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Sent:	Wednesday, March 14, 2007 7:28 AM
To:	NIOSH Docket Office (CDC)
Subject:	FW: Comments re: Draft Seal Report
Follow Up Flag:	Follow up
Flag Status:	Purple
Attachments:	Review of NIOSH Analysis.pdf; Baker Status Review final.pdf; Baker-Quentin Resume_Sept06.pdf; Geng-Jihui resume_ July 06.pdf; Kolbe-Max Resume Nov-06.pdf; Thomas-Kelly Resume_Apr04.pdf; Torero Jose CV.PDF; Van Brunt Vincent CV.PDF; Schemel Christopher.pdf

Attached are comments prepared for the National Mining Association by Packer Engineering and Baker Engineering and Risk Consultants that analyze the NIOSH draft report on the Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines. Also attached are the resumes of the individuals that participated in the review and preparation of the reports. We appreciate having the opportunity to provide comments on this most important issue.

As you will note, both documents raise significant concerns with the draft report thus calling into questions the recommendations contained therein. The documents recommend further study required before definitive conclusions can be reached regarding the design of new seals for use in underground coal mines. The members of NMA remain committed to working with NIOSH and our other industry partners to develop reasonable recommendations that result in standards that are attainable and that do not in-and-of-themselves introduce unnecessary safety hazards. Unfortunately the NIOSH recommendations fail to meet these basic criteria.

We would be happy to discuss this further with you should you believe that would be beneficial.

Again, thank you for providing us the opportunity to provide comments on the draft report.

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Review of NIOSH Analysis

Packer Engineering File Number 500879

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General Review of Combustion Issues for NIOSH Draft Report: Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines

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REVIEW SUMMARY

The NIOSH Report relies upon four basic assumptions in its attempts to justify its proposed design criteria. These assumptions are highly idealized and are based on theoretical calculations and experimental conditions that do not accurately reflect the actual conditions in coal mines. These assumptions are:

1. Combustion of stoichiometric (~10%) methane-air in a closed volume raises the pressure from 101 kPa to 908 kPa (14.7 psi to 132 psi).
2. Combustion of fuel-rich coal dust and air mix in a closed volume raises the absolute pressure from 101 kPa to about 790 to 890 kPa (115 to 129 psi) which is only slightly less than combustion of methane-air mix.
3. If a detonation occurs in an ideal methane-[dry] air mix at 1 standard atmosphere, the detonation pressure developed is 1.76 MPa or 256 psi (CJ detonation pressure).
4. A methane-air detonation wave reflects from a solid surface at a pressure of 4.50 MPa (653 psi).

The pressures stated in the above assumptions are total pressures, atmospheric pressure + pressure rise form an explosion.

The methane concentration throughout a mine varies temporally and spatially thus, assuming a constant stoichiometric homogeneous mixture as the basis for a design criteria is inappropriate. The assumptions used by NIOSH and the corresponding recommendation derived from those assumptions failed to include highly relevant information that can greatly impact the calculations of constant volume overpressures. The issues include:

- Flammable cloud size potential;
- Methane-air mixing based on known methane-air behavior;
- Realistic vapor cloud concentration gradients within sealed volumes based on mixing characteristics;
- Accounting for the effects of moisture in the air on combustion;
- Effects of geometry on mixing, potential flammable volumes, and combustion characteristics; and
- Effect of existing explosion mitigation mechanisms in place in coal mines.

The NIOSH Report also presents design criteria for high overpressures from methane-air detonations. This assumption of a methane-air detonation does not take into account a large body of research that questions the ability of a methane-air mixture to detonate. In addition, the conditions required for any potentially detonatable gas mixtures to transition from a low speed deflagration to a detonation are not addressed in appropriate detail in the NIOSH analysis. The requirement set in the NIOSH Report for seal designs to protect from a detonation in a sealed area of a coal mine is not justified given the superficial level of analysis the NIOSH Report provides and the referenced literature in this review.

Finally the NIOSH Report does not adequately outline the input parameters used in the Computational Fluid Dynamics (CFD) models and incorrectly assumes that the calibration of the model that was necessary to achieve agreement with the experiments is generally applicable to larger scale scenarios with alternative geometries, concentration profiles, and blockage ratios.

INTRODUCTION

The NIOSH Draft Report: *Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines* (NIOSH Report) describes an analysis of combustion processes and an approach for seal design that applies to abandoned areas of coal mines. This report provides a review of several issues addressed in the NIOSH Report from a combustion and process safety perspective.

The seals addressed in the NIOSH Report are used as part of an engineered system intended to: lower the probability of an explosion in an abandoned area of a mine; prevent an explosion in an abandoned area of a mine from impacting a working area; and prevent propagation of an explosion form an active area into a sealed area. The current regulatory design criterion for alternative seals requires a seal to be able to withstand a 20 psi overpressure during an explosion by remaining intact and not allowing the atmosphere from one side of the seal to pass to the other. This requirement was increased to 50 psi by the Mine Safety and Health Administration in 2006.

The NIOSH Report addresses explosion seal overpressure design criteria by developing a set of three prescriptive criteria for seals to withstand overpressures and impact loading. The report examines the types of explosion scenarios that the NISOSH Report authors feel present a threat to mine seals.

The focus of this review is to examine the four assumptions developed in the NIOSH Report. These facts presented in Section 3 of the NIOSH Report are the driving ideas behind the new seal design criteria from a combustion and safety perspective.

One of the threats presented in the NIOSH Report is a detonation of methane in an abandoned area of a mine. In the NIOSH Report, the assumption is made that a methane-air detonation in a coal mine could occur. Little or no experimental data exists to support the concept that a methane-air detonation could occur in an underground coal mine environment. Historical experience in coal mines does not lend support that an underground coal mine environment can develop a detonation. Studies suggest that a methane-air detonation is not achievable at standard pressures in the absence of other combustible gases. Studies on methane-air explosion systems are presented in this review to provide some perspective on the idea of a methane-air detonation in a coal mine and provide a perspective on the risk of detonation and deflagration in a sealed area.

Baker Engineering and Risk Consulting, Inc. provided a review of the NIOSH Report for Packer Engineering, Inc. Sections of this report that reference Baker Risk's comments are noted as Baker Risk, 2007. The Baker Report is provided as an attachment to this report.

REVIEW OF KNOWN MINE SEALED AREA EXPLOSIONS

The NIOSH Report reviews known explosions in sealed areas of U.S. coal mines from 1993-2006. This provides a perspective on the type of consequences that have been experienced in explosions. The review also discusses ignition sources and a stated cause for each incident. A summary of this information is provided in Table 2 of the NIOSH Report.

The incident review section of the NIOSH Report describes a number of events in some detail, but there is no attempt to provide a correlation between the seal characteristics and the magnitude of each explosion. Seals are described within the Report as a constructive element that reduces the potential for explosion, thus a key issue in the prior incident review is if the seals failed or if they did not. Seal failure leads to an estimation of the specific overpressure and no attempt is made to relate the seal failure to any other cause.

There is no analysis in the NIOSH Report of the past explosion incidents and how seal type, their location in the mine and geometry of the area affected the development of the explosion. Faulty construction leading to seal failure in explosions has also been sited by the Mine Safety and Health Administration. From a damage prevention and safety analysis perspective, an analysis of data provided by the past incidents is essential because it is necessary to consider all variables of this problem in order to develop an analysis that correctly addresses it in the most effective manner. The Report fails to do this.

SEAL DESIGN PRACTICES IN THE U.S., EUROPE AND AUSTRALA

The conclusion of Section 2.1 of the NIOSH Report is that the 20 psi (140 kPa) requirement does not originate in the need to make a seal explosion proof, but more to avoid leakage. This is based on the work of Mitchell that is referenced in the NIOSH Report; nevertheless this conclusion is not consistent with the rest of the text. The text indicates that Mitchell (Line 361) established that an explosion seldom exceeds 20 psi (140 kPa). There is no clear description of what issues lead to such pressure increases and what measures need to be taken to guarantee that an explosion will not exceed 20 psi (140 kPa).

The NIOSH Report provides a review of the standards established by established by a few countries when sealing abandoned areas of mines. The standards in the United Kingdom, Germany, Poland and Australia are summarized in Table 3 of the NIOSH Report. The United Kingdom, Germany and Poland all require a 72 psi rated seal. These three countries are reported as never having recorded a seal destroyed in an explosion. All four countries have at least some requirements on inerting and monitoring of the sealed areas under some circumstances.

COMBUSTION AND EXPLOSION ASSUMPTIONS DEVELOPED IN THE NIOSH REPORT

The NIOSH Report addresses the fundamentals of explosions and detonations. NIOSH uses a series of experimental results to establish what potential overpressures can be attained. The focus is on the idealized version of the calculations and experiments and not on the parameters that influence the predicted overpressure. The NIOSH Report references both constant volume combustion tests and pipe/tube combustion tests, but no emphasis or analysis is made on what the necessary conditions are to attain the reported overpressures in these referenced tests. There is no link illustrating how the test conditions compare to real mine conditions and the resulting possible explosion scenarios are not developed at any point in the NIOSH Report.

The NIOSH Report states that there are two possible explosion scenarios. The first explosion scenario is an explosion involving a large volume of flammable gas mixture covering a long stretch of the mine entry. This scenario is intended to address the possibility of an ignition creating a flame front capable of ramping up to a strong turbulent deflagration or, given enough flame travel distance (e.g., 50 meters or more), undergoing a deflagration-to-detonation transition (DDT). [Baker Risk, 2007]

The second explosion scenario consists of a flammable mixture being formed directly behind or in front of the mine seal as a result of leakage through the seal. In this scenario, it is unclear how much flammable volume would be created due to seal leakage. [Baker Risk, 2007]

The NIOSH Report in Figure 3 presents three different potential explosive volumes to be considered when designing seals. This description of methane volumes assumes that the filling volume is uniform and creates a homogenous methane-air mixture. Methane is lighter than air and has mixing characteristics that would lead to concentration gradients within the mixture. Concentration gradients would create different combustion characteristics of the methane-air mixture and affect the magnitude of pressures created in the confined space. Thus, it is inappropriate to assume that the response mechanisms envisioned by the Report's authors, even if one were to accept them, could be applied universally throughout the underground coal mining industry given the range of potential applications

Review of NIOSH Report assumptions:

Assumption 1: ***Combustion of stoichiometric (~10%) methane-air in a closed volume raises the pressure from 101 kPa to 908 kPa (14.7 psi to 132 psi).***

Assumption 2: ***Combustion of fuel-rich coal dust and air mix in a closed volume raises the absolute pressure from 101 kPa to about 790 to 890 kPa (115 to 129 psi) which is only slightly less than combustion of methane-air mix.***

The chemical equation presented by NIOSH for methane combustion is a simplistic approximation; methane combustion is a very complex phenomenon which has many intermediate steps [Glassman, 1987]. An example of issues from an over simplified approximation is the statement in the Report "the [chemical] energy content of 1 m^3 of ideal methane-air mix is about the same as 0.75 kg of TNT." This statement is offered by NIOSH to design engineers as guidance when evaluating hazards. However, in application vapor clouds convert a small amount of the chemical energy to kinetic energy during an explosion. Therefore, factors like confinement and obstructions are far more important influences on explosion magnitude more than fuel values in the cloud [CCPS, 1994]. This is one example of why understanding the entire system when evaluating explosion hazards is important.

A stoichiometric mixture of methane-dry air combusted under ideal experimental conditions can result in a pressure increase of ~120 psi. The NIOSH analysis does not address the assumptions that are involved in this calculation as they apply to a sealed area of a coal mine. The NIOSH Report asserts that a worst case is considered; however, real effects in coal mine atmospheres should be considered. Both carbon dioxide and water vapor, usually at saturation, will considerably narrow the flammability and detonability limits [Zabetakis, 1965] and additionally, may significantly reduce the probability for mixtures to transition from deflagrations to detonations. In addition, experiments with atmospheres containing both water and carbon dioxide need to be conducted. The addition of these species on deflagration and detonation characteristics needs to be verified before a tight three tiered prescriptive regulation can be considered.

The NIOSH Report does not consider the effect of water vapor on the combustion of the methane-air system or on a dust cloud. Underground mines usually have high humidity levels and this parameter will affect the energy created during combustion of a vapor cloud in a mine. Idealized treatment of explosion chemistry and physics can lead to some conclusions that cannot be realized in real methane-moist air systems. This fact may lead to misrepresentations of some phenomenon and an over estimation of the risks that are present in coal mines.

The NIOSH Report assumes that the methane filling process is homogenous throughout the entire sealed area. This assumption is not valid as methane is less dense than air and will stratify in stagnant conditions, thus creating a vertical gradient within the sealed area. The Nagy, 1981 Explosion Hazard in Mining report that the NIOSH Report references, reports on experiments that indicate methane layering lowers the overpressures realized during an explosion. The assumption that stoichiometric conditions will prevail is also incorrect as the filling process is temporal and spatial in nature. There is only one segment in time during which stoichiometric conditions will exist at any given location throughout the mine. If ignition occurs before or after time the pressures will decay quickly. Extensive literature exists on methane filling and the pressure variation resulting from ignition of various mixtures. [Eltschlager, 2001, Cashdollar, 2000, Cote].

It is known that the naturally evolving methane from the coal seam will fill the volume of the sealed area, replacing air with methane. The methane volume will accumulate over time to a percentage in the air so that the mixture is not flammable. For a methane-air system, the flammable limits by percent volume are 5.0-15.0% [Glassman, 1987]. It is recognized that during the methane filling process a time period exists where the methane-air mixture in the abandoned area will be flammable and if ignited could explode. Common thinking in the mine industry is that this filling process takes anywhere from several days to several weeks.

It has been well documented that gradients will exist in a quiescent environment in which a gas is introduced based on its relative density in comparison to air. This implies that it is unrealistic to expect a homogeneous mixture to exist within the sealed area. Thus the location of the ignition source relative to the mixture is important.

A more valid approach to this problem would be to generate risk curves based on the volume of the space and a range of liberation rates to determine estimates of overpressure as a function of time (based on the mixture fraction in the space). This could further be refined by introducing stratification and horizontal gradients.

Assumption 3: If a detonation occurs in an ideal methane-[dry] air mix at 1 standard atmosphere, the detonation pressure developed is 1.76 MPa or 256 psi (CJ detonation pressure).

A detonation depends on three conditions; confinement, mixture ratio and ignition source [Glassman, 1987]. Detonations come about in two ways, by a large ignition source like a high explosive, or by detonation to deflagration transition (DDT), resulting from turbulence induced mixing and reaction acceleration in the run-up distance [CCPS, 1994].

Some uncertainty exists whether methane can in fact detonate in air [Glassman, 1987]. The NIOSH Report references literature that a methane-air detonation was realized in an experimental mine during a set of experiments [Cybulski, 1967]. The methods for determining the maximum pressures observed are in most of the cited cases *back-calculated* from observations and empirical correlations that may or may not be realistic or applicable. Few of the tests showed pressures and velocities representative of a detonation and those that claimed to have shown a detonation were not based on values obtained with measurement devices, but rather were determined based on damage done to objects that were then further extrapolated to infer a specific pressure. Cybulski's use of electric blasting caps, black powder and dynamite as ignition sources is unrealistic in its relation to most underground coal mining. Cybulski concludes that differences exist between the tests conditions and the assumed amounts of methane accumulations expected in actual operation regarding both flammable volume and methane layering. A more in depth analysis should be undertaken to ascertain if or when detonations can arise in a mine scenario.

The issues of distance and flammable volume are not clearly separated in some portions of the NIOSH Report. Although the Report does classify and identify the potential of methane detonations, the use of distance can be misleading with regards to implementing distance as a safety factor or criteria. The explosion energy is determined by the flammable gas mixture volume and concentration, rather than by the length of the flammable gas column. The rate at which this energy is released, for a given fuel mixture, is controlled by boundary conditions and geometry (degree of congestion and level of confinement). Severe confinement and or congestion can lead to detonations. [Baker Risk, 2007]

In the case of tunnels, a one dimensional (1D) analysis is justified since the length to diameter ratio (or equivalent hydraulic diameter) is normally large (i.e., an L/D ratio of 30 or more). This 1D approach can utilize a "run-up" distance concept to determine the potential for a DDT. The tunnel lengths that the flammable mixture is present in impacts both the explosion strength and the potential to "run-up" or DDT. [Baker Risk, 2007]

No known work exists examining detonations in rectangular geometries. The applicability of tunnel geometry for the analysis of mine geometry needs to be examined. The sealed areas of mines represent complex geometries consisting of linked tunnels and cross cuts. These areas can span several miles. How one dimensional analysis relates to this geometry should be analyzed.

To categorize the explosion scenarios by lengths alone can be misleading, as there are optimum situations which promote DDT. For example, some tunnels may be more congested than others or have more favorable boundary conditions that would promote DDT. The "run-up" distances are dependent on the boundary condition in congested environments. Better criteria for explosion strength categorization may be the tunnel L/D ratio. [Baker Risk, 2007]

The energy required for ignition of a deflagration is on the order of 10^{-4} Joules. The energy required to ignite a detonation is on the order of 10^{6} Joules [CCPS, 1994]. The ignition sources in sealed areas are limited by the active removal of known, man made ignition sources. Rock falls may be the most credible source of sparking that could provide the minimum ignition energy required for the ignition of a deflagration in a methane-air system. Some research in this general area has been done for machine tools contacting rock [Blickensderfer, 1975, Ward, 2000] and frictional contact [Ward, 2005].

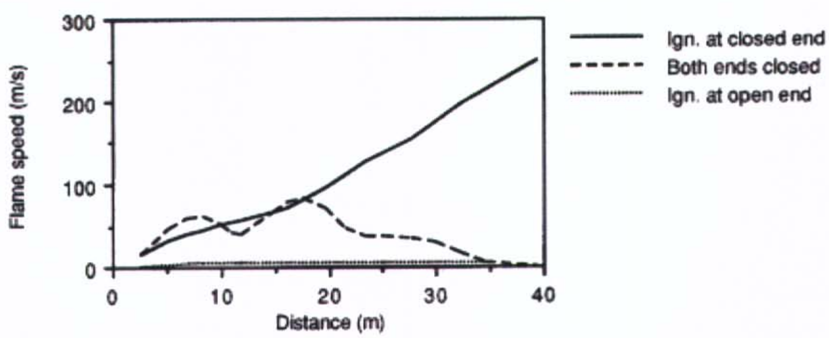
Some of the explosions in the incident summary provided in the NISOH Report stated that lightning was the ignition source. Lightning as an ignition source in an actively isolated sealed area of a mine is not a greatly researched area. One study stated that lightning could be transferred to an underground sealed area and act as an ignition source for methane [Novak, 2001]. The implication of the report was that the energy transfer was not at a high energy level when transferred through rock strata. This issue requires more research to develop a better understanding of the hazard.

An important concept the NIOSH Report used in establishing the seal design criteria for a detonation is the cell size required for detonation. NIOSH uses the cell size to create the parameter referred to in the NIOSH Report as the run-up length to a detonation. Cell size is a characteristic for a detonation of a given gas mixture and is based on the equilibration velocity of the wave and the corresponding cell size needed to complete chemical reactions. The minimum cell sizes for a given gas system usually exist at the most detonatable mixture of the gases and are representative of the sensitivity of a mixture. The NIOSH Report gives a methane detonation cell size of 300 mm which is consistent with other references [Glassman, 1987, Knystautas, 1986].

Methane is particularly insensitive to detonation compared to a corresponding cell size of ~ 535 mm for other alkanes (ethane, propane, etc.) [Glassman, 1987, Lee, 1984].

A literature search conducted as part of this review was not able to find experiments where a successful methane-air detonation was established. Two projects were found that conducted experiments in semi-confined spaces where no methane-air detonations were achieved [Bull, 1979, Inaba, 2004]. It is important to note that these two tests were **not** performed in tunnels and had only partial confinement of the explosive mixture, but the studies do provide some insight into the difficulty of achieving a methane detonation. One paper reported that based on the model developed from the experimental data, 22 kg of tetryl (a highly explosive compound) would be needed to initiate a methane-air detonation [Bull, 1979].

Experiments that examined methane in air were carried out by Bartknecht in 1971 and reported in the Gas Explosion Handbook [Bjerketvedt, 1992]. These tests were done at 1 atmosphere pressure in a 1.4 meter diameter 40 meter long pipe with test conditions of one end closed and both ends closed. Two ignition point scenarios were used, one at the closed end and one at the open end of the pipe. Test were done with the pipe open at one end and closed at both ends, a case similar to the scenarios pictured in Figure 8 of the NIOSH Report. The experiment found that the highest flame speed was achieved when the ignition was at the closed end of the pipe and the other end was open. When the pipe was closed at both ends, the flame accelerated at first, but after 15-20 meters started to decelerate. This testing did not have obstructions in place in the pipe. The graph below illustrates the experiments findings.



Flame speed in a 1.4 m diameter pipe with methane-air. (Bartknecht 1971) [Bjerketvedt, 1992]

Research conducted by [Knystautas, 1986] examined several hydrocarbons in air to understand detonations. This research was conducted in confined tubes with obstructions in the diameter and confirmed that critical values of flame velocity exist for deflagration to detonation transitions.

Obstructions in the flow field of the explosion gases are very important because the methane-air (or any fuel-air) mixture interacts with the obstructions to create turbulence which accelerates the flame fronts during the propagation along the length of the geometry. Knystautas did not get methane-air mixtures to detonate and found that the flame speeds propagated in the obstruction fields for all tests were below the Chapman-Jouget (C-J) predictions. In short, the Knystautas research indicates that a high degree of obstruction is required in a closed tube (on the order of 0.43 fraction of the diameter) to propagate any of the tested hydrocarbons to a DDT. At no time during these tests was methane accelerated to near DDT velocities.

Assumption 4: A methane-air detonation wave reflects from a solid surface at a pressure of 4.50 MPa (653 psi).

NIOSH states that any seal with a tunnel run-up of 50 meters or more requires a seal capable of withstanding an explosion overpressure load of 640 psi. The idea of an explosion containment system designed to withstand a detonation that is made of a single element, such as one big mine seal, may not be a very effective strategy. A detonation overpressure containment seal would have to be built to standards that may not be attainable, reliable or a cost effective use of safety resources given the real risk presented by a methane-air detonation in a mine.

Inherently, gas explosions are not the same as condensed phase explosions (e.g. TNT). A good discussion of the differences is found in Baker, W.E. et al. Explosion Hazards and Evaluation, Elsevier, New York, (1983) [Baker, 1983]. Baker discusses several significant factors that are not considered in the Report. First, the difference between constant pressure energy addition and constant volume-isentropic expansion is discussed in detail including how the combustion wave spreads.

The transition from a three dimensional source wave to one with reflected pressures is a complex issue. Baker, 1983, makes clear that reflected pressures are extremely geometry dependent and the effects from a non-spherical explosive source that is not a high explosive need to be evaluated. The simple formula presented in section 3.6 (line 793) gives only one such limit. Using a single equation to estimate the pressure of a reflected wave is extremely misleading. Rather, as Baker et al. point out, the effects of the specific impulse from an explosion need to be considered. Using a single equation to express reflected wave characteristics implies that Fact 4 (lines 801, 802) may not, in fact be valid.

The NIOSH Report uses explosion pressure and explosion pulse, not the terms used in the bulk of explosion literature, i.e. peak side-on overpressure and impulse. The NIOSH Report should make it clear what is being calculated or measured. For example, Figures 20-22 are given with explosion pressures on the axes. This term "explosion pressure" is not clearly defined in the NIOSH Report. Explosion pressure (see Lines 1817, 1823, and 1829) is not a term normally found in the literature and this complicates analysis of the Report.

MODELING OF EXPLOSIONS

The NIOSH Report provides a summary of the different model packages that are available to analyze explosions. The model runs that simulate the Lake Lynn Experimental Mine provide a degree of validation to both model codes and their application to understanding overpressures in mine configurations.

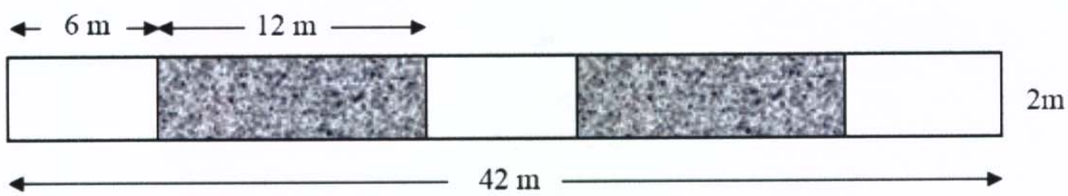
These models can provide valuable information if used appropriately in designed studies to develop configuration and scenario specific seal evaluations. Different design concepts can be evaluated using these programs to help understand the mine and sealed area specific configuration elements that govern the potential overpressures.

The practice of calibrating a model based on small scale experiments and applying the same baseline conditions for different scenarios can be problematic. The calibration process typically involves adjusting various properties and model parameters that will affect turbulence, temperatures, pressures, and speed of the flame front. These adjustments are valid for a specific set of conditions but may not be generally applicable. Thus, the results predicted by the models that are not supported by any experimental/literature values must be treated extremely cautiously if they are based on calibrated baseline conditions.

The simulation codes are continuously under development as new information is found and better representations of physics and chemistry is included in them. FLACS, AutoReaGas, NASA-Lewis, and the Wall Analysis Code all have version numbers and dates of release. These need to be included in the report as an appendix. As the Report presently reads, there is no means of comparing results with any additional information about geometry, temperature and concentration gradients, etc. For each code the version and date needs to be specified. For each application run for comparison purposes, the full initial decisions, assumptions, and conditions need to be provided. If new information is obtained, no comparison with the results from these simulations can be obtained. This is the bare minimum needed for each simulation. Detailed output from each case simulated would be a part of any proper and careful analysis.

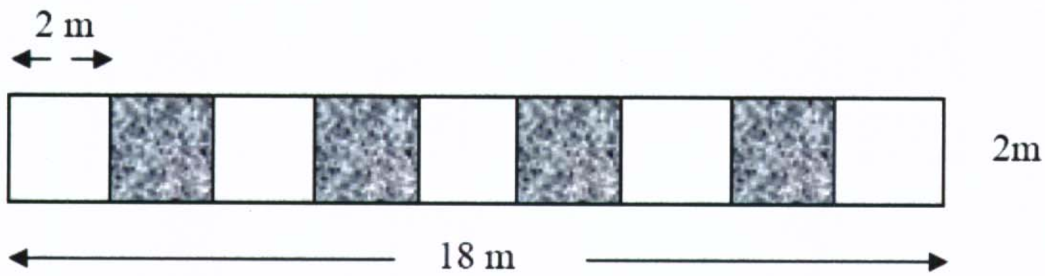
The following analysis is extracted from the Baker Risk report to Packer. The full Baker Risk report is an attachment to this review.

The models assumed for the AutoReaGas and FLACS trials are based on the Lake Lynn layout. This layout, if a 2 meter tunnel height is assumed, has a blockage ratio of about 0.57 and essentially consists of a rectangular cross section with three venting shafts and two pillars (see figure below). [Baker Risk, 2007]

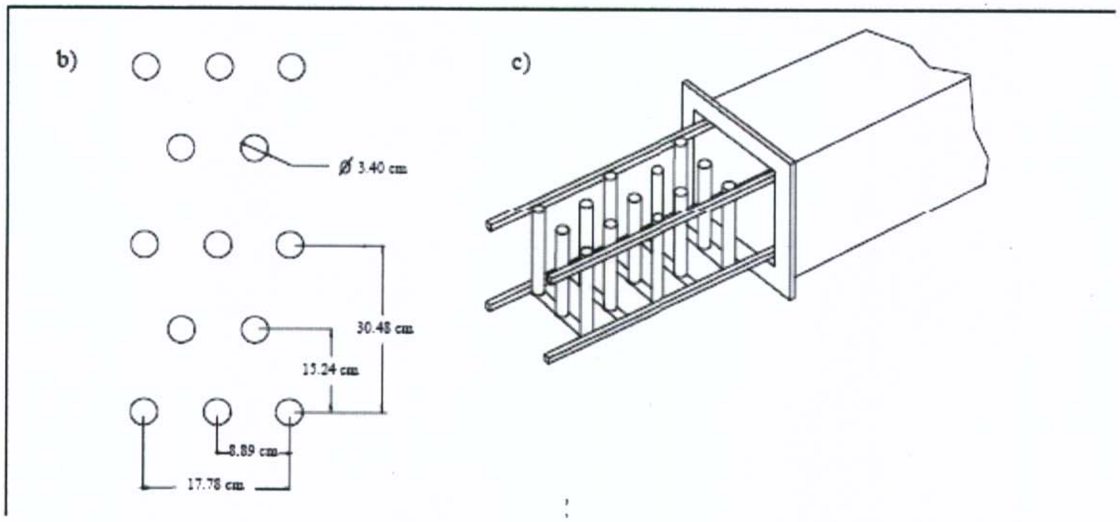


Conversely, the tunnel designs and layouts illustrated in Figures 1A and 1B of the

NIOSH Report contains more obstacles and a blockage ratio of about 0.44 (see figure below). [Baker Risk, 2007]



The differences between these arrangements can have a significant impact on the potential for a DDT. For example, in methane air tests carried out at McGill University by Chao, 1999, with tubes of square cross sectional areas, the obstacle arrangement consisted of a staggered array of 3x2 cylinders. The blockage ratio used was 0.41 and the layout can be seen in the figure below. [Baker Risk, 2007]



Previous experiments carried out by Knystautas, R., and Lee, J.H.S., in round cross sectional tubes with a blockage ratio of 0.43 and orifice plates as obstacles did not exhibit the high flame velocities that the square tube tests revealed. The results of these tests showed that the steady state flame velocities for the circular tube were all below the speed of sound, whereas significant portion of the velocities for the square tube achieved a state of "quasi-detonation" (i.e., above the speed of sound). The tests concluded that although both tubes had similar blockage ratios, the obstacle array of staggered cylinders yielded more flame acceleration than the orifice plates. [Baker Risk, 2007]

CONCLUSIONS

This review provides an analysis of the NIOSH Report and raises questions about each of the design assumptions that NIOSH used to justify the pressure requirement for the seals. The NIOSH Report does not present a convincing argument for providing a prescriptive seal standard that is many times in excess of successful standards in other countries throughout the world. It uses a theoretical homogeneous methane-air (dry) combustion conditions to represent the stratified methane combustion in the moist conditions in coal mines. This assumption is used in spite of data indicating that both of these conditions will significantly reduce the flammable mass and severity of combustion. Furthermore, the NIOSH Report uses the pressure obtained in ideal explosion conditions in narrow tube geometries to approximate the conditions in mine tunnels and entries. This method of developing design criteria is not appropriate for this application. Before a prescriptive regulation that is so much greater than the international standards is applied more analysis and data is needed.

REFERENCES

Baker, W.E, P.A. Cox, P.S. Westine, J.J. Kulesz, and R.A. Strehlow, *Explosion Hazards and Evaluation*, Elsevier Scientific Publishing Company, New York (1983)

Bjerketvedt, D., Bakke, J.R., van Wingerdan, K., *Gas Explosion Handbook.* Christian Michelsen Research, Website maintained by GexCon, Bergin, Norway. www.GexCon.com. 1992.

Blickensderfer, R. *Methane Ignition by Frictional Impact Heating,* Combustion and Flame 25, 143-152 (1975).

Bull, D.C., Elsworth, J.E., Hooper, G. *Susceptibility of Methane-Ethane Mixtures to Gaseous Detonation in Air*, BRIEF COMMUNICATIONS: Combustion and Flame 34: 327-330 (1979).

Cashdollar, K.L., Zlochower, I.A., Green, G.M. Thomas, R.A. Hertzberg, M. 2000. *Flammability of Methane, Propane and Hydrogen Gases,* Journal of Loss Prevention Industries. National Institute for Occupational Safety and Health. Pittsburgh, PA.

CCPS, 1994, *Guidelines for Evaluation the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs*. Center for Chemical Process Safety of the American Institute of Chemical Engineers, New York, New York. 1994.

Chao, 1999, J., Kolbe, M., and Lee, J.H.S., *Influence of Tube and Obstacle Geometry on Turbulent Flame Acceleration and Deflagration to Detonation Transition* presented at the 1999 ICDERS Symposium in Heidelberg, Germany.

Cote, M. *Abandoned Coal Mine Emissions Estimation Methodology*, Raven Ridge Resources, Inc., Grand Junction, Colorado, United States.

Eltschlager, K.K., Hawkins, J.W., Ehler, W.C., Baldassare, F. *Investigation and Mitigation of Fugitive Methane Hazards in Areas of Coal Mining,* Office of Surface Mining Reclamation and Enforcement, 2001.

Glassman, I, 1987, *Combustion*, Academic Press, Inc. Harcourt Brace Jovanovich, Publishers, London, England.

Knystautas, R., Lee, J.H., Peraldi, O., Chan, C.K. *Transition of a Flame from a Rough to a Smooth-Walled Tube,* 10th ICDERS, Berkeley, California, August 4-9, 1985. American Institute of Aeronautics and Astronautics.

Nagy, J. *The Explosion Hazard in Mining,* Mine Safety and Health Administration. Pittsburgh, PA: IR1119, 1981.

Inaba, Y., Nishihara, T., Groethe, M.A., Nitta, Y. *Study of characteristics of natural gas and methane in semi-open space for the HTTR hydrogen production system,* Nuclear Engineering and Design 232 (2004) 111-119.

Novak, T., Fisher, T. *Lightning Propagation Through the Earth and Its Potential for Methane Ignitions in Abandoned Areas of Underground Coal Mines,* IEEE Transactions on Industry Applications, Vol. 37, No. 6 November/December 2001.

Ward, C.R., Crouch, A. Cohen, D. *Identification of potential for methane ignition by rock friction in Australian coal mines,* International Journal of Coal Geology 45 (2001) 91-103.

Ward, C.R., Nunt-jaruwong, S., Swanson, J. *Use of mineralogical analysis in geotechnical assessment of rock strata for coal mining,* International Journal of Coal Geology 64 (2005) 156-171.

Zabetakis, M.G, Deul, M., Skow, M.L. Methane Control in United States Coal Mines, Information Circular 8600, 1972.

Zabetakis, M.G., "*Flammability Characteristics of Combustible Gases and Vapors*," Bulletin 627, Bureau of Mines, U.S. Department of the Interior (1965).

Baker Engineering and Risk Consultants, Inc.
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March 8, 2007

Christopher F. Schemel
Vice President
Packer Engineering, Inc.

-- VIA EMAIL --

Re: ***Draft of Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines***
BakerRisk Project 01-01743-001-07

Dear Mr. Schemel:

On February 22, 2007, Packer Engineering requested the support of Baker Engineering and Risk Consultants, Inc. (BakerRisk) in the review a NIOSH draft report on the Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines. This memorandum provides BakerRisk's commends on the NIOSH draft report along with references to further documentation in support of these comments.

1. BACKGROUND

In response to several coal mine related explosions, and the recent Sago mine explosion, the 2006 MINER Act requires the MSHA to amend the current 20 psi explosion pressure design load on mine seals to a higher design load by the end of 2007. NIOSH engineers have produced a report outlining the necessity to approach mine seal design using a three-tiered explosion pressure design criteria for possible mine explosion scenarios.

2. BAKERRISK COMMENTS

2.1 General Comments

The NIOSH report basically states that there are two possible explosion scenarios. The first explosion scenario is an explosion involving a large volume of flammable gas mixture covering a long stretch of mine shaft. This scenario is intended to address the possibility of an ignition creating a flame front capable of ramping up to a strong turbulent deflagration or, given enough flame travel distance (e.g., 50 meters or more), undergoing a deflagration-to-detonation transition (DDT).

The second explosion scenario would consist of a flammable mixture being formed directly behind, or even in front of, the mine seal as a result of leakage through the seal. In this scenario, it is unclear how much flammable volume would be created due to seal leakage.

The issues of distance and flammable volume are not clearly separated in some portions of the NIOSH report. Although the report does properly classify and identify the potential of methane detonations, the use of distance can be misleading with regards to implementing distance as a safety factor or criteria. The explosion energy is determined by the flammable gas mixture volume and concentration, rather than by the length of the flammable gas column. The rate at which this energy is released, for a given fuel mixture, is controlled by boundary conditions and geometry (degree of congestion and level of confinement).

In the case of tunnels, a one dimensional (1D) analysis is justified since the length to diameter ratio (or equivalent hydraulic diameter) is normally large (i.e., an L/D ratio of 30 or more). This 1D approach can utilize a "run-up" distance concept to determine the potential for a DDT. The tunnel lengths that the flammable mixture is present in impacts both the explosion strength and the potential to "run-up" or DDT.

To categorize the explosion scenarios by lengths alone can be misleading, as there are optimum situations which promote DDT. For example, some tunnels may be more congested than others or have more favorable boundary conditions that would promote a DDT. The "run-up" distance are dependent on the boundary condition in congested environments. A better criteria for explosion strength categorization may be the tunnel L/D ratio.

2.2 Specific Comments

The following are specific comments regarding the NIOSH report.

i. The discussion relating to the phenomenon of spontaneous combustion given at the top of pages 6 and 7 may merit additional discussion. Coal is known to undergo spontaneous ignition but under very specific conditions. It is not clear how probable such scenario is?

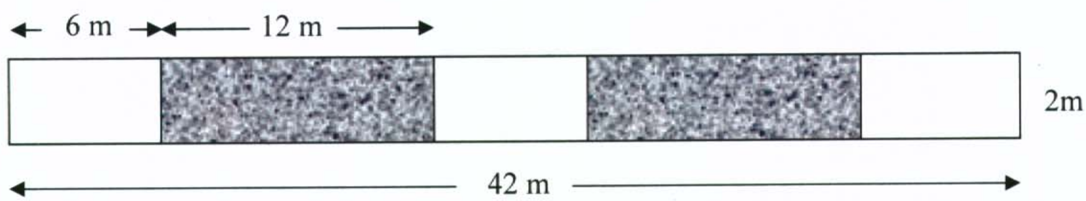
ii. Reference is made on page 8, line 157, about several hundred meters of open entry to be likely behind the seals and later on line 159 reference is made to potentially having 3-4 kilometers of open entries. These distances do not speak to how much flammable volume may actually exist in these open spaces and the order of magnitude difference between the two open entry distances is noteworthy and can make significant impacts to the blast loads produced. The duration of the pressure pulse associated with a detonation is a function of the gas column length, with a longer column length yielding a longer duration pressure pulse.

iii. On page 10, the reference to coal oxidation indicates a release of carbon dioxide in the atmosphere of the abandoned mine section, but no discussion is provided of expected carbon dioxide concentrations. This may be relevant in that the presence carbon dioxide, or any other inert gas species, will increase the detonation cell width of the mixture and hence make it less like to undergo a DDT.

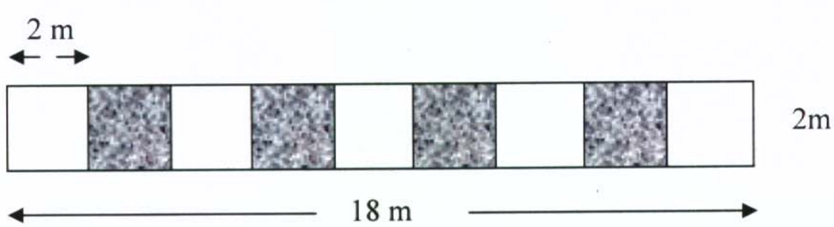
iv. Page 27 has a reference to 0.75 kg of TNT as having an energy equivalent to a cubic meter of methane-air flammable mixture. This reference is misleading to the industry. Although the potential energy is equivalent in this two examples, the energies are released at an entirely different rate. The cubic meter of gas, if placed in an uncongested and unconfined volume, will simply burn out as a flash fire causing a rush of hot air, but no real overpressure. Conversely, a 0.75 kg mass of TNT will detonate and create a 8 psig side-on load at a distance of 10 feet (approximately 19 psig reflected load).

v. The reference on page 35 states that detonation propagation in an elongated confined environment can occur when the diameter of the confinement (tunnel or pipe) is approximately 5 times the detonation cell size. The bulk of the technical literature on this topic would support that a stable detonation can occur in a pipe with a diameter equal to about 3 times the detonation cell width; in the case of methane, this would imply a diameter of less than 1 meter (about 90 cm). Furthermore, unstable detonations can occur in a pipe with a diameter equivalent to roughly one cell width.

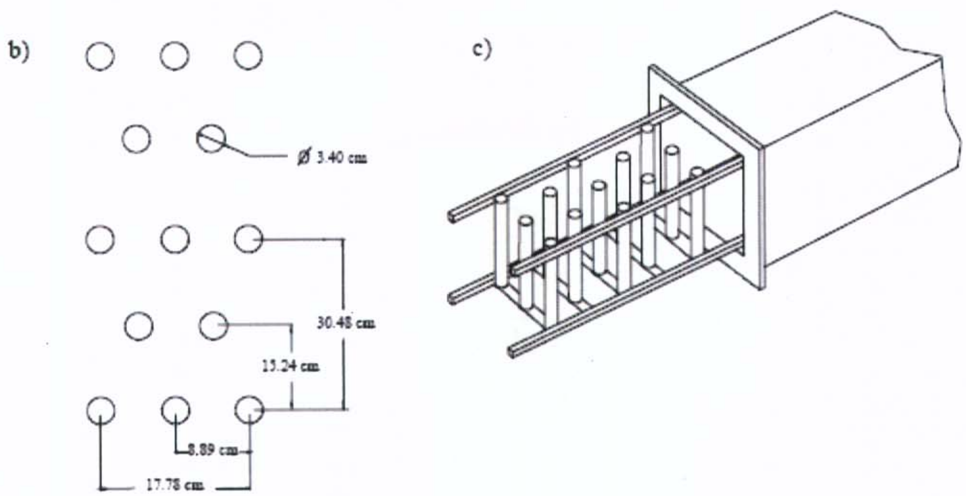
vi. The models assumed for the AutoReaGas and FLACS trials are based on the Lake Lynn layout. This layout, if we assume a 2m tunnel height, has a blockage ratio of about 0.57 and essentially consists of a rectangular cross section with three venting shafts and two pillars (see figure below).



Conversely, the tunnel designs and layouts illustrated in Figures 1A and 1B of the NIOSH report contain more obstacles and a blockage ratio of about 0.44 (see figure below).



The differences between these arrangements can have a significant impact on the potential for a DDT. For example, in methane air tests carried out at McGill University by Chao, J., Kolbe, M., and Lee, J.H.S., (*Influence of Tube and Obstacle Geometry on Turbulent Flame Acceleration and Deflagration to Detonation Transition* presented at the 1999 ICDERS symposium in Heidelberg, Germany) with tubes of square cross sectional areas, the obstacle arrangement consisted of a staggered array of 3x2 cylinders. The blockage ratio used was 0.41 and the layout can be seen in the figure below.



Previous experiments carried out by Knystautas, R., and Lee, J.H.S., in round cross sectional tubes with a blockage ratio of 0.43 and orifice plates as obstacles did not exhibit the high flame velocities that the square tube tests revealed. The results of these tests showed that the steady state flame velocities for the circular tube were all below the speed of sound, whereas significant portion of the velocities for the square tube achieved a state of "quasi-detonation" (i.e., above the speed of sound). The tests concluded that although both tubes had similar blockage ratios, the obstacle array of staggered cylinders yielded more flame acceleration than the orifice plates.

3. Closure

This letter report has been a review of the NIOSH report on Explosion Pressure Design Criteria for Mine Seals. BakerRisk looks forward to hearing from you after you and other members of the review committee have had an opportunity to review the comments provided in our letter report. BakerRisk remains eager to develop a path forward in the near future that will serve Packer Engineering's needs.

Please feel free to contact me if you have any questions or comments on this matter.

Sincerely,

Massimiliano Kolbe
Project Consultant

Approval:

Kelly Thomas, Ph.D.
Blast Effects Manager

Notice

Baker Engineering and Risk Consultants, Inc. (BakerRisk) made every reasonable effort to perform the work contained herein in a manner consistent with high professional standards.

The work was conducted on the basis of information made available to BakerRisk. Neither BakerRisk nor any person acting on its behalf makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of this information. All observations, conclusions and recommendations contained herein are relevant only to the project, and should not be applied to any other facility or operation.

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BakerRisk regards the work that it has done as being advisory in nature. The responsibility for use and implementation of the conclusions and recommendations contained herein rests entirely with the client.

QUENTIN A. BAKER, P.E.
President
Baker Engineering and Risk Consultants, Inc.

B.S., Mechanical Engineering, Texas A&M University
M.B.A., University of Texas at San Antonio

Mr. Baker's career has focused on explosion and combustion phenomena. He has conducted numerous R&D projects, hazards analysis and engineering studies involving airblast effects from a wide variety of explosion sources, development of blast loads, fragmentation effects, debris throw, and personnel injury. Injury prediction and risk analysis have also been the subject of Mr. Baker's research; he has contributed to the development of a building occupant vulnerability model.

Mr. Baker's experience with explosion phenomena includes experimentation. He conducted a R&D program to develop a distributed explosives systems to neutralize landmines, testing the system both on land and in shallow water to investigate blast output of arrays of parallel explosive chargers and sympathetic detonation of an acceptor charge. He has conducted tests to study shaped charge initiation of cased acceptor charges from long standoffs, with the acceptor charges positioned above ground and buried. Mr. Baker researched airblast propagation through openings into buildings and he designed and tested passive devices to protect ventilation systems, which resulted in a patented design. He contributed to the design of a vapor cloud explosion test apparatus and participated in vapor cloud explosion tests. Mr. Baker also developed shock tubes to simulate the blast loading from very large explosive charges and vapor cloud explosions. He subsequently tested glass/glazing systems to protect building occupants from glass fragments from vapor cloud explosion threats.

Mr. Baker has worked on numerous safe siting, safety analysis review, consequence analysis, explosion hazard analysis and blast-resistant structural design projects during which he predicted internal and external blast loads from deflagrations or detonations. The blast sources have included high explosives, runaway chemical reactions, dust explosions, electrical arc, vapor clouds, bursting pressure vessels, and propellants. He has predicted fragment size, velocity, and throw for bursting pressure vessels and cased explosives. Mr. Baker has inspected numerous petrochemical plants, specialty chemical plants, refineries, offshore platform, and other industrial facilities, identified explosion hazards and developed explosion scenarios. He was involved in the development of a hydrocode to predict bursting pressure vessel and vapor cloud explosion blast parameters, and with the use of this code he developed blast curves for both classes of explosions. He has conducted facility-wide risk analyses to predict the risk to personnel from potential explosion hazards. Mr. Baker also provides short course instruction in blast and fragmentation effects.

Mr. Baker has investigated over 75 accidental explosions, both domestic and international, to determine the number and magnitude of explosions, their locations on the site, probable causes of initiation of each explosion, and root cause of the accident. These accidents include internal and external vapor cloud explosions at refineries, chemical plants, offshore platforms and a drill barge; an ammonium-perchlorate plant explosion; internal explosion and fragmentation of pipes due to highly reactive liquid and solid phase materials; an electrical arc in a rail-gun research laboratory; runaway reactions in reactors, pipes and tanks resulting in vessel burst and fragmentation including an ethylene oxide reactor, a waste products mixing tank, an agricultural products settling tank, an ammonium nitrate reactor, a fertilizer pump, and a pressure relief valve; large power generation boiler explosions; BLEVEs of a rail car and a pulp digester; and dust explosions in food processing, grain, rubber recycling, foundry, and rubber compounding facilities. He has provided accident investigation training to private industry and government personnel.

Mr. Baker has managed a number of projects to develop computer programs to calculate the blast loads on structures from high explosive, vapor cloud explosion, and bursting pressure vessel sources considering ground reflection, Mach stem formation, receptor structure orientation, and reaction rate, and predicted dynamic structural response of components and frames. Among the programs is ERASDAC, developed for DDESB and COE for compliance with DoD siting criteria for explosion hazards.

Professional Chronology: Southwest Research Institute, 1978-1987; Baker Engineering and Risk Consultants, Inc., 1987- present.

Professional Registrations/Certifications: Registered Professional Engineer (Texas), Certified Fire and Explosion Investigator (CFEI)

Professional Memberships: American Society of Mechanical Engineers (ASME); American Institute of Chemical Engineers (AIChE); National Fire Protection Association (NFPA), National Association of Fire Investigators (NAFI); National/Texas Society of Professional Engineers (NSPE, TSPE)

Committee Memberships: ACI Committee 370, Short Duration Dynamics & Vibration Load Effects; NFPA 921, Guidelines for Fire and Explosion Investigations, Major Case Management Task Group; API Facility Siting Task Force; CCPS Vapor Cloud Explosion Committee

Sept 2006

JIHUI GENG, Ph.D.

Senior Scientist
Baker Engineering and Risk Consultants, Inc.

B. Eng., Mechanical Eng., National University of Defense Technology, China
M. Eng., Mechanical Eng., Univ. of Science and Technology of China, China
Ph.D., Chemical Eng., Nanjing Univ. of Science and Technology, China

Dr. Geng joined Baker Engineering and Risk Consultants, Inc. in 2003 to perform research and development of 3-D CFD code and visualization systems capable of simulating generation and propagation of blast and shock waves and their interaction with structures or buildings.

Prior to joining BakerRisk, Dr. Geng was a Professor at Nanjing University of Science and Technology where he managed a number of projects, focusing on the simulation of unsteady flows with moving components. He developed object-oriented 3D and 2D codes and visualization systems for application to flow-structure interactions, industrial explosions, detonation phenomena, and thermal and multiphase reacting flows. He taught several mechanical engineering courses in the areas of gas dynamics, computational fluid dynamics and combustion.

As an AvH (Alexander von Humboldt) research fellow at the Aachen University of Technology in Germany, Dr. Geng managed a project and conducted research in the field of multiphase reacting flow.

Professional Chronology: AvH Research Fellow, Aachen University of Technology, 1995-1997; Associate Professor, Nanjing Univ of Science and Technology, 1998-2000; Professor, Nanjing Univ of Science and Technology, 2001-2003; Baker Engineering & Risk Consultants, Inc., 2003-present

Memberships: Member of AvH (Alexander von Humboldt) Foundation, Germany; Committee member in Division of Shock Wave and Shock Tube, The Chinese Society of Mechanics

July 2006

MASSIMILIANO (MAX) KOLBE

Project Consultant II
Baker Engineering and Risk Consultants, Inc.

B.Eng., Mechanical Engineering, McGill University, Montreal, Canada
M.A.Sc., Mechanical Engineering, Concordia/McGill University, Montreal, Canada

Mr. Kolbe began work at Baker Engineering and Risk Consultants, Inc. (BakerRisk) in November of 2002. He has extensive experience in dynamic response instrumentation and high-speed data acquisition. His research background includes dust flammability and explosion, high-pressure detonations, and gas combustion in tubes. Since joining BakerRisk, Mr. Kolbe has been extensively involved in the West Pharmaceutical dust explosion investigation and conducted numerous experimental research projects including large-scale vapor cloud explosion tests (VCE's), vented enclosure explosions, high-pressure flammability tests and large-scale detonation tests.

Mr. Kolbe's background in combustion includes research work and participation in an accident investigation involving extreme high-pressure gas combustion. He specialized in gas detonations and dust combustion research in the Shock Wave Physics Group at McGill University, working with leading researchers in the field of detonations, Dr. J. H.S. Lee and Dr. R. Knystautas. He has also conducted research on the influence of obstacle geometry (congestion) on the transition from deflagration to detonation, and the mitigation and attenuation of detonations through porous and acoustic absorbing material.

In coordination with the Canadian Space Agency and the National Research Council (NRC) of Canada, Mr. Kolbe played an integral part in the testing and development of SHS technology (Self-Propagating High Temperature Synthesis). This technology involves the production of property specific materials through the combination and high-pressure combustion of elemental metal powders.

Professional Chronology: Shock Wave Physics Group, (Research Assistant, 2001-02); Baker Engineering and Risk Consultants, Inc. 2002-Present.

Registrations: Junior Engineer, Quebec Order of Engineers

Memberships: American Society of Mechanical Engineers (ASME)

Nov. 2004

J. KELLY THOMAS, Ph.D.

Manager, Blast Effects Section
Baker Engineering and Risk Consultants, Inc.

B.S., Nuclear Engineering, Texas A&M University
M.S., Nuclear Engineering, Texas A&M University
Ph.D., Nuclear Engineering, Texas A&M University

Dr. Thomas' current activities are focused on the development and application of empirical, analytical and numerical models and codes for the characterization of flammability and explosion phenomena. Dr. Thomas is also actively involved in the investigation of accidental industrial explosions, including vapor cloud explosions, bursting pressure vessels, runaway reactions, and internal explosions. Dr. Thomas's other activities include experimental investigations, explosion hazard evaluations, vented deflagration assessments, and the development of siting studies for petroleum and chemical processing plants.

Dr. Thomas has a broad range of experience in the safety analysis area, focusing on the development of phenomenological models to support consequence assessments, with the primary focus on explosions and energetic events modeling. Dr. Thomas developed numerous methods to calculate the potential for and consequences of gas-phase explosions involving radioactive liquid waste storage transport and processing facilities. The phenomena addressed by these methods include flammability criteria, peak deflagration pressure, deflagration source terms, and the potential for detonation. He wrote the explosion phenomena section for the Savannah River Site methodology manual, served on a panel which defined methodologies for explosion related phenomena to be used within the DOE complex, developed and taught a short course on explosion source term modeling, and has served on expert panels examining flammable gas issues at the Hanford DOE site. Dr. Thomas has also participated in the development of models for combustible gas transport and mixing in waste tanks and process vessels.

Dr. Thomas has also participated in evaluations of other technical areas in support of facility safety analyses. He led or participated in the development of accident scenarios, accident modeling, and quantification of resulting source terms for numerous DOE facilities. He developed operating parameter envelopes used to govern startup and test operations, and participated in the development of plant control and safety strategies for a radioactive liquid waste processing facility. Dr. Thomas has developed specifications for waste tank backup inerting, waste drum purge, and hydrogen bus venting systems, and participated in the development of vessel ventilation and purge system design modifications to enhance plant safety. He also participated in hazard and frequency evaluations for radioactive liquid waste storage, transport and processing facilities, and for hydrogen powered bus and mining vehicles.

Dr. Thomas has also managed and participated in projects dealing with the behavior of nuclear reactor materials and reactor systems integrity analysis, including: response of reactor core components to severe accidents, oxidation and emittance of reactor materials, irradiated steel mechanical properties, and reactor system structural integrity. In addition, Dr. Thomas led a nuclear fuels and materials research group at Texas A&M prior to beginning work in the safety analysis area. He directly participated in projects dealing with: fuel element thermal and mechanical analysis, space reactor design, development of a nitride fuels irradiation performance data base and associated correlations, validation and verification of fuel performance models and codes, space reactor material property correlations, and radioisotopic space power system design.

Professional Chronology: Texas A&M University (1986-90, Research Associate); Westinghouse Savannah River Company (Principal Engineer, 1995-98; Senior Engineer, 1990-95); Westinghouse Safety Management Solutions (1998-99, Principal Engineer); Baker Engineering and Risk Consultants, Inc. (Senior Engineer 1999-2000; Manager 2000-present).

Professional Registrations/Certifications: Certified Fire and Explosion Investigator (CFEI)

Professional Memberships: National Association of Fire Investigators (NAFI)

April 2004

José L. Torero, Ph.D.

Adjunct Consultant

PROFESSIONAL EXPERIENCE

2004–Present	Building Research Establishment Trust/Royal Academy of Engineering Professor of Fire Safety Engineering Director of the Edinburgh Centre for Fire Research School of Engineering and Electronics The University of Edinburgh, Edinburgh, UK
2004–Present	Technical Director, Fire Research Station (FRS) Building and Research Establishment (BRE), UK
2001-2004	BRE Trust/RAEng Chair in Fire Safety Engineering School of Engineering and Electronics The University of Edinburgh, Edinburgh, UK
2002-Present	Adjunct Associate Professor Department of Fire Protection Engineering University of Maryland, College Park, Maryland, USA
2000–2003	Affiliate Associate Professor Department of Aerospace Engineering University of Maryland, College Park, Maryland, USA
2000–2002	Associate Professor (on Leave 2001)
1995-2000	Assistant Professor Department of Fire Protection Engineering University of Maryland, College Park, Maryland, USA
1999-Present	Charge de Recherche, 1ere classe (en disponibilité) Centre National de La Recherche Scientifique, France
1996-2000	Visiting Researcher National Institute of Standards and Technology Building and Fire Research Laboratory Gaithersburg, MD 20899, USA
1995-1999	Charge de Recherche, 1ere classe (detaché) Centre National de La Recherche Scientifique Laboratoire de Combustion et de Detonique ENSMA-Université de Poitiers-UPR9028, France

1993-1995	Charge de Recherche, 2eme classe Centre National de La Recherche Scientifique Laboratoire de Combustion et de Detonique ENSMA-Université de Poitiers-UPR9028, France
1993	Post-Doctoral Fellow European Space Agency at the Laboratoire de Chimie Physique de la Combustion URA 872 au CNRS – Université de Poitiers, France
1992	Research Associate University of California at Berkeley at NASA Lewis Research Center - Cleveland, Ohio, USA
1989-1992	Research Assistant Combustion Laboratory University of California at Berkeley, USA

APPOINTMENTS

1993-94, 1997-98	University of Bremen (ZARM), Germany
1995	University of Texas at Austin
1995, 1996, 1998	Instituto Nacional de Tecnica Aeroespacial (INTA), Spain
1999	University of Poitiers, France
2001	University of Aix-Marseille, France
2002, 2003, 2004	Ecole des Mines St. Etienne
2002	Pontificia Universidad Catolica de Chile, Chile
2002, 2003, 2004	University of California, Berkeley
2003	ENSTIB, Epinal, France
2003	Universite de la Mediterranee, France
2004	University of California, San Diego

External Examiner

2003-Present	Glasgow Caledonian University, Fire Risk Engineering

ACADEMIC

Ph.D.	Mechanical Engineering – University of California, Berkeley
M.S.	Mechanical Engineering – University of California, Berkeley
B.S.	Mechanical Engineering – Pont. Universidad Catolica del Peru

CONTINUING EDUCATION

- Fire Phenomena/Enclosure Fires – Bureau of Alcohol Tobacco and Firearms, Maryland Fire and Rescue Institute, University of Maryland, August 1998.
- Control de Riesgos de Incendio – Pontificia Universidad Catolica de Chile, Santiago, Chile, November 1998.

- Feu et Combustion – Ecole National Superieure de Mecanique et d'Aerothechnique (ENSMA), Universite de Poitiers, France, March 1999.
- Seminaire sur le Management des risques d'Incedie, Univeriste de Poitiers-Site de Niort, France, January, 2000.
- Fire Phenomena/Enclosure Fires – Bureau of Alcohol Tobacco and Firearms, Maryland Fire and Rescue Institute, University of Maryland, August 2000.
- Fire Safety – Masters of Science Loss Prevention and Risk Management, ENSI-Bourges, Bourges, France, November 2000.
- Fire Safety – Masters of Science Loss Prevention and Risk Management, ENSI-Bourges, Bourges, France, December 2001.
- Fire Safety Engineering – Ecole des Mines St. Etienne, St. Etienne, France, January, 2002.
- Fire Science and Fire Investigation – The University of Edinburgh, April 2002.
- Performance Based Design of Fire Safety Systems – Pontificia Universidad Catolica de Chile, June 2002.
- Introduction to Fire Safety Engineering, – Ecole des Mines St. Etienne, St. Etienne, France, February, 2003.
- Fire Science and Fire Investigation – The University of Edinburgh, March 2003.
- Fire Dynamics and Fire Safety Engineering Design - The University of Edinburgh, March 2003.
- Ingenieria de Proteccion Contra el Fuego - Pontificia Universidad Catolica de Chile, June 2003.
- Fire Science and Fire Investigation – The University of Edinburgh, March 2004.
- Introduction to Fire Safety Engineering, – Ecole des Mines St. Etienne, St. Etienne, France, February, 2004.
- Concrete Structures in Fire – Pontificia Universidad Catolica de Chile, September, 2004.
- Introduction to Fire Safety Engineering, – Ecole Polytechnique de Marseille, Marseille, France, September, 2004.
- Introduction to Fire Safety Engineering, – Ecole des Mines St. Etienne, St. Etienne, France, February, 2005.

PROFESSIONAL REGISTRATION and AFFILIATIONS

MEMBERSHIP

Chartered Engineer – Engineering Council (2004)
The Institution of Fire Engineers (IFE)
Salamander Fire Protection Engineering Honour Society (Honorary)
American Society of Mechanical Engineers (ASME)
American Institute of Aeronautics and Astronautics (AIAA)
Combustion Institute
International Association for Fire Safety Science (IAFSS)
Society of Fire Protection Engineers (SFPE)
National Fire Protection Association (NFPA)
    NFPA - Latin American Section

PROFESSIONAL ACTIVITIES

1. Fire Technology Journal – Editorial Board, (2002-Present)

2. Fire Safety Journal – Editorial Board (2003- Present)

3. Fire Science and Technology – Editorial Board (2004-Present)

4. Republic of Peru – Special Advisor to the Vice-President of Peru on Fire Related Matters (2002-2003)

5. Pontificia Universidad Catolica de Chile: Consultant of Fire Safety Matters (2003-present)

6. Advisor to the National Association for State Fire Marshals (USA)

7. American Institute of Aeronautics and Astronautics (AIAA)
   - Member of the Micro-Gravity and Space Processes Technical Committee (1998-Present)
   - 37th AIAA Aerospace Science Meeting/13th Microgravity Science and Space Processing Symposium - Combustion Science Session Chair, 1999.
   - 38th AIAA Aerospace Science Meeting/14th Microgravity Science and Space Processing Symposium - Combustion Science Session Chair, 2000.
   - 39th AIAA Aerospace Science Meeting/15th Microgravity Science and Space Processing Symposium - Combustion Science Session Chair, 2001.

8. Combustion Institute
   - British Section: Committee Member (2002-Present)
   - Colloquium Chair –Fire and Explosions – 30th International Symposium on Combustion, Chicago, Illinois, USA (2004).
   - International Center for Heat and Mass Transfer, Mediterranean Combustion Symposium (1999) - Session Chair (Fire & Explosions).
   - 2nd Joint Sections Meeting of the Combustion Institute, Session Chair (Fire Research), March 2001.

9. European Space Agency (ESA).
   - Panel Reviewing the European Micro-gravity Combustion Programme (April 2004)
   - Peer Review Panels (1993-Present).

10. International Association for Fire Safety Science (IAFSS)
    - International Committee (2002-Present)
    - Program Committee, 8th International Symposium , Beijing, China, 2005.
    - Organizing Committee and Session Chair, 6th International Symposium, Poitiers, France,1999.
    - Web Page Manager.
    - Publication Committee, 4th International Seminar on Fire and Explosions Hazards, Londonderry, September 2003.
    - Nominating Committee Member (2001-Present)

11. NATO-International Science and Technology Center – ISTC Program
    - Review of the Program: Experimental and Theoretical Investigation on Filtration Combustion-Ignition and Development of a set of Criteria for Fire and Explosion Safety at some Industrial and Agricultural Enterprises *(Prof. Institute of Chemical Physics, Russian Academy of Science, Chernogolovka, Russia)*, September 1998.
    - Review of the Program: Experimental and Theoretical Investigation of a Procedure for Solid Waste Incineration Based on Filtration Combustion *(ENSMA, France), (CRITT, University of Poitiers, France) (Rusian Academy of Science, Chernogolovka, Russia))*, July 2000.
    - Proposal Reviewer: 2003-Present

12. National Aeronautics and Space Administration (NASA)
    - Peer Review Panels (1995-present)
    - HEDS-Mars or Bust, Fire Safety Group (1997)
    - Fires Safety Working Group (2001)

13. National Institute of Standards and Technology (NIST)
    - Office of Technology Innovation-Patent Reviewer
    - Proposal Reviewer (1996-2001)

14. National Science Foundation (NSF)
    - Proposal Reviewer

15. The World Bank
    - Consultant on Tropical Forest Fires – Environmental and Social Sustainable Development-Latin and the Caribbean Region (1998-99)

16. American Society of Mechanical Engineers
    - Member of the K-11 Committee on Fire and Combustion (2000-Present)

17. American Institute of Chemical Engineers
    - Session Chair – Heat Transfer in Porous Media, 35th International Heat Transfer Conference, Anaheim, California, 2001.

18. Underwriters Laboratory
    - STP-162 Foams Fire Suppression Systems Committee (2000-present)

19. Other:
    - Office of the Deputy Prime Minister (UK) – Fire Research Academy – Project Committee
    - Scientific Committee: 3rd Conference on Modeling and Simulation in Biology, Medicine and Biomedical Engineering, BioMedSim 2003, Beirut, 2003.
    - Scientific Committee/Session Chair: Jornada Técnica sobre "Los Modelos de Simulación Computacional de Incendios en la Ingeniería y la Investigación de Incendios" Universidad de Cantabria, Spain, 2004.
    - Session Co-Chair: Eurotherm 2006: Wildland Fire behaviour and effects: modelling and experiments.

- Invited Member: Groupement de Recherche (GDR) Feux, Centre National de la Recherche Scientifique, France (2004-Present).
- Session Chair in numerous other conferences and workshops.

REVIEWING ACTIVITIES

International Association for Fire Safety Science
Fire Safety Journal
Fire Technology Journal
The Combustion Institute
Combustion and Flame
Combustion Science and Technology
Combustion Theory and Modelling
Construction and Building Materials
ASME-Heat Transfer Division
AIAA Journal
AIChE-Heat Transfer Division
Measurement Science and Technology
Microgravity Science and Technology
ABCM - Associação Brasileira de Ciências Mecânicas
Journal of Physics:D-Applied Physics
International Journal of Thermal Sciences
Journal de Chimie Physique
Journal de Mecanique et Industries
Journal of Hazardous Materials
John Wiley and Sons (Book & Chapter Reviewer)
Encyclopedia of Polymer Science

PUBLICATIONS, PRESENTATIONS, and PATENTS

PUBLICATIONS

Chapters in Books

1. H. Y. Wang, J.L. Torero, L. Bonneau and P. Joulain "Numerical Simulation of Ethane-Air Diffusion Flames Established over a Flat Plate Burner: Comparison with Different Gravity Experiments," *Transport Phenomena in Combustion,* S.H. Chan Editor, **2**, Taylor and Francis Publishers, 1141-1152, 1996.

2. J. L. Torero, H. Y. Wang, P. Joulain and J. M. Most "Flat Plate Diffusion Flames: Numerical Simulation and Experimental Validation for Different Gravity Levels," *Lecture Notes in Physics*, Ratke, L. Walter, H. and Feuerbacher, Eds., Springer-Verlag, **464**, 401-408, 1996.*(Invited & Refereed)*

3. J. T'ien, H-Y. Shih, C-B. Jiang, H.D. Ross, F.J. Miller, A.C. Fernandez-Pello, J.L. Torero and D. C. Walther, "Mechanisms of Flame Spread and Smolder Wave propagation," Fire in Free Fall: Micro-Gravity Combustion, H. Ross, Editor, Academic Press Chapter 5, pp.299-418, 2001.

4. J.L. Torero, "The Risk Imposed by Fire to Buildings and how to Address it," The Protection of Civil Infrastructure from Acts of Terrorism, NATO Advanced Science Institute series, Kluwer Academic Publishers, Frolov and Becker Eds. (in press) 2004.

5. C. Lautenberger, J.L. Torero and A.C. Fernandez-Pello, "Considerations for Material Flammability," Chapter 2, *Flammability Testing of Materials in Building, Construction, Transport and Mining Sectors*, Apte Editor (in press) 2004.

Articles in Refereed Journals

1. J. L.Torero, M. Kitano and A. C. Fernandez-Pello, "Opposed Flow Smoldering of Polyurethane Foam," *Combustion Science and Technology*, **91** (1-3), 95-117, 1993.

2. J. L. Torero, A. C. Fernandez-Pello and D. Urban "Experimental Observations of the Effect of gravity Changes on Smoldering Combustion, " *AIAA Journal*, **31** (5), 991-996, 1994.

3. J.L. Torero, L.Bonneau, J.M.Most and P.Joulain "The Effect of Gravity on a Laminar Diffusion Flame established over a Horizontal Flat Plate," *Proceedings of the Combustion Institute*, 25, 1701-1709, 1994.

4. J. L. Torero, A.C.Fernandez-Pello and M.Kitano "Downward Smolder of Polyurethane Foam," *Fourth International Symposium on Fire Safety Science,* 409-420, 1994.

5. X. Zhou, J. L. Torero, J. C. Goudeau and B. Bregeon "On the Ignition and Propagation of a Reaction Front Through a Porous Fuel: Application to Mixtures Characteristic of Urban Waste," *Combustion Science and Technology,* 110-111 (1-6), 123-146, 1995.

6. J. L. Torero and A. C. Fernandez-Pello "Natural Convection Smolder of Polyurethane Foam, Upward Propagation," *Fire Safety Journal*, 24 (1), 35-52, 1995.

7. L. Audouin, G. Kolb, J. L. Torero and J. M. Most "Average Centerline Temperatures of a Buoyant Pool Fire Obtained by Image Processing of Video Recordings," *Fire Safety Journal*, 24 (2), 167-187, 1995.

8. J. L. Torero, L. Bonneau, J. M. Most and P. Joulain "On the Geometry of Laminar Diffusion Flames Established over a Flat Plate Burner," *Advances in Space Research*, 16 (7), 149-152, 1995.

9. L. Audouin, G. Kolb, J.L. Torero and J.M. Most "Response to the Letter by D.Milov Commenting the Paper Entitled: "Average Centerline Temperatures of a Buoyant Pool Fire Obtained by Image Processing of Video Recordings" (F.S.J., 24, 2, 1995)," *Fire Safety Journal*, 24 (4), 361-363, 1995.

10. D. P. Stocker, S. L. Olson, D. Urban, J.L. Torero, D. Walther and A.C. Fernandez-Pello,"Small Scale Smoldering Combustion Experiments in Microgravity," *Proceedings of the Combustion Institute*, 26, 1361-1368, 1996.

11. N. Wu, M. Baker, G. Kolb and J. L. Torero "Ignition, Flame Spread and Mass Burning Characteristics of Liquid Fuels on a Water Bed," *Spill Science and Technology Bulletin*, **3** (4), 209-213, 1996.

12. J. L. Torero and A. C. Fernandez-Pello "Forward Smoldering of Polyurethane Foam in a Forced Air Flow," *Combustion and Flame*, 106 (1-2), 89-109, 1996.

13. L. Brahmi, T. Vietoris, P. Joulain and J. L. Torero, "Experimental Study on the Stability of a Diffusion Flame Established in a Laminar Boundary Layer," *Microgravity Abstracts*, **5**, 80-87, 1998. *(in Japanese)*

14. L. Brahmi, T. Vietoris, J. L. Torero and P. Joulain, "Determination par camera Infrarouge des distributions de Temperature sur l'Enveloppe d'une Flamme de Diffusion Etablie sur un Bruleur Poreux Plan en Microgravite," *Enthropie,* 215, 69-73, 1998. *(in French)*

15. N. Wu, G. Kolb and J. L. Torero, "Piloted Ignition of a Slick of Oil on a Water Sublayer: The Effect of Weathering," *Proceedings of the Combustion Institute*, 27, 2783-2790, 1998.

16. T. Vietoris, J. L. Torero and P. Joulain, "Experimental Characterization of a Laminar Diffusion Flame in Micro-Gravity," *Journal de Chimie Physique*, 96, 1022-1030, 1999.

17. J. P. Garo, J. P. Vantelon, S. Gandhi and J. L. Torero "Determination of the Thermal Efficiency Pre-boilover Burning of a Slick of Oil on Water," *Spill Science and Technology Bulletin,* 5 (2), 141-151, 1999.

18. L. Brahmi, T. Vietoris, J. L. Torero and P. Joulain, "Estimation of Boundary Layer Diffusion Flame Temperatures by Means of an Infra-Red Camera under Micro-Gravity Conditions," *Measurement Science and Technology*, 10, 859-865, 1999.

19. R. T. Long, J. L. Torero, J. G. Quintiere and A. C. Fernandez-Pello, "Scale and Transport Considerations on Piloted Ignition of PMMA," *Sixth International Symposium on Fire Safety Science,* 567-578, 1999.

20. H. Y. Wang, J. L. Torero and P. Joulain, "Calculation of Vertical Parallel Wall Fires with Buoyancy Induced Flow," *Sixth International Symposium on Fire Safety Science,* 671-678, 1999.

21. T. Vietoris, P. Joulain and J. L. Torero "Experimental Observations on the Geometry and Stability of a Laminar Diffusion Flame in Micro-Gravity," *Sixth International Symposium on Fire Safety Science,* 373-386, 1999.

22. S. Leach, G. Rein, J. Ellzey, O. A. Ezekoye and J. L. Torero, "Kinetic and Fuel Property Effects on Forward Smoldering Combustion," *Combustion and Flame*, 120, 3, 2000.

23. M. K. Anderson, R. T. Sleight and J. L. Torero, "Ignition Signatures of a Downward Smolder Reaction," *Experimental Thermal and Fluid Science*, 21,1-3, 33-40, 2000.

24. M. Anderson, R. Sleight and J. L. Torero "Downward Smolder of Polyurethane Foam: Ignition Signatures," *Fire Safety Journal*, 35, 131-148, 2000.

25. Fernandez-Pello, A.C., Walther, D.C., Cordova, J.L., Steinhaus, T., Quintiere, J.G., Torero, J.L., and Ross, H., "Test Method for Ranking Materials Flammability in Reduced Gravity," *Space Forum*, 6, 237-243, 2000.

26. T. Vietoris, J. L. Ellzey, P.Joulain, S.N. Mehta and J.L. Torero, "Laminar Diffusion Flame in Micro-Gravity: The Results of the Mini-Texus 6 Sounding Rocket Experiment, *Proceedings of the Combustion Institute,* 28, 2000.

27. N. Wu, G. Kolb and J. L. Torero, "The Effect of Weathering on the Flammability of a Slick of Crude Oil on a Water Bed," *Combustion Science and Technology*, 161, 269-308, 2000.

28. M. Roslon, S. Olenick, D. Walther, J.L. Torero, A.C. Fernandez-Pello and H. Ross, "Micro-Gravity Ignition Delay of Solid Fuels," *AIAA-Journal,* v.39, No.12, pp. 2336-2342, Dec. 2001.

29. J.L. Cordova, D. C. Walther, J. L. Torero and A.C. Fernandez-Pello, "Oxidizer Flow Effects on the Flammability of Solid Combustibles," *Combustion Science and Technology,* v. 164, N0. 1-6, pp. 253-278, 2001.

30. Vietoris, T., Joulain, P. and Torero, J.L., "Gas-Gas and Gas-Solid Laminar Flat Plate Diffusion Flames in Micro-Gravity: Structure and Stability," *Micro-Gravity Science and Technology*, 13, 1, 3-7, 2001.

31. Worrell, C., Gaines, G., Roby, R., Streit, L. and Torero, J.L., "Enhanced Deposition, Acoustic Agglomeration and Chladni Figures in Smoke Detectors," *Fire Technology*, Fourth Quarter, Volume 37, Number 4, pages 343-363, 2001.

32. Wolin, S. D., Ryder, N. L., Leprince, F., Milke, J.A., Mowrer, F. W. and Torero, J.L., "Measurements of Smoke Characteristics in HVAC Ducts," *Fire Technology*, Fourth Quarter, Volume 37, Number 4, pages 363-395, 2001.

33. Torero, J.L., Vietoris, T., Legros, G., Joulain, P. "Evaluation d'un Nombre de Transfert de Masse Réel d'une Flamme Ascendante" *Journal de Physique IV*, 11, pp. 291-300, 2001. *(in French)*

34. Milke, J.A., Mowrer, F. W. and Torero, J.L., "Use of Optical Density-Based Measurements as Metrics for Smoke Detectors," *ASHRAE Transactions*, 8, 2002.

35. Torero, J.L., Vietoris, T., Legros, G., Joulain, P. "Estimation of a Total Mass Transfer Number from Stand-off Distance of a Spreading Flame," *Combustion Science and Technology*, 174 (11-12), pp.187-203 , 2002.

36. Rouvreau, S., Cordeiro, P., Joulain, P., Wang, H.Y. and Torero, J.L., "Numerical Evaluation of the Influence of Fuel Generation on the Geometry of a Diffusion Flame: Implications to Micro-Gravity Fire Safety," *Seventh International Symposium on Fire Safety Science,* 283-295, 2002.

37. Dakka, S.M., Jackson, G. S. and Torero, J.L., "Mechanisms Controlling the Degradation of Poly(methyl methacrylate) Prior to Piloted Ignition" *Proceedings of the Combustion Institute*, 29, 281-287, 2002.

38. Rouvreau, S., Joulain, P., Wang, H.Y., Cordeiro, P. and Torero, J. L. "Numerical Evaluation of Boundary Layer Assumptions Used for the Prediction of the Stand-off Distance of a Laminar Diffusion Flame" *Proceedings of the Combustion Institute*, 29, 2527-2534, 2002.

39. T. Rogaume, F. Jabouille, M. Auzanneau, J.C. Goudeau and J.L. Torero, "The Effects of Different Airflows on the Formation of Pollutants During Waste Incineration," *Fuel*, 81, 2277-2288, 2002.

40. G. Rein Soto-Yarritu, J.L. Torero and J.L. Ellzey, "Simulacion Numerica de Combustión Latente en Flujo Directo," *Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingenieria*, vol. 18, No. 4, 459-474, December 2002. *(in Spanish)*

41. Zhou, Y.Y., Walther, D.C., Fernandez-Pello, A.C., Torero, J.L., Ross, H.D., "Theoretical Predictions of Micro-Gravity Ignition Delay of Polymeric Fuels in Low Velocity Flows," *Micro-Gravity Science and Technology*, vol. XIV, 1, 44-50, 2003.

42. J.L. Torero, S.M. Olenick, J.P. Garo and J.P. Vantelon, "Determination of the Burning Characteristics of a Slick of Oil on Water, Spill Science and Technology Bulletin, v.8, 4, pp.379-390, 2003.

43. T. Rogaume, M. Auzanneau, F. Jabouille, J.C. Goudeau and J.L. Torero, "Computational Model to Investigate the Effects of Different Airflows on the Formation of Pollutants During Waste Incineration," *Combustion Science and Technology,* volume 175 (8), 2003.

44. A.S. Usmani, Y.C. Chung and J.L. Torero, "How Did the World Trade Center Collapsed: A New Theory," *Fire Safety Journal*, Volume 38, Issue 6, Pages 501-591, 2003.

45. C.L. Worrell, J.A. Lynch, G. Jomaas, R.J. Roby, L. Streit and J.L. Torero, "Effect of Smoke Source and Horn Configuration on Enhanced Deposition, Acoustic Agglomeration and Chladni Figures in Smoke Detectors," *Fire Technology*, 39, 309-346, 2003.

46. T. Rogaume, F. Jabouille, J.L. Torero, "Computational Model to Investigate the Mechanisms of NO_x Formation During Waste Incineration," *Combustion Science and Technology*, 176, 5-6, 925-943, 2004.

47. T.Ma, S.M. Olenick, M.S.Klassen, R.J. Roby and J.L. Torero, "Burning Rate of Liquid Fuel on Carpet (Porous Media)" *Fire Technology*, 40,3, 227-246, 2004.

48. G. Legros, P. Joulain, J.-P. Vantelon, C. Breillat and J. L. Torero "Epaisseur Optique d'une couche de suie formee par une flamme de diffusion en micropesanteur," *Journal de Mecanique et Industries*, 5, September-October, 2004. *(in French)*

49. Bar-Ilan, G. Rein, A.C. Fernandez-Pello, J.L. Torero, D.L. Urban, "Effect of Buoyancy on Forced Forward Soldering," *Experimental Thermal and Fluid Science*, 28, 743-751, 2004.

50. S. Olenick, M. Spearpoint, T. Steinhaus and J.L. Torero, "A flammability evaluation of motor vehicle upholstery materials," *Fire and Materials*, (in press), 2004.

51. F. Mowrer, J. Milke and J.L. Torero, "Comparative Driving Forces for Smoke Movement in Buildings," *Journal of Fire Protection Engineering* (in press), 2004.

52. G. Rein, A. Bar-Ilan, A. C. Fernandez-Pello, J. L. Ellzey, J. L. Torero, D. L. Urban, "Modeling of One-Dimensional Smoldering of Polyurethane in Microgravity Conditions," *Proceedings of the Combustion Institute*, vol. 30, (in press) 2004.

53. S. Rouvreau, P.Cordeiro, J.L. Torero and P. Joulain, Influence of g-jitter on a laminar boundary layer type diffusion flame, *Proceedings of the Combustion Institute*, vol. 30, (in press) 2004.

54. J.-P. Vantelon, B. Lodeho, S. Pignoux, J. L. Ellzey and J. L. Torero, Experimental Observations on the Thermal Degradation of a Porous Bed of Tires, *Proceedings of the Combustion Institute*, vol. 30, (in press) 2004.

55. A. Bar-Ilan, G. Rein, D.C. Walther, A.C. Fernandez-Pello, J.L. Torero and D.L. Urban, "The effect of Buoyancy on Opposed Smoldering," *Combustion Science and Technology*, (in press) 2004.

56. S. Rouvreau, J.L. Torero and P. Joulain, "Numerical evaluation of boundary layer assumptions for laminar diffusion flames in micro-gravity" *Combustion Theory and Modelling*, (in press) 2004.

57. G. Legros, P. Joulain, J.-P. Vantelon, A. Fuentes and J. L. Torero Influence of the Oxidizer Velocity on the Sooting Behaviour of a Laminar diffusion Flame Established in Micro-gravity," *Micro-gravity Science and Technology*, (in press) 2004.

Other Journal Publications

1. V. Brannigan and J. L. Torero, "The Expert's New Clothes: Arson "Science" After Kumho Tire," *Fire Chief Magazine*, 60-65, July 1999.

2. J.L. Torero and A. Atreya, "Book Review: Modélisation et Théorie des Flammes, by Borghi and Champion," *Applied Mechanics Reviews*, Book Review, 54, 5, B93, 2001.

3. J.D. Rivera, P. Matamala and J.L. Torero "Laboratorio de Ensayo y de Resistencia al Fuego," *Seventh International Symposium on Fire Safety Science,* 111-113, 2002.

4. J.L. Torero, "Review of the Book: Industrial Fire Protection Engineering by Robert G. Zalosh," Fire Safety Journal 39, 6, 528-533, 2004.

5. J.L. Torero, "Review of: Ignition Handbook, Principles and Applications to Fire Safety Engineering, Fire Investigation, Risk Management and Forensic Science by Vytenis Babrauskas, PhD," Journal of Fire Protection Engineering, 14, 229-232, 2004.

6. J.L. Torero, "Review of: Ignition Handbook, Principles and Applications to Fire Safety Engineering, Fire Investigation, Risk Management and Forensic Science by Vytenis Babrauskas, PhD," Fire Protection Engineering, 21, p.3, 2004.

7. J.L. Torero and B. Lane, "The Changing Face of Structural Design for Fire," *International Fire Buyers Guide*, August, 2004.

Articles in Refereed Proceedings (published or in press)

1. D. P. Stocker, S. L. Olson, J. L. Torero and A. C. Fernandez-Pello "Micro-Gravity Smoldering Combustion on the USML-1 Space Shuttle Mission," *ASME-HTD,* **269**, pp.99-110, 1993.

2. J. L. Torero, D. Urban and A. C. Fernandez-Pello, "Experimental Observations of the Effect of Gravity Changes on Smoldering Combustion," 31st Aerospace Science Meeting, Reno, NV, paper AIAA-93-0829, January 1993.

3. J. L. Torero, H. Y.Wang, L. Bonneau and P. Joulain, "Numerical Simulation of Ethane-Air Diffusion Flames Established over a Flat Plate Burner: Comparison with Normal and Micro-Gravity Experiments," *Zel'Dovich Memorial, International Conference on Combustion*, Moscow, Russia, 1994.

4. J. L. Torero, "A Theoretical Approach to Incineration as an Energy Efficient Way to Deal With Municipal Waste" *XIII Congresso Brasileiro e II Congresso Ibero-Americano de Engenharia Mecânica*, Belo Horizonte, Brasil, December 1995.

5. J. L. Torero, "A Simplified Theory to Asses the Burning Characteristics of a Slick of Oil on Water", *XIV Congresso Brasileiro de Engenharia Mecanica, COBEM 97*, Bauru, Sao Paulo, Brazil, December 1997.

6. J. L. Torero, N.J. Bahr, E. J. Carman, "Assessment of Material Flammability for Micro-Gravity Environments" *48th International Astronautical Federation Congress*, Turin, Italy, *IAF-97-J.2.02*, October 1997.

7. N. Wu, M. Baker, G. Kolb and J. L. Torero, "Ignition and Flame Spread Characteristics of Liquid Fuels on a Water Bed" *20th Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, Vancouver, Canada, vol.2, pp.769-795, June 1997.

8. G. Kolb, J. M. Most and J. L. Torero "Simulated Pool Fires Tilted by Wind: Flame Characteristics and Geometrical Considerations," *ASME-HTD*, 341-3, 19-36, 1997.

9. L. Brahmi, T. Vietoris, P. Joulain, L. David and J. L. Torero, "Experimental observations on the effect of parietal fuel injection on a low velocity reacting flow" 8th International Symposium on Flow Visualization/*Optical Diagnostics in Engineering*, Sorrento, Italy, September, 1998.

10. N. Wu, T. Mosman, S. M. Olenick and J. L. Torero, "Piloted Ignition of a Slick of Oil on a Water Sublayer: The Effect of Weathering and Flash Point," *21st Arctic and Marine Oil Spill Program (AMOP) Technical Seminar*, Edmonton, Canada, vol.2, pp. 633-651, June 1998.

11. J. Borlik, O. A. Ezekoye and J. L. Torero, "Strain and Heat Loss Modifications to a Counterflow Diffusion Flame," 7th AIAA/ASME Heat Transfer Conference, *ASME-HTD*, 357-1, 115-121, 1998.

12. M. K. Anderson, R. T. Sleight and J. L. Torero, "Ignition Signatures of a Downward Smolder Reaction," *Mediterranean Combustion Symposium*, 1263-1274, Antalya, Turkey, 1999.

13. J. L. Torero, T. Vietoris and P. Joulain, "Material Flammability Studies for Micro-Gravity Environments," *14th ESA Symposium on European Rocket and Balloon Programs and Related Research*, Potsdam (Berlin), Germany, ESA-SP-437, p. 505-510, June 1999.

14. J. L. Cordova, Y. Zhou, C. C. Pfaff, A. C. Fernandez-Pello, R. T. Long and J. L. Torero, "Effects of oxidizer Flow Characteristics on the Flammability Diagrams of Solid Combustible Materials," 5th ASME/JSME Thermal Engineering Joint Conference, *AJTE99-6244*, 1999.

15. L. Brahmi, T. Vietoris, P. Joulain, L. David and J. L. Torero, "The Effects of Parietal Fuel Injection on the Geometry of a Low Velocity Laminar Diffusion Flame," *37th AIAA Aerospace Science Meeting/13th Microgravity Science and Space Processing Symposium*, Reno, Nevada, paper AIAA -99-0581, January, 1999.

16. M. Roslon, S. Olenick, D. C. Walther, J. L. Torero, A. C. Fernandez-Pello and H. D. Ross, "Flow Effects on the Micro-Gravity Ignition Delay of Solid Fuels," *38th AIAA Aerospace Science Meeting,* Reno, Nevada, January, 2000.

17. J. L. Torero, "Material Properties that Control Ignition and Spread of a Fire in Micro-Gravity Environments," ASME Heat Transfer Conference, *ASME-NHTC-2000-12314*, 2000.

18. G. Jomaas, Y. Dagorn, B.T. Roberts, J. DuBois and J.L.Torero, "Flow Parameters Controlling a Diffusion Flame Established Behind a Backward Facing Step," ASME Heat Transfer Conference *ASME-NHTC-2000-12029*, 2000.

19. Y. Y. Zhou, D.C. Walther, J.L. Torero, A.C. Fernandez-Pello and H. D. Ross, "Theoretical Predictions of Microgravity Ignition Delay of Polymeric Fuels in Low Velocity Flows," *39th AIAA Aerospace Science Meeting,* Reno, Nevada, January, 2001.

20. B. Wentworth and J. L. Torero, " The Effect of External Radiation and a Porous Media on Ignition and Mass Burning of a Liquid Fuel," ASME-AIAA-AICHE 35th National Heat Transfer Conference, HTD-2001-11441, 2001.

21. H.Y. Wang, P. Joulain and J.L. Torero, "Using Direct Numerical Simulation and Large Eddie Simulation to Understand non-Premixed Flames in a Wind Tunnel," ICECA, China, 2001.

22. P. Cordeiro, P. Joulain, and J.L. Torero, "Experimental Study of Low Reynolds Number Reacting Flows: Gas-Gas Laminar Flat Plate Diffusion Flame in Micro-Gravity," 18th Colloquium on the Dynamics of Explosions and Reactive Systems, Seattle, Washington, July 2001.

23. S. Dakka and J.L. Torero, "The Effect of Pyrolysis Kinetics on Piloted Ignition of PMMA," ASME 2001 International Congress and Exposition, New York, November 2001.

24. A.C. Fernandez-Pello, J.L. Torero and H.D.Ross, "Forced Ignition and Flame Spread Tests," AIAA-2001-5080, ISS Utilization Conference, Orlando, December 2001.

25. Torero, J.L., Vietoris, T., Legros, G., Joulain, P. "Estimation of a Total Mass Transfer Number from Stand-off Distance of a Spreading Flame," *Second Mediterranean Combustion Symposium*, Egypt, 2002.

26. Bar-Ilan, G. Rein, and A.C. Fernandez-Pello, J.L. Torero and D.L. Urban, "Micro-Gravity Forward Smolder Experiments in the Space Shuttle," *41st AIAA Aerospace Science Meeting,* Reno, Nevada, January, 2003.

27. Bar-Ilan, G. Rein, A.C. Fernandez-Pello, J.L. Torero, D.L. Urban, "Effect of Buoyancy on Forced Forward Soldering," 3rd Mediterranean Combustion Symposium, Marrakech, June 2003.

28. G. Legros, J.L. Torero, P. Joulain, J.-P. Vantelon and C. Breillat "Estimation of a Soot Layer Optical Thickness Produced by a Diffusion Flame Established in Micro-Gravity," 3rd Mediterranean Combustion Symposium, Marrakech, June 2003.

29. J.-P. Vantelon, B. Lodeho, S. Pignoux, J. L. Ellzey and J. L. Torero "Experimental Study of the Degradation of a Porous Bed of Tires," 3rd Mediterranean Combustion Symposium, Marrakech, June 2003.

30. T. Rogaume, F. Jabouille, J.L. Torero, "Computational Model to Investigate the Mechanisms of NO_x Formation During Waste Incineration, 3rd Mediterranean Combustion Symposium, Marrakech, June 2003.

31. Rogaume, T., Auzanneau, M., Jabouille, F., Goudeau, J.-C. and Torero, J.L. "The Effects of Different Combustion Regimes on the Formation of NO in Municipal Waste Incineration" Clean Air 2003, Lisbon, Portugal, July 2003.

32. A.Usmani, Y.C. Chung and J.L. Torero, "An Assessment of the Stability of the World Trade Center Twin-Towers in a Major Fire," SFPE-SEI Conference on Designing Structures for Fire, Baltimore, Maryland, September, 2003.

33. D. J. Hill, J.L. Torero, "Experimental Characterization of the Effect of Charring on the Residual Load Carrying Capacity of a Structural Fibre Reinforced Composite" Interflam, July 2004.

34. B. Lane, S. Lamont, A.S. Usmani, J.L. Torero, G. Flint and A. Jowsey, "Robust Design of Tall Buildings in Fire-The Use of Analysis for Structural Fire Engineering Solutions," Interflam, July 2004.

35. Jowsey, J.L. Torero and A.S. Usmani, "Modelling of Structures in Fire: An Example of the Boundary Condition," Los Modelos de Simulación Computacional en la Ingeniería y la Investigación de Incendios, Universidad de Cantabria, October, 2004.

Monographs and Reports

1. P. Joulain, and J. L. Torero, "Gas Generator Induced Flow and Its Effects on Fire Flame Extinction," NIST-GCR-98-745, 1998.

2. N. Wu and J. L. Torero, " Enhanced Burning of Difficult to Ignite/Burn Fuels Including Heavy Oils," NIST-GCR-98-750, 1998.

3. Friedman, R., Altenkirch, R., Pedley, M. and Torero, J.L., "Workshop on Research for Space Exploration: Physical Sciences and Process Technology - Fire Safety," NASA/CP-1998-207431, May 1998.

4. Jomaas, G., Roberts, B.T., DuBois, J. and Torero, J.L., "A Study of the Mechanisms Leading to the Re-Ignition in a Worst-Case Fire Scenario," NIST GCR 01-806-2001.

5. Usmani, A. and Torero, J.L. "Disaster Simulation and Emergency Response," HPC and Scientific Opportunity, *The Scientific Case for the Large Facilities Roadmap Computing Infrastructure*, EPSRC Report, 2003.

Articles in Conference Proceedings

1. J. L. Torero, M. Kitano and A. C. Fernandez-Pello, "Gravitational Effects on Smoldering Combustion" *Joint Canadian and WSS / Combustion Institute*, Banff, Canada, April 1990.

2. J. L. Torero, M. Kitano and A.C. Fernandez-Pello, "Mixed Flow Smolder of Polyurethane Foam," *WSS / Combustion Institute, Fall Session*, La Jolla, California, paper 90-41, September 1990.

3. J.L. Torero, M. Kitano and A. C. Fernandez-Pello, "Co-Current Smolder of Polyurethane Foam" *WSS / Combustion Institute, Fall Session*, Boulder, Colorado, paper 91-27, October 1991.

4. J. L. Torero, A. C. Fernandez-Pello and D. Urban, "Variable Gravity Experiments on Smoldering Combustion," *WSS / Combustion Institute, Fall Session*, Berkeley, California, September 1992.

5. J. L. Torero, L. Bonneau, J. M. Most and P. Joulain, "On the Effect of Gravity on Large Scale Diffusion Flames Representative of Fires" *International Workshop on Micro-gravity Experiments, COMET 7*, Orleans, France, July 1993.

6. J. L. Torero, L. Bonneau, J. M. Most and P. Joulain, "Laminar Diffusion Flames Established over a Flat Plate Burner under Micro-Gravity Conditions: The Effect of Oxygen Concentration" *Microgravity Science Symposium, COSPAR '94*, Hamburg, Germany, July 1994.

7. J. L. Torero, L. Bonneau, J. M. Most, and P. Joulain, "Laminar Diffusion Flames Established over a Flat Plate Burner under Micro-Gravity Conditions" International Workshop on Short Term Experiments under Strongly Reduced Gravity Conditions, Bremen, Germany, July 1994.

8. J. M. Most, J. Chen, J. L. Torero, P. Mandin, B. Sztal and J. Baillargeat, "Caracterisation d'une Flamme de Diffusion en Surgravité" *4ème Congres Francophone de Velocimetrie Laser*, Poitiers, France, September 1994.

9. J. L. Torero, L. Bonneau, H. Y. Wang, J. M. Most, P. Joulain, D. Durox, M. Briant and J. P. Têtu, "On the Effect of Gravity on Gas Diffusion Flames" *Scientific Workshop on Parabolic Flights,* November 1994.

10. B. Fungtammasann, P. Jitreepit, J. L. Torero and P. Joulain "An Experimental Study on the Combustion Characteristics of Sawdust in a Cyclone Combustor" *European-Asian Conference on Combustion of Solids and Treatment of Products*, Hua Hin, Thailand, February 1995.

11. D. P. Stocker, S. L. Olson, J. L. Torero and A. C. Fernandez-Pello, "Micro-Gravity Smoldering Combustion on the USML-1 Space Shuttle Mission," *Third International Micro-gravity Combustion Conference*, NASA Conference Publication 10174, NASA-Lewis Research Center, Cleveland-Ohio, U.S.A., April 1995.

12. J. L. Torero, J. M. Most and P. Joulain, "On the Effect of Pressure, Oxygen Concentration, Air-flow and Gravity on Simulated Pool Fires," *Third International Micro-gravity Combustion Conference*, NASA Conference Publication 10174, NASA-Lewis Research Center, Cleveland-Ohio, U.S.A., April 1995.

13. J. M. Most, J. L. Torero and P. Joulain, "Influence des Forces de Floittabilite sur le Comportement d'une Flamme de Diffusion, Flammes en Apesanteur" *Point Science, Institute Pour la Surete Nucleaire (IPSN),* May 1995.

14. H. Y. Wang, J. L. Torero, P. Joulain and J. M. Most, "Numerical and Experimental Study of Ethane-Air Diffusion Flames at Different Gravity Levels" *Joint Meeting of the French and German Sections of the Combustion Institute*, Mulhouse, France, October 1995.

15. J. P. Garo, J. P. Vantelon and S. Gandhi and J. L. Torero, "Some Observations on the Pre-Boilover Burning of a Slick of Oil on Water" *19th Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, Calgary, Canada, vol. 2, pp. 1611-1626, June 1996.

16. S. Gandhi , J. L. Torero, J. P. Garo and J. P. Vantelon , "Pre-Boilover Burning of a Slick of Oil on Water" *Annual Conference on Fire Research*, NIST-IR-5904, NIST, October 1996.

17. G. Kolb, L. Audouin, J. M. Most and J. L. Torero, "Confinement Effects on the Mean Flame Height of a Buoyant Diffusion Flame," *Spring Meeting, Central States Section*, The Combustion Institute, Point Clear, Alabama, April, 1997.

18. J. Borlik, O. A. Ezekoye and J. L. Torero, "Flame Extinction in a Strained Vortical Flow," *Spring Meeting, Central States Section*, The Combustion Institute, Point Clear, Alabama, April, 1997.

19. J. L. Cordova, J. Ceamanos, A. C. Fernandez-Pello, R. T. Long, J. L. Torero and J. G. Quintiere, "Flow Effects on the Flammability Diagrams of Solid Fuels" *4th International Micro-Gravity Combustion Workshop*, NASA Conference Publication 10194, Cleveland, Ohio, May, 1997.

20. J. Sutula, J. Jones, J. L. Torero, J. Borlik and O. A Ezekoye, "Diffusion Flame Extinction in a Low Strain Flow" *4th International Micro-Gravity Combustion Workshop*, NASA Conference Publication 10194, Cleveland, Ohio, May, 1997.

21. L. Brahmi, T. Vietoris, P. Joulain and J. L. Torero, "Experimental Study on the Stability of a Diffusion Flame Established in a Laminar Boundary Layer" *4th International Micro-Gravity Combustion Workshop*, NASA Conference Publication 10194, Cleveland, Ohio, May, 1997.

22. P. Joulain, and J. L. Torero, "Influence des Forces de Gravite sur la Structure des Flammes de Diffusion Representatives d'Incendies," E.S.A. Workshop on Advanced Combustion Research, Orleans, France, September, 1997.

23. N. Wu and J. L. Torero, "Piloted Ignition of a Slick of Oil on Water," *Eastern States Section of the Combustion Institute*, Fall Technical Meeting, October, 1997.

24. G. Kolb, J. L. Torero, J. M. Most and P. Joulain "Cross-Flow Effects on the Flame Height of an Intermediate Scale Diffusion Flame," *International Symposium on Fire Science and Technology (ISFST-97),* Seoul, Korea, November, 1997.

25. N. Wu, M. Baker, G. Kolb and J. L. Torero, "Burning Characteristics of Liquid Fuels on a Water Bed: Ignition and Flame Spread" *2nd International Conference on Fire Research and Engineering*, NIST Gaithersburg, Maryland, August 1997.

26. L. Brahmi, T. Vietoris, J. L. Torero and P. Joulain "Etude de la Stabilite et de l'Extinction d'une Flamme de Diffusion Laminaire Etablie sur une Bruleur Plat en Micro-Gravite", *13eme Congres Francais de Mecanique*, Poitiers, France, September 1997.

27. L. Brahmi, T. Vietoris, J. L. Torero and P. Joulain, "Utilisation d'une Camera Infra-Rouge Pour Determiner les Distributions de Temperature d'une Flamme de Diffusion Etablie Sur une Bruleur Plat en Micro-Gravite" *5eme Journees Europeennes de Thermodynamique Contemporaine*, Toulouse, September 1997.

28. L. Brahmi, T. Vietoris, J. L. Torero and P. Joulain, "Etude de la Structure des Flammes de Diffusion Etablies sur une Surface Combustible dans un Environnement a Gravite Reduite," *Journees du Programme de Recherche Concertee-Groupement de Recherche 1185*, CNRS, St.Pierre D'Oleron, May, 1998.

29. C. Fernandez-Pello, D. C. Walther, J. L. Cordova, T. Steinhaus, J. G. Quintiere, J. L. Torero and H.D. Ross, "Flow Effects on Flammability Diagrams of Solid Fuels: Micro-Gravity Influence on Ignition Delay," Drop Tower Days, JAMIC, Hokkaido, Japan, 1998.

30. P. Joulain, H. Y.Wang and J. L. Torero, "Contribution to the Modeling of Vertical Burning Walls," *3rd Asia-Oceania Symposium on Fire Science and Technology*, Singapore, June 1998.

31. L. Brahmi, L. David, T. Vietoris, J. L. Torero and P. Joulain, "Resultats Experimentaux Concernant un Ecoulement Etabli sur une Plaque Plane Avec Injection Parietale Uniforme Pour de Tres Basses Vitesses," *6ème Congres Francophone de Velocimetrie Laser*, Institute Saint Louis, France, September 1998.

32. J. G. Quintiere, J. L. Torero, R. T. Long, S. E. Dillon, N. Wu and D. Heater, "Material Fire Properties," international Aircraft Fire and Cabin Safety Research Conference," Atlantic City, New Jersey, November, 1998.

33. T. Steinhaus, S. M. Olenick, A. Sifuentes, R. T. Long and J. L. Torero, "A Method for Assessing Material Flammability for Micro-Gravity Environments," Joint Meeting of the United States Sections, The Combustion Institute, Washington, D.C., March 1999.

34. J. A. Sutula, S. N. Mehta, J. L. Torero and O. A. Ezekoye, "Buoyancy Effects on a Counter-Flow Diffusion Flame," Joint Meeting of the United States Sections, The Combustion Institute, Washington, D.C., March 1999.

35. T. Vietoris, P. Joulain and J. L. Torero, "Flow Considerations on the Stability of a Laminar Diffuison Flame in Micro-Gravity," Joint Meeting of the United States Sections, The Combustion Institute, Washington, D.C., March 1999.

36. J. L. Cordova, D. C. Walther, A. C. Fernandez-Pello, T. Steinhaus, J. L. Torero, J. G. Quintiere and H. Ross, "Flow Effects on the Flammability Diagrams of Solid Fuels: Micro-Gravity Influence on Ignition Delay," *5th International Micro-Gravity Combustion Workshop*, NASA Conference Publication, Cleveland, Ohio, May, 1999.

37. J. A. Sutula, J. L. Torero and O. A. Ezekoye, "Experimental Observations on a Low Strain Counter-Flow Diffusion Flame: Flow and Buoyancy Effects," *5th International Micro-Gravity Combustion Workshop*, NASA Conference Publication, Cleveland, Ohio, May, 1999.

38. T. Vietoris, P. Joulain, J. L. Torero, "Laminar Diffusion Flames In Micro-Gravity: Experimental Results Leading to Mini-Texus-6," *5th International Micro-Gravity Combustion Workshop*, NASA Conference Publication, Cleveland, Ohio, May, 1999.

39. P. Joulain, T. Vietoris and J. L. Torero, "Structure and Stability of a Laminar Flat Plate Difusion Flame in Micro-Gravity," *International Seminar on Micro-Gravity Combustion*, Tokyo, Japan, August, 1999.

40. S. Olenick, M. Roslon, D. Walther, J. L. Torero, A.C. Fernandez-Pello and H. Ross, "Flow Effects on the Microgravity Piloted Ignition Delay of Solid Fuels" *Proceedings of the International Seminar on Microgravity Combustion*, Institute of Fluid Science, Tohoku University, Sendai, Japan, August, pp 172-181, 1999.

41. P. Joulain, T. Vietoris, L. Brahmi, J. L. Torero, "Etude de la Structure des Flammes de Diffusion Representatives de Situation d'Incendie dans une Environement de Micro-gravite," *Journees du Programme de Recherche Concertee-Groupement de Recherche 1185*, CNRS, September, 1999.

42. J. L. Torero, "Computations and Experiments to Support Fire Investigations: Applying Fire Science in Fire Investigations," *NFPA Fall Meeting*, November, 1999.

43. M. Roslon, S. Olenick, D. Walther, J.L. Torero, A.C. Fernandez-Pello and H. Ross "Microgravity Ignition Delay of Solid Fuels in Low Velocity Flows," Spring Meeting of the Western States Sections, The Combustion Institute, Boulder, Colorado, March 2000.

44. P. Joulain, T. Vietoris, P. Cordeiro, S. Rouvreau, "Etude de la Structure des Flammes de Diffusion Representative des Situationes d'Incendie dans un Environement de Microgravite," *Phenomenes de Transport et Transition de Phase en Micropesanteur*, Grenoble, France, June 2000.

45. J.L. Torero and F.W. Mowrer "A New Approach to Interpreting Ignition Test Data," *31st International Conference on Fire Safety*, Columbus, Ohio, July 2000.

46. P. Joulain, T. Vietoris and J.L. Torero, "Gas-Gas and Gas-Solid Laminar Flat Plate Diffusion Flames in Micro-Gravity: Structure and Stability," *Drop Tower Days*, Bremen, Germany, September 2000.

47. T. Vietoris, P. Joulain and J.L. Torero, "Study of Micro-Gravity Gas-Solid Combustion in a Sounding Rocket," *First International Symposium on Microgravity Research and Applications in Physical Sciences and Biotechnology*, Sorrento, Italy, September 2000.

48. P. Joulain, H.Y. Wang and J.L. Torero, "Modelisation des Incendies: Cas des feu des Parois Horizontales et Verticales," La Combustion et sa Modelisation, Marseille, France, October 2000.

49. C. Worrell, M. Holton, R. Roby, L. Streit and J.L. Torero, "Acoustic Agglomeration and Deposition of Soot in Smoke Detectors, a Method For Determining if a Smoke Detector Alarmed," *NFPA Fire Detection and Suppression Research Application Symposium*, Orlando, Florida, February 2001.

50. S.D. Wollin, N.L. Ryder, F. Leprince, J.A. Milke, F.W. Mowrer and J.L. Torero, "Measurements of Smoke Characteristics in HVAC Ducts," *NFPA Fire Detection and Suppression Research Application Symposium*, Orlando, Florida, February 2001.

51. G. Legros, K. Blase, J.L. Torero and P. Joulain, "Evaluation of a Realistic Mass Transfer Number from Images of an Upward Spreading Flame," 2nd Joint Sections Meeting of the Combustion Institute, March 2001.

52. S.M. Dakka, G.S. Jackson and J.L. Torero, "TGA/MS Studies of Thermal and Oxidative Degradation of Poly(methyl methacrylate), 2nd Joint Sections Meeting of the Combustion Institute, March 2001.

53. S.M. Dakka, G.S. Jackson and J.L. Torero, "On the Effect of Pyrolysis Kinetics on Ignition Delay Times of Poly(methyl methacrylate)," International Mechanical Engineering Congress and Exposition (IMECE), New York, November 2001.

54. S. Rouvreau, H.Y. Wang, P. Joulain and J.L. Torero, "Simulation Numerique Directe sur les feux de Parois sous Gravite Reduite," Colloque Science de la Matiere et Microgravite, ESPCI, Paris, France, May 2001.

55. P. Cordeiro, G. Legros, P. Joulain and J.L. Torero, "Characterisation de la Structure des Flammes de Diffusion de Type Plaque Plane par Differents Methodes optiques (emission Visible et Radicalaire OH et CH, PIV)," Colloque Science de la Matiere et Microgravite, ESPCI, Paris, France, May 2001.

56. G. Legros, P. Joulain and J.L. Torero, "Characterizsation du nom de Mransfert de Masse par des Images Video," Colloque Science de la Matiere et Microgravite, ESPCI, Paris, France, May 2001.

57. P. Cordeiro, P. Joulain, and J.L. Torero, "Characterization of a Laminar Flat Plate Diffusion Flame in Micro-Gravity Using P.I.V., Visible and CH Emissions," *6^th^ International Micro-Gravity Combustion Workshop*, NASA Conference Publication, Cleveland, Ohio, May, 2001.

58. Y.Y. Zhou, D.C. Walther, A.C. Fernandez-Pello, S. Olenick, J.L. Torero and H. Ross, "Experimental and Numerically Predicted Piloted Ignition Delay in Reduced Gravity," *6^th^ International Micro-Gravity Combustion Workshop*, NASA Conference Publication, Cleveland, Ohio, May, 2001.

59. J.A. Milke, F. W. Mowrer and J.L. Torero, " Duct Smoke Detector Research," NFPA World Fire Safety Congress and Exposition, Anaheim, California, May 2001.

60. S.Wolin, N. Ryder, F. LePrince, J. Milke, F. Mowrer and J.L. Torero, NFPA World Fire Safety Congress and Exposition, Minneapolis, Minnesota, May 2002.

61. J.A. Milke, F. W. Mowrer and J.L. Torero, " Duct Smoke Detector Research: Final Report" NFPA World Fire Safety Congress and Exposition, Minneapolis, Minnesota, May 2002.

62. C. Worrell, J. A. Lynch, G. Jomaas, R. J. Roby, L. Streit and J. L. Torero, "Effect of Smoke Source and Horn Configuration on Enhanced Deposition, Acoustic Agglomeration, and Chladni Figures in Smoke Detectors," *NFPA Fire Detection and Suppression Research Application Symposium*, Orlando, Florida, February 2002.

63. S. Rouvreau, H.Y. Wang, P. Joulain and J. L. Torero, "Numerical Simulations of Gas Diffusion Flames in Micro-Gravity on a Flat Plate in a Flow of Oxidizer Parallel to its Surface: Stand-off Distance and Boundary Layer Assumptions," 9th International Symposium on Numerical combustion, Sorrento, Italy, April 2002.

64. T. Rogaume, J. Tezanou, F. Jabouille, and J.L. Torero, "The effects of different combustion regimes on the formation of NO in municipal waste incineration," Joint Meeting of the US Sections of the Combustion Institute, Chicago, March 2003.

65. G. Legros, P. Joulain, J.-P. Vantelon, C. Breillat and J. L. Torero "Comportement Radiatif d'une Flamme de Diffusion se Propageant en Micropesanteur," Congres Française de Mécanique, Nice, France, September 2003.

66. P. Cordeiro, G. Legros, S. Rouvreau, P. Joulain and J. L. Torero, "Detailed Description of the Structure of a Low Velocity Laminar Diffusion Flame in Microgravity," 7th International Workshop on Microgravity Combustion, Cleveland, June 2003.

67. A.C. Fernandez-Pello, D.Rich, J.L. Torero and H. Ross, "Flammability Diagrams of Combustible Materials in Microgravity: Effect of Fiber concentration on Polyethylene," 7th International Workshop on Microgravity Combustion, Cleveland, June 2003.

68. A.C. Fernandez-Pello, A. Bar-Ilan, G. Rein, D.L. Urban and J.L. Torero, "Forced Forward Smoldering Experiments Aboard the Space Shuttle," 7th International Workshop on Microgravity Combustion, Cleveland, June 2003.

69. M. Coutin, A. S. Rangwala, J. L. Torero and S.G. Buckley, "Material Properties Governing Co-current Flame Spread: The Effect of Air Entrainment" 7th International Workshop on Microgravity Combustion, Cleveland, June 2003.

70. R. Carvel, D.D. Drysdale and J.,L. Torero, "Fire Behaviour of Composite Walls," 4th International Seminar on Fire and Explosion Hazards, Londonderry, September 2003.

71. C. Lautenberger, A. Stevanovic, D. Rich, J. L. Torero , A.C. Fernandez-Pello, "An experimental and theoretical study on the ignition delay time of composite materials," *Western States Fall Technical Meeting*, UCLA, Los Angeles California, USA, October 2003.

72. S. Rangwalla, J. L. Torero and S. G. Buckley, "Towards determination of the B number for co-current flame spread using the Fire Dynamic Simulator (FDS) code: Comparison between model and experiment," *Western States Fall Technical Meeting*, UCLA, Los Angeles California, USA, October 2003.

73. C. Lautenberger, A. Stevanovic, D. Rich, J. L. Torero , A.C. Fernandez-Pello, "Effect of Material Composition on Ignition Delay of Composites," *COMPOSITES 2003 Convention and Trade Show,* Composites Fabricators Association, Anaheim, California, USA, October 2003.

74. G. Legros, J.P. Vantelon, P. Joulain and J.L. Torero, "Influence of the oxidizer velocity on the sooting behaviour of a laminar diffusion flame established in microgravity," International Symposium on Physical Sciences in Space (ISPS), Toronto, May 2004.

75. S. Rouvreau, P. Cordeiro, G. Legros, P.Joulain and J.L. Torero, "On the influence of G-jitter on the stand-off distance of a laminar diffusion flame," International Symposium on Physical Sciences in Space (ISPS), Toronto, May 2004.

76. S. G. Buckley, A. Rangwala, J.L. Torero, Modeling and analysis of co-current flame spread Applied to the upward burning of PMMA," Workshop on Strategic Research to Enable NASA's Exploration Missions, July, 2004.

77. Roby, R., Klassen, M., Olenick, S. and Torero, J.L., Modelling of Fire Suppression in Spacecraft, Workshop on Strategic Research to Enable NASA's Exploration Missions, July, 2004.

78. Fernandez-Pello, A.C., Rich, D., Lautenberg, C. and Torero, J.L. "Forced Ignition and Spread Test for Microgravity Material Flammability Assessment, Workshop on Strategic Research to Enable NASA's Exploration Missions, July, 2004.

79. Jowsey, L.A. Drnge and J.L. Torero, "A Case Study on Building Specifications," 5th International Conference on Performance Based Codes and Fire Safety Design Methods in Fire Safety Engineering, Luxemburg, October, 2004.

80. Jowsey and J.L. Torero, "Determination of Fire Triggered Collapse Mechanisms of Multi-Storey Steel Framed Structures: A Case Study," Fire Service College Annual Conference (RE04) November 24-25, 2004.

81. Fuentes, G. Legros, P. Joulain, J.P. Vantelon and J. Torero, Evaluation of the Extinction Factor in a Laminar Flame Established over a PMMA Plate in Microgravity, Drop Tower Days, Bremen, September 2004.

82. Jowsey, J.L. Torero, A. Usmani, S. Lamont and B. Lane, Determination of Fire Triggered Collapse Mechanisms of Multi-Storey Steel Framed Structures: A Case Study, Eurostel, 2005.

83. G. Flint, A. Usmani, J.L. Torero, S. Lamont and B. Lane, "Analysis of undamaged WTC Twin-Towers structure subjected to large fires", Eurostel, 2005.

84. A.S. Usmani, G.R. Flint, Allan Jowsey, Susan Lamont, Barbara Lane and Jose Torero, "Modelling of the collapse of large multi-storey steel frame structures in fire," 4th International Conference on Advances in Steel Structures, Shanghai, June, 2005.

85. G. Rein, A. C. Fernandez-Pello, J. L. Torero and D. L. Urban, "On the Derivation of Polyurethane Foam Kinetics using Genetic Algorithms and its Application to Smoldering," ICCMHT, Paris, 2005.

86. G. Legros, A. Fuentes, B. Rollin, P. Joulain and J.L. Torero, "Extinction Simulation of a Diffusion Flame Established in Microgravity," ICCMHT, Paris, 2005.

Invited Conference Lectures

1. J. L. Torero, "Laminar Diffusion Flames Established over a Flat Plate Burner under Micro-Gravity Conditions," *International Workshop on Short Term Experiments under Strongly Reduced Gravity Conditions*, Bremen, Germany, July 1994.

2. J. L. Torero, "Diffusion Flames in Micro-Gravity," *Meeting of the Physical Sciences Working Group*, Berlin, Germany, April, 1995.

3. J. L. Torero, "Numerical Simulation of Flat Plate Ethane-Air Diffusion Flames and Experimental Validation at Different Gravity Levels," *9th European Symposium on Gravity Dependent Phenomena in Physical Sciences*, Berlin, May 1995.

4. J. L. Torero, *The Emmons Problem: Experimental Results and Progress Leading to a MiniTexus Experiment*, ESA-Sounding Rocket Experiments Workshop, ESTEC, Noordwijk, The Netherlands, September 1998.

5. J. L. Torero, *Material Flammability and Fire Safety*, Society of Fire Protection Engineers, Chesapeake Chapter, Maryland, September, 1998.

6. J. L. Torero, *La Formation de l'Ingenieur Incendie-Programmes Developpes aux Etats Unis et dans d'Autres Pays*, SFPE Chapitre Francaise, Les Salons du Grand Louvre, October 1998.

7. J. L. Torero, *Educación en Ingeniería de Protección Contra Incendios*, Primer Foro Regional NFPA, Lima '99, Lima, Peru, October, 1999.

8. J.L. Torero, *Challenges and Needs in Fire Protection Engineering Research and Education*, European Seminar on Environmental Risks, Niort, France, October 2000.

9. J.L. Torero, "Cooperation and Student Exchange Between the University of Maryland and French Higher Education Institutions," Global E3 Annual Meeting, Lake George, New York, June 2001.

10. J.L. Torero, "The Mass Transfer Number as a Criterion for Spacecraft Material Flammability," Workshop on Research Needs in Fire Safety for the Human Exploration and Utilization of Space, NASA Glenn Research Center, Cleveland, Ohio, June 2001.

11. J.L. Torero, "The Role of Fire Science in Fire Investigation," Fire Safety and Rescue Asia Conference, Singapore, November, 2001.

12. Torero, J. L., Quintiere, J. G. & Steinhaus, T., "Fire Safety in High-rise Buildings: Lessons Learned from the WTC," 51st Jahresfachtagung der Vereingung zur Forderrung des Deutschen Brandschutzez e. V., Dresden, Germany, 2002.

13. Torero, J.L. "Fire and the Environment," International Workshop on Environmental Risk Assessment, Damascus, Syria, October, 2002.

14. Torero, J.L., "Scaling of Micro-gravity Combustion Systems, Implications to Spacecraft Fire Safety" European Workshop on Micro-gravity Combustion, Poitiers, France, October 2002.

15. J.L. Torero, "Desarrollo de una Reglamentacion Adecuada en Materia de Seguridad Contra Incendios," Conference on Fire Safety organized by the Vice-President of the Republic, Lima, Peru, November 2002.

16. J.L. Torero, "Conclusiones para una Reglamentacion Adecuada en Materia de Seguridad Contra Incendios," Conference on Fire Safety organized by the Vice-President of the Republic, Lima, Peru, November 2002.

17. Torero, J.L., "Fire Safety Science in Support of Performance Based Design: Innovation or Just Filling the Gaps?," The Graduate Lecture, The Institution of Fire Engineers, Preston, Lancashire, April 2003.

18. Torero, J.L., "Fire Modeling and Fire Performance," The Rasbash Lecture and ECD Conference, Ministry of Defense, Whitehall, London, UK, June 2003.

19. Torero, J.L. "La Experiencia del World Trade Center," Seminario Donde Hubo Fuego, Que hacemos con las Cenizas, Santiago, Chile, June 2003.

20. Torero, J.L., "L'Approche des Risques en Europe et aux Etats-Unis," Colloque Les risques Industriels & Technologiques, Enjeux Internes et Effets Externes, Bourges, France, October 2003.

21. Torero, J.L. and Drysdale, D.D., "Ignition and Flame Spread Studies as they Relate to Material Flammability," Joint Meeting of the Fire Engineering Research Network (FERN) and the Fire Chemistry Network (FCHEM), March, 2004.

22. Torero, J.L., "FireGrid: Data Base Needs," Digital Library Workshop, National Institute of Standards and Technology (NIST), Maryland, USA, April 2004.

23. Torero, J.L., "Structures in Fire: An Overview of the Boundary Condition," Fire And Structures: The Implications of the World Trade Center Disaster Conference, The Royal Society of Edinburgh, Edinburgh, April, 2004.

24. Torero, J.L., "The Use and Misuse of Fire Modelling" Society of Fire Protection Engineers, California Chapter Spring Meeting, Luncheon Speaker, May, 2004.

25. Torero, J.L., "The Risk Imposed by Fire to Buildings and how to Address it," NATO-Russia Workshop on the Protection of Civil Infrastructure from Acts of Terrorism, Russian Academy of Sciences, May 2004.

26. Torero, J.L. and Steinhaus, T. "Applications of Computer Modelling to Fire Safety Design," 53rd Jahresfachtagung der Vereingung zur Forderrung des Deutschen Brandschutzez e. V., Essen, Germany, June, 2004.

Invited Talks

1. J. L. Torero, "The Effect of Buoyancy on the Geometry of Laminar Diffusion Flames Established Over a Flat Plate Burner," Borwn Bag Seminar Series, Department of Mechanical Engineering, *The University of Texas at Austin*, Texas, U.S.A., February, 1995.

2. J. L. Torero, "Buoyancy Effects on Smoldering of Polyurethane Foam," BFRL Lecture Series, National Institute of Standards and Technology, Gaithersburg, Maryland, U.S.A. December, 1995.

3. J. L. Torero, "The Role of Micro-Gravity Experiments on Spacecraft Fire Safety," Serie Annual de Conferencias, Escuela Tecnica Superior de Ingenieros Aeronauticos, Madrid, Spain, January, 1998.

4. J. L. Torero, *Material Flammability Studies for Micro-Gravity Environments*, BFRL Lecture Series, National Institute of Standards and Technology, Gaithersburg, Maryland, U.S.A., October 1998.

5. J. L. Torero, "Seguridad Contra-Incendios en Naves Espaciales - Combustion en Micro-Gravedad," Serie de Conferencias Distinguidas de la Escuela de Ingenieros, *Pontificia Universidad Catolica de Chile*, Santiago, Chile, November 1998.

6. J. L. Torero, "Combustion et Securite d'Incendie," Seminaire du LCD, *Ecole National Superieure de Mecanique de d'Aerotechnique*, Poitiers, France, February, 1999.

7. J. L. Torero, "Energy Release Rate: Determination and Application," Danish Technical University, March, 2000.

8. J.L. Torero, "Flammability Criteria Relevant to Material Selection for Spacecraft Applications" Department of Mechanical and Aerospace Engineering Combustion Seminar Series, Princeton University, April, 2000.

9. J.L. Torero, "Ignition Signatures of a Smolder Reaction in Polyurethane Foam," IUSTI Marseille, France, July 2000.

10. J.L. Torero, "Fire Protection Engineering: Current Accomplishments and Challenges," Ecole National Superieure des Mines de Saint-Etienne, Saint-Etienne, November, 2000.

11. J.L. Torero, "Material Flammability, The Screening of Complex Materials for Complex Applications: The International Space Station," Distinguished Lecture Series in Thermofluid Mechanics, Department of Mechanical Engineering, Purdue University, West-Lafayette, Indiana, March 2001.

12. J.L. Torero, "Material Flammability Assessment for the International Space Station," Union College, Schenectady, New York, April, 2001.

13. J.L. Torero, "El World Trade Center: Algunas Preguntas," Serie de Conferencias Distinguidas de la Escuela de Ingenieros, Pontificia Universidad Catolica de Chile, April 2002.

14. J.L. Torero, "Fire Safety Engineering after September 11^{th}, 2001," Herriot-Watt University, Edinburgh, November 2002.

15. J.L. Torero, "A Case for the Use of the Mass Transfer Number as a Flammability Criterion," Factory Mutual Global, Massachusetts, USA, June 2003.

16. J.L. Torero, "The Role of Fire Safety Engineering in Fire Reconstruction: A Case Study – WTC 1&2," Department of Physics Distinguished Lecture Series, University of Bergen, Norway, September 2003.

17. J.L. Torero, "The Use of Fire Safety Engineering in the WTC Investigation," Stord-Haugesund College, Norway, September 2003.

18. J. L. Torero, "Specialized Studies in Fire Safety Engineering," Packer Engineering, Chicago, March 2004.

19. J.L. Torero, "Fire Safety Engineering Analysis of the WTC Collapse," SFPE Norwegian Chapter, Stord-Haugesund College, Norway, March 2004.

20. J.L. Torero, "The Use of the Mass Transfer Number as a Flammability Criterion for Micro-Gravity Environments," Lecture Series of the Mechanical and Aerospace Engineering Department, University of California, San Diego, May, 2004.

21. J.L. Torero, "Ingenieria de Proteccion Contra Incendios Despues del 11 de Septiembre del 2001," Pontificia Universidad Catolica de Chile, Septiembre 2004.

MISCELLANOUES

RESEARCH INTERESTS

- Fire Safety Engineering: Fire Dynamics, Material Flammability, Spacecraft Fire Safety, Numerical Modelling of Fire, Smoke Management, Smoke Detection, Fire Suppression, Structural Behaviour in Fire, Thermal Injuries and Protective Clothing, Performance Based Design.
- Sustainable Development: Urban waste management, waste incineration, forest management/forest fires, urban/wild land interface fire management, In-situ oil spill management, Nuclear Power Plant Safety.

FELLOWSHIP PRIZES AND AWARDS

PROFESSIONAL

- NASA-Certificate of Recognition for Outstanding Contributions to Space Shuttle Mission.
- Honorary Member: Salamander Fire Protection Engineering Society
- Faculty Achievement Award, Office of the President (University of Maryland)
- Faculty Service Award, A. J. Clark School of Engineering (University of Maryland)
- William M. Carey Award for the Best Paper Presented at the Fire Suppression and Detection Research Application Symposium for the paper "Enhanced Deposition, Acoustic Agglomeration and Chladni Figures in Smoke Detectors," C. Worrell, R.Roby, L. Streit and J.L. Torero.
- Harry C. Bigglestone Award for the Best Paper Published in Fire Technology in 2002 for the paper "Measurements of Smoke Characteristics in HVAC Ducts" by Wolin, S. D., Ryder, N. L., Leprince, F., Milke, J.A., Mowrer, F. W. and Torero, J.L., Fire Technology, Fourth Quarter, Volume 37, Number 4, pages 363-395, 2001.
- Royal Academy of Engineering Research Professorship
- James Marshall Wells Memorial Fellowship (UC Berkeley)
- FAO-GIA Fellowship (UC Berkeley)
- Department of Mechanical Engineering Fellowship (UC Berkeley)
- The European Space Agency Post-Doctoral Research Fellowship
- International Travel Fund Fellowship (University of Maryland)
- Minta Martin Aeronautical Research Fellowship (University of Maryland)

- Minta Martin Aeronautical Research Fellowship (University of Maryland)
- Minta Martin Aeronautical Research Fellowship (University of Maryland)

EDUCATIONAL

Main Awards

- 1996 - Lilly-Center for Teaching Excellence Fellowship – Office of the Dean for Undergraduate Studies and the Center for Teaching Excellence.
- 1996 - Outstanding Mentor of the Year Award – Office of Multi-Ethnic Student Education.
- 1998 - E. Robert Kent Outstanding Teaching Award for Junior Faculty - A.J. Clark School of Engineering.
- 1999 - Outstanding Teacher Award, Office of the Dean for Undergraduate Studies

Other Awards

- 1997 - Nominated for Outstanding Faculty Award – Association of Parents.
- 1997 - North American Mobility in Higher Education Travel Award – Undergraduate Student Affairs, A.J. Clark School of Engineering.
- 1999 - Certificate of Appreciation, in Recognition for Generous Service to the Diversity Initiative – Office of Human Relation Programs.
- 1999 - North American Mobility in Higher Education Travel Award – Undergraduate Student Affairs, A.J. Clark School of Engineering.
- 2001 - Nominated for Outstanding Faculty Award – Association of Parents.
- 2001 - Nominated for Outstanding Advisor Award – Association of Parents.

Other Distinctions

- 1992 - Smouldering Glovebox Combustion Experiment on USML-1 Space Shuttle Mission
- 1995 - Opposed Smouldering Gas Canister Experiments on Space Shuttle (STS-69 Mission)
- 1996 - Opposed Smouldering Gas Canister Experiments on Space Shuttle (STS-77 Mission)
- 1999 - MiniTexus-5 Sounding Rocket Experiment
  2003 - Selection to place the Forced Ignition and Spread Test (FIST) on board of ISS in 2007.

Vincent Van Brunt, Ph.D., P.E.

Chemical Engineer

PROFESSIONAL EXPERIENCE

2001-Present Combustion Science and Engineering, Columbia, Maryland

1976-Present Consultant to Several Multinational Chemical Companies.

1975-Present University of South Carolina, Columbia, South Carolina

Professor, Chemical Engineering Department. Professor Van Brunt taught chemical engineering separations and flowsheeting for 28 years, including over 85 classes across the whole discipline from freshman to graduate level.

1990-1991 University of California at Berkeley

Visiting Associate Professor and Guest of Lawrence Berkeley Laboratory. During Sabbatical, worked with C. Judson King on dicarboxalic acid recovery using solvent extraction/stripping/precipitation/filtration flowsheet. Characterized these type flowsheets. Taught Separation Processes.

1974-1975 Clarkson University, Potsdam, New York

Assistant Professor, Chemical Engineering Department, Taught Material Science and Thermodynamics. Research on diffusion coefficient measurement.

1974 University of Tennessee

Instructor, Chemical and Metallurgical Engineering Department. Taught both Mass Transfer and Heat Transfer in Spring and Summer.

ACCOMPLISHMENTS

- Received 11 teaching awards, including the highest university teaching award, the AMOCO in 2003, the second highest university award, the Mungo in 1999, the Golden Key university award for integration of teaching and undergraduate research in 1994, the College of Engineering teaching award and the Litman in 1988.

- Taught the first required chemical process safety course in the United States.

- Was a member of the Center for Chemical Process Safety undergraduate education committee, SACHE for five years.

- Performed research on separation processes for separation of cesium, strontium, and palladium from nuclear waste. Separation process research includes absorption, adsorption, precipitation, solvent extraction, distillation, azeotropic distillation, extractive distillation, stripping, filtration including crossflow filtration, and flowsheet design.

  Applications include titanium dioxide decontamination, uranium oxides manufacturing, krypton and xenon recovery, tritium recovery, heavy water purification, tritiated water recovery, isotopic separations, mercuric chloride recovery, acetic acid recovery, terephthalic acid production, dicarboxylic acids recovery, nuclear waste flowsheeting, characterization of extraction column flooding and performance, characterization of extraction-reaction systems.

- National Academy of Engineering - sole engineer reviewer of cesium processing report.

- US Department of Energy - process architecture development for treating Hanford waste, technical advisory for technetium recovery at Hanford, sole academic member of a technical review team for Tank Waste Remediation System proposals and sole liaison with a review team for the Undersecretary of Energy for Environmental Management.

- For multiple years as technical reviewer of Efficient Separations Crosscutting Program, served as chairman of an independent review team for Tank Waste Remediation pilot-scale projects

- State of South Carolina as a member of South Carolina Governor's Nuclear Advisory Council. Technical Advisor to the Process Safety Center at Texas A&M University.

- 2 process patents – acetic acid recovery, emulsion degreasing agent

- Author of 3 book chapters - "Extraction," "Extraction with Reaction," and "Gravity Settling Chambers;" 56 articles and technical reports; delivered 87 technical papers; advisor to 3 postdoctoral students, 3 doctorates, and 16 masters.

ACADEMIC

Ph.D. University of Tennessee, Knoxville, Tennessee - Chemical Engineering

M.S. Polytechnic Institute of Brooklyn, Brooklyn, New York - Chemical Engineering

B.S. Carnegie Institute of Technology, Pittsburgh, Pennsylvania - Chemical Engineering

MEMBERSHIPS

- American Institute of Chemical Engineers (AIChE)
- American Nuclear Society (ANS)
- American Chemical Society
- Omicron Delta Kappa
- Tau Beta Pi
- Golden Key National Honor Society
- Service to National AIChE includes Extraction Programming Chairman for 8 years, and as a Director of Separations Division. Local Chapter service includes as vice chairman and chairman of local sections of both AIChE and ANS.

PROFESSIONAL REGISTRATION

1979-Present Professional Engineer, South Carolina

Fellow, American Institute of Chemical Engineers

Christopher F. Schemel

Vice President

PROFESSIONAL EXPERIENCE

2003-Present Packer Engineering, Inc. - Columbia, Maryland
Fire Sciences and Explosion Analysis
Chemical Engineering

Perform comprehensive fire and explosion incident investigations and fire reconstruction analysis. Researcher and Ph.D. student at the University of Edinburgh's BRE Center for Fire Safety Engineering, Edinburgh, Scotland. Specific project experience includes:

Major Fire and Explosion Investigations: lead investigator and team member for numerous fire/explosion incidents involving large, multifaceted investigations and analysis. Specific expertise includes applying chemical engineering and fire safety engineering to the analysis of fuels, vapor dispersion and combustion processes. Experience working in a range of industrial facilities including: chemical and petrol-chemical production and storage facilities, combustible dust handling processes, food manufacturing facilities, flammable/combustible liquid storage facilities, mining operations, semi-conductor facilities and pharmaceutical manufacturing facilities.

Process Fire Hazard Analysis and Fire Related Problem Solving: conduct analysis to determine causes of nuisance (non-catastrophic) fire issues associated with a variety of manufacturing processes and products. Develop product and system modifications to minimize fire hazards and prevent fires.

Research and Development: perform research projects investigating fundamental fire science and engineering issues including fire spread in porous media, wildland fuel analysis and fire spread model development. Conducted several projects applying statistical methods and analysis for process description and problem solving.

1999-2003 Combustion Science & Engineering, Inc. - Columbia, Maryland
Senior Engineer

Responsible for leading and performing a variety engineering projects related to fire science, fire safety engineering and research and development. Both lead and participated in fire incident investigations and fire hazard analysis in support of the company's fire group. Provided statistical analysis and design of experiments support to research and development efforts. Conducted research of fire science and combustion projects, including being an inventor on two projects leading to U.S. patents.

(Continued)

Project experience in incident investigations includes failure analysis related to fires and explosions including the following: chemical reactors and process lines, solids transport operations and packaging units, electro-plating processes, effluent stream combustors, industrial furnaces, gas turbines, distribution pipeline failures including underground gas migration and structure infiltration, electrical system failures, along with general manufacturing and warehousing.

Other projects include: operational risk quantification for U.S. Antarctic flight operations, development of a smoke detector notification device for the deaf funded by National Institutes of Health (US patent), development if a lean, pre-mixed combustor fuel conditioner (US patent), spontaneous combustion and other fire research, and third party commercial product development/patent support.

1996-1999 Hughes Associates, Inc. - Baltimore, Maryland
Chemical Engineer

Performed fire and explosion hazard analysis along with general chemical/process engineering support for several company operation areas. Fire and explosion analysis experience includes: a waste fuels operations plant, a resin mold facility, and a Process Fire Hazard Analysis for an experimental bio-mass reactor. Conducted statistical analysis and experimental design for projects including: multiple sensor signatures for early fire detection systems and large scale fire tests.

In addition, supported several Department of Energy nuclear weapons facilities:

Rocky Flats Environmental Technology Site: a pre-startup Process Fire Hazard Analysis for the Radio Active Waste Repack facility, preformed an analysis defining operability standards for the site–wide alarm reporting system, developed a pilot study for risk-based maintenance of fire protection systems, perform and write Fire Hazards Analysis for several nuclear facilities. In addition, filled a rotating staff Site Fire Protection position supporting site-wide operations.

Savannah River Site: provided support to Site Fire Protection operations, in addition, conducted a safety analysis and safety level calculations for the Consolidated Incinerator Facility including a review of the Programmable Logic Controllers Interlock System.

Hanford Site: developed the conceptual design and cost analysis for a controlled atmosphere system for 177 high level waste tanks, performed an ignition source risk assessment of PUREX storage tunnels, and performed fire protection assessments on approximately 30 buildings at the facility.

ACADEMIC

Currently enrolled in Ph.D. program in the School of Engineering and Electronics, Department of Fire Safety Engineering, University of Edinburgh, Edinburgh, Scotland. Expected graduation in August, 2007.

M.S., Chemical Engineering, University of South Florida, Tampa, Florida,

B.S., Chemical Engineering, University of South Florida, Tampa, Florida,

B.A., Social and Behavioral Sciences, University of South Florida, Tampa, Florida,

PROFESSIONAL AFFILIATIONS

Senior Member, American Institute of Chemical Engineers
Member, The Society of Fire Protection Engineers

PUBLICATIONS AND PRESENTATIONS

1. Bukosski, R.W., Budnick, E.K., Schemel, C.F. "Estimates of the Operational Reliability of Fire Protection Systems," Third International Conference on Fire Research and Engineering. National Institute of Standards and Technology, Chicago, IL, October, 1999.

2. Gottuk, D.T., Hill, S.A., Schemel, C.F., Strehlen, B.D., "Identification of Fire Signatures for Shipboard Multi-criteria Fire Detection Systems," Naval Research Laboratory, Washington, D.C., 1999.

3. Schemel, C.F., Van Brunt, V., Budnick, E.K. "Developing Inspection, Testing and Maintenance Programs for use in Risk Based Analysis," Proceeding of the Reliability and Risk Management Symposium, Society of Fire Protection Engineers. May, 1999.

4. Schemel, C.F., Budnick, E.K., "Pilot Study: Analyzing Fire Protection System Reliability Using Limited Databases," Proceeding of the Fire Suppression and Detection Research Application Symposium, Fire Protection Research Foundation, February, 1999.

5. Schemel, C.F., Hopkins, J.L., Campbell, S.W., Bhethanabotla, V.R. "Pressure Swing Adsorption as a Separations Experiment," 1992 Annual Meeting: American Society of Engineering Educators, Toledo, Ohio, June 1992.

6. Schemel, S.D., Schemel, C.F., Van Brunt, V., "Methodology for Determining Reliability of a Foam Suppression."

7. System Using Fuzzy Set Theory and Fault Tree Analysis," Proceeding of the International Conference and Workshop on Reliability and Risk Management, Center for Chemical Process Safety of the American Institute of Chemical Engineers, September, 1998.

8. Ryder, N., Sutula, J., Schemel, C., Brunt, V.V., and Hamer, A., "Consequence modeling of fire using Large Eddy Simulation," Proceedings 2003 Mary Kay O'Connor Process Safety Symposium, College Station, TX.

9. Ryder, N., Sutula, J., Schemel, C., Brunt, V.V., and Hamer, A., "Consequence modeling using the fire dynamics simulator," Journal of Hazardous Materials, November 2004.

10. Ryder, N., Schemel, C., and Jankiewicz, S., "Comparing Large Eddy Simulation and Finite Element Analysis Predicted Failure Criteria to ASTM Standards," presented to the ASM 2004 Materials Solutions Conference, Columbus, Ohio, 2004.

11. Ryder, N., Schemel, C., and Jankiewicz, S., "Near and Far Field Contamination Modeling in a Large Scale Enclosure: Fire Dynamics Simulator comparisons with measured observations," Proceedings 2004 Mary Kay O'Connor Process Safety Symposium, College Station, TX.