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US Department of Transportation
Pipeline and Hazardous Materials Safety Administration
East Building, 2nd Floor
1200 New Jersey Avenue SE
Washington DC 20590
USA

Attention: Patrick Landon

Dear Sir:

Re: Comments on Draft Valve Study: Report No. ORNL/TM-2012/411

The draft 'Valve Study' prepared by Oak Ridge National Laboratory (ORNL) includes a critical evaluation of the jet fire hazard zone model contained in the Gas Research Institute (GRI) report by Stephens,[1] which is the basis for the current potential impact radius (PIR) formula for natural gas pipelines. It goes on to develop an alternate hazard zone estimation approach, which involves a transient release rate model developed by ORNL and a thermal radiation model adapted from API Standard 521.

With regard to the release rate model developed by ORNL, it is first noted that the effective release rate in the GRI model is set equal to a fraction of the peak initial release rate. The fractional multiplier on the peak initial release rate is meant to acknowledge that the release rate will decay rapidly in the early stages of a rupture event because the driving pressure falls as gas escapes and, more importantly, because the gas required to sustain the release event must come from progressively further upstream and downstream of the breakpoint. These in-pipe gas streams are subject to significant frictional drag forces that throttle the discharge. ORNL has elected to replace the single effective sustained release rate in the GRI model with a model that is intended to calculate the release rate as a function of time. While this would seem to be a reasonable and desirable refinement, the outflow model developed by ORNL is analogous to a reservoir or storage tank discharge model in the sense that the entire volume of gas contained in the pipeline upstream and downstream of the break point is assumed to be in close proximity to the break point. No consideration is given to the effects on the discharge rate of the pressure gradient that develops and evolves in a long pipe over time or the effects of pipe wall drag forces. Such a model will significantly overestimate the release rate in the early stages of a release event. The ORNL report concedes this point, but its authors accept the approximation by noting that it produces conservative

[1] Stephens, M. 2001. A Model for Sizing High Consequence Areas Associated with Natural Gas Pipelines. Topical Report Prepared for Gas Research Institute, GRI Report No. GRI 00/0189, Contract No. 8174, C FER Report No. 99068, December.

results. It is suggested that the overestimation of outflow that will result from the use of the ORNL model goes well beyond conservatism to the point where it can only be considered inappropriate for the intended purpose.

In justifying a move away from the thermal radiation model described in the GRI report to the model provided in API 521, the two models are first compared and contrasted in the ORNL report. A careful read shows that the major difference between the two is that the radiation intensity model in the GRI report incorporates an ‘efficiency factor’, whereas the proposed alternative model incorporates an atmospheric ‘transmissivity factor’ instead. On page 39 of the ORNL report, the validity of the efficiency factor is called into question by stating that the basis for this factor is not explained in the GRI report. However, on page 37, the ORNL report states that the adjustment factors incorporated in the GRI model (including the efficiency factor) are discussed in a report prepared by Michael Baker Jr., Ltd.[2] The study by Baker, which was funded by the US Department of Transportation - Research and Special Programs Administration, was carried out with significant input from the GRI report author, and in Appendix A of this report Stephens provides a detailed discussion of the basis for the efficiency factor. The discussion provided therein states that the efficiency factor is intended to address a number of conservatisms inherent in using a simple point-source radiation model to characterize large-scale fires associated with gas pipeline ruptures. Specifically, the issues addressed by the inclusion of an efficiency factor include the following: 1) the effect of high speed jetting and fire size on the total radiant energy produced; 2) the effect of flame opacity on the amount of radiant energy released from the flame; 3) the effect of flame height on the effective radiation distance to ground level receptors; and 4) the effect of atmospheric absorption on the amount of radiant heat reaching ground level receptors. By replacing the efficiency factor in the GRI point-source fire radiation model with a transmissivity factor that accounts only for atmospheric absorption of radiation three of the four sources of model conservatism outlined above are effectively ignored in the ORNL model.

As discussed on page 40 of the ORNL report, for a representative value of the atmospheric transmissivity factor, the proposed alternate fire model will (for a given mass flow release rate) produce a radiant heat intensity estimate that is about 2.4 times greater than that given by the original GRI model. From this it can be shown that for a given release rate and heat intensity threshold, the proposed alternate model will yield a hazard zone radius that is about 1.5 times larger than that obtained from the GRI model. When the higher effective release rate of the proposed outflow model is factored in, it follows that for a given pipeline the hazard zone distance obtained from the proposed model will be much larger than that obtained from the GRI model. (While no outflow results are provided in the ORNL report, given the nature of the outflow model employed therein, it is conceivable that this model will predict hazard zone radii in the early stages of a fire that exceed those of the GRI model by more than a factor of two.)

[2] Michael Baker Jr., Inc. 2005. Potential Impact Radius Formulae for Flammable Gases Other Than Natural Gas Subject to 49 CFR 192. TTO Number 13, Integrity Management Program Delivery Order DTRS56-02-D-70036, Department of Transportation, Research and Special Programs Administration, Office of Pipeline Safety, June.

Given the above, the ORNL report can be interpreted to suggest that the jet fire hazard model described in the GRI report is non-conservative to a significant degree. However, while this is implied by the ORNL report, no direct evidence is provided to support the position. In this regard, it is noted that the implied claim of non-conservatism is not supported by the model verification exercise that was carried out as part of the original GRI study. The verification study compared the calculated PIR to the actual hazard zone extent for a number of real-world natural gas pipeline rupture incidents and showed that the actual hazard zone extent was for the most part conservatively overestimated by the PIR formula. The only justification for the adoption of a much more conservative jet fire hazard zone model would appear to be provided in Section 3.1.4.5 of the ORNL report where an effort is made to show that the proposed model, when used in conjunction with an alternate heat intensity threshold for property damage, better predicts the radial extent of property damage at the San Bruno, California pipeline rupture site.

Given the significance of the San Bruno incident and the concerns raised by the number of casualties and the extent of property damage, it is important that the pipeline industry and regulatory authorities re-examine the current basis for gas pipeline hazard zone determination and make appropriate adjustments if necessary. However, based on a review of the San Bruno incident information compiled and disseminated by the National Transportation Safety Board (NTSB), it is suggested that the final extent of the zone of severe property damage was significantly influenced by factors not explicitly addressed by either the GRI model or the proposed new model.

In particular, because fire containment and fire suppression during the early stages of the San Bruno incident were hampered by a lack of water pressure, given the density of development in the area, follow-on house fires would be expected to develop and spread, particularly downwind (i.e. north-east) of the initial burn zone. (Information contained in the NTSB Accident Docket clearly indicates that the start of fire fighting was significantly delayed because the water main supplying hydrants in the area was unable to deliver water at pressure, this being attributed to damage caused by the initial failure of the pipeline.)

The PIR formula was developed to delineate the zone of significant impact resulting directly from a natural gas pipeline rupture. It was not intended to account for follow-on effects that can be significant in unusual situations. If other factors are to be accounted for in determining the likely extent of the zone of significant impact in the event of gas pipeline rupture, it is suggested that adoption of a grossly conservative fire hazard model is not the preferred approach. This approach masks the significance of other issues and compromises the validity of other hazard distance assessments that depend on an accurate representation of jet fire radiation characteristics (e.g. the determination of safe approach distances for fire fighters and/or members of the public).

Finally, with regard to the adoption of 2.5 kW/m^2 (800 $Btu/hr\text{-}ft^2$) in the ORNL report as the threshold heat intensity for conducting continuous fire fighting and emergency response activities, it is noted that a significantly higher threshold value of 5 kW/m^2 (1,600 $Btu/hr\text{-}ft^2$) is cited in various standards and guidance documents (including the National Fire Protection Association's LNG

Standard, NFPA 59A, and by reference in 49 CFR 193.2057) as a tolerable threshold heat intensity level. Furthermore, recent field tests conducted by Technology Management Systems,[3] which were funded in part by PHMSA, suggest that extended exposure to a heat intensity of 5 kW/m^2 can be sustained without injury by persons wearing normal civilian clothing. Given this, the selection of 2.5 kW/m^2 as the heat intensity threshold for emergency responders wearing protective clothing would appear to be unduly conservative.

To summarize, the key areas of concern with the natural gas pipeline hazard zone analysis approach described in the ORNL report are as follows:

1. The proposed hazard zone model is based on an extremely conservative and inappropriate approach to pipeline outflow estimation and a fire radiation model that ignores significant sources of conservatism inherent in using a point-source radiation model (without appropriate adjustments) to characterize a large-scale fire resulting from pipeline rupture.

2. No evidence is provided to demonstrate that validity of the assumptions employed in developing the proposed hazard zone model or in the sizes of the hazard zones predicted by this model.

3. To the extent that the size of the zone of severe impact resulting from the San Bruno pipeline failure is perceived to be inconsistent with that predicted by the GRI model, it is emphasized that the final extent of the zone of impact was significantly influenced by factors not explicitly addressed by either the GRI model or the proposed new model. To adopt a grossly conservative fire hazard model to account for other case-specific factors is not the preferred approach because it masks the significance of these other issues and it compromises the validity of hazard distance estimates obtained from such a model.

Yours sincerely,

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[3] Raj, P.K. 2008. Field Tests on Human Tolerance to (LNG) Fire Radiant Heat Exposure, and Attenuation Effects of Clothing and Other Objects. Journal of Hazardous Materials, Vol. 157, p. 247-259.