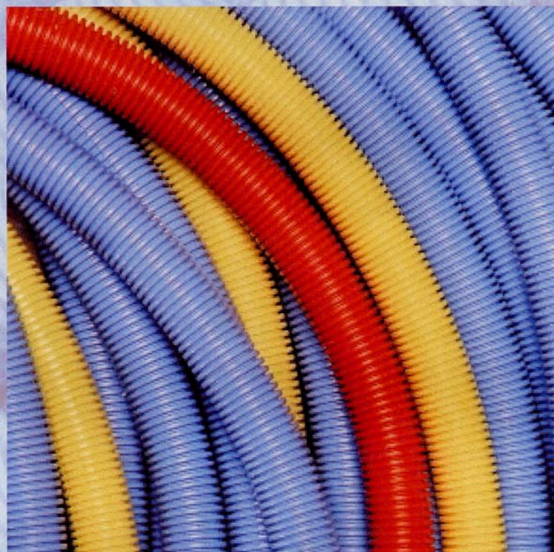
Fire Safety of PVC Raceways and The Model Building Codes



(2000 Version)

Carlon®
LAMSON & SESSIONS

Fire Safety of PVC Raceways and the Model Building Codes
(2000 Version)

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Foreword

The report reviews each of the model building codes used in the United States with regard to PVC raceways and addresses the relationship of those building codes to the **National Electrical Code**®.

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Table of Contents

1.0 Introduction

This section describes the history of safe use attained by PVC (polyvinyl chloride) raceways, and presents the rationale of Carlon in sponsoring this report.

PVC Rigid Nonmetallic Conduit (RNC) and PVC Electrical Nonmetallic Tubing (ENT) are electrical raceways, which have been used for over 25 years in the United States and Canada, and over 35 years in Europe. Because they are made from combustible materials, the fire performance of these products has been the subject of intense scrutiny from the beginnings of their use.

Test work and evaluations conducted to address fire safety issues associated with PVC electrical raceways have included:

- Analyses of ways in which fires start (fault scenarios) in electrical installations,
- Assessments of the impact of different kinds of electrical raceways on firespread potential,
- Assessments of the impact of installation techniques and types of construction on the fire safety of PVC electrical raceways.

The assessments conducted have utilized recognized fire test methods, such as the ASTM E-119, and ASTM E-814 standards.

Since 1968, RNC has been recognized by the **National Electrical Code**®, which is promulgated by the National Fire Protection Association (NFPA). The performance of RNC and the performance of ENT, which was developed later, have permitted these materials to be used as part of recognized electrical installations.

Figure 1: ENT being installed in highrise building construction. Huntington Beach, California

Likewise, the requirements of the model building codes, which govern the manner in which construction materials are utilized in structures, are met if PVC raceways used in buildings are installed as prescribed in the model codes and as described in this report.

It is the objective of this report to review relevant technical and code related aspects of the use of PVC raceways. In doing so:

- Rationale for use of RNC and ENT products and accessories are reviewed,
- Conformance of PVC raceway products with model codes is described,
- References and summaries of research work upon which approvals for PVC product use were issued are provided.

2.0 Fire and Building Technology and the Use of PVC Raceways

This section overviews experimental and theoretical bases for code acceptance and use of PVC raceway products. It also presents general information on performance of buildings exposed to fire and related fire situations. One focus is on "de-rating"–a possible reduction in fire endurance due to the presence of PVC raceways. Fire safety levels of gypsum wallboard faced cavity walls containing PVC raceways are also examined.

This report surveys and summarizes recognized information that describes the fire performance of RNC and ENT. In addition to sources like peer reviewed journal articles, it includes and discusses:

- Test data from independent third-party laboratories such as Underwriters Laboratories, Inc. and Factory Mutual,
- Federal Government laboratory test results, and
- Reviews by agencies such as the International Code Council (ICC) formerly administered by the Council of American Building Officials (CABO) and The National Fire Protection Association (NFPA), producers of **The National Electrical Code**.

In understanding test results on which code approval of PVC raceways have been made, underlying principles of fire science and construction technology need to be considered. To do this, analyses of assemblies including PVC raceways are conducted. Such analyses begin by selecting a particular, accepted fire resistant [floor, floor/ceiling or wall] assembly design. Such an assembly possesses known levels of fire endurance without penetrations or any included electrical (or other) components. The impact of adding components, such as PVC raceways, is evaluated by direct fire testing and/or engineering calculations. Such testing is carried out under the ASTM E-119 Standard.[1] Determinations utilizing accepted methods of calculation and engineering analysis relate baseline fire resistance data to a particular type or class of fire resistive assembly to perform with PVC raceways and related components installed.

Fire testing typically utilizes accepted generic wall or slab designs to develop needed data. Such tests can assess assembly performance directly and also produce needed data for engineering analysis, which can be applied to other construction situations. This is important since all possible combinations of elements cannot, for economic reasons, be subjected to direct fire testing. As accepted in the model building codes, performance data from tested designs allow the use of heat transfer relationships to predict fire performance of assemblies built in the field which are similar to tested ones, but which may differ in geometry in some aspect[2].

[1] For a brief description of this test method and its utility the reader is referred to "Facing the Fire," ASTM Standardization News, January 1990, p.23.

[2] Zicherman, J.B., 1992. "Performance of Plastic Plumbing and Electrical Products in Fire Resistive Assemblies," Fire Hazard and Risk Assessment, ASTM STP 1150, Marcelo Hirschler, Ed., American Society for Testing Materials, Philadelphia.

Also worthy of consideration are common design "rules" which govern the fire endurance of assemblies[3]. Such generalized "rules" show that:

- Thicker walls or floor/ceilings show greater fire endurance than ones built with identical materials, but with a thinner, overall cross-section,
- Smaller penetrations reduce fire endurance less than penetrations of larger diameter, and
- Walls or floor/ceilings (containing PVC raceways) that have no penetrations will perform as well or better than similar assemblies with penetrations.

For the last reason above, a fire test of an assembly with a penetration is a more conservative one than a test of an unpenetrated wall.

A frequently asked fire safety question relates to possible "de-rating" of walls and floor/ceiling assemblies that include PVC raceways. ("De-rating" is sometimes used to describe a possible reduction in expected fire performance of an assembly from its stated fire endurance level).

Figure 2: ENT installation in Marriott Hotel project. Cleveland, Ohio.

Over the past 25 or more years, numerous assemblies containing PVC raceways (or even larger amounts of PVC drain, waste and vent plumbing pipe) have been fire endurance tested according to the ASTM E-119 time-temperature curve. In those assemblies that successfully attained a rating, no significant reduction in the fire endurance period or finish ratings of wall designs have been observed due to inclusion of PVC materials where installations were made according to accepted practice and where penetrations were properly made.

Examples of this performance can be seen in accompanying Table 2.1, which was assembled from third-party ASTM E-119 fire endurance testing data. The data presented compares finish ratings[4] of 1 and 2-hour steel stud wall assemblies with and without PVC

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[3] For an interesting treatment of general rules relating to fire endurance of assemblies, the reader is referred to "Ten Rules of Fire Endurance Rating," by T. Z. Harmathy (Fire Technology, May, 1965, Vol. 1, pp. 93).

[4] The time for a thermocouple placed between a stud and its covering layer of gypsum wallboard to increase 325°F above room ambient.

components, Electrical Metallic Tubing (EMT) and PVC-DWV (drain, waste and vent) plumbing components installed. The information shows that the presence of properly installed PVC raceways does not reduce the fire performance of such a construction. This is evident from the finish ratings of wall membranes in assemblies with PVC components. That period, during which the finish rating is measured, is also the period when post-flashover fire growth is in the early stages. It is also the period when life safety considerations are arguably the greatest.

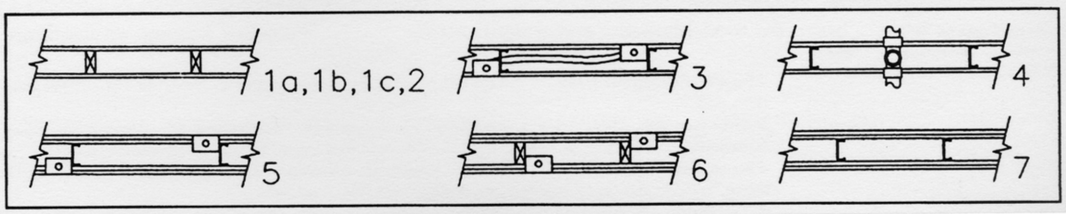
TABLE 2.1

FINISH RATINGS OF ONE AND TWO-HOUR WALLS INCLUDING PVC PIPE, TUBE, CONDUIT AND EMT

TEST WALL	INCLUDED ELEMENT	FINISH RATING (min.)	FIRE ENDURANCE
1A	None	20	1 Hr.
1B	None	19.5	1 Hr.
1C	None	19	1 Hr.
2	None	21	1 Hr.
3	ENT	22	1 Hr.
4	PVC-DWV	19.5	1 Hr.
5	EMT	67	2 Hr.
	ENT	67	2 Hr.
6	EMT	60	2 Hr.
	ENT	60	2 Hr.
7	None	66	2 Hr.

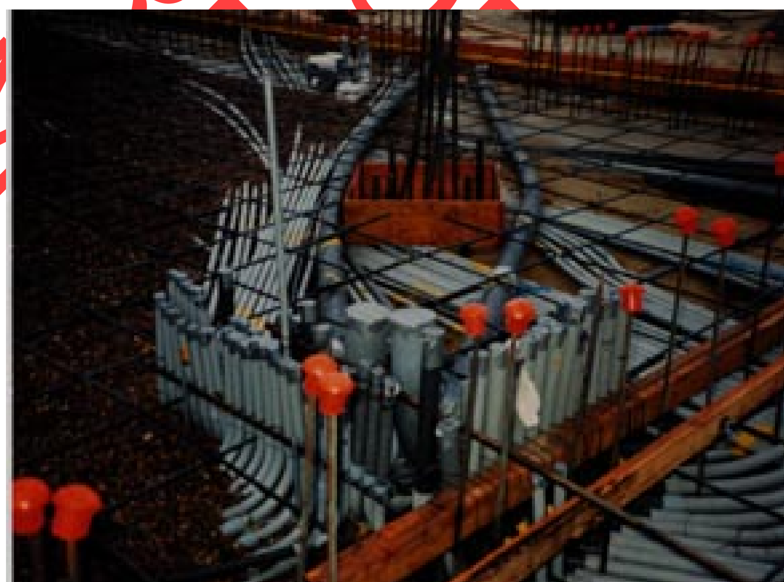
Test report references for the above test walls are:

1. Underwriter's Laboratories, Inc. File NC505, Project 76NK1268 - 1976.
2. Omega Point, ASTM E-119 Test Report, Project No. 1149-92509, January 27, 1992.
3. Omega Point, ASTM E-119 Test Report, Project No. 1149-92509, January 27, 1992.
4. Zicherman, J.B., "Performance of Plastic Plumbing and Electrical Products in Fire Resistive Assemblies," Fire Hazard and Risk Assessment, ASTM STP 1150, Marcelo M. Hirschler, Ed., American Society for Testing Materials, Philadelphia, 1992.
5. Underwriter's Laboratories, Inc. File NC546-1,-2, Project 73NK7657 - 12/21/73.
6. Underwriter's Laboratories, Inc. File R8326-4, Project 80NK11747 - 9/17/80.
7. Underwriter's Laboratories, Inc. Fire Resistance Directory, Design No. U301 - 1986.



3.0 Performance of PVC Raceways In Fire

This chapter describes characteristics of fires in buildings. It details how a fire may grow from a small isolated ignition to become a large fire incident whose products of combustion may extend and travel, threatening both life safety and the structural integrity of a building. Differences in pre- and post-flashover fires are described and related to fire performance of PVC electrical raceway. The section also reviews the ASTM E-119 and ASTM E-814 tests and describes their importance in assessing fire performance of assemblies that include PVC electrical products.



To assess the fire performance of PVC raceways in detail, general concepts of fire behavior in buildings and specifics of electrical fire occurrence must be considered.

Figure 3: Use of ENT in hotel foundation application Disney World, Florida

3.1 Fires in Buildings

When early fire growth occurs, a fire that begins within a room will not threaten fixed electrical wiring installed in wall cavities until well after the whole room is fire involved. For this reason, it is important to consider types of fires occurring in buildings and their effects on fixed wiring.

Growth of a fire to where it may threaten a room is divided into two regimes or periods:

(a) The pre-flashover period.
(b) The post-flashover period.

During a pre-flashover fire incident or the pre-flashover period of a fire, the physical boundaries of a room (walls, floor, doors, windows, etc.) are not threatened. By definition, a pre-flashover fire will be contained within the boundaries of the room of occurrence. Occupants of rooms where such fires occur are usually not at risk and, unless they are confined, can generally reach safety readily in the absence of extremely rapid fire growth.

Not coincidentally, Article 331 published in the 1987 **National Electrical Code** required that ENT be installed concealed behind wall, ceiling or floor surfaces if the building exceeded three floors above grade. Since such wall surfaces are not threatened during the pre-flashover period of a fire incident, it follows logically that ENT installed behind such surfaces is not at risk either.

In post-flashover fires, the situation is reversed, and barriers and boundaries (walls, doors, floor/ ceilings, etc.) are threatened with destruction due to high temperatures and heat transfer conditions present. To reach this situation, a post-flashover fire must first fully involve the space in which it occurs, before it will spread. Spread, either by convection of flames and hot gases, or by destruction through boundary burn-through or fracture, may then occur. Thus, the post-flashover fire performance of a room is strongly influenced by the integrity of its boundaries. Since maintenance of boundary integrity is so important, fire-rated construction techniques may be used. These protect building occupants from small developing room fires, which eventually grow to become post-flashover fires.

The transition between these two regimes– FLASHOVER–is characterized by:

1) A sudden, rapid rise in room temperature to over 1000°F ((550ºC)
2) A change in the character of a fire from a localized or two-dimensional phenomena (with the fire seen as a single burning object or a fire moving up a wall) to a three-dimensional one involving the whole room rather uniformly, in a volumetric manner
3) A tendency of the fire to spread from its compartment of origin.

Point (3) is relevant to the fire performance of PVC raceways because the ability of a room [or compartment] to contain a fire without allowing it to spread (i.e., its fire endurance) is strongly influenced by the condition of its boundaries– walls, floors, and ceilings. For this reason, much fire testing has focused on the impact of including PVC raceways in such boundary walls and floor/ceiling assemblies, as evaluated by exposure to post-flashover fire test conditions[5] in ASTM E-119 testing.

To do this, the ASTM E-119 fire endurance test protocol, which is referenced and/or accepted by model code agencies and the NFPA, are used. Similar fire endurance test methods also exist in Europe and Japan under various British Standards, DIN and ISO designations.

The ASTM E-814 standard used to assess through-penetration firestop performance was first accepted in the 1980's. Unlike the ASTM E-119 Standard, which addresses overall performance of construction assemblies (but does not have specific provisions for penetrating elements), ASTM E-814 was specifically conceived to assess the impact of

[5] *Conversely, pre-flashover fire tests of PVC raceway are rarely conducted because these products will not be exposed to the initial fire threat when fires start within rooms. Additionally, these materials are not considered finish materials and thus are not subject to flamespread testing*

penetrations on fire endurance and the integrity of accepted fire resistive assembly designs.

Figure 4: Highrise apartment complex utilizing ENT. Patterson, New Jersey

3.2 Electrical Fire Scenarios

This section considers fire performance of buildings and structures related to foreseeable electrical fire scenarios. It also addresses fires occurring when electrical components may be initially involved.

As indicated previously, pre-flashover fire conditions do not threaten fixed wiring. However, when a fire in a compartment makes the transition from a pre-flashover condition to a post-flashover one, the situation changes. In the case of electrical receptacles and switches, once flashover is reached, room temperatures surpass 1000°F, and fire will impact electrical boxes. Short circuits may develop at box locations if and when insulations fail. However, such failures are a secondary result of the fire and are not causative to fire occurrence. Consistent with this, the presence of PVC raceways or boxes will not exacerbate this situation (as accepted by CABO after extensive 3rd party testing). Additionally, the presence of PVC boxes at these locations will not pose a life-safety threat since tenability levels in such affected rooms will have been exceeded long before such boxes become fire involved.

Testing has been conducted by the Factory Mutual Research Corporation[6] to consider the impact of various fire scenarios on different types of electrical raceways. Specifically, Factory Mutual research evaluated exposure of PVC raceway (as well as metallic conduit and tubing) to various levels of heat flux simulating different fire scenarios. The results of those tests led to the following findings:

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[6] . *Kahn, M.M., 1984. Electrical Failure of Wires Inside 1-inch Conduit Under Simulated Fire Conditions. Factory Mutual Research Technical Report FMRCJ.I. OH4R4.RC 10/84.Tenero, W., 1982. Comparison of 1" PVC Schedule 40 Conduit and 1" EMT Conduit in a Fire Situation. Springborn Testing Institute, Inc. Project No. 707.29 (12/27/82).*

- Electrical failures did not occur until wire insulations reached their melting temperatures.
- PVC raceways showed substantially longer time to electrical failure than metal conduits under similar conditions of heat exposure due to their lower thermal conductivity.

Another common scenario involves an electrical fault (often known as a ground fault), as the cause of a fire. In such cases, energized conductor transfer energy to either a ground or neutral wire because of a non-fire related insulation failure. In addition, if metallic conduit is used, a ground fault can transfer to the raceway with it becoming a conductor since it also provides a path to ground. Finally, in such a situation, metal framing may also become energized. With ENT, because it is non-conductive, a fault-to-ground will not occur to the raceway, while with metallic conduit or raceway the "fault-to ground" can continue almost indefinitely if the over-current protection device is not activated.

Perhaps the most significant example of such a fault-to-ground scenario can be found in the cause and origin of the MGM Grand fire, which killed over 80 people. In that case, an arcing ground fault between an energized conductor and surrounding metal raceway continued undetected until a major fire incident initiated. Such a fire start would not have been possible with PVC raceway since it is a non-conductor and will not allow a fault-to-ground to occur.

3.3 PVC Raceways in Fire-Resistive Assemblies

This section considers questions which regulators– building officials and electrical inspectors and other authorities having jurisdiction–may have concerning use of PVC raceways and accessories in typical fire resistive assemblies. Specific fire test data for these classes of assemblies–cavity walls, floor/ceiling assemblies and slabs–are presented in Chapter 5.

3.3.1 Cavity Walls

A cavity wall is the most common type of partition found in construction today. For this reason, it is important to understand the fire performance of such walls in relation to the electrical products, which may be included in them.

When a fully developed, post-flashover fire occurs in a room bounded by cavity walls, such as those faced with 1/2 inch or 5/8 inch thick gypsum wallboard on studs, a minimum of 15 minutes is required for the cavities of such walls to reach 325°F. This property is reflected by the "finish rating" of typical finish materials (such as 1/2 inch gypsum wallboard). The finish rating is the time required for the backside of that membrane to increase to 325°F above ambient. From a regulatory perspective the issue of "Finish Rating" is considered in Article 331 of **The National Electrical Code**®.

Technical issues related to finish ratings of gypsum wallboards are discussed in a recent article[7].

As it is intuitively obvious, walls faced with thicker wallboard or multiple layers of wallboard will take longer to reach high internal temperatures than thinner walls or walls with fewer layers of facing. Thus, in general, raceways contained within cavity walls have a substantial margin of safety before they become hot enough to impact conductor insulations. Only then, long after conditions supporting human tenability have ceased in the room, will fire impact electrical raceways there. In order to address what happens after this early period, extensive fire endurance testing of walls of both 1 and 2-hour designs and including PVC raceways have been conducted. These will be discussed in detail later.

3.3.2 Floor/Ceilings

Fire performance of floor/ceiling assemblies is also important with respect to PVC raceways. Important questions relate to both finish rating issues and fire performance of branch circuit power distribution systems that are routinely located in such assemblies.

Fire resistive, wood-framed floor/ceiling assemblies with lower membranes of gypsum wallboard [attached to joists] perform similarly to cavity walls in terms of fire endurance. The wallboard used in both assemblies will protect PVC raceway from direct exposure to flame for 15 minutes or more. Additionally, the NEC requires that PVC raceways NOT be installed in floor/ceiling assemblies in which the space above the ceiling membrane is used for handling of return air. A regulation governing this (NEC Section 300-22) was specifically enacted by the NFPA to address concerns about combustion toxicity.
In the case of fire-rated, non-combustible floor/ ceiling assemblies, tests conducted by Underwriters Laboratories (1988) showed no differences in fire endurance between assemblies incorporating PVC raceways and identical ones with metallic raceways installed. NER-290, published by the National Evaluation Service, incorporates the results of much of this testing. The conclusions of NER-290 describe how PVC raceways may be installed in floor/ceiling assemblies having up to 3-hour fire resistance ratings.

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[7] *Zicherman, J.B., Eliahu, A., 1998. "Finish Ratings of Gypsum Wallboards." Fire Technology (November 1998), Vol. 34, No. 4, pp. 356-362*

Figure 5: Highrise apartment utilizing ENT

3.3.3 Concrete Slabs

Fire resistant slabs 4-1/2 inches or greater in thickness are perhaps the most consistently recurring fire resistive assembly in contemporary, non-combustible highrise buildings. The use of electrical products in such slabs and their penetration by electrical raceways is important.

Since 1968, the NEC has accepted the use of RNC in concrete slabs. Beginning with the 1987 NEC, use of ENT has also been accepted in concrete slabs. Situations outlined in the following two sections–through-penetration of slabs by PVC raceway, and encasement of PVC raceway slabs–are of major importance.

3.3.3.1 Through-Penetration of PVC Raceway in Slabs

Through-penetration of slabs (or poke-through as such installations are sometimes called) are important features used to distribute power from floor to floor and within local areas of floors. This practice can be accomplished safely based on installation methodologies evaluated in hundreds of tests run at Underwriters Laboratories, Inc. as well as other third party laboratories and in an early test series by the Portland Cement Association in the 1970's[8]. The latter test series initially established the safety of poke-through type construction in slabs incorporating proper firestop detailing.

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[8] *Abrams, M.S., and Gustafo, A.H., 1971. "Fire Tests of Poke-Trough Assemblies" (RD 008.01B), Portland Cement Association*

When slabs are used horizontally or vertically, through-penetrations are frequently utilized to transfer electrical runs from one compartment to another. Many fire tests have been conducted with PVC elements penetrating such slabs. To safeguard the integrity of such through-penetrations, proprietary systems have been developed which can be found in third party listing documents from Underwriters Laboratories, Inc. and Intertek Testing Services (formerly Warnock Hersey Labs). In such systems, tested materials, devices, and assemblies are described which can be used to properly firestop through-penetrations.


Figure 6:ENT use in steel stud partitions

Generic firestopping approaches for protection of poke-through installations have also been evaluated. An extensive test series was conducted by the Portland Cement Association in 1971 and included PVC components amongst the more than 100 assemblies tested.8 For firestopping of PVC raceway, in addition to the proprietary listed systems referred to above, firestopping materials enumerated in the codes, such as grout and thermal insulation materials, may be used. Many such products have been evaluated and found to be in compliance with the model building codes by agencies such as the National Evaluation Service of the International Code Consortium (ICC) formerly administered by the Council of American Building Officials (CABO). References cited in the appendix include further details describing such systems as well as the listing and labeling associated with their use.

3.3.3.2 Encasement of PVC Raceways in Slabs

When PVC raceways are cast in place within slabs, code officials are occasionally concerned that the material might act as a “wick” and allow the fire to travel within that slab. Because chlorine (part of the PVC molecule) prevents combustion in the absence of high, directly applied heat fluxes and adequate levels of oxygen [both of which are not present within a slab subjected to a high fire load] the PVC raceway acts as an insulator, creating a void in the slab. Field experience, as well as extensive test work, and engineering calculations illustrate that fire will not follow PVC raceway embedded parallel to the face of a concrete slab. Thus, the presence of PVC raceways in slabs will not lead to untimely propagation of a fire across the slab.

PVC raceways encased in concrete slabs and running parallel to the slab surface will not reduce fire endurance of the slab. This is because the raceway and the air space in its center both have appreciably lower thermal conductivity than the concrete itself. In addition, because such raceways do not actively burn within the slab, fire will not spread along their length. This is a consequence of both the heat transfer characteristics of the slab and the combustion characteristics of the unplasticized PVC. Together, these properties do not permit combustion to occur since heat fluxes high enough to cause combustion do not impinge on the conduit internally in the slab. Direct testing of such assemblies has been carried out and is reported on in Chapter 5.

3.4 Proprietary Through-Penetration and Membrane Firestop Systems

As noted in Section 3.3.3.1, many different systems for PVC raceway, from a variety of manufacturers have been qualified through third party testing, for materials installed in and penetrating concrete slabs. Such systems are also available in listed and labeled versions for use with cavity walls. Examples of these systems tested with nonmetallic raceway are presented in three summary tables that follow. The data contained in the tables comes directly from third party listing directory information.

Figure 7:ENT installed during concrete slab pour
Key West, Florida

Figure 8:ENT use in type V construction
Penta Hotel, Orlando, Florida

Figure 9:Type 1 highrise construction incorporating ENT products
Cleveland, Ohio

Figure 10:Marriott Hotel project using ENT products
Cleveland, Ohio

Figure 11:Distribution box in Marriott Hotel project
Cleveland, Ohio

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000)

CONCRETE WALL/FLOOR LESS THAN OR EQUAL TO 5" THICK RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40/80	4" OR SMALLER	2	1.5 & 2	C-AJ-2001	1305	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	2	2	C-AJ-2002	1307	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	3	0.5	C-AJ-2003	1307	MINNESOTA MINING & MFG. CO.
RNMC 40/80	2" OR SMALLER	2	2	C-AJ-2007	1309	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	2	2	C-AJ-2007	1309	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	2 & 3	0.75, 2 & 3	C-AJ-2027	1314	MINNESOTA MINING & MFG. CO.
ENT	1¼" OR SMALLER	2	2	C-AJ-2028	1315	MINNESOTA MINING & MFG. CO.
ENT	2" OR SMALLER	2	2	C-AJ-2029	1315	MINNESOTA MINING & MFG. CO.
ENT	2" OR SMALLER	2	1.5 & 2	C-AJ-2030	1316	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	2 & 3	1.5 & 3	C-AJ-2031	1317	SPECIFIED TECHNOLOGIES INC.
ENT	2" OR SMALLER	2 & 3	1.5 & 4	C-AJ-2031	1317	SPECIFIED TECHNOLOGIES INC.
PLENUM-GARD	1" OR SMALLER	2 & 3	1.5 & 5	C-AJ-2031	1317	SPECIFIED TECHNOLOGIES INC.
RISER-GARD	1" OR SMALLER	2 & 3	1.5 & 6	C-AJ-2031	1317	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	4" OR SMALLER	2 & 3	2 & 3	C-AJ-2038	1318	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	3" OR SMALLER	2 & 3	1 & 1.5	C-AJ-2039	1319	PROSET SYSTEMS, INC.
RNMC 40	4" OR SMALLER	3	3	C-AJ-2042	1319	INTERNATIONAL PROTECTIVE COATINGS
ENT	2" OR SMALLER	2	2	C-AJ-2056	1320	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	2 & 3	2 & 3	C-AJ-2063	1322	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	2 & 3	2 & 3	C-AJ-2064	1322	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	2 & 3	1.5 & 2	C-AJ-2086	1325	NELSON FIRESTOP PRODUCTS
RNMC 40	4" OR SMALLER	3	3	C-AJ-2088	1326	ISOLATEK INTERNATIONAL
RNMC 40	6" OR SMALLER	3	2	C-AJ-2089	1326	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	1" OR SMALLER	3	3	C-AJ-2092	1327	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	2 & 3	1 & 2	C-AJ-2093	1327	SPECIFIED TECHNOLOGIES INC.
ENT	2" OR SMALLER	3	3	C-AJ-2098	1329	HILTI CONSTRUCTION CHEMICALS, INC.
ENT	2" OR SMALLER	2	2	C-AJ-2107	1332	INSTANT FIRESTOP MFG. INC.
FNMC	2" OR SMALLER	2	2	C-AJ-2107	1332	INSTANT FIRESTOP MFG. INC.
RNMC 40	4" OR SMALLER	2 & 3	2	C-AJ-2108	1332	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	3	2	C-AJ-2124	1337	SPECIFIED TECHNOLOGIES INC.
RNMC 40	6" OR SMALLER	3	3	C-AJ-2125	1338	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	3	1.5 & 2	C-AJ-2126	1339	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	2	2	C-AJ-2136	1342	SPECIFIED TECHNOLOGIES INC.
RNMC 40	3" OR SMALLER	2	2	C-AJ-2138	1343	SPECIFIED TECHNOLOGIES INC.

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000) Continued.

CONCRETE WALL/FLOOR LESS THAN OR EQUAL TO 5" THICK RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40	1" OR SMALLER	2	2	C-AJ-2140	1344	SPECIFIED TECHNOLOGIES INC.
ENT	1" OR SMALLER	2	2	C-AJ-2140	1344	SPECIFIED TECHNOLOGIES INC.
PLENUM-GARD	1" OR SMALLER	2	2	C-AJ-2140	1344	SPECIFIED TECHNOLOGIES INC.
RISER-GARD	1" OR SMALLER	2	2	C-AJ-2140	1344	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	2	0.25	C-AJ-2143	1345	MINNESOTA MINING & MFG. CO.
RNMC 40	6" OR SMALLER	3	2	C-AJ-2148	1348	NELSON FIRESTOP PRODUCTS
RNMC 40	4" OR SMALLER	2	2	C-AJ-2149	1348	NELSON FIRESTOP PRODUCTS
RNMC 40	2" OR SMALLER	2	1	C-AJ-2150	1349	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	4" OR SMALLER	2	1	C-AJ-2159	1352	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	2	2	C-AJ-2161	1353	MINNESOTA MINING & MFG. CO.
RISER-GARD	1¼" OR SMALLER	3	2	C-AJ-2162	1353	NELSON FIRESTOP PRODUCTS
ENT	1¼" OR SMALLER	3	2	C-AJ-2162	1353	NELSON FIRESTOP PRODUCTS
RISER-GARD	2" OR SMALLER	3	3	C-AJ-2163	1353	NELSON FIRESTOP PRODUCTS
ENT	2" OR SMALLER	3	3	C-AJ-2163	1353	NELSON FIRESTOP PRODUCTS
RNMC 40	2" OR SMALLER	2	1	C-AJ-2166	1354	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	3	2 & 3	C-AJ-2173	1357	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	6" OR SMALLER	2	2	C-AJ-2186	1361	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	4" OR SMALLER	2	2	C-AJ-2187	1362	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	4" OR SMALLER	2	2	C-AJ-2189	1362	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	3	2	C-AJ-2202	1364	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	2	2	C-AJ-2207	1364	NUCO INC.
RNMC 40	6" OR SMALLER	2.5	2.5	C-AJ-2214	1367	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	2	1	C-AJ-2216	1368	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	2	1.5	C-AJ-2222	1370	FIRESTOP SYSTEMS INC.
RNMC 40	2" OR SMALLER	2	1.5	C-AJ-2223	1370	JOHNS MANVILLE INTERNATIONAL INC.
RNMC 40	2" OR SMALLER	2	1.75	C-AJ-2224	1370	JOHNS MANVILLE INTERNATIONAL INC.
RNMC 40	2" OR SMALLER	2	1.75	C-AJ-2225	1371	FIRESTOP SYSTEMS INC.
RNMC 40	4" OR SMALLER	3	3	C-AJ-2226	1371	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	2	0.75 & 1.25	C-AJ-2227	1372	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	2 & 3	2	C-AJ-2228	1372	MINNESOTA MINING & MFG. CO.
ENT	1" OR SMALLER	2	1.75	C-AJ-2229	1373	TREMCO
RNMC 40	4" OR SMALLER	1	1	C-AJ-2241	1376	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	2	1.75 & 2	C-AJ-2242	1376	MINNESOTA MINING & MFG. CO.

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000) Continued.

CONCRETE WALL/FLOOR LESS THAN OR EQUAL TO 5" THICK RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
ENT	1" OR SMALLER	2	1.5	C-AJ-2245	1377	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	1.5	C-AJ-2245	1377	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	1.5	C-AJ-2245	1377	RECTORSEAL
ENT	1" OR SMALLER	2	1.5	C-AJ-2246	1377	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	1.5	C-AJ-2246	1377	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	1.5	C-AJ-2246	1377	RECTORSEAL
ENT	1" OR SMALLER	2	1.5	C-AJ-2247	1378	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	1.5	C-AJ-2247	1378	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	1.5	C-AJ-2247	1378	RECTORSEAL
RNMC 40	1" OR SMALLER	3	3	C-AJ-2259	1379	PREMIER REFRACTORIES INC.
RNMC 40	1" OR SMALLER	2	2	C-AJ-2260	1379	PREMIER REFRACTORIES INC.
RNMC 40	4" OR SMALLER	2	2	C-AJ-2262	1379	PREMIER REFRACTORIES INC.
RNMC 40	2" OR SMALLER	3	0.75	C-AJ-2263	1380	PREMIER REFRACTORIES INC.

CONCRETE WALL/FLOOR GREATER THAN 5" THICK RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40/80	4" OR SMALLER	3	3	C-BJ-2001	1583	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	2	2	C-BJ-2007	1585	MINNESOTA MINING & MFG. CO.

FRAMED WALL ASSEMBLIES RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40/80	2" OR SMALLER	2	2	W-L-2001	1982	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	2	2	W-L-2001	1982	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	4" OR SMALLER	1 & 2	1 & 2	W-L-2002	1982	MINNESOTA MINING & MFG. CO.
ENT	1" OR SMALLER	1 & 2	1 & 2	W-L-2002	1982	MINNESOTA MINING & MFG. CO.
RNMC 40/80	4" OR SMALLER	1 & 2	1 & 2	W-L-2003	1983	MINNESOTA MINING & MFG. CO.
RNMC 40	4" AND 3.5"	2	1.5	W-L-2004	1984	MINNESOTA MINING & MFG. CO.
RNMC 40	3" OR SMALLER	2	2	W-L-2004	1984	MINNESOTA MINING & MFG. CO.
ENT	1" OR SMALLER	2	2	W-L-2004	1984	MINNESOTA MINING & MFG. CO.
RNMC 40/80	2" OR SMALLER	1	0.75	W-L-2010	1986	NELSON FIRESTOP PRODUCTS
ENT	0.5"	2	2	W-L-2011	1986	NELSON FIRESTOP PRODUCTS
RNMC 40/80	4" & 3"	1 & 2	1 & 2	W-L-2029	1991	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	2" & 1.5"	1 & 2	1 & 1.5	W-L-2029	1991	SPECIFIED TECHNOLOGIES INC.

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000) Continued

FRAMED WALL ASSEMBLIES RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
ENT	2" OR SMALLER	2	1.5	W-L-2032	1992	MINNESOTA MINING & MFG. CO.
ENT	2" OR SMALLER	2	1.5	W-L-2033	1992	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	1 & 2	0.75 & 1.5	W-L-2037	1994	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	1 & 2	1 & 2	W-L-2038	1994	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	1 & 2	1 & 2	W-L-2038	1994	INTERNATIONAL PROTECTIVE COATINGS
ENT	1.5" OR SMALLER	1 & 2	0.75 & 1.5	W-L-2039	1995	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	1 & 2	1, 1.5 & 2	W-L-2048	1996	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	4" & 3"	1 & 2	1 & 2	W-L-2059	1998	SPECIFIED TECHNOLOGIES INC.
RNMC 40/80	2" & 1.5"	1 & 2	1 & 1.5	W-L-2059	1998	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	1 & 2	1 & 2	W-L-2067	1999	ISOLATEK INTERNATIONAL
ENT	1.5" OR SMALLER	1 & 2	0.5 & 1.5	W-L-2068	2000	ISOLATEK INTERNATIONAL
RNMC 40	4" OR SMALLER	1 & 2	0.75 & 1.5	W-L-2070	2000	ISOLATEK INTERNATIONAL
RNMC 40	2" OR SMALLER	1 & 2	1 & 1.5	W-L-2072	2001	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	4" OR SMALLER	1 & 2	1 & 2	W-L-2073	2002	MINNESOTA MINING & MFG. CO.
RNMC 40	6" OR SMALLER	1 & 2	1 & 2	W-L-2074	2002	SPECIFIED TECHNOLOGIES INC.
ENT	2" OR SMALLER	1 & 2	2	W-L-2075	2003	HILTI CONSTRUCTION CHEMICALS, INC.
RNMC 40	2" OR SMALLER	1 & 2	1 & 1.5	W-L-2077	2003	ISOLATEK INTERNATIONAL
RNMC 40	3" OR SMALLER	1 & 2	1 & 2	W-L-2088	2009	MINNESOTA MINING & MFG. CO.
ENT	1" OR SMALLER	1 & 2	1 & 2	W-L-2088	2009	MINNESOTA MINING & MFG. CO.

FRAMED WALL ASSEMBLIES RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40	2" OR SMALLER	1 & 2	1 & 1.5	W-L-2093	2011	SPECIFIED TECHNOLOGIES INC.
PLENUM-GARD	1.25" OR SMALLER	1 & 2	2 & 1.5	W-L-2093	2011	SPECIFIED TECHNOLOGIES INC.
RISER-GARD	2" OR SMALLER	1 & 2	3 & 1.5	W-L-2093	2011	SPECIFIED TECHNOLOGIES INC.
ENT	2" OR SMALLER	1 & 2	4 & 1.5	W-L-2093	2011	SPECIFIED TECHNOLOGIES INC.
RNMC 40	3" OR SMALLER	1 & 2	0.75, 1 & 2	W-L-2097	2012	MINNESOTA MINING & MFG. CO.
RNMC 40	4" OR SMALLER	1 & 2	1 & 1.5	W-L-2101	2014	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	2	2	W-L-2113	2018	FIRESTOP SYSTEMS INC.
RNMC 40	4" OR SMALLER	1 & 2	1, 1.5 & 2	W-L-2131	2024	NELSON FIRESTOP PRODUCTS
RNMC 40	4" OR SMALLER	1 & 2	0.75 & 1.25	W-L-2143	2028	NUCO INC.
RNMC 40	4" OR SMALLER	1 & 2	1 & 2	W-L-2147	2029	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	1	1	W-L-2148	2030	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	2	2	W-L-2149	2030	MINNESOTA MINING & MFG. CO.
RNMC 40	6" OR SMALLER	2	1.5	W-L-2150	2031	MINNESOTA MINING & MFG. CO.
RNMC 40	6" OR SMALLER	1 & 2	1 & 2	W-L-2154	2031	MINNESOTA MINING & MFG. CO.
RNMC 40	6", 4" & 3"	2	1.5 & 2	W-L-2155	2032	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	2" OR SMALLER	1.5	0.5	W-L-2156	2032	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	2" OR SMALLER	2	1	W-L-2157	2033	A/D FIRE PROTECTION SYSTEMS INC.
ENT	1" OR SMALLER	1 & 2	0.75 & 1.75	W-L-2158	2033	TREMCO
RNMC 40	4" OR SMALLER	1, 2, & 3	1, 2, & 3	W-L-2162	2034	MINNESOTA MINING & MFG. CO.
ENT	2" OR SMALLER	2	2	W-L-2165	2035	HILTI CONSTRUCTION CHEMICALS, INC.
PLENUM-GARD	2" OR SMALLER	2	2	W-L-2165	2035	HILTI CONSTRUCTION CHEMICALS, INC.
RISER-GARD	2" OR SMALLER	2	2	W-L-2165	2035	HILTI CONSTRUCTION CHEMICALS, INC.
RNMC 40	4" OR SMALLER	1 & 2	1 & 1.5	W-L-2167	2036	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	2	1	W-L-2170	2037	INTERNATIONAL PROTECTIVE COATINGS
ENT	2" OR SMALLER	1 & 2	0.75 & 2	W-L-2182	2041	JOHNS MANVILLE INTERNATIONAL INC.

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000) Continued

FRAMED WALL ASSEMBLIES

RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
ENT	1" OR SMALLER	1 & 2	1, 1.75 & 2	W-L-2190	2043	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	1 & 2	1, 1.75 & 3	W-L-2190	2043	RECTORSEAL
RISER-GARD	1" OR SMALLER	1 & 2	1, 1.75 & 4	W-L-2190	2043	RECTORSEAL
ENT	1" OR SMALLER	1 & 2	1, 1.75 & 5	W-L-2191	2044	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	1 & 2	1, 1.75 & 6	W-L-2191	2044	RECTORSEAL
RISER-GARD	1" OR SMALLER	1 & 2	1, 1.75 & 7	W-L-2191	2044	RECTORSEAL
ENT	1" OR SMALLER	1 & 2	1 & 2	W-L-2192	2044	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	1 & 2	1 & 2	W-L-2192	2044	RECTORSEAL

FRAMED WALL ASSEMBLIES

RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RISER-GARD	1" OR SMALLER	1 & 2	1 & 2	W-L-2192	2044	RECTORSEAL
ENT	1" OR SMALLER	1 & 2	1 & 2	W-L-2193	2045	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	1 & 2	1 & 2	W-L-2193	2045	RECTORSEAL
RISER-GARD	1" OR SMALLER	1 & 2	1 & 2	W-L-2193	2045	RECTORSEAL
RNMC 40	6" OR SMALLER	3 & 4	3	W-L-2195	2046	SPECIFIED TECHNOLOGIES INC.
PLENUM-GARD	1" OR SMALLER	1	0.5	W-L-2197	2047	HILTI CONSTRUCTION CHEMICALS, INC.
RISER-GARD	1" OR SMALLER	1	0.5	W-L-2197	2047	HILTI CONSTRUCTION CHEMICALS, INC.
RNMC 40	4" OR SMALLER	3 & 4	3 & 4	W-L-2198	2047	SPECIFIED TECHNOLOGIES INC.

CONCRETE/MASONRY WALL LESS THAN OR EQUAL TO 8" THICK

RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
RNMC 40/80	2" OR SMALLER	2	2	W-J-2001	1830	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	2	2	W-J-2001	1830	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40/80	2" OR SMALLER	1	0.75	W-J-2002	1831	NELSON FIRESTOP PRODUCTS
ENT	0.50"	2	2	W-J-2003	1831	NELSON FIRESTOP PRODUCTS
RNMC 40	2" OR SMALLER	2	2	W-J-2014	1834	INTERNATIONAL PROTECTIVE COATINGS
ENT	1" OR SMALLER	2	2	W-J-2014	1834	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	2" OR SMALLER	2	2	W-J-2015	1834	ISOLATEK INTERNATIONAL
RNMC 40	2" OR SMALLER	2	1 & 1.5	W-J-2018	1835	SPECIFIED TECHNOLOGIES INC.
PLENUM-GARD	1.25" OR SMALLER	2	2 & 1.5	W-J-2018	1835	SPECIFIED TECHNOLOGIES INC.
RISER-GARD	2" OR SMALLER	2	3 & 1.5	W-J-2018	1835	SPECIFIED TECHNOLOGIES INC.
ENT	2" OR SMALLER	2	4 & 1.5	W-J-2018	1835	SPECIFIED TECHNOLOGIES INC.
RNMC 40	2" OR SMALLER	2	1.5 & 2	W-J-2020	1836	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	2	1.5	W-J-2022	1837	SPECIFIED TECHNOLOGIES INC.
RNMC 40	3" OR SMALLER	1 & 2	1 & 2	W-J-2029	1839	MINNESOTA MINING & MFG. CO.
ENT	1" OR SMALLER	1 & 2	1 & 2	W-J-2029	1839	MINNESOTA MINING & MFG. CO.
RNMC 40	2" OR SMALLER	2	2	W-J-2037	1842	FIRESTOP MATERIAL SUPPLIER
RNMC 40	4" OR SMALLER	2	1.5	W-J-2046	1844	FIRESTOP MATERIAL SUPPLIER
RNMC 40	2" OR SMALLER	2	1	W-J-2050	1845	A/D FIRE PROTECTION SYSTEMS INC.
RNMC 40	2" OR SMALLER	2	1	W-J-2051	1846	INTERNATIONAL PROTECTIVE COATINGS
RNMC 40	6" OR SMALLER	4	3	W-J-2060	1849	SPECIFIED TECHNOLOGIES INC.
RNMC 40	4" OR SMALLER	4	4	W-J-2061	1849	SPECIFIED TECHNOLOGIES INC.

Underwriters Laboratories Classified Through-Penetration Firestop systems for nonmetallic raceways.(2000) Continued

CONCRETE/MASONRY WALL LESS THAN OR EQUAL TO 8" THICK RACEWAYS	SIZES	F RATING (HR)	T RATING (HR)	SYSTEM NO.	PAGE[1]	FIRESTOP MATERIAL SUPPLIER
ENT	1" OR SMALLER	2	1.75 & 2	W-J-2063	1850	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	1.75 & 2	W-J-2063	1850	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	1.75 & 3	W-J-2063	1850	RECTORSEAL
ENT	1" OR SMALLER	2	1.75 & 4	W-J-2064	1851	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	1.75 & 5	W-J-2064	1851	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	1.75 & 6	W-J-2064	1851	RECTORSEAL
ENT	1" OR SMALLER	2	2	W-J-2065	1851	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	2	W-J-2065	1851	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	2	W-J-2065	1851	RECTORSEAL
ENT	1" OR SMALLER	2	2	W-J-2066	1851	RECTORSEAL
PLENUM-GARD	1" OR SMALLER	2	2	W-J-2066	1851	RECTORSEAL
RISER-GARD	1" OR SMALLER	2	2	W-J-2066	1851	RECTORSEAL

FOR FIRESTOP PRODUCT DISTRIBUTOR INFORMATION CONTACT THE MANUFACTURERS LISTED BELOW:

A/D FIRE PROTECTION SYSTEMS INC.
SCARBOROUGH, ONTARIO, CANADA
(416) 292-2361

FIRESTOP SYSTEMS INC.
SURREY, BRITISH COLUMBIA, CANADA
(604) 580-1788

HILTI CONSTRUCTION CHEMICALS, INC.
TULSA, OK
(918) 252-6000
(800) 879-8000

INSTANT FIRESTOP MANUFACTURING, INC.
NIAGARA FALLS, NY
(716) 285-0848

INTERNATIONAL PROTECTIVE COATINGS CORP.
OCEAN, NJ
(908) 531-3667
(800) 334-8796

ISOLATEK INTERNATIONAL
STANHOPE, NJ
(201) 347-1200

MINNESOTA MINING & MFG. CO.
ST. PAUL, MN
(612) 733-1110

JOHNSMANVILLE INTERNATIONAL INC.
DENVER, CO
(303) 978-3304

NELSON FIRESTOP PRODUCTS
TULSA, OK
(918) 627-5530
(800) 331-7325

NUCO, INC.
MISSISSAUGA, ONTARIO, CANADA
(704) 366-7000

PROSET SYSTEMS, INC
LAWRENCEVILLE, GA
(770) 339-1782

PREMIER REFRACTORIES INC.
KING OF PRUSSIA, PA

RECTORSEAL
HOUSTON, TX
(713) 263-8001
(800) 231-3345

SPECIFIED TECHNOLOGIES INC.
SOMERVILLE, NJ
(908) 526-8000

TREMCO INC.
BEACHWOOD, OH
(800) 321-7906

Intertek Testing Services classified through-penetration firestop system for PVC Pipe, tube and conduit.(2000)

CONCRETE WALL/FLOOR LESS THAN OR EQUAL TO 8" THICK RACEWAYS	SIZE	E814/S115	F	T	DESIGN NO	Page	FIRESTOP MATERIAL SUPP.
PVC	2"		1	1	3M/PH 60-05	804	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2" - 4"		1&2	1&2	3M/PH 120-05	805	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2" - 3"		1&2	1&2	3M/PH 120-06	805	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2" - 3"		2	2	3M/PH 120-08	806	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2 - 4"		2	2	3M/PHV 120-03	807	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2 - 3"		2	2	3M/PHV 120-08	810	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2 - 4"		1&2	1&2	3M/PV 120-01	811	3M CanadaCo.
PVC	2"		1&2	1&2	3M/PV 120-02	812	3M CanadaCo.
ccPVC/PVC/CPVC	1-1/2 - 3"		1&2	1&2	3M/PV 120-05	813	3M CanadaCo.
CPVC	2-1/2"		2	NA	BF/PHV 120-01	819	BFGoodrich
PVC	3"		2	NA	BF/PHV 120-01	819	BFGoodrich
PVC and CPVC	1/2" - 4"	nonvented	1	1	FG/PH 60-02	822	F.G.C. Fireguard Corp.
PVC DWV	1 1/4" -1 1/2"		1	1	FG/PH 60-02	822	F.G.C. Fireguard Corp.
PVC DWV	1 1/4- 2"		1	1	FG/PH 60-02	822	F.G.C. Fireguard Corp.
PVC Vacuum pipe	2"		1	1	FG/PH 60-02	822	F.G.C. Fireguard Corp.
PVC & CPVP	1/2 - 4"	nonvented	2	2	FG/PHV 120-01	823	F.G.C. Fireguard Corp.
PVC DWV	1 1/4- 2"		2	2	FG/PHV 120-01	823	F.G.C. Fireguard Corp.
PVC & DWV pipe & fittings	1 1/4 - 2"		2	2	FG/PHV 120-01	823	F.G.C. Fireguard Corp.
PVC Vacuum pipe	2"		2	2	FG/PHV 120-01	823	F.G.C. Fireguard Corp.
PVC & CPVP	1/2 - 4"	nonvented	2	2	FG/PV 120-03	823	F.G.C. Fireguard Corp.
PVC DWV pipe	1 1/4 -2"		2	2	FG/PV 120-03	823	F.G.C. Fireguard Corp.
PVC DWV pipe & fittings	1 1/4- 1 1/2"		2	2	FG/PV 120-03	823	F.G.C. Fireguard Corp.
PVC Vacuum pipe	2"		2	2	FG/PV 120-03	823	F.G.C. Fireguard Corp.
PVC	<4"		1	1	GP/PH 60-02	824	GP Gypsum Corp.
PVC	4"		1	1	GP/PV 60-03	825	GP Gypsum Corp.
PVC	4"		1	1	GP/PV 60-04	825	GP Gypsum Corp.
PVC	4"		2	2	GP/PV 120-04	826	GP Gypsum Corp.
PVC 40	4"		3	2.48	GP/PV 180-02	826	GP Gypsum Corp.
PVC/ccPVC/CPVC	1"		0	0	JMI/PH 60-01	829	Johns Manville International Corp.
PVC/ccPVC/CPVC	4"		1	1	JMI/PH 60-02	829	Johns Manville International Corp.
PVC/ccPVC/CPVC	4"		2	2	JMI/PH 120-01	830	Johns Manville International Corp.
PVC/ccPVC/CPVC	2"		2	2	JMI/PH 120-02	830	Johns Manville International Corp.
PVC/ccPVC/CPVC	2"		2	2	JMI/PHV 120-01	831	Johns Manville International Corp.
PVC/ccPVC/CPVC	2"		2	2	JMI/PHV 120-02	831	Johns Manville International Corp.
PVC	2"		0/1	0	JMI/PV 60-01	832	Johns Manville International Corp.
PVC/ccPVC/CPVC	2"		1	1	JMI/PV 60-02	832	Johns Manville International Corp.
CPVC/PVC	2"		1	1	NI/PH 60-01	832	NUCO, INC.
CPVC/PVC	2"		2	2	NI/PHV 120-01	833	NUCO, INC.
CPVC/PVC	2"		2	2	NI/PV 120-01	833	NUCO, INC.
ccPVC/CPVC	4"		1	1	PFP/PH 60-01	834	Passive Fire Protection Partners
PVC/ccPVC/CPVC	4"		1	1	PFP/PH 60-02	834	Passive Fire Protection Partners
PVC/ccPVC/CPVC	1 1/2"		1	1	PFP/PHV 60-01	836	Passive Fire Protection Partners
Non-metallic tubing	1 1/2"		1	1	PFP/PHV 60-02	836	Passive Fire Protection Partners
PVC	2 1/2"		2	2	PFP/PHV 120-02	838	Passive Fire Protection Partners

CPVC	3"	2	2	PFP/PHV 120-02	838	Passive Fire Protection Partners
PVC/ccPVC/CPVC	4"	2	2	PFP/PHV 120-14	842	Passive Fire Protection Partners
PVC	4"	2	2	PSI/PH 120-03	844	Pipe Shields INC.
PVC	4"	2	1.08	PSI/PV 120-03	845	Pipe Shields INC.
PVC	<4"	2	0	PS/PH 120-02	847	PROSET Systems INC.
CPVC	<1"	2	2	PS/PH 120-05	848	PROSET Systems INC.
PVC 40	<2"	2	2	PS/PH 120-06	848	PROSET Systems INC.
PVC	<4"	2	0	PS/PH 120-07	848	PROSET Systems INC.
PVC	3"	2	2	PS/PH 120-08	848	PROSET Systems INC.
PVC	3"	2	2	PS/PH 120-09	849	PROSET Systems INC.
PVC	1 1/2"	2	2	PS/PH 120-10	849	PROSET Systems INC.
PVC	1 1/2"	2	1	PS/PH 120-11	849	PROSET Systems INC.
PVC	4"	2	2	PS/PH 120-12	849	PROSET Systems INC.
PVC	4"	2	2	PS/PH 120-14	850	PROSET Systems INC.
PVC	3"-4"	2&3	2	PS/PH 120-15	850	PROSET Systems INC.
PVC	<4"	3	3	PS/PH 180-01	850	PROSET Systems INC.
CPVC/PVC	1 1/2"	2	2	PS/PHV 120-04	852	PROSET Systems INC.
PVC	4"	3	3	PS/PHV 180-03	853	PROSET Systems INC.
CPVC	1/2" - 1 1/2"	2	2	PS/PV 120-01	854	PROSET Systems INC.
PVC	1" - 1 1/2"	2	2	PS/PV 120-02	854	PROSET Systems INC.
PVC DWV 40	4"	1	1	TRC/PH 60-03	856	Rectorseal Corp.
PVC DWV/CPVC	4"	1	1	TCR/PH 60-06	857	Rectorseal Corp.
PVC DWV/CPVC	4"	1	1	TCR/PH 60-07	857	Rectorseal Corp.
PVC	2"	2	0	TCR/PH 120-05	858	Rectorseal Corp.
PVC DWV	4"	2	1	TCR/PHV 120-05	860	Rectorseal Corp.
PVC	2"	2	2	TRC/PHV 120-07	860	Rectorseal Corp.
PVC	6"	2	NA	TCR/PHV 120-08	861	Rectorseal Corp.
CPVC	4"	2	NA	TCR/PHV 120-08	861	Rectorseal Corp.
PVC	2"	1	1	TCR/PH 60-01	861	Rectorseal Corp.
PVC	6"	1	1	TRC/PV 60-07	863	Rectorseal Corp.
PVC	4"	1	1.5	TCR/PV 120-05	863	Rectorseal Corp.
PVC 40	2"	2	2	TCR/PV 120-12	865	Rectorseal Corp.
PVC	4"	2	1	TRC/PV 120-18	866	Rectorseal Corp.
PVC	2"	1	NA	TL/PH 60-01	868	TREMCO LTD
PVC	1 1/2"	1	NA	TL/PH 60-01	868	TREMCO LTD
PVC	6"	2	2	WR/PHV 120-01	869	Wirsbo CO, USA
PVC	6"	2	2	WC/PHV 120-01	870	Wirsbo CO, CANADA

Omega Point Laboratory Inc. classified through penetration firestop system for PVC pipe, tube and conduit. (2000)

CONCRETE WALL/FLOOR LESS THAN OR EQUAL TO 5.5" Raceways	Sizes	F Rating (Hr)	T Rating (Hr)	Design No.	Page	Firestop Material Supplier
PVC	1.5"	2	1.5	FS 115F	341	Tremco, Inc.
PVC	2"	2	0.38	FS 526F/T2	357	Fire Can Manufacturing Co.
PVC	3"	2	0.77	FS 526F/T3	357	Fire Can Manufacturing Co.
PVC	4"	2	0.65	FS 526F/T4	357	Fire Can Manufacturing Co.
PVC	6"	2	2	FS 526F/T6	357	Fire Can Manufacturing Co.
PVC	1.5"	2	0.92	FS 526F/TWST	357	Fire Can Manufacturing Co.
PVC	3"	2	0.77	FS 534F/T3	373	Tremco, Inc.
PVC	4"	2	0.65	FS 534F/T4	373	Tremco, Inc.
PVC	6"	2	2	FS 534F/T6	373	Tremco, Inc.
PVC	8"	2	0.92	FS 534F/TWST	373	Tremco, Inc.

3.5 Performance of PVC Raceways In Fire: Carlon ENT Performance: Fire in a Restaurant San Jose, California

This 1999 fire incident in San Jose, California (SJ FD Incident No. 43070) demonstrates how Carlon ENT performs in a fire including a post-flashover condition even when located at the area of fire origin. The fire in question occurred in a single-story restaurant of wood frame construction and originated at the main electrical distribution panel.

Figure 12: Post-fire view of restaurant roof: fire plume penetrated roof at center of photo. San Jose, California

The cause and origin investigation, conducted per NFPA Standard 921, “Fire and Explosion Investigations”, identified the area of origin as the 200 amp electrical sub-panel in the restaurant’s supply room. This panel was fed by a Rigid Metallic Conduit (RMC) and Carlon ENT raceways which housed conductors for individual circuits. Analysis of burn/char patterns showed that the fire started at a defective breaker causing internal arcing leading to eventual fire spread upwards into the building’s attic along wood framing members.

The arcing event was sufficiently severe that two areas of the panel’s steel case eroded, as can be seen in the accompanying photos. The larger of the two areas is at the top of the sub-panel where circuit breakers are energized. The other affected area was a 2-inch RMC which fed the panel. The slag created by the later arcing could have ignited nearby combustibles. What is particularly remarkable about this incident is that although the arcing vaporized significant areas of the RMC and spread the fire in the process, adjacent runs of Carlon ENT immediately adjoining the RMC did not ignite. Also, except for areas immediately adjoining the sub-panel where the ENT melted locally, the structure of the tubing is completely intact and the conductors were well protected. Likewise areas of ENT located away from the initial arcing, which were directly exposed to fire conditions, were also found intact.

Figure 13: Close-up view of restaurant interior from above.
San Jose California

Figure 14:Collateral damage to metal and ENT raceways.
San Jose, California

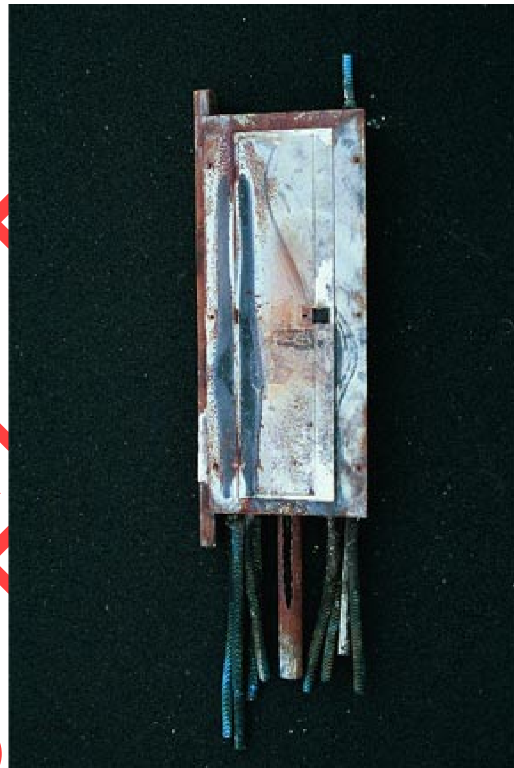


Figure 15:Distribution panel where fire originated.
San Jose, California

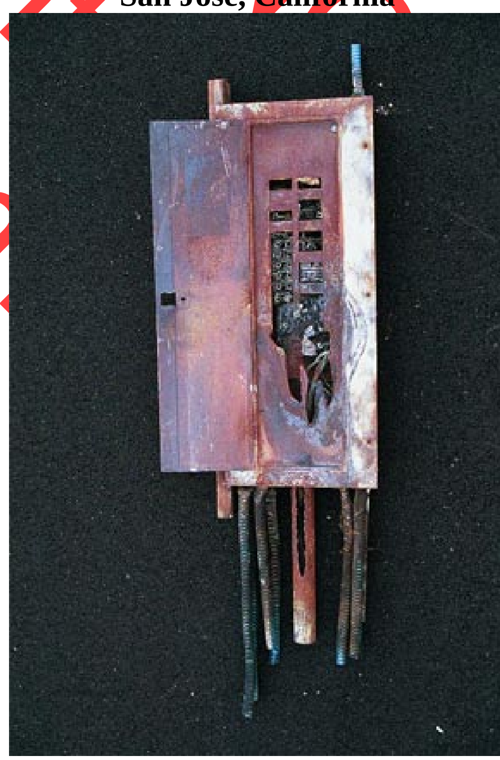


Figure 16:Interior panel showing where ground fault led to destruction of panel components
San Jose, California

Figure 17:Condition of conductors after fire in ENT and Rigid Metal Conduit (RMC)
San Jose, California

4.0 The Model Building Codes

It is important for designers, specifiers and other users of PVC raceways to understand the interrelationship of **The National Electrical Code** (NEC) with the three model building codes, specifically the **BOCA National Building Code**, **Standard Building Code**, and **Uniform Building Code**. Questions often arise concerning how the NEC interrelates to a specific building code and how that individual building code addresses fire safety along with other issues related to the use of PVC raceways and related products. While each model building code has associated plumbing, mechanical, and (additional) subsidiary codes, each model building code specifically references **The National Electrical Code** (NEC) as its companion electrical code.

The term "building code" brings all sorts of images to mind. In fact, the system under which most of the U.S. operates, is based on local adoption of model codes usually after reviews at the state and/or local level. These generally include consideration and possible inclusion of amendments prior to adoption.

The model codes are themselves promulgated by three, independent model code writing agencies each of which has a full time administrative and technical staff. However, these agencies do not themselves author the code text. Rather, representatives of local, county, and state jurisdictions develop the text jointly with input from industry and other interested parties. Committees made up of building officials and professional experts on a regular basis act upon proposed changes to the existing model building codes. Final voting is restricted to active building officials. Approved changes are then added to existing codes, which are republished every three years with the new revisions included.
In addition to local codes, based on adopted model codes, some cities–such as Chicago–have their own historically based codes as do states such as Wisconsin and New York. Others, such as California, adopt model codes as an aid to uniformity of enforcement after making suitable amendments. While each model building code has associated plumbing, mechanical, and other necessary subsidiary codes, each model code specifically references **The National Electrical Code** (NEC) as its companion electrical code. The NEC is promulgated by the National Fire Protection Agency (NFPA) and is a consensus standard.

4.1 The *BOCA National Building Code* and PVC Raceways

The **BOCA National Building Code**, promulgated by the Building Officials and Code Administrators International (BOCA, Country Clubs Hills, Illinois) regulates the use of PVC raceway in construction in jurisdictions in which it is adopted and defines the relationship of the **BOCA National Building Code** to the NEC.

4.1.1 Code Format

The 1999 **BOCA National Building Code** utilizes two definitions to most broadly define a building; they are "occupancy type" – which relates to projected use of the building and "type of construction"– which defines materials allowed for use in the construction of a particular class of building. Together, these define endurance properties required for a particular building constructed in accordance with the **BOCA National Building Code**.

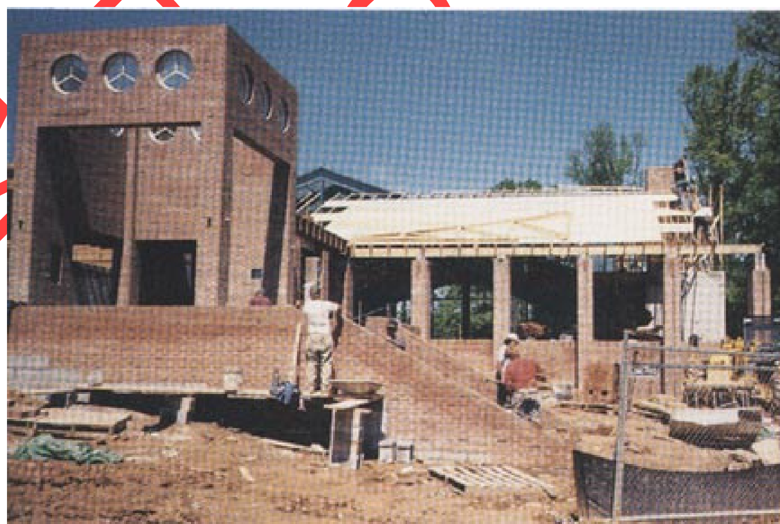


Figure 18:Natatorium-Swim Center built with ENT used in walls and ceilings Greenbelt, Maryland

Occupancy classifications, found in **BOCA National Building Code** section 302, range from those necessitating the highest, most demanding levels of fire performance (e.g., highrise buildings or others having large occupant loads or hazardous uses) through less hazardous formats such as individual dwellings or low rise, detached commercial buildings. The "type of construction" designation refers specifically to the nature of a building's structural system and materials used for construction as either non-combustible (i.e. masonry or steel) or combustible (wood or polymer based). Type of construction also regulates fire endurance levels required. Levels of fire endurance performance run from non-rated (no hourly requirements) through various levels of fire-rated performance under which specific hourly requirements are invoked.

Figure 19:ENT stubbed out from concrete slab under construction

Figure 20:ENT application to lower floors of highrise construction

"Occupancy type" and "type of construction" are presented in matrix form in Tables 503 and 602 of the **BOCA National Building Code**. Here, general performance based requirements for critical walls, floors, shafts, etc., for a given building design and end-use, are specified.

The tables and text that follow, for example, show that an interior bearing wall for a "Type I" non-combustible building must have 3-hour fire endurance. Conversely, interior walls needed for Types II through V buildings vary from designs requiring 2-hour fire endurance to those of non-rated design. New text has been added to the 1999 **BOCA National Building Code**, which clarifies conditions under which ENT may be used. These include the beginning of Section 602.4.1, which addresses when combustible elements are permitted and Section 602.4.2, which addresses use of non-metallic materials such as ENT in plenums.

The tables and code text that interrelate occupancy types and fire resistive requirements in the **BOCA National Building Code** can be found on the following pages:

SECTION 302.0 CLASSIFICATION

302.1 General: All structures shall be classified with respect to occupancy in one or more of the use groups listed below. Where a structure is proposed for a purpose which is not specifically provided for in this code, such structure shall be classified in the use group which the occupancy most nearly resembles.

1. Assembly (see Section 303.0):	Use Groups A-1, A-2, A-3, A-4 and A-5
2. Business (see Section 304.0):	Use Group B
3. Educational (see Section 305.0):	Use Group E
4. Factory and Industrial (see Section 306.0):	Use Groups F-1 and F-2
5. High Hazard (see Section 307.0):	Use Groups H-1, H-2, H-3 and H-4
6. Institutional (see Section 308.0):	Use Groups I-1, I-2 and I-3
7. Mercantile (see Section 309.0):	Use Group M
8. Residential (see Section 310.0):	Use Groups R-1, R-2, R-3 and R-4
9. Storage (see Section 311.0):	Use Groups S-1 and S-2
10. Utility and Miscellaneous (see Section 312.0):	Use Group U

Table 503
HEIGHT AND AREA LIMITATIONS OF BUILDINGS

Height limitations of buildings (shown in upper figure as stories and feet above grade plane)[m], and area limitations of one- or two-story buildings facing on one street or public space not less than 30 feet wide (shown in lower figure as area in square feet per floor[m]). See Note a.

Use Group			Type of construction									
			Noncombustible					Noncombustible/Combustible			Combustible	
			Type 1		Type 2			Type 3		Type 4	Type 5	
			Protected Note b		Protected		Unprotected	Protected	Unprotected	Heavy timber	Protected	Unprotected
		Note a	1A	1B	2A	2B	2C	3A	3B	4	5A	5B
A-1	Assembly, theaters		Not limited	Not limited	5 St. 65′ 19,950	3 St. 40′ 13,125	2 St. 30′ 8,400	3 St. 40′ 11,550	2 St. 30′ 8,400	3 St. 40′ 12,600	1 St. 20′ 8,925	1 St. 20′ 4,200
A-2	Assembly, nightclubs and similar uses		Not limited	Not limited 7,200	3 St. 40′ 5,700	2 St. 30′ 3,750	1 St. 20′ 2,400	2 St. 30′ 3,300	1 St. 20′ 2,400	2 St. 30′ 3,600	1 St. 20′ 2,550	1 St. 20′ 1,200
A-3	Assembly	Lecture halls, recreation centers, terminals, restaurants other than nightclubs	Not limited	Not limited	5 St. 65′ 19,950	3 St. 40′ 13,125	2 St. 30′ 8,400	3 St. 40′ 11,550	2 St. 30′ 8,400	3 St. 40′ 12,600	1 St. 20′ 8,925	1 St. 20′ 4,200
A-4	Assembly, churches	Note c	Not limited	Not limited	5 St. 65′ 34,200	3 St. 40′ 22,500	2 St. 30′ 14,400	3 St. 40′ 19,800	2 St. 30′ 14,400	3 St. 40′ 21,600	1 St. 20′ 15,300	1 St. 20′ 7,200
B	Business		Not limited	Not limited	7 St. 85′ 34,200	5 St. 65′ 22,500	3 St. 40′ 14,400	4 St. 50′ 19,800	3 St. 40′ 14,400	5 St. 65′ 21,600	3 St. 40′ 15,300	2 St. 30′ 7,200
E	Educational	Note c	Not limited	Not limited	5 St. 65′ 34,200	3 St. 40′ 22,500	2 St. 30′ 14,400	3 St. 40′ 19,800	2 St. 30′ 14,400	3 St. 40′ 21,600	1 St. 20′ 15,300 Note d	1 St. 20′ 7,200 Note d
F-1	Factory and industrial, moderate		Not limited	Not limited	6 St. 75′ 22,800	4 St. 50′ 15,000	2 St. 30′ 9,600	3 St. 40′ 13,200	2 St. 30′ 9,600	4 St. 50′ 14,400	2 St. 30′ 10,200	1 St. 20′ 4,800
F-2	Factory and industrial, low	Note h	Not limited	Not limited	7 St. 85′ 34,200	5 St. 65′ 22,500	3 St. 40′ 14,400	4 St. 50′ 19,800	3 St. 40′ 14,400	5 St. 65′ 21,600	3 St. 40′ 15,300	2 St. 30′ 7,200
H-1	High hazard, detonation hazards	Notes e, i, k, l	1 St. 20′ 16,800	1 St. 20′ 14,400	1 St. 20′ 11,400	1 St. 20′ 7,500	1 St. 20′ 4,800	1 St. 20′ 6,600	1 St. 20′ 4,800	1 St. 20′ 7,200	1 St. 20′ 5,100	Not permitted
H-2	High hazard, deflagration hazards	Notes e, i, j, l	5 St. 65′ 16,800	3 St. 40′ 14,400	3 St. 40′ 11,400	2 St. 30′ 7,500	1 St. 20′ 4,800	2 St. 30′ 6,600	1 St. 20′ 4,800	2 St. 30′ 7,200	1 St. 20′ 5,100	Not permitted
H-3	High hazard, physical hazards	Notes e, l	7 St. 85′ 33,600	7 St. 85′ 28,800	6 St. 75′ 22,800	4 St. 50′ 15,000	2 St. 30′ 9,600	3 St. 40′ 13,200	2 St. 30′ 9,600	4 St. 50′ 14,400	2 St. 30′ 10,200	1 St 20′ 4,800
H-4	High hazard, health hazards	Notes e, l	7 St. 85′ Not limited	7 St. 85′ Not limited	7 St. 85′ 34,200	5 St. 65′ 22,500	3 St. 40′ 14,400	4 St. 50′ 19,800	3 St. 40′ 14,400	5 St. 65′ 21,600	3 St. 40′ 15,300	2 St. 30′ 7,200
I-1	Institutional, residential care		Not limited	Not limited	9 St. 100′ 19,950	4 St. 50′ 13,125	3 St. 40′ 8,400	4 St. 50′ 11,550	3 St. 40′ 8,400	4 St. 50′ 12,600	3 St. 40′ 8,925	2 St. 35′ 4,200
I-2	Institutional, incapacitated		Not limited	Not limited	4 St. 50′ 17,100	2 St. 30′ 11,250	1 St. 20′ 7,200	1 St. 20′ 9,900	Not permitted	1 St. 20′ 10,800	1 St. 20′ 7,650	Not permitted
I-3	Institutional, restrained		Not limited	Not limited	4 St. 50′ 14,250	2 St. 30′ 9,375	1 St. 20′ 6,000	2 St. 30′ 8,250	1 St. 20′ 6,000	2 St. 30′ 9,000	1 St. 20′ 6,375	Not permitted
M	Mercantile		Not limited	Not limited	6 St. 75′ 22,800	4 St. 50′ 15,000	2 St. 30′ 9,600	3 St. 40′ 13,200	2 St. 30′ 9,600	4 St. 50′ 14,400	2 St. 30′ 10,200	1 St. 20′ 4,800
R-1	Residential, hotels		Not limited	Not limited	9 St. 100′ 22,800	4 St. 50′ 15,000	3 St. 40′ 9,600	4 St. 50′ 13,200	3 St. 40′ 9,600	4 St. 50′ 14,400	3 St. 40′ 10,200	2 St. 35′ 4,800
R-2	Residential, multiple-family		Not limited	Not limited	9 St. 100′ 22,800	4 St. 50′ 15,000 Note f	3 St. 40′ 9,600	4 St. 50′ 13,200 Note f	3 St. 40′ 9,600	4 St. 50′ 14,400	3 St. 40′ 10,200	2 St. 35′ 4,800
R-3	Residential, one- and two-family and multiple single-family		Not limited	Not limited	4 St. 50′ 22,800	4 St. 50′ 15,000	3 St. 40′ 9,600	4 St. 50′ 13,200	3 St. 40′ 9,600	4 St. 50′ 14,400	3 St. 40′ 10,200	2 St. 35′ 4,800
S-1	Storage, moderate		Not limited	Not limited	5 St. 65′ 19,950	4 St. 50′ 13,125	2 St. 30′ 8,400	3 St. 40′ 11,550	2 St. 30′ 8,400	4 St. 50′ 12,600	2 St. 30′ 8,925	1 St. 30′ 4,200
S-2	Storage, low	Note g	Not limited	Not limited	7 St. 85′ 34,200	5 St. 65′ 22,500	3 St. 40′ 14,400	4 St. 50′ 19,800	3 St. 40′ 14,400	5 St. 65′ 21,600	3 St. 40′ 15,300	2 St. 30′ 7,200
U	Utility, miscellaneous		Not limited	Not limited	5 St. 65′ 19,950	4 St. 50′ 13,125	2 St. 30′ 8,400	3 St. 40′ 11,550	2 St. 30′ 8,400	4 St. 50′ 12,600	2 St. 30′ 8,925	1 St. 20′ 4,200

Note a. See the following sections for general exceptions to Table 503:
Section 504.2 Allowable height increase due to automatic sprinkler system installation.
Section 506.2 Allowable area increase due to street frontage.
Section 506.3 Allowable area increase due to automatic sprinkler system installation.
Section 506.4 Allowable area reduction for multistory buildings.
Section 507.0 Unlimited area one-story buildings.

Note b. Buildings of Type 1 construction permitted to be of unlimited tabular heights and areas are not subject to special requirements that allow increased heights and areas for other types of construction (see Section 503.1.3).

Note c. For height exceptions for auditoriums in occupancies in Use Groups A-4 and E, see Section 504.3.

Note d. For height exceptions for day care centers in buildings of Type 5 construction, see Section 504.4.

Note e. For exceptions to height and area limitations for buildings with occupancies in Use Group H, see Chapter 4 governing the specific use groups.

Note f. For exceptions to height of buildings with occupancies in Use Group R-2 of Types 2B and 3A construction, see Sections 504.6 and 504.7.

Note g. For height and area exceptions for open parking structures, see Section 406.0.

Note h. For exceptions to height and area limitations for special industrial occupancies, see Section 507.1.

Note i. Occupancies in Use Groups H-1 and H-2 shall not be permitted below grade.

Note j. Rooms and areas of Use Group H-2 containing pyrophoric materials shall not be permitted in buildings of Type 3, 4 or 5 construction.

Note k. Occupancies in Use Group H-1 are required to be detached one-story buildings (see Section 707.1.1).

Note l. For exceptions to height for buildings with occupancies in Use Group H, see Section 504.5.

Note m. 1 foot = 304.8 mm; 1 square foot = 0.093 m^2.

Table 602
FIRERESISTANCE RATINGS OF STRUCTURE ELEMENTS[k]

Structure element Note a		Type of construction Section 602.0									
		Noncombustible					Noncombustible/Combustible			Combustible	
		Type 1 Section 603.0		Type 2 Section 603.0			Type 3 Section 604.0		Type 4 Section 605.0	Type 5 Section 606.0	
		Protected		Protected		Unprotected	Protected	Unprotected	Heavy timber Note c	Protected	Unprotected
		1A	1B	2A	2B	2C	3A	3B	4	5A	5B
1 Exterior walls	Loadbearing	4	3	2	1	0	2	2	2	1	0
		Not less than the fireresistance rating based on fire separation distance (see Section 705.2)									
	Nonloadbearing	Not less than the fireresistance rating based on fire separation distance (see Section 705.2)									
2 Fire walls and party walls (Section 707.0)		4	3	2	2	2	2	2	2	2	2
		Not less than the fireresistance rating required by Table 707.1									
3 Fire separation assemblies (Section 709.0)	Fire enclosure of exits (Sections 1014.11, 709.0 and Note b)	2	2	2	2	2	2	2	2	2	2
	Shafts (other than exits) and elevator hoistways (Sections 709.0, 710.0 and Note b)	2	2	2	2	2	2	2	2	1	1
	Mixed use and fire area separations (Section 313.0)	Not less than the fireresistance rating required by Table 313.1.2									
	Other separation assemblies (Note i)	1	1	1	1	1	1	1	1	1	1
		Note d									
4 Fire partitions (Section 711.0)	Exit access corridors (Note g)	Not less than the fireresistance rating required by Section 1011.4									
		Note d									
	Tenant spaces separations (Note f)	1	1	1	1	0	1	0	1	1	0
		Note d									
5 Dwelling unit and guestroom separations (Sections 711.0, 713.0 and Notes f and j)		1	1	1	1	1	1	1	1	1	1
		Note d									
6 Smoke barriers (Section 712.0 and Note g)		1	1	1	1	1	1	1	1	1	1
7 Other nonloadbearing partitions		0	0	0	0	0	0	0	0	0	0
		Note d									
8 Interior loadbearing walls, loadbearing partitions, columns, girders, trusses (other than roof trusses) and framing (Section 716.0)	Supporting more than one floor	4	3	2	1	0	1	0	see Sec. 605.0	1	0
	Supporting one floor only or a roof only	3	2	1½	1	0	1	0	see Sec. 605.0	1	0
9 Structural members supporting wall (Section 716.0 and Note g)		3	2	1½	1	0	1	0	1	1	0
		Not less than fireresistance rating of wall supported									
0 Floor construction including beams (Section 713.0 and Note h)		3	2	1½ Note l	1	0	1	0	see Sec. 605.0 Note c	1	0
1 Roof construction, including beams, trusses and framing, arches and roof deck (Section 715.0 and Notes e, m)	15′ or less in height to lowest member	2	1½	1	1	0	1	0	see Sec. 605.0 Note c	1	0
				Note d							
	More than 15′ but less than 20′ in height to lowest member	1	1	1	0	0	0	0	see Sec. 605.0	1	0
		Note d									
	20′ or more in height to lowest member	0	0	0	0	0	0	0	see Sec. 605.0	0	0
		Note d									

Note a. For fireresistance rating requirements for structural members and assemblies which support other fireresistance rated members or assemblies, see Section 16.1.
Note b. For reductions in the required fireresistance rating of exit and shaft enclosures, see Sections 1014.11 and 710.3.
Note c. For substitution of other structural materials for timber in Type 4 construction, see Section 2304.2.
Note d. For fireretardant-treated wood permitted in roof construction and nonloadbearing walls where the required fireresistance rating is 1 hour or less, see Sections 03.2 and 2310.0.
Note e. For permitted uses of heavy timber in roof construction in buildings of Types 1 and 2 construction, see Section 715.4.
Note f. For reductions in required fireresistance ratings of tenant separations and dwelling unit separations, see Sections 1011.4 and 1011.4.1.
Note g. For exceptions to the required fireresistance rating of construction supporting exit access corridor walls, tenant separation walls in covered mall buildings, and moke barriers, see Sections 711.4 and 712.2.
Note h. For buildings having habitable or occupiable stories or basements below grade, see Section 1006.3.1.
Note i. Not less than the rating required by this code.
Note j. For Use Group R-3, see Section 310.5.
Note k. Fireresistance ratings are expressed in hours.
Note l. In buildings which are required to comply with the provisions of Section 403.3, the required fireresistance rating for floor construction, including beams, shall e 2 hours (see Section 403.3.3.1).
Note m. 1 foot = 304.8 mm.

602.4.1 Building components: Combustible elements shall be permitted to be used for the following building components:

1. Interior finish and trim materials as regulated by Sections 803.0, 804.0 and 806.0.
2. Light-transmitting *plastics* as permitted by Chapter 26.
3. Fireretardant-treated wood complying with Section 2310.0 as permitted by Table 602.
4. Mastics and caulking materials applied to provide flexible seals between components of exterior wall construction.
5. Roof covering materials as regulated by Chapter 15.
6. Thermal and sound insulation as permitted by Sections 707.5, 723.0, 1509.0, 2309.4 and 2603.0.
7. Exterior veneer and trim as permitted by Section 1407.0.
8. Nailing or furring strips as permitted by Section 804.0.
9. Windows and doors as permitted by Section 706.4.
10. Heavy timber as permitted by Sections 1006.3.1, 715.2 and 715.4.
11. Partitions as permitted by Section 603.2.
12. Roof structures as permitted by Section 1510.0.
13. Platforms as permitted by Section 412.4.1.
14. Aggregates, component materials, and admixtures as permitted by Section 701.3.1.
15. Sprayed cementitious and mineral fiber fireresistive materials installed to comply with Section 1705.12.
16. Materials used to protect joints in fireresistance rated assemblies in accordance with Section 709.7.
17. Materials used to protect penetrations in fireresistance rated assemblies in accordance with Section 714.0.

602.4.2 Ducts and plenums: Nonmetallic ducts and materials exposed within plenums shall be permitted in accordance with the mechanical code listed in Chapter 35.

701.2 Performance standards: The requirements of this chapter shall constitute the minimum functional performance standards for fire protection purposes, and shall not be deemed to decrease or waive any strength provisions or in any other manner decrease the requirements of this code in respect to structural safety.

701.3 Combustible materials: All materials and forms of construction which develop the fireresistance ratings required by this code shall be acceptable for providing the required fireresistance rating and for structural purposes, except that combustible component materials in structural units or structural assemblies shall be limited in the types of construction specified in Sections 603.0, 604.0 and 605.0, and in Sections 602.4 and 701.3.1.

701.3.1 Combustible components: Combustible aggregates are permitted in gypsum concrete mixtures approved for fireresistance rated construction. Any approved component material or admixture is permitted in assemblies that meet the fireresistive test requirements of this code.

SECTION 703.0 CONSTRUCTION DOCUMENTS

703.1 General: *Construction documents* for all buildings shall designate the type of construction and the fireresistance rating of all structure elements as required by this code. The *construction documents* shall include documentation or supporting data substantiating all required fireresistance ratings, including details and materials for providing the required fireresistance rating at *joints* and penetrations of fireresistance rated assemblies. The *construction documents* shall also indicate details and methods for *fireblocking*.

703.1.1 Inspection: Protection of *joints* and penetrations in fireresistance rated assemblies shall not be concealed from view until inspected and approved.

703.2 Penetrations: *Construction documents* for buildings more than two stories in *height* shall indicate where penetrations will be made for electrical, mechanical, plumbing, environmental and communication conduits, pipes and systems.

SECTION 704.0 FIRE TESTS

704.1 General: Building elements and assemblies, including loadbearing and nonloadbearing walls and partitions, columns, girders, beams, slabs and floors and roof assemblies, shall provide the minimum fireresistance ratings specified in Table 602 for the type of construction unless otherwise required by the provisions of this code.

704.1.1 Fireresistance ratings: The fireresistance ratings of building assemblies and structural elements shall be determined in accordance with the test procedures set forth in ASTM E119 listed in Chapter 35, specific methods as provided for herein, or shall be determined in accordance with Section 704.1.2. Where materials, systems or devices are incorporated into the assembly which have not been tested as part of the assembly, sufficient data shall be made available to the code official to show that the required fireresistance rating is not reduced. Materials and methods of construction used to protect *joints* and penetrations in fireresistance rated assemblies shall not reduce the required fireresistance rating.

Exception: In determining the fireresistance rating of exterior loadbearing walls, compliance with the ASTM E119 criteria for unexposed surface temperature rise and ignition of cotton waste due to passage of flame or hot gases is required only for a period of time corresponding to the required fireresistance rating of an exterior nonloadbearing wall with the same *fire separation distance*, and in a building of the same use group. Where the fireresistance rating determined in accordance with this exception

SECTION 714.0 PENETRATIONS

714.1 Fireresistance rated wall assemblies: Penetrations of wall assemblies required to be fireresistance rated in accordance with Section 707.0, 709.0 or 711.0 shall comply with Sections 714.1.1 through 714.1.6.2. Penetrations of an *exit* enclosure shall also comply with Section 1014.11.2. The required fireresistance rating of the wall assembly shall be determined in accordance with Section 704.1.1.

714.1.1 Noncombustible penetrations: Cables and wires without combustible jackets and noncombustible pipes, tubes, conduits and vents which penetrate a fireresistance rated wall assembly shall be tested in accordance with ASTM E119 listed in Chapter 35 as part of a fireresistance rated assembly, or shall be protected by an approved through-penetration firestop system in accordance with Section 714.1.3, or the annular space around the penetrating item shall be protected in accordance with Sections 714.1.4 and 714.1.4.1.

714.1.2 Combustible penetrations: Cables and wires with combustible jackets and combustible pipes, tubes, conduits and vents which penetrate an assembly shall be tested in accordance with ASTM E119 listed in Chapter 35 as part of a fireresistance rated assembly, or shall be protected with a through-penetration firestop system in accordance with Section 714.1.3.

714.1.2.1 Sleeves: Where sleeves are installed, the sleeves shall be noncombustible and shall be securely fastened to the assembly penetrated. All space around the combustible items contained in the sleeve and the sleeve itself shall be filled with materials that comply with Section 714.1.2 or 714.1.3.

714.1.2.2 Insulation: Combustible insulation and coverings on the penetrating item shall not pass through the assembly unless these materials are protected in accordance with Section 714.1.2 or 714.1.3.

714.1.3 Through-penetration firestop system: The through-penetration firestop system shall be tested in accordance with ASTM E814 listed in Chapter 35 with a minimum positive pressure differential of 0.01 inch of water column (3 Pa). The penetration firestop system shall have an "F" rating of not less than the required rating of the assembly penetrated.

714.1.4 Annular space protection: Where permitted by Section 714.1.1 for noncombustible penetrating items, the annular space between the penetrating item and the fireresistance rated assembly being penetrated shall be protected with a material capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste when subjected to the time-temperature fire conditions of ASTM E119 listed in Chapter 35, under a minimum positive pressure differential of 0.01-inch water column (3 Pa) at the location of the penetration for the time period equivalent to the required fireresistance rating of the assembly penetrated or shall be protected in accordance with Section 714.1.4.1.

714.1.4.1 Concrete or masonry wall assemblies: Penetration of concrete or masonry wall assemblies by a maximum 6-inch nominal diameter copper, iron or steel pipe, tube, conduit or wires and cables with steel jackets shall be permitted provided that the maximum opening size is 144 square inches (0.09 m^2) and the penetration is protected with concrete, grout or mortar for the full thickness of the assembly or the thickness required to provide a fireresistance rating equivalent to the required fireresistance rating of the assembly penetrated.

714.1.4.2 Sleeves: Where sleeves are installed, the sleeves shall be noncombustible and shall be securely fastened to the assembly penetrated. All space between the item contained in the sleeve and the sleeve itself and any space between the sleeves and the assembly penetrated shall be filled with materials that comply with Section 714.1.4 or 714.1.4.1.

714.1.4.3 Insulation: Insulation and coverings on the penetrating item shall not pass through the assembly unless these materials maintain the required fireresistance rating of the assembly.

714.1.5 Ducts: Ducts that penetrate a wall assembly shall be provided with approved *fire dampers* that comply with Section 718.0.

Exceptions

1. *Fire dampers* are not required at penetrations of *fire separation assembly* walls or *fire partitions* where:
   - 1.1. Steel exhaust air subducts extend at least 22 inches (559 mm) vertically in an exhaust shaft in which there is a continuous air flow upward to the outside.
   - 1.2. Penetrations are tested in accordance with ASTM E119 listed in Chapter 35 as a part of the fireresistance rated assembly.
   - 1.3. Such walls are penetrated by ducted HVAC systems, have a required fireresistance rating of 1 hour or less, are in areas of other than Use Group H and are in buildings equipped throughout with an automatic sprinkler system in accordance with Section 906.2.1.
   - 1.4. The penetrations are in garage exhaust or supply shafts which are separated from all other building shafts by not less than a 2-hour fireresistance rated *fire separation assembly*.
2. In occupancies in other than Use Group H, *fire dampers* are not required at the penetration of *fire partitions* where:
   - 2.1. The partitions are tenant separation and corridor walls in buildings equipped throughout with an automatic sprinkler system in accordance with Section 906.2.1.
   - 2.2. The partitions are *corridor* walls and the ducts are constructed of steel and do not have openings which communicate the *corridor* with adjacent spaces or rooms.

714.1.5.1 Smoke barriers: Ducts which penetrate smoke barriers shall comply with Section 712.5.

714.1.5.2 Access: Access shall be provided to all dampers for inspection and servicing. The access shall not reduce the rating of any fireresistance rated assembly. Access shall comply with the requirements of the mechanical code listed in Chapter 35.

714.1.6 Single membrane penetrations: Openings to accommodate noncombustible conduits, pipes and tubes through a single membrane that is an integral component of a fireresistance rated wall assembly shall be permitted, provided that the aggregate area of all such openings does not exceed 100 square inches (0.064 m^2) in any 100 square feet (9 m^2) of wall area and the openings are *fireblocked* with approved noncombustible materials.

714.1.6.1 Electrical outlet boxes: Openings for steel electrical outlet boxes that do not exceed 16 square inches (10323 mm^2) in area are permitted. Outlet boxes on opposite sides of the assembly shall be separated by a horizontal distance of not less than 24 inches (610 mm). These limitations shall not apply to openings for electrical boxes of any material, provided that such boxes are tested for installation in fireresistance rated assemblies and installed in accordance with the tested assembly.

714.1.6.2 Fire sprinkler penetrations: Where sprinklers penetrate a single membrane of a fireresistance rated assembly in buildings equipped throughout with an approved automatic fire sprinkler system, noncombustible escutcheon plates shall be allowed as a means of *fireblocking* such penetrations, provided that the annular space around each sprinkler penetration does not exceed $^1/_2$ inch (13 mm) measured between the edge of the membrane and the sprinkler.

714.2 Fireresistance rated floor/ceiling and roof/ceiling assemblies: Where permitted as an alternative to a shaft enclosure in accordance with Section 713.4, penetrations of fireresistance rated floor/ceiling and roof/ceiling assemblies shall comply with Sections 714.2.1 through 714.2.7.5. The required fireresistance rating of floor/ceiling and roof/ceiling assemblies shall be determined in accordance with ASTM E119 listed in Chapter 35.

714.2.1 Noncombustible penetrations: Cables and wires without combustible jackets and noncombustible pipes, tubes, conduits, chimneys and vents which penetrate a fireresistance rated floor/ceiling or roof/ceiling assembly shall be installed in accordance with the approved ASTM E119 rated assembly or shall be protected in accordance with Section 714.2.3.

Exceptions

1. Penetrations by noncombustible vents, chimneys, conduits, pipes and tubes through a fireresistance rated floor assembly which connect not more than two stories are permitted. The annular space between the penetrating item and the assembly shall be protected in accordance with Section 714.2.3 or 714.2.4.
2. Penetrations by noncombustible conduit, pipe and tubes through fireresistance rated floor assemblies which connect more than two stories are permitted, provided that the aggregate area of the penetrating items shall not exceed 1 square foot (0.09 m^2) in any 100 square feet (9 m^2) of floor area. The annular space between the penetrating item and the assembly shall be protected in accordance with Section 714.2.3 or 714.2.4.

714.2.2 Combustible penetrations: Cables and wires with combustible jackets and combustible pipes, tubes, conduits and vents which penetrate an assembly shall be tested in accordance with ASTM E119 listed in Chapter 35 as part of a fireresistance rated assembly, or shall be protected with a through-penetration firestop system in accordance with Section 714.2.3.

714.2.2.1 Sleeves: Where sleeves are installed, the sleeves shall be noncombustible and shall be securely fastened to the assembly penetrated. All space around combustible items contained in the sleeve and the sleeve itself shall be filled with materials that comply with Section 714.2.2 or 714.2.3.

714.2.2.2 Insulation: Combustible insulation and coverings on the penetrating item shall be protected in accordance with Section 714.2.2 or 714.2.3.

714.2.3 Through-penetration firestop system: Where cables, cable trays, conduits, tubes or pipes penetrate a floor assembly, such penetrations shall be protected by an approved through-penetration firestop system. Through-penetration firestop systems shall be tested in accordance with ASTM E814 listed in Chapter 35 with a minimum positive pressure differential of 0.01 inch of water column (3 Pa). Through-penetration firestop systems shall have an "F" rating and a "T" rating of not less than 1 hour but not less than the required rating of the assembly penetrated.

Exceptions

1. A "T" rating shall not be required for floor penetrations that are contained and located within the cavity of a wall.
2. A "T" rating shall not be required for floor penetration by pipe, tube and conduit that are not in direct contact with combustible material.

714.2.4 Annular space protection: Where permitted in accordance with the exceptions to Section 714.2.1 for noncombustible penetrating items, the annular space between the penetrating item and the fireresistance rated assembly being penetrated shall be protected with a material capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste when subjected to the time-temperature fire conditions of ASTM E119 listed in Chapter 35, under a minimum positive pressure differential of 0.01-inch water column (3 Pa) at the location of the penetration for the time period equivalent to the required fireresistance rating of the assembly penetrated or shall be protected in accordance with Section 714.2.4.1.

714.2.4.1 Concrete floor assemblies: Penetrations of concrete floor assemblies by a maximum 6-inch nominal diameter copper, iron or steel pipe, tube, conduit or wires and cables with steel jackets shall be permitted provided that the maximum opening size is 144 square inches (0.09 m^2) and the penetration is protected with concrete, grout or mortar for the full thickness of the assembly or the thickness required to provide a fireresistance rating equivalent to the required fireresistance rating of the assembly penetrated.

714.2.4.2 Sleeves: Where sleeves are installed, the sleeves shall be noncombustible and shall be securely fastened to the assembly penetrated. All space between the item contained in the sleeve and the sleeve itself and any space between the sleeve and the assembly penetrated shall be filled with materials that comply with Section 714.2.4 or 714.2.4.1.

714.2.4.3 Insulation: Insulation and coverings on the penetrating item shall not pass through the assembly unless these materials maintain the required fireresistance rating of the assembly.

714.2.5 Ducts: Penetrations by an air duct or plenum through a fireresistance rated floor assembly, which connect not more than two stories, are permitted where a *fire damper* that complies with Section 718.0 is installed at the floor line. A *fire damper* is not required at penetrations of a roof/ceiling assembly where the ducts are open to the atmosphere.

714.2.6 Floor fire doors: Floor fire doors used to protect openings in fireresistance rated floors shall be tested in the horizontal position in accordance with ASTM E119 listed in Chapter 35, and shall achieve a fireresistance rating not less than the assembly being penetrated. Floor fire doors shall be labeled by an approved agency.

714.3 Nonfireresistance rated floor/ceiling assemblies: Where permitted as an alternative to a shaft enclosure in accordance with Section 713.4, penetrations of floor assemblies without a required fireresistance rating shall comply with Sections 714.3.1 through 714.3.2. All penetrations through the ceiling membrane of a roof assembly without a required fireresistance rating shall be *fireblocked* in accordance with Section 721.6.4.

714.3.1 Noncombustible penetrations: Penetrations by noncombustible vents, chimneys, conduits, pipes, and tubes through unprotected floor assemblies which connect not more than three stories are permitted, provided that the annular space between the penetrating item and the floor is *fireblocked* in accordance with Section 721.6.4.

714.3.1.1 Ducts: Penetrations by noncombustible air ducts through unprotected floor assemblies which connect not more than three stories are permitted, provided that a *fire damper* complying with Section 718.0 is installed at each floor line.

714.3.2 Noncombustible or combustible penetrations: Penetrations by noncombustible or combustible vents, chimneys, cables, wires, air ducts, conduits, pipes and tubes through unprotected floor assemblies which connect not more than two stories are permitted, provided that the annular space is *fireblocked* in accordance with Section 721.6.4.

4.1.2 Performance Specifications

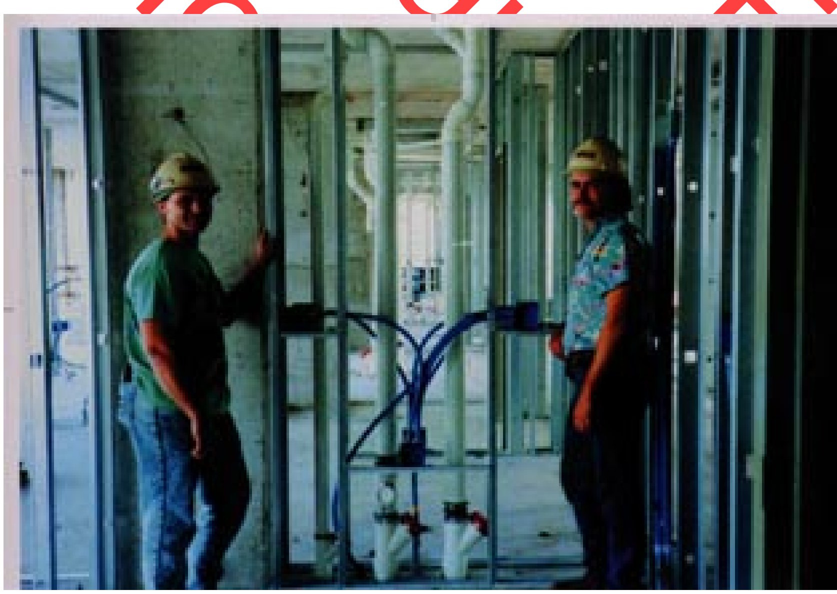


Figure 21:ENT use in metal stud-based wall

The **BOCA National Building Code** utilizes both performance based and prescriptive specifications to establish what materials and methods are permissible for use. This is consistent with the manner in which the code treats fire resistive penetrations which occur when tubing, conduit, vents, pipe, ducts enter or exit construction assemblies and its treatment of materials contained within the construction envelope (walls, slabs, floor/ceiling assemblies) of a given "Type of Construction".

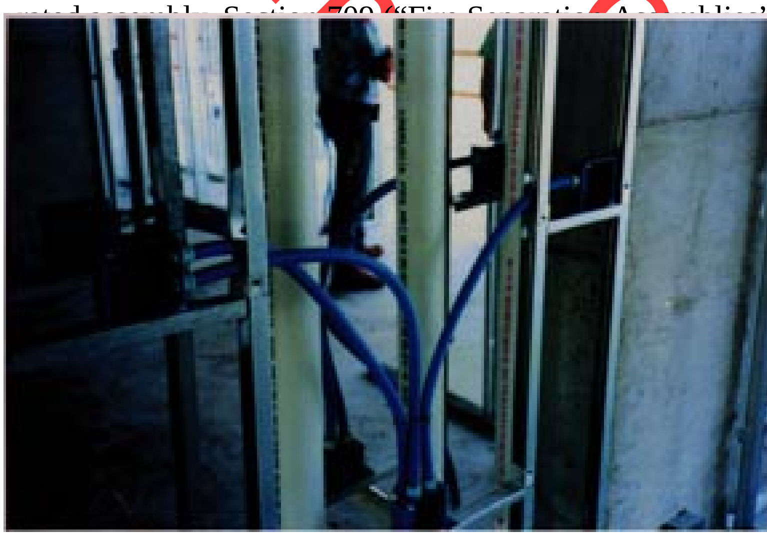
Of primary importance in utilizing PVC raceway in buildings regulated by **BOCA National Building Code** are Section 701.2 ("Performance standards") and Section 701.3

("Combustible materials ") included below, which permits their use in fire-rated assemblies in buildings of Types I and II construction provided such designs have been qualified by tests[9].

BOCA National Building Code Sections 702 ("Definitions") and 704 ("Fire Tests") contain general information related to those subject areas, which can impact use of PVC raceways. New to the 1999 **BOCA National Building Code** is Section 704.1.2.2. which allows for the use of accepted analytical methods to calculate fire resistance of assemblies.

Figure 22: ENT application in data handling system

Section 707 ("Fire Walls and Party Walls") includes a charging section relating to penetrations (Section 707.10) that refers the reader to BOCA National Building Code Sections 714.1. through 714.1.6.2 for specific requirements related to that class of fire-rated assembly. Section 709 ("Fire Separation Assemblies")



ng wall

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[9] The primary method used to meet the "qualifications by test criteria" is through the use of the ASTM E-814 test method. This test method is referenced by the *BOCA National Code* and is discussed further in Section 5.1

Important paragraphs in Section 714 include;

- 714.1, 714.1.2 (including new subsections 714.1.2.1 and 714.1.2.2), 714.1.3, 714.1.6 for rated wall assemblies,
- 714.2, 714.2.2 (including new subsections 714.2.2.1 and 714.2.2.2), 714.2.3, 714.2.6 (new in 1999), and 714.2.7 (renumbered in 1999) for Floor/Ceiling and Roof/Ceiling Assemblies and
- 714.3 and 714.3.2 for penetrations of non-fire resistance rated assemblies.

These text items define required performance and provide test criteria of complying systems as well and are listed below.

It is accepted by BOCA that the **BOCA National Building Code** (and not subsidiary electrical, plumbing or mechanical codes) defines levels of fire performance required in building constructions. Thus, if a product meets the functional requirements of a subsidiary code, as PVC raceway meet requirements found in **The National Electrical Code**, that product's acceptability for a given application is regulated by its ability to demonstrate required fire safety levels.

This treatment takes into account installation requirements spelled out in the **BOCA National Building Code** sections discussed and presented previously as well as other sections, which may be relevant for a particular installation. Meeting these requirements is necessary in all cases, and is required by **BOCA National Building Code** Section 703.1 ("General") and 703.2 ("Penetrations") of the "Construction Documents" section which mandate that sufficient detail be presented in plans to show how it is intended to maintain the fire resistive integrity of a structure including penetrations that incorporate electrical raceways.

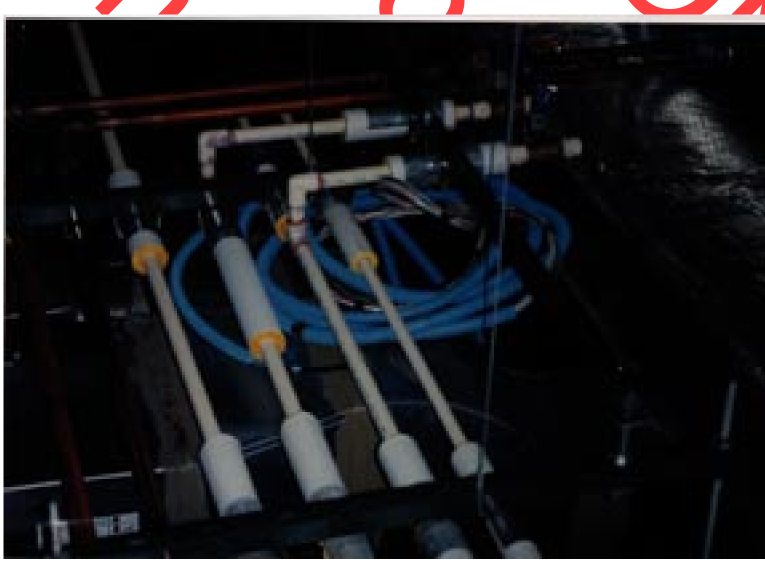


Figure 24: Caption: ENT above suspended ceiling

Figure 25:Installation of ENT in Type I Building
Disney World, Florida

4.2 The *Standard Building Code* and PVC Raceway

The 1999 **Standard Building Code**, promulgated by the **Southern Building Code** Conference International (SBCCI, Birmingham, Alabama), regulates use of PVC raceway in buildings in jurisdictions in which it is adopted and defines the relationship of the **Standard Building Code** to **The National Electrical Code®.**

4.2.1 Code Format

The **Standard Building Code** utilizes classifications of "occupancy type" (which relates to projected use of a building) and "type of construction" (which defines types of materials allowed for a particular building and its required fire resistance.). Together, these define fire resistance properties for a particular building built in accordance with **Standard Building Code** Section 301.

Occupancy types range from those necessitating high, demanding levels of fire performance (e.g. buildings having large occupant loads or hazardous uses) through other formats such as individual dwellings or lowrise, detached commercial buildings. "Types of construction" refer specifically to the nature of the structural system and materials used. These categories are either non-combustible (i.e. masonry, concrete or steel) or combustible (wood based). The **Standard Building Code** also addresses fire resistance levels required for buildings as being either "protected" or "unprotected" in accordance with table 600. Here, general performance based requirements for critical walls, floors, shafts, etc., for a given building design and end-use, become specified.

SECTION 301
GENERAL

301.1 Scope. Provisions of this chapter shall govern the classification of building occupancies.

301.2 Occupancy or use categories. Every new and existing building, structure or part thereof shall, for the purpose of this code, be classified according to its use, or occupancy as a building or structure of one of the following occupancy groups:

Group A	–Assembly (see 304)
Group B	–Business (see 305)
Group E	–Educational (see 306)
Group F	–Factory Industrial (see 307)
Group H	–Hazardous (see 308)
Group I	–Institutional (see 309)
Group M	–Mercantile (see 310)
Group R	–Residential (see 311)
Group S	–Storage (see 312)

The tables and text that follow, for example, show that an interior bearing wall for a "Type I" non-combustible building must have 3-hour fire endurance. Conversely, interior walls needed for Types II through V buildings vary from designs requiring 2-hour fire endurance to those of non-rated design. The tables and code text, which interrelate occupancy types and fire resistance requirements in the **Standard Building Code**, follow:

TABLE 600
FIRE RESISTANCE RATINGS
REQUIRED FIRE RESISTANCE IN HOURS

STRUCTURAL ELEMENT	TYPE I	TYPE II	TYPE III	TYPE IV		TYPE V		TYPE VI	
				1-Hour Protected	Unprotected	1-Hour Protected	Unprotected	1-Hour Protected	Unprotected
PARTY AND FIRE WALLS (a)	4	4	4	4	4	4	4	4	4
INTERIOR BEARING WALLS	(l)								
Supporting columns, other bearing walls or more than one floor	4	3	2	1	NC	1 (h)	0 (h)	1	0
Supporting one floor only	3	2	1	1	NC	1	0	1	0
Supporting roofs only	3	2	1	1	NC	1	0	1	0
INTERIOR NONBEARING PARTITIONS	See 609.2, 704.1, 704.2 and 705.2								
COLUMNS (q)	(l)		See 605						
Supporting other columns or more than one floor	4	3	H(d)	1	NC	1	0	1	0
Supporting one floor only	3	2	H(d)	1	NC	1	0	1	0
Supporting roofs only	3	2	H(d)	1	NC	1	0	1	0
BEAMS, GIRDERS, TRUSSES & ARCHES	(l)		See 605						
Supporting columns or more than one floor	4	3	H(d)	1	NC	1	0	1	0
Supporting one floor only	3	2	H(d)	1	NC	1	0	1	0
Supporting roofs only	1 1/2(e,p)	1(e,f,p)	H(d)	1(e,p)	NC(e)	1	0	1	0
FLOORS & FLOOR/CEILING ASSEMBLIES	(l) 3	2	See 605 H (o)	(n) 1	(n,o) NC	(n) 1	(m,n,o) 0	1	(o) 0
ROOFS & ROOF/CEILING ASSEMBLIES (g)	1 1/2(e,p)	1 (e,f,p)	See 605 H(d)	1(e,p)	NC(e)	1	0	1	0
EXTERIOR BEARING WALLS and gable ends of roof (g, i, j)	(% indicates percent of protected and unprotected wall openings permitted. See 705.1.1 for protection requirements.)								
Horizontal separation (distance from common property line or assumed property line).									
0 ft to 3 ft (c)	4(0%)	3(0%)	3(0%)(b)	2(0%)	1(0%)	3(0%)(b)	3(0%)(b)	1(0%)	1(0%)
over 3 ft to 10 ft (c)	4(10%)	3(10%)	2(10%)(b)	1(10%)	1(10%)	2(10%)(b)	2(10%)(b)	1(20%)	0(20%)
over 10 ft to 20 ft (c)	4(20%)	3(20%)	2(20%)(b)	1(20%)	NC(20%)	2(20%)(b)	2(20%)(b)	1(40%)	0(40%)
over 20 ft to 30 ft	4(40%)	3(40%)	1(40%)	1(40%)	NC(40%)	1(40%)	1(40%)	1(60%)	0(60%)
over 30 ft	4(NL)	3(NL)	1(NL)	1(NL)	NC(NL)	1(NL)	1(NL)	1(NL)	0(NL)
EXTERIOR NONBEARING WALLS and gable ends of roof (g, i, j)	(% indicates percent of protected and unprotected wall openings permitted. See 705.1.1 for protection requirements.)								
Horizontal separation (distance from common property line or assumed property line).									
0 ft to 3 ft (c)	3(0%)	3(0%)	3(0%)(b)	2(0%)	1(0%)	3(0%)(b)	3(0%)(b)	1(0%)	1(0%)
over 3 ft to 10 ft (c)	2(10%)	2(10%)	2(10%)(b)	1(10%)	1(10%)	2(10%)(b)	2(10%)(b)	1(20%)	0(20%)
over 10 ft to 20 ft (c)	2(20%)	2(20%)	2(20%)(b)	1(20%)	NC(20%)	2(20%)(b)	2(20%)(b)	1(40%)	0(40%)
over 20 ft to 30 ft	1(40%)	1(40%)	1(40%)	NC(40%)	NC(40%)	1(40%)	1(40%)	0(60%)	0(60%)
over 30 ft (k)	NC (NL)	NC(NL)	NC(NL)	NC(NL)	NC(NL)	NC(NL)	NC(NL)	0(NL)	0(NL)

For **SI**: 1 ft = 0.305 m.

NC = Noncombustible
NL = No Limits
H = Heavy Timber Sizes

Notes:

a. See 704.5 for extension of party walls and fire walls.

b. See 704.5 for parapets.

c. See 705 for protection of wall openings.

d. Where horizontal separation of 20 ft or more is provided, wood columns, arches, beams, and roof deck conforming to heavy timber sizes may be used externally.

e. In buildings not over two stories approved fire retardant treated wood may be used.

f. In one-story buildings, structural members of heavy timber sizes may be used as an alternate to unprotected structural roof members. Stadiums, field houses and arenas with heavy timber wood dome roofs are permitted. An approved automatic sprinkler system shall be installed in those areas where 20 ft clearance to the floor or balcony below is not provided.

g. See 1511 for penthouses and roof structures.

h. The use of combustible construction for interior bearing partitions shall be limited to the support of not more than two floors and a roof.

i. Exterior walls shall be fire tested in accordance with 601.3. The fire resistance requirements for exterior walls with 5 ft or less horizontal separation shall be based upon both interior and exterior fire exposure. The fire resistance requirements for exterior walls with more than 5 ft horizontal separation shall be based upon interior fire exposure only.

j. Where Appendix F is specifically included in the adopting ordinance, see F102.2.6 for fire resistance requirements for exterior walls of Type IV buildings in Fire District.

k. Walls or panels shall be of noncombustible material or fire retardant treated wood, except for Type VI construction.

l. For Group A - Large Assembly, Group A - Small Assembly, Group B, Group E, Group F, Group R occupancies and Automobile Parking Structures, occupancies of Type I construction, partitions, columns, trusses, girders, beams, and floors may be reduced by 1 hour if the building is equipped with an automatic sprinkler system throughout, but no component or assembly may be less than 1 hour.

m. Group A - Large Assembly (no stage requiring proscenium opening protection) and Group A - Small Assembly occupancies of Type V Unprotected construction shall have 1-hour fire resistant floors over any crawl space or basement.

n. For Group B and Group M occupancies of Type IV or Type V construction, when five or more stories in height a 2-hour fire resistant floor shall be required over the basement.

o. For unsprinklered Group E occupancies of Type III, Type IV Unprotected, Type V Unprotected or Type VI Unprotected, floors located immediately above useable space in basements shall have a fire resistant rating of not less than 1 hour.

p. In buildings of Group A, B, E, and R occupancies, the required fire resistance of the roof or roof/ceiling assembly including the beams, girders, trusses, or arches that support the roof only may be omitted where every part of the roof structural members have a clear height of 20 ft (6096 mm) or more above any floor, mezzanine or balcony.

q. See 701.4.

TABLE 500
ALLOWABLE HEIGHTS AND BUILDING AREAS

Lower case letters in table refer to Notes following table.
Height for types of construction is limited to the number of stories and height in feet shown.
Allowable building area (determined by definition of "Area, Building") is shown in thousands of sq ft per floor.

TYPE CONSTRUCTION	I		II		III		IV 1-HOUR		IV UNPROT.		V 1-HOUR		V UNPROT.		VI 1-HOUR		VI UNPROT.	
Maximum Height In Feet:	NL		80'		65'		65'		55'		65'		55'		50'		40'	
OCCUPANCY	uns	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j
A-1 ASSEMBLY LARGE (stage requiring proscenium opening protection) a,b																		
Max. No. of stories	NL	NL	NL	NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area: Multistory	UA	UA	UA	UA														
One Story only	UA	UA	UA	UA														
A-1 ASSEMBLY LARGE (no stage requiring proscenium opening protection) a, b																		
Max. No. of Stories	NL	NL	NL	NL	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Area: Multistory	UA	UA	UA	UA														
One Story only	UA	UA	UA	UA	12.0	36.0	12.0	36.0	8.0	24.0	12.0	36.0	8.0	24.0				
A-2 ASSEMBLY SMALL (stage requiring proscenium opening protection) a,b																		
Max. No. of Stories	NL	NL	NL	NL	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Area: Multistory	UA	UA	UA	UA														
One Story only	UA	UA	UA	UA	10.0	30.0	10.0	30.0	6.0	18.0	10.0	30.0	6.0	18.0	4.5	13.5	3.0	9.0
A-2 ASSEMBLY SMALL (no stage requiring proscenium opening protection) a, b																		
Max. No. of Stories	NL	NL	NL	NL	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Area: Multistory	UA	UA	UA	UA	12.0	24.0	12.0	24.0	8.0	16.0	12.0	24.0	8.0	16.0				
One Story only	UA	UA	UA	UA	12.0	36.0	12.0	36.0	8.0	24.0	12.0	36.0	8.0	24.0	7.5	22.5	5.0	15.0
B BUSINESS a,b																		
Max. No. of Stories	NL	NL	NL	NL	5	5	5	5	2	5	5	5	2	5	2	2	2	2
Area: Multistory	UA	UA	UA	UA	25.5	51.0	25.5	51.0	17.0	34.0	21.0	42.0	14.0	28.0	13.5	27.0	9.0	18.0
One Story only	UA	UA	UA	UA	25.5	76.5	25.5	76.5	17.0	51.0	21.0	63.0	14.0	42.0	13.5	40.5	9.0	27.0
E EDUCATIONAL a, b																		
Max. No. of stories	NL	NL	NL	NL	2	2	2	2	1	1	2	2	1	1	2	2	1	1
Area: Multistory	UA	UA	UA	UA	18.0	36.0	18.0	36.0			18.0	36.0			12.0	24.0		
One Story only	UA	UA	UA	UA	18.0	54.0	18.0	54.0	12.0	36.0	18.0	54.0	12.0	36.0	12.0	36.0	8.0	24.0
F FACTORY-INDUSTRIAL a,b,g																		
Max. No. of Stories	NL	NL	NL	NL	3	6	2	4	2	4	2	4	2	4	1	1	1	1
Area: Multistory	UA	UA	UA	UA	31.5	63.0	31.5	63.0	21.0	42.0	22.5	45.0	15.0	30.0				
One Story only	UA	UA	UA	UA	31.5	94.5	31.5	94.5	21.0	63.0	22.5	67.5	15.0	45.0	15.0	45.0	10.0	30.0
H-1 HAZARDOUS c																		
Max. No. of Stories	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0
Area: Multistory																		
One Story only		15.0		12.0		7.5		7.5		5.0		7.5						
H-2 HAZARDOUS c																		
Max. No. of Stories	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0
Area: Multistory																		
One Story only		15.0		12.0		7.5		7.5		5.0		7.5		4.0		2.5		
H-3 HAZARDOUS c																		
Max. No. of Stories	0	4	0	3	0	2	0	2	0	1	0	2	0	1	0	1	0	0
Area: Multistory		30.0		20.0		10.0		10.0				10.0						
One Story only		30.0		20.0		10.0		10.0		7.5		10.0		7.5		4.0		
H-4 HAZARDOUS c																		
Max. No. of Stories	0	NL	0	6	0	3	0	4	0	4	0	4	0	4	0	1	0	1
Area: Multistory		UA		UA		48.0		48.0		32.0		48.0		32.0				
One Story only		UA		UA		72.0		72.0		48.0		72.0		48.0		27.0		18.0

(continued)

TABLE 500 *(continued)*
ALLOWABLE HEIGHTS AND BUILDING AREAS

Lower case letters in table refer to Notes following table.
Height for types of construction is limited to the number of stories and height in feet shown.
Allowable building area (determined by definition of "Area, Building") is shown in thousands of sq ft per floor.

TYPE CONSTRUCTION	I		II		III		IV 1-HOUR		IV UNPROT.		V 1-HOUR		V UNPROT.		VI 1-HOUR		VI UNPROT.	
Maximum Height In Feet:	NL		80'		65'		65'		55'		65'		55'		50'		40'	
OCCUPANCY	uns	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j	uns h	spr j
I INSTITUTIONAL–RESTRAINED b							i											
Max. No. of stories	NL	NL	NL	NL	0	2	2	3	0	2	0	3	0	2	0	3	0	2
Area: Multistory	UA	UA	UA	UA		24.0	15.0	30.0		20.0		21.0		14.0		15.0		10.0
One Story only	UA	UA	UA	UA		36.0	15.0	45.0		30.0		31.5		21.0		22.5		15.0
I INSTITUTIONAL–UNRESTRAINED b																		
Max. No. of Stories	0	NL	0	NL	0	2	0	3	0	1	0	1	0	0	0	1	0	0
Area: Multistory		UA		UA		24.0		30.0										
One Story only		UA		UA		36.0		45.0		30.0		31.5				22.5		
M MERCANTILE a,b	f		f		f		f		f		f		f		f		f	
Max. No. of Stories	NL	NL	NL	NL	5	5	5	5	2	5	5	5	2	5	2	2	2	2
Area: Multistory	15.0	UA	15.0	UA	13.5	27.0	13.5	27.0	9.0	18.0	13.5	27.0	9.0	18.0	9.0	18.0	6.0	12.0
One Story only	15.0	UA	15.0	UA	13.5	40.5	13.5	40.5	9.0	27.0	13.5	40.5	9.0	27.0	9.0	27.0	6.0	18.0
R RESIDENTIAL a,b,d																		
Max. No. of Stories	NL	NL	NL	NL	3	3	5	5	2	5	5	5	2	5	3	3	2	2
Area: Multistory	UA	UA	UA	UA	18.0	36.0	18.0	36.0	12.0	24.0	18.0	36.0	12.0	24.0	10.5	21.0	7.0	14.0
One Story only	UA	UA	UA	UA	18.0	54.0	18.0	54.0	12.0	36.0	18.0	54.0	12.0	36.0	10.5	31.5	7.0	21.0
S STORAGE a,b,e,g																		
Max. No. of Stories	NL	NL	6	6	2	6	2	4	2	4	2	4	2	4	1	1	1	1
Area: Multistory	UA	UA	30.0	60.0	24.0	48.0	24.0	48.0	16.0	32.0	24.0	48.0	16.0	32.0				
One Story only	UA	UA	30.0	90.0	24.0	72.0	24.0	72.0	16.0	48.0	24.0	72.0	16.0	48.0	9.0	27.0	6.0	18.0

For **SI:** 1 ft = 0.305 m, 1 sq ft = 0.0929 m^2.

NL = No Limit
UA = Unlimited Area

Notes:

a. For height modifications and limitations by occupancy, see:
   1. Mezzanines . . . 503.2.3
   2. Basements . . . 503.2.4
   3. Assembly Basements . . . 503.2.5
   4. Business . . . 503.2.6
   5. Educational Basements . . . 503.2.5
   6. Mercantile . . . 503.2.6
   7. Residential . . . 503.2.2, 503.2.6

b. For area modifications and limitations by occupancy see:
   1. Area increase for separation (All occupancies except H) . . . 503.3.2
   2. Assembly . . . 503.4.3, 503.4.4 ,503.4.5, 503.4.6, 503.4.8
   3. Business . . . 503.4.1, 503.4.8
   4. Educational . . . 503.4.2, 503.4.7
   5. Factory-Industrial . . . 503.4.1, 503.4.8
   6. Mercantile . . . 503.4.1, 503.4.8, 503.4.10
   7. Storage . . . 503.4.1, 503.4.8, 503.4.11

c. Modifications in height and area shall not be permitted in Group H occupancies.

d. See 903.7.5 and 903.7.6 for height limitations of unsprinklered R1 and R2 occupancies. Height and area increases in 503 are not permitted for NFPA 13D and NFPA 13R sprinkler systems installed in accordance with 903.7.7 or as an option in 903.7.6.

e. See 411.3.1 for allowable height and floor areas of Open Automobile Parking Structures.

f. Total area for unsprinklered Group M occupancies after increase permitted by 503.3 shall not exceed 15,000 sq ft.

g. Height in ft not applicable to Group S and Group F occupancies.

h. When all portions of buildings are sprinklered in accordance with the standards listed in 903.2, the height of buildings listed under this column may be increased one story. A general area increase provided for in 503.3.2 may be applied before using footnote h. (Also, see note j.)

i. Automatic sprinkler protection required throughout all buildings where Use Condition 5 is used. See 409.2.3. and 1024.2.2.

j. When all portions of buildings are sprinklered in accordance with the standards listed in 903.2, the allowable heights and areas of buildings shall be as listed under this column. (Also, see note h.)

SECTION 601
GENERAL

601.1 Scope. Provisions of this chapter shall govern the classification of construction type by materials and fire resistance of its elements and the use of more than one construction type in a building.

601.2 Classification by type of construction

601.2.1 Every building shall be classified by the building official into one of the types of construction as set forth in this section.

- Type I
- Type II
- Type III
- Type IV
  - 1-Hour Protected
  - Unprotected
- Type V
  - 1-Hour Protected
  - Unprotected
- Type VI
  - 1-Hour Protected
  - Unprotected

601.2.2 Materials for any one of the six types of construction may be used as specified in Table 600, or as permitted in this chapter.

601.3 Fire resistance requirements

601.3.1 All fire resistance requirements are expressed in terms of the number of hours of satisfactory performance in accordance with ASTM E 119.

601.3.2 Construction required to have a fire resistance rating shall be supported by construction of equal or greater fire resistance.

> **Exception:** In Types IV Unprotected, V Unprotected and VI Unprotected construction, structural elements supporting exit access corridor walls and tenant separation walls of not more than 1-hour fire resistance need not be rated provided a fire resistance rating is not required by other provisions of this code.

601.4 Materials and construction approved for fire resistance

601.4.1 The degree of fire resistance and the materials, assemblies, and constructions providing such resistance shall be defined in Chapter 7 of this code, except that other materials, assemblies, and constructions shall be approved, provided test data of a recognized engineering or testing laboratory are submitted, establishing that they develop the required fire resistance rating under tests made in accordance with ASTM E 119 or based on calculations and accepted engineering practice as set forth in 709.

601.4.2 Where structural requirements necessitate assemblies providing greater fire resistance than specified in this chapter, such structural requirements shall govern.

SECTION 706
COMBUSTIBLES IN FIRE RATED ASSEMBLIES

706.1 Plumbing, electrical and air handling systems in fire rated assemblies. In Type I and Type II construction, materials used for piping, conduit raceways or duct systems which do not qualify as noncombustible in accordance with the requirements of part 1 of the definition of noncombustible material contained in 202 shall neither

1. penetrate any assembly which is required to have a fire resistance rating unless such materials and methods of penetration have been tested in accordance with 705.4, nor
2. be concealed within any assembly which is required to have a fire resistance rating unless enclosed by or totally embedded within noncombustible materials or unless such materials and methods have been tested in accordance with 701.2.

SECTION 707
COMBUSTIBLES IN CONCEALED SPACES

707.1 Concealed spaces in Types I, II and IV construction. Combustibles shall not be permitted in concealed spaces of Types I, II, or IV construction.

Exceptions:

1. Materials complying with 609.1.2 of the Standard Mechanical Code.
2. Class A interior finish materials.
3. Fire retardant treated wood used in accordance with Table 600 and wood used in accordance with 609.
4. Floor finish complying with 803.7.
5. Conduit or raceway systems complying with 706.
6. Foam plastic insulation complying with 2603.
7. Thermal insulation materials complying with 708.
8. Combustible piping within partitions or enclosed shafts installed in accordance with the provision of this code. Combustible piping may also be used within concealed ceiling spaces when approved.

707.2 Combustibles in plenums. The use of combustible materials in plenums shall be restricted in accordance with the Standard Mechanical Code.

705.4 Protection of penetrations

705.4.1 General. Protection of penetrations through fire rated and nonfire rated assemblies shall comply with 705.5 and 705.6.

705.4.2 Sleeves. Where sleeves are used, the sleeves shall be securely fastened to the assembly penetrated. All space between the item contained in the sleeve and the sleeve itself and any space between the sleeve and the assembly penetrated shall be protected in accordance with 705.5 or 705.6.

705.4.3 Insulation. Insulation and coverings on the penetrating item shall not penetrate the assembly unless the specific material used has been tested as part of the assembly in accordance with 705.5 or 705.6.

705.5 Penetrations of fire rated walls. Penetrations into or through fire resistant walls required to have opening protectives shall comply with 705.5.1 through 705.5.3.

705.5.1 Through-penetrations. Through-penetrations of fire rated walls shall comply with 705.5.1.1 or 705.5.1.2.

Exception: Where the penetrating items are steel, ferrous or copper pipes or steel conduits, the annular space shall be permitted to be protected as follows:

1. In concrete or masonry walls where the penetrating item is a maximum 6-inch nominal diameter and the opening is a maximum 144 square inches, concrete, grout, or mortar shall be permitted when installed the full thickness of the wall or the thickness required to maintain the fire rating, or
2. The material used to fill the annular space shall prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to ASTM E 119 time temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water at the location of the penetration for the time period equivalent to the fire rating of the construction penetrated.

705.5.1.1 Fire rated assembly. Penetrations shall be installed as tested in the approved ASTM E 119 rated assembly.

705.5.1.2 Penetration firestop system. Penetrations shall be protected by an approved penetration firestop system installed as tested in accordance with ASTM E 814, with a minimum positive pressure differential of 0.01 inch of water and shall have an F rating of not less than the required rating of the wall penetrated.

705.5.2 Membrane penetrations. Membrane penetrations shall comply with 705.5.1 through 705.5.1.2.

Exceptions:

1. Steel electrical boxes that do not exceed 16 square inches in area provided that the area of such openings does not exceed 100 square inches for any 100 sq ft of wall area. Outlet boxes on opposite sides of the wall shall be separated by a horizontal distance of not less than 24 inches. Membrane penetrations for electrical outlet boxes of any other material are permitted provided that such boxes are tested for use in fire rated assemblies and installed in accordance with the tested assembly.
2. The annular space created by the penetration of a fire sprinkler provided it is covered by a metal escutcheon plate.

705.6 Penetrations of horizontal assemblies. All penetrations of a floor, floor/ceiling assembly, or the ceiling membrane of a roof/ceiling assembly shall be protected by a shaft enclosure in accordance with 705.2 or shall comply with 705.6.1 through 705.6.4.

705.6.1 Through-Penetrations. Through-penetrations of fire rated horizontal assemblies shall comply with 705.6.1.1 or 705.6.1.2.

Exceptions:

1. Steel, ferrous or copper conduits, pipes, tubes, vents, concrete, or masonry penetrating items that penetrate a single fire rated floor or floor/ceiling assembly where the annular space is protected with materials that prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to ASTM E 119 time temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water at the location of the penetration for the time period equivalent to the fire rating of the construction penetrated. Penetrating items with a maximum 6-inch nominal diameter shall not be limited to the penetration of a single fire rated floor or floor/ceiling assembly provided that the area of the penetration does not exceed 144 square inches in any 100 sq ft of floor area.
2. Penetrations in a single concrete floor by steel, ferrous or copper conduits, pipes, tubes and vents with a maximum 6-inch nominal diameter provided concrete, grout or mortar is installed the full thickness of the floor or the thickness required to maintain the fire rating. Penetrating items with a maximum 6-inch nominal diameter shall not be limited to the penetration of a single concrete floor provided the area of the penetration does not exceed 144 square inches.
3. Electrical outlet boxes of any material are permitted provided that such boxes are tested for use in fire rated assemblies and installed in accordance with the tested assembly.

705.6.1.1 Fire rated assemblies. Penetrations shall be installed as tested in the approved ASTM E 119 rated assembly.

705.6.1.2 Penetration firestop system. Penetrations shall be protected by an approved penetration firestop system installed as tested in accordance with ASTM E 814, with a minimum positive pressure differential of 0.01 inch of water. The system shall have an F rating and a T rating of not less than 1 hour but not less than the required rating of the floor penetrated.

Exception: Floor penetrations contained and located within the cavity of a wall do not require a T rating.

705.6.2 Membrane penetrations. Penetrations of membranes which are part of a fire rated horizontal assembly shall comply with 705.6.1 through 705.6.1.2.

Exceptions:

1. Membrane penetrations of steel, ferrous or copper conduits, electrical outlet boxes, pipes, tubes, vents, concrete, or masonry penetrating items where the annular space is protected in accordance with 705.6.1, 705.6.2 or is protected to prevent the passage of flame and hot gases. Such penetrations shall not exceed an aggregate area of 100 square inches in any 100 sq ft of ceiling area in assemblies tested without penetrations.
2. Membrane penetrations for electrical outlet boxes of any material are permitted provided that such boxes are tested for use in fire rated assemblies and installed in accordance with the tested assembly.
3. The annular space created by the penetration of a fire sprinkler provided it is covered by a metal escutcheon plate.

705.6.3 Nonfire rated assemblies. Penetrations of horizontal assemblies without a required fire rating shall comply with 705.6.3.1 through 705.6.3.2.

705.6.3.1 Noncombustible penetrating items. Noncombustible penetrating items which connect not more than three stories are permitted provided that the annular space is filled with an approved material to resist the passage of flame and hot gases.

705.6.3.2 Combustible penetrating items. Combustible penetrating items which connect not more than two stories are permitted provided that the annular space is filled with an approved material to resist the passage of flame and hot gases.

104.2.4 Structural and fire resistance integrity. Plans for all buildings shall indicate how required structural and fire resistance integrity will be maintained where a penetration of a required fire resistant wall, floor or partition will be made for electrical, gas, mechanical, plumbing and communication conduits, pipes and systems. Such plans shall also indicate in sufficient detail how the fire integrity will be maintained where required fire resistant floors intersect the exterior walls and where joints occur in required fire resistant construction assemblies.

Figure 26:Signaling application with ENT in a Type 1 building

Figure 27: Holiday Inn utilizing ENT, Vallejo, California

4.2.2 Performance Specifications

The **Standard Building Code** utilizes both performance based and prescriptive requirements to establish what materials and methods are permissible for use. This is consistent with the manner in which the code treats fire resistant penetrations which occur when tubing, conduit, vents, pipe, or ducts enter or exit construction assemblies and its treatment of materials contained within the construction envelope (walls, slabs, floor/ceiling assemblies) of a given "Type of Construction".

Of primary importance in utilizing PVC raceway in buildings regulated by The **Standard Building Code** is Section 706 ("Combustibles in Fire Rated Assemblies") included below, which permits their use in fire-rated assemblies in buildings of Types I and II construction provided such designs have been qualified by test. Exception 5 of Section 707 addresses use of combustible raceway and conduit systems in concealed spaces.

The **Standard Building Code** Section 705.4 begins the discussion found in the section related to through-penetration involving electrical raceways including those of PVC. Relevant sections include provisions for use of sleeves and insulations, Sections 705.4.2 and 705.4.3 and provisions for use as both through-penetrations (Sections 705.5.1 and 705.5.1.1 or 705.5.1.2) or in membrane penetrations as covered in Section 705.5.2.

Treatments of penetrations of horizontal assemblies begin with Section 705.6 and continue through Section 705.6.3.2

The **Standard Building Code** (and not subsidiary electrical, plumbing or mechanical codes) defines levels of fire performance required in building construction. Thus, if a given product meets the functional requirements of a subsidiary code, as PVC raceway meet requirements found in **The National Electrical Code**, that product's acceptability for a given building application is regulated by its ability to demonstrate required fire safety levels. That takes into account its installation as defined in The **Standard Building Code** sections presented previously as well as other sections, which may be relevant for a particular installation. Meeting the appropriate requirements is in all cases consistent with and required by The **Standard Building Code** Section 104.2.4 "Structural and fire resistance integrity" which mandates "sufficient detail" will be presented in plans to show how fire integrity of a structure will be maintained with fire resistant assemblies incorporating electrical and other systems including conduits.

4.3 The Uniform Building Code (UBC) and PVC Raceway

The **Uniform Building Code**, promulgated by the International Conference of Building Officials (ICBO, Whittier, California) regulates the use of PVC raceway in jurisdictions in which it is adopted and defines the relationship of the **Uniform Building Code** (UBC) to **The National Electrical Code**®.

4.3.1 Code Format

The 1997 **Uniform Building Code** utilizes the classifications of “occupancy type” (which relate to projected use of a building) and “type of construction” (which defines materials allowed in the construction of a particular building). Together, these concepts are used to define fire endurance properties for a particular building built in accordance with the ICBO code.

Occupancy classifications range from those necessitating the highest, most demanding levels of fire performance (e.g., highrise buildings or others having large occupant loads or hazardous uses) through less hazardous formats such as individual dwellings or lowrise, detached commercial buildings. These are described in detail in Chapter 3 of the **Uniform Building Code** and are introduced in UBC Section 301 (“Occupancy Classified”–see below).

The “type of construction” designation refers specifically to the materials used for construction as either non-combustible (i.e. masonry, concrete or steel) or combustible (wood or polymer based). Type of construction also regulates fire endurance levels required. Levels of fire endurance performance run from non-rated (no hourly requirements) through various levels of fire-rated performance under which specific hourly requirements are invoked.

“Occupancy type” and “type of construction” are brought together and presented in matrix form in Tables 5-A and 5-B and 6-A of the **Uniform Building Code.** In these tables, general performance based requirements as well as specific requirements for critical walls, floors, shafts, etc., for a given building design and end use, are specified.

The tables and text that follow, for example, show that an interior bearing wall for a “Type I” non-combustible building must have 3-hour fire endurance. Conversely, interior walls needed for Types II through V buildings vary from designs requiring 2-hour fire endurance to those of non-rated design. The **Uniform Building Code** tables and code text sections, which interrelate occupancy types and fire resistive requirements follow:

SECTION 301 — OCCUPANCY CLASSIFIED

Every building, whether existing or hereafter erected, shall be classified by the building official according to its use or the character of its occupancy, as set forth in Table 3-A, as a building of one of the following occupancy groups:

Group A—Assembly (see Section 303.1.1)

Group B—Business (see Section 304.1)

Group E—Educational (see Section 305.1)

Group F—Factory and Industrial (see Section 306.1)

Group H—Hazardous (see Section 307.1)

Group I—Institutional (see Section 308.1)

Group M—Mercantile (see Section 309.1)

Group R—Residential (see Section 310.1)

Group S—Storage (see Section 311.1)

Group U—Utility (see Section 312.1)

Any occupancy not mentioned specifically or about which there is any question shall be classified by the building official and included in the group that its use most nearly resembles, based on the existing or proposed fire and life hazard.

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS: Bearing	EXTERIOR WALLS: Nonbearing	OPENINGS[5]
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
S-4	I-F.R. II-F.R. II One-hour II-N[3]	One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	III One-hour III-N IV-H.T. V One-hour V-N	Group S, Division 4 open parking garages are not permitted in these types of construction.		
S-5	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
	II-N[3]	One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V-N[3]	One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
U-1[3]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 3 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 3 feet
	II-N[2]	One-hour N/C less than 3 feet[3] NR, N/C elsewhere	Same as bearing	Not permitted less than 3 feet
	V-N	One-hour less than 3 feet[3] NR elsewhere	Same as bearing	Not permitted less than 3 feet
U-2	All	Not regulated		

N/C — Noncombustible.
NR — Nonrated.
H.T. — Heavy timber.
F.R. — Fire resistive.

[1]See Section 503 for types of walls affected and requirements covering percentage of openings permitted in exterior walls. For walls facing streets, yards and public ways, see also Section 601.5.

[2]For additional restrictions, see Chapters 3 and 6.

[3]For special provisions and exceptions, see also Section 503.4.

[4]See Table 3-A for a description of each occupancy type.

[5]Openings requiring protection in exterior walls shall be protected by a fire assembly having at least a three-fourths-hour fire-protection rating.

[6]Group E, Divisions 2 and 3 Occupancies having an occupant load of not more than 20 may have exterior wall and opening protection as required for Group R, Division 3 Occupancies.

[7]See Section 308.2.1, Exception 3.

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS		OPENINGS[5]
		Bearing	Nonbearing	
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
H-5[2]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 40 feet One-hour N/C less than 60 feet NR, N/C elsewhere	Protected less than 60 feet
	II One-hour	One-hour N/C	Same as bearing, except NR, N/C 60 feet or greater	Protected less than 60 feet
	II-N	One-hour N/C less than 60 feet NR, N/C elsewhere	Same as bearing	Protected less than 60 feet
	V One-hour	One-hour	Same as bearing	Protected less than 60 feet
	V-N	One-hour less than 60 feet NR elsewhere	Same as bearing	Protected less than 60 feet
I-1.1 I-1.2 I-2 I-3	I-F.R. II-F.R.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
I-1.1 I-1.2 I-3[2]	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
I-1.1 I-1.2 I-2 I-3	II-N III-N V-N	These occupancies are not allowed in buildings of these construction types.[7]		
I-3	IV-H.T.	Group I, Division 3 Occupancies are not allowed in buildings of this construction type.		
I-1.1 I-1.2 I-2 I-3	III One-hour	Four-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
I-1.1 I-1.2 I-2	IV-H.T.	Four-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
I-2	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
R-1	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 3 feet Two-hour N/C elsewhere	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet
	II-N	One-hour N/C less than 5 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet
	V-N	One-hour less than 5 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet
R-3	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 3 feet
	II-N	One-hour N/C less than 3 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 3 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 3 feet
	V-N	One-hour less than 3 feet NR elsewhere	Same as bearing	Not permitted less than 3 feet

(Continued)

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS		OPENINGS[5]
		Bearing	Nonbearing	
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
E-1 E-2[6] E-3[6]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N	Two-hour N/C less than 5 feet One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	Two-hour less than 5 feet One-hour less than 10 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
F-2 S-2	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N[3]	One-hour N/C less than 5 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	One-hour less than 5 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
H-1[2,3]	I-F.R. II-F.R.	Four-hour N/C	NR N/C	Not restricted[3]
	II One-hour	One-hour N/C	NR N/C	Not restricted[3]
	II-N	NR N/C	Same as bearing	Not restricted[3]
	III One-hour III-N IV-H.T. V One-hour V-N	Group H, Division 1 Occupancies are not allowed in buildings of these construction types.		
H-2[2,3] H-3[2,3] H-4[3] H-6 H-7	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II-N	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V One-hour	Four-hour less than 5 feet Two-hour less than 10 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V-N	Four-hour less than 5 feet Two-hour less than 10 feet One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet

(Continued)

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]
For exceptions, see Section 503.4.

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS — Bearing	EXTERIOR WALLS — Nonbearing	OPENINGS[5]
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
A-1	I-F.R. II-F.R.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour II-N III One-hour III-N IV-H.T. V One-hour V-N	Group A, Division 1 Occupancies are not allowed in these construction types.		
A-2 A-2.1 A-3 A-4	I-F.R. II-F.R. III One-hour IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
A-2 A-2.1[2]	II One-hour	Two-hour N/C less than 10 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N III-N V-N	Group A, Divisions 2 and 2.1 Occupancies are not allowed in these construction types.		
	V One-hour	Two-hour less than 10 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-3	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N	Two-hour N/C less than 5 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	III-N	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	Two-hour less than 5 feet One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-4	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Protected less than 10 feet
	II-N	One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Protected less than 10 feet
	III-N	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Protected less than 10 feet
	V-N	One-hour less than 10 feet NR elsewhere	Same as bearing	Protected less than 10 feet
B, F-1, M, S-1, S-3	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
B F-1 M S-1, S-3	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N[3]	One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet

(Continued)

TABLE 5-B—BASIC ALLOWABLE BUILDING HEIGHTS AND BASIC ALLOWABLE FLOOR AREA FOR BUILDINGS ONE STORY IN HEIGHT[1]

TYPE OF CONSTRUCTION		TYPES OF CONSTRUCTION								
		I	II			III		IV	V	
		F.R.	F.R.	One-hour	N	One-hour	N	H.T.	One-hour	N
		Maximum Height (feet)								
		UL	160 (48 768 mm)	65 (19 812 mm)	55 (16 764 mm)	65 (19 812 mm)	55 (16 764 mm)	65 (19 812 mm)	50 (15 240 mm)	40 (12 192 mm)
Use Group	**Height/Area**	Maximum Height (stories) and Maximum Area (sq. ft.) (× 0.0929 for m²)								
A-1	H A	UL UL	4 29,900	Not Permitted						
A-2, 2.1[2]	H A	UL UL	4 29,900	2 13,500	NP NP	2 13,500	NP NP	2 13,500	2 10,500	NP NP
A-3, 4[2]	H A	UL UL	12 29,900	2 13,500	1 9,100	2 13,500	1 9,100	2 13,500	2 10,500	1 6,000
B, F-1, M, S-1, S-3, S-5	H A	UL UL	12 39,900	4 18,000	2 12,000	4 18,000	2 12,000	4 18,000	3 14,000	2 8,000
E-1, 2, 3[4]	H A	UL UL	4 45,200	2 20,200	1 13,500	2 20,200	1 13,500	2 20,200	2 15,700	1 9,100
F-2, S-2	H A	UL UL	12 59,900	4 27,000	2 18,000	4 27,000	2 18,000	4 27,000	3 21,000	2 12,000
H-1[5]	H A	1 15,000	1 12,400	1 5,600	1 3,700	Not Permitted				
H-2[5]	H A	UL 15,000	2 12,400	1 5,600	1 3,700	1 5,600	1 3,700	1 5,600	1 4,400	1 2,500
H-3, 4, 5[5]	H A	UL UL	5 24,800	2 11,200	1 7,500	2 11,200	1 7,500	2 11,200	2 8,800	1 5,100
H-6, 7	H A	3 UL	3 39,900	3 18,000	2 12,000	3 18,000	2 12,000	3 18,000	3 14,000	1 8,000
I-1.1, 1.2[6,10]	H A	UL UL	3 15,100	1 6,800	NP NP	1 6,800	NP NP	1 6,800	1 5,200	NP NP
I-2	H A	UL UL	3 15,100	2 6,800	NP NP	2 6,800	NP NP	2 6,800	2 5,200	NP NP
I-3	H A	UL UL	2 15,100	Not Permitted[7]						
R-1	H A	UL UL	12 29,900	4 13,500	2[9] 9,100[9]	4 13,500	2[9] 9,100[9]	4 13,500	3 10,500	2[9] 6,000[9]
R-3	H	UL	3	3	3	3	3	3	3	3
	A	Unlimited								
S-4[3]	H A	See Table 3-H								
U[8]	H A	See Chapter 3								

A—Building area in square feet.
H—Building height in number of stories.
H.T.—Heavy timber.
NP—Not permitted.
N—No requirements for fire resistance.
F.R.—Fire resistive.
UL—Unlimited.

[1]For multistory buildings, see Section 504.2.
[2]For limitations and exceptions, see Section 303.2.
[3]For open parking garages, see Section 311.9.
[4]See Section 305.2.3.
[5]See Section 307.
[6]See Section 308.2.1 for exception to the allowable area and number of stories in hospitals, nursing homes and health-care centers.
[7]See Section 308.2.2.2.
[8]For agricultural buildings, see also Appendix Chapter 3.
[9]For limitations and exceptions, see Section 310.2.
[10]For Type II F.R., the maximum height of Group I, Division 1.1 Occupancies is limited to 75 feet (22 860 mm). For Type II, One-hour construction, the maximum height of Group I, Division 1.1 Occupancies is limited to 45 feet (13 716 mm).

TABLE 6-A—TYPES OF CONSTRUCTION—FIRE-RESISTIVE REQUIREMENTS (In Hours)
For details, see occupancy section in Chapter 3, type of construction sections in this chapter and sections referenced in this table.

BUILDING ELEMENT	TYPE I	TYPE II			TYPE III		TYPE IV	TYPE V	
	Noncombustible				Combustible				
	Fire-resistive	Fire-resistive	1-Hr.	N	1-Hr.	N	H.T.	1-Hr.	N
1. Bearing walls—exterior	4 Sec. 602.3.1	4 Sec. 603.3.1	1	N	4 Sec. 604.3.1	4 Sec. 604.3.1	4 Sec. 605.3.1	1	N
2. Bearing walls—interior	3	2	1	N	1	N	1	1	N
3. Nonbearing walls—exterior	4 Sec. 602.3.1	4 Sec. 603.3.1	1 Sec. 603.3.1	N	4 Sec. 604.3.1	4 Sec. 604.3.1	4 Sec. 605.3.1	1	N
4. Structural frame[1]	3	2	1	N	1	N	1 or H.T.	1	N
5. Partitions—permanent	1[2]	1[2]	1[2]	N	1	N	1 or H.T.	1	N
6. Shaft enclosures[3]	2	2	1	1	1	1	1	1	1
7. Floors and floor-ceilings	2	2	1	N	1	N	H.T.	1	N
8. Roofs and roof-ceilings	2 Sec. 602.5	1 Sec. 603.5	1 Sec. 603.5	N	1	N	H.T.	1	N
9. Exterior doors and windows	Sec. 602.3.2	Sec. 603.3.2	Sec. 603.3.2	Sec. 603.3.2	Sec. 604.3.2	Sec. 604.3.2	Sec. 605.3.2	Sec. 606.3	Sec. 606.3
10. Stairway construction	Sec. 602.4	Sec. 603.4	Sec. 603.4	Sec. 603.4	Sec. 604.4	Sec. 604.4	Sec. 605.4	Sec. 606.4	Sec. 606.4

N—No general requirements for fire resistance.
H.T.—Heavy timber.

[1]Structural frame elements in an exterior wall that is located where openings are not permitted, or where protection of openings is required, shall be protected against external fire exposure as required for exterior-bearing walls or the structural frame, whichever is greater.
[2]Fire-retardant-treated wood (see Section 207) may be used in the assembly, provided fire-resistance requirements are maintained. See Sections 602 and 603.
[3]For special provisions, see Sections 304.6, 306.6 and 711.

SECTION 601 — CLASSIFICATION OF ALL BUILDINGS BY TYPES OF CONSTRUCTION AND GENERAL REQUIREMENTS

601.1 General. The requirements of this chapter are for the various types of construction and represent varying degrees of public safety and resistance to fire. Every building shall be classified by the building official into one of the types of construction set forth in Table 6-A. Any building that does not entirely conform to a type of construction set forth in Table 6-A shall be classified by the building official into a type having an equal or lesser degree of fire resistance.

A building or portion thereof shall not be required to conform to the details of a type of construction higher than that type that meets the minimum requirements based on occupancy even though certain features of such building actually conform to a higher type of construction.

When specific materials, types of construction or fire-resistive protection are required, such requirements shall be the minimum requirements, and any materials, types of construction or fire-resistive protection that will afford equal or greater public safety or resistance to fire, as specified in this code, may be used.

SECTION 709 — WALLS AND PARTITIONS

709.1 General. Fire-resistive walls and partitions shall be assumed to have the fire-resistance ratings set forth in Table 7-B.

Where materials, systems or devices are incorporated into the assembly that have not been tested as part of the assembly, sufficient data shall be made available to the building official to show that the required fire-resistive rating is not reduced. Materials and methods of construction used to protect joints and penetrations in fire-resistive, fire-rated building assemblies shall not reduce the required fire-resistive rating.

709.6 Through Penetrations.

709.6.1 General. Through penetrations of the fire-resistive walls shall comply with Section 709.6.2 or 709.6.3.

EXCEPTION: Where the penetrating items are steel, ferrous or copper pipes or steel conduits, the annular space shall be permitted to be protected as follows:

1. In concrete or masonry walls where the penetrating items are a maximum 6-inch (152 mm) nominal diameter and the opening is a maximum 144 square inches (92 903 mm^2) concrete, grout or mortar shall be permitted when installed the full thickness of the wall or the thickness required to maintain the fire rating, or

2. The material used to fill the annular space shall prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to UBC Standard 7-1 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) at the location of the penetration for the time period equivalent to the fire rating of the construction penetrated.

709.6.2 Fire-rated assembly. Penetrations shall be installed as tested in the approved UBC Standard 7-1 rated assembly.

709.6.3 Penetration firestop system. Penetrations shall be protected by an approved penetration firestop system installed as tested in accordance with UBC Standard 7-5 and shall have an F rating of not less than the required rating of the wall penetrated.

709.7 Membrane Penetrations. Membrane penetrations of the fire-resistive walls shall comply with Section 709.6.

EXCEPTIONS: 1. Steel electrical boxes that do not exceed 16 square inches (10 323 mm^2) in area, provided that the area of such openings does not exceed 100 square inches for any 100 square feet (694 mm^2/m^2) of wall area. Outlet boxes on opposite sides of the wall shall be separated by a horizontal distance of not less than 24 inches (610 mm). Membrane penetrations for electrical outlet boxes of any material are permitted, provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

2. The annular space created by the penetration of a fire sprinkler shall be permitted to be unprotected, provided such space is covered by a metal escutcheon plate.

Noncombustible penetrating items shall not be connected to combustible materials on both sides of the membrane unless it can be confirmed that the fire-resistive integrity of the wall is maintained in accordance with UBC Standard 7-1.

SECTION 710 — FLOOR CEILINGS OR ROOF CEILINGS

710.1 General. Fire-resistive floors, floor-ceiling or roof-ceiling assemblies shall be assumed to have the fire-resistance ratings set forth in Table 7-C. When materials are incorporated into an otherwise fire-resistive assembly that may change the capacity for heat dissipation, fire test results or other substantiating data shall be made available to the building official to show that the required fire-resistive time period is not reduced.

Where the weight of lay-in ceiling panels used as part of fire-resistive floor-ceiling or roof-ceiling assemblies is not adequate to resist an upward force of 1 pound per square foot (0.048 kN/m^2), wire holddowns or other approved devices shall be installed above the panels to prevent vertical displacement under such upward force.

710.2 Through Penetrations.

710.2.1 General. Through penetrations of fire-resistive horizontal assemblies shall be enclosed in fire-resistive shaft enclosures in accordance with Section 711.1 or shall comply with Section 710.2.2 or 710.2.3.

EXCEPTIONS: 1. Steel, ferrous or copper conduits, pipes, tubes, vents, concrete, or masonry penetrating items that penetrate a single fire-rated floor assembly where the annular space is protected with materials that prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to UBC Standard 7-1 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) at the location of the penetration for the time period equivalent to the fire-resistive rating of the construction penetrated. Penetrating items with a maximum 6-inch (152 mm) nominal diameter shall not be limited to the penetration of a single-fire-resistive floor assembly, provided that the area of the penetration does not exceed 144 square inches in any 100 square feet (100 000 mm^2 in 10 m^2) of floor area.

2. Penetrations in a single concrete floor by steel, ferrous or copper conduits, pipes, tubes and vents with a maximum 6-inch (152 mm) nominal diameter provided concrete, grout or mortar is installed the full thickness of the floor or the thickness required to maintain the fire-resistive rating. The penetrating items with a maximum 6-inch (152 mm) nominal diameter shall not be limited to the penetration of a single concrete floor, provided that the area of the penetration does not exceed 144 square inches (92 903 mm^2).

3. Electrical outlet boxes of any material are permitted provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

710.2.2 Fire-rated assemblies. Penetrations shall be installed as tested in the approved UBC Standard 7-1.

710.2.3 Penetration firestop system. Penetration shall be protected by an approved penetration firestop system installed as tested in accordance with UBC Standard 7-5. The system shall have an F rating and a T rating of not less than one hour but not less than the required rating of the floor penetrated.

EXCEPTION: Floor penetrations contained and located within the cavity of a wall do not require a T rating.

710.3 Membrane Penetrations. Penetrations of membranes that are part of a fire-resistive horizontal assembly shall comply with Section 710.2.

EXCEPTIONS: 1. Membrane penetrations of steel, ferrous or copper conduits, electrical outlet boxes, pipes, tubes, vents, concrete, or masonry penetrating items where the annular space is protected in accordance with Section 709.6 or 710.2 or is protected to prevent the free passage of flame and the products of combustion. Such penetrations shall not exceed an aggregate area of 100 square inches in any 100 square feet (694 mm^2/m^2) of ceiling area in assemblies tested without penetrations.

2. Membrane penetrations for electrical outlet boxes of any material are permitted, provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

3. The annular space created by the penetration of a fire sprinkler shall be permitted to be unprotected, provided such space is covered by a metal escutcheon plate.

SECTION 714 — THROUGH-PENETRATION FIRE STOPS

Through-penetration fire stops required by this code shall have an F or T rating as determined by tests conducted in accordance with UBC Standard 7-5.

Through-penetration fire stops may be used for membrane penetrations.

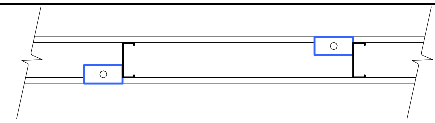
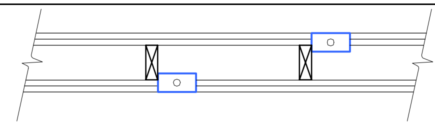
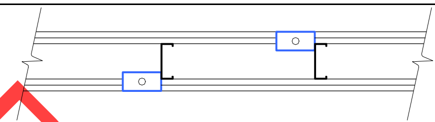
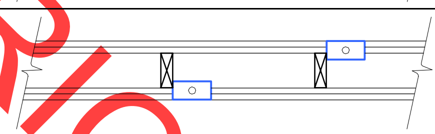
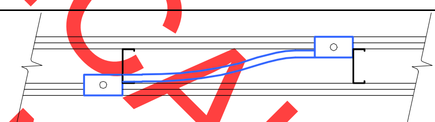
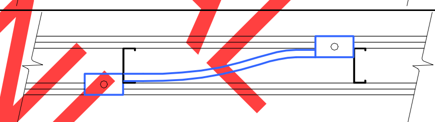
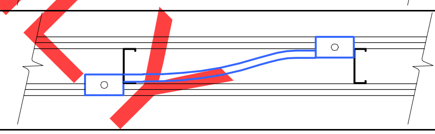
The F rating shall apply to all through penetrations and shall not be less than the required fire-resistance rating of the assembly penetrated.

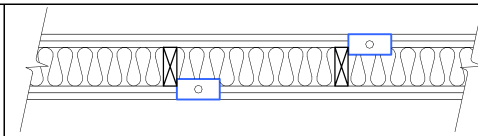
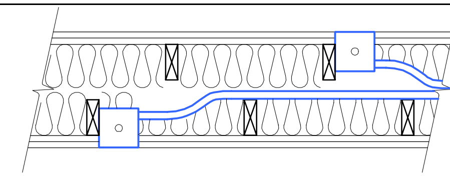
The T rating shall apply to those through-penetration locations required to have T ratings as specified in Section 710.3 and shall not be less than the required fire-resistance rating of the assembly penetrated.

Where sleeves are used, the sleeves shall be securely fastened to the assembly penetrated. All space between the item contained in the sleeve and the sleeve itself and any space between the sleeve and the assembly penetrated shall be protected. Insulation and coverings on the penetrating item shall not penetrate the assembly unless the specific materials used have been tested as part of the assembly.

EXCEPTION: Fire damper or combination fire damper/smoke damper sleeves shall be installed in accordance with their listing.

TABLE 5.1 Tested Fire Resistive Wall Assembly Designs Including PVC Nonmetallic Electrical Raceways and Boxes

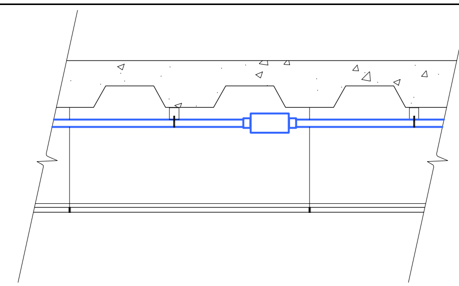
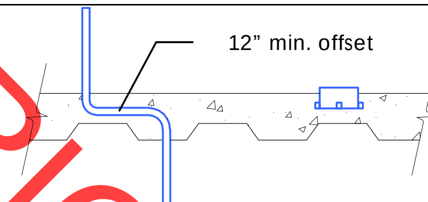
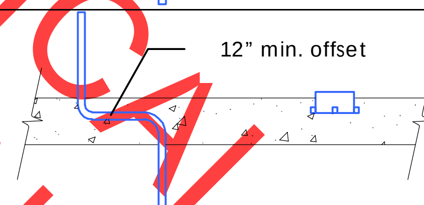
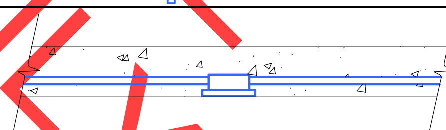
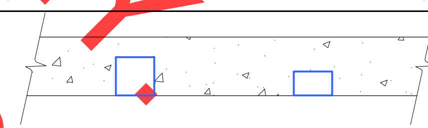
Item/Ref.	Construction	PVC Electrical Items	Fire Rating	Diagram
1	3-5/8” deep steel studs, 24” O.C. 1 layer 5/8” Type “X” gypsum wallboard	CARLON Outlet Boxes: 4”H 4”W w/duplex receptacles	1 HR.	
2	Nominal 2” X 4” wood studs, 16” O.C. 2 layers 5/8” Type “C” gypsum wallboard	CARLON outlet and switch boxes: 3 ½”H 5 5/8”W 2-7/16 ”D 4”H 4”W 1 7/16”D 4”H 3 5/8”W 2 ¾”D	2 HR.	
3	3-5/8” deep steel studs, 16” O.C. 2 layers 5/8” Type “C” gypsum wallboard	CARLON outlet or switch boxes: 21.2 sq. in. or less in surface area; aggregate surface area no more than 100 sq. in. per 100 sq. ft. of wall area.	2 HR.	
3	Nominal 2” X 4” wood, 16” O.C. 2 layers 5/8” Type “C” gypsum wallboard	CARLON outlet or switch boxes: 21.2 sq. in. or less in surface area; aggregate surface area no more than 100 sq. in. per 100 sq. ft. of wall area.	2 HR.	
4	3-5/8” deep steel studs, 24” O.C., 2 layers 5/8” stud Type “C” gypsum wallboard	CARLON Nominal ½” RNMC Appropriate CARLON PVC connectors.	2 HR.	
5	3-5/8” deep steel studs, 24” O.C. 2 layers 5/8” Type “C” gypsum wallboard	CARLON 7/8” O.D. ENT Appropriate CARLON PVC connectors	2 HR.	
6	3-5/8” deep steel studs, 24” O.C. 2 layers 5/8” Type “X” gypsum wallboard	CARLON Nominal ½” or ¾” ENT CARLON Nominal ½” or ¾” RNMC Appropriate CARLON PVC connectors	2 HR.	

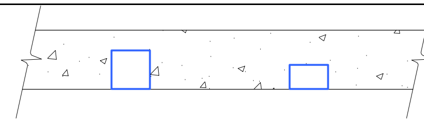
7	Nominal 2” X 4” wood studs, 16” O.C. non-load bearing wall 2 layers 5/8” Type “X” gypsum wallboard Ceramic Fiber Insulation	CARLON outlet and switch boxes: 3 ½”H 5 5/8” W 2 7/16 ”D 4”H 4”W 1 7/16”D 4” H 3 5/8”W 2 ¾”D	2 HR.	
8	Nominal 2” X 4” wood studs, 16” O.C. load bearing wall 2 layers 5/8” Type “X” gypsum wallboard Ceramic Fiber Insulation	CARLON outlet and switch boxes: 3 1/8” by 2 1/4” by 3” deep 4”H 4”W 4” D CARLON Nominal ¾” ENT Appropriate CARLON PVC connectors	2 HR.	

<u>Testing References for **Table 5.1**</u>

1. Steel Stud/Gypsum Wall Containing Two Receptacle Boxes and ENT, Omega Point Laboratories, San Antonio, Texas, Project No. 1149-92509, January 27, 1992.
2. Nonmetallic Outlet and Switch Boxes For Use in Wall and Partition Assemblies Consisting of Wood Studs and Gypsum Wallboard, Underwriters Laboratories, Inc. File R8326-3, Project 79NK13050, April 10, 1980.
3. Nonmetallic Electrical Outlet Boxes in Fire-Resistive Walls and Wall-Ceiling Assemblies, Council of American Building Officials (CABO). NESC, Report No. NER-140. April 1986.
4. PV and Rigid Metallic Conduit and Metallic outlet Boxes in a Nonbearing Partition Assembly, Underwriters Laboratories, Inc., File NC546-1, -2, Project 73NK7657, December 21, 1973.
5. Electrical Nonmetallic Tubing (ENMT), Electrical Metallic Tubing (EMT) and Metallic Outlet Boxes in a Nonbearing Partition Assembly, Underwriters Laboratories, Inc., File R8326-4, Project 80NK11747, September 17, 1980.
6. Fire Resistive Noncombustible Partition Assembly Containing Electrical Nonmetallic Tubing and Rigid Nonmetallic Conduit, Council of American Building Officials (CABO). NESC Report No. NER-290. May 1987.
7. Non Load-Bearing Wall with Nonmetallic Outlet Boxes, Underwriters Laboratories, Inc., File R8326, Project 93NK19678, November 18, 1994.
8. Load Bearing Wall with Nonmetallic Outlet Boxes and Tubing, Underwriters Laboratories, Inc., File R8326, Project 94NK17350, November 21, 1994.

TABLE 5.2 Tested Fire Resistive Floor/Ceiling and Slab Assembly Designs Including PVC Nonmetallic Electrical Raceways and Boxes

Item/Ref.	Construction	PVC Electrical Items	Fire Rating	Diagram
1	FLOOR/CEILING ASSEMBLY: 3” deep cellular steel floor units with 2 ½” normal weight concrete topping, suspended acoustical material lay-in panels as lower membrane.	JUNCTION BOXES: Nominal 8” square by 7” deep [CARLON E989SSX UL] Nominal 4” square by 2” deep [CARLON E989NNJ] RACEWAYS: ¾” CARLON ENT 2” CARLON RNMC 1” CARLON RNMC Appropriate CARLON PVC connectors	3 HR.	
2	3 ¼” lightweight concrete on 2” deep fluted metal decking.	1) 1” Raceway [CARLON ENT]	2 HR.	
3		2) 4 ½” dia. floor box [CARLON E971FB]		
4	4 ½” normal weight concrete slab.	1) 1” Raceway [CARLON ENT]	2 HR.	
5		2) 4 ½” dia. floor box [CARLON E971FB]		
6		3) ¾” CARLON ENT	2 HR	
6		4) 4” dia. by 1-1/2” deep [CARLON A862E]		
7	5” normal weight concrete slab	JUNCTION BOXES: Nominal 4” square by 2 ½” deep [CARLON A862] Nominal 4” hexagonal by 4” deep [CARLON A972N] w/ intumescent	2 HR.	

8	6” normal weight concrete slab	JUNCTION BOXES: Nominal 4” square by 2 ½” deep [CARLON A862] Nominal 4” hexagonal by 4” deep [CARLON A972N]	2 HR.	

<u>Testing References for **Table5.2**:</u>

1. Metallic and Nonmetallic Tubing, Conduits and Boxes in the Concealed Space of Floor-Ceiling Assemblies with Suspended Ceiling, Underwriters Laboratories, Inc., File NC546-5, Project 87NK27319, March 30, 1989.
2. 6’ by 8’ by 5-1/4” Lightweight Concrete Slab on Steel Decking with 1” PVC Flexible ENT, Warnock Hersey, Pittsburg, CA, File WHI-495-PSH-0169, Work Order No. 50611-C7-030320, July 16, 1990.
3. 6’ by 8’ by 5-1/4” Lightweight Concrete Slab on Steel Decking with PVC Floor Box, Warnock Hersey, Pittsburg, CA, File No. WHI-495-PSH-0169A, Work Order No. 50611-C7-030320, July 16, 1990.
4. [1] 6’ by 8’ by 4-1/2” Normal Weight Concrete Slab with 1” Flexible PVC ENT, Warnock Hersey, Pittsburg, CA, File No. WHI-495-PSH-0165, Work Order No. 50611-C7-030320. May 7, 1990.
5. 6’ by 8’ by 4-1/2” Normal Weight Concrete Slab with PVC Floor Box, Warnock Hersey, Pittsburg, CA, File No. WHI-495-PSH-0165A, Work Order No. 50611-C7-030320, May 7, 1990.
6. Outlet Boxes and Fittings Classified for Fire Resistance, Underwriters Laboratories, Inc., File R8326, Project 95NK8905, April 30, 1996.
7. Mud Boxes Cast Into A 2-Hour Rated Concrete Floor, Omega Point Laboratories, San Antonio, Texas, Project No. 1091-92055, November 18, 1991.
8. Mud Boxes Cast Into A 3-Hour Rated Concrete Floor, Omega Point Laboratories, San Antonio, Texas, Project No. 1091-92483, November 18, 1991.

4.3.2 Performance Specifications

The **Uniform Building Code** utilizes both performance based and prescriptive specifications to establish what materials and methods are permissible for use. The manner in which the code treats fire resistive penetrations which occur when tubing, conduit, vents, pipe, ducts enter or exit construction assemblies and its treatment of materials contained within the construction envelope and those used for buildings of different "Type[s] of Construction" bear this out.

Of primary importance to qualify PVC raceway systems for use in buildings regulated by the **Uniform Building Code** is Section 703 ("Fire-Resistive Materials and Systems"). This includes discussions of testing in general, qualification of alternate designs by testing and standards of quality, which must be maintained.

Uniform Building Code Section 702 ("Definitions") contains relevant text defining terms related to penetrations and maintenance of fire-resistive integrity. Section 709–Walls and Partitions, includes a general section (709.1) that discusses and provides for the impact of included materials, such as electrical components on fire resistance rated assemblies.

Section 709.6 ("Through Penetrations") includes a charging section relating to penetrations (Section 709.6.1) which refers the reader to UBC Sections 709.6.2 or 709.6.3 for details related to fire resistive assemblies incorporating penetrations. These follow below.

Section 709.7 deals with membrane penetrations. It is relevant to note that the exception to 709.7 makes reference to the acceptability of both nonmetallic and metallic outlet boxes, that text follows.

Floor/ceiling or roof/ceiling assemblies are treated in a similar manner in UBC Section 710. Sections 710–through Section 710.3 ("Membrane Penetrations") follow. These contain similar treatments incorporating performance-based language to address materials including materials in floor/ceiling and roof/ceiling assemblies, as was discussed earlier concerning wall assemblies. That text also makes specific reference to membrane and through-penetration systems, as well as combustible (made from PVC) and non-combustible penetrating elements and electrical boxes.

The section on Shaft Enclosures –UBC Section 711–also makes provision for the use of combustible electrical raceway materials in the text of Section 711.3–Special Provisions.

The **Uniform Building Code** also contains a section specifically considering and detailing requirements for through-penetration fire-stops. This includes a discussion of "F" and "T"-ratings as well as testing and the use of sleeves. This can be found in UBC Section 714 that is included below.

It is accepted by ICBO that the **Uniform Building Code** (and not subsidiary electrical, plumbing or mechanical codes) defines levels of fire performance required in building construction. Thus, if a product meets the functional requirements of a subsidiary code, as PVC raceways meet the requirements found in the **National Electrical Code**, that product's acceptability for a given application is judged, in terms of required fire safety performance in the **Uniform Building Code**.

4.4 *The National Electrical Code®* and PVC Raceway

This section describes the relationship of the **National Electrical Code** and the three model building codes. The 1999 **National Electrical Code** permits ENT to be installed exposed in buildings not in excess of three floors above grade where it is not subject to physical damage. For buildings over three floors above grade, the NEC requires that ENT must be installed concealed behind a material that meets the requirement for a 15-minute thermal barrier.

As described in the previous sections, the model building codes address design, structural and fire safety features of "building envelopes". Subsidiary codes govern the manner in which specific details of construction are performed. These include plumbing, mechanical, and electrical systems.

While the various model codes considered here each promulgated reference subsidiary codes (i.e., mechanical codes, plumbing codes, etc.), through 1998 the only nationally recognized and uniformly applied subsidiary code used has been the **National Electrical Code** promulgated by the National Fire Protection Association (NFPA). For many years that document regulated electrical installations in all construction in the United States. Thus, while the building codes define fire resistance ratings of penetrations, floors, ceilings, walls, etc., the **National Electrical Code** determines suitability of materials used to distribute electrical power in buildings.

RNC has been accepted in the codes since the 1960's. ENT was first included in the 1984 **National Electrical Code**. With the issuance of the 1984 code, ENT was permitted in structures up to three stories in an exposed fashion. Following further study of those 1984 NEC code provisions, it was determined that safe, unrestricted use without regard to height in buildings was appropriate if the product was protected by, at minimum, a 15-minute thermal barrier as is prescribed in the 1987 **National Electrical Code**. This recommendation was based in part on a report prepared by Benjamin-Clarke Associates (described in the appendix), which is also consistent with general comments on the subject made more recently by Dr. John Hall (1997)[10] related to combustion toxicity issues.

[10] *Hall, John, 1996. "Whatever Happened to Combustion Toxicity?" Fire Technology, 32,4 (351-371). See also NFPA Journal November/December 1996, pp 90-101*

Figure 28: Metal studs with bushings installed
Disney World, Florida

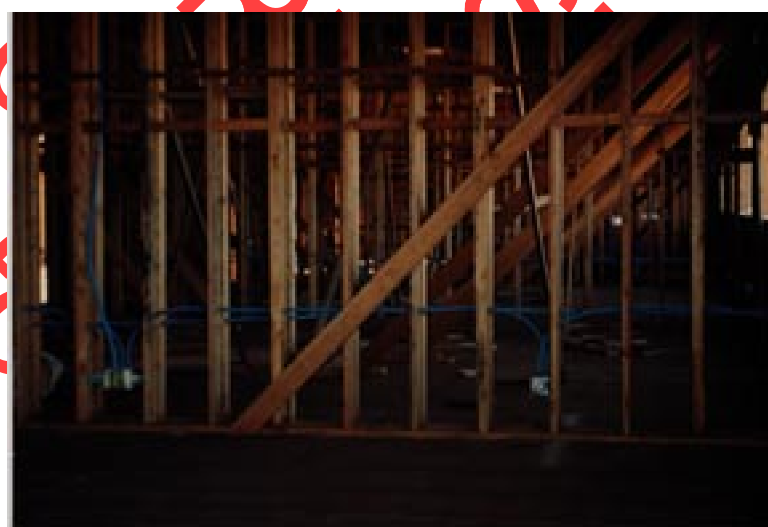


Figure 29: ENT installation in walls of Type V building
Kissimee, Florida

Figure 30:ENT riser to trough
Key West, Florida

Figure 31:ENT used with pre-manufactured wood trusses

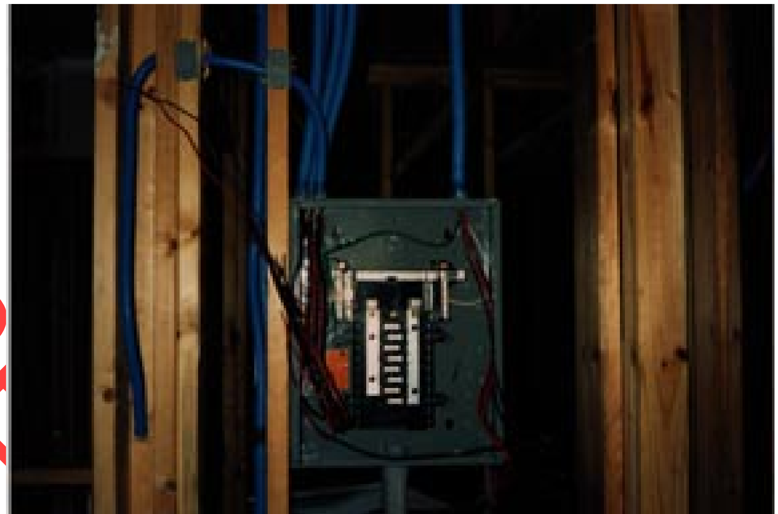


Figure 32:Distribution panel with ENT

5.0 Fire Tests-PVC Raceways, Boxes, and Accessories

This section summarizes published data describing third-party fire testing of PVC raceways and accessory installations. When coupled with field data concerning the fire performance of these products, this information constitutes an in-depth fire safety data base.

Numerous fire tests involving PVC pipe, tube and conduit have been conducted by independent third-party agencies. The results of these tests have been sufficiently well accepted by the engineering and regulatory community to demonstrate that fire performance of PVC raceways installed in fire-rated assemblies is satisfactory. Thus, inclusion of PVC raceways with proper detailing in such assemblies should not be expected to de-rate their performance.

Accompanying Table 5.1 and 5.2 summarizes generic assemblies that have undergone successful standard fire endurance testing to address public safety issues, which include PVC raceway and electrical components.

5.1 Standard Tests

Fire test methods based on ASTM Standards, are the primary method used in the U.S. to demonstrate that products meet necessary design criteria for acceptance in fire resistive assemblies. Building officials, architects and engineers depend on these standardized test results, which are generated by third party laboratories, to determine whether products and designs conform to minimum fire safety standards.

ASTM E-119 fire endurance tests have been conducted with PVC raceways and accessories installed in a variety of fire rated walls and floor/ ceiling assemblies. Assemblies successfully tested have included wood, metal and cementitious structural systems. Test durations have been one to three hours. Full test references and abstracts of test results can be found in the appendix. Examples of materials meeting this standard can also be seen in Table 5.1 and 5.2.

In addition to tests of ASTM E-119 assemblies, numerous tests have been carried out under the ASTM E-814 fire test standard which is used to assess the integrity of through-penetrations of fire resistive assemblies.

Consistent with use of the E-814 standard within the three model building codes, and as an adjunct to the testing conducted on the specific classes of assemblies described below, the Polymer Raceway Section (5R) of the National Electrical Manufacturers Association (NEMA) sponsored a test series in 1985. Its objective was to evaluate the impact of various PVC raceways up to two inches in diameter in noncombustible assemblies. Assemblies evaluated included concrete floors, steel stud walls and concrete block walls designed for 2-hour fire endurance ratings. Results of that test series showed satisfactory performance with the assemblies containing PVC products utilizing differing through-penetration firestop approaches. A full discussion of their tests can be found in the Underwriters Laboratories Test Report on the subject referenced in Appendix 1 of this report[11]. The ASTM E-814 Standard (numbered UL-1479 by Underwriters Laboratories) has been used by numerous independent third-party laboratories to conduct literally hundreds of tests certifying the performance of through-penetration and membrane penetration fire-stop systems. Many of these can be used with polymeric penetrating elements such as PVC raceway. Appendix 3 includes comments and examples of such systems available for use with PVC as described in third party listing documents.

5.1.1 Wall and Partition Test Results

As early as 1973, standard fire tests conducted by Underwriters Laboratories compared the fire endurance of PVC conduit with that of metallic raceway. In 2-hour tests of gypsum wallboard clad specimens no difference was seen in fire endurance by raceway type. Both wood and metal stud walls including PVC raceway were determined to be acceptable for field use (See Items 2 & 5 in Table 5.1). In addition, tests conducted in 1980 on PVC electrical boxes tested in 2-hour fire-rated walls showed no reduction in performance as compared with their metallic counterparts (See Item 6 in Table 5.1). Successful ASTM E-119 testing, to evaluate fire endurance and hose stream performance, has also been conducted evaluating one hour walls containing ENT, PVC boxes, outlets and wire. The designs included a single layer of 5/8 inch, "Type-X" gypsum wallboard (typified by Gypsum Association Design WP 1200[12]) on each face, affixed to metal studs 24 inch on center. In keeping with accepted practice, positive test results for metal studs demonstrate behavior that is acceptable for both wood and metal frame walls including the ENT materials and accessories for stud spacings up to 24" (See Item 1 in Table 5.1).

In 1994 two different 2-hour fire rated wood framed designs incorporating Carlon ENT, PVC outlet boxes and associated wiring were successfully fire endurance tested. The first of these assemblies resulted in a new load bearing staggered stud wall design–UL design U 351 – This design included four boxes installed within 20 inches of one another using a design incorporating a listed, ceramic fiber insulation[13]. (See item 9, Table 5.1.)
A second 2-hour wall design, successfully tested, evaluated walls of single stud design and incorporated a listed ceramic fiber insulation. The test wall in this case included Carlon ENT, PVC outlet boxes with associated wiring. Box spacing (back-to-back) of as little as 12 inch were included, providing an alternative means to those found in existing designs to reduce box spacing where needed[14]. (See item 8, Table 5.1.)

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[11] Underwriters Laboratories, Fill Void or Cavity Materials for Use in Through-penetration in Firestop Systems in Gypsum Wallboard Wall Assemblies, Project No. 85NKK17181, December 1985
[12] Gypsum Association, Fire resistance Design Manual, 15th Edition, GA-600-97, Washington D.C., 1997
[13] Underwriters Laboratories, Load Bearing wall with Nonmetallic Outlet Boxes and Tubing, Project No. 94NK17350, November 1994
[14] Underwriters Laboratories, Nonload Bearing Wall with Nonmetallic Outlet Boxes, Project No. 93NK19678, November 1994

5.1.2 Floor/Ceiling Assembly Test Results

Both combustible and non-combustible floor/ceiling designs have been successfully tested for fire endurance which included PVC raceways and accessories.

In 1980 a test series was conducted with a wood joist floor/ceiling assembly which included both PVC and metallic ceiling boxes. Comparison of assembly temperatures observed showed no difference in performance due to the presence of PVC boxes and the test assembly demonstrated 2-hour fire endurance[15].

In 1989 a 3-hour fire endurance rated, non-combustible assembly based on a concrete deck, metal structural system and fire-rated suspended ceiling design was tested. Electrical components tested allowed for comparison of PVC and metallic raceways with accessories in a variety of configurations. Once again, the PVC- based products showed satisfactory performance and did not reduce the fire endurance of the original assembly (See Item 1–Table 5.2).

5.1.3 Test Results - Concrete Slabs

Several 2 and 3-hour fire endurance tests have been conducted over the past several years with various concrete slab designs. These have included both lightweight and normal density concrete slabs cast on both the corrugated metal decks favored in highrise construction and plywood form work (See Table 5.2). In these tests ENT was included within slabs to simulate electrical service going to and from spaces both above and below the 2 and 3-hour assemblies. The test specimens (which also included EMT–Electrical Metallic Tubing) demonstrated in addition that EMT tested under the same standard ASTM E-119 conditions as the ENT exhibited unacceptably high back-face temperatures[16]. More complete references to these tests can be found in Appendix 1.

In addition to these tests, ASTM E-119 evaluations have also been conducted for 2 and 3-hour slabs incorporating cast-in-place PVC floor boxes and two types of ceiling boxes as well. In several of these cases third-party listed intumescent products were utilized in the installation detailing developed. (See Items 3, 5, 6 & 7 in Table 5.2)

5.2 Sprinklers and PVC Raceway

This section describes fire test results with PVC raceways and related products which include failure scenarios to assess the effectiveness of sprinklers.

Not only do PVC products meet building code requirements for fire safety, but as with any building in which they are used, sprinklers create a structure providing assurance of the highest levels of fire safety.

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[15] Underwriters Laboratories, Nonmetallic Electrical Outlet Boxes for use in Floor-Ceiling Assemblies Consisting of Wood Joists, Wood Flooring and Gypsum Wallboard, Project No. 81NKY4419, 1981

[16] Warnork Hersey, July 1990. Fire Endurance Pilot Scale Test to Evaluate the Fire Resistance of Metallic Electrical tubing Penetrating a Fire Resistive Concrete slab, WHI-495-PSH-0170

In addition to standard testing, fire tests of sprinklered constructions with PVC raceway have also been run. The International Association of Fire Chiefs sponsored such a series of fire tests ("Operation San Francisco– 1984") in an existing hotel structure to assess the impact of sprinkler systems on various types of construction under differing fire scenarios. Amongst the constructions tested were ones including ENT. Results showed that the ENT did not burn under the conditions tested and that the combination of ENT and use of sprinkler systems led to complete maintenance of electrical continuity throughout the test fires conducted.

5.3 Finish Rating, Thermal Barriers and ENT Fire Performance

This section deals with the concept of finish ratings. It is included to clarify the intent of the requirements found in the **National Electrical Code**, relating to use of materials meeting the 15- minute finish rating requirement for ENT. In addition, popular questions about "finish ratings" and "thermal barriers" as they relate to Article 331 of the **National Electrical Code** are addressed.

"Finish rating" is defined as the time period during which a protective membrane (installed as part of a fire-rated combustible assembly) will protect wood structural elements installed behind them. This is indicated when a maximum temperature rise of 325°F occurs. Typically the finish rating temperature is measured between the backface of the protective layer (such as gypsum wallboard) and a wood stud in the assembly. Historical examples of protective membranes for which finish ratings have been measured (in addition to 1/2 inch or thicker gypsum wallboard) are drop-in gypsum panels used in hung ceilings to protect wood or steel joists. Data on a number of designs with finish rating over 15-minutes can be found in the Underwriters Laboratories' Fire Resistance Directory. Several relevant entries from that document are summarized in Table 5.3 A. In addition, a recently completed study details the performance and reproducibility in common gypsum wallboards used for finish ratings applications[17].

In addition to the U.L. data[18] cited above, the Department of Housing and Urban Development (HUD) sponsored research leading to publication of the Guideline on Fire Ratings of Archaic Materials and Assemblies in 1980, by the National Institute of Building Sciences (NIBS). That document includes tables summarizing finish ratings of both combustible and non-combustible finish materials[19]. Those tables (along with the entire Guideline), have been incorporated by reference in BOCA engineering documents, the Uniform Code for Building Conservation (UCBC), and the NFPA 914 Standard "Fire Protection in Historic Structures" as well as in several local and state building codes. These are reproduced as Table 5.3.B and Table 5.3.C. The finish ratings in those tables

[17] Zicherman, J.B., Eliahu, A. Finish Ratings of Gypsum Wallboards. Fire Technology Vol. 34/4 (November 1998)

[18] For further details see the current version of the Underwriters Laboratories Inc. Fire Resistance Directory- Hourly ratings for Beams, Columns, Floors, Roofs, through –penetration Firestops systems and Walls and Partitions.

[19] All references from BMS-92, except F.R. 0-8 taken from Harmathy, T.Z., "Ten Rules of Fire Endurance Rating" Fire Technology Vol.1 May 1965.

are based on an assessment of the original data (primarily from the NBS-BMS 92 study of 1942[20]) by Guideline authors.

Article 331 of the **National Electrical Code** requires that ENT be installed behind a 15-minute thermal barrier where the building exceeded three floors above grade. Under the caveats of the building code, such a thermal barrier is any material which would prevent a back face temperature rise in a standard ASTM E-119 time temperature exposure of 325°F for 15 minutes. ENT installations in any wood or metal-framed wall or floor/ceiling assembly with 1/2 inch (or thicker) gypsum wallboard or lathe and plaster meet this requirement. Various tiles used in suspended ceilings where the plenum space is not used for return air circulation also meet this requirement.

Based on finish rating considerations, the use of PVC-ENT products, is not restricted to fire-rated assemblies. Such assemblies, as discussed earlier, are scattered through buildings to meet building code requirements for protection of specific corridors, occupancy separations, etc. Conversely, electrical wiring is found in all walls and floor/ceilings whether they are fire-rated or not. As such, the finish rating requirement for the materials covering the ENT is the appropriate one and 1/2 inch gypsum board (or an equivalent) meets this minimum requirement. Installation of PVC raceway can be made in any non-fire-rated assembly and suggestions that it can only be installed in fire-rated assemblies are incorrect.

Figure 33:ENT installed in concrete slab
Key West, Florida

[20] National Bureau of Standards, Building Materials and Structures, Report BMS 92, Fire-Resistance Classifications of Building Constructions, October 7, 1942.

Figure 34: Wired PVC Box and ENT installed in ASTM E-119 wall test assembly

Figure 35:3-hour ASTM E-119
test specimens incorporating PVC floor boxes

Figure 36:2-hour ASTM E-119 slab exposure

Figure 37:Preparation of 2-hour ASTM E-119 test slabs

Figure 38:Use of ENT in concrete slab application

Figure 39:Metal stud gypsum wallboard finish rating test assembly

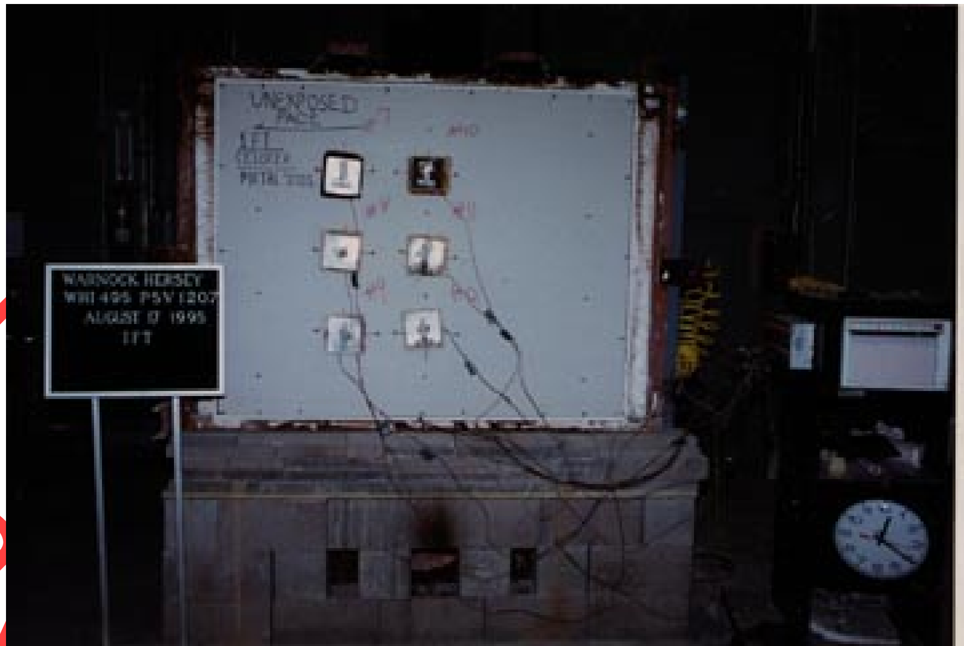

Figure 40:Per previous photo during ASTM E-119 furnace exposure

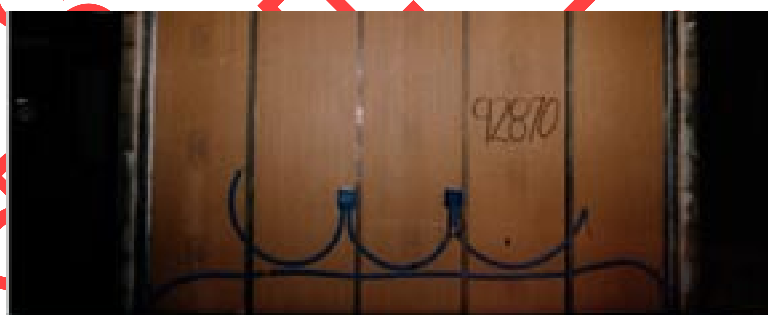
Figure 41:ASTM E-119 30 minutes hose stream specimen prior to fire exposure

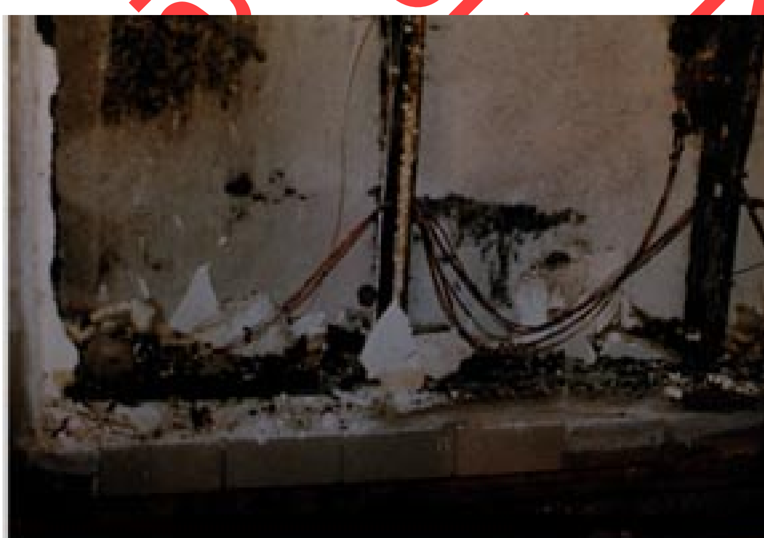
Figure 42:Same specimen after 30 minute fire exposure

Figure 43:ASTM E-119 ENT box installation, pre-test

Figure 44:ASTM E-119 ENT box installation after 30 min. fire exposure

6.0 Acceptance of PVC Electrical Nonmetallic Tubing and Conduit Products in the Field–Field Guidelines and Case Studies

Because ENT is a product which may be unfamiliar to some inspection personnel, this section has been included to assist in evaluating fire resistance of assemblies containing ENT in the field.

Specific examples of ENT and applications of associated Carlon products in uses of ENT approved at the local level are provided. In addition, reference material that may be important to local code enforcement officials, designers and specifiers is included here. In order for cost-effective, accepted uses of these products be understood, it may be useful to review these examples of how and where ENT has been successfully used in various jurisdictions.

6.1 Guidelines for Use of ENT & Related Products in the Field

Discussions of fire endurance performance of ENT equipped assemblies follow. General concepts useful in assessing performance in the field are also provided.

Most fire resistive assemblies found in buildings are not identical to specific, tested assemblies since it is not possible to fire test every conceivable wall or floor/ceiling design. Of the specific designs, which have been tested for fire endurance, many have not been fire tested with the kinds of products that frequently accompany their installation in the field. Such products may include plumbing pipes, data handling systems and electrical and air distribution systems. Often one must rely to some extent on experience when evaluating an installation or design to determine whether or not they can reasonably expect a given assembly to perform adequately in the event of a severe fire.

“Harmathy’s 10 rules of fire endurance rating[21]” were discussed earlier. Use of these rules to evaluate probable fire performance is widely accepted and can be found in various building code and commentary documents. These include the NFPA 914 Standard, the three Model Rehabilitation Codes and State codes in California, Massachusetts, Wisconsin as well as the city of Chicago amongst others. The rules are based on sound fire safety engineering practice and can be applied by the user in the field with appropriate discretion. Examples of Harmarthy’s 10 rules follow:

One rule states that “...thicker walls will have greater fire endurance than thinner ones”, i.e. 2 x 8 inch framing in a wall is “better” than 2 x 4 inch framing. The presence of deeper studs lead to greater fire endurance.

Another rule states, “...insulating a wall will provide greater fire endurance as compared to an uninsulated analog.” Thus, the presence of batt insulation to reduce sound or head

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[21] Harmathy, T.Z., Ten Rules of Fire Endurance Rating. Fire Technology, Vol. 1, May 1965

transmission, even though not fire rated types, will lead to greater fire endurance than in the same wall design without the batt insulation present.

Additionally, "...unpenetrated walls can be expected to perform better than penetrated walls due to eventual failures in cladding materials associated with penetration locations after a lengthy fire." In addition, "... while occasional, properly installed penetrations do not affect fire endurance, large numbers of penetrations may do so."

Other less obvious rules of thumb include the fact that "...multiple layers of a given material will outperform a single layer of the same total thickness." Thus, two layers of half-inch, fire- rated gypsum wallboard will outperform, show greater fire endurance than a single layer of one inch-thick fire-rated gypsum wallboard used in the same wall design. This is because of the manner in which cracks and fractures propagate when such cladding materials are exposed to fire. Similar relationships exist for multiple layers of wood or plaster cladding.

A designer, installer or regulator can use these generalizations to draw reasonable conclusions about the constructions that they are considering. If a given construction is similar to a standard design, it can be expected to perform similarly. If it's thinner than the standard tested design, it will probably not have as long a fire endurance period as compared to the thicker design. If all factors are the same but the assembly is thicker, it should last longer.

Figure 45:ENT installed prior to concrete pour in highrise structure, Southern California

If an assembly is poorly built or has many holes without specific mitigation features, it cannot be expected to perform as well as an identical design executed with a higher quality of construction or fewer void spaces. Mitigating construction features, such as the addition of local thermal barriers incorporating thermal insulation, gypsum wallboard, intumescent or other fire-rated insulating materials, should be used to improve anticipated fire endurance performance if there are doubts about the likely performance of a given design.

The examples that follow show how these concepts and others, have been applied to the use of ENT and related equipment in both standard and non-standard walls and floor/ ceilings in fire resistive construction.

Figure 46: ENT installed in highrise hotel-Four Seasons, La Jolla, California

6.2 Case Studies of ENT Use in the Field

The following sections describe field experiences with Carlon ENT Products over the past 14 years.

6.2.1. Sacramento Toxic Substances Commission–1986

In this case, an administrative hearing related to use of all plastic pipe, tube and conduit was being held. The petitioner, a local Plumber's Union was requesting a ban of these products. After extensive public hearings and a review of the record by the commission, the petition was denied.

The local plumber's union moved to have the Sacramento Toxic Substances Commission review the use of all plastic pipe, tube, and conduit in construction with the goal of banning these products. After hearing numerous witnesses from both the plumbing and electrical sides, the Commission considered the evidence and ruled against the petition.

6.2.2. Burlingame, California–1987

This section considers a retrofit approach for increasing the fire resistance of a floor/ceiling assembly based on appropriate test and calculational data recommended and used. It is interesting to note that since this situation occurred, successful fire testing of the boxes in question, as used in this assembly, have been carried out.

In this instance an 8” thick, post-tensioned concrete floor system was fabricated including Carlon PVC floor boxes. Because a fire official correctly noted that inadequate concrete cover existed between the underside of the boxes and the lower surface of the floor, an engineering study and necessary heat transfer calculations were made. Results determined that application of either of two materials (gypsum wallboard or intumescent rubber) to the underside of the floor system would yield sufficient fire endurance to allow the assembly to perform as intended and not permit excessive temperature rise on the unexposed face.

The local office of the California State Fire Marshal, which governs high-rise compliance, was also consulted. Tear-out of the boxes would have been particularly difficult and costly because of the structural systems and nature of the floor. An additional safety factor existed as designed, the building was totally sprinklered.
Reference: 6.3.23

Figure 47:ENT installed in floor of highrise apartment complex, Patterson

6.2.3. Seattle, Washington–1988, 1997

Originally the Seattle Building Code did not permit the use of PVC raceways in above ground construction and in above ground use in certain downtown fire districts. Actions taken first in 1988 and later in 1997 reversed that position to one, which is now consistent with the **National Electrical Code**.

The staff of the Seattle Building Department recommended expanded use of ENT as part of the adoption process for the 1987 NEC through the local Electrical Code Advisory Board. The local Electrical Workers Union entered objections to these recommendations. Following a series of hearings before an administrative hearing officer, the recommendations of staff on the City of Seattle Electrical Code Advisory Board were upheld. A challenge taken to the city council also upheld that decision.

In 1997, adoption of the 1996 NEC was being considered. At that time the city deleted provisions in the Seattle Electrical Code that restricted use of PVC raceways in the Downtown Fire District. This change was based on the unanimous recommendation of Seattle's Electrical Code Advisory Board and its Department of Construction and Land Use, with full concurrence of the Seattle Fire Department.
Reference 6.3.15

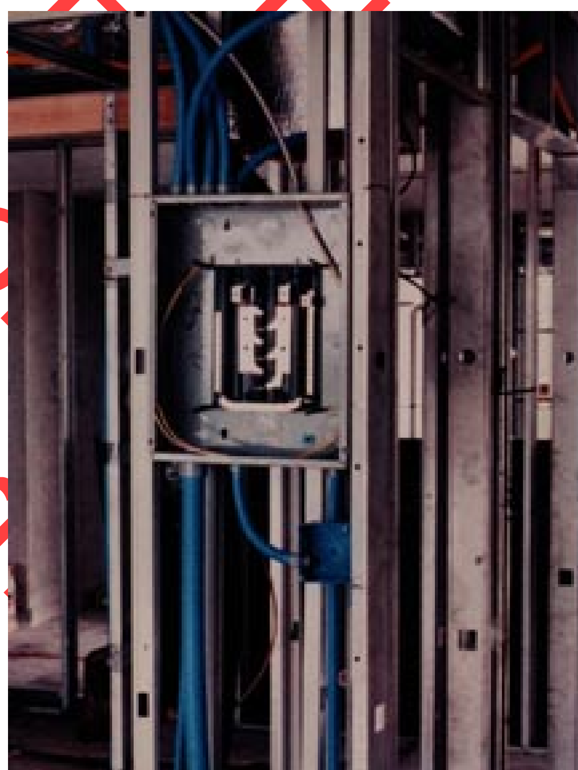

Figure 48:ENT installed in sub-panel location of highrise apartment complex, Patterson, New Jersey

6.2.4. Pittsburgh, Pennsylvania–1988

In 1988 the Pittsburgh City Council enacted an ordinance over the veto of the mayor, which effectively prohibited use of PVC raceways in structures over three stories in height. The contents of the ordinance were contrary to both the model code adopted in Pittsburgh (the BOCA **National Building Code**) and the **National Electrical Code**, also adopted by the city.

Passage of that ordinance led to legal action in which it was demonstrated that no consideration had been given to either the performance of the PVC raceways and related products or the demonstrable economic advantages the products would provide to the city's construction industry. Rather, enactment of the ordinance had been based solely on pressures applied to council membership by special interest groups.

Eventually, the matter was settled with PVC raceways now being accepted for use in Pittsburgh consistent with the BOCA National Building Code and the **National Electrical Code**.

Reference: 6.3.10

6.2.5. Lee College - Church Street Dormitory–1989

In this case, a substantially over-engineered floor/ceiling assembly plus conformance with NEC finish rating requirements proved adequate for obtaining acceptable fire performance.

A dormitory project at Lee College featured a UL listed, pre-manufactured concrete box-beam floor assembly design. The code requirement for fire endurance was 1-hour and the floor/ceiling system was listed as having 2- (or more) hours performance in the UL Directory. The combination of stated fire endurance along with engineering calculations, showed that the protection afforded by ENT included within the "beam" by its lower surface were adequate to receive the approval of local inspection officials.

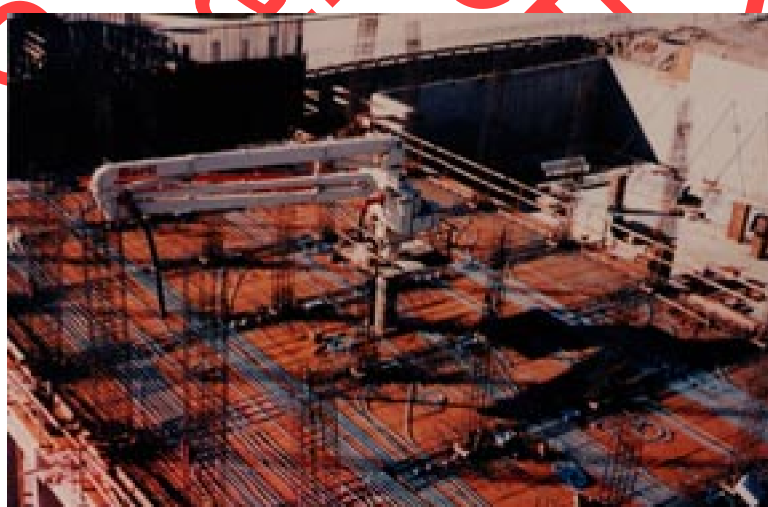

Figure 49:Street level view of ENT being installed in highrise structure, Southern California

6.2.6. Cleveland, Ohio–1989

A UL rated floor slab, (Design Number D 907) was being installed in a 10-story office building. The architect inquired as to the applicability of ENT for power distribution in floor slabs.

Consistent with standard practice in fire endurance testing, the generic slab design in question had not been fire tested with metal or PVC raceways installed. An engineering evaluation of the thermal conductivity of the concrete compared to the thermal conductivity of the PVC raceways (and the air included within the raceways) was conducted. These were also compared with an analysis of comparable metallic raceway products for the benefit of the architect as well as for the Vice-President of Code and Regulation in charge of the project.

In addition, test results of successful ASTM E-119 fire endurance exposures of several lightweight and normal weight concrete designs and specimens were provided to the architect. Those tests included ENT raceways and accessories in generic metal decks encompassing fluted designs of the type used in this project as well as more conventional slab designs. Following these reviews, the design was accepted and construction completed
Reference 6.3.20

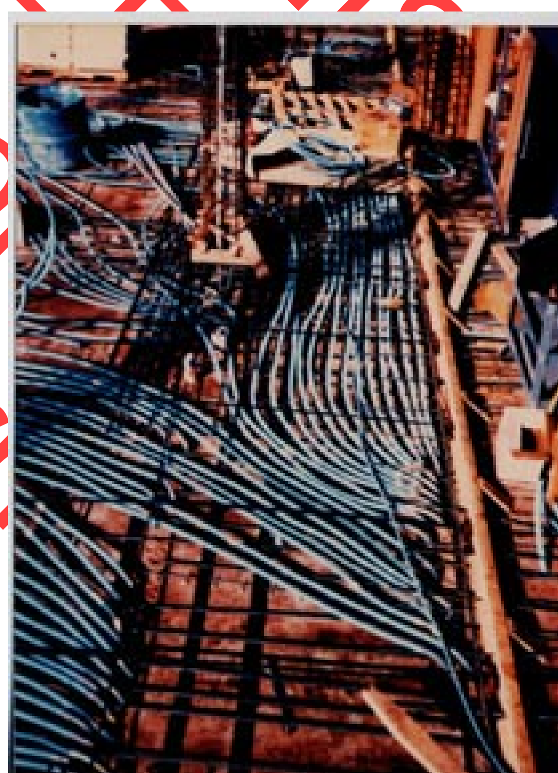

Figure 50:ENT being installed prior to concrete pout in highrise structure, Southern California

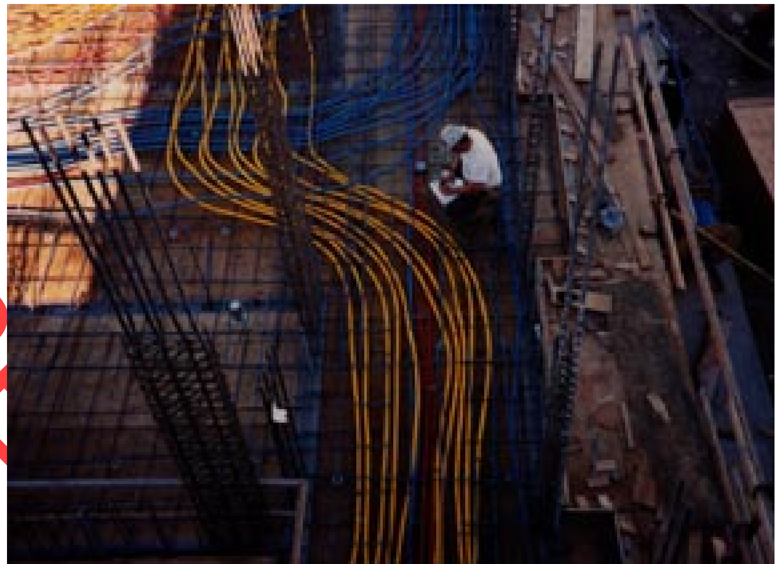

Figure 51:ENT installed in highrise hotel-Four Seasons, Southern California

6.2.7. Tampa, Florida–1989.

Riser walls, 11 to 12 inches deep, were used for distribution of mechanical and electrical services in 1-hour fire resistive multi-story buildings. A review of the construction was conducted to assess the probable fire performance of the construction details proposed.

This project was interesting because of the practical fire endurance rating/design questions it brought up. The wall design included two rows of 2-1/2 inch metal studs sets, spaced approximately one foot apart, that created a large open space in which fiberglass batt insulation, plumbing riser's and occasional runs of ENT were to be installed. This is a somewhat unusual wall system design and unlike virtually any that have been specifically tested for fire endurance.

Reference was made and inferences could be drawn from designs incorporating plastic pipes fire tested by the [then] National Bureau of Standards–Center for Fire Research in the 1960s and '70s. In those cases, similar chase walls, which included large diameter PVC plastic pipes, were successfully fire tested in ASTM E-119 exposures. In addition, use of the "rules of thumb" described earlier came into play. This is because the walls at issue were (a) significantly deeper than the tested walls and (b) included fiberglass batt insulation. Both factors significantly increase fire endurance when compared to thinner, uninsulated analog walls that had already been successfully fire endurance tested in ASTM E-119 exposures.
Reference 6.3.21

6.2.8. Newport Beach, California–1990

The use of PVC "mud boxes" in 3-hour rated assemblies was reviewed
Carlon "mud boxes" were slated for installation at underside surfaces of 12 inch thick, 3-hour rated slabs. The boxes had no interconnection with upper slab surfaces. Since the boxes were not interconnected with the upper surfaces of the slabs–which could have

created potential poke-through situations–and six inches of concrete cover remained above the boxes, their use in isolated locations did not lead to any diminution in the required fire performance of the slabs in question.

This interpretation was confirmed by reference to the [then] relevant **Uniform Building Code**, Chapter 43, which described minimum thicknesses of concrete required for approved 3-hour floor slabs.
Reference: 6.3.19

6.2.9. Boyton Beach, Florida–1990

The authority with jurisdiction requested information relating to the fire endurance performance of junctions between wood-framed, gypsum clad floor/ceiling assemblies and fire- rated walls of similar construction.

The particular installation being evaluated in this case was unusual because the contractor initially elected to install UL listed, 3M Fire Barrier® intumescent materials in addition to the full thickness lumber normally present and used to frame the assemblies. The latter form natural firestops [in the absence of oversized holes] for ENT.

The assembly interfaces, for which review was requested by the AHJ, were of interest because standard ASTM E-119 fire endurance testing of the performance of such assembly junctions is not typically required. Usually, either walls or floor/ceiling assemblies are fire endurance tested, but the junctions between these two types of assemblies have not historically been subjected to specific, code-mandated testing either in general or to study the specific fire performance impact of electrical raceways.

Test results were available however for assembly tests of plumbing assemblies involving plastic pipe with larger openings than those needed for electrical raceways penetrating from wall assemblies to floor/ceilings. These results were of interest for guidance in answering the questions posed. The tests, conducted by the Fire Test Facility at the University of California, Berkeley in the 1970's, and elsewhere, were brought to the attention of the building official who approved the ENT installation. The 1-hour assemblies in question included both 1/2 and 3/4 inch ENT.
Reference 6.3.22

Figure 52:Pouring concrete with ENT installed in highrise apartment complex, Patterson, New Jersey

Figure 53:ENT installed on top floor of highrise structure, Southern California

6.2.10. Solvang, California–1992.

A slab installation, which included ENT runs, was evaluated to establish if the ENT had sufficient cover and thermal protection.

Construction of a concrete slab was already underway when it was determined that insufficient cover existed for planned ENT runs. Mitigation was accomplished by creating troughs in local areas of the slabs where ENT runs had been installed to provide adequate cover. The project included 3/8 inch rebar, 2 feet O.C. and 15 to 20 ENT runs within the approximately 900 square foot slab. The analyses conducted included those by a structural engineer and were approved by the local authority having jurisdiction.
Reference 6.3.24

6.2.11. Arizona–1992-3.

The plan review manager and plan examiner asked a series of questions associated with use of ENT and accompanying products.

Interpretations were requested of provisions in NER-290 related to the installation of ENT in fire resistive construction. Uncertainty existed as to applicability of tested 2-hour designs to 1-hour uses as well as to wood frame designs in general. Questions also were raised relating to the penetration of ENT through fire-rated walls and when metal sleeves should be used.

Review of these questions led to an evaluation of classified designs in the UL Fire Resistance Directory and the application of the ASTM E-119 fire endurance test results with Carlon products to designs found there. In addition, it was pointed out that the then-current NER- 290 version was under revision and that additional 1-hour fire endurance test data was also available for review by the AHJ.

Concerns regarding probable performance of assemblies containing combustible framing materials and penetrations were addressed through the application of UL classified through-penetration firestop systems for nonmetallic raceway. Additional solutions discussed and developed with local code enforcement officials included the use of intumescent materials to “box-in” electrical distribution panels and use of gypsum wallboards in areas where additional fire resistance was needed for assemblies.
Reference 6.3.25

6.2.12. Orange County building Department, Florida–1993

A suite hotel was being constructed which included a UL rated, floor/ceiling assembly design. Orange County requested clarification of the anticipated fire endurance performance of that assembly when ENT was included.

In this case the project, which included UL L 530, 1-hour fire endurance rated floor/ceiling assembly, was being constructed utilizing ENT in [wood] joist cavities. Because this particular design had not been tested with ENT –or with any other raceway materials or accessories for that matter–the local building department requested comments as to how the fire performance of those standard assemblies might be affected by the presence of the nonmetallic electrical raceways. Given the availability of test data on metal-framed wall systems, known to be more sensitive in fire endurance situations than wood-framed analogs, the building department accepted the installation.

The electrical contractor reported that use of ENT saved approximately $40,000 as compared to the same assembly designs built with Electrical Metallic Tubing (EMT).
Reference 6.3.28

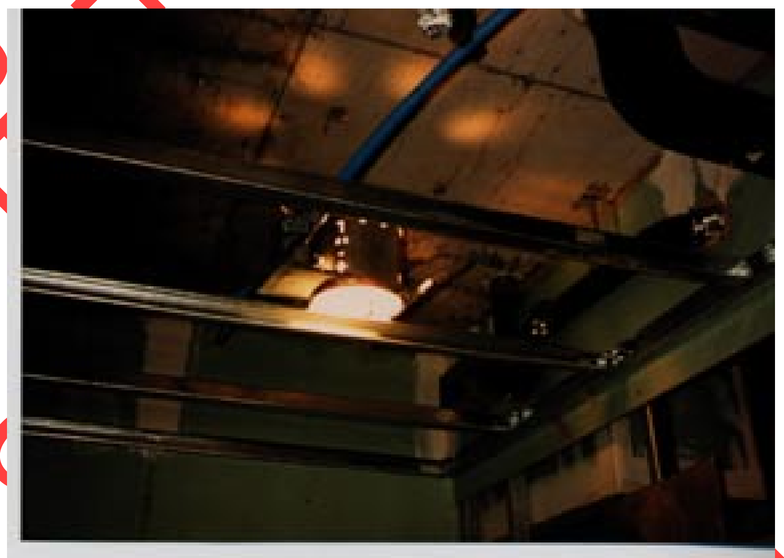

Figure 54:ENT feeding recessed lighting fixture – Penta Hotel, Orlando, Florida

6.2.13. Tampa, Florida–1993

The local authority having jurisdiction requested information concerning the maximum operating temperature performance of Carlon ENT in attics in this Southern city.

A tall attic, 11 feet in height with a roof pitch of 5 in 12 included fiberglass insulation and ENT installed across roof trusses was evaluated. The maximum anticipated ambient temperature would be 95°F. An initial analysis suggested that the installation of 4 x 8 inch eave vents in each face of the roof near the ridge would significantly reduce attic temperatures and would also create convective airflows in the attic on wind-less hot days. These vents would cool the interior of the roof deck and lead to lower interior temperatures, which would not adversely affect the performance of electrical components as prescribed in the NEC. The local AHJ concurred with these observations and the project was completed with ENT installed at the base of trusses and elsewhere in the attic.
Reference 6.3.21

6.2.14. Clearwater, Florida–1993

Inquires were received regarding use of Carlon ENT in 2-hour fire endurance rated wood- framed party walls.
Tests of 2-hour, non-load bearing, fire resistive assemblies of metal-framed walls, conducted at UL the 1970's led to the initial acceptance of ENT products in the NEC.

Those tests included side-by-side comparisons of metal and Carlon PVC raceways in full-scale ASTM E-119 fire endurance exposure. In the commentary included with those test results, the UL authors indicated that the non-load bearing, metal-framed assemblies were more sensitive than wood-framed assemblies. Issues of thermal conductivity and thermal expansion in metal framing systems lead to a different set of failure mechanisms being observed than in wood. The latter chars and maintains its load bearing ability due to overall lower thermal conductivity. These properties, which do not make one system superior to the other, (only different if properly constructed), were reviewed by the AHJ.

After the review, the jurisdiction accepted use of the products. The analysis, conducted in 1993, included the 2-hour ASTM E-119 fire endurance testing of load bearing and non-load bearing wood stud party wall designs which included Carlon ENT accessories and outlet boxes. Designs had been tested both with and without insulation. The test reports and the designs on which they were based are discussed elsewhere in this document.
Reference 6.3.26

6.2.15. Kings Point/Broward County, Florida–1994

PVC electrical boxes and ENT installed in walls based on Gypsum Association Design WP 1200, (a fire resistant 1-hour assembly with steel studs 24 inches on center), were evaluated in this case. This assembly is similar in design to one in which Carlon ENT products had evaluated for 1-hour ASTM E-119 fire endurance testing (as described elsewhere in this manual). Consistent with Florida State law, the wall design at issue was also required to include R-11 fiberglass batt insulation.

Although the builder’s design included essentially no stud cavities with more than one electrical box, spacing of boxes was, on occasion, less than the code required minimum allowed of 24 inches. Such designs were necessary because the small kitchens in these apartments also needed to meet the requirements of the NEC for numbers of outlets and circuits required for kitchens. In order to mitigate the situation, a number of possible design changes were recommended. These incorporated the use of either gypsum wallboard baffles/firestops or the inclusion of additional, UL labeled, fire endurance rated mineral fiber insulation in addition to the non-rated R-11 thermal insulation required by the Florida code. (See Chapter 5).
Reference 6.3.29

6.2.16. Milwaukee, Wisconsin–1994

Comments were requested from a local electrical inspector concerning the maximum service temperatures reached in an attic containing PVC raceways.

In this case ENT was installed along the bottom of ceiling joists and covered with 12 to 14 inches of R-38 fiberglass insulation. The design also included ridge and soffett vents. The roof deck was plywood and covered with asphalt shingles.

A heat balance test determined that the ENT temperatures would be negligently affected by seasonal variation in the roof deck or attic space above the insulation. This was due in particular to the fact that the ENT was thermally remote, that is, well insulated from the rest of the attic. Under normal conditions, including an outdoor ambient temperature of 100º F, the ENT buried in the fiberglass insulation would safely stay stable at less than the allowed maximum operating temperature of 122ºF.
Reference 6.3.30

6.2.17. Fairfield, Ohio–1994

Staggered, stud party wall designs are frequently incorporated in townhouse construction similar to designs described in ICBO Research Evaluation No. 2654. These are designs for gypsum wallboard clad and staggered stud walls incorporating fiberglass batt insulation for fire resistive construction applications.

The Chief Electrical Inspector of Hamilton County requested clarification of a developer's wall design that included both PVC electrical boxes and Nonmetallic-sheathed cable (NM Cable).

The fire performance of all of the elements in the wall design had been addressed by research through UL Reports on the specific materials concerned or through code accepted wall designs. The inspector, however, needed clarification as to how these different factors would work together.

In this case he was provided with UL reports on the fire endurance of gypsum wallboard clad assemblies including nonmetallic outlet and switch boxes wired with NM Cable. Test data for fiberglass insulated, fire endurance rated walls and the caveats of NER-140 that dealt with nonmetallic electrical outlet boxes installed in fire resistive walls and floor/ceiling assemblies were also provided. Relevant sections of the BOCA code (in effect at that time in Hamilton County) were also cited and the design under review was approved for use.
Reference 6.3.31

6.2.18. Dade County, Florida–1995

Inquiries were made by an electrical inspector regarding differences in finish rating performance of different manufacturers' non-rated gypsum wallboard products installed symmetrically as part of both metal and wood-framed assemblies.

In response to this inquiry, suitable gypsum wallboards manufactured by U.S. Gypsum, Gold Bond and Celotex were fire endurance tested over both wood and metal studs to determine individual finish ratings. In addition, another gypsum wallboard product (manufactured by Domtar, and not available in Florida at the time) was also included in the study.

ASTM E-119 pilot-scale, fire endurance testing was used to evaluate the finish rating performance of the gypsum wallboards. Average finish ratings ranged from 15 to 20 minutes for the range of products studied over the two different framing types. After a total of 8 ASTM E-119 fire endurance tests had been conducted, satisfactory finish rating performance were observed in each case.

An article published in 1998 in the peer- reviewed, NFPA journal "Fire Technology", on the subject of finish ratings is considered in Chapter 5 of this publication.22
Reference 6.3.32

6.2.19. Orlando, Florida–1996

The authority having jurisdiction questioned the anticipated fire performance of 1-hour fire endurance rated, load bearing walls including Carlon ENT products.

Clarification was requested regarding impact on fire endurance of Carlon products in load bearing wall assemblies. While metal frame systems tend to be more sensitive when subjected to identical fire endurance testing conditions than wood frame systems, non-load bearing, steel-framed assemblies of both 1- and 2-hour fire endurance including Carlon products, had been tested prior to 1996. In addition, extensive testing of 2-hour, wood-framed, loaded and non-load bearing assemblies which included complete ENT systems are described in UL reports [UL File No R8326; Project 94NK17350 and UL File No R8326; Project 93NK19678 respectively] presented elsewhere in this document.

Following review of the UL reports for both load bearing and non-load bearing assemblies (UL File No R8326; Project 94NK17350), the county accepted use of these fire endurance rated products in their jurisdiction for fire endurance rated construction.
Reference 6.3.9

6.2.20. Salt Lake City, Utah–1996

Salt Lake City's Department of Community and Economic Development requested fire safety engineering information related to the use of 1" diameter ENT in concrete floor decks.

This request for information was interesting because it included the correct observations that Carlon fire endurance testing conducted on floor slabs did not include hose stream test results. Reference was made to the requirements in the **Uniform Building Code**, 1994 edition, Section 7.108 by the AHJ.

In response, it was determined that both the UBC Std. 7-1 (referenced for testing in the code section listed), as well as the ASTM E-119 test method do not require hose stream testing for horizontal assemblies. Hose stream testing is required for vertical assemblies only. Similarly, conditions of acceptance for fire endurance rated floors in the model codes don't include any caveats related to hose stream performance. Representatives of Underwriter Labs were also consulted in this review and provided an opinion to the AHJ

that hose stream testing was also not required for horizontal assemblies. The Carlon ENT products were accepted for use in Salt Lake City.
Reference 6.3.14

6.2.21. Arizona–1996

Installation of Carlon PVC floor boxes in lightweight, 1-hour concrete slabs was the subject of inquiries because of the thickness of the slab design.

In situations where insufficient cover exists between the bottom of a floor box and the lower surface of a concrete slab, two mitigation strategies are available to prevent unwanted heat transfer across the assembly in case of a fire. These include installation of intumescent materials underneath the floor box and/or inclusion of additional layers of gypsum wallboard to the bottom surface of the slab.

Suitable intumescent materials are manufactured by numerous suppliers and are available through reference to the UL, Omega Point, Intertek or other handbooks for fire resistive materials. These materials have also been tested directly with Carlon floor boxes as discussed elsewhere in this document and reference lists. An alternative method of protection includes post-application of thicknesses of gypsum wallboard to provide additional thermal protection to the lower surfaces of concrete decks. Appropriate thicknesses are those equivalent in fire resistance to approximately 2 inches of lightweight concrete or 3 inches of normal weight concrete.
Reference 6.3.33

6.2.22. Nellis Air Force Base–Visiting Airmen's Quarters, Nevada–1996

A local electrical contractor was asked to justify use of ENT in 1-hour, steel stud framed walls of a building under construction.

An analysis found that the walls designed for the facilities at this air base were, from a fire safety perspective, significantly more robust than generic walls designed and tested to meet 1-hour fire endurance criteria with Carlon ENT. For example, the "standard walls" tested to date had included a wrap of the ENT with fiberglass insulation while the walls at Nellis were fully insulated. In addition, the walls at Nellis would include required 5/8 inch "Type X" gypsum wallboard plus inner layers of 1/4-inch gypsum wallboard. This arrangement of insulation and gypsum can be expected to increase the fire resistance of the walls by as much as 40 percent. Finally, the "standard walls" tested in the generic design used steel studs 24 inches on center. The walls at Nellis included studs that were 16 inches on center in all cases. The new design was shown to provide greater fire endurance than code minimum wall designs.
Reference 6.3.34

6.2.23. State of Oregon–Electrical Code Approvals–1996.

In 1996 the Electrical Section of the Building Codes Division of the Oregon Department of Consumer and Business Services considered State Amendments in association with adoption of the NEC. In particular, amendments to Article 110, "Wiring Methods of the Oregon Electrical Specialty Code", were under consideration.

Earlier versions of the code required that PVC raceway be encased in 2 inches of concrete when used in Oregon. It was pointed out that the use of PVC raceways without such requirements had been accepted in the NEC nationwide for more than a decade. Reports from Factory Mutual Research supported this observation. In addition, citations and research were provided that showed that in tests conducted for Carlon by recognized third party testing labs and in NEMA sponsored, UL fire endurance testing satisfactory performance had been achieved.

In 1996 the State of Oregon amended the Oregon Electrical Code to delete restrictions that went beyond the caveats in the NEC on all PVC raceways. Oregon's Electrical Board and Bureau of Labor and Industries, after review and public hearings, concluded that such additional restrictions in the stated Code served no legitimate purpose.
Reference 6.3.35.

Figure 55:ENT used in steel stud walls prior to installation of gypsum wallboard

6.2.24. City of Los Angeles–1998 through 2001.

Until recently, the City of Los Angeles required its own local review and approval for alternate materials and methods and the applications of contemporary products in construction projects within that jurisdiction. As such, over the years, City of Los Angeles personnel have reviewed Carlon ENT products on several occasions and developed and published locally applicable research evaluations.

The City of Los Angeles, like a diminishing number of cities nationwide, maintains its own testing lab and research staff to evaluate alternate materials and methods applied within its borders. Because Carlon ENT and related products were originally new when compared with metallic raceways, a number of fire endurance test results and fire safety engineering studies were requested by the City of Los Angeles Building Department. These evaluations resulted in issuance of the following City of Los Angeles Research Reports:

- RR 24957 (expired 10/1/99): Use of ENT with UL listed through-penetration firestop systems CAJ2007, WJ2001 and WL2001 for 2-hour concrete slab walls and floor/ceiling assemblies.
- RR 24426 (expired 10/1/99): Use of non-metallic electrical boxes in fire rated walls and floor/ceiling assemblies of Types III, IV and V construction.
- RR 25234 (expires 12/1/00): Use of Carlon ENT in concrete floor/ceiling assemblies of up to 3-hour fire endurance.
- RR 24909 (expires 3/1/01): Use of Carlon ENT in fire-rated, non-combustible firewalls.

In addition, effective 11/1/98 a new policy recognizing the applicability of third party research recommendations promulgated by ICBO (the ICBO-ES) and the ICC, the International Code Consortium (formerly administered by CABO) National Evaluation Service (NES) was established by the City of Los Angeles.

6.2.25. Neighborhood Center, Deland, Florida–1997

Fire performance of a floor/ceiling assembly in a building undergoing renovation for a change in use was evaluated to determine the impact of ENT on probable fire performance.

The building in question was relatively modest totaling 1,000 square feet of area over two floors. An existing floor truss system was being retained.

Four 40-foot runs of ENT, separated from each other by wood trusses and spaced evenly in the floor/ceiling assembly, were to be installed. Analysis of the amount of ENT per square foot proposed for use in the assembly was consistent with allowances under NER 290. The same analysis showed that the four runs proposed would provide a significantly lower volume of electrical nonmetallic tubing per square foot then had been tested in 3-hour floor/ceiling assemblies. Specifically, the ratio of ENT to assembly area in the proposed assembly would be in the order of 0.2 linear foot of ENT per square foot of floor area. In contrast, NER 290 allows for amounts of ENT as high as 1.20 linear feet per square foot of assembly area.
Reference 6.3.38

6.2.26. Wisconsin Rapids, Wisconsin–1997.

Installation of PVC electrical boxes, back-to-back, complying with the minimum 16 inch separation in insulated, double stud walls was evaluated.

This stud wall design, incorporating two rows of 2x4 inch studs with a 3/4 inch space separating them, provided a 7-3/4 inch deep framing system. This was clad with 5/8 inch Type-X gypsum wallboard on both sides. Sixteen inch stud spacing was utilized and a minimum of one stud separated each adjacent electrical box. In addition, full 3-1/2 inch thick, R-11 batt insulation was installed on both sides of the walls. The design was quite similar to 2-hour, staggered stud–insulated load bearing designs UL tested for Carlon and discussed elsewhere in this report.

Based on the depth of the walls, the presence of fiberglass insulation and the air spaces, the AHJ approved their use for 1-hour assemblies.
Reference: 6.3.36

6.2.27. State of Washington and Other Washington Municipalities–1997

In 1997 the State of Washington–as well as several other large municipalities–considered various amendments to the 1996 **National Electrical Code**. These included possible restrictions on PVC raceway use.

In 1997, the State of Washington amended WAC 296-46-150 to delete former State electrical code restrictions on PVC conduit and raceways, which were not found in the NEC. Carlon participated in the State's code amendment process, submitting materials into the State's decision record concerning the safety and effectiveness of its electrical materials. The Washington State Electrical Board and Washington State Department of Labor and Industries (DLI) both supported this change to the State Electrical Code.

Washington cities of Olympia, Everett and Longview also recently removed restrictions on the use of PVC raceways from their locally adopted electrical codes.
Reference 6.3.41

6.2.28. Elementary School, California–1998

A mixed occupancy elementary school was constructed using a wiring mix of ENT, MC "armored" cable and metallic electrical boxes. Inclusion of these materials in this Type V, 1-hour single story building was reviewed.

The NEC permits the use of ENT raceway in fire-rated construction in general and in certain specific class occupancies. The school in question included several different occupancy classifications including a single occupancy–a gymnasium–along with "B" and "E" occupancies.

In this particular case, the building had already been constructed with the ENT in place as part of the electrical system which was inconsistent with California State Code requirements for the occupancies in question. For this reason, an evaluation was conducted for the AHJ which included a fire hazard assessment and analysis to determine whether the presence of ENT products reduced fire endurance of the assemblies. The evaluation also included a review of overall fire safety levels provided for students and teachers using the buildings.

The fire hazard assessment of the school walls showed that the walls and floor/ceiling designs met 1-hour, Type "V" code minimal and also included multiple cladding layers. Thus in addition to specific layers of cladding required to achieve the minimum, 1-hour fire endurance rating, walls included layers of plywood for shear strength, exterior siding over gypsum sheathing and other materials to improve thermal performance. Fiberglass batt insulation was also present and in many of the assemblies (such as roof ceilings), multiple layers of gypsum board were present as well. Since this was a one-story building, egress times and associated evacuation safety were of paramount importance and were not significantly affected by the construction. After a stringent review, a certificate of occupancy was issued. Interestingly, although some of the multiple layers, like plywood used for shear, were not specifically fire resistant, it could be shown that their presence increased anticipated overall fire endurance.
Reference 6.3.39

6.2.29 Comfort Inn, Florida–1998

A somewhat unorthodox three-layer gypsum wallboard system was used to provide needed sound insulation as well as 1-hour fire resistance in a motel. Inquiries were made by the local authority having jurisdiction as to the probable fire performance of these steel stud framed walls.

The design for the walls separating the units in this hotel included three layers of 5/8 inch gypsum wallboard with a 1/2 inch air space between two of those layers. The wall was essentially a stagger stud design with a single layer of wallboard attached on one side of a row of studs. A 1/2 inch airspace occurred beyond those studs and then a conventional, 1-hour gypsum wallboard clad wall had been built. The interior layer of gypsum wallboard used in this design was completely unpenetrated by ENT or other items providing a uniquely monolithic surface.

Thus in all cases, a completely separate wall cavity would exist between potentially fire affected wall cavities and those including ENT. It was also noted that the wall designs in question were similar to less robust, 1-hour Gypsum Association designs WP 6253 and WP 6254.

Given the depth and total number of layers of gypsum wallboard involved in the assembly subject, as well as the wall design, 1-1/2 hour of fire endurance could be predicted according to principles accepted in the building codes. Thus this design, which included another 1/2-inch air space, was determined to be appropriate to receive the 1-hour required rating.
Reference: 6.3.40

6.2.30 Walnut Creek, California–1999

A local plan check engineer noted that use of PVC ceiling boxes closer than 4 1/2 feet was not specifically allowed under the terms of Carlon NER-290. In response, an engineering analysis and construction detailing were developed allowing for box use with separations of 27 inch (or more) when protected with listed, fire-resistant insulations and/ or intumescent materials.

An eight unit, wood frame apartment with 1-hour floor/ceiling assemblies was being reconstructed after a fire. The electrical contractor wanted to use two PVC ceiling boxes in each of 16 floor/ceiling assemblies with minimum separations between the boxes of 27, 28 or 32 inches. All boxes were separated by two or more 2 inch thick, solid wood ceiling joists and the boxes to be used in the attic-ceiling assemblies were covered by R-19 batt insulation.

Using an alternate material and methods approach, a treatment to enhance the fire resistance of the membrane penetrations in question was developed. This included application of 3M "Putty Pads" behind each box per UL listing R9700 (N). Inclusion of large squares of fire-rated ceramic fiber insulation at the first/second floor–floor/ceiling assemblies as detailed in UL listing R8326 (N) was also detailed and their use accepted by the authority having jurisdiction.
Reference: 6.3.42

7.0 Conclusion

The record of fire safety research, regulatory approval and acceptable field performance associated with the use of PVC raceways is substantial. In addition, detailed examination of the lengthy history of the safe use of these products when properly installed in the United States, Canada and Europe for over three decades has disclosed no fire safety problems in the laboratory or in the field.

Likewise, industrial research targeted at developing improved installation and mitigation strategies for PVC raceways has led to a mature and responsible technology. The annually increasing number of mitigation devices and strategies currently available in the commercial sector is evidence of this. This work is not static, but rather is continuing as is work leading to the introduction of other safe, new products associated with Carlon ENT products for applications in fire endurance rated construction.

Conformance with accepted performance standards and successful review by independent third party testing agencies, and by code writing and code enforcement agencies, confirms that appropriate fire safety issues have been addressed.

8.0 Appendices: Fire Test Reports, Articles, References and Abstracts

These appendices include complete references to related articles, fire tests and hazard analyses relating to the use of PVC raceways. Full texts of these test reports are available from appropriate technical libraries or Carlon representatives.

8.0 Appendices: Fire Test Reports, References, Articles and Abstracts

Appendix 1
Standard fire test report summaries and references, and building code agency approvals of PVC raceway products.

Appendix 2
Technical articles addressing questions of smoke toxicity and hazard analysis.

Appendix 3
Reviews, articles and non-standard fire test results involving PVC products which are relevant to the use of PVC raceways.

Appendix 4
Smoke toxicity - general references.

8.1 Appendix I

Standard tests and Building Code
Agency approvals of PVC Raceway and associated products.

1. Fill, Void or Cavity Materials for use in Through Penetration Firestop Systems in Gypsum Wallboard Wall Assemblies
Authors: Underwriters Laboratories Inc.
Reference: UL Report File R9700-2, Proj. 85NK17181, Northbrook, I11. (12/85).
Abstract: ASTM E-814 test of wall assembly constructed of 3-5/8" steel studs, 24" O.C. with two layers of 5/8" gypsum wallboard on each face containing PVC penetrations. Rated at 2 hours.

2. Wall Opening Protective, Multi-Cable Devices and Fill, Void or Cavity Materials in Concrete or Masonry Wall Assemblies.
Authors: Underwriters Laboratories Inc.
Reference: UL/Northbrook Files R9269-1,-2; R9700. Project 81 NK 4314; 81 NK 7951. (12/81).
Abstract: ASTM E-814 test of ABS and PVC DWV plastic pipe penetrating concrete block walls. The penetrations were firestopped with metal sleeves and an intumescent to achieve a 3-hour rating.

3. Fire Test Letter Reports on 3M FIRE BARRIER Materials in Concrete Slab Floors.
Authors: Underwriters Laboratories Inc.
Reference: UL Project 82NK2200, File R9269. (03/83).
Abstract: ASTM E-814 test of concrete floor slabs containing PVC, ABS and PB DWV plastic pipe penetrations firestopped with 3M products. Ratings varied from 1 to 3 hours.

4. Fact Finding Report on PVC and Rigid Metallic Conduit and Metallic Outlet Boxes in a Nonbearing Partition Assembly.
Authors: Underwriters Laboratories Inc.
Reference: File NC546-1,-2, Project 73NK 7657 (12/21/73).
Abstract: ASTM E-119 test of wall constructed of 3-5/8" steel studs, 24" O.C. with 2 layers of 5/8" gypsum wallboard on each face containing PVC electrical nonmetallic tubing (ENT). Attained 2- hour rating.

5. Fact Finding Report on Electrical Nonmetallic Tubing (ENT), Electrical Metallic Tubing (EMT), and Metallic Outlet Boxes in a Nonbearing Partition Assembly.
Authors: Underwriters Laboratories Inc.
Reference: UL File R8326-4, Project 80NK11747. (09/07/80).
Abstract: ASTM E-119 test of wall constructed with 3-5/8" steel studs, 24" O.C. with 2 layers of gypsum wallboard on each face containing corrugated PVC electrical tubing (ENT). Attained a 2-hour rating.

6. Report on Nonmetallic Outlet and Switch Boxes for use in Wall and Partition

Assemblies Consisting of Wood Studs and Gypsum Wallboard.
Authors: Underwriters Laboratories Inc.
Reference: File R8326-3, Project 79NK 13050. (4/10/80)
Abstract: ASTM E-119 test of wall constructed of 2”by 4” wood studs 16” O.C. with 2 layers of gypsum wallboard on each face containing PVC electric outlet and switch boxes. Attained 2-hour rating.

7. Nonmetallic Electrical Outlet Boxes in Fire-Resistive Walls and Floor/Ceiling Assemblies, NER Report-140.
Authors: The International Code Consortium (ICC) formerly administered by the Council of American Building Officials (CABO).
Reference: National Evaluation Service Committee Report No. NER-140, (04/91).
Abstract: Describes use of PVC outlet boxes in 1 and 2-hour wood and steel stud walls and wood joist ceiling assemblies.

8. Fire Resistive Noncombustible Partition Assembly Containing Electrical Nonmetallic Tubing and Rigid Non-Metallic Conduit.
Authors: The International Code Consortium (ICC) formerly administered by the Council of American Building Officials (CABO).
Reference: National Evaluation Service Committee Report No. NER-290, 12/90.
Abstract: Evaluates 1/2” and 3/4” electrical nonmetallic tubing and conduit (PVC) in a partition constructed of 3-5/8” metal studs 24” O.C. with 2 layers of 5/8” Type X gypsum wallboard on each wall face. 2-hour rating.

9. Fire Endurance Tests of Fire Resistive Assemblies Containing Nonmetallic Rigid Conduit and Electrical Nonmetallic Tubing.
Authors: Underwriters Laboratories Inc.
Reference: UL File NC546-4, Project 84NK4941. (04/23/85)
Abstract: ASTM E-814 fire endurance tests of concrete floors, steel stud walls and concrete block walls containing 1/2” and 1” PVC ENMT (ENT raceway) and 1/2”, 1”,1-1/4”, 1-1/2”, and 2” PVC rigid nonmetallic conduit. 2-hour F & T ratings.

10. Fact-Finding Report on Metallic and Nonmetallic Tubing, Conduits and Boxes in the Concealed Space of Floor-Ceiling and Roof-Ceiling Assemblies with Suspended Ceiling.
Authors: Underwriters Laboratories Inc., attn: B. Swytnyk.
Reference: UL File NC 546-5, Project 87NK27319 (03/89).
Abstract: ASTM E-119 floor/ceiling fire endurance test comparing PVC-ENT and RNMC with EMT on fire endurance. Performance of PVC products was judged equivalent to ENT.

11. Letter report on 2-hour fire endurance E-119 (pilot) slab test including PVC-ENT in concrete slab.
Authors: Warnock-Hersey International Ltd, B.D. Britain
Reference: Letter report of May 10,1990 to J. Zicherman (Work order # 50611 /C7/030320, Test # WHI-495-PSH-0165)

Abstract: 2-hour fire endurance E-119 pilot test of concrete slab including PVC-ENT.

12. Nonmetallic Electrical Outlet Boxes for use in Floor-Ceiling Assemblies Consisting of Wood Joists, Wood Flooring and Gypsum Wallboard
Authors: Underwriters Laboratories Inc.
Reference: Underwriters Laboratories Project #81NK24419, File #R8326
Abstract: Report on successful 2-hour E-119 fire endurance testing of electrical boxes - outlet boxes (PVC) for use in fire resistive assemblies.

13. Fire Endurance Test to Evaluate the Fire Resistance of a Carlon PVC Floor Box in a 6' x 8' x 4-1/2" thick, normal weight concrete, floor/ceiling assembly.
Authors: Warnock-Hersey International Ltd.; T.R. Williams, B.D. Britain, & G.E. Meyer
Reference: WHI Test#495-PSH-0165A; Work Order #50611-C7- 030320, (05/07/90).
Abstract: ASTM E-119 fire endurance test of a PVC floor box in a 6' x 8' x 4-1/2" thick reinforced concrete floor/ceiling assembly.

14. Report of the Pilot Scale Fire Endurance Test of a Carlon PVC Floor Outlet Box in an Unrestrained 6' x 8' x 4-1/2" Thick, Reinforced Concrete Slab Without an Applied Load.
Authors: Warnock-Hersey International Services, Ltd.
Reference: WHI Test #:WHI-495-PSH-0165A; Work Order #:50611-C7-030320; Date Tested: (05/07/90).
Abstract: Report on successful ASTM E-119 fire endurance test of Carlon PVC floor box in an unrestrained 6'x 8' x 4-1/2" thick reinforced concrete slab.

15. Report of the Pilot Scale Fire Endurance Test of 1" Diameter, PVC, Flexible, ENT Conduit Runs in an Unrestrained 6' x 8' x 5-1/4" Thick, Reinforced Concrete/Corrugated Steel Deck Floor/Ceiling Assembly Without an Applied Load.
Authors: Warnock-Hersey International, Ltd., T.R. Williams, B.D. Britain, G.E. Meyer
Reference: WHI Test#: WHI495-PSH-169; Work Order #50611-C7-030320; (07/16/90).
Abstract: Report on successful ASTM E-119 fire endurance test of PVC flexible ENT conduit penetrating a 6' x 8' x 5-1 /4" thick reinforced lightweight concrete/corrugated steel deck floor/ceiling assembly.

16. Fire endurance pilot scale test to evaluate the fire resistance of metallic electrical tubing (EMT) penetrating a fire resistive concrete slab.
Authors: Warnock-Hersey International, Ltd., T.R. Williams, B.D. Britain, G.E. Meyer
Reference: WHI Test #: WHI-495-PSH-0170; Work Order #: 50611-C7-034900; (7/17/90).
Abstract: Report on successful ASTM E-119 test of PVC EMT penetrating a 6' x 8' x 4-1/2" thick normal weight reinforced concrete slab.

17. Fire endurance test to evaluate the Fire Resistance of a Carlon PVC floor box in lightweight concrete slab on 6' x 8' steel decking.
Authors: Warnock-Hersey International, Ltd., T.R. Williams, B.D. Britain, G.E. Meyer
Reference: WHI Test #: WHI-495-PSH-0169A; Work Order #: 50611-C7-030320; (7/16/90).

Abstract: Report on successful ASTM E-119 test of PVC electrical outlet box in a 6’ x 8’ x 5-1/4” reinforced lightweight concrete/steel decking floor/ceiling assembly.

18. Fire Endurance Test to Evaluate the Fire Resistance of Carlon Nonmetallic Electrical Components When They Penetrate a Fire Resistive Concrete Slabs
Authors: Warnock-Hersey International, Ltd., T. R. Williams, B. D. Britain, and G. E. Meyer.
Reference: WHI Test #: WHI-495-PSH-0165; Work Order #: 50611-67-0303220; (5/7/90).
Abstract: Reports on successful ASTM E-119, horizontal test of PVC-ENT electrical flexible non metallic raceway installed in a 6’ x 8’ x 4-1/2” thick normal weight, reinforced concrete slab.

19. Fact-Finding Report on Metallic and Nonmetallic Tubing. Conduits and Boxes in the Concealed Space of Floor-Ceiling & Roof-Ceiling Assemblies with Suspended Ceiling
Authors: Underwriters Laboratories Inc.
Reference: Underwriters Laboratories Inc. File NC546 5; (3/30/89).
Abstract: Report on 3-hour fire endurance performance in ASTM E-119 exposure of 4 floor-ceiling assemblies with exposed grid suspension system ceiling containing metallic and nonmetallic PVC tubing (ENT) conduits, and boxes filled with electrical wires in assembly.

20. ASTM E 119-88 (Modified) Fire Tests of Building Construction and Materials - Mud Boxes Cast into a 2-Hour Rated Concrete Floor
Authors: Priest, Degrade, Omega Point Laboratories, San Antonio, Texas
Reference: Omega Point Laboratories, Project No. 1091-92055; (11/18/91).
Abstract: a 2-hour ASTM E-119 fire test conducted on a Carlon 5.0 inch thick, reinforced concrete slab containing various designs of electrical connection boxes (mud), cast into the concrete slab with their open sides at the bottom.

21. ASTM E 119-88 (Modified) Fire Tests of Building Construction and Materials - Mud Boxes Cast into a 3-Hour Rated Concrete Floor
Authors: Priest, Deggary, Omega Point Laboratories, San Antonio, Texas
Reference: Omega Point Laboratories, Project No. 1091-92483; (11/18/91).
Abstract: 3-hour ASTM E-119 fire test conducted on a Carlon 6.0 inch thick, reinforced concrete slab containing various designs of electrical connection boxes or mud boxes. Through-penetrations PVC.

22. ASTM E 119-88 Fire Tests of Building Construction and Materials - Steel Stud/Gypsum Wall Containing Carlon Conduit
Authors: Priest, Deggary, Omega Point Laboratories, San Antonio, Texas
Reference: Omega Point Laboratories, Project No. 1149-92509; (01/27/92).
Abstract: Successful ASTM E-119 fire test was conducted on a non-bearing wall assembly consisting of a 20 gauge Steel stud wall clad on both sides with 5/8” type X

gypsum wallboard, containing one duplex receptacle on each side of wall containing ENT.

23. Fill, Void or Cavity Materials and Wall Opening Protective Multiple-Cable Devices in
a Full-Scale Wall Fire Test Assembly.
Authors: Underwriters Laboratories, Inc.
Reference: Underwriters Laboratories Inc; Letter Report R9943 8INK25970; (2/11/82).
Abstract: ASTM E-814, 3-hour test block of block wall penetrated by PVC nonmetallic conduit and plastic pipe firestopped with sleeves.

24. Load bearing Wall with Nonmetallic Outlets Boxes and Tubing.
Authors: Carlon, Lamson & Sessions, Cleveland, OH
Reference: Underwriters Laboratories Inc. Project # 94NK17350, File # R8326; (11/94).
Abstract: ASTM E-119/E-814 test of staggered wood stud wall design including Carlon ENT and four PVC electrical boxes.

25. NonLoad bearing Wall with Nonmetallic Outlet boxes.
Authors: Carlon, Lamson & Sessions, Cleveland, OH
Reference: Underwriters Laboratories Inc. Project # 93NK19678, File # R8326; (11/94).
Abstract: ASTM E-119/E-814 test of insulated wood stud wall design including Carlon ENT and back-to-back PVC electrical box insulations with 12” offsets.

8.2 .Appendix II

Technical articles addressing questions of smoke toxicity and hazard analysis.

1. Electrical Failure of Wires Inside l-inch Conduit Under Simulated Fire Conditions.
Authors: Kahn, M.M.
Reference: Factory Mutual Research Technical Report FMRCJ.I. OH4R4.RC ; (10/84).
Abstract: Tests of electrical failure modes in PVC and metallic conduit revealed that the time to failure was substantially longer with the PVC conduit installation.

2. An Evaluation of Smoke Toxicity and Toxic Hazard of Electrical Nonmetallic Tubing Combustion Products
Authors: Packham, S.C. and Crawford, M.B.
Reference: Journal of Fire Sciences, Vol. 2.; (01/84).
Abstract: Large and small-scale toxicity tests indicated that PVC electrical nonmetallic tubing (ENT) was in a toxicity category comparable to smoke from wood. Also, non-lethal HCl concentrations were noted.

3. Comparison of 1” PVC Schedule 40 Conduit and 1” EMT Conduit in a Fire Situation.
Authors: Tenero,W.
Reference: Springborn Testing Institute, Inc. Project No. 707.29; (12/27/82).
Abstract: Experiment conducted to compare relative ability of PVC and metallic raceways to protect the integrity of electrical circuits in a fire. PVC-ENT circuit shorted in 7 minutes while EMT shorted in 4 minutes.

4. The Use of ENMT-Fire Hazard Analysis.
Authors: Benjamin, I.
Reference: Journal of Fire Sciences, Pp. 25; (01/87).
Abstract: Toxic hazard research report and hazard analysis for PVC (ENT) electrical nonmetallic tubing in a fire exposure.

5. Benjamin Clark report - The Use of ENMT - Fire Hazard Analysis.
Authors: Benjamin/Clarke Associates, Inc.
Reference: Report to NFPA by Benjamin/Clarke; (09/85).
Abstract: Study to determine toxic hazard from utilizing PVC electrical nonmetallic tubing in buildings over 3 stories. Concluded that it could be used with no significant increase in fire hazard.

6. Use of Rigid Nonmetallic Conduit In Hospital Emergency Systems: A Fire Hazard Assessment.
Authors: Clarke, F.
Reference: Report to Carlon by Benjamin/Clarke Assoc.; (02/89).
Abstract: Study of the impact of direct fire exposure of PVC conduit in a hospital situation on smoke toxicity.

7. Report Offered in Support of NER 290 Application, Fact Finding Report on Carlon Metallic & Nonmetallic Tubing, Conduits & Boxes.
Authors: Zicherman, J. B.
Reference: IFT report; (05/90).
Abstract: Evaluation of fire endurance of 3-hour UL floor/ceiling assembly including differing types of PVC raceway including Carlon ENT.

8. Whatever Happened to Combustion Toxicity?
Authors: Hall, Jr., J. R.
Reference: NFPA Fire Journal; (11/96)
Abstract: Contemporary review of combustion toxicity issues.

9. Whatever Happened to Combustion Toxicity?
Authors: Hall, Jr., J. R.
Reference: Fire Technology, 1996. 32, 4
Abstract: Contemporary review of combustion toxicity issues

10. Technical Note: Finish Ratings of Gypsum Wallboards
Authors: Zicherman, J. B.
Reference: Fire Technology, 1998. 34,4
Abstract: Presentation of ASTM E-119 finish rating testing results for a variety of gypsum wallboard products.

11. Is PVC Piping Safe?
Authors: Zicherman, J. B.
Reference: NFPA Fire Journal, November/December, 1990, 84, 6.
Abstract: Review of ASTM E-119 fire endurance testing of rated assemblies incorporating PVC plumbing pipe and associated materials.

12. Performance of Plastic Plumbing and Electrical Products in Fire Resistive Assemblies.
Authors: Zicherman, J. B.
Reference: Fire Hazard and Risk Assessment, M. Hirschler, Ed. ASTM STP 1150 pp. 66. 1992
Abstract: Evaluation of fire hazard implications associated with the installation of plastic pipe, tube and conduit in fire rated construction assemblies. Presentation includes extensive literature review and fire test results.

8.3 Appendix III

Reviews, articles and non-standard fire tests
for PVC products relevant to use of PVC raceway.

1. Fire Performance Behavior of PVC and CPVC Pipe.
Authors: B.F. Goodrich Chemical Group.
Reference: Document prepared for State of California Environmental Impact Report; (10/82).
Abstract: Summary of test reports on PVC and CPVC plastic pipe conducted under ASTM E-814, E-l l9 and ad-hoc procedures. Also comments on smoke production issues.

2. Review and Summary of the State of the Art of Studies on Role of Plastic Pipe in Fire Spread in Structures and Buildings.
Authors: Williamson, R.B.
Reference: Report by the J. Bradford Corp., Berkeley, California; (8/78). Prepared for US Army Corps of Engineers.
Abstract: Summarizes ASTM E-119 1 and 2-hour fire tests of walls and concrete slabs penetrated by ABS, PVC and Polypropylene DWV plastic pipe plumbing assemblies in combustible and non-combustible construction.

3. Ad-Hoc Fire Resistance Test PVC Pipes Penetrating Concrete Floor.
Authors: Jones, R.A.
Reference: F.I.R.T.O. Report 3529, Fire Insurer's Research & Testing Organization, Borehamwood,
UK (03/80).
Abstract: Floor slab fire test of PVC plastic pipes penetrating the concrete with various fire-stopping devices used to produce successful 1 and 2 hour performance.

4. Standard ASTM Fire Endurance Test and Fire and Hose Stream Test on Duplicate Load
Bearing Poly Vinyl Chloride Plumbing Wall Assemblies.
Authors: Bletzacker, R.W.
Reference: Ohio State Univ. Eng. Experiment Station Report, Project 5561 (03/13/84).
Abstract: ASTM E-119 test of a load-bearing wall constructed of 2 x 6 wood studs, 16" O.C. with two layers of 5/8" gypsum wallboard on each face containing a PVC DWV plumbing assembly. Attained a 2-hour rating.

5. Penetration of Fire Partitions by Plastic Pipe.
Authors: Atwood, P.
Reference: Fire Technology (Vol. 16, No.1, pp 37-62). (07/80).
Abstract: Ad hoc tests of vertical and horizontal ABS and PVC DWV penetrations with various types of firestopping. Indicates that plastic pipe can penetrate fire resistive walls safely if correctly firestopped.

6. Intumescent Fire Stoppers for UPVC Pipes Penetrating Concrete Slabs.

Authors: Burn, L.S. and Martin, K.G.
Reference: CSIRO-Div. of Bldg. Research (1980).
Abstract: Tests of UPVC plastic pipe penetrating concrete slabs with intumescent and sleeve fire-stopping. Intumescent used with sleeves performed well for up to 4 hours.

7. Ad Hoc Fire Resistance Test on 110 mm-diameter PVC pipes, with and without GRP sleeves, penetrating a brick wall, for Marley Extrusions Ltd.
Authors: Jones, R. and Day, T.
Reference: Fire Insurers' Research and Testing Organization - propriety report (01/80).
Abstract: Tests of UPVC plastic pipe penetrating a brick masonry wall with and without sleeve firestopping. Results indicated penetrations using sleeves were acceptable for a 2-hour exposure period.

8. Early Fire Hazard Assessment of UPVC Pipe Formulations.
Authors: Burn, L.S. and Martin, K.G.
Reference: CSIRO. (1981).
Abstract: Australian fire tests on UPVC plastic pipe to measure ignitability, flamespread, heat evolved and smoke produced.

9. Is PVC Piping Safe?
Authors: Zicherman, J. B.
Reference: NFPA Fire Journal, November/December, 1990, 84, 6.
Abstract: Review of ASTM E-119 fire endurance testing of rated assemblies incorporating PVC plumbing pipe and associated materials.

8.4 Appendix IV

Smoke toxicity - general references.

1. The Behavior of PVC in Fires.
Authors: Tester, D.
Reference: British Plastics Federation, Trade Association Report (09/83).
Abstract: Report summarizes behavior of PVC in terms of ignitibility, flamespread, smoke evolution and products of combustion.

2. Combustion Gases of Various Building Materials.
Authors: Vinyl Institute
Reference: Vinyl Institute Technical Information Note. (04/87).
Abstract: Discusses combustion gases produced when PVC burns including CO, C02 and HCl. Concludes that the amount of HCl produced presents a very limited hazard in a fire, and PVC is at least as safe as most other materials.

3. Toxicity of the Pyrolysis and Combustion Products of Poly Vinyl Chlorides: A Literature Assessment.
Authors: Huggett, C. and Levin, B.C.
Reference: National Bureau of Standards - Center for Fire Research Report No. NBSIR-85/3286. (05/86).
Abstract: Literature review of toxicity of PVC combustion products. Concludes that PVC decomposition products are not extremely toxic when compared to those from other common building materials.

4. The Combustion Toxicology of Polyvinylchloride Revisited.
Authors: Doe, J.
Reference: Journal of Fire Sciences, Vol. 5 (07/87).
Abstract: Toxicology of hydrogen chloride has been over estimated in the past and codes using toxicity factors for hydrogen chloride should be revised since hydrogen chloride level decays rapidly in fires.

5. Application of a Model for Transport and Decay of Hydrogen Chloride from Burning Polyvinyl Chloride, PVC, to Room-Corridor-Room Experiments
Authors: Galloway, F. M., Hirschler, M.M.
Reference: Proc. Fourteenth Int'l Conference on Fire Safety, 1989
Abstract: Presentation of an improved HCl transport and decay mode applied to predict HCl concentrations in large-scale experiments involving either burning PVC or pure HCl.

6. Whatever Happened to Combustion Toxicity?
Authors: Hall, Jr., J. R.
Reference: NFPA Journal November/December, 1996, Volume 90, 6.
Abstract: Contemporary review of combustion toxicity issues.

7. Whatever Happened to Combustion Toxicity?
Authors: Hall, Jr., J. R.

Reference: Fire Technology, 1996, Volume 32, 4.
Abstract: Contemporary review of combustion toxicity issues.