Quantitative Risk Assessment

Creating QRA Scenarios to support **Recommended Practices for Municipalities and Industry**

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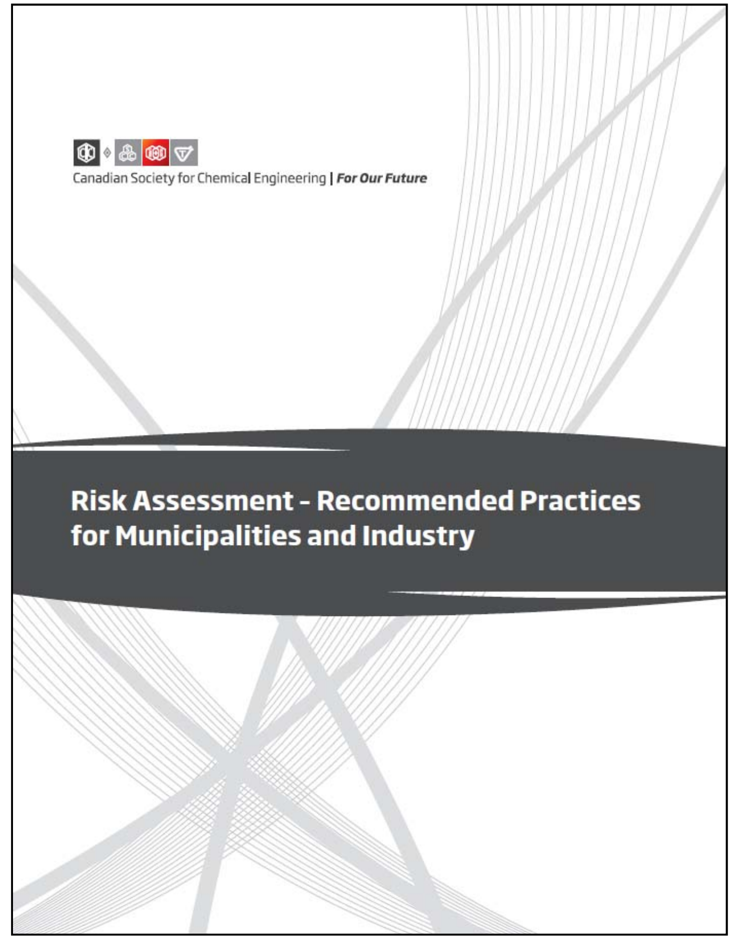
History of this Guideline

- Originally prepared by the Risk Assessment Expert Committee of the former Major Industrial Accidents Council of Canada (MIACC).
- Focuses on managing risks from acute incidents, not chronic environmental risks
- Transferred to the Canadian Society for Chemical Engineering (CSChE) as part of the work plan of the CSChE's newly-formed Process Safety Management division
- Published in 2004
- Decision made to update it in 2013
- Guideline hiatus in 2016, pending CSA Z767



2016 Developments

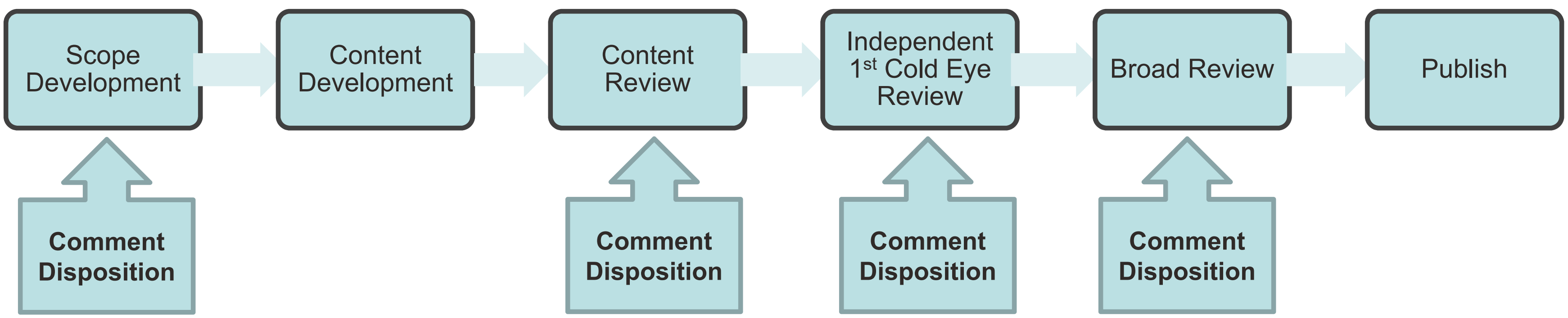
- Z767 References 2004 QRA Guideline, which is out of date
- Impetus to "fast track" completion of updated/new "People Risk" guideline to support Z767
- 2016 Scope-influencing developments:
  1. Agreement by Z767 Technical Committee to including approaches to justify ALARP in this guideline
  2. Occupational risk criteria recommendation seen as a gap – approval to include at the October 2016 PSMD meeting in Quebec City
  3. Jean Paul Lacoursiere proposal to include detailed guidance to achieve consistent QRAs – also approved at the Quebec City meeting.

Work done to date, following 2004 Guideline structure

TOC Section	Status
1. Introduction	Complete; 3rd draft stage
2. General Risk Management Framework	Complete; 3rd draft stage
3. Estimating Individual Risk In a QRA	Complete; ready for 1st review
4. Hazard Identification	Complete; ready for 1st review
5. Estimating Consequences	Being finalized
6. Estimating Frequency	Being finalized
7. Risk Reduction & Re-Iterating Risk	Not developed yet.
8. Appendix: Sample Scenarios / Methodology for Consistent Risk Assessments	Being finalized – focus of this presentation

Proposed Development Plan (No Timeline) under review

- No timeline, other than to publish early 2018
- Participation open, but:
  - Content Developers and Cold Eye Reviewers are Subject Matter Experts
  - Broad review by users and other interested parties



Purpose of developing sample scenarios

- Reproducibility in quantitative risk assessment is paramount.
- If we are to have engaged and informed discussion regarding facility design and operation – design engineers, risk assessors/consultants, regulators, municipalities, and other decision-makers must have a shared understanding of how risks are calculated and managed.
- Thus, the purpose of this appendix is to develop scenarios to demonstrate the analytic process, embedded assumptions, and modelling choices in:
  - identifying and using hazardous materials to represent the range of potential operational scenarios;
  - event tree analysis for modes of failure and loss of containment;
  - consequence analysis (source release, fire, explosion modelling, toxic cloud dispersion, and exposure modelling); and
  - frequency analysis (event tree quantification, loss of containment frequency and mitigation system modelling).

Hazardous materials are ubiquitous, yet often taken for granted

- Three people in Fernie, B.C., died from possible exposure to ammonia after emergency crews were called to the Fernie Memorial Arena for reports of an ammonia leak just before noon on Tuesday, October 17, 2017.

Hazardous materials are ubiquitous, yet often taken for granted

- Two people died as a result of Sunrise Propane Incident, in North York, Toronto, the morning of August 10, 2008.
- Thousands of people were evacuated, cleanup cost $1.8M, and Sunrise propane was fined $5.3M.
- Technical Standards and Safety Authority said that it had only inspected Sunrise once since it opened in 2005.
- TSSA have improved drastically and now are one the leading regulators in Canada for safety and risk

Chosen materials for scenarios

- For most operations, the release of hazardous materials poses the greatest risk to workers and the surrounding community.
- For the purposes of illustration, we have chosen six materials that:
  - are on the MIACC (1994) list of hazardous substances;
  - represent the MSDS (Material Safety Data Sheet) chemical classes (explosives, gases, flammable liquids, flammable solids, oxidizers, poisons, corrosive) to demonstrate how to model their release, dispersion, and exposure modes;
  - are highly prevalent and diverse in use – from large industrial facilities (mining, refineries, processing plants) to small and medium sized enterprises (hotels, machine shops, construction yards, farm supply dealers) to institutional facilities (water treatment, colleges and universities, hospitals, medical labs); and, as a result,
  - are likely to transported via multiple modes (rail, road, pipelines) and stored in various manners and quantities.
  - For a comprehensive listing of hazardous materials, see MIACC (1994) Major Industrial Accidents Council of Canada, Lists of Hazardous Substances.

Chosen materials

Material	Toxic – airborne inhalation only	Flammable	Fixed Plant	Transportation		
				Rail	Road	Pipeline
Propane / LPG / NGL, C_3H_8		X	X	X	X	X
Methane / natural gas, CH_4		X				X
Gasoline, C_4-C_{12}		X	X		X	
Chlorine, Cl_2	X		X	X	X	
Sodium Cyanide, NaCN	X					
Hydrogen Sulfide, H_2S	X	X	X			
Ammonia, NH_3	X		X	X	X	

Scenario Development for propane, hazardous material properties

Property	Value/Comments
Form	Liquid (saturated) and vapour while stored under pressure.
Boiling Point	- 42 °C
Flash Point	- 103 °C
Fluid temperature [For risk analysis. This analysis input affects release rate and]	20°C - Storage plant/Transport: Conservative yearly temperature for Canada for risk analysis purposes.
	5°C< T°C < 30°C -Storage plant/Transport: Conservative hot season and cold season temperatures for Canada for risk analysis purposes. Each value would have a probability of occurrence of 0.5
	Ambient temperature analysis - Storage plant: Ambient temperature from the nearest weather station can be analyzed to determine a yearly temperature/probability distribution. If going this route, the weather analysis should also take into consideration atmospheric stability class and wind speed.
Containment Pressure	Vapor pressure @ fluid temperature

Propane: hazardous material properties

- **Flammability:**

Limits	Comments
Lower: 2.4%	Percent by volume in air
Up	

Need to talk about thermal radiation from fires and explosion overpressures. Each of these impacts have probit equations

- **Reactivity**
  - Category 0 Substance (extremely flammable) with high reactivity

- **Toxicology**
  - Inhalation toxicity: Non-toxic to people
  - Probit equation: $Y = a + b \, Ln \, (L^{n} \, . \, t)$
  - Combustion Products: water and carbon dioxide decomposition products

Propane: Loss of Containment scenarios

Method to identify: HAZOP, What if, FMEA, Process Review:
Use of selection process applies especially for bulk shipping activity. Indication numbers for Propane include:

O_1 is the factor for the type of containment system (process or storage)
O_2 is the factor for the location of the containment system: inside, within bund or outside
O_3 is the factor for the process conditions
G is the limit value of propane (in kg) it is a measurement for the hazardous characteristics of propane based on both the physical

Need to reference – I think this is from Bevi

A is the measurement of in ... ane, the physical and flammable characteristics of the substance and the specific process conditions
Q is the total quantity of the substance inside the containment system
Selection Number for flammable substance (propane) is calculated
S = $(100/L)^3 A$
L is the distance from the containment system to the specific location in meters and is a minimum of 100 m. *See Figure a for schematic of selection of containment systems.*
*Transport pipelines containing pressurized liquefied gases must be included in QRA by default.
Scenarios included in the QRA should satisfy the following two conditions:
1. the frequency of the scenario is greater than or equal to 1×10^{-9} per annum;
2. lethal injury (1% fatality) can also occur outside the site boundary.

Containment	Type	O_1	O_2	O_3	Q	G	A_i
I_3	F	1	1	10	50000	10000	50

Propane: Loss of Containment scenarios

- LoC Scenarios for a pressurized storage tank aboveground, underground & mounded (maximum permissible pressure > 0.5 bar of overpressure.)
- Models available for: 1) outflow from vessel through small leak in vessel wall or break in piping, 2) totally ruptured vessel, 3) outflow from pipeline through small leak, and 4) outflow from full bore ruptured pipeline.

Scenarios	Frequency (per annum)	Parts included in the default Scenario	Parts not included in default scenario
• **Instantaneous release of entire contents** • **Release of entire contents in 10 min. in a continuous and constant stream** • **Continuous release of contents from a hole with an effective diameter of 10 mm**	5×10^{-7} 5×10^{-7} 1×10^{-5}	Welded stumps Mounting plates Instrumentation pipes Pipe connections up to the first flange	Transport pipelines from the (quick closing) valve Vapor return pipe Pressure relief device Pipeline system

Hazard identification

- Hazardous material properties
  - Physical properties
  - Flammability
  - Reactivity
  - Toxicology
    - Inhalation toxicity only
    - Probit equation
  - Combustion/decomposition products
- Loss of Containment (LoC) Scenarios
  - Method to identify
    - HAZOP, What if, FMEA, Process Review
  - Categories – by hole size or by release rate
  - Number and location per site

Hazard identification

- Event Tree Analysis
  - From LoC to Hazard Outcome
  - Fires
    - Pool fire
    - Jet fire
    - Fireball
    - Trench fire
  - Explosions
  - Toxic Clouds (Inhalation)

Consequence Analysis, Source Term

- Liquid release
  - Below normal boiling point
  - Above normal boiling point - flashing
- Gas/vapor release
- Pooling / Evaporation
  - Confined pool
  - Unconfined pool
- Indoor / confined explosions
- Vapour cloud explosion (VCE)

Consequence Analysis, Modelling

- Fire Modelling
  - Liquid release
  - Pool fire
  - Jet fire
  - boiling liquid expanding vapor explosion (BLEVE) Fireball
  - Trench Fire - pipelines
  - Point source model
  - Dispersion & Flash Fire

- Explosion Modelling
  - Vapor Cloud Explosion (VCE)
  - BLEVE Blast
  - Confined – vessel, building
  - Deflagration to detonation transition (DDT)
  - Computational fluid dynamics (CFD)

Consequence Analysis, Modelling

- Toxic Cloud (Inhalation)
  - Dispersion modelling
    - Heavy gas
    - Neutrally buoyant
    - Plume rise – toxic combustion products
    - Surface roughness
    - Averaging Time
  - Indoor infiltration
- Effects Modelling
  - Fire
    - Thermal radiation
    - Fire surface emissive power
    - Flame contact
    - Probit model
    - Exposure time
  - Explosion
    - Overpressure
    - Missiles / debris
  - Toxic cloud inhalations
    - Probit model
  - Exposure time

Frequency Analysis

- Event Tree Quantification
  - Quantifying post-LoC events
    - Immediate ignition
    - Delayed ignition
    - Meteorology, including wind direction
    - Time-at-risk
    - Spatial/directional probabilities
    - Mitigation system failure
- LoC Frequency Modelling
  - Equipment LoC events
  - Frequency Data sources
  - Fault Tree Analysis
    - Prevention systems
  - Ageing / end of life / bathtub curve

Mitigation System Modelling

- Equipment Probability of Failure on Demand (PFD)
  - Fractional dead time
  - Repair time
- System PFD
  - Fault Tree Analysis
- Frequency/PFD Data sources
- Common mode failure modelling
- Dependencies
- Redundant equipment
- Ageing / end of life / bathtub curve
- Process control modelling
- Electrical / pneumatic / lube oil sub systems

THANK YOU!

Questions?
Comments?
Feedback?

Interested in being involved?