point.
Reactive Operator Limit Minimum	Dynamic	The minimum reactive power limit allowed at the specified measurement point.

5.4 Response Time

Megapack will meet the performance characteristics as outlined in this section.

Response times may vary based on the application or control scenario. Real and reactive power commands and frequency droop are implemented at the site level using the SEL-735 meter for measurement by default. Inverter-based response, for use cases such as inertia response, is sub-cycle.

The table below provides maximum measurement times using the SEL-735 meter sampled at 100 ms or less.

Table 30. Response Time

Control Scenario	Measurement Point	Start of Response Definition (0 ms)	Measured Rise Time to 95% of Command (ms)	Measured Settling Time to 98% of Command (ms)
Real and reactive power commands	Meter	When the Tesla System Controller receives the command.	<= 200	<= 1000
Frequency droop response	Meter	When grid frequency steps.	<= 200	<= 1000

6 Powerhub

Powerhub is a cloud-based monitoring and diagnostics platform that provides site-level data for single sites or aggregated across portfolios of sites. Historical data can be reviewed in a graphing interface, providing visibility into site-level behavior and allowing those data to be exported.

Access to Powerhub is included by default for all Megapack customers. For more information, see the *Powerhub User Manual* or the *Application Note: Powerhub for Megapack and Powerpack*.

Revision History

Revision	Date	Details
2.5	July 18, 2023	• Simplified anchoring information (*Anchoring on page 21*) • Updated electrical termination (*Electrical Termination on page 21*) • Enhanced transportation information (*Transportation Considerations on page 20*) • Provided ocean shipping guidance (*Ocean Shipping Guidance on page 20*)
2.4	May 18, 2023	• Updated round-trip efficiency, including graphs (*Round-Trip Efficiency and Energy Consumption on page 6*) • Improved language around the Megapack electrical ratings and the losses included (*Electrical Specifications on page 6*) • Updated controls terminology to be aligned with the Tesla System Controller software (*Energy Consumption on page 8*, *Communication and Control on page 22*) • Clarified dependency of preconditioning time and energy consumption in cold conditions (*Charge and Discharge Limitations on page 10*) • Added new definitions and updated terms to clarify ratings terminology (*Definitions on page 3*)
2.3	March 29, 2023	• Simplified augmentation language and removed references to CMA for upcoming projects • Removed forward-facing 2023 statements • Updated Tesla Site Controller name to Tesla System Controller
2.2	January 17, 2023	• Corrected P040 inverter system duration description (*Power Configurations on page 15*)
2.1	December 20, 2022	• Added definitions and specifications for Peak Power Mode capability (*Peak Power on page 17*)
2.0	November 15, 2022	• Updated kVA ratings • Updated 4-Hour RTE at STC (*Round-Trip Efficiency and Energy Consumption on page 6*) • Simplified beam foundation language (*Anchoring on page 21*)
1.9	October 6, 2022	• Removed the P163 inverter configuration (*Power Configurations on page 15*) • Updated Voltage Ride Through specifications. Clarified the maximum HVRT and Overvoltage withstand capabilities of Megapack • Added definitions for High Voltage Ride Through and Overvoltage withstand (*Definitions on page 3*)

Revision	Date	Details
		• Added controls and communications details to *Communication and Control on page 22* • Removed preliminary ratings caveats
1.8	May 13, 2022	• Updated round-trip efficiency section, including graphs (*Round-Trip Efficiency and Energy Consumption on page 6*) • Simplified roof live-load language (*Roof Loading on page 19*)
1.7	April 6, 2022	• Modified 4-hour energy rating (*Power and Energy on page 6*) • Modified Voltage Ride Through settings • Modified audible noise specification (*Audible Noise on page 21*) • Updated kVA increments from 100 kVA to 50 kVA (*Power Configurations on page 15*) • Modified enclosure dimensions (*Dimensions and Mass on page 20*) • Minor updates to product language and definitions (*System Description on page 3*) • Updated nominal ratings with max configurable power to have time dependency (*Power and Energy on page 6*) • Modified round-trip efficiency figures and added more detailed energy consumption figures (*Round-Trip Efficiency and Energy Consumption on page 6*) • Updated battery module configurations; increased minimum allowable product configuration to 400 kVA (*Battery Module Configurations on page 16*, *Power Configurations on page 15*) • Improved language and made minor updates to environmental specifications • Updated *Roof Loading on page 19* and *Solar Loading on page 19* • Provided additional transportation details (*Transportation Considerations on page 20*) • Created installation section (*Installation on page 20*) • Provided additional communication and control information
1.6.4	November 9, 2021	• Real power / energy ratings update • RTE update (*Round-Trip Efficiency and Energy Consumption on page 6*) • Audible noise spec update (*Audible Noise on page 21*)
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

Revision	Date	Details
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

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Megapack 2 XL Specification - Revision 2.5

NFPA-855 COMPLIANCE GUIDE FOR TESLA MEGAPACK PRODUCTS

PRODUCT SPECIFICATIONS

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Document Scope and Purpose

This document is to be used as a reference for applicability to the NFPA 855 Standard (2020 Edition) requirements for projects using Tesla Megapack products (including Megapack, Megapack 2, and Megapack 2 XL). This document does not provide the full text for each requirement and is designed to be used alongside a full copy of the NFPA 855 Standard (not provided by Tesla).

This document describes the requirements only as far as they are applicable to the NFPA standard. There may be additional or different requirements customers must follow as described in the applicable Site Design manual:

- *Megapack Site Design Manual* - https://partners.tesla.com/home/en-US/content/download/Megapack_Site_Design_Manual.pdf
- *Megapack 2 Design and Installation Manual* - https://partners.tesla.com/home/en-US/content/download/Megapack_2_Design_and_Installation_Manual.pdf
- *Megapack 2 XL Design and Installation Manual* - https://partners.tesla.com/home/en-US/content/download/Megapack_2_XL_Design_and_Installation_Manual.pdf

Contact your Tesla representative for additional information.

NOTE: This document has been updated to consider the Tentative Interim Amendment to NFPA 855 issued by the National Fire Protection Association on August 26, 2021 and with an effective date of September 15, 2021.

Chapter 4 - General			
Section	Title	Description	Comments
4.1	General requirements	4.1.1 – No release of toxic gas during normal operation	Compliant. All Tesla industrial energy products contain hermetically sealed cells that do not release gas during normal operation.
		4.1.2 – Provision of construction documents	Product specific documents are available. Project related documents to be provided by developer / EPC. (Scope of EPC)
		4.1.3 – Emergency planning and training	Emergency response guide is provided. Tesla can support customers with additional content to establish a detailed emergency plan.
		4.1.4 – Hazard mitigation analysis	N/A for outdoor energy storage systems in remote locations (see definition in Section 4.4.3.1), or systems with an energy capacity of less than 600 kWh. Otherwise, a hazard mitigation analysis has to be provided, including:

Chapter 4 - General			
Section	**Title**	**Description**	**Comments**
			4.1.4.2. (1) – Evaluation of thermal runaway. Compliant via Section 4.1.5. 4.1.4.2. (2) – Evaluation of failure of the energy storage management system. Compliant, Tesla battery management systems are certified to UL1998 and IEC60730 Annex H. 4.1.4.2. (3) – Evaluation of failure of a ventilation or exhaust system. N/A for energy storage systems with non-walk-in outdoor enclosure. For indoor installations, TBD on a project specific basis. 4.1.4.2. (4) – Evaluation of failure of a smoke detection, fire detection, fire suppression, or gas detection system. N/A for energy storage systems with non-walk-in outdoor enclosure. For indoor installations, TBD on a project specific basis.
		4.1.5 – Large-Scale Fire Test	Compliant. Megapack testing completed to UL 9540A, report available starting Q2 2020.
		4.1.6 – Combustible Storage	Scope of EPC to comply on a project level.
4.2	Equipment	4.2.1 – Listings	Compliant. All Tesla industrial energy products are listed in accordance with UL9540.
		4.2.2 – Repairs	Compliant. All repairs are performed by Tesla certified staff.
		4.2.3 – Retrofits	Compliant. All retrofits are listed in accordance with UL1973.
		4.2.4 – Replacements	Compliant. Replacement are considered new energy storage systems and need do comply with the corresponding requirements.
		4.2.5 – Increase in Power Rating or Maximum Stored Energy	Compliant. A complete energy storage unit that is added to an existing system needs to be compliant with the requirements for new systems. An existing energy storage united that is expanded needs to be compliant with the requirements for retrofits (see Section 4.2.3).
		4.2.6 – Environment	N/A as all Tesla industrial energy products have IP66/NEMA 3R rating.
		4.2.7 – Charge Controllers	Compliant – products certified to UL1741.

Chapter 4 - General			
Section	Title	Description	Comments
		4.2.8 – Inverters and Converters	Compliant – products certified to UL1741.
		4.2.9 – Energy Storage Management System	Compliant – products certified to UL9540.
		4.2.10 – Reused and Repurposed Equipment	N/A
4.3	Installation	4.3.1 – Electrical Installation	The electrical installation has to be compliant with NFPA 70, IEEE C2, or equivalent local code. All Tesla industrial energy products are designed to be compliant. Scope of EPC to comply on a project level.
		4.3.2 – Working Space	The working space has to be compliant with NFPA 70, IEEE C2, or equivalent local code. Scope of EPC to comply on a project level.
		4.3.3 – Seismic Protection	Seismic protection has to be compliant with the local building code. Scope of EPC to comply on a project level.
		4.3.4 – Design Loads	Scope of EPC to comply on a project level.
		4.3.5 – Signage	Scope of EPC to comply on a project level.
		4.3.6 – Separation	For outdoor located energy storage systems: can be reduced based on results from 4.1.5 (9540A testing). For indoor locations, TBD on a project specific basis.
		4.3.7 – Impact Protection	The energy storage system shall be protected with guard posts (or other approved fence) when subject to impact by motor vehicles. Scope of EPC to comply on a project level.
		4.3.8 – Security of Installations	The energy storage system location shall be secured against unauthorized entry. All Tesla industrial energy products are secured against unauthorized tampering with locks. Scope of EPC to comply on a project level.
		4.3.9 – Elevation	N/A for energy storage systems located on the ground floor or within reachable elevations for external fire department laddering capabilities. For higher elevations or underground locations, TBD on a project specific basis.
		4.3.10 – Means of Egress	N/A for outdoor energy storage systems in remote locations (see

Chapter 4 - General			
Section	Title	Description	Comments
			definition in Section 4.4.3.1). Otherwise, means of egress shall be compliant with the local building code. Scope of EPC to comply on a project level.
		4.3.11 – Open Rack Installations	N/A for energy storage systems located in a non-walk-in enclosure.
		4.3.12 – Fire Command Centers	N/A for outdoor located energy storage systems. For indoor locations, TBD on a project specific basis.
4.4	Location	4.4.1 – General compliance	-
		4.4.2 – Indoor Installations	N/A for standard outdoor installations. Otherwise, TBD on a project specific basis.
		4.4.3.2 – Maximum Size	Compliant. All Tesla industrial energy product enclosures are smaller than the maximum allowed size.
		4.4.3.3 – Clearance to Exposures	N/A for energy storage systems in Remote locations (see definition in Section 4.4.3.1). Otherwise, minimum distance to any external (or hazardous) equipment is of 10 ft (3048 mm). Minimum distance can be reduced to 3 ft (917 mm) when accepted by the AHJ (authority having jurisdiction) through the results of a large-scale fire test (see Section 4.1.5). For minimum distance between battery enclosures see Section 4.6. Scope of EPC to comply on a project level.
		4.4.3.4 – Means of Egress	N/A for energy storage systems in Remote locations (see definition in Section 4.4.3.1). Otherwise, minimum distance to any means of egress of 10 ft (3048 mm). Minimum distance can be reduced to 3 ft (917 mm) when accepted by the AHJ (authority having jurisdiction) through the results of a large-scale fire test (see Section 4.1.5). Scope of EPC to comply on a project level.
		4.4.3.5 – Walk-in	N/A for energy storage systems with non-walk-in enclosure.
		4.4.3.6 – Vegetation Control	Areas within 10 ft (3048 mm) of the outer enclosure should be cleared of combustible vegetation. Exceptions can be made for single trees, cultivated cover (green grass), and other plants.

Chapter 4 - General			
Section	Title	Description	Comments
		4.4.3.7 - Enclosures	Compliant. All Tesla industrial energy products have IP66/NEMA 3R rated enclosures.
		4.4.3.8 – Access Roads	Access roads for the fire department shall be provided in accordance with the local fire code. Scope of EPC to comply on a project level.
		4.4.3.9 – Hazardous Atmospheres	N/A
		4.4.3.10 – Exterior Wall Installations	N/A
		4.4.4 – Rooftop and Open Parking Garage Installations	N/A for standard outdoor installations. Otherwise, TBD on a project specific basis.
4.5	Mobile ESS Equipment and Operations	4.5.1 – 4.5.7	N/A for standard stationary installations. Otherwise, TBD on a project specific basis.
4.6	Size and Separation	4.6.1 – 4.6.7	N/A for outdoor energy storage systems in remote locations (see definition in Section 4.4.3.1). Otherwise, all Tesla industrial energy products comply with the exception defined in Section 4.6.4. Accordingly, when provided a hazard mitigation analysis (see Section 4.1.4), there is no limitation for maximum energy capacity. For Megapack, the minimum separation between enclosures is 6 inches (150 mm), as certified by the large-scale fire test, following the UL9540A test procedure (see Section 4.1.5).
4.7	Occupied Work Centers	4.7.1 – 4.7.2	N/A for standard outdoor installations. Otherwise, TBD on a project specific basis.
4.8	Maximum Stored Energy	4.8.1 – 4.8.5	N/A according to 4.8 (2) if Remote location (see definition in Section 4.4.3.1). Otherwise, a hazard mitigation analysis (see Section 4.1.4) and results of large-scale fire testing (4.1.5) shall be provided for installations with a capacity above 600 kWh.
4.9	Exhaust Ventilation	4.9.1 – 4.9.3	N/A. In accordance with Table 9.2 (see NFPA 855), Li-ion batteries do not require exhaust ventilation.

Chapter 4 - General			
Section	Title	Description	Comments
4.10	Smoke and Fire Detection	4.10.1 – 4.10.5	N/A for standard outdoor installations. Otherwise, TBD on a project specific basis.
4.11	Fire Control and Suppression	4.11.1 – 4.11.9	N/A for outdoor-located energy storage systems with non-walk-in enclosures. Otherwise, TBD on a project specific basis.
4.12	Explosion Control	4.12.1	N/A. Per 4.12.1.2, ESS cabinets that have been designed to ensure no deflagration or ejection and validated via large-scale testing and evaluation shall be permitted in lieu of explosion control complying with NFPA 68 or NFPA 69.
		4.12.1.1	N/A
		4.12.1.2	Compliant. All Tesla industrial energy products' testing completed to UL 9540A that complies with 4.1.5. No deflagrations or ejections of hazardous materials occurred during full unit-level testing. Reports available.
4.13	Water Supply	4.13.1 – 4.13.6	As per Table 4.4.3 (see NFPA 855), for energy storage systems in remote locations (see definition in Section 4.4.3.2), fire suppression systems and water supply can be omitted when agreed between the system owner and fire safety department. Otherwise: - Where no permanent adequate and reliable water supply exists, requirements of NFPA 24 apply. - Accessible fire hydrants shall be provided where public or private water supply is available. Scope of EPC to comply on a project level
4.14	Spill Control	4.14.1 – 4.14.6	N/A. In accordance with Table 9.2 (see NFPA 855), Li-ion batteries do not require spill control.
4.15	Neutralization	4.15.1 – 4.15.3	N/A. In accordance with Table 9.2 (see NFPA 855), Li-ion batteries do not require neutralization.
4.16	Remediation Measures	4.16.1 – Authorized Service Personnel	Authorized service personnel shall be sent on site in case of a fire event, or other possible event that might cause ignition of the energy storage system. All service personnel are Tesla certified.

Chapter 4 - General			
Section	Title	Description	Comments
		4.16.2 – Fire Mitigation Personnel	Upon discretion of the local fire safety department. After a fire event, once the local fire safety personnel have left, the owner of the installation might need to provide fire mitigation personnel on-site (continuous duty) until the damaged energy storage system is removed. To be discussed and agreed-on with the local fire safety department. Scope of Owner.

Chapter 5 – System Interconnections			
Section	Title	Description	Comments
5.1	General requirements	5.1.1 – 5.1.2	All electrical connections and wiring shall be in accordance with NFPA 70, IEEE C2 or local equivalent code. All Tesla industrial energy products are compliant. Scope of EPC.
5.2	Disconnecting Means	Accessible disconnecting means for the EES	In accordance with NFPA 70 or local equivalent code. All Tesla industrial energy products are compliant. Scope of EPC.
5.3	Nonelectrical Systems	5.3.1 – 5.3.7	N/A
5.4	Communication Systems	Communication interconnection	Compliant.
5.5	Support Systems	All connections to and from the EES	National recognized standards and manufacturer's instructions. All Tesla industrial energy products are compliant. Scope of EPC.

Chapter 6 – Commissioning			
Section	Title	Description	Comments
6.1	System Commissioning	6.1.1 – 6.1.2 – Commissioning realization 6.1.3 – Commissioning report 6.1.4 – 6.1.5 – Commissioning plan 6.1.6 – System testing	Compliant. Commissioning realization and testing of all Tesla industrial energy products performed by Tesla. Required commissioning plan and report are provided. Commissioning of external systems is scope of EPC.
6.2	Issues and Resolution Documentation	6.2	-

6.3	Operations and Maintenance Documentation	6.3.1 - 6.3.3	Compliant. All Tesla industrial energy product documentation is provided. Project related documentation is scope of EPC.
6.4	Recommissioning of Existing Systems	6.4.1 - 6.4.4	To be compliant with Section 6.1.

Chapter 7 – Operation and Maintenance			
Section	Title	Description	Comments
7.1	System Operation	7.1.1 – Electric Utilities under NERC Jurisdiction	N/A
		7.1.2 – Documentation	Compliant. Operation documentation is provided for all industrial energy products.
		7.1.3 – SDS for Hazardous Materials	Compliant. SDS available for R134a refrigerant contained within industrial energy products.
		7.1.4 – Documentation for scheduled operational checks	Compliant.
		7.1.5 – Operations record	-
		7.1.6 – Operations record location	-
7.2	System Maintenance	7.2.1 – 7.2.5	Compliant. Maintenance documentation is provided for all industrial energy products. All maintenance is performed by Tesla certified personnel.
7.3	System Testing	7.3.1 – 7.3.2	Compliant.

Chapter 8 – Decommissioning			
Section	Title	Description	Comments
8.1	Decommissioning Plan	8.1.1 – 8.1.3	Scope of Owner. Documentation from Tesla to be provided, if needed.
8.2	Decommissioning Process	8.2.1 – 8.2.2	Scope of Owner
8.3	Decommissioning Report	8.3.1 – 8.3.2	Scope of Owner

Chapter 9 – Electrochemical Energy Storage Systems			
Section	Title	Description	Comments
9.1	Application	9.1.1 – 9.1.2	To be compliant with Chapter 4 – 8.
9.2	General	-	To be compliant with Chapter 4 – 8.
9.3	Thermal Runaway Protection	8.3.1 – 8.3.2	Compliant. Permitted to be part of the battery management system compliant to UL 1973 and UL 9540.
9.4	Safety Caps	-	N/A. In accordance with Table 9.2 (see NFPA 855), Li-ion batteries do not require safety caps.

Revision History

Revision	Date	Description
1.0	August 12, 2022	Initial Revision

Attachment B Emergency Response Guide

MEGAPACK

POWERPACK

Industrial Lithium-Ion Battery Emergency Response Guide

For Tesla Industrial Energy Products including Megapack and Powerpack

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.

This document does not create contractual obligations for Tesla or its affiliates and is provided without warranty of any kind, except to the extent expressly agreed in a contract.

LATEST REVISIONS

Documents are periodically updated. To ensure you have the latest revision of this document, visit the Tesla Partner Portal at *https://partners.tesla.com/*.

ERRORS OR OMISSIONS

To communicate inaccuracies or omissions in this document, reach out to your Tesla representative.

1 Introduction and Scope

This emergency response guide (ERG) serves as a resource for emergency responders and Authorities Having Jurisdiction (AHJs) with regard to safety surrounding Tesla Industrial Energy products. This guide should also be reviewed by customers, site managers, and operators to ensure a clear understanding of potential hazards and the procedures to follow in case of emergencies.

Tesla Industrial Energy products are defined as rechargeable lithium-ion battery energy storage products designed, manufactured, and sold by Tesla, and include all versions of Megapack and Powerpack, collectively referred to in this guide as "Tesla Industrial Energy products," "Tesla Energy products," or "the product" unless otherwise noted. The information and recommendations set forth in this ERG are made in good faith and believed to be accurate as of the date of preparation.

This guide is available in various languages as indicated below. Information in this guide is periodically updated and translations are periodically added. Check the Tesla First Responders Information page at *https://www.tesla.com/firstresponders* for the latest revision of this guide, for ERGs for other Tesla products, and for the latest additional translated versions.

English	*Deutsch*	*Español*	*Français*
עברית	*Italiano*	*日本語*	*한국어*
Nederlands	*简体中文*	*繁體中文*	*Português*
Slovenščina			

2 Company, Contact, & Product Info

2.1 Identification of Company and Contact Information

Table 1. Company and Contact Information

Products	Tesla Industrial Energy products, designed for industrial, utility, or commercial energy applications, and modules and sub-assemblies that can be installed in such products. Descriptions and specific part numbers are listed in *Product Descriptions on page 6*.	
Locations	Headquarters (USA)	1 Tesla Road Austin, TX 78725 USA Tel. No. +1 512-516-8177 (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	Level-14, 15 Blue Street North Sydney NSW, 2060, Australia Tel. No. 1800 686 705 (do not use for emergencies; see below)
	Manufacturer (USA)	1 Tesla Road Austin, TX 78725 USA Tel. No. +1 512-516-8177 (do not use for emergencies; see below)
Emergency Contacts	CHEMTREC (Transportation)	For hazardous materials (or dangerous goods) incidents during transportation such as spill, leak, fire, exposure, or accident, call CHEMTREC, day or night. Contract Number: CCN204273 Within USA and Canada: 1-800-424-9300 Outside USA and Canada: (+international prefix) +1 703-741-5970 (collect calls accepted)
	Tesla Energy Technical Support Contacts	Hotline telephone numbers: • North America (24x7): +1 650-681-6060 • Asia/Australia/New Zealand (24x7): +61 2 432 802 81 • Europe/Middle East/Africa (24x7): +31 2 08 88 53 32 • Japan: +0120 312-441

		• France: +33 173218702 • The Netherlands: +31 208885332 • Slovenia: +38 617778699 • South Africa: +27 213004878 • Switzerland: +41 445155607 • United Kingdom: +44 1628450645

2.2 SDS Information

Safety Data Sheets (SDS) are available for materials in Tesla Energy products. Contact Tesla for a copy of these documents.

Table 2. Thermal Contents

Materials with SDS	Approximate Quantity
Ethylene glycol 50/50 mixture with water	• Powerpack 1: 22 L of 50/50 mixture • Powerpack 2: 26 L of 50/50 mixture • Powerpack Inverter: 11 L of 50/50 mixture • Powerpack Pod module: None • Megapack: 540 L of 50/50 mixture • Megapack battery module: 20 L of 50/50 mixture • Megapack 2: 360 L of 50/50 mixture • Megapack 2 battery module: 20 L of 50/50 mixture • Megapack 2 XL: Up to 400 L of 50/50 mixture • Megapack 2 XL battery module: 20 L of 50/50 mixture
R-134a: 1,1,1,2-Tetrafluoroethane refrigerant	• Powerpack 1, 2: 400 g • Powerpack Pod module: None • Megapack: 7.6 kg • Megapack battery module: None • Megapack 2: 7.6 kg • Megapack 2 battery module: None • Megapack 2 XL: Up to 3.0 kg • Megapack 2 XL battery module: None

2.3 Lithium-Ion Cells

The products contain sealed lithium-ion battery cells (cells). Cells each contain lithium-ion electrodes, which can be composed of:

- Lithium Nickel Cobalt Aluminum Oxide (NCA material), LiNixCoyAlzO2
- Lithium Nickel, Manganese, Cobalt Oxide (NMC material) LiNixMnyCozO2
- Lithium Iron Phosphate (LFP material) LiFePO4

- 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 up to approximately 3.6 V.

2.4 Product Descriptions

Individual lithium-ion cells are connected to form modules. Modules are battery sub-assemblies. These modules are installed into the products. Approximate product specifications are listed below.

2.4.1 Powerpack

Powerpack is Tesla's energy storage system for commercial and industrial use.

> **NOTE:** Images below are indicative representations designed to assist with product identification. Existing product models may vary.

Figure 1. Powerpack: Units and Inverter

1. Powerpack Units (include lithium-ion cells)
2. Powerpack Inverter

Figure 2. Example of a Powerpack Site

Table 3. Approximate Powerpack Specifications

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight	Height	Width	Depth
Powerpack 1 Versions								
1047404-x*y*-z*	POWERPACK (2hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1680 kg (3700 lb)	219 cm (86 in)	97 cm (38 in)	132 cm (52 in)
1060119-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	1665 kg (3670 lb)	219 cm (86 in)	97 cm (38 in)	132 cm (52 in)
1121229-x*y*-z*	POWERPACK (4hr continuous net discharge)	<30 (DC)	450 (DC)	480 (AC)	2160 kg (4765 lb)	219 cm (86 in)	97 cm (38 in)	132 cm (52 in)
** The 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*								
Powerpack 1.5 Version								
1089288-x*y*-z*	POWERPACK 1.5 C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	1622 kg (3575 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)
** The 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*								
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 kg (4765 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight	Height	Width	Depth
1083932-x*y*-z*	POWERPACK 2,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 kg (4765 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)
1490025-x*y*-z*	POWERPACK 2.5,C/4 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 kg (4765 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)
1490026-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 kg (4765 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)
1490027-x*y*-z*	POWERPACK 2.5,C/2 SYSTEM	<30 (DC)	960 (DC)	480 (AC)	2160 kg (4765 lb)	219 cm (86 in)	131 cm (51.5 in)	82 cm (32.5 in)
** The 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*								
Spare Parts								
N/A	POWERPACK POD MODULE	<30 (DC)	960 (DC)	N/A	98 kg (215 lb)	12 cm (5 in)	100 cm (39 ½ in)	75 cm (29 ½ in)

2.4.2 Megapack

Megapack is Tesla's all-in-one utility-scale energy storage system.

> **NOTE:** Images below are indicative representations designed to assist with product identification. Existing product models may vary.

Figure 3. Megapack

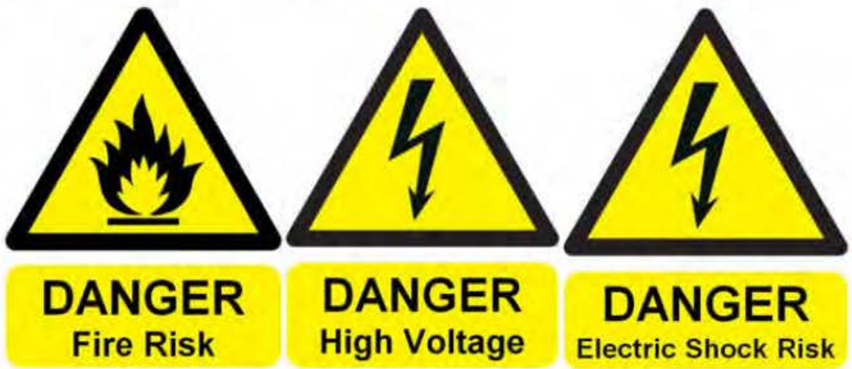
Figure 4. Example of a Megapack Site

Table 4. Approximate Megapack Specifications

Part Number (Reman Number if available)	Description	Module Voltage – as shipped (V)	Max System DC Voltage	Max System AC Voltage	Weight	Height	Width	Depth
Megapack (all versions - dimensions as measured for enclosure envelope for 1462965-x*y*-z*)								
1462965-x*y*-z*	MEGAPACK	<450 (DC)	960 (DC)	518 (AC)	25,400 kg (56,000 lb) (max)	252.2 cm (99 ¼ in)	716.8 cm (282 ¼ in) (length)	165.9 cm (65 ¼ in)
1748844-x*y*-z*	MEGAPACK 2	480 (AC)	<1230 (DC)	480 (AC)	30,500 kg (67,250 lb) (max)	250.6 cm (98 ¾ in)	725.0 cm (285 ½ in) (length)	163.7 cm (64 ½ in)
1848844-x*y*-z*	MEGAPACK 2 XL	480 (AC)	<1230 (DC)	480 (AC)	38,100 kg (84,000 lb) (max)	278.5 cm (110 in)	880 cm (346 ½ in) (length)	165 cm (65 in)
** The 8th or 9th digit could be any number or letter and the 10th digit could be any letter.*								
Spare Parts								
N/A	MEGAPACK BATTERY MODULE	<450 (DC)	960 (DC)	N/A	1,085 kg (2,400 lb)	66 cm (26 in)	81 cm (32 in)	149 cm (59 ½ in)
N/A	MEGAPACK 2 BATTERY MODULE	480 (AC)	<1230 (DC)	480 (AC)	1,250 kg (2,760 lb)	67 cm (26 ½ in)	81 cm (32 in)	149 cm (59 ½ in)
N/A	MEGAPACK 2 XL BATTERY MODULE	480 (AC)	<1230 (DC)	480 (AC)	1,250 kg (2,760 lb)	67 cm (26 ½ in)	81 cm (32 in)	149 cm (59 ½ in)

3 Handling, Use, & Hazard Precautions

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.

The 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 operating temperature range of the product as discussed in *Hazards Associated with Elevated Temperature Exposure on page 13*. 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. The 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 the product enclosure remains closed, handling the product does not pose an electrical hazard. Numerous safeguards have been designed into the product to help ensure that the high voltage battery is kept safe and secure under a number of expected abuse conditions. All of the component battery cells are sealed within the product as sub-groups within enclosures (Pods for Powerpack or battery modules for Megapack), cannot be accessed from the exterior, and are not accessible to non-Tesla personnel.

A high voltage and electrocution risk may present if the product's outer enclosure 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 the 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 product enclosure due to high voltage and electrocution risks.

For proper installation / removal instructions, contact Tesla (*Identification of Company and Contact Information on page 4*).

3.3 Hazards Associated with Elevated Temperature Exposure

This product is designed to withstand operating ambient temperatures up to 50°C (122°F), or as indicated in the product specification, with up to 100% operating humidity (condensing). This product is designed to withstand storage temperatures up to 60°C (140°F), or as indicated in the product specification, and <95% relative humidity (non-condensing) for up to 24 hours without affecting the health of the unit.

Prolonged exposure of the product to conditions beyond these limits may increase the potential of thermal runaway and result in a fire. Exposure of battery packs to localized heat sources such as flames may result in cell thermal runaway reactions and should be avoided.

3.4 Hazards Associated with Mechanical Damage

Mechanical damage to the product can result in a number of hazardous conditions (discussed below) including:

- Leaked battery pack coolant (see *Hazards Associated with Leaked Coolant on page 13*)
- Leaked refrigerant (see *Hazards Associated with Leaked Refrigerant on page 13*)
- Leaked cell electrolyte (see *Hazards Associated with Leaked Electrolyte on page 14*)
- Rapid heating of individual cells due to exothermic reaction of 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 the product, these items should be properly stored when not in use or prior to being installed (see *Storage Precautions on page 21*).

3.5 Hazards Associated with Leaked Coolant

Thermal management of the product 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). The Powerpack Inverter (fully populated) includes about 11 L of coolant. A typical Megapack includes about 540 L of coolant. A typical Megapack 2 includes about 360 L of coolant. Mechanical damage to a product that has been installed could result in leakage of the coolant. The fluid may be blue, green, or orange 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 (see *SDS Information on page 5*).

Extended exposure of the 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

The product's thermal management system includes up to 7.6 kg of R-134a: 1,1,1,2-Tetrafluoroethane refrigerant in a sealed system. Mechanical damage to the product 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 R-134a, as well as ecological effects and disposal considerations, refer to the specific Safety Data Sheet (SDS) for R-134a (see *SDS Information on page 5*).

3.7 Hazards Associated with Leaked Electrolyte

The possibility of an electrolyte spill from the product's cells is very remote for the following reasons:

- Liquid electrolyte is largely absorbed within the cell materials during the manufacturing process. The electrolyte also gets consumed during the normal operation of the batteries.
- The cells are hermetically sealed. Even if a single cell were damaged in a manner that could cause a leak, the volume would be of negligible concern.
- Cells are assembled into enclosed module compartments and inaccessible to personnel. The product architecture prevents any direct contact with the battery cells.

As such, the absence of free liquid electrolyte makes it impractical to report the volume of electrolyte within the product, and the cell and product design prevent the possibility for spills at the project site.

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. Vented gases are a common early indicator of a thermal runaway reaction – an abnormal and hazardous condition.

Regulatory testing has shown that the products of combustion of lithium-ion batteries can include flammable and nonflammable gases. Based on this testing, the flammable gases are found to be below their lower flammable limit (LFL) and do not pose a deflagration or explosion risk to first responders or the general public. The nonflammable gases were found to be comparable to smoke encountered in a Class A structure fire and do not produce any unique, or atypical, gases beyond what you would find in the combustion of modern combustible materials.

In close proximity, 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). 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 In Case of Emergency

WARNING: In case of emergency, severe physical impact, or transportation accident, do not approach the product or open any of its doors.

WARNING: In case of severe physical impact or transportation accident, it may take time before any visible indication of an abnormal and hazardous condition (e.g., smoke or fire) can be observed. Contact Tesla for guidance (*Identification of Company and Contact Information on page 4*).

CAUTION: Response should only be performed by trained professionals.

4.1 During Storage or Operation

During storage or operation, emergencies include but are not limited to:

- Suspicious odor observed near the product
- Smoke or fire emanating from the product
- Severe physical impact on the product

In case of emergency, isolate, deny entry, and perform the following:

1. If possible, and if trained and properly equipped, shut off the unit/system (see *Shutting Down in an Emergency on page 19*).
2. Evacuate the area.
3. If not already present, notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available.
4. Contact Tesla for guidance (*Identification of Company and Contact Information on page 4*).

4.2 During Transportation

During transportation, emergencies include but are not limited to:

- Suspicious odor observed near the product
- Smoke or fire emanating from the product
- Transportation accident causing a severe physical impact on the product
- Transportation accident leading to tipping over of the product

In case of emergency, perform the following:

1. If possible, move the unit/system to an open area and away from exposures (such as buildings, flammable material, or people).
2. Evacuate the area.
3. Notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available.
4. Contact Tesla for guidance (*Identification of Company and Contact Information on page 4*).

5 Firefighting Measures

WARNING: Response should only be performed by professionals trained in high voltage and arc flash emergencies. In the event of a response to a Tesla product fire or hazardous event, contact Tesla for guidance (*Identification of Company and Contact Information on page 4*).

5.1 Firefighter PPE

Firefighters should wear self-contained breathing apparatus (SCBA) and structural firefighting gear. Industry testing has shown that standard structural firefighting gear provides adequate protection.

5.2 Responding to a Venting Product

Smoke or suspicious odor 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. If fire, smoke, or suspicious odor is observed emanating from the product at any time, perform the following:

1. If possible, shut off the unit/system (see *Shutting Down in an Emergency on page 19*).
2. Evacuate the area of all non-emergency personnel.

   WARNING: When responding to a fire event, do not approach the unit and attempt to open any doors. The doors are designed to remain shut.

3. If not already done, contact Tesla Energy Technical Support for assistance (*Identification of Company and Contact Information on page 4*).
4. Maintain a safe distance from the unit and monitor for evidence of continued smoke venting or fire.

   WARNING: There may be periods of up to three hours at a time during which the thermal runaway propagates from battery modules to battery modules. During such time, the battery may not generate visible signs of thermal event although the event can still be active and the battery can flare up.

   a. Complete area size-up and establish water supply.

   b. If a fire has not developed: Position attack lines to protect neighboring exposures and neighboring battery enclosures.

   c. If a fire develops:

      - Allow the affected unit to consume itself as it is designed to do. Applying water to the burning unit will only slow its eventual combustion.
      - If advised by Tesla, use wide-fog stream, at lowest volume possible, to achieve desired cooling of neighboring battery enclosures while maintaining contact with Tesla. If communication cannot be established with Tesla, apply water at the discretion of first responders.

        NOTE: Water has been deemed appropriate for use on Tesla Energy products, thus will not create a hazard while protecting exposures.

      - At the discretion of first responders, apply water to other neighboring exposures.

5. Allow the battery pack to cool down while maintaining contact with Tesla for guidance (this process may take 12-48 hours or longer).

6. Monitor the temperature of the battery pack using a thermal imaging camera to determine if it is safe to interact with the unit.
7. Contact Tesla Energy Technical Support for next steps (*Identification of Company and Contact Information on page 4*).

6 Shutting Down in an Emergency

WARNING: Shutting off power to the 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.

WARNING: In case of flooding, stay out of the water if any part of the product or its wiring is submerged.

To shut the product down in an emergency, perform the appropriate steps below and then contact Tesla (*Identification of Company and Contact Information on page 4*):

6.1 Powerpack System

1. If an external emergency stop (E-Stop) button or remote shutdown contact to the Powerpack is present, engage it.
2. If the Powerpack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.

6.2 Megapack

1. If an external E-Stop button or remote shutdown contact to the Megapack is present, engage it.
2. If the Megapack is serviced upstream by an external AC breaker or disconnect, open the breaker or disconnect.

7 First Aid Measures

7.1 Electric Shock / Electrocution

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

7.2 Contact with Leaked Electrolyte

Battery cells are sealed. Contents of an open (broken) 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, remove all clothing around affected area, 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.

7.3 Inhalation of Electrolyte Vapors

If inhalation of electrolyte vapors occurs, move person into fresh air. If throat irritation is present, seek immediate medical assistance.

7.4 Vent Gas Inhalation

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 signs of respiratory distress are present, seek immediate medical assistance.

8 Storage Precautions

Powerpack systems 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.

Elevated temperatures can result in reduced battery service life. The product can withstand ambient temperatures of -40°C to 60°C (-40ºF to 140ºF) for up to 24 hours. Do not store the product near heating equipment.

Ideally, the product should be stored at 50% state of charge (SOC) or less. The product should not be stored for extended periods either at a full SOC or completely discharged since both conditions adversely impact battery life.

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). The product only has 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 typical Group A plastic commodity.

9 Damaged Product Handling

This section describes the handling, storage, and transportation of damaged products.

If the event of damage to a product, contact Tesla immediately (*Identification of Company and Contact Information on page 4*).

If a product has been damaged (for example, its 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 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 product may be disconnected and moved to a safe location. Contact Tesla (*Identification of Company and Contact Information on page 4*) to obtain specific instructions for evaluating, disconnecting, and preparing a damaged product for transport.

A damaged 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 (15 m) downwind of occupied structures. For example, a fenced, open yard may be an appropriate safe location. Do not store damaged products adjacent to undamaged products. It is possible that a damaged product may sustain further damage during transportation and may lead to a fire. To further reduce this risk, handle the damaged product with extreme caution.

10 Disposal Procedures

For disposal after a fire or thermal event, contact Tesla for guidance (*Identification of Company and Contact Information on page 4*).

In most cases, the product can be recycled. Contact Tesla to return the product to a Tesla facility for disassembly and further processing. If disposing of the product without returning it to Tesla, consult with local, state and/or federal authorities on the appropriate methods for disposal and recycling of lithium-ion batteries. Note that the products do not contain heavy metals such as lead, cadmium, or mercury.

11 Maintenance or Repair

Tesla requests all maintenance, service, and repairs of the product be performed by Tesla-approved service personnel or Tesla-authorized repair facilities. This includes all proactive and corrective maintenance over the lifetime of the 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 product, and potentially result in development of an unsafe condition and unexpected electrical events.

12 Transportation

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 in how to properly package, label, mark and prepare shipping documents.

NOTE: Transportation regulations vary by region. To ensure compliant transportation, always refer to local regulations as applicable.

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

Revision History

Revision	Date	Description
2.6	November 11, 2022	• Decoupled Powerwall information, now focusing on Industrial Energy products (including Megapack and Powerpack). Visit *https://tesla.com/firstresponders* for all versions. • Deleted trademarked brand name from *Firefighting Measures on page 17* • Improved language in *Hazards Associated with Vented Electrolyte on page 14* • Improved language in *Hazards Associated with Elevated Temperature Exposure on page 13* • Simplified language in *Hazards Associated with Leaked Electrolyte on page 14* • Simplified language in *Disposal Procedures on page 23* • Improved overall hazard and firefighting recommendations (*Firefighting Measures on page 17*) • Improved first aid recommendations (*First Aid Measures on page 20*) • Updated Tesla headquarters address (*Identification of Company and Contact Information on page 4*) • Modified SDS language to reflect latest guidance (*SDS Information on page 5*) • Clarified refrigerant volume (*Hazards Associated with Leaked Refrigerant on page 13*)
2.5	May 23, 2022	• Added Megapack 2 XL (*SDS Information on page 5*, *Product Descriptions on page 6*)
2.4	February 16, 2022	• Enhanced firefighting guidance regarding neighboring battery enclosures (*Firefighting Measures on page 17*) • Clarified products of combustion (*Firefighter PPE on page 17*) • Added Powerwall+ and Megapack 2 information. • Provided reference to safety data sheet specific to Australia/New Zealand (*SDS Information on page 5*) • Amended that coolant color can be blue, green, or orange (*Hazards Associated with Leaked Coolant on page 13*) • Added links and QR codes to download this guide in additional languages (*Introduction and Scope on page 2*) • Updated contact information (*Identification of Company and Contact Information on page 4*), including: Tesla headquarters, Powerwall North America hotline, Megapack and Powerpack Japan technical support
2.3	July 28, 2021	• Added coolant volume for separately shipped Megapack battery modules (*SDS Information on page 5*) • Clarified firefighting guidance (*Firefighting Measures on page 17*)

Revision	Date	Description
		• Enhanced product identification information (*Product Descriptions on page 6*) • Simplified emergency shut-down procedures for Megapack and Powerpack (*Shutting Down in an Emergency on page 19*)
2.2	June 23, 2021	• Updated contact information in *Identification of Company and Contact Information on page 4* • Updated specs according to updated products in *SDS Information on page 5* • Added Powerwall part numbers to *SDS Information on page 5* • Enhanced firefighting guidance: *Firefighting Measures on page 17* • Added guidance in case of emergency: *In Case of Emergency on page 15* • Added additional early signs of thermal runaway: *Hazards Associated with Vented Electrolyte on page 14* • Updated Powerwall instructions in *Shutting Down in an Emergency on page 19*
2.1	August 28, 2020	Added spare parts specifications: • Megapack battery module • Powerpack Pod module
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
1.8	March 11, 2020	Fixed footer; fixed styles.
07	17-Dec-2019	Updates to contact information (Tesla contact), product specs section, leaked electrolyte section, and inclusion of Megapack throughout the document.
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.
05	22-Oct 2018	Reformatted for ease of use and translation; removed Confidential status; corrected phone number for CHEMTREC
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
03	3-Oct-2016	Added part numbers, minor edits

Revision	Date	Description
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.
01	14-July-2015	ERG for Tesla Powerpack systems, Powerwalls, and Sub-assemblies

TESLA

Attachment C Calculations and Modeling Results

Tesla Battery System

Toxic Emission Calcs LFP, Based on Fisher January 2023 Report

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)	Full MP2XL Rate (g/s)	Full MP2XL Rate (lbs/hr)
Primary Compounds										
H2	50.148	48.7	2.0	4.0	0.0011	0.0088	0.3721	2.9535	2.5518	20.2525
CO	10.881	10.6	28.0	13.2	0.0037	0.0291	1.2339	9.7929	8.4611	67.1513
CO2	27.107	26.3	44.0	51.8	0.0144	0.1141	4.8305	38.3370	33.1232	262.8826
CH4	6.428	6.2	16.0	4.5	0.0012	0.0098	0.4165	3.3058	2.8562	22.6685
C2H2, C2H4	3.547	3.4	28.1	4.3	0.0012	0.0095	0.4037	3.2037	2.7680	21.9682
C2H6	1.1	1.1	30.1	1.4	0.0004	0.0032	0.1341	1.0643	0.9195	7.2977
C3H6	0.434	0.4	42.1	0.8	0.0002	0.0017	0.0740	0.5873	0.5074	4.0272
C3H8	0.125	0.1	44.1	0.2	0.0001	0.0005	0.0223	0.1772	0.1531	1.2150
C4	0.194	0.2	58.1	0.5	0.0001	0.0011	0.0456	0.3623	0.3130	2.4843
C5	0.032	0.0	72.2	0.1	0.0000	0.0002	0.0094	0.0743	0.0642	0.5092
Total	100.0	97.2	18.7	80.8	0.0224	0.1781	7.5421	59.8582	51.7175	410.4565
Trace compounds	**ppm**	**MW**								
Benzene	2000	78.1		6.7E-01	1.9E-04	1.5E-03	6.3E-02	5.0E-01	4.3E-01	3.4E+00
Toluene	2000	92.1		8.0E-01	2.2E-04	1.8E-03	7.4E-02	5.9E-01	5.1E-01	4.0E+00
HF	145	20.0		1.3E-02	3.5E-06	2.8E-05	1.2E-03	9.3E-03	8.0E-03	6.4E-02

Assumes: Atmospheric Normal Temperature and Pressure (298.15K and 100.3 kpa)

Vol % and total volume provided by Tesla manufacturer from Cell Level testing

Standard temperature and pressure (STP) is defined as 0°C (273.15 K) and 1 atm of pressure

Number of cells in multicell event	336	One module
Time of event (cell and module), minutes	60	1 hour
Number of cells in MP2XL	8064	
Time of MP2XL event, minutes	210	3.5 hrs, same as MP1 Unit Level Test

Toxics and compounds based on cell level testing, UL9540A

HF based on other LFP studies (Larson 2017)

Benzene and toluene based on tesla cell level testing, Fisher January 2023 report

Battery Malfunction Flammability Analysis: Tesla LFP Cell
CGA P-23 Method

Component	Mole %	MW	Wt %	LEL	NFN2: Non-Flamm in Nitrogen*	Mole% x NFN2	Mole Frac/LFL
H2	50.148	2	5.35	4.0	5.7	8.80	12.54
N2	0	28	0.00	-			0.00
CO2	27.107	44	63.60	-			0.00
CO	10.881	28	16.25	12.5	20	0.54	0.87
Ch4	6.428	16	5.48	5	14.3	0.45	1.29
C2	4.647	30	7.43	3	12	0.39	1.55
C3	0.504	44	1.18	2.1	6.5	0.08	0.24
C4	0.19	58	0.59	1.8	5.6	0.03	0.11
C5+	0.032	72	0.12	1.4	4.4	0.01	0.02
Total	100	18.8	100		Q factor =	10.30	
Frac flamm	72.83		36.40		LFL =		6.02

* From CGA P-23 Table 1
LFL estimated based on Le Chatelier’s formula

Case Inputs

```
Case Type            : Vapor Dispersion
Case Name            : MegaPack2XL-B-1Flamm
User ID              : GC
Project Number       :
Type of Units        : English Units

  NOTES:

MATERIAL MENU
Materials Released   : Number  Formula   Name                         Fraction
Component  1         :    51 = H2        Hydrogen                     0.501500
Component  2         :    43 = CO        Carbon Monoxide              0.108814
Component  3         :     1 = CH4       Methane                      0.064283
Component  4         :     2 = C2H6      Ethane                       0.046472
Component  5         :     3 = C3H8      Propane                      0.005590
Component  6         :     4 = C4H10     Isobutane                    0.001940
Component  7         :     6 = C5H12     Isopentane                   0.000320
Component  8         :    17 = CO2       Carbon Dioxide               0.271081
Component  9         :
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
Release duration                                60 min
Regulated flow rate                           0.11 lb/sec
Pipe inner diameter                          12.00 inches
Equivalent release diameter                  12.00 inches
Height of release point                        9.2 feet
Angle of release from horizontal              90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor dispersion - Flammable endpoints
  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 endpoints
  Overpressure endpoint 1                     3.00 psi
  Overpressure endpoint 2                     1.00 psi
  Overpressure endpoint 3                     1.00 psi

  NOTES:
```

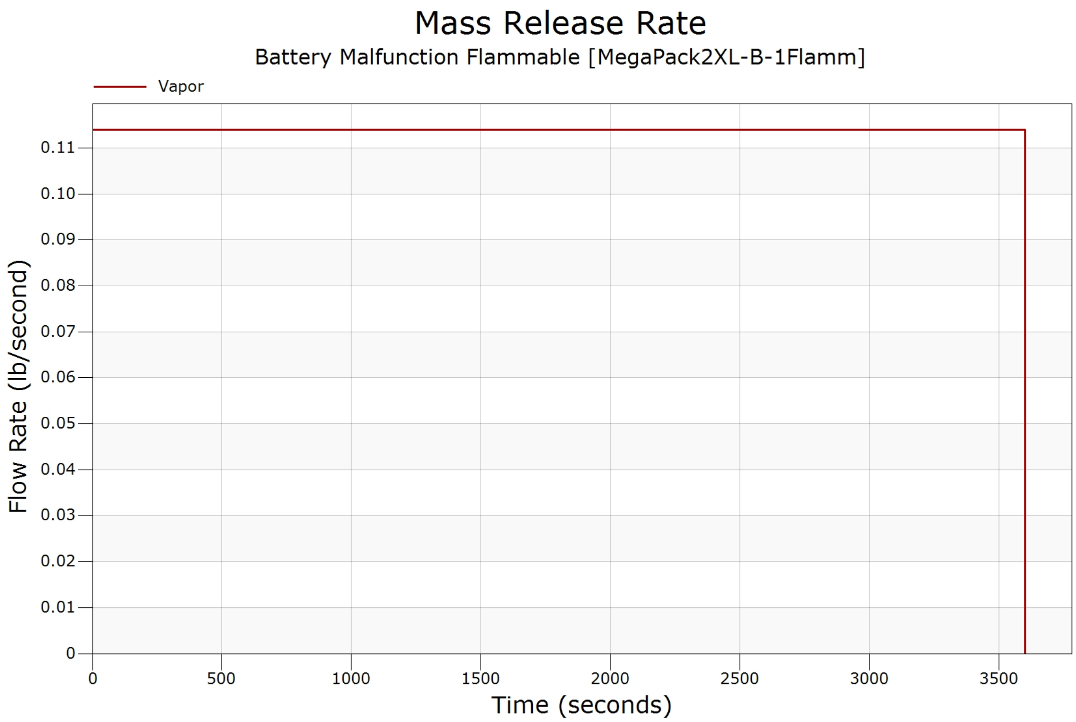
Release Model

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	.1140000	0.000000	0.000000	.1140000
0.1000000	.1140000	0.000000	0.000000	.1140000
0.3000000	.1140000	0.000000	0.000000	.1140000
0.5000000	.1140000	0.000000	0.000000	.1140000
0.7000000	.1140000	0.000000	0.000000	.1140000
1.000000	.1140000	0.000000	0.000000	.1140000
3.000000	.1140000	0.000000	0.000000	.1140000
5.000000	.1140000	0.000000	0.000000	.1140000
7.000000	.1140000	0.000000	0.000000	.1140000
10.00000	.1140000	0.000000	0.000000	.1140000
20.00000	.1140000	0.000000	0.000000	.1140000
30.00000	.1140000	0.000000	0.000000	.1140000
40.00000	.1140000	0.000000	0.000000	.1140000
50.00000	.1140000	0.000000	0.000000	.1140000
60.00000	.1140000	0.000000	0.000000	.1140000
70.00000	.1140000	0.000000	0.000000	.1140000
85.00000	.1140000	0.000000	0.000000	.1140000
100.0000	.1140000	0.000000	0.000000	.1140000
200.0000	.1140000	0.000000	0.000000	.1140000
300.0000	.1140000	0.000000	0.000000	.1140000
400.0000	.1140000	0.000000	0.000000	.1140000
500.0000	.1140000	0.000000	0.000000	.1140000
600.0000	.1140000	0.000000	0.000000	.1140000
700.0000	.1140000	0.000000	0.000000	.1140000
850.0000	.1140000	0.000000	0.000000	.1140000
1000.000	.1140000	0.000000	0.000000	.1140000
2000.000	.1140000	0.000000	0.000000	.1140000
3000.000	.1140000	0.000000	0.000000	.1140000
3600.000	.1140000	0.000000	0.000000	.1140000
Totals (lb)	410.4000	0.000000	0.000000	410.4000

Flowrate for Jet Fire [1st minute] = 0.1140000 lb/sec.
Jet Fire [2-3 minutes] = 0.1140000 lb/sec.

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction Flammable [MegaPack2XL-B-1Flamm]
Vapor
Flow Rate (lb/second)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

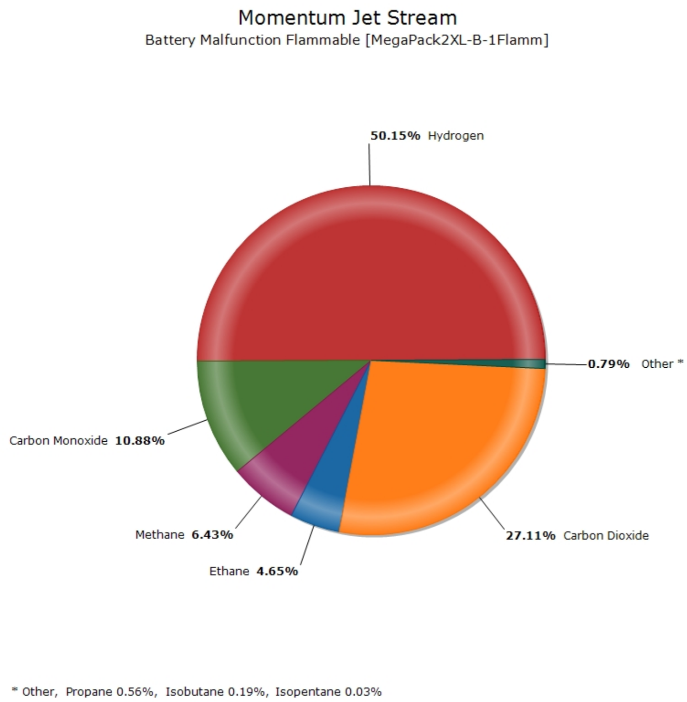
Component Number	Component Name, Formula
51	Hydrogen, H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
4	Isobutane, C4H10
6	Isopentane, C5H12
17	Carbon Dioxide, CO2

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	0.501500	0.501500	0.000000	0.000000	0.501500	0.000000
43	0.108814	0.108814	0.000000	0.000000	0.108814	0.000000
1	0.064283	0.064283	0.000000	0.000000	0.064283	0.000000
2	0.046472	0.046472	0.000000	0.000000	0.046472	0.000000
3	0.005590	0.005590	0.000000	0.000000	0.005590	0.000000
4	0.001940	0.001940	0.000000	0.000000	0.001940	0.000000
6	0.000320	0.000320	0.000000	0.000000	0.000320	0.000000
17	0.271081	0.271081	0.000000	0.000000	0.271081	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	6.01	6.01	
UFL	45.69	45.69	
LBV		0.59 m/s	


Momentum Jet Stream
Battery Malfunction Flammable [MegaPack2XL-B-1Flamm]
50.15% Hydrogen
0.79% Other *
Carbon Monoxide 10.88%
Methane 6.43%
Ethane 4.65%
27.11% Carbon Dioxide
* Other, Propane 0.56%, Isobutane 0.19%, Isopentane 0.03%

Momentum Jet Dispersion

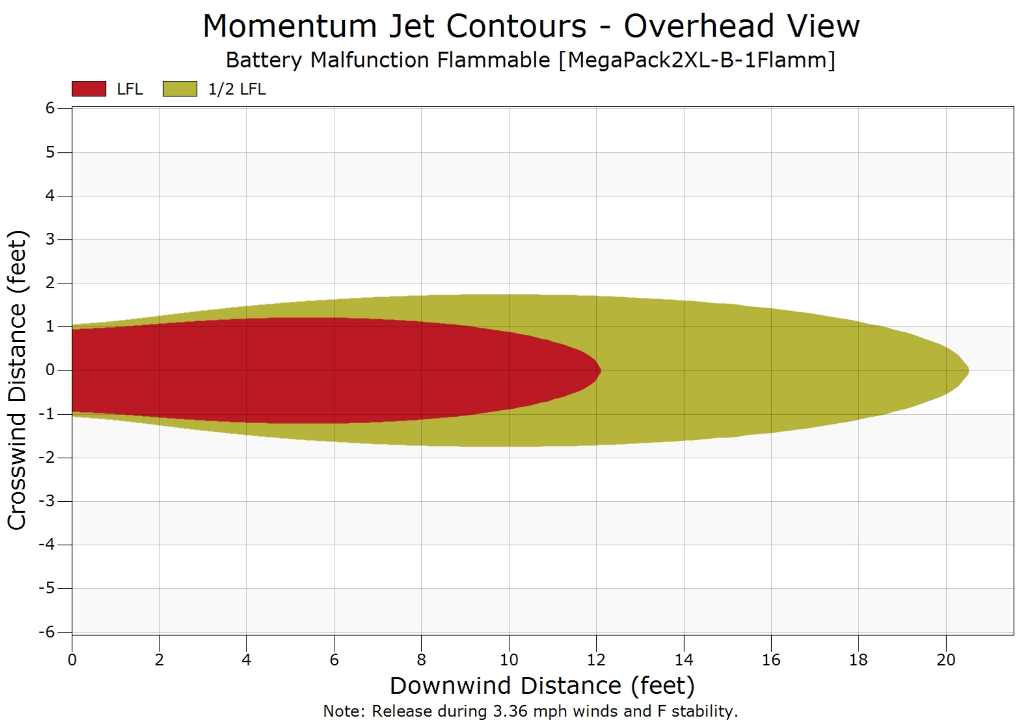
concentration limits

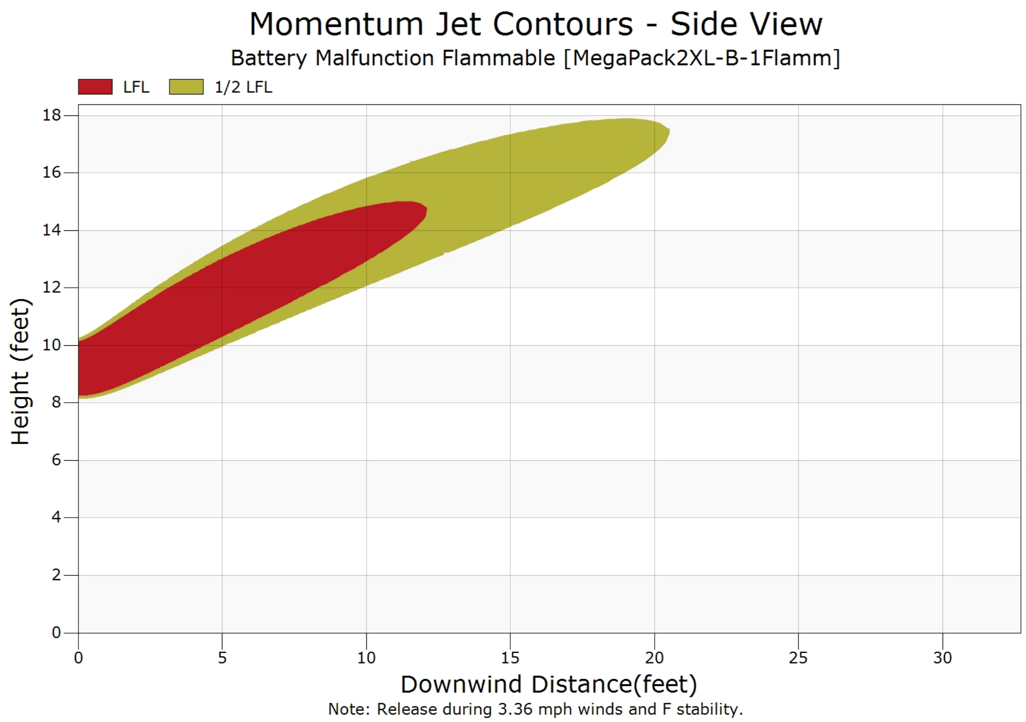
Endpoint 1 (highest) = 0.060098 mole fraction
Endpoint 2 (middle) = 0.030049 mole fraction
Endpoint 3 (lowest) = 0.030049 mole fraction

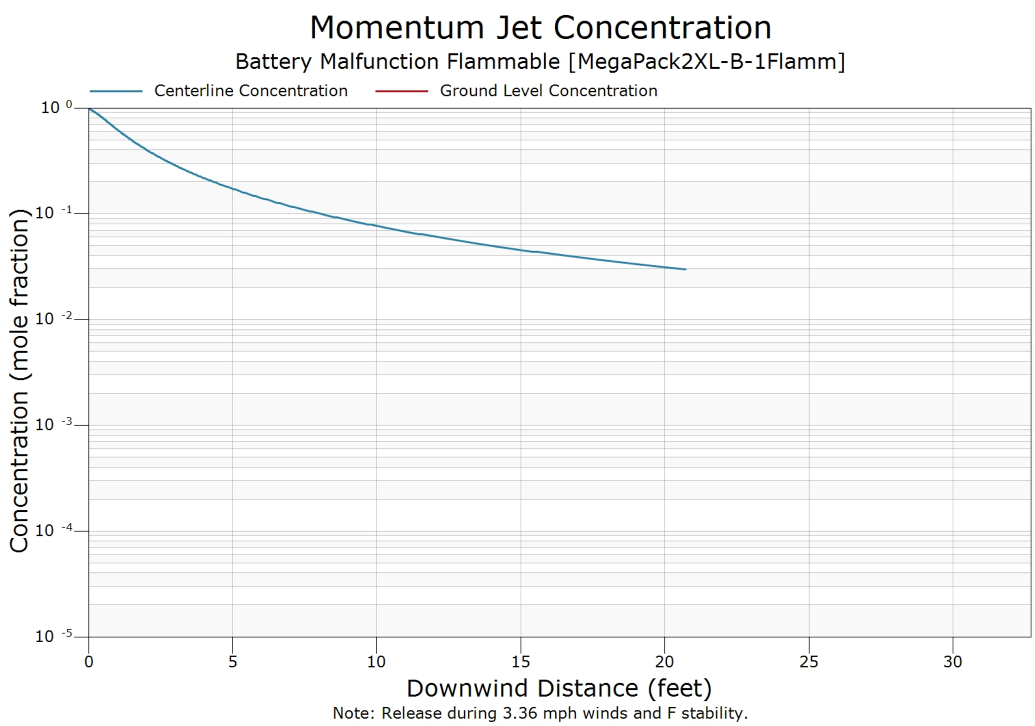
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	1.1	1.1	0.9	9.2
0.5	0.801012	0.000000	1.1	1.1	1.0	9.3
1.0	0.622901	0.000000	1.1	1.1	1.0	9.5
1.5	0.494700	0.000000	1.2	1.2	1.0	9.7
2.0	0.403747	0.000000	1.3	1.3	1.1	10.0
2.5	0.337367	0.000000	1.3	1.3	1.1	10.3
3.0	0.287253	0.000000	1.4	1.4	1.1	10.6
3.5	0.248409	0.000000	1.4	1.4	1.2	10.9
4.0	0.217557	0.000000	1.5	1.5	1.2	11.1
4.5	0.192659	0.000000	1.5	1.5	1.2	11.4
5.0	0.172282	0.000000	1.6	1.6	1.2	11.7
5.5	0.155103	0.000000	1.6	1.6	1.2	11.9
6.0	0.140687	0.000000	1.6	1.6	1.2	12.2
6.5	0.128426	0.000000	1.7	1.7	1.2	12.4
7.0	0.117801	0.000000	1.7	1.7	1.2	12.6
7.5	0.108613	0.000000	1.7	1.7	1.2	12.9
8.0	0.100602	0.000000	1.7	1.7	1.1	13.1
8.5	0.093468	0.000000	1.7	1.7	1.1	13.3
9.0	0.087151	0.000000	1.7	1.7	1.0	13.5
9.5	0.081536	0.000000	1.7	1.7	1.0	13.7
10.0	0.076486	0.000000	1.7	1.7	0.9	14.0
10.5	0.071977	0.000000	1.7	1.7	0.8	14.2
11.0	0.067883	0.000000	1.7	1.7	0.7	14.4
11.5	0.064183	0.000000	1.7	1.7	0.5	14.5
12.0	0.060780	0.000000	1.7	1.7	0.2	14.7
12.5	0.057697	0.000000	1.7	1.7	0.0	14.9
13.0	0.054835	0.000000	1.7	1.7	0.0	15.1
13.5	0.052233	0.000000	1.6	1.6	0.0	15.3
14.0	0.049818	0.000000	1.6	1.6	0.0	15.5
14.5	0.047604	0.000000	1.6	1.6	0.0	15.6
15.0	0.045540	0.000000	1.5	1.5	0.0	15.8
15.5	0.043630	0.000000	1.5	1.5	0.0	16.0
16.0	0.041852	0.000000	1.4	1.4	0.0	16.1
16.5	0.040186	0.000000	1.4	1.4	0.0	16.3
17.0	0.038634	0.000000	1.3	1.3	0.0	16.4

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	0.037186	0.000000	1.2	1.2	0.0	16.6
18.0	0.035804	0.000000	1.1	1.1	0.0	16.7
18.5	0.034519	0.000000	1.0	1.0	0.0	16.9
19.0	0.033313	0.000000	0.9	0.9	0.0	17.0
19.5	0.032166	0.000000	0.7	0.7	0.0	17.2
20.0	0.031095	0.000000	0.5	0.5	0.0	17.3
20.5	0.030080	0.000000	0.1	0.1	0.0	17.5

Endpoint (mole frac., mixture)	Downwind Distance (feet)	Approximate Time (seconds)
1 0.060098 (LFL)	12.1	3
2 0.030049 (1/2 LFL)	20.5	5
3 0.030049 (1/2 LFL)	20.5	5




Momentum Jet Contours - Side View
Battery Malfunction Flammable [MegaPack2XL-B-1Flamm]
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 Flammable [MegaPack2XL-B-1Flamm]
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.

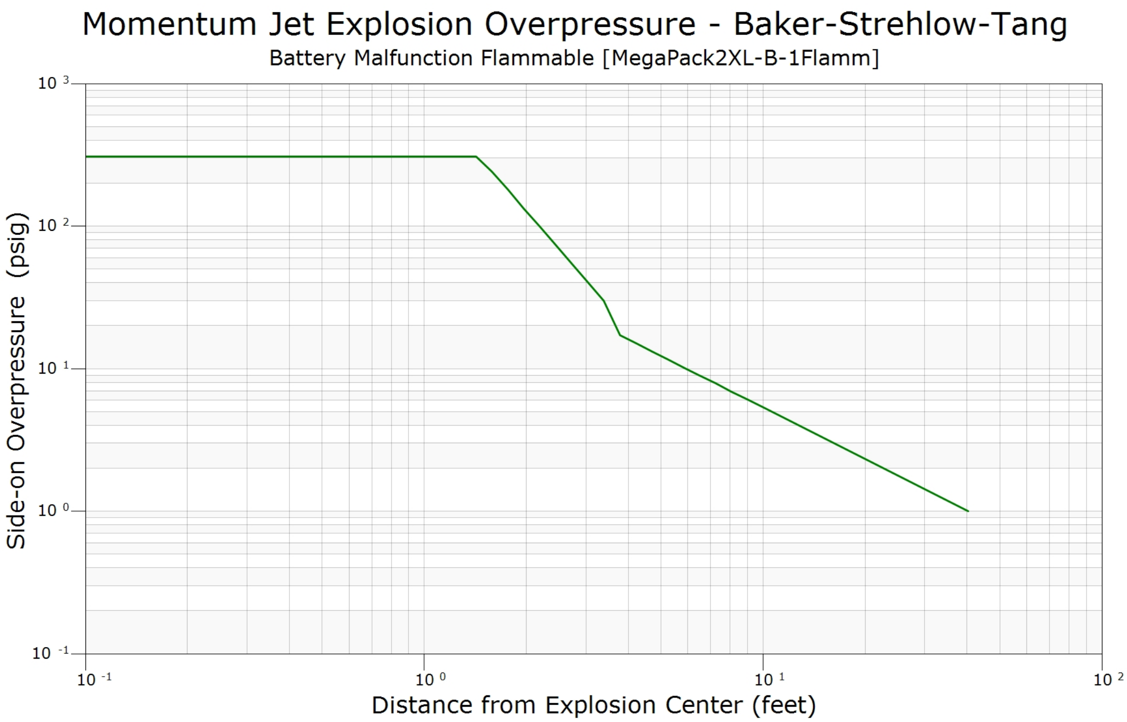
Momentum Jet Explosion

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

Mass of released material involved in explosion: 0.324903 lbs.

Distance from Center of Flammable Cloud (feet)	Overpressure (psi gauge)	Impulse (psi-s)
0.0	308.61	0.0352
0.9	308.61	0.0352
1.0	308.61	0.0316
1.1	308.61	0.0284
1.3	308.61	0.0256
1.4	308.61	0.0230
1.6	241.22	0.0207
1.8	179.05	0.0186
2.0	132.90	0.0167
2.2	98.65	0.0150
2.4	73.22	0.0135
2.7	54.35	0.0122
3.0	40.34	0.0109
3.4	29.95	0.0098
3.8	17.18	0.0088
4.2	15.08	0.0080
4.7	13.24	0.0072
5.2	11.63	0.0064
5.8	10.21	0.0058
6.5	8.97	0.0052
7.2	7.87	0.0047
8.1	6.91	0.0042
9.0	6.07	0.0038
10.0	5.33	0.0034
40.4	1.00	0.0009

The downwind distance to 3.00 psi is 26.3 feet
The downwind distance to 1.00 psi is 40.4 feet
The downwind distance to 1.00 psi is 40.4 feet


Momentum Jet Explosion Overpressure - Baker-Strehlow-Tang
Battery Malfunction Flammable [MegaPack2XL-B-1Flamm]
Side-on Overpressure (psig)
Distance from Explosion Center (feet)
10 3
10 2
10 1
10 0
10 -1
10 -1
10 0
10 1
10 2

Case Inputs

Case Type : Vapor Dispersion
Case Name : MegaPack2XL-B-1toxicBenz
User ID : GC
Project Number :
Type of Units : English Units

NOTES:

MATERIAL MENU

Materials Released	Number	Formula	Name	Fraction
Component 1	51	= H_2	Hydrogen	0.499430
Component 2	43	= CO	Carbon Monoxide	0.108365
Component 3	1	= CH_4	Methane	0.064017
Component 4	2	= C_2H_6	Ethane	0.046280
Component 5	3	= C_3H_8	Propane	0.005567
Component 6	4	= C_4H_{10}	Isobutane	0.002251
Component 7	17	= CO_2	Carbon Dioxide	0.269962
Component 8	266	= C_6H_6	Benzene	0.001992
Component 9	281	= C_7H_8	Toluene	0.001992
Component 10	50	= HF	Hydrogen Fluoride	0.000144

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
Release duration                                   60 min
Regulated flow rate                              0.11 lb/sec
Pipe inner diameter                             12.00 inches
Equivalent release diameter                     12.00 inches
Height of release point                           9.2 feet
Angle of release from horizontal                 90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic endpoints
Tracking component  266 = C6H6      Benzene
  Concentration endpoint 1                     1000.0 ppm
  Concentration endpoint 2                      500.0 ppm
  Concentration endpoint 3                      150.0 ppm
Dispersion coefficient averaging time              30 min


  NOTES:
```

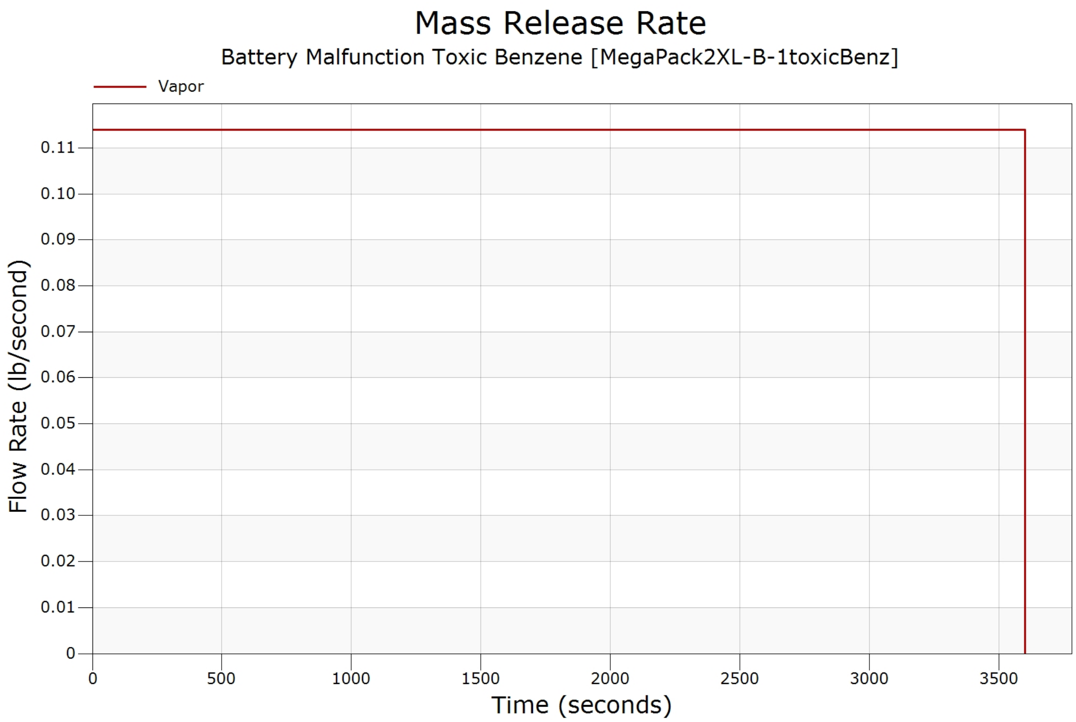
Release Model

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	.1140000	0.000000	0.000000	.1140000
0.1000000	.1140000	0.000000	0.000000	.1140000
0.3000000	.1140000	0.000000	0.000000	.1140000
0.5000000	.1140000	0.000000	0.000000	.1140000
0.7000000	.1140000	0.000000	0.000000	.1140000
1.000000	.1140000	0.000000	0.000000	.1140000
3.000000	.1140000	0.000000	0.000000	.1140000
5.000000	.1140000	0.000000	0.000000	.1140000
7.000000	.1140000	0.000000	0.000000	.1140000
10.00000	.1140000	0.000000	0.000000	.1140000
20.00000	.1140000	0.000000	0.000000	.1140000
30.00000	.1140000	0.000000	0.000000	.1140000
40.00000	.1140000	0.000000	0.000000	.1140000
50.00000	.1140000	0.000000	0.000000	.1140000
60.00000	.1140000	0.000000	0.000000	.1140000
70.00000	.1140000	0.000000	0.000000	.1140000
85.00000	.1140000	0.000000	0.000000	.1140000
100.0000	.1140000	0.000000	0.000000	.1140000
200.0000	.1140000	0.000000	0.000000	.1140000
300.0000	.1140000	0.000000	0.000000	.1140000
400.0000	.1140000	0.000000	0.000000	.1140000
500.0000	.1140000	0.000000	0.000000	.1140000
600.0000	.1140000	0.000000	0.000000	.1140000
700.0000	.1140000	0.000000	0.000000	.1140000
850.0000	.1140000	0.000000	0.000000	.1140000
1000.000	.1140000	0.000000	0.000000	.1140000
2000.000	.1140000	0.000000	0.000000	.1140000
3000.000	.1140000	0.000000	0.000000	.1140000
3600.000	.1140000	0.000000	0.000000	.1140000
Totals (lb)	410.4000	0.000000	0.000000	410.4000

Flowrate for Immediate Jet [1st minute] = 0.1140000 lb/sec.
Delayed Jet [2-3 minutes] = 0.1140000 lb/sec.

Reason for Ending: Reached Stop Time

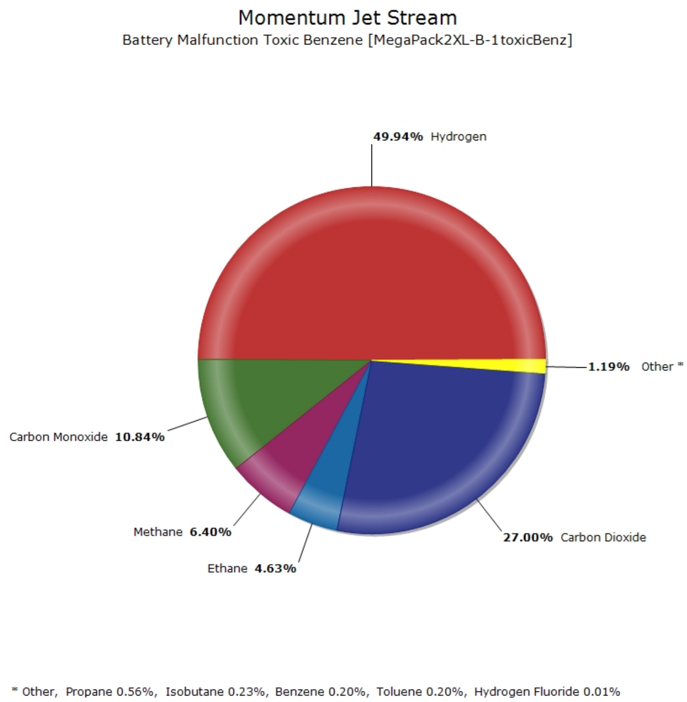

Mass Release Rate
Battery Malfunction Toxic Benzene [MegaPack2XL-B-1toxicBenz]
Vapor
Flow Rate (lb/second)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen, H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
4	Isobutane, C4H10
17	Carbon Dioxide, CO2
266	Benzene, C6H6
281	Toluene, C7H8
50	Hydrogen Fluoride, HF

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	0.499430	0.499430	0.000000	0.000000	0.499430	0.000000
43	0.108365	0.108365	0.000000	0.000000	0.108365	0.000000
1	0.064017	0.064017	0.000000	0.000000	0.064017	0.000000
2	0.046280	0.046280	0.000000	0.000000	0.046280	0.000000
3	0.005567	0.005567	0.000000	0.000000	0.005567	0.000000
4	0.002251	0.002251	0.000000	0.000000	0.002251	0.000000
17	0.269962	0.269962	0.000000	0.000000	0.269962	0.000000
266	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
281	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
50	0.000144	0.000144	0.000000	0.000000	0.000144	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000


Momentum Jet Stream
Battery Malfunction Toxic Benzene [MegaPack2XL-B-1toxicBenz]
49.94% Hydrogen
1.19% Other *
Carbon Monoxide 10.84%
Methane 6.40%
Ethane 4.63%
27.00% Carbon Dioxide
* Other, Propane 0.56%, Isobutane 0.23%, Benzene 0.20%, Toluene 0.20%, Hydrogen Fluoride 0.01%

Momentum Jet Dispersion

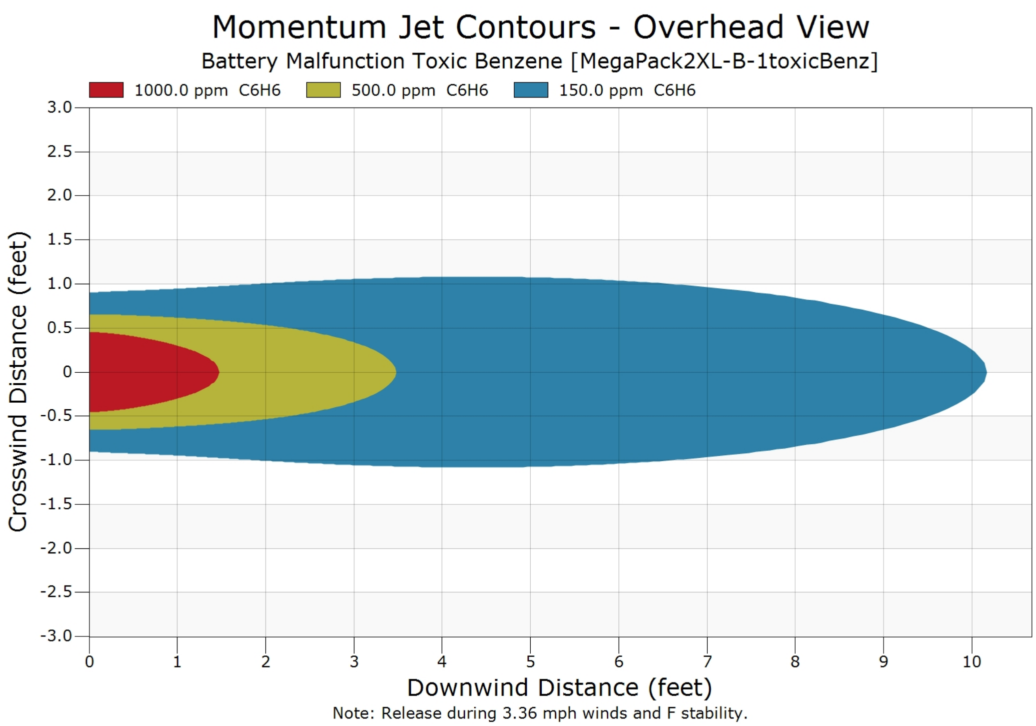
concentration limits

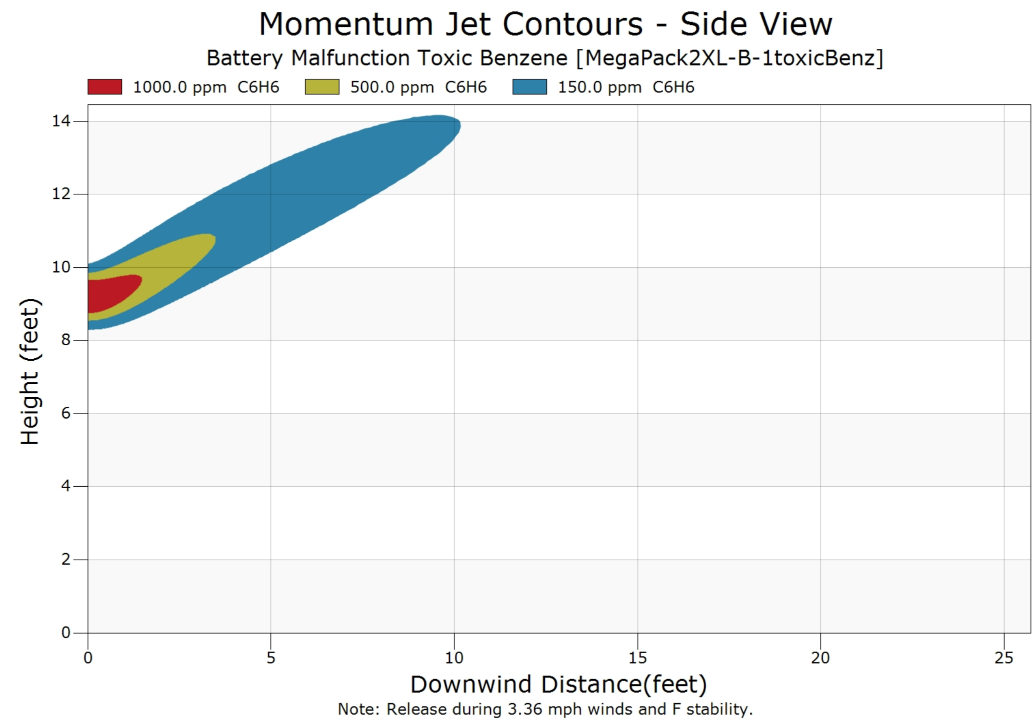
Endpoint 1 (highest) = 1000.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 150.0 ppm

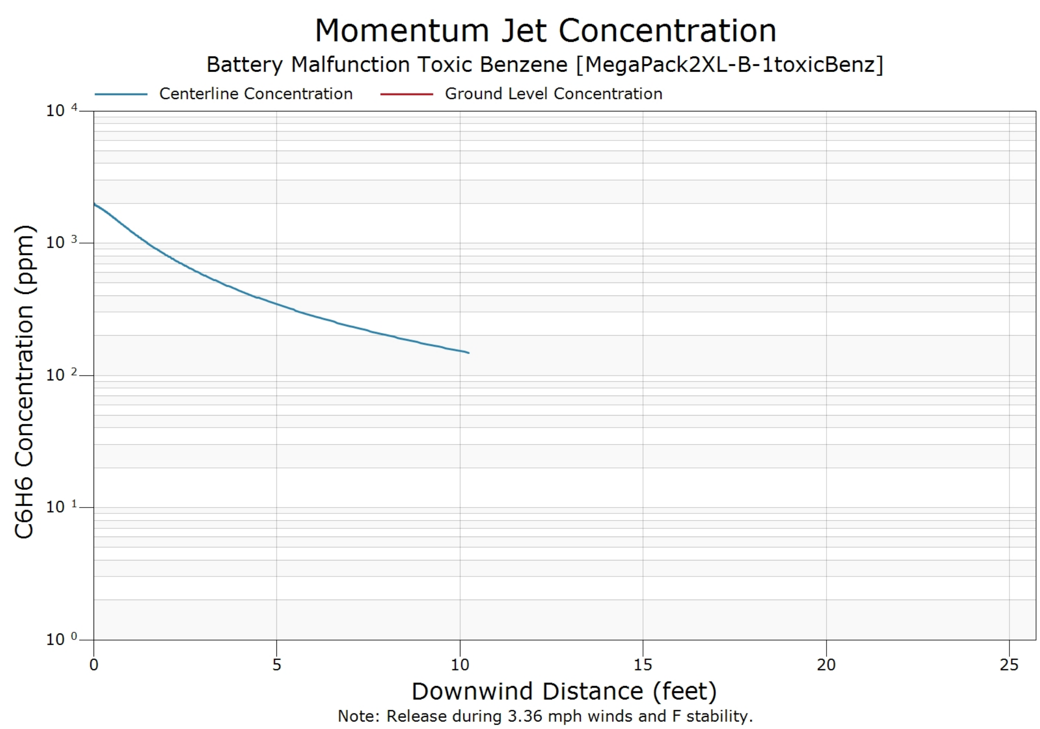
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1991.820	0.000	0.9	0.7	0.5	9.2
0.2	1797.569	0.000	0.9	0.7	0.4	9.2
0.5	1597.885	0.000	0.9	0.6	0.4	9.3
0.8	1408.314	0.000	0.9	0.6	0.4	9.4
1.0	1244.053	0.000	0.9	0.6	0.3	9.5
1.2	1106.052	0.000	1.0	0.6	0.2	9.6
1.5	989.019	0.000	1.0	0.6	0.0	9.7
1.7	891.045	0.000	1.0	0.6	0.0	9.9
2.0	807.881	0.000	1.0	0.5	0.0	10.0
2.2	736.424	0.000	1.0	0.5	0.0	10.1
2.5	675.156	0.000	1.0	0.5	0.0	10.3
2.8	621.508	0.000	1.0	0.4	0.0	10.4
3.0	574.724	0.000	1.1	0.3	0.0	10.6
3.2	533.675	0.000	1.1	0.2	0.0	10.7
3.5	497.249	0.000	1.1	0.0	0.0	10.8
3.7	464.487	0.000	1.1	0.0	0.0	11.0
4.0	435.351	0.000	1.1	0.0	0.0	11.1
4.2	409.348	0.000	1.1	0.0	0.0	11.2
4.5	385.718	0.000	1.1	0.0	0.0	11.4
4.8	364.181	0.000	1.1	0.0	0.0	11.5
5.0	344.773	0.000	1.1	0.0	0.0	11.6
5.2	326.770	0.000	1.1	0.0	0.0	11.8
5.5	310.482	0.000	1.1	0.0	0.0	11.9
5.8	295.497	0.000	1.1	0.0	0.0	12.0
6.0	281.739	0.000	1.0	0.0	0.0	12.1
6.2	268.846	0.000	1.0	0.0	0.0	12.3
6.5	257.148	0.000	1.0	0.0	0.0	12.4
6.8	245.950	0.000	1.0	0.0	0.0	12.5
7.0	235.781	0.000	1.0	0.0	0.0	12.6
7.2	226.302	0.000	0.9	0.0	0.0	12.7
7.5	217.457	0.000	0.9	0.0	0.0	12.8
7.8	209.085	0.000	0.9	0.0	0.0	12.9
8.0	201.365	0.000	0.8	0.0	0.0	13.1
8.2	194.015	0.000	0.8	0.0	0.0	13.2
8.5	187.059	0.000	0.8	0.0	0.0	13.3

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)
8.8	180.599	0.000	0.7	0.0	0.0	13.4
9.0	174.445	0.000	0.7	0.0	0.0	13.5
9.2	168.720	0.000	0.6	0.0	0.0	13.6
9.5	163.220	0.000	0.5	0.0	0.0	13.7
9.8	158.012	0.000	0.4	0.0	0.0	13.8
10.0	153.111	0.000	0.3	0.0	0.0	13.9

Endpoint (ppm, C6H6)		Downwind Distance (feet)	Approximate Time (seconds)
1	1000.0	1.5	0
2	500.0	3.5	1
3	150.0	10.2	2




Momentum Jet Contours - Side View
Battery Malfunction Toxic Benzene [MegaPack2XL-B-1toxicBenz]
1000.0 ppm C6H6
500.0 ppm C6H6
150.0 ppm C6H6
Height (feet)
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction Toxic Benzene [MegaPack2XL-B-1toxicBenz]
Centerline Concentration
Ground Level Concentration
C6H6 Concentration (ppm)
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

Case Type	: Vapor Dispersion
Case Name	: MegaPack2XL-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	0.499430
Component 2	: 43 =	CO	Carbon Monoxide	0.108365
Component 3	: 1 =	CH4	Methane	0.064017
Component 4	: 2 =	C2H6	Ethane	0.046280
Component 5	: 3 =	C3H8	Propane	0.005567
Component 6	: 4 =	C4H10	Isobutane	0.002251
Component 7	: 17 =	CO2	Carbon Dioxide	0.269962
Component 8	: 266 =	C6H6	Benzene	0.001992
Component 9	: 281 =	C7H8	Toluene	0.001992
Component 10	: 50 =	HF	Hydrogen Fluoride	0.000144

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
Release duration                                 60 min
Regulated flow rate                            0.11 lb/sec
Pipe inner diameter                           12.00 inches
Equivalent release diameter                   12.00 inches
Height of release point                         9.2 feet
Angle of release from horizontal               90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic endpoints
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           30 min


  NOTES:
```

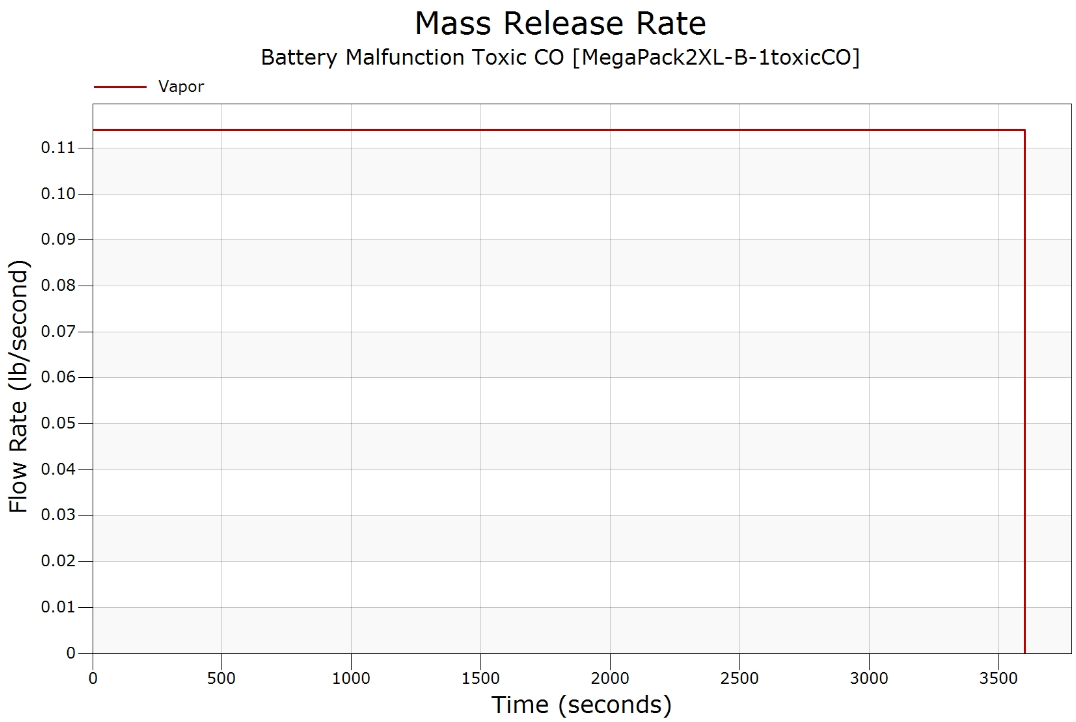
Release Model

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	.1140000	0.000000	0.000000	.1140000
0.1000000	.1140000	0.000000	0.000000	.1140000
0.3000000	.1140000	0.000000	0.000000	.1140000
0.5000000	.1140000	0.000000	0.000000	.1140000
0.7000000	.1140000	0.000000	0.000000	.1140000
1.000000	.1140000	0.000000	0.000000	.1140000
3.000000	.1140000	0.000000	0.000000	.1140000
5.000000	.1140000	0.000000	0.000000	.1140000
7.000000	.1140000	0.000000	0.000000	.1140000
10.00000	.1140000	0.000000	0.000000	.1140000
20.00000	.1140000	0.000000	0.000000	.1140000
30.00000	.1140000	0.000000	0.000000	.1140000
40.00000	.1140000	0.000000	0.000000	.1140000
50.00000	.1140000	0.000000	0.000000	.1140000
60.00000	.1140000	0.000000	0.000000	.1140000
70.00000	.1140000	0.000000	0.000000	.1140000
85.00000	.1140000	0.000000	0.000000	.1140000
100.0000	.1140000	0.000000	0.000000	.1140000
200.0000	.1140000	0.000000	0.000000	.1140000
300.0000	.1140000	0.000000	0.000000	.1140000
400.0000	.1140000	0.000000	0.000000	.1140000
500.0000	.1140000	0.000000	0.000000	.1140000
600.0000	.1140000	0.000000	0.000000	.1140000
700.0000	.1140000	0.000000	0.000000	.1140000
850.0000	.1140000	0.000000	0.000000	.1140000
1000.000	.1140000	0.000000	0.000000	.1140000
2000.000	.1140000	0.000000	0.000000	.1140000
3000.000	.1140000	0.000000	0.000000	.1140000
3600.000	.1140000	0.000000	0.000000	.1140000
Totals (lb)	410.4000	0.000000	0.000000	410.4000

Flowrate for Immediate Jet [1st minute] = 0.1140000 lb/sec.
Delayed Jet [2-3 minutes] = 0.1140000 lb/sec.

Reason for Ending: Reached Stop Time

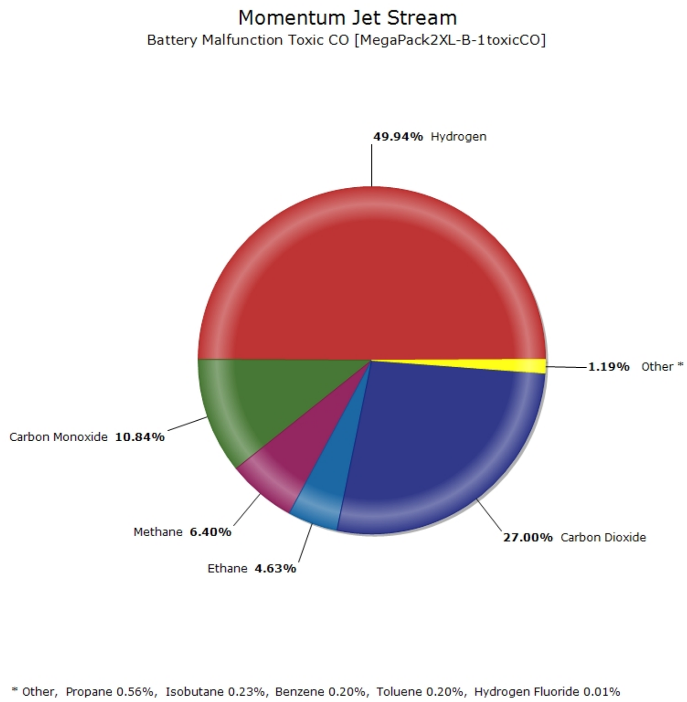

Mass Release Rate
Battery Malfunction Toxic CO [MegaPack2XL-B-1toxicCO]
Vapor
Flow Rate (lb/second)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen, H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
4	Isobutane, C4H10
17	Carbon Dioxide, CO2
266	Benzene, C6H6
281	Toluene, C7H8
50	Hydrogen Fluoride, HF

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	0.499430	0.499430	0.000000	0.000000	0.499430	0.000000
43	0.108365	0.108365	0.000000	0.000000	0.108365	0.000000
1	0.064017	0.064017	0.000000	0.000000	0.064017	0.000000
2	0.046280	0.046280	0.000000	0.000000	0.046280	0.000000
3	0.005567	0.005567	0.000000	0.000000	0.005567	0.000000
4	0.002251	0.002251	0.000000	0.000000	0.002251	0.000000
17	0.269962	0.269962	0.000000	0.000000	0.269962	0.000000
266	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
281	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
50	0.000144	0.000144	0.000000	0.000000	0.000144	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000


Momentum Jet Stream
Battery Malfunction Toxic CO [MegaPack2XL-B-1toxicCO]
49.94% Hydrogen
1.19% Other *
27.00% Carbon Dioxide
Ethane 4.63%
Methane 6.40%
Carbon Monoxide 10.84%
* Other, Propane 0.56%, Isobutane 0.23%, Benzene 0.20%, Toluene 0.20%, Hydrogen Fluoride 0.01%

Momentum Jet Dispersion

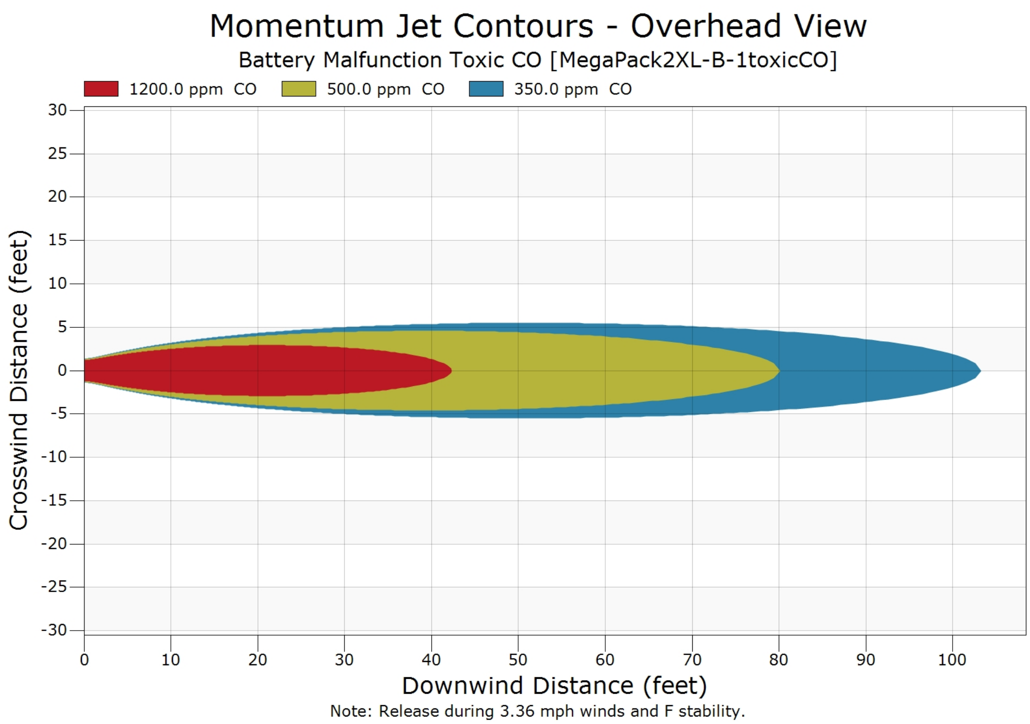
concentration limits

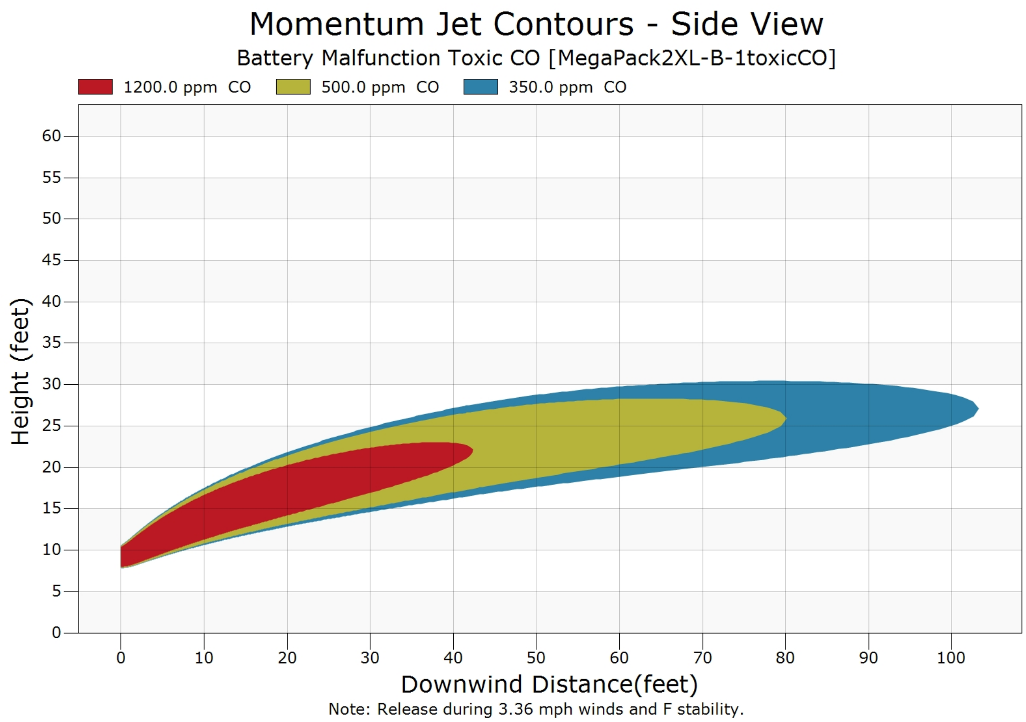
Endpoint 1 (highest) = 1200.0 ppm
Endpoint 2 (middle) = 500.0 ppm
Endpoint 3 (lowest) = 350.0 ppm

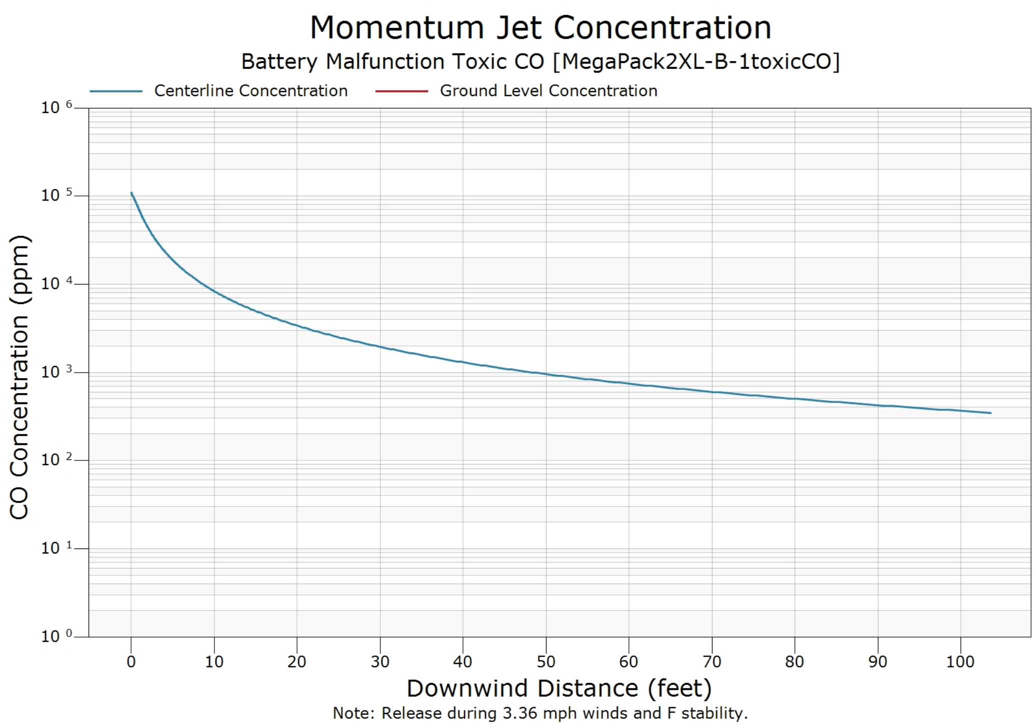
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	108365.000	0.000	1.4	1.3	1.2	9.2
2	36709.803	0.000	1.8	1.8	1.6	10.3
5	18752.502	0.000	2.4	2.3	2.0	11.6
7	11831.827	0.000	2.8	2.7	2.3	12.8
10	8329.762	0.000	3.2	3.0	2.5	13.9
12	6281.122	0.000	3.6	3.3	2.7	14.9
15	4960.315	0.000	3.8	3.6	2.8	15.7
18	4049.627	0.000	4.1	3.8	2.9	16.5
20	3388.053	0.000	4.3	4.0	2.9	17.2
22	2888.967	0.000	4.5	4.1	2.9	17.9
25	2503.028	0.000	4.7	4.3	2.9	18.5
28	2196.441	0.000	4.9	4.4	2.8	19.1
30	1947.734	0.000	5.0	4.5	2.7	19.7
32	1743.493	0.000	5.1	4.5	2.5	20.2
35	1570.405	0.000	5.2	4.6	2.2	20.7
38	1425.422	0.000	5.3	4.6	1.9	21.2
40	1300.747	0.000	5.4	4.6	1.3	21.7
42	1194.824	0.000	5.4	4.6	0.0	22.1
45	1102.756	0.000	5.5	4.5	0.0	22.5
48	1023.486	0.000	5.5	4.5	0.0	22.9
50	954.565	0.000	5.5	4.4	0.0	23.2
53	892.755	0.000	5.5	4.3	0.0	23.5
55	838.215	0.000	5.5	4.2	0.0	23.8
58	788.640	0.000	5.5	4.1	0.0	24.1
60	744.493	0.000	5.4	3.9	0.0	24.3
62	703.882	0.000	5.4	3.8	0.0	24.6
65	667.261	0.001	5.3	3.5	0.0	24.8
68	633.780	0.001	5.2	3.3	0.0	25.0
70	602.643	0.001	5.1	3.0	0.0	25.2
72	574.350	0.002	5.0	2.6	0.0	25.4
75	548.437	0.002	4.9	2.2	0.0	25.6
78	523.997	0.003	4.7	1.6	0.0	25.7
80	501.415	0.005	4.6	0.2	0.0	25.9
82	480.438	0.007	4.4	0.0	0.0	26.0
85	460.711	0.009	4.2	0.0	0.0	26.2

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)
88	442.373	0.012	3.9	0.0	0.0	26.3
90	425.113	0.015	3.6	0.0	0.0	26.5
92	409.077	0.019	3.3	0.0	0.0	26.6
95	393.916	0.025	3.0	0.0	0.0	26.7
98	379.641	0.031	2.5	0.0	0.0	26.8
100	366.216	0.039	1.9	0.0	0.0	27.0
102	353.573	0.048	0.9	0.0	0.0	27.1

Endpoint (ppm, CO)		Downwind Distance (feet)	Approximate Time (seconds)
1	1200.0	42.4	10
2	500.0	80.2	18
3	350.0	103.2	23




Momentum Jet Contours - Side View
Battery Malfunction Toxic CO [MegaPack2XL-B-1toxicCO]
1200.0 ppm CO
500.0 ppm CO
350.0 ppm CO
Height (feet)
Downwind Distance(feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction Toxic CO [MegaPack2XL-B-1toxicCO]
Centerline Concentration
Ground Level Concentration
CO Concentration (ppm)
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.

Case Inputs

Case Type : Vapor Dispersion
Case Name : MegaPack2XL-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	0.499430
Component 2	43	= CO	Carbon Monoxide	0.108365
Component 3	1	= CH4	Methane	0.064017
Component 4	2	= C2H6	Ethane	0.046280
Component 5	3	= C3H8	Propane	0.005567
Component 6	4	= C4H10	Isobutane	0.002251
Component 7	17	= CO2	Carbon Dioxide	0.269962
Component 8	266	= C6H6	Benzene	0.001992
Component 9	281	= C7H8	Toluene	0.001992
Component 10	50	= HF	Hydrogen Fluoride	0.000144

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
Release duration                                   60 min
Regulated flow rate                              0.11 lb/sec
Pipe inner diameter                             12.00 inches
Equivalent release diameter                     12.00 inches
Height of release point                           9.2 feet
Angle of release from horizontal                 90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic endpoints
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              30 min


  NOTES:
```

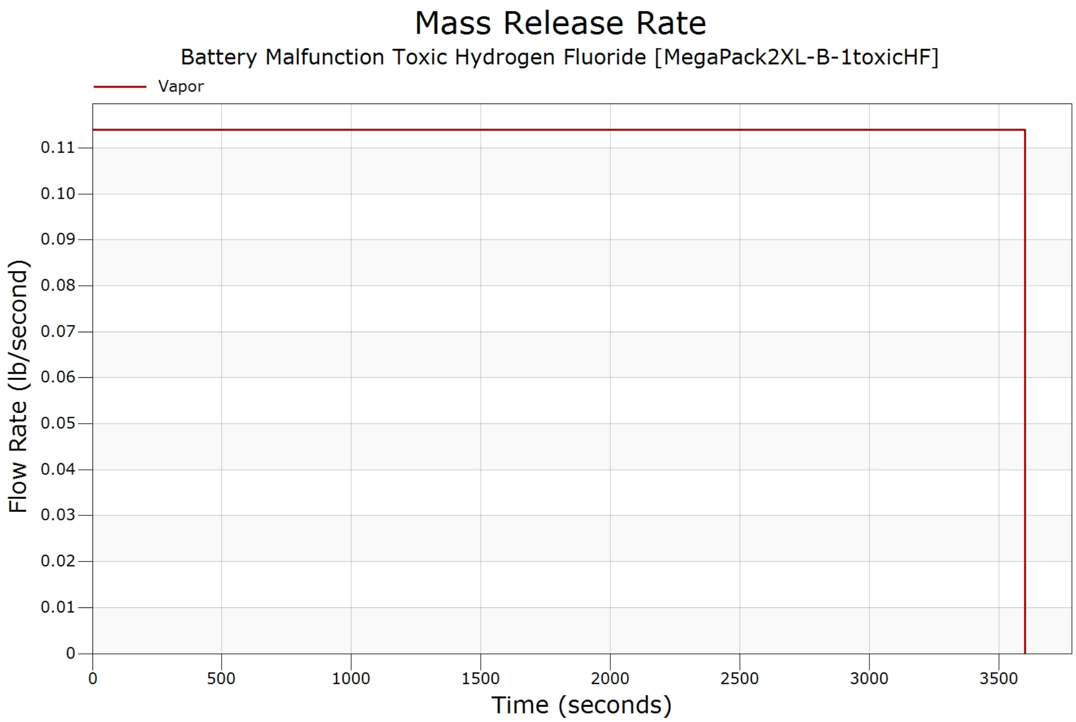
Release Model

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	.1140000	0.000000	0.000000	.1140000
0.1000000	.1140000	0.000000	0.000000	.1140000
0.3000000	.1140000	0.000000	0.000000	.1140000
0.5000000	.1140000	0.000000	0.000000	.1140000
0.7000000	.1140000	0.000000	0.000000	.1140000
1.000000	.1140000	0.000000	0.000000	.1140000
3.000000	.1140000	0.000000	0.000000	.1140000
5.000000	.1140000	0.000000	0.000000	.1140000
7.000000	.1140000	0.000000	0.000000	.1140000
10.00000	.1140000	0.000000	0.000000	.1140000
20.00000	.1140000	0.000000	0.000000	.1140000
30.00000	.1140000	0.000000	0.000000	.1140000
40.00000	.1140000	0.000000	0.000000	.1140000
50.00000	.1140000	0.000000	0.000000	.1140000
60.00000	.1140000	0.000000	0.000000	.1140000
70.00000	.1140000	0.000000	0.000000	.1140000
85.00000	.1140000	0.000000	0.000000	.1140000
100.0000	.1140000	0.000000	0.000000	.1140000
200.0000	.1140000	0.000000	0.000000	.1140000
300.0000	.1140000	0.000000	0.000000	.1140000
400.0000	.1140000	0.000000	0.000000	.1140000
500.0000	.1140000	0.000000	0.000000	.1140000
600.0000	.1140000	0.000000	0.000000	.1140000
700.0000	.1140000	0.000000	0.000000	.1140000
850.0000	.1140000	0.000000	0.000000	.1140000
1000.000	.1140000	0.000000	0.000000	.1140000
2000.000	.1140000	0.000000	0.000000	.1140000
3000.000	.1140000	0.000000	0.000000	.1140000
3600.000	.1140000	0.000000	0.000000	.1140000
Totals (lb)	410.4000	0.000000	0.000000	410.4000

```
Flowrate for Immediate Jet [1st minute]  = 0.1140000     lb/sec.
             Delayed Jet   [2-3 minutes] = 0.1140000     lb/sec.
```

Reason for Ending: Reached Stop Time


Mass Release Rate
Battery Malfunction Toxic Hydrogen Fluoride [MegaPack2XL-B-1toxicHF]
Vapor
Flow Rate (lb/second)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

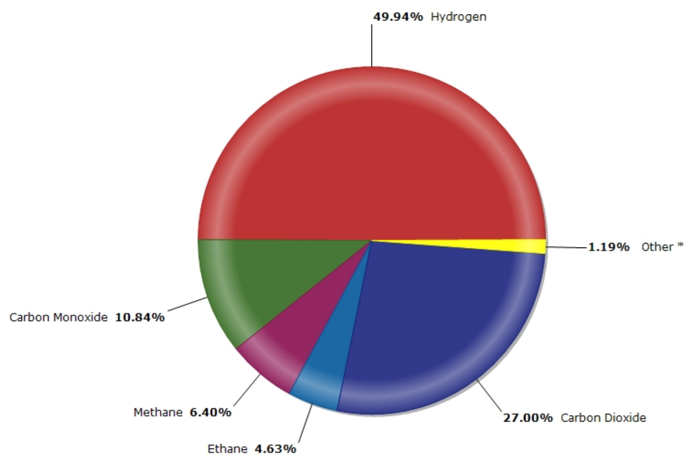
Release Compositions

Component Number	Component Name, Formula
51	Hydrogen, H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
4	Isobutane, C4H10
17	Carbon Dioxide, CO2
266	Benzene, C6H6
281	Toluene, C7H8
50	Hydrogen Fluoride, HF

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	0.499430	0.499430	0.000000	0.000000	0.499430	0.000000
43	0.108365	0.108365	0.000000	0.000000	0.108365	0.000000
1	0.064017	0.064017	0.000000	0.000000	0.064017	0.000000
2	0.046280	0.046280	0.000000	0.000000	0.046280	0.000000
3	0.005567	0.005567	0.000000	0.000000	0.005567	0.000000
4	0.002251	0.002251	0.000000	0.000000	0.002251	0.000000
17	0.269962	0.269962	0.000000	0.000000	0.269962	0.000000
266	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
281	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
50	0.000144	0.000144	0.000000	0.000000	0.000144	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000

Momentum Jet Stream
Battery Malfunction Toxic Hydrogen Fluoride [MegaPack2XL-B-1toxicHF]



* Other, Propane 0.56%, Isobutane 0.23%, Benzene 0.20%, Toluene 0.20%, Hydrogen Fluoride 0.01%

Momentum Jet Dispersion

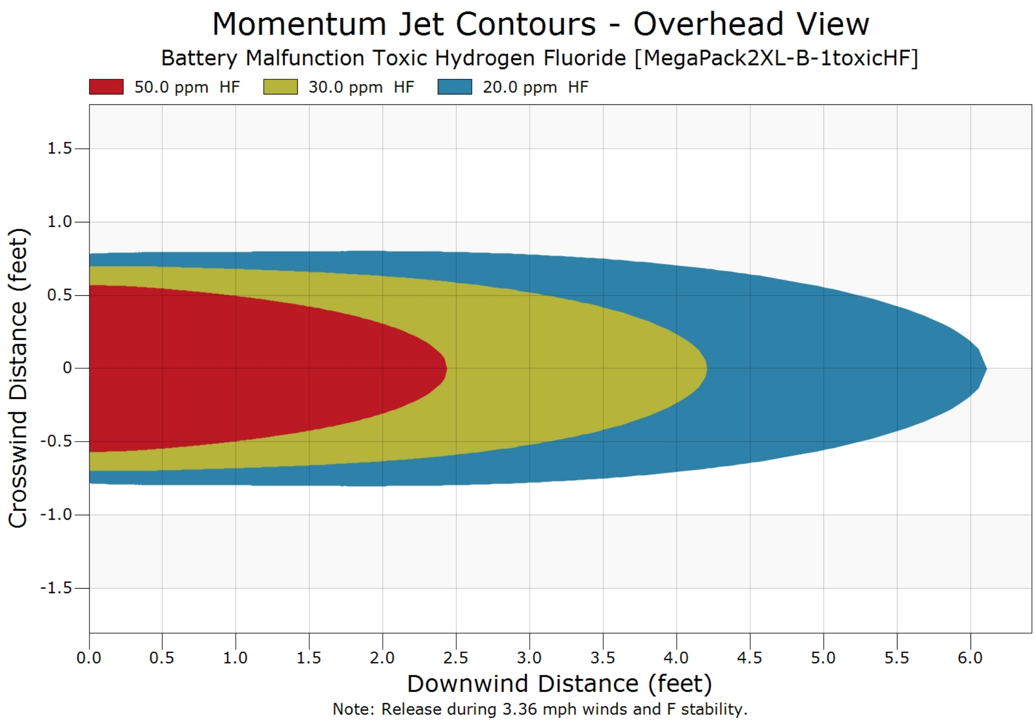
concentration limits

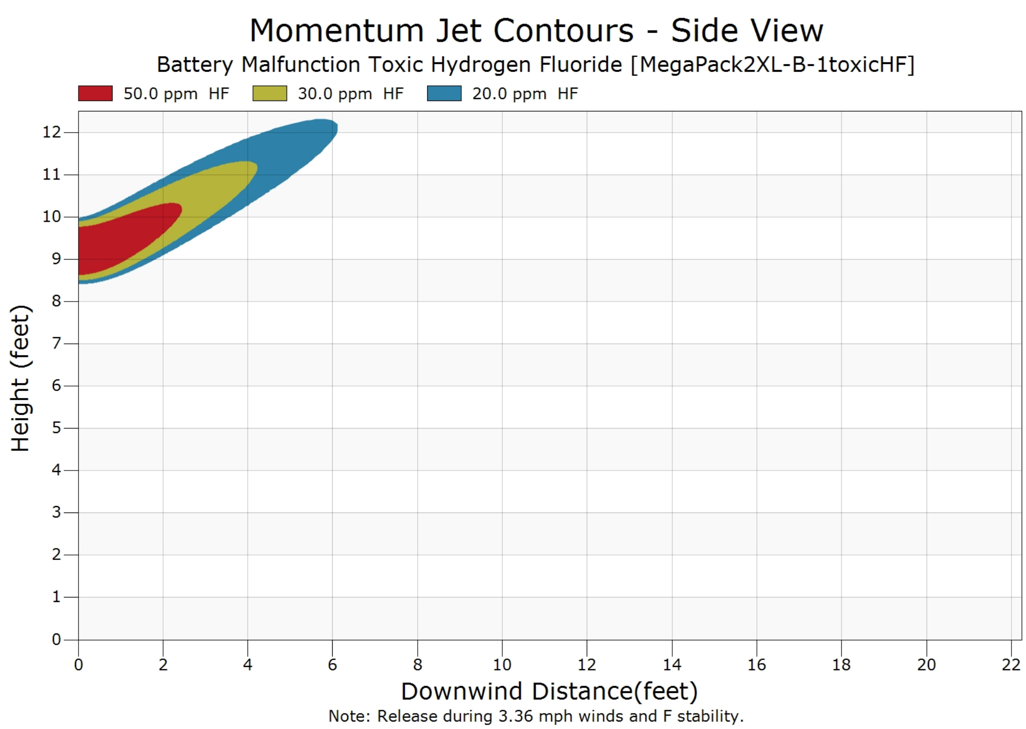
Endpoint 1 (highest) = 50.0 ppm
Endpoint 2 (middle) = 30.0 ppm
Endpoint 3 (lowest) = 20.0 ppm

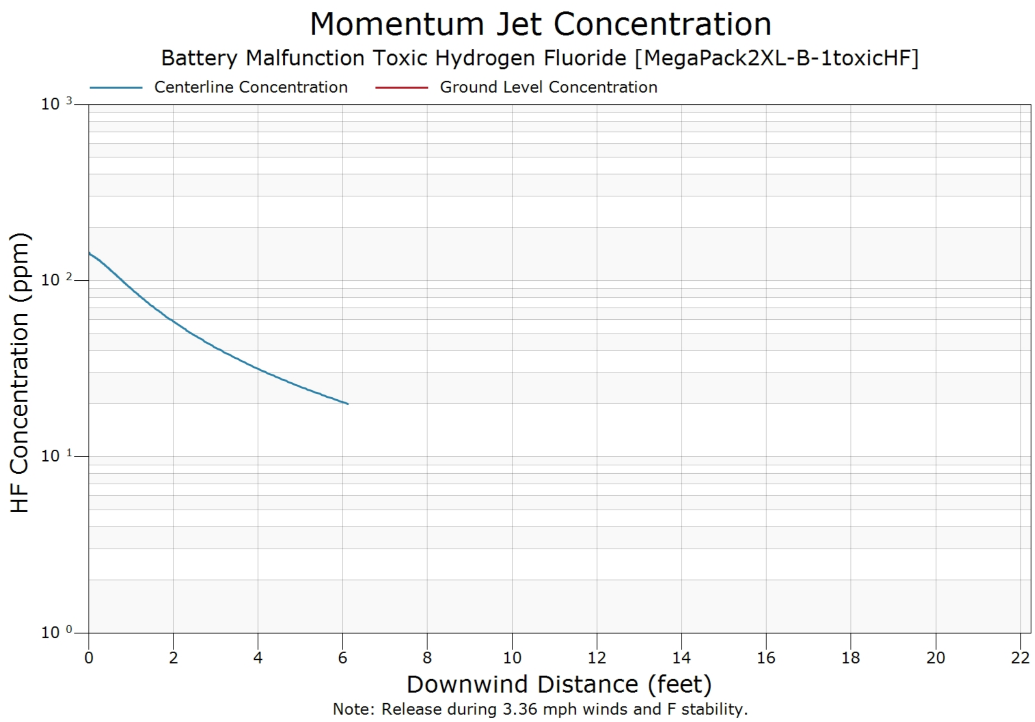
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	144.410	0.000	0.8	0.7	0.6	9.2
0.1	137.967	0.000	0.8	0.7	0.6	9.2
0.2	133.045	0.000	0.8	0.7	0.6	9.2
0.3	127.483	0.000	0.8	0.7	0.6	9.2
0.4	121.631	0.000	0.8	0.7	0.6	9.3
0.5	115.828	0.000	0.8	0.7	0.5	9.3
0.6	110.210	0.000	0.8	0.7	0.5	9.3
0.7	104.751	0.000	0.8	0.7	0.5	9.4
0.8	99.621	0.000	0.8	0.7	0.5	9.4
0.9	94.744	0.000	0.8	0.7	0.5	9.4
1.0	90.207	0.000	0.8	0.7	0.5	9.5
1.1	85.967	0.000	0.8	0.7	0.5	9.5
1.2	82.029	0.000	0.8	0.7	0.5	9.6
1.3	78.349	0.000	0.8	0.7	0.5	9.6
1.4	74.913	0.000	0.8	0.7	0.4	9.7
1.5	71.717	0.000	0.8	0.7	0.4	9.7
1.6	68.733	0.000	0.8	0.7	0.4	9.8
1.7	65.942	0.000	0.8	0.7	0.4	9.8
1.8	63.317	0.000	0.8	0.6	0.4	9.9
1.9	60.866	0.000	0.8	0.6	0.3	10.0
2.0	58.576	0.000	0.8	0.6	0.3	10.0
2.1	56.402	0.000	0.8	0.6	0.3	10.1
2.2	54.366	0.000	0.8	0.6	0.2	10.1
2.3	52.458	0.000	0.8	0.6	0.2	10.2
2.4	50.638	0.000	0.8	0.6	0.1	10.2
2.5	48.949	0.000	0.8	0.6	0.0	10.3
2.6	47.318	0.000	0.8	0.6	0.0	10.3
2.7	45.798	0.000	0.8	0.6	0.0	10.4
2.8	44.341	0.000	0.8	0.6	0.0	10.5
2.9	42.982	0.000	0.8	0.5	0.0	10.5
3.0	41.671	0.000	0.8	0.5	0.0	10.6
3.1	40.431	0.000	0.8	0.5	0.0	10.6
3.2	39.246	0.000	0.8	0.5	0.0	10.7
3.3	38.157	0.000	0.8	0.5	0.0	10.7
3.4	37.070	0.000	0.8	0.4	0.0	10.8

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	36.057	0.000	0.7	0.4	0.0	10.8
3.6	35.068	0.000	0.7	0.4	0.0	10.9
3.7	34.117	0.000	0.7	0.4	0.0	11.0
3.8	33.223	0.000	0.7	0.3	0.0	11.0
3.9	32.385	0.000	0.7	0.3	0.0	11.1
4.0	31.558	0.000	0.7	0.2	0.0	11.1
4.1	30.777	0.000	0.7	0.2	0.0	11.2
4.2	30.046	0.000	0.7	0.0	0.0	11.2
4.3	29.327	0.000	0.7	0.0	0.0	11.3
4.4	28.624	0.000	0.7	0.0	0.0	11.3
4.5	27.968	0.000	0.6	0.0	0.0	11.4
4.6	27.324	0.000	0.6	0.0	0.0	11.4
4.7	26.718	0.000	0.6	0.0	0.0	11.5
4.8	26.109	0.000	0.6	0.0	0.0	11.5
4.9	25.536	0.000	0.6	0.0	0.0	11.6
5.0	24.998	0.000	0.6	0.0	0.0	11.6
5.1	24.455	0.000	0.5	0.0	0.0	11.7
5.2	23.949	0.000	0.5	0.0	0.0	11.7
5.3	23.445	0.000	0.5	0.0	0.0	11.8
5.4	22.967	0.000	0.5	0.0	0.0	11.8
5.5	22.508	0.000	0.4	0.0	0.0	11.9
5.6	22.065	0.000	0.4	0.0	0.0	11.9
5.7	21.632	0.000	0.4	0.0	0.0	12.0
5.8	21.214	0.000	0.3	0.0	0.0	12.0
5.9	20.811	0.000	0.3	0.0	0.0	12.1
6.0	20.423	0.000	0.2	0.0	0.0	12.1
6.1	20.038	0.000	0.0	0.0	0.0	12.2

Endpoint (ppm, HF)		Downwind Distance (feet)	Approximate Time (seconds)
1	50.0	2.4	1
2	30.0	4.2	1
3	20.0	6.1	1


Momentum Jet Contours - Overhead View
Battery Malfunction Toxic Hydrogen Fluoride [MegaPack2XL-B-1toxicHF]
50.0 ppm HF
30.0 ppm HF
20.0 ppm HF
Crosswind Distance (feet)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Downwind Distance (feet)
Note: Release during 3.36 mph winds and F stability.


Momentum Jet Contours - Side View
Battery Malfunction Toxic Hydrogen Fluoride [MegaPack2XL-B-1toxicHF]
50.0 ppm HF
30.0 ppm HF
20.0 ppm HF
Height (feet)
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 Toxic Hydrogen Fluoride [MegaPack2XL-B-1toxicHF]
Centerline Concentration
Ground Level Concentration
HF Concentration (ppm)
10 3
10 2
10 1
10 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.

Case Inputs

```
Case Type           : Vapor Dispersion
Case Name           : MegaPack2XL-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                      0.499430
Component  2        :    43 = CO        Carbon Monoxide               0.108365
Component  3        :     1 = CH4       Methane                       0.064017
Component  4        :     2 = C2H6      Ethane                        0.046280
Component  5        :     3 = C3H8      Propane                       0.005567
Component  6        :     4 = C4H10     Isobutane                     0.002251
Component  7        :    17 = CO2       Carbon Dioxide                0.269962
Component  8        :   266 = C6H6      Benzene                       0.001992
Component  9        :   281 = C7H8      Toluene                       0.001992
Component 10        :    50 = HF        Hydrogen Fluoride             0.000144

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
Release duration                                    60 min
Regulated flow rate                               0.11 lb/sec
Pipe inner diameter                              12.00 inches
Equivalent release diameter                      12.00 inches
Height of release point                            9.2 feet
Angle of release from horizontal                  90.0 degrees

  NOTES:

IMPOUNDMENT MENU
Unconfined

  NOTES:

VDVE MENU
Vapor generation and dispersion - Toxic endpoints
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               30 min


  NOTES:
```

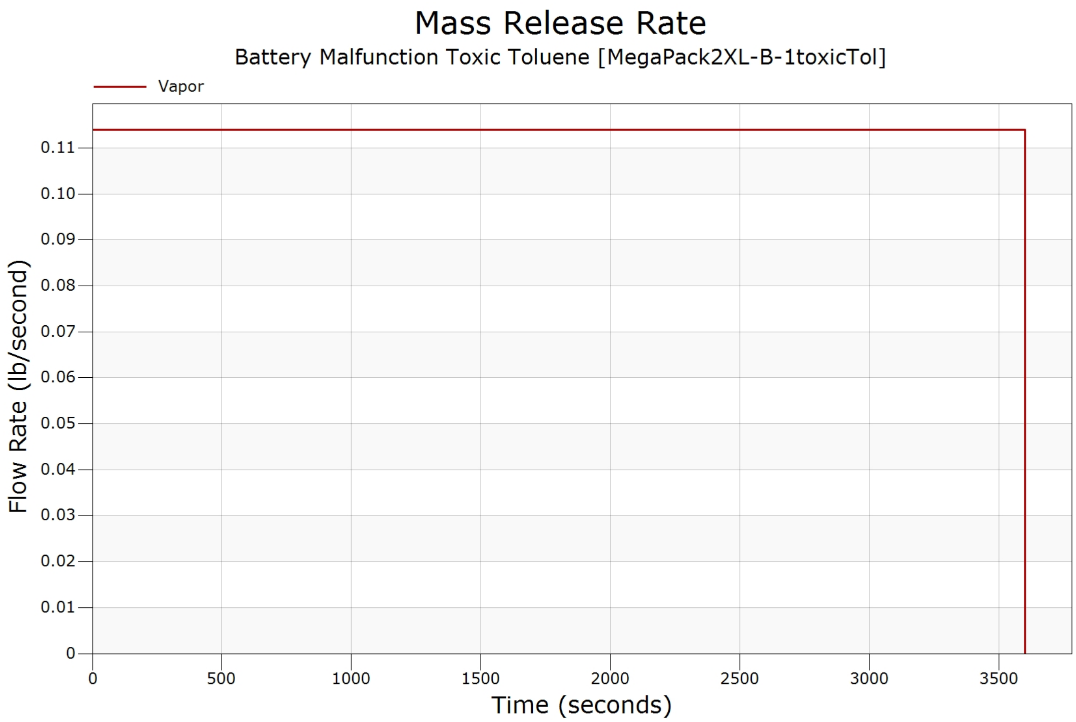
Release Model

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	.1140000	0.000000	0.000000	.1140000
0.1000000	.1140000	0.000000	0.000000	.1140000
0.3000000	.1140000	0.000000	0.000000	.1140000
0.5000000	.1140000	0.000000	0.000000	.1140000
0.7000000	.1140000	0.000000	0.000000	.1140000
1.000000	.1140000	0.000000	0.000000	.1140000
3.000000	.1140000	0.000000	0.000000	.1140000
5.000000	.1140000	0.000000	0.000000	.1140000
7.000000	.1140000	0.000000	0.000000	.1140000
10.00000	.1140000	0.000000	0.000000	.1140000
20.00000	.1140000	0.000000	0.000000	.1140000
30.00000	.1140000	0.000000	0.000000	.1140000
40.00000	.1140000	0.000000	0.000000	.1140000
50.00000	.1140000	0.000000	0.000000	.1140000
60.00000	.1140000	0.000000	0.000000	.1140000
70.00000	.1140000	0.000000	0.000000	.1140000
85.00000	.1140000	0.000000	0.000000	.1140000
100.0000	.1140000	0.000000	0.000000	.1140000
200.0000	.1140000	0.000000	0.000000	.1140000
300.0000	.1140000	0.000000	0.000000	.1140000
400.0000	.1140000	0.000000	0.000000	.1140000
500.0000	.1140000	0.000000	0.000000	.1140000
600.0000	.1140000	0.000000	0.000000	.1140000
700.0000	.1140000	0.000000	0.000000	.1140000
850.0000	.1140000	0.000000	0.000000	.1140000
1000.000	.1140000	0.000000	0.000000	.1140000
2000.000	.1140000	0.000000	0.000000	.1140000
3000.000	.1140000	0.000000	0.000000	.1140000
3600.000	.1140000	0.000000	0.000000	.1140000
Totals (lb)	410.4000	0.000000	0.000000	410.4000

Flowrate for Immediate Jet [1st minute] = 0.1140000 lb/sec.
Delayed Jet [2-3 minutes] = 0.1140000 lb/sec.

Reason for Ending: Reached Stop Time

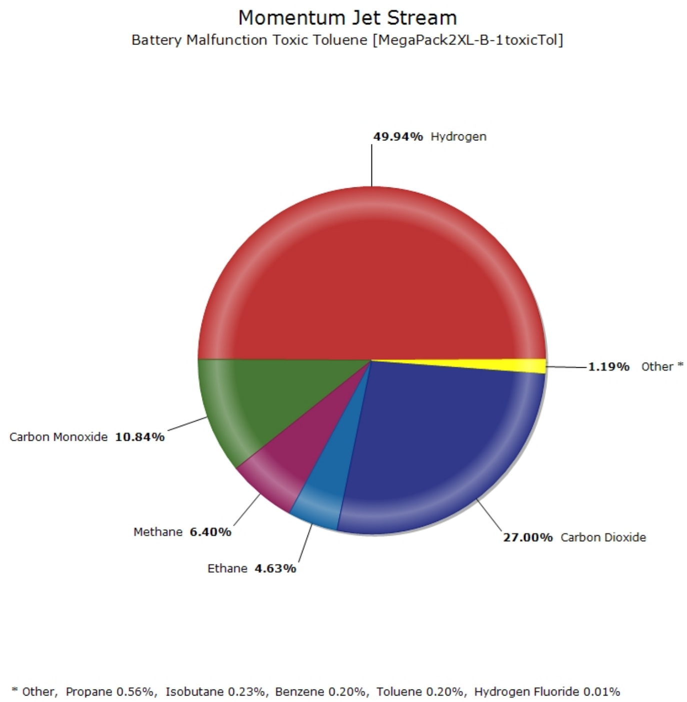

Mass Release Rate
Battery Malfunction Toxic Toluene [MegaPack2XL-B-1toxicTol]
Vapor
Flow Rate (lb/second)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)

Release Compositions

Component Number	Component Name, Formula
51	Hydrogen, H2
43	Carbon Monoxide, CO
1	Methane, CH4
2	Ethane, C2H6
3	Propane, C3H8
4	Isobutane, C4H10
17	Carbon Dioxide, CO2
266	Benzene, C6H6
281	Toluene, C7H8
50	Hydrogen Fluoride, HF

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	0.499430	0.499430	0.000000	0.000000	0.499430	0.000000
43	0.108365	0.108365	0.000000	0.000000	0.108365	0.000000
1	0.064017	0.064017	0.000000	0.000000	0.064017	0.000000
2	0.046280	0.046280	0.000000	0.000000	0.046280	0.000000
3	0.005567	0.005567	0.000000	0.000000	0.005567	0.000000
4	0.002251	0.002251	0.000000	0.000000	0.002251	0.000000
17	0.269962	0.269962	0.000000	0.000000	0.269962	0.000000
266	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
281	0.001992	0.001992	0.000000	0.000000	0.001992	0.000000
50	0.000144	0.000144	0.000000	0.000000	0.000144	0.000000
	1.000000	1.000000	0.000000	0.000000	1.000000	0.000000


Momentum Jet Stream
Battery Malfunction Toxic Toluene [MegaPack2XL-B-1toxicTol]
49.94% Hydrogen
1.19% Other *
Carbon Monoxide 10.84%
Methane 6.40%
Ethane 4.63%
27.00% Carbon Dioxide
* Other, Propane 0.56%, Isobutane 0.23%, Benzene 0.20%, Toluene 0.20%, Hydrogen Fluoride 0.01%

Momentum Jet Dispersion

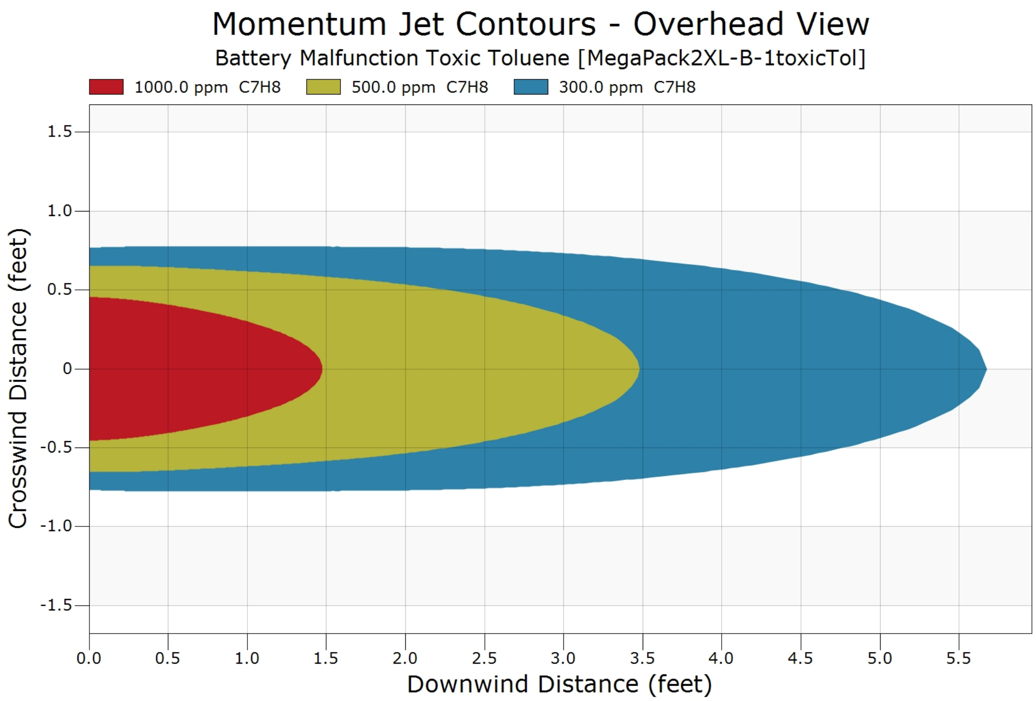
concentration limits

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

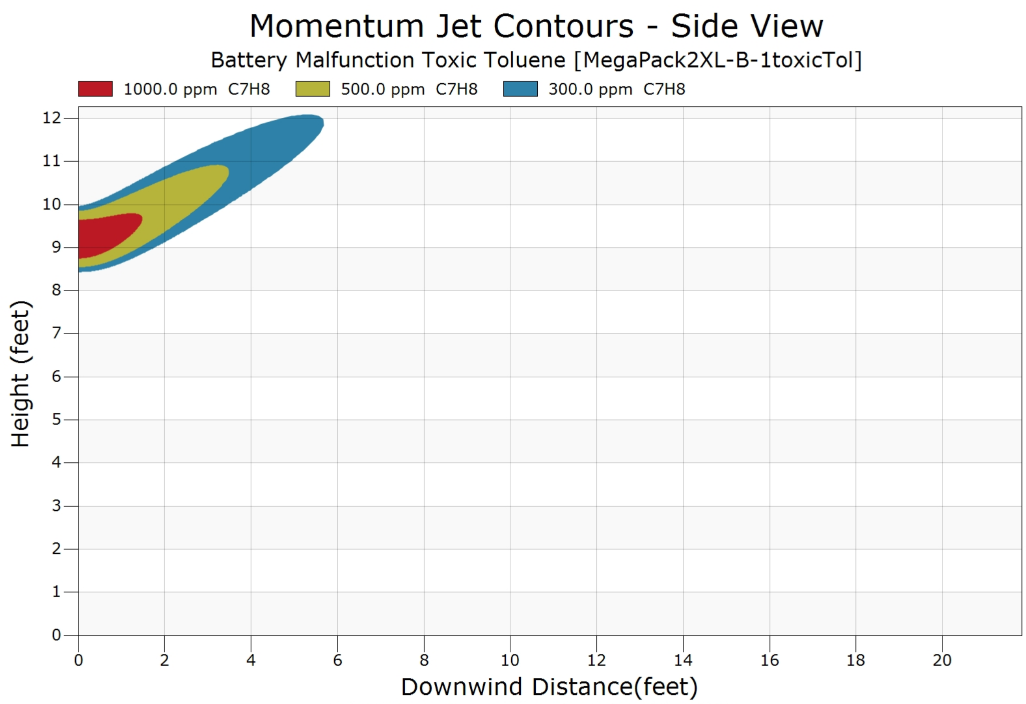
downwind distance (ft)	centerline conc. (ppm)	ground conc. (ppm)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1991.820	0.000	0.8	0.7	0.5	9.2
0.1	1903.435	0.000	0.8	0.7	0.5	9.2
0.2	1834.986	0.000	0.8	0.7	0.4	9.2
0.3	1757.998	0.000	0.8	0.7	0.4	9.2
0.4	1678.115	0.000	0.8	0.6	0.4	9.3
0.5	1597.885	0.000	0.8	0.6	0.4	9.3
0.6	1520.338	0.000	0.8	0.6	0.4	9.3
0.7	1444.159	0.000	0.8	0.6	0.4	9.4
0.8	1374.558	0.000	0.8	0.6	0.4	9.4
0.9	1306.910	0.000	0.8	0.6	0.3	9.4
1.0	1244.053	0.000	0.8	0.6	0.3	9.5
1.1	1185.742	0.000	0.8	0.6	0.3	9.5
1.2	1131.562	0.000	0.8	0.6	0.2	9.6
1.3	1081.035	0.000	0.8	0.6	0.2	9.6
1.4	1033.334	0.000	0.8	0.6	0.1	9.7
1.5	989.019	0.000	0.8	0.6	0.0	9.7
1.6	948.025	0.000	0.8	0.6	0.0	9.8
1.7	909.560	0.000	0.8	0.6	0.0	9.8
1.8	873.278	0.000	0.8	0.6	0.0	9.9
1.9	839.451	0.000	0.8	0.5	0.0	10.0
2.0	807.881	0.000	0.8	0.5	0.0	10.0
2.1	777.950	0.000	0.8	0.5	0.0	10.1
2.2	749.882	0.000	0.8	0.5	0.0	10.1
2.3	723.568	0.000	0.8	0.5	0.0	10.2
2.4	698.461	0.000	0.8	0.5	0.0	10.2
2.5	675.156	0.000	0.8	0.5	0.0	10.3
2.6	652.660	0.000	0.8	0.4	0.0	10.3
2.7	631.696	0.000	0.7	0.4	0.0	10.4
2.8	611.584	0.000	0.7	0.4	0.0	10.5
2.9	592.815	0.000	0.7	0.4	0.0	10.5
3.0	574.724	0.000	0.7	0.3	0.0	10.6
3.1	557.618	0.000	0.7	0.3	0.0	10.6
3.2	541.263	0.000	0.7	0.3	0.0	10.7
3.3	526.209	0.000	0.7	0.2	0.0	10.7
3.4	511.213	0.000	0.7	0.1	0.0	10.8

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	497.249	0.000	0.7	0.0	0.0	10.8
3.6	483.620	0.000	0.7	0.0	0.0	10.9
3.7	470.555	0.000	0.7	0.0	0.0	11.0
3.8	458.281	0.000	0.7	0.0	0.0	11.0
3.9	446.776	0.000	0.7	0.0	0.0	11.1
4.0	435.351	0.000	0.6	0.0	0.0	11.1
4.1	424.551	0.000	0.6	0.0	0.0	11.2
4.2	414.451	0.000	0.6	0.0	0.0	11.2
4.3	404.509	0.000	0.6	0.0	0.0	11.3
4.4	394.784	0.000	0.6	0.0	0.0	11.3
4.5	385.718	0.000	0.6	0.0	0.0	11.4
4.6	376.834	0.000	0.5	0.0	0.0	11.4
4.7	368.484	0.000	0.5	0.0	0.0	11.5
4.8	360.099	0.000	0.5	0.0	0.0	11.5
4.9	352.201	0.000	0.5	0.0	0.0	11.6
5.0	344.773	0.000	0.4	0.0	0.0	11.6
5.1	337.294	0.000	0.4	0.0	0.0	11.7
5.2	330.310	0.000	0.4	0.0	0.0	11.7
5.3	323.373	0.000	0.3	0.0	0.0	11.8
5.4	316.800	0.000	0.3	0.0	0.0	11.8
5.5	310.482	0.000	0.2	0.0	0.0	11.9
5.6	304.379	0.000	0.1	0.0	0.0	11.9

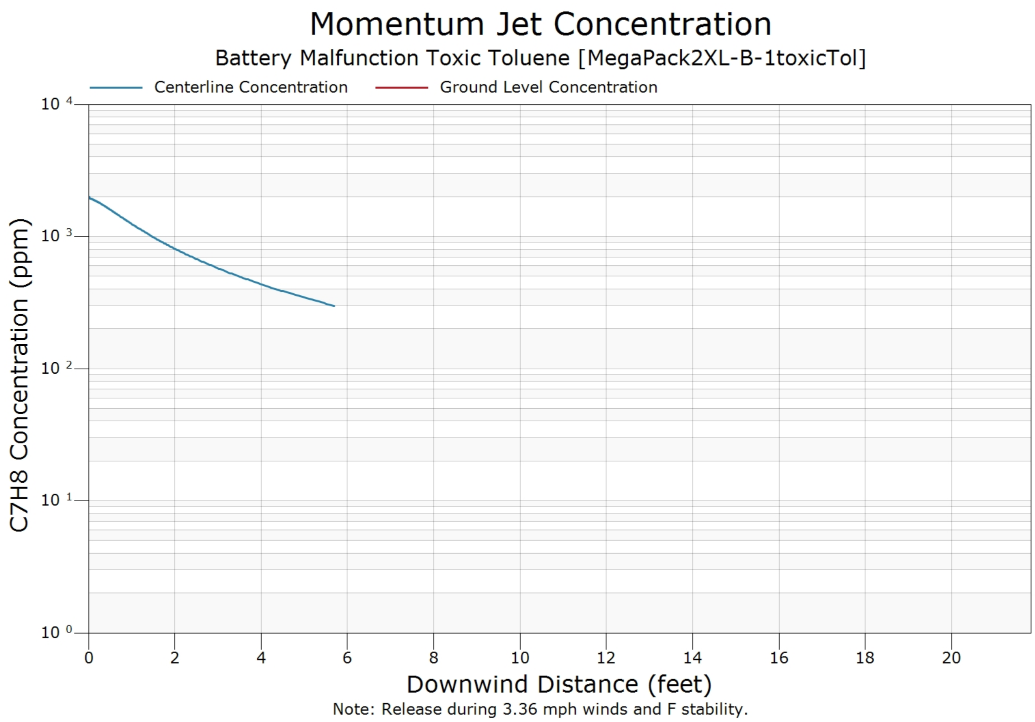
Endpoint (ppm, C7H8)		Downwind Distance (feet)	Approximate Time (seconds)
1	1000.0	1.5	0
2	500.0	3.5	1
3	300.0	5.7	1



Note: Release during 3.36 mph winds and F stability.



Note: Release during 3.36 mph winds and F stability.


Momentum Jet Concentration
Battery Malfunction Toxic Toluene [MegaPack2XL-B-1toxicTol]
Centerline Concentration
Ground Level Concentration
10 4
10 3
10 2
10 1
10 0
C7H8 Concentration (ppm)
0
2
4
6
8
10
12
14
16
18
20
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:
```

```
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:
```

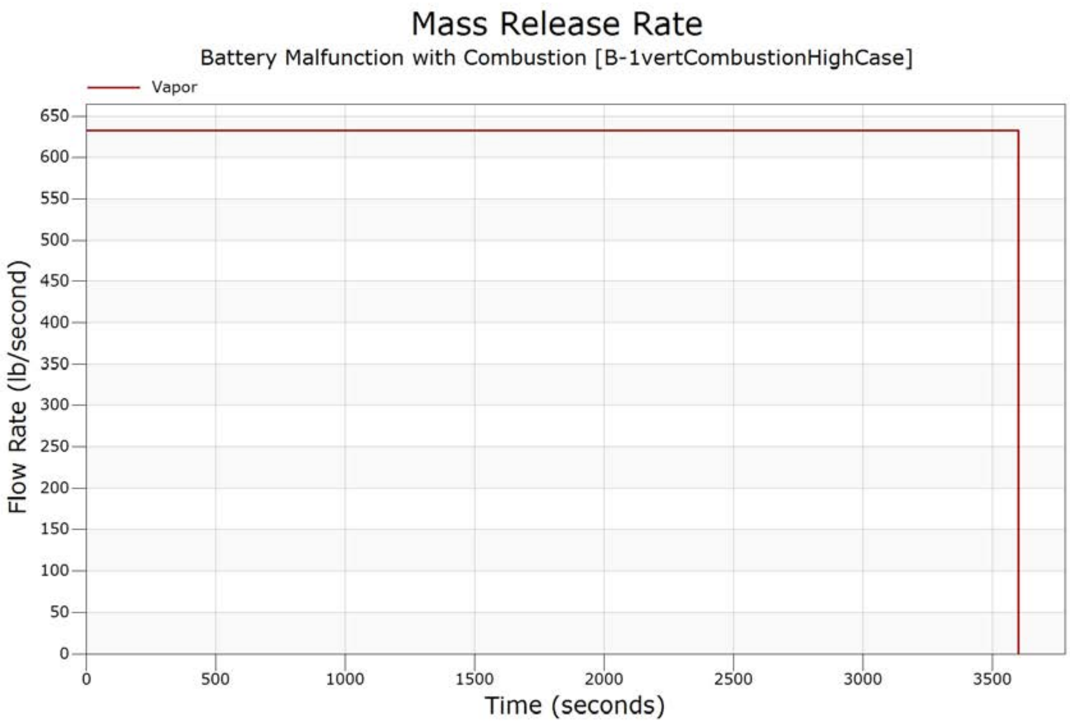
Release Model

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)
Time (seconds)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
0
500
1000
1500
2000
2500
3000
3500

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

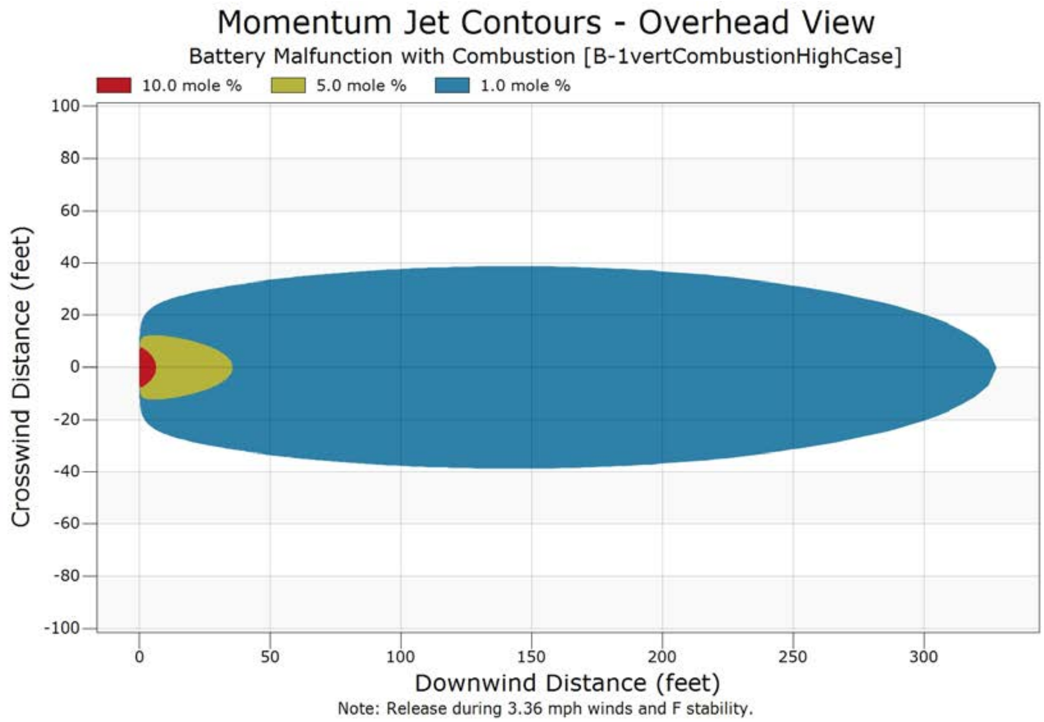
concentration limits

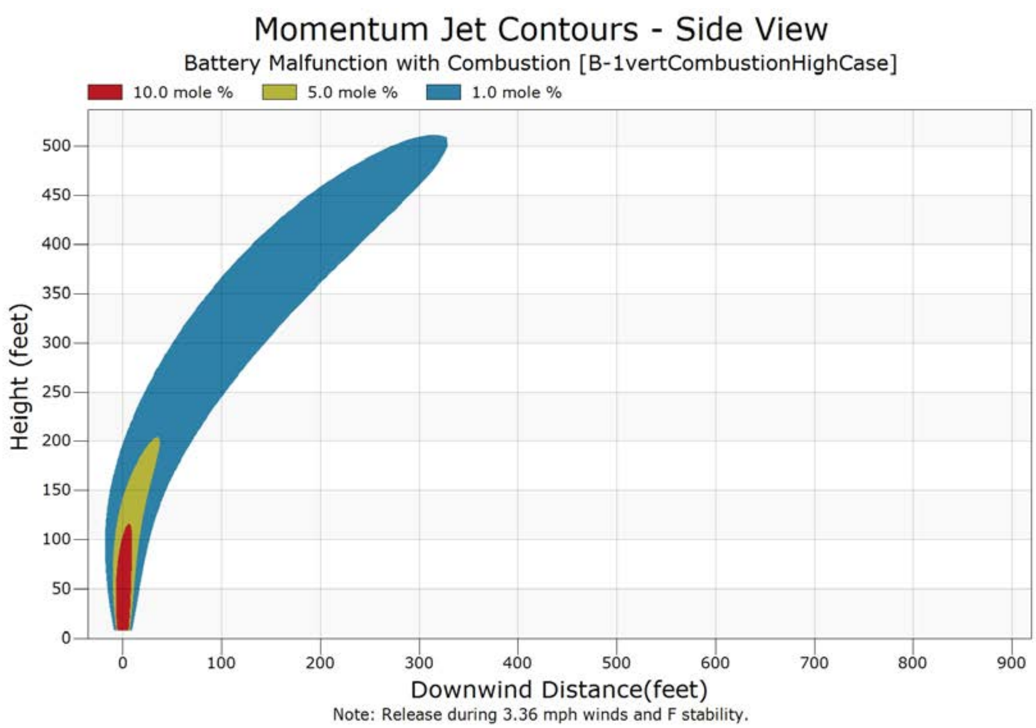
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

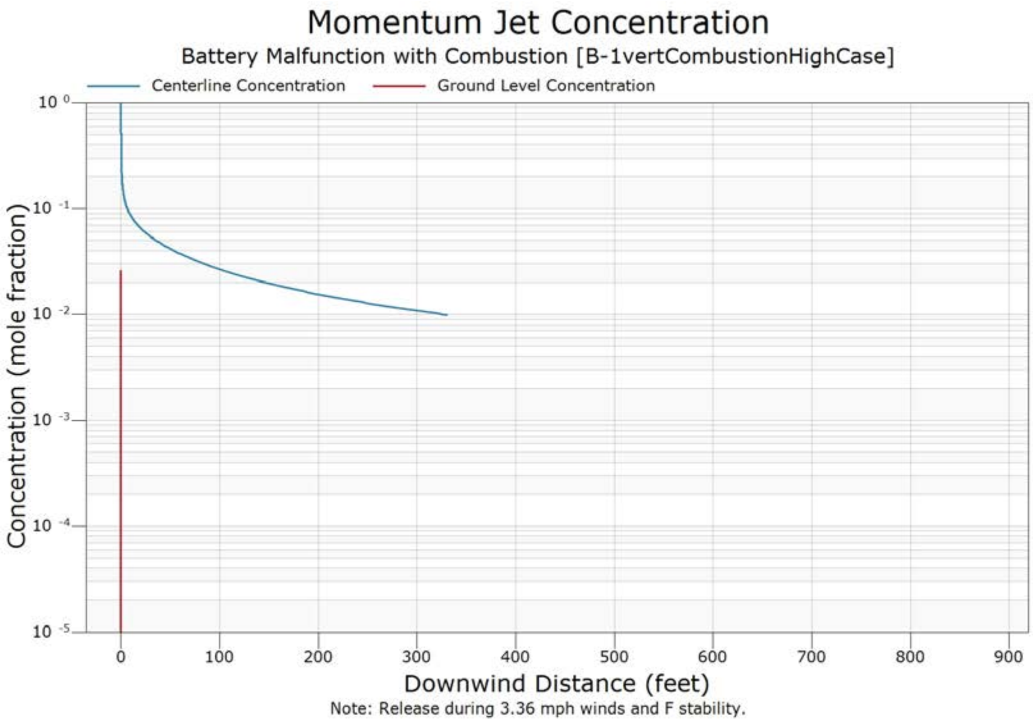
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
5	0.108710	0.000000	23.1	12.4	3.9	107.7
10	0.085169	0.000000	25.6	12.1	0.0	133.8
15	0.073108	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:
```

```
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:
```

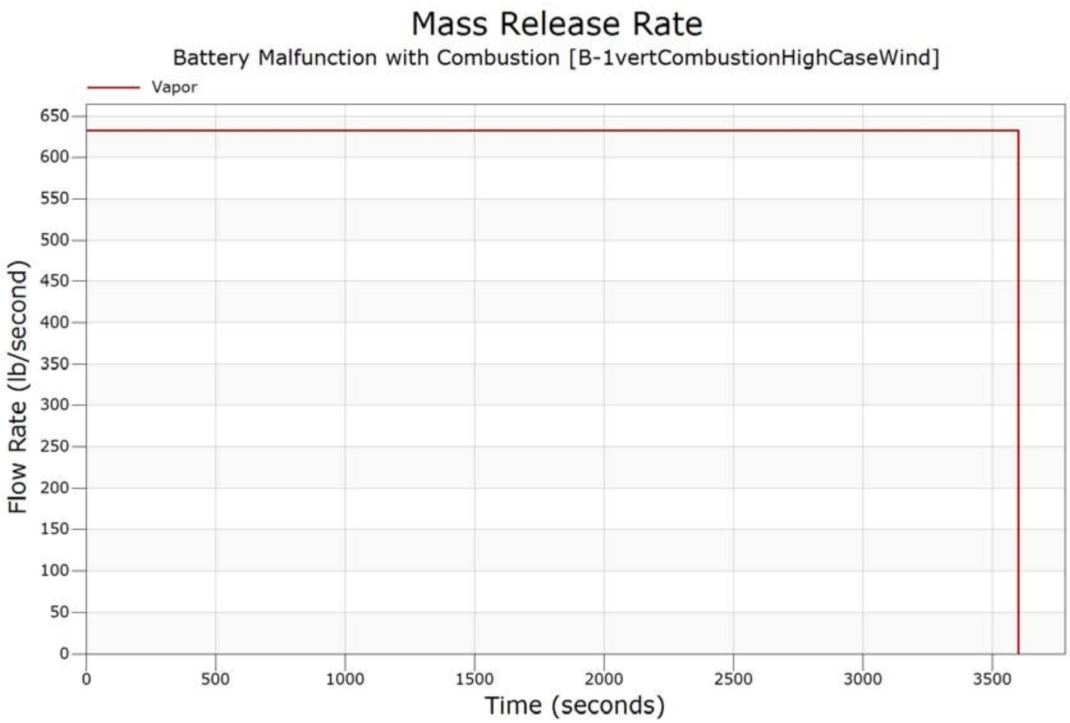
Release Model

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)
Time (seconds)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
0
500
1000
1500
2000
2500
3000
3500

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

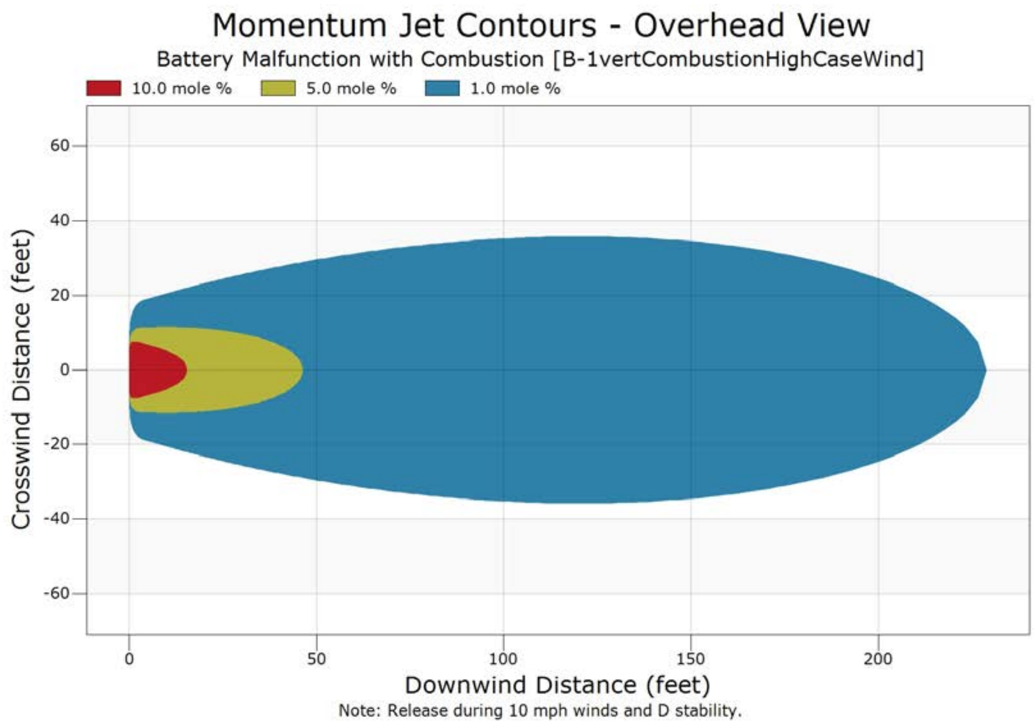
concentration limits

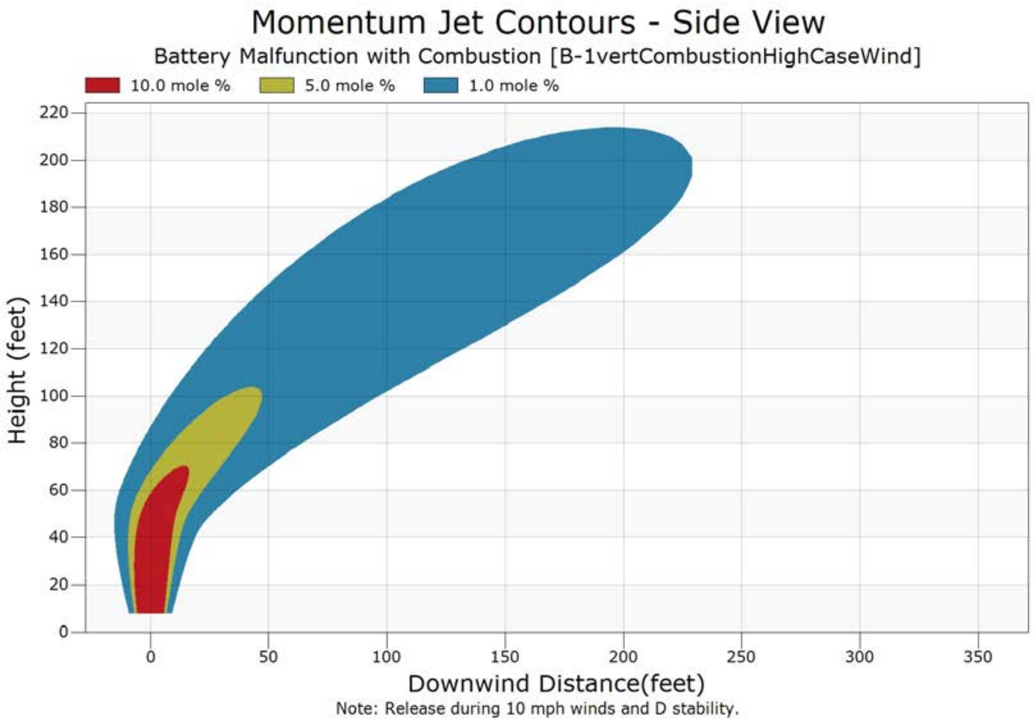
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

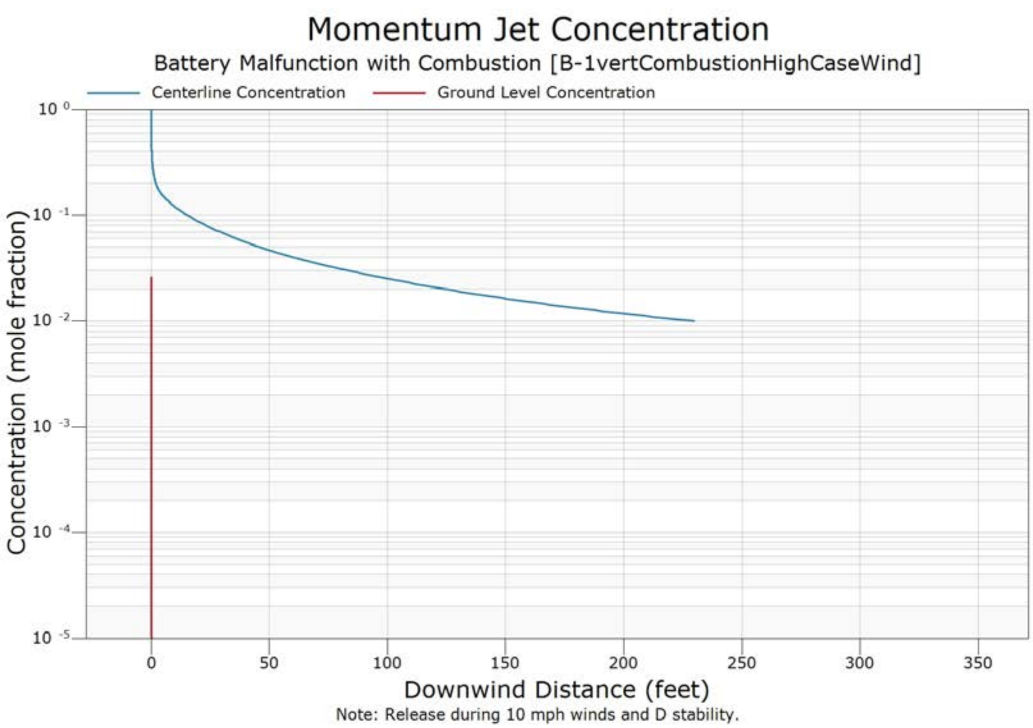
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
5	0.152590	0.000000	19.1	11.5	6.8	54.1
10	0.121143	0.000000	20.5	11.5	5.1	62.7
15	0.101440	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:
```

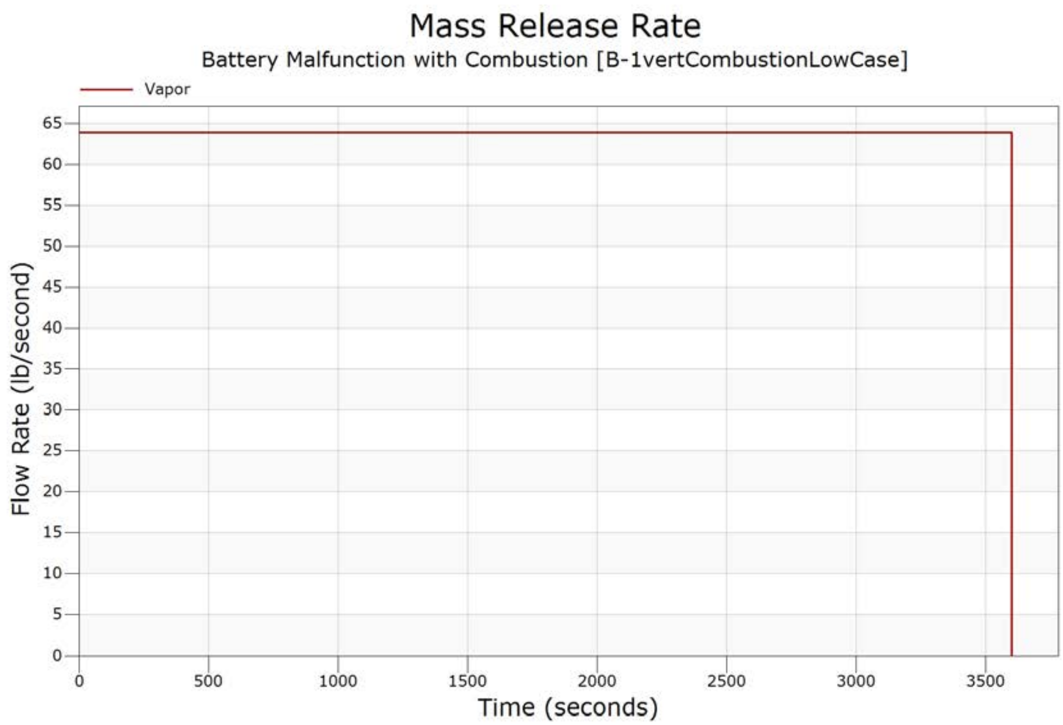
Release Model

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)
Time (seconds)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
500
1000
1500
2000
2500
3000
3500

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

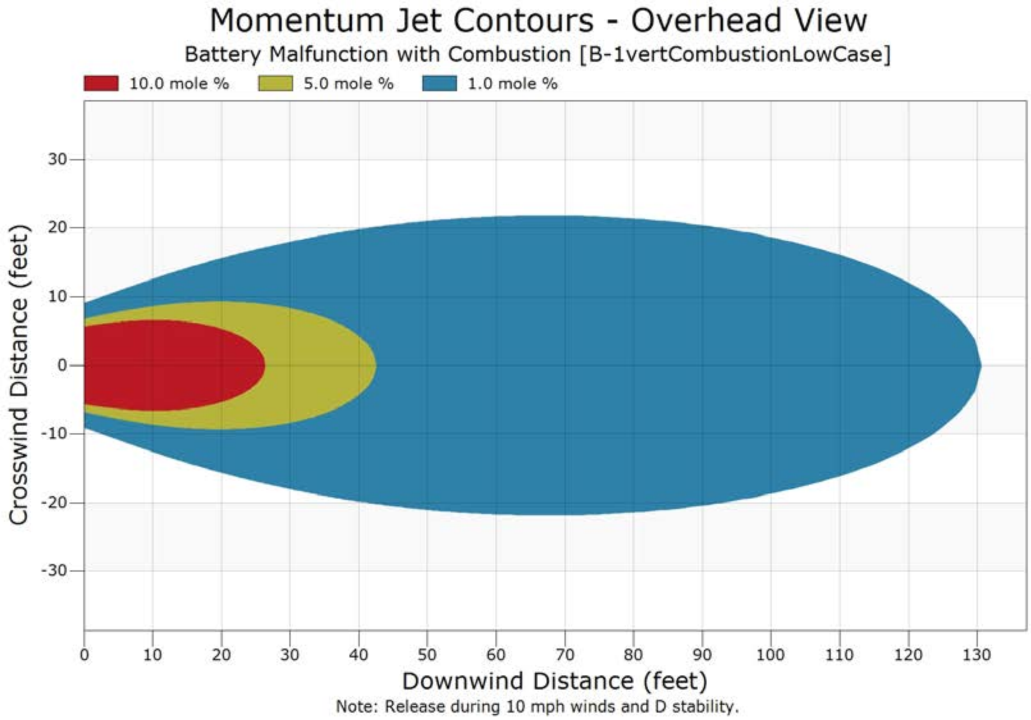
concentration limits

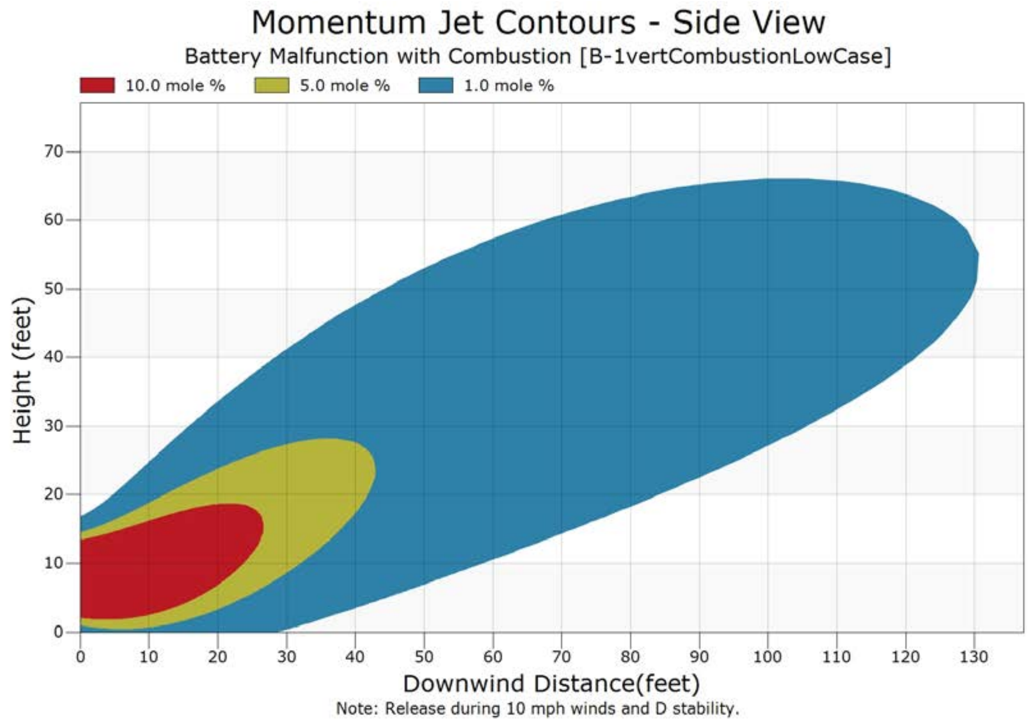
Endpoint 1 (highest) = 0.100000 mole fraction
Endpoint 2 (middle) = 0.050000 mole fraction
Endpoint 3 (lowest) = 0.010000 mole fraction

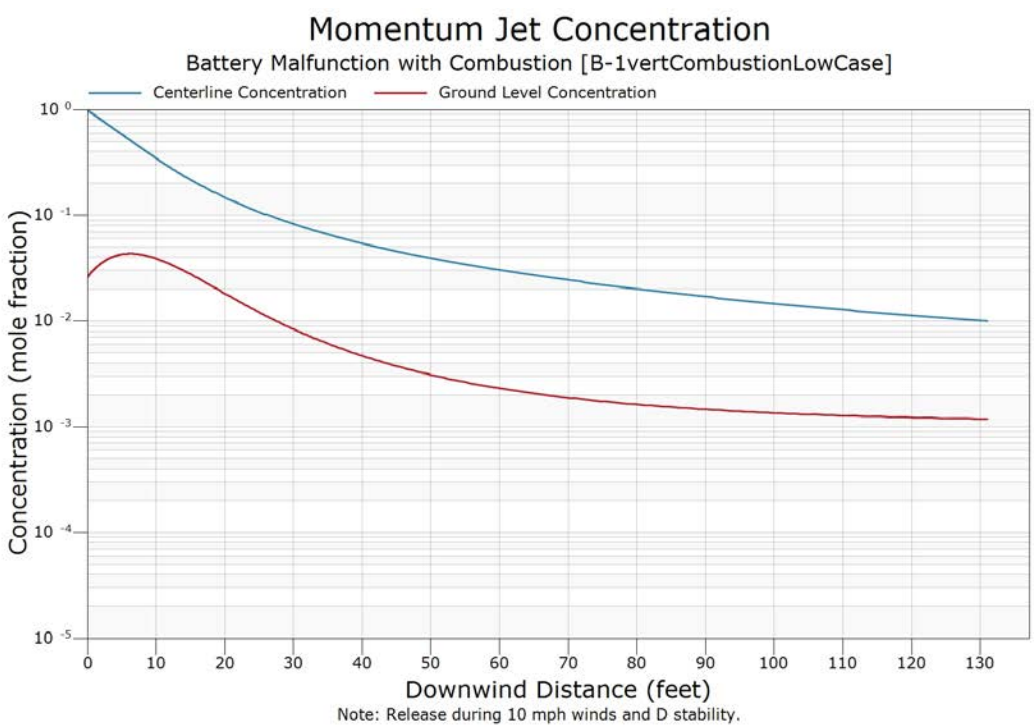
downwind distance (ft)	centerline conc. (mole frac.)	ground conc. (mole frac.)	Endpoint3 1/2 width (ft)	Endpoint2 1/2 width (ft)	Endpoint1 1/2 width (ft)	centerline height (ft)
0	1.000000	0.000000	9.1	6.8	5.7	7.7
3	0.760889	0.037002	10.0	7.3	6.0	7.8
5	0.584698	0.042718	10.9	7.8	6.3	8.1
7	0.449199	0.042792	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)
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100
110
120
130
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)
10 ⁰
10 ⁻¹
10 ⁻²
10 ⁻³
10 ⁻⁴
10 ⁻⁵
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Downwind Distance (feet)
Note: Release during 10 mph winds and D stability.