Assessing the Risks of the “Domino Effect”

HazAus2016/1624
Presenter: Dr Patrick Walker
Position: Senior Risk Engineer

Agenda

- The Domino Effect
- An Historical Example
- Domino Effects and Quantitative Risk Assessments (QRA)
- Methodology for Inclusion in QRA
- An Industrial Example

The Domino Effect

- An event from one source (Primary Event) that causes an event at another (Secondary Event)

- Primary Event:
  - Fire – ignition of a flammable release, e.g. propane
  - Explosion – detonation of explosive material
  - Projectile fragments – vessel burst

- Secondary Event:
  - Fire, Explosion, Toxic Release

The Domino Effect: Example

- A loss of containment at one source (Primary Event) that leads to the loss of containment at another (Secondary Event)

Primary Event

Localised fire

Leads to…

Secondary Event

Fire, BLEVE, Explosion

An Historical Example

- Feyzin Disaster
  - Release from LPG sphere, vapour cloud formed
  - Ignited pool fire impinged on the LPG sphere
  - Boiling-liquid expanding-vapour explosion (BLEVE)
  - Projectile fragments from burst LPG sphere

- Incident Impact
  - 18 deaths
  - 81 injuries
  - Projectile damaged to adjacent spheres leading to failures

Domino Effects and QRA

- QRA assesses a facility's risk profile
  - Risk acceptability at offsite land uses and onsite locations, e.g. occupied buildings
- Domino effects potentially impact key areas
- QRA focuses on significant Secondary Events
  - Avoid analysis of events with minimal influence
- Criteria for inclusion:
  - Secondary Event consequence is significantly larger
  - Risk of Secondary Event influences the risk profile

Methodology for QRA Inclusion

1. Identify Primary Event
2. Identify Secondary Event
3. Characterise Secondary Event
4. Estimate Secondary Event Frequency
5. Insert into QRA Model

Step 1: Identify Primary Event

- Events with the potential to impact equipment failure and cause a hazardous scenario

- Primary Events are identified by reviewing the consequences of events within the QRA
  - Specification of impact criteria associated with failure

- Possible impact criteria:
  - Heat flux from a fire: 23 kW/m2
  - Overpressure from an explosion: 21 kPa
  - Fragment from a vessel burst: Impact Kinetic Energy

Step 2: Identify Secondary Event

- Identify equipment potentially involved in Secondary Event
  - Assess impact zone of Primary Events

- Focus on equipment with the potential for large impact zones
  - Larger Flammable Inventory
  - Highly Toxic Substance
  - Pressurised Storage
  - Potential for BLEVE

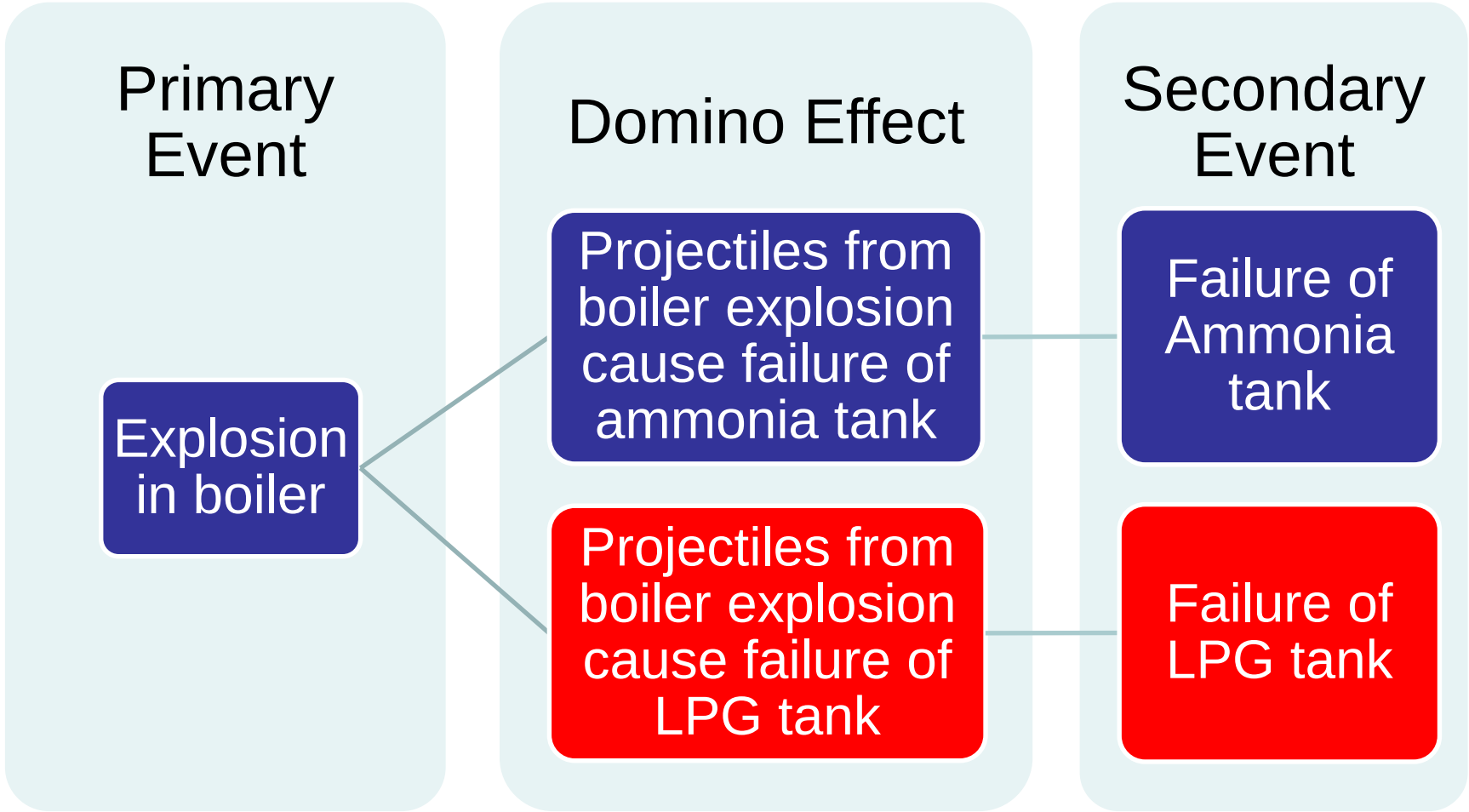
Step 3: Characterise Secondary Event

- Secondary Event characterised by:
  - Size of the failure, process conditions, inventory
- Magnitude of event depends on:
  - Nature of the Primary Event
  - Type / strength of equipment involved
- Process conditions and inventory
  - State of the process at time of the Primary Event
- Consequence modelling used to determine the extent of the impact zone

Step 4: Secondary Event Frequency

- Secondary Event frequency depends on:
  - Frequency of the Primary Event
  - Conditional probabilities leading to Secondary Event
- Primary Event frequency drawn from QRA
- Conditional probabilities to estimate the likelihood that the Secondary Event occurs:
  - Potential that the Primary Event impacts vessel
  - Potential that the impact results in a failure
- Insert Secondary Event data into QRA Model (Step 5)

An Industrial Example: Steps 1 and 2



An Industrial Example
Step 3: Characterise Secondary Event

- Characteristics evaluated from the nature of the projectile impact

- Size of failure from Impact Kinetic Energy
  - Fragment **mass**, **shape** and **initial velocity**

- Baker Method for fragment velocity and range
  - Vessel dimensions and material
  - Mass and size of fragment
  - Blast energy

An Industrial Example:
Step 3: Characterise Secondary Event

- Characteristics of impacting fragment:
  - Shape: ~spherical (vessel end)
  - Mass: 3,000 kg
  - Energy: 90 MJ
  - Initial Velocity: 250 m/s
  - Range: 640 m (Target: ~100 m)
- Estimated hole size to represent size of failure
  - Thin steel wall impacted by heavy fragment
  - Large to very large failure
- Normal process conditions at impacted vessel
  - Release of a significant amount of toxic material

An Industrial Example: Step 4: Secondary Event Frequency

- Secondary Event frequency calculated from:
  - Frequency of boiler explosion (from QRA)
  - Fragment Impact Probability (i.e. direction, range)
  - Damage Likelihood Factor
- Impact probability – Gubinelli model (2004)
  - target > 50 m away - probability of 0.01
  - target < 50 m away - probability of 0.1
- Damage Likelihood Factor - Department of Defense Explosives Safety Board (2009)
  - Kinetic energy vessel can withstand on impact
  - Material of construction

An Industrial Example: Step 5: Insert into QRA Model

- Secondary Event details entered into model
- Consequence:
  - Normal process conditions & inventory
  - Very large hole size (~150 mm)
- Frequency:
  - Frequency of boiler explosion: 1×10^{-3} /yr
  - Impact Probability (> 50 m away): 1×10^{-2}
  - Damage Likelihood (thin steel): 1
  - Secondary Event Frequency: 1×10^{-5} /yr
- Evaluate risk to determine influence on profile

Overview: Domino Effects & QRA

- Secondary Events can have significant consequence impacts
- Potentially influences the risk profile
  - Risk tolerability at offsite and onsite areas
- Methodology for inclusion in QRA model
  - Criteria for identifying Primary / Secondary Events
  - Estimating consequence and frequency of Secondary Events