LITERATURE SURVEY OF CRUDE OIL PROPERTIES RELEVANT TO HANDLING AND FIRE SAFETY IN TRANSPORT

Presentation to:

OHMS Research & Development Forum

Rick Elliott, PE, CEM

Director, Advanced Supply & Facilities Division

Office of Oil & Natural Gas

April 16, 2015

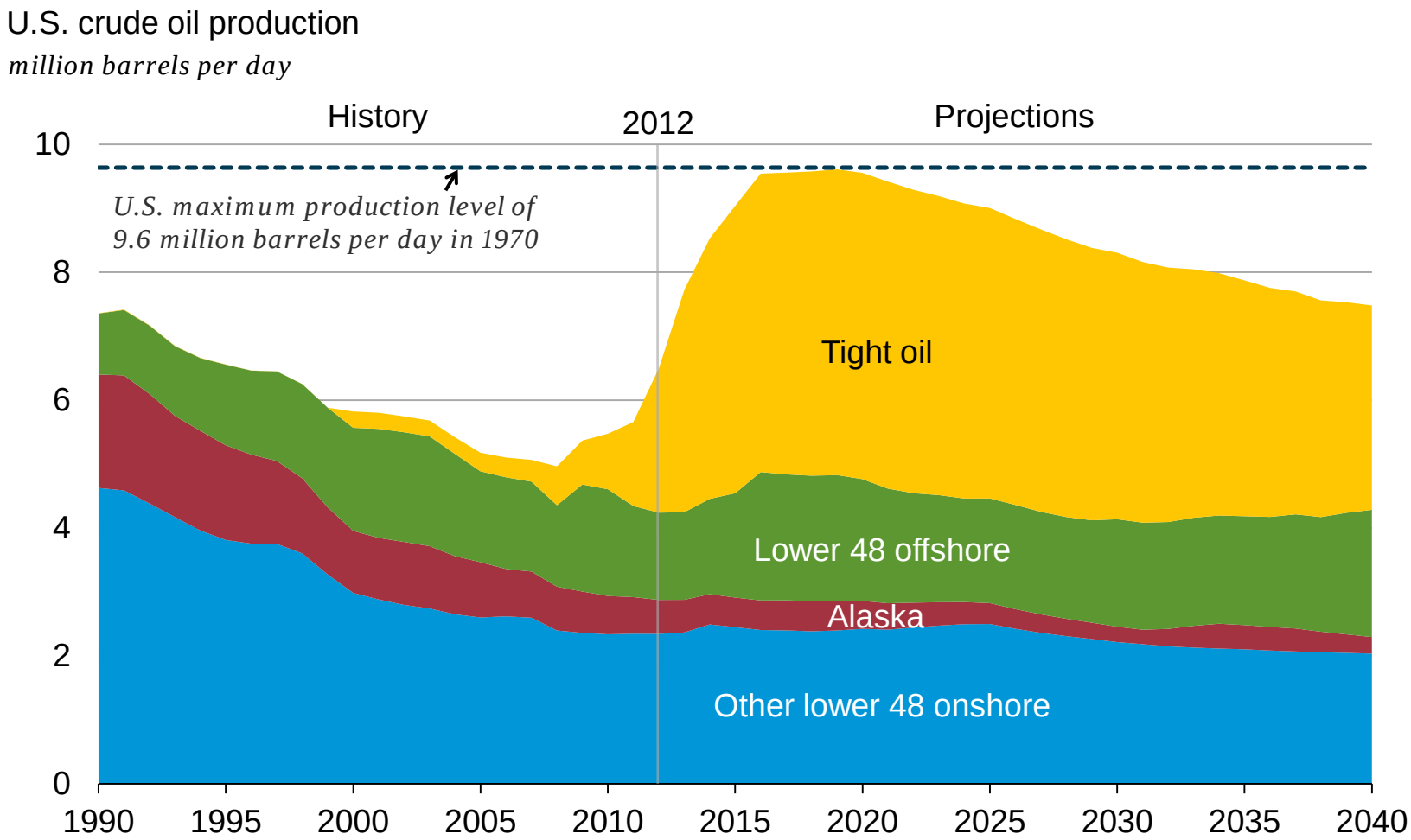
U.S. DEPARTMENT OF ENERGY | Fossil Energy

OIL & NATURAL GAS RESEARCH & DEVELOPMENT FOCUS AREAS

	Area	Description
	Unconventional Oil & Gas	Unconventional oil and gas refers to resources that cannot be produced economically through standard drilling and completion practices – such as shale gas, shale oil, tight gas and tight oil.
	Offshore	Given the growing importance of deepwater and ultra-deepwater production worldwide, it is imperative that U.S. producers and technology developers maintain a focus on technologies that can help to minimize environmental impacts as companies move into deeper and deeper water around the globe.
	CO_2 Enhanced Oil Recovery	As much as two thirds of the nation's known oil resource remains "stranded" and may not be recoverable without the development and use of advanced technologies. We are investigating ways to enhance oil production using carbon dioxide (CO_2).
	Methane Hydrates	The most plentiful supplies of natural gas throughout the world may be the methane molecules trapped in ice-like structures called hydrates. Our research is helping to unlock the mysteries of hydrates and develop future ways to tap their massive energy potential.
	Transmission & Delivery (Including Rail)	The U.S. has a robust natural gas delivery infrastructure, consisting of over 2.4 million miles of pipelines. We will develop technologies and leading practices to mitigate methane emissions from natural gas transmission, distribution, and storage facilities.

DOMESTIC OIL PRODUCTION OUTLOOK TO 2040

Growing tight oil & offshore crude oil production drive U.S. output close to historical high.

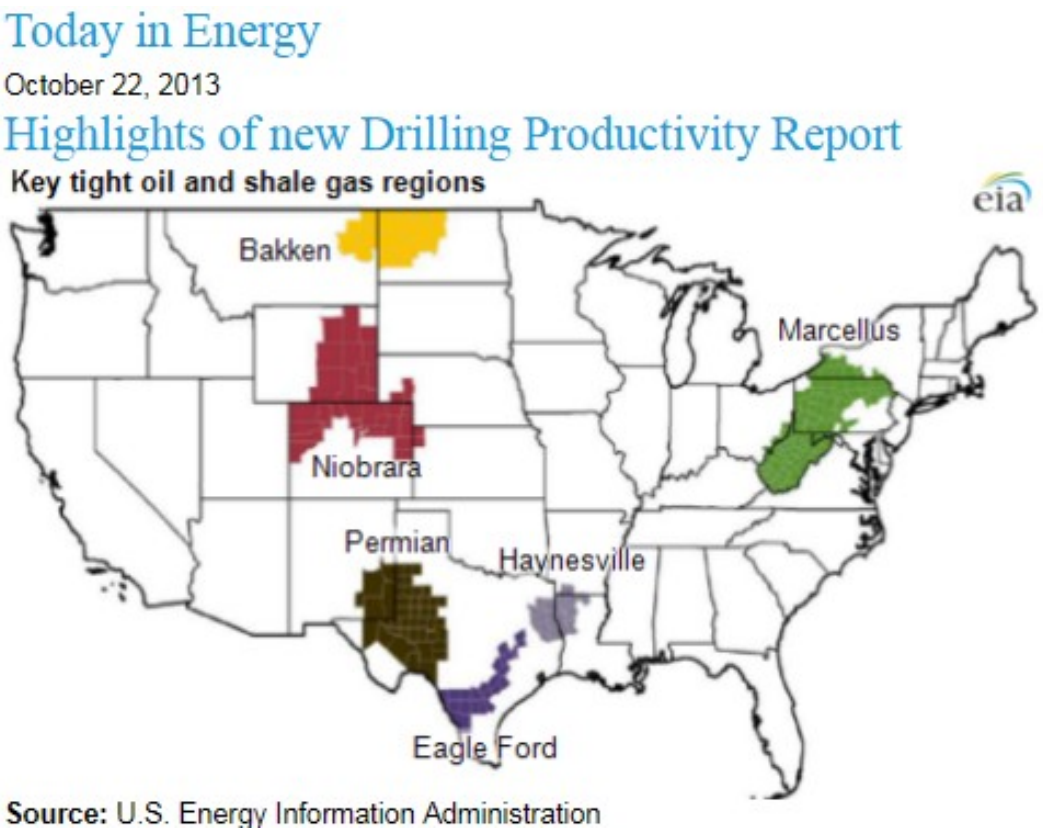


U.S. DEPARTMENT OF ENERGY | Fossil Energy

Source: U.S. Energy Information Administration, Annual Energy Outlook 2014

OPERATING ENVIRONMENT RELEVANT TO STUDY – TIGHT OIL

- Oil produced from low-permeability reservoir rock
- Typically stimulated with hydraulic fracturing to produce at economic rates



Crude	API gravity	Sulfur (wt%)
Bakken	40-43	0.1
WTI	37-42	0.42
LLS	36-40	0.39
Eagle Ford	47.7	0.1
Eagle Ford Light	58.8	0.04

Source: Auers, J. R., R. M. Couture and D. L. Sutton (2014). "The North Dakota Petroleum Council Study on Bakken Crude Properties." Bakken Crude Characterization Task Force. North Dakota Petroleum Council, Bismarck, ND 58501. 4-Aug-2014.

SCOPE OF WORK - PROBLEM DEFINITION PHASE

Currently Authorized – Problem Definition

- Collaborative effort by DOE and PHMSA
  - Work performed by Sandia National Laboratories
- Survey the current state of scientific knowledge - Complete
- Define crude oil properties that have a bearing on handling and transport safety with attention to flammability risks in spill scenarios – Complete
- Prepare Sampling, Analysis and Experiment (SAE) Plan to address gaps in current knowledge of crude oil properties and to correlate measured properties with combustion potential – Complete in Draft
- Outreach and Peer Review – Ongoing
  - Interested parties include Transport Canada, Crude Oil Quality Association, API, Transportation Resources Board, North Dakota Industrial Commission

Literature Survey Report Link:
http://energy.sandia.gov/wp/wp-content/gallery/uploads/dlm_uploads/SAND2015-18233.pdf

Total of Six Tasks

DOE recommends implementing these tasks over next 24 months:

1 - Review/ analyze existing and emerging crude oil data
2 - Sampling method evaluation
3 - Combustion experiments and modeling
4 - Crude oil characterization – tight versus conventional oil

DOE recommends implementing these tasks in FY2017 and later:

5 - Railcar combustion testing and modeling
6 - Comprehensive crude oil characterization

LITERATURE SURVEY – FINDINGS

- Objective is to describe physical properties of crude oil relevant to flammability and transport safety
- If and how these properties will relate to fire and explosion hazard is the key research question
- The vapors (not liquid) from a flammable liquid actually burn - so understanding what leads to vapor formation during handling, transport and spill scenarios is key to understanding the flammability risks
- A general lack of uniformity in methods and QA/QC across industry makes comparisons of crude oil vapor pressure difficult, leaving room for improvement
- Bakken crude, a representative tight oil, exhibits statistically higher vapor pressure than typical oils stored at SPR due to slightly higher mole fractions of light hydrocarbons
- Several different combustion events (pool fire, BLEVE, fireball, explosion, flash fire, flare) can occur from an accidental release of a liquid hydrocarbon
- No single parameter defines the degree of flammability of a fuel; rather, several parameters are relevant
- In an accident scenario enough energy will be generated to cause ignition, far exceeding any hydrocarbon flammability classification threshold

IMPORTANCE OF PHASE BEHAVIOR

- A primary motivation for this study is understanding the fire and explosion hazards associated with accidental release of crude oil in the transport environment
  - **It is the vapor emissions from a "flammable liquid" that actually burn**
  - Conditioned/stabilized crude is typically tested, transported, and sold in the liquid phase and associated vapor losses during handling and transport, if any, are not well-characterized
  - Vapor losses may not cause measurable financial impact from a sales perspective but could lead to elevated risk from a hazards perspective
- It is therefore prudent to examine the phase behavior of crude, specifically the potential for formation of vapor phase emissions, in order to understand the conditions that contribute to fire and explosion hazards around spills

PURE SUBSTANCE VS. MIXTURE

Contrasting behavior in vapor-liquid region of phase diagram

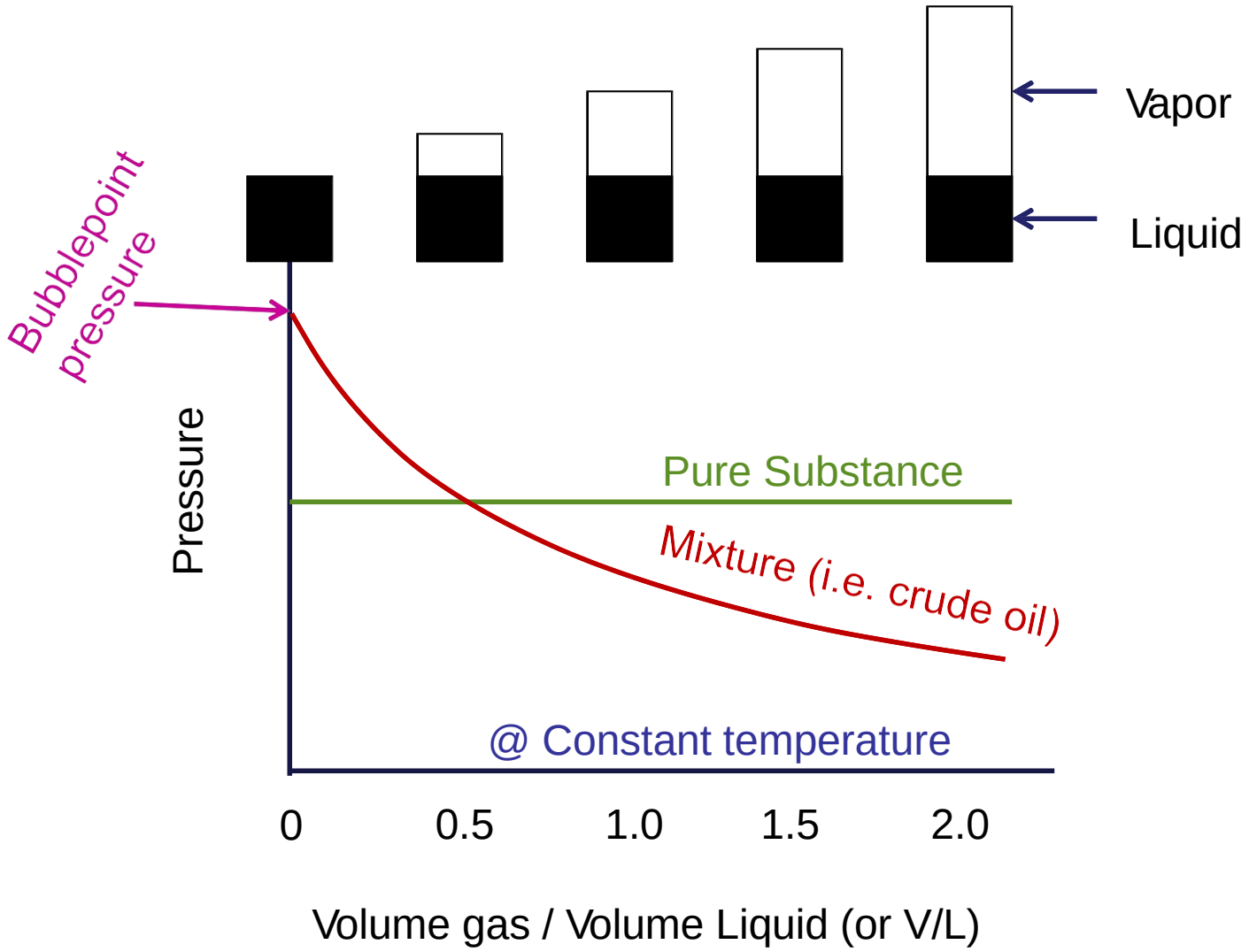
Pure Substance (typical light alkane)

- Single boiling point temperature at a given pressure
- Vapor pressure is constant with V/L at a given temperature
- Step change in density as temperature crosses boiling point at constant pressure

Mixture (crude oil)

- Series of component boiling temperatures at a given pressure
- Vapor pressure is variable with V/L at a given temperature
- Gradual decrease in mixture density as temperature increases through boiling range at constant pressure

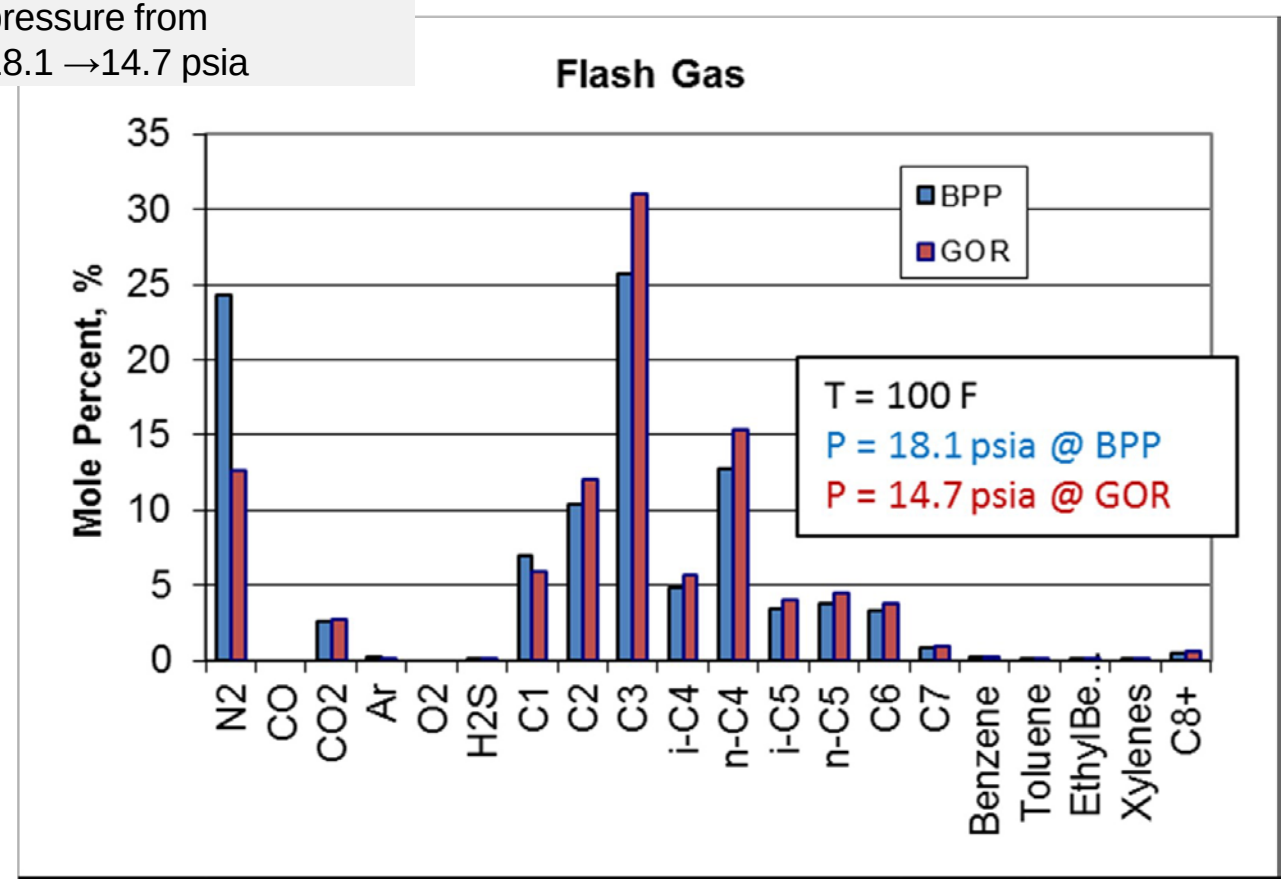
PURE SUBSTANCE VS. MIXTURE



FLASH GAS COMPOSITION

N2 and C1 decrease, C2- C6 increase with drop in confining pressure from 18.1 →14.7 psia

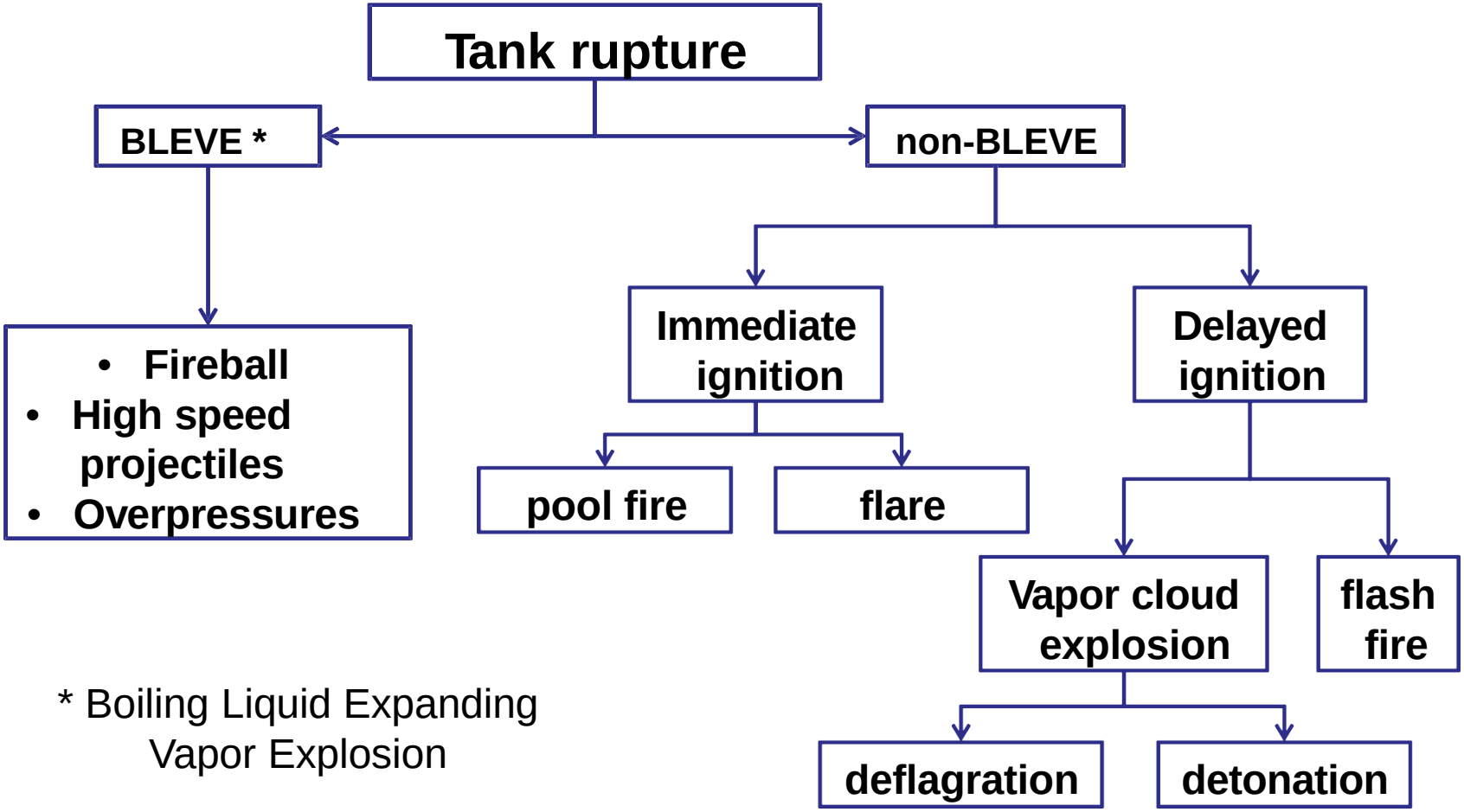
SPR* crude oil WH108, April 2011, API = 37.2



Vapor space composition will change to favor incrementally heavier components with decrease in confining pressure and/or increase in V/L

* Strategic Petroleum Reserve

COMBUSTION EVENT TREE



* Boiling Liquid Expanding Vapor Explosion

POTENTIAL COMBUSTION EVENTS

- These events can occur with any liquid hydrocarbon
- Severity of an accident will depend upon the amount of fuel, surrounding infrastructure, and environment
- **No single parameter defines the degree of flammability**
  - Lower flashpoint, wider range of flammability limits, lower auto- ignition temperature, lower minimum ignition energy, and higher maximum burning velocity is considered more flammable
  - In an accident scenario enough energy will be generated to cause ignition, far exceeding any hydrocarbon flammability classification threshold

PROPERTIES FOR HAZARD CALCULATIONS
(Potential Burn Tests)

Combustion Event	Properties	Scale
Pool fire measurements	• Burn rate • Surface emissive power • Flame height	• ~1 to 10 m, • bund and free spill
Fireball/BLEVE	• Geometry • Surface emissive power • Duration • Fragment characterization (velocities, geometry, range) • Overpressures	Rail car (could help design/test the modified rail car)
Vapor cloud (flash fire, explosion)	• Composition	Rail car ('Damaged' mock)