

NFPA TECHNICAL COMMITTEE ON HM/WMD EMERGENCY RESPONSE HIGH HAZARD FLAMMABLE LIQUID TRAIN (HHFT) INCIDENTS WHITE PAPER

FINAL – 6/28/16

I. INTRODUCTION

Changes in the North American energy sector have brought new challenges to the emergency response community, especially in many geographic areas where there has not historically been a large energy sector footprint. These changes have involved upstream oil and gas exploration, production and manufacturing facilities, as well as in midstream operations where transportation modes, corridors and operations have been expanded to meet the needs of the emerging marketplace.

In response to a task from the NFPA Standards Council, the *NFPA Technical Committee on HazMat / WMD Emergency Response (NFPA 472)* has been requested to address the competencies and procedures for emergency response to flammable liquid incidents involving high hazard flammable liquid trains (HHFT). The U.S. Department of Transportation – Pipeline and Hazardous Materials Safety Administration (DOT / PHMSA) defines High Hazard Flammable Liquid Trains (HHFT) as trains that have a continuous block of twenty (20) or more tank cars loaded with a flammable liquid or thirty-five (35) or more cars loaded with a flammable liquid dispersed through a train.

The objectives of this White Paper are to assist emergency planning and response personnel in preparing for and responding to HHFT emergencies. Topics covered in this paper will include:

- Emergency Planning for HHFT Scenarios
- The HHFT Technical Specialist
- Understanding Crude Oil
- The Tank Cars
- Incident Management
- Tactical Considerations
- Risk Based Response: The HHFT Incident Timeline

II. EMERGENCY PLANNING FOR HHFT SCENARIOS

The volume of HHFT movements is influenced by economics, market forces, and political policy decisions. While there will be some variation in the total number of future tank car movements, the HHFT issue will likely challenge communities for the foreseeable future. Even as new transmission pipelines are approved and constructed, the continued movement of both crude oil and ethanol HHFT's from their source to refineries and the marketplace is likely to continue.

Pre-incident relationships between emergency responders and their railroad points-of-contact is a critical element in establishing the trust and credibility needed during a major response. By reviewing commodity flow studies, transportation corridor assessments and operational capability assessments, responders can determine and prioritize the overall risks posed by different scenarios to their community.

Key components of local-level planning include the Local Emergency Planning Committee (LEPC) (or its equivalent) and the community Emergency Operations Plan (EOP). The LEPC provides a vehicle for bringing together all of the key stakeholders to the hazardous materials planning process, including public safety responders, manufacturers and shippers, and key transporters such as the railroad industry. Communities are mandated by government regulation and law to develop an EOP that addresses identified hazards, risks and vulnerabilities. EOP's normally have an "all hazards" focus; however, many EOP's will also have more detailed annex information for critical risks and vulnerabilities involving railroad facilities and corridors. Within Canada, emergency responders have access to Emergency Response Assistance Plans (ERAP), which are currently required by Transportation of Dangerous Goods Regulations (Protective Direction 33 or PD33) for certain higher risk dangerous goods and have recently been expanded to include most flammable and combustible liquids.

A review of HHFT incidents over the last decade provides the following planning observations:

- HHFT incidents are low frequency, high consequence response scenarios. Critical response considerations will include the location of the incident, the overall size and scope of the problem, the potential for rapid growth of the fire and spill problem, and the level of resources initially available.
- HHFT scenarios involving fire are typically large, complex response incidents that will generate numerous response issues beyond those normally seen by most local-level response agencies. Depending upon incident size and location, HHFT scenarios can be categorized at a minimum of a NIMS Type 3 incident.
- Given the length of flammable liquid unit trains (over a mile long), derailments can cause road closures, create significant detours, and require response from more than one direction to access the incident scene.
- In addition to the inherent spill and fire control problems, response issues can include public protective actions, logistics and resource management, situational awareness, information management, public affairs, and infrastructure restoration.
- The number of tank cars involved in a HHFT derailment will be dependent upon a number of factors, including train speed, train make-up and track configuration (e.g., curve, grade).
- As part of the planning process, be aware of the potential impacts a rail incident may have on surrounding infrastructure. For example, transportation corridors often run next to the rail corridor, while communication, water and sewer utilities and pipeline right-of-ways may run adjacent to or within the railroad right-of-way. During an incident, be aware of downed signal and communications lines, power lines, buried utilities and above ground switch heating systems.
- Early establishment of a unified command structure and expanding the ICS organization to include command and general staff positions will be critical in both recognizing and managing these response issues.
- While emergency response operations are often conducted within 24 hours or less, post-emergency response operations (i.e., clean-up and recovery) can extend over a period of several days and potentially weeks. Clean-up and recovery operations are normally coordinated by the railroad and environmental agencies; emergency responders may continue to monitor and support these activities, as necessary.

The application and use of a risk-based response (RBR) methodology for both HHFT planning and response purposes is a critical success factor. As background, RBR is defined by *NFPA*

472 – Standard for the Competence of Responders to HM/WMD Incidents as a systematic process by which responders analyze a problem involving hazardous materials, assess the hazards, evaluate the potential consequences, and determine appropriate response actions based upon facts, science, and the circumstances of the incident. Knowledge of the behavior of both the container involved and its contents are critical elements in determining whether responders should and can intervene.

III. THE HHFT TECHNICAL SPECIALIST

It is the opinion of the Technical Committee on HazMat / WMD Emergency Response that First Responder Operations training requirements for railroad scenarios, including HHFT emergencies, are currently addressed in *NFPA 472, Chapter 5 – Core Competencies for Operations Level Responders*. In addition, additional skills and competencies for Hazardous Materials Technician can be found in *NFPA 472, Chapter 12 – Competencies for Hazardous Materials Technicians with a Tank Car Specialty*.

The Technical Committee believes that one area where additional HHFT-related skills and competencies may be valuable is the utilization of a Specialist Employee (per OSHA and NFPA 472) or Technical Specialist (per the National Incident Management System or NIMS). Examples of these individuals already exist within the response community; these include Hazardous Materials Officers (HMO) and Dangerous Good Officers (DGO) from the railroad, product and container specialists representing the shipper, and emergency response specialists representing emergency response contractors who specialize in high hazard response operations. A number of emergency response organizations are now considering the establishment of internal or discipline-specific HHFT Technical Specialists.

For the purposes of this white paper, the term “Technical Specialist” is used to describe product and container specialists who provide product / container-specific technical and tactical information to the Incident Commander during response operations. Technical Specialists can also be a valuable resource to emergency management and preparedness agencies during the planning process.

The HHFT Technical Specialist may be affiliated with a range of agencies or organizations, including the shipper, the railroad, public safety response agencies, or specialized emergency response contractors. In line with NFPA 472, the HHFT Technical Specialist should possess knowledge and skills in the four major domains of emergency response, including Analysis, Planning, Implementation and Evaluation (APIE).

The role of the HHFT Technical Specialist can vary depending upon the incident timeline. For example:

- Planning Phase – provide product, container and response technical support for the planning process. Knowledge of needed and available resources is critical.
- Response Phase (Initial Operational Period) – provide product, container and response technical support for emergency response operations, including fire control and spill control strategies and tactics. May also provide support to the initial establishment and implementation of the ICS organization.

- Response Phase (Second and Later Operational Periods) – provide liaison support (i.e., role as a facilitator or collaborator) between public safety responders and other governmental and industry response organizations and representatives.

Pre-Requisites, Skills and Competencies. A wide range of options and opinions exists on what specific skills and competencies the HHFT Technical Specialist should possess. The Technical Committee believes that emergency responders should have the flexibility to make decisions based upon local risks, resource levels and operational capabilities.

HHFT Technical Specialist pre-requisites and considerations should include the following:

- *Hazardous Materials Emergency Response* - minimum qualification should be the First Responder Operations (FRO) level and preferably Hazardous Materials Technician (HMT), with an emphasis on the following topics:
 - Properties and behavior of Hazard Class 3 – Flammable Liquids, with emphasis on petroleum crude oil and ethanol.
 - Design, construction and operation of terminals and distribution facilities where HHFT's are loaded / unloaded.
 - Design and construction of transportation containers, including cargo tank trucks and railroad tank cars (e.g., DOT-111A, CPC-1232, DOT-117 / 117R).
 - Ability to apply risk-based response methodologies at HHFT incidents.
 - Spill control operations for both ground and water-borne releases of flammable liquids.
- *Firefighting Operations* – minimum qualifications should be equivalent to NFPA 1001 - Firefighter II or NFPA 1081 – Advanced Exterior Industrial Fire Brigade Member (Chapter 6). Emphasis should be placed on the selection, application and use of Class B extinguishing agents for large flammable liquid fire scenarios.
- *Incident Management* – minimum qualifications should be ICS-300 – Intermediate ICS for Expanding Incidents or equivalent. Emphasis should be placed on managing a minimum of Type 4 incident response scenarios, with a preference for Type 3 qualifications involving activation of the full command and general staff organization.

NFPA 472 Goal Statements - HHFT Technical Specialist. The following goal statements follow the format as used in NFPA 472 and provide an overview of the expected knowledge and skills that the Technical Committee believes would be required for a HHFT Technical Specialist:

- 1.1 The goal of the competencies shall be to ensure that the HHFT Technical Specialist has the knowledge and skills to perform the tasks in 1.2 safely.
- 1.2 When responding to HHFT incidents, the HHFT Technical Specialist shall be able to perform the following tasks:
 - (1) Analyze a HHFT incident to determine the complexity of the problem and potential outcomes by completing the following tasks:
 - (a) Survey an incident involving a HHFT, including the following:
 - i. Identify and verify the hazardous materials involved.
 - ii. Identify the types of tank cars involved
 - iii. Safely operate in and around railroad corridors and facilities

- (b) Collect and interpret hazard and response information from printed resources, technical resources, computer databases, and detection and monitoring equipment
 - i. Identify the owner / operator of the affected rail line and their contact information
 - ii. Access hazardous materials shipping papers and establish communications with the railroad
 - (c) Determine the extent of damage to involved train cars, including tank cars
 - (d) Predict the likely behavior of tank cars and their contents in an emergency
 - (e) Estimate the potential outcomes of an incident involving a HHFT
- (2) Plan a response to a HHFT emergency within the capabilities and competencies of available personnel, personal protective equipment, and control equipment by determining the response options (offensive, defensive, and nonintervention).
- (a) Identify the response objectives for an incident involving a HHFT
 - (b) Identify the potential response options for each response objective for an incident involving a HHFT
 - (c) Select the personal protective equipment required for a given response option for an incident involving a HHFT
 - (d) In conjunction with the Incident Commander, develop an incident action plan (within the capabilities of the available resources), including site safety and control plan, for handling a HHFT incident consistent with the emergency response plan and/or standard operating procedures
- (3) Operating under the incident management system/incident command system (IMS/ICS), implement or oversee the planned response (as developed with the incident commander) to a HHFT incident consistent with the emergency response plan and/or standard operating procedures.
- (4) Evaluate the results of implementing the planned response to a HHFT incident

IV. UNDERSTANDING CRUDE OIL

The word “oil” in the product crude oil can incorrectly imply that this product has a high flash point (like motor oil) and therefore presents a low risk of ignition. This is NOT accurate – crude oil is a flammable liquid and can present a significant risk of ignition, especially on a warm day.

When removed from the ground, crude oil is often a mixture of oil, gas, water and impurities (e.g., sulfur). The viscosity of the crude oil and its composition will vary based upon the oil reservoir from which it is drawn, well site processing, and residence time in storage tanks. When transferred into a storage tank or a railroad tank car, it is often a mixture of crude oil and related constituents drawn from various locations and even different producing formations.

It is impossible to determine from which well site any one individual rail car load has originated. Shipments of crude oil are analyzed at the loading location and will have a certification of analysis for the mixture that is loaded on the train. While primarily used for refinery engineering purposes the certificate of analysis includes a characterization of the crude oil and its fractions,

and can provide critical information on how the crude oil will behave in a water-borne spill scenario.

Emergency responders must have a basic understanding of the physical properties (i.e., how it will behave) and chemical properties (i.e., how it will harm) of the materials involved. Considerations should include (a) whether the crude oil is a light or heavy crude oil (in terms of viscosity), and (b) if the crude is a sweet or sour crude oil. **Table 1** (see pages X-X) provides an overview of the common types of crude oils currently being encountered in HHFT incidents.

The viscosity of petroleum liquids is often expressed in terms of American Petroleum Institute or API gravity, which is a measure of how heavy or how light a petroleum liquid is as compared to water. Water has an API gravity of 10: if the gravity is greater than 10 the petroleum product is lighter and will float on water; if less than 10 it is heavier and will sink. Crude oils are classified by the petroleum industry into the following general categories based upon their API gravity:

<u>Viscosity</u>	<u>API Gravity</u>
Light	> 31°
Medium	22 to 31°
Heavy	< 22°
Extra Heavy	< 10°

Sour crude oil is a crude oil containing a large amount of sulfur (greater than 0.5% or 5,000 ppm hydrogen sulfide concentrations) and may pose a toxic inhalation hazard (Threshold Limit Value – Time Weighted Average of 1 ppm and Immediately Dangerous to Life and Health (IDLH) exposure value of 100 ppm). Hydrogen sulfide levels can be an issue in a spill scenario, with higher concentrations typically being found within the container or directly outside of a tank car opening.

Shale crude oils tend to be a light sweet crude oil with a low viscosity, low flashpoint, and low benzene content. Shale crudes may also have the possibility of producing significant amount of C₆ - hexane in some locations. In contrast, oil sands crude oils (e.g., Alberta Tar Sands, bitumen) tend to be a heavier crude oil with an API gravity of approximately 8°. Canadian tar sand crudes also tend to be sour unless they have been partially refined before being loaded onto tank cars.

Bitumen is a tar-like material that is extracted from tar sands. It is highly viscous and must be heated to make it flow. The majority of bitumen being extracted in North America originates in Alberta, Canada. In order to thin bitumen enough to make it pumpable for transport, a diluent is usually added to decrease the viscosity and density of the crude oil. The most commonly used diluent is natural gas condensate (liquid byproduct of natural gas processing). Typically these mixtures are 70% bitumen and 30% diluent, resulting in a API gravity of less than 22°.

Bitumen that is partially refined is known as syncrude, with the refining process generating a liquid that is similar to a medium-weight sweet crude oil. In Canada, diluents can also be found being transported under the UN 1993 placard with varying levels of both hydrogen sulfide and benzene. At a 2010 pipeline incident in Michigan involving bitumen, responders reported the presence of floating oil, submerged oil, and sunken oil. Incident experience has noted that the behavior of bitumen oils in water will ultimately depend upon the density of the oil, weathering, and the turbulence of the water.

TABLE 1	LIGHT SWEET CRUDE OIL	DILBIT/SYNBIT (BITUMEN WITH DILUENT*)	BITUMEN (OIL SANDS)	DILUENT
TRANSPORTED AS HAZMAT	Yes - DOT Class 3, UN1267 (ERG Guide No. 128)	Yes - DOT Class 3, UN1267 (ERG Guide No. 128)	Maybe - DOT Class 9, UN3257 (ERG Guide No. 128) If shipped above 212° F and below its flash point	Yes - DOT Class 3, UN1268 or UN 3295 (ERG Guide No.128)
FLASH POINT	Varies: -30° F - 104° F	Range: 0.4° F (dilbit) - 68° F (synbit)	330° F	<-30° to -4° F
BOILING POINT	Varies: PGI = <95° F, PGII = >95° F	95° F - >500° F	554° F	100 - 118° F
REID VAPOR PRESSURE	8 - 14 psi	11 psi	4 psi	8 - 14 psi
VISCOSITY** IN CENTIPOISE (CPS) @ ~75 °F:	6-8 (Low - Flowable)	60-70 (Low - Flowable)	100,000-1,000,000 (very high - semi solid when cold)	6-8 (Low - Flowable)
API GRAVITY	Bakken 40° - 43°	Will vary based on amount of diluent; approximately 20°	Approximately 8°	
SPECIFIC GRAVITY	0.80 (Floats on water)	0.90-0.98 Initially (Floats then sinks as light ends volatilize)	0.95 - 1.05 (Will sink in Salt Water; Likely to sink in Fresh Water)	0.480-0.75 (Floats on water)
VAPOR DENSITY	1.0 - 3.9 (Heavier than Air)	>1 (Heavier than Air)	>1 (Heavier than Air)	1.0 - 3.9 (Heavier than Air)
HYDROGEN SULFIDE	0.00001% (potential to accumulate as H ₂ S in head space of vessels) If H ₂ S concentrations ≥ 0.5% or 5,000 ppm classified as Sour Crude DOT Class 3, UN3494	<0.1% (potential to accumulate as H ₂ S in head space of vessels) If H ₂ S concentrations ≥ 0.5% or 5,000 ppm shipped as Sour Crude DOT Class 3, UN3494 (ERG Guide No. 131)	Negligible (contains bonded sulfur, generally not available as H ₂ S)	<0.5

	(ERG Guide No. 131)			
BENZENE	Generally <1.0%	0% - 5%	Negligible (Monitor, however it should not be a concern)	0% - 5%

TABLE 1 (continued)	LIGHT SWEET CRUDE OIL	DILBIT/SYNBIT (BITUMEN WITH DILUENT*)	BITUMEN (OIL SANDS)	DILUENT
EVAPORATION RATE (TEMPERATURE DEPENDENT)	>1 (High Evaporation Rate)	Diluent will evaporate quickly, Bitumen will not evaporate	None	>1 (High Evaporation Rate)
SOLUBILITY	Low to Moderate	Moderate	Extremely Low	Slightly Soluble
WEATHERING	Quickly	Diluent weathers fairly quickly, will then form tar balls	Very Slow - Like Asphalt	Quickly
RESIDUES	Films and Penetrates	Films and Penetrates - residue is very persistent	Heavy Surface contamination - very Persistent	Films and Penetrates
AIR MONITORING	LEL (combustible gas indicator), Benzene (direct read or tubes), H₂S (direct read or tubes)	LEL (combustible gas indicator), Benzene (direct read or tubes), H₂S (direct read or tubes)	LEL (combustible gas indicator), Benzene (direct read or tubes), H₂S (direct read or tubes)	LEL (combustible gas indicator), Benzene (direct read or tubes), H₂S (direct read or tubes)
RECOMMENDED PPE	<u>Clothing:</u> Turnout Gear / Fire Retardant Coveralls (subject to task and air monitoring) <u>Respiratory Protection:</u> SCBA/APR/Nothing (subject to task & benzene, H ₂ S & particulate concentrations)	<u>Clothing:</u> Turnout Gear / Fire Retardant Coveralls (subject to task and air monitoring) <u>Respiratory Protection:</u> SCBA/APR/Nothing (subject to Task & benzene, H ₂ S & particulate concentrations)	<u>Clothing:</u> Thermal Protection (if hot) / Fire Retardant Coveralls (subject to task and air monitoring) <u>Respiratory Protection:</u> SCBA/APR/Nothing (subject to Task & benzene, H ₂ S & particulate	<u>Clothing:</u> Turnout Gear / Fire Retardant Coveralls (subject to task and air monitoring) <u>Respiratory Protection:</u> SCBA/APR/Nothing (subject to Task & benzene, H ₂ S & particulate concentrations)

			concentrations)	
COMMUNITY, WORKER & RESPONDER SAFETY	Flammability, Benzene, LEL, H ₂ S	Flammability, Benzene, LEL, H ₂ S, PAH's (poly- aromatic hydrocarbons)	H ₂ S, PAH's (poly-aromatic hydrocarbons)	Flammability, Benzene, LEL, H ₂ S

Crude Oil Firefighting. Considerable research and experience exists on crude oil firefighting, especially as it pertains to crude oil storage tank firefighting and the behavioral concepts of frothover, slopover and boilover. Frothovers and slopovers can be a safety issue when applying extinguishing agents, especially in the later stages of a crude oil tank car fire. Application of foam and water in the later stages of a crude oil tank car fire can result in some of the tank car contents spewing out of tank car openings.

In contrast, the risk of a boilover at a crude oil derailment scenario remains subject to debate. Questions exist on whether the findings seen in crude oil storage tank firefighting can be directly extrapolated to HHFT scenarios. As background, in order for a boilover to occur in a storage tank scenario, three criteria are needed:

- The oil must have a range of light ends and heavy ends capable of generating a heat wave;
- The roof must be off of the tank (i.e., full surface fire); and
- A water bottom (i.e., water at the bottom of the tank) necessary for the conversion of the water to steam (1,700:1).
- As the oil burns, the light ends burn off and a heat wave consisting of the heavier oil elements is created. When this heat wave reaches the water bottom, the water rapidly flashes over to steam at an expansion ratio of 1,700:1 and forces the ejection of the crude oil upward and out of the tank.

While always possible, the conditions needed for a boilover appear to lower the probability of a boilover occurring in a tank car derailment scenario as compared to a crude oil storage tank scenario. A key factor in assessing the probability of a boilover is the amount of water in the container. Based upon observations at a number of refineries, shale oil tank cars are typically arriving at refineries with <1% water. Mechanical agitation from the transportation of crude oil in a tank car keeps the water content in suspension. In addition, crudes in rail transport do not have the same residence time for the water to accumulate at the bottom of a moving tank car as it does in a static fixed storage tank. It is difficult to achieve all of the conditions needed for a boilover to occur in this scenario. However, the indiscriminate application of large water streams into a pile of burning tank cars that result in water getting inside of a tank car may increase the risk of a boilover later in the incident.

General Observations. The following general observations have been noted with respect to the behavior of crude oils and ethanol as found in HHFT scenarios:

- Incidents involving crude oil products with varying percentages of dissolved gases have not generated significant emergency response issues in terms of fire behavior once ignition occurs. Dissolved gases and light ends may facilitate easier ignition of the released product when the initial tank car stress / breach / release events take place. There does not appear to be significant differences in fire behavior once ignition occurs. Once light ends burn off, a heavier, more viscous crude oil product will often remain.
- When shipped as a freight rail commodity, ethanol can be either straight or “neat” ethyl alcohol, or denatured fuel ethanol which has been denatured with 2 – 5% unleaded gasoline to make the liquid unfit for drinking. Table 2 outlines the physical and chemical properties of ethanol products that may be found in HHFT trains.

In its pure form, ethanol does not produce visible smoke and has a hard-to-see blue flame. In a denatured form, there is little to no smoke with a slight orange visible flame. A thermal imaging camera can be used to identify whether a flame is truly present or not.

- Responders will likely have environmental challenges for water-borne spill scenarios involving crude oil and ethanol, especially if the incident impacts a navigable waterway. Ethanol has a very low persistence and will evaporate or dissolve into the water column. Low concentrations of ethanol in water (as low as 10%) will have a flash point in the area of 120° F. In contrast, crude oil will weather and leave a very persistent heavy residue. These differences will require different spill response tactics.
- In non-fire spill scenarios, vapor concentrations have been confirmed via air monitoring. Air monitoring at non-fire events has also shown that the light ends will boil off within several hours. Obtaining the Certificate of Analysis (or comparable information) from the shipper may provide key information on the crude oil viscosity and make-up for assessing potential spill behavior in water.
- Air monitoring results at both incidents and test fires have shown that the products of combustion (i.e., soot and particulates) from crude oil and ethanol fires have not been significantly different than those seen at fires involving Class A materials.¹
- Incident experience has shown that very seldom does the fire completely consume all of the product within a tank car. Responders have noted that once the light ends have burned off and the intensity of a crude oil tank car fire levels off to a steady state fire, the heavier ends continue to burn similar to a “smudge pot.”

TABLE 2	DENATURED FUEL ETHANOL
TRANSPORTED AS HAZMAT	Yes - DOT Class 3, UN 1170 – Ethyl Alcohol UN 1987 – Denatured Fuel Ethanol – US UN 3475 – Denatured Fuel Ethanol - Canada (ERG Guide No. 127)
FLASH POINT	Varies: -5° F
BOILING POINT	Varies: PGII = 165-175° F.
REID VAPOR PRESSURE	2.3 psi
VISCOSITY** IN CENTIPOISE (CPS) @ ~60 °F:	1.19
API GRAVITY	46° - 49°
SPECIFIC GRAVITY	0.79 (Floats on water)
VAPOR DENSITY	1.59 (Heavier than Air)
BENZENE	Generally ≤1.0%
EVAPORATION RATE	>1 (High Evaporation Rate)

(TEMPERATURE DEPENDENT)	
SOLUBILITY	High
AIR MONITORING	LEL (combustible gas indicator), Benzene (direct read or tubes)
RECOMMENDED RESPONDER PPE	<u>Clothing:</u> Turnout Gear/Fire Retardant Coveralls (subject to task and air monitoring) <u>Respiratory Protection:</u> SCBA/APR/Nothing (subject to task & benzene & particulate concentrations)
COMMUNITY, WORKER & RESPONDER SAFETY	Flammability, Benzene, LEL

V. THE TANK CARS

Flammable liquids, including crude oil and ethanol, have been transported in DOT-111 or CPC-1232 tank cars. These non-pressure tank cars (also called general service or low-pressure tank cars) are built to transport low-vapor pressure commodities, including regulated (hazardous materials / dangerous goods), as well as non-regulated commodities. Key construction features of these containers include:

- May be single shell or jacketed containers, with a tank shell thickness of 7/16 inches.
- Capacity of 33,000 gallons (125,000 litres)
- Weight of approximately 286,000 lbs. (130,000 kilograms).
- Top fittings and bottom belly valve.

On May 8, 2015, the US DOT/PHMSA issued a final rule (HM-251) that provided risk-based regulations pertaining to HHFT operations and new tank car standards for HHFT's. As specified in the final rule, during the period of 2017 through 2025 DOT-111 and CPC-1232 tank cars used for the shipment of flammable liquids in HHFT service will be either (a) removed from service; (b) retrofitted to meet a new DOT-117R standard; or (c) replaced by the new DOT-117 tank car. New tank cars constructed after October 1, 2015 must meet the DOT-117 design or performance criteria.

On December 4, 2015, the Fixing America's Surface Transportation (FAST) Act was signed into law and revised the May 8, 2015 rulemaking to now apply to all flammable liquids transported by rail. See Table 3 for an overview of the U.S. regulatory retrofit schedule.

Table 3 – DOT-111 Tank Car Retrofit Schedule

Commodity	Tank Car	Phase-out /Retrofit
Crude Oil	DOT-111 Non-jacketed	January 1, 2018
	DOT-111 Jacketed	March 1, 2018
	CPC-1232 Non-Jacketed	April 1, 2020
	CPC-1232 Jacketed	May 1, 2025
Ethanol	DOT-111 Jacketed & Non-Jacketed	May 1, 2023
	CPC-1232 Non-jacketed	July 1, 2023
	CPC-1232 Jacketed	May 1, 2025
Other Class 3, PG I		
	DOT-111, CPC-1232	May 1, 2025
Other Class 3, PG II & III		
	DOT-111, CPC-1232	May 1, 2029

From a risk-based response perspective, the enhanced DOT-117R and DOT-117 tank cars will have most of the same construction features currently found on pressure tank cars used for the transportation of liquefied gases (e.g., LPG, anhydrous ammonia, etc.). These features will include full-height 1-2-inch thick head shields, jacketing, thermal protection, increased shell thickness (DOT-117), top fitting protection, and either removal or redesign of the bottom outlet handle. The DOT-117R will have a minimum shell thickness of 7/16 inches, while the DOT-117 will have a shell thickness of 9/16 inches.

The following facts can be noted with respect to the product / container behavior in a HHFT scenario:

- Tank cars equipped with jacketing and thermal protection have performed better than the legacy DOT-111 and non-jacketed CPC-1232 (i.e., Interim DOT-111) tank cars in derailment scenarios involving fire.
- The number of tank cars that breach or fail is dependent on the type of tank car involved (e.g., DOT-111, CPC-1232 jacketed vs. non-jacketed tank car) and the configuration of the derailment (i.e., in-line vs. accordion style). Tank cars that pile up generally sustain greater numbers of car-to-car impacts that result in breaches, or will be susceptible to cascading thermal failures from pool fires. Tank cars that roll over in-line are less susceptible to a container breach, but may leak from damaged valves and fittings.
- It may be difficult for emergency responders to easily differentiate between jacketed and non-jacketed tank cars in a derailment scenario. Railroad and container technical specialists can provide assistance in the container identification and damage assessment process.

- After the initial mechanical stress associated with a derailment, crude oil and ethanol tank cars may breach based upon a combination of (a) thermal stress from an external fire impinging on the tank car shell, (b) the heat-induced weakening and thinning of the tank car shell metal, and (c) the tank car internal pressure. The hazards posed by the release of flammable liquids include flash fires, pool fires, fireballs from container failure (i.e., radiant heat exposures) and any associated shock wave.

For example, all of the crude oil tank cars involved in the Mount Carbon, WV derailment were CPC-1232 tank cars with no thermal protection. During the derailment sequence, two tank cars were initially punctured releasing more than 50,000 gallons of crude oil. Of the 27 tank cars that derailed, 19 cars became involved in the pileup and post-accident pool fire. The pool fire caused thermal tank shell failures on 13 tank cars that otherwise survived the initial accident.²

- Understanding the possible timing of tank shell failures is critical. Emergency responders at the Mount Carbon, WV incident reported the first thermal failure about 25 minutes after the accident. Within the initial 65 minutes of the incident, at least four tank car failures with large fireball eruptions occurred. The 13th and last thermal failure occurred more than 10 hours after the accident.³
- The size of the area potentially impacted by both the fireball and radiant heat as a result of a tank car failure are key elements in a risk-based response process. A review of research literature by the Sandia National Laboratory for U.S. DOT / PHMSA showed that a 100 ton release of a flammable liquid (approximately equivalent to a 30,000 gallon tank car) with a density similar to kerosene or gas oil would produce a fireball diameter of approximately 200 meters (656 feet) and a duration of about 10 – 20 seconds.⁴ This information can assist Incident Commanders in determining protective action distances as part of a risk-based response process.

Observations that can be made with respect to the behavior of the railroad tank cars in a HHFT scenario include:

- Derailments resulting in a liquid pool fire scenario will lead to the failure of valve gaskets, which leads to additional tank car leaks and associated issues during derailment clean-up and recovery operations.
- Clues and indicators of an increasing probability for an HHFT incident to rapidly grow or cascade can include:
 - Running or unconfined spill fires and releases. Spills may flow into storm drains and other underground structures creating secondary spills and fires. In addition, the use of large water streams for cooling may also spread the fire to unintentional areas.
 - Direct flame impingement on tank cars from either a pool fire or torch fire.
 - Presence of heat induced blisters appearing on the tank car shell.
 - Activation of pressure relief devices (PRD).
 - Fire area has grown since emergency responders have arrived on-scene.

Any tank car that is subject to flame impingement and venting from a PRD is susceptible to container failure and the generation of a large fireball.

- Heat induced tears (HIT) have been observed on tank cars containing both crude oil and ethanol, and may occur on any flammable liquid tank car. These tears may initially appear as a “blister” on the upper side of the tank shell. When HIT’s occur, the majority of the thermal energy is released upwards as compared to moving outward a significant distance. At this time no relationship between the activation of a pressure relief device and the blistering of the tank car shell has been observed. While the majority of heat induced tears (HIT) have occurred during the initial 1-6 hours of an incident, tank car failures can occur at any time. Heat induced tearing has occurred within 20 minutes of the derailment and as long as 10+ hours following the initial derailment.
- There can be significant differences in product behavior (e.g., physical properties, internal pressure), tank car design and construction, and breach-release behaviors between pressure tank cars such as the DOT-105 and DOT-112/114 tank cars, and non-pressure tank cars such as the DOT-111 and CPC-1232.

There has been no evidence of runaway linear cracking or separation as historically observed with pressure tank car failures occurring in unit train scenarios involving crude oil. However, based upon Federal Railroad Administration (FRA) reports, the following container behavior observations have been noted: ^{5, 6}

- Container separation has occurred at derailments involving ethanol tank cars in Arcadia, OH and Plevna, MT. A separation occurs when a thermal tear propagates circumferentially from each end of the tear and results in the tank car completely or nearly fragmenting into multiple pieces.
- The FRA report also noted that some of the “explosions” at these derailments may be the result of either a rapid massive vapor release in a matter of seconds which can cause a blast wave the effects of which are limited to relatively short distances or the misrepresentation of the fire ball type of burning as an “explosion.”
- As defined by NFPA, a BLEVE is a major container failure, into two or more pieces, at a moment in time when the contained liquid is at a temperature well above its boiling point at normal atmospheric pressure. DOT-111 and CPC-1232 tank cars transporting crude oil do not appear to be susceptible to the separation / fragmentation of the tank car, similar to that seen with pressure tank cars. However, as noted above, separation of ethanol tank cars has occurred at two incidents.
- The term “equilibrium” is used at various places within this paper to describe the point in which the fire problem is no longer expanding and has achieved a “steady state” of fire and container behavior. It usually takes place after most of the light ends have burned off and the intensity of the fire is no longer increasing. The following fire behavior and incident characteristics would be indicative of the state of “equilibrium:”
 1. The fire is confined to a specific area with little probability of growth in either size or intensity.
 2. There is low probability of additional heat induced tears or container breaches caused by fire impingement directly upon tank cars.
 3. There are no current pressure relief device (PRD) activations indicating continued heating of tank cars.

- Flammable liquid tank cars that have been breached and involved in fire will usually contain some residual product that will continue to produce internal vapors (i.e., typically a vapor rich environment). Anticipate that valve gaskets have failed, which will result in additional tank car leaks and associated issues during derailment clean-up and recovery operations. Responders should expect vapor flash fires at any time and in any direction, especially during wreck clearing and clean-up operations.

VI. INCIDENT MANAGEMENT

HHFT incidents are large, complex and lengthy response scenarios that will generate numerous response issues beyond those normally seen by most local-level response agencies. In addition to the hazmat issues associated with the response problem, there will be a number of other secondary response issues that will require attention by Incident Command / Unified Command. These will include public protective actions, logistics and resource management, situational awareness, information management, public affairs, and infrastructure restoration.

Expanding the ICS organization early to include command and general staff positions will be critical in both recognizing and managing these issues. All-Hazard Incident Management Teams (AHIMT's) at the regional, state and federal levels can serve as an excellent resource to support unified command activities.

Unified command will be critical for the successful management of the incident. The make-up of unified command during the first operational period will likely change in subsequent operational periods as the incident transitions and incident objectives change. Initial unified command will primarily consist of local response agencies that routinely work together at the local level (e.g., fire, LE, EMS and an initial railroad representative). As the incident expands and other agencies arrive on-scene, unified command will evolve to the organizational structure outlined in the National Response Framework or Canadian equivalent for oil and hazardous materials scenarios (i.e., Emergency Support Function (ESF- 10). Under ESF-10, unified command will likely consist of the following:

- Local On-Scene Coordinator (most likely the Fire Department during emergency response operations)
- State On-Scene Coordinator (usually designated state environmental agency)
- Federal On-Scene Coordinator (U.S. Environmental Protection Agency (EPA) or U.S. Coast Guard (USCG), based upon the location of the incident and its proximity to navigable waterways.)
- Responsible Party or RP (e.g., Senior Transportation Officer, shipper).
- For incidents on tribal lands of Federally recognized Indian tribes, a representative from the Indian tribe should be invited to participate.

Class 1 railroads will often integrate their operational capabilities as a Railroad Branch within the Operations Section, based upon the following four major organizational elements:

- Transportation – monitors the network, routes traffic and schedules trains and crews
- Mechanical - responsible for all rolling stock (railcars) and locomotives

- Engineering – responsible for all infrastructure including track, signals, bridges, tunnels, etc.
- Risk Management – contains emergency response functions such as Railroad Police, Hazardous Materials, Environment, Public Affairs, Claims, etc.

It should be stressed that the basic approach for managing HHFT incidents is not much different than other hazmat response scenarios – do not under-estimate the need or the value of basic HM-101 skills. Knowledge of the product, its container, incident location and exposures will be critical in evaluating response options using a risk-based response process.

VII. TACTICAL CONSIDERATIONS

Operational Modes. The Incident Action Plan (IAP) is developed based upon the IC's assessment of (1) incident potential (i.e., visualizing hazardous materials behavior and estimating the outcome of that behavior), and (2) the initial operational strategy. The IAP should clearly identify critical factors, the strategic goals, tactical objectives, and assignments that must be implemented to control the problem, as well as required resources and support materials.

- *Strategic goals* are the broad game plan developed to meet the incident priorities (life safety, incident stabilization, environmental and property conservation). Strategic goals are “what are you going to do to make the problem go away?”
- *Tactical objectives* are specific and measurable processes implemented to achieve the strategic goals. Tactical objectives are the “how are you going to do it” side of the equation, which are then eventually tied to specific tasks that are assigned to particular response units.
- *Modes of Operation* – Tactical response objectives to control and mitigate the response problem may be implemented in either an offensive, defensive or nonintervention mode.

Offensive Operations are aggressive leak, spill, and fire control tactics designed to quickly control or mitigate the emergency. Although increasing the risks to responders, offensive tactics may be justified if rescue operations can be quickly achieved, if the spill can be rapidly contained or confined, or the fire quickly extinguished. The success of an offensive-mode operation is dependent on having the necessary resources available in a timely manner. Critical risk considerations will include:

- This is a high-risk operation that involves attempting to extinguish the fire.
- Flammable liquid firefighting and Class B foam operations require large water supplies to support cooling operations, exposure protection and fire extinguishment. Most railway corridors do not have hydrant-based water supplies immediately available. In addition, using natural water sources such as streams and rivers may not be easily and safely accessible.
- If your agency does not have the operational capability in terms of resources (Class B foam and water), equipment (foam appliances and large volume application devices) and properly trained personnel to intervene, defensive or nonintervention strategies will likely be the preferred strategic option.
- Well-intentioned actions to extinguish a flammable liquid fire may actually create long-term environmental impacts. Contamination of water supplies and sensitive areas need to be considered priorities.

Defensive Operations are less aggressive spill and fire control tactics where certain areas may be conceded to the emergency, with response efforts directed toward limiting the overall size or spread of the problem. Defensive objectives focus upon limiting the growth of the problem (if safely possible) and cooling exposed tank cars to minimize the potential for a sudden heat induced tear (HIT) or additional fire growth. Critical risk considerations will include:

- Based upon research on propane containers, tank shells exposed to a pressure fed fire in the vapor space will require a minimum of 500 gpm at the point of impingement.
- Look for clues that cooling operations are not being effective, including activation of PRD's, blisters forming on the top of the tank car, and significant steaming continues as water is applied to the tank shell.
- Consider potential run-off issues when applying large flow cooling streams, as response operations may spread the fire or enlarge the incident footprint.
- Tank cars that have already breached cannot build up pressure and explode (e.g., heat induced tear scenario). Do NOT spray cooling water directly into a breached tank car containing flammable liquids, as it may potentially lead to a slopover, frothover or a boilover.

Nonintervention Mode is taking “no action” to change or influence the incident outcome. Essentially, the risks of intervening are unacceptable when compared to the risks of allowing the incident to follow its natural outcome. Critical risk considerations will include:

- Nonintervention or defensive strategies may be required until “equilibrium” is achieved. This strategy allows the flammable liquid to burn until the bulk of the flammable liquid has been consumed, then to extinguish the remaining fires.
- Environmental impacts may be reduced by allowing a flammable liquid fire to burn itself out. All personnel are withdrawn to a safe location, with unmanned master streams left in place to protect exposures.

Class B Foam Operations. HHFT incidents can be regarded as low frequency, high consequence scenarios. Critical response considerations will include the location of the incident, the overall size and scope of the problem, potential for rapid growth of the fire and spill problem, and the level of resources initially available.

Class B foam agents are the recommended extinguishing agents for flammable liquid fires. These can include aqueous film-forming foams (AFFF) for use on hydrocarbons (e.g., crude oil, refined products) and alcohol-resistant AFFF concentrates for use on both hydrocarbons and polar solvents (e.g., ethanol). Foam application rates will be based upon the product(s) involved. Tactical foam planning should consider the amount of foam needed for both initial knockdown and extinguishment and post-extinguishment maintenance of the foam blanket to prevent re-ignition.

The use of Class B firefighting foams in combination with dry chemical extinguishing agents (e.g., Purple K or potassium bicarbonate) will be critical tools in the controlling and extinguishing pressure-fed fire scenarios (i.e., three-dimensional fires).

Initiating and sustaining large volume cooling and Class B foam operations at HHFT scenarios will be a significant operational challenge, and will likely pose significant risks to emergency

responders if offensive strategies are employed. In light of these risks, some jurisdictions have developed tactical pre-plans based upon local risk exposures to assess their ability to safely initiate offensive or defensive operations. A critical element of this process is the identification of “go / no go” areas where tactical response operations may not be possible based upon incident location, topography and scene access.

Formulas for calculating Class B foam concentrate requirements are referenced from *NFPA 11 – Standard for Low-, Medium-, and High Expansion Foam*, and are based upon either spill scenarios (i.e., less than 2-inches product depth) or product storage in depth scenarios. In contrast, flammable liquid spills along a railroad right-of-way or which extend into adjoining structures and exposures are a hybrid, multi-dimensional scenario that can consist of surface spills, pooled product, and product absorbed into the railbed, soil, etc. As a result, foam calculations based upon NFPA 11 parameters on the area of involvement may not be accurate for HHFT scenarios. Non-traditional use and application of Class B foams may be warranted based upon incident requirements (as compared to spill or product in-depth applications. These non-traditional use and applications should be coordinated through the Incident Commander / Unified Command as part of the IAP process.

A review of previous HHFT incidents shows that potential foam operations may fall into two different operational environments: (1) offensive operations to rapidly control or extinguish the fire in the early phases of the incident timeline, and (2) final extinguishment of the fire in the later phases of the incident timeline after the size and intensity of the fire have greatly diminished (i.e., equilibrium has occurred). Observations include the following:

- No HHFT scenarios have been controlled or extinguished in the early phases of the incident timeline.
- Fire extension into adjoining exposures and structures in close proximity to the rail corridor (e.g., Lac Megantic, Quebec) will influence strategies, tactics and resource requirements. There is an increased probability that incidents where the derailment scenario extends into both aboveground and underground structures will require greater foam and water resources than those based upon the NFPA 11 parameters.
- The actual quantity of Class B foam concentrate supplies used for the control and extinguishment of HHFT incidents in the later phases of the incident timeline have been substantially less than the “area-based” planning values based upon the NFPA 11 parameters.
- Once a “state of equilibrium” has been achieved and tank car metals cooled, individual tank cars with breaches and internal fires have been extinguished using as little as 8 gallons of Class B foam concentrate per tank car. The majority of firefighting operations after the initial response period have been conducted by emergency response contractors contracted by the Responsible Party (RP), with public fire departments in a supporting role.
- The use of Class B firefighting foams in combination with dry chemical extinguishing agents (e.g., Purple K or potassium bicarbonate) will be critical tools in the controlling and extinguishing pressure fed fire scenarios.

Risk-Based Tactical Considerations. Clues and indicators of an increasing probability for an HHFT incident to rapidly grow or cascade can include:

- Running or unconfined spill fires and releases. Spills may flow into storm drains and other underground structures creating secondary spills and fires. In addition, the use of large water streams for cooling may also spread the fire to unintentional areas.
- Direct flame impingement on tank cars from either a pool fire or torch fire.
- Presence of heat induced blisters appearing on the tank car shell.
- Activation of pressure relief devices (PRD).
- Fire area has grown since emergency responders have arrived on-scene.

Any tank car that is subject to flame impingement and venting from a PRD is susceptible to container failure and the generation of a large fireball. Cooling tank cars adjacent to the fire can decrease the possibility of a tank car breach, such as a heat induced tear. Critical risk considerations will include:

- Cooling water should first be directed at the point of flame impingement, then on the vapor space of tank cars adjacent to the fire exposure from radiant heat.
- Cars that have already breached do not have to be cooled.
- Do NOT spray cooling water directly into a crude oil tank car if breached. This may lead to a slopover, frothover or longer term, potentially a boilover.
- Remote unmanned monitors are recommended, especially for extended cooling operations.

Most public safety emergency response agencies do not have a robust spill control capability, especially if waterways are involved. The majority of spill control resources (both land and water-based) used at HHFT incidents have been provided by Oil Spill Response Organizations (OSRO's) and emergency response contractors retained by the Responsible Party. First responder spill control priorities will primarily be focused towards defensive tactics for non-fire scenarios to either keep the product out of the water (e.g., protect sewers and drains) or protect downstream water intakes, users and environmentally sensitive areas. Identification of these downstream sites and locations are critical elements in the planning process.

Based upon a review of previous HHFT incidents, once rapid growth of the fire occurs and PRD's begin to activate offensive strategies cannot be safely implemented until the fire problem achieves a "state of equilibrium," which is often 8+ hours into the incident. Fire behavior and incident characteristics indicative of a "state of equilibrium" can include:

- Fire is confined to a specific area with little probability of growth.
- Low probability of additional heat induced tears or container breaches.
- No current PRD activations indicating continued heating of tank cars.
- Fire is primarily a two-dimensional fire versus a pressure-fed three-dimensional fire.

When these facts and observations are combined, the following factors can provide an initial operational baseline for determining if the fire scenario can be controlled:

- Is the fire confined to a specific area with little likelihood of growth, or is the problem rapidly expanding?
- Is there a low probability of additional heat induced tears or container breaches?
- Is the fire primarily a two-dimensional fire versus a large number of pressure-fed three-dimensional fires?

- Are sufficient water supplies available for container cooling BEFORE foam operations are initiated? These cooling operations will also be critical to the operational success of post-equilibrium fire attack operations.
- Are sufficient Class B foam supplies, appliances and personnel competent in foam operations available? Once initiated, can the required foam operations be sustained?

Post-Equilibrium Fire Operations. Once the state of equilibrium is achieved, the involved tank cars will likely have to be cooled before offensive operations can be initiated. Responders can use thermal imagers or look for steam coming off the tank car shell to assess the product temperature. Product temperatures as high as 450° F. (232° C) have been observed in previous derailments. Assessment of the product temperature will be complicated if the tank car is jacketed.

Key elements of offensive strategies that have been employed at HHFT scenarios **after equilibrium** include (1) adopting a “divide and conquer” approach whereby involved tank cars are addressed one at a time; (2) tank cars being cooled to ensure the ability of Class B foams to seal against hot metal surfaces; (3) foam handlines being used to apply foam into breached tank cars; and (4) dry chemical agents, such as Purple K, being used to control any three-dimensional fires.

VIII. RISK-BASED RESPONSE: THE HHFT INCIDENT TIMELINE

Incident size-up initiates the process of assessing the hazards and evaluating the potential risks at a HHFT scenario. As part of a risk-based response process, understanding the behavior of the container involved, its contents, the location of the incident and surrounding exposures are critical elements in determining whether responders should and can safely intervene.

To assist emergency responders in this process, an HHFT Incident Timeline was developed as a training tool (see pages 16-17). The timeline is designed to show the relationship between (a) the behavior of the tank car(s) and their contents; (b) key incident management benchmarks, and (c) strategic response options. An incident timeline can be an effective training tool. While specific timeline elements will vary based upon incident dynamics, local / regional timelines and operational capabilities, the timeline provides a visual tool that “helps to connect the dots” for incident action planning considerations.

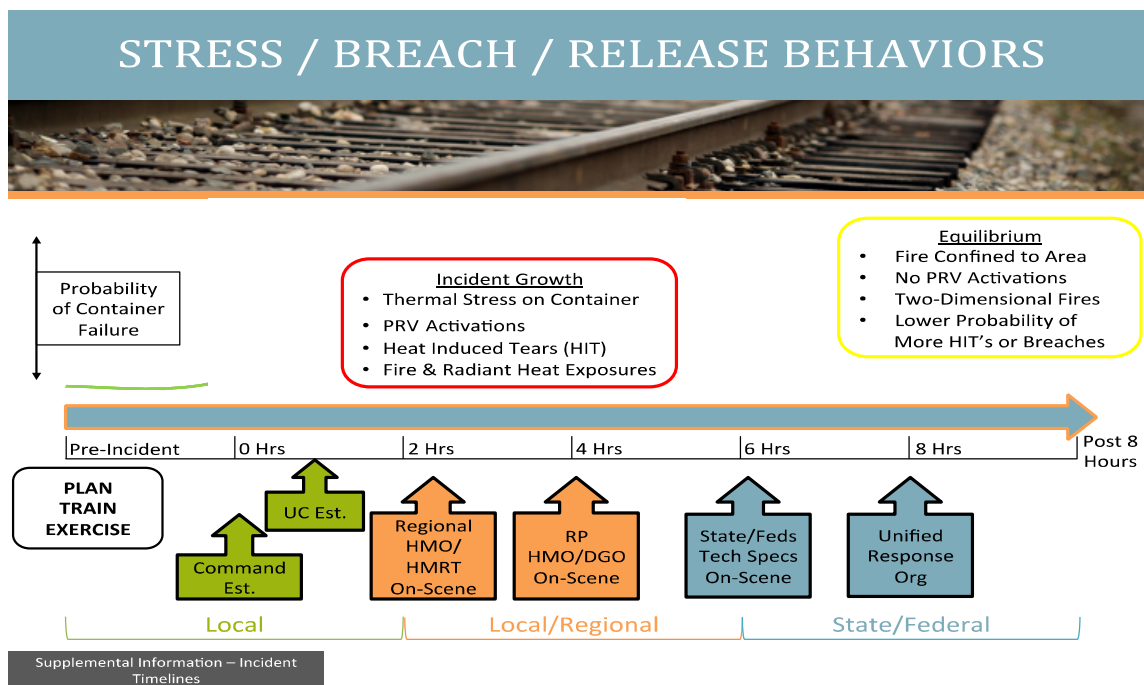
The Incident Timeline consists of three screens. Key points of each screen include the following:

1. Stress / Breach / Release Behaviors

- The incident timeline focuses upon the first operational period.
- The curve represents the probability of container failures, which leads to a cascading and growing response scenario.
- The initial container stress / breach / release behaviors are directly influenced by the speed of the train, the kinetic energy associated with the derailment, and the properties of the commodities being transported. After the initial mechanical stress caused by the derailment forces, subsequent container stress / breach / release behaviors will be thermal or fire focused.
- Incident growth will generally follow a process of (a) thermal stress from the initial fire upon the tank cars (level of thermal stress will be dependent upon whether the tank cars

are provided with thermal blanket protection); (b) activation of tank car pressure relief devices; (c) continued thermal stress on adjoining tank cars from a combination of both pool fires and pressure-fed fires from PRD's; (d) increasing probability of container failures through heat induced tears; and (e) subsequent fire and radiant heat exposures on surrounding exposures when explosive release events occur.

- Fires will continue to burn off the available flammable liquid fuel until such time that it achieves a level of “equilibrium” and is no longer growing in size or scope. **An analysis of historical incidents shows that equilibrium at a major incident may not occur for approximately 8-12 hours.** There is a lower probability of additional heat induced tears or tank car breaches once equilibrium is achieved.
- “Equilibrium” benchmarks would include the fire being confined to a specific area and no longer increasing in size or scope; no PRD activations, and the fire scenario primarily being a two-dimensional scenario, with any three dimensional pressure-fed fires decreasing in intensity.



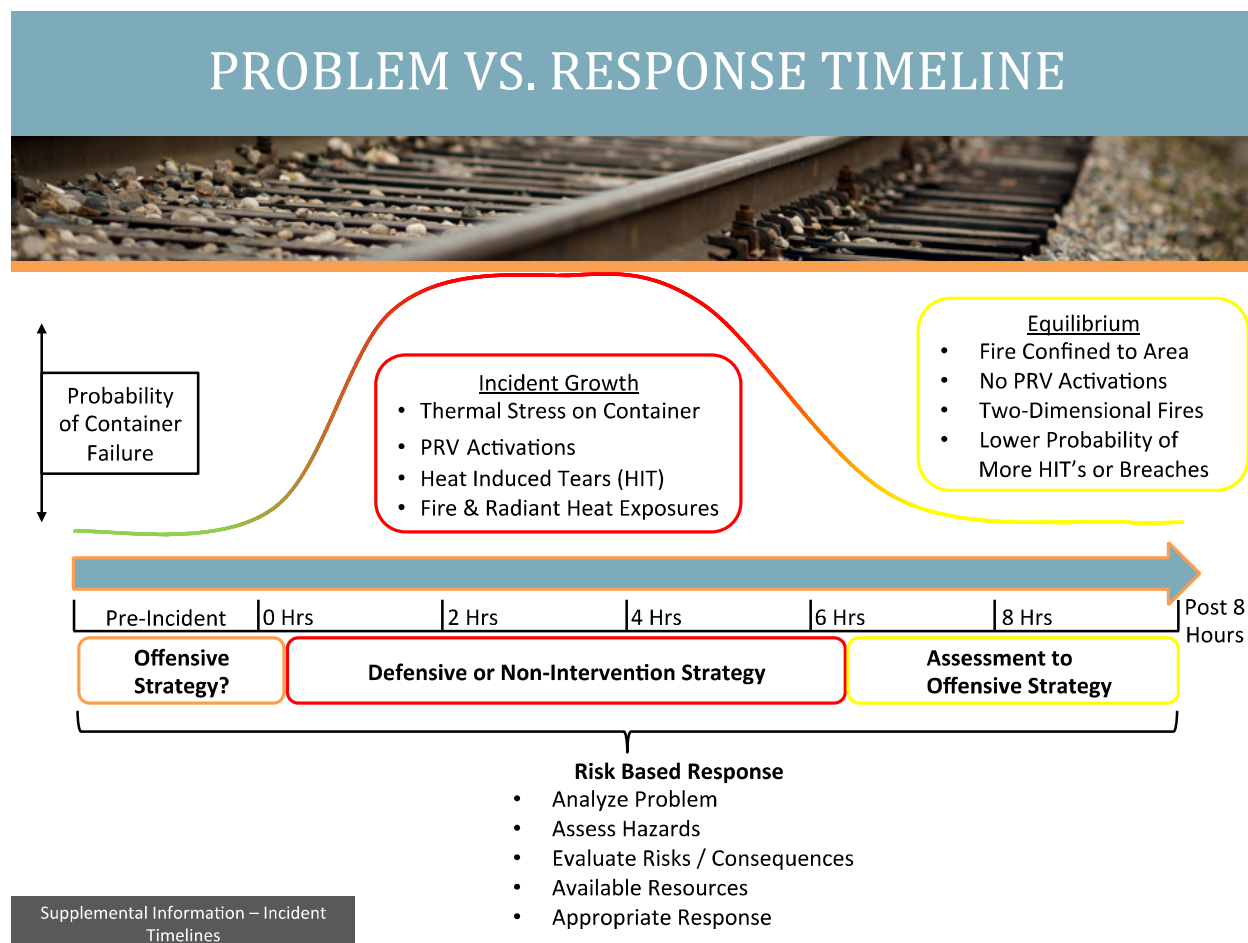
2. Incident Management Benchmarks

- Lessons learned from previous incidents shows that communities that engage in pre-incident planning, training and exercise activities with fellow stakeholders establish the foundation for a safe and effective response. The importance of establishing relationships among all of the key players before the incident cannot be over-emphasized.
- While the exact timeline will vary based upon local / regional resources and response times, key incident management benchmarks within hour 1 will include (a) conducting an incident size-up, identification of critical incident factors, and development of initial incident objectives; (b) establishment of command and an Incident Command Post (ICP) and (c) establishment of a unified command organization. Unified command at this

phase of an incident will be local-centric and focus upon the integration of fire / rescue, law enforcement and EMS resources. Railroad personnel will primarily function in a liaison role during this initial window.

- Arrival of resources that can provide technical assistance to Incident Command / Unified Command (IC/UC) within the first several hours of the incident. Based upon local / regional capabilities and response times, this technical assistance may be provided through any combination of Technical Specialists, HazMat Officers, Hazardous Materials Response Teams (HMRT) or HazMat / Dangerous Goods Officers from the Responsible Party (RP).
- Arrival of additional governmental and RP representatives, as well as contractors working on behalf of the RP. Based upon incident location and response times, these elements will likely arrive on-scene in the later half of the first operational period.
- Once all of the players are on-scene, unified command will evolve to an organizational structure that will likely challenge the organizational skills of many response agencies. Unified Command will likely consist of:
 - Local On-Scene Coordinator (most likely the Fire Department during emergency response operations)
 - State On-Scene Coordinator (usually designated state environmental agency)
 - Federal On-Scene Coordinator (U.S. Environmental Protection Agency (EPA) or U.S. Coast Guard (USCG), based upon the location of the incident and its proximity to navigable waterways.
 - Responsible Party or RP (e.g., railroad carrier, shipper)

Other local, state, federal and non-governmental organizations will work through their respective On-Scene Coordinator or the Liaison Officer to bring their issues to the table.



3. Strategic Response Options

- Once responders understand the relationship between the fire growth curve and the incident timeline, the strategic level options available to control the problem can be better assessed.
- In order to safely and successfully control a HHFT fire scenario, the following criteria must be considered:
 - What is the likely outcome without intervention?
 - What is the status and growth pattern of the fire? Is the fire relatively small and not rapidly growing? Or is the incident rapidly expanding in both its size and scope?
 - What is the probability of heat induced tears or container breaches occurring and preventing responders from safely approaching the incident close enough to apply foam and water streams? Once there is significant thermal stress on tank cars, PRD's start to activate and additional tank car breaches occur, the ability of emergency responders to influence the outcome is not likely.
 - Are sufficient water supplies and water movement capabilities available to support all exposure cooling and fire extinguishment operations? In areas with limited water

- supplies, it may be necessary to re-use cooling water by collecting water run-off and drafting from a pit or basin.
- Are sufficient Class B foam supplies and appliances available to support the required flow and concentrate requirements?
- Are emergency response personnel trained and competent in large volume foam operations, and can they implement and sustain large volume foam operations in a time-constrained scenario?
- Based upon an analysis of previous, there is a very limited window of opportunity in the early stages of an incident for implementing offensive fire control strategies. There is a higher probability that response options will be limited to defensive strategies (e.g., exposure protection) to minimize the spread of the problem or non-intervention strategies (i.e., no actions) until equilibrium is achieved. Using a risk-based response process will be critical for this re-assessment process.
- Once the equilibrium phase is achieved, responders may choose to switch to an offensive fire control strategy.

SUMMARY

Changes in the North American energy sector and the increased utilization of HHFT's have brought new challenges to the emergency response community. The objectives of this white paper are to assist emergency planning and response personnel in preparing for an HHFT incident within their community. The information provided is based upon an analysis of approximately twenty-five HHFT incidents that have occurred, the lessons learned, and the input and experiences of emergency response peers representing the railroad and petroleum industries, emergency response contractors, and the public safety emergency response community.

TERMS AND DEFINITIONS

Alcohol Resistant - Aqueous Film Forming Foam (AR-AFFF). A Class B foam concentrate that, when proportioned at the appropriate rate, forms a vapor-suppressing seal to rapidly control both hydrocarbon fuel fires (e.g. gasoline, diesel, kerosene) and polar solvent fuel fires (alcohol, ketones, methanol, and MTBE products).

API (American Petroleum Institute) Gravity. The density measure used for petroleum liquids. API gravity is inversely related to specific gravity – the higher the API gravity, the lower the specific gravity. Temperature will affect API gravity and it should always be corrected to 60°F (16°C). API gravity can be calculated using the formula - $API\ Gravity = 141.5 / Specific\ Gravity - 131.5$.

Aqueous film Forming Foam (AFFF). A Class B foam concentrate that, when proportioned at the appropriate rate, form a vapor-suppressing seal to control hydrocarbon spill fires (e.g., gasoline, diesel fuel, kerosene).

Boiling Liquid, Expanding Vapor Explosion (BLEVE). A major container failure, into two or more pieces, at a moment in time when the contained liquid is at a temperature well above its boiling point at normal atmospheric pressure (NFPA).

Boilover. The expulsion of crude oil (or certain other liquids) from a burning tank. The light fractions of the crude oil burn off producing a heat wave in the residue, which on reaching a water strata, may result in the expulsion of a portion of the contents of the tank in the form of a froth.

Certificate of Analysis. The characterization of the crude oil and its fractions produced by the product shipper. While primarily used for refinery engineering purposes, it can also provide critical information on how the crude oil will behave in a water-borne spill scenario.

Crude Oil. A mixture of oil, gas, water and other impurities, such as metallic compounds and sulfur. Its color can range from yellow to black. This mixture includes various petroleum fractions with a wide range of boiling points. The exact composition of this produced fluid varies depending upon from where in the world the crude oil was produced.

Equilibrium. Describes the point at which a HHFT flammable liquid fire is no longer expanding and has achieved a “steady state” of fire and container behavior. Fire behavior and incident characteristics indicative indicators of equilibrium are (1) the fire is confined to a specific area with little probability of growth in either size or intensity; (2) there is low probability of additional heat induced tears or container breaches caused by fire impingement directly upon tank cars; and (3) there are no current pressure relief device (PRD) activations indicating continued heating of tank cars.

Frothover. Can occur when water already present inside a tank comes in contact with a hot viscous oil which is being loaded

Heat Induced Tear. Also referred to as a thermal tear, a longitudinal failure that occurs in the upper portion of the tank car shell surrounding the vapor space of the tank following exposure to pool fire conditions. Thermal tears have been measured from 2 feet to 16 feet in length.

High Hazard Flammable Liquid Train (HHFT). A train that has a continuous block of twenty (20) or more tank cars loaded with a flammable liquid (i.e., unit train), or thirty-five (35) or more cars loaded with a flammable liquid dispersed through a train (i.e., manifest train with other cargo-type cars interspersed).

Natural Gas Liquids (NGL). Heavier hydrocarbon products, such as pentane, hexane and heavier gasoline-range molecules, that may be found with natural gas found in production fields. NGL's are to prevent them from condensing in the pipeline and interfering with the natural gas flow.

Pool Fire. A fire burning above a horizontal pool of vaporizing flammable liquid fuel under conditions where there is little movement of the fuel.

Post-Emergency Response Operations (PERO). That portion of an emergency response performed after the immediate threat of a release has been stabilized or eliminated, and the clean-up of the site has begun.

Risk Based Response. A systematic process by which responders analyze a problem involving hazardous materials, assess the hazards, evaluate the potential consequences, and determine

appropriate response actions based upon facts, science, and the circumstances of the incident (NFPA 472).

Slopovert. Can result when a water stream is applied to the hot surface of a burning oil, provided that the oil is viscous and its temperature exceeds the boiling point of water. It can also occur when the heat wave contacts a small amount of water stratified within a crude oil. As with a boilover, when the heat wave contacts the water, the water converts to steam and causes the product to “slop over” the top of the tank.

Sour Crude Oil. Crude oil with a high concentration of hydrogen sulfide.

Sweet Crude Oil. Crude oil with a low concentration of hydrogen sulfide.

Three Dimensional Fires. A liquid fuel fire that flows freely from a vertical height, such as a stream of flowing product discharging into a pool fire. It cannot be extinguished using Class B foam as a vertical blanket or seal cannot be achieved and usually requires the combined use of dry chemical (e.g., potassium bicarbonate or Purple K) and Class B foam agents for extinguishment.

Unit Train. A train in which all cars except for the buffer car(s) carry the same commodity and are shipped from the same origin to the same destination, without being split up or stored en-route.

ENDNOTES

- 1 Center for Toxicology and Environmental Health, “Bakken Crude Oil Burn Demonstration – Air Monitoring and Sampling Report Prepared for Williams Fire & Hazard Control” (North Little Rock, AR: Center for Toxicology and Environmental Health, January 16, 2014), 12.
- 2 National Transportation Safety Board, Safety Recommendations to US DOT/PHMSA Ref: Retrofitting of Thermal Protection Systems for DOT Specification DOT-111 Tank Cars Used to transport Class 3 Flammable Liquids” (Washington, DC: NTSB, April 3, 2015), 5.
- 3 Ibid. 8.
- 4 Sandia National Laboratories, “Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport” (Albuquerque, NM: Sandia National Laboratories, March 2015), 78.
- 5 Alexy, Karl, “Comparative Analysis of Documented Damage to Tank Cars Containing Denatured Alcohol or Crude Oil Exposed to Pool Fire Conditions” (Washington, DC: US DOT / Federal Rail Administration - date unknown), page 4.
- 6 Raj, Phani K., “Comparison of Magnitude of Hazards Resulting from the Release of Crude Oil and Ethanol from Tank Cars.” 8.

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