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CMR

October 20, 1992

To: Pipe Resource Organization (PRO)

RE: Article on PVC Piping in ICBO Journal

The enclosed article " Is PVC Piping Firesafe?" appeared in the September-October 1992 issue of *Building Standards*, the ICBO bi-monthly journal and was sent to me by the author, Dr. Joseph B. Zicherman.

It is for your information and files.

Roy

cc: Pat Benkner
Bob Burnett

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# Is PVC Piping Firesafe?

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*He has been active in the ICBO code development process and has worked extensively on the recent code changes to the* Uniform Building Code™ *(U.B.C.), including adoption of the American Society for Testing and Materials (ASTM) E 814 Standard,* Fire Test Method for Through-Penetration Firestops *as U.B.C. Standard No. 43-6.*

*Dr. Zicherman and IFT, Inc., have developed manuals on the use of various products as components in fire-resistive assemblies, and he is developing software to assist in product selection and specification processes. Dr. Zicherman's professional experience also includes teaching, writing for publication and directing product development programs.*

Because polyvinyl chloride (PVC) is an organic polymer, there are frequent firesafety questions about its use as piping in fire-resistive construction. What measures must be taken to ensure the integrity of fire-resistive assemblies penetrated by PVC piping or of assemblies containing PVC piping in wall cavities or floor/ceiling spaces? What is the firesafety record of PVC piping used in plumbing applications?

Answers to these questions lie in a review of testing and research results, performance in the field, and applicable codes and standards.[1]

**Historical Review**

The performance of PVC pipe was originally evaluated in extensive ASTM E 119 fire-endurance test programs conducted in the early 1970s at the National Institute of Standards and Technology's (NIST) Center for Fire Research (CFR), at Ohio State University, and at the University of California at Berkeley.[2] These programs were designed to determine whether fire-resistive wall assemblies whose cavities contained plastic drain, waste and vent (DWV) piping and whose membranes had been penetrated by fixture connections could maintain their fire ratings. The test results showed that, depending on how the pipe was installed, the piping would not reduce the fire ratings of such walls.

American Society for Testing and Materials E 119 was used in these programs because it was the only test method available to assess uniformly the performance of such elements as plastic pipe that entered, exited or went all the way through—that is, "through penetrated"—a test assembly at the time the fire-endurance performance of assemblies containing plastic pipe became important to regulators. However, ASTM E 119 was not a perfect test method. It required a specimen no smaller than 100 square feet, but it did not provide specifics on instrumentation or specimen configuration. Nor were there any criteria defining the atmospheric pressures applied to specimens in the test furnace. Overlaying this situation, which contributed to variability in testing methods, was the large number of fire-resistive assemblies the codes accepted, none of which had ever been tested with piping installations of metal *or* plastic.

These factors, as well as the large number of plumbing system configurations and combinations possible, made it necessary to

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*The views expressed here are those of the author and do not necessarily reflect the opinion or agreement of the International Conference of Building Officials.*

[1]The specific products considered here include PVC drain, waste and vent piping; CPVC (chlorinated polyvinyl chloride) domestic hot or cold water piping; and CPVC sprinkler piping. Chlorinated polyvinyl chloride is derived from PVC. None of these products includes plasticizing additives. They are based on unplasticized PVC, which is referred to in Europe as "UPVC."

[2]See also NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials.*

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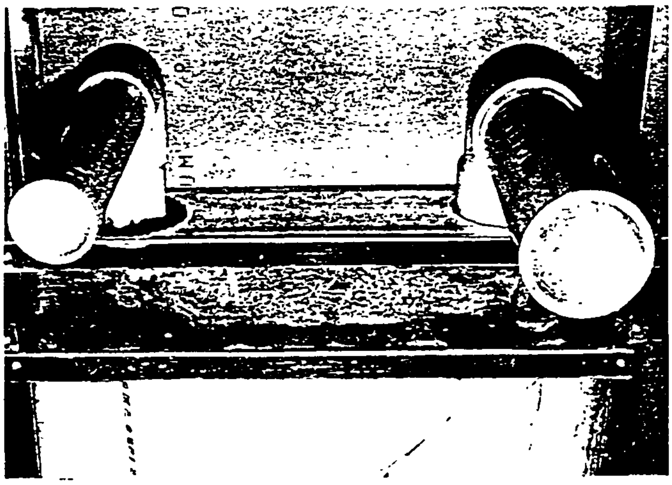
select and test the most basic plumbing wall designs available. The designs chosen were based on certain considerations. Among these was the fact that the most commonly used and most economical plumbing wall is the wood-stud cavity wall of minimum depth faced with gypsum wallboard. The DWV system is a more vulnerable plastic piping system than supply piping because it uses larger pipe sizes, the pipe is empty most of the time, the system is vented



Polyvinyl chloride piping was tested using ASTM E 814, *Fire Test Method for Through-Penetration Firestops*. The piping was installed in a fire-resistive wall assembly whose fire rating had been previously established in full-scale ASTM E 119 tests.

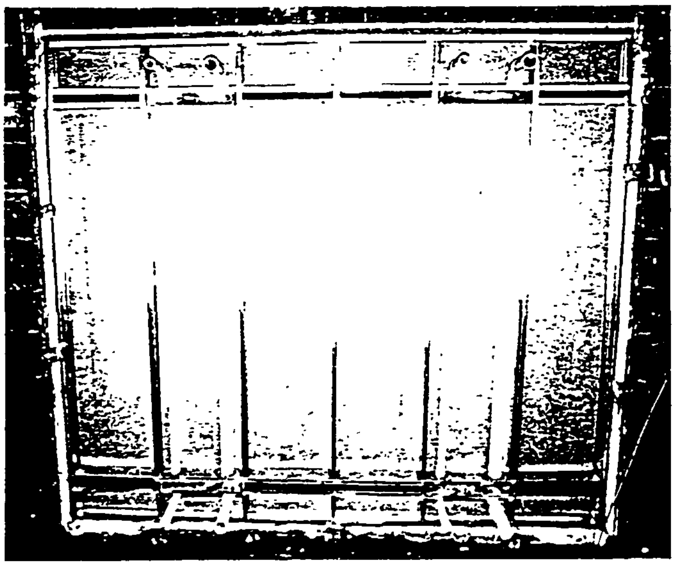


**Figure No. 1—Fire-endurance Testing of PVC pipe products, ASTM E 814 test preparation (before).**

and includes stacks, and the connections must penetrate wall membranes at various locations. From a firesafety standpoint, the worst penetrations for DWV piping are back-to-back penetrations for trap connections Single-side trap connections and pipe stacks or branches that are within a cavity wall, but have no trap connections, are less critical.

With these parameters in mind, each of the initial ASTM E 119 test series approached the problem from a different perspective. The CFR series, which was the most extensive, assessed the performance of PVC pipe on a side-by-side basis with cast iron, copper and acrylonitrile-butadiene-styrene (ABS) plastic pipe systems. This series evaluated walls as narrow as those based on 2- by 4-inch wood framing and as deep as double-stud walls on wide plates, which are commonly found as party walls in townhouse-style construction. Test configurations also included various plumbing chase designs and a metal stud wall.

The CFR tests provided information on the base-line performance of the materials in various framing and piping configurations. The tests also demonstrated the importance of clearance between elements of PVC piping that penetrate gypsum wallboard and the importance of preventing stresses on wallboard, especially those which could be caused by fittings at through penetrations, oversized pipe and fitting contact. Installation methods, which included metal sleeving for plastic pipes, were also tested.

The Ohio State University tests evaluated relatively standard ASTM E 119 test wall assemblies without attempting to account for vertical fire spread to simulated upper or lower floors. Grout was used as the firestopping material where plumbing traps connected to waste and vent stacks. One- and two-hour-rated designs of 2- by 4-inch and 2- by 6-inch wood-frame walls with PVC DWV pipes were successfully tested for both fire endurance and hose stream resistance.

The University of California series tested one-hour-rated, 2- by 6-inch wood-frame test walls with simulated floors above and below a fire floor. Two tested methods were successfully used to fire-stop locations where PVC traps penetrated gypsum wallboard: Either 16-gauge sheet metal heat shields were installed to protect the penetration area or fiberglass batt insulation was placed in the piped stud cavity to a height of 48 inches.

These three test series revealed the importance of installation methods which included the use of grout, metal sleeves, heat shields and thermal insulation. Installation detailing, which prevented pipe and fittings from pressing against gypsum wallboard membranes, was shown to help performance and to prevent the formation of openings that might lead to premature burn-through. Penetration diameters could not be oversized, and annular spaces had to be sealed with the appropriate materials. Nor could openings in plates be oversized unless they were filled with firestopping materials.[3]

### New Test Method Adopted

In 1981, the adoption of ASTM E 814, *Fire Test Method for Through-Penetration Firestops,* provided a needed methodology for testing items penetrating fire-resistive assemblies. It was developed to define instrumentation, appropriate specimen sizes and configurations to evaluate through penetrations of an assembly whose fire rating had been previously established in full-scale ASTM E 119 format. American Society for Testing and Materials E 814 uses the ASTM E 119 time-temperature curve, but it allows

[3]This is consistent with good practice, since oversized openings at plates or other penetration locations for any penetrating elements, plastic or otherwise, run counter to building code regulations that are designed to prevent spread of fire and smoke from compartment to compartment. Each of the model codes contains language to this effect.



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TABLE NO. 1—FIRE ENDURANCE TESTING OF PVC PIPE PRODUCTS

| | CAVITY WALLS AND PARTITIONS | CAVITY FLOOR/CEILINGS | SOLID CONCRETE SLAB MASONRY WALLS AND FLOOR/CEILINGS |
|---|---|---|---|
| Construction | Bearing and nonload-bearing gypsum-clad assemblies with wood or steel studs, minimum frame 2- by 4-inch nominal; tests have included plumbing chases to 20 square inches | Wood- and metal-framed assemblies with 10-inch nominal joist systems with gypsum wallboard lower membrane and plywood or concrete upper surfaces | Thickness ranges from 4- to 8-inch details |
| PVC piping systems tested | $1^1/_2$-inch laterals with maximum 4-inch vertical DWV pipe, with generic firestopping approaches: maximum 6-inch through-penetrating elements tested with proprietary approaches tested | Maximum through-penetration size of 4 inches | Maximum opening size tested of 12 inches |
| ASTM E 119 and ASTM E 814 fire ratings achieved | One and two hours | Two hours | Two and three hours |
| Summary of test conducted | Twelve using generic firestopping approaches; four using proprietary approaches | Two using proprietary firestopping | Seven using proprietary firestopping[1] |

[1]These are included as examples. Substantially greater numbers of assemblies have been tested with proprietary systems than are presented here.

for smaller specimens, since the test assembly need only be representative; from a practical standpoint, this means having sufficient clearances between the edge of the specimen, the test furnace and the fire stop itself. This does not preclude using ASTM E 814 with large specimens such as those required for ASTM E 119, evaluating multiple penetrations or assessing other firesafety aspects of an assembly while assessing the integrity of the through penetration.

The ASTM E 814 method has proven useful in developing new roducts because it provides a specific test method for regulators concerned with through-penetration integrity. It has proven especially appropriate for evaluating straight through penetrations, such as those made for sprinkler piping, supply piping, and elements of other mechanical or electrical systems. American Society for Testing and Materials E 814 has been adopted by all three United States model code organizations and is referenced in the Council of American Building Officials' (CABO) guidelines dealing with ducts, shafts, and pipe and cable penetrations. A similar standard was developed by Underwriters Laboratories® (UL®) as UL 1479.

In contrast to generic plumbing elements installed in cavity walls, which typically are subjected to tests under ASTM E 119 or ASTM E 814 with ASTM E 119-sized specimens, most of the listed and labeled proprietary penetration firestopping systems and devices deal with straight through penetrations of monolithic assemblies, such as slabs or walls. They are not generally applicable to plumbing wall penetrations of gypsum wallboard membranes, though exceptions do exist.

While few technical articles referring to the fire performance of PVC pipe were published in the 1980s, third-party laboratories and listing agencies conducted numerous ASTM E 119 and ASTM E 814 tests during that period. The outcome of these tests reflect a maturation of industrial technology and constitute a substantial database. Table No. 1 summarizes such fire-endurance test results on PVC pipe products with generic and proprietary firestopping systems, conducted by both public and private testing agencies under the ASTM E 119, ASTM E 814 and UL 1479 test protocols.

More recently published were the findings of an independent dy conducted over the past several years to evaluate the firesafe- of plastic piping products. As part of an environmental impact report for the State of California's Department of Housing and Community Development, the study examined the appropriateness of revising the state plumbing code to allow expanded use of plastic pipe. These findings indicate that PVC piping products are safe for use in fire-rated buildings, provided compartmentation is maintained (SRI 1983, 1989). The report recommends appropriate construction techniques and through-penetration firestopping methods to achieve this and stresses effective enforcement of applicable codes and standards.

**Fire Endurance of PVC Pipe**

Once flashover has occurred in a building plumbed with PVC pipe, what can be expected to happen? And what have we learned from fire-endurance testing of these products over the past 20 years?

The ASTM E 119 test models a conservative, postflashover structural fire. In such a situation, most heat transfer within the space affected by the fire is by radiation and re-radiation, as opposed to conduction through building elements, or by convection, as through the movement of hot gases (Kanury and Holve 1988). From a practical standpoint, PVC pipe found in cavity walls is strongly affected by this balance of heat transfer modes because increased temperatures cause PVC pipe to soften, sag and eventually fall to the bottom of a stud cavity or plumbing chase well before the gypsum wallboard protecting the cavity falls away. This results in minimal exposure of the pipe to direct thermal radiation.

For example, wallboard fall off does not typically occur in a two-hour ASTM E 119 fire exposure of an assembly that consists of two layers of $^5/_8$-inch gypsum wallboard on each side of metal or wood studs. As a result, the cavity heats up far more slowly than the fire compartment because it is shielded by the wallboard. Polyvinyl chloride pipe within such a stud cavity will soften, melt and drop to the bottom of the cavity in the first hour of the test. Rather than being distributed throughout the height of the wall, the pipe is thus found as a charred mass at the bottom of the stud cavity when interior temperatures there begin to approximate furnace temperatures. This observation has been borne out by examination of hose-stream specimens, whose exposure duration is half the rating of a test wall, where PVC stack materials are found at the bottom of plumbing chases.

How does PVC piping in a wall cavity or passing through a wall affect the fire performance of the rated assembly? The fire endurance of rated assemblies built with steel or wood framing; gypsum wallboard; and concrete-and-masonry walls, floor slabs and floor/ceilings are well characterized from a regulatory standpoint. Examples of many wall, floor, and floor/ceiling designs that have one-, two-, or three-hour fire ratings are found in the model codes, in UL's *Fire Resistance Directory*, and in the *Fire Resistance Design Manual* published by the Gypsum Association. One of the reasons the concept of generic, fire-rated assemblies is so widely accepted is that such designs have been tested repeatedly through the years under the ASTM E 119 method in similar, generally accepted configurations.

However, an almost unlimited variety of assemblies may exist when plumbing is installed in the field. For example, a wall is the most common type of fire-rated assembly used with plumbing systems. It may include a simple through penetration, as for sprinkler piping; various configurations of pipe without penetrations, as for runs of drain and vent pipe; or a single penetration, as for a single sink, often called a "membrane penetration." Back-to-back penetrations, such as those that occur in certain fire-rated, multiple-unit dwellings and include vertical runs of DWV pipe, are perhaps the most common, most critical configurations from a firesafety standpoint.

In principle, a wall assembly penetrated by any material is more prone to failure than the same assembly without penetrations. This is because openings or disruptions in protective membranes such as gypsum wallboard cause stress that is absent from unpenetrated assemblies. For wall assemblies, the most stressful situations include DWV lines running vertically within the wall and through penetrations, as opposed to membrane penetrations of only one side. For this reason, satisfactory fire test results from wall assemblies with vertical pipe runs and a through penetration provide the "worst-case" fire test scenario. Assemblies in which PVC piping materials run within cavities but do not through-penetrate the wall or penetrate just one side of the wall are less stressed and thus less prone to failure than the designs incorporating both through penetrations and vertical runs of PVC drain and vent piping.

In the past, concern has been raised about the use of exposed PVC pipe in areas such as parking garages and the basements of fire-resistive buildings. Since such buildings incorporate compartmentation, the boundaries of the fire-resistive construction envelope are required to prevent fire spread, and they are designed accordingly. If through penetrations are properly protected, fire spread from affected compartments is thus mitigated. In addition, PVC pipe will not ignite readily before flashover because it contains chlorine, which provides built-in resistance to ignition and does not contain plasticizers, which would reduce that resistance. After flashover, the exposed PVC piping will contribute to the fire and smoke developed, along with any other combustibles in the affected compartment.

### Firestopping Approaches and Systems for PVC Pipe

Firestopping for PVC piping systems falls into two categories. The first involves generic, passive approaches and nonproprietary materials such as grout, thermal insulation, and other filling or back-packing materials at penetration locations. These methods have been demonstrated in ASTM E 119 tests on cavity walls with DWV stack-and-trap connections. This approach has been successful for various one- and two-hour-rated plumbing wall assemblies, provided construction detailing was performed reasonably. The most typical of these methods uses nonshrinking grouts or commonly available fiberglass batt insulation to prevent fire spread.

The second approach to firestopping PVC through penetrations of fire-rated walls, slabs or assemblies involves the use of proprietary firestopping products. Most of these products are specialized mastics, insulations or thermally activated systems based either on mechanical closure of openings or chemical closure achieved through intumescent technology.[4] These systems rely on the fact that, during a fire exposure, PVC pipe becomes soft before igniting. Thus, an appropriate intumescent material will close and seal an opening containing such a pipe before fire can spread.

Successful one-, two-, and three-hour fire tests have been conducted with intumescent systems for openings in masonry walls up to 12 inches in diameter under positive-pressure fire test conditions (UL 1988).Tested and listed thermally activated mechanical firestopping devices include those that can plug a pipe at a through penetration or cut through a plastic piping assembly and seal it with a guillotine-like device to prevent fire spread when elevated temperatures occur.

### Recent Research

Since the early 1980s, research into PVC piping firesafety has focused on two areas. The first is proprietary systems for firestopping that requires extended fire endurance or involves larger openings and pipe sizes and larger numbers of penetrating elements. These efforts have led to the development of specific systems and associated installation methodologies to protect such openings, and to listing with approved third-party agencies. In most cases, the research committee of one or more of the model code organizations has also reviewed the performance of these products.

The second area of research involves development of generic firestopping systems for metal-framed walls similar to those demonstrated in the 1970s for one- and two-hour-rated wood-frame walls. In a recent test series conducted with generic firestopping based on grout or fiberglass batt insulation, PVC DWV stack systems with through-penetrating $1^1/_2$-inch laterals and traps were installed in one- and two-hour noncombustible steel-stud wall assemblies faced with gypsum wallboard. The tests were conducted under positive pressure, as called for in the codes for ASTM E 814 testing. Both small- and large-scale assemblies—that is, 4- by 5-foot and 10- by 12-foot assemblies—were tested so that correlations between the former, which are most typically used in ASTM E 814 tests, and the latter, required for ASTM E 119 testing, could be observed. In the latter, instrumentation of through penetrations was conducted according to the ASTM E 814 standard, and test specimens included vertical penetration of concrete inserts that simulated slabs at the top and bottom of exposed sections of test walls (see Figures Nos. 1 and 2). Post-test photos of such penetrations show no vertical fire spread beyond the tested area (Warnock Hersey 1989a and 1989b).

These tests confirm that generic firestopping approaches for PVC pipe perform as satisfactorily with steel-frame assemblies as they did with the wood-stud wall assemblies tested earlier by NIST's Center for Fire Research, Ohio State University and the University of California at Berkeley.

### Pressure Effects on Fires Involving PVC Pipe

During a postflashover fire, there are pressure gradients that increase from negative values in the range of –0.02 to –0.01 inch of water at floor level to zero at about one third the height of the affected room. These pressures continue to increase so that, near the ceiling, positive pressure may be in the range of +0.02 to +0.04 inch of water (Fang 1984).

The effect of such pressure gradients on fire travel through assemblies that include penetrations has been debated extensively in code forums, where the pressures in test furnaces have been an issue. In response, each model code organization has stipulated that positive pressure be applied to assemblies tested under ASTM E 814. This is a conservative assessment, however, since a fire-resistive assembly is most commonly penetrated by a pipe at a sink,

[4]Intumescent materials are those which are engineered to expand during a fire and create an insulating char barrier.



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which will be under negative pressure during a postflashover fire. Yet such pressure requirements are appropriate in testing, since piping may also pass through fire-resistive assemblies high in a room, as at floor penetrations or above a hung ceiling. Sprinkler piping, for example, is usually run overhead, as is domestic hot and cold water piping.[5]

### Water Distribution Piping

Because the cooling effect of the water contained in both chlorinated polyvinyl chloride sprinkler systems and domestic hot and cold water systems prevents ignition and because the additional chlorine atom on the CPVC molecule enhances its fire performance compared to the usual PVC piping materials, generic firestopping approaches are appropriate for these systems. For openings with a diameter greater than 2 inches, devices and proprietary systems that have been tested with PVC or CPVC in these size ranges should be used as required by the codes.

Listings for CPVC-based fire sprinkler systems were obtained after fire tests that included both direct and indirect exposure of sprinkler piping and fittings to fire conditions. These included ambient exposures with temperatures up 1,700°F. from burning wood cribs secondarily fueled with heptane. Various types of sprinklers were evaluated with the CPVC systems, and listings for both light and ordinary occupancies, as well as residential use under NFPA 13D, *Standard for Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes,* have been issued (UL 1985; Wilging 1988).

### Codes and Standards

In the 1980s, the plastic pipe industry increased its efforts to make systematic installation information available to code officials, specifiers and engineers wanting to use PVC piping products in fire-resistive construction. These efforts included publication of the installation manual, *Plastic Pipe in Fire Resistive Construction*[6], which addressed questions of installation detailing, materials to use and which classes of fire-resistive assemblies had undergone testing according to ASTM E 119, ASTM E 814 or both. An updated edition of that document has been published in collaboration with the National Evaluation Service of CABO.

While few changes affecting the use of PVC pipe and fire-resistive construction were made in the 1982, 1985 and 1988 editions of the *Uniform Building Code,* the 1991 U.B.C. includes substantial changes to Chapters 17 and 43, which directly affect PVC pipe products as well as other plastic pipe, tube and conduit products. Along with these changes to U.B.C. Sections 1706 and 4301 through 4308, U.B.C. Standard No. 43-6 has been added. This standard is based on ASTM E 814, with appropriate provisions for measurement of test pressure so that the U.B.C. requirement for positive pressure is satisfied. This standard will augment U.B.C. Standard No. 43-1 for the full-scale testing of walls and floor/ceiling assemblies containing PVC piping products.

At this time there are no restrictions in the U.B.C. on the use of PVC plastic pipe products in buildings of all construction types. For use of PVC piping in concealed spaces, however, reference is made to sections of the *Uniform Mechanical Code*™ which relate to plenums and the use of combustibles in concealed places. In all

[5]Interestingly, the building code in Canada calls for positive-pressure testing to be conducted at a level 10 times that called for in the United States. The justification for this is, in part, based on "stack effect" arguments. One can question the requirement for such high-pressure differentials at tests based on the presence of engineered smoke-control pressurization systems in high-rise buildings constructed today. Such buildings in the United States are also required to incorporate fire-resistive construction and sprinkler systems. Conversely, the stack effect is not a factor in low-rise, fire-resistive buildings.

[6]This manual is available from the Plastic Pipe and Fittings Association, Glen Ellyn, Illinois.

The results of the ASTM E 814 fire endurance test of PVC piping in a fire-resistive assembly are evident in these two photos taken after the test was completed.

**Figure No. 2—Fire-endurance testing of PVC pipe products, ASTM E 814 test results (after).**

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cases, PVC pipe should not be exposed in plenums having an air-handling function without protection. The 1983 *Uniform Plumbing Code*™ (U.P.C.®) restricted use of PVC drain waste and vent piping to buildings of "combustible construction." The 1991 U.P.C. abolishes the combustible construction clause, but—unlike the other model plumbing codes in the United States—will restrict use of PVC drain waste and vent piping to structures three stories or less in height.

### Field Data on Fire Performance

Polyvinyl chloride plastic piping has been used widely in the United States for drains, waste removal, vents, roof drains, chilled water, and low-temperature heating and cooling in nonfire-rated construction for over two decades. The firesafety record for these materials and the fire test results discussed above have been largely responsible for their increased use in more restrictive construction applications.

In addition, the sections on alternate materials and methods in each of the model codes have permitted installation of PVC drain, waste removal and vent piping in fire-rated construction for some years. These include multiple-unit, fire-resistive structures, including high rises. In those projects, no evidence of a fire-related product defect or failure has been reported or has been the subject of a product liability action. The latter is a good barometer of PVC piping fire performance, given the litigious climate in which we work and live.

Rarely have products used in fire-resistive construction been subjected to as extensive an evaluation as PVC-based piping products. They have been the subject of fire-endurance testing at both publicly and privately funded laboratories on numerous occasions and in a variety of configurations, and this test work has been further evaluated by third parties involved in the regulatory process at local, state, regional and federal levels. The results of this testing and evaluation, as well as many years of field use, indicate that properly installed PVC-based piping products do not constitute a fire hazard in structures. ■

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