The International Plumbing Code:

A Guide for Use and Adoption

ICC
INTERNATIONAL CODE COUNCIL™

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Foreword

The *International Plumbing Code* (IPC) was developed by the International Code Council (ICC) to be the most technically up-to-date plumbing code. The IPC is founded on plumbing principles utilized in the plumbing codes of more than 30 states across the country. Every code requirement is based on engineering principles, years of research, and field experience. When a modern, up-to-date plumbing code is introduced to new regions of the country, it is subject to criticism for the changes that are instituted. Although new to these areas, the requirements within the IPC represent plumbing practices utilized throughout the United States. The ICC developed this *Guide for Use and Adoption* to help assist in the analysis of the code.

When reviewing the *International Plumbing Code* some requirements may appear to be new. It should be noted that every code requirement has been enforced in a plumbing code somewhere in the United States. The IPC is the first attempt to accumulate all of the acceptable plumbing practices into one code.

The major technical provisions of the IPC are evaluated in this guide. Commentary is provided, with reference to supporting documentation, that justifies the technical content of the code.

The IPC should not be considered a liberal code, conservative code, permissive code, restrictive code, cost-saving code, or increased-cost code. The IPC is merely a very technical plumbing code. It was developed with the philosophy of recognizing all acceptable plumbing practices that have been proven safe and reliable in the annals of plumbing.

This guide is not intended to criticize any other plumbing code. It is only intended to provide insight into the technical substantiation of the IPC.

Part 1
Overview of the
International Plumbing Code

Scope: The *International Plumbing Code* (IPC) was the first code developed with the full cooperation of the three model code groups: Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International, Inc. (SBCCI). The intent was to regulate plumbing with the most technically accurate code. The original intent of the IPC was to recognize all acceptable methods for the various plumbing systems. The Code did not attempt to restrict arbitrarily any method, material, concept or system. Since its initial development, the IPC has been updated through an annual code change process with participation from nationally recognized industry experts.

Development of the Code

The *International Plumbing Code* (IPC) was developed through a cooperative effort of BOCA, ICBO and SBCCI (see Figure 1). The first draft of the IPC was prepared by a select group of plumbing officials working with the staff of the three organizations. This committee reviewed the contents of the *BOCA National Plumbing Code*, the ICBO *Plumbing Code*, and the SBCCI *Standard Plumbing Code*.

A draft of the Plumbing Code was prepared for review by the industry. The first draft contained only excerpts from the three plumbing codes, with no new concepts or ideas added. All of the allowable practices were already permitted and used by one of the model plumbing codes. The premise was that the Code should have its origins based on the code content of the existing plumbing codes.

It was recognized that no one part of the United States had used all of the plumbing practices that would be permitted in the new plumbing code. Terminology would also be an initial difficulty since different parts of the country use the same name to describe different plumbing systems.

When the draft was issued, it was subject to a review process through a series of public hearings. A committee of plumbing officials was appointed to consider all of the testimony on the first draft. The hearings were well attended by plumbing experts from all areas of the industry. New provisions were proposed for inclusion at the hearings, including a complete rewrite of the backflow section. The new requirements received overwhelming support at the public hearings.

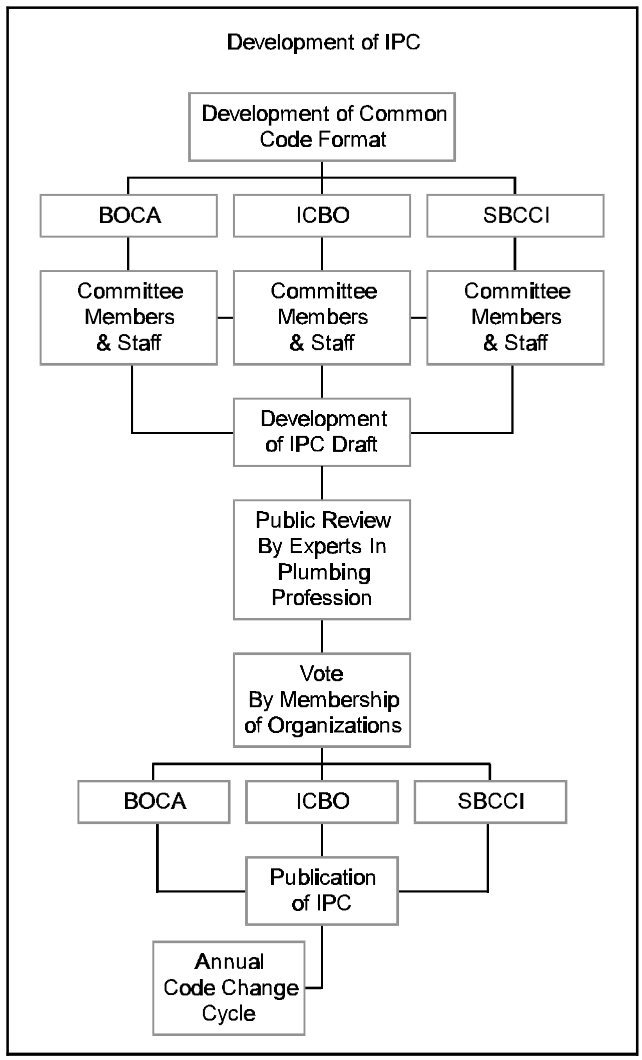


Figure 1, Development of the IPC.

After modifying the draft to include the acceptable changes based on testimony at the public hearings, the document was forwarded to the membership of BOCA, ICBO, and SBCCI. The three organizations voted unanimously to accept the new code as a replacement document for their organizations' plumbing code. In 1995, the first edition of the *International Plumbing Code* was published by the International Code Council, Inc.

Recognition of New Technology

The original committee that drafted the IPC developed a philosophy based on acceptance of new technology including new materials and products, as well as new methods of installation.

While the acceptance of new technology was paramount to the IPC, any new idea, concept or material must be substantiated with technical documentation and reviewed through the open code change process.

Code Change Process

The IPC has an annual code change cycle for the review of all new proposals, which is open and available to everyone. The ICC accepts code change proposals submitted before the deadline date, with no limitations placed on the submittal of code changes. Every code change is reviewed by the staffs of the three model code groups to address any administrative concerns. This provides every proponent of a code change with the best opportunity of being considered favorably.

The code changes are published in a document for distribution to any interested party. A public hearing is scheduled for discussion by the proponents and opponents of each code change. The hearings are conducted before the ICC Plumbing Code Change Committee, a select group of plumbing professionals appointed by the sponsoring organizations: BOCA, ICBO and SBCCI. The committee is made up of plumbing inspectors, plumbing engineers, labor representatives and representatives of testing laboratories.

After hearing public testimony, the committee votes to recommend either approval, approval with modification, or disapproval of the code change. The results of the committee are published with reasons for every action taken.

The recommendations of the committee can be challenged during the second series of public hearings where any challenged code change is open for discussion. The vote at the second hearing is by the voting membership of BOCA, ICBO and SBCCI. The membership can either agree or disagree with the committee's recommendation. A two-thirds majority of those voting is required to overturn the committee's recommendation and approve a code change.

The approved code changes are published in the supplement to, or the new edition of, the IPC.

Administration and Enforcement

Chapter 1 of the IPC follows the guidelines established by the legal community for the regulation of a construction code. The IPC is consistent with the recommendations of *Legal Aspects of Code Administration*.[1] The administration requirements in the IPC recognize that once adopted by a jurisdiction, the code becomes a legal document. The administration and enforcement become the responsibility of the local jurisdiction. This is the philosophy regarding the adoption of any model code.

Alternative Approval

Section 105 of the IPC includes the requirements for alternative approval. This section, often considered the most powerful section of the code, follows the guidelines of the Federal Trade Commission for permitting the acceptance of new technology. It permits the code official to accept any alternative material, method, or equipment that may not be recognized directly in the code.

The IPC is unique in specifying the requirements for alternative engineered design in the approval section. These provisions are consistent with the various state engineering and architectural registration acts. A registered design professional is permitted to design any plumbing system provided that he or she has adequate technical documentation and testing to justify the alternative design. The alternative engineered design section was originally developed by Bernie McCarty, P.E., Past President of the American Society of Plumbing Engineers (ASPE). Mr. McCarty submitted the code text on behalf of ASPE, in support of the Society's position regarding engineering design.

Consistent with Federal Guidelines

The IPC was developed consistent with federal guidelines regarding seismic protection and floodproofing. The seismic requirements in the IPC are consistent with the recommendations of the National Earthquake Hazards Reduction Program (NEHRP). The IPC references the building code for specific regulations relating to the location of the building.

The floodproofing requirements in the IPC were developed through a contract with the Federal Emergency Management Agency (FEMA). FEMA requested that references be located throughout the Code to address the necessary floodproofing requirements.

Referenced Standards

The IPC relies on references to nationally developed consensus standards. To assist the code user, the IPC directly references the appropriate standard throughout the body of the code. The complete list of the referenced standards appears in Chapter 14, listed in order of the promulgating organization.

The ICC developed a criterion for the acceptance of referenced standards. To ensure fairness, the standards are required to be developed by the consensus process.

The standards are also required to be written in mandatory language without permissive or subjective text, allowing the standard to be a legally enforceable document. If there is any permissive text in a standard, it raises the issue of enforceability and who makes the decision regarding the permissive requirement.

All standards are reviewed for adherence to the ICC policy.

Part 2
Fixture Requirements

Scope: Chapter 4 of the IPC regulates the installation of plumbing fixtures. One of the key elements in this chapter is the table specifying the minimum number of plumbing fixtures required based on building occupancy. Quite often, fixture tables are perceived to be arbitrarily developed without significant technical basis. The IPC table is based on various studies and is intended to provide equal access to fixtures. It contains specific requirements for handicapped-accessible plumbing fixtures and coordinates with the building codes and Fair Housing Act in specifying requirements for accessible dwelling units. Special requirements for each type of fixture are specified in detail with references to appropriate requirements in other sections of the Code.

Minimum Number of Fixtures Required (Table 403.1)

Table 403.1 of the IPC specifies the minimum number of plumbing fixtures required for every building occupancy. The minimum fixture requirements are based on both the number of building occupants and the occupancy classification. To avoid confusion in determining the minimum number of fixtures, the table has been converted to values that are consistent with the building code occupant load tables.

Number of Occupants

The occupant load of a building, as determined by the building code, is based on the means of egress requirements. The means of egress occupant does not typically relate to the normal building occupancy, with the exception of assembly-type buildings. For example, in a factory and industrial building, the normal occupancy is approximately 10 to 15 percent of the means of egress occupant load. In a mercantile building, during heavy business hours, the normal occupancy is approximately 25 percent of the means of egress occupant load.

In assembly buildings, the occupancy and means of egress occupant load are often the same. For example, a sold-out theater performance will have an occupancy equal to the means of egress occupant load.

Table 403.1 has been adjusted to reflect the normal occupant load anticipated for the building. Rather than changing the means of egress occupant load, the table adjusted the number of fixtures required. Hence, the IPC table is very accurate since it is directly related to the referenced building codes.

Potty Parity

Around 1980, it was recognized that plumbing codes were providing an injustice to the female population by requiring an inordinate amount of plumbing fixtures for the male population. This prompted a response that was referred to as “potty parity.” The inequity resulted from plumbing codes specifying a minimum number of water closets, as well as a minimum number of urinals, for the male population. The men’s room could end up with twice as many fixtures used for the human elimination process as the women’s room.

It was also recognized that when evaluating assembly buildings with large occupancies, the waiting period for the female population far exceeded any waiting time incurred by the male population. Studies were performed by Dr. Sandra Rawls at the University of Virginia,[2] Stevens Institute of Technology,[3] the National Restaurant Association, and the ASPE Research Foundation. These studies are reflected in Table 403.1 of the IPC.

The studies consistently showed that the time required for a woman to use a toilet room was twice as long as the time required for a man to use the facilities. When the timing is related to the defecation process, the time required for the male population was more than twice as long as the female population. When the values were averaged, the time required for the male and female population was approximately equal.

TABLE 403.1
MINIMUM NUMBER OF PLUMBING FACILITIES[a]
(see Sections 403.2 and 403.3)

	OCCUPANCY	WATER CLOSETS (Urinals see Section 419.2)		LAVATORIES	BATHTUBS/ SHOWERS	DRINKING FOUNTAINS (see Section 410.1)	OTHERS
		Male	Female				
ASSEMBLY	Theaters	1 per 125	1 per 65	1 per 200	—	1 per 1,000	1 service sink
	Nightclubs	1 per 40	1 per 40	1 per 75	—	1 per 500	1 service sink
	Restaurants	1 per 75	1 per 75	1 per 200	—	1 per 500	1 service sink
	Halls, museums, etc.	1 per 125	1 per 65	1 per 200	—	1 per 1,000	1 service sink
	Coliseums, arenas	1 per 75	1 per 40	1 per 150	—	1 per 1,000	1 service sink
	Churches[b]	1 per 150	1 per 75	1 per 200	—	1 per 1,000	1 service sink
	Stadiums, pools, etc.	1 per 100	1 per 50	1 per 150	—	1 per 1,000	1 service sink
	Business (see Sections 403.2, 403.4 and 403.5)	1 per 25		1 per 40	—	1 per 100	1 service sink
	Educational	1 per 50		1 per 50	—	1 per 100	1 service sink
	Factory and industrial	1 per 100		1 per 100	(see Section 411)	1 per 400	1 service sink
	High hazard (see Sections 403.2 and 403.4)	1 per 100		1 per 100	(see Section 411)	1 per 1,000	1 service sink
INSTITUTIONAL	Residential care	1 per 10		1 per 10	1 per 8	1 per 100	1 service sink
	Hospitals, ambulatory nursing home patients[c]	1 per room[d]		1 per room[d]	1 per 15	1 per 100	1 service sink per floor
	Day nurseries, sanitariums, nonambulatory nursing home patients, etc.[c]	1 per 15		1 per 15	1 per 15[e]	1 per 100	1 service sink
	Employees, other than residential care[c]	1 per 25		1 per 35	—	1 per 100	—
	Visitors, other than residential care	1 per 75		1 per 100	—	1 per 500	—
	Prisons[c]	1 per cell		1 per cell	1 per 15	1 per 100	1 service sink
	Asylums, reformatories, etc.[c]	1 per 15		1 per 15	1 per 15	1 per 100	1 service sink
	Mercantile (see Sections 403.2, 403.4 and 403.5)	1 per 500		1 per 750	—	1 per 1,000	1 service sink
RESIDENTIAL	Hotels, motels	1 per guestroom		1 per guestroom	1 per guestroom	—	1 service sink
	Lodges	1 per 10		1 per 10	1 per 8	1 per 100	1 service sink
	Multiple family	1 per dwelling unit		1 per dwelling unit	1 per dwelling unit	—	1 kitchen sink per dwelling unit; 1 automatic clothes washer connection per 20 dwelling units
	Dormitories	1 per 10		1 per 10	1 per 8	1 per 100	1 service sink
	One- and two-family dwellings	1 per dwelling unit		1 per dwelling unit	1 per dwelling unit	—	1 kitchen sink per dwelling unit; 1 automatic clothes washer connection per dwelling unit[f]
	Storage (see Sections 403.2 and 403.4)	1 per 100		1 per 100	(see Section 411)	1 per 1,000	1 service sink

[a] The fixtures shown are based on one fixture being the minimum required for the number of persons indicated or any fraction of the number of persons indicated. The number of occupants shall be determined by the building code.

[b] Fixtures located in adjacent buildings under the ownership or control of the church shall be made available during periods the church is occupied.

[c] Toilet facilities for employees shall be separate from facilities for inmates or patients.

[d] A single-occupant toilet room with one water closet and one lavatory serving not more than two adjacent patient rooms shall be permitted where such room is provided with direct access from each patient room and with provisions for privacy.

[e] For day nurseries, a maximum of one bathtub shall be required.

[f] For attached one- and two-family dwellings, one automatic clothes washer connection shall be required per 20 dwelling units.

The problem with using the average value is that it is deceiving for a large population in an assembly building that has a high demand for use of the plumbing fixtures. This occurs in theaters during intermission or at football stadiums during halftime.

In developing code requirements, the studies used the most demanding time factors to evaluate the waiting time required. Hence, the urination process was analyzed for determining minimum number of fixtures. If the female population requires twice as long to complete the urination process, they would need twice as many fixtures to have the same waiting period as the male population. Thus, Table 403.1 in the Code reflects requirements for twice as many water closets and urinals in the ladies' room when compared to the men's room. While the number of fixtures required will not eliminate waiting time during heavy use periods, it will result in equal waiting periods for both the men and the women.

Studies by the National Restaurant Association indicated that "potty parity" was not required for restaurants or nightclubs. For these types of occupancies, there is rarely an instantaneous demand on the fixture usage. It is uncommon for a waiting line to appear in restaurants or nightclubs. As a result, the average time factor for fixture use can be applied, resulting in an equal distribution of the number of plumbing fixtures.

Urinal as Substitute Fixture (See also Section 419.2)

To prevent the inequality of fixtures from occurring in the future, the requirement for a urinal to be a mandatary fixture was removed from the code. This was necessary for smaller toilet rooms that were designed for one fixture. If only one water closet is provided in the women's room, then only one water closet should be provided in the men's room.

The urinal is permitted to be substituted for a maximum of 50 percent of the required number of water closets. This value for substitution is based on the urination process accounting for more than half of the toilet room usage. Hence, when two or more water closets are required for the men's room, the designer or building owner can substitute with urinals.

Basis for Minimum Fixture Requirements

The fixture requirements for assembly buildings with large occupancies are based on permitting between one-quarter and one-third of the population to use the facilities during a major break. The numbers differ based on the anticipated break time. For example, the halftime at a football game lasts between 12 to 15 minutes while the intermission at a theater will last between 15 to 25 minutes. The resulting values in the table attempt to adjust the fixture usage based on length of the anticipated heavy use period.

The requirements for restaurants and nightclubs are based on a study by the National Restaurant Association, which determined that nightclubs required almost twice as many plumbing fixtures because of the consumption of alcoholic beverages.

Factory and industrial complexes had their fixture values determined based on one of the first contracts with GM employees. They had a constant complaint that there was inadequate time for using plumbing fixtures during the breaks on the assembly line. The contract specified that there had to be a minimum number of water closets and urinals. The number always cited for this contract was 1 water closet for every 15 employees. This allowed everyone an opportunity to use the fixtures during the break. The values have remained the same with the adjustment for means of egress occupant load.

For prisons and dormitories, fixture studies by the military were utilized. The military distinguished between highly regimented and partially regimented societies. In prison, there is a high level of discipline similar to a highly regimented military facility. For dormitories and lodges, there is less regimentation, resulting in the need for additional plumbing fixtures.

The lightest usage of plumbing fixtures occurs in mercantile establishments where the general population has a low demand for fixture use. The table takes this into consideration. Various studies have shown the values to be too demanding; however, those studies are based on moderate use of covered mall buildings. During periods of heavy use, the population of the covered malls increases, placing a greater demand on the plumbing fixtures.

The International Code Council has recognized the importance of continually reviewing the requirements for the minimum number of plumbing fixtures. At the current time, an ad-hoc committee of industry professionals is studying the code requirements.

Accessible Plumbing Fixtures (Section 404)

One of the perplexing requirements in any plumbing code is the method for regulating the requirements for handicapped-accessible plumbing fixtures. The IPC takes a direct approach by including all of the necessary requirements for the design, installation, and enforcement of accessible plumbing fixtures. The IPC directly references CABO/ANSI A117.1, which regulates accessible plumbing fixture requirements.

In addition to referencing the standard, the IPC specifies the minimum number of fixtures required to be accessible. While the standard supplies requirements for providing accessible fixtures, the standard does not specify which fixtures are required to be accessible. This clarity is provided in the IPC.

The accessible requirements are also coordinated with the building code, which identifies the requirements for accessibility for various buildings. This includes Type A dwelling units which are required to be completely accessible for persons with physical disabilities.

Type B Dwelling Unit Accessibility (Sections 404.2 and 404.3)

The IPC is the only model plumbing code to include specific requirements for Type B dwelling units. Type B dwelling units are designed to be readily adaptable to handicap access. The requirements have been coordinated with the Fair Housing Act.[4]

The IPC specifies the clear space requirements for a kitchen, kitchen sink and the appliances. Additional requirements specify the clear space and access requirements for the water closets, lavatories and bathtubs in the dwelling unit. For accessible dwelling units, the code also references CABO/ANSI A117.1.

Without the guidance in the plumbing code, the designer, contractor, and inspector would have to search the provisions in the federal law. The IPC codifies these requirements to ensure compliance with the Fair Housing Act.

Installation of Fixtures (Section 405)

The IPC regulates the spacing of plumbing fixtures to provide both comfort and social privacy. Figure 405.3.1 in the Code identifies the minimum spacing requirements for various plumbing fixtures.

The spacing requirements are based on the results of a study conducted at Cornell University, published in a book entitled, *The Bathroom.*[5] Prof. Alexander Kira headed a study that completely analyzed the use of the various plumbing fixtures. The study concluded that adequate spacing was required between fixtures in public toilet rooms to help facilitate the user. The public needs privacy and space to avoid direct body contact with other users of fixtures.

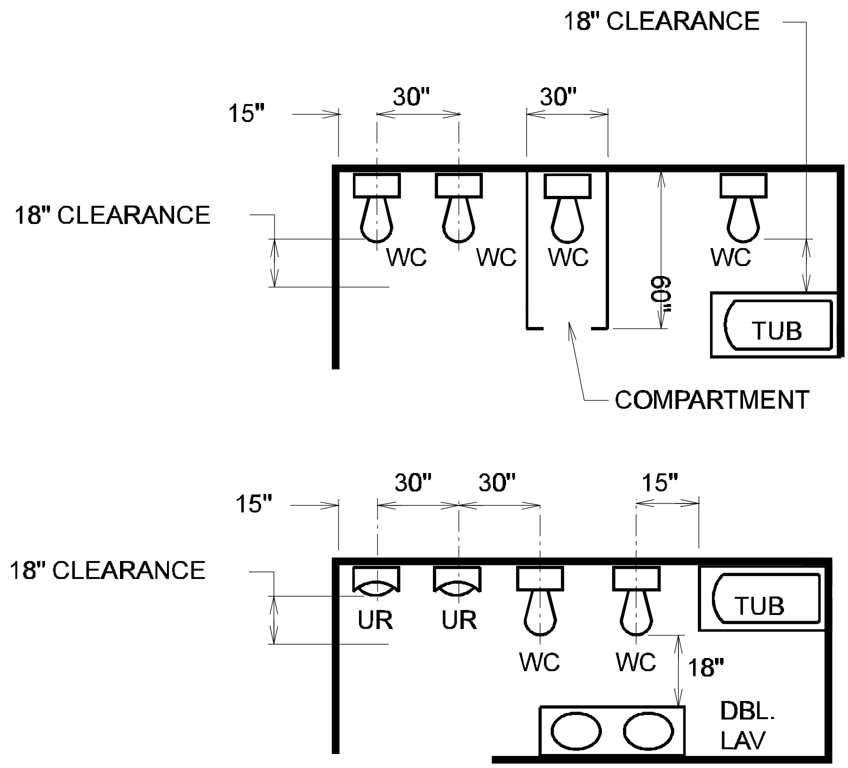
The spacing for urinals reflects dimensions that are typically not followed in other plumbing codes. A 30-inch spacing prevents direct body contact from the user of the adjacent urinal. If a 24-inch spacing is provided, the result will be direct contact with the user of the adjacent fixture.

The study at Cornell was also used to determine the minimum size of a shower. The shower must accommodate the movement of the individual to allow the cleansing of the lower extremities.

Individual Fixture Requirements (Section 406 through 425)

The IPC specifies minimum code requirements for each plumbing fixture. The individual requirements are designed to address the full range of use for each fixture. The Code often references other sections to guide the user to the appropriate code sections.

An example would be the backflow requirements for fixtures and appliances. Section 406.2 requires automatic clothes washers to have an integral air gap built into the machine, or the water supply must be protected against backflow in accordance with the requirements of Section 608. While residential and coin-operated automatic clothes washers have integral air gaps, this is not true for many large commer-



IPC Figure 405.3.1
FIXTURE CLEARANCES

For **SI:** 1 inch = 25.4 mm.

cial machines. For these larger machines, backflow protection is provided on the water supply to the appliance.

The backflow requirements are also similar for dishwashers. Again, residential dishwashers have built-in backflow protection. However, commercial dishwashers found in restaurants, cafeterias and hospitals must have the water supply protected against backflow.

Many plumbing codes have a tendency to specify requirements for residential appliances and fixtures while leaving out the requirements for commercial equipment. The IPC is complete in specifying regulations for both residential and commercial appliances and fixtures.

Shower Valves

Section 424.4 is considered one of the more important requirements in the IPC. This section requires all shower valves to be pressure balancing, thermostatic or combination mixing valves. These valves protect against any sudden change in temperature. The referenced standard only permits a change in water temperature of 3°F. maximum. This minimal temperature change is barely detectable and has little impact on the individual taking a shower. The valves also reduce the incidence of scalding in the shower.

Part 3
Water Piping Systems

Scope: The IPC regulates water piping systems in Chapter 6 and water heaters in Chapter 5. The requirements are consistent with accepted engineering practice for the design of water distribution systems. One of the most important aspects of water distribution systems is the protection against backflow. The IPC has extensive requirements that maintain the highest level of protection of the potable water system.

Piping Material (Section 605)

The acceptable piping materials for water service and water distribution systems are listed in Tables 605.4 and 605.5. The IPC accepts all of the common water piping materials, such as copper tubing, CPVC, galvanized steel, cross-linked polyethylene, and PEX-AL-PEX. There are no arbitrary restrictions or prohibitions placed on the installation of any water piping materials.

The tables identify the acceptable materials by reference to the ASTM or CSA standard(s). The IPC relies on these organizations for the development of acceptable material standards. Each standard is reviewed for completeness and compliance with the ICC standards policy. The standard must properly address all technical matters in regulating a given material for use in a potable water piping system.

Design Criteria for Sizing (Section 604)

Table 604.3 of the IPC specifies the minimum criteria for the design of a water distribution system. This table is often mistaken as being the minimum flow rates required for the specified plumbing fixtures; however, the criteria are only used for purposes of sizing a water distribution system.

While the table identifies both minimum flow rates and minimum pressures, these values are used independently of one another. When sizing a water distribution system, the flow rate values are used in determining the peak demand of the system. The pressure values are the minimum requirements for the most demanding fixture operating under a peak demand condition. The flow rates are similar to the values published in the *ASPE Data Book.*[6] The minimum pressure requirements are consistent with the fixture requirements specified in ANSI/ASME A112.18.1[7] and ANSI/ASME A112.19.6.[8] When a fixture is not listed in the table, Section 303.2 stipulates that the manufacturer shall establish the minimum requirements for flow rates.

Maximum Flow Rates

The federal government imposed mandatary requirements for plumbing fixtures as part of the legislation for water and energy conservation. The IPC maintains consistency with the federal legislation by specifying the maximum flow rates (at specified pressures) in Section 604.4 and Table 604.4. The published values in the IPC are the same as the federal legislation.

It should be noted that one of the referenced standards, ANSI/ASME A112.18.1, requires the maximum flow rates for lavatory faucets and kitchen sinks to be 2.2 gpm at 60 psi. This value appears to be lower than the IPC's (and the federal government) maximum flow rate of 2.5 gpm at 80 psi. When a flow restrictor is utilized to control the flow rate, a flow of 2.5 gpm at 80 psi would flow 2.2 gpm when lowered to a pressure of 60 psi. The lower flow rate in the referenced standard would only impact faucets that use flow control devices rather than flow restructures.

Minimum Pipe Size

Table 604.5 of the IPC specifies the minimum water pipe size required on the supply to each fixture. The minimum pipe sizes specified are consistent with those specified in the *ASPE Data Book.*

The table has an exception for sizing individual fixture lines in a manifold parallel distribution system. Although this type of system is normally installed with PEX pipe, it is also possible to have a copper tubing manifold system.

Bathtubs, kitchen sinks, dishwashers, showers and one-piece water closets are permitted to have the minimum supply pipe reduced one pipe diameter provided that the maximum length of pipe is 60 feet and there is a minimum pressure of 35 psi. The reduction in pipe size is still within the engineering limitations for sizing a water distribution system. If an individual water supply pipe from a manifold has a flow rate of 2.5 gpm, $^3/_8$-inch Type M copper tubing would have a flow velocity of 5.04 feet per second, $^3/_8$-inch Type L copper tubing would have a velocity of 5.52 feet per second, and $^3/_8$-inch PEX tubing would have a flow velocity of 8.3 feet per second. These velocities are within the acceptable range for the given piping material.

The worst-case condition for the exception in Table 604.5 would be the supply to a pressure balancing shower valve. Figure 2 depicts an example of the maximum piping limitation for $^3/_8$-inch PEX tubing, 60 feet in length, having an initial pressure of 35 psi. Shower valves are limited to a maximum flow rate of 2.5 gpm at 80 psi. If the pressure balancing shower valve had a pressure compensating shower head, the maximum flow rate at 20 psi would be approximately 2.2 gpm. Assuming a hot water temperature of 120°F. and a cold water temperature of 50°F., the flow rate through the hot water tubing would be 1.5 gpm. The velocity of flow in $^3/_8$-inch PEX tubing would be 5 feet per second. The pressure loss, based on the Darcy-Weisbach equation would be 0.126 psi per foot, or 7.56 psi for 60 feet of tubing. With an initial pressure of 35 psi, the pressure at the shower valve would be 27.44 psi. This is above the minimum pressure of 20 psi required for a pressure balancing shower valve.

The pressure balancing shower valve may be located on an upper floor in a building. With an excess pressure of 7.44 psi, the shower valve could be located 17 feet above the manifold, while still complying with the minimum pressure requirement for the pressure balancing shower valve. This would allow a manifold to be located in the basement with the shower valve located on the second floor.

Manifold Systems

The IPC has specific requirements for sizing the manifold for a manifold system. The sizing of the manifold is designed to prevent any pressure differentials in the individual supplies resulting from the

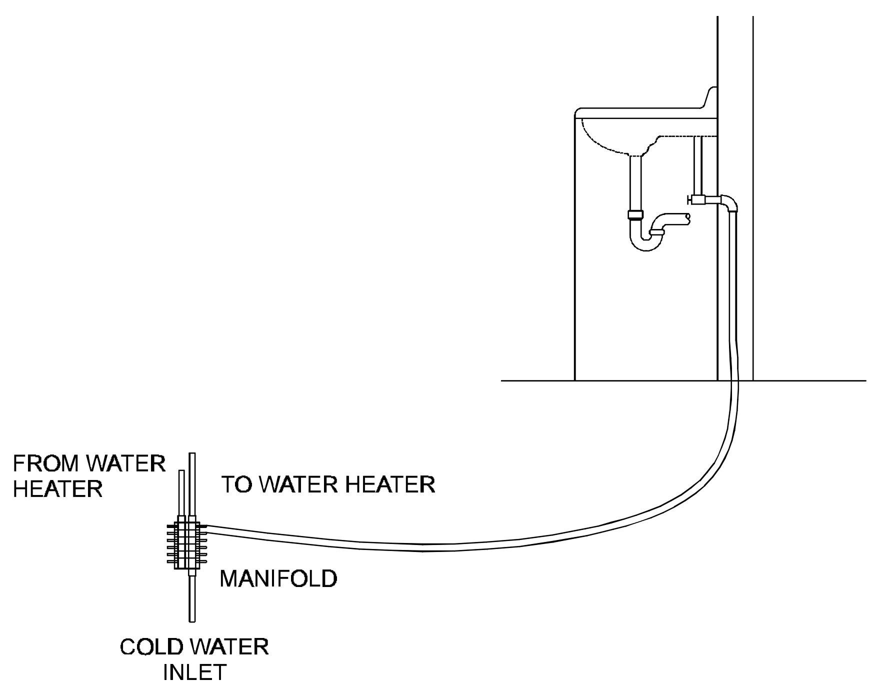


Figure 2, A manifold system has a separate hot and cold water supply pipe to each fixture. The system is designed for better control of the water flow and pressure fluctuations.

flow in adjacent lines. The balancing of the pressure by controlling the flow in the manifold results in uninterrupted flow at the individual fixtures.

System Sizing Requirements (Section 604.1)

The IPC requires the water distribution system to be designed in accordance with accepted engineering practice. This provides the system designer with the flexibility to use any approved sizing method. Some plumbing codes choose to have a mandatory method for sizing the water distribution system, even though the method is inaccurate.

Many of the water pipe sizing procedures utilize the concept of supply fixture units to determine the minimum pipe size. This method was originally developed by Dr. Roy B. Hunter. Hunter wrote in BMS 79[9] that, “the design or piping layout and the selection of material and pipe sizes should be delegated to an engineer experienced in this field.” The ASPE Research Foundation called for the abandonment of supply fixture unit sizing methods in a report to the plumbing engineering community.[10] The fixture unit sizing method is considered out of date for properly sizing water distribution systems. The engineering community has converted to sizing by a direct analytical method.

The IPC permits the plumbing engineer to evaluate each water distribution system for peak demand, and size the system accordingly. Plumbing engineers and system designers have been employing computer programs to size water distribution systems more accurately.

Appendix E Water Pipe Sizing Method

While the IPC does not mandate a method that must be followed for the sizing a water distribution system, one method of sizing is provided in Appendix E. This method follows the precepts of Hunter’s original water pipe sizing procedure.

The IPC recognizes that sizing methods will not always provide accurate water pipe sizes. The sizing method in Appendix E is provided for assistance to the code user, especially for smaller buildings that are designed by plumbing contractors.

Table E101B in Appendix E assigns the supply fixture unit load for the various plumbing fixtures. This table has been adjusted from the original values developed by the Hunter method to account for the lower water flow rates to water-conserving fixtures.

Appendix E includes a series of nomographs for various water piping materials. These graphs can be used to determine the velocity and pressure loss in a water piping system for a given flow rate. Since the nomographs provide information for the specific piping material, they can be utilized for any water pipe sizing method.

Water Hammer (Section 604.9)

The plumbing community has recognized that water hammer in a piping system can only be controlled by preventing the occurrence, or with the installation of water-hammer arrestors (see Figure 3). Julius Ballanco, P.E., reported that controlling velocity to prevent water hammer was dependent on the type of water piping material installed.[11]

Section 604.9 of the IPC follows the engineering guidelines for water-hammer control. Some plumbing codes require air chambers for controlling water hammer. However, both Ballanco and Steele[12] reported that air chambers are ineffective in controlling water hammer. Both individuals reported that the only viable method for preventing the occurrence of water hammer was the installation of water-hammer arrestors, or by controlling the velocity of flow in the piping.

Backflow Protection (Section 608)

Backflow protection is considered the most important aspect of a plumbing code. The backflow protection requirements in the IPC have been developed with the input of the leading backflow protection experts in the country. This section was specially developed for the IPC with the latest information and references to national consensus standards.

The IPC lists the requirements for backflow protection based on the type of backflow preventers intended to be installed. The Code presents every viable option for determining the specific method of protecting the potable water supply.

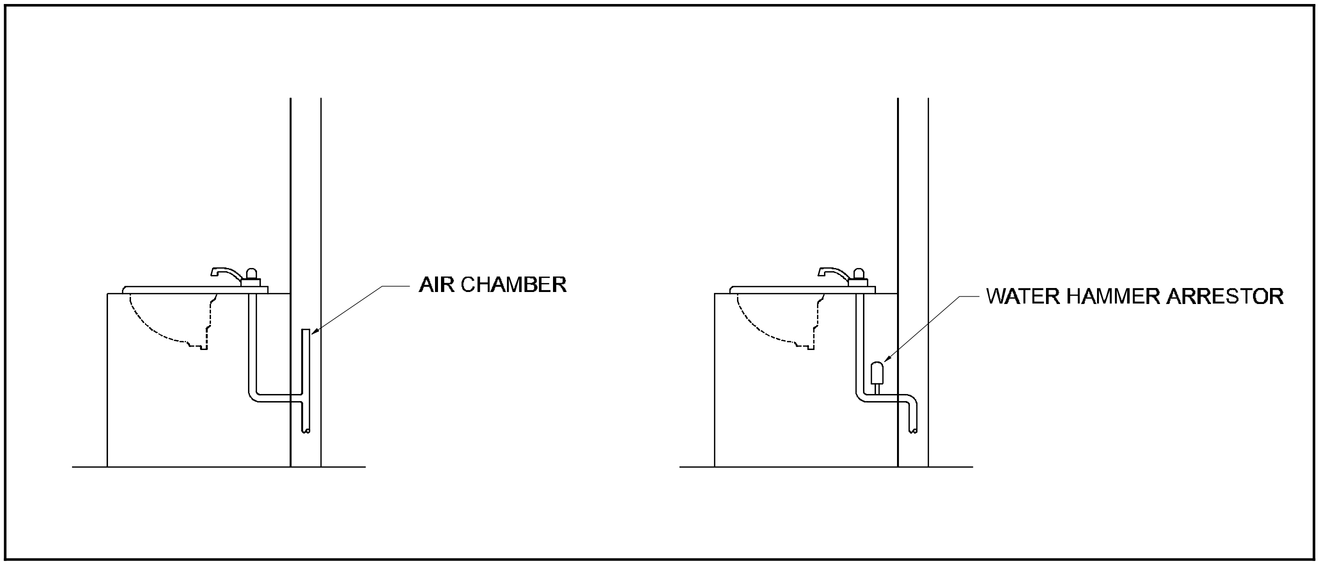


Figure 3, When a high velocity in the water piping system causes water hammer, the only recognized method of controlling it is with water-hammer arrestors, as shown on the right. A typical air chamber shown on the left has been determined to be ineffective.

Application Table

Table 608.1 lists all of the acceptable backflow preventers with reference to the ASSE, CSA and AWWA standards. These standards are the nationally developed consensus documents for regulating and testing all acceptable backflow preventers. The table is designed to avoid confusion in the selection of an acceptable backflow preventer.

Section 303.4 requires all backflow preventers to be listed and labeled by a third-party agency. This is to ensure the performance of the backflow preventer and is consistent with the policy of the American Society of Sanitary Engineering.

Air Gap

The most common method of protecting the potable water supply is with an air gap. Table 608.15.1, specifying the minimum air gap requirements, is consistent with the air gap requirements specified in ANSI/ASME A112.1.2.[13] This standard, originally developed in 1942, has been the mainstay of the plumbing industry for air gap requirements.

Sprinkler Backflow Protection

The IPC requires a fire sprinkler or standpipe system to be protected with a double check-valve assembly or a reduced pressure principle backflow preventer. One exception to this requirement is the installation of a fire sprinkler system that is piped as a part of the potable water system. These systems are commonly installed in single-family dwellings. The piping is identified as multipurpose piping and is regulated by NFPA 13D[14] (see Figure 4).

There has been no demonstrated need for backflow protection when the water distribution system is a part of the fire sprinkler system. This is consistent with AWWA recommendations.[15]

A residential sprinkler system is designed to be a low-cost system that is an extension of the water distribution system. Ballanco[16] stated that backflow protection was not required for these types of systems since there was no possibility of contamination.

Testing of Backflow Preventers

Section 312.9 of the IPC references the ASSE Series 5000 standard for the inspection and testing of backflow preventers. To ensure the performance of testable backflow preventers, there must be a program for periodic testing of the devices (see Figure 5).

Hot Water Systems (Chapter 5 & Section 607)

The IPC and the *International Mechanical Code* (IMC) have been correlated for the regulation of water heaters. If a water heater is either gas fired or oil fired,

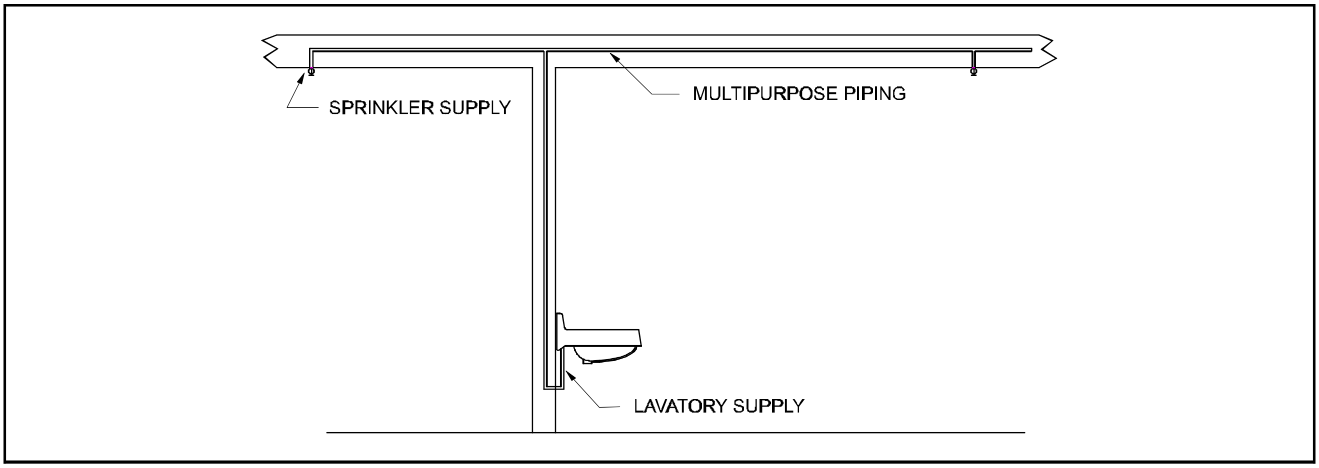


Figure 4, With a multipurpose piping system for a residential sprinkler system, the water piping provides water supply to the plumbing fixtures and the fire sprinklers. The water supply to the sprinklers is not subject to contamination; hence, the IPC does not require any backflow protection.

the appliance is required to be installed in accordance with the IPC and the fuel-burning appliance requirements of the IMC. This reference prevents the occurrence of overlapping and conflicting provisions.

Since the federal government requires furnaces and boilers to have a higher efficiency rating, the dynamics of all of the appliance installations change. A water heater cannot be installed without due consideration of the installation of the other appliances in the building. For example, a fan-assisted furnace connecting to the same chimney or vent as a gas water heater will typically be required to increase the size of the vent connector by 1 inch. A plumbing code can no longer require the water heater to connect to a vent with a connector the same size as the flue outlet on the water heater.

The failure of the plumbing industry to correct water heater installation procedures has resulted in the failure of many chimneys and vents. Other plumbing codes have not been revised to address this installation provision properly. However, the IPC references the IMC, which has the appropriate code requirements (see Figure 6).

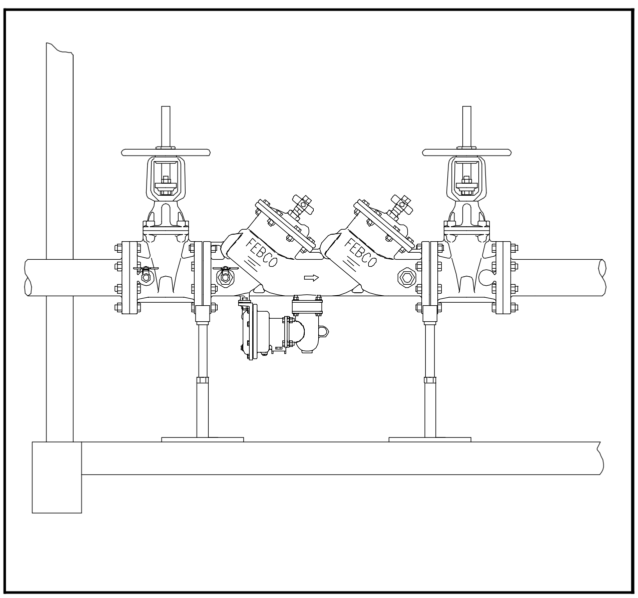


Figure 5, Reduced pressure principle backflow preventers have test cocks that allow the valve to be periodically tested. The test determines if the valve is functioning properly to protect the potable water supply against backflow.

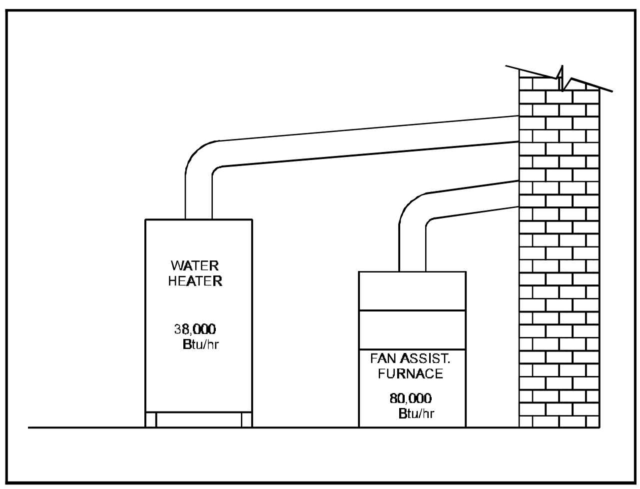


Figure 6, For this installation, the *International Mechanical Code* would require the vent connector for the water heater to be increased from 3 inches to 4 inches. If a 3-inch connector was installed for the water heater, it would result in a failure of the masonry chimney within a short period of time. The vent connector for the furnace would be required to be a double wall (Type B) vent from the appliance to the chimney.

The IPC and the IMC have included the necessary code requirements to regulate the installation of vents and vent connectors for water heaters. The requirements of the IMC are based on studies conducted by the Gas Research Institute[17] to evaluate the performance of chimneys and vents for higher efficiency appliance connections.

Combustion Air

The requirements for combustion air for a fuel-fired water heater are also listed in the IMC. The combustion air requirements for water heaters apply to all types of fuel-burning appliances, such as gas-fired, oil-fired, and solid fuel-burning appliances.

In many installations, the water heater is located in an area with other fuel-burning appliances. The total combustion air required is based on all of the fuel-burning appliances, not just the water heater.

Safety Device

The IPC requires all water heaters to have pressure and temperature relief protection. The level of protection is consistent with the requirements of ASPE and ASHRAE.[18]

Maintenance of Hot Water

In large buildings, the design professional will often design a water distribution system with long runs of piping for the hot water. The IPC requires the hot water temperature to be maintained in the piping to conserve both water and energy. The recognized methods of maintaining the water temperature are a recirculation system or a temperature maintenance system such as heat tapes. The maintenance of the temperature in hot water piping systems is consistent with the engineering practices of both ASPE and ASHRAE.

Part 4
Sanitary Drainage Systems

Scope: Chapter 7 of the IPC regulates the installation of sanitary drainage systems. The system design requirements are based on the studies conducted at the National Bureau of Standards, with most of the work spearheaded by Dr. Roy Hunter. More recent research has resulted in the allowance of alternative engineered systems. There are supplemental requirements for sanitary drainage systems found in Chapters 8 and 10. Chapter 8 regulates indirect waste systems. Indirect waste is required when there is a need to provide additional safeguards to protect the fixtures from a backup in the sanitary drainage system. Chapter 8 also contains requirements for the installation of special waste and chemical waste systems. Chapter 10 regulates traps and interceptors.

Piping Material (Section 702)

The acceptable piping materials for sanitary drainage systems are clearly listed in three tables: Tables 702.1, 702.2, and 702.3. The IPC accepts all of the common drainage piping materials, such as ABS plastic pipe, cast-iron soil pipe, copper tubing, galvanized steel pipe, polyolefin pipe and PVC plastic pipe. There are no arbitrary restrictions placed on the installation of any of the piping materials.

The tables identify the acceptable material by reference to the appropriate ASTM or CSA standard. The IPC relies on these organizations for the development of material standards. Each standard is reviewed for completeness and compliance with the ICC standards policy. The standard must address properly all technical matters in regulating a given material for use in a plumbing drainage and vent system.

One of the concerns with the installation of a sanitary drainage system is the impact the piping material has on the fire protection aspects of a building. Section 307.3 of the IPC references the building code for regulating pipe penetrations of floor/ceiling assemblies and fireresistance rated assemblies. The building code requirements for pipe penetrations distinguishes between combustible piping materials, such as ABS and PVC, and noncombustible piping materials, such as cast-iron soil pipe and copper tubing.

Drainage Fittings (Section 706)

Sanitary drainage systems must have fittings that provide a smooth pattern of flow to reduce the likelihood of a stoppage. To avoid confusion, the IPC identifies the acceptable drainage fittings in Table 706.3. This table lists the type of fitting with the corresponding change in direction for which it may be used.

Table 706.3 refers to the fittings by the name used in the various fitting standards. The listed fittings are not available for every piping material. For example, there is only one copper tubing 90-degree fitting designated a DWV elbow. This fitting would be classified as a long sweep in the Code. Cast-iron soil pipe has three 90-degree fittings: a quarter bend, short sweep, and long sweep.

The IPC is one of the few plumbing codes that recognizes the use of short pattern 90-degree fittings for a horizontal change in direction on fixture drains 2 inches in diameter and smaller. The fixture drain is only permitted to serve one fixture. When the fixture drain connects to main piping, long sweep fittings are required for a horizontal change in direction.

The shorter pattern fitting permits the piping connected to an individual fixture to be enclosed within a 2 by 4 stud wall assembly. Field experience has proven that shorter pattern fittings are acceptable when only one fixture connects to the drain. These are the most popular fittings for connecting sinks and lavatories with ABS or PVC plastic pipe.

Back-to-Back Water Closets

The flushing dynamics for a 1.6-gallon-per-flush water closet has had an impact on the use of double sanitary tee fittings. To avoid an interruption of flow, the IPC

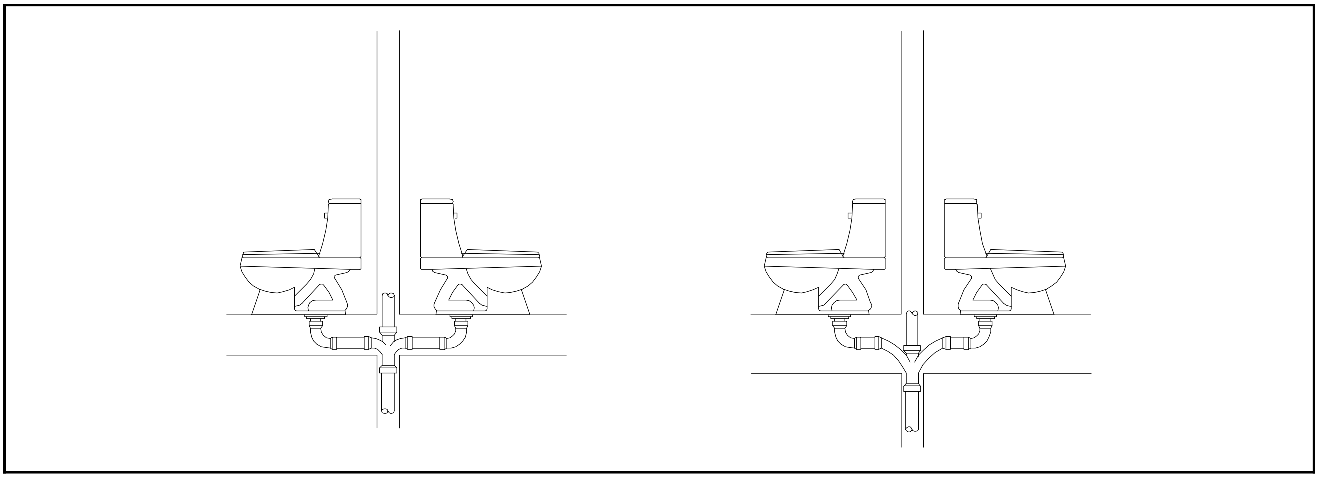


Figure 7, The figure on the left depicts a back-to-back water closet arrangement using a double sanitary tee fitting. The force of the flush from one water closet will cause a blow back in the bowl of the other water closet. The drawing on the right depicts a back-to-back water closet arrangement using a double tee-wye (or double combination fitting). It is mistakenly thought that this fitting is not permitted for a water closet arrangement since it will not permit the proper vent piping arrangement. However, the IPC permits this arrangement since the fitting limitation for vent piping is designed to prevent self-siphonage. The water closet must self-siphon to operate properly. The water closet is unique in that it refills the trap seal after the trap has siphoned.

prohibits the installation of double sanitary tee fittings for back-to-back water closets. When water closets are installed back to back, either a double tee-wye or a double wye fitting must be used (see Figure 7).

Fixture Units (Section 709)

The fixture unit sizing method in the IPC was developed by Dr. Roy B. Hunter at the National Bureau of Standards. The concept was reported in BMS 65.[19] In a companion report, BMS 66,[20] the fixture unit sizing method was codified. This report has served as the basis for the fixture unit sizing method in all modern-day plumbing codes. Hunter's original concept was to assign every fixture a probability value for purposes of sizing a system to prevent uninterrupted flow.

Various plumbing codes have modified the table by adding extensive listings of numerous fixtures. The IPC maintains the original philosophy by listing the major category of fixtures. For example, a commercial kitchen sink would have a fixture unit value of 2 dfu's based on the classification of sink. Similarly, a mop sink in a janitor's closet would also have a fixture unit value of 2 dfu's under the same classification.

Hunter only distinguished between public and private fixtures in the listing of water closets and bathroom groups. The IPC maintains the notion of private and public in the fixture unit values for water closets.

Since the publication of BMS 66 in 1940, there have been a few changes to the fixture unit values. These changes resulted from additional work using Hunter's methods. However, the values assigned to the majority of the fixtures have remained largely unchanged.

Low-Consumption Water Closets

With the introduction of 1.6-gallon-per-flush water closets, there have been various research evaluations to determine if the fixture unit table should be adjusted for the low-consumption water closets. In a paper delivered by Dr. Larry Galowin and Prof. John Swaffield,[21] it was reported that the drainage fixture unit method for low-consumption water closets may cause a problem since the fixtures have a higher peak flow rate (although for a shorter period of time). Galowin and Swaffield reported the need for having smaller pipe sizes for the discharge of 1.6 gpf water closets.

Rather than adjusting the fixture unit value, the IPC permits manufacturers to have their products individually tested for establishing a low fixture unit value. This is necessary with the different flushing performance of the various manufacturers water closets.

TABLE 709.1
DRAINAGE FIXTURE UNITS FOR FIXTURES AND GROUPS

FIXTURE TYPE	DRAINAGE FIXTURE UNIT VALUE AS LOAD FACTORS	MINIMUM SIZE OF TRAP (inches)
Automatic clothes washers, commercial[a]	3	2
Automatic clothes washers, residential	2	2
Bathroom group consisting of water closet, lavatory, bidet and bathtub or shower	6	—
Bathtub[b] (with or without overhead shower or whirlpool attachments)	2	$1^1/_2$
Bidet	2	$1^1/_4$
Combination sink and tray	2	$1^1/_2$
Dental lavatory	1	$1^1/_4$
Dental unit or cuspidor	1	$1^1/_4$
Dishwashing machine,[c] domestic	2	$1^1/_2$
Drinking fountain	$^1/_2$	$1^1/_4$
Emergency floor drain	0	2
Floor drains	2	2
Kitchen sink, domestic	2	$1^1/_2$
Kitchen sink, domestic with food waste grinder and/or dishwasher	2	$1^1/_2$
Laundry tray (1 or 2 compartments)	2	$1^1/_2$
Lavatory	1	$1^1/_4$
Shower compartment, domestic	2	2
Sink	2	$1^1/_2$
Urinal	4	Footnote d
Urinal, 1 gallon per flush or less	2[e]	Footnote d
Wash sink (circular or multiple) each set of faucets	2	$1^1/_2$
Water closet, flushometer tank, public or private	4[e]	Footnote d
Water closet, private installation	4	Footnote d
Water closet, public installation	6	Footnote d

For **SI:** 1 inch = 25.4 mm.
[a] For traps larger than 3 inches, use Table 709.2
[b] A showerhead over a bathtub or whirlpool bathtub attachments does not increase the drainage fixture unit value.
[c] See Sections 709.2 through 709.4 for methods of computing unit value of fixtures not listed in Table 709.1 or for rating of devices with intermittent flows.
[d] Trap size shall be consistent with the fixture outlet size.
[e] For the purpose of computing loads on building drains and sewers, water closets or urinals shall not be rated at a lower drainage fixture unit unless the lower values are confirmed by testing.

3-inch Limitation for Water Closets

The IPC has no limitation on the number of water closets permitted on a 3-inch drain. Many plumbing codes limit the number of water closets permitted to discharge to a 3-inch horizontal pipe to two or three. Hunter, in BMS 65 and BMS 66, never placed any limitation on the number of water closets on a 3-inch drain. His sizing method was based solely on the fixture unit values.

The limitations on 3-inch drains were placed into plumbing codes long after Hunter's death, in what has been identified as a misinterpretation of his original research. Hunter had assigned water closets two different fixture unit values: 6 dfu's and 10 dfu's. When later research lowered the fixture unit values of water closets to 4 dfu's for private and 6 dfu's for public, an arbitrary adjustment was made to 3-inch drains. A 3-inch horizontal branch was limited to a discharge of 20 dfu's. If water closets originally had a fixture unit value of 10 dfu's, this would limit the number of water closets to two. If the value of 6 dfu's was used for water closets, that would limit the number of water closets to three.

In a report by Galowin and Swaffield,[22] and later by Galowin, Campbell, and Swaffield,[23] the arbitrary limitation on the number of water closets permitted to connect to a 3-inch drain was denounced. The IPC has chosen to base the code requirements on the latest technical information, hence, there is no limitation on the number of water closets permitted to connect to a 3-inch drain. The sizing is based on fixture unit value only.

Trap Size

The IPC lists the minimum trap size for every fixture in the fixture unit table, Table 709.1. This is provided for the convenience of the code user. When determining the fixture unit value, the minimum trap size can be determined at the same time with the same table. The trap sizes are the minimum size permitted. A fixture is permitted to have a larger size trap, if preferred by the system designer.

The trap size for urinals and water closets is not listed in the table because traps are integral with these fixtures and regulated by the fixture standards.

Sizing of Drainage System (Section 710)

The drainage pipe sizing method in the IPC also follows Hunter's methods. Hunter developed drainage pipe sizing tables based on fixture unit values in his research. The tables were modified based on follow-up research published in NBS Monograph 31.[24]

The IPC has two tables for sizing drainage piping, Tables 710.1(1) and 710.1(2). Table 710.1(1) is for sizing building drains and building sewers. This is the main artery of the drainage system in the building that discharges horizontally. The sizing is based on the pipe being a maximum of half full. The building drain and building sewer are permitted to have the largest discharge capacity since there is no interference from flow in a vertical stack.

Table 710.1(2) is a more complex table for sizing branches and stacks. The second column is used for sizing the horizontal branch connecting to a stack. The remaining columns in the table are used for sizing a stack.

For a horizontal branch connecting to a stack, the sizing limitation is based on the impact the branch has on the vertical stack. Hence, the maximum fixture unit values permitted for a given branch size are lower than for a building drain. When the flow from a branch transitions to a stack, there must be a smooth pattern of flow to prevent a temporary backup of flow in the branch. This was reported by Hunter, as well as Wyly and Eaton. If the branch is completely loaded to half-full flow, there can be an interruption of flow when the drainage merges with the flow in the stack from the upper floors.

There are two requirements for sizing a drainage stack. There is a maximum capacity of flow permitted from the discharge of one floor and the total discharge into the entire stack. If the flow from a single floor is too high, there can be an overloading of the drainage stack. This could occur even though the loading does not exceed the total permitted discharge for the entire stack (see Figure 8).

TABLE 710.1(1)
BUILDING DRAINS AND SEWERS

DIAMETER OF PIPE (inches)	MAXIMUM NUMBER OF FIXTURE UNITS CONNECTED TO ANY PORTION OF THE BUILDING DRAIN OR THE BUILDING SEWER, INCLUDING BRANCHES OF THE BUILDING DRAIN[a]			
	Slope per foot			
	$^{1}/_{16}$ inch	$^{1}/_{8}$ inch	$^{1}/_{4}$ inch	$^{1}/_{2}$ inch
$1^{1}/_{4}$	—	—	1	1
$1^{1}/_{2}$	—	—	3	3
2	—	—	21	26
$2^{1}/_{2}$	—	—	24	31
3	—	36	42	50
4	—	180	216	250
5	—	390	480	575
6	—	700	840	1,000
8	1,400	1,600	1,920	2,300
10	2,500	2,900	3,500	4,200
12	2,900	4,600	5,600	6,700
15	7,000	8,300	10,000	12,000

For **SI:** 1 inch = 25.4 mm, 1 inch per foot = 0.0833 mm/m.
[a] The minimum size of any building drain serving a water closet shall be 3 inches.

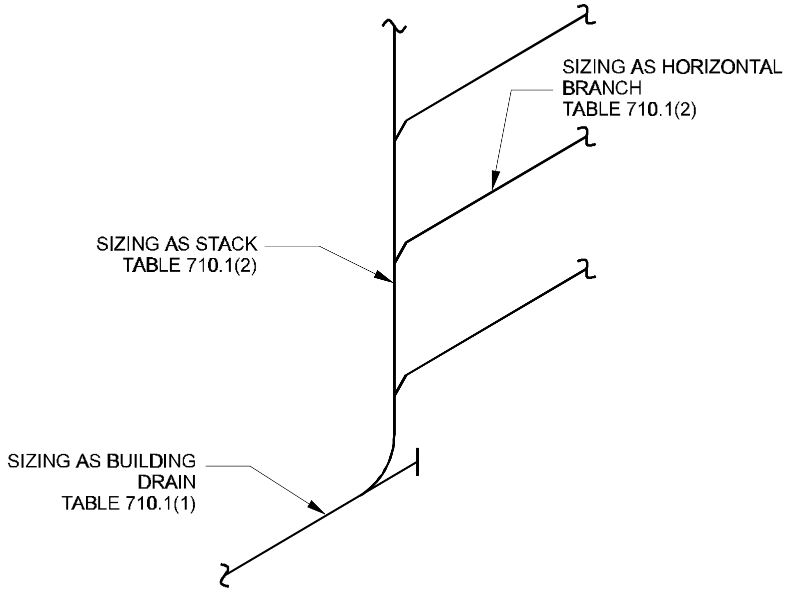


Figure 8, When the flow from the horizontal branch intersects with flow in the stack, there must not be an interruption of flow. The sizing is based on this criterion. The flow in the horizontal piping at the base of the stack can be greater since there is no concern about the interference from the stack flow.

TABLE 710.1(2)
HORIZONTAL FIXTURE BRANCHES AND STACKS[a]

DIAMETER OF PIPE (inches)	MAXIMUM NUMBER OF FIXTURE UNITS (dfu)			
		Stacks[b]		
	Total for a horizontal branch	Total discharge into one branch interval	Total for stack of three branch intervals or less	Total for stack greater than three branch intervals
$1^1/_2$	3	2	4	8
2	6	6	10	24
$2^1/_2$	12	9	20	42
3	20	20	48	72
4	160	90	240	500
5	360	200	540	1,100
6	620	350	960	1,900
8	1,400	600	2,200	3,600
10	2,500	1,000	3,800	5,600
12	3,900	1,500	6,000	8,400
15	7,000	Footnote c	Footnote c	Footnote c

For **SI:** 1 inch = 25.4 mm.

[a] Does not include branches of the building drain. Refer to Table 710.1(1).

[b] Stacks shall be sized based on the total accumulated connected load at each story or branch interval. As the total accumulated connected load decreases, stacks are permitted to be reduced in size. Stack diameters shall not be reduced to less than one-half of the diameter of the largest stack size required.

[c] Sizing load based on design criteria.

Table 710.1(2) has sizing for drainage stacks in plumbing systems that are four stories or less in height and systems that exceed four stories in height. The designer is credited with a greater discharge capacity in taller buildings. The sizing criteria are derived from NBS Monograph 31.

Sizing of Offsets in Stacks

An offset in a drainage stack has special sizing requirements in the IPC. The sizing method is based on the procedures originally specified in BMS 66. The offset is permitted to have a greater amount of flow than a connecting horizontal branch since it is considered a part of the stack. The sizing is the same as the sizing for a building drain.

Pitch of Drain Pipe

The minimum pitch required for a drainage pipe is specified in Table 704.1. The IPC permits a 3- inch drain to be pitched $^1/_8$ inch per foot.

Many plumbing codes require 3-inch drains to be pitched a minimum of $^1/_4$ inch per foot. The discrepancy arises from the calculated velocity of flow in a drain using the Manning Expression.[25]

The minimum velocity in a horizontal drain used by the plumbing industry is 2 feet per second. When using a roughness factor of 0.015, the calculated velocity of flow in a 3-inch drain pitched $^1/_8$ inch per foot is 1.59 feet per second. When the roughness factor is changed to 0.010, the velocity increases to 2.39 feet per second.

A roughness of 0.015 is the value that would be assigned to a rough surface of cast iron in poor condition. A roughness of 0.010 is the value assigned to plastic pipe and smooth interior cast iron in good condition. Hence, when using the proper roughness value, 3-inch pipe can be pitched at $^1/_8$ inch per foot and meet the minimum velocity requirements.

It should be noted that Hunter specified a minimum pitch of $^1/_8$ inch per foot in BMS 66. The ASA A40.8[26] also permitted a pitch of $^1/_8$ inch per foot for a 3-inch drain.

Computerized Sizing Methods (Section 714)

The IPC allows the drainage system to be designed by computerized method. This method of sizing is more accurate than the method originally developed by Hunter.

There are two computer programs recognized for sizing drainage systems. One program was developed at the National Bureau of Standards.[27] The other program is a complete system modeling program developed at Heriot-Watt University in Edinburgh, Scotland, and introduced to the plumbing engineering community at the 1996 ASPE Convention.

The Heriot-Watt University computer program permits the design to simulate any condition in the drainage system. The program permits total versatility in the design of drainage systems.

The IPC recognizes the role computers will play in the future design of plumbing systems. More exact designs will result in better-performing plumbing systems.

Cleanouts (Section 708)

The requirements for cleanouts have changed over the years with the improvement of drain-cleaning equipment. The IPC bases the cleanout requirements on using modern-day drain-cleaning equipment (see Figure 9).

Some plumbing codes retain cleanout spacing requirements based on fitting patterns. This concept assumes the use of rod snakes for cleaning drains. The hand rods were sectioned in 5-foot lengths, making them inflexible and difficult to maneuver. This equipment has not been used in the plumbing industry for many years with the advent of electric drain-cleaning equipment.

For 8-inch-diameter pipes and larger, the IPC requires manholes for cleanouts for outside underground sewers. Manholes provide better access for cleaning large-diameter drains.

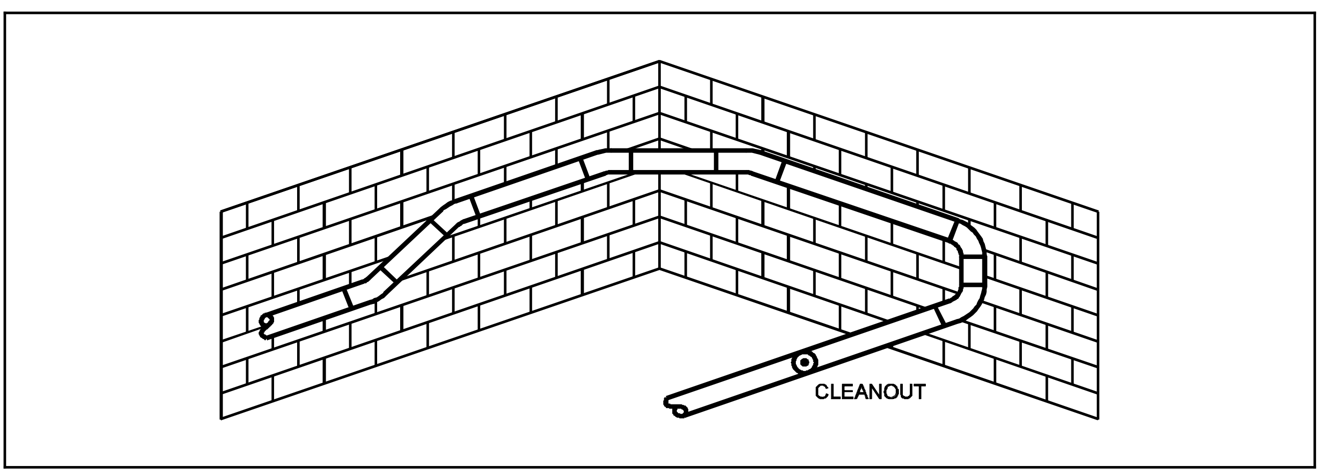


Figure 9, There are various horizontal piping arrangements that can extend a distance of 40 feet before a second cleanout is required. However, even these complex drainage systems can have a blockage cleared with modern-day cleaning equipment.

Sewage Pumps and Ejectors (Section 712)

The IPC follows the recommendations of the Sewage and Sump Pump Manufacturers Association for the design and installation of sewage pumps and ejectors. The sizing of the drain pipe from a sewage pump is based on full flow with a minimum velocity of 2 feet per second.

Grinder pumps that reduce the solid waste to a slurry solution are also permitted. These pumps often result in the use of smaller-diameter drainage pipes from the pump.

The IPC does not arbitrarily require the installation of dual pumping equipment for sewage sumps. The use of this equipment is a decision for the building owner or designer to make. The added expense of dual pumping equipment (more than double the price because of the required controls) does not provide any additional protection of public health or safety.

Grease Interceptors (Section 1003)

Grease interceptors are required for all restaurants, commercial kitchens and similar food-handling establishments. The grease interceptor separates the grease before discharging to the public sewer, thus protecting the sewage treatment system.

The IPC is one of the few plumbing codes to permit food waste grinders, which are the largest sources of grease, to discharge to a grease interceptor. Some manufacturers of grease interceptors rate their units for the discharge of food waste grinders. A study in the State of Wisconsin discovered that large volumes of grease were not being intercepted in commercial kitchens because the grease was flushed down the food waste grinder during the initial washing of the dishes.

Part 5
Venting Systems

Scope: Venting of the sanitary drainage system is one of the most misunderstood areas of plumbing. Venting was invented to protect the trap seal. The odors emanating from the drainage system were kept out of the building by use of a water seal trap. The trap, however, would lose its seal. When venting was added to the drainage system, the trap seal remained in place. The venting requirements in the IPC are designed to maintain the trap seal, and thus prevent the escape of sewer gas. There are many studies that have been performed on venting systems. Chapter 9 of the IPC attempts to recognize all of the viable means of venting the drainage system.

Material Requirements (Section 902)

Similar to the requirements for sanitary drainage piping systems, the IPC does not place any arbitrary restrictions on the use of various piping materials for venting systems. All of the viable materials are permitted to be used for a vent system, including: cast-iron soil pipe, copper tubing, ABS plastic pipe, PVC plastic pipe, polyolefin plastic pipe, and galvanized steel pipe.

Concept of Venting (Section 901)

The purpose of venting is to protect the trap seal of every fixture. The minimum trap seal required by the IPC is 2 inches. Section 901.2 requires the venting system to be designed to protect the trap seal from pressure differentials in excess of 1 inch of a water column. This assures that an adequate amount of water will remain in the trap to prevent the escape of sewer gas.

Section 901.2.1 establishes that every trap, and trapped fixture, must be protected by some form of venting. Any of the various methods of venting can be utilized to protect the trap seal. The designer and installer are granted many options for venting the traps. Every method in the IPC has been proven to be effective in protecting the trap seal.

Acceptable Venting Methods (Sections 907 through 913)

The most common form of venting is an individual vent. A trap would have a separate vent pipe protecting the trap seal. The vent pipe allows air to enter as well as relieve any pressure that might be experienced in the drainage system. This method of venting has been included in every plumbing code since the advent of modern indoor plumbing.

The vent only serves that one fixture trap (see Figure 10). While an individual vent is considered the easiest method of protecting the trap, it is also a system that results in the most extensive amount of piping.

Common Venting

Common venting is considered to be a form of individual venting. Rather than serving a single fixture, the common vent serves two fixtures that are located in the same general area (see Figure 11). The vent pipe can connect to either a vertical drain serving both fixtures, or to a horizontal drain. Another form of common venting is an offset common vent. This arrangement allows the two fixtures being vented to connect at different levels to a vertical drain (located on the same floor level). Common venting was recognized by Hunter in BMS 66.[28] Offset common venting, including the piping arrangement and sizing, was reported in BMS 119.[29]

Wet Venting

Wet venting is a system that combines the venting of fixtures in a bathroom within a dwelling unit. The system can be extended to include all of the fixtures located in two adjacent bathrooms. Hunter first reported on wet venting, including the concept, in BMS 66. It was further investigated by French, Eaton, and Wiley.

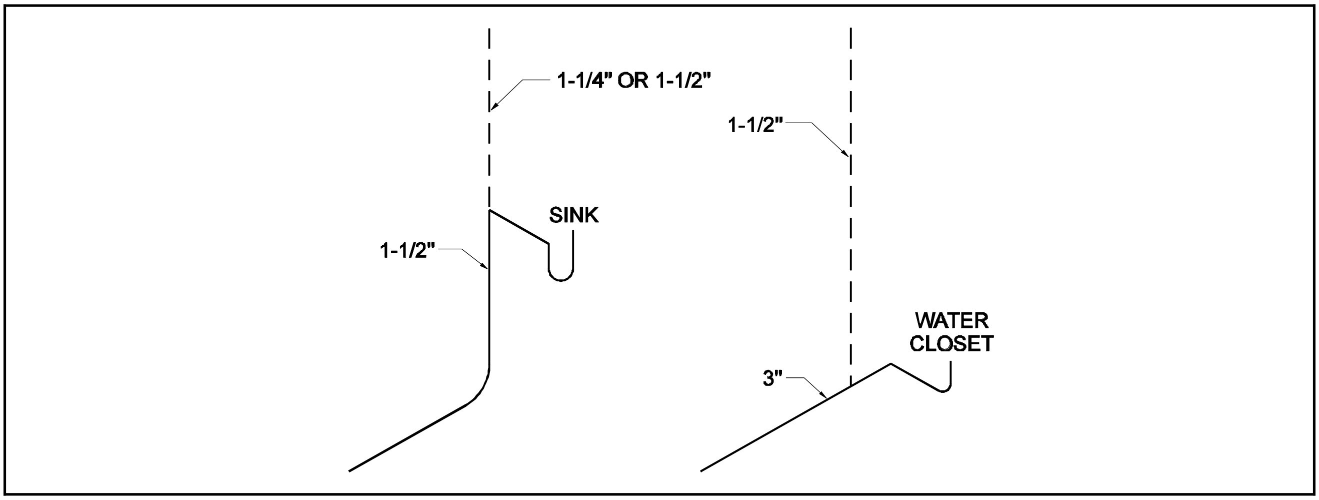


Figure 10, Individual vent. Each trap is provided with a separate vent when individually venting.

The piping arrangement in a wet vent system permits the designer and installer the versatility to combine the fixtures with a single vent pipe connection (see Figures 12 and 13). The vent for the wet-vented system typically connects to the lavatory fixture drain.

The wet-venting systems permitted by the IPC are also recognized in the *ASPE Data Book* [30] as an acceptable design. Wet venting is also addressed in numerous other widely recognized plumbing design manuals, including *Engineered Plumbing Design*[31] and *Practical Plumbing Engineering*.[32]

The sizing of the wet vent is consistent with the sizing determined through research at the National Bureau of Standards. Additional testing at Stevens Institute of Technology verified the sizing of the wet vent piping.

Circuit Venting

Circuit venting is an arrangement that permits up to eight fixtures to be protected with a single vent pipe (see Figure 14). The requirements for a circuit-vented system are very specific to ensure the performance of the system. The fixtures must all connect on the horizontal plane. The vent connects between the last two fixtures.

The system performs so well because the drainage flow is on a horizontal plane. The siphon action from horizontal flow is very minimal. The piping is designed for half-full flow, hence the air movement is maintained, even during heavy use periods.

Extensive research into the performance of circuit-vented systems was conducted at the State University

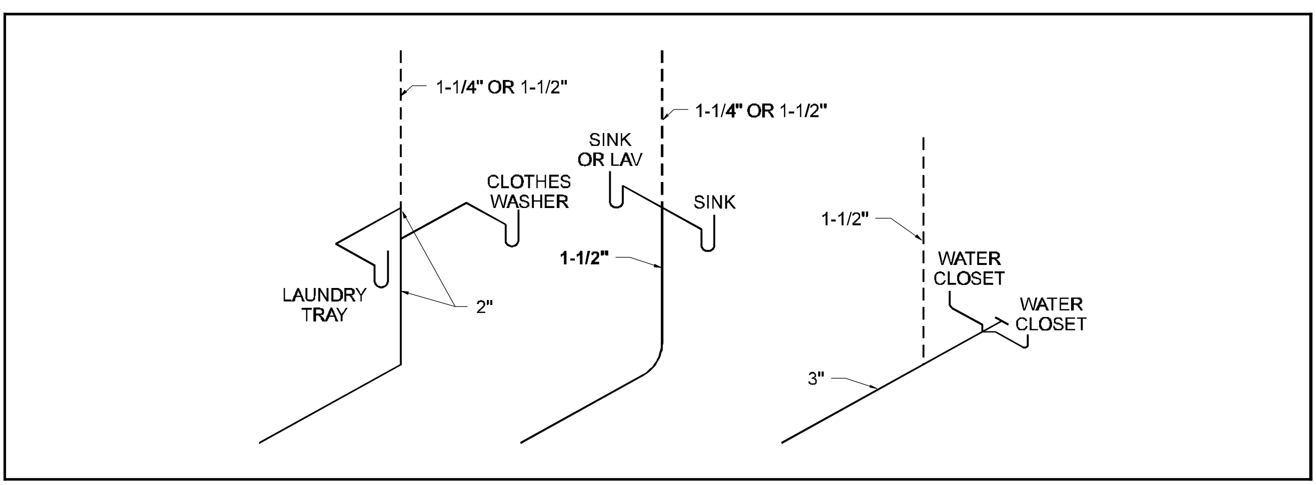


Figure 11, Common vent. Common venting allows one vent to serve as the vent for two fixtures. There are a variety of piping design layouts permitted when common venting.

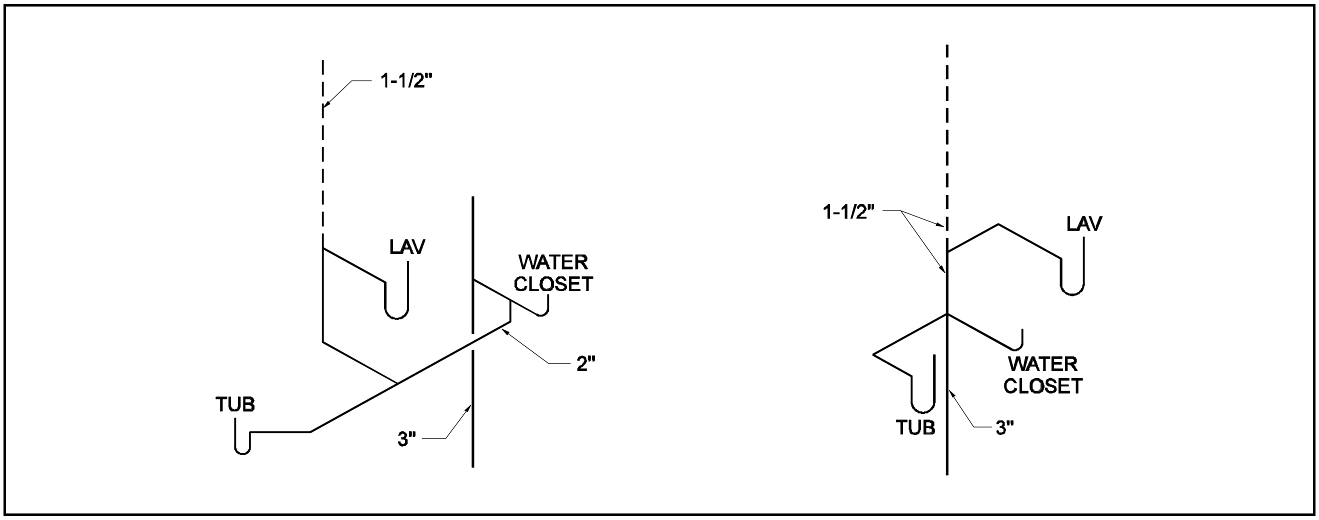


Figure 12, Wet vent. Typical wet-venting arrangements for a single bathroom group are shown. The system on the left utilizes the wet venting in a horizontal configuration. The system on the right uses a vertical piping arrangement.

of Iowa.[33] The research concluded that the single vent for the eight fixtures provided the necessary protection of the trap seal.

Circuit venting was included in Hunter's research and reported in BMS 66. The venting method has long been recognized by the plumbing community and is included in the *ASPE Data Book*. Circuit venting is also recognized in all other plumbing engineering design books, including those previously referenced.

The circuit-venting requirements in the IPC are very similar to the requirements found in ASA A40.8[34] and ANSI A40.[35] The IPC has more updated requirements, providing greater control of the piping arrangements to ensure horizontal flow.

Waste Stack Venting

There have been many types of single stack plumbing systems utilized throughout the world. One of the most

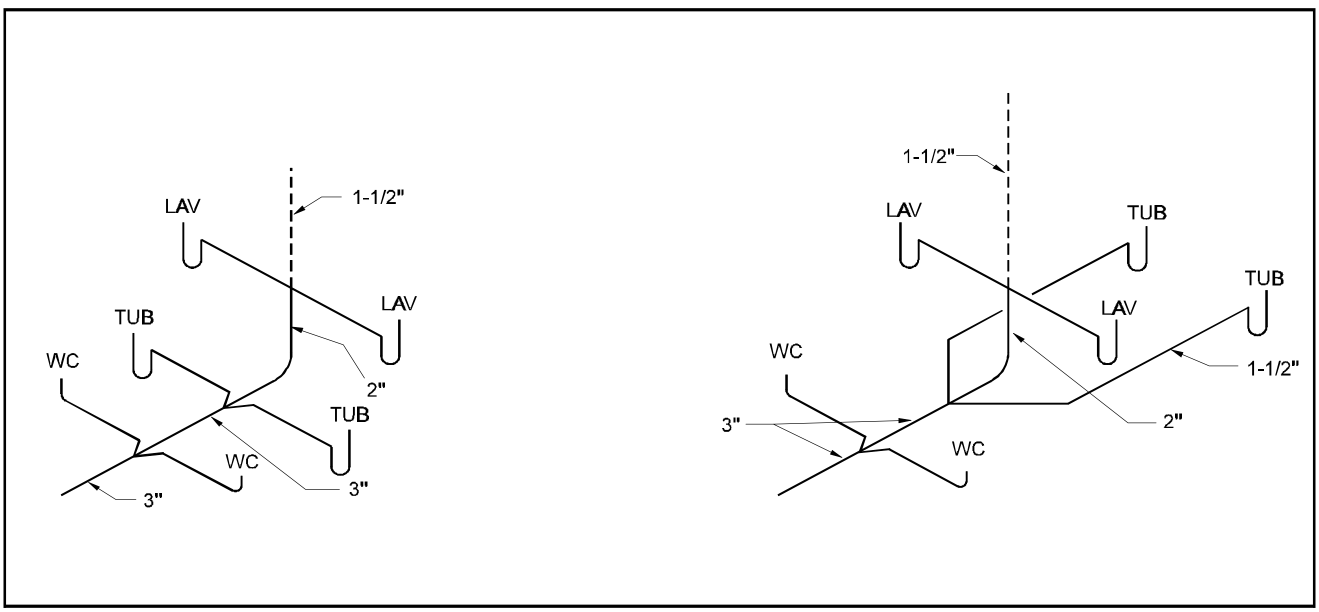


Figure 13, Wet venting. Back-to-back bathrooms can have all of their fixtures vented with one vent when arranged in a double bathroom group wet vent. The sizing of the wet vent pipe is based on the fixture unit discharge. The dry vent extension of the wet vent is required to be $1^1/_2$ inches in diameter.

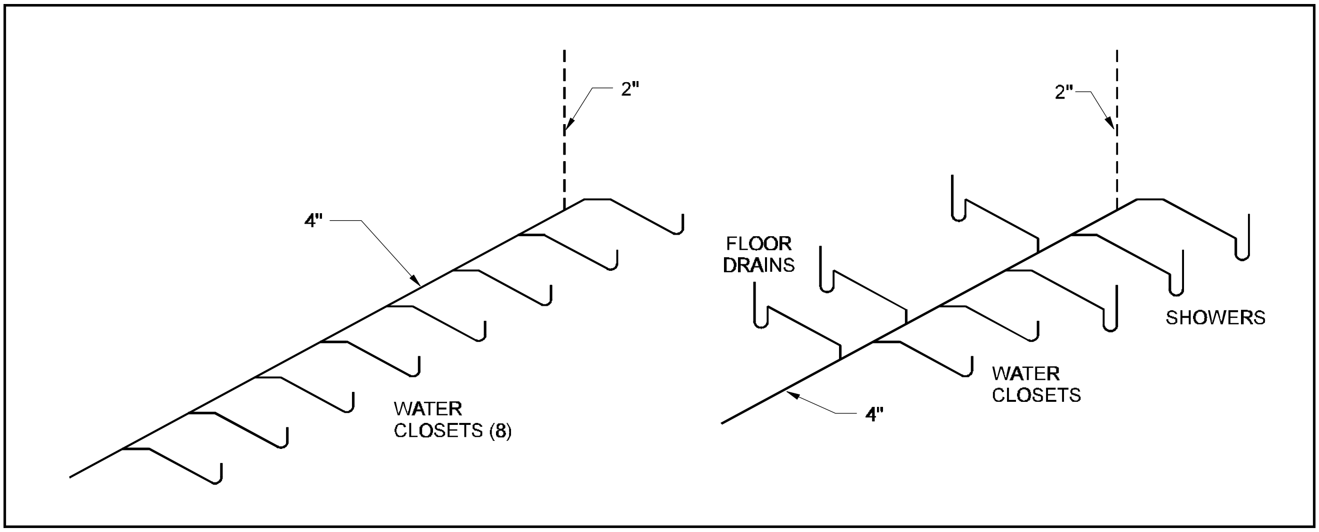


Figure 14, Circuit vent. A total of eight fixtures can be protected with a single vent in a circuit-vented system. The common use of a circuit-vented system is floor-mounted fixtures such as water closets, shower drains, floor drains, and indirect waste receptors. This method of venting is very popular in commercial construction, especially food-handling establishments and grocery stores. Both facilities have many floor drains and indirect waste receptors.

common systems used in the United States is the waste stack vent. This venting method allows fixtures other than water closets and urinals to connect directly to a stack without any additional venting (see Figure 15). The stack must extend to the outdoor air full size to provide venting of all of the connected fixtures.

The performance of the system is based on the oversizing (or underloading) of the drainage stack. When the stack capacity is less than 10 percent, adverse pressure differentials are not created in the stack. Testing of stack venting arrangements were performed by French[36] at the National Bureau of Standards.

A waste stack vent system also requires every fixture to connect to the stack independently. This prevents interference of flow from one fixture to another. The system is included in the *ASPE Data Book* as an acceptable venting system.

Combination Drain and Vent

The combination drain and vent system is based on the same premise as the circuit-vented system. Most plumbing codes place arbitrary restrictions on combination drain (waste) and vent systems because the systems appear too good to be true.

The combination drain and vent is a method of venting sinks, lavatories, floor drains and standpipes located on the same floor. The main drain pipe must be

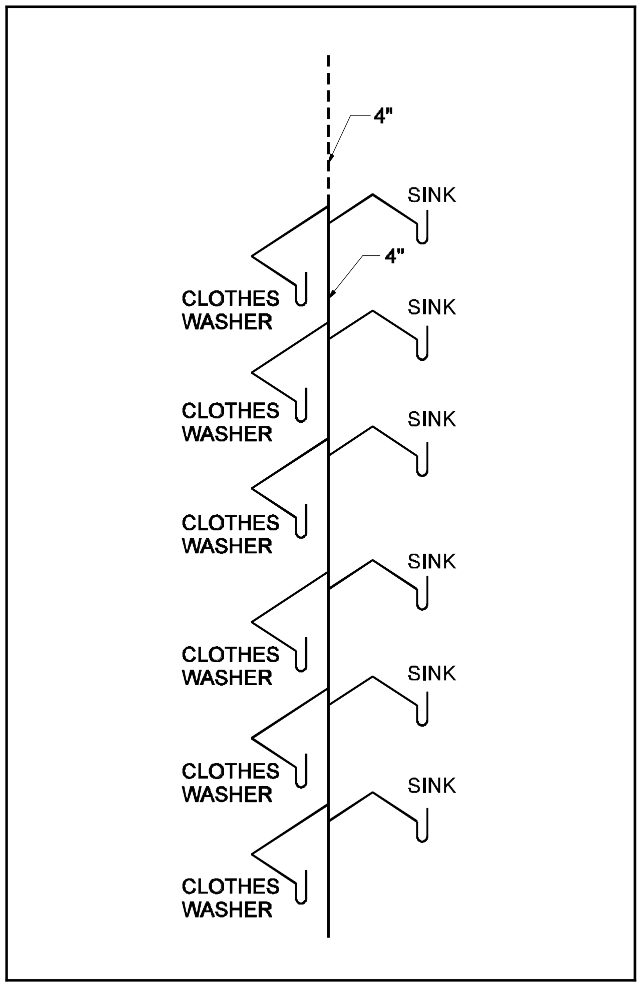


Figure 15, Waste stack vent. The stack serves as the vent when each fixture connects independently to the stack. The system does not permit the connection of water closets or urinals.

oversized for the intended discharge load. This reduces the siphonic action and prevents the development of any pressure condition in the piping. A single vent must connect to the main drain.

The performance of the combination drain and vent system was verified in tests conducted at Stevens Institute of Technology.[37] If sized according to the table in the IPC, the study concluded that the distance from a trap to a vent does not have to be limited in length (see Figure 16).

A combination drain and vent is typically used to vent floor drains in the middle of storage or warehouse spaces. It is the only allowable system for venting the fixtures that are not located near a wall to accommodate the vent piping. The vent is not permitted to run horizontally below the floor because of the likelihood of becoming blocked.

Island Fixture Venting

The island fixture venting in the IPC is a holdover provision that precedes the expanded use of combination drain and vent systems. Because the system is still used in parts of the United States, the IPC continues to regulate the installation.

Island fixture venting is a method of individually, or common venting, fixtures with a vent offsetting horizontally below the flood level rim of the fixture(s) (see Figure 17). The Code specifies additional requirements for the vent to protect against any stoppage in the pipe.

This method of venting is disappearing because of the high cost of installation. Island fixtures are routinely vented by combination drain and vent systems or with air admittance valves.

Vent Pipe Sizing (Sections 916 & 918)

The vent pipe sizing requirements in the IPC are based on studies conducted at the National Bureau of Standards. Table 916.1, the main venting table, is derived from Wyly and Eaton's research, published in NBS Monograph 31.[38] This was one of the most conclusive studies on the air movement requirements in a plumbing drainage and vent system. Most modern plumbing codes base their drainage stack sizing and vent stack sizing on the results published in this report.

The sizing of vent systems in the IPC is based on the latest technical information. There are no arbitrary requirements for sizing based on sewer sizing.

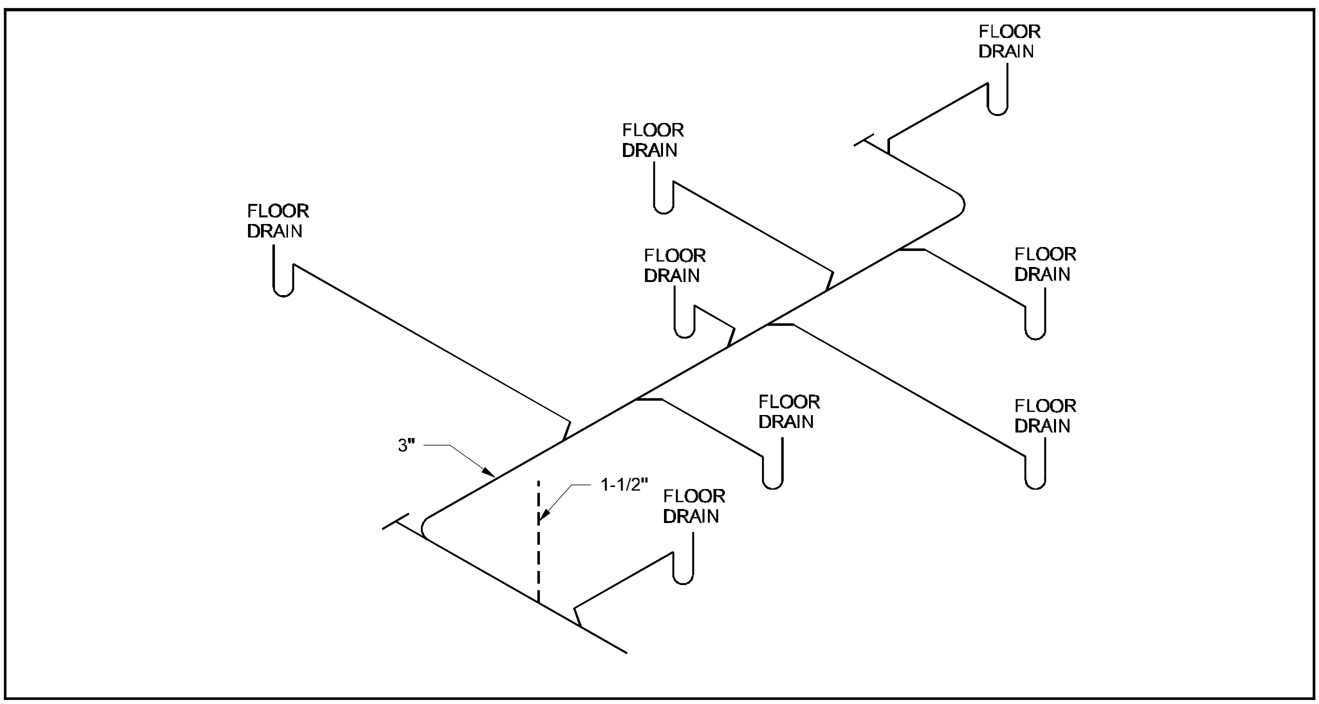


Figure 16, Combination drain and vent. When floor drains are not located near an adjacent wall, a combination drain and vent system is the ideal method for venting the traps. The system has no limitations on the distance from trap to vent, provided it is properly sized and pitched.

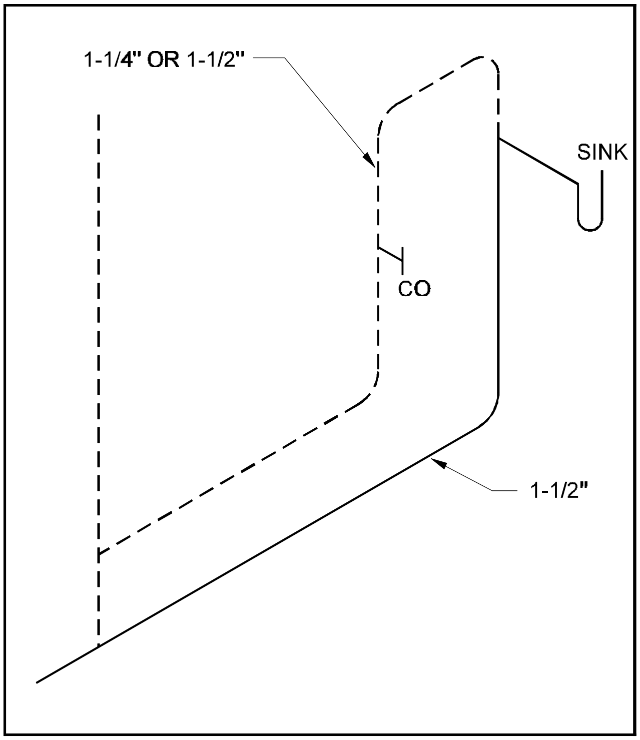


Figure 17, Island fixture venting. This method of venting has been replaced with other methods that are more economical. The IPC continues to recognize this design since it protects the trap seal.

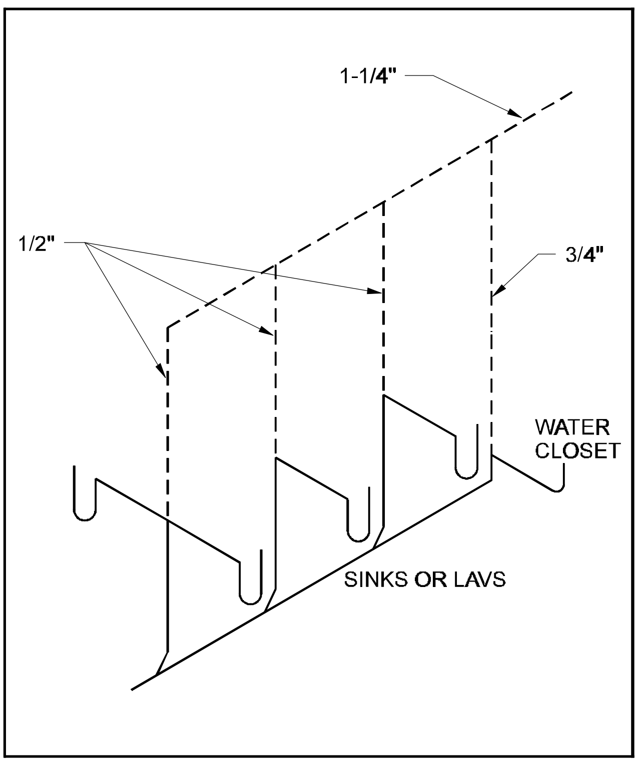


Figure 18, Reduced size venting. The individual vents can be reduced to $^1/_2$ inch in diameter. The system performance is based on half of the vents being completely blocked.

Reduced Size Venting

The National Bureau of Standards followed up the studies on vent stack air flow movement with studies on the sizing of branch vents. This led to investigations into reducing the size of branch vents (see Figure 18). Orloski and Wyly published their findings of reduced size venting in 1975.[39] This study was continued with research by Wyly and Galowin with a report issued in 1984.[40]

The requirements for reduced-size venting in the IPC were written by Galowin following his research. Because of the negative response to the concept of reduced-size venting, Galowin added many safety factors into the code requirements. In addition to sizing for worst-case conditions, Galowin assumed that 50 percent of the vents would be blocked. While this is a completely unrealistic field condition, Galowin found it necessary to respond directly to those opposed to reduced size venting. Galowin's interest in the recognition of reduced-size venting was directed toward future consideration of sizing by computer modeling.

Computerized Sizing Method

The IPC recognition of the computerized drainage sizing method includes the sizing of the vent system. Hence, when computer modeling is utilized in accordance with Section 714, the vent piping system is a part of the computer modeling.

The computer modeling was developed at the National Bureau of Standards and Heriot-Watt University. The main authors of these studies were Galowin and Swaffield.[41,42] The computer modeling system developed by Swaffield is recognized worldwide by the plumbing engineering community. Vent pipe sizing and arrangements can be economically designed for the specific installation.

Distance from Trap to Vent (Section 906)

The distance from the fixture trap to the vent connection is limited to prevent the self-siphonage of the trap seal. The distances are based on the study by French and Eaton.[43] It was recognized that when the branch drain is increased in diameter, the distance from trap to vent can be extended since the depth of flow in the drain is reduced. French and Eaton also reported in BMS 126 that "there does not appear to be any need of limiting the unvented length of water closet drains. . . ." The water closet relies on self-siphonage to operate correctly. The fixture refills the trap seal after each flush; hence, there is no need for limiting the distance from a water closet to a vent.

Vent Terminal (Section 904)

The IPC permits a vent to terminate through the roof, through the sidewall, or to an air admittance valve. In colder climates, the vent extending to the outdoors must be increased in size to a minimum of 3 inches in diameter. This is based on the research from the National Bureau of Standards.[44]

For many years, plumbing codes restricted the use of sidewall venting. The restrictions were based on the fact that birds tended to build nests in sidewall vents, thus blocking the entrance of air. The IPC has specific requirements designed to maintain the vent opening.

There has always been concern voiced regarding wind conditions for sidewall vents. However, wind has never been a cause for restricting the location of a vent terminal. Under high wind conditions, every vent has a resulting change in pressure. Some studies have shown that a fixture can lose its seal under adverse wind conditions. These studies were based on vents terminating through the roof. While a change in pressure does exist in strong winds, it rarely results in a complete loss of the trap seal.

Air Admittance Valves

The IPC accepts the use of air admittance valves for vent terminals of individual and branch vents (see Figure 19). These devices are regulated by a nationally recognized consensus standard. There has been extensive research into the performance of air admittance valves. Swaffield and Galowin, whose studies validated their performance of air admittance valves, reported on this in their engineering design book.[45]

Air admittance valves have been the subject of criticism from the time they were introduced to the plumbing industry in 1988. The concerns range from placing faith in a mechanical device to the amount of material and labor saved resulting from their use. However, Swaffield and Campbell[46] reported that the use of air admittance valves improves the performance of a drainage system by controlling the amount of air introduced into the system.

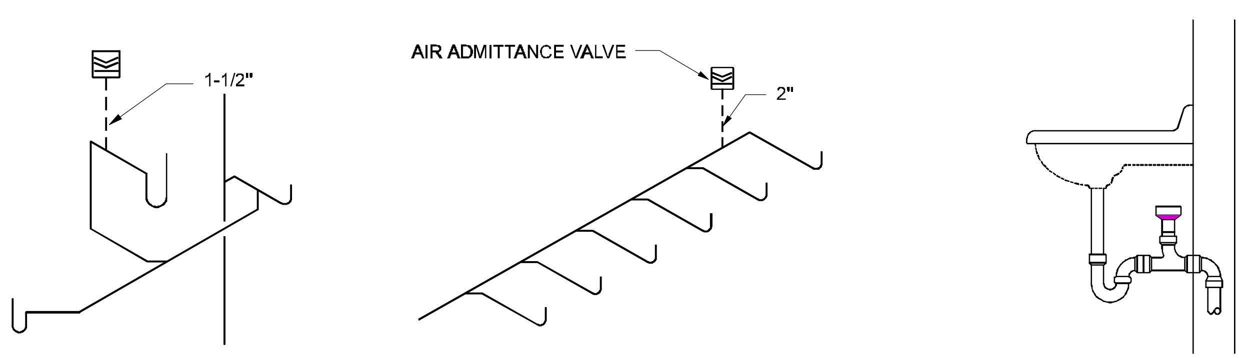


Figure 19, Air admittance valves. The vent can terminate locally to an air admittance valve rather than extending to the outdoor air. The system on the left shows an air admittance valve being used for a wet-vented bathroom group. The center drawing shows a circuit-vented system terminating to an air admittance valve. The drawing on the right shows the common location of an air admittance valve under the sink or lavatory.

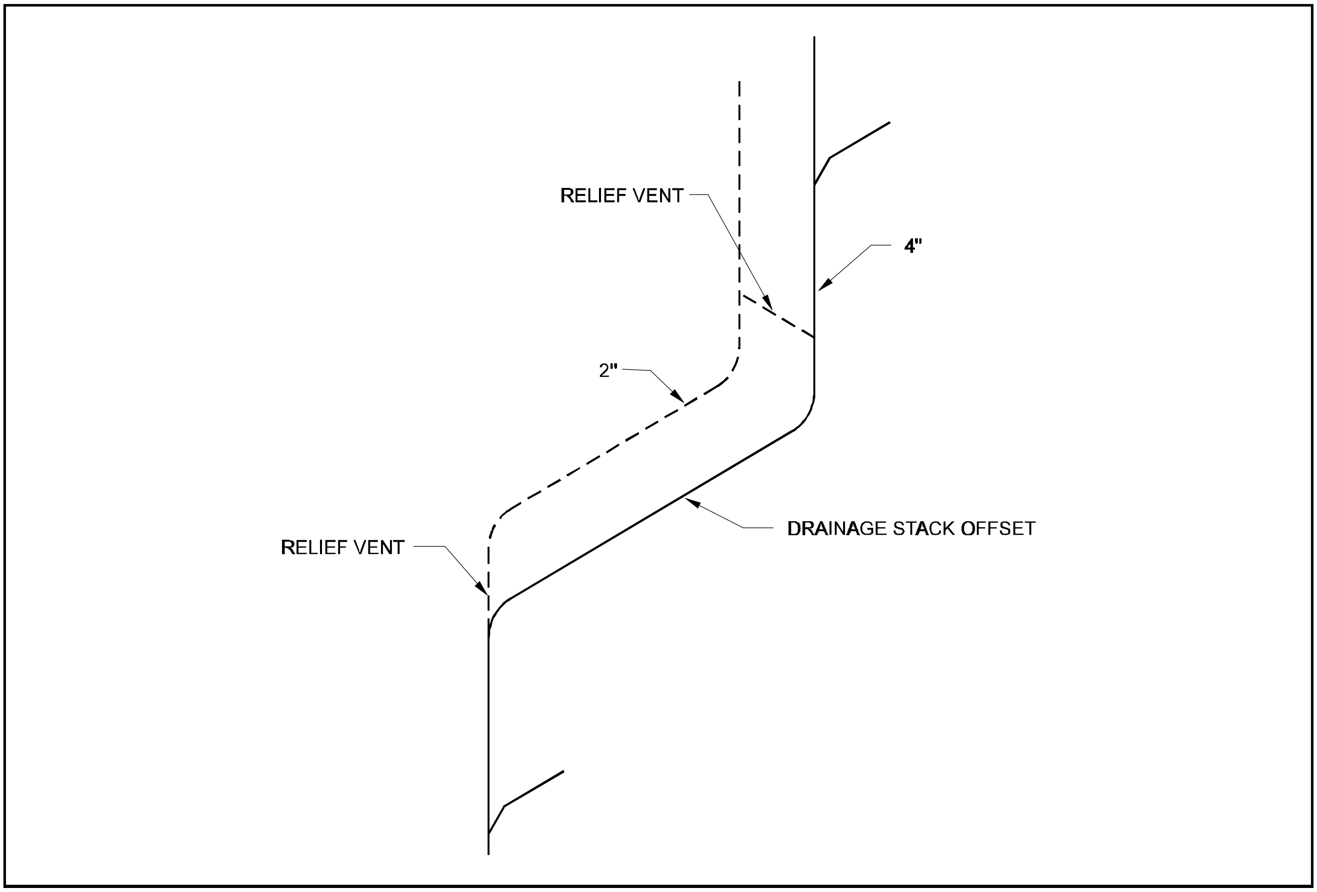


Figure 20, Offset vent. The drainage offset must be vented in taller buildings to relieve the pressure developed when drainage flow transitions from the vertical to the horizontal and back to vertical.

Venting of Stack Offsets (Section 915)

In tall buildings, an offset in the drainage stack results in adverse pressure differentials. The IPC requires such offsets to be vented (see Figure 20). This requirement is consistent with the findings of Hunter as reported in BMS 66. Venting of a drainage stack offset is addressed in every major plumbing engineering design manual, including books authored by Steele, Swaffield, Neilson, Harris, and Manas.[47]

Part 6
Storm Drainage Systems

Scope: Chapter 11 of the IPC regulates storm drainage systems. The primary purpose of a storm drainage system is to remove the rainwater from the roof surface; however, the IPC also contains requirements intended to protect the building from structural collapse. The storm drainage requirements are consistent with the engineering guidelines of the American Society of Plumbing Engineers and the American Society of Civil Engineers.

Primary Storm Drainage System (Section 1106)

The IPC includes sizing tables for piping systems based on various rainfall rates. The tables are established on sizing the storm drain for the maximum open channel flow conditions. These are the flow rates that prevent any pressure from being developed in the piping systems.

Vertical conductors and leaders are permitted to have the maximum capacity of discharge as indicated in NBS Monograph 31.[48] Stacks are permitted to flow 33 percent full. This value is greater than the allowable flow for a sanitary drainage stack since there are no concerns for pressure differentials in the storm drainage systems. There are no trap seals from fixtures on connecting floors that have to be protected from pressure excursions.

For horizontal storm drains, the pipe sizing is based on a full-flow condition. Sanitary drainage systems are designed on a maximum of half-full flow because of connecting fixtures and pressure differentials. Since the storm drainage system has no intervening fixtures connecting, the piping system can be designed for the maximum capacity of the drain.

Rainfall Rates

The IPC primary storm drainage system is required to be designed for a storm of 1-hour intensity with a 100-year return period. The rainfall rate values, published in the IPC, are provided by the U.S. National Weather Service.

There has never been a consensus in the engineering community regarding the storm intensity for the design of primary storm drainage systems. The IPC uses a longer intensity storm, which lowers the rainfall rates, with a higher return period, which increases the rainfall rates.

The IPC supplements the rainfall rate requirements by requiring all roofs to be designed for the maximum amount of water ponding, with all primary roof drainage means blocked. This requirement follows the engineering practices of the American Society of Civil Engineers[49] and the American Society of Plumbing Engineers.[50]

Controlled Flow Systems (Section 1110)

The IPC permits the storm drainage system to be designed as a controlled flow system. This system utilizes the roof as a temporary retention area during intense rainstorms.

The sizing of the controlled flow roof drainage system is consistent with the engineering guidelines of ASPE, Steele in *Engineered Plumbing Design*,[51] and Ballanco and Shumann in *The Illustrated National Plumbing Code Design Manual*.[52]

Secondary Roof Drainage (Section 1107)

Secondary roof drainage is required by the IPC as an emergency measure for protecting the roof from a structural collapse. The secondary roof drainage must be an independent system sized to prevent any accumulation of water in excess of the amount calculated for the roof loading. The piping for the secondary drainage system must be larger in size to manage catastrophic weather occurrences. The requirements would only apply to roofs that can have an accumulation of water. The secondary drainage means is permitted to be either scuppers, openings in the parapet, or a separate piping system.

Part 7
Fuel Gas and Specialty Piping

Scope: Piping systems that are often designed by plumbing engineers and installed by plumbing contractors include fuel gas piping, medical gas piping, and oxygen piping systems. The *International Plumbing Code* recognizes that these systems need to be addressed in the plumbing code. Appropriate reference is made in the IPC to standards and codes for regulating these systems.

Fuel Gas Piping (Chapter 12)

The requirements for fuel gas piping are located in either the plumbing code, the mechanical code, or the fuel gas code. The ICC decided to locate the complete fuel gas piping requirements in the *International Mechanical Code* (IMC). To assist the plumbing professional, the fuel gas piping requirements from the IMC are duplicated in Appendix G of the IPC. This was done to avoid confusion as to which code change committee would review proposed code changes regarding fuel gas piping.

The ICC has recently published the first edition of the *International Fuel Gas Code*. With the development of this code, a separate code change committee will be able to address the requirements regulating the installation of fuel gas piping and appliances. The ICC is coordinating the *International Codes* to regulate properly all building construction requirements.

Specialty Piping (Chapter 13)

The IPC references NFPA 99C for regulating the installation of medical gas systems. This is the nationally recognized consensus standard for medical gas systems. The Joint Commission on Accreditation of Health Care Organizations, which accredits the majority of hospitals and health care facilities in the United States, also relies on NFPA 99C for the regulation of medical gas systems. It is preferable to reference directly the appropriate standard, rather than attempting to rewrite the content of the standard in the code. This allows the code to remain consistent with the latest requirements developed by the medical community.

For nonmedical oxygen systems, the IPC references NFPA 50 and 51. Similar to the medical gas requirements, these standards are the nationally recognized consensus standards for nonmedical oxygen piping systems.

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where: V = velocity in feet/second
n = coefficient of roughness
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