2018產業安全衛生
技術輔導成果發表會

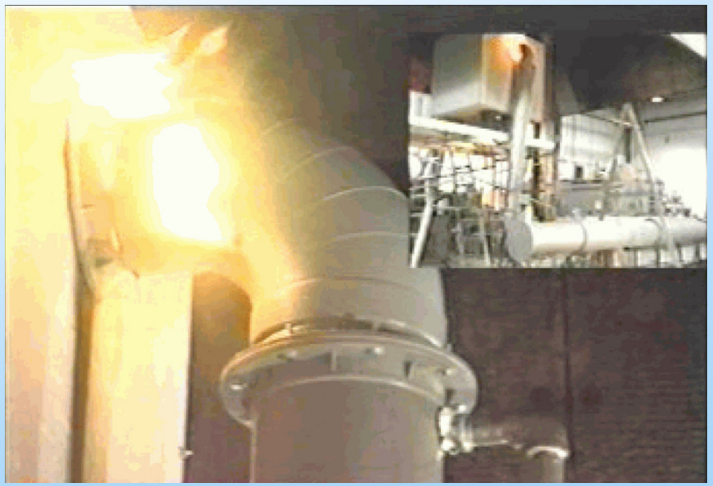
廠房製程排氣系統安全與風管材質測試標準

黃建平

November 22, 2018

課程大綱

1. 開始之前
2. 排氣系統設計程序/安全設計
3. FM認證(FM4910/FM4922)



http://www.fmglobal.com/

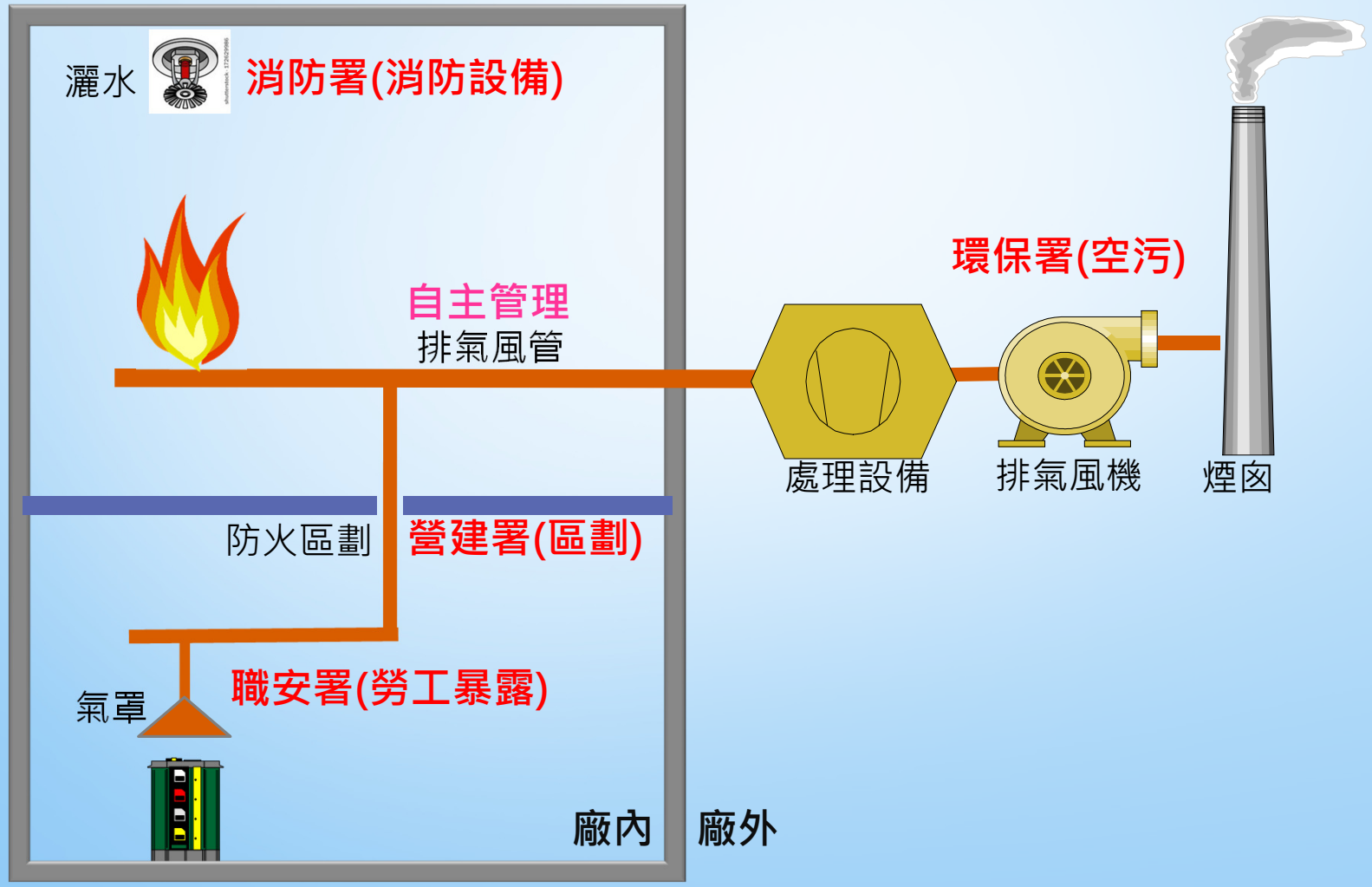
http://global.ihs.com/

開始之前

2018.04.28

敬鵬平鎮廠火災事件

製程排氣系統國內相關法規



國際標準/法令(美國)

NFPA 91 Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids (2015)

第4、9章明確說明製程排氣系統之設計、建造、不/耐燃材質、設備裝置、防火設置、測試及維護。

Chapter 4 Design and Construction (摘錄第4章)

4.2.9 Fire dampers shall be permitted to be installed in exhaust systems in the following situations:

(1)Where ducts pass through fire barrier

(2)Where a collection system installed on the end of the system is protected with an automatic extinguishing system

(3)Where the duct system is protected with an automatic extinguishing system

(4)Where ducts have been listed with interrupters

(5)Where necessary to facilitate the control of smoke pursuant to the applicable NFPA standards

4.2.11 Exhaust ducts shall not pass through fire walls, as defined by NFPA221.

美國消防協會

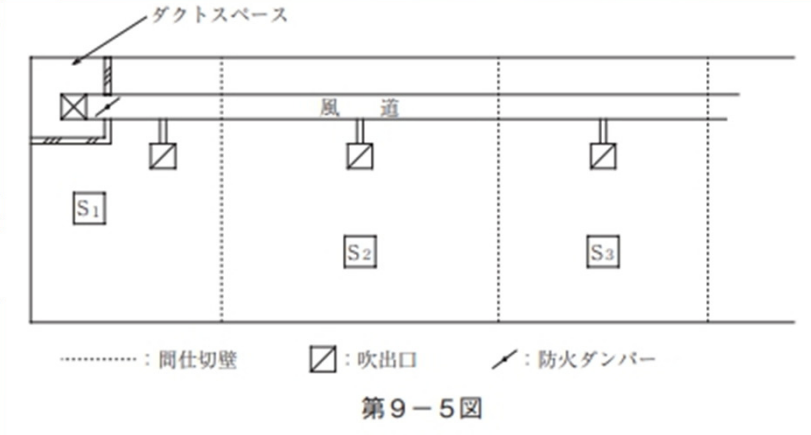
國際標準/法令(日本)

建基令第112條(建築基準法施行令)

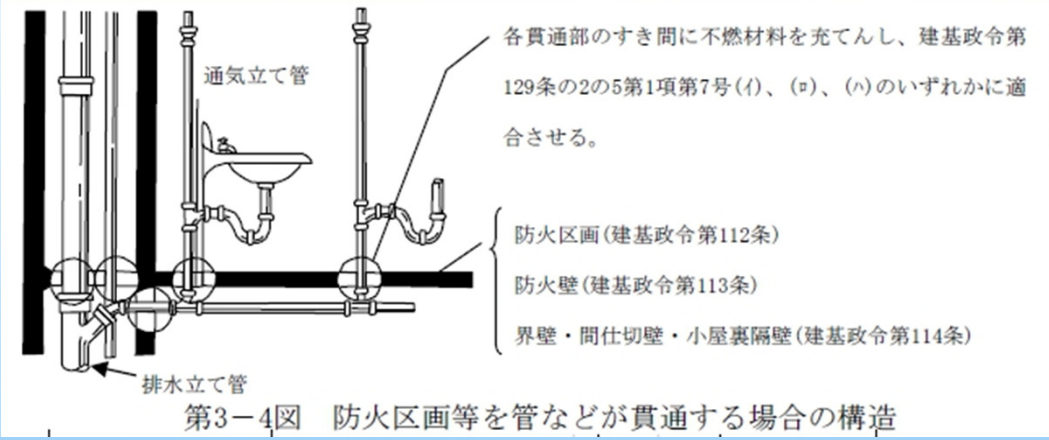
第2 or 3章 消防同意審查基準(摘錄神戶市、札幌市)
第3 or 9節 防火區劃

5. 風道及び防火ダンパー(換気、冷暖房の風道)

防火閥應盡可能**安裝在防火隔層的牆壁或地板的穿透部位**。如果不可避免地要安裝在穿透部分的附近，穿透部分和防火閥之間的管道應該是厚度為1.5mm或更厚的鐵板，或者應該用鐵網砂漿或其他不可燃材料塗覆。



第９－５図



第3－4図　防火区画等を管などが貫通する場合の構造

高科技廠事故案例

	華邦電子 股份有限公司	聯瑞積體電路 股份有限公司*	天下電子 股份有限公司
發生時間	1996.10.14	1997.10.3	1997.11.11
人員傷亡	無	無	1人受傷
損失金額	60億元以上	120億元以上	30億元以上
起火原因	機臺起火蔓延	廢氣未妥善處理，廢氣排放管起火延燒	蝕刻槽多種溶劑起化學反應起燃，引燃上方管線向外延燒

※備註：聯瑞公司大火保險公司理賠101億元，居亞洲之冠。

高科技廠現有作法

- 因高科技廠房火災損失金額極大(財產及營業損失)，業者相對重視廠內安全管理，多優於國內法令規定。
- 因投保金額高，需透過國外再保機制，轉嫁分擔風險。保險公司要求排氣風管使用FM認證合格材質或不燃性材質，提升保險公司承保意願與降低保險費之效用。

FM4922
2016.08

Fume Exhaust Ducts or Fume and Smoke Exhaust Ducts

測試排氣、排氣及排煙管道暴露於火中時防火性能和之後的排煙能力

FM4910
2009.09

Cleanroom Materials Flammability Test Protocol

評估無塵室各組件限制火蔓延和煙塵損害能力

PCB產業自主安全標準(TPCA)

經費來源　工業局　工業局　TPCA自籌

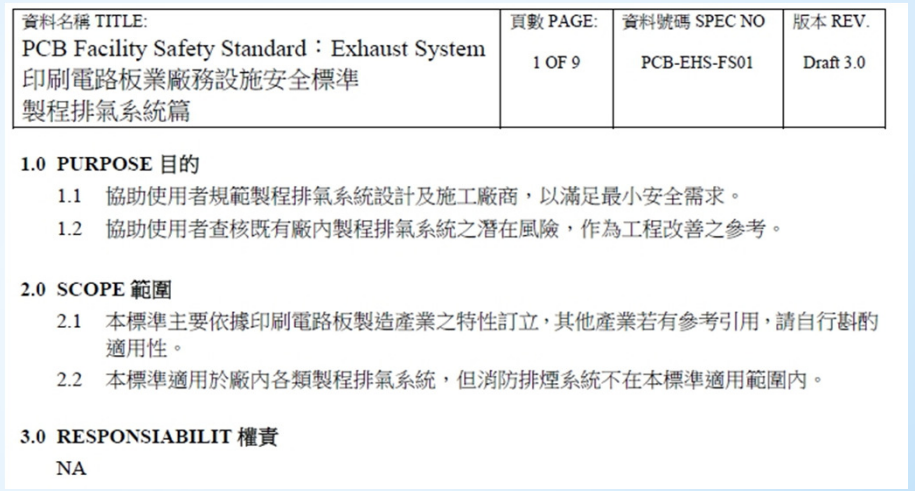
1st Stage	2016	2017	2018	2019	2020	2nd Stage
個別設備標準(C類)	完成高風險設備標準訂定及驗證制度					1.其他設備 2.標準修訂
烤箱	輔	標		驗		
電鍍		輔	標	驗		
驗證程序			標			
其他關鍵設備				輔+訓	標+驗	
通用設備標準(A類)	完成標準訂定與推廣訓練					1.實施驗證 2.擴大訓練
標準制定			標			
推廣(訓練及輔導)				訓+輔	訓+輔	
廠務設施標準	完成關鍵設施標準訂定					1.其他設施 2.驗證制度
製程排氣系統			標+輔	訓+輔	訓+輔	
化學品儲存與供應			標+輔	訓+輔	訓+輔	
其他關鍵系統				標	訓+輔	

備註:「輔」代表「輔導」、「訓」代表「訓練」、「標」代表「標準」、「驗」代表「驗證」

廠務設施安全標準-製程排氣系統篇

安全標準章節：

- 1.0-PURPOSE 目的
- 2.0-SCOPE 範圍
- 3.0-RESPONSIBILITY 權責
- 4.0-DEFINITION 名詞定義
- 5.0-REFERENCE 參考資料
- 6.0-PRECAUTION 注意事項
- 7.0-CONTENT 安全標準內容 »
- 8.0-APPENDIX 附錄



資料名稱 TITLE:	頁數 PAGE:	資料號碼 SPEC NO	版本 REV.
PCB Facility Safety Standard：Exhaust System 印刷電路板業廠務設施安全標準 製程排氣系統篇	1 OF 9	PCB-EHS-FS01	Draft 3.0

1.0 PURPOSE 目的

1.1 協助使用者規範製程排氣系統設計及施工廠商，以滿足最小安全需求。

1.2 協助使用者查核既有廠內製程排氣系統之潛在風險，作為工程改善之參考。

2.0 SCOPE 範圍

2.1 本標準主要依據印刷電路板製造產業之特性訂立，其他產業若有參考引用，請自行斟酌適用性。

2.2 本標準適用於廠內各類製程排氣系統，但消防排煙系統不在本標準適用範圍內。

3.0 RESPONSIABILIT 權責

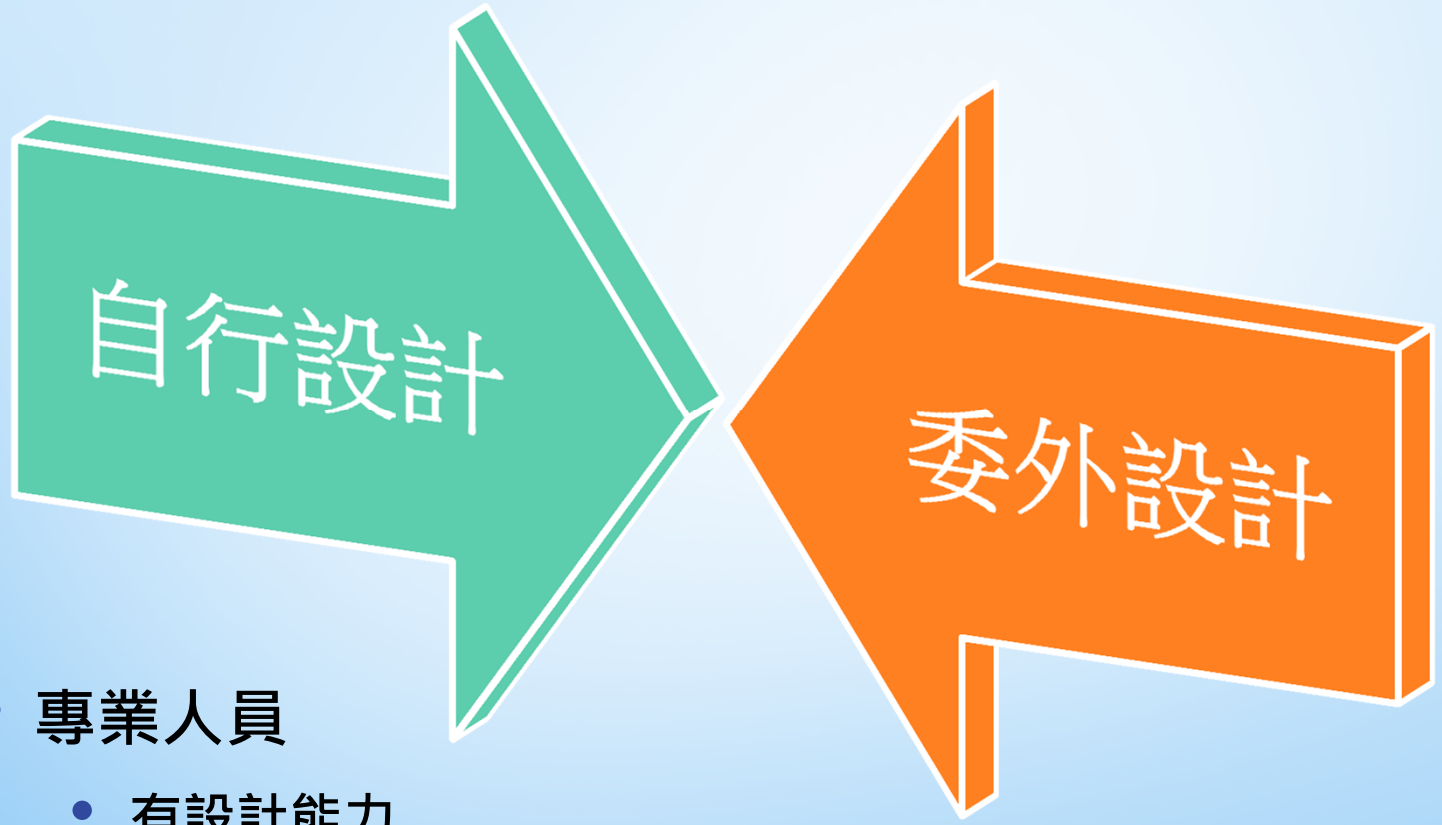
NA

- 7.1 一般性設計要求
- 7.2 排氣分類與材質選用
- 7.3 防火性設計要求
- 7.4 排氣風機及處理設備
- 7.5 運轉及維護保養
- 7.6 排氣監測與控制
- 7.7 風管內灑水系統

排氣系統設計程序/安全設計

通風裝置的一生

通風裝置設計



- 專業人員
  - 有設計能力
  - 有實務經驗

- 負責人員
  - 有基本判斷能力

通風裝置設計

- 讓廠商在發包時可以據此來要求與確認承包商的設計與設置通風裝置的專業能力
- 避免非專業的承包商採用錯誤的設計概念進而導致裝置設置完成後，無法發揮有效的換氣效果
- 如果資料不齊全的話，即要求承包商補齊，若無法提供，則需更換有專業設計能力的包商。

- 整體換氣裝置設計圖(平面圖)
- 風量設計的依據(法令規定)
- 風機規格
- 氣流路徑規劃

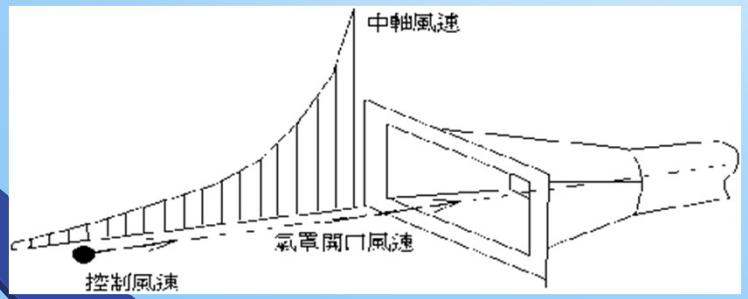
- 局部排氣裝置設計圖
- 氣罩規格
- 導管規格
- 排氣機規格
- 空氣清淨裝置設計規格及圖面
- 風量設計壓力平衡計算書

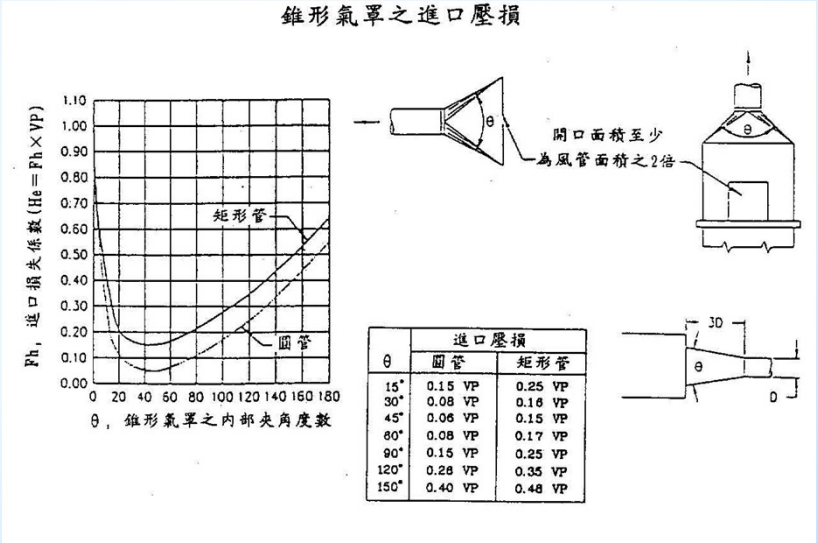
排氣系統設計程序

- 資料收集 Q↓
  - 風量及靜壓需求、使用化學品、機台位置等
- 製程排氣分類
- 排氣風管材質選用 安全性
- 風管配置圖(Layout) P↓
- 風管內搬運風速選用
- 風管管徑選用與風速確認
- 排氣系統壓損計算
- 處理設備選用
- 排氣風機選用 η↑

資料收集

- 製程設備的了解
- 氣罩形式
  - Type
    - 依據ACGIH
    - 經驗
  - 決定風量





θ	進口壓損	
	圓管	矩形管
15°	0.15 VP	0.25 VP
30°	0.08 VP	0.16 VP
45°	0.06 VP	0.15 VP
60°	0.08 VP	0.17 VP
90°	0.15 VP	0.25 VP
120°	0.28 VP	0.35 VP
150°	0.40 VP	0.48 VP

表五、一般控制風速之範圍

污染物之發生條件	例	控制風速（m/s）
於極靜之大氣中，實際上近於無速度狀態下發散時	自液面發生之氣體、蒸氣、燻煙等	0.25~0.5
於較靜之大氣中以較緩之速度發散時。	崗亭式氣罩內之吹噴塗飾作業，間斷性容器儲裝作業，低速輸送帶，熔接作業、鍍金作業、酸洗作業	0.5~1.0
在氣體流動較高之作業場所，飛散較活躍時。	於室內隅角處使用小型崗亭式氣罩從事吹噴塗飾作業、裝桶作業、輸送帶之落卸口、破碎機。	1.0~2.5
在氣體流動極速之作業場所，以高初速度飛散時	研磨作業、鼓風作業、搗塞作業。	2.5~10.0

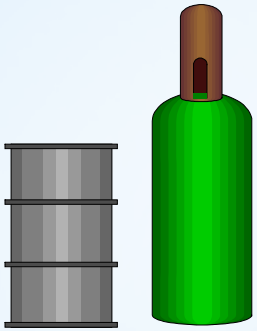
Facility Table

Index	Mach-Fun	Mach-ID	Exhaust						Bulk Gas	Chemical	Special Gas	
			F	Exh. Duct	Pre.	Flow	Duct	Material			Type	Flow
6	Ultrasoric Cleaner (ETCH)	EPCN010-050	5	GE		500/400	8"	PP	N2			
19	Part Clean-Oven (ETCH)	EOVE010-040	5	GE		116	5"	SUS	N2			
26	Part Clean-sand blaster (ETCH)	ESBE010	5	SE-G		30	6"	G/S				
125	Backside Poly Etch	EBPO010-050	3	SE-G	0.0035	882	250	PP	N2	HNO3/HF,HF,DHF		
			2	SE-G		412	160	PP				
			2	SE-G		412	160	PP				
			2	SE-G		412	160	PP				
			3	GE	0.002	560	104	SUS304				
136	Metal Etch	EMET01Z-07Z	3	GE		400	6"	SUS304	N2,Ar,O2,He		BCl3	200
			2	SE		5	50	SUS305			Cl2	400
			2	SE	0.03	5	40	SUS306			SF6	400
			2	SE	0.03	5	40	SUS307			CF4	200
			2	SE	0.03	5	40	SUS308			CHF3	40
			2	SE	0.03	5	40	SUS309				
			2	SE	0.03	30	40	SUS310				
			2	SE	0.03	30	40	SS				
			2	GE			4"					

Safety Consideration

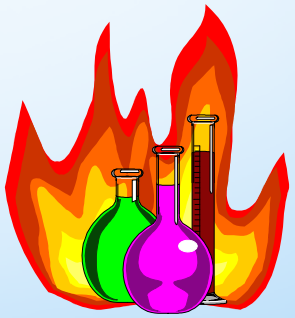
- Chemical & Special Gas
  - Flammable, Combustible
  - Toxic
  - Corrosion

  SDS, FM7-7/17-12, ASTM…



- Compatibility
  - C/SG & C/SG
  - C/SG & Duct Material

  Facility Table, FM7-7/17-12, SEMI S4-92…



- Fire Protection
  - Monitoring System (Pressure, Temperature, Concentration)
  - Suppression System (Automatic Sprinkler System)

  NFPA318, FM7-7/17-12, FM4922/4910…

不相容物質排氣系統必須分離

- 腐蝕或一般洗滌排氣(Ak, Ac)
  - 酸與溶劑(solvent)排氣系統要獨立(沒有法規要求)
- 碳氫類溶劑(即VOC)
  - 通常以每年排放噸數為單位減量至可接受程度
- 毒性排氣處理(T)

  焚燒或中和以降至1/2IDLH程度
- 一般排氣或熱排氣(G)
- 易爆性或易燃性氣/汽體(F)
  - 焚燒或中和以降至25LEL; 25%LFL程度
- 其他:含NH_3廢氣;含NO_x廢氣;含O_3廢氣

不相容物質資料表

29	Hydrocarbons, Aliphatic,Saturated	飽和碳氫化合物(脂肪族)		H F						
30	Peroxides and Hydroperoxides,Organic	有機過氧化物及水合過氧化物	H G	H E		H F	H G		H GT	H F E	H F GT
31	Phenols and Cresols	酚及甲酚類	H	H F						H G	
32	Organophosphates,Phosphothioates,Phosphodithioates	有機磷酸鹽類	H GT	H GT						U	
33	Sulfides, Inorganic	無機硫化物	GT GF	H F GT	GT		H			E	
34	Epoxides	環氧化物	H P	H P	H P	H P	U		H P	H P	
101	Combustible and Flammable Materials,Miscellaneous	可燃及易燃物	H G	H F GT							
102	Explosives	爆炸物	H E	H E	H E					H E	
103	Polymerizable Compounds	可聚合物	P H	P H	P H					P H	
104	Oxidizing Agents,Strong	強氧化物	H GT		H GT	H F	H F	H F GT	H F GT	H E	H F GT
105	Reducing Agents,Strong	強還原物	H GF	H F GT	H GF	H GF F	H GF F	GF H	H GF	H G	
106	Water and Mixtures Containing Water	水及含水混合物	H	H						G	
107	Water Reactive Substances	遇水起反應物質	107								
ESRG-026-87			1	2	3	4	5	6	7	8	9

排氣分類與材質選用

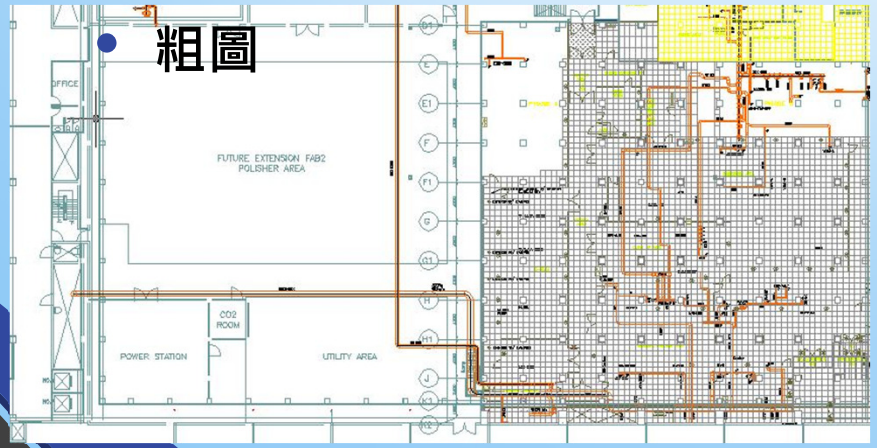
風管分類	代號	一次配管 (Main、Sub-Main)	二次配管 (Hook-up)
Toxic/Acid Exhaust、Scrubbed Exhaust	T/A、SE、SEX	FM Approved	SUS304
			PPs
			FM Approved
Ammonia Exhaust、Alkali Exhaust	AE、AEX、ALE、ALK	FM Approved	PPs
			FM Approved
			鍍鋅螺旋管
Solvent Exhaust、VOC Exhaust	SLE、SOX、VE、VEX	SUS304	SUS304
			鍍鋅螺旋管
General Exhaust、Heat Exhaust	GE、GEX、HE、HEX	鍍鋅螺旋管	SUS304
			鍍鋅螺旋管
Pyrophoric Exhaust、Flammable Exhaust	PE、PEX、FE、FEX	SUS304	SUS304
			鍍鋅螺旋管

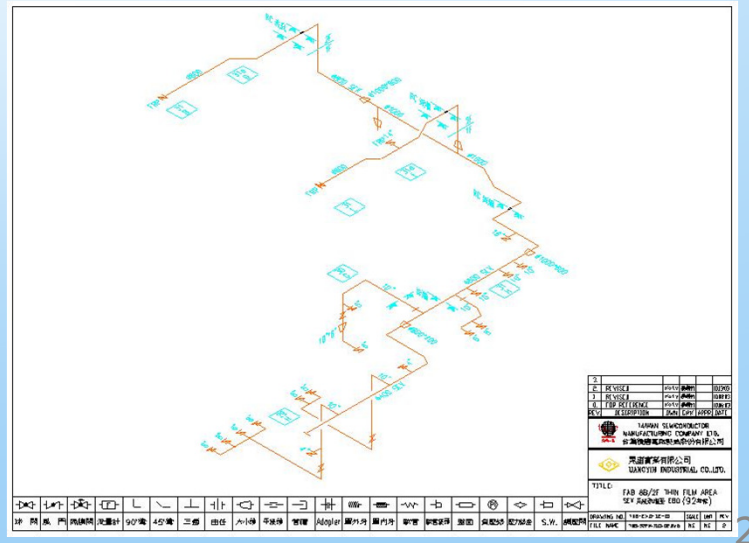
風管材質

- 不燃性風管材質：本風管材質於其受熱或燃燒後，皆無法點火、燃燒、助熱或釋放易燃蒸氣等，例如不鏽鋼、鍍鋅鐵等金屬材質。
- 耐燃性風管材質：本風管材質雖不符合4.1的要求，但經過下列至少一項標準測試後，能滿足該標準之相關要求：
  - 採用ASTM E84測試標準，該風管材質之火焰擴散指數（FSI）不超過50者。
  - 採用FM4910測試標準，該風管材質之火焰傳遞指數（FPI）不超過6.0者。
  - 採用FM4922測試標準，並通過該標準測試要求者。
  - 塑膠類風管材質採用UL94測試標準，並通過該標準之對應項目測試要求者。
- 易燃性風管材質：無法滿足4.1或4.2之風管材質。
- 可燃性風管材質：耐燃性風管材質及易燃性風管材質皆屬於可燃性風管材質的一種。

管路走向配置(Layout)

- 配合現場狀況
  - 管道間, 機台位置等
- 空間管理(Space manage)
  - 建廠時期
  - 供水系統、廢水系統、電力系統、氣體供應系統、化學供應系統、廢液系統、消防系統、空調系統
- 單線圖
  - 粗圖





導管

配管大原則為低壓損、減少不必要的阻力

- 使用圓管(結構強；較佔空間)
- 採用大管徑(需考慮搬運速度)
- 支管須斜插匯入主管(迴流造成粉塵累積)
- 避免使用撓性管(防火材質，壓損極大)
- 彎管採用較大的迴轉半徑(R/D≥1.5)
- 盡量採用直管(彎管易有迴流)
- 採用較短的距離

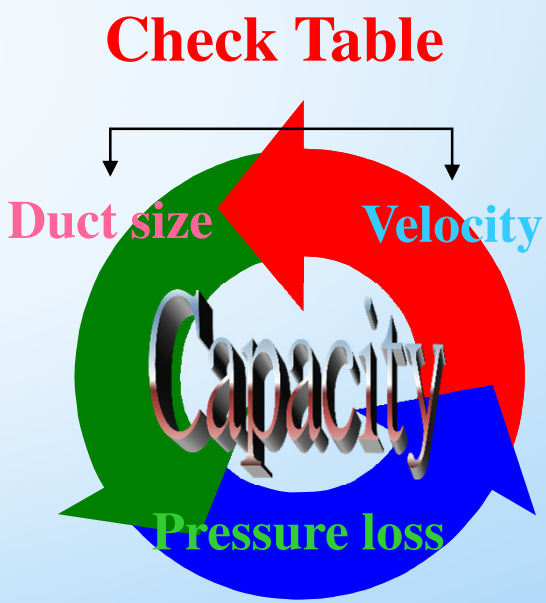
搬運風速

資料來源: ACGIH

污染物種類	實際污染物例	設計風速
蒸汽、氣體、煙	所有蒸汽氣體及煙	1000-1200fpm (5.0-6.0m/s)
煙霧	鋅和氧化鋁煙霧	1400-2000fpm (7.0-10.0m/s)
非常微細的輕灰塵	棉紗、木粉、石粉	2000-2500fpm (10.0-12.5m/s)
乾塵、粉	細橡皮塵、電木塑粉塵、黃麻絨、棉塵、刮下削（輕的）、肥皂粉塵、皮革刮下削	2000-2500fpm (10.0-12.5m/s)
一般工業塵	鋸木削（重而濕的）、研磨塵、咖啡豆、製鞋灰塵、花崗石塵、矽粉、一般物料處理、切磚、黏土塵、鑄造、石灰石塵、石綿打包與秤重時所放出之粉塵	3500-4000fpm (17.5-20.0m/s)
重粉塵	鑄造鼓轉筒及搖動器塵、噴砂灰塵、木塊與鋸廢料等處理粉塵、鉛塵	4000-4500fpm (20.0-22.5m/s)
重或潮濕粉塵	鉛塵夾有小切塊、潮濕黏合料塵、切管機切管時之石綿或塑膠塵、生石灰塵	>4500fpm (>22.5m/s)

管徑選用與速度查核

Sys.	No.	Main			Sub-Main				Shaft
		mm	CMH	m/s	mm	CMH	m/s	F	
SOX	SOX1	650	13,500	11.30				1F	A-B/2
	SOX2	1400	70,000	12.63				2F	
	SOX3	1400	70,000	12.63				2F	C-D/2
	SOX4	1000	30,000	10.61				4F	
	SOX5	550	10,000	11.69				1F	G-H/1
	SOX6	1100	41,100	12.01	600	11,100	10.91	3F	
					1000	30,000	10.61	4F	
	SOX7	1000	30,000	10.61				2F	G-H/1



Design Flow Rate → Choose Velocity → Choose Duct Size

→ Choose Duct Size → Check Velocity

管徑與搬運速度

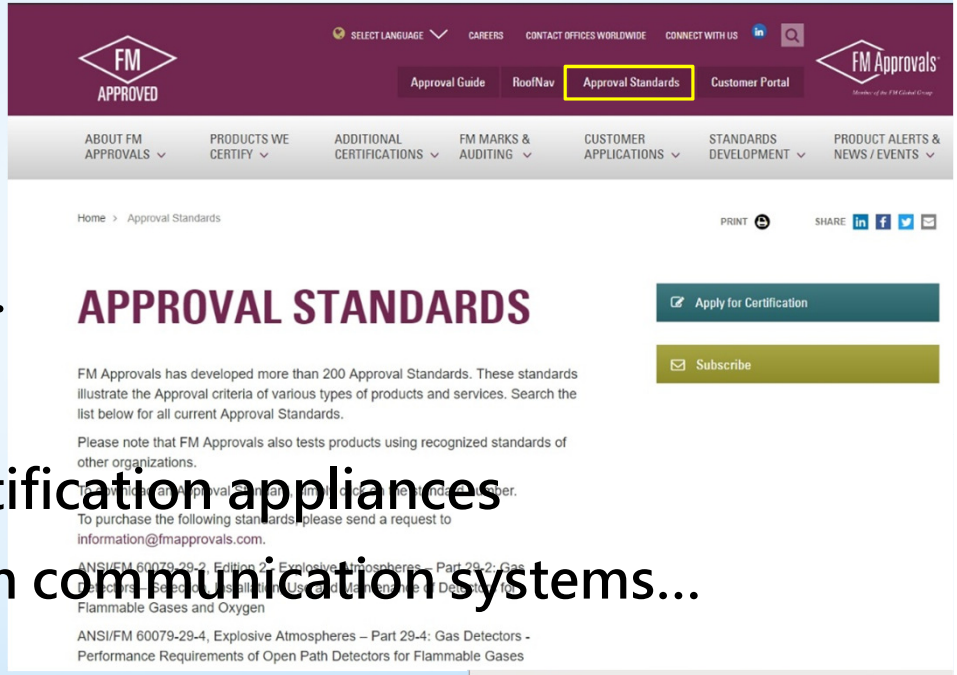
速度	管徑	優點	缺點
風速大	管徑小	■ 不易造成沉積堵塞 ■ 材料成本較低 ■ 佔用空間較小	■ 壓損大，運轉成本較高 ■ 易產生摩擦靜電，需做好接地 ■ 震動與噪音較大
風速小	管徑大	■ 壓損小，運轉成本較低 ■ 震動與噪音較小	■ 有粉塵時易造成沉積堵塞 ■ 初設成本較高 ■ 佔用較多的空間

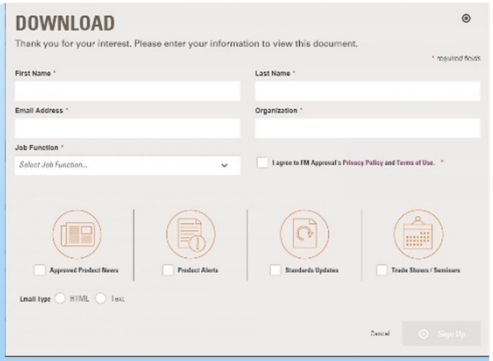
（附註：針對相同排氣量下的比較）

FM認證(FM4910/FM4922)

FM 認證種類

- Fire Protection
  - Automatic sprinklers
  - Fire hose and nozzles…
- Electrical Equipment
  - Audible and visible notification appliances
  - Emergency voice/alarm communication systems…
- Building Materials
  - Air handling, systems components
  - Clean room materials…





FM APPROVED Web.：填寫資料即可下載
https://www.fmapprovals.com/approval-standards

FM 認證標準

#	Title	Issued (Month/Yr)
1011,12	Deluge Systems and Preaction Systems	11/73
1020	Automatic Water Control Valves	01/76
1021	Dry Pipe Valves	11/73
1031	Quick Opening Devices (Accelerators, Exhausters) for Dry Pipe Valve	5/77
1032	Air Pressure Maintenance Device	8/70
1041	Alarm Check Valves	7/70
1042	Waterflow Alarm Indicators (Vane Type)	7/70
1045	Waterflow Detector Check Valves	2/76
4910	**Clean Room Materials Flammability Test Protocol**	**9/97**
4911	Wafer Carriers for Use in Clean Rooms	12/02
4922	**Fume Exhaust Ducts or Fume and Smoke Exhaust Ducts**	**4/01**
4924	Pipe Insulation	3/73
4970	Fire Protection of Steel Framing Members for High Hazard Occupancies	1/80

FM 認證標章

FM APPROVED mark: authorized by FM Approvals as a certification mark for any product that has been FM Approved.

There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.

The mark should be produced in black on a light background, or in reverse on a dark background.

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Quality System Registration

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Plastic Used in Cleanroom

PLASTIC	USE IN CLEAN ROOMS
Polypropylene (PP)	Wet benches, ductwork, wafer boxes, process equipment enclosures, wall panels
Fire Retardant Polypropylene (FRPP)	Wet benches, process equipment enclosures
Polyvinylchloride (PVC)	Wet benches, ductwork, process piping, process equipment enclosures
Polyvinylidene Fluoride (PVDF)	Process piping, chemical baths
Polyether ether ketone (PEEK)	Wafer carriers
Fiberglass Reinforced Plastic (FRP)	Ductwork, scrubbers, wall panels
Polycarbonate (PC)	Mini-environment enclosures, valve manifold boxes, wafer boxes
Polymethymethacrylate (PMMA)	Mini-environment enclosures, valve manifold boxes
Polyethylene (PE)	Process piping, process equipment enclosures, wafer boxes
Perfluoroalkoxy (PFA)	Process piping, chemical baths
Polyetrafluoroethylene (PTFE)	Wet benches, coating on stainless steel ductwork
Polyphenylene Oxide (PPO)	Exhaust ducts
Polyoxymethylene, or Delrin (POM)	Not used in clean rooms except for fire protection fine water spray nozzles

From FM7-7/17-12 Table 8. (1997)

FM4910 & FM4922

- FM4922 for Exhaust Ducts
  - Horizontal Duct Fire Test
    - 15 minutes, Velocity = 3.0m/s
    - 火焰不可擴散到距離管路入口火源處7.0公尺外的內管
    - 距離火源7.0公尺的內管測試點溫度必須不超過538℃
  - Horizontal/Vertical Combination Duct Fire Test
    - 另外須符合外管的火焰只可侷限在垂直管段而不可擴散到水平管段
  - Smoke Removal Test
    - 10 minutes, Velocity = 10.0m/s
    - 管路必須保持完整且沒有煙從火源開口或管路外表散出
  - Small Scale Quality Control Tests (Include ASTM E-84)
    - Flame Spread ≦ 25
    - Smoke Density ≦ 50
- FM4910 for Tool Material
  - Fire Propagation Index (FPI) ≦ 6.0
  - Smoke Damage Index (SDI) ≦ 0.4

FM4910
Clean Room Materials Flammability Test Protocol

Indices

	Limit	Uncertain results	Ranges	Rounded
FPI	6	6 ~ 7	2 ~ 36	whole number (1.0, 2.0)
SDI	0.40	0.40 ~ 0.50	0.06 ~ 4.10	tenth (0.1, 0.2)

Note:

- FPI: $[(m/s^{1/2})/(kW/m)^{2/3}]$
- SDI: $[(m/s^{1/2})/(kW/m)^{2/3}][g/g]$

Various Material

MATERIAL	FPI	SDI	CDI
ABS（5）	8	0.84	0.48
PS	34	5.58	2.00
POM	15	0.03	0.90
PMMA（2,3）	20	0.44	1.20
Wood	14	0.21	0.84
PVC/PVC cable（4）	36	4.10	43.20
PE/PVC CABLE（4）	28	3.80	33.60
PP（1,2,6,7）	30	1.77	1.80
FRPP（1.2）	30	10.98	54.00
PE（2,6）	29	1.74	1.74
PVC（1,2,4,5,7）	16	1.58	19.20

MATERIAL	FPI	SDI	CDI
PVDF（5）	6	0.08	1.74
PEEK（5,6）	4	0.36	0.24
PPO（7）	9	1.60	1.26
PE/25 Chlorine	15	1.73	2.00
PE/36 Chlorine	11	1.53	16.50
PE/48 Chlorine	8	1.07	15.20
Rigid PVC（1,2,5）	7	0.69	12.60
PTFE（5）	4	0.01	1.68
Silicone/PVC	17	2.02	1.02
Polyester-70 fiberglass（3,7）	13	0.91	0.78
Epoxy-65 fiberglass（3,7）	11	0.62	0.77

1 – Wet Benches

2 – Other Processing Tools

3 – Wall and Floor Panels

4 – Electrical Power Cables

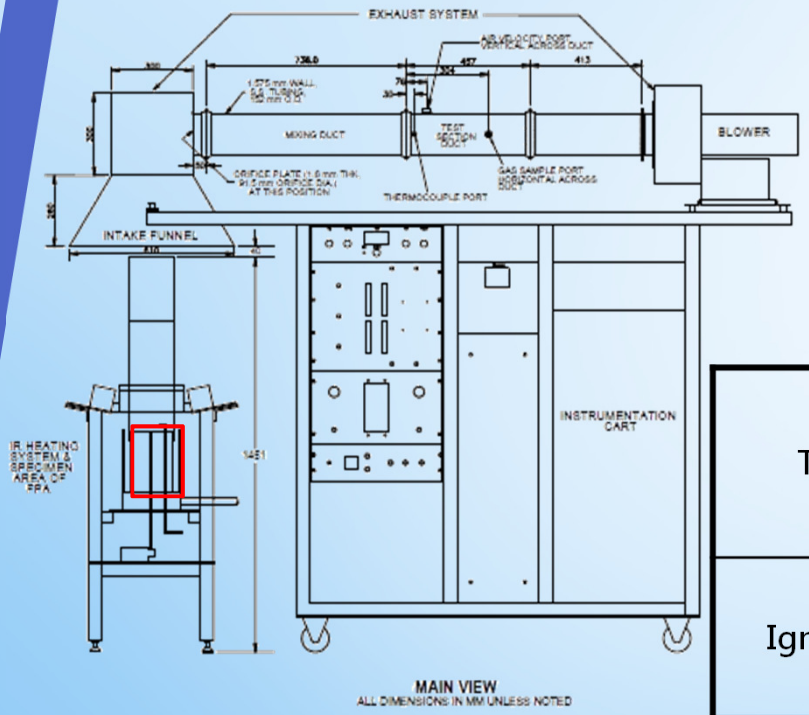
5 – Piping, Valves, Tanks

6 – Wafer Boxes

7 – Exhaust Ducts

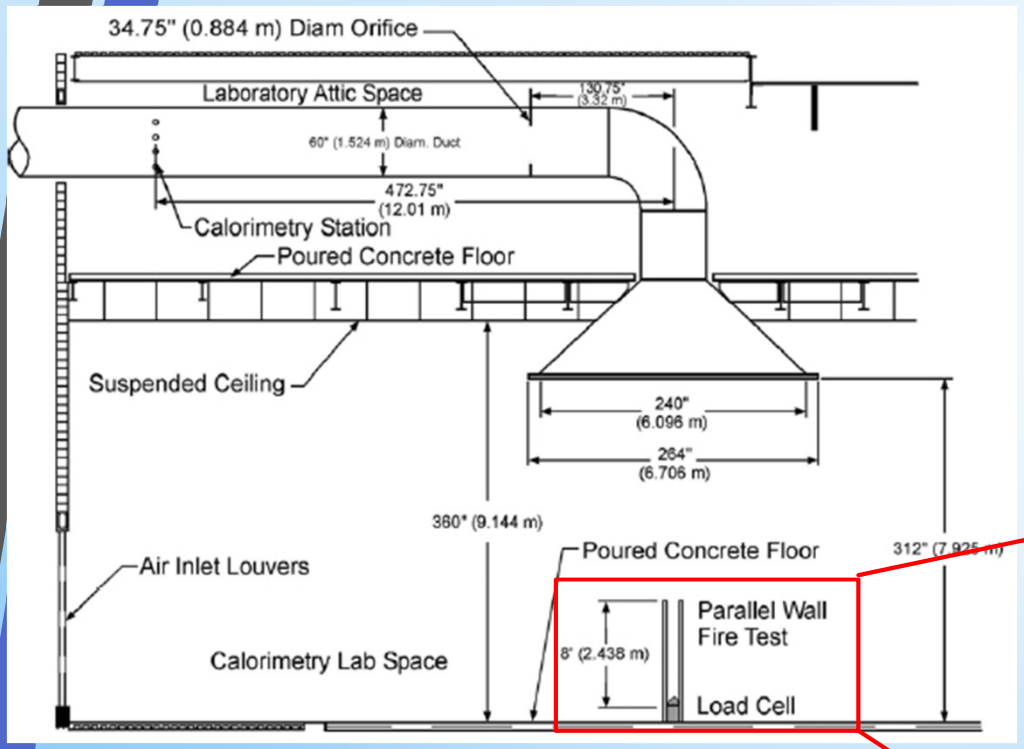
From FM7-7/17-12 Table 8. (1997)

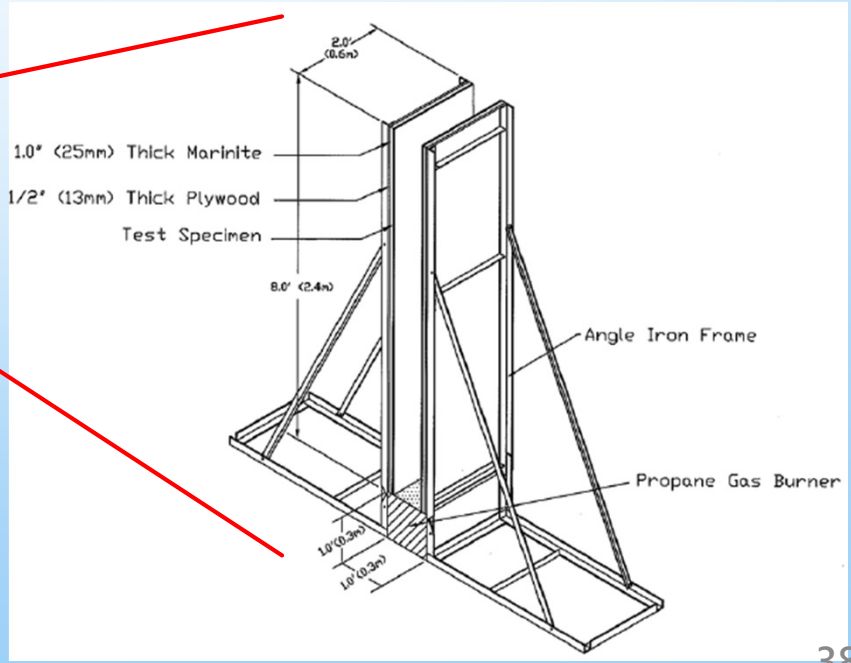
Small Scale Test



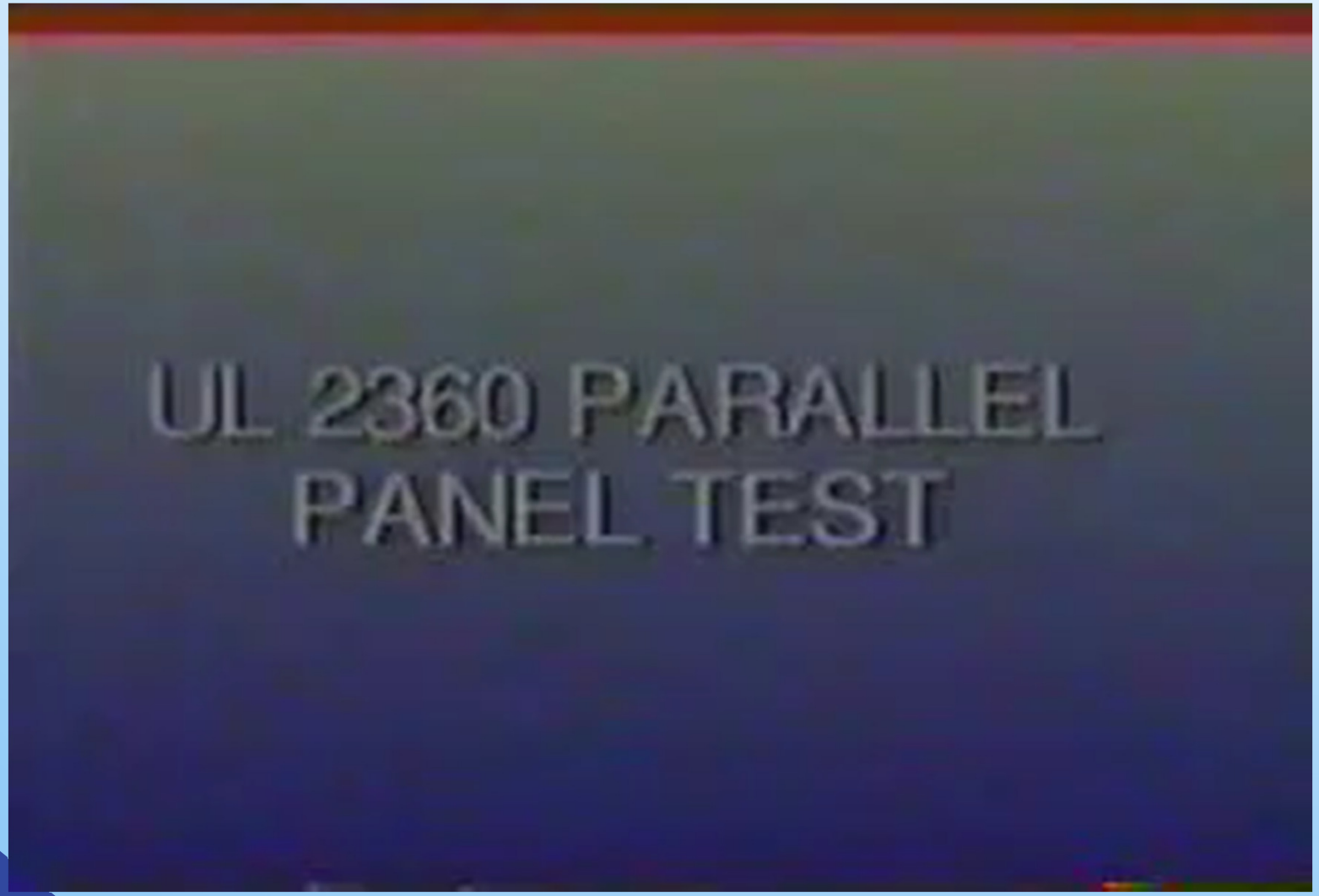
Test	Sample (L*W*t,mm)	Coated	Quartz Tube	Heat Source
Ignition	100*100*6~25	Surface:石墨粉或黑漆	No	Pilot Flame
Combustion	100*100*6~25	No	Yes	50kW/m^2
Fire Propagation	300*100*6~25 (L≤100 I.Z.)	Sides: 13mm Ceramic Paper	Yes	50kW/m^2

Large Scale Test





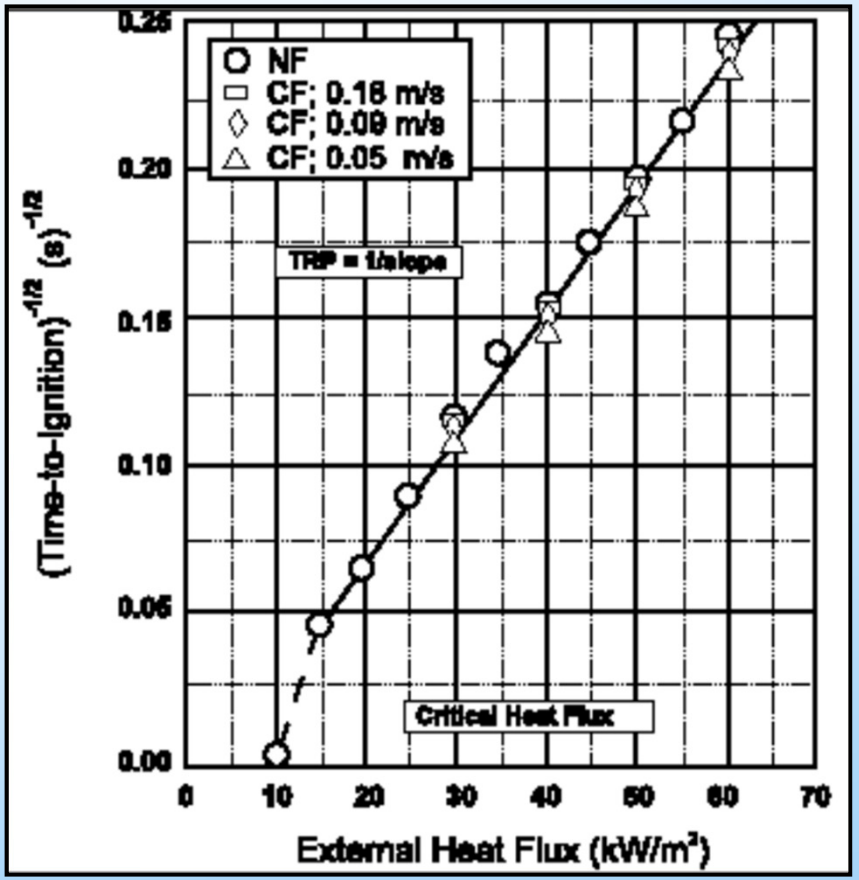
Large-scale Test



1:38 From Takiron Co., Ltd.

TRP from Ignition Test

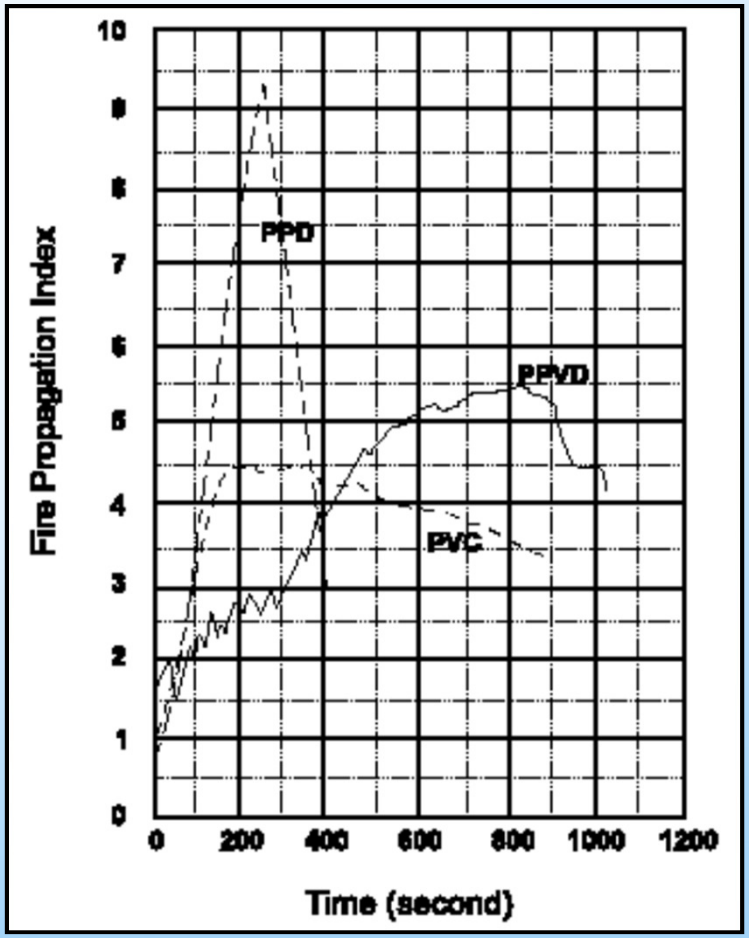
- Thermally Thick Material Relationship at Higher External Heat Flux Values
  - $\sqrt{\frac{1}{t_{ig}}} = \frac{4}{\pi}\frac{\dot{q}''_e}{TRP_{thick}}$
- Thermally Thin Material Relationship at Lower External Heat Flux Values
  - $\frac{1}{t_{ig}} = \frac{\dot{q}''_e}{TRP_{thin}}$
- TRP value ≥ 450 kW-S$^{1/2}$/m^2
  - For no fire propagation beyond the ignition zone (FPI ≤ 6)



PMMA

FPI from Fire Propagation Test

- Function of time
  - $FPI = 750 \frac{(\dot{Q}_{ch}/w)^{1/3}}{TRP}$
  - $\dot{Q}_{ch}'$ is the chemical heat release rate per unit width or circumference (kW/m)



Definition

- Average Corrosion Index (ACI)
  - ACI = C_C x Y_C
- Critical Heat Flux (CHF)
  - Minimum heat flux (no ignition)
- Fire Propagation Index (FPI)
  - FPI = heat flux / Response
- Ignition Zone
  - Area of the surface of a material heated by an outside source resulting in ignition.

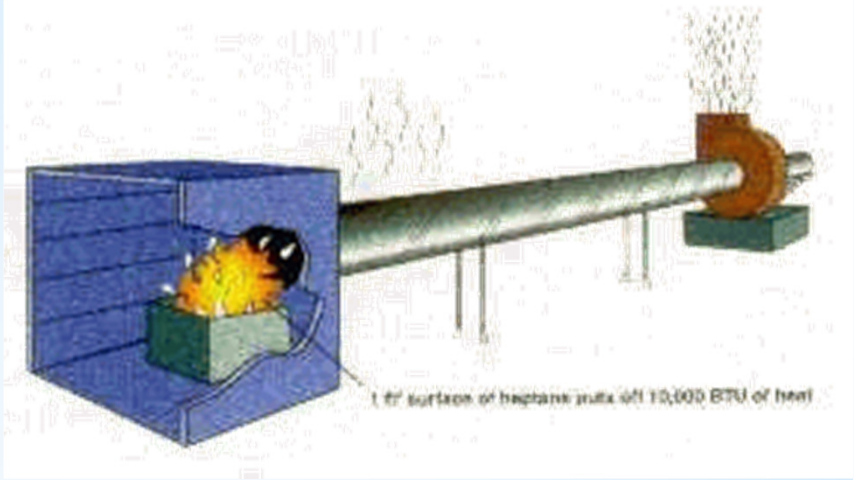
Definition (Cont.)

- PHRR
  - Peak heat release rate
- Smoke Damage Index (SDI)
  - SDI = Y_S x FPI
- Smoke Yield (Y_S)
  - Y_S = total mass of smoke released / total mass of material vaporized
- Specific Corrosion Constant (C_C)
  - Average corrosion rate per unit concentration of the corrosive products of combustion.
- Thermal Response Parameter (TRP)
  - Indicator of the ignition resistance of a material.

FM4910 Listed Materials

- Compression Polymers Corp. - CP7-D FRPP Sheet
- Compression Polymers Corp. - Flametec CPVC
- Compression Polymers Corp. - Halar 901LC
- Compression Polymers Corp. - Cleanroom PVC-C
- Empire Plastics - Boltaron™ 4225 White CPVC
- HPG International, Inc. - Brigade?/sup> CPVC
- Mitsubishi Plastics, Inc. - Hishi Plate 101-FM-CA
- Mitsubishi Plastics, Inc. - Hishi Plate 101-FM-HC Sheet
- Simona AG, Simona?PVC-C Rod (10-100mm diameter)
- Simona AG, Simona?PVC-C Sheet
- Takiron FM Plate FMEH 4305 (C-PVC)
- Takiron FM Plate FMET 4315 (PVC) ...

(Updated: Feb-2003)



FM4922
Fume Exhaust Ducts or Fume and Smoke Exhaust Ducts

Introduction

- Purpose
  - Duct used in exhausting
    - noncombustible chemical fumes
    - corrosive vapors
    - smoke in fire situations

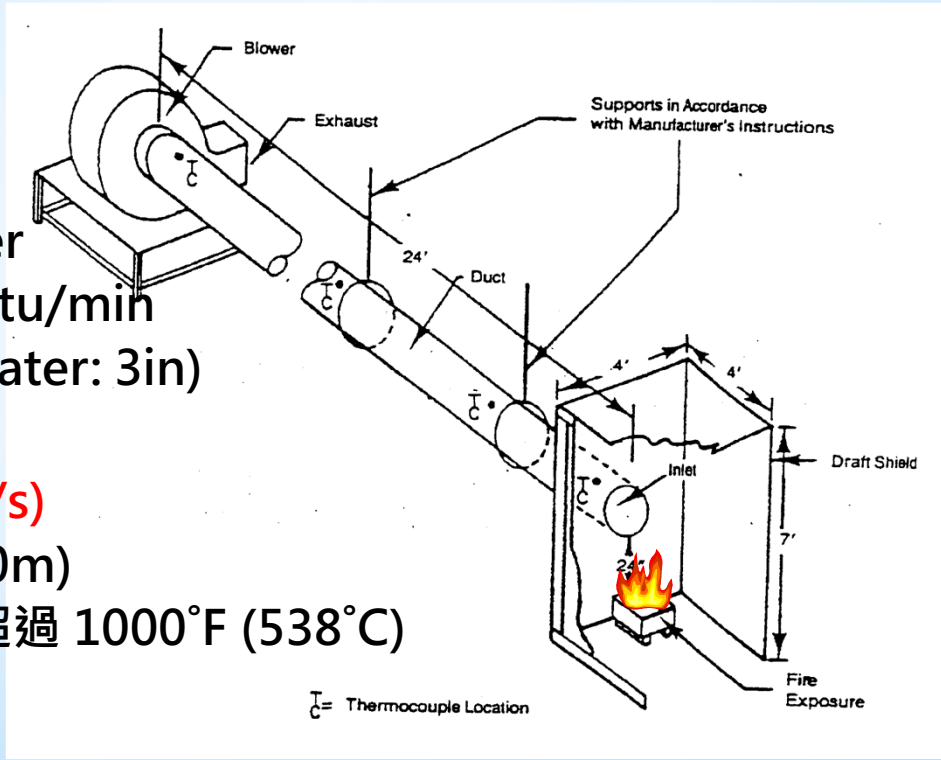
    No Portion of the duct or joint material fall, drip or melt
- Requirements
  - Diameter 12~60in (305~1524mm)
  - Vertical sections shall not exceed 15ft (4.6m)
    - Internal sprinkler protection shall be required

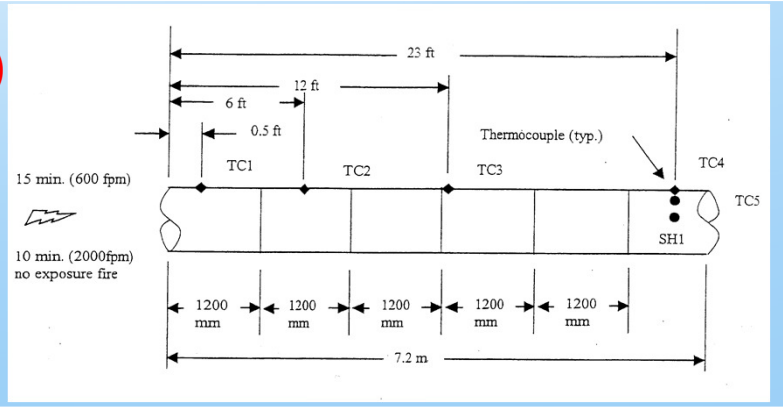
Performance Requirements

- Fume Exhaust Ducts
  - Horizontal Duct Fire Test
  - Horizontal/Vertical Duct Combination Fire Test
  - Vertical Duct Fire Test
- Fume and Smoke Exhaust Ducts
  - Horizontal Duct Fire Test
  - Horizontal/Vertical Duct Combination Fire Test
  - Teat for Smoke Removal Ability (Horizontal Duct)
  - Vertical Duct Fire Test
- Small Scale Quality Control Tests
- Clean Room Materials

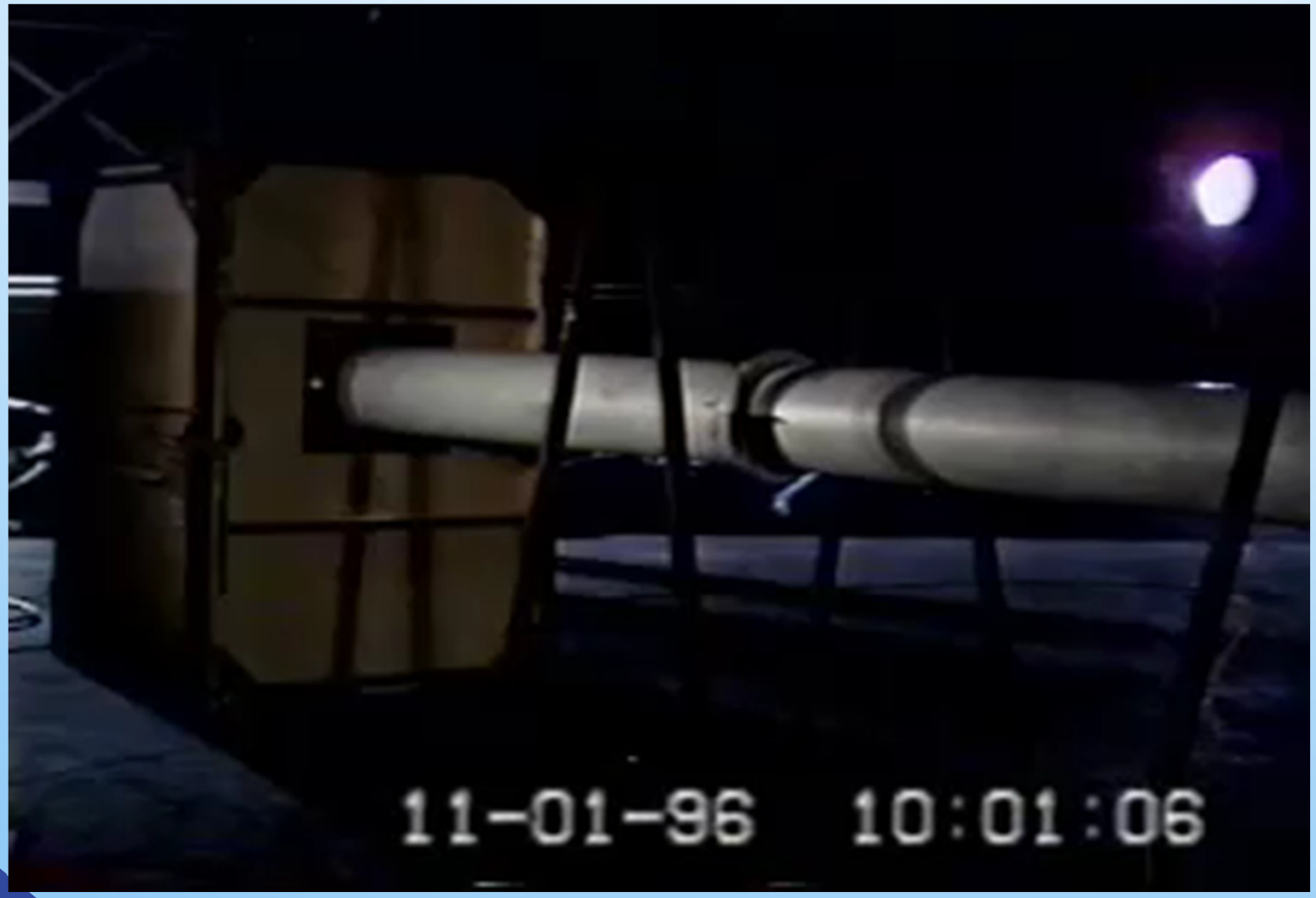
Horizontal Duct Fire Test

- 實驗配置
  - Report Appendix C
  - 24ft length, 12in diameter
  - 庚烷(1ft*1ft*8in) 10,000Btu/min
    (pan: 8in, heptane: 4in, water: 3in)
- 火焰測試要求
  - 15 minutes, 600fpm (3m/s)
  - 火焰擴散不可超過 23ft (7.0m)
  - 23ft (7.0m)內管溫度不可超過 1000˚F (538˚C)
  - 結構保持完整
- 排煙測試要求
  - 10 minutes, 2000fpm (10m/s)
  - 結構保持完整
  - 煙不會從火源端與管壁溢散
    (例外: 通過FM4910認證)





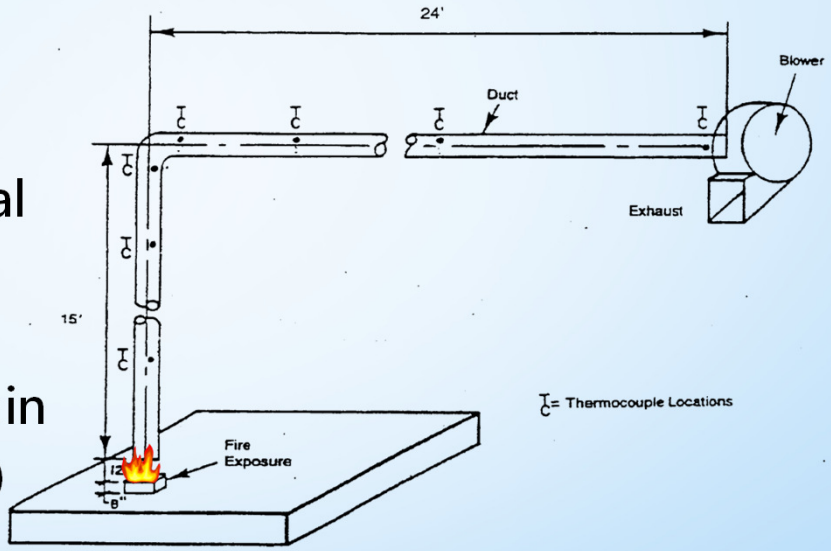
PP Fire (FM)

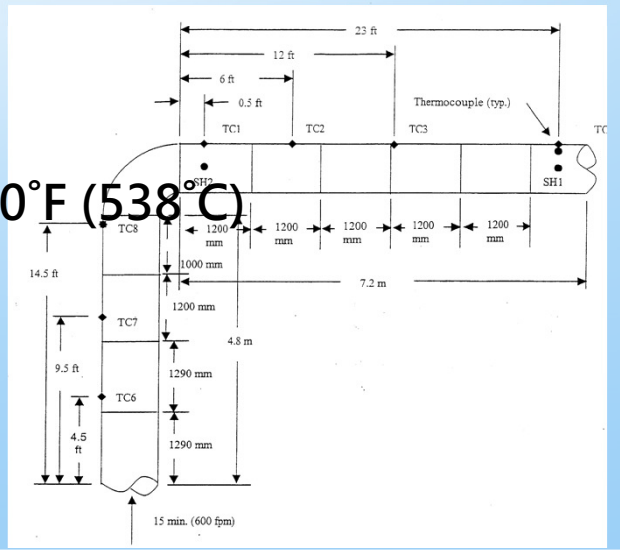


Horizontal/Vertical Combination Duct Fire Test

- 實驗配置
  - Report Appendix D
  - 24ft(7.3m) length of horizontal
  - 15.7ft(4.6m) length of vertical
  - 12in(305mm) diameter
  - 庚烷(1ft*1ft*8in) 10,000Btu/min

  (pan: 8in, heptane: 4in, water: 3in)
- 火焰測試要求
  - 15 minutes, 600fpm (3m/s)
  - 火焰擴散不可超過水平管 23ft (7.0m)
  - 水平管出口前1ft內管溫度不可超過 1000˚F (538˚C)
  - 管道外部的火焰應限制在垂直管段
  - 結構保持完整





Vertical Duct Fire Test

- 要求
  - Vertical runs of ducts exceed 15ft (4.6m)
- 實驗配置
  - 尚無配置圖與認證製造商
  - Field-assembled joints every 5ft (1.5m)
  - 12in diameter
  - 庚烷(1ft*1ft*8in) 10,000Btu/min
- 火焰測試要求
  - 15 minutes, 600fpm (3m/s)
  - 內管火焰不可擴散到管頂 10ft (3.1m)
  - 外管火焰不可擴散到管頂 5ft (1.6m)
  - 管頂 1ft (0.3m)內管溫度不可超過 1000˚F (538˚C)
  - 結構保持完整
  - 煙不會從火源端與管壁溢散 (例外: 通過FM4910認證)

Test Report Item

1. Introduction
   - Standard
2. Description
   - Duct Type and Construction
3. Examinations and Tests
   - Horizontal Duct Fire Test
   - Horizontal/Vertical Combination Duct Fire Test
   - Small Scale Quality Control Tests
4. Marking
   - Manufacturer’ s name and address
   - Product trade name
   - Approval Mark of FM Approvals
   - Wording that it is Approved as a fume and/or smoke exhaust duct

Test Report Item (Cont.)

5. Remarks
   - 符合SMACNA Round Industrial Duct Construction Standards
6. Facilities and Procedures Audits
   - Coating manufacturer
   - Coating Grinder
   - Duct manufacturer
   - Coating Applicator
7. Manufacturer’ s Responsibilities
8. Documentation
9. Conclusions

• Appendices

Test Result

- Horizontal Duct Test

Time(min:sec)	Observations
-1:00	Ambient air temp., 600 ft/min (3 m/sec) air velocity
0:00	Test begins – fuel source ignited
2:25	Sustained ignition of the interior coating
3:20	Coating flowing/dripping down duct wall at inlet
5:00	Duct exterior glowing orange to 2 ft (610 mm)
7:30	Coating consumed to 1 ft (305 mm)
14:00	Duct exterior discolored (bronze) to 4 ft (1.2 m)
15:00	Fuel source extinguished; air velocity increase to 2000 ft/min. (10 m/sec); no fire in duct
25:00	Test terminated

- Maximum temperature: 702˚F (372˚C)

Test Result (Cont.)

- Horizontal/Vertical Combination Duct Test

Time(min:sec)	Observations
-1:00	Ambient air temp., 600 ft/min (3 m/sec) air velocity.
0:00	Test begins – fuel source ignited
2:05	Droplets of coating falling from duct into fuel source
3:40	Duct exterior red to 21/2 ft (762 mm)
4:15	Falling droplets ceased
5:40	Duct exterior red-purple to 4 ft (1.2 m)
7:40	Duct exterior red to 41/2 ft (1.3 m)
9:10	Flame flicker inside horizontal section at 6 in. (150 mm) downstream of outlet from elbow
15:00	Test terminated

- Maximum temperature: 745˚F (396˚C)

Test Result (Cont.)

- Quality Control Tests
  - 50 kW-scale FM Approvals Flammability Apparatus Test

    CHF 45 kW/m^2

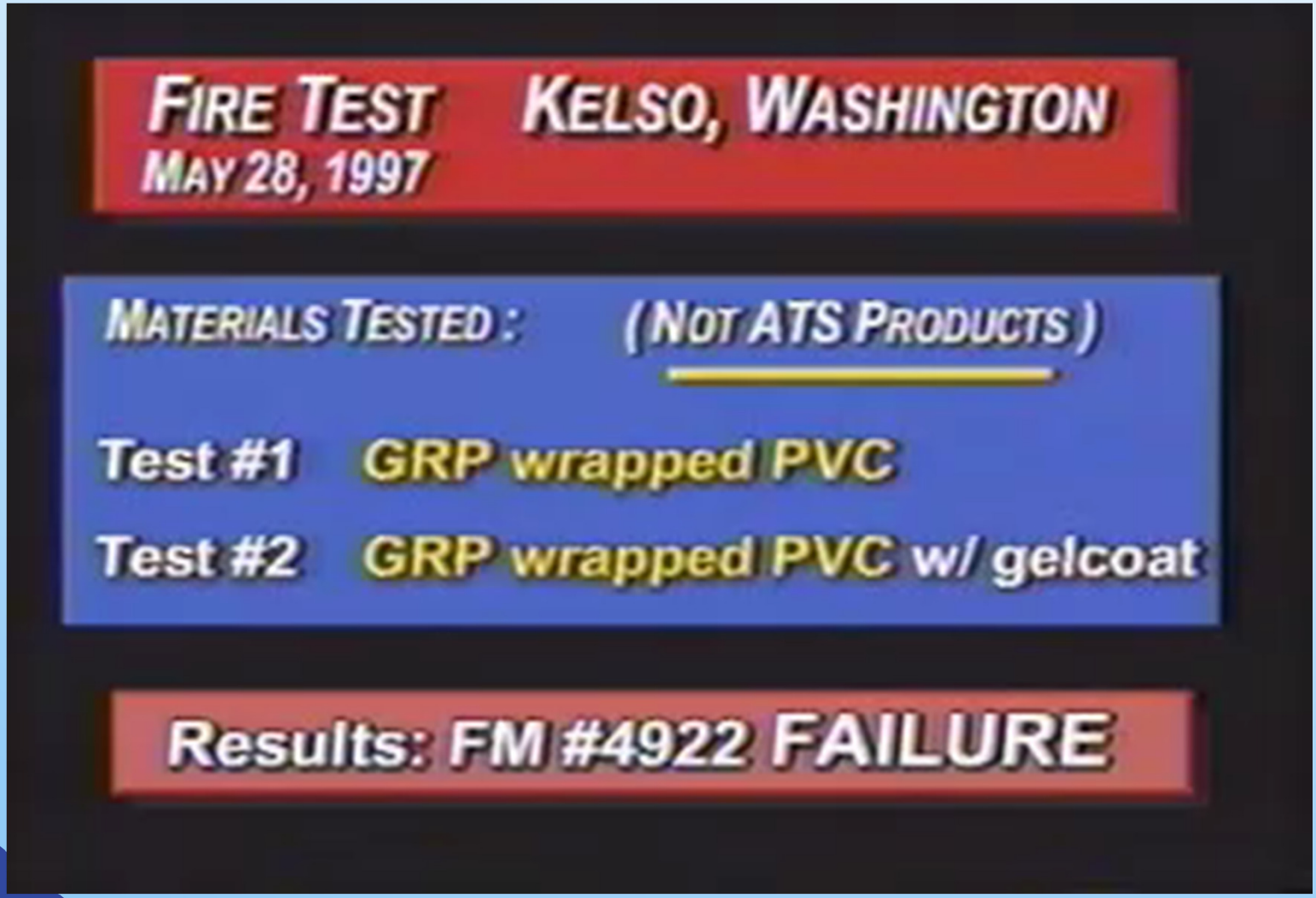
    TRP 254 $kW/m^2s^{-1/2}$

    CHRR 61 kW/m^2
  - ASTM E-84 surface burning and smoke developing characteristics
    - ECTFE coated, 1.2 mm thick, Type 316 stainless steel.

      Flame Spread 10 (<25 ?)

      Smoke Density 10 (<50 ?)

Test Video



2:05 From ATS Products Inc.

FM4922 Listed

- Fume and/or Smoke Exhaust Duct Systems for Use in Cleanrooms
  - Allied Supreme Corporation, Taipei, Taiwan (TEFPASS®)
  - ATS Products Inc, CA 94801 (Mark VII, Mark VIII and ATS 4910CR)
  - Aerotech Chemical Transfer System Co Ltd, Taoyuan Taiwan (A-TECH Duct)
  - Chern Dar Enterprise Co, Ltd, Taipei County, Taiwan (CRD Ductwork)
  - Composites USA Inc, MD 21901 (Model Dual Guard 1000/2000)
  - Edlon, A unit of Robins and Myers UK Ltd, Scotland, UK (Guardian Coated Duct SC2001/5001 FM/FMC)
  - Eurox Co Ltd, Taipei Taiwan ROC (Model *Super* Mark VIII)
  - Further Materials Inc, Taoyuan Taiwan (Model *Super* Mark VIII)
  - Hueng Luei Co, Ltd, Taipei, Taiwan, ROC (HL ECTFE Coated SUS Duct)
  - LBF Industrietechnik GmbH Postfach, Germany (DUCoaT Rohrsystem)
  - Shea Technology, NV 89509 (Model *Super* Mark VIII)
  - Sicore SA, France (GAINES INOX Type 304L Revêtues Intérieur Halar)
  - SPUNSTRAND Inc, WA 98057 (Model Super Mark VIII)
  - Tan Hou Co Ltd, Taipei Taiwan (TH ECTFE Coated SUS Duct)
  - Woo Jin Installation Co, Ltd, Seoul, Korea (SEMI-CON DUCT)

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Ping ~
「雖非一蹴可幾，
但有努力就會有收穫。」

敬請指教...

James Cameron ~
只要盡全力，即使失敗，還是會比停留原地走得更遠！
Hillary Clinton ~
Do your best and leave others' judgements as background music!