Summary tabletop pilot results from Utility 2

Incipient Detection Configuration:

The configuration analyzed is for an incipient detection system installed in a low power (less than 480V) panel with limited ventilation. The panel is installed in a fire zone with an ionization detection actuated Halon automatic suppression system. The panel has targets within 1' of the top of the panel including multiple trays which will result in a rapid increase in fire size that will quickly lead to a hot gas layer impact of all cables in the fire zone. A hot gas layer configuration will occur if the incipient detection system fails and the Halon system fails.

Calculation of Non-Suppression Probabilities

Evaluation Using FAQ 08-0046:

The Non-Suppression Probability (NSP) for the hot gas layer is calculated as the product of the Halon NSP (0.05) and the FAQ 08-0046 credit for the incipient detection system (0.02). These two values when multiplied together give a NSP value of 1E-3 for fires that lead to a hot gas layer fire. For all other scenarios where a hot gas layer does not form a NSP value of 0.999 is used.

Evaluation Using NUREG-2180 spreadsheet:

Evaluation of this configuration using the NUREG-2180 spreadsheet results in the following, based on the inputs specified below:

Table 1 – Inputs to NUREG-2180 Excel Spreadsheet

Parameter	Value Used	Source/Notes
Detection System Unavailability/Unreliability Probability (β)	ASD Very Early Warning (3.60E-03)	Detection type specified in S table of LAR.
Fraction of Fires that DO NOT have an Incipient Stage (α)	Low Voltage Control Cabinet (2.80E-01)	Cabinets credited in the Fire PRA
System In-Effectiveness (τ)	Natural or Forced Ventilation up to 100 Cabinet ACH (5.30E-01)	Chosen system per the design change package.
System Type	LS1	
Human Error Probability for MCR Operator Response (μ)	Default MCR HEP (1.00E-04)	Default value
Human Error Probability for 1st Level Field Response (ξ)	Default Field Operator HEP (4.58E-04)	Default Value
Electrical non-suppression rate parameter (λ-Electrical)	0.098	Default Value
MCR non-suppression rate parameter (λ-MCR)	0.324	Default Value

Table 1 – Inputs to NUREG-2180 Excel Spreadsheet

Parameter	Value Used	Source/Notes
Time to Target Damage (minutes)	4.057	See Attachment #1
Redundant Automatic Fire Detection	[YES] Other conventional spot-type detector system (5.00E-02)	Analysis Configuration
Time to Detection for Automatic Fire Detection Response (minuets)	1	Assumed value
Automatic Fire Suppression System	[YES] Halon System (5.0E-02)	Analysis Configuration
Automatic Fire Suppression System Dependency	Yes	Analysis Configuration
Manual Fixed Suppression	No (1.0E+00)	No credit for manual suppression

Figure 1 – NUREG-2180 Spreadsheet Screen Shot

Using the input parameters from Table 1 the calculated NSP value is 3.1E-02.

Comparison of FAQ 08-0046 and NUREG-2180 results:

The NSP value calculated for NUREG-2180 compared to the values from FAQ 08-0046 are increased by a factor of 31.

Review of Parameters Impacting the NUREG-2180 calculation:

A parametric evaluation was performed for three cases. The base case described above, a case similar to the above case but without automatic suppression available and a case with only spot ion detection available (in-panel smoke detection). These cases were evaluated to provide a better understanding of the impact of the NUREG-2180 methodology on different panel configurations, beyond the base case.

Detection System Type

Varying the configuration with Automatic Halon Suppression results in a no more than a 10% variation in the NSP. The maximum NSP was for Ionization Spot (0.032) and the minimum value was for the Cloud Chamber device (0.028).

Variation in the NSP for no Automatic Halon Suppression varied more significantly. For the base case without Halon suppression the NSP value was 0.540, the highest value of the detection systems. The Cloud Chamber devices provided the lowest value (0.380) which is roughly 30% less than what was observed from the LS1 device. The other types LS2 and Ion Spot both produced values about 18% lower than what was observed for the LS1 device.

β – Detection System Reliability/Unavailability

Variation in the Beta value, detection system reliability/unavailability, was 6% or less for the nominal and no Auto Halon cases for a range of Beta values 1/10 to 10 times the nominal value.

For the Ion Spot detection, for a range of Beta values $1/10^{th}$ to 10 times the nominal value, resulted in an increase in the NSP of 61% for the increased Beta and a 5% decrease for the decreased Beta.

α – Fraction of Fires That Do Not Have an Incipient Stage

This parameter was expected to have a significant impact on the results but when it was varied between 1/10 to 1/100 of its nominal value it resulted in a decrease in the NSP of 9% maximum for the Halon and non-Halon LS1 case. For the Ion Spot detection case the same variation in this parameter resulted in a reduction of the NSP by 18 to 20% only.

The small impact that this parameter has on the NSP value requires further evaluation since it would be expected that the fraction of fires without an incipient stage would have a large impact on the NSP value since the incipient detection system would not be considered at all effective for that fraction of fires. The development of this factor, based on a review of fire data, may also require further investigation.

τ and ξ - System In-Effectiveness Related Human Error Probability for 1^{st} Level Field Response

These two parameters were varied between 1/10 and 1/100 of their nominal value and resulted in a 6% reduction in the NSP from the Nominal Auto Halon Suppression case. For the LS1, no Halon configuration the same range in these parameters resulted in a decrease of the NSP between 26 and 28%. For the Ion Spot detection configuration the same range in these parameters resulted in a decrease of the NSP between 5 and 7%.

μ – Human Error Probability for MCR Operator Response

This parameter was varied from 1/10 to 10 times its nominal value and resulted in no change in the NSP.

Time to Damage

Varying the time to damage from 1 minute to 40 minutes (with the nominal value based on a time of 4.057 minutes) resulted in the following range of NSPs:

- Nominal Auto Halon Suppression case - +75% to -84%
- LS1 no Halon case - +57% to -97%
- Ion Spot detection case - +82% to -87%

Overall sensitivity of NUREG-2180 calculated NSPs to the above parameters appear to be small with the exception of the damage time parameter. Further review of the sensitivity of the results to the key parameters appears to be necessary given the expectation that a higher dependency would be expected from some of the above parameters.

Comparison of NUREG-2180 calculated NSPs to NSP associated with manual suppression

The NUREG-2180 calculated NSP was converted to a damage time based on the NUREG-2169 electrical panel fire non-suppression curve (lambda of 0.098). The resulting time to damage was compared to the time to damage used in the NUREG-2180 calculation and a delta time to damage was calculated. This delta represents the effective duration of the incipient fire phase. This delta ranged from -10.8 minutes (calculated NSP was greater than manual suppression NSP by a value corresponding to a reduction in the time to damage from 40 minutes to 29.2 minutes; for the Ion Spot detection case) to +6.4 minutes. This range in damage time indicates that the incipient phase detection time applied was no larger than 6.4 minutes. Given the assumption that the max temperature applied was to be in the range of auto ignition temperatures for the cables tested, without any flaming during the tests, a review of the appropriate incipient phase duration may be warranted (this may require additional testing).

Impact of NUREG-2178 HRRs on results

The above evaluation was performed using NUREG-2178 HRR distributions. The impact was a reduction in the fraction of fires impacting the targets as follows:

Distance to target	Large Panel HRR distribution	Medium Panel HRR distribution
1’	10% reduction in SF	20% reduction in SF
2’	20% reduction in SF	40% reduction in SF

Since the baseline evaluation provided above is based on the 6850 peak HRR, an additional reduction factor can be applied based on application of the NUREG-2180 spreadsheet results on a bin by bin basis. Performing a convolution of the NUREG-2180 results over the HRR distribution bins results in a reduction in the effective NSP by approximately 30%. Use of the NUREG-2178 HRRs and application of a HRR distribution convolution approach would result in a reduction in the results discussed above by about a factor of 2. This still results in an increase in the NSP with respect to FAQ 08-0046 of about a factor of 15.