

LOSS of PROCESS CONTAINMENT – Need for New Reporting Criteria

 NOVA Chemicals

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LOPC – New Criteria

Overview

- Majority of chemical/petrochemical catastrophic accidents involve loss of flammable/toxic chemicals
- CCPS published its guideline “Process Safety Leading and Lagging Metrics” to measure and improve process safety performance

Category	Process Safety Incident Threshold
TIH Hazard Zone A Materials ¹	5kg (11lbs.)
TIH Hazard Zone B Materials ¹	25kg (55lbs.)
TIH Hazard Zone C Materials ¹	100kg (220lbs.)
TIH Hazard Zone D Materials ¹	200kg (440lbs.)
Other "Packing Group I" materials ² & "Flammable Gases/Vapors"	500kg (1,100lbs.)
Other "Packing Group II" materials ² & "Flammable Liquids"	1,000kg (2,200lbs.)
Other "Packing Group III" materials ² & "Combustible Liquids" and Division 2.2 - Nonflammable, Nontoxic Gases	2,000kg (4,400lbs.)

¹: Specified by the US Department of Transportation regulations (49 CFR 172.101).
²: Packing group definition based upon UN Dangerous Goods definitions.

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Problem

- Toxic materials have different thresholds, why?
 - Different characteristics, e.g. zone A materials are more hazardous than zone B materials!
- All flammable gases/vapors have the same threshold!, e.g. Hydrogen and Methane have the same thresholds
- **Same quantity would not result in similar/comparable consequences**

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Characteristics

- Flammable gases have different characteristics:
 - **Molecular weight**, e.g. Hydrogen has the lowest
 - **Minimum ignition energy**, e.g. Hydrogen has the lowest
 - **Flammability limits**, e.g. Hydrogen has the lowest LFL (Mass Fraction)
 - **Heating value**, e.g. Hydrogen has the highest (J/kg)
 - **Flame speed**, e.g. Hydrogen has the highest
 - **Auto ignition**, e.g. Hydrogen has the highest

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Dispersion - Outdoor

- Release rate: 500kg/hr, Pressure: 8 Barg, Temperature: 100 °C

Material	Hole Diameter (mm)	UFL Distance (m)	LFL Distance (m)	1/2LFL Distance (m)
Hydrogen	20.4	0.2	12.6	17.4
Methane	12.5	0.7	3.1	5.8
Ethane	10.6	0.6	2.7	5.1
Ethylene	10.7	0.2	3.6	6.5
Acetylene	10.9	-	3.5	6.5
Propane	9.6	0.6	2.8	5.3
Propylene	9.7	0.5	2.9	5.4

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Dispersion - Outdoor

- Hole Diameter: 17.35mm, Pressure: 3 Barg, Temperature: 10 °C

Material	Release Rate (kg/hr)	UFL Distance (m)	LFL Distance (m)	1/2LFL Distance (m)
Hydrogen	179	0.2	6.6	8.9
Methane	500	1.4	5.1	8.3
Ethane	678	1.4	5.5	10.3
Ethylene	660	0.5	6.7	15.2
Acetylene	636	-	6.5	14
Propane	821	1.8	6.4	14
Propylene	804	1.5	6.5	14.4

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Dispersion - Outdoor

- Hole Diameter: 20.0mm, Release Rate: 4kg/s, Temperature: 50 °C

Material	Pressure (Barg)	Maximum Flammable Mass (kg)
Hydrogen	61.6	17.0
Methane	21.3	8.7
Ethane	15.2	9.2
Ethylene	15.7	18.3
Acetylene	16.2	17.7
Propane	12.2	13.0
Propylene	12.5	13.8

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Dispersion - Indoor

- Building Dimensions: 31m x 20m x 5m, Concentration: 1.2 Stoichiometry concentration

Material	Mass (kg)	Hole Diameter (mm) @ 3Barg & 10°C	Mass/Mass H ₂
Hydrogen	90	12.3	1
Methane	251	12.29	2.8
Ethane	285	11.25	3.2
Ethylene	307	11.83	3.4
Acetylene	333	12.55	3.7
Propane	296	10.42	3.3
Propylene	315	10.86	3.5

LOPC – New Criteria

Jet Fire

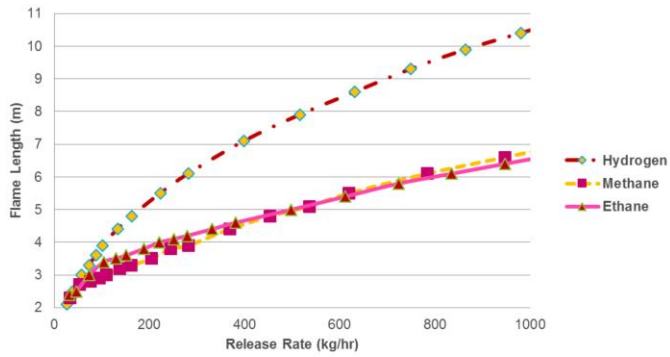
- Release rate: 500kg/hr, Pressure: 8 Barg, Temperature: 100 °C

Material	Hole Diameter (mm)	Flame Length (m)
Hydrogen	20.4	7.8
Methane	12.5	5
Ethane	10.6	4.8
Ethylene	10.7	4.8
Acetylene	10.9	4.8
Propane	9.6	4.8
Propylene	9.7	4.8

LOPC – New Criteria

Jet Fire

- Flame length vs Release Rate; Hole Diameter: 20.0 mm, Temperature: 50 °C

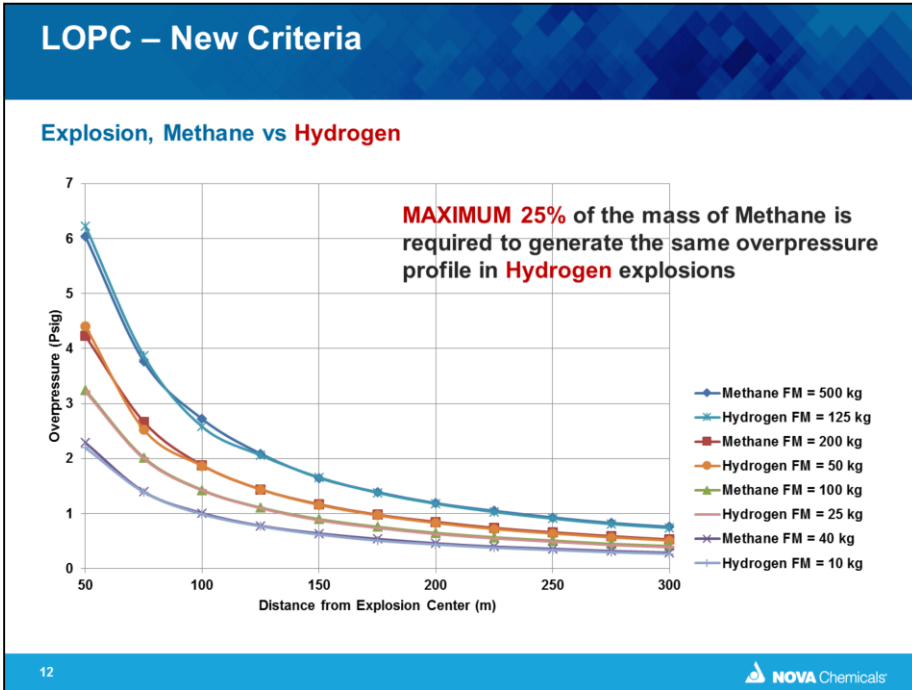


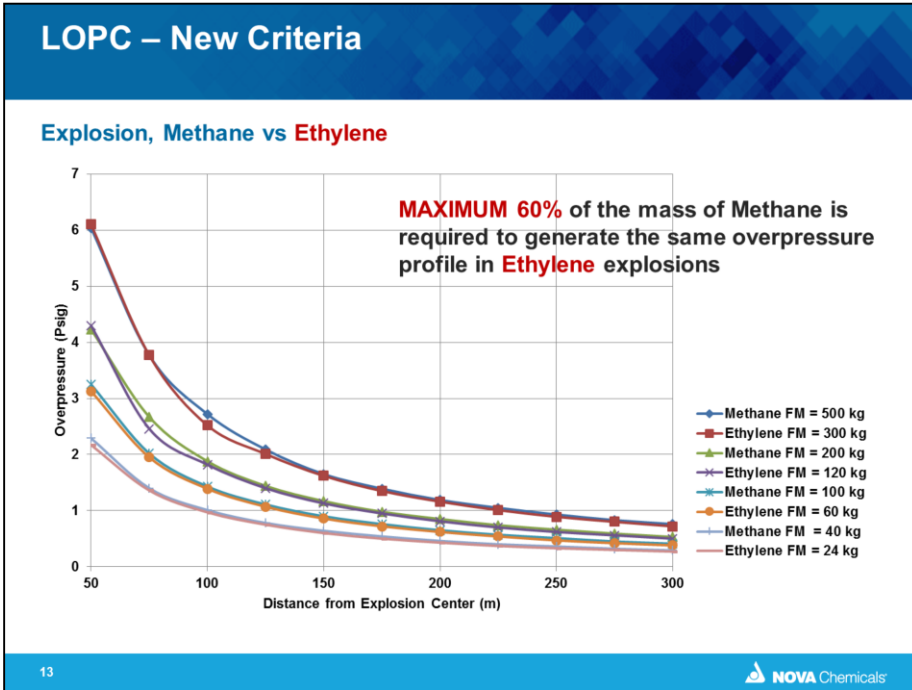
LOPC – New Criteria

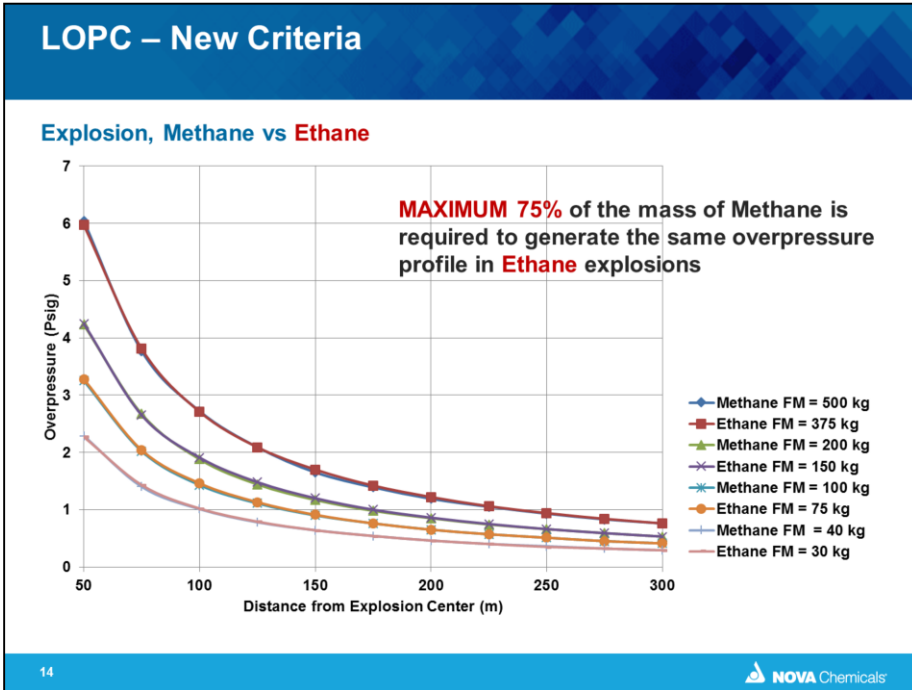
Explosion

- Flammable Mass: 10kg, BTS Model, Flame Expansion: 3D, Obstacle Density: Medium

Material	Fuel Reactivity	Max Overpressure (Psig)	Distance to 1 Psig (m)
Hydrogen	High	294	100
Methane	Low	2.6	18
Ethane	Medium	7.6	51
Ethylene	High	294	73
Acetylene	High	294	74
Propane	Medium	7.6	51
Propylene	Medium (High)	7.6	51







LOPC – New Criteria

Material Effects on Overpressure Profile

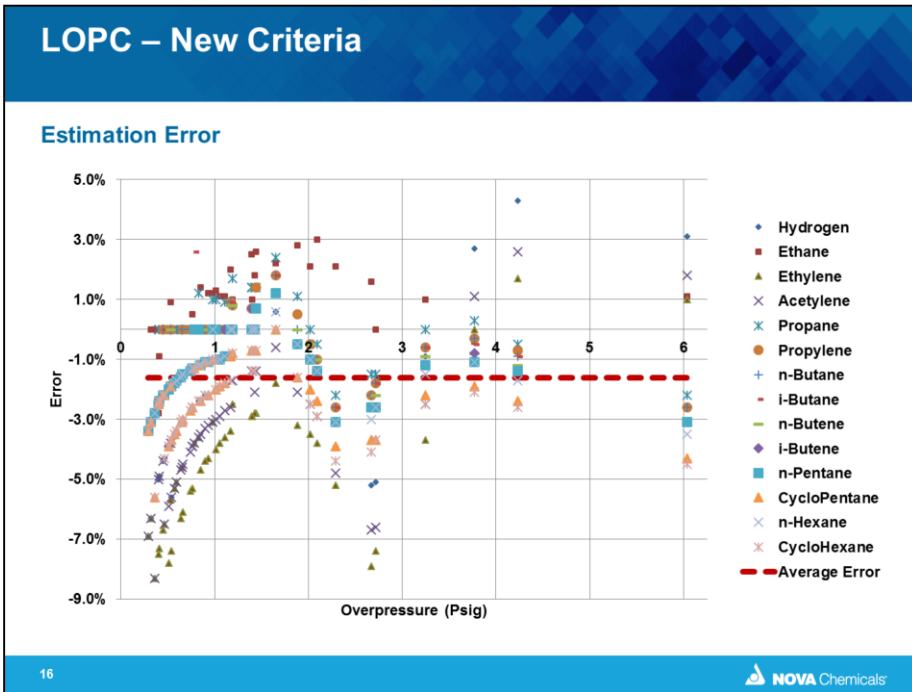
Reactivity	Material	Fraction of 500kg	Overpressure Profile	
			Max Error	Ave Error
High (LFS ¹ > 75 ² cm/s)	Hydrogen	25%	6.9%	3.0%
	Ethylene	60%	8.3%	4.7%
	Acetylene		8.3%	3.8%
Medium (75 ² ≥ LFS > 45 ² cm/s)	Ethane	75%	3.0%	0.9%
	Propane		3.4%	1.0%
	Propylene ³		3.4%	1.1%
	n-Butane		3.4%	1.1%
	n-Butene		3.4%	1.3%
	i-Butane		3.4%	1.3%
	i-Butene		3.9%	1.4%
	n-Pentane		3.4%	1.4%
	CycloPentane		5.6%	2.3%
	n-Hexane		3.9%	1.6%
Low (LFS ≤ 45 cm/s)	Methane	100%	-	-
Overall⁴			8.3%	2.0%

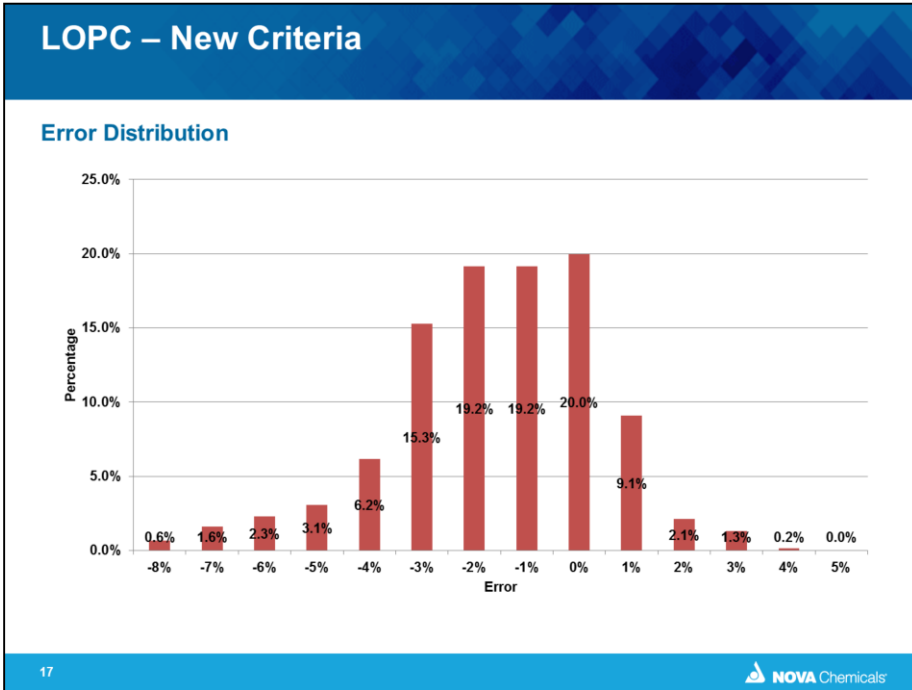
¹: Laminar Flame Speed

²: These are not exactly the same values used in BST Model

³: Propylene could be considered as an exception and categorized as a highly reactive fuel.

⁴: **616** points in total.





LOPC – New Criteria

New Criteria

Category	Process Safety Incident Threshold Quantity <i>(Proposed)</i>
TIH Hazard Zone A Materials ¹	5kg (11lbs.)
TIH Hazard Zone B Materials ¹	25kg (55lbs.)
TIH Hazard Zone C Materials ¹	100kg (220lbs.)
Hydrogen	125kg (275lbs.)
TIH Hazard Zone D Materials ¹	200kg (440lbs.)
Highly² Reactive Flammable Gases/Vapors	300kg (660lbs.)
Moderately³ Reactive Flammable Gases/Vapors	375kg (825lbs.)
Other "Packing Group I" materials ⁴ & "Flammable Gases/Vapors"	500kg (1,100lbs.)
Other "Packing Group II" materials ⁴ & "Flammable Liquids"	1,000kg (2,200lbs.)
Other "Packing Group III" materials ⁴ & "Combustible Liquids" and Division 2.2 - Nonflammable, Nontoxic Gases	2,000kg (4,400lbs.)

¹: Specified by the US Department of Transportation regulations (49 CFR 172.101).
²: Laminar Flame Speed > 60 cm/s, e.g. Ethylene and Acetylene. Propylene could be included as an exception.
³: 60 cm/s² Laminar Flame Speed > 40 cm/s, e.g. Ethane, Propane, n-Butane.
⁴: Packing group definition based upon UN Dangerous Goods definitions.

LOPC – New Criteria

Benefits

- Reporting based on the same hazard potential, rather than material quantity
- Reinforcing the idea that these flammable gases have different properties and characteristics
- Driving process safety culture (**how much was released?→ what was released and how much was it?**)
- Driving process safety performance (reduce the number of 125+kg hydrogen releases rather than 500+kg hydrogen releases)



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