Acoustics in Plumbing Systems

CEU 258

Continuing Education from the
American Society of Plumbing Engineers

April 2018

ASPE.ORG/ReadLearnEarn

Note: In determining your answers to the CE questions, use only the material presented in the corresponding continuing education article. Using information from other materials may result in a wrong answer.

Plumbing system noise is a common irritant to building owners and tenants. Three main factors contribute to this problem: 1) lack of awareness on the part of owners/developers and design teams regarding the application of specific products and practical installation solutions; 2) lack of contractor awareness and training regarding the application of specific solutions; and 3) design teams fearful of uncertain solutions and seemingly uncontrollable expenses. On many high-end projects, building design teams and contractors have faced litigation as a result of insufficient or poorly installed attempts at plumbing noise mitigation.

Luckily, much advancement has been made regarding the issue of plumbing noise mitigation. Resources are available from a product and service standpoint that can help the engineering community find application solutions, plumbing installation detail drawings, and third-party laboratory test data to recognized International Organization for Standardization (ISO) standards.

To a building occupant or perspective buyer, the perceived quality of a building is based on numerous observations. A building deemed excessively noisy will likely be viewed as low quality. In cases where building occupants are dissatisfied with the comfort of a building, one of the common complaints includes noise from adjoining tenants. Noise through floor and ceiling systems and noise through walls are the main issue. The noise sources and solutions vary widely. Issues can be very difficult and costly to remedy, especially after the fact. A quiet building does not usually happen accidentally, and steps to ensure success must be planned from the early stages of design and specification. Attention to acoustics and the successful implementation of effective noise control are added value.

Plumbing system noise mitigation is inconsistently addressed in many buildings, although it can be one of the most intrusive and difficult sounds to mitigate. Varying levels of plumbing noise are expected and tolerated without complaint by many people. Noise generated within a tenant's or owner's own space and resulting from their use of plumbing fixtures is often tolerated. Conversely, intrusive plumbing noise from an adjoining space that results in sleep disturbance or interruption or even in some cases where it is simply identifiable may be regarded as annoying. In multifamily residential buildings, plumbing noise is a significant source of complaint.

NOISE

Noise issues within a building fall into one of two categories: airborne noise and structure-borne noise. Airborne noise sources include voices, amplified music, televisions, and radios. The ability of a construction (such as a door, wall, or window) to reduce airborne noise passing through it is quantified by the metric transmission loss, which is usually measured over a number of different frequency bands that are used to generate a single-figure Sound Transmission Class (STC) rating. The higher the STC, the better the system is at isolating airborne noise. However, the use of STC ratings is generally not recommended for noise from plumbing and other building systems because the frequency content of this noise is dissimilar to that of the human voice.

Structure-borne noise is produced when part of the building fabric transmits vibration, which is subsequently heard as radiated noise. Examples are footsteps on hard floor surfaces like tile or bare timber, banging doors, scraping furniture, and plumbing noise. Controlling structure-borne noise is usually achieved through vibration isolation.

CONTRIBUTING FACTORS

Plumbing systems generate both airborne and structure-borne noise. Following are the four main categories comprising a building's plumbing system and how these systems create noise.

Drainage Systems

This category includes sanitary waste piping receiving drainage from plumbing fixtures and appliances, as well as rain leader/roof drain piping receiving drainage from roof drains, deck drains, and similar receptacles.

Drainage piping is manufactured in a variety of materials that radiate airborne and structure-borne noise at varying levels. The most common pipe and fitting materials used in these systems within buildings include Schedule 40 PVC or ABS plastic DWV, type DWV copper, several weight classifications of hub-and-spigot cast iron, standard weight hub-less cast iron, and tubular thin-wall PVC, ABS, or chrome-plated brass (used in the fixture outlet connection/p-trap location under sinks and similar fixtures).

Drainage piping receiving gravity flow includes roof drains, rain leaders, deck drains, condensate drains, and sanitary drains receiving flow from typical plumbing fixtures such as sinks, wash basins, water closets, bathtubs, and showers. Drainage piping receiving liquids intermittently and under pressure includes the discharge from laundry washers, dishwashers, funnel drains in mechanical rooms, floor sinks in commercial foodservice establishments, and similar indirect waste receptacles. In each of these cases, the density and wall thickness of the pipe and fittings have a direct bearing on the amount of both airborne and structure-borne noise generated. The thicker, more dense, and more highly damped the pipe's wall construction, the quieter is its performance.

In a gravity system, drainage liquid traveling vertically adheres to the walls of the pipe and travels in a spiral motion. In this mode, very little noise is generated. The flow of the pipe's contents generates the most noise when liquids and solids hit fittings at changes in direction within the piping system, especially when a vertical stack hits a horizontal pipe. It is most noticeable in plastic drainage systems. This should be a consideration when engineering a single-stack DWV system with the required aerators, offsets, and deaerators.

Drainage piping also generates noise, especially in thermoplastic systems, when it experiences thermal expansion and contraction due to temperature changes. (PVC and ABS pipe expand and contract at approximately five to eight times the rate of cast iron pipe.) The pipe can be heard creaking or squeaking as it moves and rubs against various building components, especially if the penetrations in the wall and ceiling framing are cut or drilled to a size that results in a tight fit. An example of this is when a roof drain system within the warmth of a building receives cold rainwater. In this case, the piping contracts as the rainwater lowers the pipe's temperature. After the rainwater stops flowing, the pipe warms up and expands once again. As this occurs, structure-borne noise transmits to the interior of the building through various contact points throughout the system, such as floor, wall, and ceiling penetrations and at various support or hanger locations. While accommodations for expansion and contraction should be engineered into thermoplastic systems, airborne and structure-borne noise still may persist.

Water Distribution Systems

Water distribution systems include domestic/potable water piping delivering water under pressure to plumbing fixtures and appliances throughout a building, nonpotable water piping delivering water under pressure to systems such as irrigation and mechanical equipment, and industrial water, process piping, and HVAC piping delivering water under pressure to various equipment components within a building.

Water piping/tubing is constructed from a variety of materials that radiate airborne and structure-borne noise at varying levels. The most common pipe and fitting materials used in these systems within buildings include copper (types M, L, or K), CPVC (CTS and Schedule 80), PEX, PVC Schedule 40 or 80, Schedule 40 galvanized steel, Schedule 10 stainless, corrugated, or smooth-wall chrome-plated brass (for fixture connections), and braided stainless steel (at fixture and equipment supply connections).

A common cause of noise generation in a water system is simply the flow of water due to the operation of a fixture or faucet. In this scenario, several factors contribute to increased levels of noise generation: water pressure, flow velocities, undersized tubing, turbulence caused by changes in direction, and obstructions in valves and equipment. The largest contributing factor is direct contact between the water system's tubing and the building's various components.

Another common noise generator is water hammer, which results when water moving at a high velocity stops suddenly. This occurs when valves are closed quickly, producing a shock wave in the system that causes the pipes to vibrate. Some of the items in a common plumbing system that cause this problem are laundry washing machines, icemakers, and dishwashers, each of which have electric solenoid, or fast-closing, valves. Other common contributors include flush valves on urinals and water closets in commercial buildings.

Another noise source in pressurized water systems is similar to that described in the drainage section. When water tubing experiences thermal expansion and contraction due to temperature changes, water piping can be heard creaking or squeaking at contact points with various building components and support points. This is especially pronounced in thermoplastic water systems such as CPVC, which expands and contracts at a much higher rate than metallic tubing. (CPVC tubing expands and contracts at nearly four times the rate of copper tubing.)

Fixtures, Faucets, Appliances, and Appurtenances

Fixtures are manufactured using a wide variety of materials including vitreous china, plastic, cultured marble, fiberglass, stainless steel, cast iron, enameled steel, nonvitreous ceramic, terrazzo, and various composite materials. Each material contributes to both airborne and structure-borne noise differently. A thin steel fixture can sound like a drum being struck when it is hit with a flow of water. When fixtures are in direct contact with building components, such as is often the case with a bathtub or shower pan, they generate not only airborne noise, but a high level of structure-borne noise as well.

Faucets typically are constructed of brass (with a variety of plated finishes), stainless steel, plastic, or cast metals. The wall thickness of these items contributes to the level of noise generation, as does the degree of direct contact with the fixture they serve or the building itself, such as a hard surface countertop or ceramic tile tub deck. The level of noise generating turbulence emitted from faucets varies greatly depending on the level of attention each manufacturer has given to this issue.

Appliances vary widely in their ability to control the noise each one emits. The cost of an appliance often relates to a manufacturer's published operating noise level.

Valves, Pumps, and Equipment

Valves emit varying levels of noise depending on the amount of friction and turbulence they generate. Globe valves, for instance, are very noisy because they are designed in such a way that turbulence is very high. Alternatively, full-port ball valves generate less noise than standard port due to reduced water velocity.

Pumps often generate high levels of structure-borne noise if they are in direct contact with building components or are piped incorrectly, resulting in turbulence and cavitation.

Equipment generates noise and vibration over a wide frequency range. Equipment noise control and vibration isolation have been handled by plumbing and mechanical engineers for many years and are better controlled than many of the other components of a plumbing or piping system.

MITIGATING NOISE FROM DRAINAGE SYSTEMS

A number of common approaches can be used to mitigate unwanted noise from drainage systems.

A very common and effective method of controlling noise generated from drain, waste, and vent systems is to use cast iron pipe and fittings rather than thermoplastic or copper pipe and fittings. The density of the cast iron, as well as the neoprene couplings, has effective dampening properties. Often, a hybrid DWV system is specified consisting of cast iron drainage piping and thermoplastic vents. Ideally, the choice of cast iron rather than thermoplastic or copper also should be applied to the selection of drainage system components such as roof drains, deck drains, and floor drains. When mounting roof drain bodies on wood sheathing or pan decking, isolate the drain body and under-deck clamps from direct contact with the sheathing with the use of ¼-inch (6.35-mm) neoprene rubber padding. This should be addressed within the body of the specification and/or in plumbing installation detail drawings.

To minimize noise and vibration transferred to the building, the contact between the piping and the building's components (drywall, studs, joists, floor structure, etc.) should be broken (see Figures 10-1, 10-2, and 10-3). This often is accomplished by the use of various types of isolating materials such as felt or rubber when passing through studs, joists, hangers, etc. The use of engineered laboratory-tested products specifically designed for this purpose makes this task fast, easy, and affordable when compared to makeshift or field-devised attempts to isolate these pipelines from contact with building components. All contact points should be isolated; failure to achieve this for even a small percentage of contact points can result in a noise issue. This requirement should be clearly expressed within the project specifications and installation detail pages.

When pipes pass through floors, noise transfer often is minimized with the use of various types of rubber or neoprene pads placed under the ears of riser clamps. On very large and heavy riser pipes, the use of spring-loaded riser isolators is effective. Numerous manufacturers provide these types of isolation pads in various thicknesses ranging from ¼ to ¾ inch (6.35 to 19.05 mm) and even thicker. These typically are made of rubber or neoprene, which is often more resistant to chemicals than rubber. Others are also available with steel bearing plates, which help evenly distribute the weight across the surface of the pad. Use only lab-tested and proven materials.

Additionally, piping must be isolated from contact with the edges of the floor penetration, whether wood, concrete, or metal pan decking. This typically is done with the use of acoustical sealant within the annular space surrounding the piping. When the floor system caries a fire rating, the sealant used must meet or exceed the required rating. Failure to eliminate contact in the annular space can negate any attempt at effective vibration isolation. Clearly express this requirement within the project specification and installation detail pages. (See Figures 10-4 and 10-5.)

A number of methods can be used to reduce noise from piping to support hangers and thus to the supporting structure. One method is the use of spring or rubber-isolated hanger rod attachments at the structure above. Another method is by isolating the noise transfer by installing felt, rubber, or neoprene material within the hanger (between the pipe and the hanger). When applying isolation lining between the hanger and the piping, use only materials engineered and tested for this application. As a caution, some pipe support products contain plasticizers such as plasticized vinyl, which may have a detrimental effect on the drainage piping (e.g., CPVC lab drainage materials).

Figure 10-1 Pipe Isolation Through Framing Member

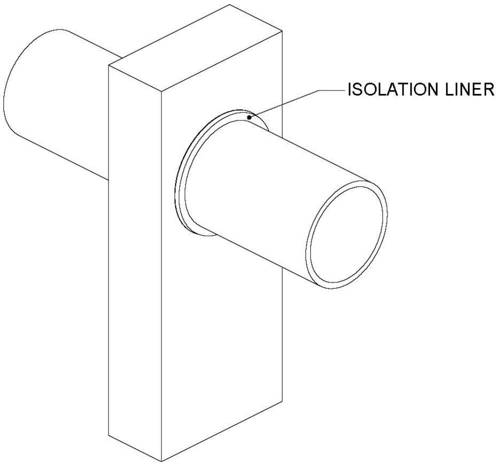


Figure 10-2 Resilient Pipe Isolation

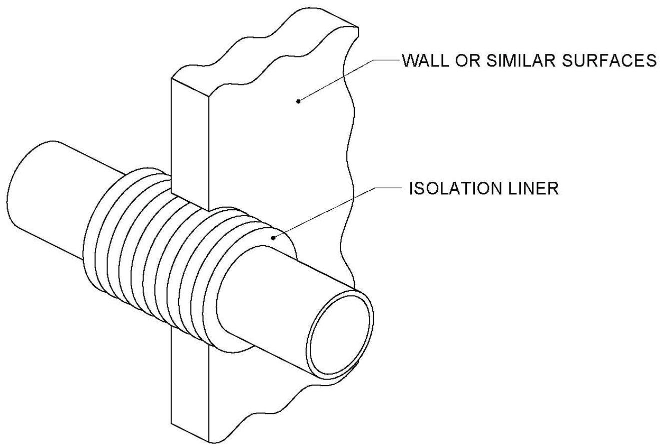


Figure 10-3 Vertical Mid-Span Support

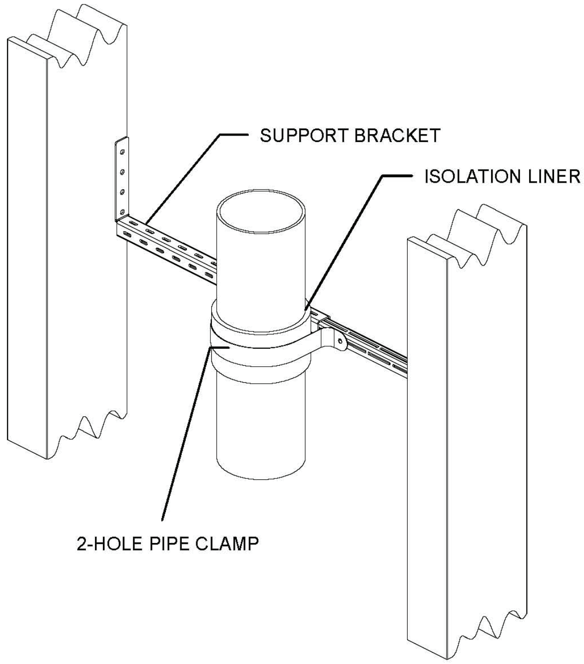
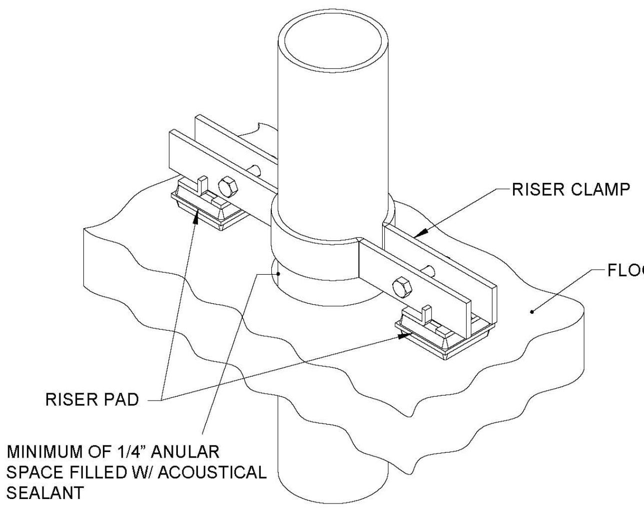


Figure 10-4 Riser Clamp Isolation



When drainage and vent piping are being supported at mid-story or mid-span locations, care must be taken to isolate the piping from contact with the support brace as well as the pipe clamp used to attach the pipe to the bracket itself through the use of rubber felt or neoprene materials engineered and tested to be effective in this application (see Figures 10-6, 10-7, and 10-8).

In seismic regions, be sure to avoid the use of rigid seismic/sway bracing methods. Use systems that include aircraft cable and accessories designed to allow minimal movement. These help avoid short-circuiting of vibration transfer to the building. Several manufacturers provide these types of materials and performance data. Clearly express these requirements in the project specifications and detail pages.

Another noise isolation method involves the addition of some form of lagging to the outside of the piping to minimize airborne noise. Lagging is done by wrapping the piping with foam rubber or fiberglass insulation and surrounding the insulation with a layer of dense, limp material such as vinyl impregnated with an inert metal or other dense material. Commercially manufactured and tested products ranging from adhesive wraps to sound baffles are available. They often list their tested NRC (Noise Reduction Coefficient). For example, an NRC of 0.85 indicates that the product has been proven to reduce noise by 85 percent. Unfortunately, in some cases, makeshift methods are employed, such as attaching carpet padding or similar scrap materials poorly held in place with wire tie, bailing wire, duct tape, or similar methods.

When attempting to reduce airborne noise, dense materials work best. Use only materials and methods with tested and proven results. Various insulation manufacturers provide test data to indicate the level of noise reduction to be expected in this application. Specifically disallow makeshift attempts on the jobsite, such as taping or wire-tying carpet padding around piping.

Figure 10-5 Vertical Cast Iron Stacks and Water Risers

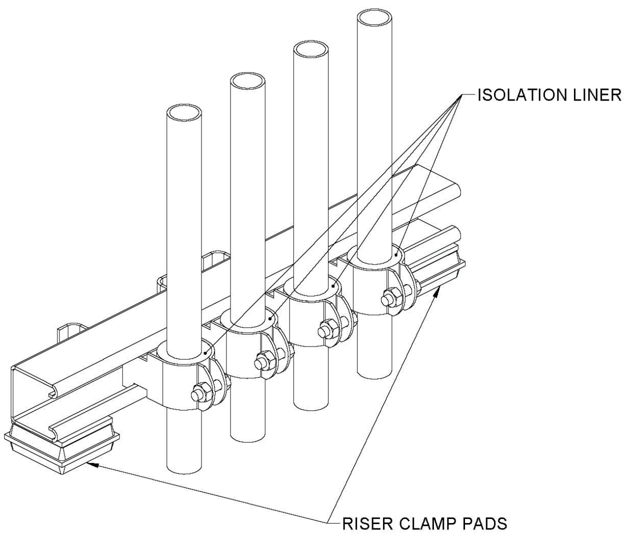


Figure 10-6 Suspended Waste, Vent, or Other Piping

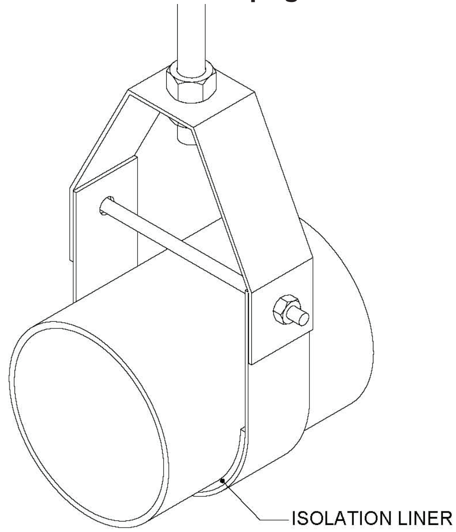


Figure 10-7 Horizontal Joist Bay Support

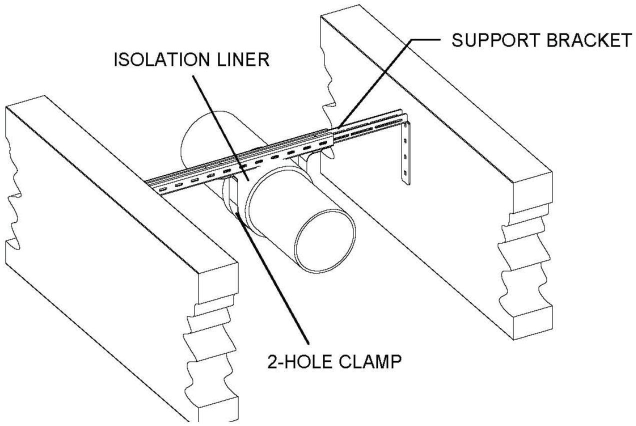
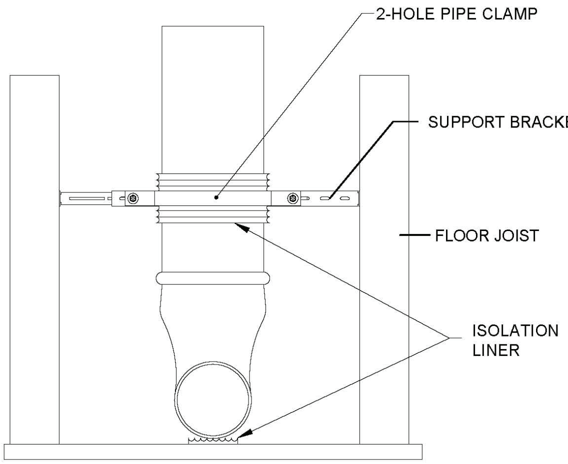


Figure 10-8 Isolation of Toilet Fixture Waste Pipe



MITIGATING NOISE IN WATER DISTRIBUTION SYSTEMS

Three main factors affect the noise in water distribution systems: water pressure, water velocity, and the number and type of constrictions and fittings. Water piping noise is usually transmitted as structure-borne vibration eventually radiating from lightweight surfaces.

The choice of water tubing materials can have some effect on water distribution system noise. For instance, some independent laboratory tests have shown that plastic tubing is up to four times quieter than copper tube, despite its often thicker pipe wall, smaller internal diameter, and higher fluid velocities. However, local building and plumbing code requirements may dictate which material types are allowed.

Very similar to drainage piping, steps should be taken to break any direct contact between the water piping system and the building's components. Some contractors use plastic isolators to break this contact, and others wrap tubing with some kind of felt or install a rubber isolator. The use of tested and proven pipe isolators and clamps for through-stud situations and surface-mounted attachments is critical. Specifications and plumbing detail drawings should clearly disallow makeshift, field-devised attempts at isolating water lines from structure contact. Specify products with proven performance that are compatible with the piping material. (See Figures 10-9, 10-10, 10-11, and 10-12.)

Figure 10-9 Isolation Through Wall Stud or Other Wood Framing Member

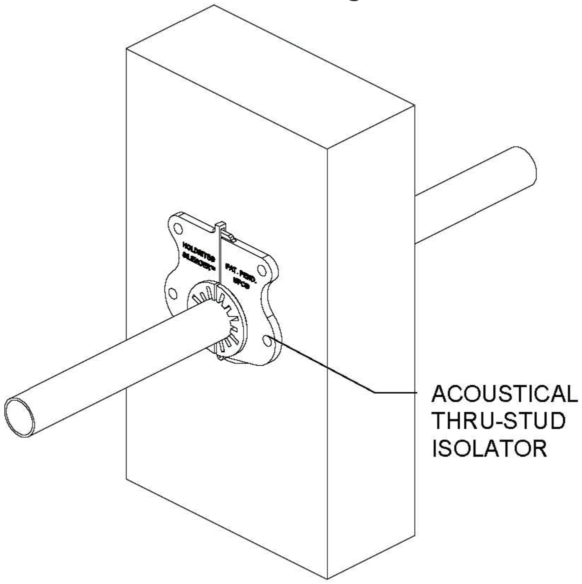


Figure 10-10 Surface-Mounted Pipe Clamp

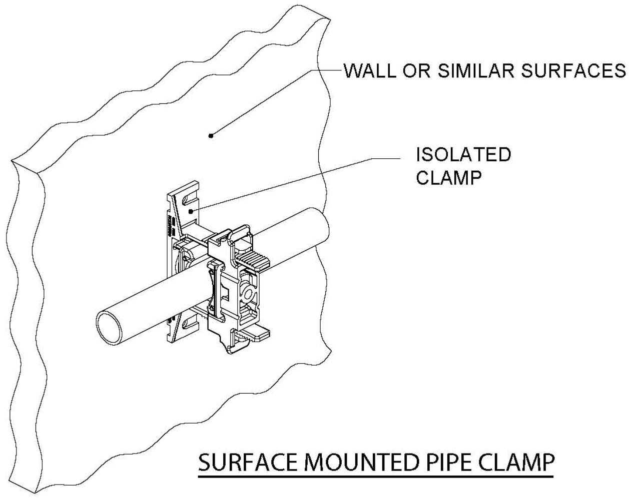


Figure 10-11 Horizontal/Vertical Piping Isolation

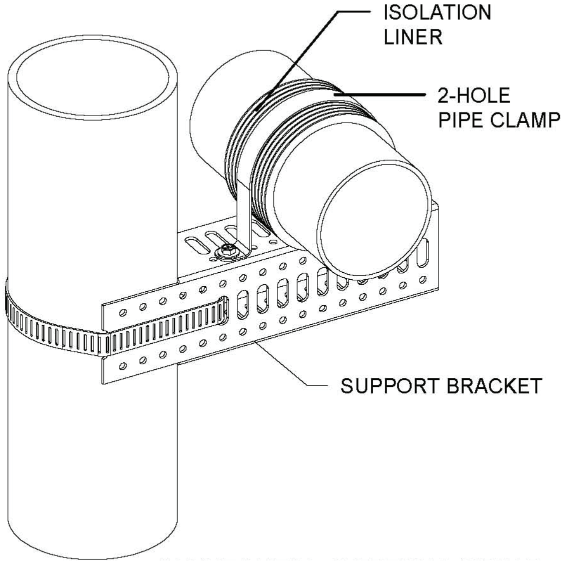
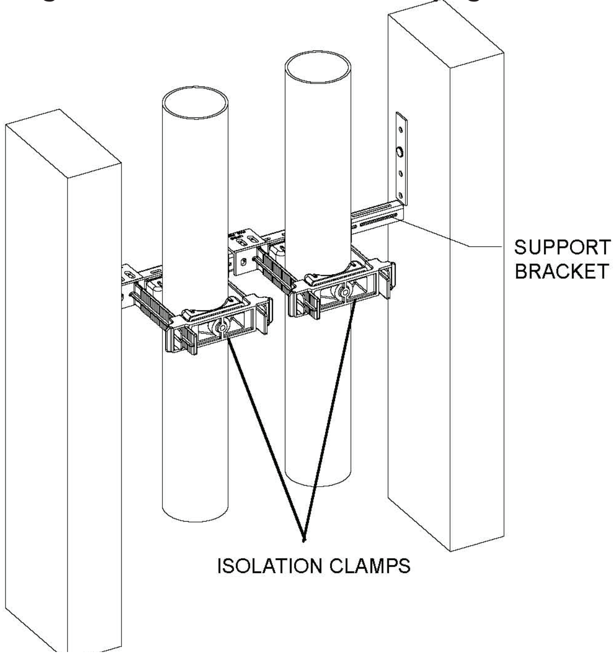


Figure 10-12 Horizontal/Vertical Piping Isolation



As with drainage systems, when passing through floors, steps should be taken to isolate noise transfer to the wood, metal, or concrete floor system by placing rubber or neoprene pads under the ears of riser clamps. Additionally, the piping must be isolated from contact with the edges of the floor penetration with the use of acoustical sealant within the annular space surrounding the piping. (See Figures 10-13 and 10-14.)

Another important factor is the isolation of water piping from hangers and other support systems. In the case of hangers, this often is accomplished by the use of either a spring-isolated hanger attachment point at the supporting structure or a hanger lining of felt or a rubber/neoprene material to break the connection between the hanger and the water tube. As a caution, some pipe support products contain plasticizers such as plasticized vinyl, which may have a detrimental effect on the water piping material (e.g., CPVC materials). Pipe insulation that runs continuous through the hanger or support is another effective method of isolating the pipe from the support.

All chilled, condenser, domestic, and hot water equipment, including the heat exchanger and the hot water storage tank, should be isolated from the following:

- All piping in the equipment room
- All piping outside of the equipment room within 50 feet (15.24 m) of the connected pump
- All piping more than 2 inches (50.8 mm) in diameter (nominal size) and any piping suspended below or near a noise-sensitive area

Supports should be of a pre-compressed type to prevent a load transfer to the equipment when the piping systems are filled. The first three vibration isolators from the equipment should provide the same deflection of the pump isolators with a maximum deflection of 2 inches (50.8 mm); the remaining hangers should be spring or combination spring and rubber with ¾-inch (19.05-mm) deflection. All piping connected to plumbing equipment should be resiliently supported or connected.

Figure 10-13 Riser Clamp Isolation

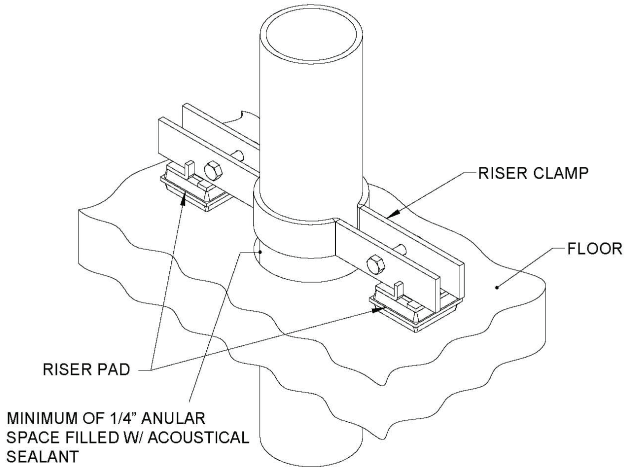
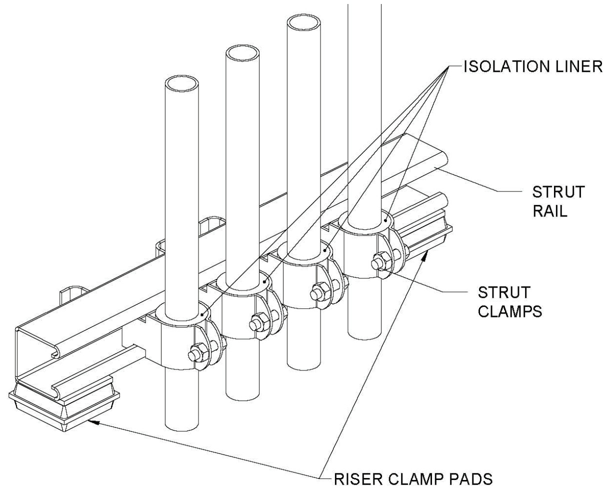


Figure 10-14 Vertical Cast Iron Stacks and Water Risers



When water tubing is supported by a mid-span or mid-story brace attached to the building's structure, steps must be taken to keep the tubing from contacting the support brace or the clamp that holds the tube to the support by the use of an effective isolating material, such as felt, rubber, or neoprene. Use only materials tested and proven to be effective in this application and approved for use with the pipe material. (See Figures 10-15 through 10-20.)

In seismic regions, avoid the use of rigid bracing methods. Instead, use systems that include aircraft cable and accessories designed to allow minimal movement, which aids in avoiding short-circuiting of vibration transfer to the building.

Another common step taken is the addition of pipe insulation or lagging to the outside of the tubing to help minimize airborne noise transfer. To effectively isolate airborne noise, dense materials are always best. Use materials tested and proven to be effective for this purpose.

A practice that is growing in use is the routing of PEX domestic water within the structural slab (see Figure 10-21). This is more common in structures with post-tensioned concrete slabs and occupancies such as hotels and apartments. The installation eliminates noise from water flow within the living space.

Another common source of water system noise is water hammer, which occurs when valves are closed quickly, producing a shock wave in the system and causing the pipes to vibrate. Reducing pressure and velocity and avoiding quick-closing valves helps reduce water hammer. Air-filled stubs referred to as air chambers can be used, but they are effective only for a very short time, and their presence in specifications has drastically decreased in recent years.

An effective solution is the use of shock arrestors or water hammer arrestors, which are sealed, pre-charged mechanical devices similar to spring-loaded shock absorbers. These should be introduced in the piping near appliances or equipment with fast-closing valves, such as washing machines, and act as cushions to reduce the shock. Both the Uniform Plumbing Code (UPC) and the International Plumbing Code (IPC) require water hammer arrestors to be installed at the location of quick-acting or quick-closing valves such as found in dishwashers, clothes washers, and icemakers. The IPC specifically requires that these devices shall conform to ASSE 1010: *Performance Requirements for Water Hammer Arresters*. Another reference standard is PDI WH 201: *Water Hammer Arresters Standard*.

MITIGATING NOISE FROM FIXTURES

While addressing noise sources involving various piping systems within a building, it is important to not overlook fixture and faucet selection. Fixtures, faucets, and appliances can be chosen based on third-party test data regarding

Figure 10-15 Suspended Waste, Water, or Other Piping

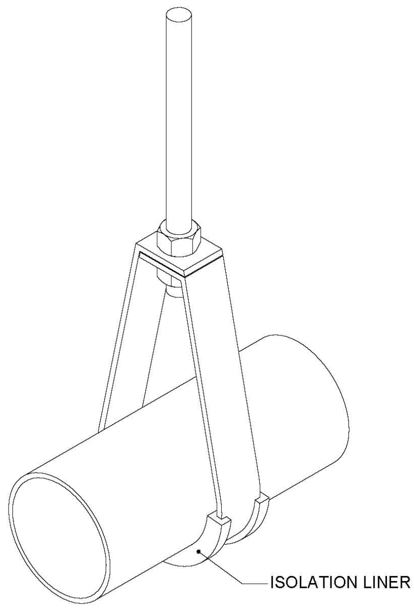


Figure 10-16 Suspended Horizontal Overhead

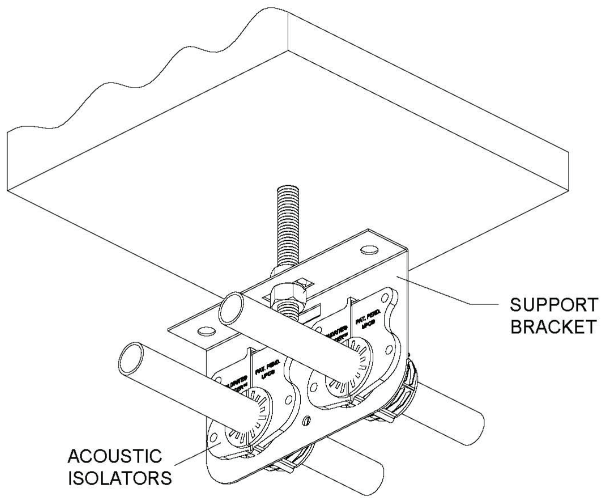


Figure 10-17 Horizontal Overhead

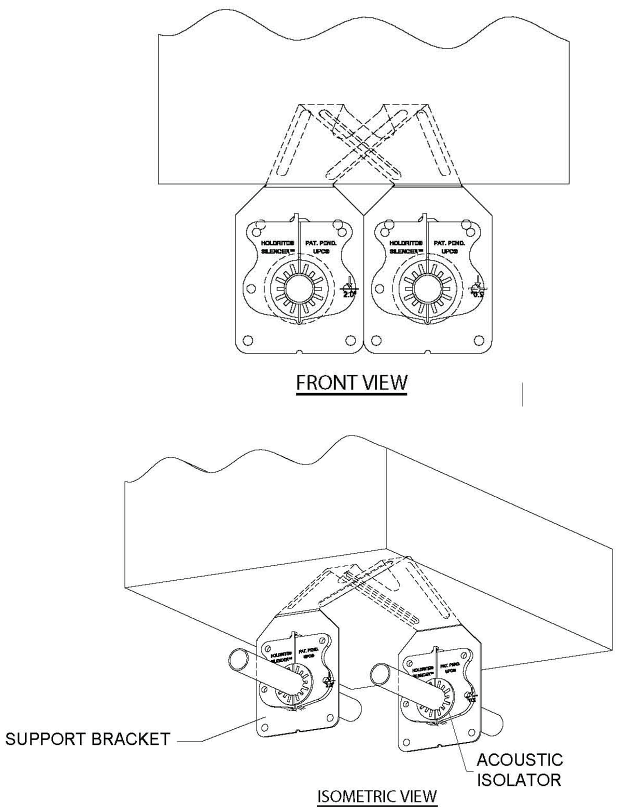


Figure 10-18 Water, Vent, Waste

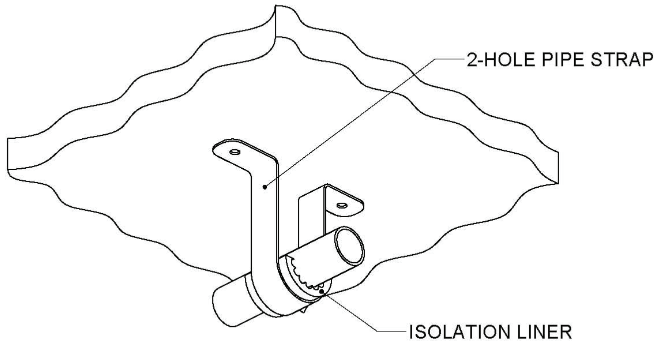


Figure 10-19 Overhead Trapeze Piping

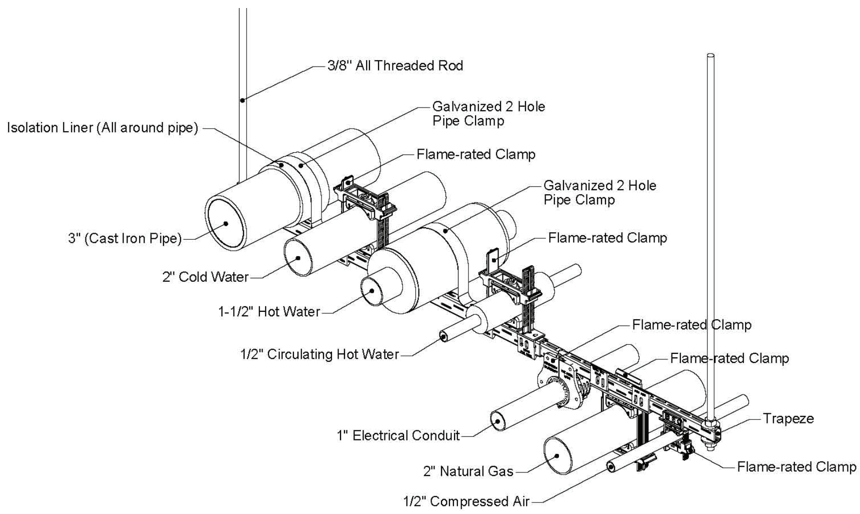


Figure 10-20 Horizontal Joist Bay Support

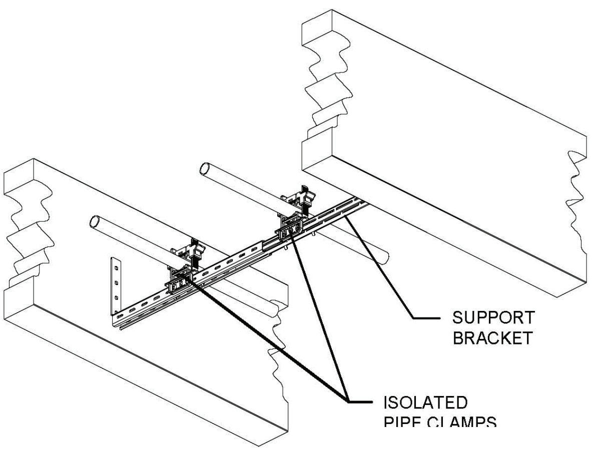
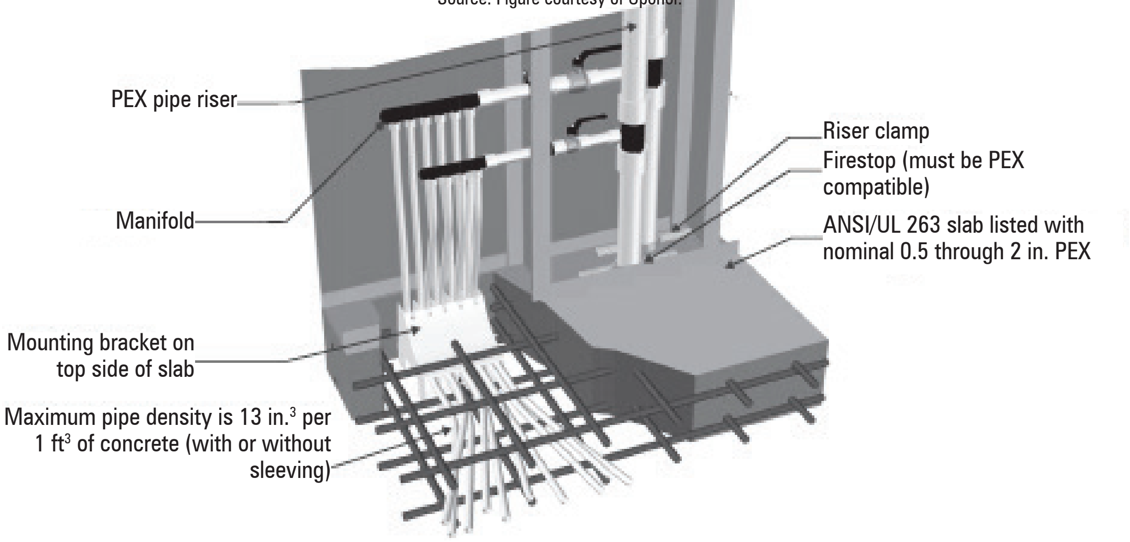


Figure 10-21 In-Slab PEX Installation

Source: Figure courtesy of Uponor.



their inherent sound qualities. ISO 3822 sets out a test method and uniform rating system for evaluating noise emissions from plumbing fixtures. Other methods to reduce noise from fixtures and faucets are as follows.

One common way to ensure that fixtures will be quieter than others is by choosing those made of materials that are heavier and better damped, such as vitreous china, terrazzo, or cast iron rather than thin-gauge stainless, enameled steel, or fiberglass. As an example, when choosing a kitchen sink, consider various factors that determine how much noise will result under normal operation. A stainless steel sink without the addition of a dense damping sound pad applied to the bottom of the bowl will experience a loud drumming sound when water hits the bowl, resulting in both airborne and structure-borne noise. Additionally, if the faucet is in direct contact with the upper surface of the sink or the countertop, devoid of a gasket, putty, or similar isolation, it will transfer noise generated from the operation of water running through the faucet itself. Instead, consider choosing a cast iron sink combined with a faucet made of heavy gauge metal and rubber isolation gaskets at both the base of the faucet and the attachment points under the ledge of the sink. Another example is to use flush tank-type toilets rather than flushometer valve or pressure-assisted water closets. Flush tank toilets are much quieter, and some are nearly silent. (See Figures 10-22 through 10-31.)

Water supply connections between the wall and the faucet constructed by rigid supply tubing will produce more noise than those made with flexible or braided supply lines. Flexible tubing made of corrugated stainless steel or braided nylon will perform better than chrome or rigid brass supply lines. (See Figure 10-32, in the case of a clothes washer.)

Figure 10-22 Wall-Hung Water Closet or Similar

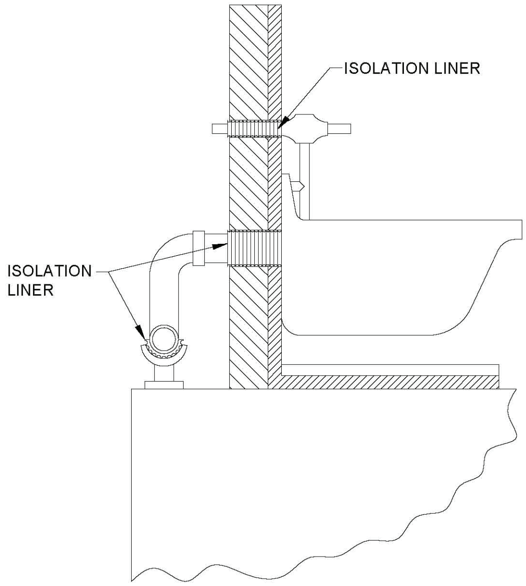


Figure 10-23 Wall-Mounted Urinal, Sink, or Similar Fixture

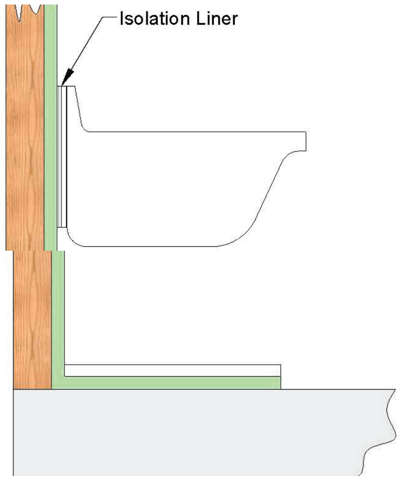


Figure 10-24 Sink Isolation Detail

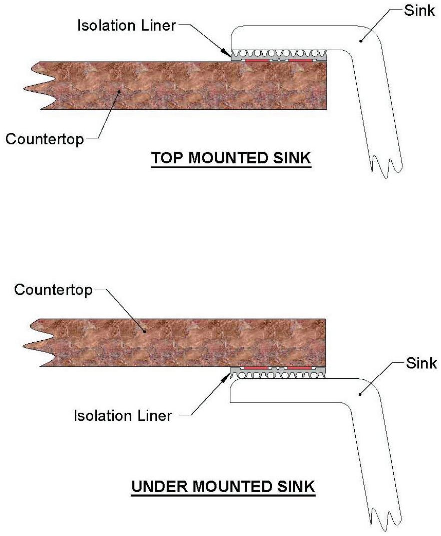


Figure 10-25 Wall-Hung Fixture with Carrier Support System

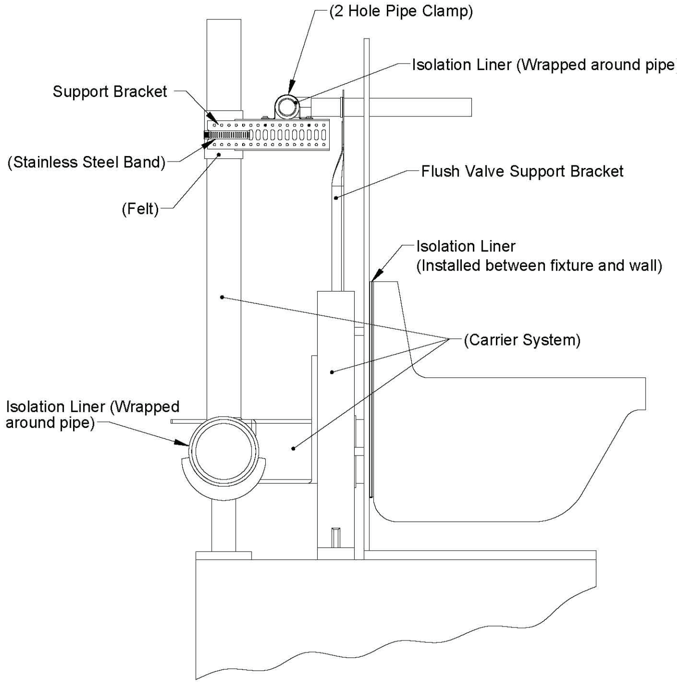


Figure 10-26 Typical Floor-Mounted Toilet Flange

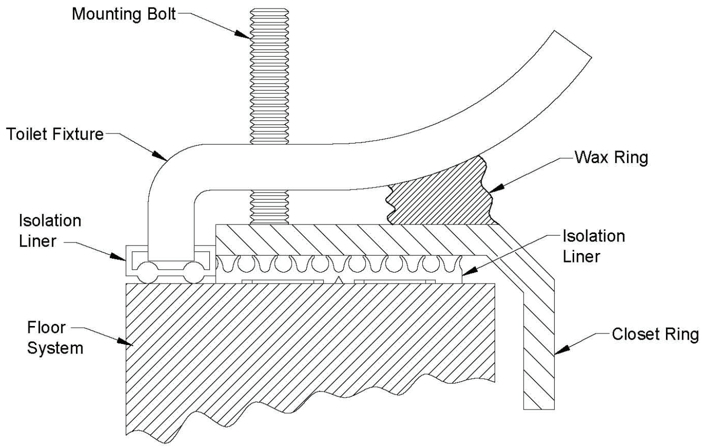


Figure 10-27 Floor-Mounted Bathtub or Shower Isolation

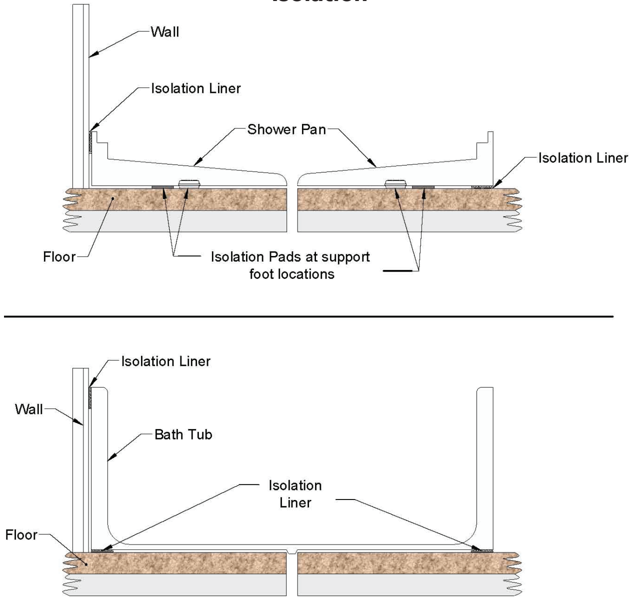


Figure 10-28 Lavatory, Service Sink, or Sink

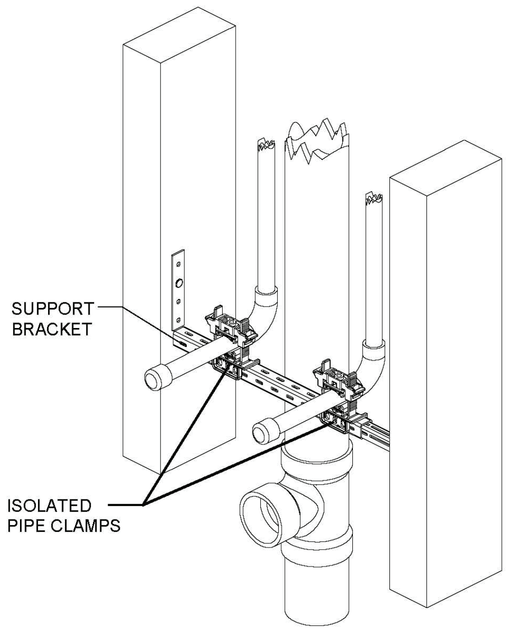


Figure 10-29 Icemaker Box

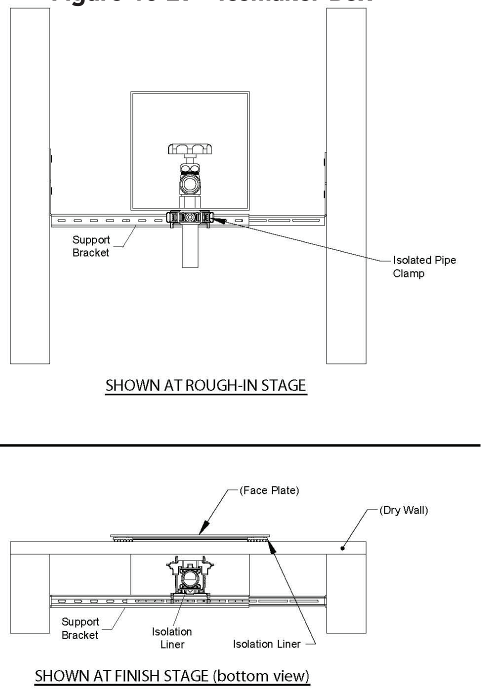


Figure 10-30 Laundry Outlet Box

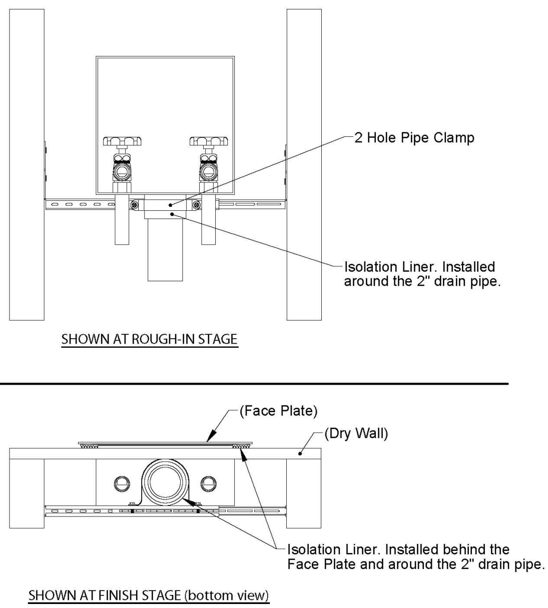


Figure 10-31 Hot Water Tank Rough-In

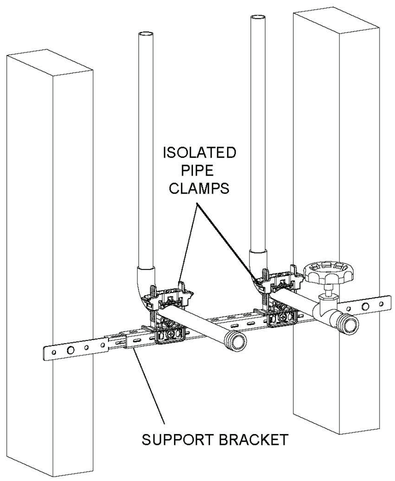


Figure 10-32 Flexible Connections for Clothes Washer

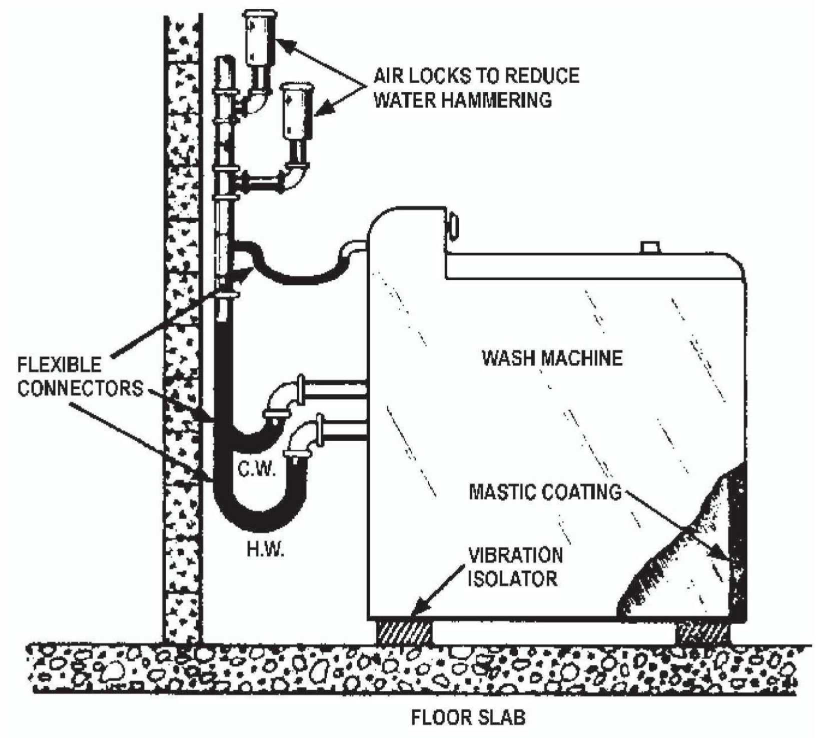


Figure 10-33 Typical Bathtub Spout

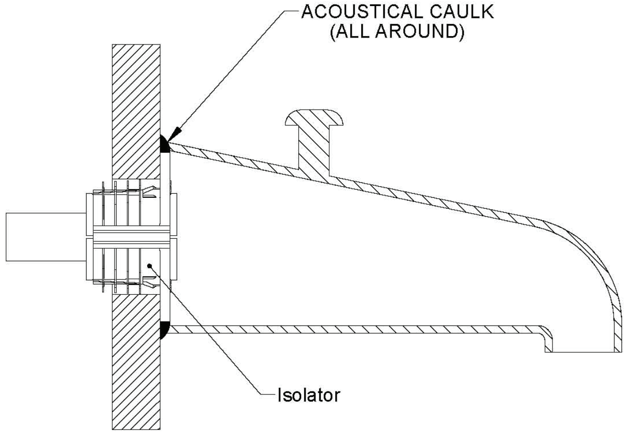
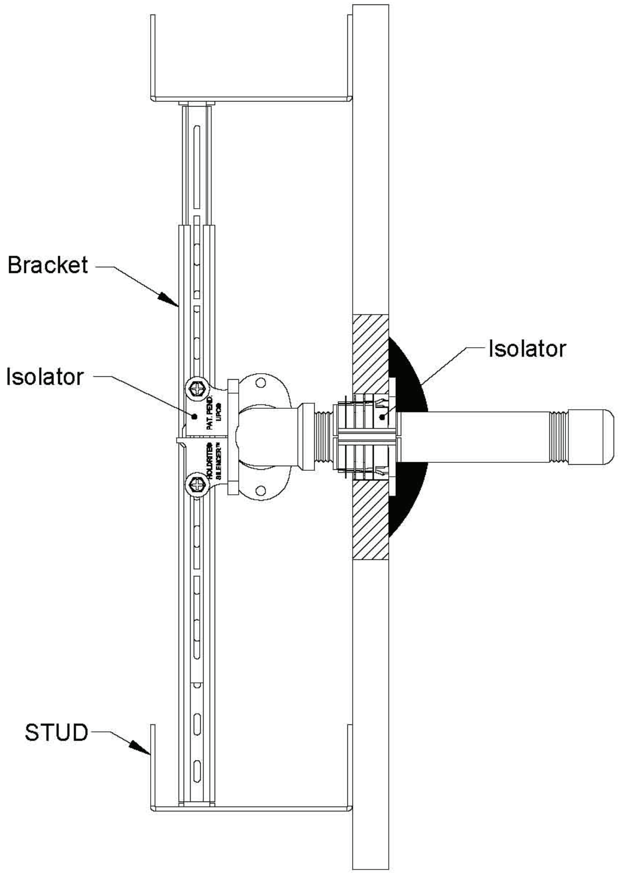


Figure 10-34 Showerhead Isolation



It is important to keep wall surface materials from contacting fixture supply stub-outs or escutcheons positioned behind angle stops. Provide rubber or dense foam isolation spacers behind the escutcheons so that a slight void is provided. Fill the void space around each escutcheon with an acoustical caulking compound, and use acoustical caulk or ¼-inch (6.35-mm) felt within the annular space between the stub-out pipe and the wall surface material.

Tub and shower mixing valves and associated parts such as showerheads and tub spouts should be treated much the same as the water distribution system to which they are connected. Tub and shower fixtures and faucets are among the worst culprits regarding unwanted noise generation.

The attachment points between the supports within the wall at the showerhead fitting, tub spout fitting, and supply lines feeding the diverter valve must be isolated from hard contact. Use only tested and proven isolating materials specifically engineered to accomplish this.

The showerhead arm and the sub-spout supply lines must be kept from contact with the wall surface as well. Provide a ¼-inch (6.35-mm) clear annular space around both pipe supply locations, and fill this space with a flexible caulking compound. Clearly define these isolation requirements within the specification as well as on plumbing installation detail drawings.

Additional noise and vibration isolation can be provided at tub and/or shower locations by selecting fixtures made of dense materials such as cast iron, as well as by eliminating direct contact with the floor sheathing and the wall framing surrounding the edges of the tub or shower. This should be accomplished by the use of a rubber or neoprene liner and ¼-inch (6.35-mm) rubber pads between heavy contact points and the building structure. Provide clear specification language and plumbing detail drawings to the installing contractor. (See Figures 10-33 through 10-36.)

MITIGATING NOISE FROM VALVES, PUMPS, AND OTHER EQUIPMENT

Valves, pumps, and other equipment are common contributors of noise in a plumbing system. Most valve manufacturers provide flow and turbulence data to assist in the choice of valves. Typically, the quietest valves are those with smooth waterways such as full-way ball valves and full-way gate valves. Specify appropriate valves with this in mind.

Pumps can be extremely loud and must be isolated in several ways. Rubber or spring isolators commonly are used when mounting pumps on floors. Concrete bases with spring isolators or neoprene pads are preferred for all floor-mounted pumps. Select the appropriate rubber or spring isolator based on third-party testing and load data provided by various manufacturers.

When connecting the piping system to pumps and equipment, especially ones that generate a great deal of vibration, pay special attention to the use of flexible connectors and effective hanger isolation. Select and specify flexible connectors that are appropriate for the pipe system's material and fluid content. Various manufacturers can provide the necessary data on which to base decisions. Table 10-1 contains the recommended static deflections for the selection of pump vibration-isolation devices.

Vibration-control devices generally consist of steel springs, air springs, rubber isolators, slabs of fibrous (or other resilient) materials, isolation hangers, flexible pipe connectors, concrete inertia bases, or any combination of these items.

Steel springs are available for typical required static deflections to 4 inches (101.6 mm). These devices generally are used as vibration isolators that must carry heavy loads where more isolation performance is desired than rubber or glass fiber provides or where environmental conditions make other materials unsuitable. The basic types of steel spring mountings are housed-spring mountings, open-spring mountings, and restrained-spring mountings. Because steel springs have little inherent damping and can amplify vibration at resonance frequencies, all steel-spring mountings should be used in series with pads of rubber, fibrous, or other resilient materials to interrupt any possible vibration-transmission paths.

Air springs are employed when deflections of 6 inches (152.4 mm) or more are required. By varying the air pressure in the bladder, air springs are capable of carrying a wide range of loads. The shape, rather than the pressure, determines the spring's frequency. Air springs have the advantage of virtually no transmission of high-frequency noise. They have the disadvantage of higher cost, higher maintenance, higher failure rates, and low damping.

Rubber or neoprene isolators generally are used where deflections of 0.3 inch (7.62 mm) or less are required. These devices can be molded in a wide variety of forms designed for several combinations of stiffness in the various directions. The stiffness of a rubber or neoprene isolator depends on many factors, including the elastic modules of the material used, which vary with the temperature and frequency and are usually a characteristic of a durometer number, measured at room temperature. Materials in excess of 60 durometers are usually ineffective as vibration isolators. Rubber or neoprene isolating devices can be relatively light, strong, and inexpensive; however, their stiffness can vary considerably with the temperature. They are effective primarily against high-frequency disturbances with very limited performance at low frequencies.

Pre-compressed glass-fiber pads generally are used where deflections of ¼ inch (6.35 mm) or less are required. They are available in a variety of densities and fiber diameters. Although glass-fiber pads usually are specified in terms of their densities, the stiffness of the pads supplied by different manufacturers may differ greatly, even for pads of the same density.

Sponge-rubber vibration-isolation materials are commercially available in many variations and degrees of stiffness. The stiffness of such a material usually increases rapidly with increasing load and frequency. This material is rarely used in manufactured isolators, but often is used in jobsite-fabricated installations.

Concrete base devices are usually masses of concrete, poured with steel channel, weld-in reinforcing bars, and other inserts for equipment hold-down and vibration-isolator brackets. These devices maintain the alignment of the component parts; minimize the effects of unequal weight distribution; reduce the effects of the reaction forces, such as when a vibration-isolating device is applied to a pump; lower the center of gravity of the isolated system, thereby increasing its stability; and reduce motion. Concrete bases can be employed with spring isolators, rubber vibration isolators, and neoprene pads. Industry practice is to make the base in a rectangular configuration approximately 6 inches (152.4 mm) larger in each dimension than the equipment being supported. The base depth needs not exceed 12 inches (304.8 mm) unless specifically required for mass, rigidity, or component alignment. A concrete base should weigh at least as much as the items being isolated. (Preferably, the base should weigh twice as much as the items.) The plumbing designer should utilize the services of a structural engineer when designing a concrete base.

When providing vibration isolation for any plumbing system or component, the engineer must consider and treat all possible vibration-transmission paths that may bypass (short-circuit or bridge) the primary vibration isolator. Flexible connectors commonly are used in pipe connecting isolated and un-isolated plumbing components. Flexible pipe connectors usually are used to provide flexibility of the pipe and permit the vibration isolators to function properly, to protect the plumbing equipment from strains due to the misalignment and expansion or contraction of the piping, and to attenuate the transmission of noise and vibration along the piping system. Most commercially available flexible pipe connectors are not designed primarily for noise reduction. For noise control, resilient pipe isolators should be utilized. (See Figures 10-37 through 10-44.)

Figure 10-35 Bathtub/Shower Rough-In

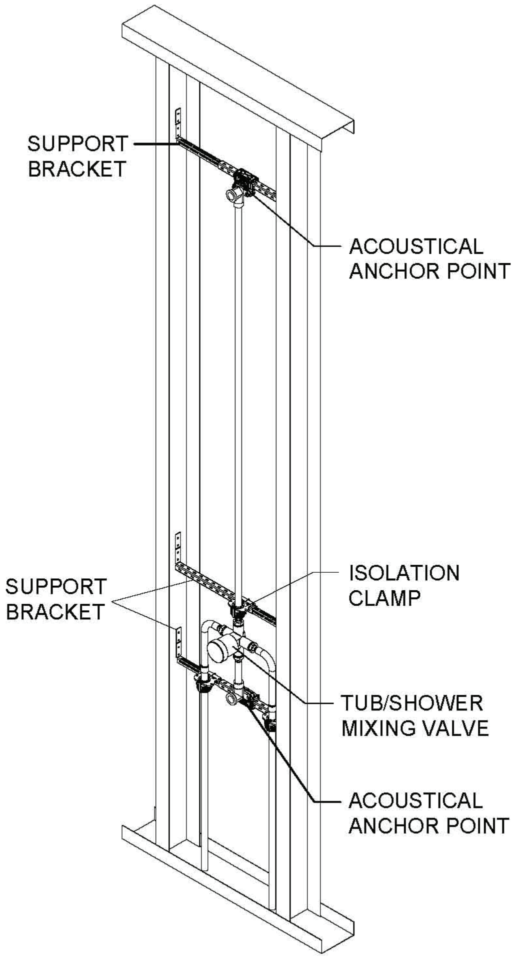


Figure 10-36 Shower Rough-In

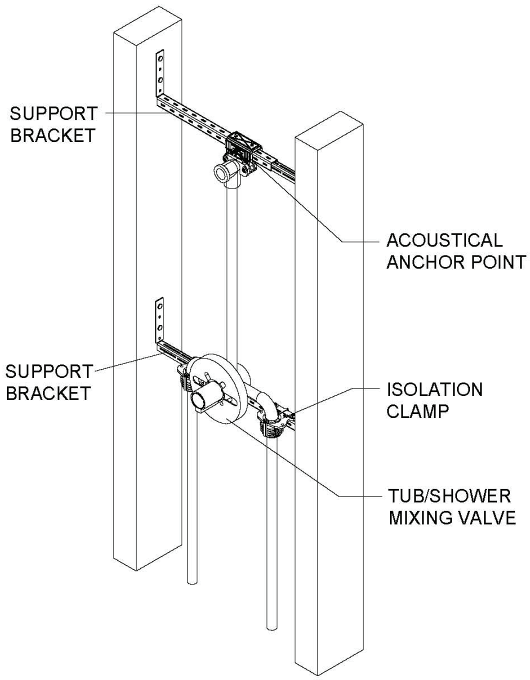


Table 10-1 Recommended Isolator Types and Static Deflections for Pumps

Pump Type	Power Range, hp (kW)	Speed, rpm	Slab on Grade			Indicated Floor Span, ft (m): Up to 20 ft (6 m)			20–30 ft (6–9 m)			30–40 ft (9–12 m)		
			Base Type[a]	Isolator Type[b]	Minimum Deflection, in. (mm)	Base Type[a]	Isolator Type[b]	Minimum Deflection, in. (mm)	Base Type[a]	Isolator Type[b]	Minimum Deflection, in. (mm)	Base Type[a]	Isolator Type[b]	Minimum Deflection, in. (mm)
Close-coupled	≤7.5 (≤5.5)	All	B	2	0.25 (6)	C	3	0.75 (19)	C	3	0.75 (19)	C	3	0.75 (19)
	≥10 (≥7.5)	All	C	3	0.75 (19)	C	3	0.75 (19)	C	3	1.50 (38)	C	3	1.50 (38)
Inline	5–25 (4–18.5)	All	A	3	0.75 (19)	A	3	1.50 (38)	A	3	1.50 (38)	A	3	1.50 (38)
	≥30 (≥22)	All	A	3	1.50 (38)	A	3	1.50 (38)	A	3	1.50 (38)	A	3	2.50 (64)
End-suction and double-suction/ split case	≤40 (≤30)	All	C	3	0.75 (19)	C	3	0.75 (19)	C	3	1.50 (38)	C	3	1.50 (38)
	50–125 (37–90)	All	C	3	0.75 (19)	C	3	0.75 (19)	C	3	1.50 (38)	C	3	2.50 (64)
	≥150 (≥110)	All	C	3	0.75 (19)	C	3	1.50 (38)	C	3	2.50 (64)	C	3	3.50 (89)
Packaged pump systems	All	All	A	3	0.75 (19)	A	3	0.75 (19)	A	3	1.50 (38)	C	3	2.50 (64)

[a]Base Type: A = No base; isolators attached directly to equipment; B = Structural steel rails or base; C = Concrete inertia base

[b]Isolator Type: 1 = Neoprene or rubber pad (not used); 2 = Neoprene or rubber mount/floor isolator or hanger; 3 = Spring floor isolator or hanger

Source: ASHRAE 2011 *HVAC Applications Handbook,* Chapter 48: Noise and Vibration Control

Figure 10-37 Neoprene Hanger Isolator

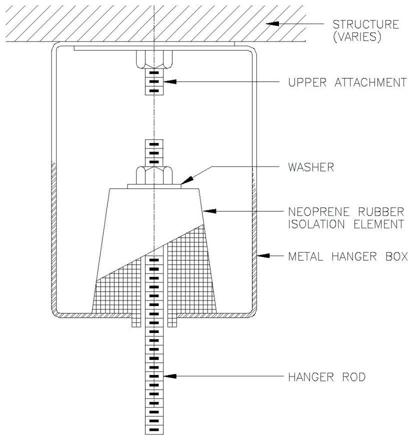


Figure 10-38 Sump Pumps

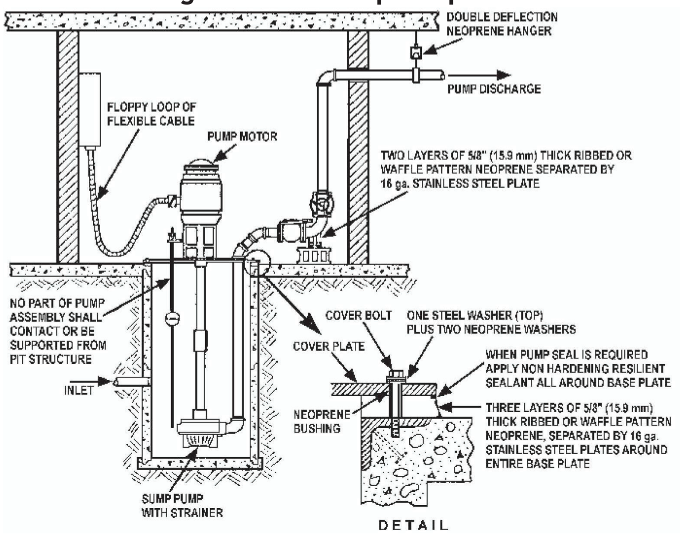


Figure 10-39 Neoprene Mount, Double Deflection

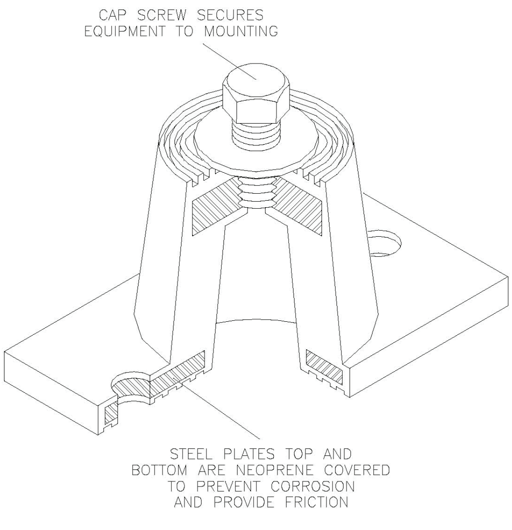
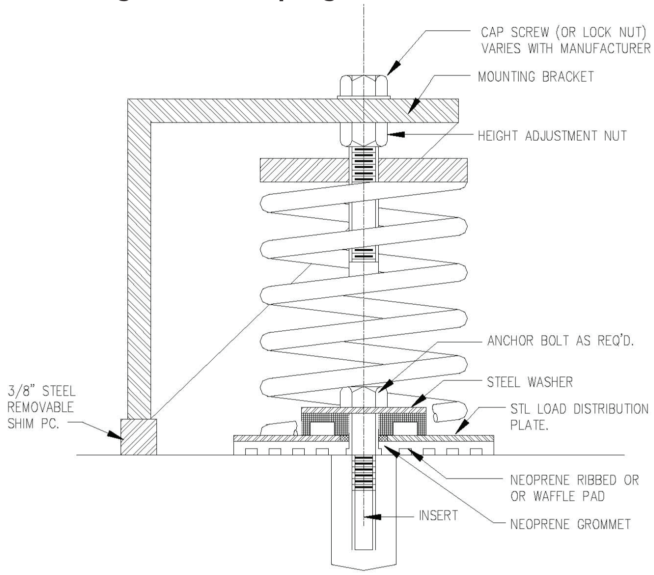


Figure 10-40 Spring-Mount Isolator



Grooved flexible mechanical couplings are a great alternative to U-shaped expansion loops, offsets, braided expansion joints, and rubber bellows. These couplings are often easier and faster to install and accommodate deflection and linear movement within the design capability of the coupling, all the while doing this within the product's free range of motion. This means that imparted deflections can be accommodated in smaller spaces, with low stress on the components. (See Figure 10-45.)

Note that sometimes the simplest solution may involve relocating the equipment to a less sensitive location. Many electric water coolers incorporate a small chiller, which generates noise on an intermittent basis as the compressor cycles. A potential approach for reducing the noise output of a water cooler to sensitive spaces is to ensure that it is not installed near the space in question or in a sensitive wall. If the location of the cooler cannot be moved, consider using a remote chiller to move the primary noise source as far from the receiver as possible. Locating centralized equipment in a dedicated equipment room far from acoustically sensitive spaces often provides better energy efficiency in addition to increased noise reduction.

Figure 10-41 Neoprene Pad Isolator

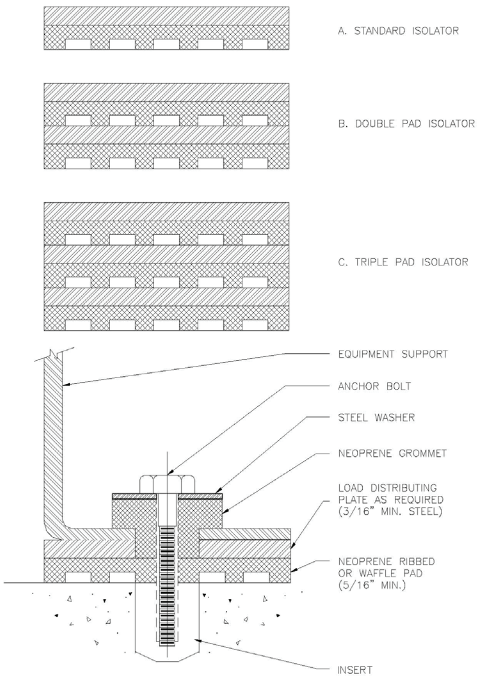


Figure 10-42 General Mounting Detail for End-Suction, Close-Coupled Pump

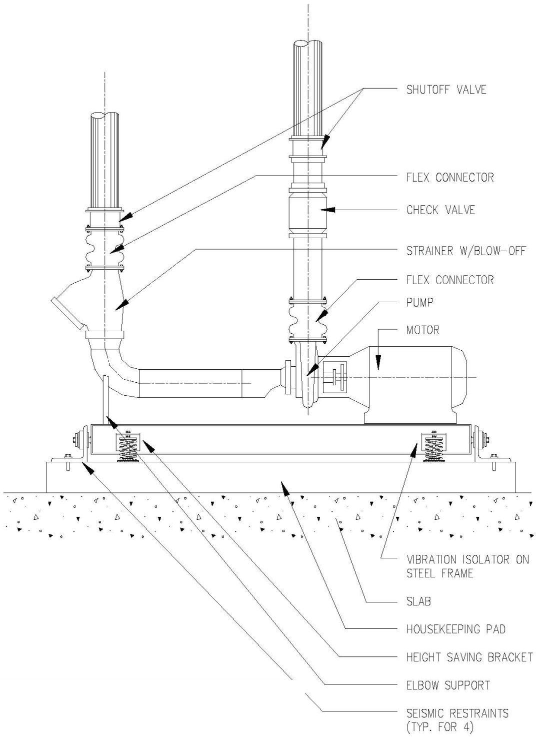


Figure 10-43 Examples of Flex Connectors

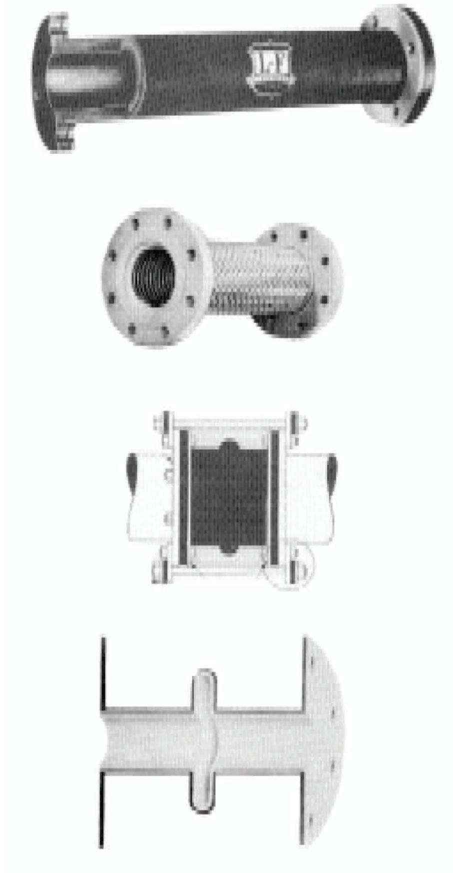
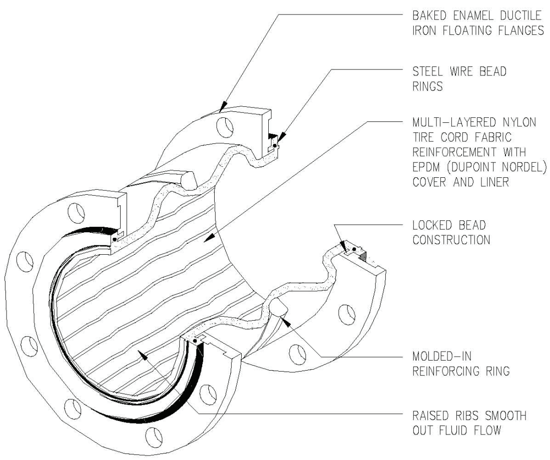


Figure 10-44 Flex Connector Detail

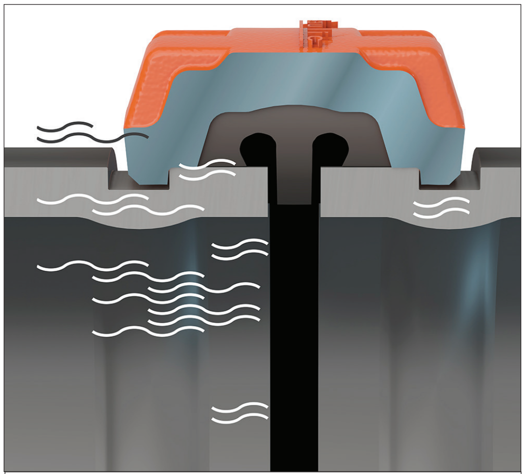


BENEFITS OF EARLY INVOLVEMENT IN DESIGN AND THROUGHOUT CONSTRUCTION

Once the engineer has a clear understanding of the owner's requirements regarding the level of noise abatement expected for a particular project, a plan of attack can be formulated. While this chapter covers acoustics in plumbing systems, it is apparent that the building layout must also be carefully considered. Coordination with the project architect and the plumbing/mechanical design team should occur early in the design stage. For some projects, an acoustical consulting firm may be an essential addition to the project team. These specialists, or acousticians, are typically members of the Acoustical Society of America and/or the Institute of Noise Control Engineering.

Figure 10-45 Attenuation Through the Use of Flexible Grooved End Couplings

Source: Reprinted with the permission of Victaulic. All rights reserved.



Noise and vibration attenuation – by isolating the transference of vibration at each joint.

Party and Plumbing Walls

Ideally, plumbing walls should not be located near quiet rooms. Party walls should be constructed to minimize sound transfer from one tenant to another or from common areas to tenant spaces and vice versa. Consider designs and configurations including increased physical separation (air space) between walls, staggered studs, dense insulation within wall cavities, multiple layers of sheetrock, and a variety of resilient channel configurations.

Floor and Ceiling System Construction and Configuration

Avoid routing plumbing system piping in ceiling spaces that are positioned above sensitive areas such as bedrooms. Minimize the use of hard floor surfaces where possible. Soft floor coverings help minimize the transfer of noise generated by plumbing fixtures and appliances between occupant levels of a building.

If pipes must be installed in the walls and ceilings of acoustically sensitive rooms, provide noise reduction as appropriate with sound-absorbing materials. Pipes should be decoupled from lightweight walls through the use of vibration-isolating clamps or other materials.

Documenting Construction Requirements and Observing Installation

After building-related design issues are resolved, the acoustical engineer or other responsible entity should draft the needed documents and establish means and methods that will be required of the plumbing or mechanical contractor. These documents typically include a project-specific plumbing noise and vibration specification, which establishes submittal requirements and procedures and specifies the acoustical materials and methods required for the project, and plumbing installation detail drawings, which establish how quality control will be monitored throughout construction.

On-site inspection during the building process often reveals errors that can be corrected easily and early. Waiting too long to visit the site can result in concealed errors that cannot be easily uncovered or repaired in a finished building.

Acoustical testing in a partially completed building can be helpful to prevent repeated errors and allow for timely correction.

RESOURCES

- ISO 3822: *Acoustics -- Laboratory tests on noise emission from appliances and equipment used in water supply installations -- Part 1: Method of measurement*
- *Sound & Vibration Magazine*
- UPC Section 609.10
- IPC Section 604.9
- *ASHRAE HVAC Applications Handbook,* Chapter 48: Noise and Vibration Control
- *Noise and Vibration Control,* Leo L. Beranek, McGraw-Hill
- *Handbook of Acoustical Measurements and Noise Control,* Cyril M. Harris, McGraw-Hill
- *Noise and Vibration Control in Buildings,* Robert S. Jones, McGraw-Hill
- *Noise Control in Building Services,* Alan Fry, Sound Research Laboratories
- ASTM E413: *Classification for Rating Sound Insulation*
- ASTM E90: *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements*

ASPE Read, Learn, Earn Continuing Education

You may submit your answers to the following questions online at **aspe.org/readlearnearn**. If you score 90 percent or higher on the test, you will be notified that you have earned 0.1 CEU, which can be applied toward CPD renewal or numerous regulatory-agency CE programs. (Please note that it is your responsibility to determine the acceptance policy of a particular agency.) CEU information will be kept on file at the ASPE office for three years.

Notice for North Carolina Professional Engineers: State regulations for registered PEs in North Carolina now require you to complete ASPE's online CEU validation form to be eligible for continuing education credits. After successfully completing this quiz, just visit ASPE's CEU Validation Center at aspe.org/CEUValidationCenter.

Expiration date: Continuing education credit will be given for this examination through **April 30, 2019**.

CE Questions — "Acoustics in Plumbing Systems" (CEU 258)

Test written by Ron Bartley, PE, CPD, CPI/CPE

1. For fixture supply stub-outs, use felt of what thickness within the annular space between the stub-out pipe and the wall surface material?
   a. 3/16 inch
   b. ¼ inch
   c. 5/16 inch
   d. 3/8 inch

2. Which of the following contributes to increased levels of noise generation in water systems?
   a. oversized tubing
   b. obstructions in valves and equipment
   c. turbulence caused by straight-line direction
   d. all of the above

3. On very large and heavy riser pipes, the use of _________ riser isolators is effective.
   a. neoprene
   b. rubber
   c. spring-loaded
   d. vinyl

4. Which of the following is not part of a spring-mount isolator?
   a. vinyl grommet
   b. steel removable shim
   c. height adjustment nut
   d. neoprene ribbed or waffle pad

5. The IPC specifically requires shock arrestors to conform to what standard?
   a. ASTM E413
   b. PDI WH 202
   c. ASTM E90
   d. ASSE 1010

6. What is the recommended base and isolator type for 75-hp end-suction pumps mounted slab-on-grade?
   a. B/2
   b. B/3
   c. C/3
   d. A/1

7. Which of the following is not a basic type of steel spring mounting?
   a. restrained-spring
   b. housed-spring
   c. open-spring
   d. pre-tensioned-spring

8. Which of the following features of a drainage pipe's wall construction provides quieter performance?
   a. more dense
   b. more highly damped
   c. thicker
   d. all of the above

9. Which of the following fixture materials is considered to be the lesser damped?
   a. cast iron
   b. enameled steel
   c. vitreous china
   d. terrazzo

10. Preferably, the concrete base should weigh _________ as the items being isolated.
    a. as much
    b. 1.5 times as much
    c. twice as much
    d. 2.5 times as much

11. For in-slab PEX installation, what is the maximum pipe density per 1 ft3 of concrete?
    a. 13 in^3
    b. 15 in^3
    c. 18 in^3
    d. 20 in^3

12. Materials in excess of _________ durometers are usually ineffective as vibration isolators.
    a. 20
    b. 40
    c. 60
    d. 80