National Academy of Sciences Identifying safety issues with diluted bitumen pipelines

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July 23,2012

Scope of Study

Pipeline Safety, Regulatory Certainty and Job Creation Act of 2011:

"The Secretary of Transportation shall complete a comprehensive review of hazardous liquid pipeline facility regulations to determine whether the regulations are sufficient to regulate pipeline facilities used for the transportation of diluted bitumen."

1. Incidence and severity of spills on tar sands pipelines
2. Impact of spills for PHMSA spill response planning

NAS Study Design Issues

"In conducting the review, the Secretary shall conduct an analysis of ***whether any increase in the risk of a release*** *exists for pipeline facilities transporting* ***diluted bitumen****."*

- What is diluted bitumen?
- What is the point of reference?

Defining “Diluted Bitumen”

- Combination of bitumen and natural gas liquid condensate and/or other lighter diluents
  - Bitumen
  - Natural gas liquid condensate or other diluents
- Dilbit as a ‘dumbbell crude”
  - High fractions of very heavy carbon chains
  - High fractions of very light hydrocarbons

Characteristics of diluted bitumen

- Heavy (low API)
- High Viscosity
- High total acid number (TAN)
- Sediment content and type
- Sulfur content
- Heavy metal content

Comparison of Diluted Bitumen with Conventional Crudes

Characteristics	Conventional U.S. Crude (West Texas Intermediate)	Venezuela crude in U.S. pipeline system	Diluted Bitumen
Gravity (Density)	39.6 API	30-32 API	19-21 API
Acidity (Total Acid Number)	0 – 0.3	0.03 – 0.3	0.8 – 4.3
Viscosity	5 Centistokes (cST)	7 – 12 cST	201 cST
Sulfur Content	0.3% - 0.5%	0.8% -1.3%	2.5% - 4.5%
Pipeline Temperature	A few degrees above soil temperature	A few degrees above soil temperature	Up to 158 F
Pipeline Pressure	Varies. Average operating pressure below 800 pounds per square inch (psi).	Below 800 psi on average.	Up to 2160 psi (Enbridge's Proposed Northern Gateway diluted bitumen pipeline)
Abrasives	Nil	Unknown	Refineries report hundreds of pounds of sediment per 1000 barrels of diluted bitumen.

Pipeline conditions for diluted bitumen

- High pressure and pumping capacity
- High frictional temperature of pipeline transmission
- Pressure variation due changes in viscosity and temperature in pipeline

Identifying reference crudes to compare safety risks of Dilbit

Criteria for reference crudes:

1) Transported on significant pipeline facility mileage,
2) Extended history on those pipeline facilities and,
3) Significant volume share on those pipelines.

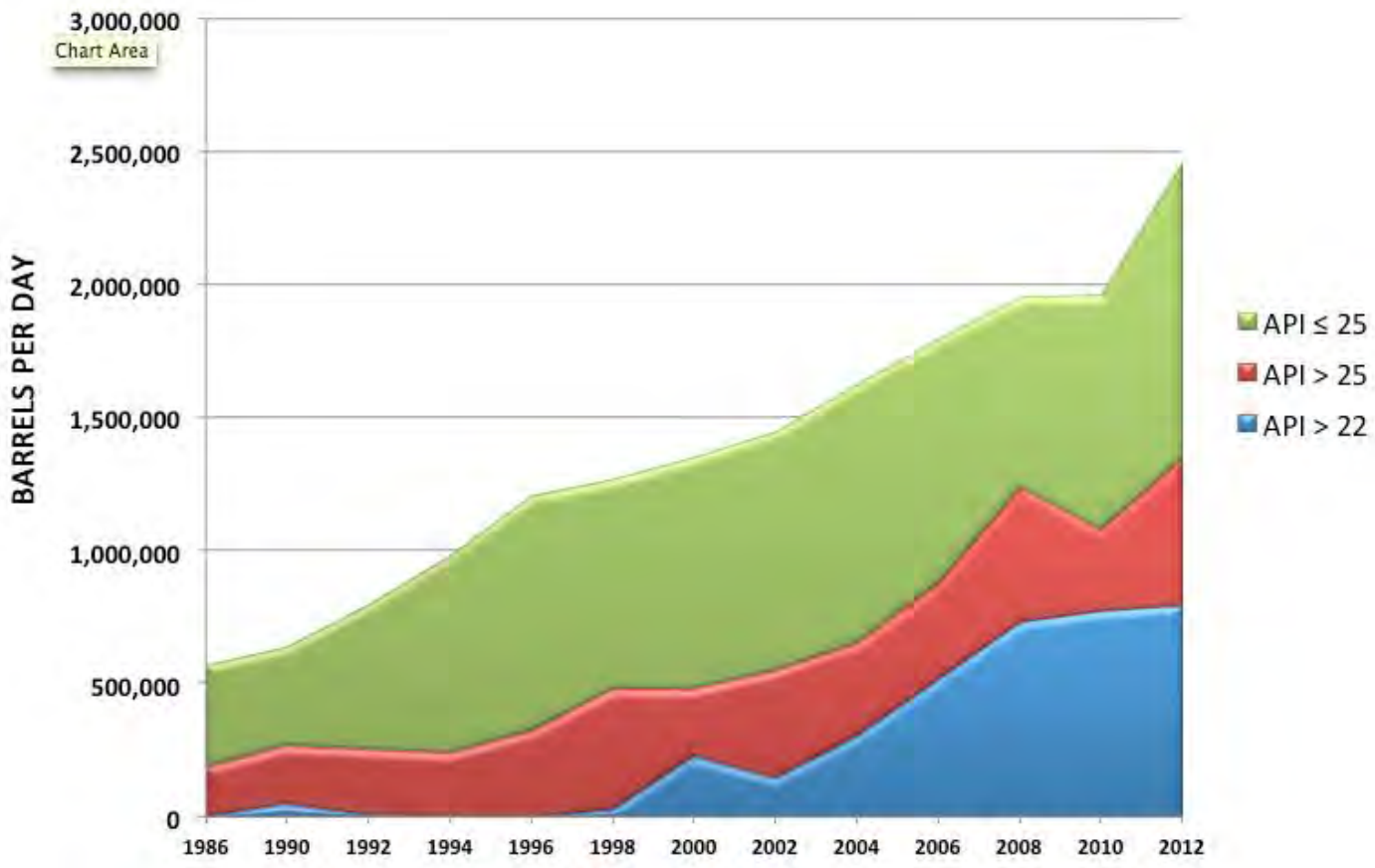
Problems with previously proposed ‘reference crudes’

- High volumes of Canadian ‘conventional’ heavy crudes recent development.
- Venezuelan and Mexican heavy crudes refined at port of entry
  - Crude import data shows characteristics of crude refined in the U.S., not transported in pipelines.
- California heavy crude moved on small pipeline network to onsite refineries

Problem with Canadian heavy crudes as reference

- Canadian ‘conventional’ heavy crudes used in Alberta Innovates Report do not have significant history on U.S. pipelines system
  - Bow River North
  - Bow River South
  - Lloyd Blend
  - Fosterton
  - Lloyd Kerrobert

Canadian crude imports to U.S. by API gravity



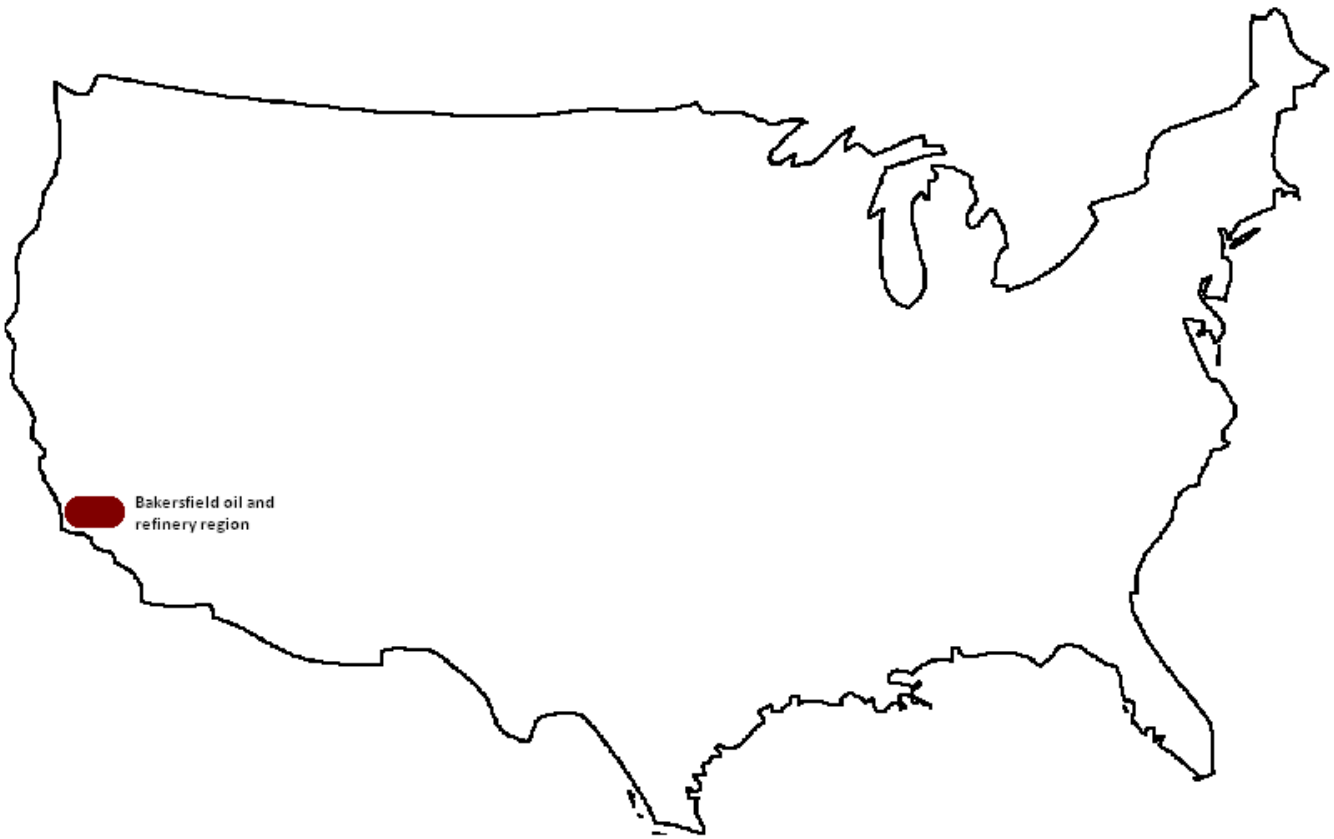
Source: U.S. Energy Information Administration

Canadian Export Pipeline Network

Source: Canadian Association of Petroleum Pipelines

Venezuela Crude 2012 Imports
Ports of entry and refining locations

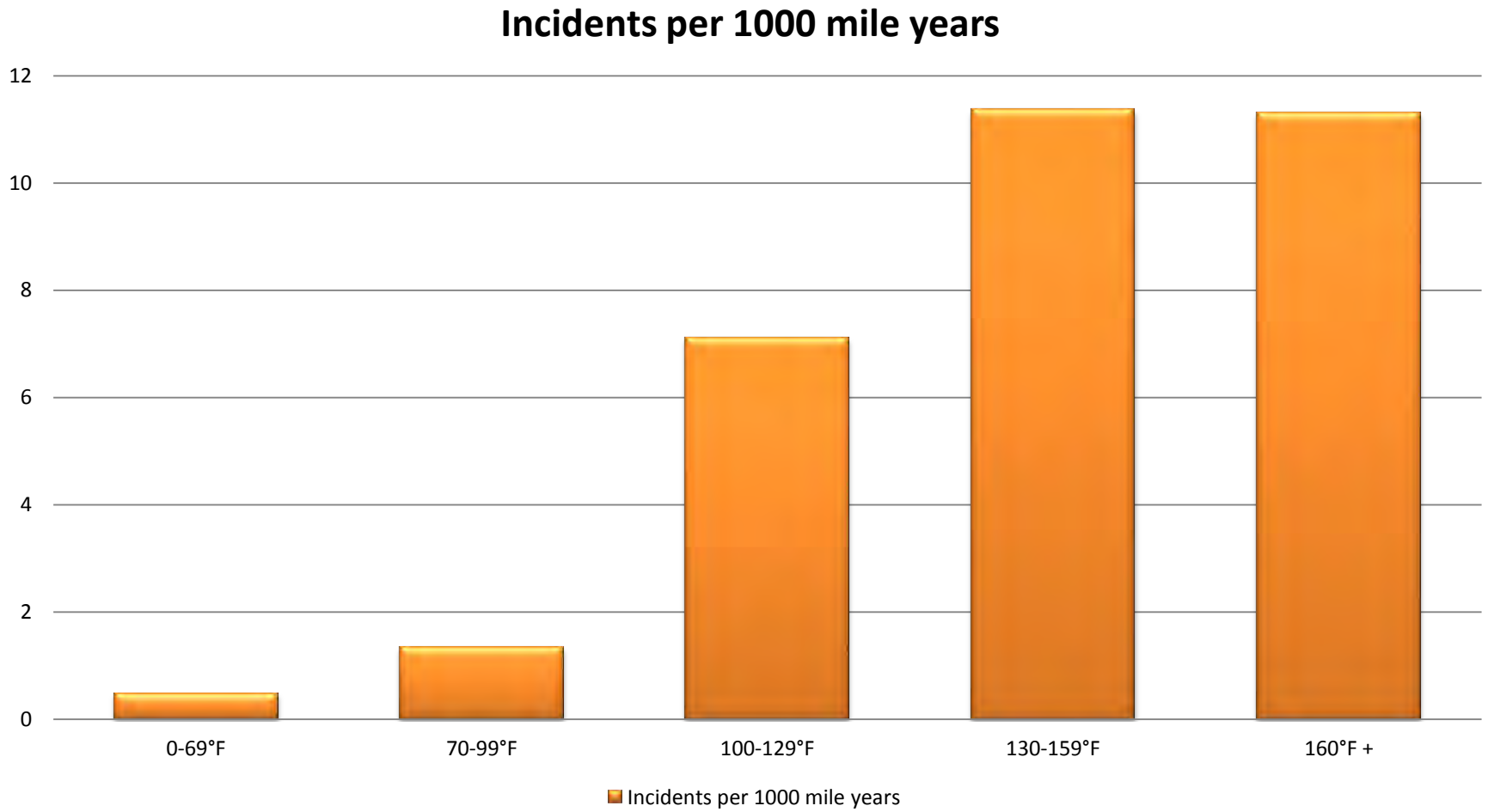
California heavy crudes moved on relatively small pipeline network



California Heavy Crude Production and Refining

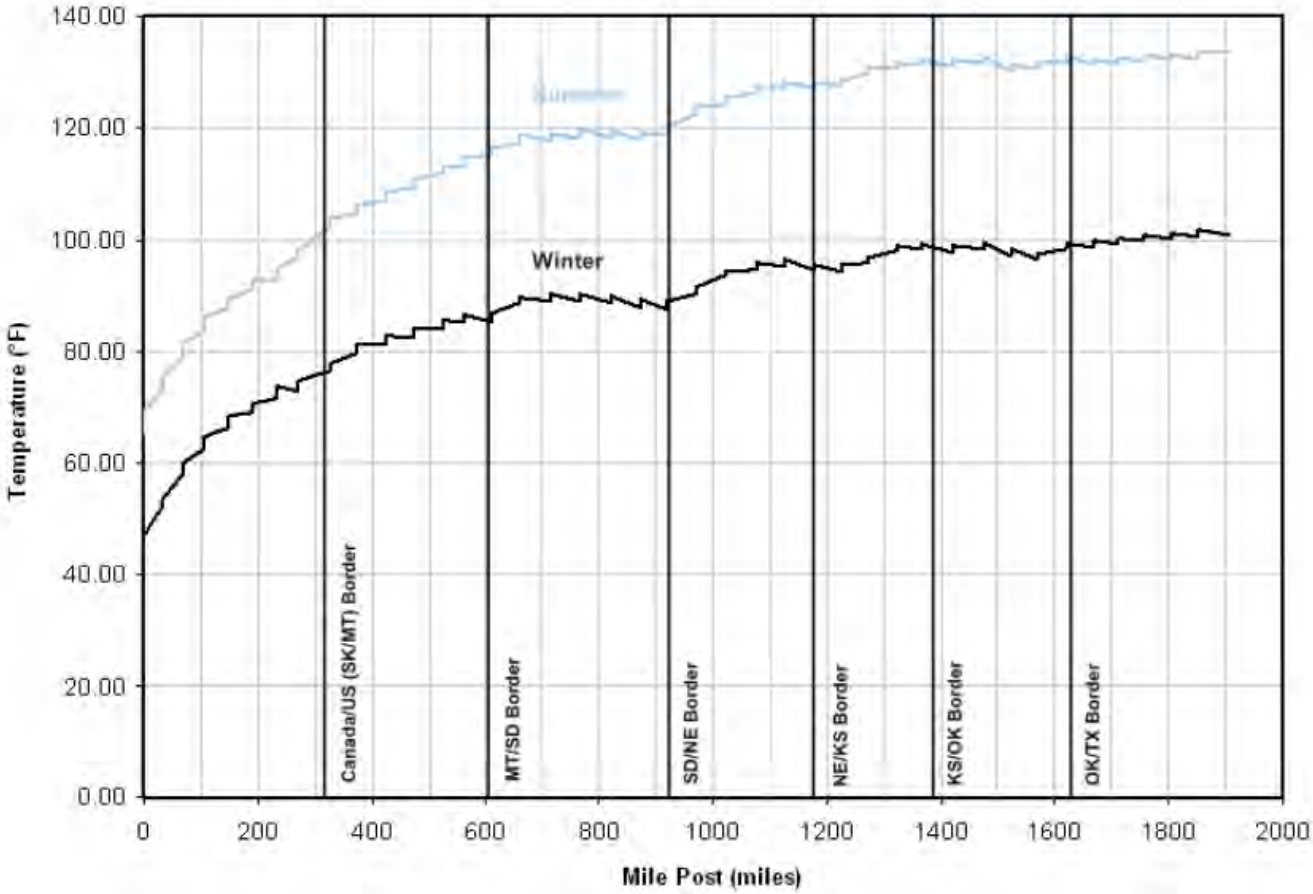
Source: California Energy Commission

California pipeline failure rates by temperature of operation



Source: California State Fire Marshals, 1993

Temperature of Proposed Keystone XL



Source: TransCanada

California Heavy Crudes

- Concerns that have surfaced with studies of California pipeline networks
  - Direct correlation between pipeline temperature and pipeline failure rates
  - High failure rate for Fusion Bonded Epoxy (FBE) coated pipelines
    - FBE pipelines in study less than 10 years old but in the highest temperature category
  - Limited pipeline mileage for heavy crude

Conclusions regarding selection of reference crudes

- NAS should compare diluted bitumen to crudes historically moved in significant volumes on large portions on the U.S. pipeline network
  - E.g. West Texas Intermediate, Louisiana Sweet, Mars, Tia Juana Light

- Crudes with properties similar to diluted bitumen generally have not been moved on the U.S. pipeline system in significant volumes until recently

Caution with comparison to Alberta Pipeline system

- The U.S. pipeline system is over 40 years old on average.
- The Alberta pipeline system is less than 20 years old on average.
- Need to probe characteristics of data used
- Difficult to isolate records of diluted bitumen lines.
  - Diluted bitumen is relatively new for large transmission lines in both Canada and the U.S.

Interaction of threats to pipeline integrity

- Understanding the interaction of specific risk factors for diluted bitumen
  - Problems with identifying threats in isolation
    - NTSB noted the Kalamazoo tar sands spill was due in part to evaluating stress cracking and external corrosion in isolation
  - NAS should consider the interaction of threats on pipeline integrity and materials – temperature, viscosity, physical and chemical properties.

Specific concerns with diluted bitumen

Higher incidence of spills

- External Corrosion
  - High pipeline temperature
- Stress corrosion cracking
  - High Temperature
  - Cyclic stress
  - Corrosive media
- Internal corrosion
  - Acidity issue*
  - Sediment
  - Abrasion (quantity and hardness of sediment)
  - Microbiological Induced Corrosion (MIC)

Naphthenic Corrosion

- Refineries and crude oil transmission pipelines are built to different standards.
  - Refineries use corrosion resistant alloys
  - Temperatures above 250 C create highly corrosive environment
  - Monitored for known, high risk of corrosion

- Carbon steel transmission pipelines are vulnerable to a lower threat of corrosion.
  - Diluted bitumen pipeline operate at higher temperature than conventional crude pipelines

Low Temperature TAN Corrosion

Corrosion of carbon steel UNS G10100 in pure NA at different temperatures (70 minutes)

NA type	T_b, °C	TAN mg KOH/g	Corrosion rate, mm/year		
			at T_b, °C	at 195°C	at 100°C
Cyclopentane carboxylic acid	216	486	105	30	9
Cyclohexane carboxylic acid	232	428	175	68	2
Cyclopentane acetic acid	234	416	188	176	3
Cyclohexane acetic acid	242	394	269	14	1
Cyclopentane propionic acid	252	392	205	6	2
Cyclohexane propionic acid	265	353	211	27	5
Cyclohexane butyric acid	270	327	403	67	2

Source: Low Temperature Naphthenic Acid Corrosion Study

Leak Detection Issues

Higher pressure variability

- Viscosity and temperature variation creates “noise” for pressure/flow monitoring leak detection systems
- Relationship between temperature, viscosity and pressure creates more pressure variation for high viscosity crudes.

QUESTIONS