Safety Corner

How to calculate the probability of fire-induced damage or fatality?

It is common to see a facility or a system is declared damaged from fires by demonstrating $t_d < t_c$; where t_d = time to damage, t_c = time to control/suppress the fire before damage. This approach of yielding a "yes/safe" or "no/unsafe" answer is indeed a common mistake in QRA in representing risk by a safety/unsafe conclusion rather than a product of undesirable consequence and its likelihood.

In the last article, we have shown that the probability of fire-induced damage, or the fire non-suppression factor, f_{NS} = Probability [$F(t_d) < F(t_c)$], where $F(t_d)$ and $F(t_c)$ are probability distributions that represent t_d and t_c, respectively. While t_c are usually derived from engineering judgment or past fire drill/accident records with great uncertainties, t_d are assessed by sophisticated fire model with confidence. Therefore, it is reasonable to assume that the uncertainties in t_c overwhelm those in t_d. Thus, t_c would be represented by a random variable, *T(t),* with t_d being a scenario dependent variable. Applying calculus,

$f_{NS} = \Pr[t_d < T(t)] = \int_{t_d}^{\infty} T(t)dt$.

Typically, *T(t)* is modeled by an exponential function $T(t) = \lambda e^{-\lambda t}$ due to the behavior of fire suppression time data. Then, $f_{NS} = \int_{t_d}^{\infty} T(t)dt = \int_{t_d}^{\infty} \lambda e^{-\lambda t} dt = e^{-\lambda t_d}$. If we have a rather good size of data for suppression time (which shall include decision time, travel time, set up time fire fighting time, etc.), λ is the reciprocal of the mean value of the data, T_c, then $f_{NS} = e^{-t_d/T_c}$, which is a fraction smaller than 1 to reflect the probability of fire induced damage or failure to suppress fire before damage. The same token can be applied to evacuation analysis by replacing T_c and t_d with the corresponding value of RSET and ASET values.

This application of Bayesian probability theory to obtain $f_{NS} = \int_{t_d}^{\infty} T(t)dt$ is a reason why QRA was originally called Probabilistic Risk Assessment in advanced applications.

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