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HIGH HAZARD FLAMMABLE TRAINS (HHFT) On-Scene Incident Commander Field Guide

FINAL REPORT BY:

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July 2016

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FOREWORD

In the recent past there have been several pipeline and rail car incidents involving flammable liquids in municipalities in North America. These incidents often involve a complex interaction with municipal authorities, the fire service as the first responders, and industry personnel. Despite the extensive efforts of all parties to ensure that emergency responders are properly trained and equipped, there remain gaps in the application and use of risk-based response processes to manage these incidents. Likewise, there is no standardized template or reference point to provide emergency response agencies with emergency planning and response best practices; this challenge is shared by small and large departments alike.

NFPA 472: *Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*, Chapter 8 provides requirements for competencies for incident commanders responsible for the on-scene management of hazardous materials emergencies and is the primary response industry standard. NFPA 472 is written from a broad perspective - establishing a framework that can be applied to a wide variety of incidents regardless of the hazardous material(s) that may be involved, but does not provide product specific guidance for individual products, such as the crude oil or ethanol. The goal of this project is to develop a guidance document for incident commanders at rail incidents involving crude oil and ethanol that addresses the competencies for incident commanders as outlined in Chapter 8 of NFPA 472. This document supports pre incident preparation by guiding the user to identify how a response organization agency can meet the Chapter 8 incident commander competencies, and generate a complete document that could serve as the foundation for an Incident Action Plan (IAP).

The Fire Protection Research Foundation expresses gratitude to the report authors Gregory Noll and Michael Hildebrand, who are with Hildebrand & Noll Associates, Inc. located in Lancaster, PA. The Research Foundation appreciates the guidance provided by the Project Technical Panelists, the funding provided by the project sponsor – Pipeline and Hazardous Material Safety Administration (PHMSA), U. S. Department of Transportation, and all others that contributed to this research effort.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

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Keywords: HHFT, Tank car, Flammable liquids, Crude oil, Ethanol, Oil spill, Competency, Incident Commander, HAZMAT, Hazardous materials, Emergency responders, NFPA 472, Risk-based response

Report number: FPRF-2016-12

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Executive Summary:

This Guide provides tactical guidance and information for the On-Scene Incident Commander responsible for the management of bulk flammable liquid emergencies involving High Hazard Flammable Trains (HHFT), with a focus upon petroleum crude oil and ethanol. The application and use of a risk-based response (RBR) methodology for both planning and response purposes are critical success factors in the successful management of a HHFT incident.

In order to safely and effectively employ risk-based processes at HHFT incidents, emergency responders must initially be qualified at the First Responder – Operations and On-Scene Incident Commander levels, and have an understanding of the following:

- The physical properties (i.e., how it will behave) and chemical properties (i.e., how it will harm) of the materials involved.
- Tank car design and construction of the DOT-111 / CPC-1232 and DOT-117 specification tank cars, and their potential behavior in an emergency scenario.
- Knowledge of the strategic and tactical considerations to be evaluated at a hazardous materials incident.
- Selection, application and use of large-flow water and firefighting foam streams at train derailments involving Class B fuels.

Among the key factors that Incident Commanders operating at HHFT incidents must know are the following:

- 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. Although emergency response operations may be limited to less than 24 hours, post-response clean-up and recovery operations may continue for weeks.
- Unified command will be critical for the successful management of the incident.
- 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 influenced by the presence and integrity of thermal blanket protection); (b) subsequent 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.
- Heat induced tears (HIT) have been observed on tank cars containing both crude oil and ethanol. 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.
- Based upon an analysis of approximately 25 HHFT incidents, 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.

- Fires will continue to burn off the available flammable liquid fuel until such time that the incident 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
- Once the equilibrium phase is achieved, responders may choose to switch to an offensive fire control strategy.

HIGH HAZARD FLAMMABLE TRAINS (HHFT)
On-Scene Incident Commander Field Guide

I. BACKGROUND

Scope. This document provides tactical guidance and information for the On-Scene Incident Commander responsible for the management of bulk flammable liquid emergencies involving High Hazard Flammable Trains (HHFT), including petroleum crude oil and ethanol.

Purpose. The purpose of this document is to provide individuals currently trained and certified as Hazardous Materials On-Scene Incident Commanders with the requisite knowledge and information to safely and effectively manage an HHFT emergency.

Incident Commander pre-requisites and qualifications for HHFT scenarios should include the following:

- NFPA 472, Chapter 8 – Incident Commander or NFPA 1072, Chapter 8 – Incident Commander
- ICS-300 – Intermediate ICS for Expanding Incidents or equivalent
- Knowledge on the selection, application and use of Class B extinguishing agents for large flammable liquid fire scenarios.

Background. A review of approximately twenty-five HHFT incidents between 2006 and 2016 provides the following 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 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 often be categorized at a minimum of a NIMS Type 3 incident.
- Given the length of the 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 scenario will be dependent upon a number of factors, including train speed, train make-up and track configuration (e.g., curve, grade).
- 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 the response issues previously noted.
- 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.

The application and use of a risk-based response (RBR) methodology for both planning and response purposes is a critical success factor in the successful management of a HHFT incident. 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.

This document is broken into the following sections:

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II. PRODUCT INFORMATION

A. Understanding Petroleum Crude Oils

- 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 Hazard Class 3 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, the liquid 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. Key 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 5 - 6) 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:

Viscosity	**API Gravity**
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 (TLV/TWA) 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 C_6 - hexane in some locations.

- 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. The refining process generates a liquid material 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 outlines the physical and chemical properties of crude oil and related products that may be transported in HHFT's.

Table 1: Physical and chemical properties of crude oil and related products that may be transported in HHFT's

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 -4F° 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 - 0.8 (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_2S in head space of vessels) If H2S concentrations ≥ 0.5% or 5,000 ppm shipped as Sour Crude DOT Class 3, UN3494 (ERG Guide No. 131)	<0.1% (potential to accumulate as H_2S in head space of vessels)	Negligible (contains bonded sulfur, generally not available as H_2S)	<0.5

TABLE 1 (continued)	**LIGHT SWEET CRUDE OIL**	**DILBIT/SYNBIT (BITUMEN WITH DILUENT*)**	**BITUMEN (OIL SANDS)**	**DILUENT**
BENZENE	Generally <1.0%	0% - 5%	Negligible (Monitor, however it should not be a concern)	0% - 5%
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), **H_2S** (direct read or tubes)	**LEL** (combustible gas indicator), **Benzene** (direct read or tubes), **H_2S** (direct read or tubes)	**LEL** (combustible gas indicator), **Benzene** (direct read or tubes), **H_2S** (direct read or tubes)	**LEL** (combustible gas indicator), **Benzene** (direct read or tubes), **H_2S** (direct read or tubes)
RECOMMENDED PPE	Clothing: Structural FF Clothing / Fire Retardant Clothing (subject to task and air monitoring) Respiratory Protection: SCBA/APR/Nothing (subject to Task & benzene, H_2S & particulate concentrations)	Clothing: Structural FF Clothing / Fire Retardant Clothing (subject to task and air monitoring) Respiratory Protection: SCBA/APR/Nothing (subject to Task & benzene, H_2S & particulate concentrations)	Clothing: Thermal Protection (if hot) / Fire Retardant Clothing (subject to task and air monitoring) Respiratory Protection: SCBA/APR/Nothing (subject to Task & benzene, H_2S & particulate concentrations)	Clothing: Structural FF Clothing / Fire Retardant Clothing (subject to task and air monitoring) Respiratory Protection: SCBA/APR/Nothing (subject to Task & benzene, H_2S & particulate concentrations)
COMMUNITY, WORKER & RESPONDER SAFETY	Flammability, Benzene, LEL, H_2S	Flammability, Benzene, LEL, H_2S, PAH's (poly-aromatic hydrocarbons)	H_2S, PAH's (poly-aromatic hydrocarbons)	Flammability, Benzene, LEL, H_2S

B. Ethanol

- 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.
  - Highly recommended to use a thermal imaging camera to identify whether a flame is truly present or not.

Table 2: Physical and chemical properties of ethanol products that may be found in HHFT trains.

TABLE 2	DEANTURED 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 (TEMPERATURE DEPENDENT)	>1 (High Evaporation Rate)
SOLUBILITY	High
AIR MONITORING	**LEL** (combustible gas indicator), **Benzene** (direct read or tubes)
RECOMMENDED PPE	Clothing: Structural FF Clothing /Fire Retardant Coveralls (subject to task and air monitoring) Respiratory Protection: SCBA/APR/Nothing (subject to task & benzene & particulate concentrations)
COMMUNITY, WORKER & RESPONDER SAFETY	Flammability, Benzene, LEL

III. TANK CAR DESIGN AND CONSTRUCTION

- Flammable liquids, including crude oil and ethanol, have been transported in DOT-111 or CPC-1232 tank cars. The CPC-1232 tank car is a DOT-111 tank car modified with head shields, top fitting protection, and bottom handle protection. 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 jacked containers, with a tank shell thickness of 7/16 to 1/2 inches. If equipped, the jacket is generally 1/8 inch thick steel.
    - Capacity of 33,000 gallons (125,000 litres)
    - Weight of approximately 286,000 lbs. (130,000 kilograms).
    - Top fittings and bottom outlet 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) retrofit 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.

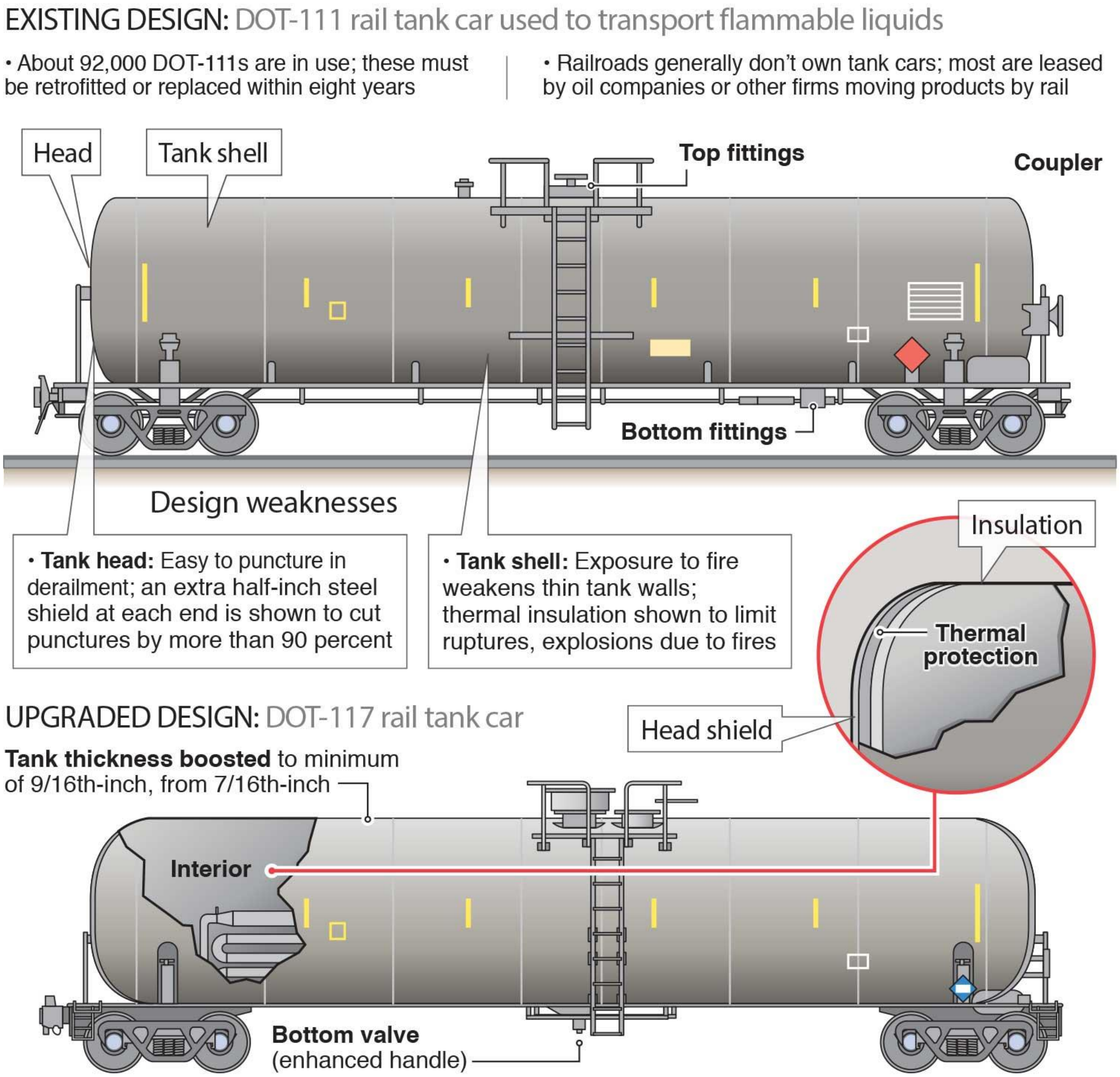

Figure 1: Existing DOT-111 rail tank car versus new DOT-117 rail tank car

Reprinted with permission: "New rules on oil trains draw flak from firefighters, too" Source: http://www.mcclatchydc.com/news/nation-world/national/economy/article24784321.html

IV. UNDERSTANDING PRODUCT AND CONTAINER BEHAVIOR

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 non-jacketed DOT-111 and 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 speed of the train, the type of tank car involved (e.g., DOT-111, CPC-1232 jacketed vs. non-jacketed tank car) train speed, location 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. When not involved in fire, tank cars that roll over in-line are often less susceptible to a container breach, but may leak from damaged valves and fittings. If the tank car PRD is buried or blocked, it will be unable to relieve pressure at its full rated capacity. Also, if the tank car is lying on its side and the PRD is relieving liquid product, it is not relieving pressure at its full capacity.

- 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 increasing tank car internal pressure. The hazards posed by the release of flammable liquids include flash fires, pool fires, fireballs from container failure (i.e., which cause direct flame impingement and 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 initial derailment sequence, two tank cars were 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.

- 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.

- 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. This information can assist Incident

Commanders in determining placement of resources and protective action distances as part of a risk-based response process.

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

- 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. 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 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. Avoid rushing into the incident scene.

- 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 pressurized tank cars. However, as noted above, separation of ethanol tank cars has occurred at two incidents.

- The term "equilibrium" is used 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. Fire is confined to a specific area with little probability of growth in either size or intensity.
  2. Low probability of additional heat induced tears or container breaches caused by fire impingement directly upon tank cars.
  3. 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 manway and valve gaskets have failed, which will result in additional tank car leaks and associated issues during derailment clean-up and recovery operations.
  - There have been instances where tank cars being moved during clean-up and recovery operations have allowed air to enter the tank resulting in a flash fire / jet fire from the container breach. Responders should expect vapor flash fires at any time and in any direction, especially during wreck clearing and clean-up operations.

V. INCIDENT MANAGEMENT CONSIDERATIONS

- 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 managing the size and complexity of the incident. 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 early stages of the incident will likely change as the incident timeline advances, state and federal agencies arrive on-scene, 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 with 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.

VI. TACTICAL CONSIDERATIONS – FIRST OPERATIONAL PERIOD

A. Incident Management Principles

- Initial site management and control will be a key benchmark in managing the problem.
    - Isolate and secure the area
    - Avoid committing or positioning personnel and units in a hazardous position. Consider escape routes out of the area if conditions suddenly deteriorate.
    - Establish an incident Command post (ICP)
    - Establish an isolation perimeter, access control, and inner perimeter / hot zone
    - Establish a Staging Area

- Follow initial guidance provided by the Emergency Response Guidebook (ERG). The following ERG guides pages would be pertinent:

    - Petroleum Crude Oil (UN 1267) – Guide Page 128
    - Petroleum Sour Crude Oil (UN 3494) - Guide Page 131
    - Ethyl Alcohol / Ethanol (UN 1170)– Guide Page 127
    - Denatured Ethanol (UN 1987) – Guide Page 127

- The National Incident Management System (NIMS) should be the framework for managing incident operations. Unified command should be established that integrates those agencies and organizations with legal and jurisdictional responsibility.

- 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 HazMat-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.

B. Problem Identification

- Identify, confirm and verify the presence of hazardous materials and the extent of the problem. This can be done through shipping papers (i.e., train consist), placards, container shapes and senses.
    - If shipping papers are not available, use binoculars to try to locate any four-digit identification numbers on the placards (or orange panels) displayed on the rail cars.
    - If shipping papers, placards and markings are destroyed, the railcar reporting marks and number can be used to identify the commodities present.
    - *The "AskRail™" app is a safety tool that can provide first responders immediate access to accurate, timely data about what type of hazardous materials a railcar is carrying. It is a back-up resource if information from the train conductor or train consist is not available. Additional information about the app and how to request the app can be found at www.askrail.us*

- Identify the rail carrier and locate the train crew. The conductor will have the complete train consist immediately available on the scene. Maintain contact with the conductor and crew until they are relieved by a railroad official.

- Notify the rail carrier's operations center to have rail traffic stopped. If not already available, request that a copy of the train consist or wheel report be sent to the ICP. Emergency numbers are listed below:

Company	Emergency Telephone Number
BNSF Railway	1-800-832-5452
Canadian National (CN) Railway	1-800-465-9239
Canadian Pacific (CP) Railway	1-800-716-9132
CSX Transportation	1-800-232-0144
Kansas City Southern Rail Network	1-800-892-6295
Norfolk Southern Railroad	1-800-453-2530
Union Pacific Railroad	1-888-877-7267

- When contacting the railroad, provide the following information:
  - Your name, location, organization name and telephone number
  - Location of the incident (provide the railroad with the DOT Crossing Number or the railroad milepost)
  - Type and number of containers involved
  - Presence of markings, reporting marks or placards on tank car
  - Presence of smoke, fire or spill
  - Extent of damage
  - Topography
  - Weather conditions
  - If digital pictures can be safely taken, do so and send to a railroad representative as soon as possible

- 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. Look for downed signal and communications lines, power lines, buried utilities and above ground switch heating systems.

C. Hazard Assessment and Risk Evaluation

NOTE: *The level and sophistication of the risk evaluation process may vary based upon the level of hazardous materials response resources on-scene. For example, when available Hazardous Materials Response Team (HMRT) personnel, Hazardous Materials Technicians or Technical Specialists (i.e., product or container specialists) can collect and interpret the pertinent hazard and response information, and then provide options and recommendations to the Incident Commander.*

- Risk-based Response - 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.

- Sources of hazard and response information that may be utilized to support response operations include the following:
  - *Hazardous Materials Guidebooks and Databases* – common references include the Emergency Response Guidebook, NIOSH Pocket Guide to Chemical Hazards, and the Wireless Information System for Emergency Responders (WISER).
  - *Detection and Monitoring equipment* – Equipment will vary based upon spill vs. fire scenarios, and the incident timeline. For example, emergency responders will primarily rely upon combustible gas indicators (CGI) used in combination with a three to five gas meter, and photo-ionization detectors (PID's) during initial response operations. During clean-up and recovery operations, more sensitive monitoring instruments will be used (i.e., flame ionization detector [FID], gas chromatograph mass spectrometer [GC/MS]).

Spill Scenario Risks	*Fire Scenario Risks*
Flammability Levels (LEL/UEL)	Carbon Monoxide
Volatile Organic Compounds (VOC)	Flammability Levels (LEL/UEL)
Hydrogen Sulfide	Hydrogen Sulfide
Benzene	Benzene
	Volatile Organic Compounds (VOC)
	Sulfur and Nitrogen Sulfides
	Particulates (Smoke)

  - *Reference Manuals* –Tank car-specific information, including cutaways and schematics of railroad tank cars and valving, may be acquired from the railroad or through a tank car manufacturer.
  - *Technical Information Centers*
    - CHEMTREC® - 1-800-424-9300).
    - National Response Center (NRC – 1-800-424-8802) is the federal government's central reporting point for all oil, chemical, radiological, biological and etiological releases into the environment within the United States and its territories.
  - *Technical Specialists* – Individuals who have specialized knowledge of the product(s) or containers involved. For railroad scenarios, these can include HazMat Officers / Dangerous Goods Officers from the railroad, product and container specialists from the shipper or consignee, and specialized emergency response contractors who focus on high hazard response operations.
    - NOTE: The role of the HHFT Technical Specialist can vary depending upon the incident timeline. For example: during the Initial Operational Period they may 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. During the second and later Operational Periods they can provide liaison support (i.e., role as a facilitator or collaborator) between public safety responders and other governmental and industry response organizations and representatives.

- Based on the risk evaluation process, develop the Incident Action Plan (IAP). Determine whether the incident should be handled in an offensive, defensive, or nonintervention mode.

STRATEGY	OFFENSIVE	DEFENSIVE	NON-INTERVENTION
Rescue	X		
Public Protective Actions	X	X	X
Spill Control	X	X	
Leak Control	X		
Fire Control	X	X	
Clean-Up & Recovery	X	X	

Additional tactical-level information on fire control and spill control tactics can be referenced in *Section VII – Tactical Considerations: Spill and Fire Control.*

D. Select Personal Protective Clothing and Equipment

- Assure that emergency responders are using the proper personal protective clothing and equipment equal to the hazards present and the tasks being performed. Structural firefighting clothing (SFC) and positive-pressure SCBA should be the initial level of PPE selected.
    - **<u>CAUTION</u>**: Levels of H_2S may pose a toxic inhalation hazard (TLV/TWA of 1 ppm and IDLH of 100 ppm). Positive-pressure SCBA should be used until the site is characterized through air monitoring.

- Any changes in the level of PPE should be based upon the results of air monitoring operations. Continuous monitoring with a combustible gas indicator and instruments capable of detecting the toxic components of the flammable liquid (e.g., hydrogen sulfide, benzene) are important in ensuring site safety.

- SFC will provide thermal protection for flammable liquid fires; however, SFC is porous and will absorb liquids. For scenarios that have a low probability of fire, such as spill control and clean-up activities including decontamination, chemical splash protective clothing and a compatible NIOSH-approved respirator may be required depending upon the concentrations and properties of the contaminant.

- Information and guidance on the selection of PPE for oil spill response is available in American Petroleum Institute (API) *Recommended Practice (RP) 98 – Personal Protective Equipment Selection for Oil Spill Responders*.

E. Logistics and Resource Management

- Order specialized equipment and technical resources early in the incident. If unsure of your initial resource requirements, always call for the highest level of assistance available. Do not wait to call for additional resources or activate mutual aid agreements.

- Establishing and staffing a Logistics Section and a coordinated resource ordering system early in the incident will be critical in providing the necessary support, resources and services to meet incident objectives. The size, scope and resources needed to successfully manage a HHFT incident will overwhelm the capability of most emergency response agencies.

- The railroads will be the primary providers of logistical support and resources as the incident timeline expands. Rail carriers can provide emergency response resources, air monitoring and environmental response capabilities, technical specialists and contractors to safely manage the consequences of a HHFT train scenario.

- The total time required for assets to arrive on-scene and initiate operations must be considered, as delays will impact operational effectiveness.

F. Implement Response Objectives

- **REMINDER**: The ERG should be used by emergency responders to obtain initial response guidance for HHFT incidents.

  - Petroleum Crude Oil (UN 1267) – Guide Page 128
  - Petroleum Sour Crude Oil (UN 3494) - Guide Page 131
  - Ethyl Alcohol / Ethanol (UN 1170)– Guide Page 127
  - Denatured Ethanol (UN 1987) – Guide Page 127

- *Traditional firefighting strategies and tactics may not be effective in these situations*. HHFT incidents need to be approached and managed as a hazardous materials incident to ensure that proper and appropriate technical assistance and the support of outside resources are notified and requested as soon as possible.

- Railroad HazMat Officers and Technical Specialists can provide technical assistance with size up and damage assessment.

- The following factors should be considered as part of developing and implementing initial response strategies:

QUESTION	RESPONSE CONSIDERATIONS
Are there any life safety exposures that responders must immediately address? Can responders safely conduct evacuation or protection-in-place operations?	Number of people to be protected; ability of the public to move; available time; adequate facilities to shelter evacuees.
Can responders safely approach the incident?	Location of the incident, including access and terrain; number of tank cars involved; extent of damage including tank car breach / release behaviors; size of spill, leak or fire involvement. Reminder that fireball can be approximately 650 ft. in diameter.
Do responders fully understand the nature and scope of the problem?	Hazard assessment and risk evaluation must be completed and the results shared / coordinated with Technical Specialists from railroad and shipper.

If fire is involved, do responders have immediate access to sufficient Class B foam and water supplies required for effective fire control / fire suppression operations?	Most fire departments will not have immediate Class B foam, water or spill control resources for an initial attack on a HHFT scenario involving a large amount of fire. Defensive operations will likely be required until the size of the problem decreases to the level of resources on-scene (i.e., foam, water, spill control and related support).
If a spill is involved, do responders have the necessary spill control equipment readily available on-site?	Most public safety agencies will be limited in their spill response activities to the protection of water intakes and sensitive areas. Large-scale spill control operations will likely be delayed until the arrival of spill response contractors or Oil Spill Response Organizations (OSRO) working on behalf of the railroad or RP.
Can fire suppression agents be effectively applied to the tank car(s) involved? Can cooling water be effectively applied to any exposures impacted by direct flame impingement?	Class B foam streams and cooling water streams must be able to reach their intended targets to be effective.
If the spill has not been ignited, can potential ignition sources be removed and/or eliminated?	Both rail and vehicle traffic may need to be curtailed. Automatic switching devices (i.e., industrial AC units, traffic signals) may need to be switched off.
Will fire extinguishment improve or worsen the incident? What are the environmental impacts of doing so?	In many fire scenarios involving flammable liquids, the best and safest response option may be defensive or non-intervention tactics which allow the fires to burn out. Attempting to extinguish the fire(s) may cause additional risks to personnel and damage to the environment. The decision to protect exposures and let the product burn must be considered.
Have appropriate agency notifications been made? Has the organization's Emergency Response Plan been activated?	These incidents cannot be safely and effectively managed alone. Additional technical support and resources must be requested immediately in accordance with the agency's Emergency Response Plan. The railroads and shippers will be the primary means of technical support and resources.

G. Clean-Up and Post-Emergency Response Operations

- As appropriate, establish a decontamination corridor in the warm zone away from the contaminated area. Ensure proper decontamination of emergency response personnel before they leave the scene. Flammable liquid vapors can saturate protective clothing and be carried off-site. Personnel should monitor for hazardous vapors before removing PPE.

- Use water rinse on the outer shell of protective of protective clothing and contain all runoff. Maintain appropriate respiratory protection throughout the decontamination process.

- Upon the termination of emergency response activities, formally transfer command from the lead response agency to the lead agency for post-emergency response operations (PERO).

- 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). There have been instances where tank cars being moved during clean-up and recovery operations have allowed air to enter the tank resulting in a flash fire / jet fire from the container breach. Responders should expect vapor flash fires at any time and in any direction, especially during wreck clearing and clean-up operations.

- Ensure that the following elements are documented:
  - All operational, regulatory and medical phases of the emergency, as appropriate.
  - Equipment and/or supplies used during the incident.
  - Names and contact information of all key individuals, including railroad representatives, contractors, and agency officials.
  - Emergency response point-of-contact for all post-incident questions and issues.

- Conduct / coordinate termination activities, including incident debriefing, post-incident analysis, and incident critique.

VII. TACTICAL CONSIDERATIONS: SPILL AND FIRE CONTROL

This section provides more detailed information and guidance on spill and fire control operations, with emphasis upon crude oil fire control operations.

A. Operational Modes

- The 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* - 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.
    - 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. See Section VIII - HHFT Incident Timeline.
    - Well-intentioned actions to extinguish a flammable liquid fire may actually create long-term environmental impacts. The possible contamination of water supplies and sensitive areas need to be considered incident priorities.

- *Defensive Operations* - 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. See Section VII – D.

- *Nonintervention Mode* **–** 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.

B. Spill Control Operations

- While not all flammable liquid releases result in a fire when the incident occurs, ignition is always a concern responders must keep in mind when developing response strategies. The guidance provided is based upon a non-fire spill scenario.
  - Continuous air monitoring is critical safety benchmark in characterizing the site and determining PPE requirements.
  - Consider water safety issues when personnel are operating in and around waterways.

- 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.
  - Crude oil will weather and may leave a very persistent heavy residue.

- Spill control considerations will include:
  - What is spilled and how much?
  - Where is the spill going?
  - How fast is the spill moving?
  - What will the spill impact and when?
  - What can responders do about it?
    - Keep it in the container
    - Keep it to as small a footprint as possible
    - Minimize the spread of the product
    - Keep it out of the water

- Spill Control Priorities – If the container has breached and the product is being released:
  - #1 - Keep it confined to a specific land area if safely possible.

- #2 - Keep the product out of the water.
- #3 - If the product is in the water, protect downstream water intakes and sensitive areas.

- Spill control tactical options and considerations include:
  - Land Spills - Minimize the spread of product both horizontally and vertically.
    - Response tactics would include using dikes, berms, dams, trenches and pits, based on the available time, incident environment and available resources.
  - Water Borne Spills - First responder spill control capabilities will focus mainly on defensive tactics for non-fire scenarios to either keep product out of the water or protect downstream water intakes and sensitive areas.
    - Most first responders agencies do not have a robust spill control capability, especially when waterways are involved.
    - Response tactics will include booming operations to minimize the spread of spilled oil on water and concentrate it for recovery.
    - Remember – ethanol is a polar solvent and will mix with water. Ethanol cannot be contained or collected using booms once it enters a waterway.

C. Fire Control Operations

- Cooling tank cars adjacent to the fire can decrease the possibility of a tank car breach, such as a heat induced tear.
  - 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.
  - 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.

- 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).
  - 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).
  - Class B 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.

- Initiating and sustaining large volume 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.
  - Observation: 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 Commanders as part of the IAP process.

- A review of previous HHFT incidents shows that potential foam operations may fall into two different operational environments:
  - First - offensive operations to rapidly control or extinguish the fire in the early phases of the incident timeline
  - Second - 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).

- Fire control observations include the following:
  - As of this date, no HHFT scenarios have been controlled or extinguished in the early phases of the incident timeline.
  - Fire extension into adjoining structures and exposures 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 of this nature may 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 8-10 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.

D. 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.
    - The risk of a boilover at a crude oil derailment scenario remains subject to debate and study. 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.

- 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.

- 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.

- 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.

- 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."

VIII. PUTTING IT ALL TOGETHER: THE HHFT INCIDENT TIMELINE

To assist emergency responders in the initial size-up process, an HHFT Incident Timeline was developed as a training tool. 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. While the specific timeline elements will vary based upon incident dynamics, local / regional response timelines and operational capabilities, the timeline provides a visual tool that helps the Incident Commander "to connect the dots" for incident action planning considerations.

The Incident Timeline consists of three inter-related screens shown on the following pages. Key points of each screen include the following:

A. Stress / Breach / Release Behaviors

- The Incident Timeline focuses upon the first operational period.

- The curve represents the probability of container failures, which in turn 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 influenced by the presence and integrity of thermal blanket protection); (b) subsequent 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 the incident 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.

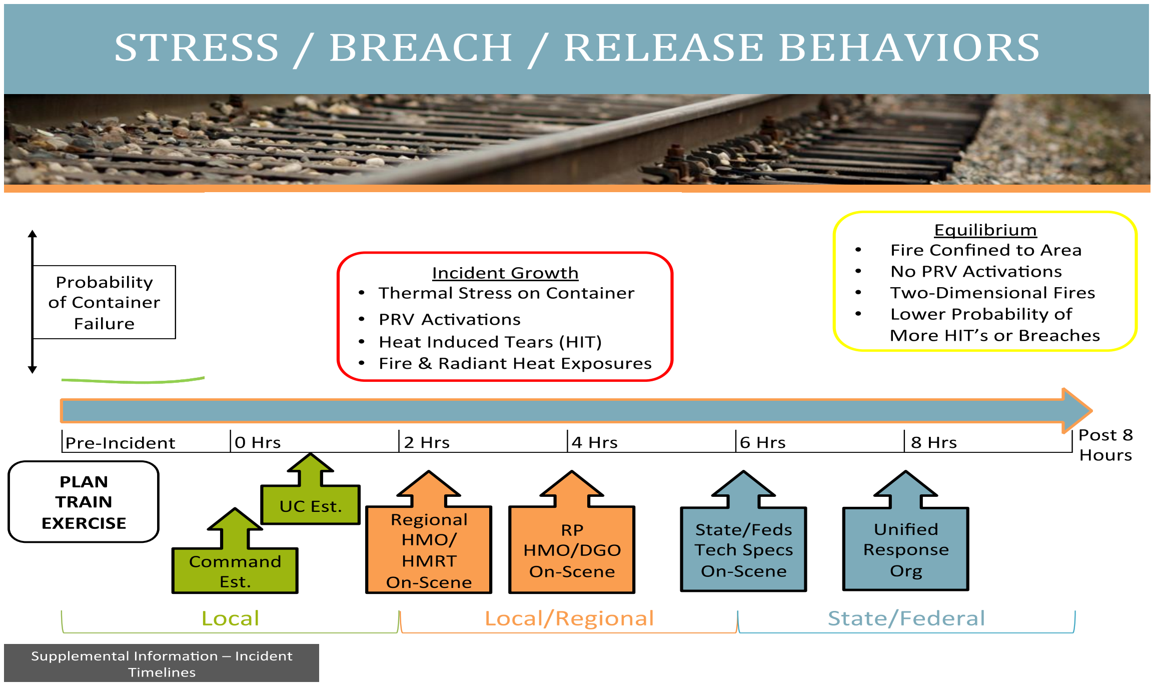

Figure 2: Stress/Breach/Release Behaviors

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B. Incident Management Benchmarks

- Lessons learned from previous incidents shows that communities that engage in pre-incident planning, training and exercise activities with their response partners establish a foundation for a safe and effective response. The importance of establishing relationships between all of the key players before the incident cannot be over-emphasized.

- While the exact incident timeline will vary based upon local / regional resources and response times, key incident management benchmarks within hour 1 will include:
  - Conducting an incident size-up, identification of critical incident factors, and development of initial incident objectives.
  - Establishment of command and an Incident Command Post (ICP)
  - Establishment of a unified command organization. Unified command at this initial 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. As the incident timeline progresses, unified command will evolve to the following structure:
  - 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.

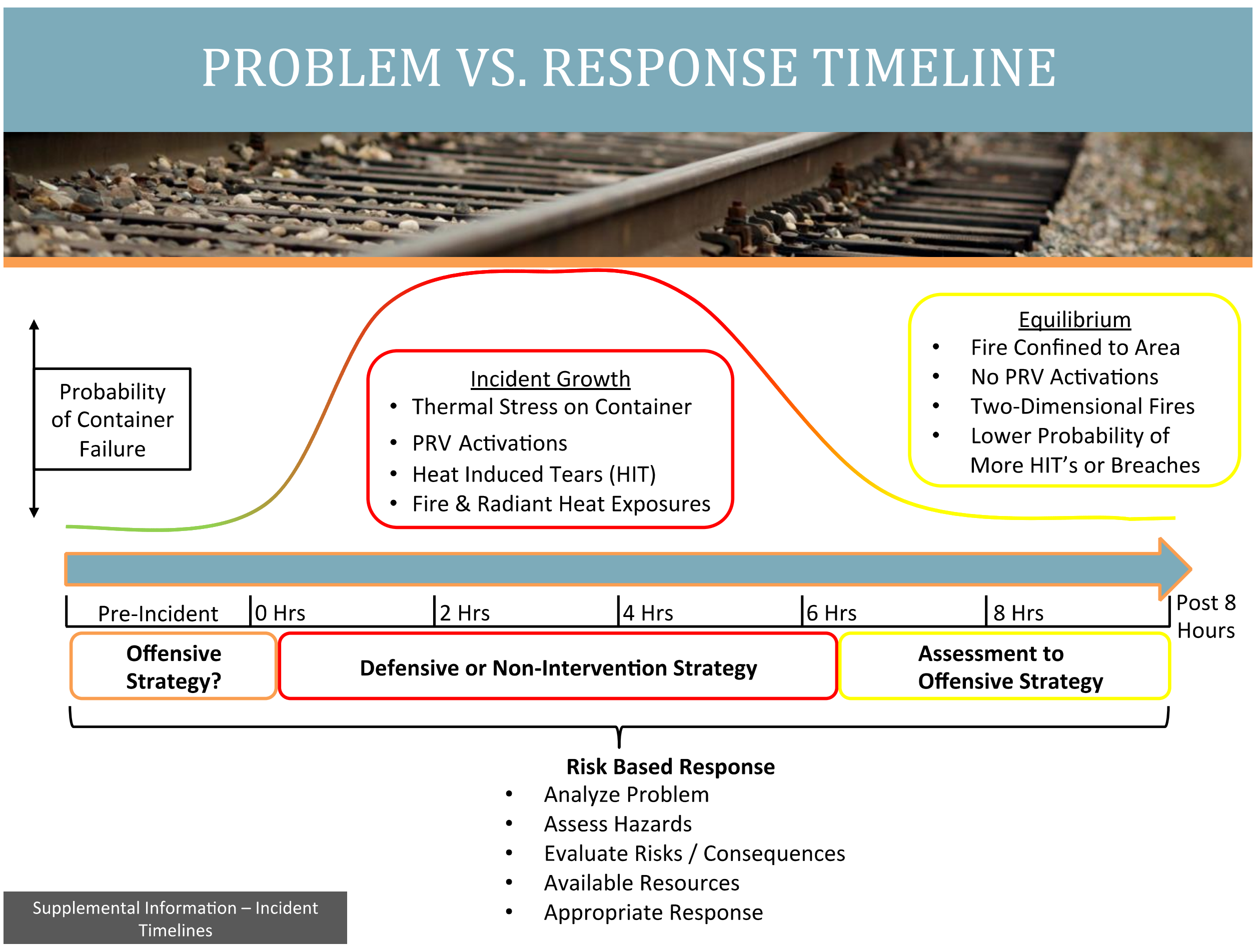

Figure 3: Problem vs Resonse Timeline

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C. 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?
    - 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 approximately 25 HHFT incidents, 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.

IX. 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).

AskRail™. A mobile application developed by the railroad industry to access train information during an emergency. It allows first responders to view real-time information on rail cars through their mobile devices for use in emergencies and for training purposes. Available by contacting a Class I railroad.

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 the geographical location where it originated.

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 portion of the tank car shell surrounding the vapor space of the tank following exposure to pool fire conditions. Normally generates a large fireball and intense heat wave. Thermal tears have been measured from 2 feet to 16 feet in length and have occurred as quickly as 20 minutes.

High Hazard Flammable 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).

Slopover. 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.

Structural Fire-Fighting Protective Clothing (SFPC) The fire-resistant protective clothing normally worn by fire fighters during structural fire-fighting operations, which includes a helmet, coat, pants, boots, gloves, PASS device and a fire-resistant hood to cover parts of the head and neck not protected by the helmet and respirator facepiece

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.

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