出國報告（出國類別：其他-國際會議）

參加第七屆國際火災爆炸危害研討會並發表論文

服務機關：國立高雄第一科技大學
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派赴國家：美國
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摘要

第七屆國際火災爆炸危害研討會(7th International Seminar on Fire and Explosion Hazards)是一國際性的火災爆炸危害研討會，本研討會最初的招開的目的是在冷戰結束後提供東西歐雙方研究人員能將軍事爆炸導引到民生的安全研究。第一、二屆是在俄羅斯的莫斯科舉行(1995, 1997)，而後 2000 年在英國湖區、2003 年在北愛爾蘭、2007 年在英國愛丁堡、2010 年在英國里茲，今年是第一次移到美國，由 FM Global 公司與馬里蘭大學的消防工程糸共同主辦。

本研討會包括火災與爆炸兩大領域,出國人投稿一篇國科會計畫所產出的氫氣高壓外洩自燃機制之研究成果論文,此論文為口頭發表,另投稿兩篇矽甲烷外洩測試的海報論文，整體研究成果受到學界與業界的重視，本報告摘要研討會的心得。

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參加第七屆國際火災爆炸危害研討會
並發表論文
出國報告

出國人：國立高雄第一科技大學 環境與安全衛生工程系 教授 陳政任

目的

火災爆炸是產業最常發生的災害事故，在過去十多年中僅台灣的石化、半導體等產業所發生的火災爆炸事故即造成數百億台幣的直接損失與數十人的人員傷亡，由於產業的發展迅速，如何預防火災爆炸的發生便有賴提高對火災爆炸危害的瞭解，本研討會便是以促進火災爆炸危害的研究，以期降低火災爆炸的危害。

過程

第七屆國際火災爆炸危害研討會(7th International Seminar on Fire and Explosion Hazards)是一國際性的火災爆炸危害研討會，本研討會最初的招開的目的是在冷戰結束後提供東西歐雙方研究人員能將軍事爆炸導引到民生的安全研究。第一、二屆是在俄羅斯的莫斯科舉行(1995, 1997)，而後 2000 年在英國湖區、2003 年在北愛爾蘭、2007 年在英國愛丁堡、2010 年在英國里茲，今年是第一次移到美國，由 FM Global 公司與馬里蘭大學的消防工程系共同主辦。

本研討會是在 5 月 5 日至 5 月 10 日於美國羅德島州首府 Providence 市的 Renaissance 飯店舉行，約有 200 人參與，本研討會的議題包括：

- 裂解與火災化學(PYROLYSIS AND FIRE CHEMISTRY)
- 粉塵爆炸(DUST EXPLOSION)
- 震波分析與消減(BLAST ANALYSIS AND MITIGATION)
- 氫氣安全(HYDROGEN SAFETY)
- 引燃與熄滅(IGNITION AND EXTINCTION)
- 建物、隧道與礦場(COMPARTMENTS, TUNNELS, AND MINES)
- 爆轟與爆燃爆轟的轉換(DETONATION AND DDT)
- 爆燃排放(DEFLAGRATION VENTING)
- 火災動力學歷(FIRE DYNAMICS)
- 抑制與消減(SUPPRESSION AND MITIGATION)
- 火燄傳播與成長(FLAME SPREAD AND GROWTH)

會議的主席是由 FM Global 公司的 Franco Tamanini 博士擔任，來自北愛爾蘭 Ulster 大學的 Vladimir Molkov 教授擔任副主席，Tamanini 博士是哈佛大學的物理博士，是 FM

Global 公司研究部門的主管，專門負責修訂規範有關的測試與研究，是火災爆炸領域中頗受尊敬的學者。Molkov 教授是俄羅斯人，冷戰結束後為追求較高的收入來到北愛爾蘭擔任防火安全的教授，其為人豪邁、開放，喜歡開玩笑，但研究成果相當豐碩，應該得利於其冷戰前蘇聯時代所建立的優良基礎。

研討會的進行包括專題報告(Keynote speech)、分組口頭發表與海報論文發表，共計有三個整天與兩個半天的論文發表，另有一個半天安排到羅德島州著名的觀光景點 Newport 市參訪，另一個半天則安排到 FM Global 公司的研究中心參訪。全部共計有 105 篇頭發表論文，另有海報論文 25 篇。

本次會議出國人最感興趣與收獲最多的是爆轟與爆燃爆轟的轉換議題，本議題並邀請加拿大 McGill 大學退休教授 John H. S. Lee 擔任專題演講，講題是 Comment on Detonations in Accidental Explosions，李教授來自中國大陸，雖已七十餘歲，但仍相當活耀，著有 Detonation Phenomena 一書，是爆轟研究的重要著作之一。李教授就過去四十餘年所參與的大型爆轟實驗的經驗與分析許多爆炸事故，提出爆炸事故多未達到爆轟的程度，應更正為超音速燃燒(supersonic combustion)或紊流爆燃(turbulent deflagration)，李教授的深入精闢的分析令人受益良多，也提醒目前的產業爆炸事故仍有許多問題待研究。

出國人投稿一篇國科會計畫所產出的氫氣高壓外洩自燃機制之研究成果論文(附錄一)，此論文為口頭發表，安排在會議第二天，另投稿兩篇矽甲烷外洩測試的海報論文(附錄二)。出國人投稿之排放管道對氫氣高壓外洩自燃機制之影響的論文是利用可視化的技術探討不同排放管道對氫氣高壓外洩自燃機制的影響，由於實驗難度高，引起許多氫氣安全學者的興趣。另投稿的兩篇矽甲烷外洩測試的海報論文則廣受各領域學者的重視，主因為矽甲烷是高科技產業使用最普遍的危險性氣體，然高科技產業並非普及於所

有國家，特別是歐洲與俄羅斯，對傳統研究火災爆炸的學者是屬於全新的領域，故雖是海報論文，仍受各領域學者的重視與詢問。

心得及建議

本研討會許多與會者多已熟識，例如會議主席 FM Global 公司的 Franco Tamanini 博士便多次在國際研討會相遇，他也道出舉辦研討會的辛勞，且為鼓勵學生的參與，學生的註冊費降得很低，慶幸的是整體而言收支尚能平衡，與會者多表滿意。

本研討會另一現象為中國大陸的學者參與極為踴躍，包括中國科技大學、南京理工大學等約有十餘人參加，突顯中國大陸的經濟發展已逐漸擴展到學術研究，其量與質逐漸趕上西方各國，以台灣有限的資源與人力，集中發展與高科技產業相關的火災爆炸研究或許是可突破的方法。

反觀台灣，一方面可能是國科會的補助日益減少，再者也可能是許多學者為了避免語文的困擾，僅出國人一人參加，實為可惜。近年來許多台灣學者捨棄真正的「國際研討會」，選擇到對岸中國大陸參加其所謂的「國際研討會」，不僅語文相通，食宿交通更是方便，費用也不會透支。但中國大陸的優秀學者卻更積極的參與各國的「國際研討會」，甚至擔任分組主持人與委員會的成員，影響力日益擴大。建議台灣的學者應更積極的參與「國際研討會」，這是為台灣發聲的好機會。

此外因為過去十多年來雖然國內物價持平，但國外物價飛漲，食宿等都是數倍於台灣，在扣除高昂的註冊費與機票費後，所剩的經費早已不夠支付旅館的費用，故也建議國科會能提高補助金額，至少不需自掏腰包，方能大幅提高出國與會的意願。

附錄一、氫氣高壓外洩自燃機制之研究成果論文

Effect of Channel Width on the Shock and Ignition of High-Pressure Hydrogen Release

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ABSTRACT

In this work, rectangular visualization channels with different widths were used to study the shock wave and ignition from pressure release of hydrogen into air. The minimum pressure required for ignition was determined for each channel. Shock wave speed was also measured from the high-speed shadowgraph. The results found that with diminishing channel width, the minimum release pressure required for ignition is also decreased which suggests that most accidental release from a thin crack will favors spontaneous ignition. This result is in consistent with the our observation that most accidental release from a leak of a pressure source did result in prompt ignition.

KEYWORDS: Hydrogen, autoignition, shock wave.

INTRODUCTION

Numerous studies, both experimental [1-3] and numerical [4-7], have been done to elucidate the mechanism of hydrogen autoignition following accidental pressure release. The mechanisms and conditions of the ignition are not yet completely clear but are generally agreed to be caused by the shock wave compression from the high pressure release which heats up the hydrogen/air mixture in the contact surface. To achieve spontaneous ignition, it requires a proper combination of downstream geometry (channel length and channel geometry) and failure pressure that provide a critical level of shock heating as well as a critical volume of mixed hydrogen and air that is capable of undergoing flame spreading [1]. These critical values for spontaneous ignition are however yet to be determined completely.

Recently, Kim et al. [8] studied the shock and flow structure inside the flow channel with the aids of double glass window. The visualization channel has a square cross-section of 10×10 mm and a total tube length of 300 mm. Two high-speed cameras with shadowgraph and direct image recording were taken. Detailed structure of shock wave, mixing spot, ignition, and flame propagation were revealed.

Although the work of Kim et al. [8] is valuable for better understanding of the ignition mechanism, there remains lack of systematic studies on the conditions of ignition. There also lacks of information on how the shock compression theory can be extended to splits in actual incidents. As most splits or cracks in vessels are longitudinal with large aspect ratio, it is of interest to study the effects of channel width on conditions of ignition. In particular, it would be interested to study the release from a thin channel which resembles the most accidental release from a crack of a vessel wall. With a diminishing channel width, the boundary layer will strongly perturb the flow and shock wave, which in turn will affect the shock compression, mixing and ignition of hydrogen and air mixture.

In this work, visualization channels similar to that of Kim et al. [8] with different widths were used to study the shock wave and ignition from pressure release of hydrogen into air. The

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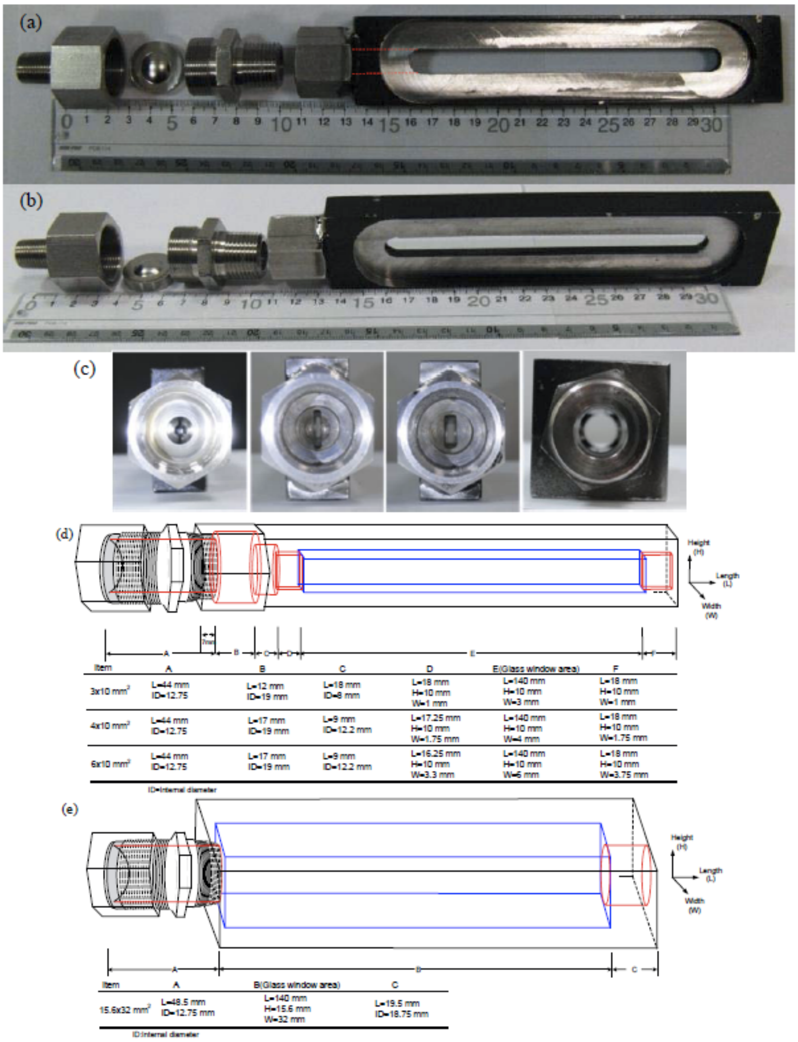
minimum pressure required for ignition was determined for each channel. Shock wave speed was also measured. The result found that with diminishing channel width, the minimum release pressure required for ignition is also decreased which suggests that most accidental release from a thin crack will favor spontaneous ignition. This result is in consistent with the our observation that most accidental release from a leak of a pressure source did result in prompt ignition. For example in August 10 2012, a leak and fire was developed for a hydrogen compressor in a refinery in Kaohsiung, Taiwan [9]. The compressor output had a reported pressure about 4 MPa while the leak was believed to develop from a pipe flange. The leak evolved into a fire rather than an explosion as there was no sign of explosion damage. A leak without prompt ignition but was ignited remotely would produce a vapor cloud explosion that is distinctive compared with a ignited flame.

EXPERIMENTAL SETUP

A rectangular visualization channel was used to study the shock, ignition and flame propagation following the release. The channel was bounded by two pressure-resistant glasses. Four different visualization channels were used. The cross-sectional dimensions for the visualization channel are 15.6×32 mm, 6×10 mm, 4×10 mm and 3×10 mm, respectively. The lengths for the visualization channels are the same of 140 mm. A circular bursting disk of 12.7 mm is used for all tests. The disk is mounted in a disk holder by a union connector and connected to the visualization channel through a welded 1/2" NPT female connector as shown in Figure 1. In order to accommodate the pressure-resistant glasses, it is necessary to have additional area around the visualized section for supporting. The additional area is an annulus with width of 12.3 mm circled around the visualized section. At overlapping of flow channel and the supporting annulus as shown by the dash line in Fig. 1(a), the channel cross-sectional dimensions were reduced to 3.3×10 mm, 1.75×10 mm and 1×10 mm for channel size of 6×10 mm, 4×10 mm and 3×10 mm, respectively. Thus, the actual flow area went from a circular diameter of 12.7 mm, a contraction to rectangular bounded by supporting annulus, and then slightly expanded to the visualized section. The detailed dimensions are shown in Fig. 1(d). For the largest channel, the flow area went into an expansion of 15.6×32 mm^2 directly; see Figure 1(c) and (e).

The channel is connected to a pressure vessel with a volume of $5\times10^{-4} m^3$. Hydrogen was supplied from a cylinder directly or through a booster compressor that can boost the pressure to above cylinder pressure. All tests were initiated by gradually increasing the pressure in the vessel until the bursting disk ruptured. Bursting disk with rated pressure of 20, 30, 40, 50, 70, 100, and 150 bar were used. Pressure at upstream of bursting disk was measured to record the exact bursting pressure. Two Phantom V711 high-speed cameras with shadowgraph and direct image recording were taken at rate of 100,000 fps. Color video cameras were also used to record the flame outside the channel.



Item	A	B	C	D	E(Glass window area)	F
3x10 mm^2	L=44 mm ID=12.75	L=12 mm ID=19 mm	L=18 mm ID=8 mm	L=18 mm H=10 mm W=1 mm	L=140 mm H=10 mm W=3 mm	L=18 mm H=10 mm W=1 mm
4x10 mm^2	L=44 mm ID=12.75	L=17 mm ID=19 mm	L=9 mm ID=12.2 mm	L=17.25 mm H=10 mm W=1.75 mm	L=140 mm H=10 mm W=4 mm	L=18 mm H=10 mm W=1.75 mm
6x10 mm^2	L=44 mm ID=12.75	L=17 mm ID=19 mm	L=9 mm ID=12.2 mm	L=16.25 mm H=10 mm W=3.3 mm	L=140 mm H=10 mm W=6 mm	L=18 mm H=10 mm W=3.75 mm

ID=Internal diameter

Item	A	B(Glass window area)	C
15.6x32 mm^2	L=48.5 mm ID=12.75 mm	L=140 mm H=15.6 mm W=32 mm	L=19.5 mm ID=18.75 mm

ID:Internal diameter

Figure 1. Combinsation of bursting disk and visualization channel. (a) Front view of the combination. (b) Top vide of the combination. (c) Front view of entrance contraction for 3x10 mm^2, 4x10 mm^2, 6x10 mm^2, 15.6x32 mm^2 from left to right, respectively. (d) Detailed dimension of channels with contraction. (d) Detailed dimension of 15.6x32 mm^2 channel.

RESULTS

Visualization of Shock Wave and Flame

Vast video data were obtained from the visualization of shock wave and flame inside the channel. The observed structure is in general similar to those of Kim et al. [8] which visualized the detaileds structure of the shock wave and flame for a 10×10 mm square channel. The focus here is to highlight the difference for narrow channels. Figure 2 shows the shock wave and flame for 4×10 mm channel with release pressure of 3.50 MPa. This figure refer to a typical shock wave and flame formation with successful ignition inside the channel. This test however failed to form a sustained jet flame outside the channel as shown in Figure 3.

Also showed for comparison in Figure 4 are the shock wave for the same 4×10 mm channel with release pressure of 2.36 MPa and shock wave for the 6×10 mm channel with release pressure of 3.51 MPa. The later two in Fig. 4 highlight the cases for failed ignition with reduced driver pressure or increased channel width. Both cases showed a similar mixing front as Fig. 2(a) but with redcued intensity. The most striking feature found in Fig. 4 is that a second shock front emerged from the mixing front which accelerated and eventually merged with the first shock front. It is not clear how the second shock front generated. It is however confirmed that all tests without ignition in the contraction channels showed a second shock front. The tests with flame inside the channel showed only a fast shock front followed by a slower flame front. For the 15.6×32 mm channel, only the first shock front and the mixing front were identified. Thus, the second shock front is likely to originate from the reflection and interaction of initial shock on the channel contraction.

Fig. 2(b) also shows that the flame was initiated from the contraction. In fact, all channels with contraction showed flame initiated from the contraction. Also, all flame inside the channels showed similar profile as those in Fig. 2(b) which developed quickly over the cross-section area and persisted downwind. Flamelet initiated from the channel boundary layer which was observed in Kim et al. [8] never appear in current channels with contraction. It however appears in the tests with 15.6×32 mm channel such as Figure 5.

Shock Speed, Release Pressure, and Channel Width

Figure 6 summarizes the overall results of measured shock speed as a function of release pressure and channel width. Data with solid symbol indicates test with ignition. The test, test with 4×10 mm channel and release pressure of 3.50 MPa, with ignition and flame observed in the visualization section but no sustained jet flame is indicated by symbol with 50% shade. It is interesting to note that the shock speed is a more strong function of release pressure compared with the channel size. Reducing channel size do however reduces the shock speed as shown in the data points in Fig. 6 near release pressure 2.4 MPa.

Figure 7 shows the comparison of minimum pressure with ignition and maximum pressure without ignition as a function of channel width. The minimum pressure with ignition decreases with diminishing channel width, reaching 1.9934 MPa at limiting small channel width. This limiting value is close to the critical value of 2.27 MPa for ignition reported by Dryer et al. [1]. Dryer et al. [1] suggested that such a low driver pressure cannot possibly explain the spontaneous ignition observed in the experiments with the small channel length. The reduction in cross-sectional area after the bursting disk are the main factor which results in partial reflection of the initial transient shock through the cross sectional area constriction. The result is an increase in local temperatures and pressures ahead of the progressing initial contact surface by the partial reflection of the initial transient shock [1]. Xu and Wen [7] also drawn similar conclusions based their numerical simulation of hydrogen release through a contraction.

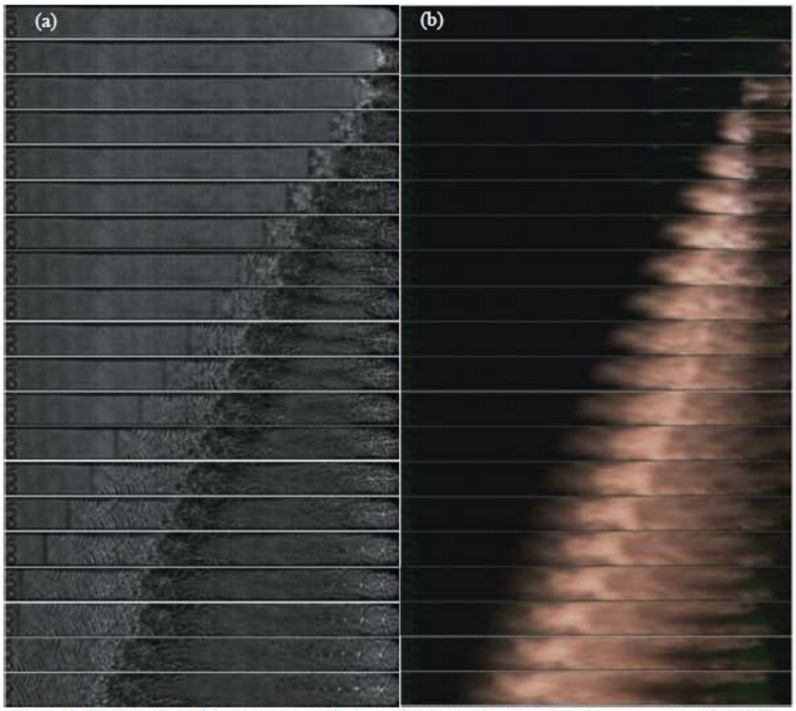


Figure 2. Visualization of shock wave and flame for 4×10 mm channel with release pressure of 3.50 MPa. (a) shock wave shadowgraoh. (b) flame color video. Each frame differs by 10 μs.

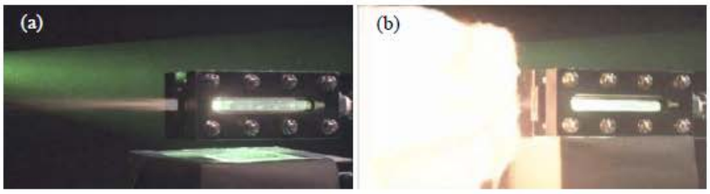


Figure 3. Comparison of flame emerging from the channel with a failed jet flame and a successful, sustained jet flame. (a) a failed jet flame, 4×10 mm channel with release pressure of 3.50 MPa. (b) a successful, sustained jet flame, 4×10 mm channel with release pressure of 4.41 MPa.

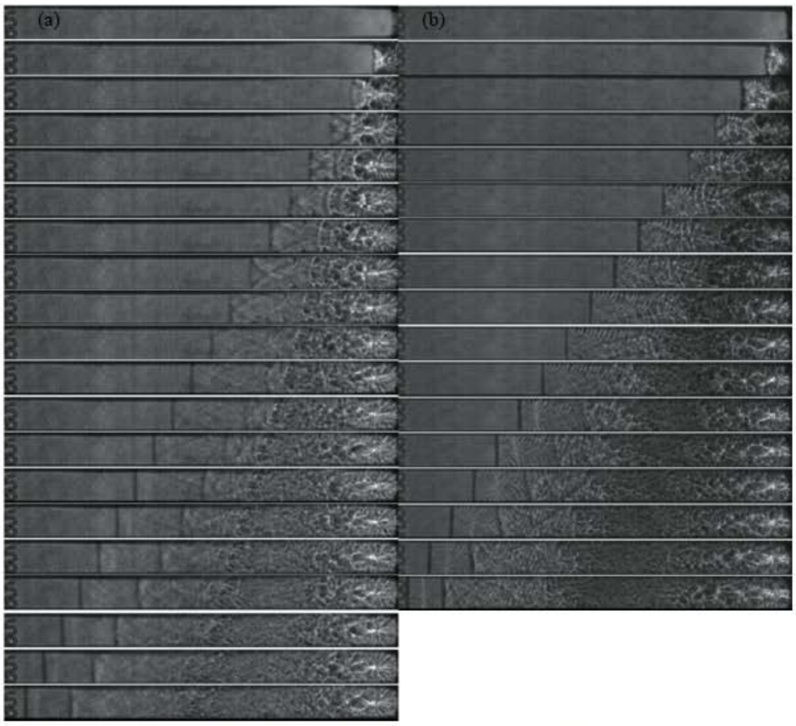


Figure 4. Visualization of shock wave of two failed ignition case. (a) 4×10 mm channel with release pressure of 2.36 MPa. (b) 6×10 mm channel with release pressure of 3.51 MPa.. Each frame differs by 10 µs.

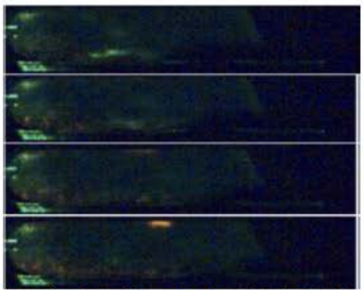


Figure 5. Flamelet initiated from the channel boundary layer in test with channel dimension 15.6×32 mm and release pressure of 16.2 MPa. Each frame differs by 6.66 µs.

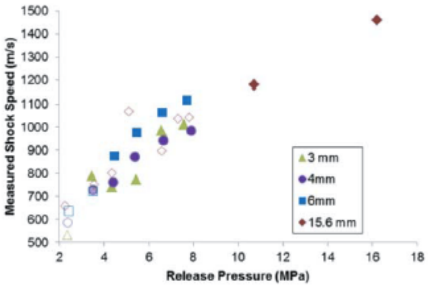


Figure 6. Overall results of measured shock wave speed as a function of release pressure and channel width.

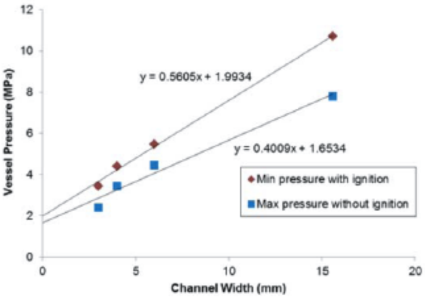


Figure 7. Comparison of minimum pressure with ignition and maximum pressure without ignition as a function of channel width.

Discussions

Although the current work suffers the drawbacks of contraction between the bursting disk and the rectangular channel, the comparison between different channel widths and release pressures did provide some insights on the effects of channel width. Dryer et al. [1] suggests that to achieve spontaneous ignition it requires a proper combination of downstream geometry and failure pressure that provide a critical level of shock heating to cause autoignition of mixtures formed with hydrogen, as well as a critical volume of mixed material that is capable of undergoing flame spreading. It is most likely that the channel width contributes to the ignition in two folds. The boundary layer in a narrower channel will contribute to better mixing and therefore more flammable volume for shock heating and flame spreading for the same release pressure as the shock speed were reduced slightly with reduced channel width as shown in Fig. 6 for the cases of 3, 4, and 6 mm. In addition, the critical volume of mixed material with a smaller channel required for undergoing flame spreading is reduced as any small flamelet formed in a large channel such as those in Fig. 5 will easily fill the whole cross-section in a narrower channel and thus easier flame spreading.

For release from a crack in a pressure vessel, it is unlikely that the flow will undergo contraction as in the present work. However, the cracked surface is never smooth and may promote boundary layer mixing and hence facilitate the formation of ignition kernel with the aids of driver pressure. Furthermore the minimum release pressure required for ignition is also decreased with diminishing channel width, which suggests that most accidental release froms a thin crack will favor spontaneous ignition. This result is in consistent with the common observation that most accidental release from a crack of a vessel wall did result in ignition. The present studies however indicates that ignition is unlikely with a storage pressure less than 1.99 MPa. This value is also roughly consistent with the 1-D shock theory analyzed by Dryer et al.[1].

CONCLUSIONS

Rectangular visualization channels with different widths were used to study the shock wave and ignition from pressure release of hydrogen into air. The minimum pressure required for ignition was determined for each channel. Shock wave speed was also measured from the high-speed shadowgraph. The results found that with diminishing channel width, the minimum release pressure required for ignition is also decreased.

Comparison of the shock shadowgraphs between different channel widths and release pressures also provided some insights on the effects of channel width. It is likely that the channel width contributes to the ignition in two folds. With smaller channel, the critical volume of mixed material required for undergoing flame spreading is also reduced. On the other hand, the boundary layer in a narrower channel will also contributes the better mixing for the same release pressure as the shock speed were reduced slightly with reduced channel width. Thus, in most accidental release with a thin crack spontaneous ignition is favored. This result is in consistent with the our observation that most accidental release from a leak of a pressure source did result in prompt ignition. The present studies also indicates that ignition is unlikely with a storage pressure less than 1.99 MPa.

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附錄二、矽甲烷外洩測試的海報論文

CGA G-13 Large-Scale Silane Release Tests

Part I. Silane Jet Flame Impingement Tests and Thermal Radiation Measurement

Eugene Y. Ngai[1], Ron Fuhrhop[2], Jenq-Renn Chen[3*], Jenny Chao[4], C. Regis Bauwens[4], Crystal Mjelde[5], Gary Miller[6], Jerry Sameth[7], John Borzio[8], Michael Telgenhoff[9], Bruce Wilson[10]
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Background

Silane is one the most important hazardous gas that is widely used in semiconductor, flat panel, and photovoltaic industries. The storage and handling of silane is regulated by the ANSI/ Compressed Gas Associations (CGA) G-13 Standard which is recognized worldwide. G-13 establishes safety setback distances by assuming worst case events. The currents distances however are considered to be over-conservative. A series of tests was proposed to better define silane behavior during unintentional, large-scale release.

Objectives

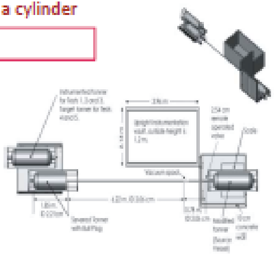
Over 20 releases were proposed that were focused on determining:

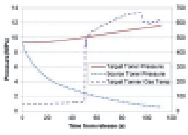
- Heat conductance from flame impingement
- The effect of flame impingement and radiant heat on a tonner filled with nitrogen from discharge of an adjacent tonner
- Radiant heat from vertical and horizontal jets
- Overpressure from open air vent delayed ignition
- Overpressure from obstructed ignition

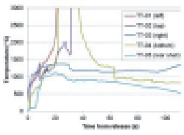
The first part of the summary describes the detailed results of the silane flame impingement and thermal radiation tests. These tests included:

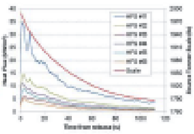
- 2 nitrogen releases from a ton cylinder
- 3 silane flame releases from a ton cylinder with flame impingement onto an adjacent ton cylinder
- 2 silane flame jet releases from a ½" tube diameter
- 5 ethylene flame jet releases from a ½" tube diameter
- 4 silane flame jet releases from a cylinder

Flame Impingement Test

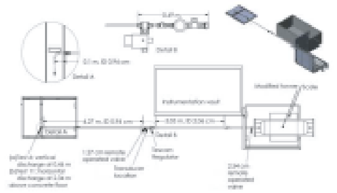


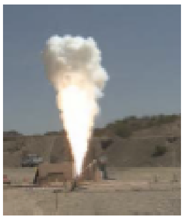






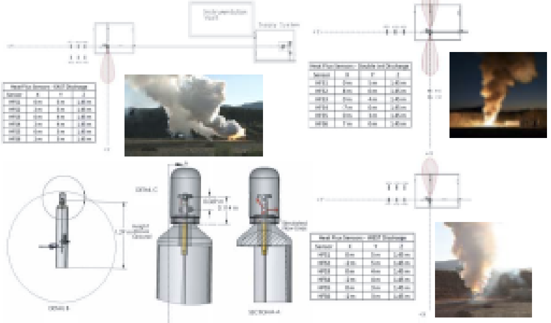
Thermal Radiation Tests: ½" Tube





Test no.	6	11	12(a)	12(b)	13(a)	13(b)	13(c)
Fuel	Silane	Silane	Ethylene	Ethylene	Ethylene	Ethylene	Ethylene
Discharge direction	Vertical	Horizontal	Horizontal	Horizontal	Vertical	Vertical	Vertical
Source pressure (MPa)	9.30	8.61	9.34	8.84	6.85	6.16	4.95
Ambient temp (°C)	33.9	36.1	31.7	31.7	31.7	31.7	31.7
Relative humidity	30	15	28	28	28	28	28
Wind speed (m/s)	4.7	1.7	1.7	1.7	2.4	2.4	2.4
Wind gust speed (m/s)	7.1	2.4	3.1	3.1	3.1	3.1	3.1
Wind direction	S	SW	SW	SW	S	S	S
Average release rate (kg/s)	0.79	0.77	0.119	0.128	0.137	0.133	0.131
Average heat flux (kW/m²)							
Position 1	12.52	10.05	2.70	2.81	3.02	2.88	2.95
Position 2	9.81	8.56	2.14	2.24	2.40	2.23	2.32
Position 3	5.74	5.69	1.40	1.47	1.52	1.35	1.47
Position 4	10.53	8.40	1.85	1.93	2.97	3.04	2.89
Position 5	7.87	8.40	1.74	1.85	2.33	2.34	2.27
Position 6	4.61	7.21	1.39	1.50	1.31	1.36	1.33

Thermal Radiation Test: Cylinder PRD



Test no.	20	21	22	23
Discharge direction	1-hole cap, east discharge	1-hole cap, west discharge	2-hole cap	No cap
Source pressure (psig)	1541	1469	1418	1234
Wind speed (mph)	5.5	5.0	<2.5	<2.5
Wind direction	NW	NW	-	-
Average release rate (kg/s)	0.228	0.220	0.250	0.194
Average heat flux (kW/m²)				
Position 1	4.92	4.57	7.48	3.63
Position 2	5.43	2.91	2.50	1.24
Position 3	6.86	7.01	10.91	5.63
Position 4	8.84	3.27	5.57	1.87
Position 5	12.44	10.69	17.47	9.67
Position 6	18.91	4.20	23.16*	2.62

CGA G-13 Large-Scale Silane Release Tests

Part II. Silane Vapor Cloud Explosion Overpressure Measurement

Eugene Y. Ngai[1], Ron Fuhrhop[2], Jenq-Renn Chen[3*], Jenny Chao[4], C. Regis Bauwens[4], Crystal Mjelde[5], Gary Miller[6], Jerry Sameth[7], John Borzio[8], Michael Telgenhoff[9], Bruce Wilson[10]
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Summary of Test Results

The second part of the summary describes the detailed results of the silane release vapor explosion and overpressure (OP) measurement. These tests included:

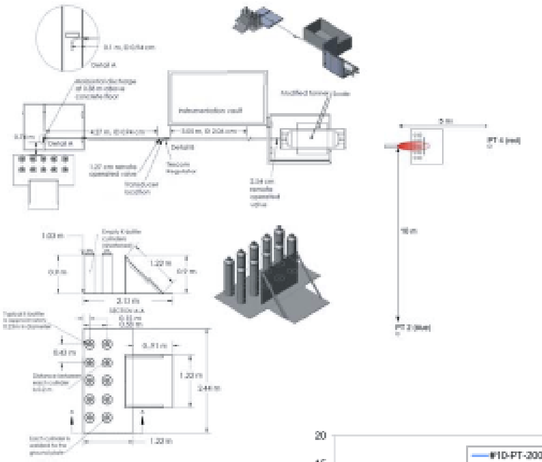
Phase I

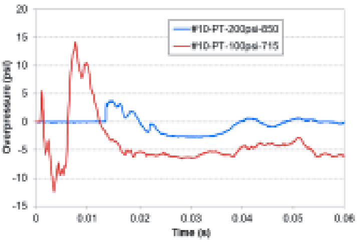
- 1 delayed ignition without obstruction ⇒ no OP (#7)
- 3 delayed ignition with obstruction ⇒ 2 with OP (#8~10)

Phase II

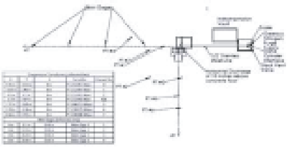
- 4 delayed ignition without obstruction ⇒ no OP (#1~3,19)
- 2 delayed ignition with obstruction ⇒ no OP (#4, 6)
- 9 piloted ignition with obstruction ⇒ strong OP (#5,7~14,)
- 4 piloted ignition without obstruction ⇒ 2 with OP (#15~18)

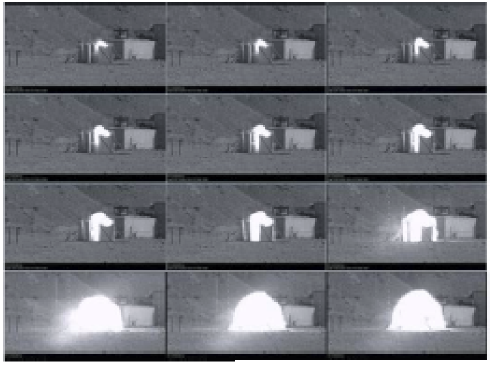
Delayed Ignition with Obstruction: Test 10/Phase I

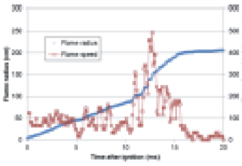


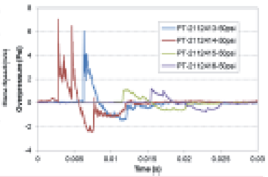


Piloted Ignition with Obstruction: Test 9/Phase II

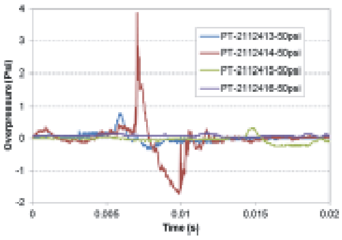






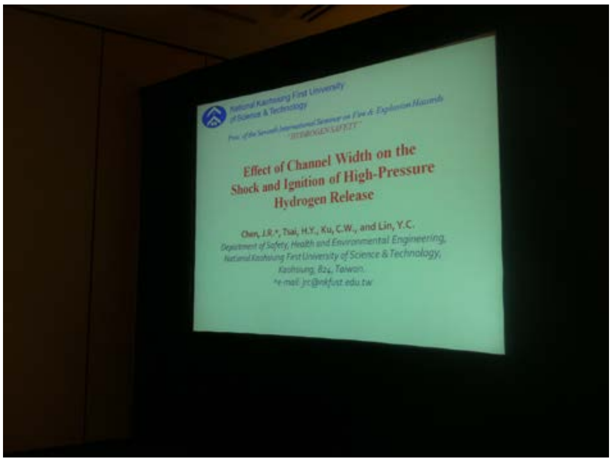


Pilot Ignition without Obstruction: Test 17/Phase II



附錄三、研討會照片

照片一、甲烷外洩測試的海報論文。



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Effect of Channel Width on the Shock and Ignition of High-Pressure Hydrogen Release

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照片二、氫氣高壓外洩自燃機制之論文。

照片三、John H. S. Lee 教授的專題演講。