10. Standards for materials used in plumbing systems

10.1 Standards

Standards are sets of rules that outline specification of dimensions, design of operation, materials and performance, or describe quality of materials, products or systems. These standards should cover the performance expectations of the product for particular applications, as well as, in the case of drinking-water contact, the chemicals that may be leached from the product into the water. The intent of standards is to provide at least minimum quality, safety or performance specifications so as to ensure relatively uniform products and performance, and to remove ambiguity as to the suitability of certain commercial products for particular applications. They reduce the risk of error by installers, and also provide assurance to the plumbing system owners. Standards also provide direction to manufacturers in respect to the expectations of the products that they produce. Internationally accepted standards provide economies to both the manufacturer and the user by reducing the number of products of the same type that must be produced. Standards may be developed by industry, non-profit organizations or trade associations, as well as national or international bodies. The existence of credible standards and certifiers relieves the regulatory authority of the need to develop its own case-by-case standards and product assessment system.

The existence of a standard does not always ensure that all available products meet a specific standard. In order to be confident of uniformity in a product there must be checks and balances. This is accomplished by assessment conformity. Assessment conformity, product listing and certification all have the same meaning. Simply stated, it means that a product, material or device has been tested and verified to meet the specification that has been developed. There are at least three types of certification: where the manufacturer or seller self-certifies and guarantees the product by warranty or contract; where the manufacturer or seller obtains verification by a contract laboratory; or where the specific commercial product (not just the class of product) has been evaluated by a credible independent third-party testing or certifying organization that is in no way related to or a part of the manufacturer or seller, and which has a system for policing the validity of its certifications.

Assessment conformity, by any name, means that a product, service, material, system, device or component has undergone testing to ensure it meets the intended standard for such product, material, system, device or component. There are several organizations that perform assessment conformity and, in most cases, if a specific product, material, system, device or component meets a designated standard, the testing organization may allow placement of a mark or logo of the organization on the product, material, system, device or component to certify that the relevant standard was successfully met.

10.2 Products and materials used in plumbing

10.2.1 Standards for plumbing products and materials

The durability of a plumbing system is dependent on the quality of its component parts and the assembly skills of those who install it. No plumbing system, however well designed, can be expected to operate safely or hygienically if the products or materials used are unsatisfactory. The inverse is also true – if the best-quality products or materials are used but are installed incorrectly, the system will be a failure.

Most industrialized countries have national standards or codes that set out the minimum requirements for the material specifications, design and use of specific plumbing products. However, plumbing codes of practice vary considerably according to the extent to which they specify the detailed standards for plumbing products and other matters. Some countries take the view that the level of detail should be minimized, whereas others are very prescriptive. However, even prescriptive codes should allow for the introduction and innovative use of promising new products, materials and installation practices without undue delay. Countries that are members of the International Organization for Standardization (ISO) may choose to adopt the ISO framework as a minimum standard set for plumbing products and materials. WHO Guidelines for Drinking-water Quality should be used as reference in decisions concerning health-related matters. Several national and international standards and certifying organizations utilize and expand upon those basic principles by identifying specific products that comply. It is important to ensure that commonly used plumbing products and materials are of the same type, at least throughout a country, to take advantage of economies of scale in manufacturing and to ensure easy accessibility.

The process of certification of quality of plumbing products may necessitate the setting up of testing establishments where products can be assessed. In many cases it will be more economical to simply adopt an existing qualified standards and certification programme that already has international acceptance. This will also avoid unnecessary proliferation of standards. Product certifiers and their testing facilities must be of the highest standard and subject to external auditing.

The application of suitable materials and products must be supported by adequate levels of training of plumbers who use them so that they can identify and use only appropriate products.

10.2.2 Selecting suitable products

Numerous standards and certification bodies exist nationally and internationally, so it may not be necessary for a country to develop a unique set of standards. It could decide to adopt one of the existing systems and require that products are certified to meet that system's requirements. In judging a product or material, the regulating authority (or certifier) must consider factors such as the following:

- Is the product or material under consideration suitable for the application or purpose?
- Will it be harmful to the health of the community in its normal use?
- Is there a risk of these materials being released into the environment (e.g. the water) in the first instance or after the working life of the product or material has expired?

All pipes, valves, taps and other fittings used for the supply of drinking-water or the removal of wastewater must not contain harmful substances above the specified amount that could leach into the water. Lead, cadmium and arsenic are examples of many possible contaminants that could be present. The pipes, valves, taps and other fittings must be capable of conveying water at a nominated pressure within a prescribed environment, and must be of sufficient strength to contain anticipated internal pressures. They must also be able to withstand external pressures if they are to be buried. The impact of environmental factors such as heat, cold, expansion, contraction, corrosion, pH and bacteria levels also need to be considered.

WHO and many national authorities have developed guidelines or standards that set out the maximum acceptable levels of metals and chemicals and other contaminants in public drinking-water supplies (WHO 2004a). These are then converted to apply to contaminants that may leach from the fixtures and the associated network of piping systems. For example, a pipe standard might require that the leaching level of a heavy metal must not exceed 10% of the drinking-water standard based upon a standard test that simulates use and exposure conditions. Some authorities also insist that piping systems for soil and waste-water drainage systems comply with the same material criteria. Manufacturers in these areas are obliged to comply or risk losing market share or perhaps face prosecution. The standards set for materials in contact with drinking-water are minimum requirements and are based upon a specified use condition range; for example, a product suitable for a cold water system will, in most cases, not be acceptable for a hot water system. It is common for piping and construction materials, as well as the water being conveyed, to be seriously affected by aggressive environments and local conditions. In summary, it is still very much in the hands of the individual project adviser or installer to ensure that the plumbing products and materials selected for the application are in accordance with official requirements, will not be unduly affected or influenced by local factors and are correct for the application.

As well as deciding what is an acceptable plumbing product or material, the water authority or governing organization must set standards for the level of training attained by the installation personnel, a point that cannot be over-emphasized. In some countries, for reasons of economy, transport, proximity to manufacturing plants or restricted access to international markets, the choice of available materials for plumbing products and piping systems is often limited. Socioeconomic reasons may also dictate the quality and standard of plumbing in domestic dwellings.

10.3 Metallic and non-metallic materials used in pipework

There are two families of materials available for water pipework systems: metallic and non-metallic materials. Of these the most commonly used materials for drinking-water supply piping are galvanized steel or iron, copper, polybutylene, unplasticized polyvinylchloride (PVC), chlorinated polyvinylchloride (CPVC) and polyethylene (PE). Metal alloys, which far exceed the performance specifications of their respective parent materials, are also widely used. New materials and construction technologies are continually being developed for the building industry and the plumbing industry. Without some form of control at the respective levels within the plumbing and building industries it would be easy for unscrupulous manufacturers to use inferior materials to the detriment of installers and end-users. This can ultimately damage the environment and the health of the community and lead to greater costs later when systems fail prematurely.

10.3.1 Galvanized steel or iron

Galvanized steel or iron was the traditional piping material in the plumbing industry for the conveyance of water and wastewater. The term "galvanizing" once referred to hot dipped galvanizing, in other words total immersion in molten zinc after pretreatment cleaning. This technology afforded a reasonable level of internal and external protection to the metal pipe. In more recent times, the use of electroplating technologies has provided a more attractive external finish, but little or no internal protection. Although still included in many codes of practice throughout the world, the popularity of galvanized piping is declining. It is still being used extensively in the fire protection industry, but overall there are increasing limitations on how and where galvanized piping may be used. Internal and external corrosion is a particular problem where galvanized steel or iron piping is connected to dissimilar materials, such as copper alloy (brass) in taps and valves. Internal corrosion can add iron, which causes an undesirable taste and may also cause unsightly precipitation of iron salts on clothes. Aesthetic guidelines contained in the WHO Guidelines for Drinking-water Quality address these matters.

The use of galvanized steel or iron as a conduit for drinking-water is a greater problem where the water flow is slow or static for periods of time due to rust discoloration caused by internal corrosion. Galvanized steel or iron piping may also impart an unpalatable taste and smell to the water conveyed under corrosive conditions. Galvanized steel piping systems are generally accepted for outdoor use, but because of the size or bulk of the pipe and fittings, and the inflexibility of such systems overall, the material is not desirable for internal water plumbing. Galvanized pipe is heavy to handle and is generally joined by threading and screwing the components together. This is a lengthy procedure when compared to the assembly of competing non-metallic pipework systems.

10.3.2 Copper tubing

Copper tubing is extremely flexible in the hands of a competent installer and smaller in overall diameter than the equivalent galvanized steel pipes and fittings. Corrosion can be a problem, though usually to a lesser degree than with galvanized steel; care must be exercised to avoid contact with dissimilar metals. Copper tubing, due to its thinner wall section, is relatively light to handle and is available in coil form or straight lengths as required. When assembled and installed correctly it can blend into building structures without difficulty. Piping systems can be assembled with the aid of compression fittings, couplings, or by lead-free solder or brazing. A high degree of skill is required of installers who perform braze welding. Compression fittings are much simpler, but may be obtrusive.

Copper tube or pipe is also particularly useful for hot water supply systems. However, heat loss can become an issue if adequate insulation is not provided. As with all metallic materials, the risk of electrolytic corrosion should be considered. This occurs most commonly where galvanized steel pipes or fittings connect with copper alloy (brass) fittings.

System designers must be aware that water flows through copper tube piping systems must not exceed 3 metres per second. When this occurs there is a high risk that the internal bore of the piping system will be eroded by high flow and velocity scouring. Due to its electrical conductivity there is a need for care to ensure that grounding connections are separated from piping systems and any electrical wiring.

10.3.3 Polybutylene

Polybutylene in non-metallic piping systems is becoming accepted as a suitable material for the conveyance of drinking-water in domestic dwellings in some industrialized countries. However, it is banned by plumbing codes in USA due to problems with leaks at joints resulting in significant water damage in dwellings. It is a light, flexible material that is easy to handle and install. It can be used in domestic dwellings for both hot and cold water supplies. Caution must be exercised as it can suffer degradation if exposed to excessive pressure and temperature, and exposure to ultraviolet light (sunlight) is also detrimental to the material.

There are several jointing systems available for the connection of polybutylene pipework systems, including electrofusion and socket fusion welding and a variety of mechanical jointing methods. Some mechanical joints rely on an integral grab ring while others have a compression-type joint, via a nut or a compression crimp ring or band. Some jointing systems comprise metal in-line as well as end-of-line fittings, which may not be appropriate in some locations or conditions. Polybutylene pipe is generally available in straight lengths up to 6 metres or coils 60 metres in length.

10.3.4 Chlorinated polyvinylchloride (CPVC)

CPVC is widely used in water and sanitary systems for hot and cold water distribution. It is a thermoplastic produced by polymerization of vinyl chloride, with additional chlorination. CPVC piping is manufactured by extrusion methods in sizes of diameter 0.25 inch (0.635 centimetres) to 12 inch (30.5 centimetres) in Schedule 40, Schedule 80 and standard dimension ratio (SDR) dimensions.[1] It is manufactured to copper tube size (CTS).[2] It offers much better resistance to corrosion and has a high tolerance to acids. It is fire resistant, though toxic fumes are emitted when it is burned. CPVC is lightweight, non-toxic and odourless, and reduces growth of fungi, algae and bacteria. It is designed to withstand continuous operating pressure of 600 kPa at a temperature of 95 °C. Pipe and fittings are readily cut, and joined by solvent welding.

10.3.5 Unplasticized polyvinylchloride (PVC)

PVC, when used with a solvent cement jointing system, is comparable in bulk to galvanized steel or iron for drinking-water piping, but much lighter. It does not suffer the same corrosion problems internally or externally as does galvanized steel. However, it is susceptible to physical damage if exposed above ground and it becomes brittle when exposed to ultraviolet light. The pipe is light to handle, but it is too bulky for aesthetically acceptable internal use in domestic buildings. It is used extensively around the world for drainage (waste or soil and storm water) applications.

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1 Pipe dimensions are nominal rather than actual; 1-inch Schedule 40 pipe, for example, has an actual outside diameter of 1.32 inches and an inside diameter of 1.049 inches.

2 Copper tube size (CTS) was added to iron pipe size (IPS) when copper tubing was developed. CTS is closer to actual size than IPS. Generally, a product made in IPS is called "pipe", and a product in CTS is called "tubing". CPVC is an exception, being called "pipe" but being sold in CTS.

PVC is available with a solvent cement or rubber (elastomeric) ring jointing system for internal or external drainage systems. Caution must be exercised when using PVC close to water heaters and similar heat sources. In addition to the inherent problems associated with the expansion and contraction of PVC, the material will soften and deform if exposed to a heat in excess of 65 °C.

10.3.6 Polyethylene (PE)

PE pipes and fittings of numerous types and designs have been available for over forty years. The market requirements today have been refined to three general groupings, as follows:

High-density PE is available in a post-manufactured stress-relieved state (best-practice PE), or as extruded product with no treatment. It is used mainly for drainage applications where it can withstand higher temperature discharges than PVC. To avoid ovality and installation problems when laying to grade the pipe is best used in straight lengths, normally up to 6 metres long. Jointing is achieved by electrofusion or butt-fusion welding or with compression-type joints for smaller diameter pipes and fittings.

Medium-density PE is more flexible than the high-density pipe. It has a slightly thinner wall thickness and is capable of withstanding higher internal pressure. It is the preferred material for long-distance drinking-water piping. Because of the application and the robust nature of the material it is generally available in coils of up to 200 metres (650 feet) length, depending upon the diameter. The method of jointing is the same as for high-density PE pipe. In colder climates coiled polyethylene piping can be very difficult to use and may be impractical.

Low-density PE is suitable for the irrigation industry, where operating pressures are very low and a high degree of flexibility and low cost is required. Low-density PE pipe and fittings are not acceptable for use for connection to the water mains in many countries because of the low pressure rating of the material and its high leakage rate.

10.4 General issues related to use of plastic piping

There are numerous composite PE piping systems available and new plastic materials are constantly being developed. Each must be considered on its merits for the particular application in hand. In some types, the molecular structure is cross-linked to attain a stronger product with a reduced wall thickness, allowing savings in the amount of raw material needed. Combining different types of raw material together with lamination, overlay extrusion or simply adding selected reinforcement into the extrusion process can further enhance specific qualities of the structure of the material to make it more acceptable for use in both domestic and specialized plumbing applications.

Providing that the health, safety and durability standards are met, pipes and fittings manufactured from plastic materials have many advantages for use in both hot and cold water plumbing systems. They are light, easily handled and transported, and require fewer joints than metal pipes when available in long lengths. Pipes and fittings manufactured from plastic materials may cost more to purchase than metal pipes or tubes and their ancillary fittings, but the time spent installing a plastic pipe system is generally much less than a metallic system and this may result in overall savings.

Where a large project is to be undertaken, it is not uncommon for a plastic pipe manufacturer to bring in moulding or just extruding machines with the appropriate dies, tooling and raw materials, and commence manufacturing in close proximity to the market or project site. This in turn can bring about savings in transportation and handling costs. Long delays in supply can also be averted, resulting in rapid on-site progress. Sometimes only the pipe is made at the remote locations due to its bulk, and fittings, especially when there is a large and varied range, are brought in separately.

It is important for plumbing systems that different pipe types remain separated and not intermixed with similar products. For example, rainwater or storm water drainage pipes and fittings should not be used for sanitary plumbing (soil, waste or vent pipe) applications. They have a thinner wall section and are not designed for higher temperatures or deeper than near-surface and above-ground applications where durability is not a major concern. Conversely soil, waste and vent pipes and fittings could be used for rainwater or storm water, but they are unnecessarily expensive for those applications.

Some standards and codes call for different-coloured pipes and fittings to define the designated application of the product and to assist installers, as well as for future identification to prevent cross-connections. For example, PVC pipe and fittings are easily manufactured in various colours; other materials that are not so easy to colour may rely on a stripe of colour set onto the pipe during extrusion or painted bands and labels applied after installation, with specific markings or instructions with regard to fittings, etc. Other authorities, such as electricity and gas providers, may also utilize colour coding for their buried pipelines. To avoid confusion care should be taken to coordinate the identification strategies or policies for all pipes and services.

10.5 Earthenware pipes

Earthenware is also referred to as glazed stoneware, terracotta or vitrified clay. Furnace-baked earthenware has been the most commonly used material for underground drainage systems. It can be locally produced in almost any country provided there is a source of good-quality clay and an energy supply to fire it. In the past, glazing was achieved by throwing salt into the fire towards the end of the firing process. This method of salt glazing damages kilns and does not always create an even finish or glaze. Advanced material and management technologies, combined with the use of sophisticated tunnel kilns, have in recent years seen the emergence of a completely new generation of vitrified earthenware pipes and fittings of a quality previously unattainable. They are chemical and temperature resistant with elastomeric jointing couplings. The high cost currently precludes their use in domestic dwellings, but there are many special commercial or industrial applications.

Installing old-style earthenware drainage systems is difficult and maintenance is demanding because of breaks and blockages. The inherent rigidity of the system can cause the pipes to break loose at the joints or cause the pipe itself to break close to the joint just behind the collar. Tree roots can grow into the open joint or broken pipe and will eventually block the drain. In some cases groundwater can infiltrate the drain, causing the system to become overloaded. There is also the risk of contaminating the groundwater by the leakage of raw sewage from the broken joint or pipe. A further disadvantage is that earthenware pipes are heavy to transport and expensive to install compared to lighter materials such as plastics.

Plastic, mainly PVC, is now the most commonly used material for drainage systems for the conveyance of sewage and wastewater from dwellings. Other materials, such as cast iron, ductile iron, copper, fibre cement and vibrated concrete, are sometimes used for drainage systems. Each has its strengths and weaknesses; their longevity in service is dependent on how well they are installed, the nature of the water or other materials passing through them, and the installation environment.

10.6 Design of plumbing fixtures

Both the component materials and the design of plumbing fixtures (baths, washbasins, sinks, tubs, toilet pans, etc.) should be subject to standards and certification to ensure integrity and safety. Fixtures should be free of sharp projections and sharp corners that may cause injury. In order to prevent drainage sewer gases from entering the area where the fixture is installed, a fixture trap should be incorporated into the fitting, or provision should be made for fitting one at a later date. To protect the drinking-water supply, all plumbing fixtures should be designed so as to ensure that incoming water is delivered through an air gap. Tapware should be appropriately matched to the fixture that it is intended to serve. When installed, all taps and water delivery outlet fittings should have an adequate clearance between the water outlet and the spill level or water overflow level of the fixture being served. It is possible for the overflow on any fixture to become blocked, which would compromise the air gap by not leaving the correct clearance. In situations where a portable or flexible hose or tube is attached to the water outlet, and an air gap cannot be provided, an appropriate backflow prevention device should be installed in the pipework supplying the fixture.

Local usage and customs should be considered when assessing plumbing requirements. An example is the choice of pedestal toilet bowls or squats. It may also be necessary to conduct training sessions in the use of particular fixtures to ensure that they are maintained in a satisfactory and hygienic state. In some areas it is customary to provide a drinking-water supply tap adjacent to the toilet fixture to facilitate personal ablutions. In such cases strict precautions must be taken to prevent contamination or cross-connection with the drinking-water supply system.

10.7 Sanitary fixtures

Sanitary fixtures should be durable, smooth and impermeable to water. There should be no hidden surface that can become fouled or polluted. Both internal and exposed outside surfaces should be accessible for cleaning. The most common and most economical material for domestic fixtures such as toilet bowls, urinals, and washbasins is vitreous china. For more durable day-to-day use in kitchen sinks and laundry tubs, stainless steel is recommended, but enamelled pressed steel and suitable plastic materials may be acceptable.

Plastics are commonly used for bathtubs, shower trays, laundry tubs, cisterns, washbasins and toilets and are often reinforced with fibreglass for extra strength and durability. Plastic materials, although generally durable in themselves, are readily prone to surface damage such as scratches and cuts. Stainless steel is a preferred material for plumbing fixtures where there is a risk of damage from users, such as in institutions and public amenities. Stainless steel is currently the only suitable choice in commercial or industrial food preparation areas.

10.8 Concrete products

The manufacture of plumbing products of any kind is expensive because of the capital investment in plant and the associated tooling. Unless high production volumes are anticipated, it is often more economical to import such items. To save foreign currency, materials such as concrete can be used for the local manufacture of fixtures for some domestic applications. These products are inferior to those discussed above, but they may be a realistic option. Ideally, concrete products should be designed so that angles, both internal and external, are rounded for ease of cleaning, and outlet pipes may be integrally cast into the body of the fixture. Concrete fixtures should be restricted to shower trays and baths, and possibly laundry fixtures such as troughs. It is recommended that concrete fixtures be cast in place wherever possible to eliminate the need for transportation. Concrete should not be approved for kitchen or food preparation sinks or benches. Local codes should cover all probable issues involving concrete fixtures, general design principles, etc., and also specify the proportions of sand, aggregate, cement and water required with general mixing, placement and finishing instructions. Preliminary investigations should ascertain the availability of local materials of the appropriate quality to ensure that the products can be produced satisfactorily. Concrete products cannot be made completely impervious; surface treatments such as ceramic tiles are sometimes used to address this problem.