壹．緒論

一．緣起目的

國內歷年來「電線走火」在火災原因排行榜上一直是名列前茅，尤其是台北市，由歷年公佈之消防資料顯示，因電纜電線走火造成火災之比例最高時，超過百分之五十，可見因電纜電線使用不當，造成生命財產的損失是一個很嚴重的問題。而國外，如美國在1980年代也是以電線走佔失火原因之首位，但近年比例已降低很多，是因爲美國地方政府對建築法及保險法中電纜線之防火規範能遵守執行之故。

桃園平鎭文雅麗嬰房於82年5月5日清晨發生大火，起火原因是電子鍋電線走火，悶燒附近的嬰兒用品，進而起火延燒一小時，造成祖孫三代共十一人，在親人目睹下活活被燒死之慘劇。事後甚多媒體均報導「鐵門鐵窗絕生路」，但卻忽略了現場之電力鐵捲門在火災開始不久，電力電纜被燒壞導致電力中斷，使屋外之家人無法啓動鐵捲門進入火場救人，以致造成如此悲劇。

由這些血跡斑斑之例證可以看出，加強電纜電線之防火性能在建築物防火安全中是如此迫切需要。而認定基準更是要清楚地訂定，以提供供主管單位作爲執行之參考依據。

二·研究範圍

1. 本研究耐火電纜部份，採用IEC 331(International Electrotechnical Commission)標準規範，世界各國採用此標準之國家甚多，而我國 CNS 11359也參考此標準。此法爲 750℃±40℃之明火將電纜以水平方式架設燃燒 3小時，電纜之中心線以5A接地，試料接一個 3相星形或 3個單相接頭容量爲 3A之變壓器，樣品接通電源調整至600V AC連續燃燒 3小時後熄火，量測導電性是否劣損，12小時後再通電量測一次。設備組裝完成後，將以國內購得之電纜作一連串之測試，求取經驗並獲得數據。
2. 有關耐燃電纜線部份則採用IEEE 383(Institute of Electrical and Electronics Engincers)。美國UL 1581、IEC 332-3 亦爲相同之規範。但其中燃燒位置與燃燒器調整方式略有不同外，進行此 實驗時須加裝燃燒室。在燃燒設備獲得後，將依照規範中所規定之尺寸裝設，另外將採購國內外電纜線乙批進行燃燒測試，並將數據與國外資料比對作爲認定基準之參考。

貳·研究內容

歐美日等諸工業先進國家，在電纜安全之研究發展及應用上均有相當長之時間，因此訂定了許多安全法規、測試方法以及判定標準。由於每個國家國情及環境不同，爲了要確實瞭解本研究案之內容與方法是否恰當，因此，首先要清楚瞭解各國電纜安全法規及檢測標準之特點，才能分析研判適合我國電纜防火性之認定基準。

國外在電纜安全考慮方面，大多著重在以下四方面：

1. 電纜防火性：電纜外被覆及絕緣材之點燃性及火焰傳播性。
2. 電纜發煙性：電纜所有可燃物燃燒後造成之煙塵，遮蔽逃生者視線。
3. 電纜燃燒毒性：電纜燃燒後之有毒性氣體，對人體之影響。
4. 電纜含鹵量及腐蝕性：電纜燃燒後所產生之鹵化氫，對各種電器之接點造成之損壞。

本研究案雖然只針對電纜之防火性作研究，但爲了國內往後在電纜安全規格上作整體考量。因此先對四種安全特性資料先行整理探討，至於實驗及判定基準，只針對電纜之防火性作報告。

電纜防火性

美國測試方法

美國於1960年代因爲工業急速發展，物質生活提高而大量使用電線電纜，電氣造成的火災與傳統火災不儘相同，使**防火**科技人員開始理會到電纜之外包覆材料不單是可燃物料(fuel load)， 同時也是起火的源頭(ignition source) 。電纜業者爲了良心道德，提出許多經費給學術界進行研究。而美國芝加哥保險業聯合實驗室(UL)爲了社會安全，投下了許多力量開發了許多測試方法，給美國三大建築法規訂定許多防火法規(fire code)， 這些測試方法經過不斷修改汏換，演變到今日的標準，在早期有名的測試方法有：

UL Standard 44：Rubber-Insulated Wires and Cables.
UL Standard 62：Flexible Cord and Fixture Wire.
UL Standard 83：Thermoplastic-Insulated wires.
UL VW-1：Vertical Wire Flame Test.

以上這些測試方法到如今尚有一些研究人員在使用，新的測試方法均是由這些方法逐漸衍生而來，許多國家將美國的標準全盤吸收或修改部份後納入國家法規内。

一・IEEE 383 Test

在1960年代由美國Philadelphia Electric Co. 等五家公司共同提出構想，再經通用電氣等公司作進一步研發。在1971年向IEEE提出一個3英呎長，使用費雪燃燒器 (Fisher burner) 測試之方法，但未被IEEE接受，後來再經數家公司努力改進，終於在1974年被接受(如圖一)，其重要規格如下：

⊙垂直金屬樣品梯架高 2.4米、寬0.31米。

⊙樣品之間距離爲其直徑之半，架設之寬度爲0.15米。

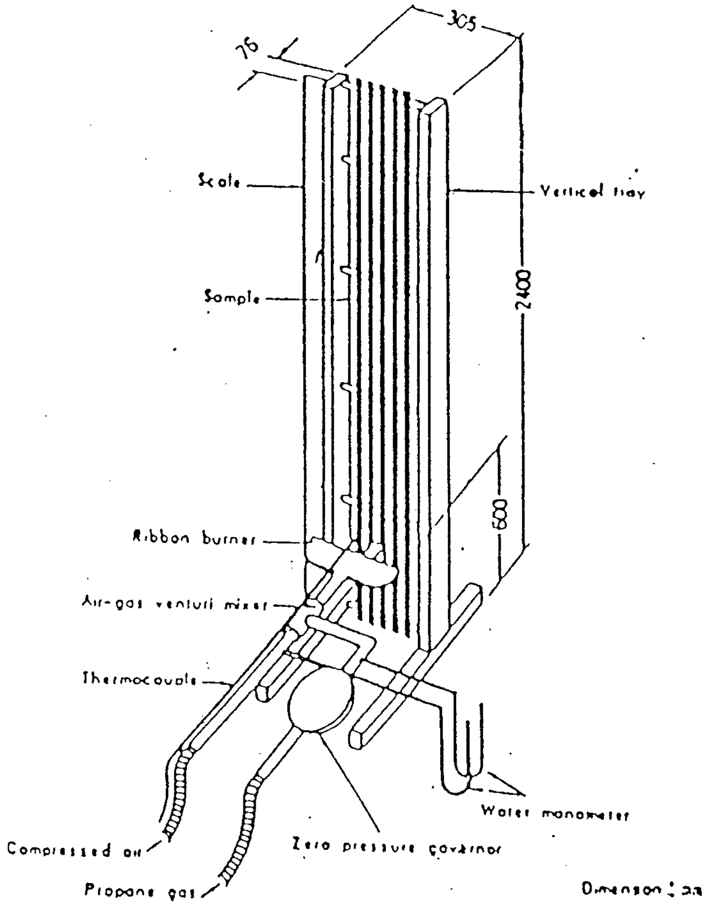
⊙使用帶狀空氣與丙烷混合燃燒器，其火口距樣品75mm。

⊙燃燒器熱量爲21Kw，其火焰之溫度在距離樣品 3mm處爲816℃。

⊙燃燒時間20分鐘。

⊙炭化長度不得燒過 2.4米。

其後於1984年ＩＣＥＡ(Insulated Cable Engineers Association)與ＵＬ(Underwriter Laboratories)進行 round robin program， 對測試之燃燒器、燃氣與空氣之量、燃燒器位置、樣品數量等均予以規定，更新爲新標準 IEEE 1202規範，加拿大ＣＳＡ FT-4 判定標準與其相似。



圖一 IEEE Std.383 Equipment of vertical tray flame test

二．UL 1581 Test

ＵＬ公司最早的電纜耐火測試定名為Vertical Wire flame test (VW-1)，是使用第瑞爾燃燒器(Tirrill burner)。將樣品點 5次，每次 15秒鐘，觀察其燃燒情況。其測試步驟與ASTM D2633相似。而後ＵＬ取消了VW-1方法，改用IEEE 383標準。但在燃燒器高度、丙烷與空氣量測方法有所不同。茲將UL 1581 與 IEEE 383,ICEA及 CSA等著名垂直電纜測試做異同對比如下表：

	IEEE 383 UL 1581	ICEA T-29-520	CSA FT-4	IEEE 1202	UL 1685 /UL	UL 1685 /IEEE	IEC 332-3
熱量(Kw)	２１	６２	２０	２０	２１	２１	２０
燃燒時間 (min)	２０	２０	２０	２０	２０	２０	２０，４０
燃燒器位置	600 mm 75 mm in back	300 mm 200 mm in back	300 mm 75 mm in front	300 mm 75 mm in front	457 mm 75 mm in back	457 mm 75 mm in back	600 mm 75 mm in front
燃燒器角度	horiz.	horiz.	20° up	20° up	horiz.	20° up	horiz.
梯架長度(m	２．４	２．４	３．０	２．４	２．４	２．４	３．５
梯架寬度(m	０．３	０．３	０．３	０．３	０．３	０．３	０．５
樣品長度(m	２．４	２．４	２．３	２．３	２．４	２．４	３．５
樣品排列 寬度(m)	0.15 front only	0.15	0.25 front only	full front only	0.15 front only	full front only	0.30 front or front+ back
測試次數	3	2	2	2×2	1	1	1
炭化長度(m	２．４	２．４	1.786	1.786	２．４	1.786	３．１

三·UL 910 Test

此項測試是使用在美國建築界相當有名之ASTM E84史坦勒隧道測試(Steiner Tunnel Test)。這個方法是美國電纜法規NEC(National Electric Code)於1975年所提出。電纜在水平狀態下，以24呎長之樣品測試其火焰傳播率(Flame Spread rate)及煙釋放率(Smoke Release rate)，其重要規定如下：

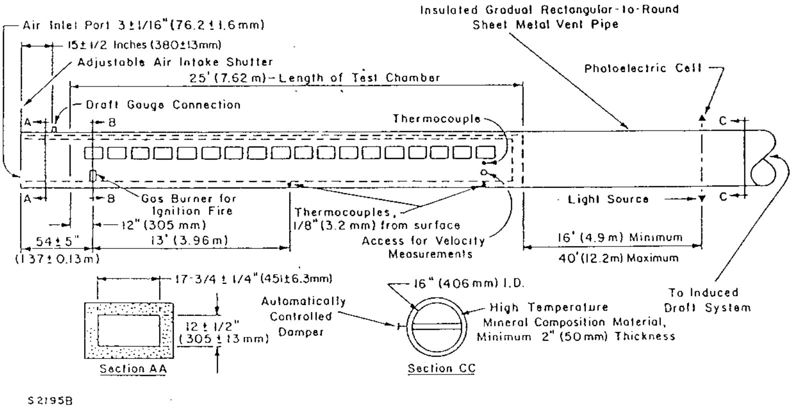
⊙爐體熱通量爲87.9Kw/m^2。
⊙火焰長度4.5呎。
⊙樣品以水平方式鋪架在鋼樑上。
⊙樣品寬度爲1呎。
⊙其火焰伸展距離應低於5呎。
⊙煙釋放之光學密度之峰值應低於0.5，而平均值應低於0.15。

美國National Fire Protection Association於1990年以NFPA 262納入標準，其測試設備示意圖如圖二及圖三：

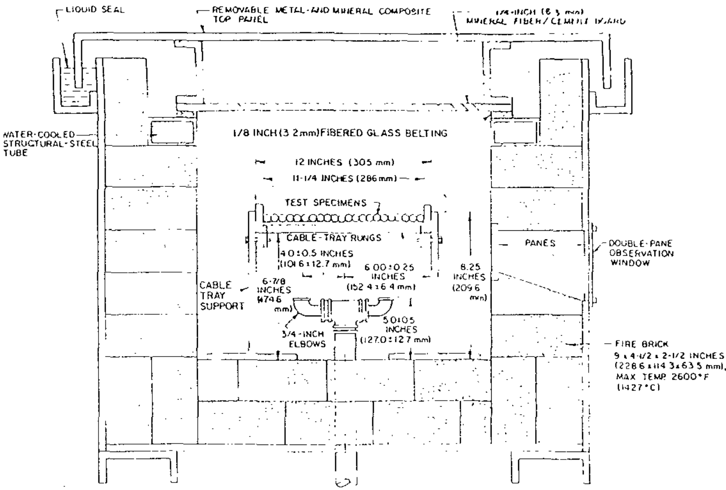
四·UL 1666 Test

1984年美國NEC 規定通訊電纜應通過UL 1666 梯間垂直測試(Riser Cable test)，這是僅次於UL 910之嚴格測試。後來ANSI亦將其列入爲測試標準，其重要規定如下：

⊙扇形之爐火熱通量爲145Kw/m^2。
⊙電纜樣品長19呎。
⊙電纜鋪設之寬度爲1呎。
⊙火爐燃燒時間爲30分鐘。
⊙判定合格標準爲火焰不可燒到第一樓層至第二樓層之中間(12呎高度)。


Air Inlet Port 3±1/16"(76.2±1.6mm)
15±1/2 Inches (380±13mm)
Adjustable Air Intake Shutter
25'(7.62 m)-Length of Test Chamber
Draft Gauge Connection
Insulated Gradual Rectangular-to-Round Sheet Metal Vent Pipe
Photoelectric Cell
Thermocouple
A
B
C
Gas Burner for Ignition Fire
Thermocouples, 1/8"(3.2 mm) from surface
Access for Velocity Measurements
Light Source
12"(305 mm)
54±5"
(1.37±0.13m)
13'(3.96m)
16'(4.9m) Minimum
40'(12.2m) Maximum
To Induced Draft System
17-3/4±1/4"(451±6.3mm)
12±1/2"
(305±13mm)
Automatically Controlled Damper
16"(406mm) I.D.
High Temperature Mineral Composition Material, Minimum 2"(50mm) Thickness
Section AA
Section CC
S2195B

圖二· 史坦勒隧道縱面



SC1970A

圖三· 史坦勒隧道橫截面

五．UL 1685 Test

1990年美國NEC 推動電纜"低煙"之規定，因此指示UL公司重新訂定並改良UL 1581之測試規範，定名爲UL 1685規範，美國建築法規也配合執行。其測試判定基準在防火性方面與UL 1581相同，其炭化長度需低於2.4m，但是增加了煙之要求。

⊙煙釋放率峰值≦$0.1m^2.s^{-1}$。

⊙總煙釋放量≦$25m^2$。

六．ICEA Test

美國絕緣電纜工程協會ICEA(Insulated Cable Engineers Association)規定較IEEE 383爲嚴格，其規定如下：

⊙燃燒器熱通量$62Kw/m^2$。

⊙燃燒器距電纜樣品 200mm，距梯架底部 300mm。

⊙梯架必須距牆0.3m。

⊙測試時環境溫度必須在10℃以上。

⊙綁電纜樣品之銅線及鋼線其徑粗爲1.0～1.6mm。

⊙此種標準只有少數特殊場所使用。

七．IEEE 1202 Test

與加拿大CSA FT-4相似，都是由IEEE 383延伸出來，主要是應用於核能電廠，其規定重點如下：

⊙燃燒器之熱通量應爲 $21Kw/m^2$，但因從公制轉換 70,000 Btu/hr時降爲$20Kw/m^2$。

⊙燃燒器之角度爲20°。

⊙測試時與IEEE 383完全無抽風條件不同，其抽風速率爲$0.65m^3/s$。

⊙綁樣品之銅線其徑粗不得超過2.08mm。

⊙炭化長度最大爲1.786m。

八．MIL-C-24642 Test

美國海軍規範規定船艦上之電纜均需符合此種標準。而此方法是英國海軍工程標準NES 711 延伸而來，除了有防火性之要求外，另外尚有低煙之要求以及毒性要求。

九．FMRC Test

美國工廠互助研究公司於1989年訂出兩套電纜火焰傳播率測試方法。

1. 12.7cm 長之電纜樣品置於熱釋放率測試儀上燃燒，其熱反應參數TRP 可由下列公式得到。

$$t_{ig}^{-\frac{1}{2}} = \frac{q_e''}{\triangle T(k_\rho C_p)^{\frac{1}{2}}} - a$$

t_{ig}：點火時間

$\triangle T(k_\rho C_p)^{\frac{1}{2}}$：熱反應參數

2. 61cm 長之電纜樣品放在50Kw/m^2 之輻射熱源下測試，其火焰擴散指數FPI 可由下列公式得出：

$$FPI = \frac{(0.40q''_{peak}/\pi D)^{1/3} \times 10^3}{TRP}$$

q''_{peak} = peak HRR (Kw/m^2)

D = the cable outer diameter (m)。

加拿大測試方法

一．Ontario Hydro Cable Tray test

⊙測試時環境溫度沒有限制。

⊙有一套校正燃燒器溫度之規定。

⊙樣品梯架距牆應超過0.3M。

⊙樣品長度2.7m。

⊙燃燒器角度20°。

⊙另外附加腐蝕性測試。

二．CSA FT-4 Test

加拿大標準協會(Canadian Standard Association) 訂出一套較 UL 1581與IEEE 383更嚴格之測試方法，其主要之不同處有以下數項：

⊙燃燒箱其抽風速率爲$10m^3/min$，空氣流通速率爲 $1 m.s^{-1}$。

⊙測試時燃燒箱之最低溫爲5℃。

⊙梯架長3.0m。

⊙燃燒器角度爲20°。

⊙樣品較短，只有2.3m。

⊙由上而下樣品每隔0.45米，以銅線固定之。

⊙樣品數目視徑粗而定，均爲奇數。

⊙最大炭化長度不得超過1.5m。

英國測試方法

一．BS 4066 Test與IEC 332 part1,332 part2,332part3相同。

二．BS 6387 Test

此種標準爲測試電纜的"電流完整性"，一共有三種不同之方法，簡述如下：

1.單純抗火性(Resistance to fire alone)

1200mm之電纜樣品以水平方式置於 610mm長之丙烷與空氣混合燃燒器明火下，在 650,750,950℃不同之溫度以通電方法測試之法。

2.抗火性及灑水頭測試(Resistance to fire with water)

樣品較第一項長，爲1500mm。測試方法與第一項同，但火炬溫度爲650℃ ，先燃燒15分鐘，其後再燃15分鐘，並以灑水頭噴水，在30分鐘內要求其電流之完整性。

3.抗火性及機械震動(Resistance to fire with mechanical shock)

此法用ASTM E119 抗火測試法燃燒，樣品在測試時以機械方法持續震動。

以上三種測試方法如通過其不同條件之樣品，可冠上下列之符號代表。

A resistanceto fire alone, at 650℃ for 3h。
B resistanceto fire alone, at 750℃ for 3h。
C resistanceto fire alone, at 950℃ for 3h。
S resistanceto fire alone, at 950℃ for 20min。
W resistanceto fire and water, at 650℃ for 30 min。
X resistanceto fire and mechanical shock, at 650℃。
Y resistanceto fire and mechanical shock, at 750℃。
Z resistanceto fire and mechanical shock, at 950℃。

義大利測試方法

CEI 20-22 Test

1967年義大利開始以每公尺含10Kg可燃之電纜材料做梯架測試，而後於1973年改爲每米 5Kg及10Kg爲測試量，最近在1989年規定PVC電纜用10Kg爲測試量，而非PVC電纜則依照IEC 332 part3 Catagory C 1.5 L/m量測試。義大利CESI使用30Kw/m^2 之燃燒器，樣品長度爲4.5米，炭化長度不超過 3.5米爲合格，而CEGB標準則不得超過 1.5米，比較嚴格。

法國測試方法

NF X70-100 只有測試電纜燃燒氣體之酸度。

瑞典測試方法

SS 424 14 75 與IEC 332 part1,2,3相同。

比利時測試方法

NBN 713-020 Test

使用里奇大學(University of Liege) 及哥汗大學(University of Ghent)之燃燒爐測試電纜之"電流完整性"，其溫度是依照 ISO 834防火曲線標準，而測試時間爲30, 60及120分鐘。

歐體國際標準測試方法

歐洲共同體組織要求歐洲各國將原有之各種測試標準儘量一元化，並轉換到ISO 標準，美國因市場壓力而逐漸認同ISO，日本亦以五年計劃配合轉換中，歐洲以外之各工業國家目前均在考慮如何轉換配合，謀取最大經濟利益。IEC 是ISO 中有關電纜規格之單一標準，其重要性不言而喻。

一·IEC 331 Test

此測試標準與BS 6387 中標號"B" 之測試相同，在嚴苛程度上列為中上等級，有關重點已在緒論中陳述。

二·IEC 332 Part1 Test

此項測試與美國UL 1581 VW-1規範有部份近似，是以特定本生燈對徑粗在50mm以上之電纜以45度斜度在 T=60+m/25 (m:600mm長電纜之重量)時間內燃燒，如果炭化長度不超過475mm即合格。此標準主要為歐體採用。

三·IEC 332 Part2 Test

與IEC 332 Part1 近似，只是本生燈之火焰較短，另外點燃時間只有20秒。

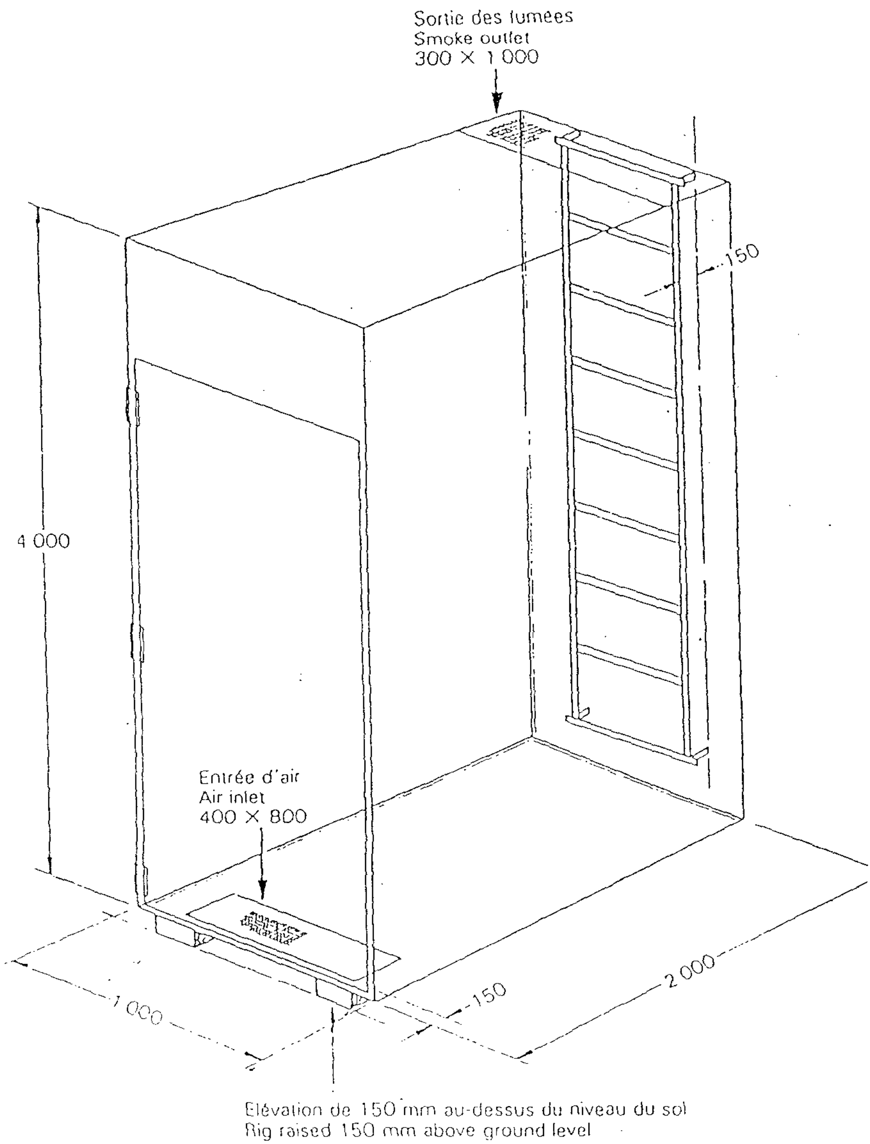
四．IEC 332 Part3 Test

歐體使用之IEC 332-3 所使用之燃燒器與IEEE 383相同，但有數項條件不同，玆檢附如下：

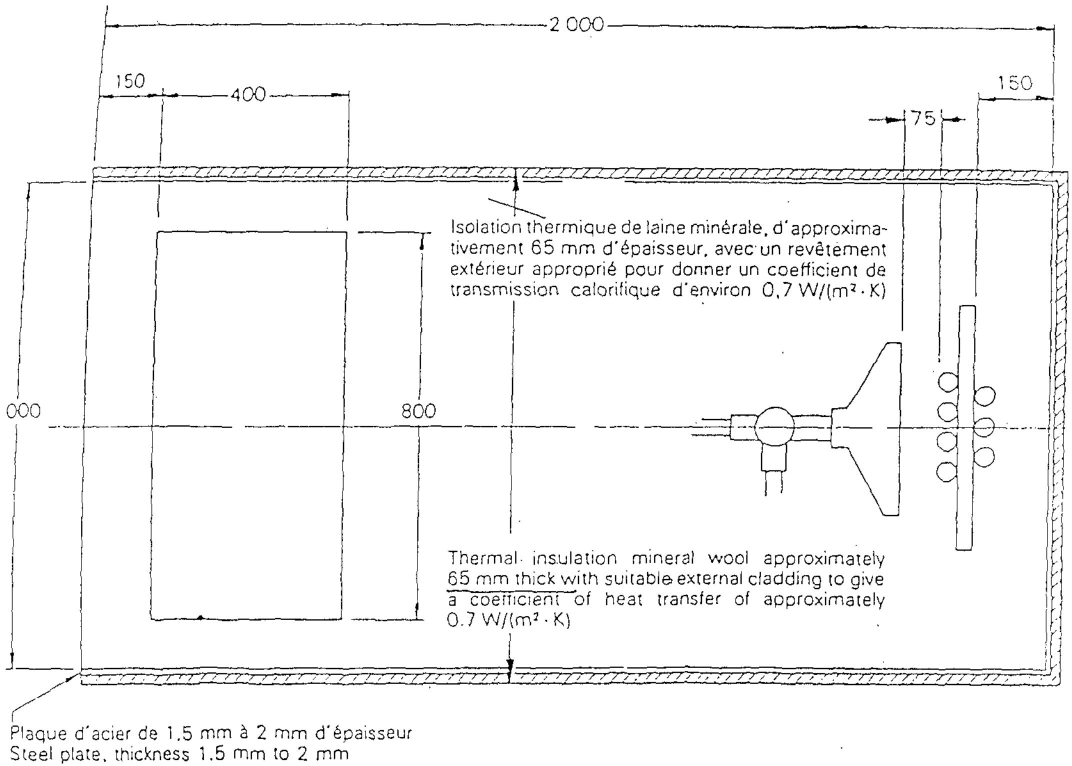
	IEC 332-3	IEEE 383(UL 1581)
1.燃燒時間	20 min(Category C*) 40 min(Category A*) 40 min(Category B*)	20 min
2.燃燒架寬度	0.5 m	0.3 m
3.樣品長度	3.5 m	2.4 m
4.最大炭化長度	3.1 m	2.4 m
5.樣品位置	梯前＋梯後	梯前
6.樣品寬度	0.3 m	0.15 m
7.測試次數	1 次	3 次(取平均值)

* 註：IEC 332-3 樣品分類
  Category A 可燃物量 7 L/M
  Category B 可燃物量 3.5 L/M
  Category C 可燃物量 1.5 L/M

IEC 332-3 測試法與IEEE 383(UL1581)顯著不同，但大體測試步驟類似，而IEC 332-3 之燃燒室(Chamber) 設計比較理想，其樣品架設位置及燃燒時空氣流動方式較符合一般建築眞實狀況(如圖四及圖五)。


Sortie des fumées
Smoke outlet
300 × 1 000
150
4 000
Entrée d'air
Air inlet
400 × 800
1 000
150
2 000
Elévation de 150 mm au-dessus du niveau du sol
Rig raised 150 mm above ground level

圖四· 燃 燒 室



圖五· 帶狀燃燒器及樣品位置圖

日本測試方法

日本消防廳第七號

主要規格爲使用日本JIS 1301建築用防火門測試方法，溫度條件在 840±84℃，燃燒時間爲30分鐘，因爲是封閉性爐體，其受輻射熱之條件較IEC 331 爲嚴苛，但燃燒時間較短。我國CNS 11174 標準與此法相同。

中華民國測試方法

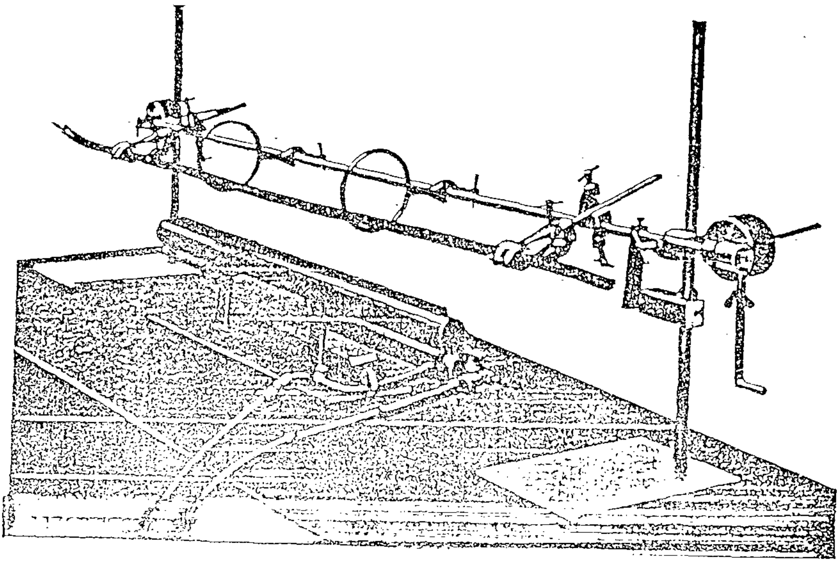
一·CNS 11359 聚乙烯(交連聚乙烯)、絕緣聚氯乙烯（聚乙烯)被覆耐火電纜與IEC 331 相同(如圖六)。

二·CNS 11174 耐燃電線

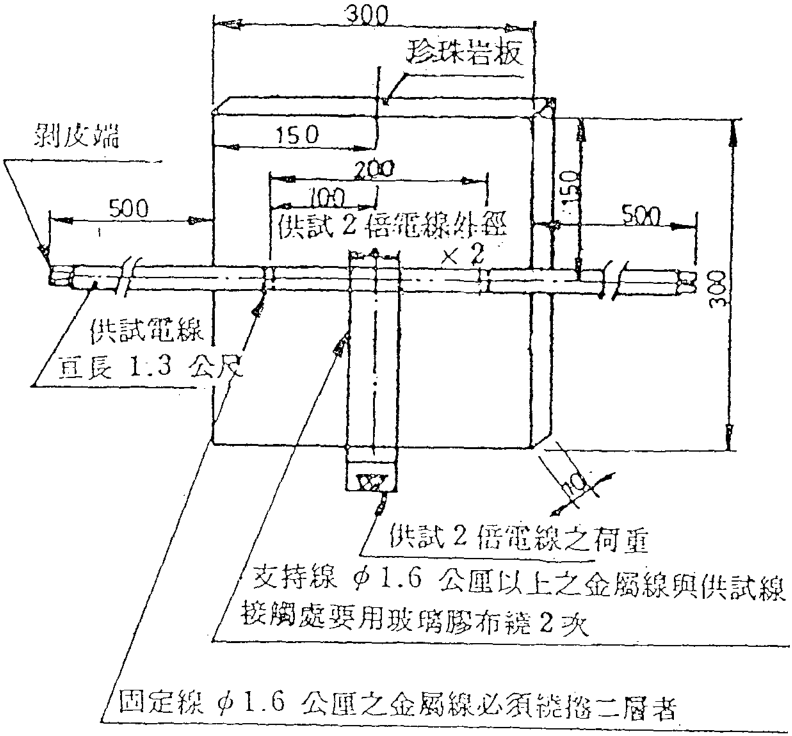
與日本消防廳七號相同，使用CNS 11227(建築物防火門防火試驗方法) 加熱爐，溫度控制在840℃± 84℃、燃燒30分鐘，測試時通交流電，不得發生短路現象，如圖七－1、七－2、七－3：

三·CNS 11175 耐熱電線

使用CNS 11227 建築物防火門防火試驗方法，加熱爐溫度控制在 310℃±10℃、燃燒30分鐘，加熱時通 250V 交流電，不得發生短路現象，如圖八－1、八－2：

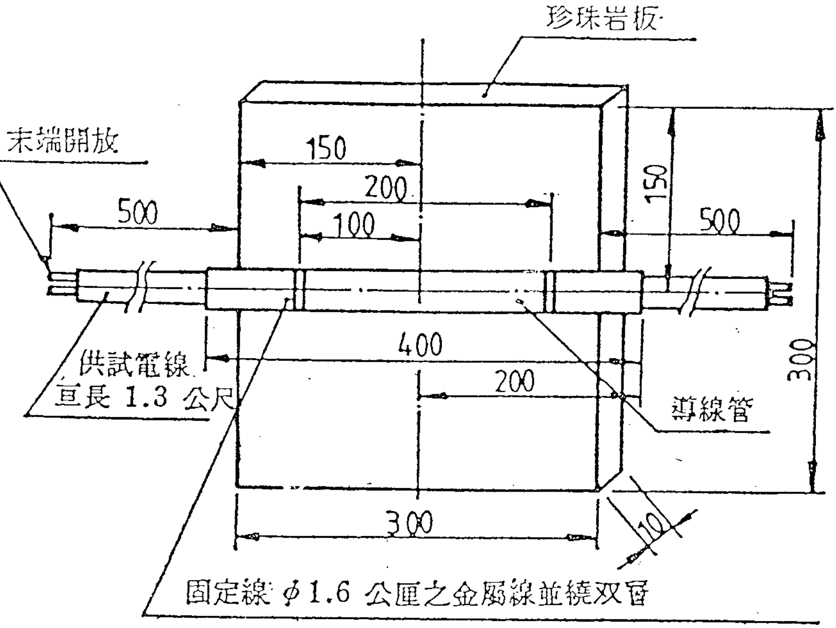


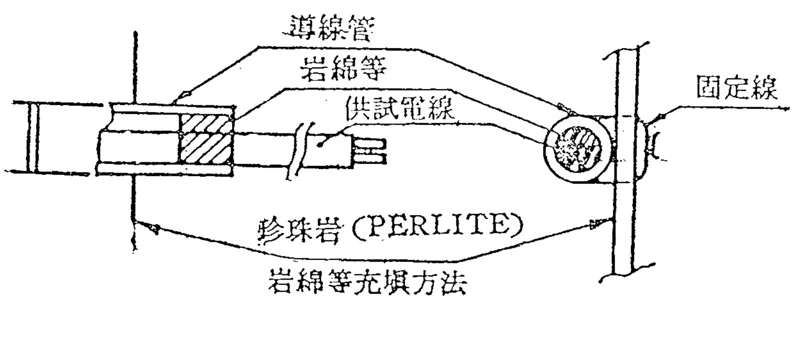
圖六· CNS 11359 (IEC 331) 設備



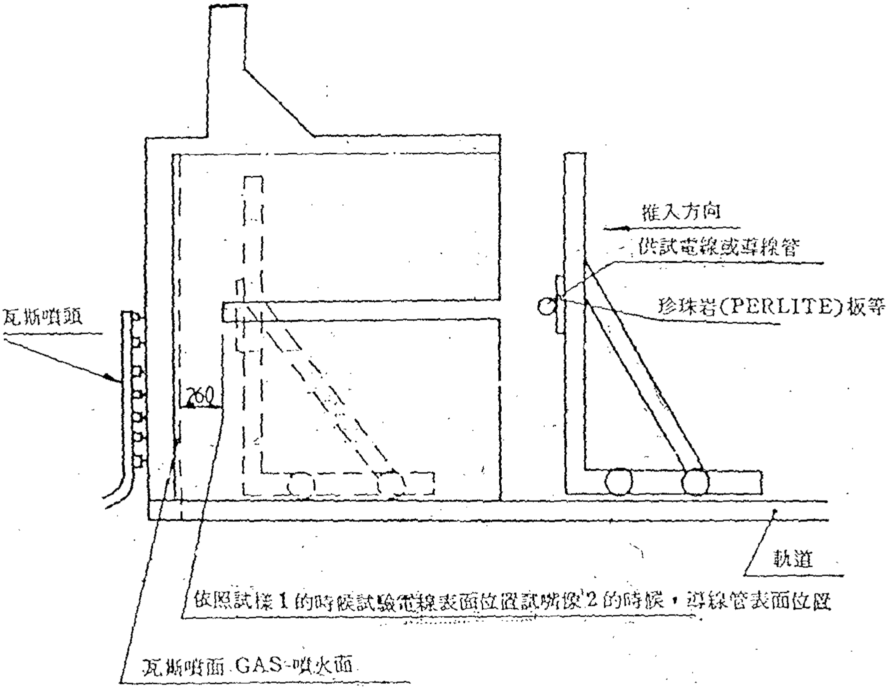
單位公厘（耐燃電線之基準）

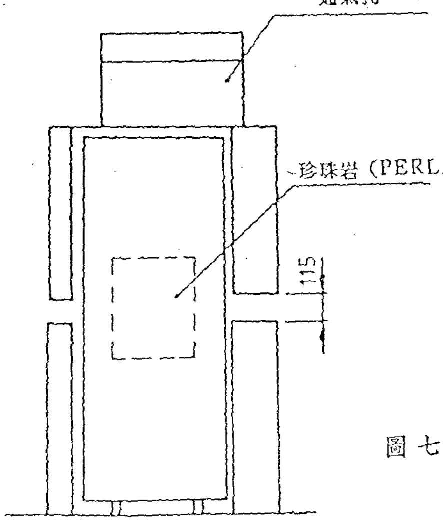
圖七－1． 電纜架設圖


珍珠岩板
末端開放
150
200
100
500
150
500
400
供試電線
亘長 1.3 公尺
200
導線管
300
300
10
固定線 φ1.6 公厘之金屬線並繞双會

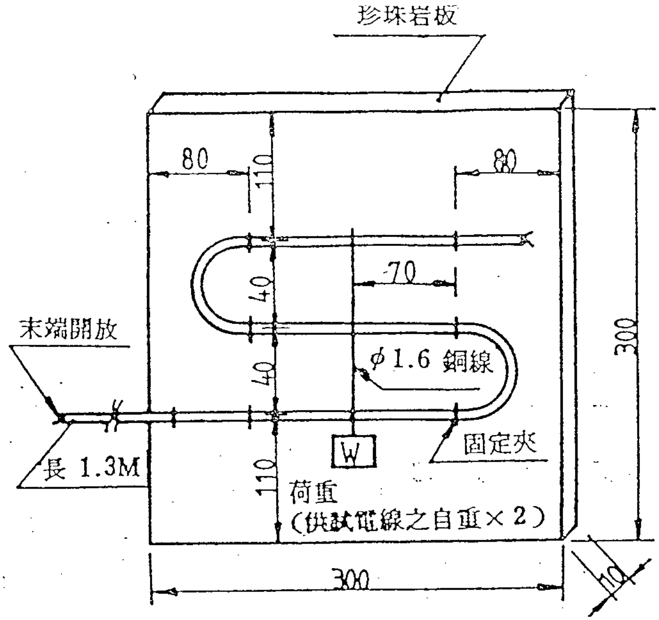

導線管
岩綿等
供試電線
固定線
珍珠岩 (PERLITE)
岩綿等充塡方法

圖七－2· 電纜架設圖

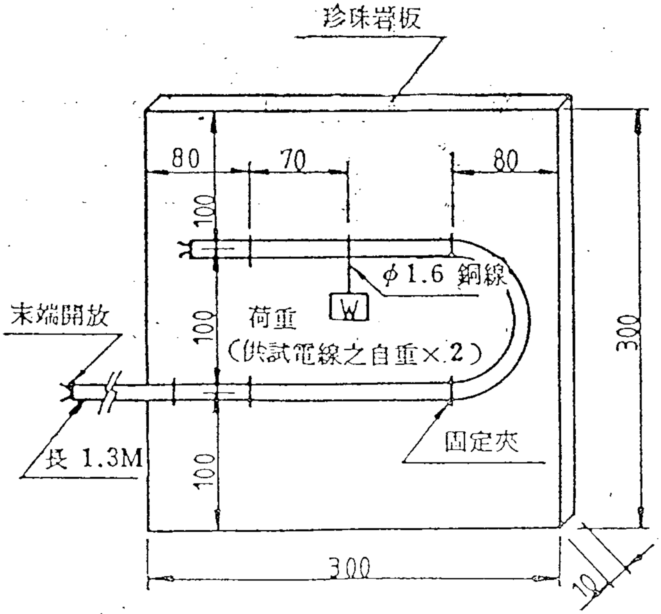

推入方向
供試電線或導線管
珍珠岩(PERLITE)板等
瓦斯噴頭
260
軌道
依照試樣1的時候試驗電線表面位置試樣2的時候，導線管表面位置
瓦斯噴面 GAS-噴火面


通氣孔
珍珠岩 (PERLITE) 板等
115

圖七－3・ 加 熱 爐

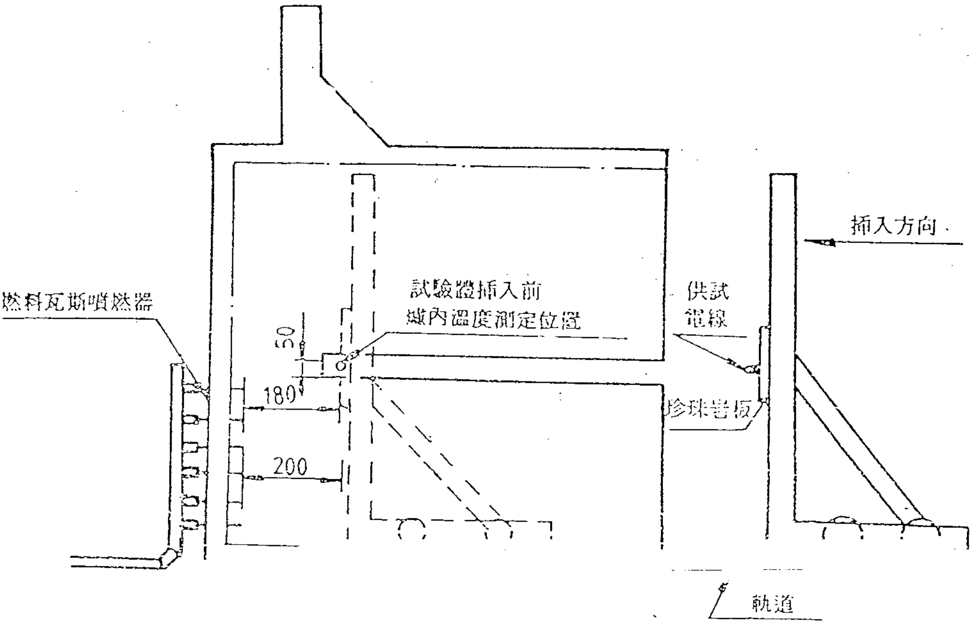


珍珠岩板
80
110
80
70
40
40
末端開放
φ1.6 銅線
固定夾
長 1.3M
110
荷重
(供試電線之自重×2)
300
300
10



珍珠岩板
80
70
80
100
φ1.6 銅線
100
荷重
(供試電線之自重×2)
末端開放
固定夾
長 1.3M
100
300
300
10

圖八－1． 電纜架設圖



圖八－2· 加 熱 爐

電纜發煙性

美國測試方法

一・ASTM E662

1967年美國國家標準局Gross D.等人開發出一種沒有單位之特定光學密度來量測物質經燃燒或悶燃後產生之煙濃度。經過多年改進，在1979年進入ASTM標準，這個特定光密度(Specific Optical density Ds) 是以Bouguer's或Beer's 公式推算出：

$$Ds = G\left[\log_{10}(100/T)\right]$$

optical density: $\log_{10}(100/T)$

$$G(\text{geometrical factor}) = \frac{V}{LA} = \frac{18ft^3}{3ft \times 0.0456ft^2} = 132$$

V：chamber volume

L：light beam path

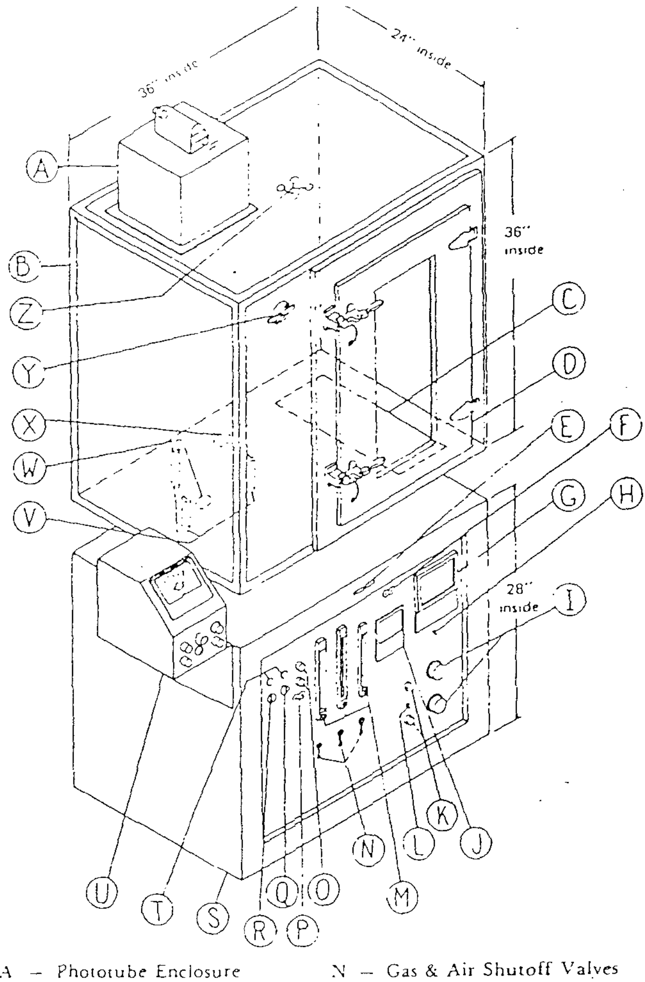
A：exposed sample area

Ds：$132\left[\log_{10}(100/T)\right]$

此種規範應用範圍很廣泛，除了塑膠、電纜產品外、建材、織品等均可測試（如圖九）。

二・UL 1685 Test

利用UL 1581 方法，並加裝光量管設備，其判定標準爲煙釋放峰值應小於 $0.25m^2s^{-1}$，總煙釋放量應低於$95m^2$。



A – Phototube Enclosure
B – Chamber
C – Blowout Panel
D – Hinged Door with Window
E – Exhaust Vent Control
F – Radiometer Output Jack
G – Temperature (Wall) Indicator
H – Temperature Indicator Switch
I – Autotransformers
J – Voltmeter (furnace)
K – Fuse Holders
L – Furnace Heater Switch
M – Gas & Air Flowmeters
N – Gas & Air Shutoff Valves
O – Light Intensity Controls
P – Light Voltage Measuring Jack
Q – Light Source Switch
R – Line Switch
S – Support Frame
T – Indicating Lamps
U – Photometer Readout
V – Rods
W – Glass Window
X – Exhaust Vent
Y – Inlet Vent
Z – Access Ports

圖九． ASTM E662 Smoke Density Chamber

三・UL 910 Test

與前法相同，均爲防火性測試設備外加煙釋放測試儀，其判定標準，煙光學密度峰值應小於 0.5，而平均光學密度應低於0.15。

四・ASTM E1354與ASTM E906

前者爲圓錐量熱儀Cone Calorimeter，後者爲俄亥俄大學Calorimeter， 但尚無定出判定標準(如圖十、圖十一)。

英國測試方法

一・3M Cube Test

英國人Grayson 使用長寬高均爲3m之燃燒室(總體積爲 $27m^3$)，將電纜樣品懸放於室中一個含已知重量之酒精槽中點燃電纜，其所產生之煙經水平之光徑測試可知其煙量。此法係測試電纜成品，而不是試片。其遮煙量(Smoke obscuration) A。可由下列公式算出：

$$A_o = \frac{V}{L} \log \left(\frac{I_o}{I_t} \right)$$

V：chamber volume

L：light path length

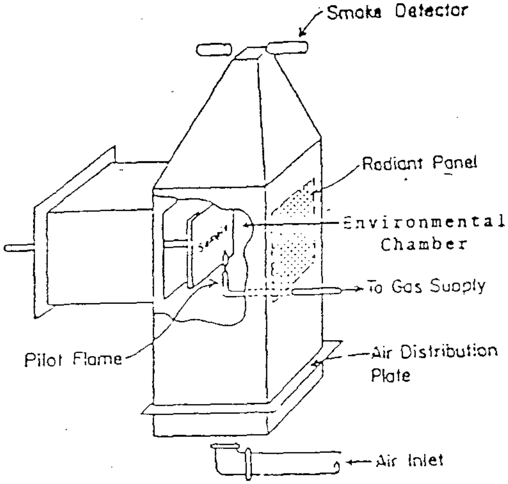
Io：initial transmittance

It：measured transmittance

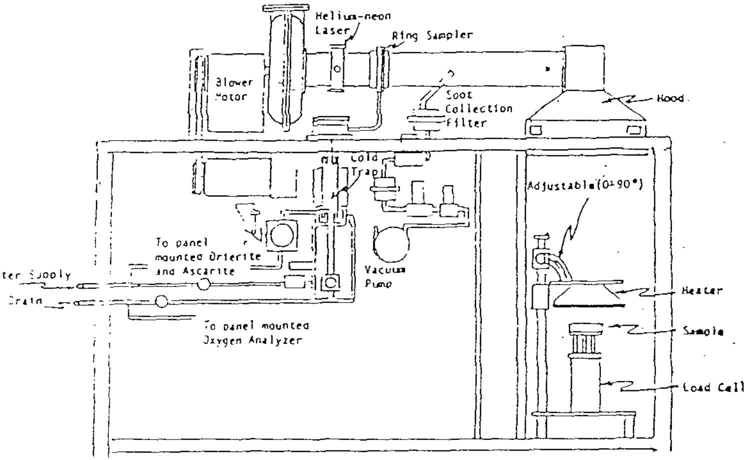
OHIO STATE HEAT AND VISIBLE SMOKE RELEASE RATE APPARATUS, ASTM E-906

DEVELOPED BY THE OHIO STATE UNIVERSITY

INTRODUCED DURING THE 1975 IWC'S TO THE WIRE AND CABLE INDUSTRY



圖十· OSU熱釋放率測試儀



圖十一． NBS CONE CALORIMETER

二·BS 6724 Test

與3M立方測試相同。

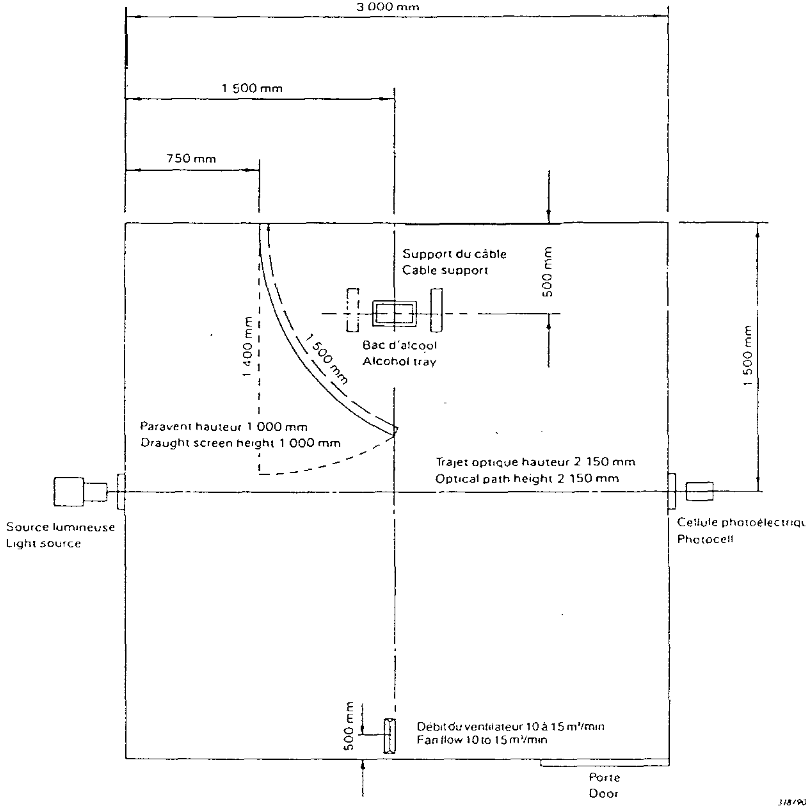
日本測試方法

將IEEE 383設備加裝JIS D1201 測煙筒裝置來測發煙係數。

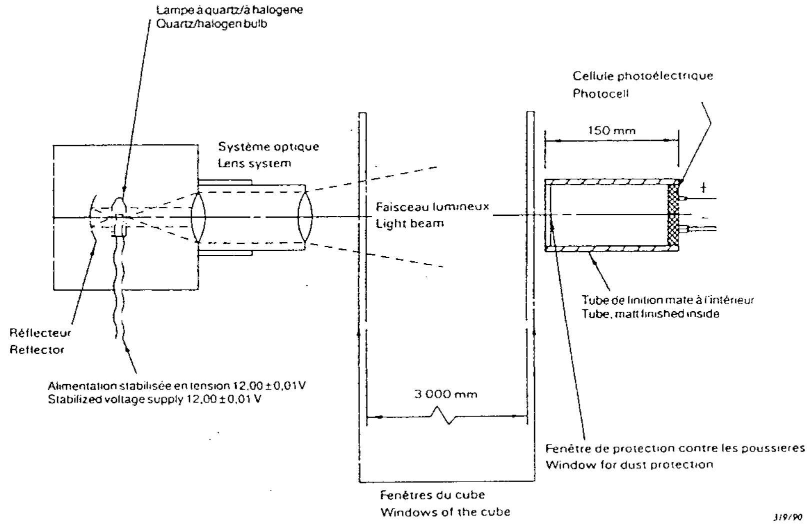
歐體測試方法

IEC 1034-1,1034-2 Test

與3M Cale Test相同(如圖十二－1、十二－2)。



圖十二－1· 3M立方測試設備上視圖



La source lumineuse et la cellule photo-électrique ne doivent pas être solidaires des parois du cube.

The light source and the photocell must be physically isolated from the walls of the cube.

Le diamètre du cône lumineux sur la surface opposée à la source est de 1,50 m environ

The diameter of the cone of light on the opposite face from the source is approximately 1,5 m

圖十二－2・ 3M立方測煙設計圖

電纜燃燒毒性

美國測試方法

一・University of Pittsburgh Toxicity Test ASTM E-5, 21,12 Task Group 評估，係以老鼠做動物實驗。

二・NIST Radiant Furnace Test ASTM E-5,21,5 Task Group評估，亦以老鼠作測試。(如圖十三)

三・NES 713 (British Naval Engineering standard) 使用英國海軍工程標準，係光學方法，將在英國部份介紹。(如圖十四)

英國測試方法

NES 713 (British Naval Engineering Standard)

任何用途電纜其毒性指數(Toxicity Index)低應於5

$$\text{Toxicity Index} = \left[\frac{C_{\theta 1}}{C_{f1}} + \frac{C_{\theta 2}}{C_{f2}} + \frac{C_{\theta 3}}{C_{f3}} + \ldots \frac{C_{\theta n}}{C_{fn}}\right]$$

$$C_{\theta} = \frac{C \times 100 \times V}{m} \text{ ppm}$$

C = Concentration of gas in test chamber(ppm).

m = Fire test mass (gram).

V = Volume of test chamber (m^3).

C_f = Concentration of the gas considered fatal to man for a 30 minute exposure time (ppm) as below.

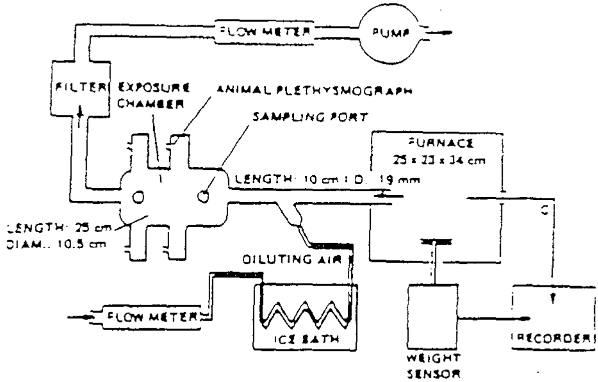
Toxicity Concentration	PPM
Carbon dioxide	100,000

Carbon monoxide	4,000
Hydrogen sulphide	750
Ammonia	750
Formaldehyde	500
Hydrogen chloride	500
Acrylonitrile	400
Sulphur dioxide	400
Nitrogen oxides	250
Phenol	250
Hydrogen cyanide	150
Hydrogen bromide	150
Hydrogen fluoride	100
Phosgene	25

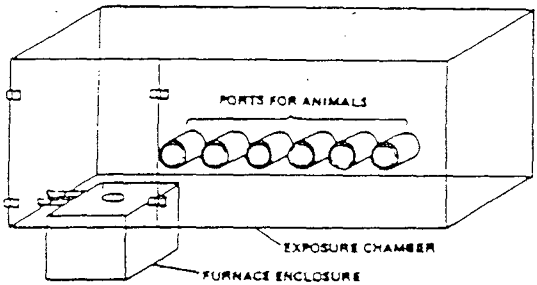
APPARATUS OF U OF PITTSBURGH, NBS, DIN 53436

SFPE Handbook of Fire Protection Engineering, Toxicity Assessment,
David A. Purser

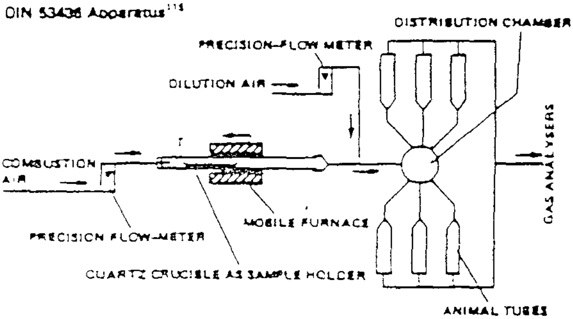
University of Pittsburgh Apparatus



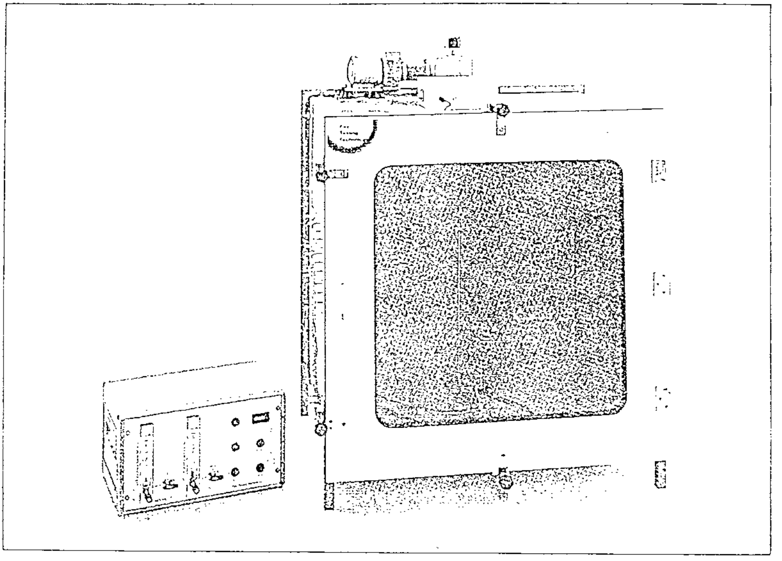
National Bureau of Standards (NBS) Apparatus[7]



DIN 53436 Apparatus[115]



圖十三· U.PITT,NBS,DIN 53436煙毒測試圖



圖十四· NES 713 U.K. NAVAL ENGINEERING STANDARD

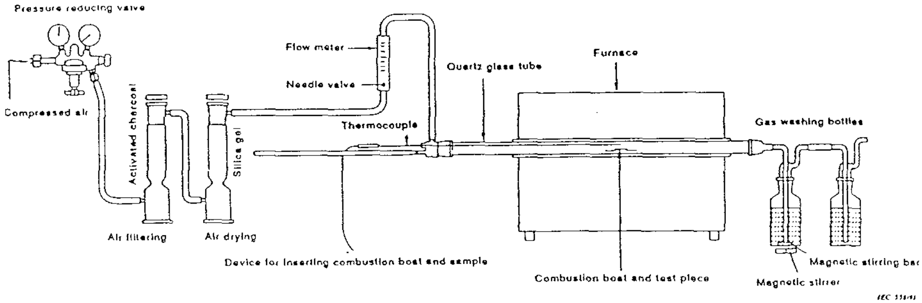
電纜含鹵量及腐蝕性

一・IEC 754-1 Test

測試電纜燃燒氣體是否含有鹵素，其濃度上限之標準，可自行訂定，一般爲 1%以下，燃溫應控制在 750℃，如溫度過高則HCl 將逸出而測不準。

二・IEC 754-2 Test

測試電纜燃氣之酸度及導電性，此兩項測試爲低煙低毒電纜所必須通過之測試標準(如圖十五)。



Test apparatus for pH and conductivity of fire gases, IEC 754-2: Use of Compressed Air

圖十五．　電纜燃氣酸度及導電性測試圖

參・研究發現

由研究內容中可看出IEEE 383標準爲屋內一般性用途之電纜防火性測試方法，廣爲世界各國所接受。因此本研究案採購此項設備並進行一連串測試，以瞭解其詳情。另外IEC 331 標準爲緊急消防用途電纜防火性測試方法，亦採購乙套進行測試研究，茲將兩種規範之研究狀況報告如后：

一・IEEE 383測試方法：

IEEE 383(Institute of Electrical and Electronics Engineers)是美國電機電子工程學院所發展出的一種垂直開放式電纜匣盤防火測試規範，簡稱VOT(Vertical Open Tray)。其方法是以長26cm之銅質多排細孔帶狀氣體燃燒器，以定量混合之丙烷與空氣點火，產生規定長度之火焰，其溫度爲1500°F (815℃) 以明火方式燃燒架在不鏽鋼梯上之電纜20分鐘，觀察電纜外層燃燒及延燒情形。

美國保險業聯合實驗室(Underwriters Laboratories Inc.)亦提出 UL 1581規範，其原理均相同而其測試條件與IEEE 383大致相同，如燃燒器、不鏽鋼梯樣品架、燃燒室、燃燒時間以及判定結果"火焰不得燒至頂端"均相同，相異處如下：

	IEEE 383	UL 1581
1.燃燒器高度 (離地面)	2 ft	1.5 ft
2.空氣條件	manometer 1.7±0.2(H_2O)	flowmeter 163±10 SCFH
3.丙烷條件	manometer -1.0±0.1(H_2O)	flowmeter 28±1 SCFH
4.燃溫條件	1500°F(815℃)	2500btu/ft^3(93Mj/m^3)

因爲有以上四項不同之規定，因此這兩個非常近似之規範目前尚不能賦予等號，雖然絕大部份測試如能通過其中之一規範，必能通過另一規範，而不合格者亦同，一般還是擇一測試。

陸續蒐集測試國內外電線電纜共12種，將測試結果整理如下表一：

樣品編號	氧指數(%)	外徑(mm)	炭化長度(cm)	最大火焰高度(cm)	判定
TS-1 絕緣 PE 被覆 PVC	18 28	3.5	頂部	頂部	不合格
TS-2 絕緣 PE* 被覆 PVC	29 30	3.5	162	175	合格
TS-3 絕緣 PE* 被覆 EVA	30 32	6.5	84	115	合格
TS-4 絕緣 PE 被覆 PVC	18 29	10.2	頂部	頂部	不合格
TS-5 絕緣 PVC 被覆 PE*	29 30	10.2	81	125	合格
TS-6 絕緣 EVA 被覆 PE*	32 33	11.8	63	78	合格
TS-7 絕緣 EVA 被覆 PE	35 19	9.0	頂部	頂部	不合格
TS-8 絕緣 PVC 被覆 PE	29 18	12.3	頂部	頂部	不合格
TS-9 絕緣 PVC 被覆 PE*	30 30	11.8	55	65	合格
TS-10 絕緣 EVA 被覆 PVC	35 30	12.3	75	95	合格

註：* 爲改質材料

TS-11 至TS-20 爲防火塗料處理，A,B爲國外塗料，C,D,E 爲本國塗料。

樣品編號	塗料種類	塗料厚度 (mm)	炭化長度 (cm)	最大火焰高度 (cm)	判定
TS-11 被覆PVC	A	1.5	頂部	頂 部	不合格
TS-12 被覆PVC	A	2.0	150	175	合格
TS-13 被覆PVC	B	1.6	170	190	合格
TS-14 被覆PVC	B	2.1	145	175	合格
TS-15 被覆PVC	C	1.6	頂部	頂 部	不合格
TS-16 被覆PVC	C	2.0	160	185	合格
TS-17 被覆PVC	D	1.2	130	150	合格
TS-18 被覆PVC	D	1.4	120	135	合格
TS-19 被覆PVC	E	1.0	頂部	頂部	不合格
TS-20 被覆PVC	E	0.8	頂部	頂部	不合格

討論事項：

1. 由TS-1 至TS-10之氧指數數據上可看出絕緣PE材質在20以下，外被覆PVC 材質在30以下均不能通過測試。
2. 耐火效果與電纜材質有關與電纜徑粗無關。
3. 改質之PE及EVA(Ethylene Vinyl Acetate) 或其他耐燃性材料爲防火合格電纜必要條件。
4. 本批測試因無法取得較多電纜樣品，在量化條件上不佳。
5. 防火塗料可以使不合格電纜通過防火測試，但塗敷厚度必須足夠，且需均勻，否則容易失敗。另外防火塗料處理之電纜不能彎折扭動，整體而言仍以改質電纜爲較佳辦法。
6. 最大火焰高度均比炭化長度要高，各國法規主要以炭化長度爲判定標準，如加拿大法規CSA FT-4規定炭化長度超過 1.5m 就失敗，其他國家亦有不同地區使用不同判定標準。
7. 在樣品梯架後應架設熱電偶T/C 使測試較爲客觀可靠。
8. IEEE 383與UL 1581之燃燒室在架設電纜及操作時較方便，但以實際情況而言，IEC 332-3 之燃燒室較爲合理，UL研究人員則認爲兩種燃燒室在實驗結果上應無顯著差異。
9. 防火塗料現階段均以發泡性爲佳。
10. 火焰高度約爲 1.5呎，其溫度應在 815℃±30℃，如外在風速超過 4或 5級時不宜操作。

二・IEC 331 測試方法：

ＩＥＣ　３３１(International Electrotechnical Commission)其標準爲750℃ 以上之明火，耐熱３小時。中國國家標準CNS 11359"聚乙烯(交連聚乙烯)、絕緣聚氯乙烯(聚乙烯)被覆耐火電纜" 也是採用此種標準，其耐火測試方法簡述如下：

將測試之電纜截取1200mm，兩端各去除100mm 之被覆體及包紮帶或填充物，將電纜之一端加以適當之處理，以便與電源連接，另一端則將各絕緣心線分開，避免相互接觸。用適當夾具將試料兩端之被覆體固定，並使其保持水平狀，中間部份則用兩只金屬環加以支撐，兩環相距 300mm，金屬環及其他金屬支架部份必須接地。

試料接上一個３相星形或３個單相接頭，其容量爲3A以上之變壓器，該變壓器之各相須經過3A之熔線與電纜連接，其中性線則經過5A之熔線接地。電纜各心線在試驗時，分別連接不同相線，若心線在３心以上時，須分成３組與各相連接，相鄰之心線須連接在不同的相線。

試驗之火焰爲寬度 610mm之長管狀瓦斯火焰，將試驗溫度在距離火焰噴口處７５ｍｍ處調整爲７５０℃以上。燃燒器置於平行試料中間部份下方，其火焰噴口距離試料約７５ｍｍ，將試料接通電源，並調整至交流600V，連續燃燒３小時後熄火，觀察導電性是否有劣損。在１２小時內依上步驟通電再重覆試驗一次，量測導電性是否有劣損。

IEC 331 部份：

此種測試爲消防性緊急用電力電纜，全部爲國外產品。

電纜規格	IEC 331 規範
1. 6.6KV FT-8-C XLPE 1/C 100 SQ	合　格
2. 600V FT-8-C XLPE 1/C 5.5 SQ	合　格
3. 600V 3C×1.5 mm2	合　格
4. 600v 3c×16 mm2	合　格

討論事項：

1. 此類緊急設備電纜，主要用於室外、室內消防栓馬達電源、灑水頭(sprinkler) 設備、二氧化碳及海龍滅火系統、緊急電鈴、廣播設備、排煙設備、逃生方向指示燈等使用。
2. 此類電纜大體以FR-PVC或FR-PE 爲被覆材，XLPE爲絕緣材，另以雲母(Mica)爲主體之耐火絕緣層包覆，如無雲母包覆則無法通過 750℃±50℃ 3小時嚴苛之測試。
3. 我國國家標準CNS 11359 與IEC 331 規範完全相同。
4. 英國國家標準BS 6387 Category B與IEC 331 相同，但Category A爲 650℃、 3小時，Category C爲 950℃、3小時。 5. 日本消防廳告示第七號使用密閉燃燒爐840℃、30分鐘，有部份業者認爲條件較 IEC 331 嚴格，但美、加及歐體均不用此規範。
6. 本測試在 3小時內均須通 600V 電壓，因此工作時一定要確實禁示外人進入測試區域。

肆・電纜產品耐燃性質探討

一・交連PE電力電纜

電纜絕緣材料中，以PE爲最佳，但PE屬熱可塑性物質，當線路電流過載或短路時，導體發熱，PE絕緣體即受熱軟化而使導體位置偏移，電纜絕緣破壞，此乃PE用於絕緣材料之唯一缺點。近年來於PE材料中加入有機過氧化物，經加熱起化學反應，分子結構互相交連（分子間產生架橋）即產生所謂交連PE（ CROSS-LINK POLYETHYLENE ）簡稱XLPE。

1.交連PE電力電纜之特點

此種電纜以LDPE爲絕緣基材，加過氧化物架橋反應促進劑使其成爲立體網目狀之構造，將PE耐熱性之缺點作大幅之改善。在橡膠、塑膠…等電力電纜中，佔最大之使用比例。

2.交連PE電力電纜之用途

CV電纜使用之電壓範圍應用很廣，從600V～500,000V。特高壓110,000V級以上，以前使用 O.F.充油電纜，目前已有漸被交連PE電纜所取代之趨勢。

交連PE電纜使用於高低壓輸配電系統，無論架空直埋或地下管道皆可適用，交連PE電纜主要有下列數種：

①輸配電用電力電纜
②架空電纜
③地下電纜
④控制電纜
⑤低壓電纜
⑥高壓引下線
⑦海底電纜
⑧礦場用電力電纜
⑨中性遮蔽電纜

3.交連PE電纜之性能

①電氣的特性佳

絕緣耐力，體積固有電阻抵抗高，誘電正接及誘電率非常小。

②電流容量大

連續最高容許溫度90℃，適合大的送電容量及大的短路電流。

③物理及機械特性佳

耐衝擊性、耐磨耗性、耐熱劣化及耐低溫之特性。

④重量輕，施工及佈設容易

⑤適合落差大的場所，紙絕緣充油電纜因絕緣油洩漏，造成絕緣劣化，鉛被破裂及終端會因油滲出易發生火災…等事故，使用上較不安全。

⑥CV電纜屬於乾式之電纜，無需油槽設置，亦不需油量、油壓監視系統。

⑦無可燃性油，防災性較好。

4.交連PE電力電纜的種類

使用電壓	蕊線數	電纜略號	構　　造	主　要　用　途
600V 3300V 6600V 11000V 15000V 22000V 33000v 66000V 77000V 110000V 154000V 187000V 275000V 500000V	單 蕊 2 蕊 3 蕊	CV，CE	PVC 被覆，PE被覆	一般用、移動用
		CVT	PVC 被覆，單蕊電纜 3蕊組合	一般用
		CVM	鍍鋅鋼線自持型電纜	架空用
		CLZV	被鉛電纜	特殊環境用
		CVTXZV	波形鋼帶鎧裝電纜	直接埋設用
		CVTXZV	鋼帶鎧裝電纜	直接埋設用
		WCVWA	無被型鐵線鎧裝電纜	水底用
		MCVMA(ZV	PVC 被覆鐵線鎧裝電纜	礦坑用
		CAZV	PVC 被覆鋁被鎧裝	超高壓用
		CSZV	PVC 被覆，不鏽鋼鎧裝	超高壓用

· 低煙無鹵素電纜(LSOH、LSNH、LSFH)

一般含鹵素的材料由於耐油性、耐燃性、耐磨性、耐化學藥品、耐腐蝕…等諸多優點，所以使用含鹵素的塑膠：如聚氯乙烯、氟化物、鐵弗龍。橡膠：如烏坡林、海巴龍等材料，做耐燃電線電纜的絕緣或被覆，這些材料阻燃性很好，然而一旦發生火災，這些材料燃燒後所釋放出來的濃煙及腐蝕性的氣體會阻擋視覺，影響逃生及救災的工作，因此在有大量人群出入的地下鐵、隧道、車站、百貨公司、醫院…等，或是逃生不易的船艦、車廂特殊場合，必須使用非鹵素的材料來製造電線、電纜。

1.LSNH電纜之要求與特性

LSNH電纜與普通電纜之電氣特性要求相同，但在其他特性的要求方面較嚴苛，關於試驗方法，可分為材料及電纜成品的試驗。

①氧指數(Oxygen Index)試驗

依據ASTM D2863

所謂「氧指數」之定義，就是在氧和氮所調整的混合氣中，可以維持材料燃燒時，所需要的氧限界濃度。

②腐蝕氣及鹵素含量試驗

此兩項測試方法，分別以自電纜取下材料燃燒，將釋放出來的氣體以酸鹼值(PH)和導電度 (Conductivity)表示，含鹵素的材料如酸鹼值低，導電度高，則表示此材料含有氟、氯等之聚合物。

鹵素含量之測試，係將材料燃燒後，把釋放出來的鹵素酸氣溶於鹼液之後，利用沉澱滴定原理來分析鹵素酸氣的含量。

③煙濃度(Smoke Emissin) 試驗

依據美國ASTM E662 之規定，將材料放置於密閉燃燒室中燃燒20分鐘後之結果，以光線路徑長度、試樣之表面積、燃燒室之體積及透光率計算之。LSNH材料之發煙量僅爲一般 PVC的30% 以下，且顏色極淡，無產生公害及妨礙視線之虞。

④毒性(Toxicity Index)試驗

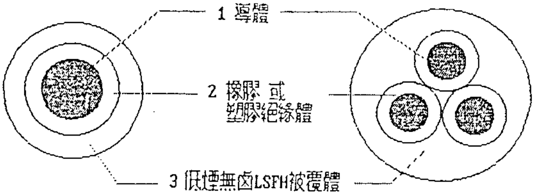
毒氣指數是指在特定的條件下，材料在空氣中完全燃燒之後，所產生的氣體內所含毒氣因子 (Toxicity Factor) 的總和。毒性和量有關，較客觀的方法是化學分析法加上動物實驗，LSNH材料不含鹵素，所以可以說是一種低毒性的材料。

⑤電纜的耐燃試驗(Flame Retardant)

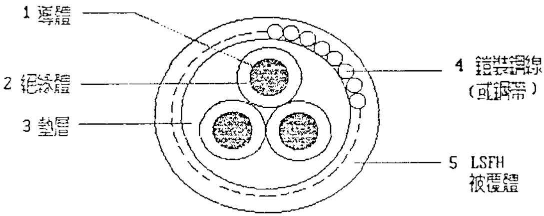
耐燃試驗是測試火源沿著電纜垂直或水平方向延燒的長度，火焰在垂直的方向延燒速度最快，因此一般垂直耐燃比水平耐燃更嚴格，垂直耐燃又分爲單一電纜耐燃試驗(依據IEC 332 PART 1)多條電纜耐燃試驗(依據IEEE 383或IEC 332 PART 3)。

2.低煙無鹵素電纜之構造(如圖十六－1、十六－2、十六－3、十六－4)

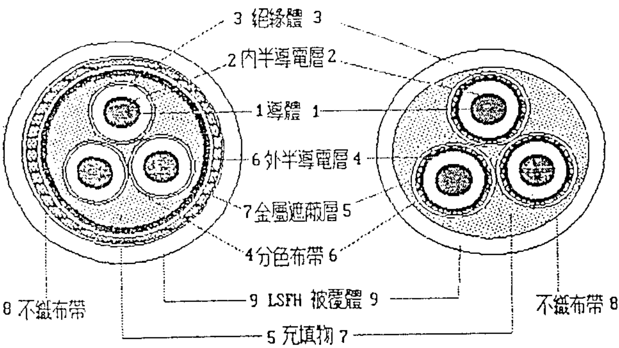
導　體：電氣用軟銅線
絕　緣：交連PE或EP橡膠
填充物：LSNH材料
綑紮帶：玻璃絲編織帶或NHFR帶
被　覆：LSNH材料



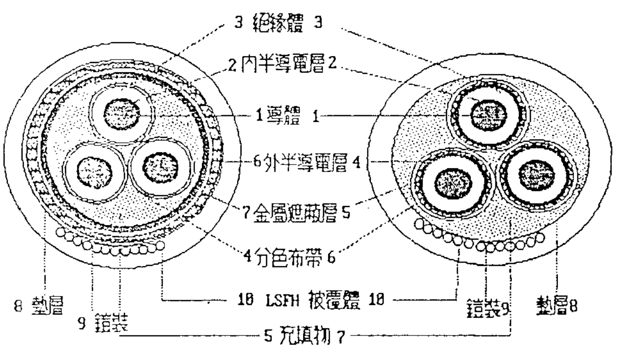
圖十六－1． 低壓電纜（無鎧裝）



圖十六－2． 低壓電纜（鎧裝）



圖十六－3． 高壓電纜（無鎧裝）



圖十六－4． 高壓電纜（鎧裝）

3.低煙無鹵素電纜之應用

LSNH電纜應用於安全性高的特殊場合(如工商大樓、百貨公司、醫院、劇院、高樓大廈、航站大廈、地下鐵車站、船艦、鑽油平台、隧道…等)，因 LSNH電纜其安全性高，發生火災時，不延燒火焰，發煙量低，且沒有腐蝕性酸氣，所以適用的範圍非常的廣泛。

三・耐火(Fire Resistant) 耐熱(Heat Resistant) 電纜

在現代生活中，如何能確保在發生火災時，電纜不受火苗之影響，在火災發生當時及火災解除之後發揮正常供電及保持線路系統之功能。

消防用緊急設備的電氣配線，如在火災中消防設備所用之緊急電源(屋內、外消防栓馬達電源、噴木消防設備、二氧化碳消防設備、自動火災警報系統、緊急警鈴、自動警笛、廣播設備、感應燈、排煙設備、緊急電源插座、無線通信補助設備…) 在一定時間內需保持供電之性能，以維持設備之正常運作。

耐火電纜因有特殊的耐火構造，可通過下列之耐火試驗：

1.日本「消防廳告示第 7號」

此規定低壓(600V)和高壓(3,300V、6,600V)二種構造，需經過「耐火、耐熱電線認定業務委員會」的認定，並通過消防廳建設省的耐火電纜試驗。

此試驗爲模擬火災發生時，電纜受熱情形。試驗溫度由自動控制設備調整昇溫至 840℃，試驗電壓爲600V之交流電壓，試驗時間30分鐘，在此時間內，電纜不得發生短路、斷路的情形，試驗終了時，另須測試交流耐壓 1500V持續 1分鐘，亦不得有耐壓不良之現象，以證明電纜仍具良好的絕緣特性。

耐火電線的性能和構造

<table>
<tr><td></td><td colspan="2">低　　壓</td><td>高　　壓</td></tr>
<tr><td>用　途</td><td colspan="2">設備電源用</td><td>緊急用電源幹線</td></tr>
<tr><td>電　壓</td><td colspan="2">600 V</td><td>3,300V、6,600V</td></tr>
<tr><td>性能概要</td><td colspan="3">840℃×30分鐘保持正常的通電</td></tr>
<tr><td rowspan="3">蕊線數</td><td>導體規格</td><td>蕊　線　數</td><td rowspan="3">1 ～ 3 蕊
14 mm² 以上</td></tr>
<tr><td>1.0～2.6mm
0.9～8 mm²</td><td>1 ～ 30</td></tr>
<tr><td>14 mm² 以上</td><td>1 ～ 7</td></tr>
<tr><td>導　體</td><td colspan="3">電氣用軟銅線</td></tr>
<tr><td>耐火層</td><td colspan="3">以雲母(Mica)爲主體的無機絕緣物</td></tr>
<tr><td>絕緣體</td><td colspan="2">PE</td><td>XLPE</td></tr>
<tr><td>被　覆</td><td colspan="3">PVC 或 FR-PVC 或耐燃 PE</td></tr>
</table>

2.IEC 331：

此試驗係將溫度調昇至 750℃後持續燃燒電纜 3小時，其間以額定之電壓加以試驗，停止燃燒後，在12小時之內再施以額定電壓加以試驗，在試驗期間，電纜均不得有短路或斷路之情形，以證明電纜仍具有正常功能。

耐熱電纜使用於消防緊急火災警報、感應、通信及控制信號傳輸等弱電回路。此試驗之規格依日本消防廳告示第 4號，參照耐熱電線技術基準第 249號。其試驗設備與耐火電纜相同，此試驗係將溫度調昇至 380℃後持續燃燒電纜15分鐘，其間以 250V 之交流電壓施加試驗，電纜不得有短路、斷路之耐壓不良情形。

耐熱電線的性能和構造

用途		低壓弱電流，通信用
性能	耐熱性	常溫昇至 380℃持續燃燒15分鐘，保持正常通電
	導體	0.65 ～ 2.0 mm 軟銅線 0.9 ～ 3.5 mm2 軟銅絞線
	耐熱層	Polyimide 樹脂帶 玻璃絲纖維系帶
構造	絕緣體	PE、XLPE、PVC
	被覆	PVC
	蕊線數	同心絞合： 2 ～ 20 蕊 對型絞合： 1 ～ 200 對

四・耐燃電纜

1.電纜的難燃化

近年來，電力及通信的諸項設備都已傾向大型化及精密化，隨著這樣的變化，連接在這些設備上的電線及電纜，其架設狀態也進展至多量化及複雜化的情形。這些電線及電纜一遇到火災時，其填充及被覆物就會助長延燒，並擴大災害之虞，其實這種實例在過去國內、外都發生過。

因爲這樣的原因，電線、電纜線路的防火對策開始進行檢討研究。1974年美國的IEEE組織就主要以核子發電廠所使用電線、電纜做爲研究對象，而公開發表及予規格化。核子發電廠 IE級(電力用、控制用、裝設測計器用) ，電纜及接續材料的定型試驗標準 STD-383。在1978年，日本電線工業會也把電纜的耐延燒性試驗方法JCS 第 366號也做了規格化。

另外，電氣協會在1978年也因爲電線、電纜的難燃性之相關問題也在該年成立了「電線、電纜難燃性調查專門委員會」，並就電線、電纜的難燃性實驗方法的技術報告，做了明細的整理編彙。現在我們僅就以電纜的難燃化作爲研討對象，並就其防災對策之一的難燃化問題做一敘述。

2.燃燒和難燃化

①塑膠(PLASTIC) 的燃燒

有機化合物的燃燒會產生OH及H 。而多數的塑膠燃燒結構，也與這樣的反應類似。可是像塑膠這樣的固體在做燃燒時，其化學性變化，以及同時進行的物理性變化也就是因熱所產生的形狀變化，必須被考慮。有關塑膠的燃燒是由熱產生熔融，並做熱分解後變成可燃性氣體，以便做燃燒。由下圖所顯氣體氧化反應過程也就是物質做發熱反應基礎。

材料 → 熔融 → 分解 → 氣體化 → 激變發生 → 燃燒

燃燒所經的歷程

要致使燃燒有三大要素：

a.燃料：由塑膠的熱分解形成分解氣體(gas) 形態做供給。

b.氧氣：從空氣中對反應部位做供給。

c.溫度：由反應熱做供給。

這種燃燒狀態的模式化，如下圖所示。圖中的灰分層是屬於像橡膠等那種多量無機填充材料所燃燒的東西。因此像塑膠那樣的燃燒一般是不存在的，如圖所示，三要素的循環周期被進行著。燃燒反應會往燃燒熱的分解層做溫度供給，被分解的氣體會往燃燒帶做燃料供應，而氧氣則對燃燒帶(反應部位) 做氧供應。相反地，要給塑膠付予難燃性時，只要將這循環周期中的一項阻絕，即能達到阻燃效果。

根據電線及電纜的使用狀況，要把氧氣的供應切斷，是很困難的。因此通常都是將燐及鹵 (HALOGEN)等難燃劑添加在塑膠上，以達到抑制燃燒反應的效果。可是有機燃料燃燒時，可能會因爲其物質所處的環境關係，而使燃燒狀態變大，因此，談起電纜的難燃化程度情形，可能就會依該電纜架設條件而有所變化。

②難燃化的方法

有關電纜的難燃化方法是將鉛等的金屬或玻璃纖維等的無機材料混合在一起，使構成電纜材料而達到難燃化效果的一種方法。尤其是玻璃纖維，不但不會改變電纜的構造，而且不會影響物理特性，而達到難燃化的效果。所以，現在這種使用方法，已變爲難燃化的應用主流。

關於電纜構成材料的難燃化問題，其效果最大，並且也是難燃化主要因素，就是指電纜的被覆(sheath)材料。特別是在CV電纜時，其絕緣體的交連聚乙烯，雖然可以達到電氣特性的要求，但要達到難燃性的效果卻有困難，所以只能藉助於所要的難燃化被覆材料，來達到難燃效果。因此，對CV電纜的構造而言，要使它具有高度難燃性效果是有困難的。

3.氧指數

顯示難燃性的另一指標就是「氧指數」方法。

所謂「氧指數」方法，就是在氧量和氮量所調整混合氣體中，把塑膠要燃成火焰所需要氧的限界濃度(Vol%) 做測定，再把下述分式所測出的數值（氧指數）當做難燃性參數(PARAMETER) 的一種表示方法。
(ASTM D2863-70T、JIS K7201)

$$氧指數=\frac{〔O_2〕}{〔N_2〕+〔O_2〕}\times 100〔Vol〕$$

氧指數在21以上的材料是屬於難燃性材料
氧指數在20.9以下的是屬於可燃性材料

下表顯示了電纜材料的氧指數，依據下表所顯示的結果，交連PE列爲可難性材料，而聚氯乙烯其氧指數佔且可列入難燃性之分類。雖然在氧指數方法中，材料的相互比較是一種有效的試驗方法，但實際的應用時，可能會因爲試驗材料的形狀以及其架設方法之不同而產生各種不同的結果。

電纜材料的氧指數

材料		氧指數	
		一般用	難燃性強化物
絕緣材料	乙烯基(Vinyl) 特殊耐熱乙烯基 聚乙烯(Polyethylene) 交連聚乙烯 EP 橡膠	24 24 18 18 21	～30 ～30 ～25 ～28 ～28
被覆材料	乙烯基 耐熱乙烯基 聚乙烯 氯丁二烯橡膠	24 24 18 30	～40 ～40 ～25 ～40
填充物	黃麻(Jute) 聚丙烯(Polypropyrene 合成纖維	18	—

1.難燃材料

有機材料做難燃化的配合劑，有下列幾種(可單獨使用或併用) 。

①鹵素(Halogen) 系難燃劑。

②磷系難燃劑。

③無機系難燃劑。代表性的有三氧化二銻(Sb_2O_3)及氫氧化鋁 [$Al(OH)_3$]等。

④其他難燃劑。例如：氮系以及硼酸(氧)鋅。

雖然大量使用上述的難燃劑以及充填劑，可以提高材料的難燃性效果，但如使用過量也會降低電氣特性及材料的物理特性(如抗張、伸長、低溫特性…)以及不經濟性等問題。

伍．結論與建議

電纜規格需要求的條件相當多，目前電纜之被覆體大多爲PVC ，而絕緣體則爲PE或XLPE材質，至於導體則以銅材或光纖等材質製作，出廠規格需按採購、使用之環境及客户需求來訂定標準嚴格與否。大體上，除了一般物理及電氣性質外(抗張強度、伸展率、熱變形率、重量損失、抗油性、熱安定性等等..) ，就是與公共防火安全有密切關係之耐火特性、發煙性、毒性指數及鹵素含量等特別規格。

建築物内使用之"室内線"有供應電源之電力配線、通訊用之電信配線、各種電腦及家用電氣設備本體使用之電線以及提供緊急照明、逃生、警報、廣播、滅火、排煙所需之緊急消防纜線等四類，這些俱爲本研究案所重視之部份。

世界上關於電纜(包括安全)最重要兩大法規爲：一是美國使用之 NEC(National Electrical Code)，一是歐體使用之IEC(International Electrotechnical Commission)。其他國家雖有一些本國自訂之規定，但不若這兩大法規完整性、權威性及共同使用性。本研究案經過蒐集資料、評估、試驗後獲得些許心得，茲將結論與建議以條列方式報告如後：

⊙世界各國對電纜垂直抗燃測試之理念均與IEEE 383接近，不同之處主要是燃燒器對試樣角度及置放位置，至於燃燒器熱量、樣品長度、架設寬度等只略有不同，但判定基準則有顯著差異。其中以加拿大最爲嚴苛，IEEE 383爲次，美國、日本與歐洲各國判定標準大多與IEEE 383接近。因此，本研究案原則採用IEEE 383測試方法及判定基準。未來將試驗設備及測試步驟加以校正及檢討後，再配合電纜發煙性、毒性指數、含鹵量等重要規格，擬訂定"建築用電纜安全規格草案"提供主管官署參考。

⊙IEEE 383燃燒室樣品架設之位置與IEC 332 Part 3不同，IEC 332 Part 3較類似於眞正建築物電纜匣道之設計狀況，因此在燃燒室構造部份係採用 IEC 332 Part 3之標準。

⊙IEC 成立各種技術委員會，其中TC89分爲 8個工作組負責評估電子科技設備之安全性。其重點爲專有名詞、火災狀況及危險性評估之指南，煙霧遮蔽性及腐蝕性、耐高熱性、毒性及熱釋放性。美國ASTM亦有類似IEC 成立各種委員會，針對電纜安全進行各種測試方法及判定基準之訂定與修正。這兩大機構在技術觀點方面也儘力互相包容，相信未來在電纜安全及其他火災安全標準必能達到全球相容一致的目標。日本近來實行更新計劃，也是希望能及早適應世界潮流。

⊙UL 1685 規範是UL公司爲因應國内建築法規對電纜安全性之要求所訂定，除了原IEEE 383與UL 1581 所規定之最大炭化長度外，另添加電纜燃燒之煙釋放率及熱釋放率之規範。

⊙UL公司近年來致力以圓錐量熱儀所測試之結果來取代傳統之UL 910電纜隧道測試法。惟測試數據尚未量化，如整體報告出來後，尚須舉行各種技術研討會才能訂定新規範，如果此項計劃成功，未來電纜業者將不需要提供龐大數量之樣品供測試用，且測試費用將大幅縮減。

⊙IEC 331 緊急消防用水平式燃燒測試法與英國 BS 6387 八種測試條件中第二嚴苛條件相同，在國際間已被許多國家模仿使用。我國CNS標準11359亦採用，能對建築物中緊急所需之電源加以規範保護，是相當重要之規範；另外我國部份電纜業界受日本規範影響很深，對日本消防廳第七號之規定亦付出許多心力，此種 840℃30分鐘之測試規格(CNS 11174)， 因係使用防火門測試設備，比 IEC 331明火及開放式空間多了熱輻射及對流熱量，雖然燃燒時間較短(只有六分之一)，但對整體燃燒之嚴苛程度或許更高。因此，評估兩項標準對消防用電纜均能提供嚴密之保護，擬建議能通過兩者之一即可。

⊙從實驗室測試的經驗可以瞭解要通過IEC 331(750℃、3小時)測試，電纜樣品最重要的規格在於導體外絕緣層(通常爲雲母帶)之材質與施工技術，在長達 3小時、750℃±50℃ 加熱情況下，雲母層不能破損，熱傳也能隔絕，其外被覆層雖然腫脹隆起，最好不要剝落或斷裂。至於能通過IEC 331 規範是否一定也能通過IEEE 383，答案是不一定。總括言之IEC 331 通過之重點在內層(絕緣層)，而 IEEE 383在外層(被覆層)。

⊙防火科技中防火測試可大致分爲兩種類別：
第一類別爲耐火測試（Fire Endurance Test）用來測試判定某項材料隔絕阻止火的蔓延擴展能力如防火門、牆、窗、地板、貫穿部防火材等材料，其能力的好壞通常以防火時效（Fire Rating）長短來界定。
第二類別爲過火反應（Reaction To Fire）檢測材料之引燃性、熱釋放、火焰蔓延、煙濃度、毒性等項目，如電纜、內裝材、塗料、傢俱等，但判定的方法比較第一類複雜。未來國內如對〝安全電纜〞重視，除了防火性外，煙濃度與煙毒性等判定方法應一併考慮。

⊙隨著科技及生活品質的進步，電線電纜使用量一天天增加，而電線電纜或電氣設備引發火災的機會也相對地增加。目前已到了不得不重視的地步，從一年多的研究中，接觸到國內電纜業界，發現各大電纜公司均已默默地開發完成了防火及低煙無毒電纜的準備工作，只是目前主管官署在建築法中，未明示使用的規定。爲了低成本競爭的原因，不得不供應具有危險性的電纜，這是主管官署應該考慮及決定的時候了。

陸・參考文獻

1. IEEE 383 standard.
2. UL 1581 standard.
3. IEC 332 part 3 standard.
4. IEC 331 standard.
5. IEC 754-1 standard.
6. CNS 11359 standard.
7. CNS 11174 standard.
8. CNS 11175 standard.
9. NES 711 standard.
10. NES 713 standard.
11. S.Stueflotten. Norway "Development of a Fire Resistant Optical Cable".
12. J.R.Pederson, Standard Telefon og Kabelfabrik. Oslo, Norway "Halogenfree Cable for Ships and Offshore Oil Platforms".
13. Underwriters Laboratory Inc USA "Electrical Construction Materials".
14. Vytenis Babrauskas, NIST Technical Note 1291 "Fire Performance of Wire and Cable".
15. K.Kanemitsuya, Mitsubishi Cable Industries Review 1988 "Characteristics of Halogen-Free Flame-Restardand Wires & Cable".
16. NFPA 262 "Standard Method of Test for Fire and Smoke Characteristics of Wires & Cable".
17. Marcelo M. Hirschler "Survey of Fire Testing of Electrical Cables" Fire And Materials, Vol. 16, PP. 107-118.

18. K. Kanemitsuya, K. Furukawa etal. "Characteristics of Halogen-Free Flame-Retardant Wires & Cables" 日本昭和 63年10月，三菱電線工業時報第76號。
19. Naoyuki Wada, Shunichi Fujimura "Development of Flame Retardant Telecommunication Cable" Furukawa Review No.6
20. IEC 1034-1 Standard.
21. IEC 1034-2 Standard.
22. IEEE 1202-1991 Standard.
23. C. Zanelli, S. Philbrick and G. Bretta "Cable and Fire Hazards" NASA TM-88493.
24. B.D.Kushler, L.L.Parks, J Simpson "Smoke Detector Behavior Under Low Energy Fire Conditions".
25. ASTM D3874-90a Standard Test Method for Ignition of Materials by Hot Wire Sources.
26. 35TH International Wire and Cable Symposium. US Army Communications-Electronics Command.
27. Marcelo M. Hirschler "Fire Hazard and Toxic Potency of the Smoke from Burning Materials" 1987 Technomic Publishing Co. Inc.
28. 宏泰電工型錄。
29. 太平洋電纜型錄。
30. 華新麗華電纜型錄。
31. 泰電電業型錄。

電線電纜防火性能探討會議記錄

建築用防火材料研發及測試座談會
—電線電纜防火性能探討會議記錄

一、時間：八十三年四月二十七日（星期三）下午二時

一、地點：台北縣五股鄉五股工業區五權五路26號

震旦教育訓練中心五〇二室

三、主席：周智中組長　　　　記錄：陳俊麟

四、引言人：嚴定萍研究員（中山科學研究院防火試驗室）

五、國外專家：卓錦德博士（美國ＵＣＣ公司）

六、出席人員：大　　同公司（顏騰雄先生、王志弘先生）

大　　亞公司（李永清先生）

太平洋公司（鄧承耀先生、廖重彬先生、尤崇光先生、郭榮忠先生、張國聲先生、徐銓旺先生、李秀伶小姐）

宏　　泰公司（葉信男先生）

泰　　電公司（李勤孝先生、連宋秋先生、張哲永先生）

華新麗華公司（曾益軒先生、閻海青小姐）

臺灣永備公司（張光男先生、何漢霖先生）

華　　榮公司（廖東平先生）

台灣３Ｍ公司（劉健洋先生）

電信研究所　（徐希白博士）

工研院化工所（蔡文賢博士、李萬中博士、張國揚先生、張榮樹先生）

計卅人

七、主持人致詞：（略）

八、引言人報告（詳附件一）：

㈠電纜防火性能認定基準

㈡電纜燃燒煙濃度認定基準

㈢電纜燃燒毒性認定基準

㈣電纜燃燒腐蝕性及導電度認定基準

九、國外專家報告：

・美國電線電纜現況及全球發展趨勢（詳附件二）

十、綜合討論：

㈠電線電纜防火性能檢測認定基準

・結論：

1.一般用電纜建議區分為：建築用線、通信用線、同軸電纜、器具用線等四種。

2.建議將電纜電線品質驗證有關問題，於本年度「建築用電纜電線防火性能認定基準之開發與應用之研究」案成果報告中提出建議方案。

3.電纜燃燒後所產生餘焰時間過久，可能造成火場二次災害，是否應增加餘焰上限時間之規定，請研究單位參酌國外先進國家有關規定及檢測標準後，再行決定。

4.有關緊急用電纜除須通過IEC 331規範或日本消防廳第七號外，是否能須通過IEEE 383規範或UL 1581規範，待函請美、英、日等國相關單位提供意見後，再行決定。美國部份，請卓錦德博士協助蒐集；英國及日本部份，請建研處函請英國建築研究所（BRE）及日本建築研究所（BRI），提供檢測基準，以利參辦。

㈡電線電纜燃燒煙濃度及毒性檢測認定基準

・結論：

1.煙濃度檢測認定基準，以美國ASTM E662為參酌依據。

2.毒性指數應低於之，各種氣體分析之容許ＰＰＭ值，暫依嚴定萍研究員參考美國ASTM所定之數值辦理。

3.下(84)年度建研處進行此項研究計畫案時，應先探討國外先

進國家之檢驗標準及判定基準，並蒐集此方面之研究報告及試驗結果，以作爲我國檢測認定基準之依據。

㈢電線電纜腐蝕性及導電度檢測認定基準

・結論：

1.電線電纜腐蝕性及導電度之檢測認定基準，實有必要，建研處應列入研究範圍內，並探討其檢驗方法、判定基準及儀器設備之建立。

2.下(84)年度建研處進行此項研究計畫案時，應先探討國外先進國家之檢驗標準及判定基準，並蒐集此方面之研究報告及試驗結果，以作爲我國檢測認定基準之依據。

3.進行此項研究計畫案，應請國內廠商參與，提供相關試驗結果及有關意見，以利基準符合國人需要。

㈣低煙低毒電線電纜開發與應用計畫

・結論：

1.有關電線電纜低煙低毒研發計畫，請有意願參與研究之廠商，逕向建研處聯繫。

2.建研處得將此項研發計畫案，送電線電纜公會轉知全體會員後，再行辦理爲宜。

十一、臨時動議：（無）

十二、主持人結論：

㈠各位先進所提意見，建請計畫主持人嚴定萍先生參酌。

㈡此項座談會達到雙向溝通之目的，並獲得許多寶貴的意見及經驗，實爲不易，未來應於適當時機多多舉行此類性質座談會。

㈢由衷感謝各位先進的蒞臨參加，未來仍請隨時提供意見及有關資料，並不吝指教。

十三、散會（十七時十分）

IEEE 383

IEEE
Std 383-1974

IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

Sponsor

Nuclear Power Engineering Committee of the
IEEE Power Engineering Society

The Institute of Electrical and Electronics Engineers, Inc.

Foreword

(This foreword is not a part of IEEE Std 383-1974, IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.)

The Institute of Electrical and Electronics Engineers has generated this document to provide guidance for developing a program to type test cables, field splices, and connections and obtain specific type test data. It supplements IEEE Std 323-1974 Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations, which describes basic requirements for equipment qualification.

Each applicant to the Atomic Energy Commission for a license to operate a nuclear power generating station has the responsibility to assure himself and others that this standard, if used in whole or part, is pertinent to his application and that the integrated performance of his station is adequate.

It is the integrated performance of the structures, fluid systems, the electrical systems, the instrumentation systems of the station, and, in particular, the plant protection system, that limits the consequences of accidents. Seismic effects on installed cable systems are not within the scope of this document.

Section 2 of this guide is an example of type tests. It is the purpose of this guide to deal with cable and connections; however, at the time of issue, detailed examples of tests for connections were not available.

The performance criteria for Class IE service have been expanding in scope during the preparation of this document, and the state of the technology has been continually advancing.

This standard will be revised from time to time to incorporate the latest information available. Topics presently under consideration for future inclusion are: (1) aging correlation procedure, (2) connections, and (3) the corrosive effects from burning cables.

Comments on this document supported by data will be reviewed for later issues.

This standard was prepared by working group 12-32 of the Insulated Conductors' Committee of the IEEE Power Engineering Society. Members of this group were:

Alfred Garshick, *Chairman*

Russ Budrow
George S. Buettner
Carmen M. Chiappetta
John Conley
John T. Corbett
Edward Donegan
Irvine N. Dwyer
John Ferencik
Harry Hilberg
Alan S. Hintze
Frank E. La Fetra
T. H. Ling
Reinhold Luther
E. E. McIlveen
Cutter D. Palmer
John G. Quin
R. E. Sharp
Joseph L. Steiner
H. K. Stolt
J. R. Tuzinski
Chuck vonDamm
William G. White

At the time it approved this standard, Subcommittee 2 (Qualification) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society had the following membership:

A. J. Simmons, *Chairman* L. D. Test, *Vice Chairman*

A. Kaplan, *Secretary*

J. F. Bates
J. T. Bauer
L. J. Blasiak
J. T. Keiper
F. Campbell
W. J. Foley
J. B. Gardner
T. H. Ling
T. R. Beans
G. W. Hammond
D. J. Meraner
F. W. Chandler
H. E. McConnell
C. E. Corley
W. Dalos
E. P. Donegan
W. D. Loftus
W. H. Steigelmann
S. Carfagno
W. A. Szelistowski
F. Tranzo
D. G. Woodward
G. T. Dowd, Jr
W. J. Denkowski
R. F. Edwards
C. F. Miller
A. S. Hintze
W. G. Stiffler
B. Gregory
A. Garshick
E. E. McIlveen

Contents

SECTION	PAGE
1. General Provisions	7
1.1 Scope	7
1.2 Definitions	7
1.3 Type Tests As Qualification Method	7
1.4 Documentation	9
1.5 Modifications	10
2. Examples of Type Tests	10
2.1 Introduction	10
2.2 Type Test Samples	10
2.3 Testing to Qualify for Normal Operation	10
2.4 Testing for Operation During Design Basis Event	12
2.5 Flame Tests	12
2.6 Documentation of Type Testing	15
3. References	15
FIGURES	
Fig 1 Flame Source	13
Fig 2 Burlap Folding Sequence	14
TABLE	
Table 1 Representative Tables for Type Tests	11

IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

1. General Provisions

1.1 Scope

1.1.1 This standard provides direction for establishing type tests which may be used in qualifying Class IE electric cables, field splices, and other connections for service in nuclear power generating stations. General guidelines for qualifications are given in IEEE Std 323-1974, Standard for Qualifying Class IE Electric Equipment for Nuclear Power Generating Stations. Categories of cables covered are those used for power control and instrumentation services.

1.1.2 Though intended primarily to pertain to cable for field installation, this guide may also be used for the qualification of internal wiring of manufactured devices.

1.1.3 This guide does not cover cables for service within the reactor vessel.

1.2 Definitions[1]

cable type. A cable type for purposes of qualification testing shall be representative of those cables having the same materials, similar construction, and service rating, as manufactured by a given manufacturer.

Class IE. The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling and containment, and reactor heat removal or otherwise are essential in preventing significant release of radioactive material to the environment.

connection. A cable terminal, splice, or hostile environment boundary seal at the interface of cable and equipment.

containment. That portion of the engineered safety features designed to act as the principal barrier, after the reactor system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive material beyond a controlled zone.

design basis events. Postulated abnormal events used in the design to establish the performance requirements of the structures, systems, and components (IEEE Std 323-1974).

field splice. A permanent joining and reinsulating of conductors in the field to meet the service conditions required.

installed life. The interval from installation to removal, during which the equipment or component thereof may be subject to design service conditions and system demands (IEEE Std 323-1974).

NOTE: Equipment may have an installed life of 40 years with certain components of the equipment changed periodically; thus, the installed life of the components would be less than 40 years.

qualified life. The period of time for which satisfactory performance can be demonstrated for a specific set of service conditions. (IEEE Std 323-1974).

type tests. Tests made on one or more units to verify adequacy of design (IEEE Std 380-1972).

1.3 Type Tests As Qualification Method. As described in IEEE Std 323-1974, type tests are the preferred method to demonstrate or assist in demonstrating that electric equipment is capable of meeting performance requirements under service conditions which include normal and design basis event environments. To perform type tests for cable, field splices, and connections requires: (1) description (identification) of cable, (2) description of significant aspects of the environment, and (3) description of cable performance required. These,

[1] Other definitions related to this document may be found in IEEE Std 100-1972 (ANSI C42 100-1972), Dictionary of Electrical and Electronics Terms, IEEE Std 323-1974, and IEEE Std 380-1972, Definitions of Terms Used in IEEE Nuclear Power Generating Stations Standards

then, with engineering knowledge and experience in insulating materials and systems form a basis for designing type tests to demonstrate the capabilities. Qualification of one cable may permit extrapolation of results to qualify other cables of the same type, with consideration being given to cable dimensions and probable modes of failure.

A sample field splice or connection or both must be type tested with the cable to demonstrate its electrical, mechanical, and chemical compatibility in the environments.

1.3.1 *Cable Description.* This description or specification should include as a minimum:

1.3.1.1 Conductor — material identification, size, stranding, coating.

1.3.1.2 Insulation — material identification, thickness, method of application.

1.3.1.3 Assembly (multiconductor cables only) — number and arrangement of conductors, fillers, binders.

1.3.1.4 Shielding — tapes, extrusions, braids, or others.

1.3.1.5 Covering — jacket or metallic armor or both, material identification, thickness, method of application.

1.3.1.6 Characteristics — voltage and temperature rating (normal and emergency). For instrumentation cables — capacitance, attenuation, characteristic impedance, microphonics, insulation resistance, as applicable.

1.3.1.7 Identification — manufacturer's trade name, catalog number.

1.3.2 *Field Splice or Connection Description or Both.* This description or specification should include as a minimum:

1.3.2.1 Whether factory or field assembled to cable.

1.3.2.2 Conductor connection — type, material identification, and method of assembly.

1.3.2.3 Items from Sections 1.3.1.2 through 1.3.1.7.

1.3.3 *Description of Significant Environmental Conditions.* Both normal operating and design basis event conditions, as well as their sequence and duration, are relevant for type testing. Separate requirements for post design basis event conditions may be required in recognition of momentary or accumulative changes in material properties due to aging, radiation, heat, and steam exposure. Environmental factors, the limits of which may be significant to the cable's operation are as follows:

1.3.3.1 *Atmosphere.* Maximum and average ambient or normal operation condition and design basis event condition or profile for the following:

(1) Gas composition and velocity
(2) Moisture content
(3) Temperature
(4) Pressure

1.3.3.2 *Radiation.*

(1) Normal dose rate and type
(2) Total normal installed life dosage
(3) Design basis event dose rate. Maximum dose rate and approximate profile
(4) Total design basis event dosage
(5) Total for the installed life plus design basis event

1.3.3.3 *Chemicals*

(1) Type of chemicals and concentration
(2) Spray or immersion rate and time
(3) Temperature of exposure

1.3.3.4 *Mechanical.* Normal operating condition and design basis event condition for the following:

(1) Bending or flexing
(2) Vibration
(3) Tension
(4) Sidewall pressure

1.3.3.5 *Fire*

1.3.4 *Operating Requirements*

1.3.4.1 *Meeting Service Conditions.* The cable, as installed, should be suitable for operation at maximum ambient temperature, radiation, and atmospheric conditions and normal electrical and physical stresses for its installed life, as specified. Evidence of this suitability may be based on compliance with appropriate published industry standards, past documented operating experience, component tests, or a combination of these.

The total station may be subdivided into zones with substantially different ambient conditions, and if segregation of cables to certain areas is assured, a cable need only be suitable for meeting service conditions in those zones in which it is located.

1.3.4.2 *Design Basis Event Conditions for Qualifying Cables*

1.3.4.2.1 *Design Basis Event — Loss-of-Coolant Accident (LOCA) (for cables in containment only).* The cable, field splices, and connections should throughout their normal lives be capable of operating through postulated environmental conditions resulting from a LOCA. Conditions of loading and signal levels shall be assumed to be those most unfavorable for cable operation which may be anticipated under such circumstances.

1.3.4.2.2 *Design Basis Event — Fire.* The cable should not propagate fire under conditions of installation.

1.3.4.2.3 *Other Design Basis Events.* These should also be considered in case they represent different types or more severe hazards to cable operation.

1.3.5 *Type Test Conditions and Sequences*

1.3.5.1 *General.* Type tests are used primarily to indicate that the cables, field splices, and connections can perform under the conditions of a design basis event. Because the design basis events may occur at any time in the station life, the thermal and radiation aging required in type tests to simulate these conditions may at the same time indicate the ability of cable types to operate under the normal service conditions within the station.

1.3.5.2 *Aging.* The effect of normal operating conditions with time may either add to or reduce the ability of cable, field splices, and connections to withstand the extreme environments and loads imposed during and following a design basis event. Thus, the type testing for design basis event conditions shall involve both aged and nonaged samples. *Aging* pertains to temperature, radiation, and atmospheric effects applied in sequence or simultaneously in an accelerated manner.

The basis for establishing time and temperature conditions for aging of samples to simulate their qualified life may be that of Arrhenius plotting (IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment, IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of, Temperature Indices of Solid Electrical Insulating Materials, IEEE Std 99-1970, Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment, and IEEE Std 101-1972, Guide for Statistical Analysis of Thermal Life Test Data) or other method of proven validity and applicability for the materials in question.

1.3.5.3 *Test Design Basis Event.* Type tests for design basis event conditions should consist of subjecting nonaged and aged cables, field splices, and connections to a sequence of environmental extremes which simulate the most severe postulated conditions of a design basis event and specified conditions of installation. Type tests shall demonstrate margin by application of multiple transients, increased level, or other justifiable means. Satisfactory performance of the cable will be evaluated by electrical and physical measurements appropriate to the type of cable during or following the environmental cycle or both.

The values of pressure, temperature, radiation, chemical concentrations, humidity, and time in Section 2 do not represent acceptable limitations for all nuclear power stations. The user of this guide should assure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable or connections will be installed.

1.4 Documentation

1.4.1 *General.* Type test data used to demonstrate the qualification of cables should be organized in an auditable form. The documentation should include:

1.4.1.1 Description or specification of cable.

1.4.1.2 Description or specification of field splice or connection.

1.4.1.3 Identification of the specific environmental features.

1.4.1.4 Identification of the specific performance requirements to be demonstrated.

1.4.1.5 The test program outline.

1.4.1.6 The test results.

1.4.1.7 Approving signature and date.

1.4.2 *Test Program Outline.* For cable and connections, this outline shall include:

1.4.2.1 The physical arrangement of the cable and test equipment description.

1.4.2.2 Time program and sequence of all environmental factors.

1.4.2.3 The type and location of all environmental and cable monitoring sensors for each variable.

1.4.2.4 The voltages or currents programmed in conjunction with Section 1.4.2.1 above.

1.4.2.5 The electrical, thermal, or mechanical tests to be performed during environmental exposure.

1.4.2.6 Testing or examinations subsequent to environmental cycle.

1.4.3 *Test Results.* Test results should demonstrate that:

1.4.3.1 The intended environmental sequences were achieved.

1.4.3.2 The cable or field splice (or connection) or both was capable of performing its intended function.

1.4.4 *Test Evaluation.* An evaluation of data should be made to demonstrate the adequacy of cable performance as outlined in Section 1.4.1.4.

1.5 Modifications. When modification in the materials or design of cables or in the conditions of installation or in the postulated environments are made, prior type tests shall be reviewed to determine the effect on the cable qualification. This evaluation shall indicate whether or not new type tests are required. The analysis of data and evaluation that demonstrates the effect of the modification on the equipment performance shall be added to the qualification documentation.

2. Examples of Type Tests

2.1 Introduction. Type tests described in this document are examples of methods which may be used to qualify electrical cables, field splices and connections for use in nuclear power generating stations. Tests of the cable or connection assembly, as applicable, should then supplement the cable tests in order to qualify the connections and other aspects unique to planned usage.

The values of pressure, temperature, radiation, chemical concentrations, humidity, and time used do not represent acceptable limits for all nuclear power generating stations. The user of this guide should assure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable or connections, or both will be installed.

Results of prior tests that are being used as the bases for the present tests should be referenced in the documentation.

2.2 Type Test Samples. The samples tested should contain the conductor, insulation, fillers, jacket, binder tape, overall jacket, shielding, and field splices which are representative of the cable category being qualified. Table 1 lists sizes which have been considered representative of these categories. The sample lengths should be sufficient to permit reliable test readings and evaluation consistent with good testing practice.

2.3 Testing to Qualify for Normal Operation

2.3.1 *Temperature and Moisture Resistance.* Evidence of qualification for normal operation may be demonstrated by providing certified evidence that the cable has been manufactured and tested and passed in accordance with the provisions of one or more of the following industry standards or criteria.

ANSI C83.21-1972 Requirements for Solid Dielectric Transmission Lines

ANSI C96.1-1964 (R1969) Temperature Measurement Thermocouples

ANSI C1-1971 National Electrical Code, NFPA 70-1971, Sections on Types RHH, RHW, and XHHW[2]

IPCEA S-19-81 Rubber-Insulated Cable

IPCEA S-66-524 Cross-Linked-Polyethylene-Insulated Cable

IPCEA S-68-516 Interim Standards for Ethylene-Propylene-Rubber-Insulated Wire and Cable, Number 1, Cables Rated 0-35 000 V, Number 2, Cables Rated 2000 V, Integral Insulation and Jacket.

AEIC 5-71 Specifications for Polyethylene and Cross-Linked-Polyethylene-Insulated, Shielded Power Cables rated 5000 – 35 000 V

AEIC 6-73 Specifications for Ethylene-Propylene-Rubber-Insulated Shielded Power Cables Rated 5 – 46 kV

2.3.2 *Long-Term Physical Aging Properties.* Aging data should be submitted to establish long-term performance of the insulation. Data may be evaluated using the Arrhenius technique. A minimum of 3 data points, including 136 °C and two or more others at least 10 °C apart in temperature, should be used.

2.3.3 *Thermal and Radiation Exposure.* The following test sequence may be used to demonstrate that the cable will be operational after exposure to simulated thermal and radiation aging.

[2]Cable types RHH, RHW, and XHHW, as specified in the National Electrical Code should meet the requirements established by the applicable standards of Underwriters' Laboratories, Inc or other recognized agencies.

Table 1
Representative Cables for Type Tests

Type	Test	Section	Size
Up to 2000 V multiconductor control cable or Shielded multiconductor signal cable (see list below for individual component) or Single conductor power cable	temperature and moisture resistance	2.3.1	1/C — 14 or 12 AWG
	thermal and radiation exposure	2.3.3	1/C or M/C — 14 or 12 AWG
	design basis event simulation	2.4	1/C or M/C — 14 or 12 AWG 1/C — 6, 4 or 2 AWG
	vertical flame test singles from cable assembly	2.5.6	1/C — 14 or 12 AWG
	vertical tray flame test	2.5.4	7/C — 16, 14 or 12 AWG
Shielded pairs, triple or quad from multiconductor signal cable	temperature and moisture resistance	2.3.1	1 pair shielded 16 AWG or actual cable
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical flame test	2.5.6	
Coaxial, triaxial or special instrument cable	temperature and moisture resistance	2.3.1	actual size
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical flame test singles from cable assembly	2.5.6	
Single pair thermocouple extension cable	temperature and moisture resistance	2.3.1	2/C — 20 AWG or actual size if smaller
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical tray flame test	2.5.4	
	vertical flame test singles from cable assembly	2.5.6	
2001—15 000 V power cable 1/C triplexed and multiconductor	vertical tray flame test	2.5.4	6 AWG (2-5kV) 2/O or 4/O or 4/O (2-15kV)

2.3.3.1 Form suitable lengths of insulated conductor which conform to the applicable standards into test coils so that the effective section of each coil under test will be not less than 10 ft.

2.3.3.2 Subject the coils to circulating air oven aging at a temperature and time developed by plotting data using the Arrhenius technique or other method of proven validity to simulated installed life.

2.3.3.3 The specimens with conditioning as covered in Section 2.3.3.2 should be subjected in air to gamma radiation from a source such as ^{60}Co to a dosage of 5×10^7 rd at a rate not greater than 1×10^6 rd per hour.

2.3.3.4 After the radiation exposure of Section 2.3.3.3 the specimen should be straightened and recoiled with an inside diameter of approximately 20 times the cable overall diameter and immersed in tap water at room temperature. While still immersed, these specimens should pass a voltage withstand test for 5 minutes at a potential of 80 V/mil ac or 240 V/mil dc.

2.4 Testing for Operation During Design Basis Event

2.4.1 *General.* This section is predicated upon a loss of coolant accident (LOCA) but not necessarily limited thereto.

Prepare two sets of specimens in accordance with the following.

2.4.1.1 One set to be unaged.

2.4.1.2 The other set to be heat aged specimens in accordance with Sections 2.3.3.1 and 2.3.3.2.

NOTE: The requirements of Sections 2.3.3.3 and 2.3.3.4 may be omitted if Section 2.4 is followed as a guide since the requirements of Section 2.4 exceed those of Sections 2.3.3.3 and 2.3.3.4.

2.4.2 *Radiation Exposure — Total.* Exposure specimens to the maximum total cumulative radiation dosage expected over the installed life (see Section 2.3.3.3) plus one LOCA exposure to radiation for the particular installation involved as covered in IEEE Std 323-1974 Appendix A or B. The rate of exposure shall not be greater than 1×10^{n} rd per hour. This restriction is removed when simulation of the LOCA profile requires a greater dose rate.

2.4.3 *LOCA Simulation.* Test irradiated specimens in a pressure vessel so constructed that the specimens can be operated under rated voltage and load while simultaneously exposed to the pressure, temperature, humidity and chemical spray of a LOCA event. Chamber designs should have provisions for monitoring and varying temperature and steam pressure, for recycling chemical spray, and for electrically loading the specimens as specified herein.

2.4.3.1 After conditioned specimens are installed inside the pressure vessel they should be energized at rated voltage and loaded with rated service current while under the average normal operating condition. The energized specimens should be exposed to one cycle of the environmental extremes according to the schedule postulated for the particular installation, see IEEE Std 323-1974.

2.4.3.2 The cable should function electrically throughout its exposure to the environmental extremes within the specified electrical parameters.

2.4.4 *Post LOCA Simulation Test.* Upon completion of the LOCA simulation, the specimens should be straightened and recoiled around a metal mandrel with a diameter of approximately 40 times the overall cable diameter and immersed in tap water at room temperature. While still immersed, these specimens should again pass the same voltage withstand test performed under Section 2.3.3.4.

NOTE: The post LOCA simulation test demonstrates an adequate margin of safety by requiring mechanical durability (mandrel bend) following the environmental simulation and is more severe than exposure to two cycles of the environment.

2.5 Flame Tests

2.5.1 *General.* This section describes the method for type testing of grouped cables via the vertical tray flame test to determine their relative ability to resist fire.

2.5.2 *Criteria*

2.5.2.1 The fire test should demonstrate that the cable does not propagate fire even if its outer covering and insulation have been destroyed in the area of flame impingement.

2.5.2.2 The fire test should approximate installed conditions and should provide consistent results.

2.5.3 *Test Specimens*

2.5.3.1 The tests proposed are for power, control, and instrumentation cables.

2.5.3.2 Sizes recommended for type tests may be as listed in Table 1 but not necessarily limited thereto.

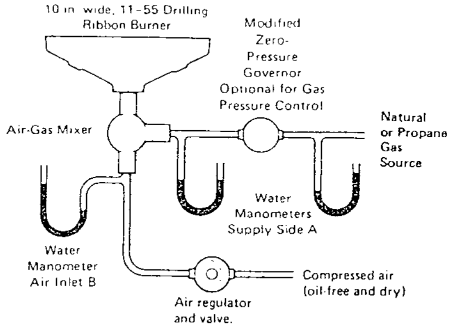
2.5.4 *Fire Test Facility and Procedure*

2.5.4.1 Test should be conducted in a naturally ventilated room or enclosure free from excessive drafts and spurious air currents.

2.5.4.2 The vertical tray configuration is recommended as the best arrangement to establish whether or not a cable could propagate a fire. The tray should be a vertical, metal, ladder type, 3 in deep, 12 in wide, and 8 ft long. The tray may be bolted at the bottom to a length of horizontal tray for support.

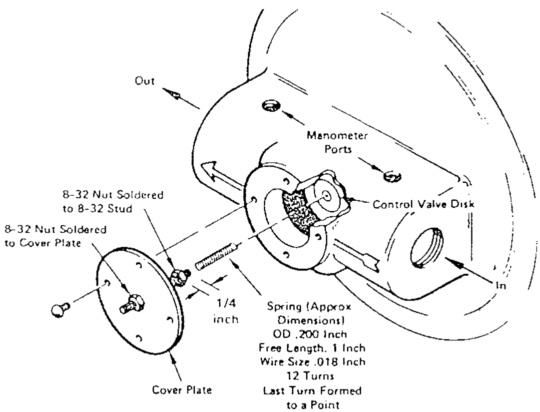
2.5.4.3 Test sample arrangement — multiple lengths of cable should be arranged in a single layer filling at least the center six inch portion of the tray with a separation of approximately 1/2 the cable diameter between each cable. The test should be conducted 3 times to demonstrate reproducibility using different samples of cable.

2.5.4.4 Flame source, when specified, the procedure detailed below shall be followed:



NOTE: All pressures measured under dynamic conditions.

A Schematic Drawing



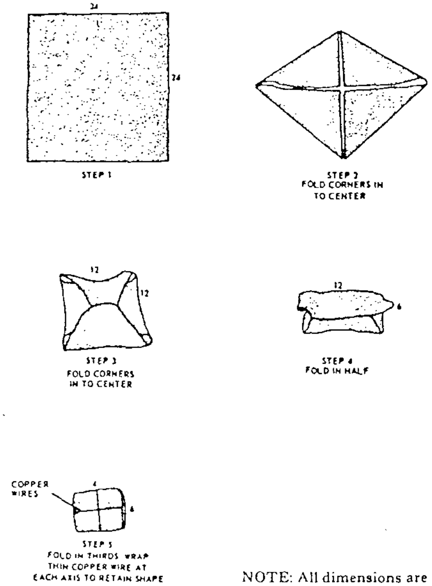
B Detail Drawing of Zero Pressure Governor Modification

Fig 1
Flame Source

2.5.4.4.1 The ribbon gas burner[3] shall be mounted horizontally such that the flame impinges on the specimen midway between the tray rungs, and so that the burner face is 3 in behind and approximately 2 ft above the bottom of the vertical tray. Because of its uniform heat content natural grade propane is preferred to commercial gas.

2.5.4.4.2 The flame temperature should be approximately 1500°F when measured by a thermocouple located in the flame close to, but not touching the surface of the test specimens (about 1/8 in spacing).

[3]An American Gas Furnace Co 10 in, 11-55 drilling, ribbon type, catalog no 10X 11-55 with an air-gas Venturi mixer, catalog no 14-18 (2 lbf/in² max gauge pressure) is the only presently available model that has been found satisfactory for purposes of these tests.



NOTE: All dimensions are in inches.

Fig 2
Burlap Folding Sequence

2.5.4.4.3 For the schematic arrangement see Fig 1. Under dynamic conditions, if propane gas is used the pressure shall be −2.6±0.3 cm of water at the supply side A to the Venturi mixer. If commercial gas is used the pressure shall be −0.9±0.1 cm of water when measured at the supply side of the Venturi mixer. For propane gas, the air pressure should be 4.3±0.5 cm of water. For commercial gas it shall be 5.6±0.5 cm of water, measured at the air inlet B to the mixer. In practice the flame length will be approximately 15 in when measured along its path.

2.5.4.4.4 Gas-burner procedure — ignite the burner and allow it to burn for 20 minutes. Record temperatures at point of impingement throughout the duration of the test, length of time flame continues to burn after gas burner is shut off, jacket char distance, and distance insulation is damaged.

2.5.4.5 Alternative flame source, oil or burlap — when specified, the procedure detailed below shall be followed.

2.5.4.5.1 Use a 24 in square piece of 9 oz per square yard burlap, folded as shown in Fig 2 into a bundle 4 in × 4 in × 6 in. Wrap with fine copper wire as shown, to retain the shape of the bundle. Immerse in a container of oil[4] for 5 minutes. Remove, hang free in air, allow to drain for approximately 15 minutes. The burlap ignitor is weighed before immersion and after draining, and the fuel pickup should be 160±5 g. The repeatability of this test is derived from constant fuel pickup in ignitors of constant size and weight. Temperature should be monitored at point of maximum flame impingement upon the test cables.

2.5.4.5.2 After draining, the ignitor should be placed in front of and approximately 2 ft above the bottom of the tray with the 4 in × 6 in face of the ignitor held in place against the cables by a suitable metal wire or band.

[4]Such as Mobilect 33.

2.5.4.5.3 Ignite the oil soaked burlap. The applied flame should be allowed to burn itself out naturally.

2.5.5 *Evaluation.* Cables which propagate the flame and burn the total height of the tray above the flame source fail the test. Cables which self-extinguish when the flame source is removed or burn out pass the test. Cables which continue to burn after the flame source is shut off or burns out should be allowed to burn in order to determine the extent.

2.5.6 ***Instrument Cable and Single Conductors from Multiconductor Assembly.*** A specimen of each type of instrument cable or the individually insulated or insulated and jacketed conductors removed from each multiconductor control cable which is type tested should pass a flame resistance test in accordance with ASTM D2220-68, Vinyl Chloride Plastic Insulation for Wire and Cable, Section 5 (IPCEA Standard S-19-81, Section 6.19.6), except the weight may be omitted if the specimen is securely clamped.

2.6 Documentation of Type Testing. Following the procedures outlined in this guide, provide data necessary to document satisfactory compliance. Certification of prior test results will be provided when required.

Section
2.3.1 Temperature and Moisture
2.3.2 Long-Term Physical Aging Properties
2.3.3 Thermal and Radiation Exposure
2.4 Testing for Operation During Design Basis Event (LOCA)
2.5.1 Flame Test on Grouped Cables in Vertical Tray
2.5.6 Flame Test on Single Conductor

3. References

IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment

IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation, and Establishment of Temperature Indices of Solid Electrical Insulating Materials

IEEE Std 99-1970, Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment

IEEE Std 100-1972 (ANSI C42.100-1972), Dictionary of Electrical and Electronics Terms

IEEE Std 101-1972, Guide for the Statistical Analysis of Thermal Life Test Data

IEEE Std 279-1971 (ANSI N42.7-1972), Criteria for Protection Systems for Nuclear Power Generating Stations

IEEE Std 308-1974, IEEE Standard Criteria for Class IE Power Systems for Nuclear Power Generating Stations

√IEEE Std 317-1971, Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations

IEEE Std 323-1974, Standard for Qualifying Class IE Electric Equipment for Nuclear Power Generating Stations

IEEE Std 334-1971, Type Tests of Continuous Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations

IEEE Std 336-1972 (ANSI N45.2.4-1972), Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations

√IEEE Std 380-1972, Definitions of Terms Used in IEEE Nuclear Power Generating Stations Standards

√ASTM D2220-68, Vinyl Chloride Plastic Insulation for Wire and Cable

IEEE 383

IEEE
Std 383-1974

IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

Sponsor

Nuclear Power Engineering Committee of the
IEEE Power Engineering Society

Foreword

(This foreword is not a part of IEEE Std 383-1974, IEEE Standard for Type Test of Class IE Electric Cables, *Field Splices, and Connections for Nuclear Power Generating Stations.*)

The Institute of Electrical and Electronics Engineers has generated this document to provide guidance for developing a program to type test cables, field splices, and connections and obtain specific type test data. It supplements IEEE Std 323-1974 Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations, which describes basic requirements for equipment qualification.

Each applicant to the Atomic Energy Commission for a license to operate a nuclear power generating station has the responsibility to assure himself and others that this standard, if used in whole or part, is pertinent to his application and that the integrated performance of his station is adequate.

It is the integrated performance of the structures, fluid systems, the electrical systems, the instrumentation systems of the station, and, in particular, the plant protection system, that limits the consequences of accidents. Seismic effects on installed cable systems are not within the scope of this document.

Section 2 of this guide is an example of type tests. It is the purpose of this guide to deal with cable and connections; however, at the time of issue, detailed examples of tests for connections were not available.

The performance criteria for Class IE service have been expanding in scope during the preparation of this document, and the state of the technology has been continually advancing.

This standard will be revised from time to time to incorporate the latest information available. Topics presently under consideration for future inclusion are: (1) aging correlation procedure, (2) connections, and (3) the corrosive effects from burning cables.

Comments on this document supported by data will be reviewed for later issues.

This standard was prepared by working group 12-32 of the Insulated Conductors' Committee of the IEEE Power Engineering Society. Members of this group were:

Alfred Garshick, *Chairman*

Russ Budrow
George S. Buettner
Carmen M. Chiappetta
John Conley
John T. Corbett
Edward Donegan
Irvine N. Dwyer
John Ferencik
Harry Hilberg
Alan S. Hintze
Frank E. La Fetra
T. H. Ling
Reinhold Luther
E. E. McIlveen
Cutter D. Palmer
John G. Quin
R. E. Sharp
Joseph L. Steiner
H. K. Stolt
J. R. Tuzinski
Chuck vonDamm
William G. White

At the time it approved this standard, Subcommittee 2 (Qualification) of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society had the following membership:

A. J. Simmons, *Chairman* L. D. Test, *Vice Chairman*
A. Kaplan, *Secretary*

J. F. Bates
J. T. Bauer
L. J. Blasiak
J. T. Keiper
F. Campbell
W. J. Foley
J. B. Gardner
T. H. Ling
T. R. Beans
G. W. Hammond
D. J. Meraner
F. W. Chandler
H. E. McConnell
C. E. Corley
W. Dalos
E. P. Donegan
W. D. Loftus
W. H. Steigelmann
S. Carfagno
W. A. Szelistowski
F. Tranzo
D. G. Woodward
G. T. Dowd, Jr
W. J. Denkowski
R. F. Edwards
C. F. Miller
A. S. Hintze
W. G. Stiffler
B. Gregory
A. Garshick
E. E. McIlveen

Contents

SECTION	PAGE
1. General Provisions	7
1.1 Scope	7
1.2 Definitions	7
1.3 Type Tests As Qualification Method	7
1.4 Documentation	9
1.5 Modifications	10
2. Examples of Type Tests	10
2.1 Introduction	10
2.2 Type Test Samples	10
2.3 Testing to Qualify for Normal Operation	10
2.4 Testing for Operation During Design Basis Event	12
2.5 Flame Tests	12
2.6 Documentation of Type Testing	15
3. References	15
FIGURES	
Fig 1 Flame Source	13
Fig 2 Burlap Folding Sequence	14
TABLE	
Table 1 Representative Tables for Type Tests	11

IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

1. General Provisions

1.1 Scope

1.1.1 This standard provides direction for establishing type tests which may be used in qualifying Class IE electric cables, field splices, and other connections for service in nuclear power generating stations. General guidelines for qualifications are given in IEEE Std 323-1974, Standard for Qualifying Class IE Electric Equipment for Nuclear Power Generating Stations. Categories of cables covered are those used for power control and instrumentation services.

1.1.2 Though intended primarily to pertain to cable for field installation, this guide may also be used for the qualification of internal wiring of manufactured devices.

1.1.3 This guide does not cover cables for service within the reactor vessel.

1.2 Definitions[1]

cable type. A cable type for purposes of qualification testing shall be representative of those cables having the same materials, similar construction, and service rating, as manufactured by a given manufacturer.

Class IE. The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling and containment, and reactor heat removal or otherwise are essential in preventing significant release of radioactive material to the environment.

connection. A cable terminal, splice, or hostile environment boundary seal at the interface of cable and equipment.

containment. That portion of the engineered safety features designed to act as the principal barrier, after the reactor system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive material beyond a controlled zone.

design basis events. Postulated abnormal events used in the design to establish the performance requirements of the structures, systems, and components (IEEE Std 323-1974).

field splice. A permanent joining and reinsulating of conductors in the field to meet the service conditions required.

installed life. The interval from installation to removal, during which the equipment or component thereof may be subject to design service conditions and system demands (IEEE Std 323-1974).

NOTE: Equipment may have an installed life of 40 years with certain components of the equipment changed periodically; thus, the installed life of the components would be less than 40 years.

qualified life. The period of time for which satisfactory performance can be demonstrated for a specific set of service conditions. (IEEE Std 323-1974).

type tests. Tests made on one or more units to verify adequacy of design (IEEE Std 380-1972).

1.3 Type Tests As Qualification Method. As described in IEEE Std 323-1974, type tests are the preferred method to demonstrate or assist in demonstrating that electric equipment is capable of meeting performance requirements under service conditions which include normal and design basis event environments. To perform type tests for cable, field splices, and connections requires: (1) description (identification) of cable, (2) description of significant aspects of the environment, and (3) description of cable performance required. These,

[1] Other definitions related to this document may be found in IEEE Std 100-1972 (ANSI C42 100-1972), Dictionary of Electrical and Electronics Terms, IEEE Std 323-1974, and IEEE Std 380-1972, Definitions of Terms Used in IEEE Nuclear Power Generating Stations Standards

then, with engineering knowledge and experience in insulating materials and systems form a basis for designing type tests to demonstrate the capabilities. Qualification of one cable may permit extrapolation of results to qualify other cables of the same type, with consideration being given to cable dimensions and probable modes of failure.

A sample field splice or connection or both must be type tested with the cable to demonstrate its electrical, mechanical, and chemical compatibility in the environments.

1.3.1 *Cable Description.* This description or specification should include as a minimum:

1.3.1.1 Conductor — material identification, size, stranding, coating.

1.3.1.2 Insulation — material identification, thickness, method of application.

1.3.1.3 Assembly (multiconductor cables only) — number and arrangement of conductors, fillers, binders.

1.3.1.4 Shielding — tapes, extrusions, braids, or others.

1.3.1.5 Covering — jacket or metallic armor or both, material identification, thickness, method of application.

1.3.1.6 Characteristics — voltage and temperature rating (normal and emergency). For instrumentation cables — capacitance, attenuation, characteristic impedance, microphonics, insulation resistance, as applicable.

1.3.1.7 Identification — manufacturer's trade name, catalog number.

1.3.2 *Field Splice or Connection Description or Both.* This description or specification should include as a minimum:

1.3.2.1 Whether factory or field assembled to cable.

1.3.2.2 Conductor connection — type, material identification, and method of assembly.

1.3.2.3 Items from Sections 1.3.1.2 through 1.3.1.7.

1.3.3 *Description of Significant Environmental Conditions.* Both normal operating and design basis event conditions, as well as their sequence and duration, are relevant for type testing. Separate requirements for post design basis event conditions may be required in recognition of momentary or accumulative changes in material properties due to aging, radiation, heat, and steam exposure. Environmental factors, the limits of which may be significant to the cable's operation are as follows:

1.3.3.1 *Atmosphere.* Maximum and average ambient or normal operation condition and design basis event condition or profile for the following:

(1) Gas composition and velocity
(2) Moisture content
(3) Temperature
(4) Pressure

1.3.3.2 *Radiation.*

(1) Normal dose rate and type
(2) Total normal installed life dosage
(3) Design basis event dose rate. Maximum dose rate and approximate profile
(4) Total design basis event dosage
(5) Total for the installed life plus design basis event

1.3.3.3 *Chemicals*

(1) Type of chemicals and concentration
(2) Spray or immersion rate and time
(3) Temperature of exposure

1.3.3.4 *Mechanical.* Normal operating condition and design basis event condition for the following:

(1) Bending or flexing
(2) Vibration
(3) Tension
(4) Sidewall pressure

1.3.3.5 *Fire*

1.3.4 *Operating Requirements*

1.3.4.1 *Meeting Service Conditions.* The cable, as installed, should be suitable for operation at maximum ambient temperature, radiation, and atmospheric conditions and normal electrical and physical stresses for its installed life, as specified. Evidence of this suitability may be based on compliance with appropriate published industry standards, past documented operating experience, component tests, or a combination of these.

The total station may be subdivided into zones with substantially different ambient conditions, and if segregation of cables to certain areas is assured, a cable need only be suitable for meeting service conditions in those zones in which it is located.

1.3.4.2 *Design Basis Event Conditions for Qualifying Cables*

1.3.4.2.1 *Design Basis Event — Loss-of-Coolant Accident (LOCA) (for cables in containment only).* The cable, field splices, and connections should throughout their normal lives be capable of operating through postulated environmental conditions resulting from a LOCA. Conditions of loading and signal levels shall be assumed to be those most unfavorable for cable operation which may be anticipated under such circumstances.

1.3.4.2.2 *Design Basis Event — Fire.* The cable should not propagate fire under conditions of installation.

1.3.4.2.3 *Other Design Basis Events.* These should also be considered in case they represent different types or more severe hazards to cable operation.

1.3.5 *Type Test Conditions and Sequences*

1.3.5.1 *General.* Type tests are used primarily to indicate that the cables, field splices, and connections can perform under the conditions of a design basis event. Because the design basis events may occur at any time in the station life, the thermal and radiation aging required in type tests to simulate these conditions may at the same time indicate the ability of cable types to operate under the normal service conditions within the station.

1.3.5.2 *Aging.* The effect of normal operating conditions with time may either add to or reduce the ability of cable, field splices, and connections to withstand the extreme environments and loads imposed during and following a design basis event. Thus, the type testing for design basis event conditions shall involve both aged and nonaged samples. *Aging* pertains to temperature, radiation, and atmospheric effects applied in sequence or simultaneously in an accelerated manner.

The basis for establishing time and temperature conditions for aging of samples to simulate their qualified life may be that of Arrhenius plotting (IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment, IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of, Temperature Indices of Solid Electrical Insulating Materials, IEEE Std 99-1970, Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment, and IEEE Std 101-1972, Guide for Statistical Analysis of Thermal Life Test Data) or other method of proven validity and applicability for the materials in question.

1.3.5.3 *Test Design Basis Event.* Type tests for design basis event conditions should consist of subjecting nonaged and aged cables, field splices, and connections to a sequence of environmental extremes which simulate the most severe postulated conditions of a design basis event and specified conditions of installation. Type tests shall demonstrate margin by application of multiple transients, increased level, or other justifiable means. Satisfactory performance of the cable will be evaluated by electrical and physical measurements appropriate to the type of cable during or following the environmental cycle or both.

The values of pressure, temperature, radiation, chemical concentrations, humidity, and time in Section 2 do not represent acceptable limitations for all nuclear power stations. The user of this guide should assure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable or connections will be installed.

1.4 Documentation

1.4.1 *General.* Type test data used to demonstrate the qualification of cables should be organized in an auditable form. The documentation should include:

1.4.1.1 Description or specification of cable.

1.4.1.2 Description or specification of field splice or connection.

1.4.1.3 Identification of the specific environmental features.

1.4.1.4 Identification of the specific performance requirements to be demonstrated.

1.4.1.5 The test program outline.

1.4.1.6 The test results.

1.4.1.7 Approving signature and date.

1.4.2 *Test Program Outline.* For cable and connections, this outline shall include:

1.4.2.1 The physical arrangement of the cable and test equipment description.

1.4.2.2 Time program and sequence of all environmental factors.

1.4.2.3 The type and location of all environmental and cable monitoring sensors for each variable.

1.4.2.4 The voltages or currents programmed in conjunction with Section 1.4.2.1 above.

1.4.2.5 The electrical, thermal, or mechanical tests to be performed during environmental exposure.

1.4.2.6 Testing or examinations subsequent to environmental cycle.

1.4.3 *Test Results.* Test results should demonstrate that:

1.4.3.1 The intended environmental sequences were achieved.

1.4.3.2 The cable or field splice (or connection) or both was capable of performing its intended function.

1.4.4 *Test Evaluation.* An evaluation of data should be made to demonstrate the adequacy of cable performance as outlined in Section 1.4.1.4.

1.5 Modifications. When modification in the materials or design of cables or in the conditions of installation or in the postulated environments are made, prior type tests shall be reviewed to determine the effect on the cable qualification. This evaluation shall indicate whether or not new type tests are required. The analysis of data and evaluation that demonstrates the effect of the modification on the equipment performance shall be added to the qualification documentation.

2. Examples of Type Tests

2.1 Introduction. Type tests described in this document are examples of methods which may be used to qualify electrical cables, field splices and connections for use in nuclear power generating stations. Tests of the cable or connection assembly, as applicable, should then supplement the cable tests in order to qualify the connections and other aspects unique to planned usage.

The values of pressure, temperature, radiation, chemical concentrations, humidity, and time used do not represent acceptable limits for all nuclear power generating stations. The user of this guide should assure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable or connections, or both will be installed.

Results of prior tests that are being used as the bases for the present tests should be referenced in the documentation.

2.2 Type Test Samples. The samples tested should contain the conductor, insulation, fillers, jacket, binder tape, overall jacket, shielding, and field splices which are representative of the cable category being qualified. Table 1 lists sizes which have been considered representative of these categories. The sample lengths should be sufficient to permit reliable test readings and evaluation consistent with good testing practice.

2.3 Testing to Qualify for Normal Operation

2.3.1 *Temperature and Moisture Resistance.* Evidence of qualification for normal operation may be demonstrated by providing certified evidence that the cable has been manufactured and tested and passed in accordance with the provisions of one or more of the following industry standards or criteria.

ANSI C83.21-1972 Requirements for Solid Dielectric Transmission Lines

ANSI C96.1-1964 (R1969) Temperature Measurement Thermocouples

ANSI C1-1971 National Electrical Code, NFPA 70-1971, Sections on Types RHH, RHW, and XHHW[2]

IPCEA S-19-81 Rubber-Insulated Cable

IPCEA S-66-524 Cross-Linked-Polyethylene-Insulated Cable

IPCEA S-68-516 Interim Standards for Ethylene-Propylene-Rubber-Insulated Wire and Cable. Number 1, Cables Rated 0-35 000 V. Number 2, Cables Rated 2000 V, Integral Insulation and Jacket.

AEIC 5-71 Specifications for Polyethylene and Cross-Linked-Polyethylene-Insulated, Shielded Power Cables rated 5000 – 35 000 V

AEIC 6-73 Specifications for Ethylene-Propylene-Rubber-Insulated Shielded Power Cables Rated 5 – 46 kV

2.3.2 *Long-Term Physical Aging Properties.* Aging data should be submitted to establish long-term performance of the insulation. Data may be evaluated using the Arrhenius technique. A minimum of 3 data points, including 136 °C and two or more others at least 10 °C apart in temperature, should be used.

2.3.3 *Thermal and Radiation Exposure.* The following test sequence may be used to demonstrate that the cable will be operational after exposure to simulated thermal and radiation aging.

---

[2] Cable types RHH, RHW, and XHHW, as specified in the National Electrical Code should meet the requirements established by the applicable standards of Underwriters' Laboratories, Inc or other recognized agencies.

Table 1
Representative Cables for Type Tests

Type	Test	Section	Size
Up to 2000 V multiconductor control cable or Shielded multiconductor signal cable (see list below for individual component) or Single conductor power cable	temperature and moisture resistance	2.3.1	1/C — 14 or 12 AWG
	thermal and radiation exposure	2.3.3	1/C or M/C — 14 or 12 AWG
	design basis event simulation	2.4	1/C or M/C — 14 or 12 AWG 1/C — 6, 4 or 2 AWG
	vertical flame test singles from cable assembly	2.5.6	1/C — 14 or 12 AWG
	vertical tray flame test	2.5.4	7/C — 16, 14 or 12 AWG
Shielded pairs, triple or quad from multiconductor signal cable	temperature and moisture resistance	2.3.1	1 pair shielded 16 AWG or actual cable
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical flame test	2.5.6	
Coaxial, triaxial or special instrument cable	temperature and moisture resistance	2.3.1	actual size
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical flame test singles from cable assembly	2.5.6	
Single pair thermocouple extension cable	temperature and moisture resistance	2.3.1	2/C — 20 AWG or actual size if smaller
	thermal and radiation exposure	2.3.3	
	design basis event simulation	2.4	
	vertical tray flame test	2.5.4	
	vertical flame test singles from cable assembly	2.5.6	
2001—15 000 V power cable 1/C triplexed and multiconductor	vertical tray flame test	2.5.4	6 AWG (2-5kV) 2/O or 4/O or 4/O (2-15kV)

2.3.3.1 Form suitable lengths of insulated conductor which conform to the applicable standards into test coils so that the effective section of each coil under test will be not less than 10 ft.

2.3.3.2 Subject the coils to circulating air oven aging at a temperature and time developed by plotting data using the Arrhenius technique or other method of proven validity to simulated installed life.

2.3.3.3 The specimens with conditioning as covered in Section 2.3.3.2 should be subjected in air to gamma radiation from a source such as ^{60}Co to a dosage of 5×10^7 rd at a rate not greater than 1×10^6 rd per hour.

2.3.3.4 After the radiation exposure of Section 2.3.3.3 the specimen should be straightened and recoiled with an inside diameter of approximately 20 times the cable overall diameter and immersed in tap water at room temperature. While still immersed, these specimens should pass a voltage withstand test for 5 minutes at a potential of 80 V/mil ac or 240 V/mil dc.

2.4 Testing for Operation During Design Basis Event

2.4.1 *General.* This section is predicated upon a loss of coolant accident (LOCA) but not necessarily limited thereto.

Prepare two sets of specimens in accordance with the following.

2.4.1.1 One set to be unaged.

2.4.1.2 The other set to be heat aged specimens in accordance with Sections 2.3.3.1 and 2.3.3.2.

NOTE: The requirements of Sections 2.3.3.3 and 2.3.3.4 may be omitted if Section 2.4 is followed as a guide since the requirements of Section 2.4 exceed those of Sections 2.3.3.3 and 2.3.3.4.

2.4.2 *Radiation Exposure — Total.* Exposure specimens to the maximum total cumulative radiation dosage expected over the installed life (see Section 2.3.3.3) plus one LOCA exposure to radiation for the particular installation involved as covered in IEEE Std 323-1974 Appendix A or B. The rate of exposure shall not be greater than 1×10^{6} rd per hour. This restriction is removed when simulation of the LOCA profile requires a greater dose rate.

2.4.3 *LOCA Simulation.* Test irradiated specimens in a pressure vessel so constructed that the specimens can be operated under rated voltage and load while simultaneously exposed to the pressure, temperature, humidity and chemical spray of a LOCA event. Chamber designs should have provisions for monitoring and varying temperature and steam pressure, for recycling chemical spray, and for electrically loading the specimens as specified herein.

2.4.3.1 After conditioned specimens are installed inside the pressure vessel they should be energized at rated voltage and loaded with rated service current while under the average normal operating condition. The energized specimens should be exposed to one cycle of the environmental extremes according to the schedule postulated for the particular installation, see IEEE Std 323-1974.

2.4.3.2 The cable should function electrically throughout its exposure to the environmental extremes within the specified electrical parameters.

2.4.4 *Post LOCA Simulation Test.* Upon completion of the LOCA simulation, the specimens should be straightened and recoiled around a metal mandrel with a diameter of approximately 40 times the overall cable diameter and immersed in tap water at room temperature. While still immersed, these specimens should again pass the same voltage withstand test performed under Section 2.3.3.4.

NOTE: The post LOCA simulation test demonstrates an adequate margin of safety by requiring mechanical durability (mandrel bend) following the environmental simulation and is more severe than exposure to two cycles of the environment.

2.5 Flame Tests

2.5.1 *General.* This section describes the method for type testing of grouped cables via the vertical tray flame test to determine their relative ability to resist fire.

2.5.2 *Criteria*

2.5.2.1 The fire test should demonstrate that the cable does not propagate fire even if its outer covering and insulation have been destroyed in the area of flame impingement.

2.5.2.2 The fire test should approximate installed conditions and should provide consistent results.

2.5.3 *Test Specimens*

2.5.3.1 The tests proposed are for power, control, and instrumentation cables.

2.5.3.2 Sizes recommended for type tests may be as listed in Table 1 but not necessarily limited thereto.

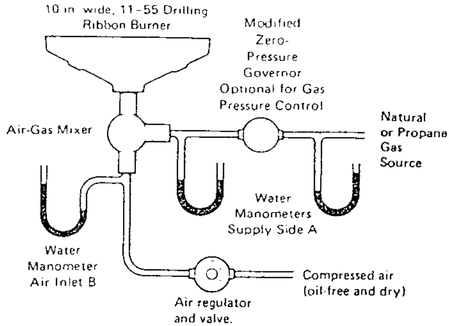
2.5.4 *Fire Test Facility and Procedure*

2.5.4.1 Test should be conducted in a naturally ventilated room or enclosure free from excessive drafts and spurious air currents.

2.5.4.2 The vertical tray configuration is recommended as the best arrangement to establish whether or not a cable could propagate a fire. The tray should be a vertical, metal, ladder type, 3 in deep, 12 in wide, and 8 ft long. The tray may be bolted at the bottom to a length of horizontal tray for support.

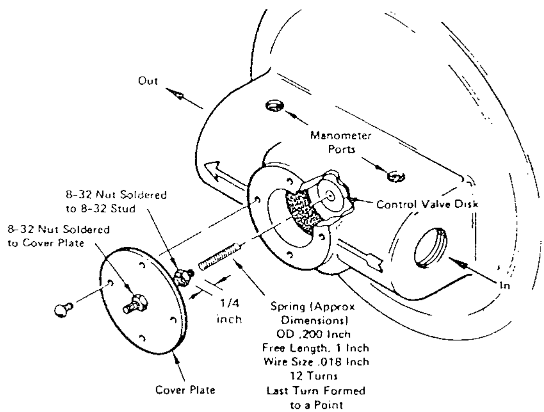
2.5.4.3 Test sample arrangement — multiple lengths of cable should be arranged in a single layer filling at least the center six inch portion of the tray with a separation of approximately 1/2 the cable diameter between each cable. The test should be conducted 3 times to demonstrate reproducibility using different samples of cable.

2.5.4.4 Flame source, when specified, the procedure detailed below shall be followed:



NOTE: All pressures measured under dynamic conditions.

A Schematic Drawing



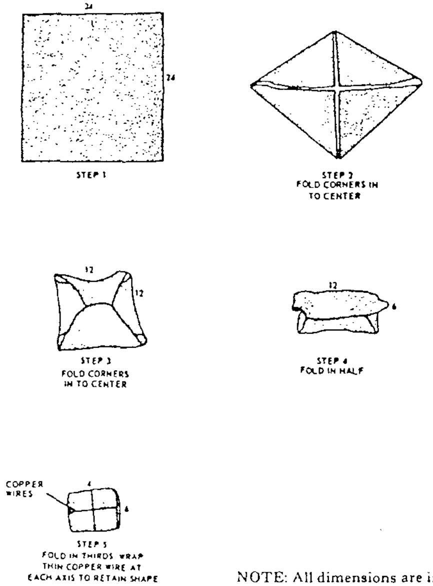
B Detail Drawing of Zero
Pressure Governor Modification

Fig 1
Flame Source

2.5.4.4.1 The ribbon gas burner[3] shall be mounted horizontally such that the flame impinges on the specimen midway between the tray rungs, and so that the burner face is 3 in behind and approximately 2 ft above the bottom of the vertical tray. Because of its uniform heat content natural grade propane is preferred to commercial gas.

2.5.4.4.2 The flame temperature should be approximately 1500°F when measured by a thermocouple located in the flame close to, but not touching the surface of the test specimens (about 1/8 in spacing).

[3]An American Gas Furnace Co 10 in, 11-55 drilling, ribbon type, catalog no 10X 11-55 with an air-gas Venturi mixer, catalog no 14-18 (2 lbf/in² max gauge pressure) is the only presently available model that has been found satisfactory for purposes of these tests.



NOTE: All dimensions are in inches.

Fig 2
Burlap Folding Sequence

2.5.4.4.3 For the schematic arrangement see Fig 1. Under dynamic conditions, if propane gas is used the pressure shall be -2.6 ± 0.3 cm of water at the supply side A to the Venturi mixer. If commercial gas is used the pressure shall be -0.9 ± 0.1 cm of water when measured at the supply side of the Venturi mixer. For propane gas, the air pressure should be 4.3 ± 0.5 cm of water. For commercial gas it shall be 5.6 ± 0.5 cm of water, measured at the air inlet B to the mixer. In practice the flame length will be approximately 15 in when measured along its path.

2.5.4.4.4 Gas-burner procedure — ignite the burner and allow it to burn for 20 minutes. Record temperatures at point of impingement throughout the duration of the test, length of time flame continues to burn after gas burner is shut off, jacket char distance, and distance insulation is damaged.

2.5.4.5 Alternative flame source, oil or burlap — when specified, the procedure detailed below shall be followed.

2.5.4.5.1 Use a 24 in square piece of 9 oz per square yard burlap, folded as shown in Fig 2 into a bundle 4 in × 4 in × 6 in. Wrap with fine copper wire as shown, to retain the shape of the bundle. Immerse in a container of oil[4] for 5 minutes. Remove, hang free in air, allow to drain for approximately 15 minutes. The burlap ignitor is weighed before immersion and after draining, and the fuel pickup should be 160 ± 5 g. The repeatability of this test is derived from constant fuel pickup in ignitors of constant size and weight. Temperature should be monitored at point of maximum flame impingement upon the test cables.

2.5.4.5.2 After draining, the ignitor should be placed in front of and approximately 2 ft above the bottom of the tray with the 4 in × 6 in face of the ignitor held in place against the cables by a suitable metal wire or band.

[4]Such as Mobilect 33.

2.5.4.5.3 Ignite the oil soaked burlap. The applied flame should be allowed to burn itself out naturally.

2.5.5 *Evaluation.* Cables which propagate the flame and burn the total height of the tray above the flame source fail the test. Cables which self-extinguish when the flame source is removed or burn out pass the test. Cables which continue to burn after the flame source is shut off or burns out should be allowed to burn in order to determine the extent.

2.5.6 *Instrument Cable and Single Conductors from Multiconductor Assembly.* A specimen of each type of instrument cable or the individually insulated or insulated and jacketed conductors removed from each multiconductor control cable which is type tested should pass a flame resistance test in accordance with ASTM D2220-68, Vinyl Chloride Plastic Insulation for Wire and Cable, Section 5 (IPCEA Standard S-19-81, Section 6.19.6), except the weight may be omitted if the specimen is securely clamped.

2.6 Documentation of Type Testing. Following the procedures outlined in this guide, provide data necessary to document satisfactory compliance. Certification of prior test results will be provided when required.

Section
2.3.1 Temperature and Moisture
2.3.2 Long-Term Physical Aging Properties
2.3.3 Thermal and Radiation Exposure
2.4 Testing for Operation During Design Basis Event (LOCA)
2.5.1 Flame Test on Grouped Cables in Vertical Tray
2.5.6 Flame Test on Single Conductor

3. References

IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment

IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation, and Establishment of Temperature Indices of Solid Electrical Insulating Materials

IEEE Std 99-1970, Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment

IEEE Std 100-1972 (ANSI C42.100-1972), Dictionary of Electrical and Electronics Terms

IEEE Std 101-1972, Guide for the Statistical Analysis of Thermal Life Test Data

IEEE Std 279-1971 (ANSI N42.7-1972), Criteria for Protection Systems for Nuclear Power Generating Stations

IEEE Std 308-1974, IEEE Standard Criteria for Class IE Power Systems for Nuclear Power Generating Stations

√IEEE Std 317-1971, Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations

IEEE Std 323-1974, Standard for Qualifying Class IE Electric Equipment for Nuclear Power Generating Stations

IEEE Std 334-1971, Type Tests of Continuous Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations

IEEE Std 336-1972 (ANSI N45.2.4-1972), Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations

√IEEE Std 380-1972, Definitions of Terms Used in IEEE Nuclear Power Generating Stations Standards

√ASTM D2220-68, Vinyl Chloride Plastic Insulation for Wire and Cable

I E C　3 3 2 − 1

A-33-01

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

NORME DE LA CEI

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC STANDARD

Publication 332-1
Deuxième édition — Second edition
1979

Essais des câbles électriques soumis au feu

Première partie: Essai effectué sur un câble vertical

Tests on electric cables under fire conditions

Part 1: Test on a single vertical insulated wire or cable

Bureau Central de la Commission Electrotechnique Internationale
1, rue de Varembé
Genève, Suisse

Révision de la présente publication

Le contenu technique des publications de la CEI est constamment revu par la Commission afin d'assurer qu'il reflète bien l'état actuel de la technique.

Les renseignements relatifs à ce travail de révision, à l'établissement des éditions révisées et aux mises à jour peuvent être obtenus auprès des Comités nationaux de la CEI et en consultant les documents ci-dessous:

- **Bulletin de la CEI**
- **Rapport d'activité de la CEI**
  Publié annuellement
- **Catalogue des publications de la CEI**
  Publié annuellement

Terminologie

En ce qui concerne la terminologie générale, le lecteur se reportera à la Publication 50 de la CEI: Vocabulaire Electrotechnique International (V.E.I.), qui est établie sous forme de chapitres séparés traitant chacun d'un sujet défini, l'Index général étant publié séparément. Des détails complets sur le V.E.I. peuvent être obtenus sur demande.

Les termes et définitions figurant dans la présente publication ont été soit repris du V.E.I., soit spécifiquement approuvés aux fins de cette publication.

Symboles graphiques et littéraux

Pour les symboles graphiques, symboles littéraux et signes d'usage général approuvés par la CEI, le lecteur consultera:

— la Publication 27 de la CEI: Symboles littéraux à utiliser en électrotechnique;

— la Publication 117 de la CEI: Symboles graphiques recommandés.

Les symboles et signes contenus dans la présente publication ont été soit repris des Publications 27 ou 117 de la CEI, soit spécifiquement approuvés aux fins de cette publication.

Autres publications de la CEI établies par le même Comité d'Etudes

L'attention du lecteur est attirée sur la page 3 de la couverture, qui énumère les autres publications de la CEI préparées par le Comité d'Etudes qui a établi la présente publication.

Revision of this publication

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology.

Information on the work of revision, the issue of revised editions and amendment sheets may be obtained from IEC National Committees and from the following IEC sources:

- **IEC Bulletin**
- **Report on IEC Activities**
  Published yearly
- **Catalogue of IEC Publications**
  Published yearly

Terminology

For general terminology, readers are referred to IEC Publication 50: International Electrotechnical Vocabulary (I.E.V.), which is issued in the form of separate chapters each dealing with a specific field, the General Index being published as a separate booklet. Full details of the I.E.V. will be supplied on request.

The terms and definitions contained in the present publication have either been taken from the I.E.V. or have been specifically approved for the purpose of this publication.

Graphical and letter symbols

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to:

— IEC Publication 27: Letter symbols to be used in electrical technology;

— IEC Publication 117: Recommended graphical symbols.

The symbols and signs contained in the present publication have either been taken from IEC Publications 27 or 117, or have been specifically approved for the purpose of this publication.

Other IEC publications prepared by the same Technical Committee

The attention of readers is drawn to the inside of the back cover, which lists other IEC publications issued by the Technical Committee which has prepared the present publication.

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ESSAIS DES CÂBLES ÉLECTRIQUES SOUMIS AU FEU

Première partie: Essai effectué sur un câble vertical

PRÉAMBULE

1) Les décisions ou accords officiels de la CEI en ce qui concerne les questions techniques, préparés par des Comités d'Études où sont représentés tous les Comités nationaux s'intéressant à ces questions, expriment dans la plus grande mesure possible un accord international sur les sujets examinés.

2) Ces décisions constituent des recommandations internationales et sont agréées comme telles par les Comités nationaux.

3) Dans le but d'encourager l'unification internationale, la CEI exprime le vœu que tous les Comités nationaux adoptent dans leurs règles nationales le texte de la recommandation de la CEI, dans la mesure où les conditions nationales le permettent. Toute divergence entre la recommandation de la CEI et la règle nationale correspondante doit, dans la mesure du possible, être indiquée en termes clairs dans cette dernière.

PRÉFACE

La présente norme a été établie par le Comité d'Études N° 20 de la CEI: Câbles électriques.

Un projet fut discuté lors de la réunion tenue à Oslo en 1976. A la suite de cette réunion, un projet, document 20(Bureau Central)141, fut soumis à l'approbation des Comités nationaux suivant la Règle des Six Mois en avril 1978.

Les pays suivants se sont prononcés explicitement en faveur de la publication:

Afrique du Sud (République d')	Italie
Allemagne	Japon
Autriche	Pays-Bas
Belgique	Roumanie
Brésil	Suède
Canada	Suisse
Danemark	Tchécoslovaquie
Égypte	Turquie
Finlande	Union des Républiques Socialistes Soviétiques
Israël	

Il est à noter que la présente norme découle d'une révision de la première édition de la Publication 332 de la CEI: Caractéristiques des câbles électriques retardant la propagation de la flamme, titre modifié en: Essais des câbles électriques soumis au feu. Elle constitue la première partie d'une série de parties qui traitera des sujets suivants:

Une méthode de détermination du volume de gaz acides dégagés au cours de la combustion de matériaux polymères.
Des essais sur câbles en nappes (essais sur les caractéristiques de propagation de flamme des câbles).
Une méthode de mesure de la densité de fumée.

La présente norme remplace et annule la Publication 332 de la CEI (1970).

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TESTS ON ELECTRIC CABLES UNDER FIRE CONDITIONS

Part 1: Test on a single vertical insulated wire or cable

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by IEC Technical Committee No. 20, Electric Cables.

A draft was discussed at the meeting held in Oslo in 1976. As a result of this meeting, a draft, Document 20(Central Office)141, was submitted to the National Committees for approval under the Six Months' Rule in April 1978.

The following countries voted explicitly in favour of publication:

Austria	Italy
Belgium	Japan
Brazil	Netherlands
Canada	Romania
Czechoslovakia	South Africa (Republic of)
Denmark	Sweden
Egypt	Switzerland
Finland	Turkey
Germany	Union of Soviet Socialist Republics
Israel	

It should be noted that this standard arises out of a revision undertaken on IEC Publication 332, Flame-retardant Characteristics of Electric Cables, being re-titled: Tests on Electric Cables under Fire Conditions, and that it forms the first part of a series of parts intended to deal with the following subjects:

— A method for determining the amount of acid gas evolved during the combustion of polymeric materials
— Test on bunched cables (a test for flame propagation characteristics of cables)
— A method for the measurement of smoke density.

This standard supersedes IEC Publication 332 (1970).

ESSAIS DES CABLES ELECTRIQUES SOUMIS AU FEU

Première partie: Essai effectué sur un câble vertical

---

1. Domaine d'application

La présente norme prescrit une méthode d'essai sur un câble vertical et indique les conditions requises d'acceptation.

Notes 1. — Etant donné qu'il ne suffit pas d'utiliser un câble retardant la propagation de la flamme pour empêcher la propagation du feu dans n'importe quelle condition d'installation, il est recommandé de prendre également des précautions spéciales d'installation chaque fois que le risque de propagation du feu est grand, par exemple dans les cas de grandes longueurs de faisceaux de câbles verticaux. Le fait qu'un échantillon de câble est conforme aux conditions requises de comportement figurant dans la présente norme n'implique pas qu'un faisceau de câbles du même type se comportera nécessairement de façon identique.

2. — La méthode décrite dans cette norme n'est pas adaptée pour les essais de certains petits conducteurs du fait de la fusion des conducteurs pendant la durée d'application de la flamme.

2. Conditions requises de comportement

L'essai est prévu pour être un essai de type et peut se rapporter à une norme particulière. Un échantillon de conducteur ou de câble, après avoir été essayé suivant les modalités des articles 3 à 7, doit satisfaire à la condition suivante:

Une fois toute combustion terminée, la surface de l'échantillon est essuyée complètement et la partie carbonisée ou affectée doit se trouver à moins de 50 mm de l'arête inférieure de la fixation supérieure.

3. Echantillon

L'échantillon d'essai est un morceau de câble terminé de 600 ± 25 mm de long.

4. Conditionnement avant l'essai

Si le conducteur ou le câble est recouvert d'une couche de peinture ou de laque, l'échantillon est conservé à une température de 60 ± 2 °C pendant 4 h avant l'essai.

5. Conditions de l'essai

L'échantillon est fixé à chaque extrémité; il est disposé verticalement au milieu d'un écran métallique à trois faces de 1 200 ± 25 mm de haut, de 300 ± 25 mm de large et de 450 ± 25 mm de profondeur, la face avant étant ouverte et le dessus et le dessous étant fermés; la base ne doit pas être métallique.

Les fixations du câble ont approximativement 25 mm de large et sont disposées de façon que la distance entre le dessus de la fixation inférieure et le dessous de la fixation supérieure soit de 550 ± 25 mm.

TESTS ON ELECTRIC CABLES UNDER FIRE CONDITIONS

Part 1: Test on a single vertical insulated wire or cable

---

1. Scope

This standard specifies a method of test on a single vertical insulated wire or cable and the requirement for compliance.

Notes 1 — Since the use of insulated wire or cable that complies with the requirement is not sufficient by itself to prevent propagation of fire under all conditions of installation, it is recommended that wherever the risk of propagation is high, for example in long vertical runs of bunches of cables, special installation precautions should also be taken. It cannot be assumed that because the sample of cable complies with the performance required in this standard that a bunch of cables will behave in a similar manner.

2 — The method specified is not suitable for the testing of some small wires due to the melting of the conductors during the time of application of the flame.

2. Performance requirement

The test is intended for type approval testing, and may be referred to in cable standards. One sample of insulated wire or cable, after having been tested in accordance with Clauses 3 to 7, shall comply with the following requirement:

After all burning has ceased, the surface of the sample shall be wiped clean and the charred or affected portion shall not have reached within 50 mm of the lower edge of the top clamp.

3. Sample

The test sample shall be a piece of the finished wire or cable 600 ± 25 mm long.

4. Conditioning before test

If the insulated wire or cable has a paint or lacquer finish, the sample shall be kept at a temperature of 60 ± 2 °C for 4 h before the test.

5. Test conditions

The sample shall be clamped at each end to position it vertically in the middle of a three-sided metallic screen, 1 200 ± 25 mm high, 300 ± 25 mm wide and 450 ± 25 mm deep, with open front and closed top and bottom; the base shall be non-metallic.

The clamps shall be approximately 25 mm wide and positioned so that the distance between the top of the bottom clamp and the bottom of the top clamp is 550 ± 25 mm.

L'essai est effectué [illegible] soit approximativement à [illegible] la base de l'écran.

Cette disposition est illus[illegible] figure 1, page 8.

6. Source de chaleur

a) Le brûleur à gaz

Si du propane est utilisé, le brûleur est celui décrit dans la figure 2, page 9 ; il est alors réglé pour donner une flamme d'environ 175 mm de long avec un dard d'environ 55 mm de long.

Lorsqu'il est alimenté par du gaz naturel, un bec Bunsen conventionnel ayant une ouverture de 9 ± 1 mm peut être utilisé ; il est alors réglé pour donner une flamme d'environ 125 mm de long avec un dard (cône bleu) d'environ 40 mm de long.

En cas de doute, le brûleur à gaz propane doit être utilisé.

b) Vérification du fonctionnement du brûleur

On vérifie que le fonctionnement du brûleur est satisfaisant de la façon suivante. l'axe du brûleur étant vertical : un fil nu en cuivre de 0,71 ± 0,025 mm de diamètre et ayant une longueur libre d'au moins 100 mm est introduit horizontalement dans la flamme, d'environ 10 mm au dessus de l'extrémité du dard, de façon que l'extrémité libre du fil soit verticalement au-dessus du bord du brûleur du côté éloigné de l'extrémité fixe du fil. Le temps nécessaire pour que le fil fonde ne doit pas être supérieur à 6 s ni inférieur à 4 s.

c) Câbles de diamètre jusqu'à 50 mm inclus

Pour les échantillons ayant un diamètre extérieur jusqu'à 50 mm inclus, la source de chaleur utilisée est un brûleur à gaz, construit et fonctionnant comme décrit ci-dessus, et placé comme indiqué dans la figure 3, page 10.

d) Câbles de diamètre supérieur à 50 mm

Pour les échantillons ayant un diamètre extérieur supérieur à 50 mm, la source de chaleur est constituée par deux brûleurs à gaz, construits et fonctionnant comme décrit ci-dessus, et disposés autour de l'échantillon comme indiqué dans la figure 3.

7. Mode opératoire

Pour l'essai, l'axe du brûleur doit former un angle de 45° avec l'axe de l'échantillon.

Lorsque le brûleur est en fonctionnement, la distance de celui-ci à l'échantillon est telle que le dard de la flamme est à une distance mesurée le long de l'axe de la flamme, d'environ 10 mm de la surface du câble et à 475 mm au-dessous de la face inférieure de la fixation supérieure.

La flamme est appliquée pendant une période continue de T secondes, donnée par la formule :

$$T = 60 + \frac{m}{25}$$

dans laquelle m est la masse, en grammes, de l'échantillon de câble rapporté à une longueur de 600 mm.

The test shall be made in an area substantially free from draughts. The sample shall be adjusted so that the bottom of the specimen is approximately 50 mm from the base of the screen.

The arrangement is illustrated in Figure 1, page 8.

6. Source of heat

a) Gas burner

When propane is used, the burner in Figure 2, page 9, shall be used, the burner being regulated to give a flame approximately 175 mm long with an inner blue cone approximately 55 mm long.

For natural gas, a conventional Bunsen burner having a bore of 9 ± 1 mm may be used, the burner being regulated to give a flame approximately 125 mm long with an inner blue cone approximately 40 mm long.

In cases of dispute, the propane gas burner shall be used.

b) Check of burner operation

The satisfactory operation of the burner shall be checked as follows, with the axis of the burner being vertical: a bare copper wire, 0.71 ± 0.025 mm in diameter, having a free length of not less than 100 mm shall be inserted horizontally in the flame about 10 mm above the top of the blue cone, so that the free end of the wire is vertically above the edge of the burner on the side remote from the supported end of the wire. The time required for the wire to melt shall be not more than 6 s and not less than 4 s.

c) Wire and cable of diameter up to and including 50 mm   Cable diameter ≥50mm

The source of heat for a sample having an overall diameter up to and including 50 mm shall be one gas burner, constructed and operated as described above, and positioned as shown in Figure 3, page 10.

d) Wire and cable of diameter greater than 50 mm

The source of heat for a sample having an overall diameter greater than 50 mm shall be two gas burners constructed and operated as described above, and arranged round the sample as shown in Figure 3.

7. Test procedure

For the test, the axis of the burner tube shall be at an angle of 45° to the axis of the sample.

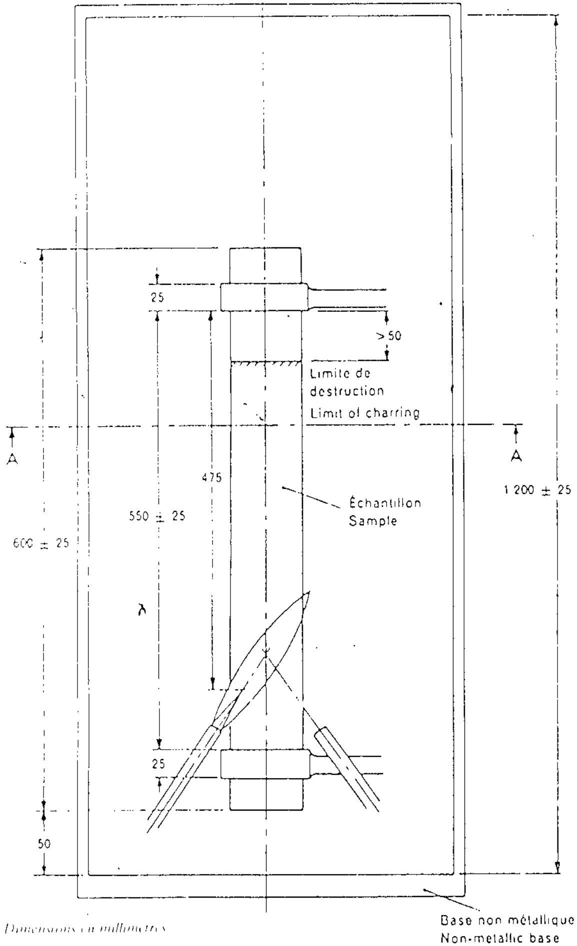
When the burner is in use the distance of the burner from the sample shall be such that the inner blue cone of the flame is at a distance of approximately 10 mm, measured along the axis of the flame, from the surface of the cable and 475 mm below the lower edge of the top clamp.

The flame shall be applied for a continuous period of T seconds derived from the formula:

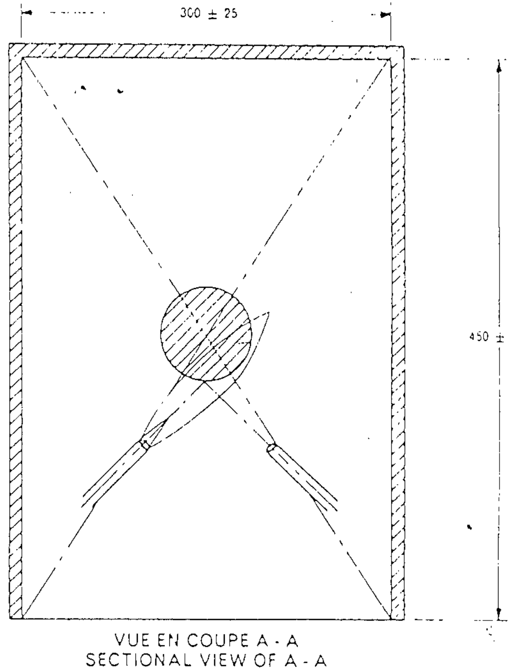
$$t = 60 + \frac{m}{25}$$

where m is the weight in grams of the wire or cable sample corrected to a 600 mm length.

600 mm cable之重量

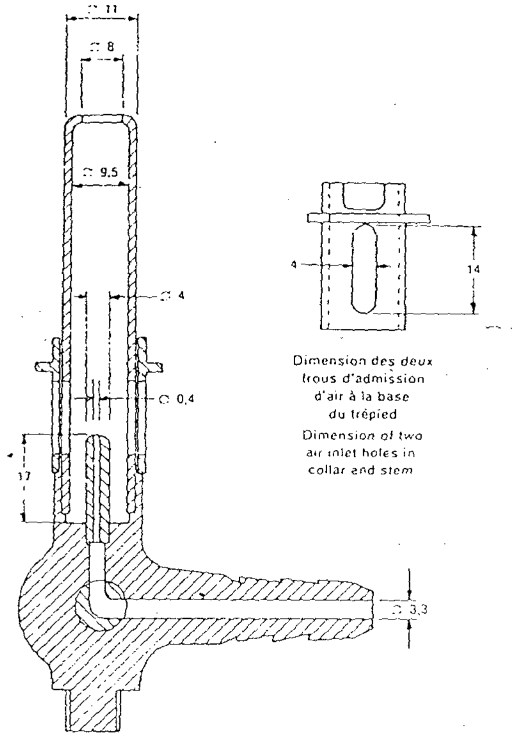


Dimensions en millimètres



Dimensions in millimetres

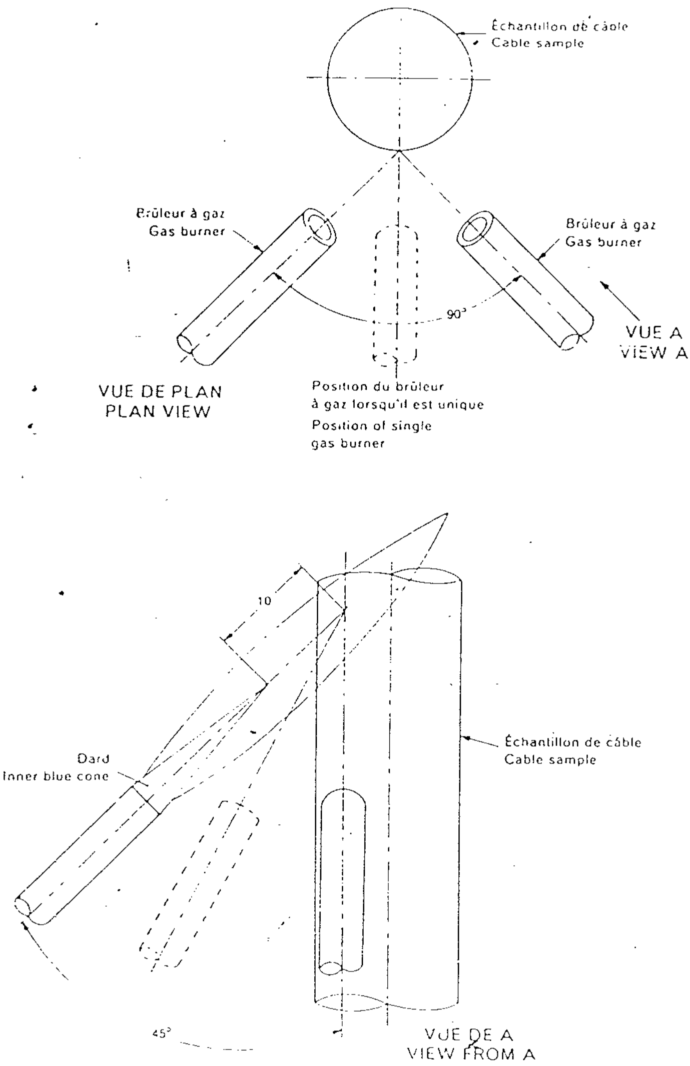
FIG. 1. — Disposition de l'échantillon dans l'écran à trois faces.
Arrangement of sample within three-sided screen



…mensions en millimètres

Dimensions in millim…

Fig. 2. — Brûleur à gaz propane normalisé (vue en coupe)
Standard propane gaz burner (sectional view)



Dimensions en millimètres

Dimensions in millimetres

FIG. 3. — Disposition des brûleurs pour l'essai des câbles.
Arrangement of burners for cable test.

Autres publications de la CEI préparées par le Comité d'Etudes N° 20

55 Câbles isolés au papier imprégné sous gaine métallique pour des tensions assignées inférieures ou égales à 18/30 kV (avec âmes conductrices en cuivre ou aluminium et à l'exclusion des câbles à pression de gaz et à huile fluide).

55-1 (1978) Première partie: Essais.

55-2 (1965) Essais des câbles isolés au papier imprégné sous gaine métallique. Deuxième partie: Câbles à imprégnation non migrante pour des tensions alternatives de 10 kV à 33 kV inclus (à l'exclusion des câbles à pression de gaz).
Modification N° 1 (1967)

141: Essais de câbles à huile fluide, à pression de gaz et de leurs dispositifs accessoires

141-1 (1976) Première partie: Câbles au papier à huile fluide et à gaine métallique et accessoires pour des tensions alternatives inférieures ou égales à 400 kV.

141-2 (1963) Deuxième partie: Câbles à pression de gaz interne et accessoires pour des tensions alternatives inférieures ou égales à 275 kV.
Modification N° 1 (1967)

141-3 (1963) Troisième partie: Câbles à pression de gaz externe (à compression de gaz) et accessoires pour des tensions alternatives inférieures ou égales à 275 kV.
Modification N° 1 (1967)

173 (1964) Couleurs pour les conducteurs des câbles souples.

183 (1965) Guide au choix des câbles à haute tension.

227 (1967) Câbles souples isolés au polychlorure de vinyle à âmes circulaires et de tension nominale ne dépassant pas 750 V.
Modification N° 1 (1969)
Modification N° 2 (1973)

227A (1972) Premier complément: Conducteurs pour filerie interne des appareils électrodomestiques.

227B (1977) Deuxième complément: Câbles souples méplats sous gaine de polychlorure de vinyle pour ascenseurs et câbles pour connexions flexibles.

228 (1978) Ames des câbles isolés.

229 (1966) Essais de revêtements de protection contre la corrosion des gaines métalliques de câbles.
Modification N° 1 (1970).

230 (1966) Essais de choc des câbles et de leurs accessoires.

245 (1967) Câbles souples isolés au caoutchouc à âmes circulaires et de tension nominale ne dépassant pas 750 V.
Modification N° 1 (1969)
Modification N° 2 (1970).
Modification N° 3 (1972)
Modification N° 4 (1973).
Modification N° 5 (1975).

287 (1969) Calcul du courant admissible dans les câbles en régime permanent (facteur de charge 100 %)
Première édition (1969) comprenant les Modifications N° 1 (1971) et N° 2 (1974)
Modification N° 3 (1977)
Modification N° 4 (1978).

287A (1978) Premier complément. Annexe C: Calcul numérique des quantités indiquées sous forme des graphiques.

331 (1970) Caractéristiques des câbles électriques résistant au feu.

502 (1978) Câbles de transport de l'énergie isolés par diélectriques massifs extrudés pour des tensions assignées de 1 kV à 30 kV.

540 (1976) Méthodes d'essais pour les enveloppes isolantes et les gaines des câbles électriques rigides et souples (mélanges élastomères et thermoplastiques).

541 (1976) Comparaison des câbles souples de la CEI et des câbles souples de l'Amérique du Nord.

Other IEC publications prepared by Technical Committee No. 20

55 Paper-insulated metal-sheathed cables for rated voltages up to 18/30 kV (with copper or aluminium conductors and excluding gas-pressure and oil-filled cables).

55-1 (1978) Part 1: Tests.

55-2 (1965). Tests on impregnated paper-insulated metal-sheathed cables. Part 2: Non-draining cables for alternating voltages from 10 kV up to and including 33 kV (excluding gas-pressure cables).
Amendment No. 1 (1967)

141: Tests on oil-filled and gas-pressure cables and their accessories.

141-1 (1976) Part 1: Oil-filled, paper insulated, metal-sheathed cables and accessories for alternating voltages up to and including 400 kV.

141-2 (1963) Part 2: Internal gas-pressure cables and accessories for alternating voltages up to 275 kV.
Amendment No. 1 (1967).

141-3 (1963) Part 3: External gas-pressure (gas compression) cables and accessories for alternating voltages up to 275 kV.
Amendment No. 1 (1967).

173 (1964) Colours of the cores of flexible cables and cords.

183 (1965) Guide to the selection of high-voltage cables.

227 (1967) Polyvinyl chloride insulated flexible cables and cords with circular conductors and a rated voltage not exceeding 750 V.
Amendment No. 1 (1969).
Amendment No. 2 (1973).

227A (1972) First supplement: Single-core cable for internal wiring of household appliances.

227B (1977) Second supplement: Flat polyvinyl chloride sheathed flexible lift cables and cables for flexible connections.

228 (1978) Conductors of insulated cables.

229 (1966) Tests on anti-corrosion protective coverings of metallic cable sheaths.
Amendment No. 1 (1970).

230 (1966) Impulse tests on cables and their accessories.

245 (1967) Rubber insulated flexible cables and cords with circular conductors and a rated voltage not exceeding 750 V.
Amendment No. 1 (1969).
Amendment No. 2 (1970).
Amendment No. 3 (1972)
Amendment No. 4 (1973).
Amendment No. 5 (1975).

287 (1969) Calculation of the continuous current rating of cables (100% load factor).
First edition (1969) incorporating Amendments No. 1 (1971) and No. 2 (1974).
Amendment No. 3 (1977)
Amendment No. 4 (1978)

287A (1978) First supplement: Appendix C: Digital calculation of quantities given graphically.

331 (1970) Fire-resisting characteristics of electric cables.

502 (1978) Extruded solid dielectric insulated power cables for rated voltages from 1 kV up to 30 kV.

540 (1976) Test methods for insulation and sheaths of electric cables and cords (elastomeric and thermoplastic compounds).

541 (1976) Comparative information on IEC and North-American flexible cord types.

IEC 332-3

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

RAPPORT DE LA CEI

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC REPORT

Publication 332-3
Première édition – First edition
1982

Essais des câbles électriques soumis au feu

Troisième partie: Essais sur câbles en nappes

Tests on electric cables under fire conditions

Part 3: Tests on bunched wires or cables

Bureau Central de la Commission Electrotechnique Internationale
3, rue de Varembé
Genève, Suisse

72. 2. 1 1

CONTENTS

Pages

FOREWORD 5

PREFACE 5

Clause

1. Introduction 7
2. Scope 7
3. Test sample and categories 7
4. Details of the test rig 9
5. Method of mounting the test sample 9
6. Ignition source 9
7. Positioning of the ignition source 11
8. Test procedure 11
9. Performance requirement 11

APPENDIX A — Details of standard burner 17

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TESTS ON ELECTRIC CABLES UNDER FIRE CONDITIONS

Part 3: Tests on bunched wires or cables

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This report has been prepared by IEC Technical Committee No. 20: Electric Cables.

A first draft was discussed at the meeting held in Florence in 1980. A new draft was circulated under the Accelerated Procedure in October 1980, as a result of which a draft, Document 20(Central Office)145, was submitted to the National Committees for approval under the Six Months' Rule in April 1981.

The National Committees of the following countries voted explicitly in favour of publication.

Argentina	Netherlands
Australia	New Zealand
Austria	Poland
Belgium	Romania
Canada	South Africa (Republic of)
China	Spain
Denmark	Sweden
German Democratic Republic	Switzerland
Ireland	Union of Soviet Socialist Republics
Italy	United Kingdom
Japan	United States of America

The French National Committee submitted a negative vote because it considers, firstly, that contrary to the contents of the introduction, the test method is not stabilized and its reliability not established and secondly, that the publication does not draw attention to the conventional views of the method and does not give any indication of its reproducibility and repeatability nor the spread of results that may arise.

TESTS ON ELECTRIC CABLES UNDER FIRE CONDITIONS

Part 3: Tests on bunched wires or cables

---

1. Introduction

IEC Publication 332-1: Tests on Electric Cables under Fire Conditions, Part 1: Test on a Single Vertical Insulated Wire or Cable, specifies a method of test for the flame propagation characteristics of a single vertical insulated wire or cable, and it cannot be assumed that because a sample of cable complies with the requirements in Part 1 that a bunch of cables will behave in a similar manner.

Consequently this report has been prepared to give a method of test for the flame propagation characteristics of a bunch of cables. Propagation of fire depends on a number of factors but it is in particular a function of the total volume of combustible material in the cable run. Three test categories are included to meet various user requirements.

2. Scope

This report recommends a method of test for the flame propagation characteristics of a bunch of cables.

This report recommends three test categories, these being assessed by the amount of combustible material contained in one metre of the bunched cables being tested.

This method of test is a type test for cables.

3. Test sample and categories

The test sample should comprise a number of pieces of cable each 3.5 m long.

The total number of 3.5 m lengths of cable in the test sample should be in accordance with one of the three categories as follows:

Category A

The number of cable lengths required to give a total volume of combustible material of 7 litres per metre.

Category B

The number of cable lengths required to give a total volume of combustible material of 3.5 litres per metre.

Category C

The number of cable lengths required to give a total volume of combustible material of 1.5 litres per metre.

Note. — When calculating the number of cables lengths in the test sample, the sample should be rounded to the nearest whole number.

test rig 1 m x 2 m x 4 m

4. Details of the test rig

The test rig (Figure 1, page 12) should comprise a vertical test chamber having a width of 1 m, a depth of 2 m and a height of 4 m and the floor of the chamber should be raised 150 mm above the ground level. The test chamber should be nominally airtight along its sides, air being admitted, without any substantial obstruction, at the base of the test chamber through an aperture 800 mm × 400 mm situated 150 mm from the front wall of the test chamber.

Note. — Consideration is being given to the use of a controlled air flow rate, in the range 4.5 m^3/min to 10 m^3/min, through the test chamber and after agreement has been reached an early amendment on speed and method is envisaged.

An outlet 300 mm × 1 000 mm should be made at the rear edge of the top of the test chamber. The back and sides of the test chamber should be thermally insulated to give a coefficient of heat transfer of approximately 0.7 W/ ($m^2 \cdot K$). For example a steel plate 1.5 mm thick covered with 65 mm of mineral wool with a suitable external cladding is satisfactory (see Figure 1a, page 13). The cables to be tested should be fixed to a steel ladder (see Figure 2, page 14) mounted within the test chamber such that the distance between the ladder and the rear wall of the chambers is 150 mm.

Smoke cleaning attachment

Legal requirements may make it necessary for equipment for collecting and washing the smoke to be fitted to the test chamber. This equipment should be such as to collect the smoke leaving the chamber but not cause a change in the air flow rate through the test chamber.

5. Method of mounting the test sample

The test sample should be attached to each rung of the steel ladder using steel wire ties. The total width of the mounted cable sample should not exceed 300 mm and the sample should be approximately centred on the ladder.

Cables having an individual conductor cross-section greater than 35 mm^2 should be fixed to the ladder spaced apart by half the cable diameter but the spacing should not exceed 20 mm.

When the number of cables to be mounted with spacing is such that mounting them all on one side of the ladder will exceed the width of 300 mm then the cables should be mounted using both sides of the ladder, first filling the front and then starting in the centre of the rear of the ladder (see Figure 3, page 15).

All other cables should be fixed to the front of the ladder in multiple layers with the cables touching one another.

6. Ignition source

The ignition source should be a ribbon type propane gas burner whose flame producing surface consists of a flat metal plate 341 mm long and 30 mm wide through which 242 holes 1.32 mm in diameter are drilled on 3.2 mm centres in three staggered rows of 81, 80 and 81 holes each to form an array having the nominal dimensions 257 mm × 4.5 mm as shown in Figure 4, page 16. As the burner plate may be drilled without the use of a drilling jig the spacing of the holes may vary slightly. Additionally a row of small holes may be milled on each side of the burner plate to serve as pilot holes with the function of keeping the flame burning.

The burner should be fitted with an accurate means of controlling the input of fuel and air to the burner. For the purpose of this test the fuel input rate should be $73.7 \pm 1.68 \times 10^6$ J/h (70 000 ± 1600 Btu/h) and the air input 4.6 ± 0.28 m^3/h (163 ± 10 ft^3/h).

Note. — To ensure reproducibility between results from different testing stations, it is recommended that a standard burner, which is readily available, be used. For details see Appendix A.

7. Positioning of the ignition source

The burner should be arranged horizontally at a distance 75 mm from the front surface of the cable sample and 600 mm above the floor of the test chamber. The point of application of the burner flame should lie in the centre between two cross-bars on the ladder and at least 500 mm above the lower end of the sample (see Figure 3, page 15).

8. Test procedure

8.1 *Test condition*

The test should not be carried out if the external wind speed measured by an anemometer fitted on the top of the test rig is greater than 5 m/s, and should not be carried out if the temperature of the walls of the chamber is below 5 °C or above 40 °C.

8.2 *Conditioning of the test rig and sample*

The cables mounted on the ladder should be conditioned at a temperature of 23 ± 5 °C for 3 h at least before commencing the test. The test chamber should be dry.

8.3 *Time of application of the flame*

In the case of cables samples in Category A and Category B the test flame should be applied for 40 min.

Cable samples in Category C should have the test flame applied for 20 min.

9. Performance requirement

Cables tested should comply with the following requirements:

After burning has ceased, the cables should be wiped clean and the charred or affected portion should not have reached a height exceeding 2.5 m above the bottom edge of the burner, measured at the front and rear of the cable assembly.

Dimensions en millimètres *Dimensions in millimetres*

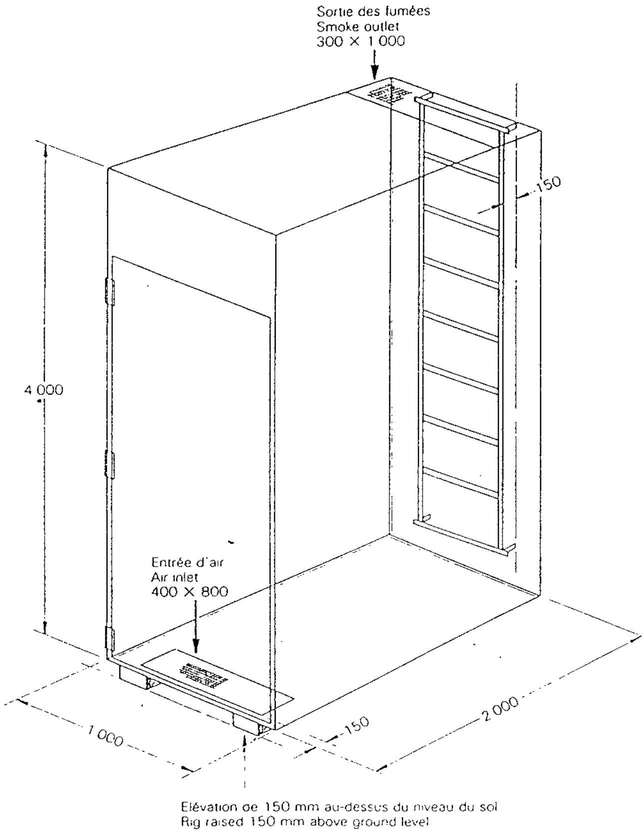


FIG. 1. — Equipement d'essai au feu.
Fire test rig.

Dimensions en millimètres *Dimensions in millimetres*

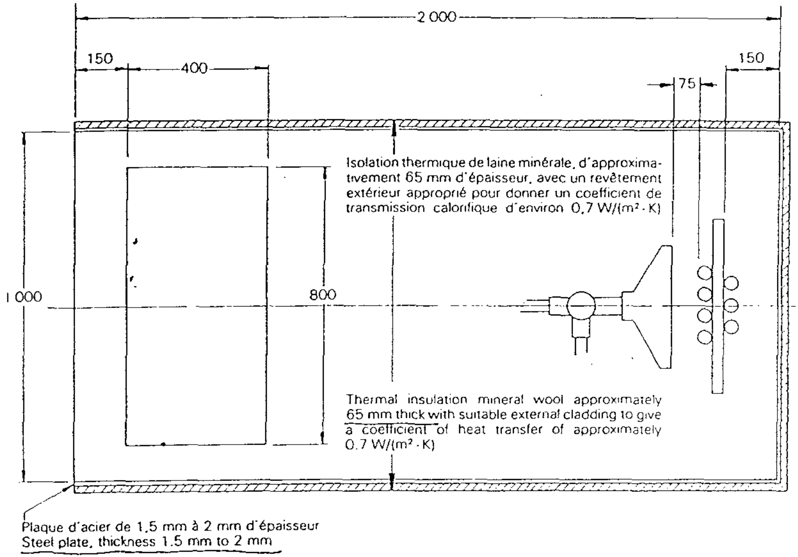
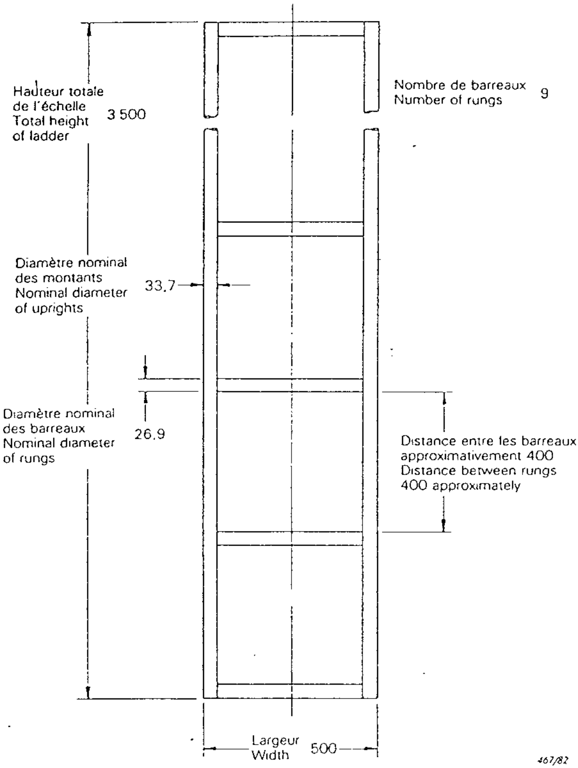


FIG. 1a. — Isolation thermique de l'arrière et des côtés de la chambre d'essai.
Thermal insulation of back and sides of the test chamber.

Dimensions en millimètres — *Dimensions in millimetres*



Note. — Les dimensions des tubes doivent être conformes à la Norme ISO 65.
Tube dimensions shall be in accordance with ISO Standard 65.

FIG. 2. — Echelle de câbles pour l'essai.
Cable test ladder.

Dimensions en millimètres *Dimensions in millimetres*

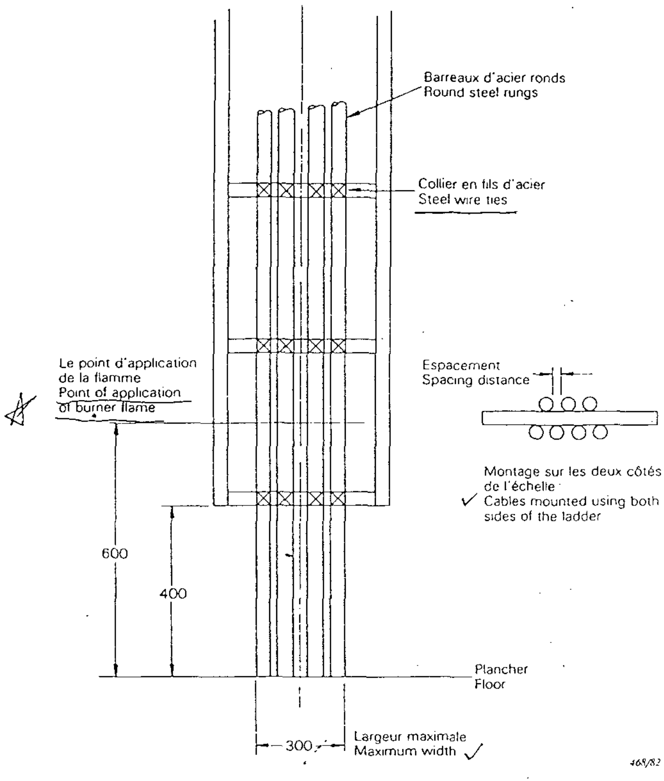
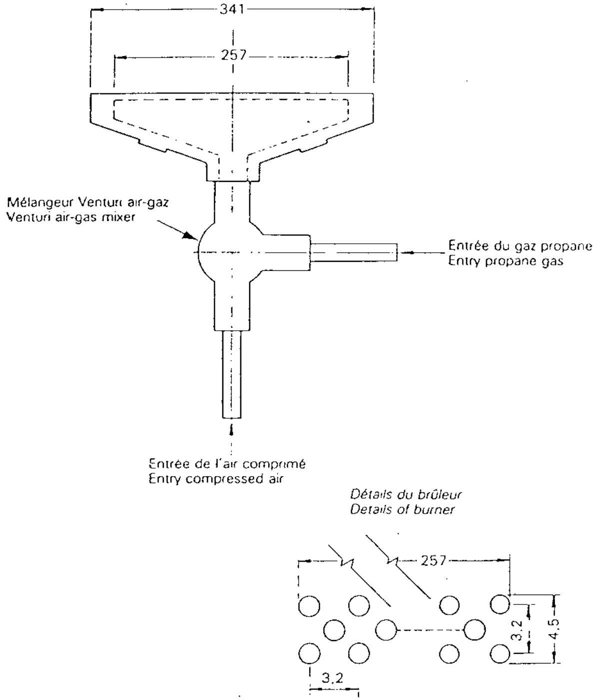


FIG. 3. — Disposition des échantillons sur l'échelle.
Arrangement of test samples on ladder.

Dimensions en millimètres *Dimensions in millimetres*



242 trous ronds de 1,32 mm de diamètre placés en quinconce à 3,2 mm de distance sur trois rangées de 81, 80 et 81 trous sur l'avant du brûleur.

242 round holes 1.32 mm in diameter on 3.2 mm centres, staggered in three rows of 81 and 80 and 81, and centred on face of the burner

Les valeurs sont approchées *Values are approximate*

FIG. 4. — Brûleurs.
Burner.

ANNEXE A

DÉTAILS DU BRÛLEUR NORMALISÉ

Un brûleur (numéro de catalogue IOL 11-55) et un mélangeur venturi (numéro de catalogue 14-18) satisfaisant aux prescriptions de l'article 6 peuvent être fournis par:

APPENDIX A

DETAILS OF STANDARD BURNER

A burner (catalogue number IOL 11-55) and venturi mixer (catalogue number 14-18) complying with the requirements of Clause 6 can be obtained from:

The American Gas Furnace Company
Spring Street
ELIZABETH
New Jersey 0721
Etats-Unis d'Amérique/United States of America

n° 1
Juillet 1984
à la

No. 1
July 1984
to

Publication 332-3

1982

Essais des câbles électriques soumis au feu

Troisième partie:
Essais sur câbles en nappes

Tests on electric cables under fire conditions

Part 3:
Tests on bunched wires or cables

Les modifications contenues dans le présent document ont été approuvées suivant la Règle des Six Mois.

Le projet de modifications, discuté par le Comité d'Etudes n° 20, fut diffusé en mars 1983 pour approbation suivant la Règle des Six Mois, sous forme de document 20(Bureau Central)150.

The amendments contained in this document have been approved under the Six Months' Rule.

The draft amendment, discussed by Technical Committee No. 20, was circulated for approval under the Six Months' Rule in March 1983, as Document 20(Central Office)150.

Prix
Price Fr.s. 6.—

Page 6

1. *Introduction*

Remplacer le texte de l'introduction par le suivant:

La première partie de la Publication 332 de la CEI: Essais des câbles électriques soumis au feu, spécifie une méthode d'essai pour les caractéristiques de propagation du feu pour un conducteur ou câble unique installé verticalement. On ne peut présumer que, parce qu'un conducteur ou câble répond aux prescriptions de la première partie, une nappe de conducteurs ou de câbles semblables se comportera de la même façon, parce que la propagation du feu le long d'une nappe de câbles dépend de nombreux facteurs, tels que:

a) Le volume de matériau combustible exposé au feu et aux flammes éventuellement produites par la combustion des câbles.

b) La configuration géométrique des câbles et leur situation par rapport à une enceinte quelconque.

c) La température à laquelle il est possible d'enflammer les gaz émis par les câbles en essai.

d) La quantité de gaz combustible dégagée par les câbles pour une élévation de température donnée.

e) Le volume d'air passant par l'installation des câbles.

Tout ce qui précède met en évidence que les câbles en essai peuvent s'enflammer quand ils sont pris dans un incendie.

Le rapport donne les détails d'un essai où un certain nombre de câbles sont installés en nappe pour simuler une installation théorique. Il y a trois catégories de volume selon les quantités de matériau combustible par mètre de câble soumis à l'essai.

L'essai est essentiellement conçu pour classer les câbles et donner aux utilisateurs un guide sur les caractéristiques relatives de propagation des trois catégories dans les conditions définies de l'essai. En conséquence cette méthode d'essai ne peut donner une estimation complète des risques d'incendie dans tous les cas pouvant se présenter dans une installation particulière et on doit prêter une attention constante aux facteurs *a)* à *e)* mentionnés ci-dessus.

Page 7

1. *Introduction*

Replace the text of the introduction by the following:

"Part 1 of IEC Publication 332: Tests on Electric Cables under Fire Conditions, specifies a method of test for flame propagation characteristics for a single vertical insulated wire or cable. It cannot be assumed that, because a cable or wire meets the requirements of Part 1, a bunch of similar cables or wires will behave in a similar manner. This is because the propagation of flame along a bunch of cables depends on a number of features, such as:

a) The volume of combustible material exposed to the fire and to any flame which may be produced by the combustion of the cables.

b) The geometrical configuration of the cables and their relationship to any enclosure.

c) The temperature at which it is possible to ignite any gases emitted from the cables.

d) The quantity of combustible gas released from the cables for a given temperature rise.

e) The volume of air passing through the cable installation.

All of the foregoing assume that the cables are able to be ignited when involved in a fire.

The report gives details for a test where a number of cables are bunched together to simulate a theoretical installation. There are three categories of varying volumes of combustible material per metre of cable subjected to the test.

The test is primarily intended to classify cables and to give a guide to users on the relative merits of the three categories from the aspect of fire propagation under the conditions defined in the test. Consequently, this test method cannot provide a full assessment of fire risk under all of the conditions which may apply to a particular installation and a constant awareness of the above factors *a)* to *e)* should be maintained.

n° 2		No. 2
Mars 1987 incorporant la Modification n° 1 (juillet 1984) à la	Publication 332-3 1982	March 1987 incorporating Amendment No. 1 (July 1984) to

---

Essais des câbles électriques soumis au feu

Troisième partie:

Essais sur câbles en nappes

Tests on electric cables under fire conditions

Part 3:

Tests on bunched wires or cables

Code prix
Price code 1

Pour prix, voir catalogue en vigueur
For price, see current catalogue

PREFACE

La présente modification (comprenant la modification n° 1 (1984)) a été établie par le Comité d'Etudes n° 20 de la CEI: Câbles électriques.

Le texte de cette modification n° 2 est issu des documents suivants:

Règle des Six Mois	Rapport de vote	Procédure des Deux Mois	Rapport de vote
20(BC)161	20(BC)172	20(BC)173	20(BC)174

Les rapports de vote indiqués dans le tableau ci-dessus donnent toute information sur le vote ayant abouti à l'approbation de cette modification.

Une ligne verticale dans la marge différencie le texte de la modification n° 2.

Page 6

1. Introduction

Remplacer le texte de l'introduction par le suivant:

La première partie de la Publication 332 de la CEI: Essais des câbles électriques soumis au feu, spécifie une méthode d'essai pour les caractéristiques de propagation du feu pour un conducteur ou câble unique installé verticalement. On ne peut présumer que, parce qu'un conducteur ou câble répond aux prescriptions de la première partie, une nappe de conducteurs ou de câbles semblables se comportera de la même façon, parce que la propagation du feu le long d'une nappe de câbles dépend de nombreux facteurs, tels que:

a) Le volume de matériau combustible exposé au feu et aux flammes éventuellement produites par la combustion des câbles.

b) La configuration géométrique des câbles et leur situation par rapport à une enceinte quelconque.

c) La température à laquelle il est possible d'enflammer les gaz émis par les câbles en essai.

d) La quantité de gaz combustible dégagée par les câbles pour une élévation de température donnée.

e) Le volume d'air passant par l'installation des câbles.

Tout ce qui précède met en évidence que les câbles en essai peuvent s'enflammer quand ils sont pris dans un incendie.

PREFACE

This amendment (incorporating Amendment No. 1 (1984)) has been prepared by IEC Technical Committee No. 20: Electric Cables.

The text of this Amendment No. 2 is based on the following documents:

Six Months' Rule	Report on Voting	Two Months' Procedure	Report on Voting
20(CO)161	20(CO)172	20(CO)173	20(CO)174

Full information on the voting for the approval of this amendment can be found in the Voting Reports indicated in the above table.

The text of Amendment No. 2 can be distinguished by a vertical line in the margin.

Page 7

1. Introduction

Replace the text of the introduction by the following:

Part 1 of IEC Publication 332: Tests on Electric Cables under Fire Conditions, specifies a method of test for flame propagation characteristics for a single vertical insulated wire or cable. It cannot be assumed that, because a cable or wire meets the requirements of Part 1, a bunch of similar cables or wires will behave in a similar manner. This is because the propagation of flame along a bunch of cables depends on a number of features, such as:

a) The volume of combustible material exposed to the fire and to any flame which may be produced by the combustion of the cables.

b) The geometrical configuration of the cables and their relationship to any enclosure.

c) The temperature at which it is possible to ignite any gases emitted from the cables.

d) The quantity of combustible gas released from the cables for a given temperature rise.

e) The volume of air passing through the cable installation.

All of the foregoing assume that the cables are able to be ignited when involved in a fire.

Le rapport donne les détails d'un essai où un certain nombre de câbles sont installés en nappe pour simuler une installation théorique. Il y a trois catégories de volume selon les quantités de matériau combustible par mètre de câble soumis à l'essai.

L'essai est essentiellement conçu pour classer les câbles et donner aux utilisateurs un guide sur les caractéristiques relatives de propagation des trois catégories dans les conditions définies de l'essai. En conséquence cette méthode d'essai ne peut donner une estimation complète des risques d'incendie dans tous les cas pouvant se présenter dans une installation particulière et il convient de prêter une attention constante aux facteurs *a)* à *e)* mentionnés ci-dessus.

Page 10

8. Procédure d'essai

Insérer le nouveau paragraphe 8.2 suivant:

8.2 *Mesure de l'indice d'oxygène*

L'indice d'oxygène de tous les matériaux combustibles intervenant pour plus de 5% en masse doit être mesuré conformément à la procédure donnée dans l'annexe B. Les valeurs doivent être notées et peuvent être utilisées comme base pour le contrôle de toute production ultérieure et pour s'assurer de sa conformité avec cet essai de type. Il n'y a pas de corrélation entre les valeurs de l'indice d'oxygène et la propagation de la flamme le long d'un câble soumis au feu.

Renuméroter les paragraphes 8.2 et 8.3, respectivement en 8.3 et 8.4.

The report gives details for a test where a number of cables are bunched together to simulate a theoretical installation. There are three categories of varying volumes of combustible material per metre of cable subjected to the test.

The test is primarily intended to classify cables and to give a guide to users on the relative merits of the three categories from the aspect of fire propagation under the conditions defined in the test. Consequently, this test method cannot provide a full assessment of fire risk under all of the conditions which may apply to a particular installation and a constant awareness of the above factors *a)* to *e)* should be maintained.

Page 11

8. Test procedure

Insert a new Sub-clause 8.2 as follows:

8.2 *Measurement of oxygen index*

The oxygen index of all combustible materials contributing more than 5% by mass shall be measured in accordance with the procedure given in Appendix B. The values shall be recorded and may be used as a basis for quality control of any subsequent production to ensure compliance with this type test. Correlation of the oxygen index values with the propagation along the cable in fire conditions is not implied.

Renumber Sub-clauses 8.2 and 8.3, as 8.3 and 8.4 respectively.

Après la page 17

Introduire la nouvelle annexe B:

ANNEXE B

Méthode de mesure de l'indice d'oxygène pour les câbles électriques

B1. Généralités

Cette méthode décrit une procédure pour la détermination de l'inflammabilité relative des matériaux prélevés sur câbles électriques ou utilisés dans les câbles électriques, fondée sur la mesure de la concentration minimale en oxygène d'un mélange oxygène-azote permettant juste de maintenir la combustion avec flamme. Cette méthode est actuellement limitée aux matériaux dont les échantillons sont assez rigides pour rester droits pendant l'essai.

B2. Définition

Indice d'oxygène: Concentration minimale en oxygène, exprimée en pourcentage en volume, d'un mélange oxygène-azote permettant juste de maintenir la combustion dans les conditions opératoires ci-dessous.

B3. Principe de la méthode

On mesure la concentration minimale d'oxygène dans un mélange oxygène-azote qui maintient la combustion dans les conditions d'équilibre d'une «bougie se consumant». L'équilibre est établi lorsque la chaleur dégagée par la combustion de l'éprouvette est compensée par les pertes de chaleur dues à l'environnement.

B4. Appareillage

B4.1 La colonne d'essai comporte un tube en verre résistant à la chaleur, de l'un des types indiqués ci-dessous. La base de la colonne contient un matériau non combustible assurant une bonne répartition du mélange de gaz entrant par cette base. Une toile métallique est placée au-dessus de ce matériau non combustible pour recueillir les particules et maintenir propre la base de la colonne.

La température du mélange de gaz entrant dans la colonne doit être maintenue à 23 ± 2 °C par des moyens appropriés. Si ces moyens exigent une sonde intérieure, sa position et ses dimensions doivent perturber le moins possible la circulation du mélange de gaz.

	Diamètre minimal intérieur	Hauteur		Diamètre de l'ouverture supérieure rétrécie	
		minimale	maximale	minimale	maximale
	(mm)	(mm)	(mm)	(mm)	(mm)
Colonne A)	75	450	-	75	-
Colonne B)	95	210	310	40	50

B4.2 Un chronomètre permettant de mesurer au moins 10 min avec une précision de 1 s.

After page 17

Insert new Appendix B:

APPENDIX B

Method of measurement of oxygen index for electric cables

B1. Scope

This method describes a procedure that examines the relative flammability of materials taken from or used in electric cables by measuring the minimum concentration of oxygen in a mixture of oxygen and nitrogen that will just support flaming combustion. This method is presently limited to the use of physically self-supporting test specimens.

B2. Definition

Oxygen index: The minimum concentration of oxygen, expressed as volume per cent, in a mixture of oxygen and nitrogen that will just support combustion of a material under the conditions of this method.

B3. Principle of method

The minimum concentration of oxygen in a mixture of oxygen and nitrogen that will just support combustion is measured under equilibrium conditions of "candle like" burning. The balance between the heat from the combustion of the specimen and the heat lost to the surroundings establishes the equilibrium.

B4. Apparatus

B4.1 The test column shall consist of a heat resistant glass tube of one of the types listed below. The bottom of the column or the base to which the tube is attached shall contain non-combustible material to mix and distribute evenly the gas mixture entering at this base. A wire screen shall be placed above the non-combustible material to catch falling fragments and aid in keeping the base of the column clean.

Means shall be provided for checking or ensuring that the temperature of the gas mixture entering the chimney is 23 ± 2 °C. If the means involves an internal probe, its position and profile shall be designed to minimize turbulence within the chimney.

	Minimum inside diameter	Height		Restricted upper opening diameter	
		minimum	maximum	minimum	maximum
	(mm)	(mm)	(mm)	(mm)	(mm)
Column A)	75	450	-	75	-
Column B)	95	210	310	40	50

B4.2 A suitable timer capable of indicating at least 10 min and accurate to 1 s.

B4.3 *Support d'éprouvette*

Tout petit dispositif permettant de maintenir l'éprouvette par sa base, en position verticale au centre de la colonne, est acceptable.

B4.4 *Sources de gaz*

Les mélanges de gaz nécessaires pour l'essai peuvent être réalisés à partir d'oxygène et/ou d'azote de grades commerciaux ou de grades meilleurs (pureté >98%) et/ou d'air propre (l'air contient 20,9% d'oxygène).

La teneur en humidité du mélange gazeux entrant dans la colonne doit être inférieure à 0,1% en masse.

Note.- On ne peut affirmer que les bouteilles d'oxygène ou d'azote du commerce contiennent toujours moins de 0,1% par masse d'eau, bien que les taux d'humidité annoncés soient habituellement de 0,003% à 0,01%. En particulier, si la bouteille a été remplie dans de mauvaises conditions, les dix derniers pour-cent de la bouteille peuvent contenir entre 0,1% et 0,5% par unité de masse d'eau, puisque la pression de gaz diminue en fonction de la pression de vapeur d'eau à la température ambiante. Aussi, la source de gaz devrait-elle comporter un dispositif de séchage, ou alors des règles visant à la mesure de l'humidité devraient-elles être établies.

B4.5 *Mesure de la concentration d'oxygène*

La concentration d'oxygène est mesurée par l'une des méthodes suivantes. En cas de contestation, la méthode i) doit être utilisée:

i) La concentration en oxygène du mélange de gaz est déterminée par la mesure du paramagnétisme de l'oxygène.

ii) Dispositifs de contrôle et de mesure des gaz. Des dispositifs de mesure et de contrôle sont utilisés pour mesurer et ajuster la composition du mélange de gaz dans la colonne pendant l'essai afin que la concentration en oxygène dans le mélange de gaz soit connue avec une précision de ±0,5% par unité de volume de mélange.

B4.6 *Source d'inflammation*

Le dispositif d'allumage consistera en une torche à gaz butane avec ses accessoires comme indiqué sur la figure B1, page 16. La longueur de la flamme sera d'environ 30 mm, mesurée dans l'air depuis le sommet de l'écran.

Note.- On peut utiliser un «Ronson Butane Blowtorch» avec un système de fixation «Stanton Redcroft» (pièce de rechange référence n° 9234).

B4.7 *Hotte d'extr. .tion*

Pour évacue. les fumées, la suie et les gaz toxiques, l'appareil est placé dans un endroit possédant un système d'extraction n'interférant pas sur les résultats d'essais.

B4.3 *Specimen holder*

Any small holding device that will support the specimen at its base and hold it vertically in the centre of the column is acceptable

B4.4 *Gas supplies*

The gas mixture required for test may be prepared using oxygen and/or nitrogen of commercial grades or better (>98% purity) and/or clean air as appropriate (air contains 20.9% oxygen).

The moisture content of the gas mixture entering the test chimney shall be less than 0.1% by mass.

Note.- It cannot be assumed that supplies of bottled oxygen or nitrogen will always contain less than 0.1% by mass of water, although moisture contents of 0.003% to 0.01% by mass are typical. In particular, if the bottle has been charged under adverse conditions, a supply drawn from the last 10% of the bottle may contain between 0.1% and 0.5% by mass of water as the gas pressure diminishes with respect to water vapour pressure at ambient temperatures. Hence the gas supply system should incorporate a drying device or provision should be made for measuring the moisture content.

B4.5 *Concentration of oxygen measurement*

The concentration of oxygen shall be measured by either of the following methods. In cases of dispute method i) shall be used:

i) The concentration of oxygen in the mixed gases shall be determined by measuring the paramagnetism of the oxygen.

ii) Gas measurement and control devices. Measuring and control devices shall be used which will measure and control the composition of the gas mixture in the test chimney so that the concentration of oxygen in the gas mixture is known to an accuracy of ±0.5% by volume of the mixture.

B4.6 *Ignition source*

The igniter should be a butane gas torch with attachments as shown in Figure B1, page 16. The flame length should be approximately 30 mm measured in air from the top of the shield.

Note.- A suitable ignition source is a "Ronson Butane Blowtorch" with a "Stanton Redcroft" attachment (spares reference No. 9234).

B4.7 *Extractor fan*

To ensure the removal of smoke, soot and toxic fumes the apparatus shall be sited in an area having efficient exhaust facilities that do not interfere with the test results.

B5. Eprouvettes

B5.1 Les éprouvettes ont des plaques rectangulaires de dimensions suivantes:

longueur = 70 mm à 150 mm,
largeur = 6,5 ± 0,5 mm,
épaisseur = 3,0 ± 0,5 mm.

B5.2 Les éprouvettes peuvent être moulées ou découpées et préparées à partir des constituants du câble à essayer. Quand cela n'est pas possible avec un câble contenant des matériaux vulcanisés, une plaque moulée et vulcanisée, préparée à partir du matériau du même lot de fabrication, est utilisée.

B5.3 Les faces des éprouvettes doivent être lisses, sans excroissance, sans bavure provenant de l'usinage et sans coulée de moulage.

B6. Mode opératoire

B6.1 Chaque éprouvette est marquée de deux lignes situées à 8 mm et 58 mm du sommet. Pour faciliter la lecture, les lignes sont tracées sur au moins deux faces adjacentes. Pour les éprouvettes blanches ou colorées, un stylo-bille ordinaire peut être utilisé. Sur les éprouvettes de couleur noir, il convient d'utiliser une encre contrastée. L'encre doit pouvoir sécher avant l'essai.

Placer l'éprouvette en position verticale approximativement au centre de la colonne de façon que son sommet se trouve à au moins 100 mm au-dessous de l'ouverture de la colonne.

Si une colonne à ouverture rétrécie est utilisée, comme indiqué au paragraphe B4.1, le sommet de l'éprouvette doit être à 40 mm au moins de l'ouverture.

B6.2 L'essai doit être effectué à 23 ± 2 °C et les éprouvettes doivent être préconditionnées à 23 ± 2 °C et dans une humidité relative de 50 ± 5% pendant 24 h.

B6.3 Injecter la concentration initiale souhaitée en oxygène dans la colonne. La vitesse du gaz dans la colonne doit être de 40 ± 10 mm/s, calculée dans les conditions du laboratoire, à partir du débit total du gaz en millimètres cubes par seconde divisé par la section de la colonne en millimètres carrés.

B6.4 Purger le système par circulation de gaz pendant au moins 30 s.

B6.5 Appliquer la source d'inflammation de telle manière que 6 mm (approximativement) de la flamme touche le sommet de l'éprouvette. A mesure que l'échantillon brûle, la source d'inflammation est déplacée afin que la flamme touche en permanence le sommet de l'éprouvette sur 6 mm. La concentration d'oxygène ne doit pas être modifiée après l'inflammation de l'éprouvette.

La source d'inflammation est appliquée jusqu'à ce que l'éprouvette brûle au niveau de la ligne des 8 mm. Elle est alors retirée et le chronomètre mis en route.

B5. Test specimen

B5.1 The test specimens are flat rectangular sheets having the following dimensions:

length	= 70 mm to 150 mm,
width	= 6.5 ± 0.5 mm,
thickness	= 3.0 ± 0.5 mm.

B5.2 The specimens may be obtained by moulding, cutting or machining from those cable constituents to be tested. Where this is not possible with a cable containing vulcanised material, a moulded and vulcanised slab prepared from material sampled during manufacture of the same production batch shall be used.

B5.3 The edges of the test pieces shall be smooth and free from fuzz or burrs of material from machining or peripheral flash from moulding.

B6. Procedure

B6.1 Each specimen shall be marked with two lines 8 mm and 58 mm from the top. For ease of viewing each line should be marked at least on two adjacent faces. For white or coloured specimens an ordinary ball-point pen can be used. For black specimens a contrasting ink should be used. The ink shall be allowed to dry before the test.

Clamp the specimen in the holder vertically in the approximate centre of the column with the top of the specimen at least 100 mm below the top of the open column.

If a restricted opening column is used as specified in Sub-clause B4.1 the top of the specimen shall be at least 40 mm below the opening.

B6.2 The test shall be carried out at 23 ± 2 °C and the samples shall be preconditioned at 23 ± 2 °C and at a relative humidity of 50 ± 5% for 24 h.

B6.3 Set the desired initial concentration of oxygen flowing through the column. The gas flow rate in the column shall be 40 ± 10 mm/s as calculated at laboratory conditions from the total flow of gas in cubic millimetres per second divided by the area of the column in square millimetres.

B6.4 Allow the gas to flow for at least 30 s to purge the system.

B6.5 Apply the ignition source so that 6 mm (approximately) of the flame shall impinge on the top of the specimen. As the specimen burns the ignition source shall be lowered to maintain the flame impingement of 6 mm approximately. The oxygen concentration shall not be adjusted after lighting the test piece.

The ignition flame shall be applied until the specimen has burnt down to the 8 mm line. It shall then be removed and timing commenced.

B6.6 i) Si l'éprouvette brûle pendant 3 min ou plus, ou sur une longueur de 50 mm ou plus, l'éprouvette est éteinte et la concentration est notée pour un temps ≥ 3 *min ou pour une longueur* ≥ 50 *mm*.

ii) Si l'éprouvette s'arrête de brûler avant 3 min et avant 50 mm, la concentration en oxygène est considérée comme trop basse. Le temps d'extinction est noté.

B6.7 *Placer* une nouvelle éprouvette (une éprouvette peut être *réutilisée si elle* est refroidie et si la partie brûlée est enlevée, dans la mesure où elle reste conforme aux paragraphes B5.2 et B6.2).

Ajuster la concentration en oxygène en fonction des résultats obtenus au paragraphe B6.6. Répéter l'essai selon la procédure des paragraphes B6.4 et B6.6.

B6.8 On poursuit les essais selon le paragraphe B6.7 avec un essai seulement pour chaque concentration d'oxygène jusqu'à obtenir deux concentrations qui satisfont aux conditions *a)*, *b)* et *c)* données ci-dessous:

a) la première concentration est celle pour laquelle l'éprouvette brûle pendant 3 min au moins ou sur une longueur de 50 mm au moins;

b) la deuxième concentration est celle pour laquelle l'éprouvette s'éteint d'elle-même en moins de 3 min et brûle sur une longueur inférieure à 50 mm;

c) le nombre exprimant la différence entre les pourcentages de concentration d'oxygène trouvés aux points *a)* et *b)* ne doit pas dépasser 0,25.

La concentration en oxygène correspondant au point *a)* est considérée comme l'indice d'oxygène approximatif à ce stade de l'essai.

B6.9 Des essais de confirmation sont ensuite effectués en utilisant les critères suivants:

A chaque concentration d'oxygène essayée, le résultat majoritaire de trois déterminations est retenu comme le résultat pour cette concentration (les résultats des séries originelles, obtenus au paragraphe B6.8 sont inclus).

La première concentration essayée est, par exemple, l'indice d'oxygène approximatif obtenu au paragraphe B6.8. Les essais sont poursuivis par paliers n'excédant pas ±0,25% de concentration d'oxygène vers le haut ou vers le bas selon le résultat majoritaire à ce stade de la détermination.

Quand les résultats majoritaires obtenus sont conformes aux dispositions des points *a)*, *b)* et *c)* du paragraphe B6.8, l'essai est arrêté.

Le résultat majoritaire correspondant au point *a)* du paragraphe B6.8 est considéré comme *l'indice d'oxygène absolu du matériau en essai*.

B6.6 i) If the specimen burns for 3 min, or longer, or for a length of 50 mm or longer, the specimen shall be extinguished and the concentration shall be recorded at or after 3 min or at or after 50 mm.

ii) If the specimen stops burning before 3 min and before 50 mm the concentration of oxygen shall be taken as being low. The extinguishing time shall be recorded.

B6.7 Insert a new specimen. (A specimen may be re-used if cooled and the burned end cut off, provided it complies with Sub-clauses B5.2 and B6.2).

Adjust the oxygen concentration based on the results of B6.6. Repeat test procedure of Sub-clauses B6.4 to B6.6.

B6.8 Continue the test according to Sub-clause B6.7 with one test only at each oxygen concentration until the results obtain two concentrations which satisfy the conditions given in Items *a)*, *b)* and *c)* below:

a) the first oxygen concentration gives the result that the specimen burns for at least 3 min or along a length of at least 50 mm;

b) the second oxygen concentration gives the result that the specimen extinguishes itself within less than 3 min and burns along a length of less than 50 mm;

c) the numerical difference between the percent oxygen concentration found in Items *a)* and *b)* shall not exceed 0.25.

The oxygen concentration corresponding to Item *a)* above is taken as the approximate oxygen index value at this stage.

B6.9 Confirmatory tests shall now be carried out using the following criteria:

At each oxygen concentration tried, the majority result of three determinations shall be recorded as the result for that concentration. (Results from the original series, obtained in Sub-clause B6.8 shall be included.)

The first concentration tried should be the approximate oxygen index value obtained in Sub-clause B6.8. Tests shall then be continued in steps not exceeding ±0.25% oxygen concentration either up or down depending on the majority result at this approximate oxygen index value.

When majority results are obtained which satisfy Items *a)*, *b)* and *c)* of Sub-clause B6.8, testing shall be discontinued.

The majority result corresponding to Item *a)* of Sub-clause B6.8 is taken as the absolute oxygen index value of the material under test.

B7. Procès-verbal d'essai

Le procès-verbal d'essai doit contenir:

i) la valeur de l'indice d'oxygène absolu,

ii) une description des comportements inhabituels observés pendant l'essai.

B8. Confirmation de l'indice d'oxygène minimal

La procédure qui vient d'être décrite permet la détermination de la valeur de l'indice d'oxygène absolu. Quand il est demandé de vérifier que l'indice d'oxygène est au-dessus d'une valeur minimale spécifiée, on adopte la procédure décrite aux paragraphes B6.3, B6.4 et B6.5 et l'exigence est satisfaite si le point ii) du paragraphe B6.6 est applicable.

Notes 1.- Colonne d'essai

Il a été démontré que si le verre de la colonne d'essai devient trop chaud, un indice d'oxygène plus faible peut être mesuré. Il est donc suggéré d'utiliser deux colonnes d'essai.

2.- Etalonnage

On utilisera des méthodes adaptées et un équipement fiable.

3.- Débitmètres

Si les débitmètres utilisés sont étalonnés pour l'air, des corrections seront faites pour tenir compte de la densité des gaz.

B7. Report

The report shall include the following:

i) the absolute oxygen index value,

ii) a description of any unusual behaviour observed during test.

B8. Confirmation of minimum oxygen index

The procedure which has been described, is for determining the absolute value of the oxygen index. Where it is required to check that the oxygen index is above a minimum specified value, the procedure outlined in Sub-clauses B6.3, B6.4 and B6.5 shall be adopted and the requirement is satisfied if Item ii) of Sub-clause B6.6 is applicable.

Notes 1.- *Test column*

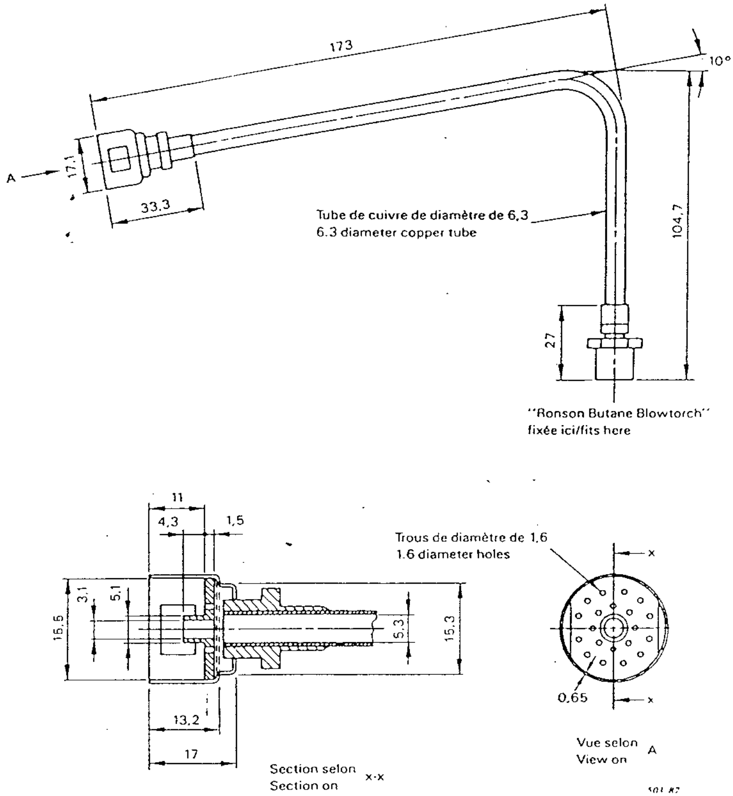
It has been found that if the glass test column becomes unduly hot, lower oxygen index values may be obtained. It is therefore suggested that two test columns should be available for use.

2.- *Calibration*

Suitable methods of calibration and degree of accuracy of equipment are to be incorporated in due course.

3.- *Flowmeters*

If flowmeters are used which are calibrated for air, corrections should be made for the densities of the gases.



Dimensions en millimètres

Dimensions in millimetres

Figure B1