A NEW RISK ASSESSMENT METHOD FOR EVALUATING ALTERNATIVE FIRE SUPPRESSION AGENTS

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The development of new fire suppression systems has created a need for criteria that will facilitate the evaluation of these new systems in comparison to traditional systems. Fire suppression system evaluation criteria are developed in this paper from a risk analysis perspective that combines historic incident data with new fire test data and with considerations of the toxicity of the suppression agent, its decomposition products, and combustion products of the fire itself.

The various probabilistic measures of suppression system performance to be considered are: 1) expected times-to-fire-suppression, 2) probabilities of re-ignition, 3) the expected numbers of injuries and fatalities associated with their operation (including inadvertent operation); and 4) expected maximum fire size before the fire is suppressed or controlled. Each of these measures needs to account for the various fire scenarios and for personnel exposure scenarios applicable to the facility in question.

If we denote the time-to-fire-suppression as t_s, time from ignition to the actuation of the suppression system as t_{do} , and the time to suppression from initiation of system discharge as t', then

$$t_s = t_{d0} + t' \qquad (1)$$

All three variable in Eqn 1 are treated as random variables with probability distributions to be determined from historic and/or test data and analysis. For example, t_{do} can be determined from historic data in the case of manually actuated suppression systems, from calculations in the case of thermally actuated systems (for which numerous computer models are available), or from test data in the case of smoke and other nonthermal detectors. Values for t' are most readily obtained from fire tests using the different suppression systems accounting for the pertinent engineering design parameters such as agent concentration or density, ceiling height or enclosure volume, fire size and perhaps oxygen concentration at system actuation. Of course, some of these parameters are dependent on t_{d0}. Results can be compared in terms of the mean (expected) value; $E(t_s)$, i.e.

$$E(t_s) = E(t_{d0}) + E(t') \qquad (2)$$

which is valid whether or not t_{d0} and t' are independent.

The probability of re-ignition, p_{re-ig}, after the fire is temporarily suppressed is a particular concern in the case of special suppression systems such as gaseous agents and aqueous foams. It can be determined either by extensive fire testing for new suppression systems, or by historical loss data for existing suppression systems and fire scenarios. It, too, is often a function of t_{d0}, and the oxygen and agent concentrations.

The expected numbers of injuries and fatalities is perhaps the most difficult challenge in this approach. However, it is a challenge requiring pursuit for suppression systems that create a personnel hazard during discharge (e.g. carbon dioxide systems and the newly developed pyrogenic propellant suppression systems) or as a result of the agent decomposition products formed during chemical suppression (e.g. fluorinated gseous agents). The expected number of fatalitites, N_{fi}, occurring during either a discharge for a toxic agent or following a suppressed fire for an agent that forms toxic decomposition products, can be written as

$$N_{fi} = n_i \, p_f(D_i) \tag{3}$$

where n_i is the number of people being exposed to the toxic gas in scenario i; p is the probability of a fatality given the exposure dosage D_i, defined as

$$D_i = \int_{t_{d0}}^{t_{fi}} c_i dt \tag{4}$$

and c_i is the toxic gas concentration history in scenario i.

If f_i is the frequncy of incidents of type i per facility-year, and if calculations are performed for various scenarios, comparisons between alternative suppression systems can be made in the form of plots of f_i versus N_{fi}. A frequency versus fatality curve can, in principle, also be conducted for the baseline case of no suppression system. In the baseline case, the fatalities would be due either to carbon monoxide or lethal temperatures or heat fluxes generated in the fire. Correlations of p_f versus D for carbon monoxide, hydrogen fluoride, and other gases are available, for example, in reference 1, which describes the use of toxic gas and fire/explosion incident risk assessments in the chemical industry.

A progress report on the implementation of this methodology for the case of shipboard machinery space fires was presented recently [2], and an update will be presented in this paper. The alternative suppression agents being considered in this application are carbon dioxide (currently used in commercial ship engine rooms), Halon 1301, FM-200™, PFC-410™, FE-13™, and representative water mist systems.

1. Guidelines for Chemical Process Quantitative Risk Assessment, AIChE Center for Chemical Process Safety, 1989.

2. Zalosh, R., "Risk Analysis Evaluation of Alternative Fire Suppression Agents for Machinery Space Fires," Fire Risk and Hazard Assessment Symposium, National Fire Protection Research Foundation, San Francisco, June 26-28, 1996.

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