3rd Party API RBI Consequence Model Review

API RBI User Group Meeting
Houston Marriott Greenspoint

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The Equity Engineering Group, Inc.

3rd Party Consequence Review

- Gregory A. Holton – President, Holton Environmental Associates, Inc. (865) 458-2051
- Ph.D and M.S., Environmental Engineering, University of North Carolina; B.S., Applied Science and Engineering, United States Military Academy
- Has over 30 years of experience as an engineer in the U.S. Environmental Protection Agency, as a research scientist at Oak Ridge National Laboratory, and as a consultant
- Specializes in performing computer-based multimedia exposure analysis, health risk assessment, accident analysis, and methodology development
- Serves as an expert witness in cases involving accidental releases of toxic materials, including several refineries and fuel storage facilities
- Has developed a state-of-the-art heavy gas atmospheric dispersion model for analysis of accidental releases of dense gas, a model to assess blast damage from explosions, and a radiation model to assess fires

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- Has developed models and databases employed in the risk assessments endorsed by the *Superfund Exposure Assessment Manual*
- Has designed and implemented the Inhalation Exposure Methodology (IEM), the first computer system to predict total public inhalation exposure to pollutants for any U.S. location. Endorsed by the CMA, IEM was actively employed by the chemical industry to respond to emergency planning requirements of air toxics
- Has developed Monte Carlo fugitive emission estimation techniques for incineration systems, automated exposure analysis methods for computer systems, mathematical models for predicting air, soil, and water concentrations, and National Academy of Sciences peer-reviewed food chain models to predict concentrations based on environmental and release conditions
- Author of over 60 publications on risk assessment topics and has taught short courses on risk assessment for professional associations and the University of Alabama
- Has served as a reviewer for the *Journal of the Air and Waste Management Association*

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- GENERAL COMMENTS
  - Level 1 methodology is a useful screening methodology that requires some modification
    - Perform two-phase releases in Level 2 only
    - Redefine instantaneous release conditions and redo tables
    - Modify event trees to incorporate the success or failure of operator intervention to limit a release
    - Remodel consequence areas to eliminate blending (not defensible)
  - Level 2 methodology is a significant improvement over Level 1 for RBI assessments, and can be also employed during unit design (plant layout) and for other safety purposes
    - Modeling the actual fluid rather than using representative fluids is inherently more accurate
    - Methods for predicting flammable consequence outcomes are more robust
    - Flammable and explosive consequences are more complete

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- GENERAL COMMENTS (Con't)
  - The equations and data employed in Levels 1 and 2 are generally correct and appropriate
  - Data employed for event tree probabilities should be based on citable, historical research, not unspecified professional judgment or expert opinion
  - The hole-size methodology employed in Levels 1 and 2 is appropriate for RBI assessments (similar to CCPS)
  - The event tree approach employed in Levels 1 and 2 to quantify the consequences of various possible accident sequences is appropriate for RBI assessments
  - Financial consequences in Levels 1 and 2 should include the effect of chlorides on control equipment

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- LEVEL 1 COMMENTS
  - Level 1 should be applied to only potential vapor or liquid releases. If the accident sequence indicates that a two-phase release would be likely to occur, it should be treated only in Level 2 because of inherent inaccuracies that crop up when assumptions are made to model the release as anything other than a two-phase release
  - The instantaneous release methodology, which relies on a subjective mass amount (10,000 lb) and time (3 min), and should be modified as follows:
    - All vapor releases lasting less than one minute should be treated as an instantaneous release.
    - All vapor releases lasting more than one minute should be treated as a continuous release.
    - All liquid releases should be treated as a continuous release.
  - Consequence area factors presented in Tables 5.8, 5.9, and 5.11 could not be reproduced. Without more information on the models and data employed, the correctness of these factors cannot be evaluated

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- LEVEL 1 COMMENTS (Con't)
  - Instantaneous and continuous modeling results should not be blended. Instead, prior atmospheric dispersion modeling performed to produce factors in Tables 5.8, 5.9, and 5.11 should be redone to reflect recommended instantaneous versus continuous conditions.
  - The current approach of reducing the release amount based on operator detection and intervention needs modification. For large leaks, a safety function should be added to the event tree which accounts for the probability of success of an operator (or an automatic system) to detect and isolate the leak. If successful, the release mass reductions following an approach similar to the current A, B, and C approach (unit-specific factors which give more credit than the current values for A, B, and C may be more appropriate) can be applied. If not successful, the consequences of the large leak should be assessed.

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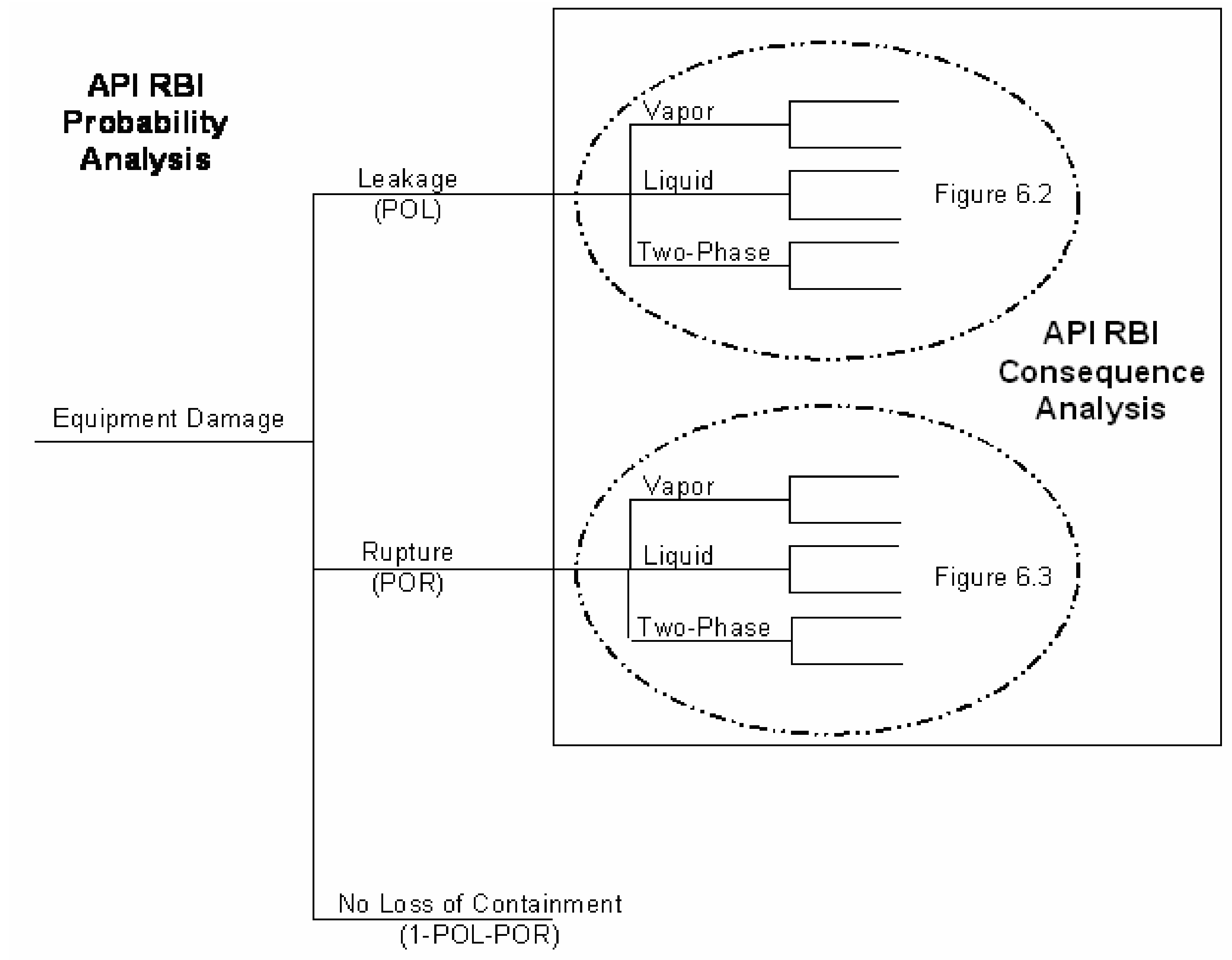

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- LEVEL 2 COMMENTS
  - The step-by-step calculation procedures documented for Level 1 should be similarly documented for Level 2
  - Additional text with one or two examples is needed to show how mixtures are treated
    - How do we model vapor and liquid releases, same composition or ideal mixture
    - Cloud coming off of pool, properties used
  - Using the actual composition of a fluid in Level 2 rather than a representative fluid in Level 1 significantly improves the defensibility of the RBI assessment.
  - Two-phase releases should be modeled as two-phase releases only. No assumptions treating the release as a liquid only should be made. Potential inaccuracies are shown by the following figure for a chlorine release which contrasts the difference only a few degrees makes on the atmospheric source strengths (predicted by ALOHA 5.2) for two-phase flow and pool evaporation.

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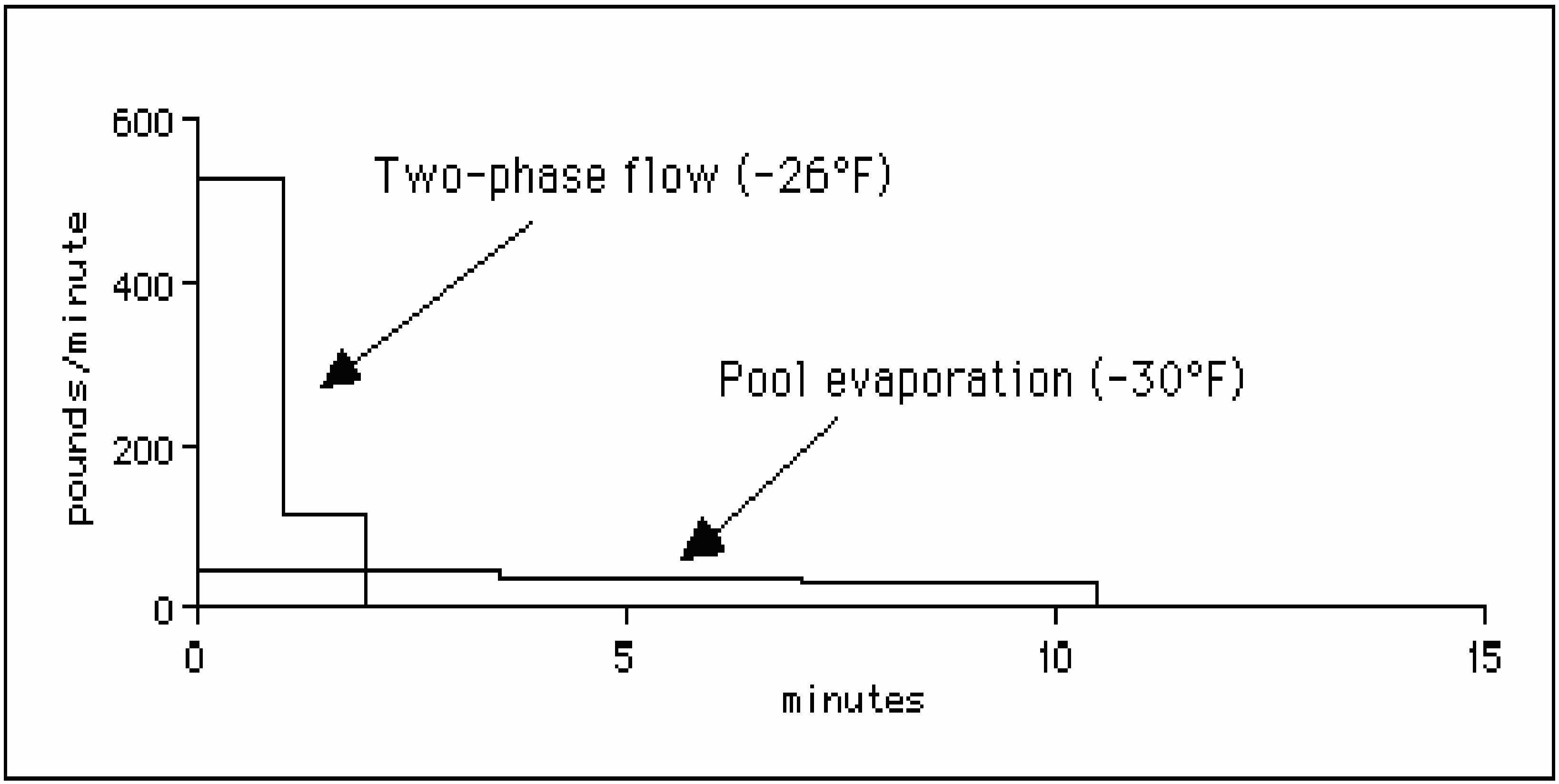
- Two-Phase Releases



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- LEVEL 2 COMMENTS (Con't)
  - Rather than recommending a dense gas model be employed for all modeling applications (see Section A.4.2), the density of each release should be evaluated first based on the release conditions and then an appropriate atmospheric dispersion model should be selected. Many commercially available models perform such density calculations based on the input source term and automatically account for density effects for applicable dense-gas releases
    - Hydrogen (incorrect but conservative)
    - Methane, Fuel Gas
    - Propane Vapor
  - The event tree, pool fire, jet fire, fireball, vapor cloud explosion, flash fire, toxic consequences, physical explosions, and BLEVEs methodologies are appropriate for Level 2 RBI assessments. Each methodology follows accepted practices and employs defensible equations to calculate impacted areas.

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- LEVEL 2 COMMENTS (Con't)
  - The values for the probability of ignition employed in the event trees are a significant improvement over Level 1 and are consistent with current research. For example, the Energy Institute in the United Kingdom has performed extensive research on ignition probabilities and has published a number of reports on this topic. One report, *Ignition Probability Review, Model Development and Look-up Correlations,* 1st ed., Jan 2006, ISBN 978 0 85293 454 8, relates ignition probability to the mass release rate. The following figure shows how curves from their research are similar to the work of Cox, Lee, and Ang cited in Section 6.8.1.2.

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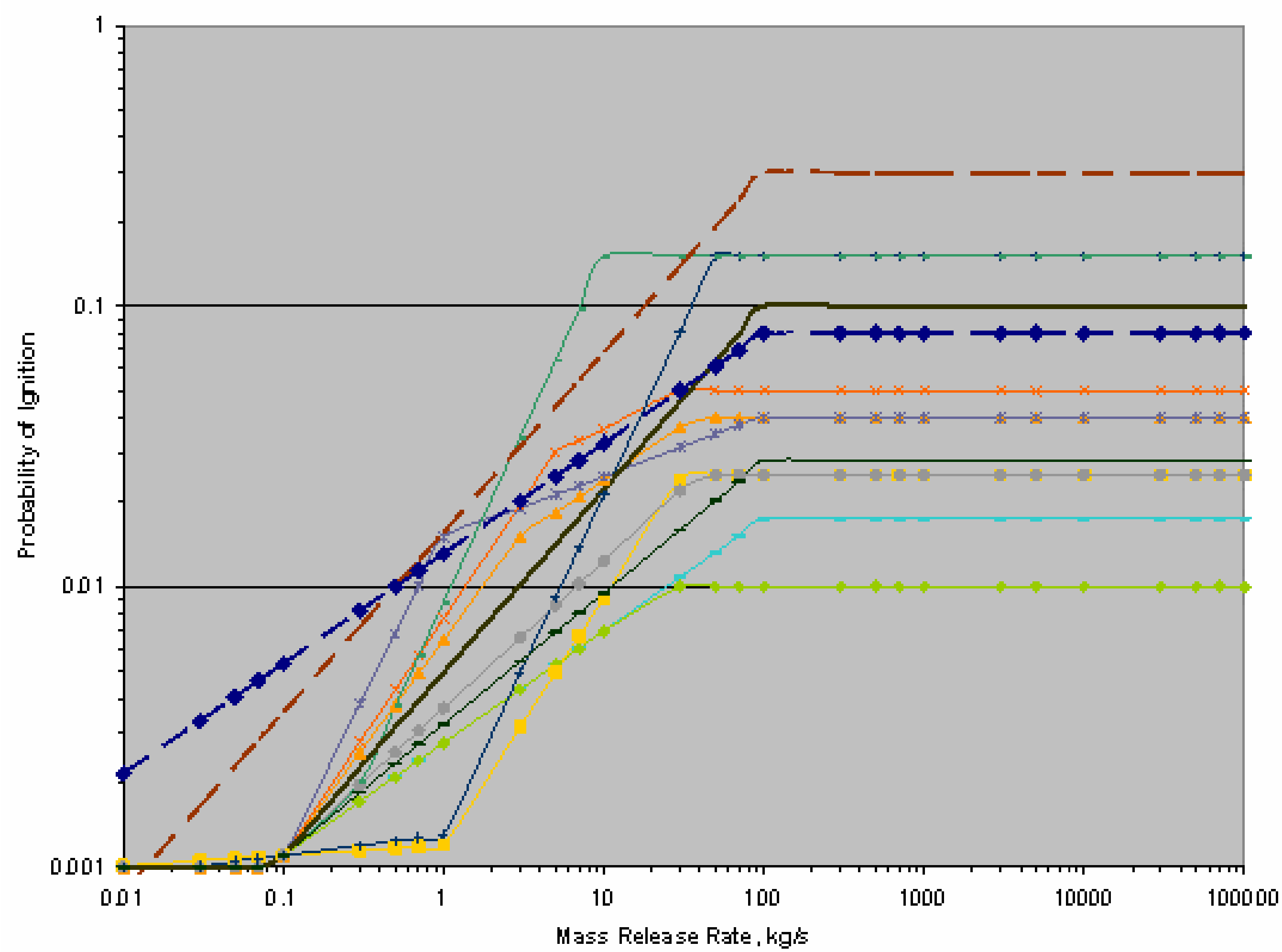
- Probabilities of Ignition



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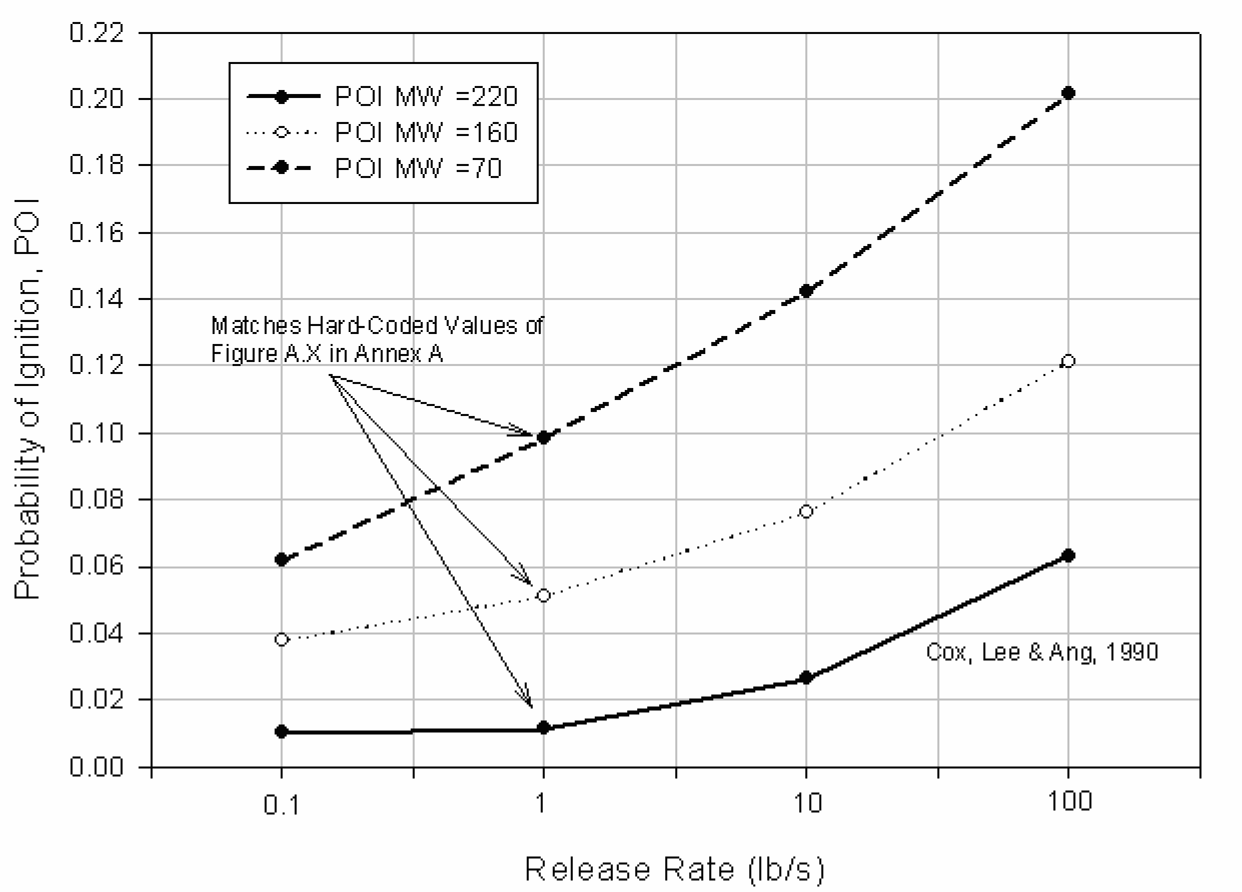
- LEVEL 2 COMMENTS (Con't)
  - Probabilities of ignition, MW curves versus flash point



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- LEVEL 2 COMMENTS (Con't)
  - While less accurate, to be consistent with the calculated consequences of physical explosions and BLEVEs, the TNT equivalency method should be used to compute blast overpressure for VCEs (needs to be cleared in Part 3)
  - The values for the probability of immediate and delayed ignition at ambient conditions presented in Table 6.1 seem arbitrary and need definitive reference to existing research rather than unspecified "expert opinion." For example, Appendix 12 of the ARAMIS D1C July, 2004 document includes a review of various immediate and delayed ignition probabilities found in the literature
  - Probability of flash fire versus VCE is arbitrary, needs more work, proposed use NFPA reactivity scale is good start

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