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Does a Safety-Class Active Ventilation System Significantly Enhance Safety?

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Unclassified – Non Sensitive

Background

- Estimation of change in risk has been an accepted addition to traditional nuclear safety analysis.
  - Reactor Safety Study (WASH 1400), NUREG-1150, etc.
- Companion to existing regulatory framework
  - Change in risk can be one input into informed decision making
  - Can serve as a basis for risk/cost-benefit studies

Examples

- Focus of paper, an evaluation of safety strategies
  - Examined the relative change in facility risk with an emphasis on the impact of safety-class active ventilation
- Examples
  - Hypothetical New Facility
  - Existing Facility
  - Generic Observations
- Risk Issues

Risk Definition

- Traditionally defined as an expression of possible loss that considers
  - Likelihood an event will occur
  - Consequences of that event
- Defined here as the product of frequency (expected annual occurrence) times consequence, where consequence is either
  - Qualitative description of an accident scenario
  - Population dose expressed in latent cancer fatalities
  - Dose to the MEOI (surrogate given that it is an imaginary dose)
- Design-basis accidents (DBAs) in facilities are examined
  - Risk evaluated relatively between accidents
  - Total DBA risk estimates total facility risk

Definitions

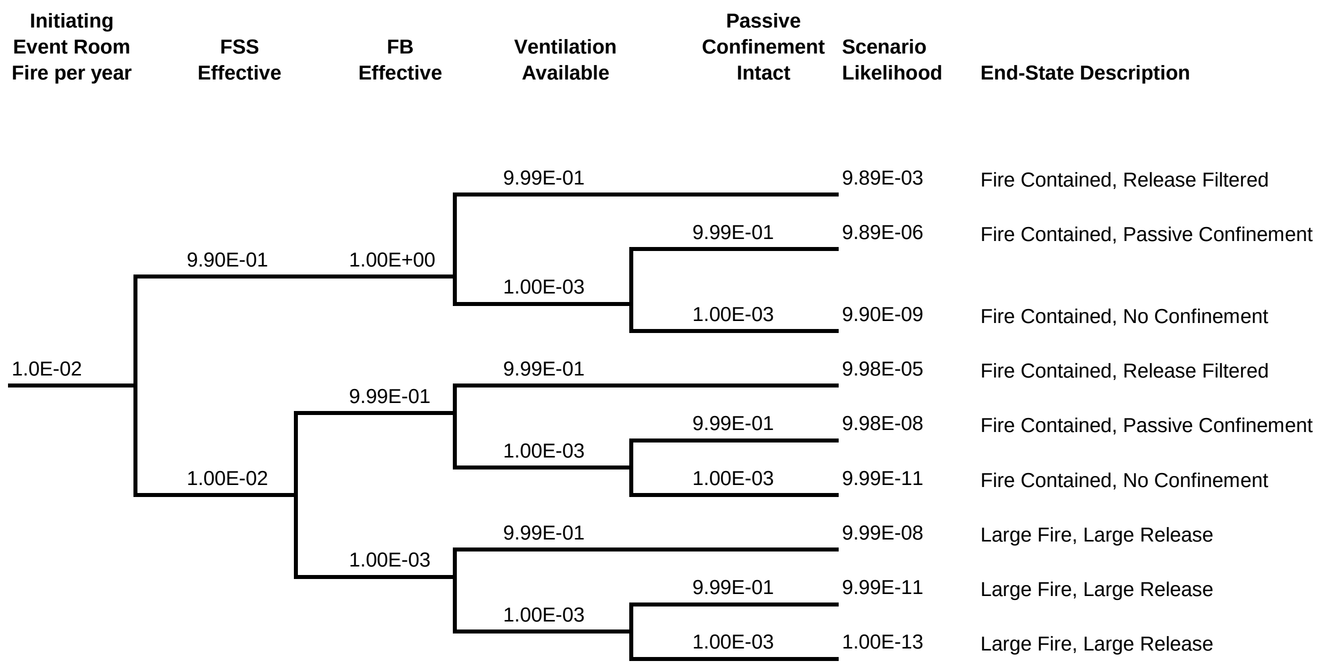
- Active Ventilation System
  - The total facilities required to supply air to, circulate air within, and remove air from a building/facility space by mechanical means.
- A Safety Class active ventilation system differs from Safety Significant only in single-point failure criterion
  - Failure of one component (equipment or control) shall not affect continuous operation
  - SC active ventilation has enhanced reliability from increased redundancy and the elimination of single-point failures

Hypothetical New Facility

- Risk evaluation was conducted that looked at three nuclear safety strategies for a potential fire in the facility:
  - A passive confinement strategy with a safety-class confinement;
  - A safety-class active ventilation strategy (HVAC and facility boundary); and
  - A passive confinement strategy, with safety-class fire barriers and fire suppression system. Active ventilation is left as safety-significant.

Base Tree for Fire (Passive Confinement)

CASE 1 - Safety Class Passive Confinement Only



Sum of Large Release End States
1.00E-07
Sum of No Confinement End States
1.00E-08
Sum of Fire Contained, Passive
9.99E-06
Sum of Fire Contained, Release filtered
9.89E-03

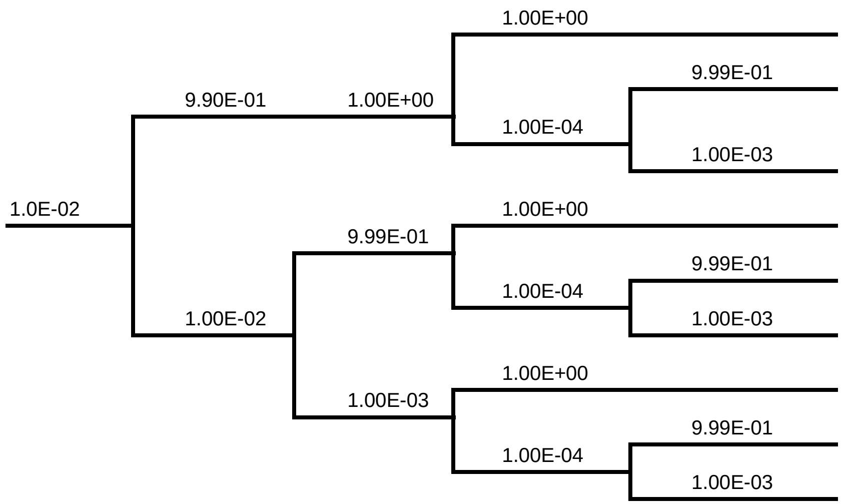
Prob Failure from Ventilation System Guidance (T6-2A a

		Pf
Fire Suppresion System	SS	1.E-02
Fire Barriers	SS	1.E-03
Active Ventilation System	SS	1.E-03
Passive Confinement	SC	1.E-03

Alternative Tree w/ Ventilation as SC

CASE 2 - Safety Class Active Ventilation and Safety Class Passive Confinement

Initiating Event Room Fire per year | **FSS Effective** | **FB Effective** | **Ventilation Available** | **Passive Confinement Intact**



Scenario Likelihood	End-State Description
9.90E-03	Fire Contained, Release Filtered
9.89E-07	Fire Contained, Passive Confinement
9.90E-10	Fire Contained, No Confinement
9.99E-05	Fire Contained, Release Filtered
9.98E-09	Fire Contained, Passive Confinement
9.99E-12	Fire Contained, No Confinement
1.00E-07	Large Fire, Large Release
9.99E-12	Large Fire, Large Release
1.00E-14	Large Fire, Large Release

Sum of Large Release End States
1.00E-07
Sum of No Confinement End States
1.00E-09
Sum of Fire Contained, Passive
9.99E-07
Sum of Fire Contained, Release filtered
9.90E-03

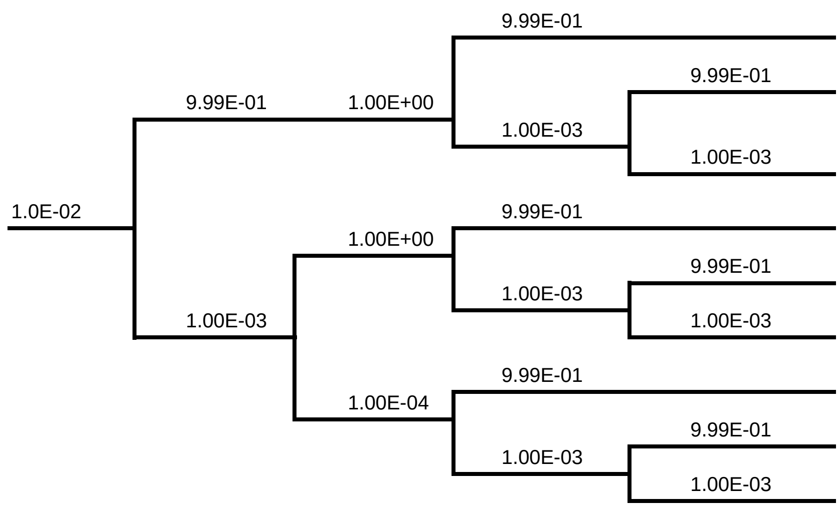
Prob Failure from Ventilation System Guidance (T6-2A a

		Pf
Fire Suppresion System	SS	1.E-02
Fire Barriers	SS	1.E-03
Active Ventilation System	SC	1.E-04
Passive Confinement	SC	1.E-03

Alternative Tree – Fire Barriers/Suppression as SC

CASE 3 - Safety Class Fire Suppression, Fire Barriers and Passive Confinement

Initiating Event Room Fire per year | **FSS Effective** | **FB Effective** | **Ventilation Available** | **Passive Confinement Intact** | **Scenario Likelihood** | **End-State Description**



Scenario Likelihood	End-State Description
9.98E-03	Fire Contained, Release Filtered
9.98E-06	Fire Contained, Passive Confinement
9.99E-09	Fire Contained, No Confinement
9.99E-06	Fire Contained, Release Filtered
9.99E-09	Fire Contained, Passive Confinement
1.00E-11	Fire Contained, No Confinement
9.99E-10	Large Fire, Large Release
9.99E-13	Large Fire, Large Release
1.00E-15	Large Fire, Large Release

Sum of Large Release End States
1.00E-09
Sum of No Confinement End States
1.00E-08
Sum of Fire Contained, Passive
9.99E-06
Sum of Fire Contained, Release filtered
9.98E-03

Prob Failure from Ventilation System Guidance (T6-2A a

		Pf
Fire Suppresion System	SC	1.E-03
Fire Barriers	SC	1.E-04
Active Ventilation System	SS	1.E-03
Passive Confinement	SC	1.E-03

Observations on Example 1

- The added availability of safety-class active ventilation lowers the frequency of No Confinement by an order of magnitude.
  - Should be noted that the frequency was already beyond extremely unlikely.
  - The availability of active ventilation is still very high with a SS ventilation system versus a SC ventilation system.
- The Large Fire, Large Release end state is of more concern.
  - This end-state occurs when a fire spreads to the entire facility, and thus could provide a larger consequence by involving more material-at-risk, with no ability to mitigate the release
- Safety-class ventilation does not change its frequency, but it can be lowered dramatically (by possibly two orders of magnitude) by improving the reliability of the fire barriers and fire suppression system.

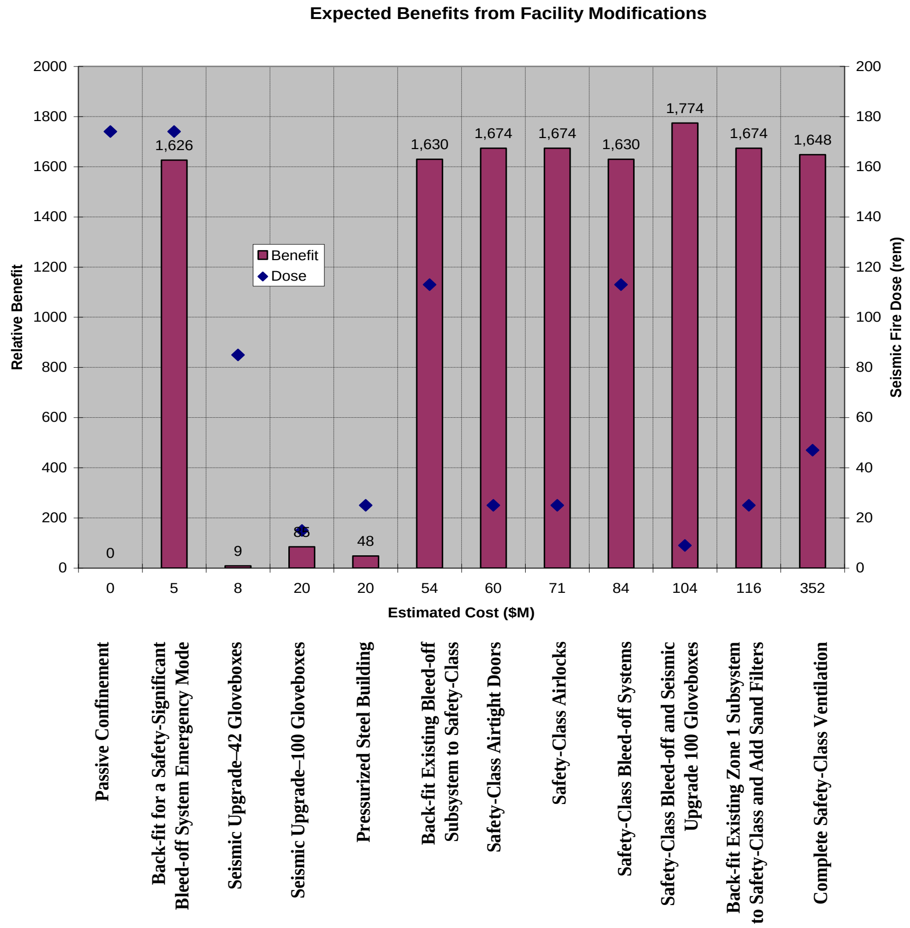
Conclusion from Example 1

- A conclusion that can be drawn from this simple example is that more risk reduction (i.e., the lowering of frequency for end-states with higher qualitative consequences) can be obtained by looking at all possible combinations of safety systems.

Existing Facility

- An operating plutonium processing facility at LANL was evaluated with baseline being the existing passive confinement
- Eleven unique modifications were evaluated, including
  - Seismic upgrades of gloveboxes
  - SC airlocks and airtight doors
  - Ventilation system bleed-off system upgrades
  - SC active ventilation system
- Offsite doses were considered for DBAs, combined for each modification, and scaled to the baseline dose (ratio)
- Several modifications had similar benefits, but had largely different costs associated with the modifications

Results for Example 2



Observations from Example 2

- Many of the modifications, including the SC ventilation, do not reduce the dose as much as some less costly modifications
  - Upgrading the seismic capacity of gloveboxes (i.e. prevent the release over mitigating the release)
- SC ventilation system has essentially the same benefit as seven other modifications
  - All other modifications have lower costs.
- A conclusion from this risk/cost-benefit analysis:
  - SC active ventilation may not produce the optimum solution in terms of risk /cost-benefit tradeoff.

Generic Observations

- Fire and Seismic dominate risk to typical DOE nuclear facility
  - Fire event:
    - Main advantage of SC active ventilation system is that it derives increased reliability (or availability) from the elimination of single-point failures and increased redundancy.
    - Very rarely is the fire in a location to impact the availability of the system and also impact MAR
    - Only risk reduction is that obtained from taking an already very reliable continuously operated system and improving its availability.
    - Said another way, the risk that is removed is based on the random failure of the ventilation system coincident with the fire occurring.
    - Other safety systems such as fire suppression systems and fire barriers can possibly lower risk significantly

More General Observations

- Seismic Events:
  - Ability of a safety-class active ventilation system appears to offer more risk reduction than for fire.
  - Must consider total risk and that we only examine up through a design-basis event. In actuality, much of the facility risk lies in the beyond-design-basis event. Therefore, any upgrade may have limited ability to impact total risk.
  - Making ventilation better able to handle seismic events clearly can impact this set of events by reducing offsite doses. However, it still can be outperformed in terms of risk reduction by safety controls that eliminate the release of material by preventing a spill during a seismic event (i.e. no consequences.)
  - Items such as shelving and containers (which prevent releases and not just mitigate them) typically perform better generically in this area than an upgraded ventilation system.

Final Point

- Hard to justify costly upgrades if we use a latent cancer fatality that has been converted to dollars
  - Use a value of $5 Million for an LCF, Max possible benefit is around $50 Million if we use the limit in the SEN-35 safety goal
  - Typical facility is orders of magnitude below this number
  - Benefit would be in the 10’s thousands of dollars
- Nuclear power plant is over 1000’s times greater in terms of maximum consequence
  - Cost of a new facility is in the same billion dollar range
- Any upgrade should be evaluated for risk/cost-benefit value