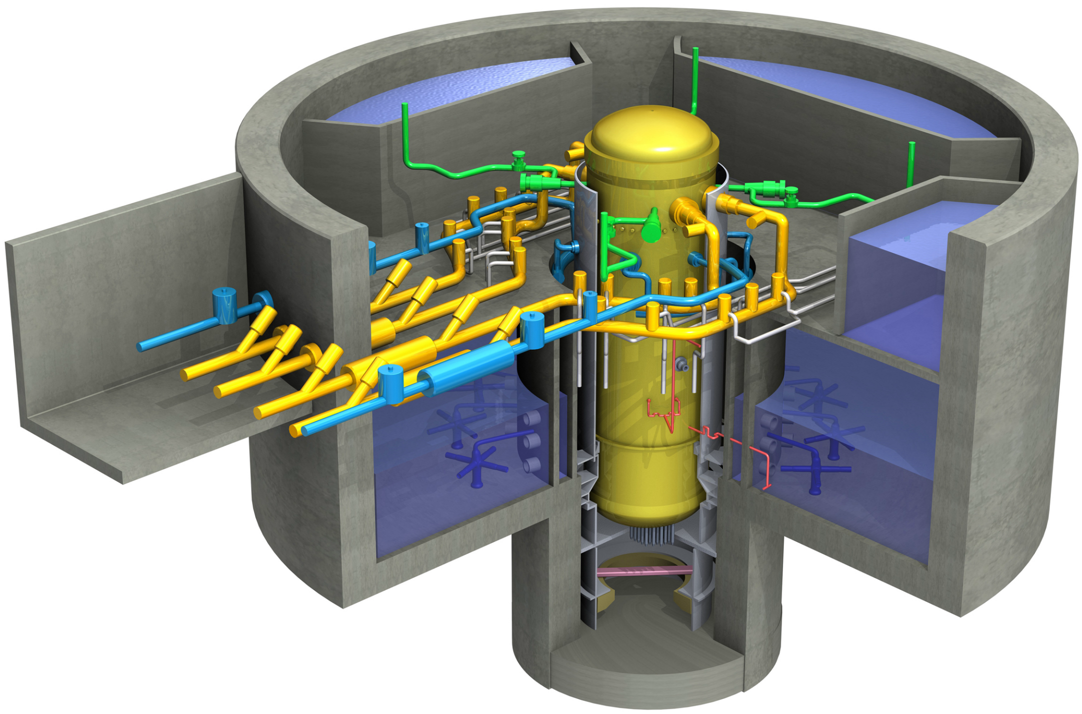
GE Hitachi Nuclear Energy

26A6642BD
Revision 6
August 2009



ESBWR Design Control Document
Tier 2

Chapter 9
Auxiliary Systems
Appendix 9B

Contents

List of Tables

List of Illustrations

9B. SUMMARY OF ANALYSIS SUPPORTING FIRE PROTECTION DESIGN REQUIREMENTS

9B.1 INTRODUCTION

This appendix is included to summarize some of the analysis associated with the design decisions and requirements stated in Subsection 9.5.1.

9B.2 FIRE CONTAINMENT SYSTEM

As addressed by Subsection 9.5.1 and Appendix 9A, the fire containment system is the structural system and appurtenances that work together to confine the direct effects of a fire to the fire area in which the fire originates. The fire containment system is required to contain a fire with a maximum severity as defined by the time-temperature curve contained in ASTM E-119 (Reference 9B-6) for a fire with duration of three hours to separate redundant divisions of safe shutdown cables and equipment.

9B.3 FIRE TYPES

The fire containment system is capable of coping with the following three general types and magnitudes of fires:

(1) Three-Hour Fire

A three-hour fire is a fully involved fire producing a time-temperature profile equal to the standard ASTM E-119 time-temperature test curve for a time period of three hours. For this condition, the temperature in the room at the end of three hours is 1,052°C (1,926°F). Complete burnout of the fire area is assumed for a fire of this magnitude. No survival or recovery of equipment in the fire area is assumed. This capability of the fire containment system meets the requirements of NUREG-0800 SRP 9.5.1 and Branch Technical Position SPLB 9.5-1 (Reference 9B-1).

It is unlikely that a true three-hour fire would ever occur as the fire would be limited to a lesser magnitude by fire suppression systems, available fuel, or available combustion air.

(2) Limited Growth Fire

A limited growth fire is a fire that produces a thermal column sufficient to create a heated layer of gases in the upper elevation of the room involved in the fire. Room flashover for this type of fire is prevented as a result of insufficient fuel, heat venting, or fire suppression activities. Although some of the equipment in the fire area would probably be unaffected by the fire, it is assumed that the function of all equipment in the fire area is lost.

(3) Limited Growth, Smoky Fire

A severely limited growth, smoky fire is a fire such as smoldering rags or an electrically initiated cable fire. The heat release from the fire is small so that the smoke is cooled by entrainment of air and the thermal column is thereby limited in size. Because the smoke is cold, its travel is highly influenced by the HVAC airflow patterns in the room. The fire does not affect most equipment in the fire area, although no credit is taken for the equipment remaining functional. It is possible, but highly unlikely, that this type of fire could progress to a limited growth or fully involved three-hour fire.

9B.4 FIRE BARRIERS

For the ESBWR design, the direct effects of a fire are confined to a single fire area by provision of three-hour rated fire barriers separating each fire area from adjacent fire areas. Rated three-hour fire barriers are formed by the following:

(1) Concrete fire barrier floors, ceilings, and walls that are at least 0.15 m (6.0 in) six inches thick (Reference 9B-2, Figure 7-8T) if made from carbonate and siliceous aggregates. Other aggregates and thickness are acceptable if the type of construction has been tested and bears a UL (or equal) label for a three-hour rating.

(2) Partitions or other constructions such as steel stud and gypsum board partition walls that have been tested in accordance to Standard ASTM E-119 to have a fire rating of at least three hours.

(3) Rated fire doors with the label of a certified laboratory that indicates that the door and frame have been tested to the requirements of ASTM E-119 for a standard time-temperature curve for three hours.

(4) Penetration seals for process pipes and cable trays that have been shown by testing to withstand a fire equal to the rating of the barrier per the standard ASTM E-119 time-temperature curve. Certain penetrations, such as the containment penetrations, may be shown by analysis rather than test to have a fire resistance equal to at least a three-hour rating.

(5) Special assemblies and constructions as listed in Subsections 9A.3.5 (Wall Deviations) and 9A.3.6 (Door Deviations) of the Fire Hazard Analysis.

(6) Fire dampers are installed in HVAC ducts that penetrate rated fire barriers as required by NFPA 90A (Reference 9B-7). Both the Reactor Building Contaminated Area Ventilation System (CONAVS) and the Reactor Building Clean Area Ventilation System (CLAVS) have redundant fans that supply air through common ducts and redundant fans that exhaust air through common ducts. See Subsections 9.4.6.2 and 9.5.1.11.

The completeness of the barriers for the fire confinement system is examined and documented on a fire area by fire area basis in the fire hazard analysis, Appendix 9A.

9B.5 ALLOWABLE COMBUSTIBLE LOADING

Subsection 9B.4 documents that the ESBWR plant design provides capability by fire barriers to cope with a standard three-hour fire where necessary. The purpose of this subsection is to discuss this in terms of the expected and allowable combustible loading in the plant.

9B.5.1 Permanent Loading

The problem associated with predicting the allowable combustible loading compatible with a given fire rating is well stated in the NFPA Fire Protection Handbook (Reference 9B-2, p. 7-111).

"Technically accurate methods for relating fire severity, fire load, and fire resistance requirements are complex but can be advantageously used in important specific applications. Such methods require consideration of parameters other than the fuel load, such as ventilation, type of enclosure walls, and ceiling. These methods are complex and currently too difficult for general use in design or selection of barrier fire resistance."

Allowable fire loading for the ESBWR is developed on the basis of information available from industry experience and testing that classifies the types of occupancies, their combustible loads, and the expected fire severity that might occur in the occupancies. This information is used to approximately relate the fire loading and expected severity for the various types of occupancies. Three examples of how this is performed for the ESBWR design are provided.

- **Example 1:**

  The first example is taken from Table 7-9B of the NFPA Fire Protection Handbook (Reference 9B-2) and reproduced here as Table 9B-1. From the table, a fire as a result of ignition of ordinary combustibles (wood, paper and similar materials) with a heat of combustion of 16.3 MJ/kg (7,000 Btu/lbm) to 18.6 MJ/kg (8,000 Btu/lbm) and a loading of 146.5 kg/m^2 (30 lbm/ft^2) of floor area in a fire resistive building is estimated to produce a fire of a severity equivalent to the standard time-temperature curve for three hours. This equates to an average fire loading of 2,725 MJ/m^2 (240,000 Btu/ft^2). This is an indication of the capacity limit for the three-hour fire containment system for the ESBWR.

  In making the comparisons in the table, it is recognized that for two fires with different temperature histories, the fires may be considered to have equivalent severity when the areas under their time-temperature curves are equal.

  Burning rate is an indication of fire severity and therefore of interest. For this example, a three-hour fire loading with an average burning rate is 2,725 MJ/m^2 (240,000 Btu/ft^2) divided by 180 minutes, or 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2).

- **Example 2:**

  Another method by which the allowable combustible loading may be determined is by reference to the information summarized in Figure 7-9B of Reference 9B-2, which is for zero to two hours. Figure 9B-1 is developed from that figure and extrapolated for the period of time of two to three hours. Figure 9B-1 plots the standard fire endurance and time-temperature curves used for occupancy classifications "A" through "E" per Table 7-9E of Reference 9B-2 and is reproduced as Table 9B-2. The fire endurance curves indicate how long a fire burns based upon amounts of combustibles involved in the fire. The time-temperature curves indicate the severity expected for the various occupancies. There is no direct relationship between the straight and curved lines, but, for example, from the straight line portion of the curves, 48.8 kg/m^2 (10 lbm/ft^2) of ordinary combustibles per floor area is capable of producing almost a 90 minute fire in a "C" occupancy. The 90-minute fire is expected to have a severity equal to that of the curved line "C". As additional examples, 48.8 kg/m^2 (10 lbm/ft^2) of combustibles per floor area produces less than 75 and 60-minute fires in "D" and "E" occupancies, respectively. The fire severity follows their respective "D" and "E" time-temperature curves.

Time-temperature curve "E" also represents the standard ASTM E-119 time-temperature curve. It is the design capability curve for the ESBWR. Given enough fuel and time, the severity of a fire in any of the types of occupancies eventually equals the standard time temperature curve. While fast-developing fires may peak above the standard curve in the early stages of fire development, such fires tend to come back to or below the standard curve with time. This early peaking has little immediate effect on the life of fire barriers, as they tend to respond to the area under the time-temperature curve more than to instantaneous values of temperature.

Figure 7-9B of the NFPA Fire Protection Handbook (reference 9B-2) covers a time frame of two hours. Figure 9B-1 has been extrapolated to three hours. Note that the extrapolated fire endurance curve for an "E" type occupancy indicates that a combustible loading of 153.7 kg/m^2 (31.5 lbm/ft^2) produces a three hour fire. This corresponds well with the 146.5 kg/m^2 (30 lbm/ft^2) determined in Example 1.

Another point of reference is that, as indicated in Table 9B-2, non-combustible power houses fall in the occupancy group defined as "Slight" and have an expected fire severity curve of "A". The "A" group has the least fire severity of the five groups. It represents a minimum challenge to the "E" capability of the ESBWR. This is another indication of the margin provided by the three-hour barriers in the ESBWR design. Such activities as paper working, printing, furniture manufacturing and finishing are within the fire containment capabilities of the ESBWR three-hour fire barriers.

The fire endurance curve, extrapolated to three hours, for an "A" type occupancy, which includes noncombustible powerhouses, is approximately 39.1 kg/m^2 (8 lbm/ft^2) for a three-hour fire. This suggests that to be consistent with normal power plant design, combustible loading in any given area of the ESBWR is limited to the equivalent of 39.1 kg/m^2 (8 lbm/ft^2) of ordinary combustibles having a heat of combustion of 18.6 MJ/kg (8,000 Btu/lbm) and in a configuration that does not exceed an average burning rate of 4.04 MJ/min/m^2 (356 Btu/min/ft^2). There is margin for higher loadings, but they are considered on a case-by-case basis and eliminated if possible or protected by automatic suppression systems. For the ESBWR design, areas with permanent loadings higher than this magnitude are protected by automatic suppression systems, except for cable tray runs as discussed below.

As shown in Figure 9B-1, choosing the defined design limit in the above fashion gives a design margin for the ESBWR fire barriers (represented by the "E" curve) of 300% above the typical power plant combustible loading (represented by the "A" curve). While this is a rather large design margin, the uncertainties are also rather large.

- **Example 3:**

The British have graded building occupancies according to hazard by three classifications as determined by the fire load per floor area. The classifications are occupancies of low, moderate, and high fire load. The occupancy is defined as low if it does not exceed an average of 1,136 MJ/m^2 (100,000 Btu/ft^2) of net floor area of any compartment, or an average of 2,271 MJ/m^2 (200,000 Btu/ft^2) in limited isolated areas. Storage of combustible material necessary to the occupancy may be allowed to a limited extent if separated from the remainder and enclosed by appropriate grade fire-resistive construction. Examples of occupancies of normal low fire load are offices, restaurants, hotels, hospitals, schools, museums, public libraries, and institutional and administrative buildings.

At 39.1 kg/m^2 (8 lbm/ft^2) of combustibles with a heat of combustion of 18.6 MJ/kg (8,000 Btu/lbm) from Example 1 above, the combustible loading is 727 MJ/m^2 (64,000 Btu/ft^2). This is low fire load occupancy per the British classification system.

The normal combustible loading limit of 700 MJ/m^2 (61,640 Btu/ft^2) average and the electrical room combustible loading limit of 1,400 MJ/m^2 (123,280 Btu/ft^2) for limited areas is chosen on the basis of the above three examples. Over a three hour fire duration, these result in average burning rate densities of 3.89 MJ/m^2/min (342 Btu/ft^2/min) for all but electrical rooms and 7.78 MJ/m^2/min (684 Btu/ft^2/min) for electrical rooms.

9B.5.2 Transient Combustibles

The above design limits are also reasonable and acceptable for transient combustible loadings. Although there are many possible types of transient loads, one of the transient combustibles most likely to occur consists of bags of protective clothing accumulating at a temporary change area. The justification of the acceptability of the stated design limit for this situation follows.

From the results of fire tests run at Southwest Research Laboratory and reported in Reference 9B-4, a 21.2 liter (5.6 gallon) bag of protective clothing weighs approximately 6.35 kg (14 lbm) and burns at an average peak rate of 5.28 MJ/min (5,000 Btu/min) with a total heat release of 148 MJ per bag (140,000 Btu per bag). Therefore, the minimum required floor area per bag in the change area is the total combustibles per bag divided by the normal combustible loading limit, or 148 MJ (140,000 Btu) per bag divided by 700 MJ/m^2 (61,640 Btu/ft^2) which results in 0.21 m^2 (2.27 ft^2) per bag. In actuality, if the bags were stacked this tightly together their burning rate would be greatly reduced as compared to the test because the available burning surface per bag would be greatly reduced. The calculation points out that a reasonable number of bags of protective clothing (up to four) located in a temporary change area would not materially threaten the limits of the fire tolerance of the plant.

Combustible liquid spills, such as lubricating oil or diesel oil, are another type of transient combustible that might be introduced into the plant during normal operation and maintenance. Although combustible liquids are required to be kept in approved containers, the possibility of a spill exists. Per Table 7-11A of the NFPA Fire Protection Handbook, (Reference 9B-2), the acceptable size for a spill may be estimated on the basis that these types of liquids burn in a pool with a heat release rate of approximately 2,270 kW/m^2 (200 Btu/sec/ft^2), which is equivalent to 136.3 MJ/min/m^2 (12,000 Btu/min/ft^2). This is equal to an energy release of 8,176 MJ/m^2 (720,000 Btu/ft^2) in one hour. The percent of room area which could be covered by a spill and still be within the defined design limit is 8.6% (700 MJ/m^2 divided by 8,176 MJ/m^2). In other words, a 10 m by 10 m (32.8 ft by 32.8 ft) room with negligible quantities of permanently installed combustibles could have an oil spill covering 8.6 m^2 (92.2 ft^2), burn for one hour, and still be within the combustible loading design limit.

It is not intended that the defined design limit be rigidly applied to spills, as it is expected that they would occur very infrequently and be cleaned up quickly. The example is included here to give an indication of the size of a postulated spill that is consistent with the restrictions of the defined design limit. It validates the requirement to store combustible liquids in limited quantities in approved containers.

The example also points out the necessity to provide automatic fire suppression for areas where oil spills that could cover the entire floor area of a room are possible.

9B.5.3 Cable Trays

Insulation for electrical cables in cable trays is the major contributor to permanent combustible loading throughout the plant. For this reason cable trays are worthy of specific attention.

Total Combustible Cable Insulation Per Area

From previous plant design experience the average weight of insulation per cable tray area is 48.8 kg/m^2 (10 lbm/ft^2) for cross-linked polyethylene flame retardant (XLPE-FR). With a heat of combustion of 29.8 MJ/kg (12,800 Btu/lbm), a six-tray stack of 0.61 m (24 in.) wide cable trays represents a heat load of 5,320 MJ/m (1,540,000 Btu/ft). For the stack of six 0.61 m (24 in.) wide cable trays to be routed through the entire length of a room, such as a corridor, without exceeding the normal combustible loading limit of 700 MJ/m^2 (61,640 Btu/ft^2), the room is required to have a minimum width of 7.6 m (25 ft), determined by 5,320 MJ/m (1,540,000 Btu/ft) of cable tray stack divided by 700 MJ/m^2 (61,640 Btu/ft^2).

Since the above is based on averages, a specific calculation is warranted. XLPE-FR and Tefzel (Registered trademark, E.I. Du Pont De Nemours & Co. Inc.) are two types of cable insulations that are commercially available and for which standard constructions are compared in Table 9B-3.

In the above tabulation, either 94 or 37 cables represent a design maximum fill of 40% for the two sizes of XLPE-FR insulated cables, with a maximum combustible loading of 1,613 MJ/m^2 (142,000 Btu/ft^2). Either 202 or 58 cables represent 40% fill for Tefzel insulated cables, with a maximum combustible loading of 550 MJ/m^2 (48,400 Btu/ft^2). To stay within the allowable average combustible loading of 700 MJ/m^2 (61,640 Btu/ft^2), each meter of 0.61 m (24 in.) wide cable tray loaded to 40% fill with XLPE-FR insulated cables requires approximately 1.4 m^2 (15 ft^2) of floor area, determined by 0.61 m (2 ft) times 1 m (3.28 ft) times 1,613 MJ/m^2 (142,000 Btu/ft^2) divided by 700 MJ/m^2 (61,640 Btu/ft^2). Similarly, each meter of 0.61 m (24 in.) wide cable tray loaded to 40% fill with Tefzel insulated cables requires approximately 0.5 m^2 (5.4 ft^2) of floor area, determined by 0.61 m (2 ft) times 1 m (3.28 ft) times 550 MJ/m^2 (48,400 Btu/ft^2) divided by 700 MJ/m^2 (61,640 Btu/ft^2) to stay within the allowable average combustible loading limit. A 40% fill restriction provides for almost twice as many Tefzel insulated cables as XLPE-FR insulated cables.

A reduced diameter cross-linked polyethylene cable is available. Its combustible loading and quantity of cables per a given tray width approaches that of Tefzel insulated cables and either type would be quite viable for use in the ESBWR.

Burning Rate of Cable Insulation

Although the effect on the fire barriers is dependent on the integral of the time-temperature curve more than the peak burning rate, the maximum burning rate that is possible with the allowable combustible load is still of interest.

Burning rate is dependent on the amount of surface area available to burn, the amount of oxygen available for the combustion process, and the properties of the combustible. For a solidly-filled ladder cable tray with one full layer of cables, the surface available for the instantaneous combustion process is the total of the circumferences of the individual cables times the length of the cables. This equates to being pi times the width of the tray times the length of the tray. For a tray 0.61 m (24 in.) wide and 1 m (3.28 ft) long, the cable surface area available for burning is 1.92 m^2 (20.6 ft^2). This is the maximum available burning surface as the top and bottom surface area is unchanged for additional layers of cables. The 0.102-meter (4 in.) deep side rails protect the sides of the cable stack in the trays, so that they do not receive combustion air.

A summary of burning rate calculations is presented in Table 9B-4 by source and material type.

The burning rate for cross-linked polyethylene was calculated by use of equation 2 from Section 5.3 of Attachment 10.4 of the draft of the Fire Vulnerability Evaluation (Reference 9B-4). For this calculation, the peak heat release rate is:

$Q_{fs} = 0.45$ qbs A (Eq. 9B-1)

where "qbs" is the bench scale-burning rate taken from Table A-7M of Attachment 10.7 of the Fire Vulnerability Evaluation document (Reference 9B-4) and "A" is the burning surface area.

The data estimated from tests at UL was taken from a series of modified IEEE 383 tests conducted in 1976 (Reference 9B-5). Although it was not the purpose of the tests to determine burning rate, it is possible to estimate the burning rate from the reported insulation consumed and cable burning time as determined by time-tagged photographs of the tests in progress. Cross-linked polyethylene and Tefzel insulated cables of the constructions discussed earlier in this section (Table 9B-3) were tested with the range of burning rates indicated in Table 9B-4 as the results.

The ventilation limited burning rate was calculated using the Fire Vulnerability Evaluation methodology using the Draft Fire Vulnerability Evaluation Plant Screening Guide (Reference 9B-4). The equation is:

$Q_{max}/V = 3600\ kW/(m^3/sec)$ (Eq. 9B-2)

where "Qmax" is the maximum heat release rate in kilowatts and "V" is the volume flow in cubic meters per second. Converting to English units:

$Q_{max}/V = 96.6\ (Btu/min)/(ft^3/min)$ (Eq. 9B-3)

For 1 m^2 (10.8 ft^2) of a room with a ceiling height of 4.57 m (15 ft) and a ventilation rate of 3 air changes per hour, the ventilation rate is 0.00381 m^3/sec (8.1 cfm). Q_{max} is equal to:

Q_{max} = 3600 kW/(m^3/sec) x 0.00381 m^3/sec = 13.7 kW = 823 MJ/min (780,000 Btu/min)(Eq. 9B-4)

over the 1 m^2 (10.8 ft^2) floor area.

The burning rate for the design normal combustible load limit is the combustible load limit of 700 MJ/m^2 (61,640 Btu/ft^2) as defined in Subsection 9B.5.1, divided by 180 minutes (3 hours), which results in 3.89 MJ/min/m^2 (342 Btu/min/ft^2).

Similarly, the equivalent burning rate of 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2) for the fire barrier capability is the 2,725 MJ/m^2 capability of the three-hour barrier divided by 180 minutes.

The normal combustible load limit of 3.89 MJ/min/m^2 (342 Btu/min/ft^2) divided into the burning rate of 6.99 to 37.85 MJ/min/m^2 (615 to 3,333 Btu/min/ft^2) of open ladder cable tray gives an allowable minimum ratio of 1.8 to 9.7 of floor area to cable tray area within a room, depending on the type of cable insulation used.

The burning rate calculations have worth in that they give an idea of what the localized burning rate might be for a cable fire that is not burning in the ventilation controlled mode. Multiple trays of cables are not run in rooms such as oil storage tank room where there is an ignition source sufficiently large to ignite the entire amount of cable in the room. Also, areas containing potential ignition sources sufficiently large to ignite large amounts of cables have sprinkler type suppression systems. For these reasons, the normal combustible loading limit, based on the total combustible per square foot, should be used in preference to using the localized burning rate as the basis for setting the limit.

There is another indication of the design margin provided by the three-hour fire barrier system. That indication is the comparison of the low ventilation controlled burning rate of 823 MJ/min (780,000 Btu/min) of floor area with the barrier system capacity of 15.14 MJ/min/m^2 (1,333 Btu/min/ft^2) as determined previously in Example 1 of Subsection 9B.5.1. The capacity of the barrier system is not approached by the fire intensity, except possibly during the time when the ventilation rate to the area experiencing the fire has been increased to facilitate fire suppression activities.

It is possible that during the detailed design phase certain areas of concentration of cable trays may exceed the normal or electrical combustible loading limit. Multiplexing of signals and the overall plant layout tends to minimize the number of these areas of concentration of cable trays. Options are available to the detail designer to allow specific concentrations of cable tray above the general stated combustible loading limits. For example, the designer could use one or more of the following options:

- **Option 1**

  One option is to use cable insulation with a lower required thickness, a low heat of combustion, or a low burning rate. The number of cable trays could be held constant or the same number of cables could be routed through fewer cable trays.

- **Option 2**

  A second option is to utilize cable trays with solid bottoms and solid covers for congested areas.

9B.6 REFERENCES

9B-1 U.S. Nuclear Regulatory Commission, “Standard Review Plan, NUREG-0800,” SRP Section 9.5.1 and Branch Technical Position SPLB 9.5-1.

9B-2 Cote, Arthur E., “NFPA Fire Protection Handbook,” National Fire Protection Association, Sixteenth Edition.

9B-3 Deleted

9B-4 Electric Power Research Institute, Palo Alto, CA, “Professional Loss Control, Fire Vulnerability Evaluation Methodology Plant Screening Guide,” Draft, EPRI7.REV, Contract No. RP 3000-41, 1990.

9B-5 E.I. Du Pont De Nemours & Co. Inc., “Flame Tests, A report on tests conducted by Underwriters Laboratories, Inc., E-12952, at Northbrook, Illinois,” September 27, 28 and 29, 1976.

9B-6 American Society for Testing and Materials Standard ASTM E-119 “Standard Test Methods for Fire Tests of Building Construction and Materials”.

9B-7 National Fire Protection Association (NFPA) 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems.

Table 9B-1

Estimated Fire Severity for Offices and Light Commercial Occupancies

Combustible Content* kg/m^2 (lbm/ft^2)	Assumed** Heat Potential MJ/m^2 (Btu/ft^2)***	Equivalent Fire Severity (hr)****
24.4 (5)	454 (40,000)	0.5
48.8 (10)	908 (80,000)	1.0
73.2 (15)	1,362 (120,000)	1.5
97.6 (20)	1,817 (160,000)	2.0
146.4 (30)	2,724 (240,000)	3.0
195.2 (40)	3,634 (320,000)	4.5
244.0 (50)	4,315 (380,000)	7.0
292.8 (60)	4,906 (432,000)	8.0
341.6 (70)	5,678 (500,000)	9.0
Data applies to fire-resistive buildings with combustible furniture and shelving*****		

* Total, including finish, floor, and trim.

** Heat of combustion of contents taken at 8,000 Btu/lbm up to 40 lbm/ft^2; 7,600 Btu/lbm for 50 lbm/ft^2, and 7,200 Btu/lbm for 60 lbm/ft^2 and more to allow for relatively greater proportion of paper. The weights contemplated by the tables are those of ordinary combustible materials, such as wood, paper, or textiles.

*** SI units: 1 lbm/ft^2 = 4.88 kg/m^2; 1 Btu/ft^2 = 0.0114 MJ/m^2

**** Approximately equal to that of a test under the standard curve for the listed periods.

***** Reproduced from Table 7-9B, NFPA Fire Protection Handbook, Reference 9B-2.

Table 9B-2

Fire Severity Expected by Occupancy*

Temperature Curve A (Slight)
Well-arranged office, metal furniture, noncombustible building. Welding areas containing slight combustibles. Noncombustible power house. Noncombustible buildings, slight amount of combustible occupancy.
Temperature Curve B (Moderate)
Cotton and waste paper storage (baled) and well-arranged, noncombustible building. Papermaking processes, noncombustible building. Noncombustible institutional buildings with combustible occupancy.
Temperature Curve C (Moderately Severe)
Well-arranged combustible storage, e.g., Wooden patterns, noncombustible buildings. Machine shop having noncombustible floors.
Temperature Curve D (Severe)
Manufacturing areas, combustible products, noncombustible building. Congested combustible storage areas, noncombustible building.
Temperature Curve E (Standard Fire Exposure-Severe)
Flammable liquids. Woodworking areas. Office, combustible furniture and buildings. Paper working, printing, etc. Furniture manufacturing and finishing. Machine shop having combustible floors.

* Reproduction of Table 7-9E, (Reference 9B-2). See Figure 9B-1 for the temperature curves identified in this table.

Table 9B-3

Cable Type and Configuration for UL Tests*

Cable Type	Cables Per Tray 0.304 M (1 Ft) Wide	Tray Combustible Loading MJ/m^2 (Btu/ft^2)
7/C#14AWG XLPE-FR	94	1,613 (142,000)
7/C#14AWG Tefzel	94	256 (22,500)
7/C#14AWG Tefzel	202	550 (48,400)
19/C#14AWG XLPE-FR	37	1,544 (136,000)
19/C#14AWG Tefzel	37	200 (17,600)
19/C#14AWG Tefzel	58	313 (27,600)

* (This table is reproduced from Reference 9B-5)

Table 9B-4

Summary of Burning Rate Calculations

Material/Design Limit	Source of Data	Burning Rate*	Burning Rate**
XLPE-FR	Fire Vulnerability Evaluation bench scale burning data (Ref. 9B-4)	10.417 (917.3)	32.724 (2882)
XLPE-FR	Estimated from tests at UL (Ref. 9B-5)	6.67 to 12.05 (587.3 to 1061)	20.955 to 37.853 (1,845 to 3,333)
Tefzel	Estimated from tests at UL (Ref. 9B-5)	2.22 to 4.367 (195 to 385)	6.988 to 13.716 (615 to 1208)
Ventilation limited (Three air changes per hour)	Fire Vulnerability Evaluation Plant Screening Guide, Equation 47 of Attachment 10.7 (Ref. 9B-4)		0.820 (72.2)
Design normal maximum limit	Typical for power houses (Ref. 9B-2)		4.040 (356)
Fire barrier capability	ASTM E-119 curve for three hours (Ref. 9B-6)		15.123 (1332)

* MJ/min per m^2 of surface area (Btu/min/ft^2)
** MJ/min per m^2 of cable tray or floor area (Btu/min/ft^2)

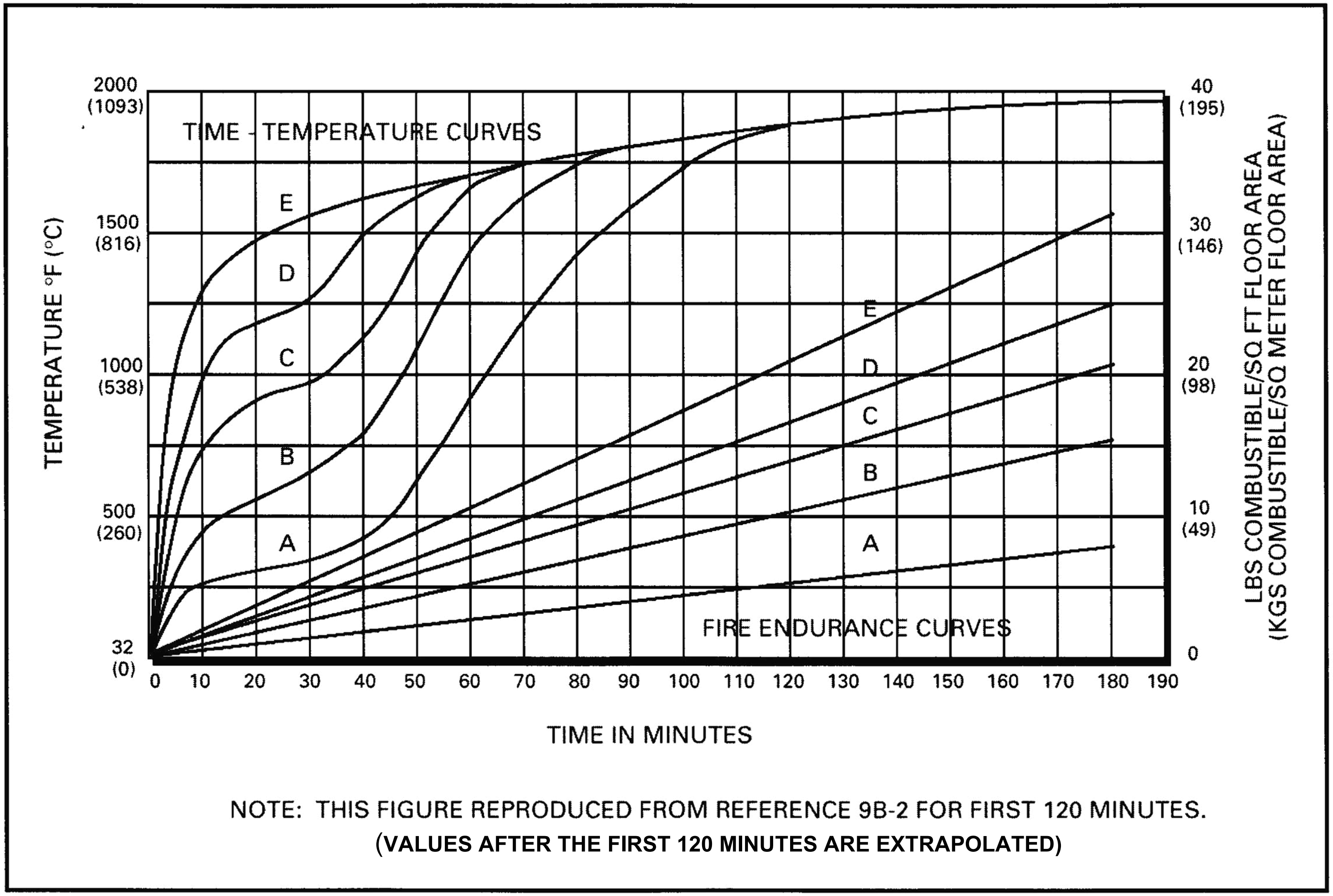


Figure 9B-1. Time-Temperature Curve and Fire Endurance Curves