HSB *Professional Loss Control*

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2001 SPRING NATIONAL MEETING
PROCESS PLANT SAFETY SYMPOSIUM

Cost-Benefit Analysis of Fire Risk Reduction Alternatives

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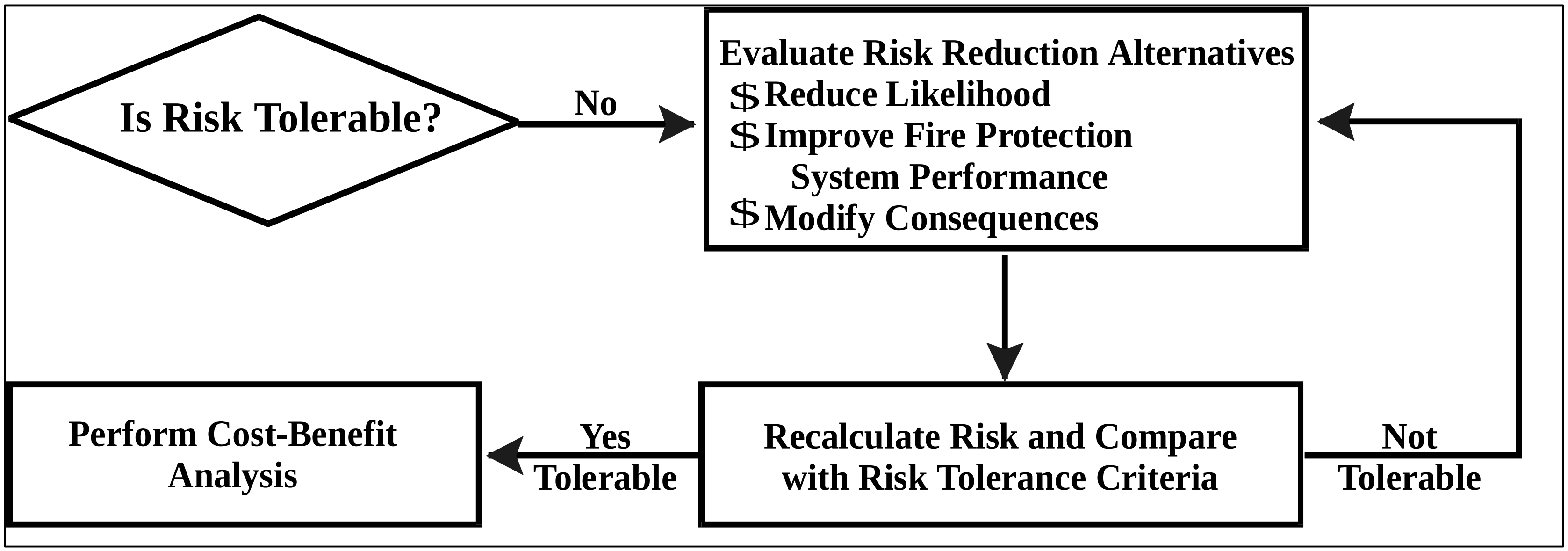
- The term “fire risk reduction” is defined as the application of technological and administrative measures to reduce fire or explosion risk to a tolerable level. Reduced fire risk means fewer fire losses, less production downtime, better employee morale, better public relations, and greater profit potential. However it is not obtained without cost.

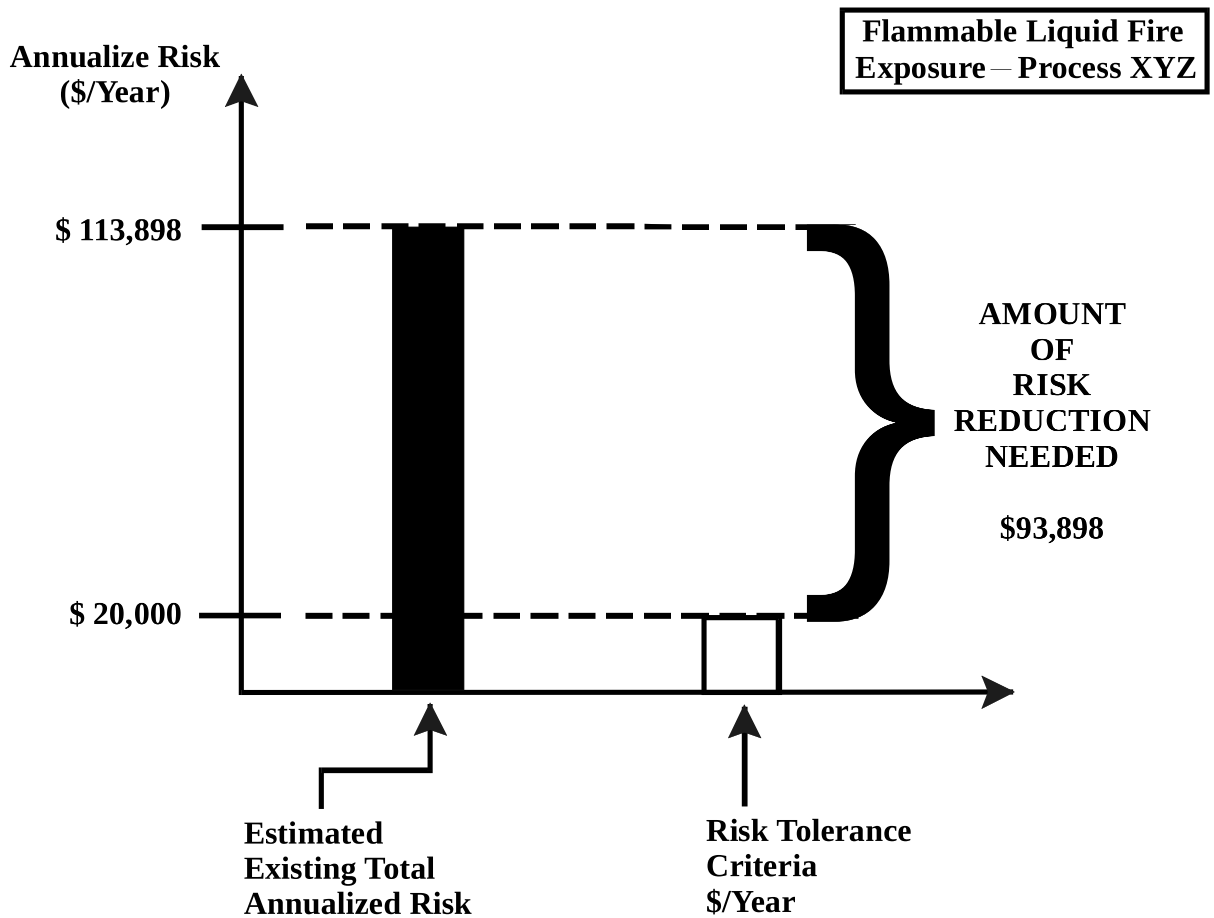
Risk-Informed, Performance Based Fire Protection Steps

APPRAISAL →	ANALYSIS →	PERFORMANCE →	ASSESSMENT
1 Program Objectives	3 Loss Scenario Development	6 Fire Protection Systems Performance Success Probability	7 Risk Estimation & Comparison With Risk Tolerance
2 Risk Tolerance Criteria	4 Initiating Event Likelihood		8 Cost/Benefit Analysis of Risk Reduction Alternatives
	5 Exposure Profile Modeling		

Risk Reduction Evaluation Process



Example Depiction of Existing Annualized Risk Versus Risk Tolerance Criteria



To clearly communicate the risk, values are converted to Aggregate Equivalent Monetary Value. To do this, all the consequence levels must be related to an equivalent monetary value:

- Building Damage Level
- Equipment Damage Level
- Stock Damage Level
- Production Downtime Level
- Life Safety Exposure Level
- 'Other' Exposure Levels

Equivalent Monetary ($)
Value at Risk

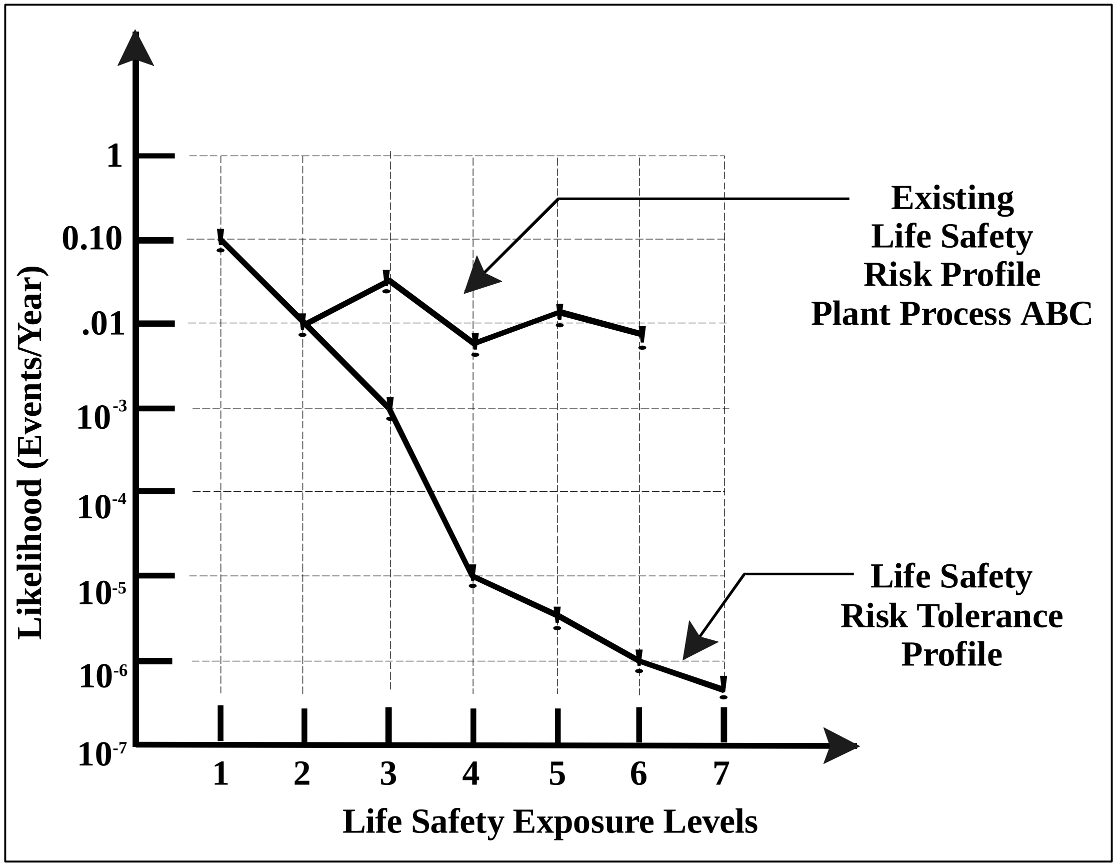
Example – Life Safety Exposure Levels

LIFE SAFETY EXPOSURE LEVELS			LS, EQUIVALENT MONETARY VALUE, EMV
Injuries	1	First Aid – One Person (primarily smoke related)	* $1,000
	2	Moderate Burn Injury – One person (may require hospital treatment)	$10,000
	3	Severe Burn Injuries – Hospital Treatment 1-3 people	$100,000 - $500,000
Fatalities	4	Employee/On-Site Contractor – Single Fatality	$1,000,000
	5	On-Site – 1-3 Fatalities	$5,000,000
	6	Off-Site Fatality	$20,000,000

EMV = Equivalent Monetary Value

*** NOTE:** The $ values in this column are for example purposes only. LS = Life Safety

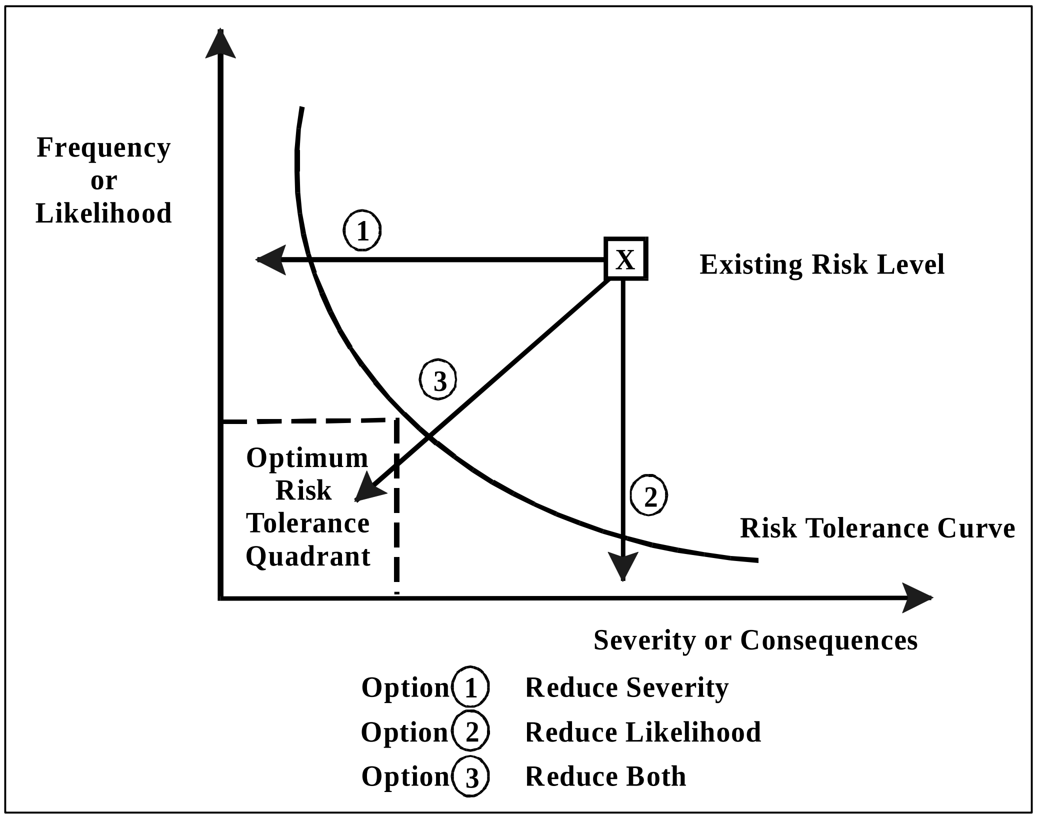
Example — Existing Life Safety Risk Versus Life Safety Risk Tolerance



Example Format For The Initial Listing and Screening of Risk Reduction Alternatives

EVENTS	EVENT FACTORS	LIST OF RISK REDUCTION ALTERNATIVES	FEASIBLE RISK REDUCTION ITEMS
Initiating Fire Events	Likelihood Modification: • Modify abnormal failure situation which provide fuel available for combustion (i.e., equipment failure, human error, external failures) • Reduce oxygen availability • Minimize ignition potential	[IDENTIFICATION]	[SCREENING]
Fire Protection Systems (FPS)	Improvements to Fire Protection Systems: • Detection Systems • Emergency Control Systems • Automatic Suppression Systems • Propagation Limiting Measures (i.e., Fire Barriers) • Manual Loss Control Intervention.		
Consequences, Exposure at the Target	Consequence Modification: • Modify source fire heat release rate • Modify life safety exposure levels • Modify production downtime exposure levels		

Risk Reduction Approaches



Fire Protection System Performance Improvement

Fire protection systems of primary interest in fire risk-based evaluations include:

- Detection Systems
- Emergency Control Systems
- Automatic Suppression Systems
- Propagation Limiting Measures (i.e., Fire Barriers)
- Manual Loss Control Intervention

Example of Primary FPS Success Measures

FPS Performance Indicators →

FAULTS	SUCCESS MEASURES
System Not Responsive to a Specific Scenario - time delay in system activation - application problems; - inappropriate design basis - system capacity, duration insufficient - system does not respond in time prior to critical conditions	Response Effectiveness [RE]
System Not On-Line at the time of Emergency - down for inspection, maintenance, testing - down because of false trips or unscheduled repairs - down because of Common Cause (i.e., freezing).	On-Line Availability [OLA]
System Did Not Function Properly at the Time of Emergency (i.e., failure on demand) - Subsystem 'Hidden' Failure Occurs - Design & Operational Common Cause Failure (mechanical damage, earthquake, etc.)	Operational Reliability [OPR]

Primary Performance Measure	RE Response Effectiveness	OLA On-Line Availability	OPR Operational Reliability

FPS Performance Success Probability (P_S)

$$P_S = P_{RE} \times P_{OLA} \times P_{OPR}$$

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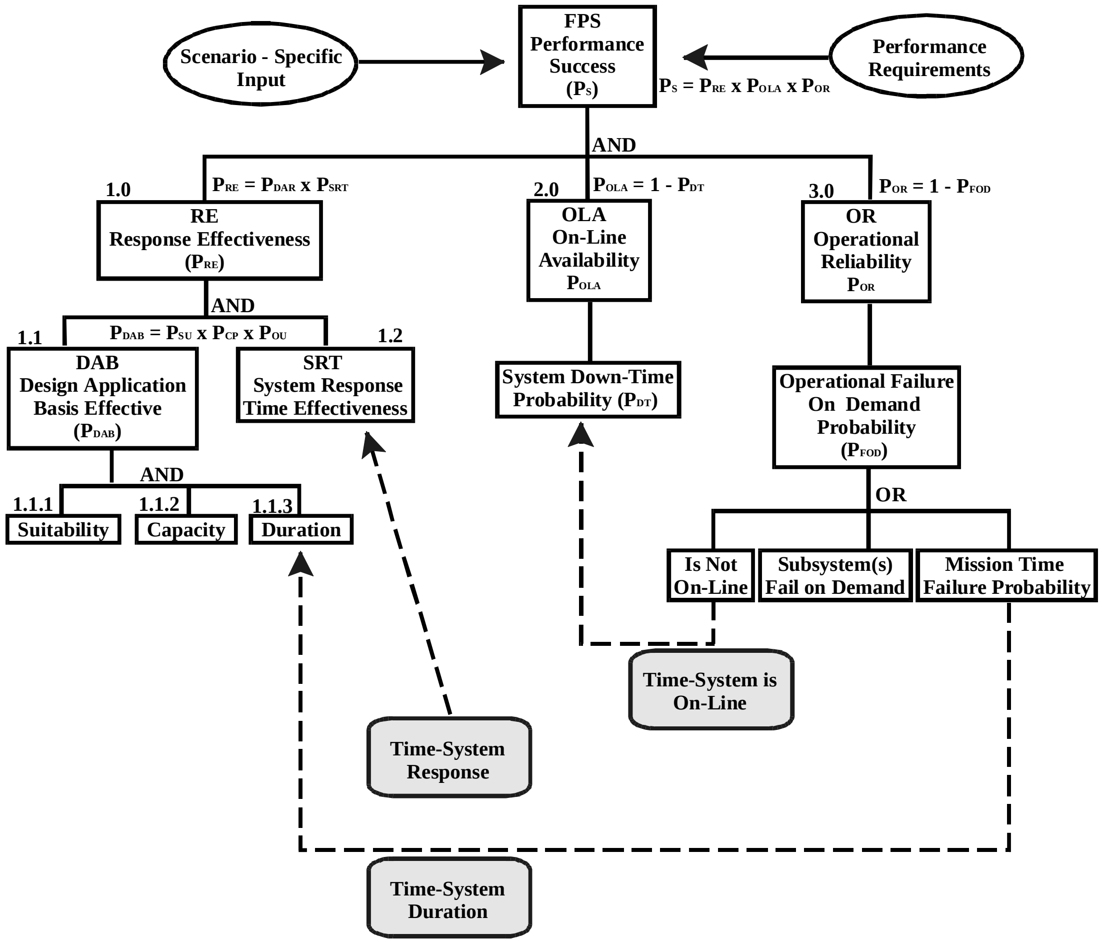
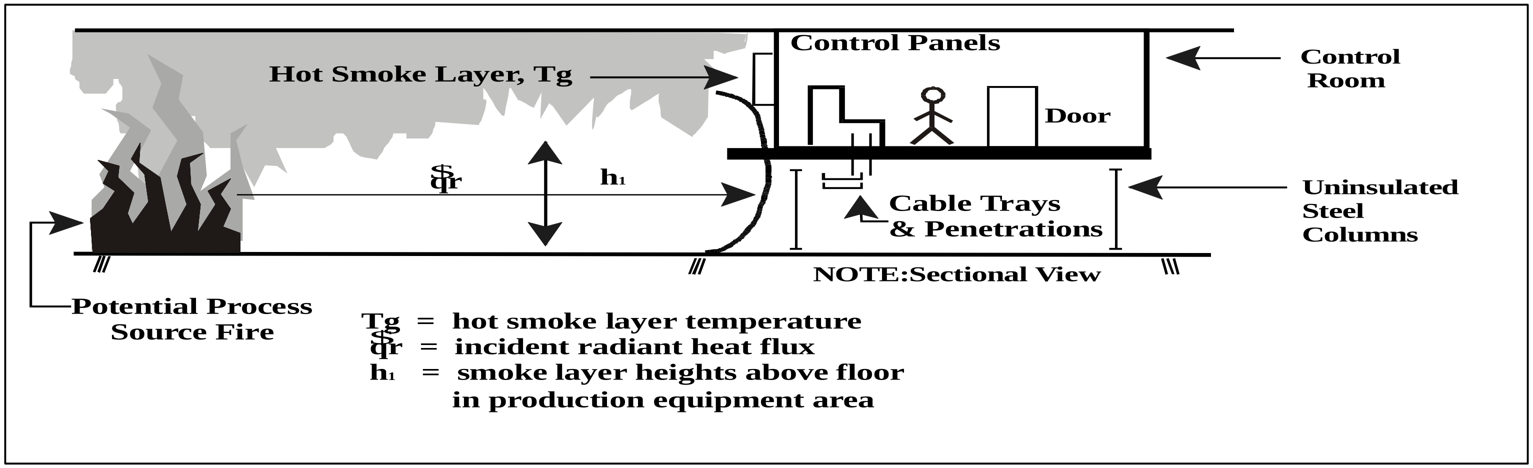
FPS Performance Success Tree Framework — Highlighting Time-Related Performance Factors



Fire Exposure to Control Room Target



Cost Considerations Associated With Risk Reduction Alternatives

INITIAL COSTS, I_c ANNUAL COSTS, A_c	REMARKS
Design Costs I_c	Conceptual design and detailed specifications
Equipment Costs I_c	Individual components or turn-key system costs
Installation Costs I_c	Consider plant or process shutdown time to install equipment
Permit / License I_c	In some cases besides a building code permit, an environmental permit may be required
Pre-Startup Acceptance Testing I_c	Very important consideration to prove reliability prior to operation
Procedures / Training I_c	Procedures and training functions may have to be conducted prior to equipment/system operation
Operating Costs A_c	Utilities usage (electrical, air)
Inspection and Testing A_c	In-house or contracted
Maintenance A_c	In-house or contracted
Replacement Costs A_c	Useful life of components, system, extinguishing agent

Calculation Approach

The benefit/cost ratio (B/C) can be calculated as follows [2]:

$$B/C = \frac{A\ (P/A,\ i,\ n)}{Ic}$$

Where A = ARB - Ac

ARB = Annualized Risk Benefit
Ac = Annualized Cost
Ic = Initial Cost
P/A = Present Worth Factor
i = Interest Rate
n = Time Frame, Years

In some cases there will be more than one alternative strategy where the B/C ratio is greater than 1.0. When this occurs then the next decision making step usually fits into one of the following three approaches:

- **Select the alternative strategy with the highest B/C ratio**
- **If the B/C ratios are close, then conduct additional Engineering Economic analysis**
- **Evaluate the decision maker’s preferences**

Decision Maker's Preferences

The risk reduction strategy selection team generally includes members of the team who conducted the risk-based study along with additional management decision makers from Risk Management, Engineering, and Operations.

Let's assume that the following decision making factors are developed by the team:

- Cost Effectiveness (defined by B/C ratios)
- Ease of Installation / Maintenance
- Independent of Manual Fire Extinguishment (i.e., minimal reliance on manual intervention and exposure to fire brigade members)

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Recent Applications of Risk-Informed, Performance-Based Fire Protection

- Nuclear Fuels Reprocessing
- Oil Terminals
- Fossil Fuel Power Plant Upgrades
- Specialty Chemical Manufacturers
- LP Gas Bulk Storage Facilities
- Hazardous Waste Processing and Storage
- Product Distribution Warehouses