PLUMBING SPECIFICATION GUIDE

2024 EDITION

SAFE PIPING MATTERS

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INFORMATION & INSIGHTS FOR AEC PROFESSIONALS

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SAFE PIPING MATTERS

INTRODUCTION

OVERVIEW

Plumbing systems perform functions vital to the performance, sustainability, and resilience of commercial and residential buildings. They distribute water throughout structures, carry away waste, vent fumes and exhaust, and provide fire protection. They also have important impacts on the health and safety of the people who work and live inside them. This guide explains key considerations that architecture, engineering, and construction (AEC) professionals should evaluate when selecting and specifying pipe, because materials matter when it comes to these critical building systems.

Recent crises across the country illustrate the impacts that piping choices can have and offer lessons that design and construction teams should apply to their current and future projects. When it was being installed, lead pipe was widely available, affordable, and believed proven safe for use across a wide range of applications. Over the last decade, however, hundreds of communities have spent billions of dollars and countless hours finding and replacing toxic pipes made of lead in local homes, schools, and businesses. Polybutylene (PB) plastic pipe represents another such example. Initially hyped as a "pipe of the future," PB was widely used for potable water piping from the 1970s until the 1990s, when it was abandoned after a series of failures triggered by chemical reactions with chlorinated water.

Changing products and emerging health and safety factors make designing piping systems a continuing challenge. This guide considers the following areas that are priorities for plumbing systems:

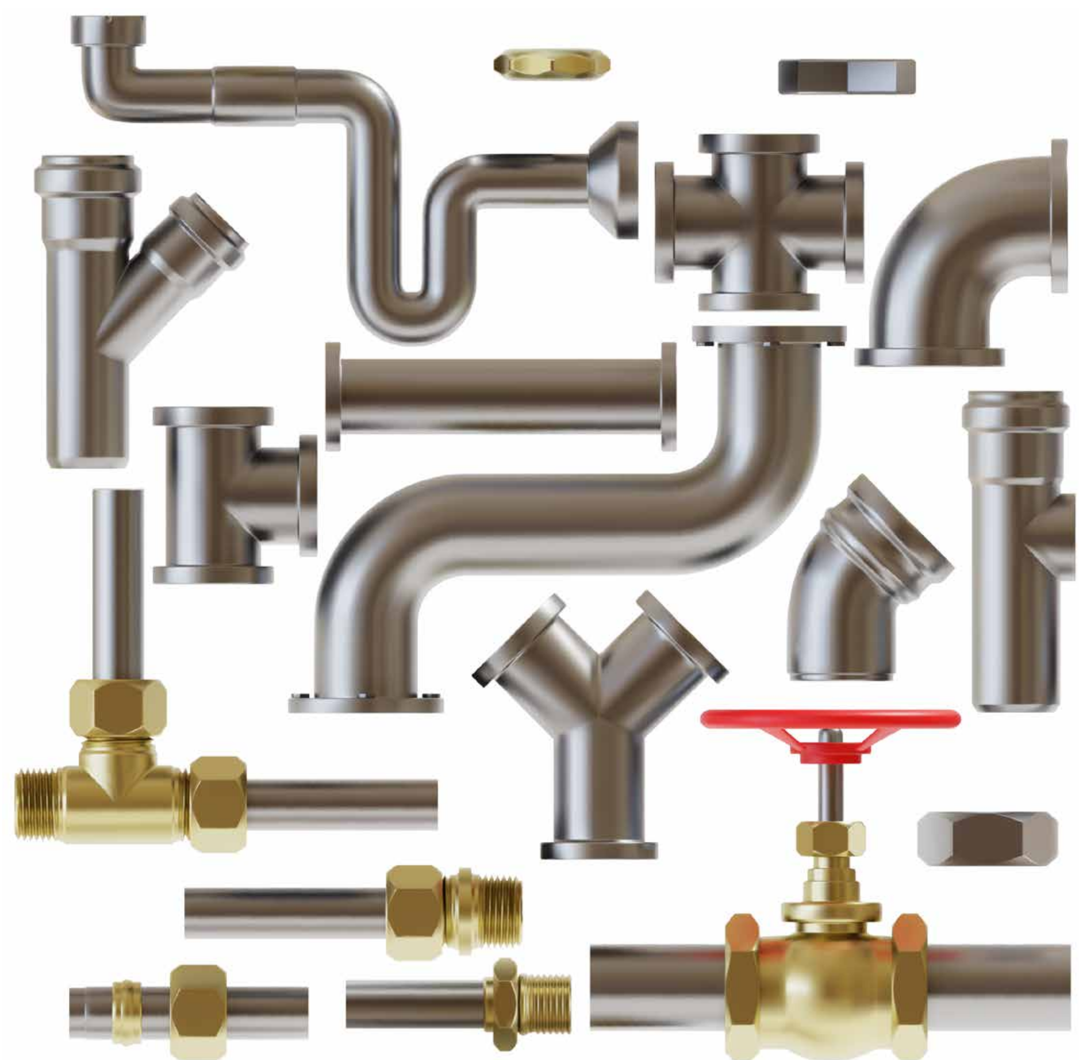
- **SAFETY:** Protecting the lives of building occupants, especially when a crisis occurs.
- **HEALTH:** Eliminating threats to human health over the short and long term.
- **RESILIENCE:** Resisting damage from accidental physical impact, chemical exposure, and other issues.
- **SUSTAINABILITY:** Minimizing environmental impacts of production, use, and disposal.
- **COSTS:** Opportunities and risks related to value engineering from initial purchase and installation, as well as during use.

HOW TO USE THIS GUIDE

Engineers and architects should use this specification guide to identify and evaluate considerations relevant to plumbing systems for current projects. They should apply this learning during the design and specification phases to select the most appropriate materials. They may also use it as a reference during construction, when change orders and value-engineering processes affect plumbing and other systems. The Considerations and Recommendations section (page 15) provides focused guidance for key building applications.

Contractors should use this guide initially to evaluate the design specifications for projects they are bidding. They can also use it to inform discussions they have with architects, owners, and subcontractors before and during construction. They may wish to consult the Codes and Standards section (page 12), which summarizes requirements specific to plumbing.

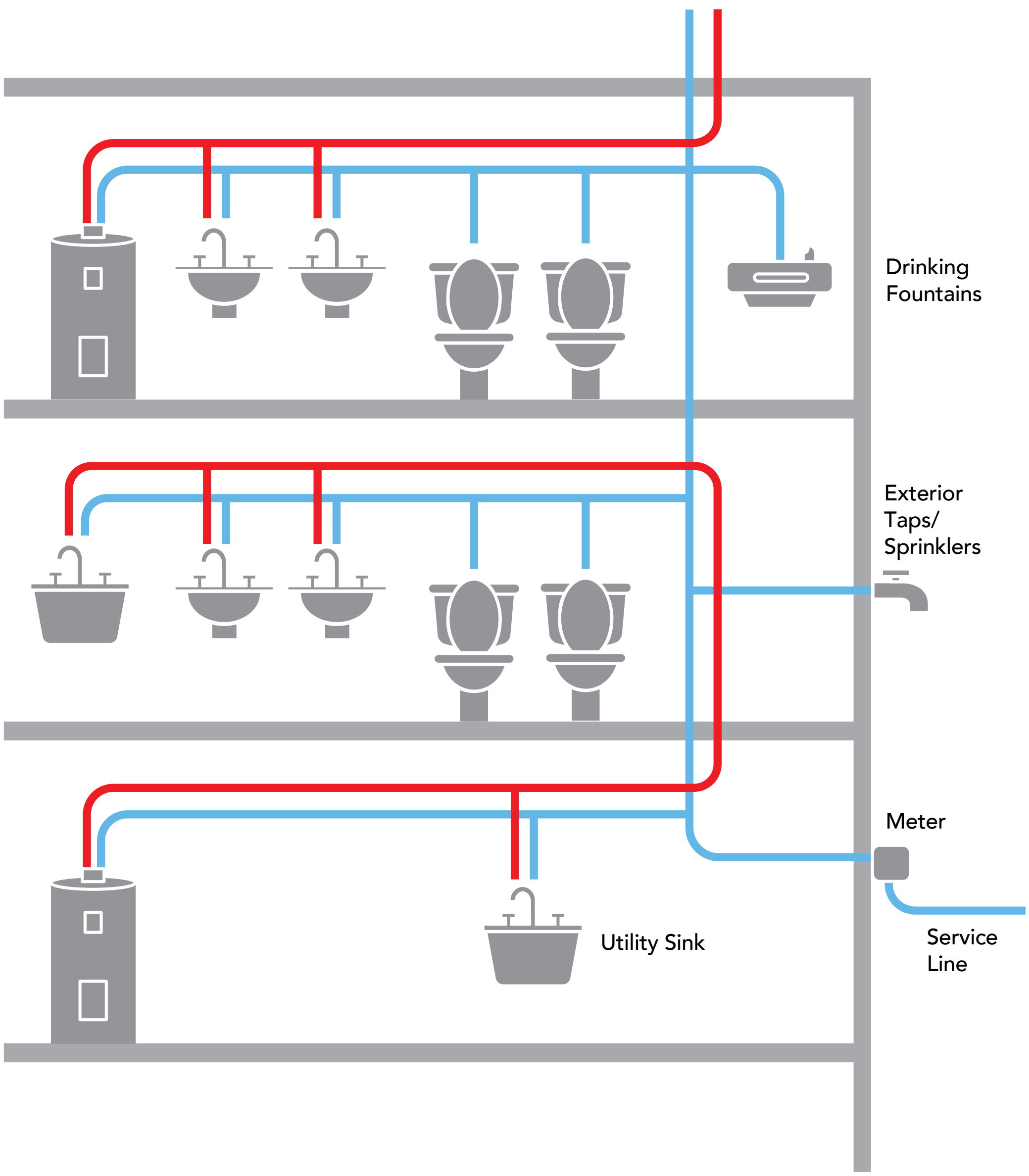
Owners can use the guide to educate themselves on plumbing issues so the buildings in their portfolio get designed and maintained appropriately. Occupants may also find parts of this guide useful to ensure the places they live and work will operate safely and protect their health.



FUNDAMENTALS

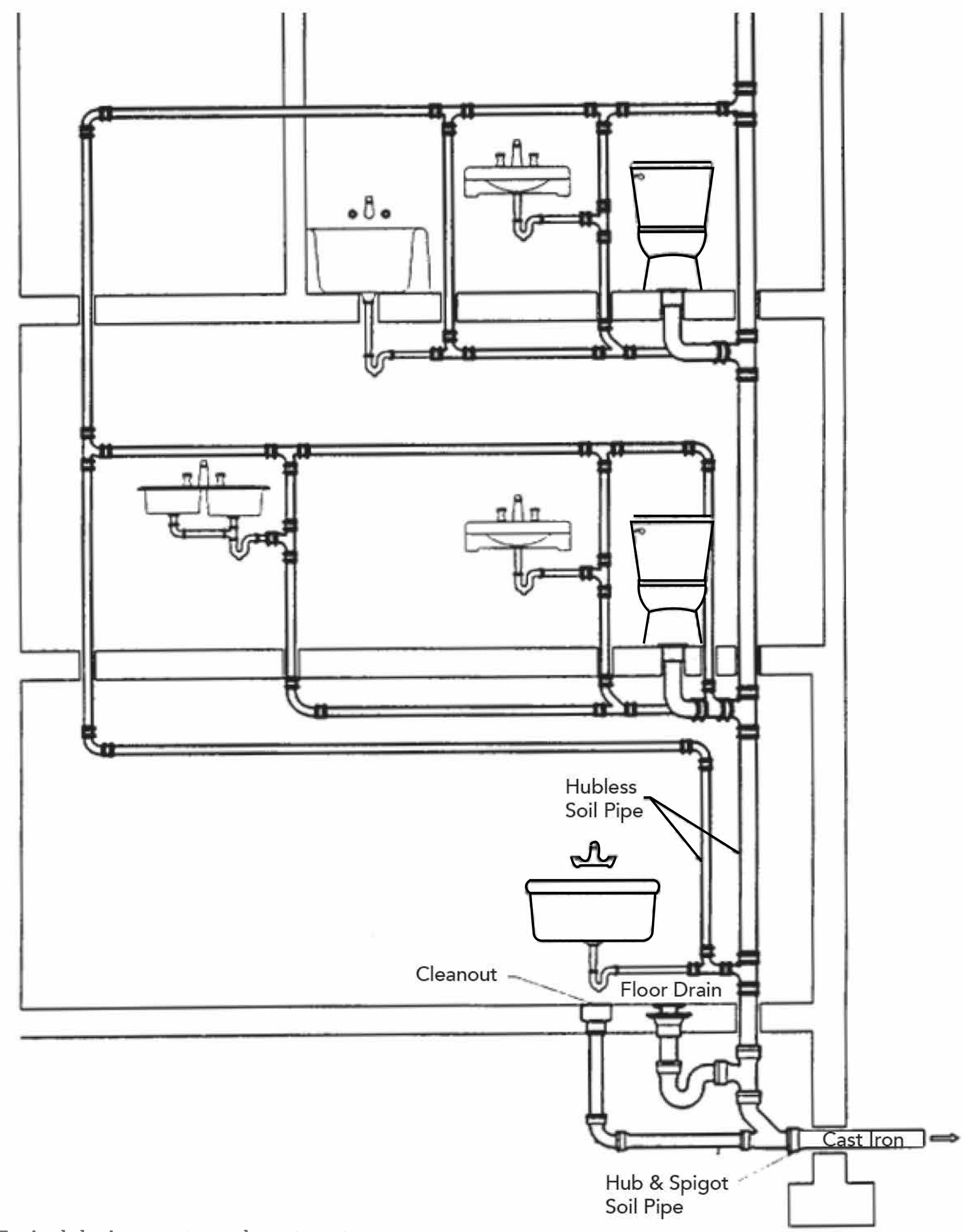
This section describes the key components and functions of common piping applications in commercial and residential buildings. Plumbing systems in buildings generally support the following functions:

- Supplying and distributing potable water for drinking, washing, sanitary use, and appliances. These systems initially connect buildings to sources of potable water, whether private or municipal supplies. They then distribute water throughout the structure via vertical "riser" pipes that pass from floor to floor and horizontal runs that connect to individual fixtures. Water heaters and storage tanks are also a part of this system, as are control valves, faucets, and other fixtures.



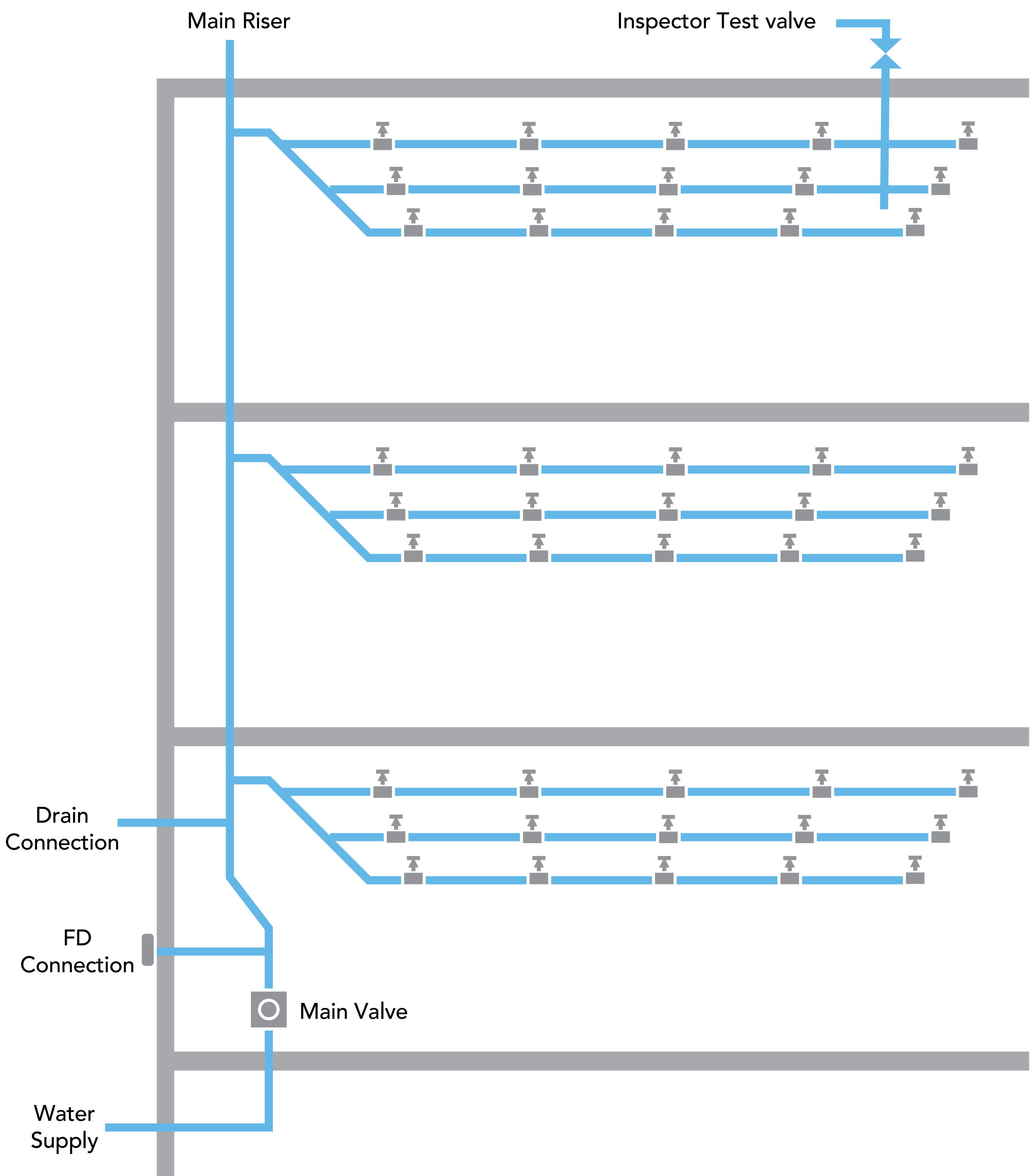
Typical building water supply and distribution system

- Removing wastewater, sewage, and associated gases via drain, waste, and vent (DWV) plumbing. This includes not only water and human waste, but also chemicals used for cleaning, grease and food waste, and a wide range of other substances. DWV systems include physical drain mechanisms, piping, traps, and fittings throughout the structure, as well as lines that return waste back to a municipal sewer or septic system for treatment. Vent pipes complement drain/waste systems by allowing mixtures of liquid and solid waste to flow easily down pipes while preventing siphonage and backflows. Vents also carry away gases and fumes, allowing them to pass out of a structure to safeguard interior air quality. Branch vents connect most if not all individual drains and piping segments of waste systems to main vent stacks.



Typical drain, waste and vent system

- Protecting occupant safety and limiting property damage during structural fires via fire-fire-sprinkler plumbing where such systems are present. Fire-sprinkler systems offer a range of protection against fire events, delivering water for suppression of flame spread, usually controlled by sensors in the protected space. The main types of systems – wet, dry, preaction, and deluge – vary in how they are triggered, but are generally similar in construction, featuring a network of pipes and control valves located in the ceiling plenum, with sprinkler heads and sensors located below the ceiling plane. Since wet-system pipes are always filled with water, resilience of the pipe material is critical to limit the risk of water leakage.



Typical fire-sprinkler system

Buildings may also feature several other types of piping, including systems that distribute gas for heating, cooking, or healthcare purposes, and conduit piping used to house electrical wiring. This guide provides less detail on these types of piping systems.

PIPING MATERIALS

This section describes the strengths and weaknesses of common plumbing materials and discusses appropriate application(s) for each type of material.

COPPER

Copper pipe has been widely used for plumbing applications for thousands of years. Its primary advantages include:

- Good structural strength and ductility, helping pipes resist damage from impact and stresses created within plumbing systems;
- Non-combustibility in structural fires;
- Resistance to leaching and corrosion even at higher temperatures;
- Excellent heat-transfer qualities; and
- Long product life with the ability to make repairs to pipes.

Sourcing and manufacturing copper creates environmental impacts and a significant carbon footprint. However, copper pipe often includes 40% or more recycled material, and pipes are widely recycled after use. Recycling copper consumes much less energy than refining it from ore, with savings ranging from 33% to 50% or more depending on the purity of the recycled material.

Weaknesses of copper include the initial cost, which may be higher than some other materials. Reduced installation and firestopping requirements of this material compared to combustible plastic pipes will mitigate the price gap by lowering labor and component costs (see page 16).

Like all plumbing systems, good design is the first step to ensure longevity of a copper-based system. Correct line sizes, operating temperature/pressures and velocity are key. Executing the proper installation steps for copper plumbing will avoid other issues that can lead to pinhole leaks, such as erosion resulting from incorrect deburring of a tube.

Other applications for copper include distribution of medical and other gases, oil products, and chemicals, as well as fire-sprinkler systems. Copper also circulates coolant in many HVAC systems. Common sizes for building water systems include nominal diameters of 0.5 inch up to 8 inches – all manufactured from alloy UNS C12200 containing at least 99.9% copper – in accordance with ASTM B88.

IRON

The material characteristics of cast-iron pipe have made it a primary choice for building plumbing systems for centuries. Advantages include:

- Superior density, structural strength, and rigidity that make cast-iron particularly appropriate for installations below grade and in areas susceptible to impact, such as parking garages;
- Simpler installation, with low requirements for support. The weight and strength of iron pipe side walls reduce effort and cost of installations below grade, within vertical and horizontal building cavities, and suspended by hangers;
- Non-combustibility and heat resistance, minimizing risks from pipe penetrations of firewalls;
- Superior acoustical qualities that dampen the sound of waste flowing through the pipe;
- Resistance to damage heat and most chemicals, elevating resilience of the system to accidents and misuse;
- Among the longest product lifespans of any piping material; and
- High levels of recycled content, ranging up to 96% for pipe produced in North America. Most iron pipes are recycled after use.

Weaknesses of cast-iron pipes include the initial material cost compared to some plastic pipes, although costs calculated including appropriate support and firestopping assemblies often offset this disadvantage. In addition, while the heavier weight of cast iron lends it strength, it also increases the environmental impact of transporting the pipe to the installation site.

Cast iron is the material of choice for plumbing applications that collect and carry away waste from toilets, sinks, appliances, and other bath and kitchen fixtures. Pipes are available in two versions:

- Hubless systems join sections of pipe using a coupling that can be tightened to seal the joint. Pipe and fittings should meet the ASTM A888 or CISPI 301 standards and are available in nominal diameters from 1.5 to 15 inches. Couplings should meet the ASTM C1277, CISPI 301, or ASTM C 1540 standards.
- Hub and spigot pipe and fittings should meet the ASTM A-74 standard. They use a gasket made of rubber or lead and oakum to seal joints. Common sizes range from 2 to 15 inches nominal diameter.

STEEL

Steel pipe has long been used in a versatile range of construction applications. Advantages parallel those of cast iron:

- Structural strength and density;
- Non-combustibility, increasing fire safety;
- A wide range of coating options for various applications;
- Close tolerances for wall thickness;
- Resistance to damage from heat and pressure, enabling use in demanding settings;
- Long product life; and
- High rates of reuse and recycling in the construction sector with a recycling rate of up to 94%, according to the Steel Recycling Institute.

Weaknesses of steel pipe also echo those of cast iron, including environmental and energy impacts of production, higher cost, and heavier weight than some other materials. In addition, many buildings that used galvanized steel pipe for plumbing have experienced significant issues with corrosion and failure. These problems often originate when teams substitute galvanized steel pipe in applications not suited for this material. For example, contractors responsible for building a hotel in Baltimore's harbor area "value-engineered" building plumbing systems by substituting galvanized steel in place of the copper pipe specified by architects. The pipes failed within 7 years, turning the $2.6 million contractors "saved" into a legal liability they reportedly settled at a cost of over $18 million.

Steel pipe can be used appropriately in fire-sprinkler systems, transporting liquids and gases, and steam systems. It is also widely used for electrical conduit. Common sizes for such systems include nominal diameters from 0.5 inch up to 24 inches.

PLASTIC

Plastic compounds have thousands of different chemicals. Plastic pipes also have widely divergent properties that range from soft and flexible to highly rigid. Further, the formulas used to manufacture plastic change continuously as manufacturers tweak them to cut manufacturing costs or update them to address performance problems. As a result, many plastic pipes have properties that work for specific applications but are inappropriate for others. Plastic pipe's advantages start with lower material price, but also include ease of installation and versatility of application depending on plastic type.

As with its advantages, the weaknesses of plastic pipe vary by type, but generally include weaker structural strength than metal, greater expansion and contraction with temperature fluctuations, and lower rigidity (requiring more installation supports). Since plastic is made from petroleum-based chemicals, plastic pipes are combustible and can burn and/or melt in fires, releasing toxic substances into air and water (see page 20). Plastic pipe has higher susceptibility to damage when exposed to chemicals – often described as "compatibility issues." Manufacturers list countless construction and maintenance products that should not be used with or near plastic pipe (see page 22). Plastics also are known to leach chemicals into water, especially when heated; recent research also suggests they release micro- and nanoplastic particles from pipe walls (see pages 20-21).

Plastic pipe has the widest range of applications in the piping industry, including water supply and distribution, DWV, fire-sprinkler systems, and other uses such as for electrical conduit. These vary by type; brief descriptions follow.

- **ABS** (acrylonitrile butadiene styrene) pipe can withstand colder temperatures than other plastics, such as PVC, going down to -40 degrees, and can handle slightly higher temperatures than PVC, up to about 158 degrees. It is also more resistant to impact damage than other plastics. ABS material contains bisphenol A (BPA), a substance known to affect the brain and glands of infants and young children, so is not generally used in drinking-water systems. It also can be damaged by chemicals, including some used by water-treatment plants to disinfect water supplies. Common applications for ABS pipe include industrial uses, drain and waste, outdoor irrigation, and electrical conduit. Sizes typically range from 3/8 to 8 inches in diameter.

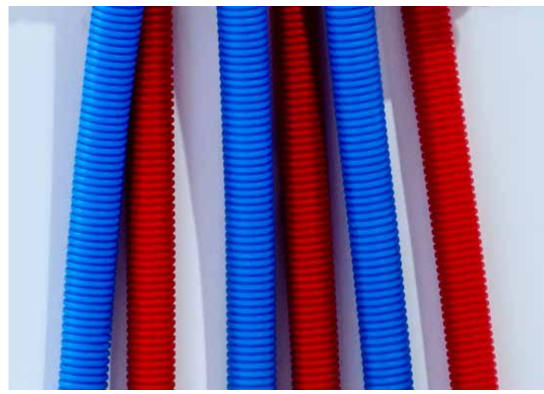
- **CPVC** (chlorinated polyvinyl chloride) pipe can withstand higher temperatures than PVC and ABS pipe. Its susceptibility to chemical damage is significant – many manufacturers provide lists of substances that must not be used on or near such pipe. CPVC is also susceptible to UV damage, so must be installed in covered locations only. Common applications include hot- and cold-water distribution and fire-sprinkler systems. Sizes for these applications include nominal diameters in regular increments from 1/4 up to 24 inches.

- **PVC** (polyvinyl chloride) pipe offers among the strongest and most rigid walls of plastic pipe, so it can be used in applications that softer and weaker plastics cannot. It is susceptible to damage from temperatures above 140 degrees and is not preferred for hot-water applications. In addition, recycled material is prohibited from use in plumbing applications, due to risk of cross-contamination and biomaterial. Main applications include water supply lines and DWV applications. Sizes for these applications include nominal diameters in regular increments from 1/4 up to 24 inches.

- **HDPE** (high-density polyethylene) pipes have grown in use due to their higher material strength compared to other plastics. Expansion and contraction of this plastic due to temperature fluctuations is significant over long runs, requiring allowances in the design to ensure system integrity. In addition, the potential for physical damage means HDPE pipe requires additional care in installation to minimize risk of impact damage. HDPE pipe is often used for potable water and gas transport applications. Sizes for these applications include nominal diameters in regular increments from 1/4 up to 24 inches.

- **PEX** (cross-linked polyethylene) pipes have become popular for interior applications. They are easy to install, very flexible (able to bend even to right angles), less prone to expansion/contraction, and can withstand a range of temperatures (though they should not be connected to hot water heaters).

Disadvantages include giving water that passes through them a distinct chemical taste and/or odor, higher cost than some other plastic materials, sensitivity to damage from UV light, and susceptibility to permeation of chemicals through the pipe walls into whatever is passing through the pipe. PEX material must contain additives that limit damage from chlorine and chloramine compounds used to treat drin king water. Situations in which these additives are consumed prematurely will shorten the lifespan of PEX pipe if exposed to water treated in this fashion. Sizes for PEX applications include nominal diameters in regular increments from 1/4 up to 24 inches.



OBSOLETE MATERIALS

LEAD piping was used in almost every major U.S. city for many plumbing applications in 1900, including to transport drinking water. Water contamination triggered by leaching of lead from pipes occurred regularly, but the chemistry driving such incidents was not well understood, so lead continued to be used. The material was not classified as a serious neurotoxin until the mid-1900s, when a research study concluded lead exposure caused irreparable brain damage, especially for children and babies, but it was not fully banned until 1986.

Millions of lead pipes are still in in use across the country. They represent a serious threat to water quality – and public health – as demonstrated by Flint, Michigan; Milwaukee, Wisconsin; Newark, New Jersey; and many other communities. Recent legislation has made extensive federal funding available to remove and replace lead pipes with copper and other safe materials.

POLYBUTYLENE pipe was a low-cost plastic pipe used for water distribution, installed widely across the Sun Belt, the MidAtlantic, and the Pacific Northwest. It was used from 1978 until 1995, as continuing failures caused hundreds of millions in property damage and forced the industry to abandon it. Polybutylene pipe is composed of a plastic compound manufactured by Shell Oil, and the cause of the failures is thought to be deterioration of the plastic material itself. Damage resulted from reactions between the plastic and oxidants such as chlorine or other substances that came into contact with the interior of the pipe walls. Since the plastic material would break down chemically from the inside out over the course of a decade or more, failures were hard to assess. Most pipe had to be removed entirely and replaced.

GALVANIZED STEEL pipes were coated with zinc to protect them against rusting. They were commonly installed for plumbing until they started getting phased out in the 1950s. Galvanized steel plumbing systems can have a lifespan of up to 50 years, but today they are rarely installed for plumbing applications. Resilience issues with the pipes can arise when the interior of the pipes corrode due to chemical reactions and oxidation.
Over time, this corrosion can weaken the pipe structure and/or restrict the flow of liquids through the pipes, increasing the risk of leaks and breakage. As noted in the Piping Materials section, improper substitution of copper or other pipe materials with galvanized steel may lead to significant property damage.

CODES & STANDARDS

This section provides an overview of codes and standards for several piping applications. Note that requirements enforced by the authority having jurisdiction for any specific project take precedence over other codes and standards.

NATIONAL/INTERNATIONAL

NSF/ANSI/CAN 61: Titled "Drinking Water System Components – Health Effects," the NSF/ANSI/CAN 61 standard is one of the most visible standards in the plumbing industry. Developed in 1989, the standard has helped prevent some harmful substances from being used to manufacture pipe intended for potable water distribution. It has a number of limitations, however, that should inform plumbing design decisions.

A primary issue with the standard is that it only tests for a limited range of contaminants and does not fully account for interactions among substances. For example, plastic pipes use ever-changing combinations of chemicals to increase performance, including new ones that have not been studied. Many of the substances used in plumbing can leach into water. A recent study of plastic pipes identified 163 separate compounds that leached into water, only a fraction of which have been tested for their health effects. Those that have been tested include substances known to be carcinogenic and/or disruptive to the endocrine system, such as halogenated compounds, phthalates, and alkyl phenols.

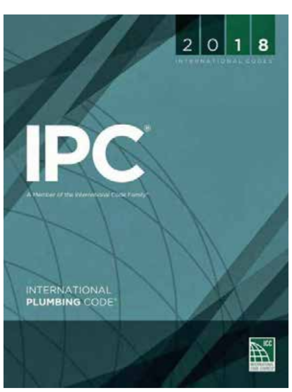
Gaps in the NSF/ANSI 61 standard's coverage appear to result from the structure of the review process. A recent critique of the standard notes that pipe manufacturers exert "heavy influence" on the committees that control decision making, according to which quotes an NSF representative who stated that adding new substances requires 90% approval from the Health Advisory Board, which sets limits.

The industry's spotty record of transparency regarding product risks and failures raises further questions. In an interview with Environmental Health News, engineering professor Andrew Whelton described significant concerns that manufacturers have yet to address: "We don't have a very good public understanding about the chemicals that are leaching out of a lot of the plastics that we install in our infrastructure," he said. "...It's a risk that we all face, drinking water from materials that we haven't necessarily tested thoroughly."

Based on this information, the standard's regulatory approach may not be conservative enough, especially for vulnerable populations such as infants, pregnant women, and those with compromised health. Further, limited information exists on long-term health effects of chronic, low-level exposure to contaminants leached from plumbing materials. The Precautionary Principle adopted by a number of leading architectural firms recommends that "in cases of serious or irreversible threats to the health of humans or ecosystems, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures ...to prevent damage to human health and to ecosystems." By that definition, plastic pipes as currently formulated would not fit with the Precautionary Principle.

CSI: The specifications created by the Construction Specifications Institute (CSI) establish a set of standardized requirements for building construction. The most relevant divisions for building piping systems include Division 21 – Fire Suppression and Division 22 – Plumbing. Fire suppression specifications cover sprinkler systems and fire extinguishing systems of all types, as well as fire pumps and fire suppression water storage if required. Plumbing specifications cover piping work done inside the building and may extend a short distance beyond the footprint as well. Plumbing includes delivery of water, heating fuels and gases, compressed air, medical gases, and fire-protection systems. See the Considerations and Recommendations section (page xxxx) for sample language reflecting the recommendations provided in this document.

IPC: The International Code Council maintains the International Plumbing Code (IPC) to establish minimum requirements for pipe, fittings, fixtures, and piping systems design and construction. It is used by many states as the basis of their state and local codes. All sections of the code apply, but the following chapters are most relevant to the issues addressed by this guide:

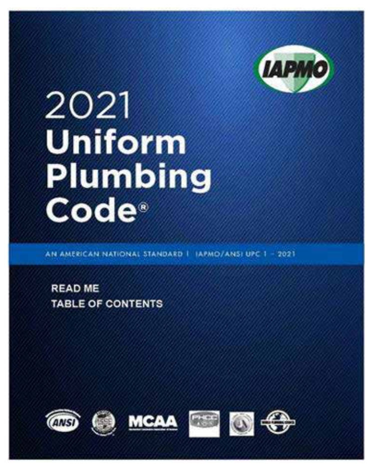


Chapter 4: Fixtures, Faucets and Fixture Fittings
Chapter 5: Water Heaters
Chapter 6: Water Supply and Distribution
Chapter 7: Sanitary Drainage
Chapter 8: Indirect/Special Waste
Chapter 9: Vents
Chapter 10: Traps, Interceptors and Separators
Chapter 11: Storm Drainage

NFPA: The National Fire Protection Association (NFPA) has established dozens of codes and standards to mitigate the risks and impacts of fires. The most relevant for the purposes of this guide are:

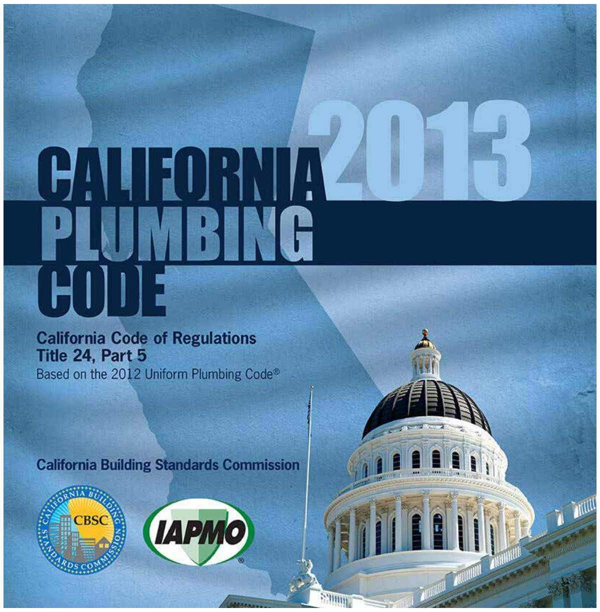
NFPA 13: Standard for the Installation of Sprinkler Systems
NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection

UPC: The International Association of Plumbing and Mechanical Officials (IAPMO) maintains the Uniform Plumbing Code (UPC) to assure "access to clean water and sanitation" by requiring use of their standards for installation, alteration, maintenance, and repair of plumbing systems. It is used by several states (mostly located in the West, including California) as the basis of their state and local codes. All sections of the code apply, but the following chapters are most relevant to the issues addressed by this guide:



Chapter 4: Plumbing Fixtures and Fixture Fittings
Chapter 5: Water Heaters
Chapter 6: Water Supply and Distribution
Chapter 7: Sanitary Drainage
Chapter 8: Indirect Wastes
Chapter 9: Vents
Chapter 10: Traps and Interceptors
Chapter 14: Firestop Protection

STATE/MUNICIPAL



As noted above, determine which local authority having jurisdiction (AHJ) covers your project to ensure compliance. Many areas have updated their requirements to address concerns specific to their jurisdiction. Key examples relevant to piping materials include the following:

- California, which does not allow use of plastic pipe in healthcare applications or residential applications greater than 2 stories.
- New York, which only allows use of plastic pipe in structures of 5 stories or less.
- Chicago, which prohibits use of PVC pipe in buildings of more than 3 stories.
- Philadelphia, which prohibits use of ABS and PVC pipe in dwellings housing more than 4 families or greater than 3 stories in height.
- Baltimore, which restricts use of plastic pipe to structures of 6 stories or less.
- Omaha places limits on use of plastic pipe by both height (maximum 4 stories) and occupancy type.

RESOURCES

Here are additional sources for learning and investigation:

- "A Brief History of Plumbing Codes," Ron George, Working Pressure Magazine, 2019, https://www.workingpressuremag.com/a-brief-history-of-plumbing-codes/
- "Why Not Just Draft One Uniform Plumbing Code?," Randy Lorge, Plumber Magazine, 2018, https://www.plumbermag.com/how-to-articles/challenge-of-mechanical-codes/why-not-just-draft-one-universal-plumbing-code
- "The Perils of PVC Pipe," Meg Wilcox, Beyond Plastics, 2023, https://www.beyondplastics.org/publications/perils-of-pvc-pipes

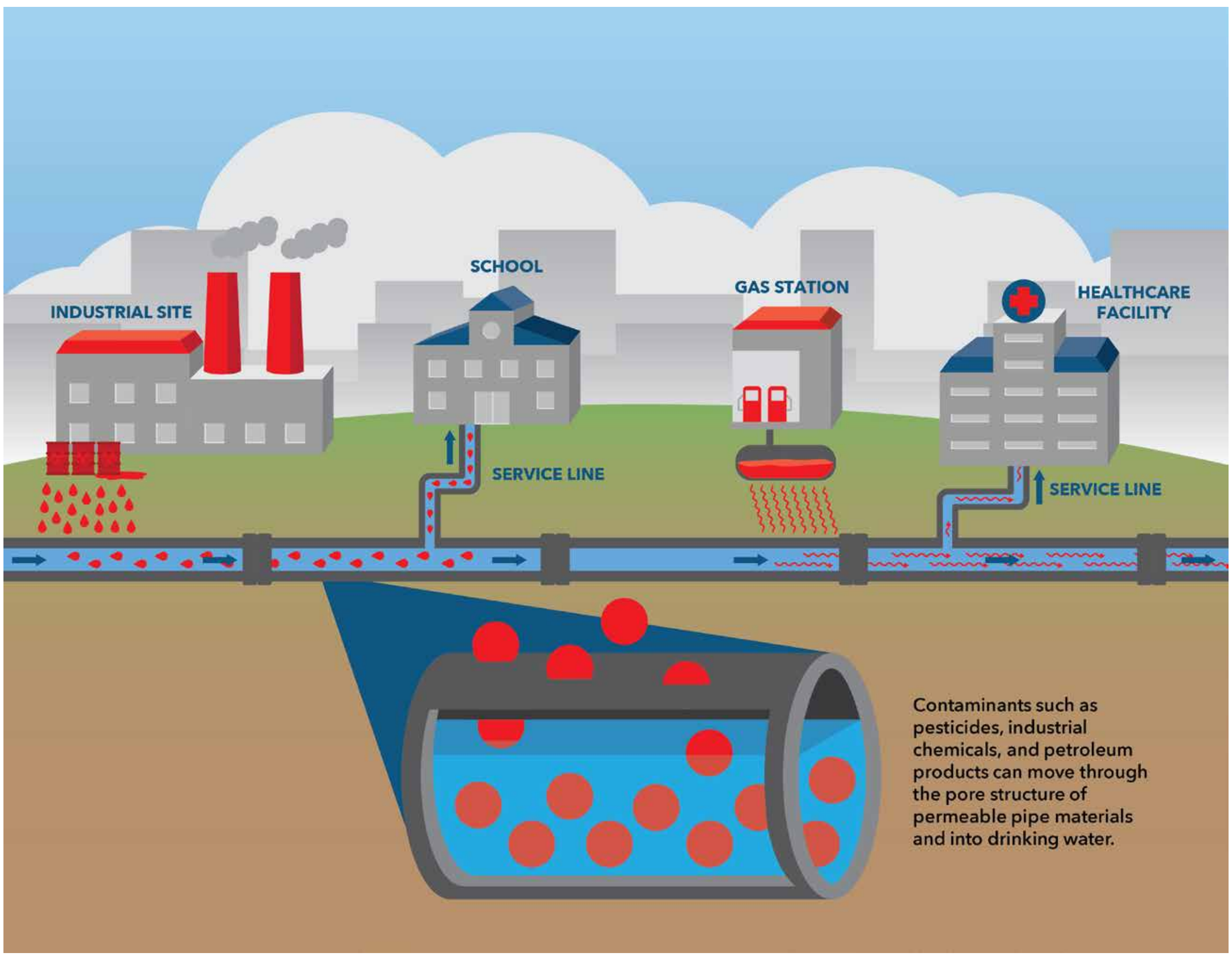
CONSIDERATIONS & RECOMMENDATIONS

The next several sections of this guide provide considerations and recommendations that should inform specification of piping, language to include in design and construction documents, and resources for further investigation.

SAFETY

Plumbing systems run throughout buildings, passing through walls and floors, so failures can compromise critical systems and structural elements, as well as damaging interior finishes. If specified or installed incorrectly, piping systems threaten structural integrity and safe functioning, putting occupants at risk. Here are some issues to consider.

PERMEATION



> "Risks from permeation into plumbing systems are limited to plastic, non-metallic materials"
> -EPA

According to the U.S. Environmental Protection Agency (EPA), permeation of substances through pipe "can be viewed as a three-step process. First, the solute partitions between the external bulk phase (e.g., water, soil) and the pipe wall exterior. Next, the solute diffuses through the pore structure of the pipe or fitting. Finally, upon penetration the solute partitions between the internal bulk phase (e.g., pipe water) and the pipe wall interior." When this occurs, it will degrade the purity of the liquid passing through the pipe.

The EPA says risks from permeation into plumbing systems are "limited to plastic, non-metallic materials," because they are more porous than substances like copper, iron, and steel. In general, this is due to the lower density of the piping material. Buildings located near manufacturing facilities, gas stations, and agricultural locations should consider the ongoing risk from leaks or spills and specify piping materials appropriate to protect against any threats.

A 2018 report from the American Water Works Association identified "over 100 incidents of drinking water contamination resulting from permeation of subsurface mains and fittings." One of the most serious occurred near Charleston, West Virginia, when a chemical tank spilled thousands of gallons of 4-Methylcyclohexanemethanol (MCHM) into water supplies that served over 300,000 people. Nearly 100,000 suffered serious health impacts after consuming the contaminated water.

Researchers found that even after flushing their pipes as directed, "residents reported odors corresponding to lingering contamination," indicating that chemicals remained in systems and raising concerns about how the pipes behaved during contamination events.

COMBUSTIBILITY

Passive fire and smoke barriers in walls, ceilings, and floors are integral to building safety, slowing the spread of fire and smoke. When pipes pass through walls, ceilings, and floors, it is essential to ensure the integrity of fire barriers by using appropriately rated firestop assemblies.

This safety requirement holds particularly for healthcare and educational facilities, other workplaces, and multi-family residential buildings, as more people could be present inside and evacuation may take longer when fires occur. To protect the lives of building occupants, as well as first responders, architects, engineers, and construction professionals must ensure firestopping meets the highest standards for safety. Failures in the event of a fire will trigger serious questions and liability.

Fire-safety differences among piping materials center on one issue: combustibility. As the following table shows, the petroleum-based compounds in plastic pipes will melt and burn, creating fuel sources for smoke and flames. Because of this, firestop assemblies for plastic pipe must not only account for the areas around the pipe (known as annular space), but for the area occupied by the pipe itself.

> "Fire-safety differences among piping materials center on one issue: combustibility."

COMBUSTIBILITY OF PLUMBING MATERIALS (ORANGE=YES; BLUE=NO) *TYPICAL STRUCTURE FIRES REACH 1,100*							
Pipe Material	Copper	Iron	Steel	CPVC plastic	PE plastic	PEX plastic	PVC plastic
Melts at (°F)	1,981	2,200	2,200	burns*	266	burns*	~415
Burns at (°F)	n/a	n/a	n/a	900[1]	650[1]	430[2]	750[1]

**CPVC & PEX spontaneously combust at the given temperature, rather than melting*
[1] corzan.com (accessed April 2023)
[2] uponor.com (accessed April 2023)

As a result, the complexity of firestop assemblies is significantly higher for PVC, CPVC, PEX, PE and other plastic pipe materials than for non-combustible pipe (typically metal). A firestop assembly for copper, iron and other non-combustible pipes may only require these two components:

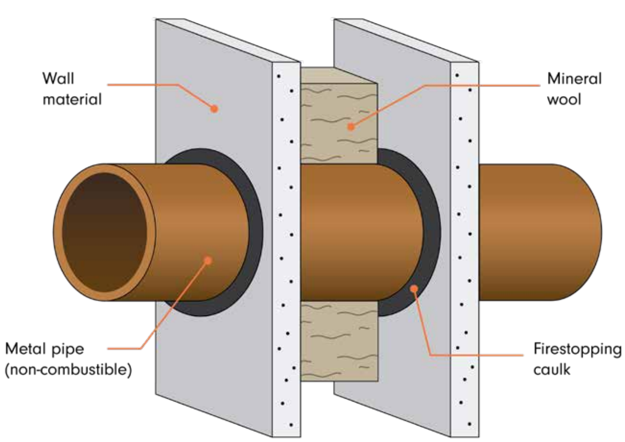
- Fire-resistant material filling the annular space (usually mineral wool)
- Firestopping caulk applied around the pipe.

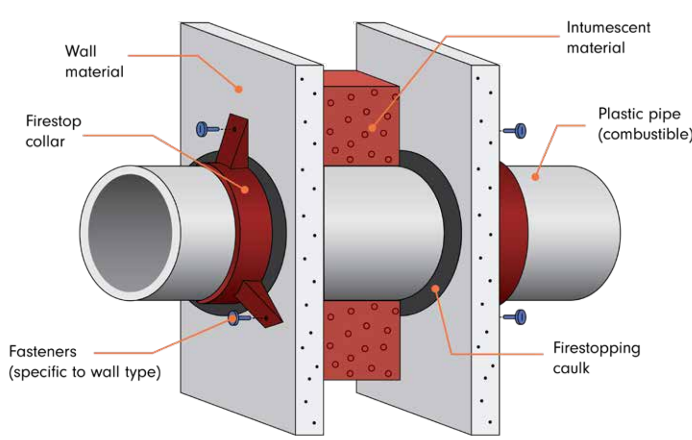
By contrast, assemblies for plastic pipes may feature all the following:

- Intumescent material in the annular space adequate to crush the pipe and fill the entire opening when heated,
- A collar or other device to secure the assembly to the wall, containing the intumescent material in the annular space,
- Fasteners appropriate for the wall type to ensure the collar remains fixed to the wall, and
- Caulk applied around the opening.

As the number of components and combinations in a firestop assembly increases, so does the risk of error. And in practice, firestop experts see more problems in the field with complex assemblies. Firestopping consultant Sharron Halpert dedicates an entire section of her excellent website to identifying "classic mistakes" she's found in the field, including one installation she says is "very rarely done correctly."

Failing to follow good practices, or installing firestop assemblies incorrectly will put occupants and first responders at risk if a fire occurs. If the firestop assembly around a plastic pipe fails, the resulting gap can seriously compromise building safety. "When a fire is actively burning, it's





going to create a lot of heat and pressure," explains Bruce Johnson, a fire marshal who works with Underwriters Laboratories. "Even the smallest void that's not protected with proper firestopping almost acts like a blowtorch. You're going to have really hot flames, gas, and smoke going through that opening... so it rapidly spreads the fire and smoke."

To build resilient, safe buildings, design and construction professionals must work to reduce fire risks, and the KISS principle – keep it simple stupid – might be the best way to prioritize safety.

PLUMBING IN PLENUM SPACES

Plumbing systems installed in plenum spaces must meet additional building codes and safety standards. As with most such requirements, the criteria vary by location, but usually include:

- **NON-COMBUSTIBILITY** To prevent the spread of fire and deadly smoke inside buildings through areas used for HVAC and other subsystems, plumbing that runs into and through plenum spaces should be non-combustible. Any system that does include combustible materials must pass the ASTM E84 test with a rating of less than 25 for flame spread and less than 50 for smoke. The test must cover the entire assembly – pipe, suspension elements, wraps, firestops, and any other components –being considered for installation. Further the E84 test of these assemblies must be unmodified, because changing elements of the test compromises the accuracy of results.
- **NOISE CONTROL** Since plenum spaces can propagate sound among areas within buildings, acoustical performance represents another important consideration. Teams should select plumbing materials that dampen noise and design the installation to reduce transmission noise by using appropriate number of supports and noise-reduction components.
- **EASE OF OPERATION** Further, teams should design plumbing within plenum spaces to facilitate inspection and maintenance. Placing vulnerable plumbing systems adjacent to or beneath other systems can create opportunities for exposure to damage from physical impacts or incompatible chemicals.

RECOMMENDED PIPING CRITERIA

To ensure piping systems protect the safety of occupants, consider including the following requirements in construction documents:

- Evaluate permeation threats adjacent to the building site, addressing risks from gasoline and petroleum products, industrial chemicals, fertilizers, and other substances that might enter or migrate into site soil and groundwater over time.
- To mitigate leaching risks, ask manufacturers to provide Health Product Declarations (HPD) that transparently list all material components of their pipe. This requirement would apply in addition to compliance with NSF 14 and NSF/ANSI 61.
- Meet with a firestopping consultant at the specification and construction drawing stage to select products that meet all safety requirements, using the Safe Piping Matters firestopping guide as part of the evaluation process.
- Require that piping materials in plenum spaces not exceed a Flame Spread Index (FSI) of 25 or a Smoke Developed Index (SDI) of 50 when tested to ASTM E84. Refuse to accept modified tests and ask that manufacturers submit listing and test data for review of compliance.

HEALTH

Even when pipes appear to perform safely within a building, they may still pose threats to short- and long-term health. Lead pipes are the poster child for this issue. Here are several issues to consider.

LEACHING

Chemical interactions between water and piping materials — typically oxidation — and the principles of osmosis mean all piping materials leach substances into water to a degree. Some materials are far safer than others, however. For example, lead pipes and fittings have emerged as a serious public health threat in homes, schools, and businesses with aging plumbing. The leaching impacts of commonly used materials such as copper and plastic are less well known. Here's an overview based on current research.

- **PLASTIC:** Leaching from plastic pipes has been well documented. In 2018, a comprehensive study found 163 substances leached from plastic piping, including known human toxins and carcinogens such as benzene, which is regulated at just 5 ppb. As concerning, 74 of the leached substances are not currently regulated, meaning their effects on human health are unknown. Plastic pipe, fittings, and the chemical solvents and adhesives used to bond and seal them all use complex chemical blends, hydrocarbons, and other additives. These substances leach from pipe walls over time, especially in plumbing exposed to heat or hot water. The effects of additives used by water companies to disinfect drinking water also can interact with chemicals in the plastics, producing secondary chemicals that are not well understood.

- **COPPER:** Copper pipes leach traces of copper at levels generally regarded as safe. Moreover, at these low levels, copper is an essential nutrient to maintain blood health and support muscle elasticity; this is especially true for the heart. Humans consume copper from a number of foods, including whole grains, dark chocolate, and shellfish. Few individuals will suffer impacts caused by leaching from lead-free copper pipe and fittings. Only those affected by Wilson's Disease, a health condition in which the body does not regulate copper, should have cause for concern. The limit for copper is 1,300 ppb, but average levels in North America range from 20- 75 ppb; much less than what is considered unsafe.

- **IRON & STEEL:** Pipes made of iron and steel may release small amounts of oxidized metal (rust particles) into water. While rust may discolor the water, it poses no health concerns.

TOXICITY (SMOKE AND GASES)

As noted in the sections on combustibility and firestopping (pages 16-17), the effect of fire on piping varies significantly from material to material.

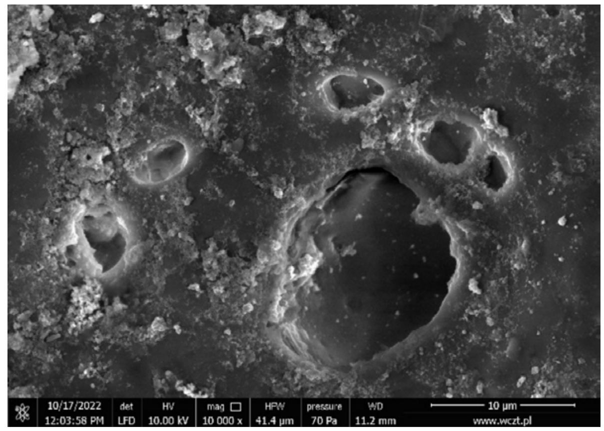
- Copper is non-combustible and will not release smoke or other gases when heated. Iron and steel also are non-combustible.
- Plastic burns at temperatures beginning around 413 degrees. Studies show that burning plastic releases smoke containing carcinogens and other toxins that will impact occupants and first responders, including dioxins, hydrochloric acid, sulfur dioxide, and heavy metals.

MICROPLASTICS

Plastics degrade due to chemical interactions with other materials, thermal effects, physical abrasion, and microbial activity gradually break the polymers down. The smallest of these particles – microplastics (from 0.1 microns to 5 mm in diameter) and nanoplastics (smaller than 0.1 microns) – raise concerns for a number of reasons, including their inability to dissolve in water, the ease with which they infiltrate the environment, and large surface area relative to their size.

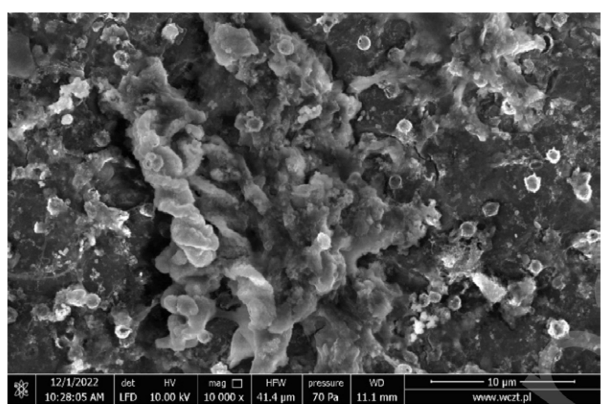
Most discussions of microplastics thus far have focused on the environmental impact of plastic pollution. However, a study by European researchers recently identified plastic pipes as a significant source of plastic contamination in potable water systems. Their analysis of PVC and PE piping material sampled from water-transmission systems found that the interior surfaces of these pipes degrade and release micro- and nanoplastics into drinking water, adding to humans' already significant exposure to plastic pollution.

Microscopic images of PVC pipe showed extensive pitting and holes along with fine, torn plastic particles on the inner surface of the pipe walls. These wear patterns existed in pipes of all ages and diameters, with "peeling and detachment of the polymeric material" forming nanoplastics that passed into the distributed water.

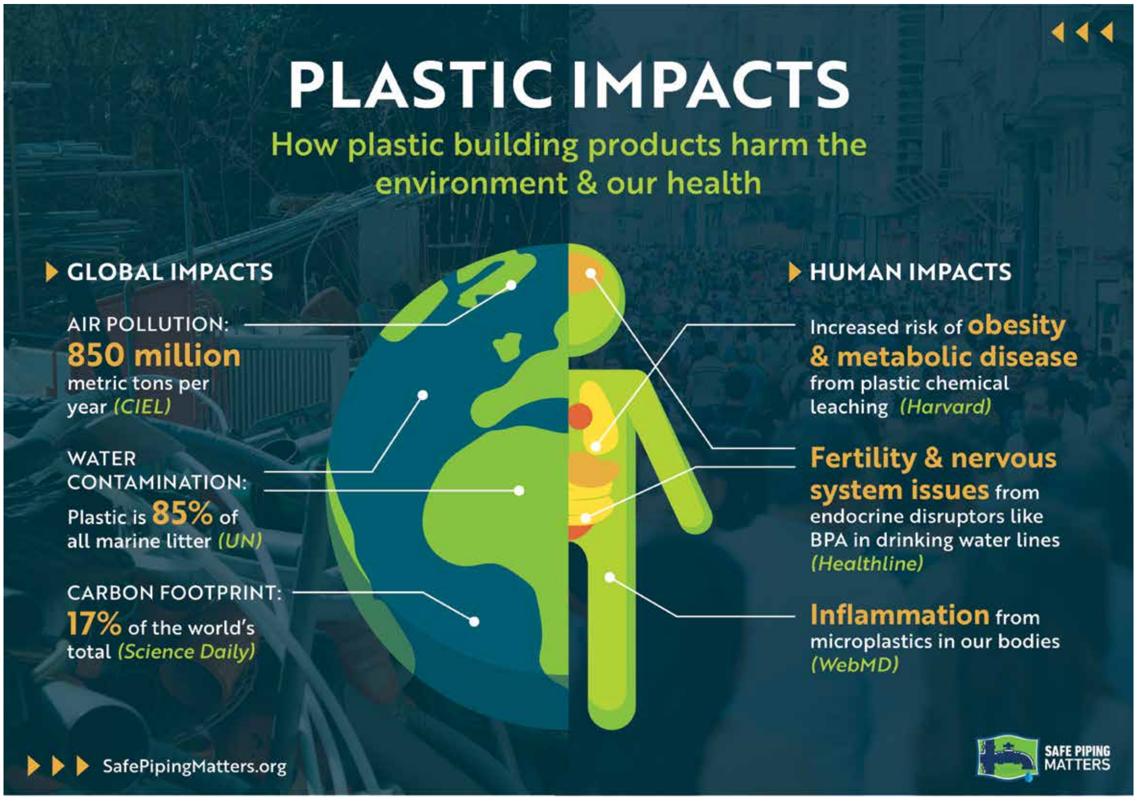


Wider pipes mainly showed "deep pits around which peeling areas and plastic particles were visible." Small-diameter pipes showed numerous particles and fragments of torn material. Since these smaller pipes are mainly found near the ends of water distribution networks, including within homes, the study concluded these pipes could "significantly" expose consumers to "unwanted microplastics… via tap water."

Scans of PE pipe interiors found similar degradation due to environmental, chemical, and biological factors. Researchers observed wrinkles on the inner surface of pipe; most damaged areas comprised "fragments of peeling antioxidant coatings and polyethylene itself."



Emerging medical studies of microplastics have found plastic particles inside a wide range of animal organs, including the gut, lungs, brain, and reproductive systems. Long-term medical impacts of microplastics ingested from water and other sources require more study, but researchers are examining issues such as tissue inflammation, degradation of organ function, carcinogenic and genotoxic effects, and reproductive and developmental damage. The existing body of evidence clearly suggests that more transparency and caution is warranted. Researchers increasingly assert that we should follow the Precautionary Principle with regard to plastics, prohibiting use of chemicals with unknown effects from being used in materials that can later impact human health.



RECOMMENDED PIPING CRITERIA

To ensure piping systems protect the health of occupants, consider including the following requirements in construction documents related to CSI Divisions 21 and Division 22:

- Install piping materials that do not release toxic chemicals such as benzene if pyrolized, as determined by testing methods described by "Drinking water contamination from the thermal degradation of plastics," published by Environmental Science: Water & Technology (Environ. Sci.: Water Res. Technol., 2021, 7, 274).
- Require that piping in plenum spaces shall be comprised of non-combustible materials that do not exceed a Flame Spread Index (FSI) of 25 or a Smoke Developed Index (SDI) of 50 when tested to ASTM E84. Modified tests shall not be accepted. Listing and test data shall be submitted for review of compliance.
- Install filters at point of use for drinking water to trap micro- and nanoplastic particles.
- Consider replacing aging plastic pipe with alternative materials such as copper, cast-iron, or other proven materials.

RESILIENCE

OVERVIEW

Piping systems should outlast the useful life of the building in most cases. Ensuring they will last demands systems and products designed to withstand natural stresses, as well as impacts from exposure to physical and chemical threats. When correctly specified and installed, most materials – from copper, iron, and steel to the range of plastic options – will perform as needed for decades. The limitations on such performance come mainly from accidental damage caused by chemical exposures that damage the pipe or from physical impacts and strains.

CHEMICAL COMPATIBILITY

Chemical compatibility is perhaps the more concerning threat to plumbing because it can occur either as a byproduct of maintenance on other building systems or as a side effect of building occupants who are unaware how their activities can affect pipe integrity. In addition, the damage caused by chemicals often occurs gradually, making it hard to identify and correct until pipes burst. Each type of piping material has differing levels of risk from chemicals:

CAST-IRON resists damage from typical substances in a DWV system. However, it may be impacted when solutions fall below a pH of 4.3. Codes and standards require a special waste DWV system for such applications.

> "Piping systems should outlast the useful life of the building"

COPPER PIPE also is generally impervious to corrosion. Copper pipe may experience pitting if exposed to water with pH levels less than 7.2.

PLASTIC PIPE varies in its resistance to the types of chemicals that may cause damage, with significant variations in performance by material type and even of subtypes (for example, different forms of PVC). The chemical, concentration present, and temperature also will influence the speed and degree of damage done. The following lists some examples of chemical threats to pipes, but construction and maintenance teams should work closely with pipe manufacturers to assess piping risks, especially for plastic piping applications under pressure or at different temperatures.

- A wide range of commonly used substances – including caulk, solder flux, spray-foam insulation, HVAC chemicals, firestopping products, thread sealants, primers, cleaners, solvent cements, food oils, and detergents – may cause deleterious effects including plasticization, brittleness, and stress cracking.
- Exposure to UV light, including sunlight as well as emissions from some light fixtures, may cause surface degradation and decrease impact resistance.
- Electrical cables and computer wiring may cause material destruction at contact points as plasticizers in the wire coatings interact with pipe material.
- Chemicals used for termite treatment and mold abatement may cause brittleness and stress cracking.
- Hot chlorinated water may cause brittleness, cracking, and swelling.
- Strong solvents, oxidants, acids, bases, halogens, and esters/ketones may also damage plastic pipe and fittings.

MATERIAL STRENGTH

The resilience of a pipe to cracking or breaking from collisions, earthquakes, and stresses during use depends on the strength of the material:

Crush Loads/Maximum Allowable Deflection for Sewer Pipes (Lbs. Per Linear Ft.)

	Crush Lod		Maximum Allowable Deflection (5%)				
	CI (No Hub)	CI (Service Wt.)	PVC SCH40 ASTM D2665 Solid Wall	PVC SCH40 ASTM F891 Cellular Core	PVC Sewer SDR 35 ASTM D3034	ABS SCH40 ASTM D2661 Solid Wall	ABS SCH40 ASTM F628 Cellular Core
4″	4877	4451	837	540	125	513	473
6″	3344	2997	596	477	183	378	298
8″	3674	3674	Not Mfg.	518	238	Not Mfg.	Not Mfg.
10″	4317	4342	503	387	297	Not Mfg.	Not Mfg.
12″	Not Mfg,	3632	482	383	352	Not Mfg.	Not Mfg.

Source: Cast Iron Soil Pipe and Fittings Handbook, cispi.org

For applications of pipe where risk of damage may be higher – such as in parking garages, under manufacturing floors, or under internal roadways – engineers and architects should consider materials rated for higher crush loads.

Thermal expansion and contraction represent another form of stress placed on piping materials. The expansion and contraction of long pipe runs will affect the fidelity of joints and fittings, as well as firestop brackets and fasteners.

- Cast-iron pipes have an expansion factor of 0.745 in.
- Copper pipes have an expansion factor of 1.110 in.
- Plastic pipes have an expansion factor of 4.08 in. (PVC) to 11.4 in. (PE type 1)
- Steel pipes have an expansion factor of 0.780 in. (mild) to 0.940 in. (stainless).(all values listed are in./100 ft./100 °F)

Architects and engineers should consider selecting more stable pipes for installations through un-conditioned spaces, including exterior walls, shafts, and soffits, as they may experience large temperature swings during the course of a day or in the transition from season to season.

RECOMMENDED PIPING CRITERIA

To ensure piping systems protect the integrity of buildings, consider including the following requirements in construction documents:

- Piping materials installed underground and in parking garages and similar structures shall have crush loads greater than 2,500 lbs.
- Piping materials installed in unconditioned and other spaces subject to anticipated ambient temperature changes of more than 30 °F during the course of a year shall have expansion factors of less than 1.5 in/100 ft./100°F).

SUSTAINABILITY

Building and construction industry professionals increasingly prioritize materials and products that minimize environmental impact in production and after disposal. This section presents an overview of each lifecycle stage.

By its nature, the initial stage of material extraction and product manufacturing consumes the most energy and creates the largest environmental impact. Companies with a commitment to improving their processes – making them cleaner and more efficient – often demonstrate transparency with customers and consumers by documenting and openly publishing these impacts.

- **PLASTIC:** Largely sourced from fracking natural gas, the building blocks of plastics are then "cracked," processes that consume large amounts of both energy and water. The chemical components are then manufactured into plastic pellets called nurdles, a manufacturing process that produces significant air pollution and presents challenges for toxic emissions due to the addition of chlorine and other compounds that define product characteristics such as flexibility, strength, resistance to UV, and others. Recent documented cases of PVC production in forced Uyghur labor camps have raised human rights questions for products produced with nurdles produced in China.

- **COPPER:** Metal mining has significant impacts on the local environment, including disruption of natural habitats and use of water. Refining and smelting are also energy-intensive processes that produce carbon footprints. The copper industry has established an independent initiative, Copper Mark, which requires the entire industry to contribute to the United Nations Sustainable Development Goals. In addition, much of the copper used to produce piping comes from recycled material, reducing the environmental impact of its production dramatically.

- **IRON:** The process of mining and refining iron has impacts on the environment very similar to those of copper. Even more so than copper, however, nearly all cast-iron piping produced in North America uses recycled materials (see below). The Cast Iron Soil Pipe Institute has documented improvements made by its members to improve the manufacturing processes, including scrubbing air pollution and recycling wastewater.

At end of life, building materials have several potential destinations: recycling, landfill, incineration (aka energy recapture), and recycling. Some in the industry describe buildings themselves as "material banks" with "deposits" to be withdrawn at end of life. To support the circular economy, such deposits should be reused wherever possible, recycled if not reused, and only disposed of as a final option.

- **COPPER:** Like all products made of copper, pipe made from this material has an infinite recyclable life. Recent recycling analysis show facilities captured nearly a million megatons of old and new copper scrap, meeting over a third of the U.S. market's need for refined copper. Market data shows premium-grade scrap retains up to 95% of its value compared to mined ore.

- **CAST IRON:** While cast iron is not a new product, it does have a green pedigree. Cast-iron soil pipe produced in North America is made from at least 96% recycled materials. Manufacturers utilize hundreds of millions of pounds of post-consumer scrap iron and steel, and the products are fully recyclable at end of life.

- **PLASTIC:** Unlike many other building materials, 95% of plastic becomes waste at end of life: from pipes to paint, tools to toys, and furnishings to fabrics. For plumbing applications in particular, recycling of pipe material is prohibited due to risk of cross-contamination and biomaterial. Once plastic enters the waste stream, it poses a range of challenges. Some plastic building waste gets burned, becoming a new source of fossil-fuel pollution and amplifying the material's carbon footprint. Most plastic just piles up in landfills, where since it can't biodegrade, it persists for decades.

PIPING SPECIFICATION LANGUAGE

Apply the following standards and language to CSI Division 21 and 22 for tube and fittings in domestic water distribution, DWV applications, and fire-sprinkler systems.

DIVISION 22: WATER DISTRIBUTION PIPING SYSTEMS (ABOVE GROUND)

A. TUBE: ASTM B 88 Type K, L or M, hard temper

B. FITTINGS: ASME B16.22, ASME B16.51, ASME B16.18, ASME B16.26, ASME B16.50

C. JOINTS: Soldered, Brazed, Flared, Press-Connect or Push-Fit. Note: ASTM B 32 Alloy Sn50 shall not be used.

DIVISION 22: WATER DISTRIBUTION PIPING SYSTEMS (BELOW GROUND)

A. TUBE: ASTM B 88 Type K or L, annealed temper, or hard temper

B. FITTINGS: ASME B16.22, ASME B16.51, ASME B16.18, ASME B16.26, ASME B16.50

C. JOINTS: Soldered, Brazed or Flared. ASTM B 32 NOTE: Alloy Sn50 shall not be used. Brazed or Flared joints are recommended

DIVISION 22: DRAIN, WASTE, VENT PIPING SYSTEM (ABOVE OR BELOW GROUND)

A. TUBE: ASTM B 306, Type DWV

B. FITTINGS: ASME B16.23, ASME B16.29

C. JOINTS: Soldered or Brazed

DIVISION 21: FIRE SPRINKLER

A. TUBE: ASTM B 88 Type M, hard temper

B. FITTINGS: ASME B16.22, ASME B16.18,

C. JOINTS: Soldered or Brazed

NOTE: Brazed joints are required for most applications, however soldered joints using ASTM B 32 Alloy Sb5 are acceptable for certain occupancy and hazard classifications.

SECTION 22 11 000
FACILITY WATER DISTRIBUTION

DOMESTIC WATER

ABOVE GROUND: Type L copper water tube, H (drawn) temper, ASTM B88; wrought copper pressure fittings, ANSI B16.22; lead free (<.2%) solder, ASTM B32; flux, ASTM B813; copper phosphorous brazing alloy, AWS A5.8 BCuP. Copper mechanical grooved fittings and couplings on roll grooved pipe may be used in lieu of soldered fittings. Mechanically formed brazed tee connections may be used in lieu of specified tee fittings for branch takeoffs up to one-half (1/2) the diameter of the main.

BELOW GROUND 2-1/2" AND SMALLER: Type K copper water tube, O (annealed) temper, ASTM B88; with cast copper pressure fittings, ANSI B16.18; wrought copper pressure fittings, ANSI B16.22; lead free (<.2%) solder, ASTM B32; flux, ASTM B813; or cast copper flared pressure fittings, ANSI B16.26.

BELOW GROUND 3" AND LARGER: Ductile iron pipe, mechanical or push on joint, thickness Class 52, AWWA C151; with standard thickness cement mortar lining, AWWA C104; ductile iron or gray iron mechanical joint cement mortar lined fittings, Class 250, AWWA C110; ductile iron mechanical joint compact fittings, Class 350, AWWA C153; rubber gasket joints with non-toxic gasket lubricant, AWWA C111. Provide 8 mil tube or sheet polyethylene encasement of iron pipe and pipe fittings, AWWA C105.

SECTION 22 13 000
FACILITY SANITARY SEWERAGE

SANITARY WASTE AND VENT

INTERIOR ABOVE GROUND: Hubless cast iron soil pipe and fittings, ASTM A888; with no-hub couplings, CISPI 301, CISPI 310, ASTM A74. Pipe and fittings shall be marked with the collective trademark of the Cast Iron Soil Pipe Institute or receive prior approval of the Engineer.

Type DWV copper water tube, H (drawn) temper, ASTM B306; with cast copper drainage fittings (DWV), ANSI B16.23; wrought copper drainage fittings (DWV), ANSI B16.29; lead free (<.2%) solder, ASTM B32; flux, ASTM B813; copper phosphorous brazing alloy, AWS A5.8 BCuP.

INTERIOR BELOW GROUND: Hubless cast iron soil pipe and fittings, ASTM A888; with no-hub couplings, CISPI 301, CISPI 310, ASTM A74. Pipe and fittings shall be marked with the collective trademark of the Cast Iron Soil Pipe Institute or receive prior approval of the Engineer.

COSTS AND VALUE ENGINEERING OF PLUMBING

Construction project teams select materials based on factors such as durability, sustainability, safety, aesthetics, and cost, among others. When well executed, the process of value engineering (VE) can optimize this last factor – cost – while still ensuring plumbing will perform all essential functions. For many architects, engineers, and owners, as well as some contractors, value engineering has a tarnished reputation, however. When VE efforts fall short, the results can be devastating, especially with building plumbing systems.

A recent example from Baltimore offers a case in point. The contractors responsible for building a harborside hotel – Hensel Phelps Construction and Southland Industries – "value-engineered" building plumbing systems by substituting a lesser material in place of what architects had specified. The pipes failed within 7 years, turning the $2.6 million contractors "saved" into a legal liability they reportedly settled at a cost of over $18 million.

In a recent discussion with a number of plumbing professionals, one of them made the following observation about value engineering of plumbing systems: "Most value-engineering efforts deliver very little value and no engineering."

That seems like the case for that ill-fated project in Baltimore, but it's not true universally. Many architects and engineers work closely with contractors to strike the right balance of cost with other factors.

> **"Most value-engineering efforts deliver very little value and no engineering."**

Competing cost-benefit analyses from manufacturers of plastic pipes, copper pipes, and iron/steel pipes each document advantages for their respective products, making it difficult to determine which is most appropriate. To resolve the conflicts in guidance, teams should evaluate how well a given pipe material matches the needs of a building. Their discussions must consider project location, building type, code requirements, and the priorities of owners, developers, and tenants. A set of initial questions to consider appears on the following page. The Safe Piping Matters publication Value Engineering in Plumbing Systems provides a more complete approach.

QUESTIONS TO CONSIDER

To avoid negative consequences from a regrettable substitution of plumbing materials, architects, engineers, and contractors should discuss the following questions when considering value-engineering tradeoffs.

SAFETY: How well does the plumbing maintain the integrity of fire-protection measures in the building? Is the building located in an area at risk of wildfires or other threats? Could occupants be compromised in their ability to evacuate in an emergency? Will activities of tenants or other building operations increase the risk or intensity of fires? For example, will the building ever have flammable or toxic materials onsite?

DURABILITY: What factors may impact how long the plumbing system will perform to the required standards? Factors to consider include ease of maintenance, system stresses in operation especially for suspended and underground installations, and temperature changes in non-climate-controlled areas, among others.

RESILIENCE: What other factors may threaten the integrity and performance of the plumbing? Consider threats such as contact with chemicals that may damage or permeate into pipes and risks from physical impacts to exposed pipes in parking garages or passageways.

HEALTH: Will the system protect occupant health? Under certain conditions, various pipes release substances into drinking water that have negative impacts on bodily systems.

SUSTAINABILITY: How great an impact does manufacturing, operating, and removing a system have on the environment? Circularity is a key differentiator.

INSURANCE LIABILITY: What are insurers finding with regard to losses related to building plumbing?

What building codes, regulations, and other recommendations could apply to the building plumbing system now and in the future?

EMERGING ISSUES

This section discusses a range of topics that are important to address, but for which full information is not yet available.

NATURAL DISASTERS

Damage from natural disasters amplified by climate change are increasing interest in building piping systems that can withstand damage from extreme weather events. The National Institute of Standards and Technology (NIST) has begun working with the Environmental Protection Agency (EPA) on a program to improve the resilience of premise plumbing systems to protect water safety, improve efficiency, enhance sustainability, and increase resilience. The two organizations will also work with academia, the private sector, nonprofits, and other government agencies, an effort that industry leaders expect to influence codes and standards, encourage upgrades of aging piping infrastructure, protect water quality, and increase efficiency.

PIPE RESIZING

Research into increased incidence of legionella and other waterborne organisms has raised questions about the impact of low-flow fixtures on water safety. Lower usage rates increase the amount of time water spends moving from the treatment center, through the piping system, and then inside a building before flowing from a fixture. Overall, this means more opportunity for pathogens like Legionella bacteria to grow. IAPMO published new sizing standards in Appendix M of the 2018 code, taking into account current flow rates; this recommends moving to smaller pipe for potable water based on peak water demand.

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What is PEX Piping	Plumbing Lab	plumbinglab.com
Why Choose Cast Iron?	Cast Iron Soil Pipe Institute	cispi.org
Why Not Just Draft One Uniform Plumbing Code?	Plumber Magazine	Plumbermag.com