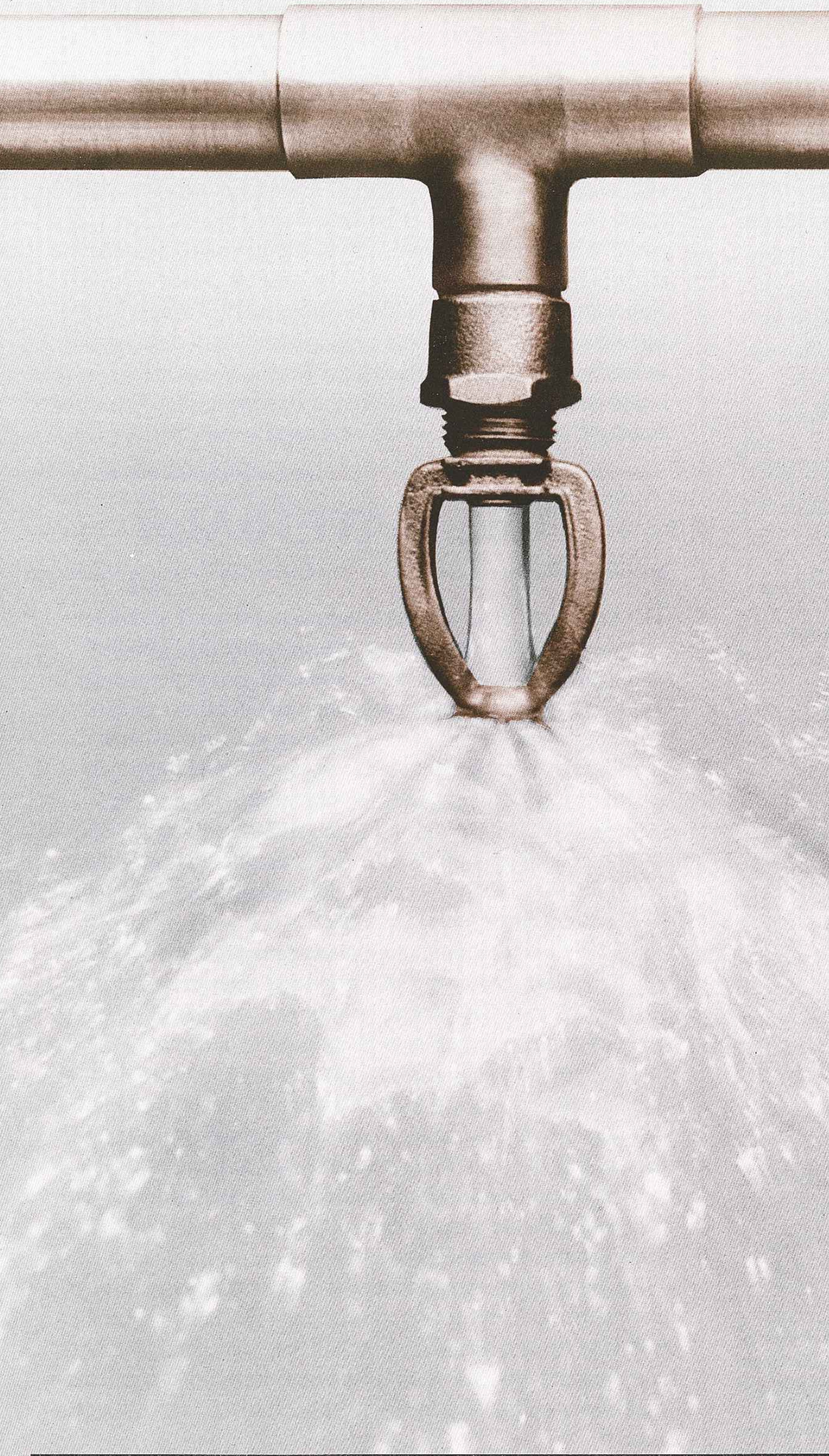
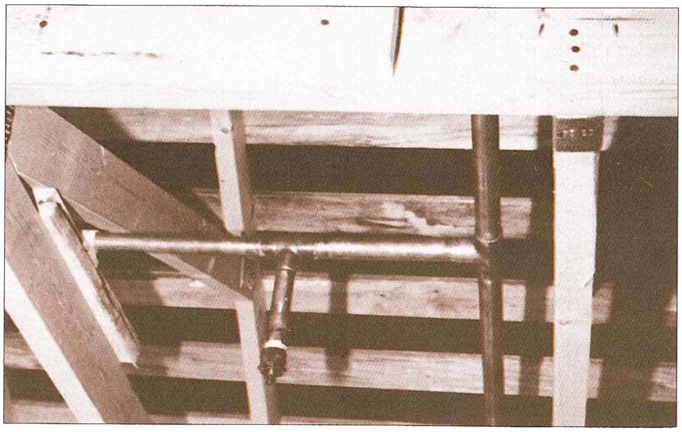
Copper Brass Bronze
Material Selection Guide



Copper vs CPVC for Automatic Fire Sprinkler Systems

Technical comparison of alternative piping materials, installation requirements, performance and system characteristics, and costs for automatic fire sprinkler systems. Material performance is discussed under normal and severe operating conditions common to fire sprinkler installations.

CDA
Copper Development Association



Copper can be installed in unfinished, combustible and/or concealed areas, even where ambient temperatures may exceed 150 F.

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INTRODUCTION

Automatic fire sprinklers, once found mainly in commercial and industrial buildings, are now being installed or retrofitted in hotels, motels, office buildings, single and multifamily residences and mobile homes. The sprinkler piping material needed to satisfy the enormous market these new installations represent must be versatile, simple to install, cost-effective and above all, safe.

For decades, steel pipe with threaded connections was the traditional material for fire sprinkler systems. Steel systems are still being installed today but their weight, high cost and labor-intensive installation are prompting a shift to lighter systems made from copper tube or chlorinated polyvinyl chloride (CPVC) plastic pipe, both approved under National Fire Protection Association (NFPA) standards.[1,2,3] There is little question that CPVC can be a valid alternative to steel systems, but it cannot compare with copper. This publication looks at copper and CPVC systems from the standpoint of safety, design freedom, installation, possible repair and installed cost.

THE MATERIALS

The most cost-effective copper tube for automatic sprinkler systems is Type M, made in accordance with ASTM Standard Specification B 88.[4] Cast bronze and wrought copper fittings for Type M tube are manufactured to ASME standards B16.18 and B16.22, respectively.[5,6] These are the same standard materials specifications that apply to the time-tested use of copper in potable water, heating and air-conditioning systems. The material itself is 99.9% pure copper: mined, refined and recycled in North America. Copper tube for water distribution systems has given safe, reliable service in literally millions of installations since its introduction in 1930.[7]

CPVC is a thermoplastic polymer made by adding extra chlorine (Cl) to ordinary PVC (polyvinyl chloride) using a variety of techniques. The chlorination process may be carried out[8] either by the dry process (in a fluidized bed under very short wavelength radiation) or by the wet process (for example, in an aqueous suspension and in the presence of a swelling agent). In this way the chlorine content may be increased from the 57% present in PVC to 73%, the theoretical maximum.

For the most usual applications, a chlorine level between 63% and 68% is normally used; above this value a conversion process becomes very difficult[8].

Composition and properties depend strongly on the degree and method of chlorination. Processing must be tightly controlled to assure uniformity. As with most plastics, CPVC is compounded with stabilizers, lubricants, fillers and pigments to optimize its processing and/or modify its properties and appearance.[9-11]

CPVC resin for piping is manufactured to ASTM D 2846.[12] CPVC products intended for automatic fire sprinkler systems conform to ASTM F437,[13] F438,[14] F439[15] and F442.[16] CPVC fittings follow iron pipe size (IPS) schedules per ANSI B36.10,[17] while CPVC pipe for fire sprinkler systems is manufactured in a single standard dimension ratio (SDR, the ratio of average outside diameter to wall thickness) of 13.5. Several North American manufacturers process this resin into pipe and fittings. CPVC pipe for water distribution systems was first introduced in 1960. NFPA acceptance of the use of CPVC in fire sprinkler systems, based on Underwriters Laboratories' listing, was granted in 1985.

INSTALLATION ENVIRONMENTS

The type and location of, and permissible installation methods for fire sprinkler systems are described in the National Fire Protection Association's standards NFPA 13, 13D and 13R.[1-3] These standards define the allowable systems in terms of the type and use of the structure or the area within a structure to be protected. Copper is approved for exposed wet pipe systems in Light Hazard Occupanices with the use of ordinary- or intermediate-rated sprinklers. Copper tube and fittings with brazed joints are accepted by NFPA 13, 13D and 13R for service in all categories and areas, including air plenums, attics and crawl spaces.

CPVC is listed for, and limited to service in:

- Light hazard occupancies as defined in NFPA 13;
- Residential occupancies as defined in NFPA 13D (one- and two-family dwellings and mobile homes);
- Residential occupancies up to four stories in height as defined in NFPA 13R;
- Mercantile, service and related storage areas classified as Ordinary Hazard Group 1 or 2, when (1) the building occupancy is primarily light hazard, and (2) they are found within a light hazard occupancy.

  There are a number of installation restrictions on the use of CPVC, including stipulations that:

  CPVC, when concealed, must be installed above a gypsum board ceiling having a minimum thickness of 3/8 inch, a suspended membrane ceiling with metallic support grids with lay-in panels or tiles having a weight of not less than 0.35 lbs/ft^2, or 1/2-inch plywood soffits. In residential systems specified under NFPA 13D or 13R, the ceiling may consist of a single layer of 1/2-inch plywood;

  Exposed CPVC must be installed below a smooth, flat, horizontal ceiling, and sprinklers must be listed quick-response types with deflectors installed within eight inches of the ceiling, or listed residential types installed in accordance with their listing.

These restrictions limit a CPVC system's ability to be retrofitted in an existing structure and can raise the cost of the installation. Copper systems lend themselves well to virtually all retrofit installations.

Sprinkler systems may operate with "wet" or "dry" piping, depending on service conditions. Wet systems are filled with water up to the sprinklers, and are typically used in dwellings and most interior installations not subject to below-freezing temperatures. Dry systems are pressurized with air or an inert gas, which acts as a pressure-sensing medium and triggers the discharge of water rapidly after a sprinkler activates. Dry systems are used where there is danger of freezing. Copper can be installed in both wet and dry systems. CPVC can be used in wet systems only; it must never be installed in a dry system because the energy of the pressurized gas, if released suddenly due to rupture of the pipe, would present a serious safety hazard.

While sprinkler systems can be designed to operate in any reasonably foreseeable ambient temperature range, obviously no system should be allowed to freeze. Installations in areas subject to low temperatures, such as unheated attics and crawl spaces, are permitted if the system is designed such that freezing is precluded. Copper doesn't become brittle at low temperatures and doesn't melt until 1,980 F (1,082 C); therefore, it is safe in normally hot and cold locations.

CPVC is far less ductile than copper, especially at low temperatures. It begins to soften at moderately elevated temperatures. CPVC is restricted to areas where ambient temperatures remain between 35 F and 150 F (1.6 C and 65.5 C). It may be installed in hot locations (ambient temperature above 150 F) only if it is adequately insulated.

PERFORMANCE CHARACTERISTICS

STRENGTH

The short-term burst strength of a pipe or a tube depends upon its dimensions and the tensile strength (at a given temperature) of the material. The short-term burst strength of Type M copper tube in the drawn temper is as much as 2 to 4.5 times that of CPVC pipe in diameters up to eight inches, **Table 1**.

Sprinkler system components can be exposed to high temperatures before sprinklers activate. The lag time is taken into consideration in system design and sprinkler selection. Nevertheless, the designer should understand how the properties of the system components react to transient temperature excursions. For CPVC materials, this information is not readily available.

Figure 1[7, 16] compares the effect of rising temperatures on copper and CPVC. Annealed copper retains essentially all of its strength over the range of temperatures of interest to sprinkler system designers. Available data for hard-drawn, 3/4-inch Type M copper tube suggest a slight decrease in burst pressure over the temperature range shown. In contrast, CPVC begins to lose considerable strength when heated to temperatures even slightly above room temperature.

TABLE 1. Room-Temperature Rated Internal Working Pressures and Burst Pressures for Type M Copper Tube and SDR 13.5 CPVC Pipe

Nominal or Standard Size, inches	Rated Internal Working Pressure, psi			Burst Pressure, psi	
	Type M Copper*		CPVC**	Measured Burst***	Burst**** Rqmt
	Drawn	Annealed	SDR 13.5	3/4" Type M Copper Drawn	CPVC SDR 13.5
3/4	611	407	315	4715	1000
1	506	357	315	3865	1000
1 1/4	507	338	313	3875	1000
1 1/2	497	331	315	3550	1000
2	448	299	315	2935	1000
2 1/2	411	274	315	2800	1000
3	380	253	315	2665	1000
4	377	251	315	2215	1000
6	328	218	315	2000	1000
8	344	229	315	2285	1000

*See explanation CDA *Copper Tube Handbook*, pp 11-12.[7] Based on ASME B31 formula for internal pressures for copper tube,
where:
P = allowable pressure, psi
S = maximum allowable stress in tension, psi
t_{min} = wall thickness (minimum), in.
D_{max} = outside diameter, in.

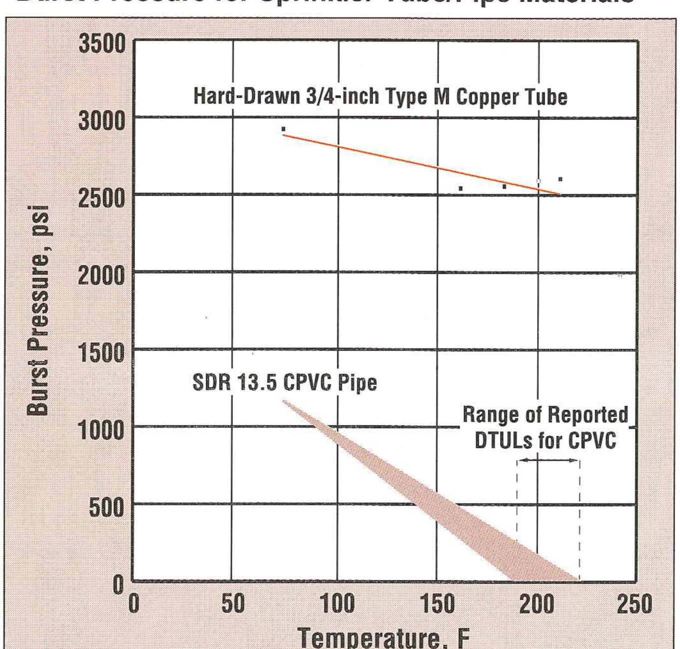
$$P = \frac{2St_{min}}{D_{max} - 0.8t_{min}}$$

**Table X1.1, ASTM F 442[16]

****Copper Tube Handbook*, Table 7, p. 3[7]

**** Table 4, ASTM F 442[16]

FIGURE 1.
Burst Pressure for Sprinkler Tube/Pipe Materials



Hard-Drawn Copper Burst Pressure Test Results from *Copper Tube Handbook*, Table 7, page 30.[7]
CPVC Burst Pressure Calculated Based on UTS Data.[16]

Another factor to consider is that CPVC's stress-strain response becomes time-dependent at even moderately elevated temperatures, such as those frequently encountered in attics and crawl spaces. Two effects are possible: subjected to a constant load, CPVC creeps, or slowly deforms; alternatively, when heated at a constant strain, the increasingly compliant plastic relaxes the applied stress. In practical terms, this means, respectively, that overheated CPVC pipes may sag, and/or threaded joints may loosen over time. Sprinklers overtorqued into CPVC fittings have been known to rotate out of position as the threaded plastic fittings relax, thus misdirecting fire-suppressant water spray patterns when activated.

A standard test, ASTM D 648, measures the distortion temperature under load (DTUL) for CPVC and other thermoplastics. As its name implies, the DTUL is the temperature at which the material no longer sustains a prescribed load without distortion. DTULs for pure, *i.e.*, uncompounded, CPVC have been reported to range from 184 to 221 F (84-105 C).[17, 18,19] Unfortunately, the DTUL for CPVC fire sprinkler pipe is not published.

THERMAL CONDUCTIVITY

Copper's thermal conductivity is about 200 times greater than CPVC's. A copper tube exposed to fire quickly conducts heat away, either along the tube or through the thin tube wall to the water inside. CPVC cannot perform in the same manner. Moreover, SDR 13.5 CPVC pipe walls are typically five to six times thicker than Type M copper tube's, thus surface heat has farther to travel before it reaches the water-cooled I.D. CPVC pipe will, therefore, suffer surface charring and loss of strength when exposed to fire, *even when water is flowing through it.*[20]

Commercial CPVC material,[21] with a chlorine content of 65-68%, starts showing considerable weakening at the softening point of the material, around 212 F (100 C). At about 230 F (110 C) the material essentially loses all it mechanical strength. Significant loss in mechanical strength begins well below the softening temperature, *e.g.*, at the DTUL. In no case can CPVC sprinkler pipe be used above 150 F (49 C).[22] One potential danger is that overheated CPVC pipe may sag between hangers, possibly drooping into the fire and melting, or pinching off the water supply to sprinklers downstream.

EMBRITTLEMENT

Materials that are ductile at room temperature sometimes become stiff and brittle when cold. Copper tube is ductile at all temperatures and will expand (e.g., circumferential expansion due to freezing water) as much as 50% before failure, even when ice cold. Rough handling in cold weather may dent copper tube but will not crack it. CPVC becomes increasingly brittle as temperatures fall. CPVC pipe and fittings are less resistant to impact at 32 F (0 C) than they are at approximate room temperature, 73 F (23 C). CPVC must be handled and stored carefully to avoid creating undetected cracks that may produce failures later on.

THERMAL EXPANSION

Thermal expansion must be accommodated in sprinkler system design to prevent tube sagging, buckling or thermal fatigue cracking. The coefficients of linear thermal expansion for copper and CPVC between 40 F and 120 F (15.5 C and 49 C) are 0.94 x 10^{-5} and 3.4 x 10^{-5} per °F, respectively.[9, 23] A 100-foot run of copper tubing will expand by 0.9 inches when heated from 40 F to 120 F. A CPVC pipe of the same length will expand 3.26 inches over the same temperature range, enough to create potential interference problems.

HYDRAULIC CHARACTERISTICS

Both copper and CPVC have excellent hydraulic properties. NFPA 13 allows the use of a C factor of 150 for both materials in the Hazen-Williams formula for friction loss. In 1-inch, 1¼-inch and 1½-inch pipe, CPVC has slightly larger inside diameters than copper, while in 2-inch and larger pipe, copper has slightly larger inside diameters than CPVC. Since friction loss is related to the internal diameter, CPVC has slightly better hydraulics in sizes 1 inch, 1¼ inch and 1½ inch, while copper has slightly better hydraulic characteristics in sizes 2 inch and larger.

FLAMMABILITY, TOXIC GAS, FIRE SAFETY

Copper is not flammable. It melts at 1,980 F (1,082 C). When heated for a long time in air, it eventually forms solid, inert copper oxides that pose no safety hazards. CPVC, like other chlorinated organics, is difficult to ignite and doesn't support combustion; this is one of the reasons it can be considered for sprinkler systems in the first place. But, even water-filled CPVC pipe begins to degrade, both physically and chemically, at modestly elevated temperatures.

CPVC materials exhibit two temperature-dependent modes of decomposition.[9] The first mode of decomposition occurs in the temperature range 520-570 F (270-300 C) which is associated with the evolution of hydrogen chloride. The second mode of decomposition occurs at a temperature higher than 570 F (300 C). In this decompostion process there is evolution of chlorinated hydrocarbons.

Hydrogen chloride, the gaseous basis for hydrochloric acid, is a toxic, choking gas. Among other dangers, HCl is believed to contribute to the "intoxication syndrome" that inhibits an individual from seeking to escape from a fire scene.[24] One study estimates that the HCl emitted by the decomposition of five feet of vinyl conduit is sufficient to generate lethal concentrations in an average bedroom in about ten minutes.[24]

Because CPVC contains more than 65% chlorine, large volumes of HCl can be produced when the plastic is heated. A simple calculation shows that the complete decomposition of 10 feet (3.05 m) of 1-inch (25-mm) SDR 13.5 CPVC pipe, weighing 3.71 lbs (1.68 kg), produces 2.60 lbs (1.04 kg) of HCl, or about 26.4 cubic feet (0.75 m^3) of the toxic gas at room temperature and atmospheric pressure. Diluted to a still-dangerous 100 parts per million, the HCl occupies 264,000 cubic feet (75,000 m^3) of space, enough to fill a 10-foot (3.05-m) high, 162-foot (49-m) square room.[24]

CHEMICAL RESISTANCE

Some manufacturers of CPVC have listed many products as *not compatible with CPVC material.* A few from the list are:[25]

MANUFACTURER	PRODUCT
Fire Stopping Systems	
Proset	Proseal Plug-Black/Proseal Plug-Red
Flame Stop	Flame Stop V
3M	Fire Barrier CP 25N/s No-Sag Caulk
	Fire Barrier 2003 Silicone Caulk
Tremco	Fyre-Sil Silicone Sealant
	X-Ferno Fyre-Sil Silicone Sealant
Leak Detector	
Federal Process	Gasoline Leak-Tech
Pipe Tape	
Pro Pak, Inc.	Pipe Wrap Tape
Pipe Insulation	
Imcoa	ImcoShield
Insecticides/Termite Sprays*	
Dow Chemical	Dursban
Miscellaneous Materials	
WD-40 Co.	WD-40 Lubricant
Various Sources	Roofing Tar, Edible Oils
Victaulic	Silicone Pipe Lubricant

***Exposure to termiticide:**
It has been found experimentally that CPVC is non-resistant to termiticide. A 15-day exposure at 130 F (54 C) to termiticide at typical concentration (10%) lowered the ultimate tensile strength (UTS) value to less than half that of unexposed samples. The same exposure condition also lowered the burst strength by 40%. Environmental stress cracking (ESC) of CPVC has been reported[26] for exposure to termiticide. ESC can occur within 24 hours with termiticide concentration as low as 1%.

SYSTEM CHARACTERISTICS

DESIGN FREEDOM

Copper combines the inherent safety of an all-metal system with the design freedom of modern, light-weight installation. For new construction, and even more so in retrofited installations, design freedom means the structure doesn't limit the designer's ability to provide the most efficient, cost-effective layout. For example:[27]

- Copper can be installed in either exposed or concealed locations without regard to ambient temperature during construction or use;
- The installation of CPVC is not permitted in combustible concealed spaces. Exposed CPVC cannot be used in any area that does not have a smooth ceiling, or in any area where the ambient temperature exceeds 150 F (66 C);
- Whenever CPVC penetrates a fire-rated wall, appropriate UL-listed fireproofing is required around the pipe penetration to maintain the fire-resistive rating;
- Suitable noncombustible packing is adequate to maintain the fire-resistive rating whenever copper tube penetrates a fire-rated wall;

- CPVC cannot be used in areas subject to freezing temperatures because it is not approved for use in dry systems;
- 3/4-inch copper tube is approved for use in sprinkler systems by NFPA 13. One-inch CPVC is the smallest CPVC pipe listed for use in sprinkler systems;
- CPVC is limited to systems where the maximum pressure does not exceed 175 psi.

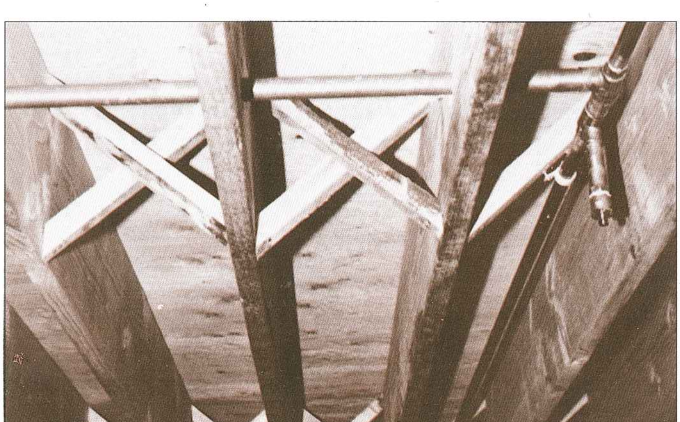
HANGAR SPACING

Copper's elasticity modulus is more than 40 times greater than CPVC's at room temperature (the difference becomes even greater as temperature rises). Therefore, copper sprinkler tube requires fewer hangers than equivalent-diameter CPVC pipe. **Table 2** compares hanger spacings for the most common sprinkler tube and pipe sizes:

TABLE 2. Hanger Spacings for Type M Copper and SDR 13.5 CPVC Sprinkler Systems

	Copper		CPVC	
Nominal Pipe/Tube Size, inches	Hanger Spacing, feet	No. of Hangers per 500 feet	Hanger Spacing, feet	No. of Hangers per 500 feet
3/4	8	62-63	5 1/2	91
1	8	62-63	6	83-84
1 1/4	10	50	6 1/2	77
1 1/2	10	50	7	71-72
2	12	41-42	8	62-63
2 1/2	12	41-42	9	55-56
3	12	41-42	10	50

On this basis alone, copper systems require between 20% and 33% fewer hangers. In addition, copper systems are strong and rigid enough to withstand the reaction forces of a discharging sprinkler. In weaker, less-rigid CPVC systems, individual sprinklers must be supported and/or anchored. The additional hangers and supports increase costs.



Copper fire sprinkler systems can fit neatly in floor-supporting joists in multistory buildings.

For example, a modest-sized 500-foot-long, 1-inch copper system will require about 62 to 63 hangers. A CPVC system of the same length will require 83 to 84 hangers. At a typical installation rate of five minutes per hanger, using copper saves more than 1 hour of labor and 20 hangers, plus sprinkler anchors!

Light Weight — CPVC's light weight, in conjunction with its low stiffness, can result in greater movement of piping from hydraulic loads. This necessitates that more attention be given to proper pipe restaint in above-ground installations.[28]

EASE OF INSTALLATION

No matter what the piping material, ease of installation has an important impact on a sprinkler system's labor costs. Both copper and CPVC can claim this as an advantage over steel pipe, particularly in residential and institutional occupancies. Here are some points to consider when estimating installation costs:

- Nominal 1-inch CPVC pipe and copper tube are about 15% and 28% the weight of 1-inch Schedule 40 steel pipe, respectively. In terms of what a person can carry, copper is a little heavier than CPVC, but CPVC is somewhat bulkier than copper. Weight is not a limiting factor;
- Neither copper nor CPVC require heavy jobsite equipment for assembly; both materials can be cut using hand tools and can be fitted and joined by one worker;
- If space is a problem, remember that SDR 13.5 CPVC pipe has a larger O.D. than the equivalent size of Type M copper tube. Also, Schedules 40 and 80 CPVC fittings have much larger outside diameters than standard copper fittings;
- Copper systems may prove simpler to install than CPVC systems. In many cases, using a convenient hand-held TEE-pulling tool eliminates one fitting and two joints. CPVC systems must use a separate TEE;
- Copper requires brazing or soldering. (Copper systems must be brazed in dry-type systems and in certain exposed wet systems.) Joining can be done with a conventional torch or, when open flames must be avoided, with a resistance heater. With copper, joining can be performed at any ambient temperature. With CPVC, joining is not recommended at temperatures below 40 F (4.5 C) or above 100 F (38 C).

Soldering and brazing copper are inherently safe joining methods when performed by competent installers. *The Copper Development Association (CDA) has for years provided on-the-jobsite training in soldering and brazing, covering proper installation and safety procedures. These training seminars are conducted for contractors, trades organizations and schools.* No program of comparable thoroughness exists for CPVC pipe.

The materials needed to solder or braze copper are not hazardous. NFPA 13, 13D and 13R permit the use of 95-5 tin-antimony solder and brazing filler metals for copper systems.

Joining CPVC calls for special primers and adhesives. These typically contain mixtures of two or more of the following organic solvents: methyl ethyl ketone (MEK), a suspected teratogen (possibly linked with birth defects) and also a potential fire hazard; tetrahydrofuran (THF), which poses risks to kidneys and the liver and can also present a fire hazard; cyclohexanone (CYH), another potential fire hazard and an eye, nose and throat irritant, and dimethylformamide (DMF).[29] Airborne concentrations of these chemicals are controlled under the Occupational Safety and Health Act. Their threshold limiting values (TLV) are given in **Table 3.**[29] Adverse worker health effects have been reported as "unlikely" but the effects of exposure to combinations of plastic pipe solvents, PVC dusts and contaminants detected in some solvent cements have not been fully evaluated.[30]

TABLE 3. Threshold Limiting Values (TLV) (mg/m^3) for Components of Plastic Primers and Adhesives

Compound	TLV
Dimethylformamide	30
Methyl ethyl ketone	590
Tetrahydrofuran	590
Cyclohexanone	200

TESTING

Copper systems can be tested hydraulically or pneumatically, as permitted by local code authorities. Despite the greater need for caution it entails, pneumatic testing is preferred by many installers because it saves time and money. CPVC systems can only be tested hydraulically. The potential risk for explosive failure under high air or gas pressure is too great to permit plastic pipe to be air-tested.

Another time-saver: brazed or soldered joints have full strength the minute they're completed — no matter what the ambient temperature. That means copper systems can be tested virtually the moment the last joint is finished. The joining compounds used to join CPVC take time to set. The time needed to reach full strength depends on the size of the pipe, the temperature, the relative humidity and the tightness of the fit. Testing may be delayed as much as *48 hours* after the job is completed.

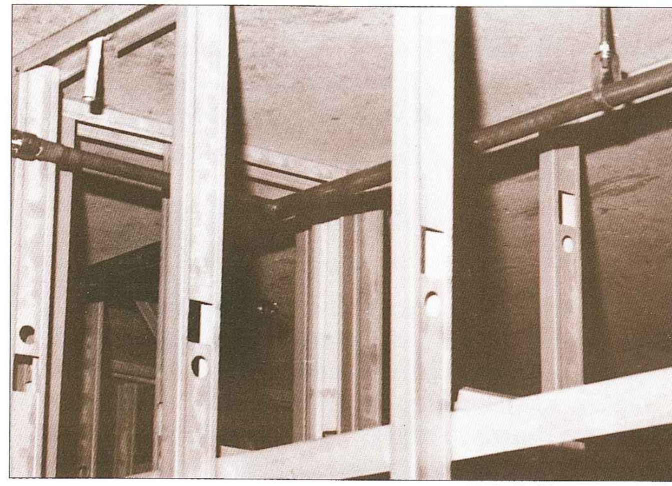
REPAIRS AND REWORK

What if there's a leak?

With copper, if it's a soldered connection, the joint is simply disassembled, cleaned and resoldered — many times re-using the original fitting — before the system is retested. If it is a brazed connection, NFPA permits re-brazing without disassembly to seal the leak.

With CPVC, the offending joint must be cut out and a new assembly glued in its place. That can be expensive. For example, replacing one leaking TEE requires cutting three lines and installing *seven* new parts (three couplings, three nipples and a new TEE) and making *nine* new glued connections!

Also, keep in mind that all applicable provisions of NFPA standards 13, 13D and 13R must be met so long as the sprinkler system is operational, even during alterations and remodeling done long after the system was installed. This means that CPVC system components which normally require shielding must continue to be protected. If, for example, ceiling panels have to be removed temporarily, steps must be taken to keep the CPVC system concealed. These costly measures are not needed in most copper installations.



Copper systems require fewer fittings, fewer joints and fewer hangers and supports than CPVC systems.

COST

When considering cost, we take into account the cost of materials, the ease of installation and the cost of repairs and rework. Copper has the advantage in all of these categories.

Copper's raw materials cost compares favorably with CPVC. Tube is made partly from recycled copper, and any new copper needed is produced very efficiently. Copper is a worldwide commodity, with numerous raw-material suppliers and fabricators. These factors tend to keep the cost of copper competitive. Whereas, sources for CPVC resin for fire sprinkler systems in North America are limited. CPVC production is not complicated, but neither is it inexpensive. Moreover, the cost of CPVC is unavoidably tied to the petroleum market, whose fluctuations in recent years are well known. These factors tend to destabilize the cost of CPVC.

- Materials for a copper sprinkler system can cost *less* than for a CPVC system, based on list prices, although actual costs may vary with the particular system size and design;
- For equivalent installations, copper systems require *fewer fittings, fewer joints* and *fewer hangers and supports* than CPVC systems. The magnitude of the installed-cost savings with copper depends on the size and complexity of the job.

Both copper and CPVC systems can be installed by one worker. Both types of systems lend themselves to shop or field assembly. The time required to cut, dress, fit, flux and solder or braze for a copper system is quite comparable with the time needed to cut, dress, fit, prime, glue, assemble and cure a plastic system. Both systems depend upon the mechanic's skill.

Copper systems cost less to repair or modify than CPVC systems. Copper systems can be repaired using existing hardware, sometimes without disassembly. Repair of CPVC systems requires new components, and more components and more joints than the original configuration.

Copper even has an economic advantage when a structure is no longer needed. With copper's high recycle value, much of the original material cost can be recovered by the building owner.

Recycling CPVC is technically possible but the economics of this kind of plastics recycling have yet to be proved.

The bottom line is that copper systems *cost less* up front, *less* to install and *less* over the life of the structure.

SUMMARY

The advantages of copper automatic fire sprinkler systems benefit the designer, the contractor and the building owner:

- Copper is strong, rigid and durable; it can be used in all categories and areas under NFPA 13, 13D and 13R;
- Copper systems offer greater design freedom than plastic systems and can be installed in both new and retrofited installations with far fewer limitations than CPVC. Ambient temperature poses no restrictions and thermal expansion is easier to accommodate;
- Copper systems can be designed for wet or dry operation, exposed or concealed;
- Installation is easy and economical; one-man crews using simple, light-weight equipment can install copper at any ambient temperature, winter or summer;
- Copper systems can be tested, hydraulically or pneumatically, immediately after assembly;
- Copper sprinkler systems are cost-competitive. They cost *less* than CPVC, up front and over the life of the structure.

For further information about copper automatic fire sprinkler systems, contact:

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REFERENCES

1. National Fire Protection Association, *Standard for Installation of Fire Sprinkler Systems*, NFPA 13, Quincy, Mass.
2. National Fire Protection Association, *Standard for Installation of Fire Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes*, NFPA 13D, Quincy, Mass.
3. National Fire Protection Association, *Installation of Fire Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height* , NFPA 13R, Quincy, Mass.
4. American Society for Testing and Materials, *ASTM B 88, Standard Specification for Seamless Copper Water Tube,* West Conshohocken, Pa.
5. American National Standards Institute, *ASME B16.18 , Cast Copper Alloy Solder Joint Pressure Fittings,* New York, NY.
6. American National Standards Institute, *ASME B16.22, Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.* New York, NY.
7. Copper Development Association Inc., *Copper Tube Handbook*, New York, 1995, Publication No. A4015-94/95.
8. The Properties of CPVC and its Applications in the Transport of Hot Fluid With or Without Applied Pressure; M. Julliard; 5th International Conference, Plastic Pipes, Sept. 1982, University of York.
9. Parker, R.G. & G.A. Martello, "Chemical Modifications; Chlorinated PVC," Ch. 4 in *Encyclopedia of PVC*, 2nd Ed., Vol. 1, L.I. Nass & C.A. Herberger, Eds., Marcel Dekker, New York, 1986, p. 619ff.
10. *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd Ed., J. Wiley & Sons, New York, 1983, p.899ff.
11. *Encyclopedia of PVC*, 1st Ed., L.I. Nass, Ed., Marcel Dekker, New York, 1976, p. 239ff.
12. American Society for Testing and Materials, *ASTM D2846, Standard Specification for Chlorinated Poly Vinyl Chloride (CPVC) Plastic Hot- and Cold-Water Distribution Systems*, West Conshohocken, Pa.
13. American Society for Testing and Materials, *ASTM F437, Standard Specification for Threaded Chlorinated Poly Vinyl Chloride (CPVC) Plastic Pipe Fittings, Schedule 80*, West Conshohocken, Pa.
14. American Society for Testing and Materials, *ASTM F438, Standard Specification for Socket-Type Chlorinated Poly VinylChloride (CPVC) Plastic Pipe Fittings, Schedule 40*, West Conshohocken, Pa.
15. American Society for Testing and Materials, *ASTM F439, Standard Specification for Socket-Type Chlorinated Poly Vinyl Chloride (CPVC) Plastic Pipe Fittings, Schedule 80*, West Conshohocken, Pa.
16. American Society for Testing and Materials, *ASTM F442, Standard Specification for Chlorinated Poly Vinyl Chloride (CPVC) Plastic Pipe (SDR-PR),* West Conshohocken, Pa.
17. American National Standards Institute, *ANSI B36.10, Welded and Seamless Wrought Steel Pipe*. New York
18. Bourland, L., "Improved CPVC Compounds; Miscible Alloying with Styrenic Copolymers," ANTEC 88 Conf. Proc., Soc. Plast. Eng., 638 (1988).
19. Newman, R.C. and M. Swanson, "Improving the Processability of CPVC Resin," ANTEC 86 Conf. Proc., Soc. Plast. Eng., 1260(1986).
20. Marks, G.E. & D.C. Shaw, *Residential Life Safety Systems Test Utilizing Plastic Pipe*, Palo Alto Fire Department Report, July 1972.
21. J.A. Brydson; *Plastics Materials*; Ch. 12, p. 291; Publ. Butterworth Heinemann; 1993.
22. BFGoodrich Co., *Blazemaster Plastics*, product brochure, 1985.
23. Copper Development Association Inc., *Standards Handbook, Part 2, Wrought Products, Alloy Data*, New York, 1985.
24. Wood, A.S., "Industry faces the challenges of toxic fire gases," Modern Plastics, 47 (March 1982).
25. Thompson Plastics, Inc. & FlowGuard Gold; Technical Data, Rev. July 1996, Huntsville, Alabama
26. *Tech-Talk*; A Technical Resource from the American Fire Sprinkler Association; Jan. 1997, Dallas, Texas
27. Smith, E.E., High Hazards of PVC, CPVC and ABS used for Pipe, Conduit or Duct Exposed to Heat or Fire, paper presented at High-Rise Fire Protection Symposium, ASHRAE Meeting, New Orleans, January 23, 1972.
28. Plumbing Materials & Drinking Water Quality Conference: Plastic Piping and Joining Materials; Stanley A. Mruk; Cincinnati, Ohio, USA, May 1984; pp 10-26; Noyes Publications, NJ, 1986.
29. Soderquist, C.F., "Study Review — Presence of Chemicals Associated with PVC/CPVC Plastic Pipe in Potable Water," Report by California Analytical Laboratories, Inc. for California Pipe Trades Council, Sacramento, September 1990.
30. *Final Report on Potential Health Hazards Associated with the Use of Plastic Pipe in Potable Water Systems,"* (California) Hazard Evaluation System and Information Service, Dept. of Industrial Relations, Berkeley, October 17, 1980.