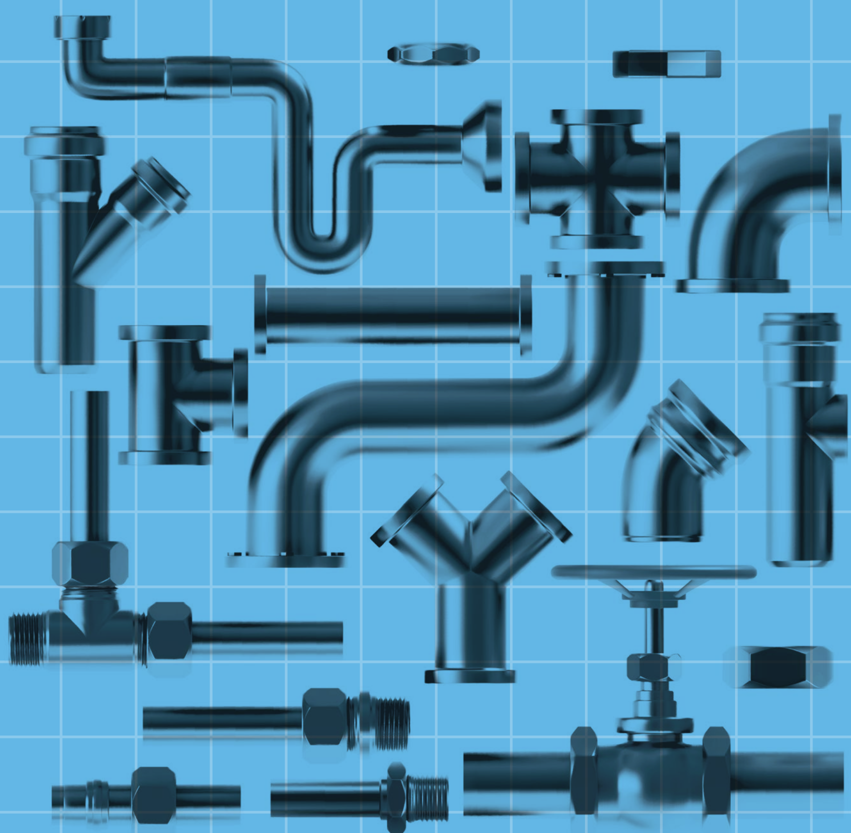
PLUMBING SPECIFICATION GUIDE



FOR AEC PROFESSIONALS

SAFE PIPING MATTERS

PLUMBING SPECIFICATION GUIDE

INFORMATION & INSIGHTS FOR AEC PROFESSIONALS

https://safepipingmatters.org/
1st Edition, 2022

SAFE PIPING MATTERS

INTRODUCTION

OVERVIEW

Piping systems represent a hidden opportunity to strengthen the performance and longevity of commercial and residential buildings. Pipe and fittings distribute water throughout structures, carry away waste, vent fumes and exhaust, and provide fire protection, among other essential functions that ensure the safety and health of occupants. During disaster incidents such as wildfires and hurricanes, piping systems also play an important role in establishing a building's sustainability and resilience. These factors must be considered when looking at total lifecycle cost of systems during and after use. This guide provides architecture, engineering, and construction (AEC) professionals considerations for specifying pipe, because materials matter when it comes to critical building systems. Recent crises across the country illustrate the impacts that piping choices can have:

When it was being installed, lead pipe was widely available, affordable, and believed safe for use across a wide range of applications. The devastating impacts of poisoning from lead leaching out of pipes showed that was not the case, forcing hundreds of communities to spend billions of dollars replacing toxic pipes made of lead in homes, schools, and businesses.

Polybutylene (PB) plastic pipe provides another such example. Initially hyped as a "pipe of the future," PB was widely used 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 issues make designing piping systems a continuing challenge. Here are some key issues to consider for piping, in a rough order of priority:

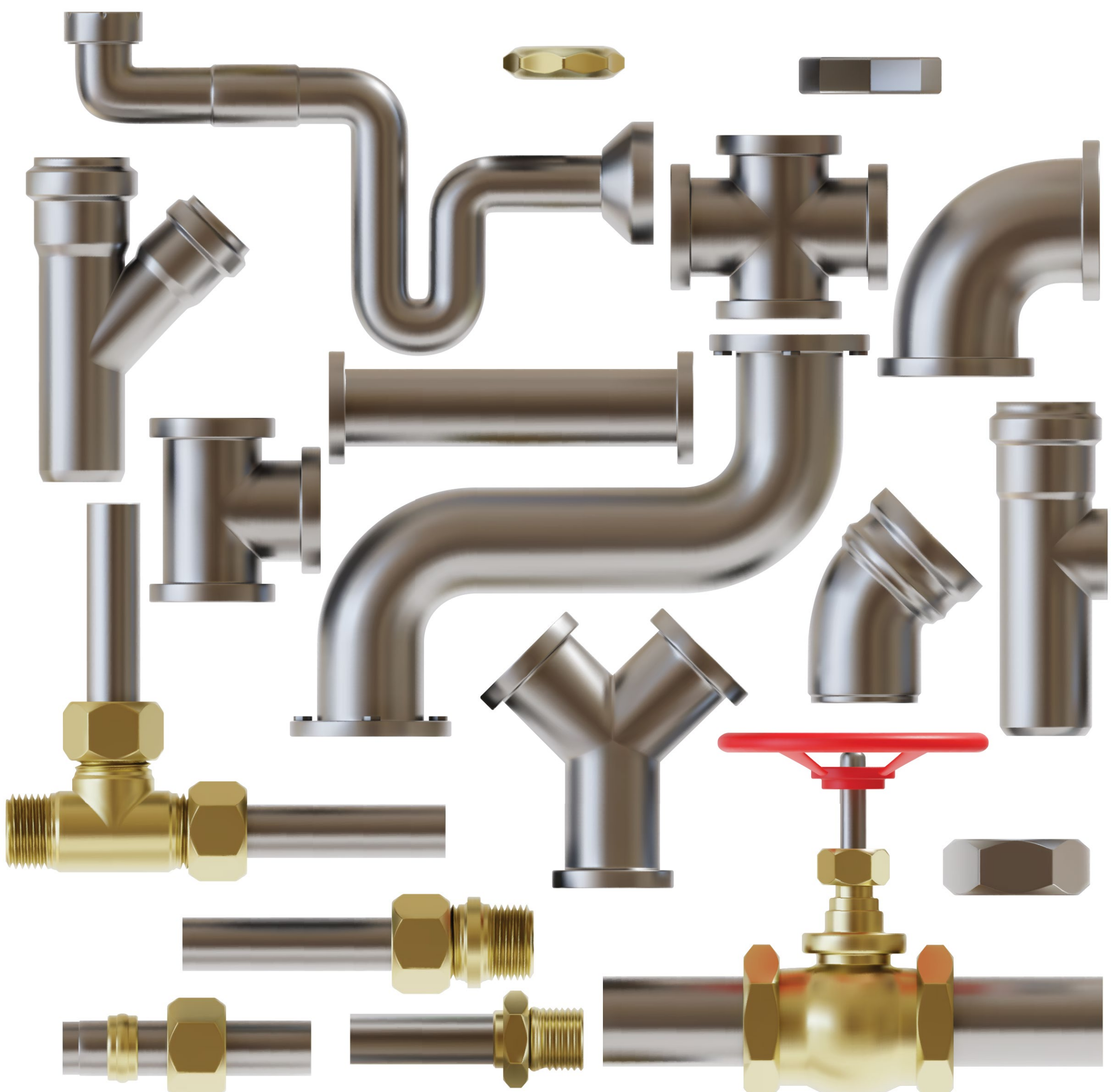
- **Safety:** Protecting the lives of occupants of a building
- **Health:** Eliminating threats to short- and long-term health of occupants
- **Resilience:** Resisting damage from wildfires, hurricanes, and other natural disasters; accidental physical impact; and chemical exposures
- **Sustainability:** Minimizing environmental impact in production, during use, and after disposal
- **Costs:** Initial purchase and install, as well as maintenance during use

HOW TO USE THIS GUIDE

This specification guide will help engineers and architects identify factors relevant to the piping systems in their project, and then select and specify the most appropriate materials. The Considerations and Recommendations section (page 13) provides focused guidance for key building applications.

Contractors should use this guide to evaluate the design specifications and to inform the decisions they make before and during construction. They may wish to consult the Codes and Standards section (page 10), which summarizes requirements specific to piping.

Owners and occupants may also find parts of this guide useful as a reference to educate themselves and to help them advocate for the safe, healthy, and sustainable operation of the buildings where they live and work.

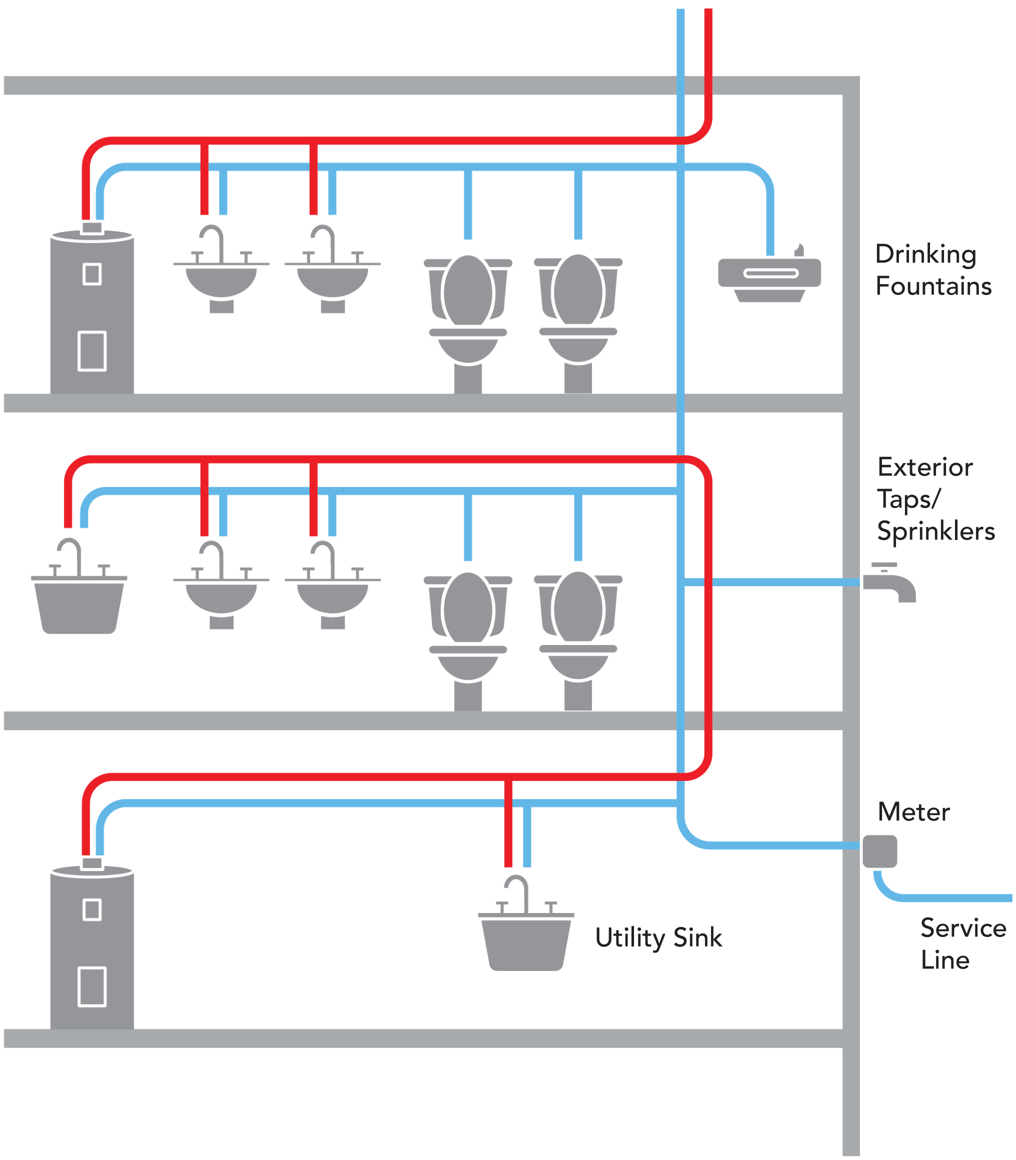


FUNDAMENTALS

This section describes the key components and functions of common piping applications in commercial and residential buildings.

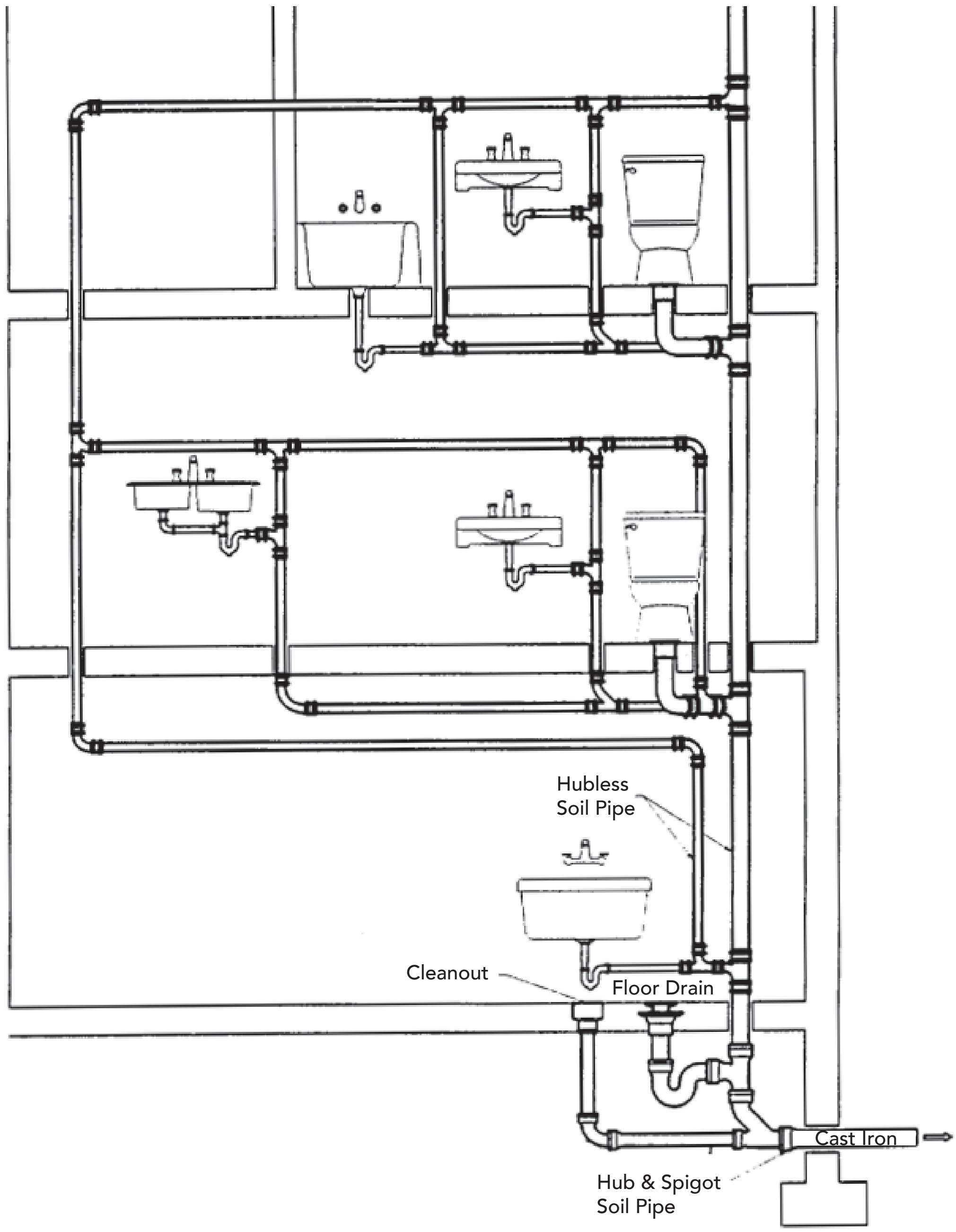
BUILDING WATER SYSTEMS

Building water systems initially connect buildings to sources of potable water, whether private sources or municipal supplies. They then distribute water throughout the structure through a system of vertical "riser" pipes that pass from floor to floor in a structure and horizontal runs that connect individual fixtures to the water supply. Water heaters and storage tanks are also a part of this system, as are control valves, faucets, and other fixtures.



DRAIN, WASTE, AND VENT SYSTEMS

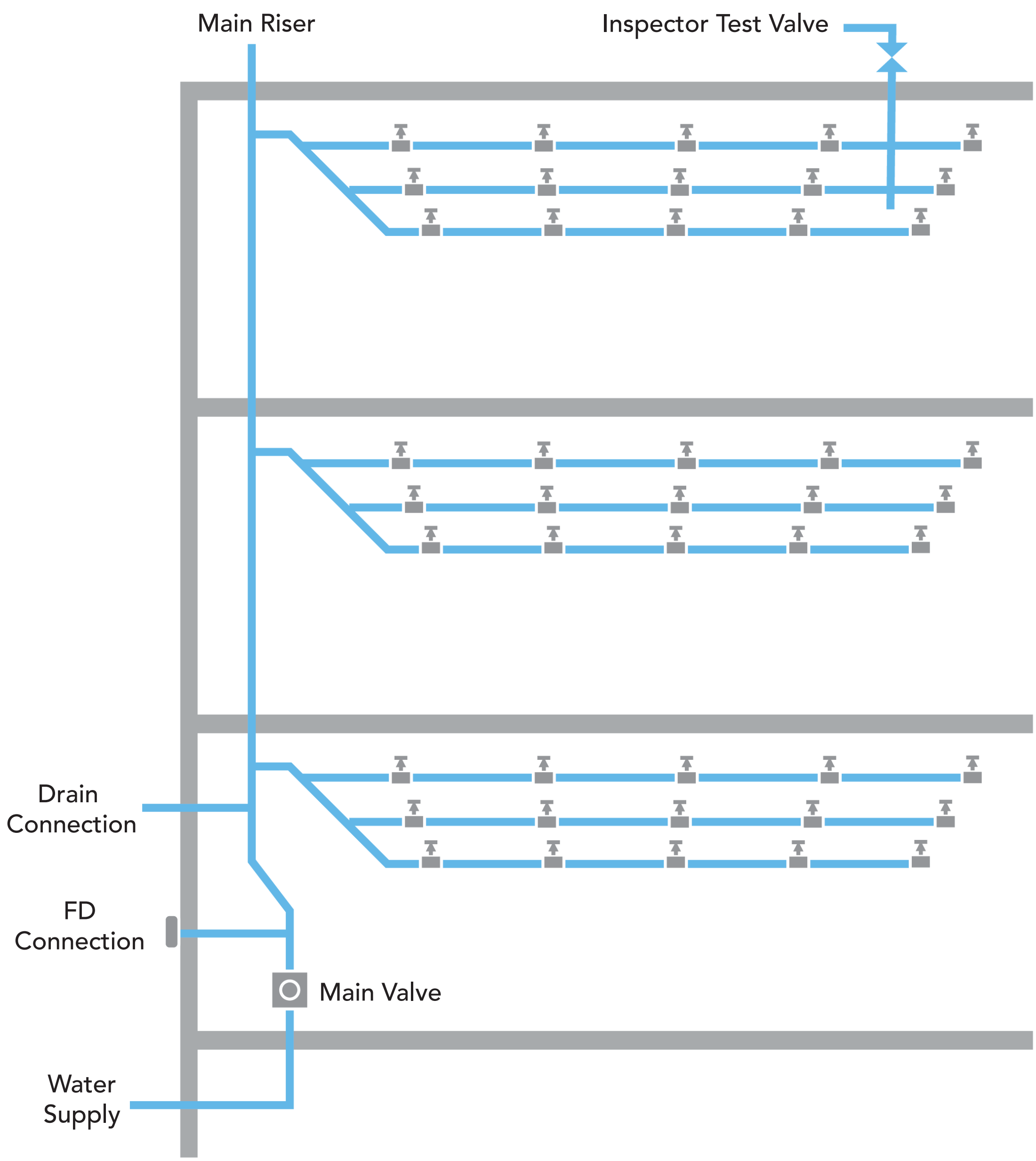
Drain/waste systems not only carry away water after use, but also must transport a wide range of other substances, from human urine and fecal matter, to grease and food waste, to chemicals used for cleaning. These systems include the physical drain mechanisms, the pipe, traps, and fittings that safely transport waste from throughout the structure, and the sewer lines that return waste back to a municipal 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 associated with waste, venting it to the exterior and safeguarding interior air quality. Branch vents connect most if not all individual drains and piping segments of waste systems to main vent stacks.

SPRINKLER SYSTEMS

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 similar in construction. They generally have 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 pipe is always filled with water, resilience of the pipe material is critical to limit the risk of water leakage.



OTHER SYSTEMS

Buildings may also feature several other types of piping systems, including pipe and valves 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 strengths and weaknesses of piping materials commonly used in the industry and introduces the best application(s) for each material type.

COPPER

Copper pipe has been widely used for plumbing applications for thousands of years. Its primary advantages include structural strength, density, non-combustible qualities, resistance to leaching and corrosion, heat transfer qualities, formability/machinability, long product life, and repairability. Copper pipe often includes 40% or more in recycled material, and pipes are widely recycled after use.

Weaknesses of copper include its base price, which may be higher than some other materials.

Copper is widely used for distribution of potable water; other applications include distribution of gases, oil products, and chemicals, as well as fire protection. Copper also circulates coolant in many HVAC systems. Common sizes for building water systems include nominal diameters of ½ up to 8 inches – all manufactured from five alloys containing at least 99.9% copper – in accordance with ASTM B88.

IRON

Cast-iron pipe has been used in buildings for centuries. Like other metal pipe, it features structural strength and rigidity, density, ease of installation, non-combustibility, heat resistance, sound-reduction qualities, and resistance to damage from heat and most chemicals. Cast-iron pipe offers among the longest product lifespans of piping material. In addition, cast-iron pipe has high levels of recycled content and most pipe is continually recycled after use. With appropriate dilution and flushing of DWV systems, cast-iron piping is suitable for pH ranges of 4.3 to 7.0, including on the outside of the pipe. Environments beyond this range should consider wrapping (for contact with corrosive soils) or utilizing cast-iron with coatings specifically designed for harsh environments.

Weaknesses of cast-iron pipe include the material cost, its heavier weight, and difficulty of repair.

Cast-iron is the material of choice for soil pipe applications that collect and carry away waste from toilets, sinks, appliances, and other bath and kitchen fixtures. The weight and strength of iron pipe side walls allow installations below grade, placed within vertical or horizontal building cavities, or suspended by hangers. Pipes are available in two versions:

Hubless pipe and fittings, which feature a coupling that can go over the ends of pipe sections and fittings and then be tightened to seal the joint. They should meet the ASTM A888 or CISPI 301 standards and are available in nominal diameters from 1-1/2" to 15".

Hub and spigot pipe and fittings should meet the ASTM A-74 standard. They use a gasket made of rubber or treated fibers to seal joints. Common sizes range from 2" to 15" nominal diameter.

STEEL

Steel pipe has long been used in a versatile range of construction applications. It balances structural strength and density with ease of fabrication, is non-combustible, offers a wide range of coating options, provides close tolerances for wall thickness, resists damage from heat and pressure, and delivers long product life. Steel is another highly reused and recycled material in the construction sector with a recycling rate of up to 94% according to the Steel Recycling Institute.

Weaknesses of steel pipe include higher purchase cost than some other materials, heavier weight, and less flexibility/bending. Higher conductivity of heat and electricity may also make it less suitable in some applications.

Steel pipe is most often used in 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 1/2 up to 24 inches.

PLASTIC

Plastic pipes include dozens of different chemical compounds, ranging from soft and flexible to highly rigid. This guide will look not only at their shared characteristics, but also at differences among main types of plastic pipe. In general, the formulas used to manufacture plastic have evolved continuously as companies reduced manufacturing costs and addressed performance issues. Today, many 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 include weaker structural strength than metal, greater expansion and contraction with temperature fluctuations, and lower rigidity (requiring more installation supports). Since it is made from petroleum-based chemicals, plastic pipes are combustible and can burn or melt in fires, releasing toxic materials into air and water. Plastic pipe has higher susceptibility to permeation and damage when exposed to chemicals – often described as "compatibility issues" – an issue addressed in part by ASTM Standard D543 and ISO 22088. Plastics also are known to leach compounds from the pipe walls, coatings, and adhesives into water, especially when heated.

Plastic pipe has the widest range of applications in the piping industry, including water supply and distribution, drain/waste/vent, sprinkler systems, and other uses such as for electrical conduit. These vary by types of plastic. Some are noted below:

- **CPVC (chlorinated polyvinyl chloride)** pipe is more flexible and can withstand higher temperatures than PVC 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 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 heat 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 drain/waste/vent 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. Sizes for these applications include nominal diameters in regular increments from 1/4 up to 24 inches.

OBSOLETE MATERIALS:

LEAD

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, and 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

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.

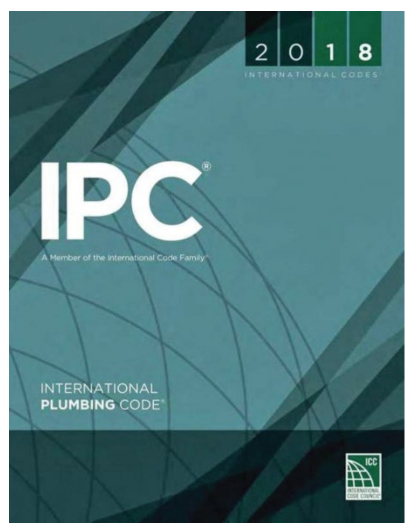
CODES & STANDARDS

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

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 7) 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 most states as the basis of their local codes. All sections of the code apply, but the following chapters are most relevant to the issues addressed by this guide:



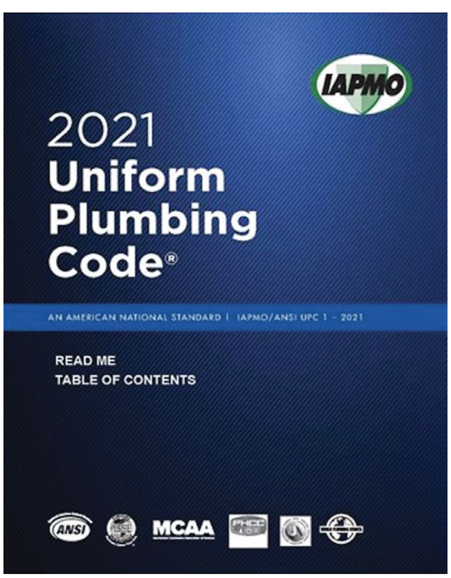
Chapter 4: Fixtures, Faucets and Fixture Fittings
Chapter 5: Water Heaters
Chapter 6: Water Supply and Distribution

Chapter 7: Sanitary Drainage
Chapter 8: Indirect/Special Waste
Chapter 9: Vents
Chapter 10: Traps, Interceptors and Separators

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 Universal 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 local codes. All sections of the code apply, but the following chapters are most relevant to the issues addressed by this guide:

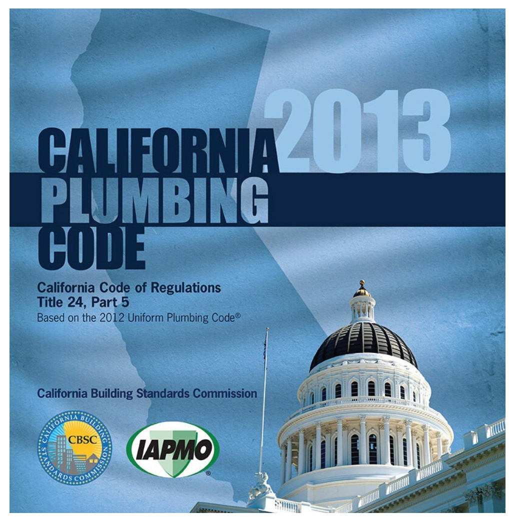


Chapter 4: Plumbing Fixtures and Fixture Fittings
Chapter 5: Water Heaters
Chapter 6: Water Supply and Distribution
Chapter 7: Sanitary Drainage
Chapter 8: Indirect Wastes
Chapter 9: Vents
Chapter 10: Traps and Interceptors
Chapter 14: Firestop Protection

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 restricts the use of plastic pipe in healthcare applications



New York, which restricts use of plastic pipe to structures of six stories or less

Chicago, which prohibits use of PVC pipe in buildings of more than three stories

Philadelphia, which prohibits use of ABS and PVC pipe in dwellings housing more than four families or greater than three stories in height.

Baltimore, which restricts use of plastic pipe to structures of six stories or less

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 Universal 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

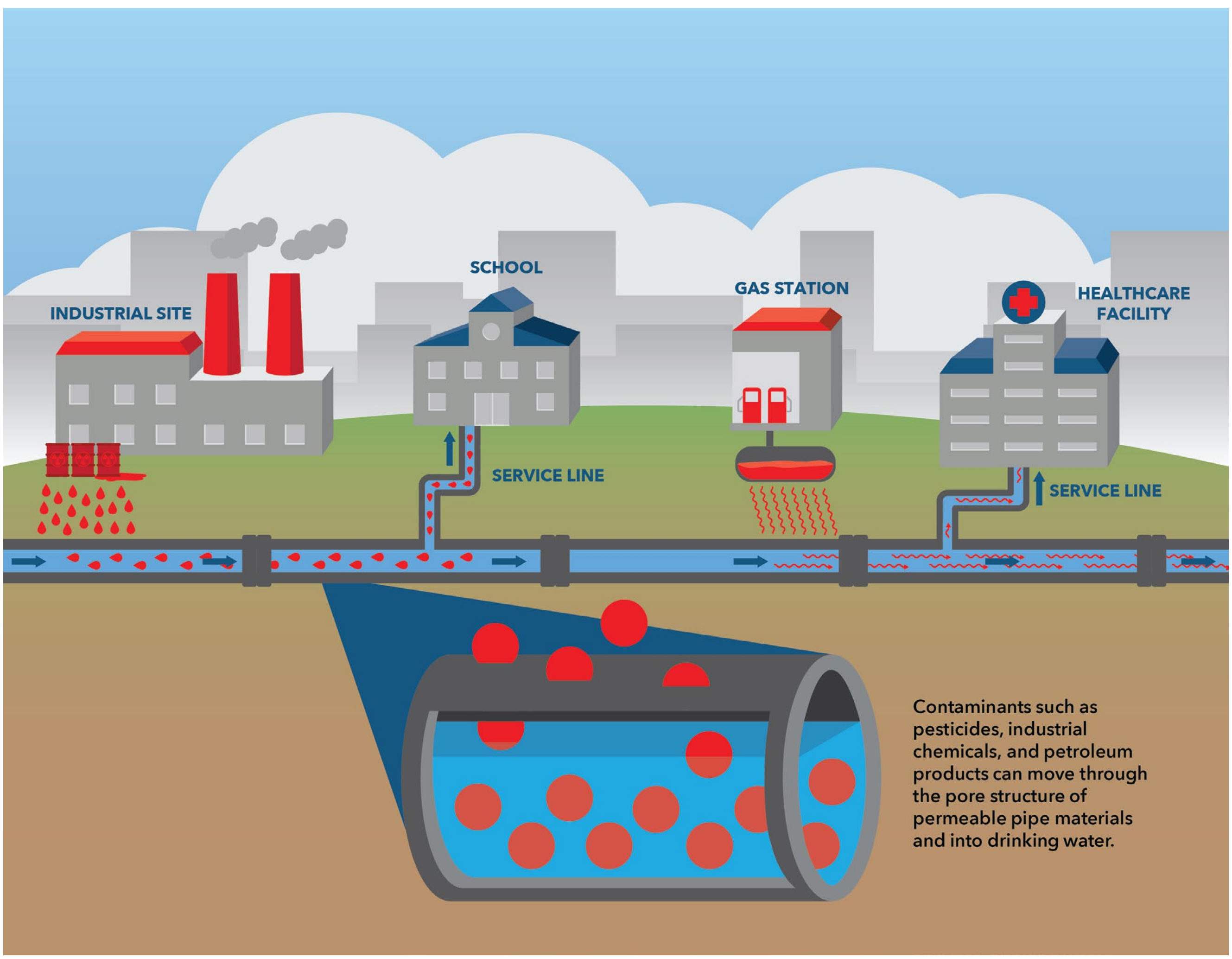
CONSIDERATIONS & RECOMMENDATIONS

This section provides considerations and recommendations that should inform specification of piping, language to include in design and construction documents, and with resources for further investigation.

SAFETY

Most important, pipe must not put building occupants at risk. If specified or installed incorrectly, piping systems can not only cause safety issues, they can threaten the integrity and functioning of a structure. Since most pipe and fittings connect to area water or waste systems, through outer and partition walls, and then among floors and rooms throughout the building, they can compromise critical systems and structural elements. Here are some issues to consider.

PERMEATION



Piping that connects buildings to water mains often passes belowground, under streets or through soil that may have contain environmental pollutants such as petroleum products, pesticides, industrial waste, or other chemicals. Research shows that many commonly used pipes can allow these substances to pass through the piping walls, a process called "permeation."

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., pore 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 quality and safety of the water (or other contents passing through the pipe).

The EPA says risks from permeable pipe 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

Research by fire-safety industry and testing laboratories have found that over the past several decades, many types of buildings have become more susceptible to fire damage. In 2020, the Fire Safety Research Institute conducted a dramatic test of flashover – the point at which a room becomes fully engulfed in flames. They tested two interiors side by side:

The first was outfitted with materials widely used in the 1960s, including wood, metal, and natural fibers.

The second interior featured synthetic materials used currently, with many plastics and engineered fabrics that meet flame and smoke standards.

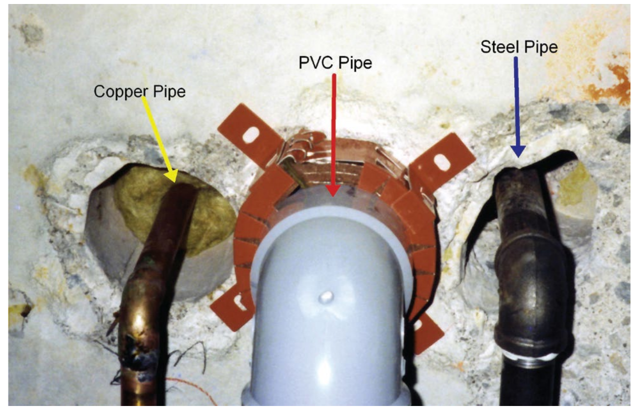
The older "natural" interior was still not fully engulfed after burning for more than 29 minutes. The newer "synthetic" interior, by contrast, was fully engulfed within 5 minutes. This difference in combustibility of materials gives occupants time to escape flames and smoke. Not to mention giving firefighters and other first responders much more time to respond.

Plastic pipes, foam, fabrics, and insulation all represent significant sources of combustible, petroleum-based materials that increase fire risk. National codes require manufacturers to test many building materials including pipe against standards for flame spread and smoke generation. To meet these standards, manufacturers of pipe made of combustible materials must treat them with flame-retardant chemicals such as bromines and halogenated compounds.

Ironically, when plastic pipe treated with flame retardants does pyrolize (melt/combust), it produces toxic smoke and chemical byproducts that pose significant health risks. Even short-duration exposures to these substances can lead to asphyxiation and poisoning of occupants trying to escape a fire.

As significant, studies of firefighter health find that exposure to the smoke and soot from fires increases incidence of many cancers, including those affecting the lungs, brain, heart, digestive, and reproductive systems. According to the National Institute of Occupational Safety and Health (NIOSH), cancer has become the leading killer of active firefighters, a disturbing trend in line with the growth of plastic content in buildings. A five-year study looking at cancer in firefighters determined they are at higher risk of cancer diagnoses and deaths than similar individuals in the wider population, likely due to toxin exposures at fire incidents.

FIRESTOPPING



Piping systems directly impact one element of building structure: its passive fire barriers. Many pipes penetrate barriers intended to slow or halt spread of fire through walls, ceiling plenums, and floors. If a pipe fails – or if the firestop material around it does not remain secured to the firewall – the resulting gap will compromise the safety of a structure. Fire incident tests demonstrate that a even a pencil-sized hole in a firewall will allow smoke to fill a 20x20 room in less than 4 minutes.

Codes require firestopping of all penetrations in passive fire barriers, but the requirements and performance of such systems varies significantly for non-combustible materials versus combustible ones. In general, metal pipes, including commonly used options such as copper, iron, and steel, require a lower degree of complexity and precision to firestop adequately than do plastic pipe materials.

These differences derive mainly from the physical properties of the pipe when heated. Plastic pipe will expand in the heat of material when heated. The following table summarizes relevant characteristics for common pipe materials:

Material	Copper	Iron	Steel	CPVC	PE (Type 1/2)	PEX	PVC
Melting Point (°F)	1,981	2,200	2,200	n/a	266	n/a	~413
Combustion (°F)	1,981	2,200	2,200	900	660	430	~790
Thermal Expansion Rate (in./100ft./ ΔT100 °F)	1.11	0.745	0.780	4.08	11.4/ 10.0	11.0	6.68

RECOMMENDED PIPING CRITERIA

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

- Potable-water pipe and components shall comply with NSF 14 and NSF 61.
- Piping shall be composed of non-combustible materials, as determined by compliance with ASTM E136.
- Piping materials in plenum spaces shall 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.

HEALTH

Even when pipes appear to perform safely within a building, they may still pose threats to short- and long-term health. Lead pipes represent a key example of such risks.

LEACHING

Chemical interactions between water and piping materials — typically oxidation — and the principles of osmosis mean all piping materials leach substances into water to some 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 8-9), 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 are non-combustible as well.

Plastic burns at temperatures beginning around 425 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.

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:

- Combustible piping materials shall 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).
- 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.

MATERIAL STRUCTURE

Overview Piping systems should outlast the useful life of the building in most cases. Ensuring such performance demands systems and products designed to withstand natural stresses, as well as impacts from exposure to physical and chemical challenges. When correctly specified and installed, most materials – from copper, iron, and steel to the range of plastic options – will perform as needed for decades, often beyond the lifespan of the building itself. 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 more concerning 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 pipe resists damage from typical substances in a sanitary drain, waste and vent 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.

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.

- Exposure 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.
- A wide range of other 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.
- Hot chlorinated water may cause brittleness, cracking, and swelling.
- Other strong solvents, oxidants, acids, bases, halogens, and esters/ketones may also damage plastic pipe and fittings.

MATERIAL STRENGTH

The resilience of a pipe 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:

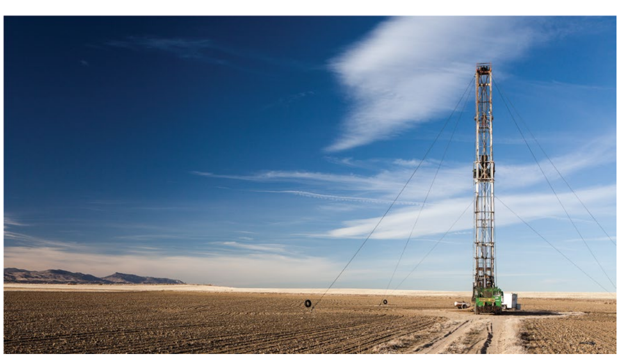
- Piping materials installed underground and in parking garages and similar structures shall have crush loads greater than 2,500 lbs.
- Piping materials installed in unconditioned and other spaces subject to anticipated ambient temperature changes of more than 30 °F during the course of a year shall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

SUSTAINABILITY

Overview 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 produces carbon footprints. The copper industry has established an independent initiative, Copper Mark, that 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.

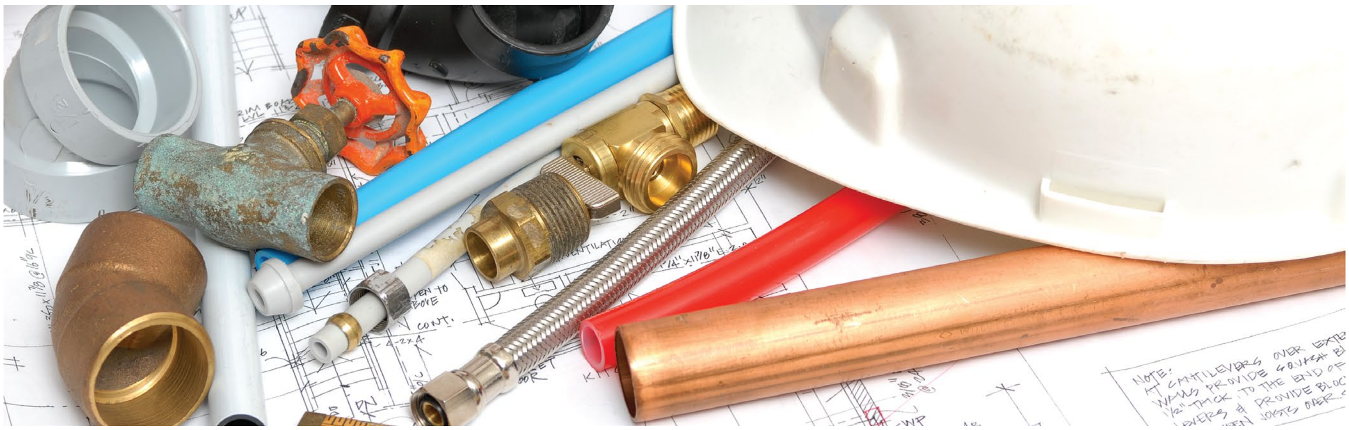
- **Copper:** Like all products made of copper, pipe made from this material has an infinite recyclable life. Recent recycling analysis show facilities captured nearly a million megatons of old and new copper scrap, meeting over a third of the U.S. market's need for refined copper. Market data shows 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, drain/waste/vent applications, and 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

In the specification and construction process, costs of piping material and installation labor are often an over-prioritized factor that is under-considered in reality. After a product is purchased and installed, factors such as safety, resilience, and sustainability will determine the actual cost over a building's lifetime. Weighing such factors must go beyond the per-foot price for purchase and installation, and yet that one dimension is all that many contractors and building owners examine. Models from the plastics industry, the copper industry, and the iron/steel industry – all showing longevity and cost advantages for their respective products – make it difficult to determine which is most appropriate.

ANALYSIS

The conflicting information may simply indicate that the most important factor required to evaluate best value is how well a given pipe material matches the needs of a building. Such analysis should incorporate discussions of project location, building type, code requirements, and the priorities of owners, developers, and tenants. Some questions to ask:

- Is the building adjacent to or downstream from industrial facilities?
- Does the building have elevated risk of fire due to its location? For example, being located in an area prone to wildfires.
- Will activities of tenants or other building operations increase the risk or intensity of fires? For example, handling or storing flammable or toxic materials onsite
- Are any occupants of the building compromised in their ability to evacuate?

- How tall is the building?
- What building codes, regulations, and transitory recommendations may apply to the building now and in the future?

EMERGING ISSUES

This section discusses a range of topics that are important to address, but for which the industry lacks enough information to understand fully.

MICROPLASTICS

The plastic pollution crisis continues to evolve, highlighting the environmental impact of discarded plastics of all types, from paint to pipes, fabric to furnishings, and toys to tools. Plastic does not biodegrade, instead disintegrating into micro- and nanoparticles as it is exposed to physical abrasion, ultraviolet light damage, and chemical interactions with other materials. All these elements break down the material's long polymer chains and release fragments into water, air, and soil. Tiny plastic particles now exist the most remote areas on earth.

Medical studies now find that contamination also extends inside human bodies. A study in the journal Environmental Science and Technology finds that Americans who drink the recommended amount of water likely consume 4,000 plastic fragments a year through tap water. Those who solely drink bottled water ingest 90,000. These particles may pass through the intestinal wall and into the bloodstream, affecting vital organs and altering immune function. Chemicals leaching from plastic pipes, bottles, and microplastics further impact health. Studies of CPVC, HDPE, PE, PEX, PP, and PVC, materials identified over 160 substances that pass into water, including known toxins and carcinogens such as formaldehyde, benzene, toluene, and dibutyl phthalate.

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.

REFERENCES

TITLE	SOURCE	WEBSITE
About Ductile Iron Pipe	Ductile Iron Pipe Research Association	dipra.org
After Use: Recycling Metal Building Products	Metal Construction News	Metalconstructionnews.com
Which plastic pipe is more reliable: PEX or CPVC?	Plastic Expert Group	Plasticexpert.com
Assessing the Cardiovascular and Chemical Risks Faced by Firefighters	Fire Safety Research Institute	Fsri.org
ASTM E136 Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C	Engineering 360	Standards.globalspec.com
Authority Having Jurisdiction	Wiley Online Library	Onlinelibrary.wiley.com
Benefits of Steel Conduit	Steel Tube Institute	steeltubeinstitute.org
Case study: the crude MCHM chemical spill investigation and recovery in West Virginia USA	Environmental Science: Water Research & Technology	Pubs.rsc.org
Cast Iron Soil Pipe and Fittings Handbook	Cast Iron Soil Pipe Institute	Cispi.org
Certification of Plastic Piping Products: NSF/ANSI 14 and NSF/ANSI/CAN 61	NSF	Nsf.org
Chemical Resistance Chart for PVC, CPVC, PVDF Pipe & Fittings	PVC Pipe Supplies	Pvcpipesupplies.com
Chemical Resistance of Plastic Piping Materials	Plastic Pipe Institute	Plasticpipe.org
Chicago Plumbing Code	Mechanical Media	Chicagoplumbingcode.com
Code Changes and Implications of Residential Low-Flow Hot Water Fixtures	California Energy Commission	Energy.ca.gov
Common Firestop Code Violations	Building Safety Journal	Media.iccsafe.org
Copper Mark Frequently Asked Questions	Copper Mark	Coppermark.org
Copper – the World's Most Reusable Resource	Copper Development Association	Copper.org
CPVC Piping Systems and Materials	Lubrizol	Lubrizol.com
CSI MasterFormat Specifications	The Engineering Toolbox	Engineeringtoolbox.com

REFERENCES

Decontaminating chemically contaminated residential premise plumbing systems by flushing	Environmental Science Water Research & Technology	Pubs.rsc.org
Different Types of Plumbing Pipes Used in Building Construction	The Constructor	theconstructor.org
Division 21 Fire Supression [sic]	Buildipedia	Buildipedia.com
Division 22 Plumbing	Buildipedia	Buildipedia.com
Expansion and Contraction of PVC Schedule 40, PVC Schedule 80, PVC PR 200 and PVC PR 160	Plastics Technical Manual	Charlottepipe.com
Firefighter Resources, Cancer and Other Illnesses	National Institute for Occupational Safety & Health	cdc.gov/niosh
General Properties of Polyvinyl Chloride Pipe, AWWA Manual M23	American Water Works Association	Awwa.org
Guide to Working with Copper and Copper Alloys	Copper Development Association	Copper.org
Healthcare Plumbing & Piping What to Expect In Healthcare Construction / Retrofit	Plumbing & Mechanical	Pmmag.com
Health Effects of HDPE Pipes and Fittings for Potable Water Applications	NSF	NSF.org
IAPMO Applauds Passage of Federal Premise Plumbing Research Legislation	International Association of Plumbing and Mechanical Officials	Iapmo.org
International Plumbing Code	International Code Council	Codes.iccsafe.org
Is Plastic Flammable? Plastic Melting Temperature Chart	Fireproof Depot	Fireproofdepot.com
Learn the Facts about Polybutylene Plumbing	Plumbing Express Info Central	Polybutylene.com
List of NFPA Standards	National Fire Protection Association	Nfpa.org
Numerical Model for Decontamination of Organic Contaminants in Polyethylene Drinking Water Pipes in Premise Plumbing by Flushing	Journal of Environmental Engineering	Ncbi.nlm.nih.gov

REFERENCES

NY Enforces Restriction on Plastic Pipe	Plumbing & Mechanical	Pmmag.com
Overview of the IPC	International Code Council (via Wayback Machine)	https://bit.ly/3x3nElH
Peak Water Demand Study; Probability Estimates for Efficient Fixtures in Single and Multi-family Residential Buildings	International Association of Plumbing and Mechanical Officials	Iapmo.org
Permeation of Petroleum-Based Aromatic Compounds Through Polyethylene Pipes Under Simulated Field Conditions	Dept. of Civil, Construction, and Environmental Engineering, Iowa State Univ.	CCEE.IAState.edu
Philadelphia Plumbing Code	UpCodes	Up.codes
Pitting Corrosion of Copper in Cold Potable Water Systems	Copper Development Association	Copper.org
Plastic Pipe 101: CPVC vs. PVC vs. PEX	Plastic Pipe and Fittings Association	Ppfahome.org
Plumbing Manufacturers International Applauds Science R&D Investments and STEM Education Provisions in New CHIPS and Science Act	Plumbing Manufacturers International	Safeplumbing.org
Polybutylene Piping: Concerns, Risks and Resolutions	Porch	Porch.com
Properties of HDPE Pipes	What is Piping	whatispiping.com
PVC versus Stainless Steel Pipe and Fittings	PVC Pipe Supplies	pvcpipesupplies.com
Reclaimed Water Piping	Plastics Pipe Institute	plasticpipe.org
SFPE Handbook of Fire Protection	Society of Fire Protection Engineers	Sfpe.org
Smoke Management in High Rise Buildings	C&S Companies	Kipdf.com
Sprinkler System Basics: Types of Sprinkler Systems	National Fire Protection Association	nfpa.org
State Plumbing Codes	Green Drain	Greendrains.com
Tech Topic: PEX pipe	Plumbing & Mechanical Engineer	Pmengineer.com

REFERENCES

The Effect of Sunlight Exposure on PVC Pipe, Conduit, and Fittings	Atkore Heritage Plastics	Heritageplastics.com
The Importance of Velocity in a Piping System; Uniform Plumbing Code Continues Dr. Hunter's Work on Effective Sizing of a Supply and Distribution System	International Association of Plumbing and Mechanical Officials	Codes.iapmo.org
The Pros and Cons of Different Types of Plumbing Pipes	Mr. Rooter	mrrooter.com
Toxic Tiles	The Intercept	Theintercept.com
Turn Over a New Leaf	Cast Iron Soil Pipe Institute	Cispi.org
Uniform Plumbing Code	International Association of Plumbing and Mechanical Officials	Epubs.iapmo.org
Uniform Plumbing Code (IAPMO/ANSI UPC 1-2021)	American National Standards Institute	Blog.ansi.org
Water Demand Calculator Study	International Association of Plumbing and Mechanical Officials	Iapmo.org
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