TEMPORARY FIRE SEALING OF PENETRATIONS ON TFTR

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ABSTRACT

The radiation shielding provided for TFTR for D-D and D-T operation will be penetrated by numerous electrical and mechanical services. Eventually, these penetrations will have to be sealed to provide the required fire resistance, tritium sealability, pressure integrity and radiation attenuation. For the initial hydrogen operation, however, fire sealing of the penetrations in the walls and floor is the primary concern. This report provides a discussion of the required and desirable properties of a temporary seal which can be used to seal these penetrations for the hydrogen operation and then subsequently be removed and replaced as required for the D-D and D-T operations. Several candidate designs are discussed and evaluated and recommendations are made for specific applications.

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INTRODUCTION

The TFTR device will probably begin initial hydrogen operation in 1982. This will be followed by deuterium-deuterium (D-D) plasmas in approximately 1983 and deuterium-tritium (D-T) plasmas approximately a year later. The primary sources of radiation during the TFTR operation will be x rays and the neutrons from the fusion reactions. The x rays will be produced in all phases of operation as a result of charged particle motion in the plasmas. The neutrons will emerge only in the D-D and D-T operations. As a result, radiation shielding of particular significance will only have to be provided for the latter two stages. This radiation shielding will be penetrated by numerous electrical and mechanical services and, eventually, means will have to be provided to seal these penetrations to provide the required fire resistance, tritium sealability, pressure integrity, and radiation attenuation. These penetration seals are the topic of another report [1]. For the hydrogen operation, fire sealing of the penetrations in the walls and floor is the only concern.

Need for Fire Sealing

On March 22, 1975, a candle flame, used to test air leaks, ignited a polyurethane foam fire-stop situated in the wall between the cable spreading room and the reactor building of the Browns Ferry, Alabama, nuclear power plant. The burning fire-stop in turn ignited highly combustible polyethylene insulated/polyvinyl chloride jacketed (PE/PVC) cables in multiple, unprotected trays in the reactor building. Smoke, inaccessiblity, improper fire fighting techniques, lack of fire protection, and eventual loss of lighting and ventilation permitted the cable fire to burn and spread unchecked for almost seven hours. The cable fire was not extinguished until lighting was restored and hose streams were used to combat the fire. The property damage was estimated at $10,000,000 and the loss due to business interruption was estimated at $200,000,000 [2].

The concern is not only with nuclear power plants. Also in 1975, there was a fire in the New York Telephone Exchange that spread through unsealed penetrations, with the result that some 78,000 phone circuits were rendered inoperative for weeks and the damage could not be estimated. Another fire in New York's World Trade Center in 1976 was essentially confined by the fire walls and floors, with major damage limited to two floors. However, some smoke and fire made their way to floors above and below the fire through unsealed electrical and telephone penetration shafts. The damage was more than $1,000,000 [3].

Standard Fire Resistance Ratings

The standard fire tests are contained in ASTM E119 [4], UL-263 [5], ANSI A2.1 [6], and NFPA 251 [7]. Ratings are established by testing in accordance with the approved standard, and are listed as the lowest time segment during which the tested unit withstands the fire exposure, prior to reaching the failure point. Ratings are published fo: 3/4 hour, one hour, one and one half hours, two hours, three hours, and four hours. The fire exposure test is performed in an enclosed (furnace) environment. Starting at room temperature, the heat is raised gradually on a controlled basis to conform with the standard fire curve shown in tabular form in Table 1 below.

Table 1

Standard Fire Curve

Temperature (°F)	Time
1000	5 minutes
1300	10 minutes
1550	30 minutes
1700	1 hour
1850	2 hours
2000	4 hours
2300	8 hours or more

Part I of this report provides a discussion of the desirable properties of a temporary seal which can be used to seal the penetrations in the walls and floor for the hydrogen operation and then subsequently be removed and replaced for the D-D and D-T operations. These properties are desirable in the sense that they are over and above the mandatory required fire rating. Several candidate designs are discussed in Part II. These are evaluated in terms of their ability to meet the desired properties in Part III. Alternate designs are recommended for specific applications in Part IV.

I. DESIRABLE PROPERTIES

Due to the temporary nature of the seals, ease of application and removal must be considered as the prime criterion to be used in evaluating any design which can provide the required fire rating. Ease of application would tend to favor those designs using materials applied as a liquid, powder, foam, or a paste as opposed to a solid which would have to be machined to conform to the contours of the piping, tubing or electrical cable. Ease of removal would weigh heavily in favor of those designs which could be mechanically unbolted to remove the seal. Lt s acceptable would be designs requiring mechanical chipping or scraping of the sealant or chemically dissolving it.

As can be inferred from the above, conformability of the seal to the electrical or mechanical services penetrating the floor or walls is also important. The seal should also be able to accommodate minor variations in eccentricity, etc., of the penetration sleeve but, at the same time, should fill the cavity as completely as possible.

The seal design chosen should be as lightweight as possible, to avoid undue stresses on the supporting structure and to avoid crushing thin wall conduit, etc.

The seal design should also provide good heat insulation properties to prevent a fire occurring on one side of the barrier causing an undue temperature rise on the other side. The thermal conductivity of the material is a measure of the rate of heat transmission through it. Thus, the thermal conductivity should be low. This property increases with increased bulk density for foams and powders and hence is decreased with increasing porosity. There is a limit to how low the thermal conductivity can be. Otherwise, power cables can develop hot spots at the insulation if the insulation is too effective. This would then require cable derating.

In addition to preventing the flow of heat, the seal design should provide high resistance to flame spread and minimum fuel contribution and smoke density. These parameters are usually determined by means of a standarized test, ASTM E84 [8]. The values are reported as compared to red oak flooring.

The seal design chosen should be chemically inert, i.e., it should not be dissolved or otherwise lose its effectiveness by exposure to a leaking process pipe, the air, etc. In addition, the seal design should be noncorrosive to process pipes, electrical cables, and structural materials used in the walls or floor being penetrated. This noncorrosivity applies not only to the seal design itself but also to any solvents, etc. which subsequently may be used to remove it.

IIa. CANDIDATE DESIGNS - U. L. LISTED

The candidate designs discussed in this section are those listed in Underwriter's Laboratories, Inc. (U.L.) Building Materials Directory [9]. It should be noted that U.L. never approves any manufacturer's product. U.L.'s function is to test and list the findings of their tests to provide the data that a designer can use in his/her selection of a fireproofing product or design. It is the engineer's responsibility to establish a credible design based on the test data available, and to obtain the approval of the responsible code or insurance authority prior to such use. Interpolations and extrapolations, if based on sound and valid reasoning, can offer a designer opportunities that are not available to those who remain inflexibly tied to U.L. listings. No one has yet tested every conceivable product use, or building assembly design. Therefore, a review of proposed applications is an important function of the enforcing authority. The U.L. listed designs discussed here are of two types, (1) wall or floor opening protective, multiple cable *devices* and (2) wall or floor opening protective, multiple cable *systems*.

Multiple Cable Devices

Wall opening protective, multiple cable devices are designed for the protection of openings in brick or concrete block masonry walls against fire passage when electrical cables and conduits need to penetrate through such walls. Floor opening protective, multiple cable devices are designed for the protection of openings in solid concrete floor slabs against fire passage when electrical cables and conduits need to penetrate through such floors. The hourly fire rating for the device indicates the duration of fire exposure to the standarized fire test. The unexposed surface temperatures of the devices and the temperatures of the cables and conduits protruding from the unexposed surface are not considered by U.L. nor is the structural fire performance of load bearing walls or floors incorporating such devices. The devices are subjected only to the standard time-temperature fire exposure as described in UL-263 [5]. The wall or floor opening protective, multiple cable devices are intended to be installed in accordance with the appropriate method described in the packaged installation instructions. The local authorities having jurisdiction should be consulted in all cases as to the particular requirements covering the installation and use of these devices.

Cable characteristics such as size, number of conductors, insulation types, and jacket types may have a significant effect on the fire retardent performance of the devices. The cable and conduit types and the percent cable fill with which the devices have been classified for use are described in the individual classification report of the device as prepared by U.L.

However, some general guidance is available [10]. As a result of the fires discussed in the introduction and other numerous, less publicized fires, the Industrial Risk Insurers (IRI) joined with the American Nuclear Insurers in organizing an industry sponsored, two phase, multi-year, fire test program to study the inherent fire hazard of grouped electrical cables. This program was conducted at U.L. during 1975-1978.

Phase I explored the effects of ignition source intensity and flame size on the fire propagation behavior of various cable constructions. To accomplish this, six 16 foot lengths of cable, arranged in a single layer in a

16 foot high open ladder tray, were exposed to gas burners rated at 70,000 BTU/hour, 210,000 BTU/hour, and 400,000 BTU/hour. Eight cable constructions were tested with two tests conducted for each of the three exposure intensities. After the 48 tests in Phase I were concluded, IRI felt that the 210,000 BTU/hour exposure provided the most conclusive differentiation of the fire propagating characteristics of various cable insulations. This is in contrast to the 70,000 BTU/hour burner used in the Institute of Electrical and Electronics Engineers (IEEE) Standard 383 [11] and U.L. Standards 83 [12] and 1277 [13].

Phase II extended the research effort to evaluate the relationships and effects of cable tray fill, burner intensity and cable construction on the fire propagation behavior of cables in cable trays. The cable tray loading or fill proved to be the dominant factor in this series of tests, and, once again, the 210,000 BTU/hour gas burner exposure (in comparison with 70,000 and 400,000) appeared to be more discriminatory of the various cable constructions tested.

As a result of this research, IRI feels that cables qualified by the 210,000 BTU/hour gas burner exposure are preferred over those listed on the basis of U.L. Standards 83 and 1277 which use a 70,000 BTU/hour burner. At present, U. L. lists Type TC cable that meets the flame test requirements of IEEE Standard 383. Cables so listed are an improvement over those with more highly combustible insulations. However, IRI feels that if higher rated (210,000 BTU/hour) cables are installed, less restrictive fixed fire protection requirements may be justified in various applications.

The value of using highly flame retardant cables is illustrated in Table 2 and 3 where the tentative IRI protection recommendations are compared for non-qualified cable constructions and those that pass the 210,000 BTU/hour burner test. In actual practice, the selection process is also influenced by how extensive the cable runs are and their overall importance to the facility. As a result, these tables should be considered only for general situations. Specific selections will vary based on a number of factors pertinent to the individual application.

The following is a description of how to use the tables. First, determine which table to use. Table 2 is for horizontal trays and Table 3 is for vertical trays. Next, choose the proper series of columns for either sprinklered or non-sprinklered areas. Within these series of columns, choose the column for the appropriate number of layers of cable trays. When the proper column has been located, read down it to determine what FIRE PROTECTION measure is recommended. If the cable does not meet IEEE Standard No. 383, (+), then it should have an approved cable coating. If it passes the 210,000 BTU/hour burner test (*), then no protection is required. FIRE DETECTION and FIRE BREAK information can be determined in the same way. Installations involving U.L. listed TC cable may often warrant more protection than that shown for the 210,000 BTU/hour rated cables.

Table 2

Protection Recommendations for Horizontal Trays

Layers of Cable Trays	Sprinklered Areas 1	Sprinklered Areas 2 or 3	Sprinklered Areas 4+	Non-sprinklered Areas 1	Non-sprinklered Areas 2 or 3	Non-sprinklered Areas 4+
FIRE PROTECTION						
Water spray sprinklers per NFPA 15			†			†*
Approved cable coating		†	*	†	†	
Single line of directional sprinklers					†	
No protection required	†*	*		*	*	
FIRE DETECTION						
Thermal wire in trays			†			
Products of combustion						
Photo-electric	†	†*	*	†*	*	†*
No detection required	*				†	
FIRE BREAKS						
15-ft. intervals					*	
20-ft. intervals						
25-ft. intervals	†	*		*		
50-ft. intervals	*		†			†
No fire breaks required		†	*	†	†	*

Table Legend

† cable not meeting flame test requirements of IEEE Standard No. 383

* cable passing 210,000 BTU/hour burner flame test

Table 3

Protection Recommendations for Vertical Trays

	Sprinklered Areas			Non-Sprinklered Areas		
Layers of Cable Trays	1	2 or 3	4+	1	2 or 3	4+
FIRE PROTECTION						
Water spray sprinklers per NFPA 15			†			†*
Approved cable coating		†	*	†	†	
Single line of directional sprinklers					†*	
No protection required	†*	*		*		
FIRE DETECTION						
Thermal wire in trays			†			†*
Products of combustion	†	†*	*	†*	†*	
Photo-electric						
No detection required	*					
FIRE BREAKS						
15-ft. intervals	†					
20-ft. intervals	*	*		*	*	
25-ft. intervals						†*
50-ft. intervals						
No fire breaks required		†	†*	†	†	

Table Legend

† cable not meeting flame test requirements of IEEE Standard No. 383

* cable passing 210,000 BTU/hour burner flame test

U.L. has listed wall or floor opening protective, multiple cable devices manufactured by two firms [9]. These are discussed individually in the paragraphs which follow.

Fire-Seal™ Fittings

The Fire-Seal™ fittings are manufactured by the O-Z/Gedney Company of Terryville, Connecticut, and have a 3 hour U.L. fire rating listing [14]. The Fire-Seal™ fittings employ a unique design to prevent the spread of fire or the products of combustion. The basic fitting consists of a thick elastomeric sealing ring placed between layers of an intumescent material and secured between two metal plates by socket head screws. It is shown pictorially in Figure 1. The complete assembly is drilled to accommodate the outside diameters of the cable, conduit or piping. When the fitting is in place and the screws are tightened, the elastomeric sealing ring is compressed between the metal plates and is forced against the hole in the concrete and also against the cable, conduit, and piping. During the early stages of a fire, the elastomeric ring seals off the cold smoke and toxic fumes. As the temperature increases, the intumescent material starts to expand and fills the voids left by destroyed cable insulation preventing the spread of fire and smoke.

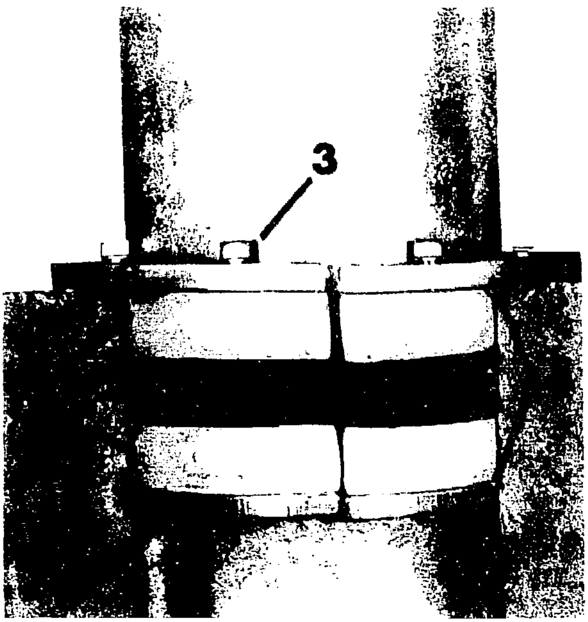


Fig. 1

(1) Intumescent material
(2) Elastomeric sealing ring
(3) Socket head cap screws
(4) Steel pressure discs

Four types of Fire-Seal™ fittings are listed by U.L. These are types CAFSF, CAFSI, CFSF, and CFSI. They may be used as either wall or floor penetration seals. The CAFS series (CAFSF and CAFSI) Fire-Seal™ fittings are used for sealing around cables in sleeves or core-drilled holes passing through fire rated walls and floors. The standard segmented version will allow installation around existing cables or conductors. Fire-Seal™ fittings have been tested for use with common cable insulations such as PVC, PE, TP, XLPE, etc. They are particularly attractive for armored cable installation. The CAFSF type is flanged; the CAFSI type is not and is intended for internal placement. The Fire-Seal™ fittings for cable are designed to accommodate a specific number and size of cables routed through a round opening such as a sleeve or core-drilled hole in concrete. Table 4 outlines the maximum cable diameters for segmented fittings. Higher fill capacities are available for non-segmented Fire-Seals™. For cables with diameters less than 0.186 inch, cables may be grouped and wrapped with a flame retardant tape and passed through a single hole up to 1.25 inch in diameter.

Table 4

Maximum Cable Diameters for Segmented Fire-Seals™

Catalog Number	Sleeve or Core Drilled Hole Dia.	Max. Diameter of Cable 1-Hole	2-Hole	3-Hole	4-Hole	5-Hole	6-Hole	7-Hole	8-Hole
CAFS-150	1-1/2"	.61	.47	.25					
CAFS-200	2"	1.05	.72	.65	.56				
CAFS-250	2-1/2"	1.38	.97	.87	.77	See Note for multiple cable applications			
CAFS-300	3"	1.90	1.22	1.12	.98				
CAFS-350	3-1/2"	2.13	1.38	1.25	1.10				
CAFS-400	4"	2.59	1.53	1.40	1.21	1.05			
CAFS-500	5"	3.50	1.94	1.77	1.54	1.34	1.17		
CAFS-600	6"	4.50	2.40	2.24	1.95	1.71	1.50		
CAFS-800	8"	6.63	3.44	3.16	2.78	2.45	2.17	1.93	1.74

NOTE TO TABLE

Any hole specified in table may be replaced with two or three holes providing that the sum of diameters is less than or equal to the maximum diameter shown. For example, a CAFSI-300 can accommodate 12 cables with each cable having a maximum diameter equal to 1/3 the value shown for 4 cables (0.325").

The CFS series (CFSF and CFSI) Fire-Seal™ fittings are for use with rigid conduit and piping passing through fire rated walls and floors. These fittings are segmented to allow installation after the conduit, EMT, IMC, or mechanical pipe is passed through the core-drilled or cast-in-place hole in the concrete. Series CFS Fire-Seal™ fittings are available with a flange (CFSF) or without a flange (CFSI). Table 5 provides the dimensions for the CFSF type of Fire-Seal™ fittings. Dimension "D" is the diameter of the flange and dimension "L" is the length of the fitting. Table 6 provides the dimensions for the CFSI type of Fire-Seal™ fittings. As above, dimension "L" is the length of the fitting.

Table 5

Dimensions for the Type CFSF Fire-Seals™

Catalog Number	Hole Size	Trade Size of Conduit or Pipe (In)*	Dim. "D"	Dim. "L"
CFSF-200-000	2"	Blank Plug †	3"	3"
CFSF-200-050, or -075	2"	1/2, 3/4		
CFSF-250-000	2-1/2"	Blank Plug †	3-1/2"	3"
CFSF-250-050, or -075, -100	2-1/2"	1/2, 3/4, 1		
CFSF-300-000	3"	Blank Plug †	4"	3"
CFSF-300-075, or -100, -125, -150	3"	3/4, 1, 1-1/4, 1-1/2		
CFSF-350-000	3-1/2"	Blank Plug †	4-1/2"	3-1/4"
CFSF-350-100, or -125, -150	3-1/2"	1, 1-1/4, 1-1/2		
CFSF-400-000	4"	Blank Plug †	5"	3-1/4"
CFSF-400-100, or -125, -150, -200	4"	1, 1-1/4, 1-1/2, 2		
CFSF-500-000	5"	Blank Plug †	6"	3-1/4"
CFSF-500-150, or -200, -250, -300	5"	1-1/2, 2, 2-1/2, 3		
CFSF-600-000	6"	Blank Plug †	7-1/8"	3-1/4"
CFSF-600-200 or -250,-300,-350,-400	6"	2, 2-1/2, 3, 3-1/2, 4		
CFSF-800-000	8"	Blank Plug †	9-1/4"	3-1/4"
CFSF-800-400, or -450, -500, -600	8"	4, 4-1/2, 5, 6		

* Because the O.D. of 2-1/2" thru 4" trade size rigid conduit is the same as EMT in these trade sizes, FIRE-SEAL fittings for rigid conduit in the 2-1/2" thru 4" trade sizes are also suitable for use with EMT. For EMT in trade sizes 1/2" thru 2", add suffix "E" to the catalog number. Example: CFSF-400-200-E.

† INTENDED FOR SEALING SPARE CONDUIT SLEEVES AND ABANDONED CONDUIT ONLY. DO NOT FIELD DRILL.

Table 6

Dimensions for Type CFSI Fire-Seals™

Catalog Number	Dim. "L"	Hole Size	Size of Conduit or Pipe (In)*
CFSI-200-000	3"	2"	Blank Plug †
CFSI-200-050, or -075	2"	1/2, 3/4	
CFSI-250-000	3"	2-1/2"	Blank Plug †
CFSI-250-050, or -075, -100	2-1/2"	1/2, 3/4, 1	
CFSI-300-000	3"	3"	Blank Plug †
CFSI-300-075, or -100, -125, -150	3"	3/4, 1, 1-1/4, 1-1/2	
CFSI-350-000	3-1/4"	3-1/2"	Blank Plug †
CFSI-350-100, or -125, -150	3-1/2"	1, 1-1/4, 1-1/2	
CFSI-400-000	3-1/4"	4"	Blank Plug †
CFSI-400-100, or -125, -150, -200	4"	1, 1-1/4, 1-1/2, 2	
CFSI-500-000	3-1/4"	5"	Blank Plug †
CFSI-500-150, or -200, -250, -300	5"	1-1/2, 2, 2-1/2, 3	
CFSI-600-000	3-1/4"	6"	Blank Plug †
CFSI-600-200, or -250, -350, -400	6"	2, 2-1/2, 3, 3-1/2, 4	
CFSI-800-000	3-1/4"	8"	Blank Plug †
CFSI-800-400, or -450, -500, -600	8"	4, 4-1/2, 5, 6	

* Because the O.D. of 2-1/2" thru 4" trade size rigid conduit is the same as EMT in these trade sizes, FIRE-SEAL™ fittings for rigid conduit in the 2-1/2" thru 4" trade sizes are also suitable for use with EMT. For EMT in trade sizes 1/2" thru 2", add suffix "E" to the catalog number. Example: CFSI-400-200-E

† INTENDED FOR SEALING SPARE CONDUIT SLEEVES AND ABANDONED CONDUIT ONLY. DO NOT FIELD DRILL.

Multi-Cable Transit™

The Multi-Cable Transit™ (MCT) devices, manufactured by Nelson Electric, function in a manner similar to the Fire-Seal™ fittings manufactured by O.Z./Gedney Co. [15]. It consists of a rectangular metal frame suitable for wall or floor installation, which is available in single or multiple units. Each frame contains an arrangement of Tecron™ elastomer modules grooved to fit snugly around cables, pipes, or conduit passing through the frame. The

Tecron™ modules expand when exposed to heat, providing a continuous seal even if the cable jackets disintegrate. The entire assembly within each frame is locked in position to prevent dislodgement and the spread of fire and the products of combustion.

The components of the MCT device are shown in Figure 2. The transit frame (1) is the housing into which the other components are fitted. The compression bolt (2) applies pressure to the compression plate when tightened, sealing the grooved insert modules around the cables. The standard end packing (3) is bolted into place to provide a fire and watertight seal above the compression plate. The standard end packing assembly is used when both sides of the transit frame are accessible. The special end packing (4) serves the same purpose as the standard and is used when the transit frame is accessible from only one side. The compression plate (5) acts as a pressure plate above the internal assembly. The stay plates (6) are inserted between every completed row to help distribute compression forces within the frame and to keep the modules from dislodging under high pressure conditions. The grooved insert modules (7) are available in seven module sizes to accommodate a range of cable/pipe from 5/32 inch to 3-3/4 inch OD. They fit snugly around the cable or pipe to form an airtight, watertight seal when compression is applied in the final assembly step. The spare insert modules (8) are solid modules used to fill voids or allow for future addition of cables. They are available in 3 module sizes. Fill insert strips (9) are used to fill space gaps. They are available in two thicknesses, 5 and 10 mm. The strips are 120 mm long and are split to allow cutting at any desired length. Also used, but not shown, are (10) MCT lubricant (tallow) which is used when packing; it allows the insert modules to slide easily over each other and (11) RTV-106 sealer for armored cable. The sealer should be applied in the grooves to seal

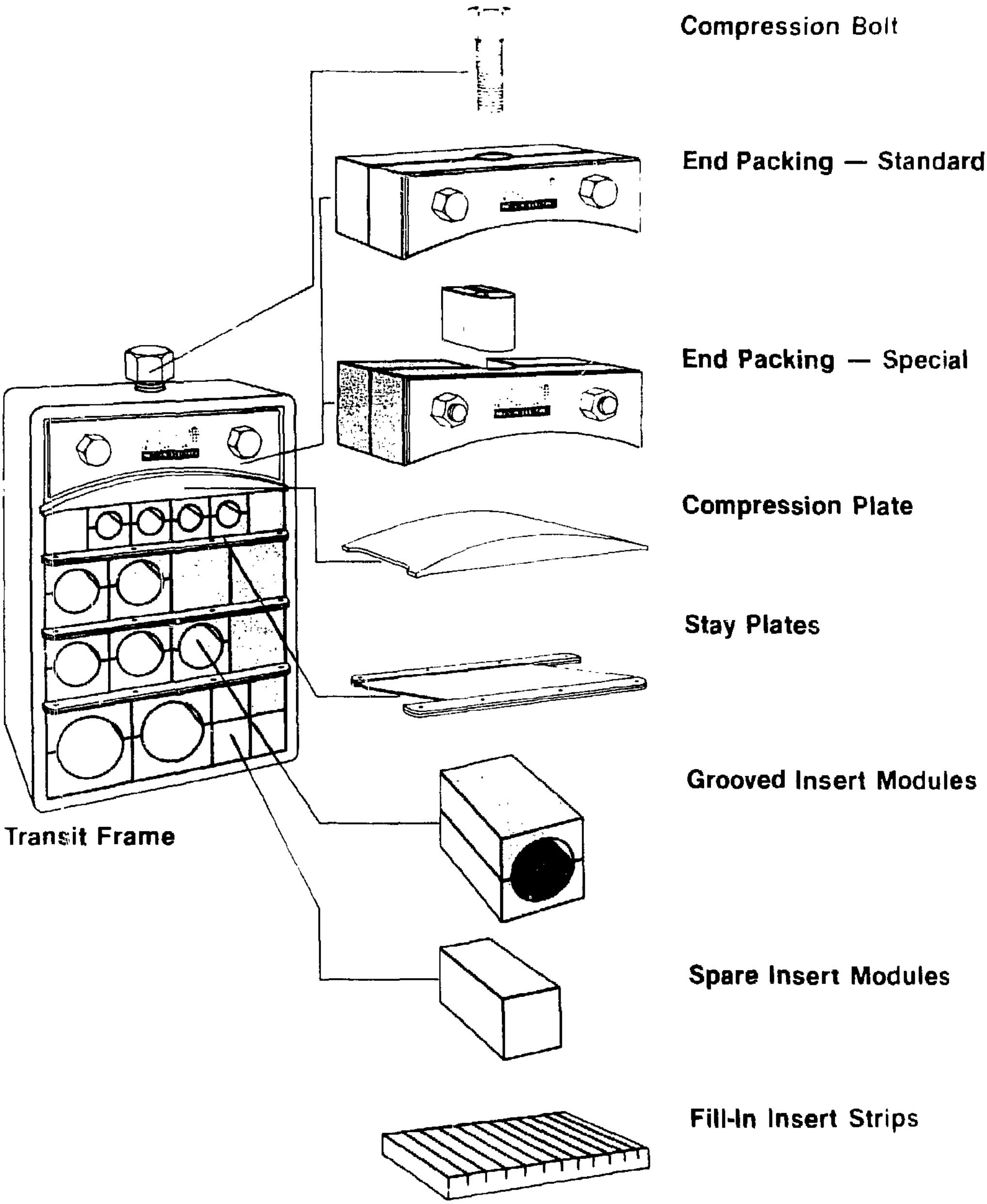


Fig. 2. MCT Device

the space between the armor and the cable sheath in navy cables, and the groove in the interlock of industrial cables.

Four types of the MCT devices are listed by U.L.: RGB-2, RGB-4, RGB-4x2, and RGB-6. Other sizes and types are available from the manufacturer. The RGB series frames are designed for immersion in concrete as the wall or floor is being constructed but before the cables are pulled. The RGS series, while not listed by U.L. in Reference 9, are claimed by the manufacturer to be U.L. listed in later editions. The RGS series frames are designed for installation in plates, channels, or in walls of equipment. The frame is welded to the plate, channel, or wall and the cable is pulled after the welding is complete. The dimensions of the U.L. listed RGB series MCT frames are shown in Table 7.

Table 7

MCT Frame Dimensions

Type	Height (inches)	Width (inches)
RGB-2	9.47	10.25
RGB-4	11.78	10.25
RGB-4x2	11.78	15.38
RGB-6	14.09	10.25

The sizes of the groove insert and spare insert modules and the size holes available in each of the groove insert modules are shown in Table 8. Each of the modules is 2.362 inches long.

Table 8
MCT Module Sizes

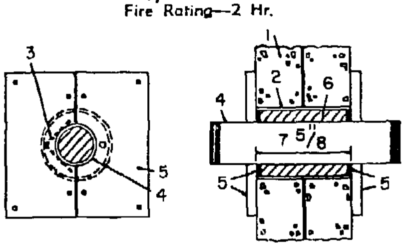
Type	Size (inches)	Holes Available (inches)
Module 15	0.591	0.157, 0.197, 0.236, 0.276, 0.315, 0.354
Module 20	0.787	0.157, 0.197, 0.236, 0.276, 0.315, 0.354, 0.394, 0.433, 0.472, 0.512, 0.551
Module 30	1.118	0.472, 0.512, 0.551, 0.591, 0.630, 0.669, 0.709, 0.748, 0.78¯, 0.827, 0.866, 0.906, 0.945
Module 40	1.574	0.866, 0.945, 1.024, 1.102, 1.181, 1.260, 1.339
Module 60	2.362	1.260, 1.339, 1.417, 1.496, 1.575, 1.654, 1.732, 1.811, 1.890, 1.969, 2.047, 2.126
Module 90	3.543	1.969, 2.165, 2.362, 2.559, 2.756
Module 120	4.724	2.953, 3.150, 3.346, 3.543, 3.740
Spare 15	0.591	Not applicable
Spare 20	0.787	Not applicable
Spare 30	1.131	Not applicable

Although not listed in Reference 9, Nelson also manufactures a product called Multi-Plug™. As opposed to the MCT devices discussed above, these are cylindrical in shape. Multi-Plug™ consists of a tapered plug with insert modules made from Tecron™ elastomer, which provides a complete and constant seal even when exposed to heat that disintegrates the cable jackets. The four Multi-Plug™ sizes (2, 4, 6 and 8 inch) will accept various combinations of the MCT insert modules for cables ranging from 0.157 to 3.74 inches outside diameter. The 2 inch Multi-Plug™ accepts the Module 30; the 4 inch uses the Module 60; the 6 inch uses the Module 90; and the 8 inch uses the Module 120. Supposedly, the smaller size modules could be ganged together to fit into one of the large openings, e.g., rather than one 120 Module, use two Module 15's, one Module 30, and one Module 60 to fill one dimension. The other dimension would be filled in a similar manner.

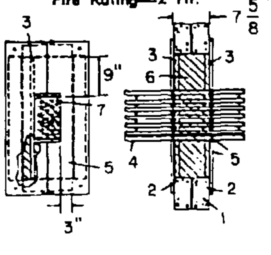
Multiple Cable Systems

The general description of the wall or floor opening protective, multiple cable systems is nearly identical to that given above for the wall or floor opening protective, multiple cable devices. However, a wall or floor opening protective, multiple cable system includes specific construction details consisting of the maximum size of the opening, types and sizes of penetrations such as cables, cable trays, conduits, and/or pipes, together with their means of support through the wall or floor opening, and the materials which seal the remaining opening. The wall or floor opening protective, multiple cable systems illustrated and described below are identified by a system number and the fire rating. The specifications for the system materials and their assembly are important details in the development of the fire ratings. The wall or floor opening protective, multiple cable systems are to be constructed as described below. The materials to be used in the systems are to be applied in accordance with any applicable application instructions. The National Electrical Code, NFPA No. 70, contains requirements for the permissible percentage of conductor fill [16].

System No. 1
Fire Rating—2 Hr.

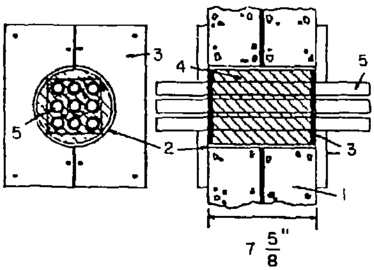


System number 1 is shown in Figure 3. The elements of this system are as follows: The wall (1) is nominally an 8 inch thick wall fabricated of concrete block, or common brick laid up with mortar. It must be a minimum 2 hour fire rated wall. The steel framing (2) is a nominal 4 inch diameter, 0.25 inch wall steel pipe rigidly attached to the wall. The support angle (3) is a 3 inch by 3 inch by 1/4 inch thick steel angle welded to the steel framing. This is for use when steel conduit is used. The steel conduit (4) is a nominal 3-1/2 inch diameter rigid steel conduit welded to the support angle. The forming materials (5) are used as a form and seal to prevent leakage of the foam sealant when it is in its liquid state. There are two parts: (a) The mineral composition units should bear the U.L. label and are 1/2 inch thick units fastened to both sides of the wall opening with 2 inch long masonry nails. The units are not removed after the foam application. (b) The packing material is loose alumina silica fiber packed about the mineral composition units, conduit, and cables sufficiently to prevent liquid foam leakage. The fill, void, or cavity material (6) is Type PR-855 RTV silicone foam, as manufactured by SEMCO [17], applied as described in the manufacturer's instructions to fill the remaining void in the wall opening to a final thickness as shown in the figure. The density shall be 17 pounds per cubic foot (pcf) minimum, 20 pcf maximum. The cables (7) are optional and are not shown in the figure. They are placed inside of the conduit, and are to be aluminum conductor with PVC jacket - 10/C, No. 14 AWG. The maximum cable/fill area is 40 percent.



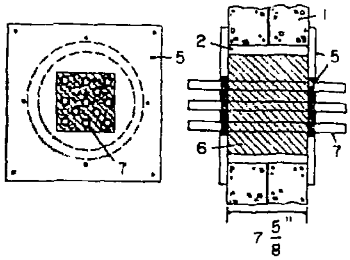
System number 2 is shown in Figure 4. The wall is as described above for system 1. The maximum size wall opening is 12 inches high and 30 inches wide. The other components are as follows: (2) Steel framing - 3 inch by 3 inch by 1/4 inch thick steel angles welded together to form a frame on both wall surfaces about the opening. (3) Support angle - 1/8 inch thick legs of channel welded to the steel framing so the outer leg is flush with the wall surface, (4) Cable tray - 24 inch wide, 6 inch high ladder or solid, minimum 16 gage, galvanized steel cable trays. These are tack welded at each side to the channel supports. The forming materials (5) and fill, void, or cavity materials (6) are as described for system 1. (7) Cables - These are 40 percent maximum cable fill area aluminum conductor of the following sizes and types: (a) PVC jacket 10/C, No. 14 AWG, (b) neoprene jacket 10/C, No. 14 AWG.

System No. 3
Fire Rating—2 Hr.



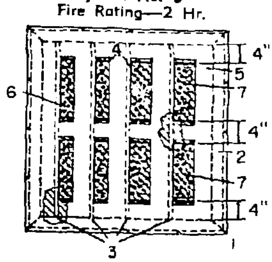
System number 3 is shown in Figure 5. The wall (1), forming materials (3) and fill, void, or cavity materials (4) are as described for system 1. The steel framing (2) is a nominal 6 inch diameter, 0.25 inch wall steel pipe rigidly attached to the wall. The cables (5) are an aluminum conductor, PVC jacket 4/C, No. 14 AWG. There is a maximum 40 percent cable fill.

System No. 4
Fire Rating—2 Hr.

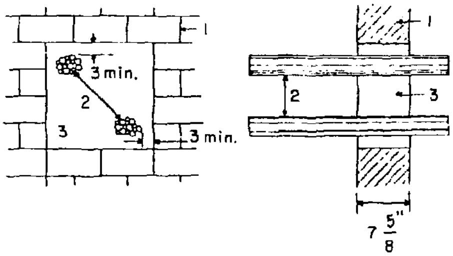


System 4 is shown in Figure 6. The wall (1), steel framing (2), steel angle (3) (optional and is not shown), forming materials (5) and fill, void, or cavity materials (6) are as described for system 1. The steel conduit (4) is optional and is not shown. If used, it is a nominal 6 inch diameter rigid steel conduit welded to the support angle. The cables (7) are placed inside of the conduit or in lieu of the conduit, aluminum conductor, PVC telecommunication cables are used. There is a 40 percent maximum cable fill area.

System No. 5
Fire Rating—2 Hr.

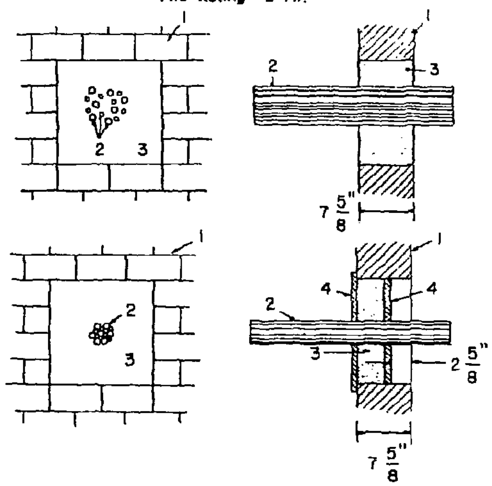


System number 5 is shown in Figure 7. The wall is as described above for system 1. The maximum size wall opening is 48 inches high and 48 inches wide. The steel framing (2) and the support angle (3) are as described above for system 2. The cable tray (4) is 18 inches wide, 4 inches high of solid, 16 gauge minimum galvanized steel. It is tack welded at each side to the channel supports. The forming materials (5) and fill, void, or cavity materials (6) are as described above for system 1. The cables (7) are 40 percent maximum cable tray fill area, aluminum conductor PVC jacket 4/C, No. 14 AWG.

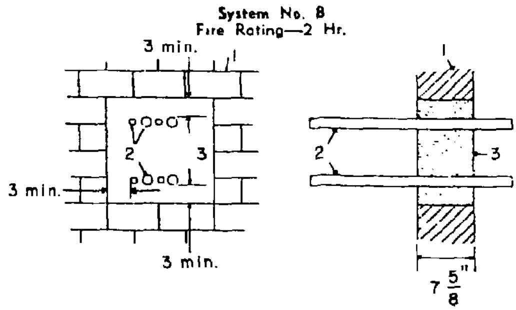


System number 6 is shown in Figure 8. The wall (1) is as described above for system 1. The maximum size wall opening is 16 inches high and 16 inches wide. The cables (2) are 10 percent maximum fill area per opening as shown. The following types and sizes of cables may be used: (a) PVC jacket - 600 volt, 5 KCMIL (nominal 1 inch or 1/2 inch diameter) aluminum and copper conductor (b) Hypalon™ jacket - 9/C (nominal 1 inch diameter) and 4/C (nominal 1/2 inch diameter), copper conductor (c) PVC jacket telecommunication 25 pair cable and (d) silicone jacket, copper conductor (nominal 1/2 inch diameter). The fill, void, or cavity material (3) is Type 3-6548 RTV silicone foam, as manufactured by Dow Corning Corporation [18], applied as described in the manufacturer's instructions to fill the remaining void in the wall opening to a final thickness as shown in the figure. The density shall be 17 pcf minimum, 20 pcf maximum. Plywood boards 1/2 inch thick are used as a form for the liquid foam material. Loose alumina-silica fiber packed about the cables and forms is used to prevent foam leakage when it is in the liquid state.

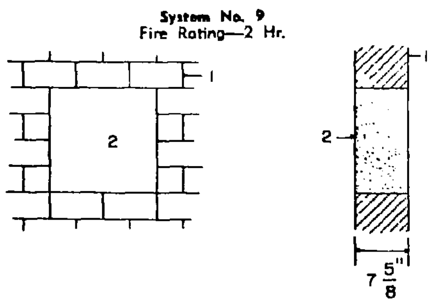
System No. 7
Fire Rating—2 Hr.



System number 7 is shown in Figure 9. The wall (1) is as described above for system 1. The maximum size wall opening is 16 inches high and 16 inches wide. The cables (2) are 5 percent maximum cable fill area per opening as shown. The cables may be grouped together or randomly scattered through the opening. The cables are Flamtrol™ jacket (nominal 1 inch diameter) 1000 volt, 12/C, No. 12 AWG and Flamtrol™ jacket (nominal 1/2 inch diameter), 11/C, No. 20 AWG, 600 volt. The fill, void, or cavity material (3) is as described above for system 6, i.e., Dow Corning silicone foam. When mineral composition units are used, the minimum foam thickness is 4 inches. The plywood form boards of system 6 may be used or mineral composition units, bearing the U.L. label, 1 inch thick may be used as an alternate. Two mineral composition units are used per wall opening. One unit is placed over the opening and attached to the wall surface with 2 inch long masonry nails. The other unit, with dimensions approximately equal to the wall opening size, is placed inside the wall opening located with its exposed face 2-5/8 inches from the wall surface.



System number 8 is shown in Figure 10. The wall (1) and maximum opening size are as described for system 7. The pipes (2) are aluminum or steel, nominally 1 inch or 1/2 inch diameter, with 0.125 inch wall. The fill, void or cavity materials (3) is as described above for systems 6 and 7. Foamed silicone is also applied to fill the interior of the pipe. A minimum 30 inch length of pipe filled with the foam material is to be symmetrically located through the wall. The pipes may be removed during foam application, then placed into position after the foam is cured. Plywood boards 1/2 inch thick are used as forms.



System number 9 is shown in Figure 11. The wall (1) and maximum opening size are as described for system 7. The fill, void, or cavity material (2) is as described for system 6.

IIb. CANDIDATE DESIGNS - NON U.L. LISTED

The candidate designs discussed in this section are not U.L. listed and their use would require approval of the responsible code or insurance authority prior to use. These designs all incorporate the use of fireproof coatings. Four types of fireproof coatings are discussed: (1) magnesium oxychloride plasters, (2) intumescent mastics, (3) cementitious sprayed, and (4) epoxy intumescent fireproofing systems.

The magnesium oxychloride plasters are classified as cementitious but do not resemble the cementitious materials described subsequently [19]. The magnesium oxychloride plasters, when applied to beams, columns, or ceiling assemblies, are more efficient fire resistive materials and have greater resistance to impact, abrasion, and vibration than the less expensive cementitious materials. U.L. tests have established fire ratings of up to 4 hours for the magnesium oxychloride plasters when used as a fireproofing material for structural steel. Fireproofing materials of this type contain water soluble chloride salts which contribute to the stress corrosion cracking of the austenitic stainless steels. There is also evidence that measurable amounts of hydrogen chloride fumes are released by the materials in normal use. This evolution increases at elevated temperatures and when the material is subjected to fire. If magnesium oxychloride plasters are exposed to high humidity, condensation, water spills, flooding, or water from fire hoses, the water will dissolve some chloride salts and transport them to other areas. The user should be aware of the risks involved in using these materials where they may come in contact with the austenitic stainless steels. The magnesium oxychloride fireproofing materials should be used in these areas only when other means of fireproofing are not viable and then only when adequate precautions are exercised in their application. The use of an impervious topcoat is effective in reducing the spread of waterborne salts if the plaster is smoothly applied and the topcoat is free of voids. The chlorinated rubber topcoats specified for exterior weathering may be used for interior surfaces to reduce the spread of chloride salts. Some epoxy coatings are also suitable for interior use. It should be noted that any topcoat will be destroyed in the event of an actual fire and the water from fire hoses will spread the chlorides. Any topcoat selected for use should be evaluated with regard to flame spread, smoke density and fuel contribution. For broad comparative purposes, magnesium oxychloride systems cost about two to three times as much as cementitious spray-on fireproofing materials.

The intumescent mastic type of fireproofing has been tested on columns, beams, and floor assemblies under ASTM E119 [20]. U.L. tests have established fire ratings of up to 2 hours for this type of material in these applications. Intumescent mastic fireproofing materials are non-cementitious, ready-mixed materials that are applied by hydraulic spray equipment directly from the shipping containers. The maximum film build is 1/4 inch per coat. Multiple coats are used to give fire ratings of up to 2 hours on direct contour applications. The intumescent mastic materials cure to hard, dense films that have better flexural and bond strength characterisitics than do the cementitious-sprayed or the magnesium oxychloride plaster types of fireproofing. They have greater resistance to impact, vibration, or abrasion. The cured materials are resistant to exterior exposure. The intumescent mastic materials are available in both interior and exterior-interior formulations. Topcoats are not required except for appearance or for decontamination requirements. The materials have a rating of zero smoke development under ASTM E84 but do burn briefly when they form the intumescent char. The products of combustion are similar to those of vinyl paints and do not in themselves constitute a serious hazard. The in-place costs of the intumescent mastic fireproofing materials are higher for a given fire rating than either the cementitious spray materials or the magnesium oxychloride materials. The use of these materials is limited to areas where the increased physical strength and durability is required and to areas where the chloride bearing types are not acceptable.

The cementitious type of fireproofing is generally used for structural steel columns, beams, and floor deck assemblies [21]. These types are usually spray fiber or spray plaster. These materials are low in cost and easy to apply. They are in no way similar to or cost competitive with the harder, stronger, more durable magnesium oxychloride plasters. U.L. tests have been performed for fire ratings of up to 4 hours for this type of material. These cementitious materials are lightweight with an applied density of 12 to 18 pounds per cubic foot. The installed material is friable, soft, and easily damaged. They are used in concealed or protected areas such as columns which will be boxed in with lath and plaster, on surfaces above suspended ceilings, and sometimes on exposed steel assemblies above eight feet from the floor level. The in-place costs of the cementitious spray fiber and spray plaster fireproofing materials are low compared to other systems.

The epoxy intumescent class of spray applied fireproofing materials were developed as a part of the space program and are similar to the coatings used on the heat shields of re-entry vessels [22]. The materials are both ablative and intumescent, absorbing heat as they burn, then forming a strong char as insulation to reduce the rate of temperature rise in the steel it protects. The epoxy intumescent materials form tough, wear resistant films that protect the steel against corrosion in exterior exposure for many years without loss of fire protective properties. These weather resistant properties have made the epoxy intumescent fireproofing materials attractive to the petroleum-chemicals industries where many installations are open to the weather and may be in place for a long period of time prior to fire exposure. The temperature requirements for the protection of structural steel in a "normal" architectural fire are represented by the time/temperature curve used in ASTM E119. In this curve, the temperature rise is quite severe, reaching 1000°F at 5 minutes, 1550°F at 30 minutes, and 2000°F at 4 hours. This curve envelops most recorded architectural fires. The fire conditions in a petroleum fire are even more severe. A butane pit fire reaches 1400°F in one minute and reaches 1800 - 2000°F almost immediately thereafter. Using the NFPA criteria for a pit fire test and the ASTM E119 criteria for an architectural fire, a rating of two hours under the ASTM method is approximately equal to one hour using the NFPA method. The epoxy intumescent fireproofing generates a dense smoke when burned. It is not recommended for use for fire protection of steel in enclosed areas.

The recommended designs for fireproofing of seals using fireproofing coatings are shown in Figures 12 to 16. Figures 12 to 15 are for fire sealing of electrical penetrations and Figure 16 shows the recommended design for sealing of a pipe penetration.

Design alternate 10 is shown in Figure 12. The elements of this system are as follows: The wall (1) is nominally 12 inch thick concrete and must be a minimum 2 hour fire rated wall. The steel framing (2) is 3 inch by 3 inch by 1/4 inch thick steel angles welded together to form a frame on both wall surfaces around the opening. The cable tray (3) is a 24 inch wide, 6 inch high ladder or solid, minimum 16 gage, steel cable tray primed with the primer required for the selected fireproofing coating. The firestop panel (4) is a

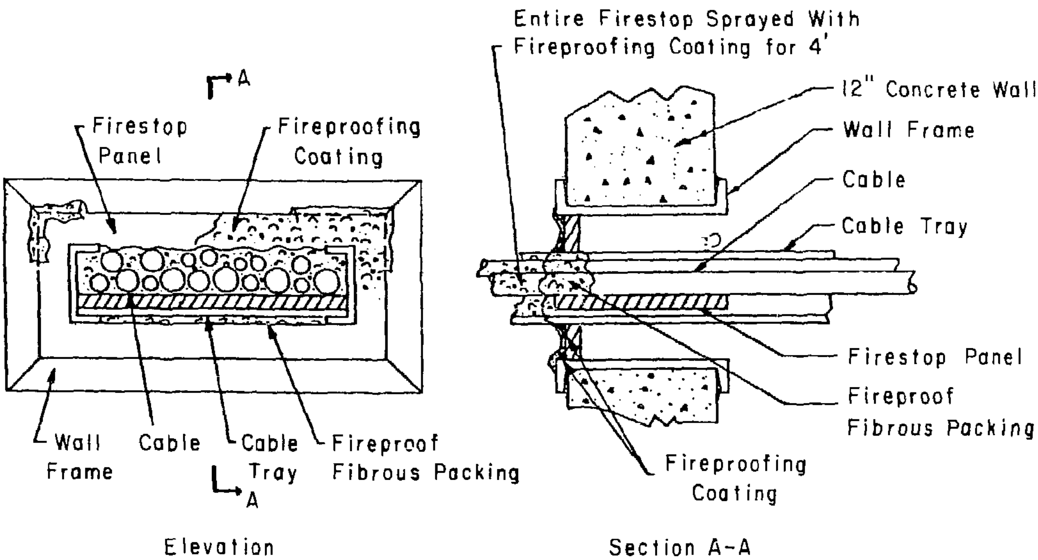


Fig. 12. Penetration Seal for Typical Prefabricated Channel Frame Wall Opening.

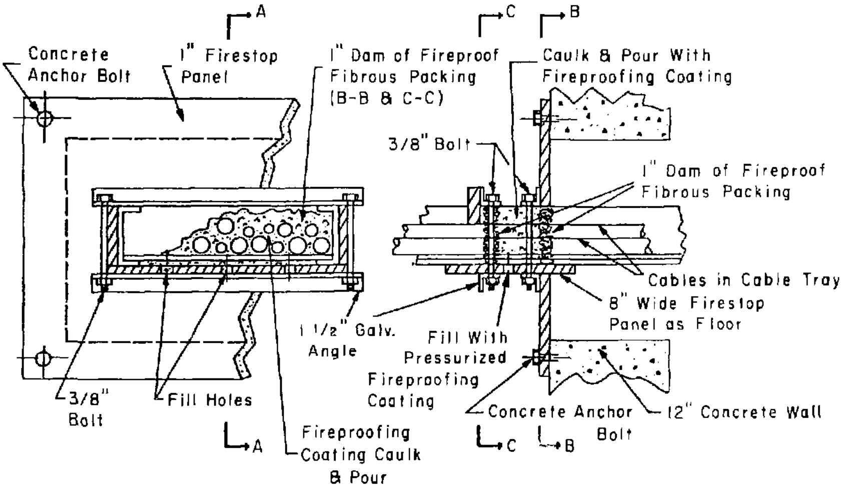


Fig. 13. 4" Long Fire and Air Seal (Along Cables) (Two Pairs of Angle Irons at Sections B-B and C-C).

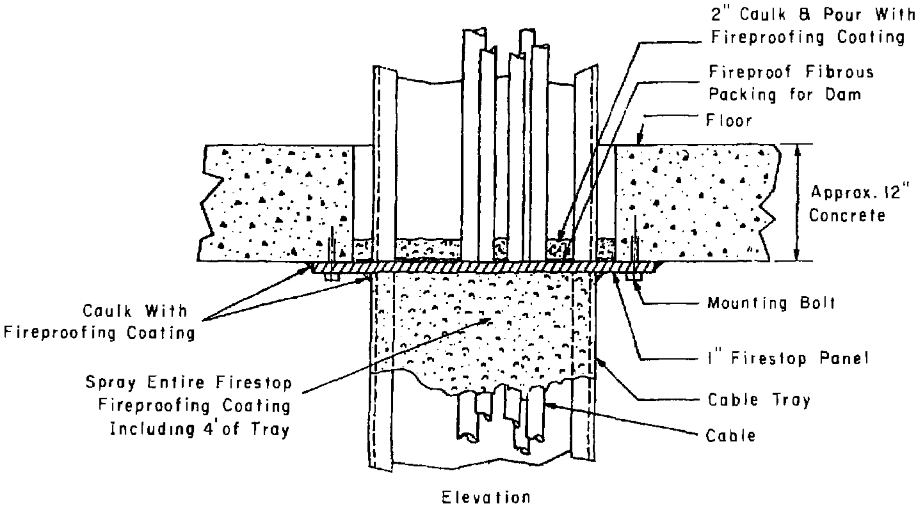


Fig. 14. Floor Penetration.

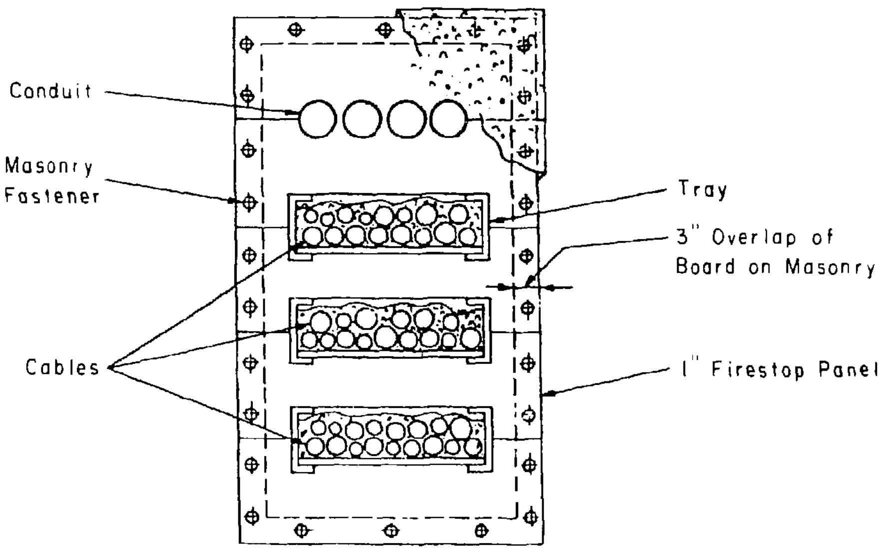


Fig. 15. Multiple Tray Penetration with Suggested Subdivision of Panels.

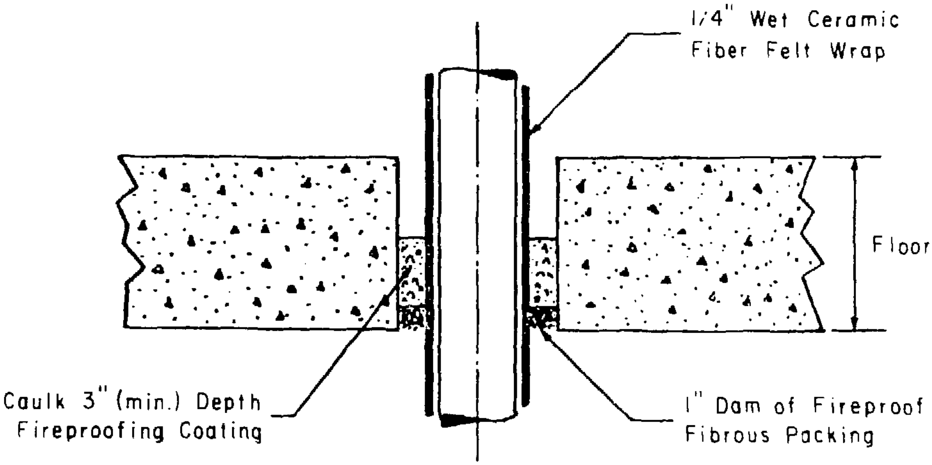


Fig. 16. Sealing Pipes or Ducts Through Wall or Floor Penetration.

1/2", 1" or 1-1/2" thick ceramic, alumina-silica board plus a 1/8" thick coating of the fireproofing coating on the fire side. The firestop panel is caulked to the cable tray and the wall frame using a caulk (5) of the fireproofing coating after packing the opening with a fireproof fibrous packing (6). The entire firestop is then sprayed with the fireproofing coating (7) for a length of 4 feet.

Design alternate 11 is shown in Figure 13. The elements of this system are as described above and as shown on the drawing. The fire and air seal is accomplished by a 4 inch sealing box at the cable tray in which all openings are thoroughly packed with the fireproof fiber to form dams. Then by caulking and troweling with the fireproofing coating, a complete seal and firestop is made. The cables are again sprayed for 4 feet on the hazard side of the wall, as in alternate 10, to prevent flame spread. In designs where 2 to 3 foot long sections of cable are completely encapsulated with low thermal conductivity materials (insulators), hot spots and consequent cable derating can occur. It is for this reason that the fire and air seal of Figure 13 is limited to a 4 inch length along the cables.

Design alternate 12 is shown in Figure 14. The elements for this system are the same as those described above for alternate 10. Figure 15 shows a multiple tray penetration with a suggested subdivision of panels. Figure 16 shows the suggested method of sealing pipes or ducts through a wall or floor penetration. The only new element introduced in this system is the 1/4 inch ceramic fiber felt wrap.

III. DESIGN EVALUATION

Ease of Application

The multiple cable devices satisfy this criterion well. They are mechanically bolted in place (Fire-Seal™ fittings and Multi-Cable Transit™) or pushed into place (Multi-Plug™). All of them allow installation around existing cables, conductors, or piping. Unfortunately, the U.L. listed RGB series of MCT devices require installation of the frame into the form before the wall or floor is poured. The RGS series are not U.L. tested but do permit installation after pouring of the concrete provided that a steel framed block-out has been incorporated into the floor or wall.

All of the multiple cable systems use a silicone foam as the fill, void, or cavity material. The silicone foams are an excellent material from the standpoint of the ease of application. Injected into dammed penetrations, the foam-in-place material quickly expands approximately three times the volume of its liquid constitutents to form an air and watertight, fire resistant seal. As the foam is forced into a dammed penetration, it swells and flows to intimately fill the interstices between the penetration elements and the walls of the opening. Once cured, the foam maintains a pressure against the walls, pipes, and other structures to provide an air and watertight fire barrier. The foam will cure in deep sections and will produce little exotherm.

The need for the forming materials in these systems does add to the difficulty of application. However, the problem is not severe. The holes can be cut in the mineral composition board or plywood using a hole saw or flycutter (for conduit), a sabre or keyhole saw (for cable trays), or a spade bit (for cable). The holes can be cut slightly oversized and the packing material stuffed into the gap. After curing, the face of the penetration can be trimmed with a knife, if needed, to remove any foam which exuded from the penetration. Welding of the support angle to the steel conduit and steel framing poses more of a problem. This can be overcome by welding the support angle to the conduit first and then placing this subassembly into the steel framing and welding it in place. In addition, several of the multiple cable systems require that either the angle iron or pipe sleeve be placed into the form prior to the pouring of the concrete.

The alternate designs using the fireproofing coatings are also easily applied. They are either sprayed or troweled into place. However, because they require evolution of solvents, the film build may be limited per coat. For example, the intumescent mastics are limited to 1/4 inch per coat. This then requires many coats to achieve the required film build, causing a very labor intensive and time consuming operation.

Ease of Removal

The multiple cable devices are, in general, easily removed. The Fire-Seal™ fittings and MCT can be unbolted. Multi-Plug™ would have to be pushed out and may offer a fairly high resistance. The MCT frame would be abandoned upon removal. This may not be entirely satisfactory.

The framing of several of the multiple cable systems would also be abandoned upon removal. The removal of the mineral composition units would be easy. Removal of the silicone foam does pose somewhat of a problem. As indicated above, it can be cut with a knife. This would still leave a residue adhering to cables and conduits. This residue can be softened with xylene or V & M naphtha [23] and scraped away, if required. Fortunately, however, McGean Chemical Company produces a water-thin, acid-activated remover for silicone sealants, resins, paints, and adhesives. This product, C-105HF Silicone Remover, completely dissolves silicone sealants, paints, resins, and adhesives. It is safe for use on ceramics, glass, aluminum, and aluminum alloys, mild steel and stainless steel. It contains petroleum solvent, chlorinated solvent, organic acids, and biodegradable surfactants [24].

The fireproofing coatings would have to be removed by mechanical chipping. This process could be speeded up somewhat by softening the coating with an appropriate solvent, but the process would be tedious and not entirely satisfactory. The cementitious materials are sufficiently friable to yield to this process but the others, particularly the epoxy intumescents, would be very difficult.

Conformability

The question of conformability is difficult to answer for the multiple cable devices. They all do a good job in sealing themselves against the walls of the opening and to the cables and piping owing to the elastomeric seals used. However, there is a limit to the expandability and compressibility of the elastomer and the penetration hole, and the cable, conduit, or piping must be reasonably close to the stock size of the device used. The Fire-Seal™ fittings and Multi-Plug™ are limited as to the number and size of service lines which may penetrate a given hole in the fire wall or floor. This is also true of the MCT devices, but to a lesser extent.

As discussed above, silicone foam displays excellent conformability. In addition, if a new cable or pipe through the penetration seal is required, an undersize hole can be cut or drilled out and the pipe or cable pushed through. The silicone foam exhibits a spring-back characteristic to reseal the opening. Larger openings can be sealed with additional silicone foam. If one adheres to the U.L. listed designs only, there are limits as to the sizes of openings which can be sealed with silicone foam.

Because they are applied as a liquid/paste, the fireproofing coatings display excellent conformability. However, because they shrink during curing, there may be some pulling away from the sleeve or cable. In addition, the fireproofing coatings do not readily accommodate the addition of new cables or piping.

Light Weight

While specific weights are not available, the multiple cable devices can be considered to be lightweight enough not to be of concern. The silicone foams satisfy this criterion very admirably, weighing from 17 to 20 pounds per cubic foot. This compares to approximately 100 pounds per cubic foot for light aggregate concrete and approximately 150 pounds per cubic foot for normal structural concrete. As noted previously, the cementitious fireproofing coatings are lightweight, with densities of 12 - 18 pcf. The other three types of fireproofing coatings are more dense, but they all have densities less than that of concrete.

Thermal Conductivity

The thermal conductivity of the Dow Corning 3-6548 silicone foam is 1.8×10^{-4} cal-cm/sec-cm^2-°C [18]. The thermal conductivity of the Quelpyre™ Fireproof Mastic 703B is 1.76×10^{-3} cal-cm/sec-cm^2-°C [25]. The thermal conductivity of Intumastic™ 285 is 1.19×10^{-3} cal-cm/sec-cm^2-°C [26]. The thermal conductivities of the multiple cable devices are not known.

Flame Spread, Fuel Contribution, Smoke Density

The flame spread (ASTM E84) of the Dow Corning 3-6548 silicone RTV foam is 20 [18]. The flame spread of the Quelpyre™ Fireproof Mastic 703B is less than 5 [25].

Chemical Reactivity and Corrosivity

The multiple cable devices satisfy both of these criteria. The multiple cable systems definitely satisfy the chemical inertness criterion. In and of themselves, the silicone foams are noncorrosive. However, the solvents of the C-105 HF silicone remover may be corrosive to certain cable jackets. Therefore, the silicone remover should be tried on the cables to be used on TFTR before the multiple cable systems can be unequivocally advocated for use. There is no concern about its use on either carbon or stainless steel piping.

As noted, the magnesium oxychloride fireproofing coatings are water-soluble. Due to the great preponderance of austenitic stainless steel in TFTR, the magnesium oxychloride fireproofing coatings are eliminated from further consideration here because of the potential stress corrosion cracking. The intumescent mastics satisfy both criteria of chemical reactivity and corrosivity. The cementitious sprayed fireproofing materials are not chemically reactive or corrosive. However, they are easily damaged and should be considered for use only where there is little possibility of physical contact to abrade them. As stated earlier, the epoxy intumescents are not recommended for interior use because of the intense smoke generation.

IV. RECOMMENDED DESIGNS

Table 9 shows the designs recommended for specific applications. The applications are listed in the first column. The alternate designs at the top of the matrix are summarized below:

(1) CAFS Series Fire-Seal™

(2) CFS Series Fire-Seal™

(3) RGB Series MCT

(4) RGS Series MCT

(5) Multi-Plug™

(6) Multiple cable system 1

(7) Multiple cable system 2

(8) Multiple cable system 3

(9) Multiple cable system 4

(10) Multiple cable system 5

(11) Multiple cable system 6

(12) Multiple cable system 7

(13) Multiple cable system 8

(14) Multiple cable system 9

(15) Intumescent mastic fireproofing

Table 9

Recommended Designs

Applications	Alternate Designs 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
U. L. Listing Required	x	x	x			x	x	x	x	x	x	x	x	x	
Non-U.L. Designs Acceptable	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Two Hour Fire Rating	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Three Hour Fire Rating	x	x	x	x	x										
Round Opening	x	x			x	x		x	x						x
Rectangular Opening			x	x			x			x	x	x	x	x	x
Standard Opening Size Req'd	x	x	x	x	x	x		x	x					x	
Non-Standard Opening Size							x			x	x	x	x	x	x
Framed Opening Req'd			x	x		x	x	x	x	x					x
Non-Framed Opening	x	x			x						x	x	x	x	
Electrical Service Only	x				x										
Mechanical Service Only		x			x										
Dual Service			x	x		x	x	x	x	x	x	x	x		x
Frequent Removal/Changes	x	x	x	x											
Infrequent Removal/Changes	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Single Conduit/Pipe	x	x	x	x	x	x		x	x		x	x	x		x
Cable Trays							x			x					x
8 or Fewer Cables	x	x	x	x	x	x	x	x	x	x	x	x	x		x
More Than 8 Cables			x	x		x	x	x	x	x	x	x	x		x

ACKNOWLEDGMENT

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