Plastic Pipe and Fire Safety

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assemblies traversing across sections, such as floor-to-floor, unit-to-unit, shaft-to-unit, etc. These same assemblies, which routinely involve plumbing, electrical, and HVAC elements, must also preserve the specific fire safety design features that were part of the original, basic wall design. Such wall designs may be considered generic, but once the utilities needed for a specific project are called out, the final design will become project specific.

The most common way to describe the performance of fire-resistive construction is through specification of an hourly rating. The hourly rating is used to describe anticipated fire endurance of specific fire-resistive elements, such as floor slabs, slab walls, and chase or shaft constructions. These assemblies are characterized by their ability to resist a standard fire determined by the ASTM E-119 time-temperature curve, with associated pass/fail criteria for a specific fire endurance period.

Given the wide variety of construction features found in fire endurance rated buildings, this review will concentrate on walls or floor/ceiling assemblies, as these are the most commonly associated with piping elements. In terms of fire rated walls and floor/ceilings, these may be built as monolithic assemblies composed of concrete slabs only, <u>or</u> they may include assemblies containing cavities. The latter occur when metal or wood studs or joists form the structural system and cladding, and include inorganic materials like gypsum wallboard or plaster.

There are many variants of these systems, for example, when concealed spaces and/or hung ceilings, shaft, or chase walls are included in a design. The latter occur when an enclosed space is deeper than a normal wall and may include single or multiple fire resistive membranes that are penetrated by piping. Walls with only one membrane that is penetrated (a cavity wall of floor/ceiling assembly) is characterized as a *membrane penetration* as opposed to a *through penetration.*

Proper execution of fire endurance rated design features is important to maintain the integrity of all fire resistive wall designs, such as those found in the Gypsum Association Handbook [9]. This is especially true when assemblies are modified by the installation of plastic piping. Figure 7 shows examples of typical fire-resistive assembly configurations.

3. PLASTIC PIPE IN FIRE-RATED BUILDINGS.

The plastic piping systems of greatest concern in fire rated buildings are, by far, those for drain, waste, and vent (DWV) functions and drainage of rainwater applications. These pipes, which transport waste and gases through a building, are hollow and combustible. Therefore without appropriate installation and mitigation their presence could create a natural weakness in a building's fire rated construction features. Potentially, smoke, hot gases, and products of combustion could pass through these pipes if the fire resistance ability of their openings is not properly addressed.

Other plastic piping systems, such as water supply piping used to transport hot and cold running water from one part of building to another, and sprinkler piping for fire suppression occur in fire resistive assemblies. Plastic pipe applications for process piping are also common, especially for movement of chilled water and (high purity) chemicals in hazardous occupancies, such as semiconductor fabrication sites.

The classes of piping materials found in the applications described above are differentiated from those installed in DWV applications because those pipes contain a liquid that enhances fire endurance during fire incidents or fire exposure. Such piping applications are not vented and are generally smaller in diameter than in DWV applications. The use of such smaller diameter sizes reduces the risk of failure in the event of a fire. It also reduces the relative size of the voids that may form if they do fail.

As discussed above, the term "through penetration" is generally taken to mean an opening that transverses an entire fire-resistive assembly. Such openings are usually made for the penetration of piping, electrical, or other building services or possibly for joints (e.g., earthquake joints or construction joints) in concrete slab assemblies. How are such openings characterized and, most importantly, how are these openings treated to prevent the unwanted spread of fire?

Membrane penetrations are a close relative to through penetrations, but differ in that they encompass openings in fire resistive membranes. Such penetrations *do not* traverse the <u>entire</u> fire-resistive assembly. Rather, only a portion of the assembly is transversed. Examples of membrane penetrations include single-sided plumbing penetrations, such as those under sinks, and openings created by electrical boxes in walls or ceilings for outlets, switches, or lighting applications.

To ensure that these penetrations maintain their integrity in the event of a fire, a through penetration or membrane penetration firestop assembly may be used. Either generic firestops or proprietary components requiring careful installation may be used. Generic fire-resistant stopping materials, such as grout or thermal insulation, can also be used to insure that the

The exception has been the Uniform Plumbing Code [28]. This plumbing code, developed and promoted by the International Association of Plumbing and Mechanical Officials (IAPMO), had been distributed until the early 1990s by ICBO as part of its "Uniform" Code series. Before 1999 the UPC severely restricted the use of plastic pipe in fire- resistive buildings in many applications. Recently, the UPC permitted plastic piping installation only in buildings three stories high or less. In the 2000 code, however, the Uniform Plumbing Code was modified, allowing unlimited use of plastic pipe in constructions of all types.

During this same period the NFPA 101 " Life Safety Code" recognized the importance of protecting through penetrations in fire-resistive construction for piping and electrical systems (see Chapter 5 and Appendix "A" in the 1991 edition of the NFPA 101 document [29]. The Life Safety Code refers to the ASTM E-814 test method and includes a table summarizing performance requirements for through penetrations for both metallic and non-metallic piping types.

One critical factor in the code development over the last 20 years is the potential impact of fire spread due to positive pressures generated in structural fires. The BMCM was the first model code group to adopt the positive pressure requirement in its testing guidelines; other code groups followed suit. Unfortunately, the positive pressure testing issue has called into question early testing of pipe penetrations in furnaces, which did not necessarily apply positive pressures to tested specimens. Concern about the effects of positive pressure on the performance of floor/ceiling penetrations is warranted. Fires generate the maximum amount of positive pressures in the top one-third of affected rooms or compartments. Pressures below the top two-third of fire-affected rooms are negative in all but unusual cases and may actually encourages an inflow of cooling air at through penetrations like low on wall sink installations. [30].

The application of ASTM E-119 and E-814 to the testing of plastic pipe and penetrations provided model code developers with a firm understanding of the characteristics and properties of plastic pipe for use in structures. Thousands of fire endurance test reports based on assembly testing are available in books from accredited third party testing labs, as well as in design compendiums prepared by manufacturers and trade associations for use by architects, engineers, and other specifiers. Much of this data is also available in automated format on CD ROMs, which include construction detailing, relevant testing data, product performance, and related codes and standards information [31].

5.PLASTIC PIPE APPLICATIONS

The use of plastic pipe in a variety of building types and applications is reviewed below.

5.1 Plastic Pipe System Used in Fire-Resistive Construction.

Thermal expansion and contraction of plastic pipe in fire-resistive construction is a factor of concern in high-rise construction. The history and techniques on such installations is available in Robert C. Wilging's recent review [32]. Given that plastic piping materials are combustible, how can satisfactory performance be maintained if these products are incorporated in fire-resistive construction elements?

First, let us consider the characteristics of post-flashover fires, which may impact the integrity of through penetrations. Based on the data obtained from ASTM E-119 and E-814 testing, three general criteria can be used to determine acceptable performance:

- Increases in temperatures on unexposed faces of samples
- Maintenance of load bearing capabilities during and after fire exposure
- Development of openings in an assembly through which smoke and hot gases can travel.

In the case of the first and second set of criteria, the presence of additional combustible materials that might lead either to unwanted heat transfer or physical damage to a structural system where plastic pipe is installed must be evaluated. The tests to determine the impact of plastic piping systems were originally conducted in metal stud framed wall or wood framed analogs. In both cases the use of the plastic plumbing pipes did not reduce the wall's fire endurance <u>if</u> penetrations were sealed carefully and were not oversized. This suggests that the inclusion of plastic pipes did not create or lead to unusual heat transfer that could affect the integrity of structural systems under normal loading.

Fire endurance tests of cavity wall constructions including plastic pipe systems have determined when failure will occur when such installations are exposed to significant fire threats:

- horizontal through penetrations by plastic pipe tend to melt readily

- **Rule #2:** Fire resistive assemblies containing hollow spaces tend to out perform similar analogs composed of the same materials without hollow spaces.

This rule reflects the greater insulating ability of air as compared to most common building materials, as well as the impact such voids have on thermal conductivity overall. For example, the thermal endurance of hollow clay tile assemblies or concrete slabs with void spaces as compared to solid analogs. Therefore, cavity walls with piping installed can be expected to perform better than the solid analogs with piping installed.

- **Rule #3:** Insulated assemblies can be expected to perform better than uninsulated ones.

In cavity walls the use of thermal insulation to reduce heat transfer in day-to-day use also leads to greater fire endurance. Thus, a stud wall of any type will be expected to perform better (with or without piping) if insulation is present. Such insulations do not have to be fire-rated materials but can simply be rated for thermal performance. These same insulations enhance fire performance and are cited in the calculated fire endurance methodologies found in the model codes for determining the performance of wood framed walls or for acoustical performance.

- **Rule #4:** Smaller openings in walls will lead to lesser diminution of fire endurance than larger openings.

As several of the fire endurance testing results presented here demonstrate [2,3,14-19], [30], it is possible to fire-stop a small diameter opening, i.e., a 1-1/2" diameter through penetration of DWV piping, by installing that pipe with minimal annular space using generic fire-stopping materials.[f] Conversely, multiple through penetrations, or those involving larger diameters of pipe, will require treatment with active through penetration fire-stopping systems, such as listed intumescent or thermal insulating materials, or cut-off devices.

Note, it is extremely rare for a fire resistive assembly to be built exactly as it is found in generic form as described in the tables of the model building codes. Such assemblies will

[f] These observations are consistent with those relating to the fire performance of small, individual electrical boxes installed with proper separation, as required by the building codes.

have piping present and/or electrical components and possibly insulation and other components for data transmission. It becomes the responsibility of the designer and regulator to understand how the inclusion of components such as piping elements will impact the performance of these walls if a serious fire occurs.

In summary, deeper walls, walls with additional layers of gypsum wallboard, and insulated walls will behave better in the event of a fire than walls without these properties. If these walls include piping components, tested fire-stopping approaches and technologies must be applied for all penetrations. Installations including larger diameter pipes or multiple pipe penetrations require more sophisticated fire-stopping approaches.