出國報告（出國類別：會議）

參加性能防火法規及設計國際研討會－2008 國際防火研究領導人論壇年會

服務機關：內政部建築研究所
姓名職稱：雷明遠約聘研究員
派赴國家：瑞典
出國期間：**97** 年 **9** 月 **14** 日至 **9** 月 **21** 日
報告日期：**97** 年 **11** 月 **30** 日

摘　要

爲執行 97 年度本所預算派員出國計畫「03 參加性能防火法規及設計國際研討會」，乃指派雷明遠研究員出席位於瑞典 Borås 舉行之「2008 國際防火研究領導人論壇年會(The International FORUM of Fire Research Directors Annual Meeting，略稱 FORUM)」。會中除有建築性能防火法規及設計議題研討，另有歐洲 5 個會員國之防火研究及性能防火法規概況介紹。此外，國際合作交流議題方面，安排本所簡介建築結構防火研究成果及未來展望規劃，此行對於本所建築性能防火法規及設計相關研究，及促進國際交流合作具有顯著參考價值與助益。

目　次

壹、目的

本次出席參加「2008 國際防火研究領導人論壇年會」，除蒐集國外有關建築性能防火法規及設計最新資料，與世界各國主要研究機構之火災安全專家交流技術、經驗及研究心得，並介紹我國在此領域之發展概況，藉此國際交流機會促進國際社會對我國之充分瞭解，特別是國內有關制度規定及近來在建築結構防火研究領域辦理情形。此外，藉此參加 FORUM 年會機會，積極分享我國（本所）之研究成果及經驗，以獲得其他國家會員之肯定認同，除有助於鞏固我國（本所）在此國際組織之地位，亦可拓展國際合作研究機會。

貳、過程

一、行程表

此行 8 天活動內容概如表 1 所示。

表 1. 2008 FORUM 會議議程概要

日期	上午	下午	備註
9/14(日)	桃園國際機場出發	到達 Borås	經曼谷、法蘭克福等地
9/15(一)		18:00 歡迎晚會	
9/16(二)	第一天會議 9:00-12:00 • 宣布開會、確認議程 • 新任主席、副主席改選 • 新會員介紹及會務簡報 • 歐洲會員專題報告(3 篇)	13:00-17:00 ▪ 歐洲會員專題報告(2 篇) ▪ 檢討 2007 年會議紀錄及決議事項	
9/17(三)	第二天會議 08:30-12:00 •Position Paper（5 項）討論：防火性能設計、避難模擬評估、熱傳、實驗資料交流等議題 •相關國際組織聯絡報告(2 項)	13:00-17:00 • 相關國際組織聯絡報告(5 項) • 參觀 SP 防火實驗室	
9/18(四)	第三天會議 08:30-12:00 •未來會議地點 •相關國際組織聯絡報告(1 項) ▪ Position Paper(1 項)討論：火災模式及實驗不確定性 ▪ 合作研究討論(3 項)：	13:00-17:00 •新合作研究討論 (4 項)：永續性與綠建築對防火安全之影響、火災調查與鑑識科學…等 •FORUM 會務討論(Sjölin Award、新會員邀請加入) ▪ 臨時動議	

	含本所鋼結構接頭耐火實驗計畫及未來工作介紹		
9/19(五)	• 平板測溫器技術討論	• 會議結束	
9/20(六)	• 前往機場		
9/21(日)	• 返抵台灣		經法蘭克福、曼谷等地

有關詳細 2008 FORUM 會議議程，詳如附錄一。

二、會議內容

經過漫長的三天半會議，概將本次會議重點整理如下：

（一）會務方面

1、 選舉產生新一屆主席及副主席，分由 NIST 之 Dr. William Grosshandler 與 NRC/IRC 之 Dr. J. Russell Thomas 當選。

2、 另修正有關選舉規則，並廣泛討論邀請各國防火組織加入新會員事宜。

3、 討論有關 FORUM 贊助 Sjölin Award 及 IAFSS 最佳論文經費事宜。

4、 明(2009)年 FORUM 會議訂於 10 月 12-15 日於韓國漢城舉行，並於 10 月 8-9 日於中國大陸北京舉辦研討會議。【Borås 會議後，中國科技大學火災科學重點實驗室副主任孫金華教授通知，確切的研討會議日期改爲 10 月 18-19 日】

5、 2010年FORUM會議將由英國BRE或芬蘭VTT主辦。【Borås會議後，VTT通知將由其負責主辦】另2011年FORUM會議將由美國NIST主辦，配合第10屆國際火災安全科學研討會在美國舉辦的時間（2011年6月）。2012年FORUM會議由亞洲會員主辦，大陸之中國科技大學已表示願意主辦。

（2）歐洲會員專題報告

由德、英、瑞典、芬蘭等國會員分別介紹近年各自研究項目及成果。有關歐洲會員之專題報告，詳如附錄二所示。

（3）FORUM立場聲明報告（Position paper）

目前有熱傳達限界條件、實驗不確定性及模式結果、實驗室之間數據傳送、性能化設計、避難模擬及評估等課題。有關部份立場聲明報告，詳如附錄三所示。

（4）國際聯絡方面

CIB W14、IAFSS、ISO TC92、EGOLF、NAFTL、NFPA皆提供有關工作報告，就可能合作項目進行討論。

（5）國際合作研究方面

去年本所於美國年會曾提出「鋼構造接頭火害行爲」研究專題報告，並於去年會議決議請本所提供進一步報告供各會員參考。本次會議由雷明遠研究員再提出「鋼構造火害行爲研究－建研所計畫現況」

專題報告，除涵蓋先前研究結果之外，另補充近年新研究成果。報告事後獲得 BAM、SP、FM Global、BRI 等熱烈回應，主席希望本所能夠於今年 12 月底前提供詳細報告給所有 FORUM 會員參考。

本會議過程圓滿成功，透過此項會議的參與，共同研商國際防火研究現況、發展問題及未來策略計畫等議題，獲得了許多寶貴的資料，可作爲我國防火研究發展的借鏡與參考依據，同時也提供一舞台讓本所相關研究有國際發表機會，有助於提昇我國形象。

圖 1. 會議進行情景 1

圖中左起依序爲 Tuula Hakkarainen, Louis Gritzo, Petra Andersson, Ulf Wickström, William Grosshandler(主席), Franco Tamanini(執行秘書), Marc Janssens, Ichiro Hagiwara (荻原一郎)

圖 2. 會議進行情景 2

圖中左起依序爲 Greg Baker, Thomas Russel, Ulrich Krause, Reinhard Grabsk, Hyun-Joon Shin(申鉉準), Craig Beyler (IAFSS 主席), Tuula Hakkarainen

圖 3. 會議進行情景 3

圖中左起依序爲 Tokiyoshi Yamada(山田常圭), Ichiro Hagiwara (荻原一郎), Sheldon Tieszen, Ming-Yuan (Alec) Lei(雷明遠), Weicheng Fan(范維澄), Milan Veljkovic, 站立者爲 Ulf Wickström

三、參觀瑞典技術研究院(SP)

9 月 17 日下午由 SP 防火技術中心安排前往位於 Borås 市郊的實驗室參觀。該中心主任 Dr. Ulf Wicktrom 安排參觀簡介及人員導覽。

圖 4. SP 防火研究中心及實驗室園區入口

圖 5. SP 防火研究中心辦公室

圖 6. 防火研究中心及實驗室職員佈告牌(共計有職員 48 人)

圖 7. Dr. Ulf Wicktrom 介紹 SP 概況及參觀計畫

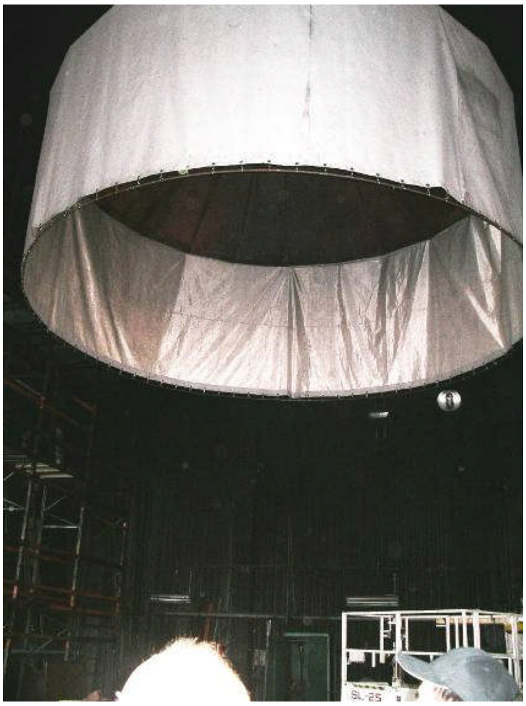


圖 8. 10 MW 大型量熱儀之集煙罩

圖 9. ISO 9705 房間火災實驗裝置(集煙罩及燃燒室)

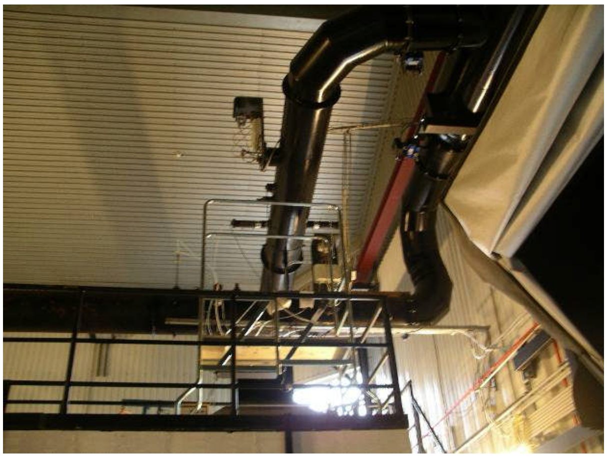


圖 10. 實驗排煙管路、煙氣採樣及濃度分析儀器

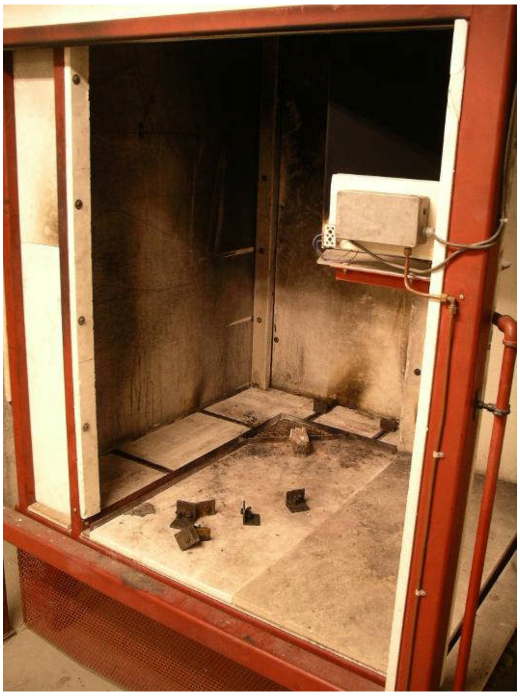


圖 11. EN 13823 單一燃燒物品試驗(Single Burning Item Test)裝置

圖 12. IEC 60332-3 電線電纜垂直燃燒試驗裝置

圖 13. 傾斜火焰延燒試驗裝置

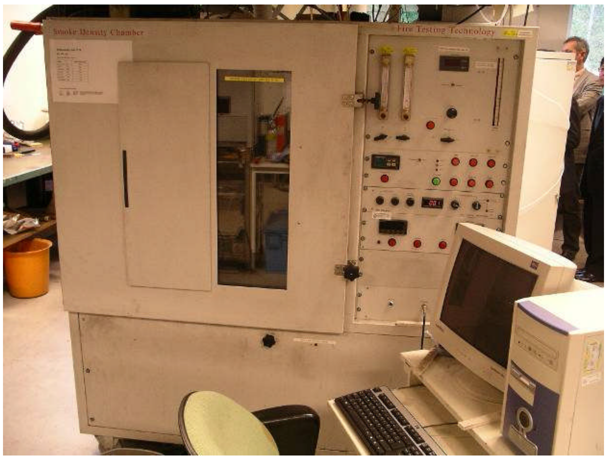


圖 14. ASTM E662/ISO 5659 發煙性試驗裝置

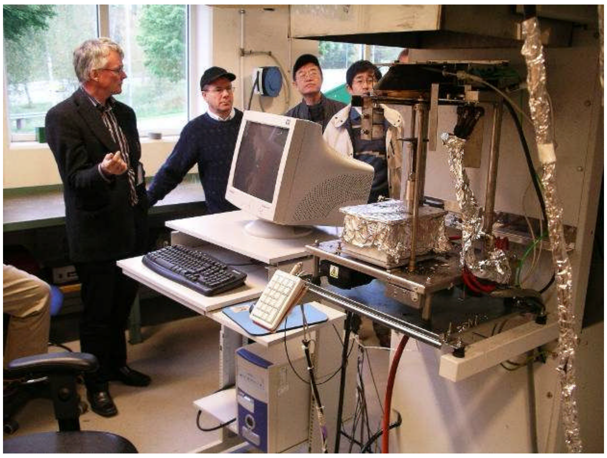


圖 15. Dr. Björn Sundström(左 1)正在介紹 ISO 5660 圓錐量熱儀

圖 16. ISO 9239-1/DIN 4102-14 地板輻射熱及發煙性試驗裝置

圖 17. UL 94 塑膠材料燃燒試驗裝置

圖 18. Dr. Lars Böstrom（右1）正介紹混凝土耐火實驗用熱感應器

圖 19. 3m×5m 樓板及梁耐火試驗爐

圖 20. 3m×3m 門及牆耐火試驗爐

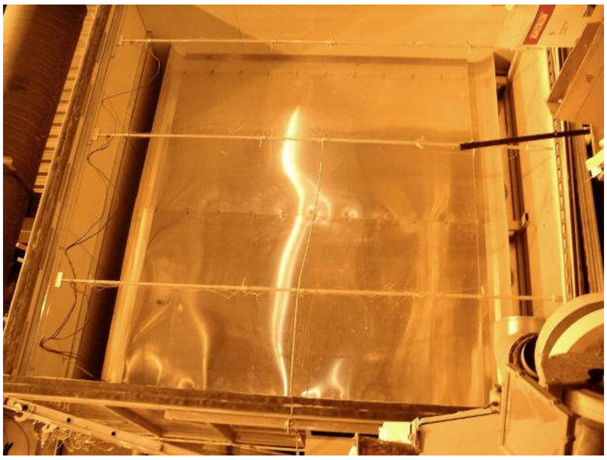


圖 21. 組件漏煙性（氣密性）實驗裝置

圖 22.材料高溫特性加熱爐

參、心得及建議

一、心得

(一)參與 FORUM 年會有助於蒐集了解最新國外防火研究動態

FORUM 乃世界級防火研究實驗機構負責人的非官方、非營利組織，設立宗旨爲透過國際合作進行相關防火研究，以減少火災造成的危害（包括：人命、財物的損失、火災對於環境生態所造成的損害及影響）。該組織創立於 1991 年，由美國、加拿大、英國、日本等國家發起，本所於 1996 年 8 月正式申請入會，目前 FORUM 已成爲重要的防火科技研究國際組織，計有 16 國 21 個防火研究組織的代表參加。今年出席會議的單位會員代表除我國（本所）外，另有瑞典技術研究院防火技術中心(SP-Fire Technology)、美國國家標準技術研究院建築及防火研究所(NIST/BFRL)、山迪亞國家實驗室(SNL)、工廠互助保險全球集團(FM Global)、西南研究所(SwRI)、加拿大國家研究院火災實驗室(NRC/IRC)、英國建築研究所(BRE)、德國消防研究所(Idf Saxony-Anhalt)、聯邦材料研究試驗研究所(BAM)、芬蘭技術研究中心(VTT)、日本建築研究所(BRI)、國家消防研究中心(NRIFD)、中國大陸科技大學火災重點實驗室(SKLFS USTU)、紐西蘭建築研究協會(BRANZ)、韓國營建技術研究所(KICT)等。此外，尚有國際建築及營建研究創新聯盟防火工作小組（CIB W14）、國際火

災安全科學學會（IAFSS）、國際標準化組織防火安全技術委員會（ISO TC92）、歐洲防火試驗認證組織聯盟（EGOLF）、北美防火試驗實驗室聯盟（NAFTL）、美國防火協會（NFPA）等組織聯絡人參加會議，詳參閱附錄六。

從議程安排可知，每年會議由歐洲、北美洲、亞洲等地輪流舉辦，並由該區之會員提研究動態簡報，如此在會議上可以知道別的國家正進行何種研究？應用何種技術？有何成果？此外，尚有若干友好的國際組織代表與會提報其研究近況，以上均提供了掌握世界各地防火研究動態的最佳途徑。

(二)FORUM 經由集體共識提出針對某特定防火議題之立場聲明報告(Position paper)，不僅具有全球舉足輕重意義，亦可提供各國研究規劃之參考

當前 FORUM 之立場聲明報告有關於避難模式與火災中人員行為(Egress Modeling and Human Behavior in Fire)、熱傳達邊界條件(Heat Transfer Boundary Conditions)、防火規範應用之性能設計(Performance-Based Design for Fire Code Applications)、防火實驗室間之數據資料傳遞交流(Inter-Laboratory Data Transfer)、火災模式及實驗之驗證與確效(Verification and Validation on Uncertainty in Experiments and Fire Model)等。每項主題先由會員於年會中提議，

討論確定後圈定若干負責主筆會員，列入決議事項，依進度提出草案後送交主席及執行祕書，再轉傳至各會員審閱，或在 FORUM 年會中提出討論，最後彙整意見提供給主筆人修正。經由以上產生之 FORUM 立場聲明報告凝聚各會員專業上共識，應是國際防火研究的重要文獻。國內近年來常有研究或實務上應用電腦火災模式及人員避難模式，期結果或結論概多宣稱所使用模式適用，然鮮少有人針對電腦模式所隱藏的問題、使用上限制加以探討。從 FORUM 之立場聲明報告就有關於此方面之報告，相信可提供我國研究規劃之參考。

(三)積極參與 FORUM 國際組織活動有助於鞏固我國（本所）在此國際組織之地位

FORUM 會員條件之一是申請人是須在其服務組織內擔任防火研究課題優先性及整合防火研究資源的職務，且其服務組織須是該國的重要防火研究機構，而非僅是實驗測試單位。此外，申請人尚需全體會員代表投票通過後始爲正式會員。本所例由所長申請加入成爲正式會員，現今何所長明錦爲本所會員代表。本次會議期間由於何所長另有要公，不克親自出席，乃指派雷明遠研究員代表出席。該組織內規要求會員至少每兩年應該出席一次年會，如無法親自出席者，可由指定人員代表，否則可能會被視爲自動棄權而遭取消會員資格，以往有丹麥、義大利等例。本所向來均遵守規定，且積極參與，應屬於認

真積極的會員。然而，本次會議期間得知大陸的天津消防研究所（本次會議未派員出席）曾致函給主席、執行秘書，對本所代表國號有所意見(本所自加入 FORUM 成為會員，即已考慮日後可能遭遇大陸不理性抗議行為，而採奧運模式使用「Chinese Taipei」)，惟主席、執行秘書回復稱本所為積極參與會員，而不予採納。因此，本所往後宜秉持現在積極參與態度，方能獲得 FORUM 組織主席與其他會員之肯定及支持。

二、建議事項

(一)建議本所應充分利用防火實驗中心設施設備的優勢，發展若干研究領域可在國際突出之項目。

從本次參加 FORUM 會議過程，得知各國研究單位為求研究突破，未來概有規劃擴充或新建防火研究設施設備之舉，而本所防火實驗中心自 91 年啓用以來，若干設施設備是當今各國所稱羨者，如梁-柱-樓板耐火加熱加載爐、實驗煙塔樓等。如何把握自身優勢，發展出可在國際突出之研究項目，當是本所應有所思考的課題。以本次在 FORUM 會議中簡報本所過去數年所進行之鋼構造接頭耐火研究為例(詳如附錄四)，各國對此應用梁-柱-樓板耐火加熱加載爐及後續應用結構分析軟體之結果，均表達興趣，尤其 FM Global、 Sandia、BAM 及 BRI 等代表表示希望能在相關研究上與本所保持聯繫(詳如

附錄六之會議決議第 11 點)，顯見該研究是國際少有的，其他國家也希望能獲得相關資訊。因此，本所除應坦開心胸提供鋼構造耐火方面之研究成果(但應注意智財權保障)，更可主動邀請有高度興趣的會員來訪(可藉明年 FORUM 年會在韓國舉行之前籌辦小型研討會，順道邀請幾個有興趣會員來台)，展示設備並推廣研究成果，相信能夠獲得國際之肯定，並拓展本所國際知名度。

(二)建議本所可將 FORUM 立場聲明報告及年會會議中重要訊息提供國內各界參考，扮演國內與 FORUM 之間的窗口。

FORUM 雖然成員不多，無法代表全世界防火有關學術界及實務界，但成員均為世界各國具代表性之防火研究機構單位之負責人(領導)，因此 FORUM 可說是全球防火研究領域之主流，其立場聲明報告表達對某項議題之看法，其實也代表著全球主流的見解。本所為國內唯一 FORUM 會員(美國有 4 個會員，日本有 3 個會員，大陸有 2 個會員)，理當扮演起國內與 FORUM 之間的窗口。首先，可將 FORUM 立場聲明報告及年會會議中重要訊息傳遞提供國內建築防火、消防有關學術界及實務界參考，其次未來本所與 FORUM 之國際研究項目，本所得評估情況後亦可邀請國內研究學者參與。甚者，亦可針對某項國內研究議題介紹合適之 FORUM 會員機構為合作夥伴。總之，本所

責無旁貸應該擔負起國際研究交流之橋樑。

(三)建議本所可與日本、韓國等國仿效北美之 NAFTL 及歐洲之 EGOLF，結爲區域研究聯盟，促進法規與標準之進步。

FORUM 會議中曾有討論到何以亞洲沒有類似於北美 NAFTL 聯盟及歐洲 EGOLF 聯盟之區域研究組織。當時本所與日本、韓國會員代表均無法說明。然而，事後與日本、韓國會員代表在會議休息時間交談時，發現彼此咸認爲該構想可行性高，並不排除未來可以組織起來的可能性。台灣、日本、韓國三國不論在民情文化及建築、消防法規，乃至標準，彼此均相當類似。因此，如果在 FORUM 架構前提下，先由本所與日本 3 個會員(BRI、NRIFD、TBTL)、韓國 1 個會員(KICT)先行組織成亞太防火實驗室聯盟或類似組織，彼此進行共通性問題探討、合作研究，促進各國法規與標準之進步，應是美事一樁。未來甚至可邀請中國大陸、印度、新加坡等國加入。相信此聯盟一旦成立，對於我國及本所之國際影響力皆有正面積極的好處。

肆、附錄

附錄一 **2008 FORUM** 會議議程

The International FORUM of Fire Research Directors Annual Meeting

Monday, September 15, through Saturday, September 20, 2008
SP Swedish National Testing and Research Institute
Borås, SWEDEN

<u>Monday, September 15</u>

1800 Welcome Reception, Scandic Hotel Plaza (Ulf Wickström)

<u>Tuesday, September 16</u>

0900 Coffee

Announcements (Ulf Wickström)
Review agenda (Bill Grosshandler)
New member introductions and brief statements:

- Ulrich Krause, Head, Fire Engineering Division, Federal Institute for Materials Research and Testing
- Tokiyoshi Yamada, National Research Institute for Fire and Disaster
- Alec M-Y Lei, Architecture and Building Research Institute

Approval of 2007 Minutes: No changes to the text. Minutes approved.
Secretary Report (Finances, Membership)(Franco Tamanini)
Sjölin Award Committee (Greg Baker)

1045 Break

Chair/Deputy Chair Nominating Committee and Election (Franco Tamanini)

Recommendation to amend election bylaws (Bill Grosshandler)

1200 Lunch

1300 Regional member presentations (continued):

- Prof. Dr. Reinhard Grabski, Director, Institut der Feuerwehr (IdF)
- Dr. Tuula Hakkarainen, VTT Building and Transport, Fire Research
- Dr. Ulrich Krause, Head of Division VII.3 “Fire Engineering,” Bundesanstalt für Materialforschung und –prüfung , Federal Institute for Materials Research and Testing

1530 Break

Regional member presentations (continued):

- Dr. Deborah Smith, Director, BRE, Building Research Establishment Ltd.
- Petra Andersson (for Dr. Ulf Wickström), SP Swedish National Testing and Research Institute

Review of the minutes from October, 2007 meeting in Albuquerque and San Antonio (Franco Tamanini)
Discussion of action items from 2007 meeting (all)

1700 Adjourn

1800 Dinner

<u>Wednesday, September 17</u>

0830 Coffee

0900 Current position papers:

- Egress Modeling (Bill Grosshandler)
- Heat Transfer Boundary Conditions (Ulf Wickström)
- Presentation of Furnace Test Results (Ulf Wickström)
- Performance-Based Design (Bill Grosshandler) : This paper was published in Vol 43, April 2008 of the Fire Safety Journal.
- Inter-Laboratory Data Transfer (Marc Janssens)
- Car Test Database (Marc Janssens)

1100 Liaison reports

- ISO TC92 (Björn Sundström)
- NAFTL (Marc Janssens)

1200 Lunch

1300 Liaison reports:

- Report on investigation result of WTC 7 collapse (Bill Grosshandle)
- EGOLF (Ulf Wickström)
- IAFSS (Craig Beyler)

1500

- CIB W14 (George Hadjisophocleous)
- LUT(Lulea University of Technology, Sweden)(Milan Veljkovic)

Open discussion on presentations (all)

1630 Tour of SP Laboratories (Ulf Wickström)

1800 Boat Excursion and Dinner

Thursday, September 18

0830 Coffee

0900 Discussion on future meeting sites:

- Seminar prior to FORUM Meeting in Peking, 8th-9th Oct 2009

- 2009 FORUM Meeting (12th-15th Oct, Seoul), Hyun-Joon Shin, KICT
- 2010, VTT or BRE(Offer made by VTT after the Borås meeting to be the host in 2010)
- 2011, North America after the IAFSS conference (June 26-29, NIST)
- 2012, Asia (August, SKLFS/USTC)

Liaison reports:

- NFPA Fire Protection Research Foundation (Bill Grosshandler for Kathleen Almand)

Current position papers:

- Uncertainty in Experiments and in Model Results(Lou Gritzo)

1030 Break

Review of current collaborations (all)

- Establishing a fire database (Fire Safety Science Search of IAFSS) (Craig Beyler)
- ABRI Projects on Fire Behaviors of Steel Structural Connections (Alec M-Y Lei)
- Load-Bearing Gypsum Board Testing at NSIT (Bill Grosshandler)

1200 Lunch

1300 New collaborations (all)

- Sustainability and Green Construction Impact on Fire Safety (All)
- Fire Investigation and Fire Forensics (All)
- Virtual Fire Community Project (Greg Baker)
- Rational Test Method (Science-Based Method)

Continued discussion on Sjölin Award
Continued discussion on New Membership

1700 Adjourn

1800 Dinner

Friday, September 19

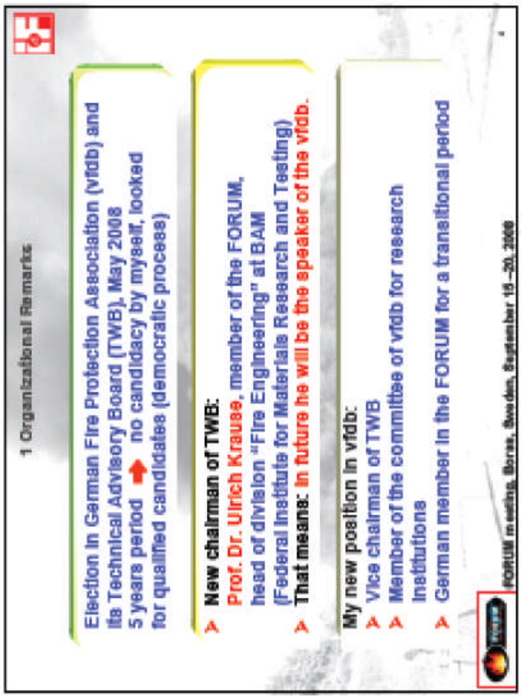
0900 Continued discussion on the Plate Thermometer at SP (Ulf Wickström and related members)

- Presentation by Marc Janssens

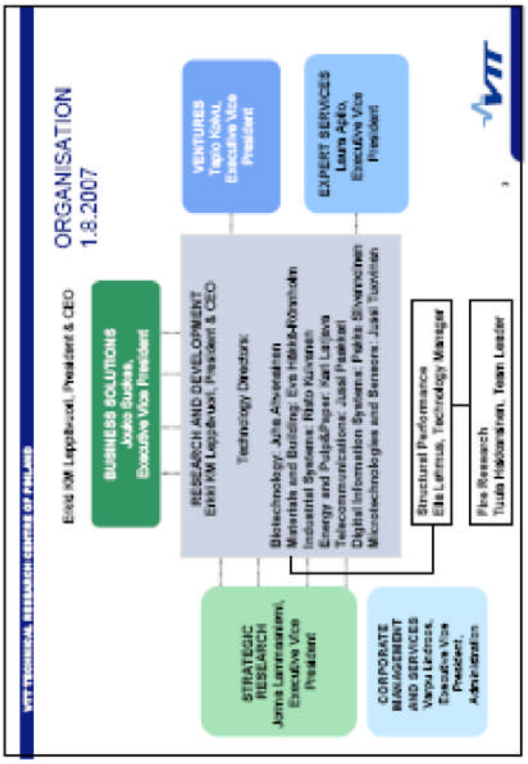
1200 Adjourn

附錄二 **2008 FORUM 會議歐洲會員之專題報告**

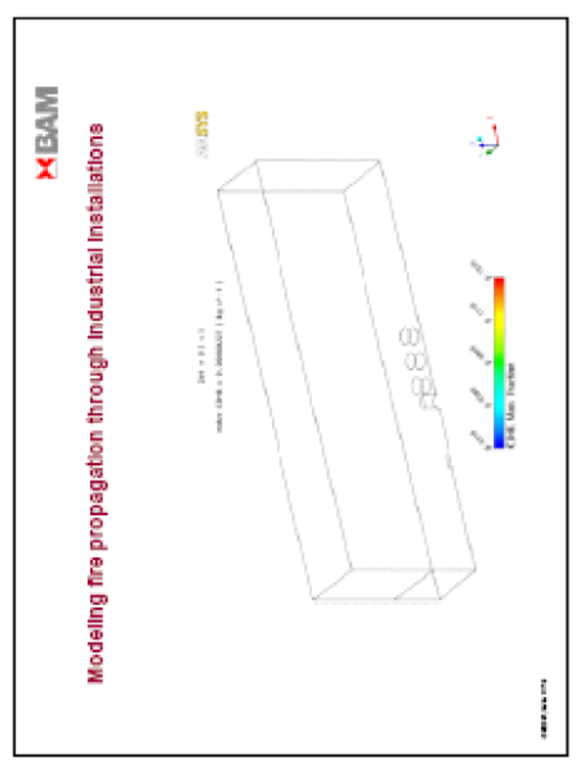
一、 德國消防研究所(Idf Saxony-Anhalt)



二、 芬蘭技術研究中心(VTT)



三、 聯邦材料研究試驗研究所(BAM)


BAM
Modelling fire propagation through Industrial Installations

四、 英國建築研究所(BRE)

BRE Trust PhDs – in progress

- Firegrid
- Material flammability assessment
- Assessment of fire damaged concrete structures
- Super-real-time Prediction of Fire and Egress for Emergency Response
- External fire spread modelling
- Real time flamespread prediction using sensor inputs
- Model assisted Fire Risk Assessment
- Behaviour of damaged structures in fire

Protecting People, Property and the Planet

bre global

Thank you for listening……..

Any questions ???

Protecting People, Property and the Planet

bre global

五、 瑞典技術研究院防火技術中心(SP-Fire Technology)

Sandwichpanels

Sandwichpanels –
Market survey

Cables

CEMac – CE marking of cables

附錄三 **FORUM** 立場聲明報告

一、防火規範應用之性能設計

The International FORUM of Fire Research Directors[1]

A Position Paper on Performance Based Design for Fire Code Applications

Paul A. Croce,[i, #] William L. Grosshandler,[ii] Richard W. Bukowski,[ii] and Louis A. Gritzo[i]

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[ii] *Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8660, U.S.A.*

Background

Fire codes and standards are developed and regulations implemented in most countries with the objective of protecting societies and reducing their losses from fire. For the majority of traditional buildings with low hazard occupancies, modern prescriptive building and fire codes, when enforced, achieve this objective. Nontraditional buildings include many of society’s largest and iconic structures, such as opera houses, museums, sports stadiums, transportation centers, super-high-rise structures, and some government buildings. Prescriptive codes cannot anticipate all of the requirements that these nontraditional structures impose; prescriptive codes do not adapt rapidly to changing materials and methods of construction, nor to radical architectural designs; and prescriptive codes based upon historical loss experiences are not designed to deal with very low probability, very high impact events or other threats such as from terrorism.

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[1] http://www.bfrl.nist.gov/info/forum/ The International FORUM of Fire Research Directors (FORUM) was formed in 1991 with a goal to reduce the burden of fire (including the loss of life and property, and effects of fire on the environment and heritage) through international cooperation on fire research. Our members include many who were involved with writing PB codes; we have met and worked with regulators, practitioners and educators worldwide; and we have carefully examined and discussed these factors in the effective application of PB design for regulation.

[#] retired

Regulating the design, construction, and operation of buildings on the basis of performance is viewed as a means to overcome many of the shortcomings of prescriptive codes for nontraditional structures, as well as for more traditional buildings on unusual sites, or for an existing building undergoing renovation or a change of occupancy. While an additional up-front investment is required to design and evaluate a project on the basis of performance rather than prescription, performance-based codes provide much greater flexibility and promote innovation in building design, materials, products and fire protection systems. Deemed-to-satisfy provisions provide continuity with prior prescriptive regulations and ensure that existing buildings do not come into violation. However, this assumes that the prescriptive rules are sufficient in all cases to meet the performance objectives, which may not be the case.

ISO TC92 has established a framework for the long term standardization of fire safety in support of performance-based design.[i] A guide for conducting performance-based fire protection design has been developed by the Society of Fire Protection Engineers (SFPE), which spells out the steps from the definition of the design scope, through the expression of the performance criteria, selection and evaluation of design fire scenarios, and ultimately to the final design.[ii] Even so, the success of performance-based design (PBD) for fire code applications hinges on the establishment of critical solution-enabling tools, a profession properly educated to implement these innovations, and code officials capable of evaluating the safety of PBD. Further, when expressing the performance criteria, serious consideration should be given to public well-being as an appropriate overall goal of performance-based regulation. An approach committed to public well-being can broaden the beneficial societal impact with likely more reliability.

Challenges of Performance Assessment

Buildings are complex collections of systems, materials and arrangements that are highly variable and interactive, and the performance objectives of the regulations relate primarily to the performance of the system as a whole. Deficiencies in one area can in some cases be compensated by use of other materials or systems and this is central to the flexibility afforded by performance-based regulation. However, compensation or substitution is not easily evaluated and not always proper or prudent. The ability to quantify the in-use performance of many fire safety systems is mixed, made difficult by: the physics of the fire, the fire protection systems, and the response of the building to the fire; our incomplete knowledge of human behavior in a fire emergency; and the complexity of validating computational design tools over a wide range of fire scenarios.

Experimental tools, e.g., mid- and large-scale calorimetry, are well developed and widely available for measuring the heat release rate of real objects and fuels (along with the yield fractions of smoke and major species) under fully ventilated fire conditions, but how these may change for vitiated conditions or when impacted by external radiant heating cannot be predicted in a quantitative sense. Small-scale testing can be particularly helpful as an economical approach if implemented in a manner that is compatible with PBD[3]; clearly, though, more work is needed. Initial sprinkler activation times can be estimated to reasonable accuracy but the influence of the water spray on the fire environment and on the combustion process, along with subsequent sprinkler activation times, can be only crudely estimated.

There has been great progress in recent years with fire models that can predict the development and spread of fires and the fire's impact on the internal environment of the building. A number of computational models are available and are now routinely accepted for some regulatory applications. Some models have been adequately validated for specific applications, but many have not been validated for broad classes of complex problems because validation-quality data are available for only limited geometric arrangements and fuel conditions. Guidance exists for fire model verification and for documentation;[4] however, few organizations have pursued the rigorous verification and validation supported by the FORUM.[5] Therefore, application of these models typically requires extrapolation to the design of interest and the associated validation.

Given the thermal environment established by a fire model, finite element models are available for predicting the resulting temperature distributions within the structure; and models have been developed to predict the stresses and response of the structure to the changing thermal environment. However, combining these models to obtain a comprehensive picture of the response of the overall structure to, say, a full building burnout is problematic. The individual models operate on vastly differing time and length scales that pose significant problems for solution of the governing equations. Sequential calculation methods recently have been employed to solve this problem,[6] but these are tedious and too costly for regular use in design and regulation. The prediction of incipient failure of individual elements is on relatively firm ground. The reaction of connections to thermally induced stresses and creep, the effects of high heating rates and thermal gradients (as well as numerical convergence difficulties near imminent structural collapse) were examined in the series of tests conducted in Cardington;[7] however, there is much yet to be learned.

Performance assessments generally involve the application of considerable engineering judgment and are subject to manipulation by the selection of calculation method and input data. This issue depends on two factors to assure confidence for regulation. First, individuals performing the calculations are generally required to be licensed or chartered and subject to the ethical constraints of a design professional. Second, most performance-based regulatory systems require third-party review of all calculations and assumptions. With a concerted long term program to increase the educational level and minimum qualifications of regulators, the issue may be brought under control within the limitations of the design tools themselves. More, however, needs to be done to assure adequately accurate models, a better educated profession, and more appropriate model application.

Research Needs

Representatives from the FORUM membership and other technical experts were invited to develop a common, international vision for how the scientific foundation might be bolstered for the next generation of performance-based design tools.[8] Methods for the attainment of this vision were identified that included the establishment of:

- a hierarchy of meaningful benchmark fire experiments and simulations;
- tractable combustion models that capture the essence of materials and finished products, and with simple multi-step reaction mechanisms for prediction of CO and soot;
- data sets and experimental facilities for unraveling the relationships within and interactions among fire dynamics, structural dynamics, and human behavior;
- efficient interfaces among fire, structural, human behavior, and risk models;
- data and means to track uncertainty in risk and hazard analysis, and to incorporate rare, high consequence events.

Five areas were identified at the top of the list of research priorities for the members of the FORUM:

- improvement of our ability to predict the impact of active fire protection systems on fire growth and the distribution of combustion products;

- estimation of uncertainty and the means to incorporate it into hazard and risk analyses;
- the relationship between aspects of the building design and the safety of building occupants;
- the impact of material and geometry changes on fire growth and products of combustion;
- the prediction of the response of a structure to full building burn-out.

FORUM Position

It is the FORUM's position that:

- the level of understanding of fire science by practitioners and the capabilities of the current generation of FPE tools are useful and adequate to support some aspects of performance-based regulations, codes and design, although numerous practical design applications and requirements exist that remain beyond the limits of these tools, and uncertainties in the predictions have not been or cannot be quantified;
- accurate tools must be available and used expertly; and PBD must be applied uniformly and consistently by properly educated practitioners and evaluated uniformly and consistently by adequately trained authorities having jurisdiction;
- for performance-based regulation to be effective, a commitment must be made to public well-being, both in the public and private sectors.

A coordinated and sustained global effort of research among FORUM members, universities, and other research organizations in support of PBD can lead to enhanced and more certain predictions of: the effects on performance of changes in building materials, active and passive fire protection systems, compartmentation, and egress systems; the structural response of a building to large fires including those leading to full building burn-out; the impact of fire on neighboring buildings and infrastructure; and the uncertainty in deterministic predictions for incorporation into reliable probabilistic calculations of hazard and risk.

FORUM members are committed to documenting and disseminating to the international regulatory, codes and standards communities progress on these collaborative efforts as well as the results of their individual research programs in support of the beneficial aspects of performance-based codes and performance-based design for fire applications.

[1] "Framework for Standards for Fire Safety," TC92 N 983, International Organization of Standards.

[1] *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*, National Fire Protection Association, Quincy, MA, U.S.A., 2000.

[3] Bill, R.G. and Croce, P.A., "The International FORUM of Fire Research Directors: A position paper on small-scale measurements for next-generation standards," *Fire Safety Journal*, Vol. 41, 2006, pp. 536-538.

[4] "Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models," ASTM E 1355-05a, ASTM International, West Conshohocken, PA, U.S.A., 2005.

[5] Gritzo, L.A., Senseny, P.E., Xin, Y. and Thomas, J.R. "The International FORUM of Fire Research Directors: A Position Paper on Verification and Validation of Numerical Fire Models" *Fire Safety Journal*, Vol. 40, No. 5, July 2005, pp. 485-490.

[6] *Final Report on the Collapse of the World Trade Center Towers,* NIST NCSTAR 1, National Institute of Standards and Technology, Gaithersburg, MD, U.S.A., September 2005.

[7] Cardington …………………………………………….

[8] Grosshandler, W. (editor), "FORUM Workshop on Establishing the Scientific Foundation for Performance-Based Fire Codes: Proceedings," NIST SP 1061, National Institute of Standards and Technology, Gaithersburg, MD, U.S.A., December 2006.

DRAFT

The International FORUM of Fire Research Directors

A Position Paper on evacuation and human behaviour in fire

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WD25 9XX, UK

Background

Most prescriptive codes do not explicitly deal with evacuation or human behaviour in fire. They normally preferring to provide guidance on egress provision or means of escape based on the type of building and the number of occupants (usually a pessimistic upper limit). The guidance usually recommends a travel distance, the number of exits, and their width as well as the number of stairs and their width (based on a number of mm/p). This approach is used in many countries and fire statistics seem to indicate that in most situations a safe outcome is possible.

This approach tends to implicitly assume that people will:

- Raise the alarm when they detect a fire;
- Know how to fight a fire and will do so if safe; or will,
- Start to move immediately towards an exit when they hear an alarm or see signs of a fire; and will,
- Stop what they are doing, will not take possessions and will not seek out family or friends;
- Follow instructions given to them;
- Know where to go;
- Go the right way even if they do not know where to go;
- Use the nearest exit;
- All walk in a fast uniform and efficient way;
- Behave differently in a fire; and will,
- Not be affected by fire hazards.

This approach does not explicitly address evacuation or human behaviour in fire.
For example, response activities and time are unknown and addressed implicitly. The movement of people to a place of safety is also addressed implicitly, sometimes with a notional value. In the UK a notional value of two and a half minutes is often used and this apparently dates back to a theatre fire in which those in the auditorium after ‘two verses and choruses of the national anthem’ (or 2.5 minutes) had perished.

The evacuation process is of course much wider than solely the movement to and flow of people through an exit and involves:

- Peoples' response to fire cues and warnings; such as fire, smoke and sounders, Public Address systems.
- Pre-movement activities; continuing with previous activities, investigation, warning others, firefigting, collecting possessions…etc
- Exit choice and/or
- The effects of fire hazards on occupants' ability to escape.

People, unlike steel, are not at all homogenous – many behavioural processes are stochastic in nature. There is increasing evidence that the behaviour of people in fires depends on; the building, the person, the fire and intervention effects.

The nature of the topic difference is quite different to our understanding of the development of hazards from fire. Our knowledge concerning the development of fire hazards is based on sciences such as physics and chemistry, some fundamental laws and a body of experimental data. Evacuation and human behaviour in fire has much closer links with psychology and toxicology and has traditionally relied on anecdote and limited experimentation (Cantor and Sime).

The development of performance based codes has led to the use of empirical data, simple and complex evacuation models to try and address the shortcomings in the application of prescriptive guidance to large, complex or non-standard buildings. This application of scientific knowledge can provide useful insight into how quickly a building might be evacuated, but it is not without its limitations.

Conceptual models and empirical data

There is some empirical data on human behaviour, evacuation and tenability.

There are some qualitative observations and cognitive models for human behaviour in fire (Canter, Sime, Brennan, Bryan et al) These insights include the response to fire cues and the myth of 'panic'. Mclintock et al, have given us insight into why people do not generally choose the nearest exit (learned irrelevance) and a raft of other human behaviour in fire phenomena have some degree of explanation based in psychology eg. Commitment to current tasks, affiliation and group behaviour, familiarity with exit routes… etc.

Data, however, on human behaviour is very sparse and does not form part of a holistic framework. There is no consensus on an appropriate cognitive model, nor does the data that has been collected fit together in a coherent way. There is also a tension between the largely qualitative conceptual approach used by psychologists and the quantitative needs of other scientists and engineers.

Human behavior is also subject to change over time and there is no organized way to identify such changes and incorporate them into models and calculation methods. For example, new evidence (Averill, Pauls) suggests that the movement speeds commonly applied to evacuation are as much as a factor of two higher than current observation, which is attributed to the ageing of society, obesity, and general reduction of physical fitness in the population. Additionally, in the aftermath of the World Trade Center collapse there is speculation that occupants of high rise buildings may be unwilling to wait their turn in phased evacuations. Since the egress system of tall buildings cannot accommodate simultaneous evacuation, this would result in jamming of the stairs and excessive evacuation times.

Evacuation has been the subject of most of the data collected so far, but in comparison to other aspects of fire safety, this data is still sparse (Pauls, Prioulx, Boyce). The data was often collected in experiments involving unrepresentative or unknown groups in unrealistic evacuation scenarios and so is highly variable in quality. There are also issues of scale where data for investigated space syntax in master planning (Fruin) does not correlate well with data used for egress from buildings (Pauls). Where data exists it may still be controversial (NIST WTC Investigation, Pauls) and there are other areas where data and models are at a very early stage in development:

- Cross flow
- Counter flow
- Flow up stairs
- Use of lifts
- Movement of mobility impaired people

Effects of fire and smoke

Data on toxicity is extremely limited due to ethical issues of deliberately exposing people to a hazardous environment (Purser). What data there is, tends to be dated and from a small set of experiments that have not been replicated (Jin). Animal models are also subject to ethical considerations in many countries and other approaches have so far been unable to adequately represent the complex interaction between fire environments and human physiology.

Simple models

There are no simple models for behavioural or cognitive response of people to fires (Hall).

The data that has been collected on evacuation has been used to develop simple mathematical and computer models to predict movement times in the evacuation from buildings on fire (Pauls, Fahy, SFPE Handbook, ISO). These models use hydraulic or ball bearing physical analogies and are used by engineers in design of specific usually complex buildings. They can provide a useful comparative insight into evacuation, but are limited in the breadth of their application and do not realistically represent the beta distribution of exit times seen in real evacuations.

There are also some simple models for the tenability of people for a range of fire hazards (Purser). There have been some attempts to combine this data to address combined dose effects. These models tend to provide mean expected tenability for consciousness and death. Other effects such as the more subtle effects on cognitive processes are not addressed.

Complex models

There are a number of computer evacuation models that treat each occupant discretely and address their interactions with each other as well as the fire and their environment (Thompson, Fraser-Mitchell, Galea et al). These models are showing some promise, but unlike CFD, there are no universal laws (with the possible exception of the conservation of mass), theoretical bases are unpublished and so unknown and they have not normally been subject to peer review in the same way as physical fire models. They are being used on large complex design projects and investigations, however, they often appear as black boxes to the user, perhaps with some limited comparison with experiment to instill confidence.

Some of these models attempt to address human behaviours, such as the response of occupants as well as their tenability. These models tend to be quite simple (based on the limited data above) and can provide counter intuitive results. These result may not be incorrect, but have to be treated with utmost caution until other scientific evidence can be considered.

A better way

Now suppose a different approach is taken in which the design and operation of a building is focused around the needs and behaviour of its occupants (Groner). This approach could be informed by an agreed cognitive/conceptual model for human behaviour in fire (Hall) and be quantified using fundamental models that are based on publicly available data and have been peer reviewed.

By using this approach we can:

- Improve the quality of prescriptive guidance;
- Develop solutions that work with human behaviour in fire (rather than against it);
- Improve the effectiveness and efficiency of performance-based fire safety designs solutions; and,
- Improve safety by avoiding the same old pitfalls – for example, from the Theatre fires to the 1800's to the Station Night Club fire in 2001;

FORUM Position

For nearly a century, egress stairs have been designed to provide a certain *capacity* in terms of the maximum number of occupants on a given floor expected to be using the system simultaneously. As the world moves to performance-based regulation the appropriate metric for egress system performance is *time* needed to get to a safe place. There is a need to revise building regulations to recognize time as the performance parameter for egress systems design.

In the post-9/11 world it is recognized that fire is not the only event for which partial or complete evacuation of buildings may be needed. Different events require different responses ranging from evacuation from the building to relocation within the building to hole in place. Design and performance evaluation methods need to be expanded and improved to reliably consider these alternatives and approaches developed to ensure that occupants understand what to do.

Emergency response to events involves much more than sending occupants down stairs and out of the building. Tall buildings in Asia are required to have refuge floors every 20-25 floors, there is much discussion of protected elevators for fire department access and for occupant egress, and escalators are now permitted (in specific circumstances) to be used as an egress system component. The interactions of all of these approaches including implications of human behavior, in providing for timely evacuation needs to be assessed and incorporated into design guidelines and regulations.

Evacuation performance and especially human behavior is highly variable, leading to significant uncertainties in performance assessment. Regulators need to understand these uncertainties and appropriate factors of safety assigned to ensure regulatory compliance. This process needs to be formalized in the engineering practice to meed the needs of the regulators.

Regulations intended to protect human subjects in research have become a serious impediment both to needed human behavior research and to training of the public in emergency procedures. Appropriate methods that permit behavioral research and training, and which protect people from unreasonable risk need to be developed.

References

To be completed:
WTC
Evrill
Pauls
Purser
Groner
Fahy/Exit 89
Galea/Exodus
STEPS
Legion
Simulex
Canter
Sime
Shields
McLintock
Proulx
HUBFIN
SFPE Handbook
Hall
VTT

The International FORUM of Fire Research Directors

A Position Paper on Verification and Validation of Numerical Fire Models

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Introduction and Background

Numerical simulation of fire environments using computational models has become increasingly widespread in fire research and fire safety engineering. The ability to accurately predict fire behavior using these models is of high utility for hazard assessment, investigations and performance based design. Accordingly, the FORUM position supports the development of accurate models, using material property data as input, as the appropriate long term goal of the fire research community [1].

In general, accurate numerical fire models must represent many nonlinear, coupled phenomena over a broad range of length and time scales. Physics-based fire computer codes typically include an order of magnitude more (>10) degrees of freedom than codes commonly employed for engineering mechanics. Models with varying degrees of development and maturity are being increasingly employed to provide predictions of fire growth, fire spread and fire suppression. These models may invoke the use of algebraic relations, zone, and computational fluid dynamics based techniques. The credibility of the results from these models has not been generally established. Guidance has been developed for evaluating model capabilities [2, 3] and for determining uses and limitations [4], however time and resources often prohibit such exhaustive prescriptive approaches from being employed by each analyst. The complexity and non-linearities inherent in fire modeling yields a significant potential for results which can be explained by the analyst as reasonable, but are sufficiently in error as to lead to incorrect conclusions by a decision maker.

The FORUM position is to require verification and validation of fire models as needed to establish known levels of confidence in model predictions. The benefit of this activity includes 1) improved quality of predictions over a broader range of applications, 2) improved confidence by decision makers as needed to encourage acceptance of model results, and 3) continual advancement of the state of knowledge. It is acknowledged that these activities require additional effort on the part of the developer and the user. This effort is a necessary and useful long term investment to allow fire safety engineering to progress from a test-based field to a knowledge and simulation-based field of practice. In some cases, a graded approach can be employed where the level of rigor is increased based on the end use of the results [5].

The Essential Features of Verification and Validation

Verification and validation are two independent processes. Verification can be simply defined as "solving the equations right," and validation as "solving the right equations." Verification deals solely with computational science and mathematics, while validation deals with physical phenomena. The theory and processes of verification and validation are well established and documented [6,7] and will therefore not be repeated in detail. The main features, and the corresponding position of the FORUM, will be highlighted and discussed in terms of their relevance to fire research and engineering.

It is necessary to verify both codes and calculations to assure that the equations have been programmed correctly and that they are being solved correctly in a given calculation. Codes cannot be validated. Only specific models, which are created by the analyst and executed by the code, can be validated. Validation is performed for the "intended uses of the model." The validity of a model is therefore restricted by model formulation and model parameters inherent in the code as well as the input parameters and conditions specified by the user. Use of the model with confidence would therefore be limited to the class of applications for which it was validated; use for any other purpose would require additional validation. Furthermore, any changes to the model, or use of the model with significantly different inputs, require additional validation.

Verification and validation must be conducted in the following sequence: 1) verification of computer codes, 2) verification of calculations and 3) validation of models. These activities should all be performed within the range of the parameter space of the intended use.

<u>Code Verification.</u> The primary purpose of this step is to establish that correct solutions to the equations *can* be obtained. Successful verification implies no coding errors and the use of sound, robust numerical methods. Code verification can be performed via comparison of the computed solution with exact, analytical solutions (which is limited to simple problems) or more recently through the used of the "method

of manufactured solutions” [8]. In this technique, a source term and boundary conditions are determined analytically for a known function which is in turn compared to code results with the use of the specified source term and boundary conditions as code input. Code verification should exercise all parts of the code for the range of values expected for general use. This generally requires access to source code, and *it is the FORUM position that code verification be performed, and documented, by the code developer.* Discovering coding errors should not be left to the analyst, although a feedback mechanism should exist to allow analyst observations to be provided to the developer in case such errors are encountered. The analyst should have access to verification documentation to ensure that the capabilities and features to be used have been verified.

Calculation Verification. In this step, the numerical accuracy of a particular calculation, which employs a code to generate a model for a specific scenario, is determined and documented. The specification of input parameters is critical for all models. Numerical models that use a discretized form of the equations to obtain a solution (generally using a computational grid) also require careful definition of boundary conditions and consideration of grid refinement. Since numerical fire models only provide resolved (i.e. discrete forms of the exact equation) solutions for a limited range of physics, they will not in general provide convergence to the exact answer with increasing discretization. Grid (or discretization) sensitivities must therefore be determined and documented. This feature is particularly important for large-eddy simulation type codes in which grid resolution and spatial filtering are intertwined. It is essential to estimate the accuracy of the computed solution, i.e., to put error bars on the computed results. Calculation verification is highly dependent on the specific scenario and therefore must be performed by the analyst. Sufficient detail should be provided in the documentation to allow future analysts, when faced with a similar problem, to use or at least compare results with the outcome of previous calculation verification activities.

Model Validation. Validation is the process of determining the degree of agreement between model predictions and real world events for one or more results of interest. The goal of validation is to quantify confidence in the predictive capability of the model. Therefore, validation assesses agreement between model output and experimental data, as determined by an appropriate metric. The comparison must include the uncertainty estimates from both verification calculations as well as experimental measurements. For example, results of verification calculations may illustrate the need for materials characterization experiments to reduce uncertainties.

Validation experiments are the standard against which the model outputs are compared. As such, they include some unique requirements. Collaboration between experimenters and modelers is essential for validation experiments. A shared understanding of the goals and conditions of the experiment is necessary. Pretest analyses should be conducted to help support experimental design. A clear understanding of the nature, resolution, and expected uncertainty of the experimental measurements that comprise the boundary and initial conditions, as well as a clear definition of the validation metric, is required. In selecting the validation metric, the primary considerations should be the desired end use of the model in conjunction with what type of data are available from the experiment. Accuracy and precision are of the utmost importance, and both should be determined through uncertainty quantification including repeated experiments. Guidance on the selection of experimental and simulation metrics (such as consideration of parameters, treatment of temporal and spatial variations) for comparison is available in the literature [9]. Field measurements are often used for visual comparison, but fall short of validation due to a lack of quantitative comparison of multi-dimensional model results and experimental data. Due to compensating errors, good agreement between prediction and experiment does not imply comprehensive confidence in all aspects of the model. It is therefore advisable to perform validation activities that address individual phenomenology before conducting integral level validation to address a complex scenario. Final calculations for comparison should be performed with careful consideration of the initial and boundary conditions, but without a priori knowledge of the results. In some cases, it is acknowledged that data are sparse and boundary conditions can not be fully characterized. The extent to which these uncertainties affect the confidence in the model should be quantified by appropriate consideration of experimental uncertainties and model sensitivities.

Because many problems show significant sensitivity to physical, numerical and model parameters, it is often easy to adjust the prediction of computer models to match measurements. Calibration of the model to agree with known test results does not constitute validation. *It is the FORUM position that adjustments should not be made to models or model constants to improve agreement between model predictions and data. Only after a compelling body of data has been obtained, and/or a clear physical explanation has been provided, should model changes (subject to software quality guidelines [10]) be implemented.*

Validation is application specific, i.e. models that provide results within acceptable levels of confidence for one application may not provide them for another. It is ultimately the responsibility of the analyst to perform or cite model validation results to ensure the achievable level of confidence is appropriate for the application of interest. *The FORUM position is to encourage baseline model validation for the intended application space of the code by the code developers such as to provide the user an* *indication of the predictive capability of models that can be employed for similar applications.* The specific cases and validation metrics will vary according to the intended use of the code.

Data from model validation experiments and validation exercises must be carefully documented to benefit future users. Otherwise, each user must repeat the validation exercise for each application, in a manner similar to a test-based approach, and the knowledge base will not progress.

FORUM Position

The FORUM cites the need for known levels of confidence in fire models used in fire protection engineering. Since the necessary procedures are now sufficiently well defined to be employed in practice, the FORUM position is to require verification and validation to include:

- Code verification by the developer to identify and reduce coding errors.
- Calculation verification including characterization of discretization (normally grid) and input parameter dependence to establish appropriate model usage.
- Model validation in the parameter space of interest, based on an established metric and employing high quality experimental data, to provide a quantitative assessment of the predictive capabilities of a model.
- Documentation of validation studies, following established guidelines, in the open literature with sufficient rigor and detail to be used as a basis for increased confidence in future analyses.

The principal barrier to verification and validation is the additional effort and cost required by the developer and analyst. Although this cost is recognized and acknowledged by the FORUM, efforts of appropriate rigor are clearly necessary to improve acceptance of model results by decision makers and to progressively advance the state of knowledge.

ACKNOWLEDGEMENTS

The valuable contributions of many of the FORUM members, specific input from William Grosshandler and Anthony Hamins at NIST, and the insight gained from numerous discussions with Martin Pilch and Sheldon Tieszen of Sandia National Laboratories are gratefully acknowledged. This work was performed in part at Sandia National Laboratories, a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

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Research on Behaviors of Steel Structure in Fire – Status of ABRI Project

Alec M. Y. Lei

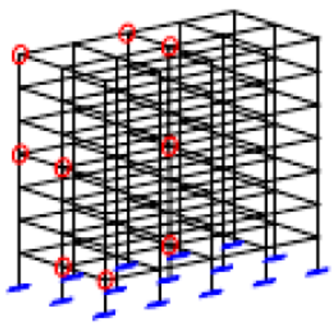
Outline

1. Planned Tests for Steel Structures
2. Planned Tests for SRC Structures
3. Demo of Recent Fire Test

2

1. Planned Test for Steel Structures (since 2002)

Typical interior, edge, and corner beam-column sub-assemblages (connections) at the roof, mid-height, and ground floors of a high-rise building.



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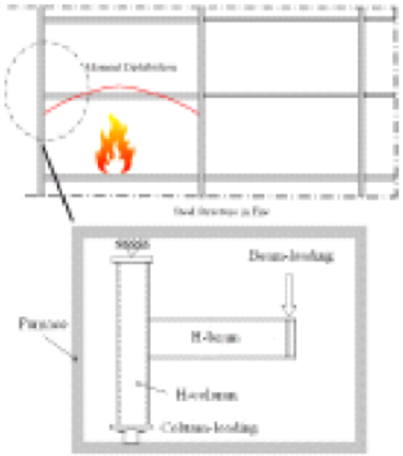
No.	Planned Fire Tests for Steel Structures in ABRI
1	H-Beam to H-Column Subassemblage Fire Test
2	H-Beam to Box-Column Subassemblage Fire Test
4	Beam-to-Column Connection Fire Test
5	Truss-Beam to H-Column Subassemblage Fire Test
6	HPC Floor Fire Test

4

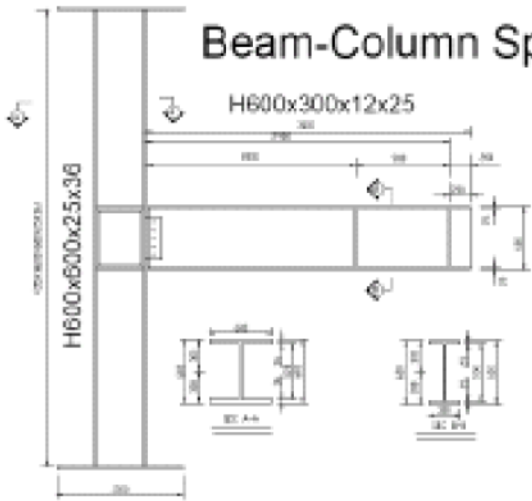
Research Planning



Specimen for modeling the
real structural behavior in fire

5

Beam-Column Specimen



ASTM A572
Gr.50 steels

6

Moment resistance connection

7

Furnace for Beam-Column Subassemblage Fire Tests
Fire Lab of ABRI ,Tainan, Taiwan

8

Test Facility

specification and function

Dimensions:

(1)Column furnace - height 3.3 m, area 4 m*4 m,
(2)Beam furnace - depth 2.3 m, area 4 m*8 m.

Heating: ISO 834, ASTM E119 (2000), BS 476...etc.

Loading:

(1)Column: 2000 tons.

(2)Beams: 100 tons.

(3)Distributed loading: 50 tons on 4 test subjects.

Loading control mode:

(1)Column and beam loading: force/displacement control.

(2)Uniform distribution loading: force control.

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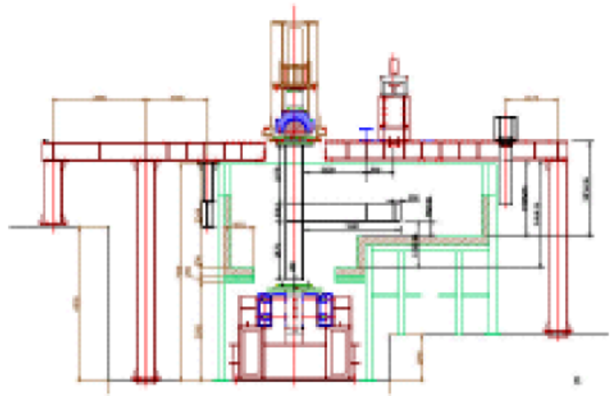

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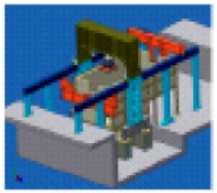
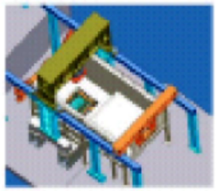
Test Facility



3D Side view



3D Top view

11

Test programs

- Steady state tests for unprotected beam-columns at 550°C and 650°C.
- Transient state tests for two unprotected and two protected beam-column specimens following ASTM E119 Time-Temperature curve.

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附錄五 **2008 FORUM** 會議紀錄

FORUM Meeting Minutes

September 15-19, 2008
SP Swedish National Testing and Research Institute
Borås, Sweden

Attendance

Members present

Greg Baker (**GB**)	BRANZ	New Zealand
Weicheng Fan (**WF**)	SKLFS	PRC
Reinhard Grabski (**RG**)	IdF	Germany
Louis Gritzo (**LG**)	FM Global	USA
Bill Grosshandler (**WG**)	NIST	USA
Ichiro Hagiwara (**IH**)	BRI	Japan
Tuula Hakkarainen (**TH**)	VTT	Finland
Marc Janssens (**MJ**)	SwRI	USA
Ulrich Krause (**UK**)	BAM	Germany
Hyun-Joon Shin (**HJS**)	KICT	Korea
Debbie Smith (**DS**)	BRE	UK (afternoon of 16 Sep to 17 Sep)
Russ Thomas (**JRT**)	IRC-NRCC	Canada
Sheldon Tieszen (**ST**)	SNL	USA
Ulf Wickström (**UW**)	SP	Sweden

Apologies

Paul Croce (**PAC**)	Ex-officio	USA
Ming-Chin Ho (**MCH**)	ABRI	Chinese Taipei
Jiansheng Jing (**JJ**)	TFRI	PRC
J. C. Kapoor (**JCK**)	CFEES	India
Shuitsu Yusa (**SY**)	TBTL	Japan

Alternates present

Ming-Yuan (Alec) Lei (**MYL**)	ABRI	Chinese Taipei

Jinhua Sun (**JS**)	SKFLS	PRC
Tokiyoshi Yamada (**TY**)	NRIFD	Japan

Liaisons present

Franco Tamanini (**FT**)	FM Global	USA

Invited Guests

Petra Andersson (**PA**)	SP	Sweden (16 Sep only)
Craig Beyler (**CB**)	IAFSS	USA
George Hadjisophocleous (**GH**)	CIB W14	Canada (afternoon of 17 Sep and afternoon of 18 Sep)
Per-Erik Johansson (**PEJ**)	Swedish Fire Res. Board,	Sweden (16-17 Sep only)
Björn Sundström (**BS**)	SP	Sweden (16-17 Sep only)
Kuang-Chung (Mark) Tsai (**KCT**)	Natl. Kaohsiung First Un. of Science & Tech.,	Chinese Taipei
Milan Veljkovic (**MV**)	Lulea Un.	Sweden (16-17 Sep only)
Kaouru Wakatsuki (**KW**)	NRIFD	Japan

Meeting Highlights

Summary of Action Items

1. Secretary to get new plaques made for Vince Dowling, Kjell Pedersen and Rick Tontarski + others who have left FORUM (Weicheng Fan, Giovanni Gallina, Dick Bukowski, Jukka Hietaniemi, Yoshiteru Murosaki). By end of this year.
2. Secretary to resolve the issue about copyright restrictions on posting of position papers on the FORUM web site – Do by Jan 1, 2009.
3. Lou Gritzo (lead), with Marc Janssens and Reinhard Grabski to develop a draft for review of a paper on experimental uncertainty by March 1st, 2009.

4. Lou Gritzo (lead), with Marc Janssens, Russ Thomas, Sheldon Tieszen and Reinhard Grabski to develop an outline of a paper on modeling uncertainty by March 1st, 2009.
5. Secretary to distribute the current draft of Egress Modeling Position Paper to the members. Now.
6. Russ Thomas and Debbie Smith with support from Bill Grosshandler to develop the FORUM position on egress modeling and circulate to the membership by March 1st, 2009.
7. Lou Gritzo to continue to pursue IRSN (France) for possible membership in the FORUM. Marc Janssens to pursue NLE (France). Russ Thomas to pursue CSTB (France). To be done by the next meeting.
8. Greg Baker, with Shuitsu Yusa and Shaoyu Zhang, to put together a description of how Japan, China, Chinese Taipei, Korea, Australia/New Zealand coordinate their internal activities (like EGOLF in Europe and NAFTL in North America). By the next meeting.
9. Russ Thomas (w. contact names provided by members – by Nov 1st) to lead a group to discuss options (interact w. Craig Beyler) and prepare a plan to share technical documents through advanced search capabilities (action plan ready for discussion at the next meeting).
10. Ming-Chin Ho (with support from Ming-Yuan (Alec) Lei and Tien-Chih Wang) to forward to the Secretary the results of the ABRI project on connections for distribution to the members and plans for future work by Jan. 1, 09.
11. Ming-Chin Ho (with support from Ming-Yuan (Alec) Lei) to continue to support the interaction among FM Global, Sandia, BAM, and BRI on the response of steel to high temperatures.
12. Marc Janssens to send information on NAFTL upcoming testing (loaded walls) to FORUM members when finalized. By Nov 1st, 2008.
13. Marc Janssens to send NAFTL testing protocol for Phase I (Open calorimeter calibration) to Secretary by mid November. Secretary to distribute to the members upon receipt. By Dec. 1st, 2008.
14. Ulf Wickström to get information on the EGOLF wall testing program and submit it to the Secretary (include time and cost estimates and specifications on the wall) when finalized. Secretary to distribute to the members upon receipt. By Dec 1st, 2008.

15. Lou Gritzo (with Ulrich Krause and Jinhua Sun) to prepare and circulate a draft of a position statement on fire science/engineering education. By March 1st, 2009.
16. Sjölin nominating committee (Greg Baker, Sheldon Tieszen and Debbie Smith) to develop a template for submission of nominations as well as the list of last year's nominations for distribution to the members. By Jan 1st, 2009.
17. Sjölin nominating committee (Greg Baker, Sheldon Tieszen and Debbie Smith) to have balloting process for the 2009 award completed by May 1st, 2009.
18. Ulf Wickström to put together a technical paper on the Plate Thermometer method for distribution to FORUM members and submittal to a fire journal by the end of 2008.
19. Ulf Wickström to distribute a refined version of the existing draft of the position paper on heat transfer measurements by the PT method, with all members providing their comments on the FORUM position, by July 1st, 2009.
20. Marc Janssens and Russ Thomas to pursue the development of a position paper on inter-laboratory data transfer and make a suggestion for a workshop at either the next FORUM, at one of the other labs, etc. Make a recommendation on how to proceed by July 1st, 2009.
21. Secretary to send the deputy chair the domain names for the FORUM. Bill Grosshandler to send link to FORUM website to members. By Oct. 1st, 2008.
22. Hyun-Joon Shin to submit draft of letter to be issued by the FORUM chair to officially request that KICT host the next meeting. By Nov. 1st, 2008.
23. Hyun-Joon Shin to submit a general plan for the logistics of the next FORUM meeting (from mid day Sunday, October 11th to mid day Thursday, Oct 15th). By Feb 1st, 2009.
24. Jinhua Sun to provide a plan for a 2-day symposium (Thursday + Friday, Oct 8th + 9th, 2009), prior to the FORUM meeting. Preliminary plan by April 1st, 2009. Final plan by July 1st, 2009.
25. Bill Grosshandler to contact NRIFD, NRC, SP, and NIST to gather information on the extent to which FORUM member labs are involved in fire investigations and see if the issue should be brought up at the next meeting. By Feb 1st, 2009.

26. Ulrich Krause (w. help from Bill Grosshandler, Lou Gritzo, Greg Baker, Ulf Wickström and Tokiyoshi Yamada) to develop a compilation of sustainability issues that have implications on fire safety by Dec. 15th, 2008.
27. Greg Baker to work through the FORUM Secretary to seek the members' input on the BRANZ project on a virtual community for fire research. By Nov 1st, 2008.
28. Marc Janssens (with Ulf Wickström and Greg Baker) to develop a technical rationale for replacing obsolete standard test methods with a science-based method. By next meeting.
29. Secretary to send a letter of appreciation to Weicheng Fan for his several years of participation in the FORUM.

Upcoming FORUM Meetings

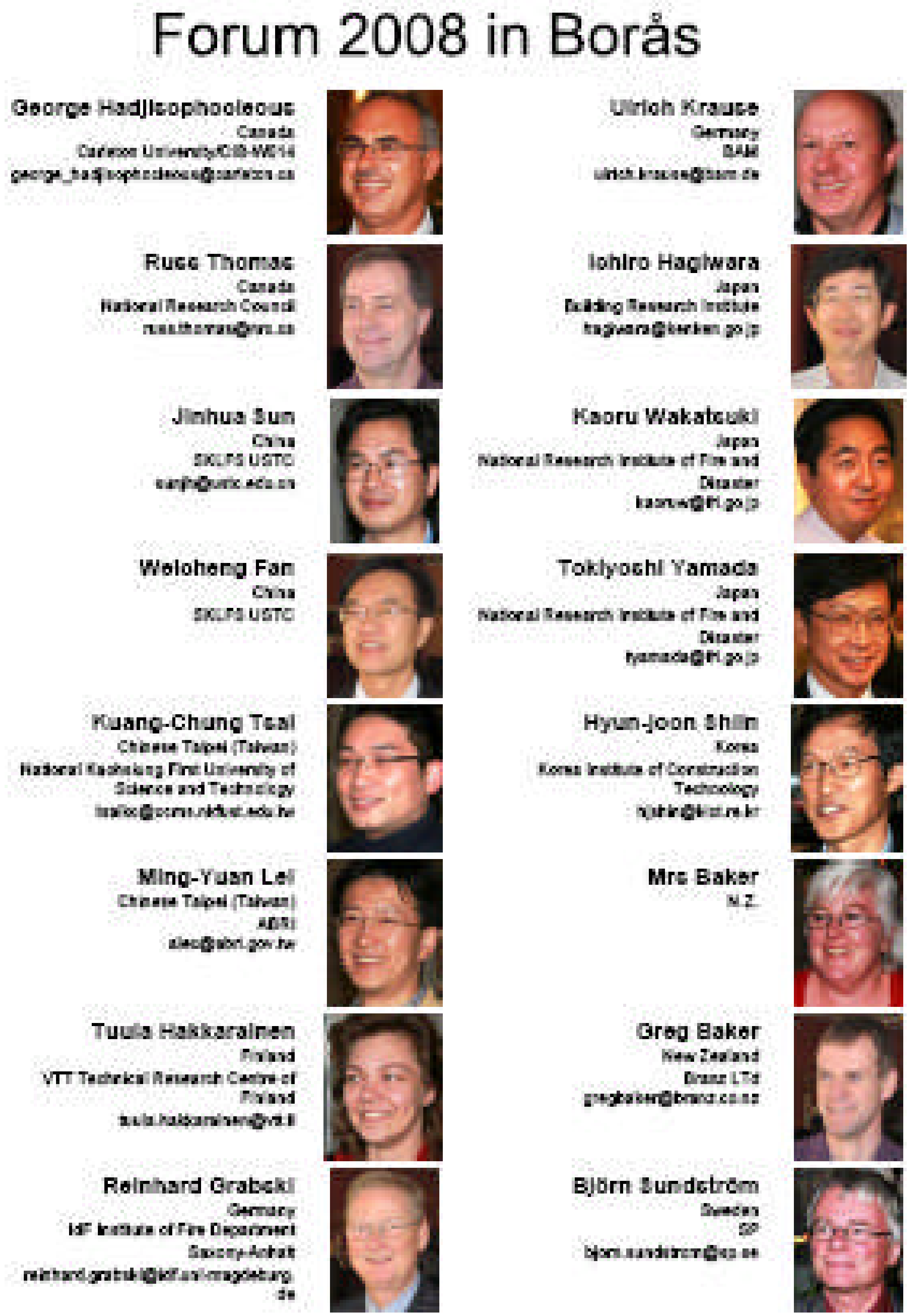
- The next (2009) meeting will be at KICT in South Korea. The tentative dates are from midday, Sunday October 11th to midday, Thursday October 15th. There is a tentative plan to hold a specialists meeting in China (probably in Beijing) Thursday and Friday, October 8th and 9th, 2009. [Note: After the Borås meeting, Jinhua Sun /SKFLS confirmed the meeting to be held on October 18th and 19th, 2009]

- For the 2010 meeting, the tentative plan is to hold it again in Europe (at VTT or BRE), despite the fact that it should be in North America, based on the traditional rotation among the three regions. [Note: After the Borås meeting, VTT made the offer to be the host in 2010]

- The 2011 meeting could be held at NIST on the week (June 26th to 29th) following the IAFSS conference.

- The 2012 meeting could be held at SKLFS in China.

附錄六 2008 FORUM 會議出席人員名單



Forum 2008 in Borås

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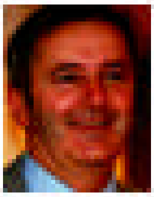

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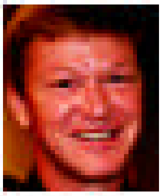

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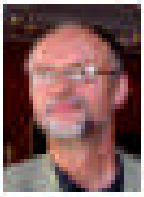

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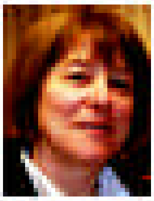

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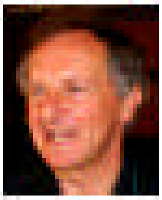

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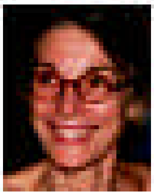

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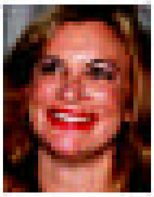

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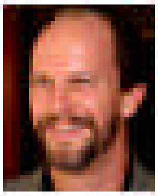

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