CROSS-CONNECTION CONTROL MANUAL

U. S. ENVIRONMENTAL PROTECTION AGENCY

WATER SUPPLY DIVISION

CROSS-CONNECTION CONTROL MANUAL

U.S. Environmental Protection Agency
Office of Water Programs
Water Supply Division

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PREFACE

Plumbing cross-connections, which connect potable water supply with nonpotable supply, are a public health problem. There are numerous and well-documented cases where such connections have been responsible for contaminated drinking water, and have resulted in spread of disease. The problem is a dynamic one, because piping systems are continually being installed, altered, or extended.

Control of cross-connections is possible, but only through knowledge and vigilance. Education is essential, for many of those who are experienced in piping installation fail to recognize cross-connection possibilities and dangers. All municipalities with public water supplies should have cross-connection control programs. Those responsible for institutional or semipublic water supplies also should be familiar with the dangers, and should exercise careful surveillance.

The *Cross-Connection Control Manual* has been designed as a tool for health officials, waterworks personnel, plumbers, and many others; it is intended to be used in educational, administrative, and technical ways in conducting cross-connection control programs. This manual is a revision of an earlier book entitled *Water Supply and Plumbing Cross-Connections* (PHS Publication No. 957), which was produced under the direction of Floyd B. Taylor by Marvin T. Skodje, who wrote the text and designed the illustrations.

This new edition contains many of the original illustrations and much of the text. Some figures and all chapters have been clarified and updated and some extraneous material has been omitted. The work was done by Peter C. Karalekas, Jr., with guidance from Roger D. Lee; it also incorporates suggestions made by the staff of the Water Supply Division, other governmental agencies, and interested individuals.

Chapter 2, "Public Health Significance of Cross-Connections," appeared in *Modern Sanitation and Building Maintenance*, vol. 14, No. 7 (July 1962). Permission to reprint has been given. Also, more recent examples of cross-connection cases have been included at the end of chapter 2.

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ILLUSTRATIONS

American Water Works Association

POLICY ON CROSS-CONNECTIONS

A statement adopted by Board of Directors on Jan. 26, 1970

The American Water Works Association recognizes that the water purveyor has a responsibility to provide its customers at the service connection with water that is safe under all foreseeable circumstances. Thus, in the exercise of this responsibility the water purveyor must take reasonable precaution to protect the community distribution system from the hazards originating on the premises of its customers that may degrade the water in the community distribution system.

It is realized that cross-connection control and plumbing inspections on premises of its customers are regulatory in nature and should be handled through the rules, regulations, and recommendations of the health authority or the plumbing-code enforcing agencies having jurisdiction. The water purveyor, however, should be aware of any situation requiring inspection and/or re-inspections necessary to detect hazardous conditions resulting from cross-connections. If, in the opinion of the utility, effective measures consistent with the degree of hazard have not been taken by the regulatory agency, the water purveyor should take such measures as he may deem necessary to ensure that the community distribution system is protected from contamination. Such action would include the installation of a backflow prevention device, consistent with the degree of hazard, at the service connection, or discontinuance of the service.

Chapter 1. PURPOSE AND SCOPE

Public health officials have long been concerned about cross-connections and backflow connections in plumbing systems and in public drinking water supply distribution systems. Such cross-connections, which make possible the contamination of potable water, are ever-present dangers. One example of what can happen is an epidemic that occurred in Chicago in 1933. Old, defective, and improperly designed plumbing and fixtures permitted the contamination of drinking water. As a result, 1,409 persons contracted amebic dysentery; there were 98 deaths. This epidemic, and others resulting from contamination introduced into a water supply through improper plumbing, made clear the responsibility of public health officials and water purveyors for exercising control over public water distribution systems and all plumbing systems connected to them. This responsibility includes advising and instructing plumbing installers in the recognition and elimination of cross-connections.

Cross-connections are the links through which it is possible for contaminating materials to enter a potable water supply. The contaminant enters the potable water system when the pressure of the polluted source exceeds the pressure of the potable source. The action may be called backsiphonage or backflow. Essentially it is a reversal of the hydraulic gradient that can be produced by a variety of circumstances.

It might be assumed that steps for detecting and eliminating cross-connections would be elementary and obvious. Actually, cross-connections may appear in many subtle forms and in unsuspected places. Reversal of pressure in the water may be freakish and unpredictable. The probability of contamination of drinking water through a cross-connection occurring within a single plumbing system may seem remote; but, considering the multitude of similar systems, the probability is great.

Why do such cross-connections exist?

First, plumbing is frequently installed by persons who are unaware of the inherent dangers of cross-connections. Second, such connections are made as a simple matter of convenience without regard to the dangerous situation that might be created. And, third, they are made with reliance on inadequate protection such as a single valve or other mechanical device.

To combat the dangers of cross-connections and backflow connections, education in their recognition and prevention is needed. First, plumbing installers must know that hydraulic and pollutional factors may combine to produce a sanitary hazard if a cross-connection is present. Second, they must realize that there are available reliable and simple standard backflow prevention devices and methods that may be substituted for the convenient but dangerous direct connection. And third, it should be made clear to all that the hazards resulting from direct connections greatly outweigh the *convenience* gained.

This manual does not describe all the cross-connections possible in piping systems. It does attempt to reduce the subject to a statement of the principles involved and to make it clear to the reader that such installations are potentially dangerous. The primary purpose is to define, describe, and illustrate typical cross-connections and to suggest simple methods and devices by which they may be eliminated without interfering with the functions of plumbing or water supply distribution systems.

Chapter 2. PUBLIC HEALTH SIGNIFICANCE OF CROSS-CONNECTIONS

According to the official investigation of the 1933 Chicago epidemic of amebic dysentery, "*. . . old and generally defective plumbing and cross-connections potentially permitting backsiphonage from fixtures such as bathtubs and toilets . . .*" were to blame for contamination of the drinking water supply.

The event and its sad result – the death of 98 persons – dramatized the concern that public health officials feel about the dangers of cross-connections. Because such plumbing defects are so frequent, and the opportunity for contaminants to invade drinking water through cross-connections is so general, enteric infections caused by drinking water may occur in almost any city on any day.

Published histories of massive enteric infections caused by cross-connections abound. While the following cases have their natural appeal as historical literature, they are listed here mainly to illustrate the serious consequences of cross-connections, their ubiquity, their frequency, and their peculiarity.

Brucellosis at the Faucet

In 1938, 80 students at a large midwestern university reported remittent fevers, malaise, headache, and anemia. Their symptoms led to a diagnosis of undulant fever (brucellosis). Curiously, only those students who had been working in the cultivation of bacteria in one of the laboratories were affected. The mystery was how the brucella cultures in the laboratory could have been transmitted to the students. Finally, a hose was found connected to a faucet in the laboratory. The other end of the hose was submerged in water containing brucella. A temporary reversal of pressure, possibly the consequence of a demand for water in another part of the system, had drawn the water teeming with brucella into the drinking supply. Of the 80 students affected, one died.

Sewage in the Water Main

In Newton, Kans., in 1942, one of the town's two water supply mains had been taken out of service on September 2, 7, and 8. A house service connection to this main supplied three frostproof hydrants and two frostproof toilets. It was assumed, from subsequent events, that some unknown person or persons tried to obtain water from a hydrant connected to the main out of service. When no water flowed, the anonymous agents departed, leaving the valve open. On September 10, it was discovered that a neighboring toilet sewer was clogged and that sewage had overflowed into the hydrant box. It was learned that for 2 days all the sewage from the toilets of 10 families had been permitted to flow into the water main. When the main was put back into service, there was no attempt to sterilize it. More than 2,500 persons in all parts of the town suffered enteric disorders as a result. Stool cultures and pathological findings from two autopsies diagnosed the illness as bacillary dysentery. In addition to the widespread illness in the town, it is believed that the infection was carried aboard a number of troop trains which were watered in Newton at that time.

Pressure Drop

In 1942 a casting plant in Pittsburgh employing 500 persons undertook to install new water connections. During installation, the city water supply was shut off. It is believed that a drop in pressure in the drinking water lines of the plant permitted river water to pass through a valved connection to the drinking water. Twelve hours after the first new connection to the city water was installed, many of the employees suffered mild intestinal disorders. Two weeks later, after another shutdown to make a second connection from the plant system to the city water, there was a second outbreak of intestinal disturbances among the employees.

Defective Valve

Aboard a vessel in a west coast shipyard in 1943, a valve on the main line, connecting the drinking water to the fire water supply, was found to be defective and the cause of an outbreak of gastroenteritis. The pumping of contaminated harbor water through the fire waterlines aboard the vessel had forced bacteria into the drinking supply through a cross-connection. As a result, 1,179 men became ill.

Arsenic in Reverse

A California laborer had been using an aspirator, attached to a garden hose, to spray a driveway with weedkiller containing arsenic. Sometime while he was at the job, the water pressure reversed. Taking no notice of the incident, the man disconnected the hose and, feeling thirsty, drank from the bib of the hose connection at the house. Arsenic in the waterline killed him.

Peak Demands

At a large aviation plant on the west coast, officials learned that the difference between a 3-inch water main and an 8-inch main was the determining cause for a high rate of absenteeism. When it was discovered that 25 to 40 percent of the employees were suffering from gastroenteritis, the plumbing system was suspected. Investigators found that there was such a demand on the 3-inch main at peak periods that the outflow produced enough of a vacuum to allow waste water to be backsiphoned through cross-connections into the drinking water system. After an 8-inch main was installed, the high rate of infection subsided.

The Vacuum Breaker

In April 1944, after an outbreak of gastroenteritis in an Oklahoma school, it was found that none of the flushometer valve toilets with submerged inlets were provided with vacuum breakers, which prevent atmospheric pressure from forcing waste water into the supply lines. Each night, to conserve water and eliminate the possibility that rooms might be flooded if a leak should develop, the custodian turned off the valve of the main supply line. As the pressure in the supply lines was cut off, atmospheric pressure on the toilet bowls moved the waste water up into the drinking supply. Most of the people affected were those who drank from faucets on the first floor of the school; there were progressively fewer cases on the second and third floors, as the atmospheric pressure moved less of the waste water to those heights.

Wrong Valve

At a school in Milford, Nebr., the fire lines and hydrants were separate from the domestic water supply, although the two systems were connected through a valve at the pumphouse. The source of water for the fire system was the river. In January 1947, following a fire, someone negligently opened the connecting valve at the pumphouse, and river water entered the domestic water supply. About 150 people came down with gastroenteritis.

Ten-Percent Polio Incidence

In 1932 during a 5-week period, more than 10 percent of the 347 children in Huskerville, near Lincoln, Nebr., contracted polio. A study of the water supply revealed that the afflicted children lived in areas where flush valve water closets lacked vacuum breakers. A time relationship was found also in places where extreme fluctuations of pressure in the water mains might have permitted waste water to be forced into the drinking supply.

Dysentery at Sea

In 1952 a large oceangoing vessel set sail from its berth with every indication that things were shipshape. A day or so later and 300 miles out, over a thousand cases of dysentery developed among those on board. Contaminated water was blamed for the episode and the evidence indicated that while tied up at its moorings, the ship's fresh-water tanks had been contaminated. A cross-connection was the most likely explanation.

A Drink of Chromates

Chromates are one of the chemicals for which the Public Health Service Drinking Water Standards prescribe the very low amount of 0.05 parts per million as the limit that can be tolerated in a drinking water supply. In 1958 an employee using a drinking water fountain in a large city library noticed that the water stream issuing from the spout was yellowish, and the matter was called to the attention of the building engineer. Upon investigation, it was found that the chilled-water pipe system supplying the fountains was directly connected to another chilled-water system in which heavy dosages of chromates were used for corrosion control. Someone forgot to close the valve!

Harbor Water Threatens Vessel Crews

At about 2 p.m. on June 29, 1960, on a large pier installation in an eastern port harbor, a worker noticed evidence of salt in the potable water supply. Investigation showed that salt water from the harbor had been pumped into the pier's potable water pipes. The fire systems of three vessels anchored nearby had been connected to the fresh water piping system and high fire-pump pressures apparently did the rest. One measurement of chlorides at a "fresh" water outlet showed 6,425 parts per million. Only prompt and vigorous action by a sanitary engineer is believed to have prevented widespread illness.

Antifreeze

Usually service stations supply antifreeze for automotive equipment, not for people to drink. The reverse was true during October of 1961 when there occurred one of the most bizarre backsiphonage episodes on record. In a midwestern city, ethylene glycol antifreeze was being pumped from a large storage tank to an antifreeze distribution system. This system was cross-connected to the city water supply lines and it was estimated that over 100 gallons of 60 percent ethylene glycol were pumped into the water mains. Samples from the water pipes showed the presence of from 1.5 to 2.0 percent ethylene glycol, or up to 20,000 parts per million of this toxic chemical agent. A homeowner reported a bitter taste and reddish color to the water department. Radio announcements, a shutdown of the water supply to the area affected, and repeated flushings were required to cope with the situation.

Outbreak Fells Shipyard Workers

The time was 7 a.m. on September 28, 1962, at a large eastern shipyard. Beginning then and throughout the day, some 700 men reported ill with gastroenteritis. All had drunk water from the yard area where they worked and one water sample showed coliforms in excess of 240 per 100 milliliters. Investigators concluded that a temporary cross-connection had been made between the potable water lines and pipes containing river water for firefighting purposes. They stated that "*... such an episode may occur again if steps are not taken to insure that such ill-considered cross-connections cannot be made by accident.*"

The following incidents occurred after the publication of the first edition of this manual. They show that cross-connection continues to be a serious hazard to water supplies and only constant vigilance in their detection and elimination can reduce the ever-present risk of contamination from these sources.

Arsenic Poisoning

On a private farm in Texas in 1963, five people were poisoned with arsenic from drinking water. The source of drinking water was a cistern. A cotton defoliant tank which contained arsenic was improperly connected to the cistern. Backsiphonage occurred, and of the five people who drank the water, three died.

Nurses Ill

Backsiphonage caused by defective plumbing in a new student nurses building was blamed for an outbreak of disease in 1963 in Ohio. It was necessary for 100 of the student nurses to be quarantined for 2 weeks. Bacteriological examination showed that the drinking water was contaminated. The city health commissioner theorized that salmonella was brought into the building by some of the girls and then spread by defective plumbing.

Eleven Vomiting Caddies

Eleven caddies experienced nausea, severe vomiting, and abdominal cramps after consuming a "soft drink" at a New York golf club in 1964. The beverage was commercially prepared by the mixture of sirup with carbonated water in a vending machine. Investigation revealed that a pipe carrying water into the machine was connected to the recirculating hot water heating system instead of the drinking water system. The day before the incident a lye and chromate solution was added to the hot water system.

Raw Water From a Drinking Fountain

A New England town had two separate water systems – one for potable water, the other for fire protection. The fire protection system pumped untreated water directly from a river. In 1967, at an industrial plant in town, workers mistook a fire system line for a fresh-water line and connected a bubbler to it. After drinking the water from the bubbler, seven people developed infectious hepatitis and over a hundred people were ill with gastroenteritis.

Shigellosis

In 1967, an outbreak of gastroenteritis occurred at a small private college in Pennsylvania. Almost one-quarter of the 700 students and faculty were affected. The only factor in common to all those who became ill was the consumption of water or food that had been prepared using water from the school water system. Investigation of the water system revealed that a waterline had broken in the kitchen of the school cafeteria flooding both the kitchen and the cafeteria. Cross-connections were found between the sewage system and the fresh-water system that could have resulted in backsiphonage of sewage into the water system as a consequence of negative pressure during the break in the waterline. It was concluded that the outbreak probably resulted from the presence of *Shigella sonnei* in the water system. The inoculum would have been of sufficient size to overcome the chlorine in the water.

Football Team Stricken

In October 1969, most of the members and coaches of a college varsity football team became ill with infectious hepatitis. The water supply on the practice field was found to be the cause. A drinking fountain and the irrigation system for the field were on the same line. A heavy fire demand in the area had created a negative pressure in the waterlines and caused contaminated surface water around the sprinklers to be siphoned into the potable water lines. Players and coaches drinking from the fountain became ill and the school was forced to cancel the remainder of the football schedule.

Temporary Hydrant Connections

A serious emergency involving the contamination of a water supply was caused by a truck filling from a city water supply. In 1971, a contractor using a tank truck with a rig designed to pump and spray a mixture of water, fertilizer, grass seed, and woodpulp was working on the grounds of a subdivision. The contractor was using a direct connection to a fire hydrant to fill the tank with water, which was then mixed with the fertilizer, etc. A high-pressure pump then sprayed the mixture onto the ground. As the woodpulp circulated through the tank piping system, it plugged one of the lines while the pump continued to run creating a very high pressure in the tank. This pressure was higher than the water supply system pressure and it forced the solution of fertilizer into the water system. Several people in the subdivision became ill after drinking the water, but the contamination was discovered and quick action in flushing and disinfecting the lines eliminated the danger.

Chapter 3. THEORY OF BACKFLOW AND BACKSIPHONAGE

A *cross-connection*[1] is the link or channel connecting a source of pollution with a potable water supply. The polluting substance, in most cases a liquid, tends to enter the potable supply if the net force acting upon the liquid acts in the direction of the potable supply. *Two* factors are therefore essential for backflow. *First*, there must be a *link* between the two systems. *Second*, the resultant *force* must be *toward* the potable supply.

An understanding of the principles of backflow and backsiphonage requires an understanding of the terms frequently used in their discussion. *Force*, unless completely resisted, will produce motion. *Weight* is a type of force resulting from the earth's gravitational attraction. *Pressure (P)* is a force-per-unit area, such as pounds per square inch (psi). *Atmospheric pressure* is the pressure exerted by the weight of the atmosphere above the earth.

Pressure may be referred to using an absolute scale, pounds per square inch absolute (psia), or gage scale, pounds per square inch gage (psig). Absolute pressure and gage pressure are related. Absolute pressure is equal to the gage pressure plus the atmospheric pressure. At sea level the atmospheric pressure is 14.7 psia. Thus,

$$P_{absolute} = P_{gage} + 14.7 \text{ psi}$$

or

$$P_{gage} = P_{absolute} - 14.7 \text{ psi}$$

In essence, then, absolute pressure is the total pressure. Gage pressure is simply the pressure read on a gage. If there is no pressure on the gage other than atmospheric, the gage would read zero. Then the absolute pressure would be equal to 14.7 psi which is the atmospheric pressure.

The term *vacuum* indicates that the absolute pressure is less than the atmospheric pressure and that the gage pressure is negative. A complete or total vacuum would mean a pressure of 0 psia or −14.7 psig. Since it is impossible to produce a total vacuum, the term *vacuum*, as used in the text, will mean all degrees of partial vacuum. In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (−14.7 psig).

Backsiphonage[1] results in fluid flow in an undesirable or reverse direction. It is caused by atmospheric pressure exerted on a pollutant liquid forcing it toward a potable water supply system that is under a vacuum. *Backflow*,

[1] See formal definition in the glossary of the appendix.

although literally meaning any type of reversed flow, refers to the flow produced by the differential pressure existing between two systems both of which are at pressures greater than atmospheric.

Water Pressure

For an understanding of the nature of pressure and its relationship to water depth, consider the pressure exerted on the base of a cubic foot of water at sea level. (See fig. 1.) The average weight of a cubic foot of water is 62.4 pounds. The pressure exerted upon the square foot area is, therefore, 62.4 pounds per square foot gage. The base may be subdivided into 144 square inches with each subdivision being subjected to a pressure of 0.433 psig.

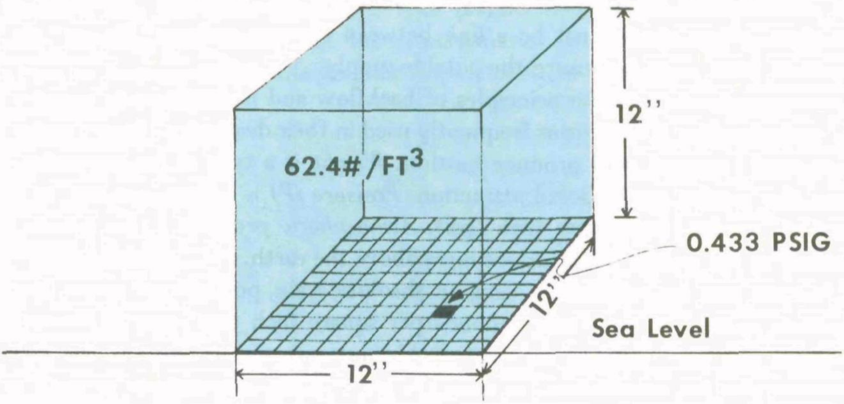

FIGURE 1. Pressure exerted by 1 foot of water at sea level.

Suppose another cubic foot of water were placed directly on top of the first. (See fig. 2.) The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.433 psig as a result of the superimposed cubic foot of water. The pressure at the base of the first cube would also be increased by the same amount to 0.866 psig, or two times the original pressure.

If this process were repeated with a third cubic foot of water, the pressures at the base of each cube would be 1.299 psig, 0.866 psig, and 0.433 psig, respectively. It is evident that pressure varies with depth below a free water surface.[1] In general, each foot of elevation change, within a liquid, changes the pressure by an amount equal to the weight-per-unit area of 1 foot of the liquid. The rate of increase for water is 0.433 psi per foot of depth.

Frequently water pressure is referred to using the terms "pressure head" or just "head," and is expressed in units of feet of water. One foot of head would be equivalent to the pressure produced at the base of a column of water 1 foot in depth. One foot of head or 1 foot of water is equal to 0.433 psig. One hundred feet of head are equal to 43.3 psig.

[1] See formal definition in the glossary of the appendix.

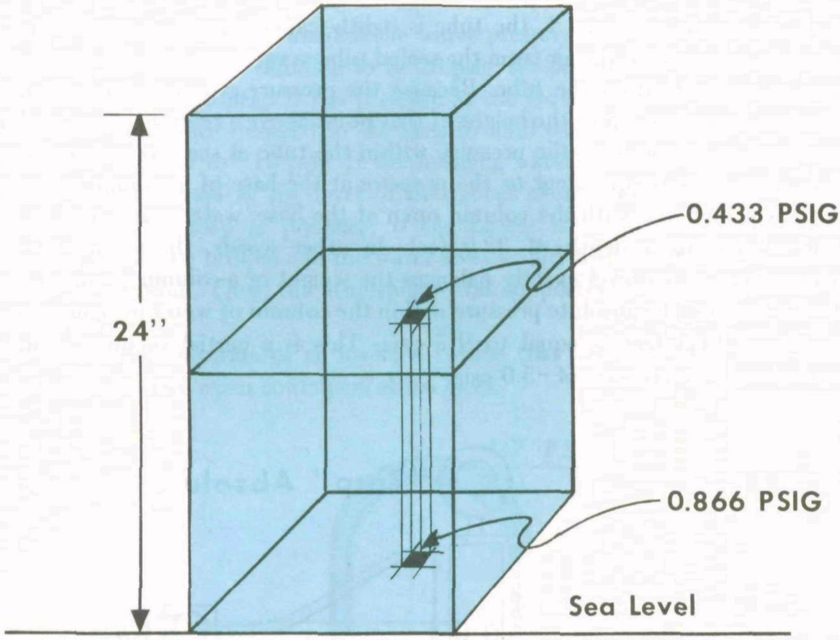

FIGURE 2. Pressure exerted by 2 feet of water at sea level.

Siphon Theory

Figure 3 depicts the atmospheric pressure on a water surface at sea level. An open tube is inserted vertically into the water; atmospheric pressure, which is 14.7 psia, acts equally on the surface of the water within the tube and on the outside of the tube.

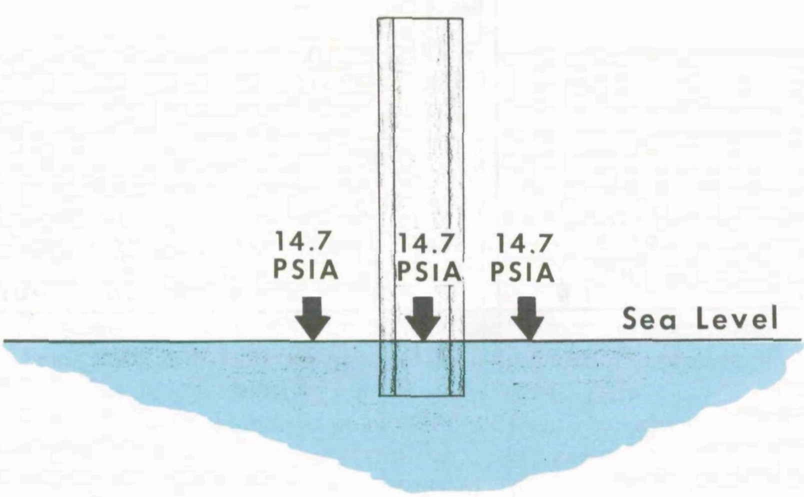

FIGURE 3. Pressure on the free surface of a liquid at sea level.

If, as shown in figure 4, the tube is tightly capped and a vacuum pump is used to evacuate all the air from the sealed tube, a vacuum with a pressure of 0 psia is created within the tube. Because the pressure at any point in a static fluid is dependent upon the height of that point above a reference line, such as sea level, it follows that the pressure within the tube at sea level must still be 14.7 psia. This is equivalent to the pressure at the base of a column of water 33.9 feet high and with the column open at the base, water would rise to fill the column to a depth of 33.9 feet. In other words, the weight of the atmosphere at sea level exactly balances the weight of a column of water 33.9 feet in height. The absolute pressure within the column of water in figure 4 at a height of 11.5 feet is equal to 9.7 psia. This is a partial vacuum with an equivalent gage pressure of -5.0 psig.

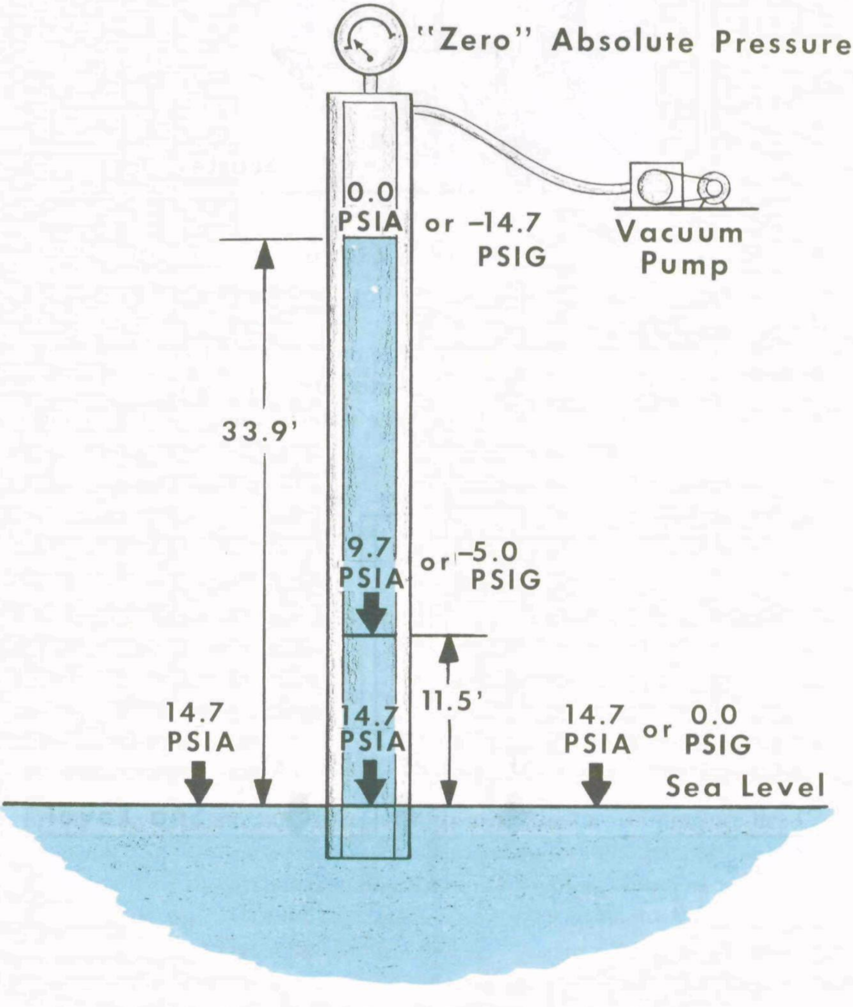

FIGURE 4. Effect of evacuating air from a column.

As a practical example, assume the water pressure at a closed faucet on the top of a 100-foot-high building to be 20 psig; the pressure on the ground floor would then be 63.3 psig. If the pressure at the ground were to drop suddenly due to a heavy fire demand in the area to 33.3 psig, the pressure at the top would be reduced to -10 psig. If the building water system were airtight, the water would remain at the level of the faucet because of the partial vacuum created by the drop in pressure. If the faucet were opened, however, the vacuum would be broken and the water level would drop to a height of 77 feet above the ground. Thus, the atmosphere was supporting a column of water 23 feet high.

Figure 5 is a diagram of an inverted U-tube that has been filled with water and placed in two open containers at sea level.

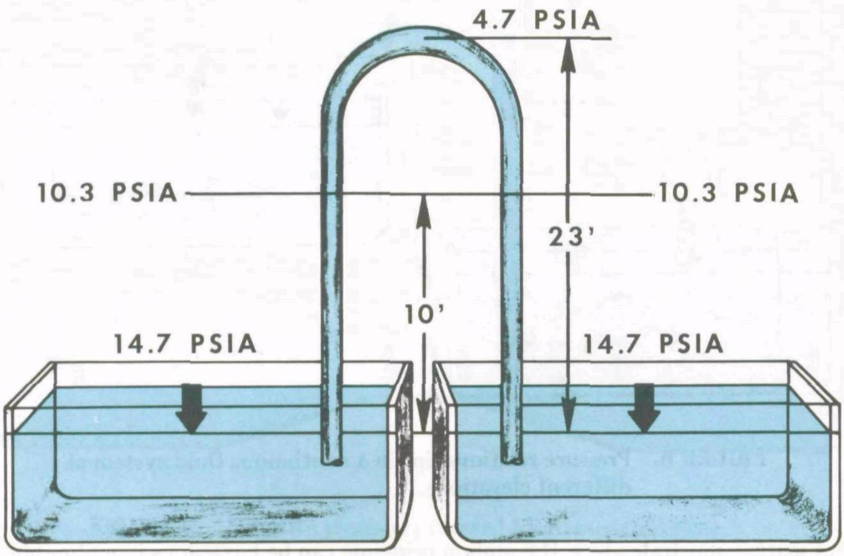

FIGURE 5. Pressure relationships in a continuous fluid system at the same elevation.

If the open containers are placed so that the liquid levels in each container are at the same height, a static state will exist; and the pressure at any specified level in either leg of the U-tube will be the same.

The equilibrium condition is altered by raising one of the containers so that the liquid level in one container is 5 feet above the level of the other. (See fig. 6.) Since both containers are open to the atmosphere, the pressure on the liquid surfaces in each container will still remain at 14.7 psia.

If it is assumed that a static state exists, momentarily, within the system shown in figure 6, the pressure in the left tube at any height above the free surface in the left container can be calculated. The pressure at the corresponding level in the right tube above the free surface in the right container may also be calculated.

As shown in figure 6, the pressure at all levels in the left tube would be less than at corresponding levels in the right tube. In this case, a static condition cannot exist because fluid will flow from the higher pressure to the lower pressure; the flow would be from the right tank to the left tank. This arrangement will be recognized as a siphon. The crest of a siphon cannot be higher than 33.9 feet above the upper liquid level, since the atmosphere cannot support a column of water greater in height than 33.9 feet.

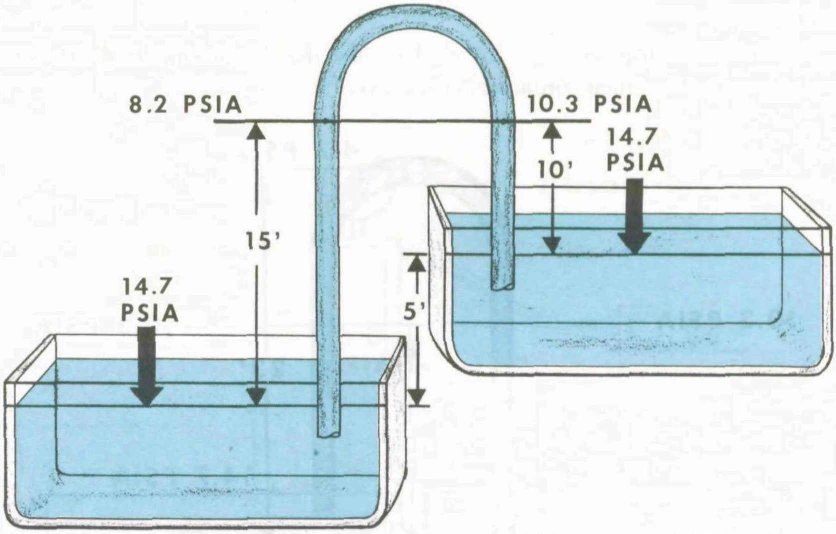

FIGURE 6. Pressure relationships in a continuous fluid system at different elevations.

Figure 7 illustrates how this siphon principle can be hazardous in a plumbing system. If the supply valve is closed, the pressure in the line supplying the faucet is less than the pressure in the supply line to the bathtub. Flow will occur, therefore, through siphonage, from the bathtub to the open faucet.

The siphon actions cited have been produced by reduced pressures resulting from a difference in the water levels at two separated points within a continuous fluid system.

Reduced pressure may also be created within a fluid system as a result of fluid motion. One of the basic principles of fluid mechanics is the principle of conservation of energy. Based upon this principle, it may be shown that as a fluid accelerates, as shown in figure 8, the pressure is reduced. As water flows through a constriction such as a converging section of pipe, the velocity of the water increases; as a result, the pressure is reduced. Under such conditions, negative pressures may be developed in a pipe. The simple aspirator is based upon this principle. If this point of reduced pressure is linked to a source of pollution, backsiphonage of the pollutant can occur.

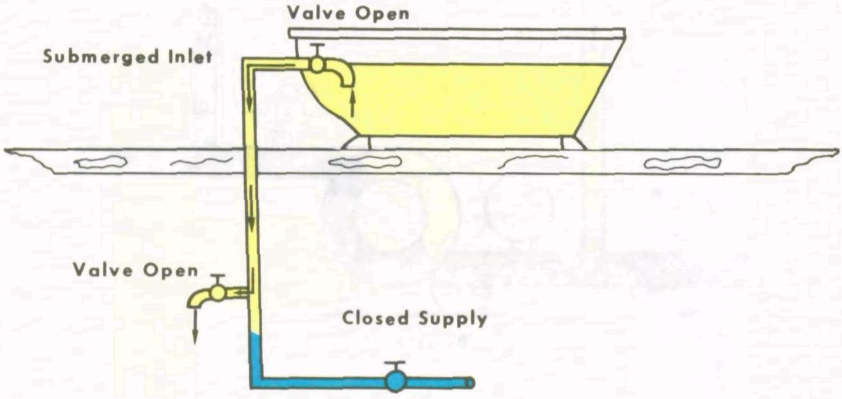

FIGURE 7. Backsiphonage in a plumbing system.

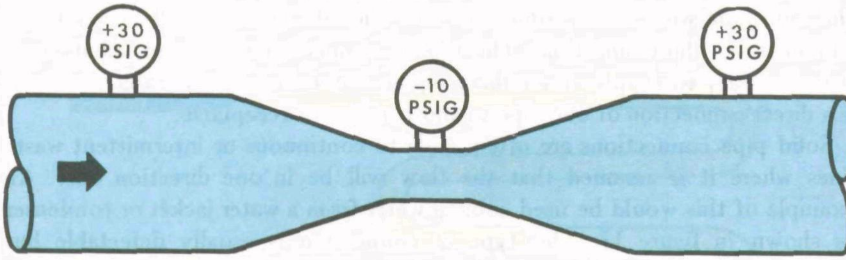

FIGURE 8. Negative pressures created by constricted flow.

One of the common occurrences of dynamically reduced pipe pressures is found on the suction side of a pump. In many cases similar to the one illustrated in figure 9, the line supplying the booster pump is undersized or does not have sufficient pressure to deliver water at the rate at which the pump normally operates. The rate of flow in the pipe may be increased by a further reduction in pressure at the pump intake. This often results in the creation of negative pressure. This negative pressure may become low enough in some cases to cause vaporization of the water in the line. Actually, in the illustration shown, flow from the source of pollution would occur when pressure on the suction side of the pump is less than pressure of the pollution source; but this is *backflow*, which will be discussed below.

The preceding discussion has described some of the means by which negative pressures may be created and which frequently occur to produce backsiphonage. In addition to the negative pressure or reversed force necessary to cause backsiphonage and backflow, there must also be the cross-connection or

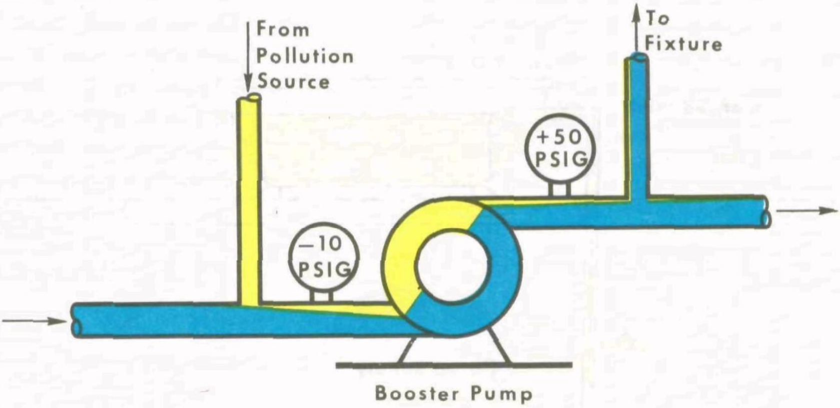

FIGURE 9. Dynamically reduced pipe pressures.

connecting link between the potable water supply and the source of pollution. Two basic types of connections may be created in piping systems. These are the *solid pipe* with valved connection and the *submerged inlet*. Figures 10 and 11 illustrate solid connections. This type of connection is often installed where it is necessary to supply an auxiliary piping system from the potable source. It is a direct connection of one pipe to another pipe or receptacle.

Solid pipe connections are often made to continuous or intermittent waste lines where it is assumed that the flow will be in one direction only. An example of this would be used cooling water from a water jacket or condenser as shown in figure 11. This type of connection is usually detectable but creating a concern on the part of the installer about the possibility of reversed flow is often more difficult. Upon questioning, however, many installers will agree that the solid connection was made because the sewer is occasionally subjected to backpressure.

Submerged inlets are found on many common plumbing fixtures and are sometimes necessary features of the fixtures if they are to function properly. Examples of this type of design are siphon-jet urinals or water closets, flushing rim slop sinks, and dental cuspidors. Oldstyle bathtubs and lavatories had supply inlets below the flood level rims, but modern sanitary design has minimized or eliminated this hazard in new fixtures. Chemical and industrial process vats sometimes have submerged inlets where the water pressure is used as an aid in diffusion, dispersion, and agitation of the vat contents. Even though the supply pipe may come from the floor above the vat, backsiphonage can occur as it has been shown that the siphon action can raise a liquid such as water almost 34 feet. Some submerged inlets difficult to control are those which are not apparent until a significant change in water level occurs or where a supply may be conveniently extended below the liquid surface by means of a hose or auxiliary piping. A submerged inlet may be created in numerous ways, and its detection in some of these subtle forms may be difficult.

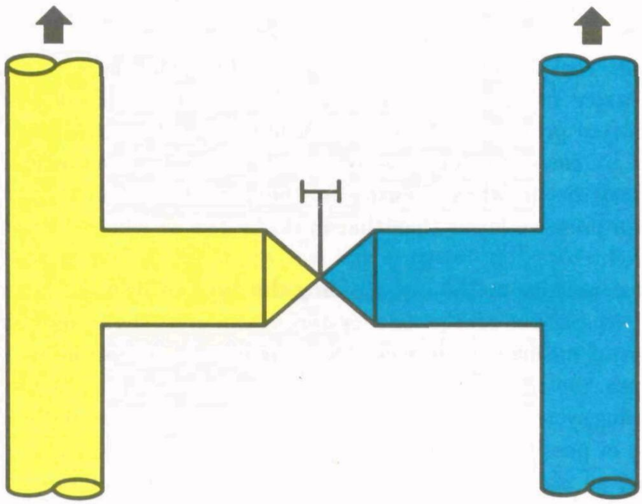

FIGURE 10. Valved connection between potable water and nonpotable fluid.

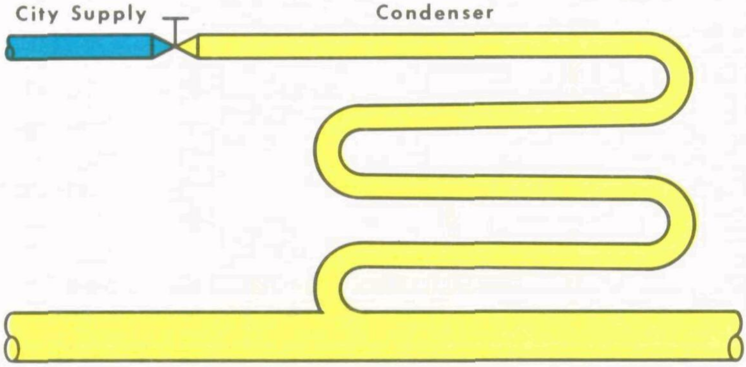

FIGURE 11. Valved connection between potable water and sanitary sewer.

The illustrations included in part B of the appendix are intended to describe typical examples of backsiphonage, showing in each case the nature of the link or cross-connection, and the cause of the negative pressure.

Backflow

Backflow,[1] as described in this manual, refers to reversed flow due to back-pressure other than siphonic action. Any interconnected fluid systems in which the pressure of one exceeds the pressure of the other may have flow from one

[1] See formal definition in the glossary of the appendix.

to the other as a result of the pressure differential. The flow will occur from the zone of higher pressure to the zone of lower pressure. This type of backflow is of concern in buildings where two or more piping systems are maintained. The potable water supply is usually under pressure directly from the city water main. Occasionally, a booster pump is used. The auxiliary system is often pressurized by a centrifugal pump, although backpressure may be caused by gas or steam pressure from a boiler. A reversal in differential pressure may occur when pressure in the potable system drops, for some reason, to a pressure lower than that in the system to which the potable water is connected.

The most positive method of avoiding this type of backflow is the total or complete separation of the two systems. Other methods used involve the installation of mechanical devices. All methods require routine inspection and maintenance.

Dual piping systems are often installed for extra protection in the event of an emergency or possible mechanical failure of one of the systems. Fire protection systems are an example. Another example is the use of dual water connections to boilers. These installations are sometimes interconnected, thus creating a health hazard.

The illustrations in part C of the appendix depict installations where backflow under pressure can occur, describing the cross-connection and the cause of the reversed flow.

Chapter 4. METHODS AND DEVICES FOR THE PREVENTION OF BACKFLOW AND BACKSIPHONAGE

The control of backflow and backsiphonage requires either the complete removal of the cross-connection or the installation of a proper cross-connection control device. Removal of the physical link is preferred because it eliminates the possibility of failure of a mechanical device. However, the operation of some fixtures, such as a siphon-jet water closet, requires a link in the form of a submerged outlet. In this case, an acceptable cross-connection control device should be employed to reduce the hazard significantly. There are *no* cases where a cross-connection cannot be removed or corrected.

Airgap Separation

The only absolute means of eliminating the physical link is through the use of the vertical airgap, as illustrated by figure 12. Airgaps should be used wherever possible, and where used must not be bypassed.

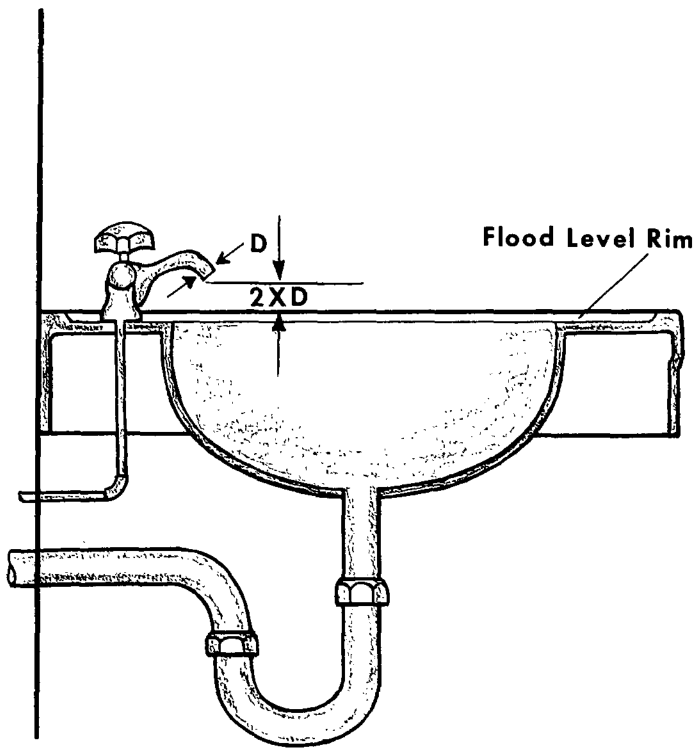

FIGURE 12. Airgap on lavatory.

The supply inlet to the fixture should be terminated above the flood-level rim of the fixture by a distance equal to at least two times the effective opening[1] of the fixture. Ideally, there should be no provision for extending the fixture outlet below the flood-level rim. If the end of the supply pipe is threaded or serrated to permit the connection of a hose, however, a properly installed vacuum breaker should also be provided.

Some examples of generally used plumbing fixtures are shown in table 3.82 in chapter 7, subsection 3.82, page 39.

If an airgap separation is provided at each fixture, complete protection will be provided within the building as well as to the municipal supply. The separation may also be made at one point where the water service enters the building. It must be remembered, however, that this protects only the municipal water supply system and not the building system.

Surge Tanks

A surge tank, illustrated in figure 13, consists of a reservoir and pump combination with the potable water supply to the reservoir delivered through an airgap. The size of each unit is determined by the water demand rate which it is to accommodate. The rate of flow into the receiving reservoir of the simple surge tank shown in figure 13 is governed by the float valve. The booster pump draws water from the reservoir, or surge tank, and discharges directly to the distribution system under pressure. When the discharge of the booster pump is to serve points where water will be withdrawn for domestic use, the surge tanks should be covered properly to prevent contamination. The surge tank is often used in installations where water is needed in industrial processes and may be used to serve single fixtures, equipment units, or entire systems.

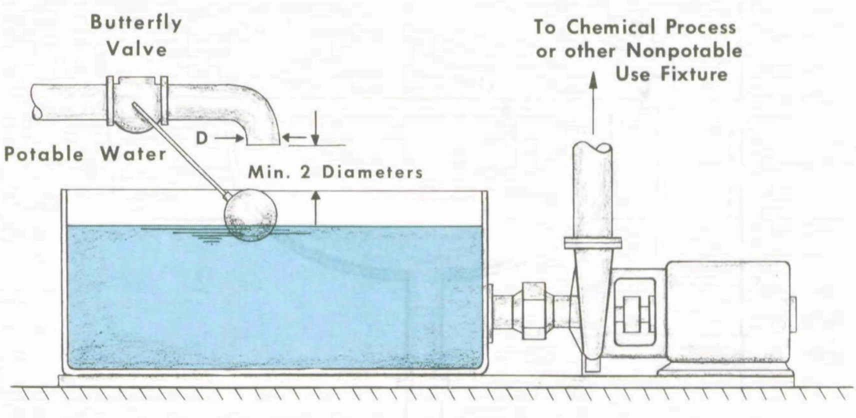

FIGURE 13. Surge tank and booster pump.

[1] See glossary in appendix.

Color Coding

When two or more piping systems are used for water in a building or industrial plant, extreme care should be taken not to interconnect the systems. There may be a potable water system and systems carrying lesser quality water such as for fire protection. To help prevent the possibility of the two systems being interconnected, pipes should be identified adequately by legends and color coding based on the American Standards Association *Scheme for Identification of Piping Systems* (ASA A13.1-1956).

Color coding should not be used solely to identify the contents of pipes but should be used supplementary to the use of legends. Potable water lines should be painted green or with bands of green and the words "potable water" stenciled on the pipe at appropriate intervals. Pipes carrying water for fire protection should be painted red and be stenciled. Piping systems carrying other material or water for other purposes should also be clearly identified with the appropriate legends and color coding.

Booster Systems

Booster pumps are often required in high buildings. Frequently these booster pumps are connected directly to the city water main or water service, under which conditions there is always the possibility of creating a negative pressure in the water main, as shown in figure 22 of appendix B. A simple surge tank could be used to protect the city main in such cases. Its disadvantage is that all or most of the city water pressure which otherwise might be available is lost through the airgap. Also there is the hazard of introducing contamination through the surge tank. A pressure limiting switch can be connected to the booster pump suction to prevent the pump from creating negative pressures in the main, but operators find it convenient to shunt around such a switch if there is any interruption in service. Figure 14 illustrates a positive method of negative pressure control, which at the same time permits the direct use of city pressure when the pressure is adequate.

When the city pressure is sufficient, the booster pump is operated with full city pressure applied to the intake side of the pump. An altitude, or pressure-reducing valve, is installed below the reservoir to minimize the required reservoir height. If the pressure in the water main drops below the pressure differential of the pressure-reducing valve, air is drawn in through the pressure-reducing valve, airbinding the pump and causing it to stop. If airbinding the pump is undesirable, a low-water-level pump shutoff switch may be added to the unit.

Vacuum Breakers

A fundamental factor in backsiphonage, as outlined in chapter 3, is vacuum or negative pressure. If atmospheric pressure is admitted to a piping system between a source of pollution and the origin of the vacuum, backsiphonage will be prevented. This is the function of a vacuum breaker. It is not designed to provide protection against backflow resulting from backpressure, and should not be installed where backpressure may occur. Because a vacuum may be created at numerous places in a piping system, a vacuum breaker must be

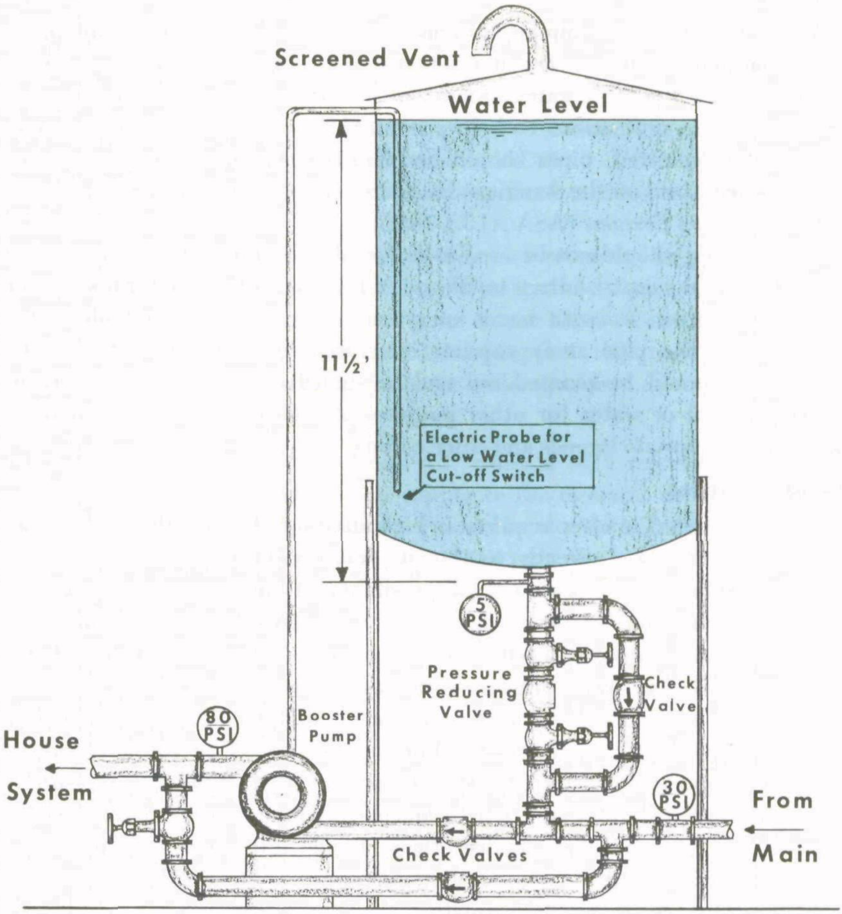

FIGURE 14. Booster system.

located as near as possible to the fixture from which contamination is anticipated. The position of a vacuum breaker must be sufficiently above the fixture flood-level rim so that flooding or submergence of the vacuum breaker or backpressure cannot occur.

A vacuum breaker may be installed either on the atmospheric side of a valve or within a pressurized distribution system. A non-pressure-type vacuum breaker is installed on the atmospheric side and will operate or cycle each time the valve is used. This type should not be installed where it will remain under pressure for long periods. A pressure-type vacuum breaker is installed in a pressurized system and will operate only when a vacuum occurs The device is usually spring loaded, and it should be specially designed to operate after extended periods under pressure because corrosion and deposition of material in the line might render it inoperable.

Installation of a vacuum breaker on the atmospheric side of the last control valve is always preferred and recommended because, by virtue of its position, it prevents any contamination from being siphoned into the water system. A vacuum breaker installed somewhere in the pressurized system does not completely protect the system, and could, with certain piping arrangements, allow backsiphonage into the water system. Vacuum breakers should be used in a pressurized system only on specific authorization of the administrative authority having jurisdiction.

The operation of one type of vacuum breaker is illustrated in figure 15. The flow of water is downward and the disc is seated in the vertical position, preventing water from spilling out the pipe (view 1). If a negative pressure should develop in the supply line, atmospheric pressure would force the disc into the horizontal position, thereby blocking the supply line, admitting air, and preventing backsiphonage (views 2 and 3).

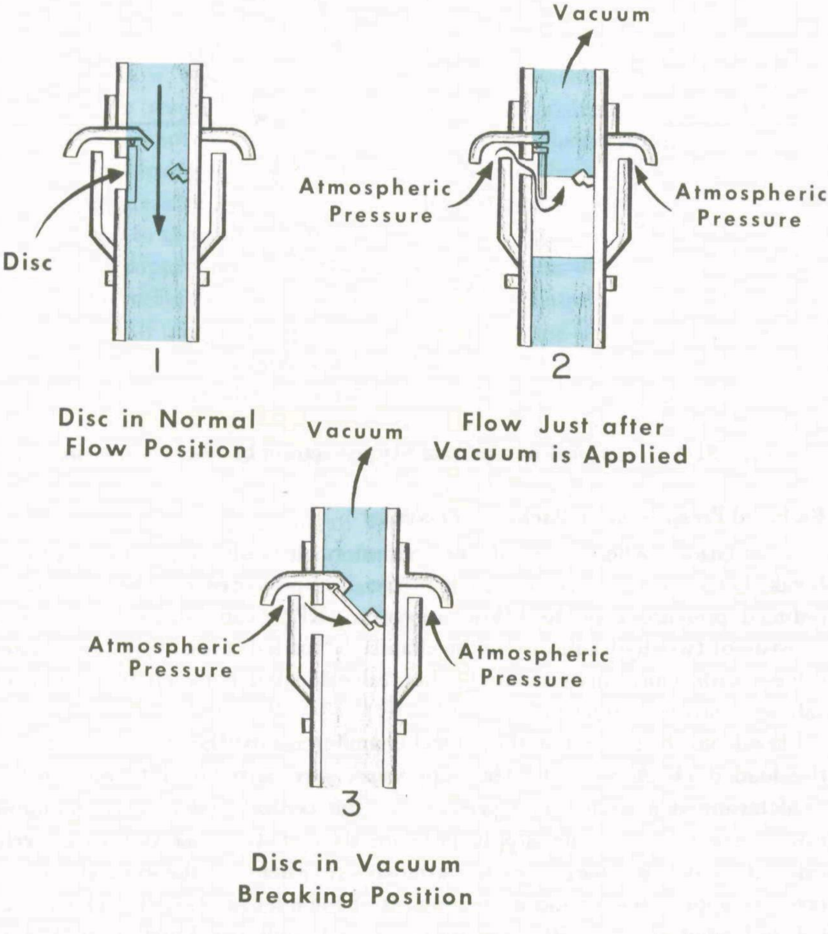

FIGURE 15. Operation of a vacuum breaker.

Figure 16 shows a non-pressure-type vacuum breaker installation. The serrated outlet laboratory sink supply might easily be extended by a hose to a point below the flood-level rim of the laboratory sink, thus producing a cross-connection. The vacuum breaker installation on the atmospheric side of the control valve and between the cross-connection effectively protects the piping system against backsiphonage.

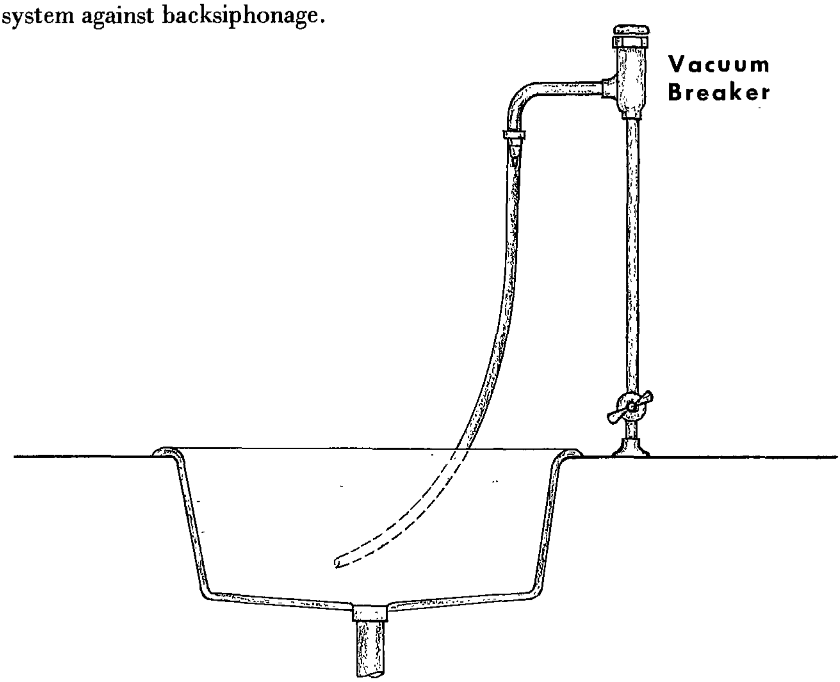

FIGURE 16. Typical non-pressure-type vacuum breaker installation.

Reduced Pressure Zone Backflow Preventer

In situations where it would be extremely difficult to provide a physical break between two systems and where backpressures can be expected, a reduced pressure zone backflow preventer (RPZ) can be used. This device consists of two, hydraulically or mechanically loaded, pressure-reducing check valves, with a pressure-regulated relief valve located between the two check valves as shown by figure 17.

Flow from the left enters the central chamber against the pressure exerted by the loaded check valve 1. The supply pressure is reduced thereupon by a predetermined amount. The pressure in the central chamber is maintained lower then the incoming supply pressure through the operation of the relief valve 3, which discharges to the atmosphere whenever the central chamber pressure approaches within a few pounds of the inlet pressure. Check valve 2 is lightly loaded to open with a pressure drop of 1 psi in the direction of flow and is independent of the pressure required to open the relief valve. In the event

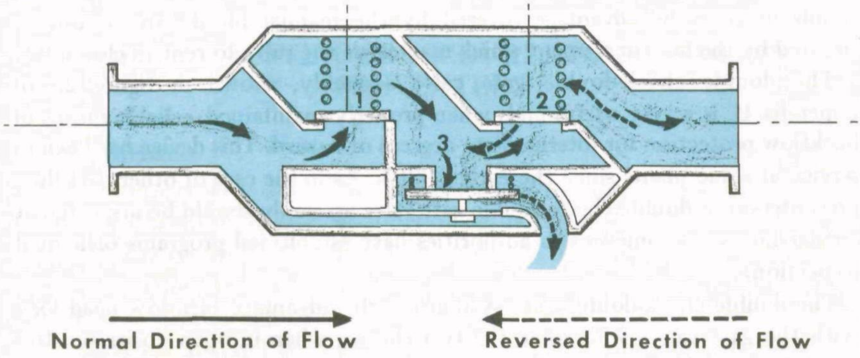

FIGURE 17. Reduced pressure zone backflow preventer – principle of operation.

that the pressure increases downstream from the device, tending to reverse the direction of flow, check valve 2 closes, preventing backflow. Because all valves may leak as a result of wear or obstruction, the protection provided by the check valves is not considered sufficient. If some obstruction prevents check valve 2 from closing tightly, the leakage back into the central chamber would increase the pressure in this zone, the relief valve would open, and flow would be discharged to the atmosphere.

When the supply pressure drops to the minimum differential required to operate the relief valve, the pressure in the central chamber should be atmospheric. If the inlet pressure should become less than atmospheric pressure, relief valve 3 should remain fully open to the atmosphere to discharge any water which may be caused to backflow as a result of backpressure and leakage of check valve 2.

Malfunctioning of one or both of the check valves or relief valve should always be indicated by a discharge of water from the relief port. Under no circumstances should plugging of the relief port be permitted because the device depends upon an open port for safe operation. The pressure loss through the device may be expected to average between 10 and 20 psi within the normal range of operation, depending upon the size and flow rate of the device.

Double Check Valve Assembly and Other Methods

Other methods and devices have been promoted for the separation of auxiliary systems or for the prevention of backflow. Among these are the single check valve, and plain double check valve assembly, the double check valve-double gate valve assembly, the swivel connection, and the barometric loop.

The single check valve offers no visual or mechanical means of determining malfunctioning, and since all mechanical devices are subject to wear and interference resulting from deposits and other factors, the single check valve is not considered an adequate backflow preventer. Double check valve assemblies in series, including those with spacers and manual bleed valves, have similar disadvantages. The advantage offered by the manual bleed valve is usually negated by the human element which may cause the valve to remain closed.

The double check-double gate valve assembly, shown in figure 25 of appendix B, is a very useful and, when properly maintained, reliable means of backflow protection for intermediate degrees of hazard. This device has been in service at some plants since the early 1900's. As in the case of other backflow preventers, the double check-double gate valve assembly should be inspected at regular intervals. Some health authorities have established programs of annual inspection.

The double check-double gate system has the advantage of a low head loss. With the gate valves wide open the two checks, when in open position, offer little resistance to flow.

Double check-double gate assemblies should be well designed and constructed. The valves should be all bronze or, for larger sizes, galvanized gray iron. The trim should be of bronze, or other corrosion-resistant material. Springs should be bronze, stainless steel, or spring steel covered with a coat of vinyl plastic. Valve discs should be of composition material with low water absorption properties. Test cocks should be provided.

The swivel connection does not offer adequate protection against backflow between the two systems that it interconnects. It should not be used to connect a hazardous system to a potable system without the inclusion of an acceptable means of backflow prevention.

The barometric loop consists of a vertical loop of pipe extending at least 35 feet above the highest fixture. The principle is that a complete vacuum cannot raise water to an elevation greater than 33.9 feet. The device, however, does not provide protection against backflow due to backpressure and the installation of a pipe loop of this height is usually difficult and expensive. As a result it is not widely used.

Chapter 5. TESTING PROCEDURES FOR BACKFLOW PREVENTERS

Vacuum Breakers

A vacuum breaker should be subjected to routine visual inspection to determine that the device is functioning normally. Malfunction may be indicated by excessive weeping or leakage of the device. Stains or watermarks on the outside body of the device may also indicate malfunction.

Internal inspection should also be made periodically. Rubber membranes and gaskets, valve seats, and the internal mechanism should be carefully inspected for rupture, scoring of metal, scaling, corrosion, or any accumulation of dirt or foreign matter that would prevent the safe operation of the device.

A complete inspection of a vacuum breaker installation also includes a determination that the device has not been bypassed and that under no conditions could it be subjected to backpressure. Vacuum breakers must be installed above the flood-level rim of the equipment supplied and should be located at the highest point in the part of the water system served so as to preclude any possibility of backpressure being applied to the device. A complete record, including date of installation and information on all inspections, tests, and repairs, should be maintained on each device. Any defects found during inspection or testing should be corrected immediately before allowing the device to be placed back in service.

The basic concept in testing of a vacuum breaker for proper operation involves a determination that the air inlet will open fully when there is little or no water pressure inside the device. The canopy or hood on the vacuum breaker should be removed, where possible, to expose the air inlet. When testing a *non-pressure-type vacuum breaker*, the closest upstream valve should be opened to allow water to fill the downstream piping. The valve is then closed; the vent ports should open allowing air to enter the device and water to flow out the downstream piping. If water does not continue to flow, or if there is a mere trickle, the vacuum breaker is not opening properly. The defect should be corrected immediately and the device retested.

When testing a *pressure-type vacuum breaker*, the system must first be under pressure. (See fig. 18.) First valve 2 is closed, then valve 1. The test cock should then be opened to lower the pressure and allow water to drain slowly from the device. As the pressure in the device drops to near 0 psi, the air inlet should open automatically if it is operating properly. If the air inlet remains closed, the valve or spring may be corroded or fouled causing it to cement shut. The defect should be corrected immediately by installing a new vacuum breaker or by repairing the old one and retesting. Next, the system should be repressurized by closing the test cock and opening valve 2 and then valve 1. As the pressure increases, some water should discharge through the vent ports. If the discharge continues as the system is repressurized, however, it means that

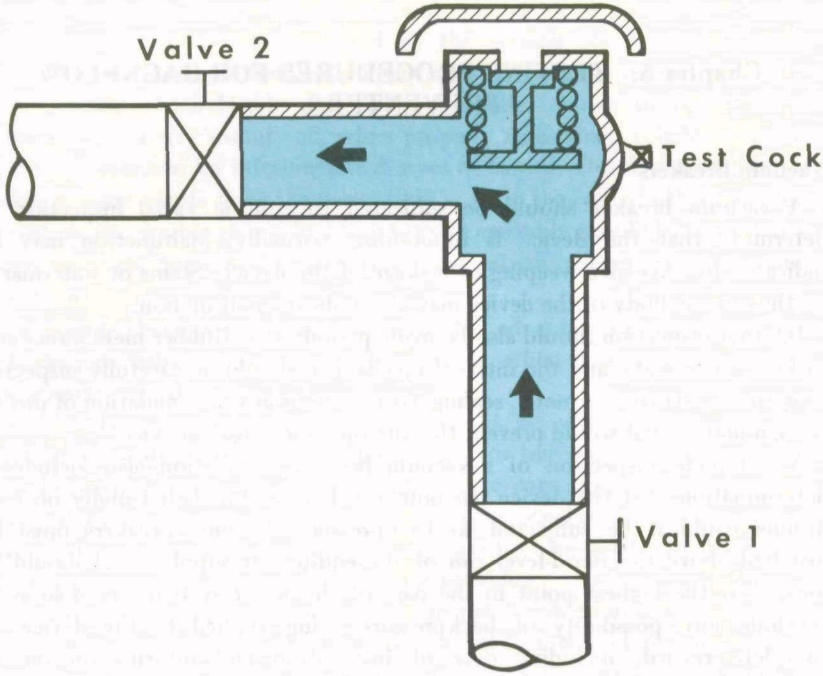

FIGURE 18. Pressure-type vacuum breaker installation.

the valve has not seated properly and may be damaged or fouled. The defect should be corrected immediately and the device completely retested.

Reduced Pressure Zone Backflow Preventer

In the operation of an RPZ, the reduced pressure zone between the two check valves is maintained at a pressure less than the supply pressure by the action of the pressure differential relief valve. The relief valve should be capable of maintaining a reduced pressure zone, which is at least 2 psi less than the supply pressure. If the supply pressure becomes less than 2 psi, the relief valve opens and the pressure in the reduced pressure zone becomes atmospheric. When field testing an RPZ, it should be observed that the device has not been bypassed and that the relief valve can freely discharge water. The device should undergo periodic internal inspection and should be cleaned or repaired as necessary. Check valves and the pressure differential relief valve should be checked for wear, corrosion, scaling, fouling, or other damage that may cause malfunction.

Occasional discharge of water through the relief valve can be caused by fluctuations in inlet pressure, and usually occurs when there is no flow through the device. Continuous discharge of water through the relief valve under flowing conditions indicates either that the relief valve is malfunctioning or that check valve 1 is held in an open position. (See fig. 17.) Continuous discharge under no-flow conditions indicates that the differential relief valve is malfunctioning, or that there is a leak in check valve 1, or that a backflow condition exists and check valve 2 is leaking.

Test Procedure

A field test of the device is used to determine if the pressure relief valve and the two check valves are operating properly. A differential pressure gage with a 0-15-psi range and a working pressure of 500 psi and appropriate lengths of hose with necessary fittings are needed for testing. (See fig. 19.)

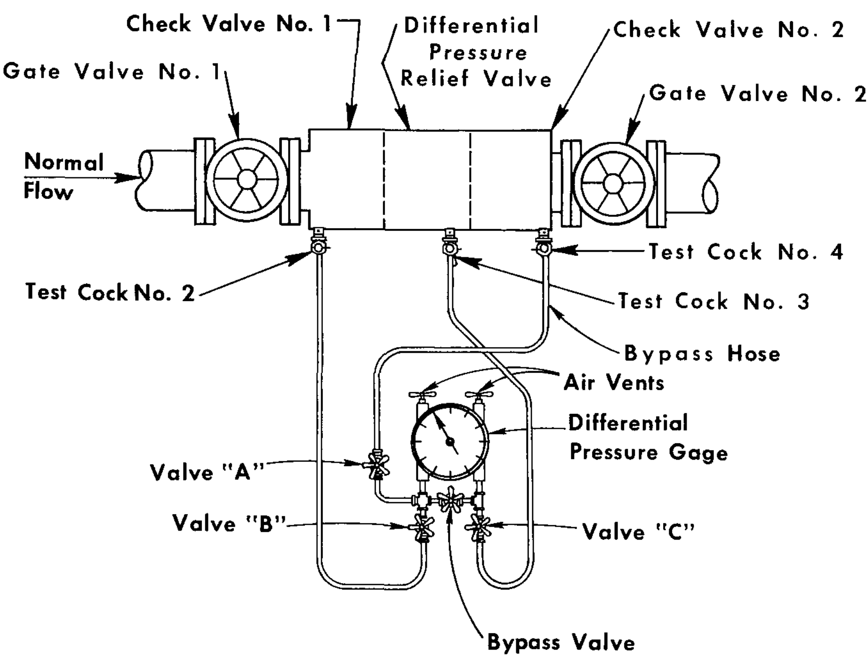

FIGURE 19. Reduced pressure zone backflow preventer field test.

Step Number 1. Steps for testing check valve 1 for tightness against backflow and measuring the pressure differential:

A. Open all test cocks individually to flush out any dirt and sediment and then close.
B. Close gate valve 2 and open gate valve 1. If there is no drainage from the relief valve, check valve 1 is closed tight.
C. Connect test hose between test cock 2 and valve B, and between test cock 3 and valve C.
D. Close valve A and gage bypass valve.
E. Open test cocks 2 and 3.
F. Open valves B and C. Open air vents on gage to clear all air, then reclose.

G. Open test cock 4 and allow it to drain slightly until gage reading stops rising, then reclose and read differential gage pressure, which should be above 5 psi.

Step Number 2. Steps for determining the differential pressure at which the pressure differential relief valve will open:

A. With pressure holding constant above 5 psi, open very slowly the gage bypass valve until pressure starts to drop slowly.
B. When the first drops of water discharge from the pressure relief valve, pressure reading should not be below 2 psi.
C. Close bypass valve. Open test cock 4 and allow it to drain slightly until gage reading stops rising. Then close test cock 4.

Step Number 3. Steps for testing check valve 2 for tightness against backflow:

A. With pressure holding constant above 5 psi, connect hose from valve A to test cock 4. Slowly open valve A and vent air from hose connection at test cock 4. Tighten connection and open test cock 4.
B. Differential pressure reading should not drop below 5 psi.

Double Check-Double Gate Valves

The double check-double gate valve assembly should include test cocks as shown in figure 20. A method for testing the check valves is as follows:

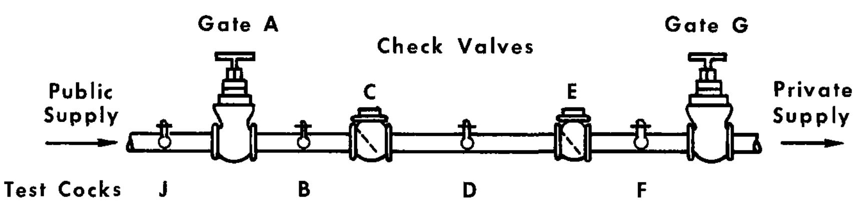

FIGURE 20. Method of testing check valves.

A. *Where Backpressure Is Available on Private Supply.*

1. Open all test cocks individually to flush out any sediment or scale.
2. Close gate valves A and G.
3. Open test cocks B and F, successively. If leakage occurs, gate valve(s) A and/or G are leaking and must be repaired before continuing test.
4. *a*. Open gate valve G and test cock D. If leakage does not cease, check valve E is leaking and must be repaired. If leakage ceases, check valve E is tight.
   b. Temporarily connect a hose between test cocks D and F and open

both. Open test cock B. If leakage does not cease, check valve C is leaking and must be repaired. If leakage ceases, check valve C is tight.

c. If check valves are repaired, repeat the test as above.

5. When the test is complete, close test cocks and remove the hose. Leave gate valves A and G in their proper position.

B. *Where Insufficient Backpressure Is Available on Private Supply.*

1. Open all test cocks individually to flush out any sediment or scale.
2. Close gate valves A and G.
3. Open test cocks B and F, successively. If leakage occurs, gate valve(s) A and/or G are leaking and must be repaired before continuing test.
4. *a.* Temporarily connect a hose between test cocks J and F and open both. Open test cock D. If leakage does not cease, check valve E is leaking and must be repaired. If leakage ceases, check valve E is tight.
   b. Close cocks J and F. Temporarily connect the hose between test cocks J and D and open both. Open test cock B. If leakage does not cease, check valve C is leaking and must be repaired. If no leakage occurs, check valve C is tight.
   c. If check valves are repaired, repeat the test as above.
5. When the test is complete, close test cocks and remove the hose. Leave gate valves A and G in their proper position.

Chapter 6. ADMINISTRATION OF A CROSS-CONNECTION CONTROL PROGRAM

Responsibility

Public health personnel, waterworks officials, plumbing inspectors, building managers, plumbing installers, and maintenance men all share to some degree the responsibility for protecting the health and safety of individuals and the public from contaminated water. These responsibilities include insuring sanitary design and installation practices in piping systems and the supervision of the installation and maintenance of these systems. Public health officials should promote the development of sanitary design of plumbing systems and encourage as well as assist in the training of persons responsible for their installation and maintenance. Officials responsible for the inspection of plumbing installations should require the maximum protection against backflow that is consistent with good judgment and the public safety. Plumbing installers and maintenance personnel should observe and avoid or eliminate possibilities for backflow and be diligent in adherence to plumbing codes and ordinances.

Where plumbing defects are detected, notification of the persons having authority for the correction of such defects should be made in writing, and the responsible person should cause these defects to be corrected as soon as possible.

Public Water Supply Protection

Waterworks officials should survey their own and their customers' distribution systems for cross-connections on a continuing basis and should provide a satisfactory program for the elimination of health hazards. Frequently, their responsibility ends at the property line but in some municipalities it extends to the building piping. Waterworks officials often prescribe the installation of a backflow prevention device in the service line to a premise where hazardous use of water is found. The requirement of an airgap in the service line to a premise where extreme hazard is possible may be warranted. Reduced pressure principle or double check-double gate backflow preventers are often used in cases of lesser hazard.

Direct connections between potable and nonpotable water supply systems should be eliminated or properly protected, and interconnections with other public water supply systems should be permitted only with the approval of health authorities. Private wells should have no connection to the potable, public water supply system.

The potable water distribution system should be so designed that the sizes of pipes are adequate to supply water in the amounts and at the pressures needed.

When a system is sized to meet the needs of peak fire demand, other uses are usually covered, but at the time of large fires water pressure in remote parts of the system may be reduced even to the point of vacuum. Following a large fire, water and health authorities should be alert for appearances of contamination.

When there are main breaks due to deterioration or damage, such as by flood, large quantities of water escape at the affected point and pressures elsewhere in the system may drop seriously. Breaks should be repaired promptly and an alert maintained for the appearance of contamination. The precaution of first thoroughly flushing, then disinfecting repaired and new pipe sections should be observed.

Priority of Action

Plumbing defects are in existence and defects are constantly being created in new plumbing systems and in altering existing systems. The elimination of these health hazards will be possible only through a well-planned and continuing program of instruction, plumbing surveillance, and repair. Many types of cross-connections exist, and the danger to public health resulting from each differs widely. The possibility of causing serious pollution of the potable water supply system is dependent upon the degree of hazard of the contaminant and the probability of reversed flow.

Although, statistically, the probability of reversed flow may seem remote, reliance should not be placed upon this factor. Complete removal of all cross-connections should be undertaken in an organized manner and a priority system based upon the degree of hazard involved should be established. It is not feasible in this manual to assign priority to all types of cross-connections, or even to classify them, except in a general way. Determining priority of action in their removal should be based primarily on the nature of the pollutant. High priority should be given any cross-connection between a potable water supply and a piping system or reservoir conveying or containing sewage, toxic or hazardous chemicals, or nonpotable water. All such connections should be broken immediately and properly protected.

Obsolete fixtures, such as tubs and lavatories having inlets terminating below the overflow level, have a lower priority but outlets should be raised or the fixtures replaced. Fixtures which have serrated or threaded inlets that would permit the extension of these inlets below the flood level rim could be particularly hazardous and should be provided with vacuum breakers. Where this is not possible, the fixtures should be replaced on a systematic, improvement basis. Fixtures that can siphon only a small amount of relatively low-hazard waste water do not warrant urgent or drastic action and can be given a lower priority. These illustrations describe the common extremes of urgency or priority, and only a careful evaluation of the circumstances surrounding each specific plumbing hazard will enable establishing reasonable priority for intermediate situations. As stated previously, in establishing a priority of action, reliance should not be placed upon the probability factor of the occurrence of reversed flow.

Method of Action

A broad program of cross-connection control should include instruction, inspection, improvements, and enforcement. Control on new installations should be accomplished through plan review and installation inspection. Control and elimination of existing hazards should be accomplished through routine inspection and periodic surveys at definite intervals. Trained personnel, competent in plan examination and hazard evaluation, should supervise the control program. Sanitary inspectors who have qualifications equivalent to licensed plumbers and who have been specially trained in cross-connection control should be assigned to the task of inspecting new and existing plumbing installations. The results of periodic surveys should be tabulated and summarized for comparison with the results of previous surveys. Only through this means will improvement, or lack of improvement, be noted. Through a summarization of the number of violations of specific types, effective action may be directed against the most prevalent and most hazardous violations.

As an aid to the less-experienced inspector, a limited tabulation of typical hazardous connections is listed in the appendix of this manual along with several illustrations of backsiphonage and backflow. Also shown in the appendix is a survey form for reporting on inspections for health hazards.

Chapter 7. CROSS-CONNECTION CONTROL ORDINANCE PROVISIONS

INTRODUCTION

The successful promotion of a cross-connection and backflow-connection control program in a municipality will be dependent upon legal authority to conduct such a program. Where a community has adopted a modern plumbing code, such as the National Plumbing Code, ASA A40.8-1955, or subsequent revisions thereof, provisions of the code will govern backflow and cross-connections. It then remains to provide an ordinance that will establish a program of inspection for an elimination of cross- and backflow connections within the community. Frequently authority for such a program may already be possessed by the water department or water authority. In such cases no further document may be needed. A cross-connection control ordinance should have at least three basic parts.

1. Authority for establishment of a program.
2. The technical provisions relating to eliminating backflow and cross-connections.
3. Penalty provisions for violations.

The following simple form is suggested for municipalities who desire to adopt a cross-connection control ordinance. The technical provisions are for the most part excerpted from a revision of the National Plumbing Code prepared by the Public Health Service Technical Committee on Plumbing Standards (1962). Where the National Plumbing Code, or subsequent revisions thereof, is in effect, the technical sections of the following can be replaced by a statement of reference to the Code. Communities adopting ordinances should check with State health officials to assure conformance with State codes. The form of the ordinance should comply with local legal requirements.

ORDINANCE FOR THE CONTROL OF BACKFLOW AND CROSS-CONNECTIONS

Section 1. Authority

1.1 *Responsibility of the Director.* The Director, Department of __________________, or his designated agent, shall inspect the plumbing in every building or premises in this City as frequently as in his judgment may be necessary to ensure that such plumbing has been installed in such a manner as to prevent the possibility of pollution of the water supply of the city by the plumbing. The director shall notify or cause to be notified in writing the owner or authorized agent of the owner of any such building or premises, to correct, within a reasonable time set by the Director, any plumbing installed or existing contrary to or in violation of this ordinance, and which in his judgment, may, therefore, permit the pollution of the city water supply, or otherwise adversely affect the public health.

1.2 *Inspection.* The Director, or his designated agent, shall have the right of entry into any building, during reasonable hours, for the purpose of making inspection of the plumbing systems installed in such building or premises provided that with respect to the inspection of any single family dwelling, consent to such inspection shall first be obtained from a person of suitable age and discretion therein or in control thereof.

Section 2. Definitions

2.1 *Agency.* The department of the municipal government invested with the authority and responsibility for the enactment and enforcement of this ordinance.

2.2 *Airgap.* The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture, or other device and the flood-level rim of the receptacle.

2.3 *Approved.* Accepted by the agency as meeting an applicable specification stated or cited in this ordinance, or as suitable for the proposed use.

2.4 *Auxiliary Supply.* Any water source or system other than the potable water supply that may be available in the building or premises.

2.5 *Backflow.* The flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable supply of water from any source or sources other than its intended source. Backsiphonage is one type of backflow.

2.6 *Backflow Preventer.* A device or means to prevent backflow.

2.7 *Backsiphonage.* Backflow resulting from negative pressures in the distributing pipes of a potable water supply.

2.8 *Barometric Loop.* A loop of pipe rising at least 35 feet, at its topmost point, above the highest fixture it supplies.

2.9 *Check Valve.* A self-closing device which is designed to permit the flow of fluids in one direction and to close if there is a reversal of flow.

2.10 *Contamination.* See *Pollution.*

2.11 *Cross-Connection.* Any physical connection between a potable water supply and any waste pipe, soil pipe, sewer, drain, or any unapproved source or system. Furthermore, it is any potable water supply outlet which is submerged or can be submerged in waste water and/or any other source of contamination. See *Backflow* and *Backsiphonage.*

2.12 *Drain.* Any pipe that carries waste water or waterborne wastes in a building drainage system.

2.13 *Fixture, Plumbing.* Installed receptacles, devices, or appliances supplied with water or that receive or discharge liquids or liquid-borne wastes.

2.14 *Flood-Level Rim.* The edge of the receptacle from which water overflows.

2.15 *Hazard, Health.* Any conditions, devices, or practices in the water supply system and its operation which create, or, in the judgment of the Director, may create, a danger to the health and well-being of the water consumer. An example of a health hazard is a structural defect in the water supply system, whether of location, design, or construction, that regularly or occasionally may prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources.

2.16 *Hazard, Plumbing.* Any arrangement of plumbing including piping and fixtures whereby a cross-connection is created.

2.17 *Hydropneumatic Tank.* A pressure vessel in which air pressure acts upon the surface of the water contained within the vessel, pressurizing the water distribution piping connected to the vessel.

2.18 *Inlet.* The open end of the water supply pipe through which the water is discharged into the plumbing fixture.

2.19 *Plumbing System.* Includes the water supply and distribution pipes, plumbing fixtures, and traps; soil, waste, and vent pipes; building drains and building sewers including their respective connections, devices, and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.20 *Pollution.* The presence of any foreign substance (organic, inorganic, radiological, or biological) in water that tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

2.21 *Reduced Pressure Principle Backflow Preventer.* An assembly of differential valves and check valves including an automatically opened spillage port to the atmosphere designed to prevent backflow.

2.22 *Surge Tank.* The receiving, nonpressure vessel forming part of the airgap separation between a potable and an auxiliary supply.

2.23 *Vacuum.* Any pressure less than that exerted by the atmosphere.

2.24 *Vacuum Breaker, Nonpressure Type.* A vacuum breaker designed so as not to be subjected to static line pressure.

2.25 *Vacuum Breaker, Pressure Type.* A vacuum breaker designed to operate under conditions of static line pressure.

2.26 *Water, Potable.* Water free from impurities in amounts sufficient to cause disease or harmful physiological effects. Its bacteriological and chemical quality shall conform to the requirements of the Federal Drinking Water Standards or to the regulations of the public health authority having jurisdiction.

2.27 *Water, Nonpotable.* Water that is not safe for human consumption or that is of questionable potability.

Section 3. General (Technical) Requirements

3.1 *General.* A potable water supply system shall be designed, installed, and maintained in such manner as to prevent contamination from nonpotable liquids, solids, or gases from being introduced into the potable water supply through cross-connections or any other piping connections to the sytem.

3.2 *Cross-Connections Prohibited.* Cross-connections between potable water systems and other systems or equipment containing water or other substances of unknown or questionable safety are prohibited except when and where, as approved by the authority having jurisdiction, suitable protective devices such as the reduced pressure zone backflow preventer or equal are installed, tested, and maintained to insure proper operation on a continuing basis.

3.3 *Interconnections.* Interconnection between two or more public water supplies shall be permitted only with the approval of the health authority having jurisdiction.

3.4 *Individual Water Supplies.* Cross-connections between an individual water supply and a potable public supply shall not be made unless specifically approved by the health authority having jurisdiction.

3.5 *Connections to Boilers.* Potable water connections to boilers shall be made through an airgap or provided with an approved backflow preventer.

3.6 *Prohibited Connections to Fixtures and Equipment.* Connection to the potable water supply system for the following is prohibited unless protected against backflow in accordance with section 3.8 or as set out herein.

(a) Bidets.

(b) Operating, dissection, embalming, and mortuary tables or similar equipment: in such installation the hose used for water supply shall terminate at least 12 inches away from every point of the table or attachments.

(c) Pumps for nonpotable water, chemicals, or other substances: priming connections may be made only through an airgap.

(d) Building drainage, sewer, or vent systems.

(e) Any other fixture of similar hazard.

3.7 *Refrigerating Unit Condensers and Cooling Jackets.* Except where potable water provided for a refrigerator condenser or cooling jacket is entirely outside the piping or tank containing a toxic refrigerant, the inlet connection shall be provided with an approved check valve. Also adjacent to and at the outlet side of the check valve, an approved pressure relief valve set to relieve at 5 psi above the maximum water pressure at the point of installation shall be provided if the refrigeration units contain more than 20 pounds of refrigerants.

3.8 *Protection Against Backflow and Backsiphonage.*

3.81 *Water Outlets.* A potable water system shall be protected against backflow and backsiphonage by providing and maintaining at each outlet:

(a) Airgap. An airgap, as specified in section 3.82, between the potable water outlet and the flood level rim of the fixture it supplies or between the outlet and any other source of contamination, or

(b) Backflow Preventer. A device or means to prevent backflow.

3.82 *Minimum Required Airgap.*

(a) How Measured. The minimum required airgap shall be measured vertically from the lowest end of a potable water outlet to the flood rim or line of the fixture or receptacle into which it discharges.

(b) Size. The minimum required airgap shall be twice the effective opening of a potable water outlet unless the outlet is a distance less than three

times the effective opening away from a wall or similar vertical surface, in which cases the minimum required airgap shall be three times the effective opening of the outlet. In no case shall the minimum required airgap be less than shown in table 3.82.

TABLE 3.82.—*Minimum airgaps for generally used plumbing fixtures*

Fixture	Minimum airgap	
	When not affected by near wall[1] (inches)	When affected by near wall[2] (inches)
Lavatories and other fixtures with effective openings not greater than ½-in. diameter	1.0	1.50
Sink, laundry trays, goose-neck bath faucets and other fixtures with effective openings not greater than ¾-in. diameter	1.5	2.25
Over rim bath fillers and other fixtures with effective openings not greater than 1-in. diameter	2.0	3.0
Drinking water fountains—single orifice 7/16 (0.437) in. diameter or multiple orifices having total area of 0.150 sq. in. (area of circle 7/16-in. diameter)	1.0	1.50
Effective openings greater than 1 inch	(3)	(4)

[1] Side walls, ribs, or similar obstructions do not affect airgaps when spaced from inside edge of spout opening a distance greater than 3 times the diameter of the effective opening for a single wall, or a distance greater than 4 times the diameter of the effective opening for 2 intersecting walls.

[2] Vertical walls, ribs, or similar obstructions extending from the water surface to or above the horizontal plane of the spout opening require a greater airgap when spaced closer to the nearest inside edge of spout opening than specified in note 1 above. The effect of 3 or more such vertical walls or ribs has not been determined. In such cases, the airgap shall be measured from the top of the wall.

[3] 2 times diameter of effective opening.

[4] 3 times diameter of effective opening.

3.83 *Approval of Devices.* Before any device for the prevention of backflow or backsiphonage is installed, it shall have first been certified by a recognized testing laboratory acceptable to the agency Director. Devices installed in a building potable water supply distribution system for protection against backflow shall be maintained in good working condition by the person or persons responsible for the maintenance of the system.

The agency Director or his designee shall inspect routinely such devices and if found to be defective or inoperative shall require the replacement thereof.

3.84 *Installation of Devices.*

(a) Vacuum Breakers. Vacuum breakers shall be installed with the critical level at least 6 inches above the flood level rim of the fixture they serve and on the discharge side of the last control valve to the fixture. No shutoff valve or faucet shall be installed beyond the vacuum breaker. For closed equipment or vessels such as pressure sterilizers the top of the vessel shall be treated as the flood level rim but a check valve shall be installed on the discharge side of the vacuum breaker.

(b) Reduced Pressure Principle Backflow Preventer. A reduced pressure principle type backflow preventer may be installed subject to full static pressure.

(c) Devices of All Types. Backflow and backsiphonage preventing devices shall be accessibly located preferably in the same room with the fixture they serve. Installation in utility or service spaces, provided they are readily accessible, is also permitted.

3.85 *Tanks and Vats–Below Rim Supply.*

(a) Where a potable water outlet terminates below the rim of a tank or vat and the tank or vat has an overflow of diameter not less than given in table 3.85, the overflow pipe shall be provided with an airgap as close to the tank as possible.

TABLE 3.85.–*Sizes of overflow pipes for water supply tanks*

Maximum capacity of water supply line to tank	Diameter of overflow pipe (inches ID)	Maximum capacity of water supply line to tank	Diameter of overflow pipe (inches ID)
0–50 gpm	2	400–700 gpm	5
50–150 gpm	2½	700–1,000 gpm	6
100–200 gpm	3	Over 1,000 gpm	8
200–400 gpm	4		

(b) The potable water outlet to the tank or vat shall terminate a distance not less than 1½ times the height to which water can rise in the tank above the top of the overflow. This level shall be established at the maximum flow rate of the supply to the tank or vat and with all outlets except the airgap overflow outlet closed.

(c) The distance from the outlet to the high water level shall be measured from the critical point of the potable water supply outlet.

3.86 *Protective Devices Required.* Approved devices to protect against backflow and backsiphonage shall be installed at all fixtures and equipment where backflow and/or backsiphonage may occur and where a minimum airgap cannot be provided between the water outlet to the fixture or equipment and its flood-level rim.

(a) Connections Not Subject to Backpressure. Where a water connection is not subject to backpressure, a vacuum breaker shall be installed on the discharge side of the last valve on the line serving the fixture or equipment. A list of some conditions requiring protective devices of this kind is given in table 3.86A, "Cross-Connections Where Protective Devices are Required and Critical Level (C-L) Settings for Vacuum Breakers."

TABLE 3.86A.—*Cross-connections where protective devices are required and critical level (C–L) settings for vacuum breakers* [a]

Fixture or equipment	Method of installation
Aspirators and ejectors . .	C–L at least 6 in. above flood level of receptacle served.
Dental units	On models without built-in vacuum breakers—C–L at least 6 in. above flood level rim of bowl.
Dishwashing machines . . .	C–L at least 6 in. above flood level of machine. Install on both hot and cold water supply line.
Flushometers (closet & urinal) .	C–L at least 6 in. above top of fixture supplies.
Garbage can cleaning machine	C–L at least 6 in. above flood level of machine. Install on both hot and cold water supply lines.
Hose outlets	C–L at least 6 in. above highest point on hose line.
Laundry machines	C–L at least 6 in. above flood level of machine. Install on both hot and cold water supply lines.
Lawn sprinklers	C–L at least 12 in. above highest sprinkler or discharge outlet.
Steam tables	C–L at least 6 in. above flood level.
Tank and vats	C–L at least 6 in. above flood level rim or line.
Trough urinals	C–L at least 30 in. above perforated flush pipe.
Flush tanks	Equip with approved ball cock. Where ball cocks touch tank water equip with vacuum breaker at least 1 in. above overflow outlets. Where ball cock does not touch tank water install ball cock outlet at least 1 in. above overflow outlet or provide vacuum breaker as specified above.
Hose bibbs (where aspirators or ejectors could be connected).	C–L at least 6 in. above flood level of receptacle served.

[a]Critical level (C-L) is defined as the level to which the vacuum breaker may be submerged before backflow will occur. Where the C-L is not shown on the preventer, the bottom of the device shall be taken as the C-L.

(b) Connections Subject to Backpressure. Where a potable water connection is made to a line, fixture, tank, vat, pump, or other equipment with a hazard of backflow or backsiphonage where the water connection is subject to backpressure, and an airgap cannot be installed, the Director may require the use of an approved reduced pressure principle backflow preventer. A partial list of such connections is shown in table 3.86B.

TABLE 3.86B.—*Partial list of cross-connections which may be subject to backpressure*

Chemical lines	Pumps
Dock water outlets	Steam lines
Individual water supplies	Swimming pools
Industrial process water lines	Tank and vats—bottom inlets
Pressure tanks	Hose bibbs

3.87 *Barometric Loop.* Water connections where an actual or potential backsiphonage hazard exists may in lieu of devices specified in section 3.86 be provided with a barometric loop. Barometric loops shall precede the point of connection.

3.88 *Double Check-Double Gate Valves.* The Director may authorize installation of approved, double check-double gate valve assemblies with test cocks as protective devices against backflow in connections between a potable water system and other fluid systems which present no significant health hazard in the judgment of the Director.

3.89 *Low Pressure Cutoff Required on Booster Pumps.* When a booster pump is used on a water pressure booster system and the possibility exists that a positive pressure of 10 psi or less may occur on the suction side of the pump, there shall be installed a low-pressure cutoff on the booster pump to prevent the creation of a vacuum or negative pressure on the suction side of the pump, thus cutting off water to other outlets.

Section 4. Maintenance Requirements

4.1 *General Requirements.* It shall be the responsibility of building and premise owners to maintain all backflow preventers and vacuum breakers within the building or on the premises in good working order and to make no piping or other arrangements for the purpose of bypassing backflow devices.

4.2 *Backflow Preventers.* Periodic testing and inspection schedules shall be established by the Director for all backflow preventers and the interval between such testing and inspections and overhauls of each device shall be established in accordance with the age and condition of the device. Inspection intervals should not exceed 1 year, and overhaul intervals should not exceed 5 years. These devices should be inspected frequently after the initial installation to assure that they have been installed properly and that debris resulting from the installation has not interfered with the functioning of the device. The testing procedures shall be in accordance with the manufacturer's instructions when approved by the Director.

Section 5. Violations and Penalties

5.1 *Notification of Violation.* The Director shall notify the owner, or authorized agent of the owner, of the building or premises in which there is found a violation of this ordinance, of such violation. The Director shall set a reasonable time for the owner to have the violation removed or corrected. Upon failure of the owner to have the defect corrected by the end of the specified time interval the Director may, if in his judgment an imminent health hazard exists, cause the water service to the building or premises to be terminated, and/or recommend such additional fines or penalties to be invoked as herein may be provided.

5.2 *Fines.* The owner or authorized agent of the owner responsible for the maintenance of the plumbing systems in the building who knowingly permits a violation to remain uncorrected after the expiration of time set by the Director shall, upon conviction thereof by the court, be required to pay a fine of not more than $100 for each violation. Each day of failure to comply with the requirements of the ordinance, after the specified time provided under 5.1, shall constitute a separate violation.

APPENDIX A—PARTIAL LIST OF PLUMBING HAZARDS

Fixtures With Direct Connections

Description

Air conditioning, air washer
Air conditioning, chilled water
Air conditioning, condenser water
Air line
Aspirator, laboratory
Aspirator, medical
Aspirator, weedicide and fertilizer sprayer
Autoclave and sterilizer
Auxiliary system, industrial
Auxiliary system, surface water
Auxiliary system, unapproved well supply
Boiler system
Chemical feeder, pot-type
Chlorinator
Coffee urn
Cooling system
Dishwasher
Fire standpipe or sprinkler system
Fountain, ornamental
Hydraulic equipment
Laboratory equipment
Lubrication, pump bearings
Photostat equipment
Plumber's friend, pneumatic
Pump, pneumatic ejector
Pump, prime line
Pump, water operated ejector
Sewer, sanitary
Sewer, storm
Swimming pool

Fixtures With Submerged Inlets

Description

Baptismal fount
Bathtub
Bedpan washer, flushing rim
Bidet
Brine tank
Cooling tower
Cuspidor
Drinking fountain
Floor drain, flushing rim

Garbage can washer
Ice maker
Laboratory sink, serrated nozzle
Laundry machine
Lavatory
Lawn sprinkler system
Photo laboratory sink
Sewer flushing manhole
Slop sink, flushing rim
Slop sink, threaded supply
Steam table
Urinal, siphon jet blowout
Vegetable peeler
Water closet, flush tank, ball cock
Water closet, flush valve, siphon jet

APPENDIX B—ILLUSTRATIONS OF BACKSIPHONAGE

The following pages illustrate typical plumbing installations where backsiphonage is possible.

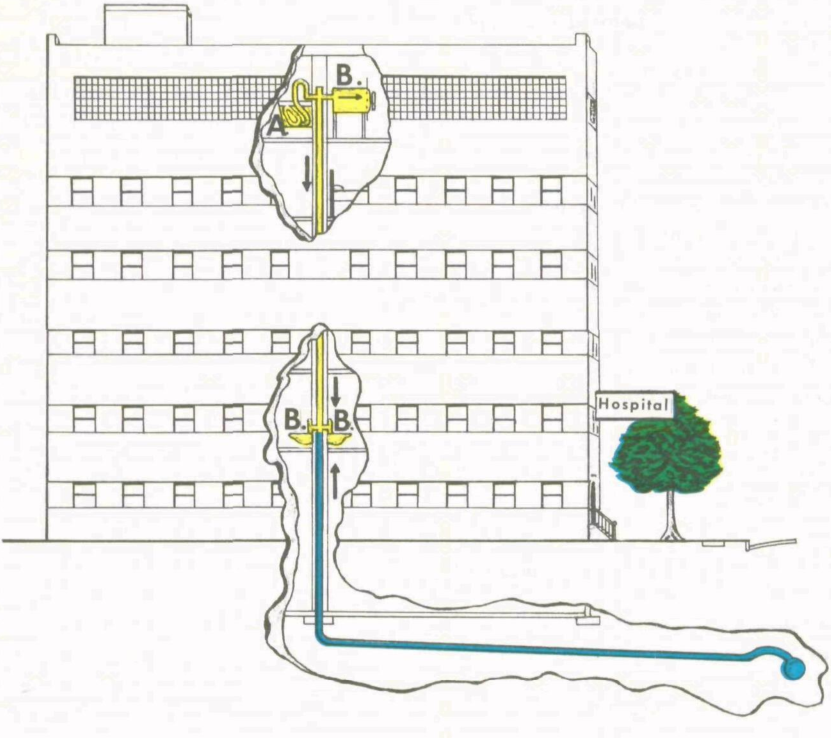

FIGURE 21. Backsiphonage—case 1.

Backsiphonage—Case 1 (fig. 21)

A. *Contact Point:* A rubber hose is submerged in a bedpan wash sink.

B. *Causes of Reversed Flow:* (1) A sterilizer connected to the water supply is allowed to cool without opening the air vent. As it cools, the pressure within the sealed sterilizer drops below atmospheric producing a vacuum which draws the polluted water into the sterilizer contaminating its contents. (2) The flushing of several flush valve toilets on a lower floor which are connected to an undersized water service line reduces the pressure at the water closets to atmospheric producing a reversal of the flow.

C. *Suggested Correction:* The water connection at the bedpan wash sink and the sterilizer should be provided with properly installed backflow preventers.

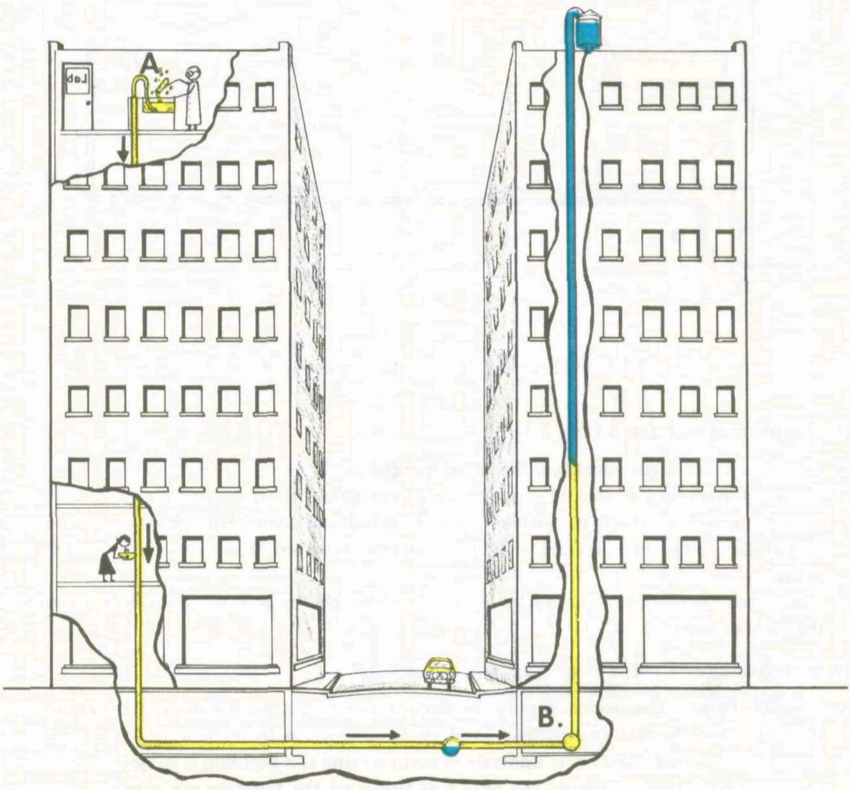

FIGURE 22. Backsiphonage–case 2.

Backsiphonage–Case 2 (fig. 22)

A. *Contact Point:* A rubber hose is submerged in a laboratory sink.

B. *Cause of Reversed Flow:* Two opposite multistory buildings are connected to the same water main, which often lacks adequate pressure. The building on the right has installed a booster pump. When the pressure is inadequate in the main, the building booster pump starts pumping, producing a negative pressure in the main and causing a reversal of flow in the opposite building.

C. *Suggested Correction:* The laboratory sink water outlet should be provided with a vacuum breaker. The water service line to the booster pump should be equipped with a device to cut off the pump when pressure approaches a negative head or vacuum.

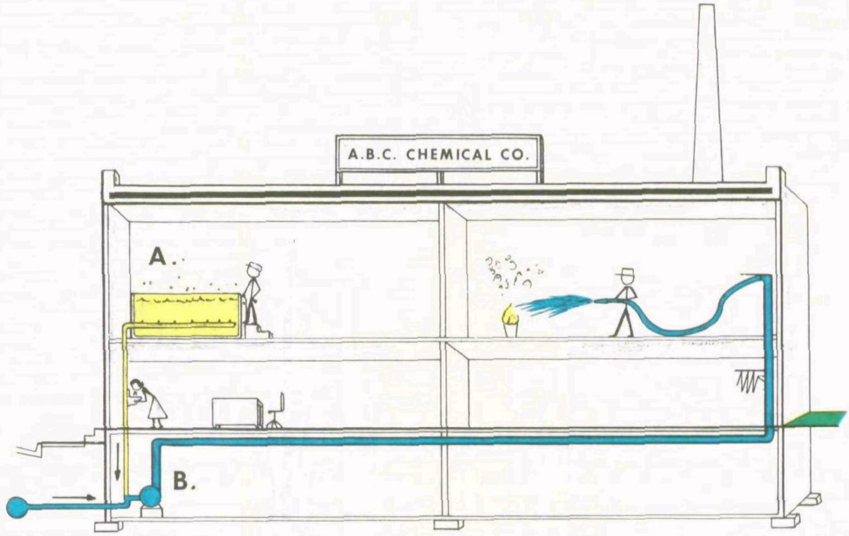

FIGURE 23. Backsiphonage–case 3.

Backsiphonage–Case 3 (fig. 23)

A. *Contact Point:* A chemical tank has a submerged inlet.

B. *Cause of Reversed Flow:* The plant fire pump draws suction directly from the city water supply line which is insufficient to serve normal plant requirements and a major fire at the same time. During a fire emergency, reversed flow may occur within the plant.

C. *Suggested Correction:* The water service to the chemical tank should be provided through an airgap.

Backsiphonage–Case 4 (fig. 24)

A. *Contact Point:* The water supply to the dishwasher is not protected by a vacuum breaker. Also, the dishwasher has a solid waste connection to the sewer.

B. *Cause of Reversed Flow:* The undersized main serving the building is subject to reduced pressures, and therefore only the first two floors of the building are supplied directly with city pressure. The upper floors are served from a booster pump drawing suction directly from the water service line. During periods of low city pressure, the booster pump suction creates negative pressures in the low system, thereby reversing the flow.

C. *Suggested Correction:* The dishwasher hot and cold water should be supplied through an airgap and the waste from the dishwasher should discharge through an indirect waste. The booster pump should be equipped with a low-pressure cutoff device.

Backsiphonage–Case 5 (fig. 25)

A. *Contact Point:* The gasoline storage tank is maintained full and under pressure by means of a direct connection to the city water distribution system.

B. *Cause of Reversed Flow:* Gasoline may enter the distribution system by gravity or by siphonage in the event of a leak or break in the water main.

C. *Suggested Correction:* A reduced pressure principle backflow preventer should be installed in the line to the gasoline storage tank or a surge tank and pump should be provided in that line.

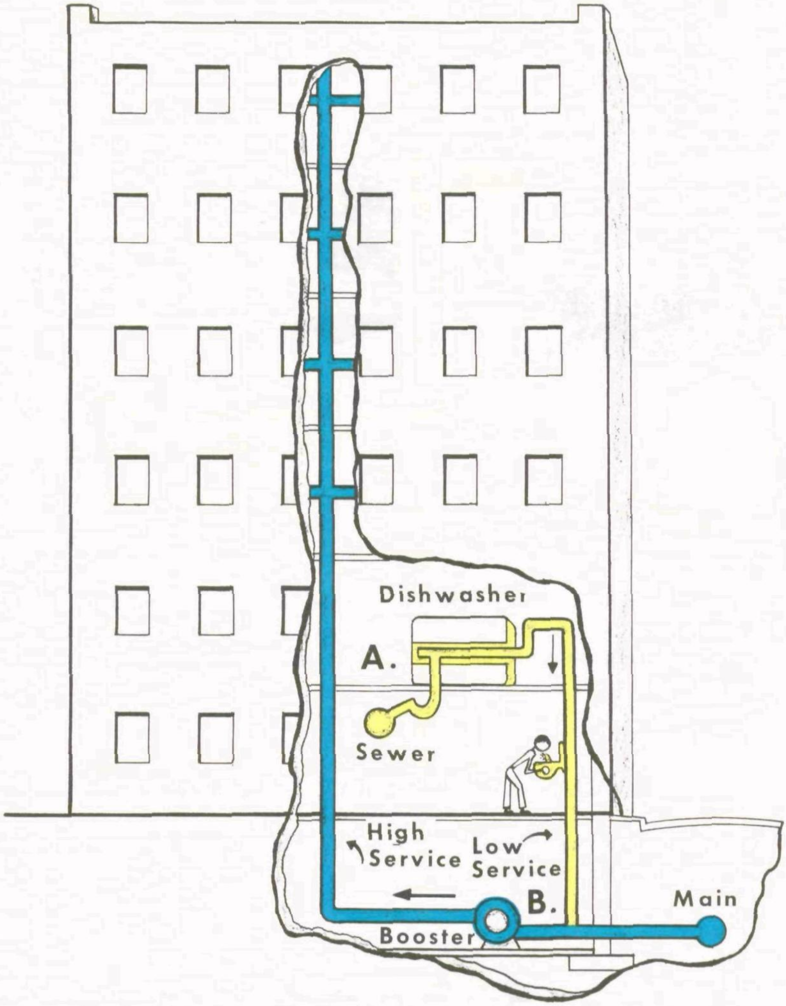

FIGURE 24. Backsiphonage—case 4.

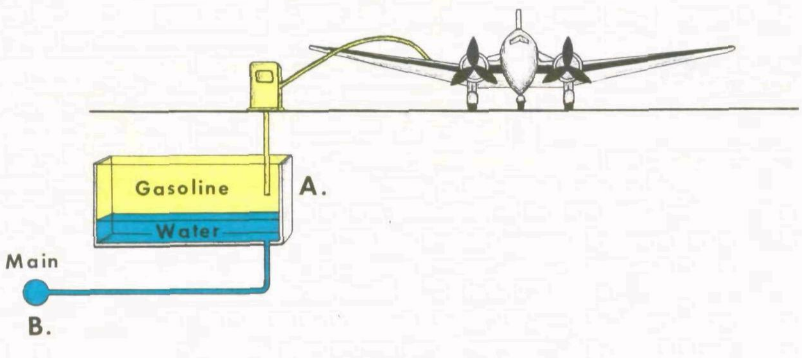

FIGURE 25. Backsiphonage—case 5.

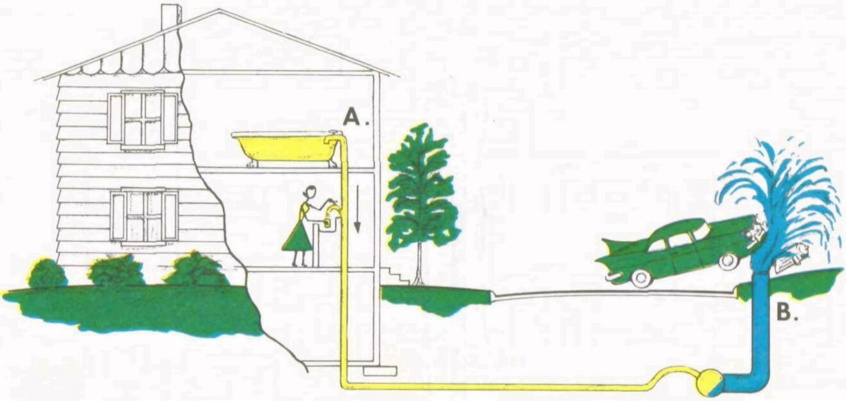

FIGURE 26. Backsiphonage–case 6.

Backsiphonage–Case 6 (fig. 26)

A. *Contact Point:* There is a submerged inlet in the second floor bathtub.
B. *Cause of Reversed Flow:* An automobile breaks a nearby fire hydrant causing a rush of water and a negative pressure in the service line to the house, sucking dirty water out of the bathtub.
C. *Suggested Correction:* The hot and cold water inlets to the bathtub should be above the rim of the tub.

APPENDIX C–ILLUSTRATIONS OF BACKFLOW

The following pages present illustrations of typical plumbing installations where backflow resulting from backpressure is possible.

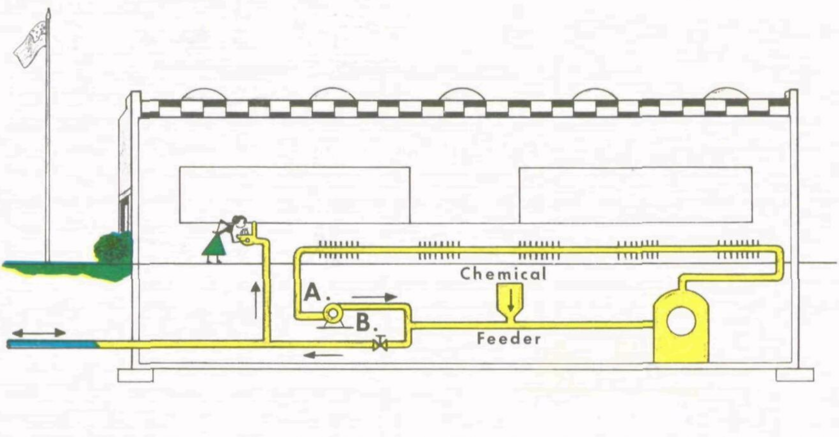

FIGURE 27. Backflow–case 1.

Backflow—Case 1 (fig. 27)

A. *Contact Point:* A direct connection from the city supply to the boiler exists as a safety measure and for filling the system. The boiler water system is chemically treated for scale prevention and corrosion control.

B. *Cause of Reversed Flow:* The boiler water recirculation pump discharge pressure or backpressure from the boiler exceeds the city water pressure and the chemically treated water is pumped into the domestic system through an open or leaky valve.

C. *Suggested Correction:* As minimum protection two check valves in series should be provided in the makeup waterline to the boiler system. An airgap separation or reduced pressure principle backflow preventer is better.

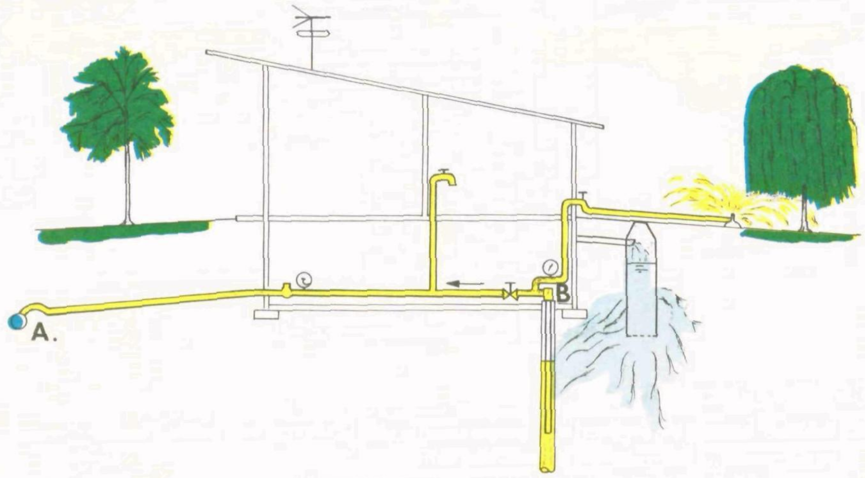

FIGURE 28. Backflow—case 2.

Backflow—Case 2 (fig. 28)

A. *Contact Point:* Sewage seeping from a residential cesspool pollutes the private well which is used for lawn sprinkling. The domestic water system, which is served from a city main, is connected to the well supply by means of a valve. The purpose of the connection may be to prime the well supply for emergency domestic use.

B. *Cause of Reversed Flow:* During periods of low city water pressure, possibly when lawn sprinkling is at its peak, the well pump discharge pressure exceeds that of the city main and well water is pumped into the city supply through an open or leaky valve.

C. *Suggested Correction:* The connection between the well water and city water should be broken.

Backflow—Case 3 (fig. 29)

A. *Contact Point:* A valve connection exists between the potable and the nonpotable systems aboard the ship.

B. *Cause of Reversed Flow:* While the ship is connected to the city water supply system for the purpose of taking on water for the potable system, the valve between the potable and nonpotable systems is opened, permitting contaminated water to be pumped into the municipal supply.

C. *Suggested Correction:* Each pier water outlet should be protected against backflow. The main water service to the pier should also be protected against backflow by an airgap or reduced pressure principle backflow preventer.

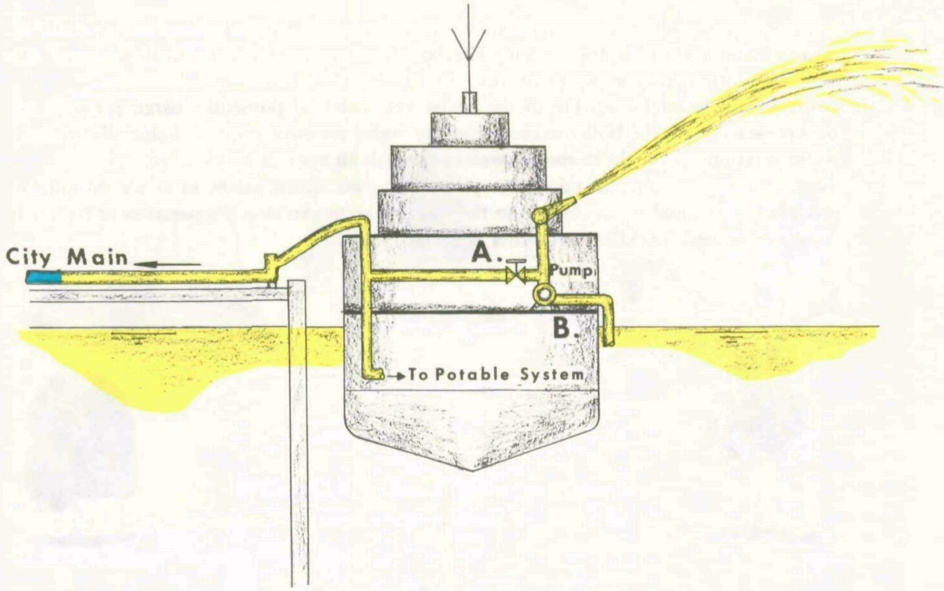

FIGURE 29. Backflow–case 3.

Backflow–Case 4 (fig. 30)

A. *Contact Point:* A single-valved connection exists between the public, potable water supply and the fire-sprinkler system of a mill.

B. *Cause of Reversed Flow:* The sprinkler system is normally supplied from a nearby lake through a high-pressure pump. About the lake are large numbers of overflowing septic tanks. When the valve is left open, contaminated lake water can be pumped to the public supply.

C. *Suggested Correction:* The potable water supply to the fire system should be through an airgap or a reduced pressure principle backflow preventer should be used.

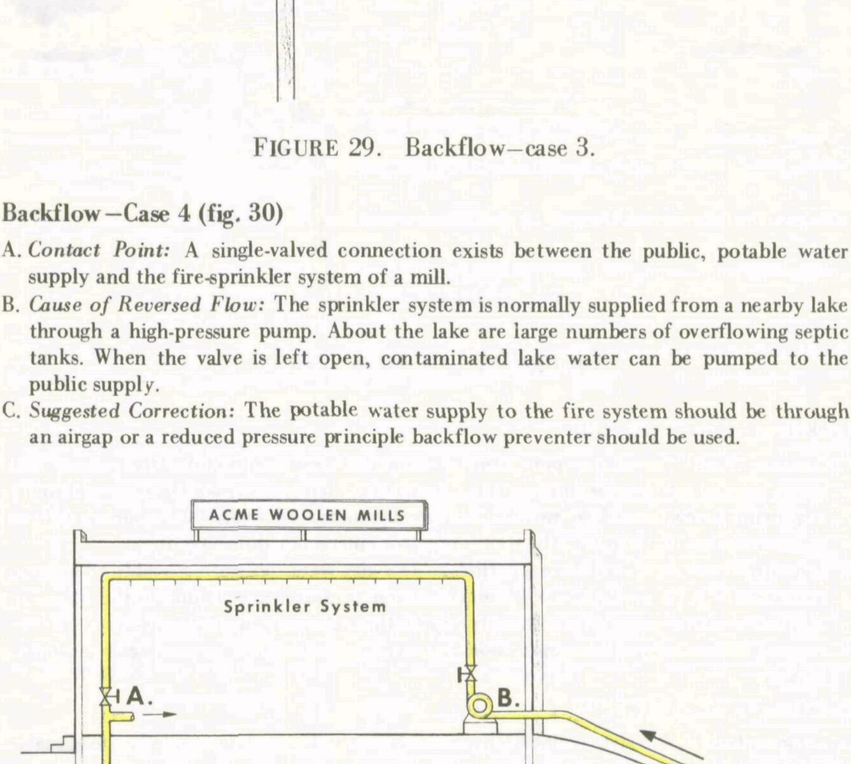

FIGURE 30. Backflow–case 4.

APPENDIX D–ILLUSTRATIONS OF AIRGAPS

The following illustrations describe methods of providing an airgap discharge to a waste line which may be occasionally or continuously subject to backpressure.

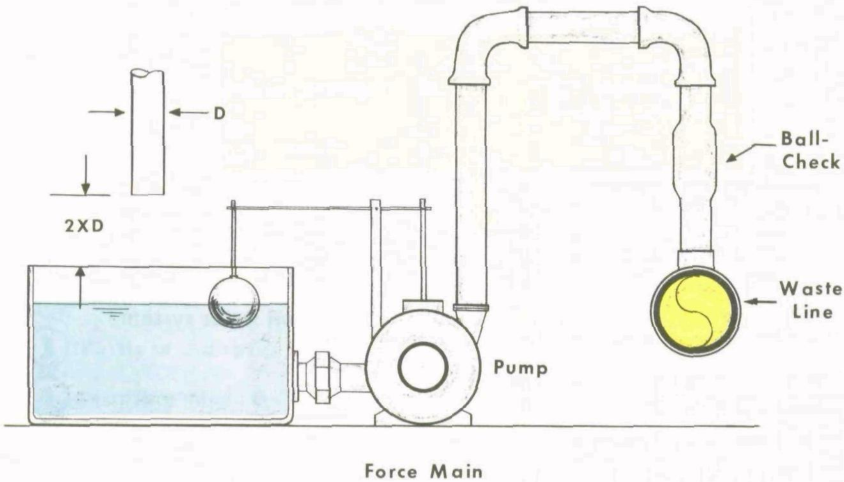

FIGURE 31. Airgap to sewer subject to backpressure–force main.

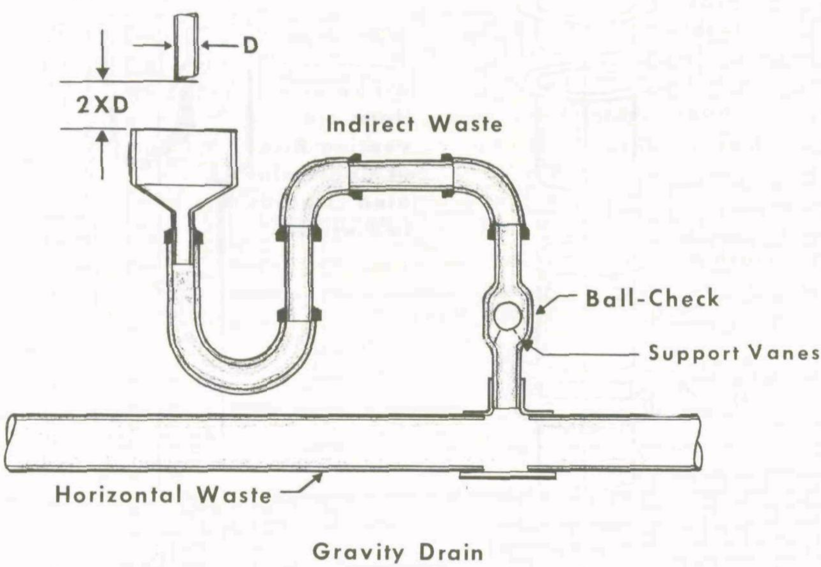

FIGURE 32. Airgap to sewer subject to backpressure–gravity drain.

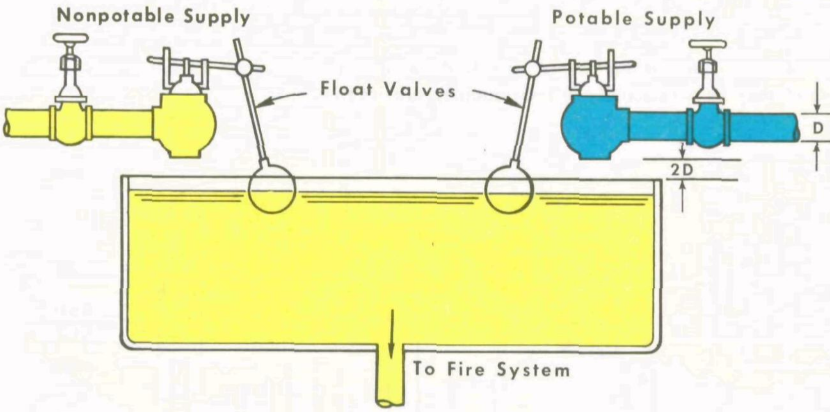

FIGURE 33. Fire system makeup tank for a dual water system.

APPENDIX E—ILLUSTRATIONS OF VACUUM BREAKERS

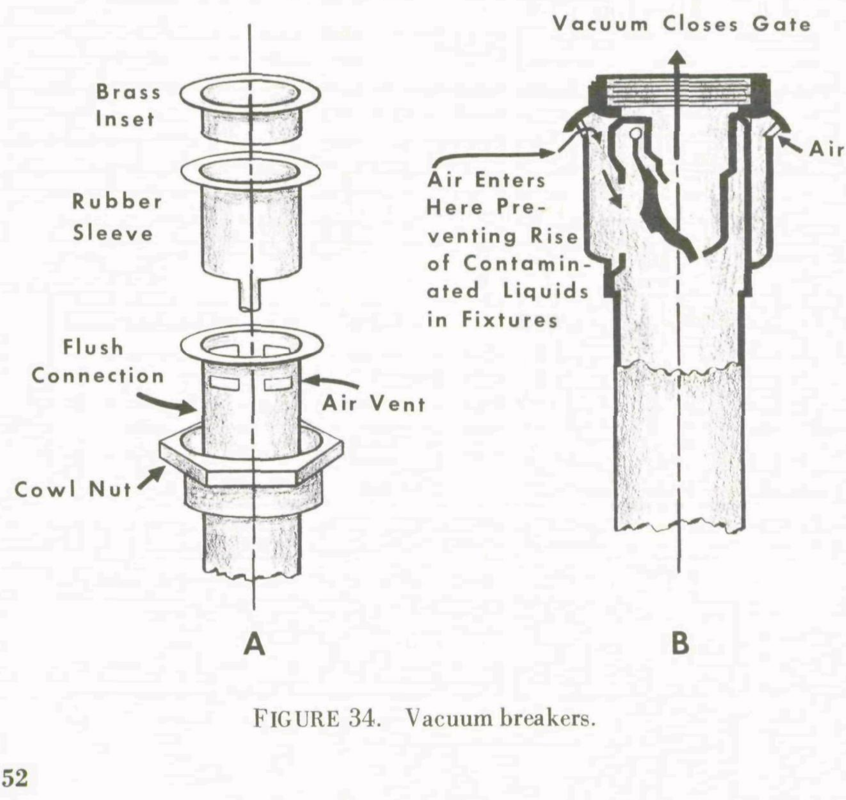

FIGURE 34. Vacuum breakers.

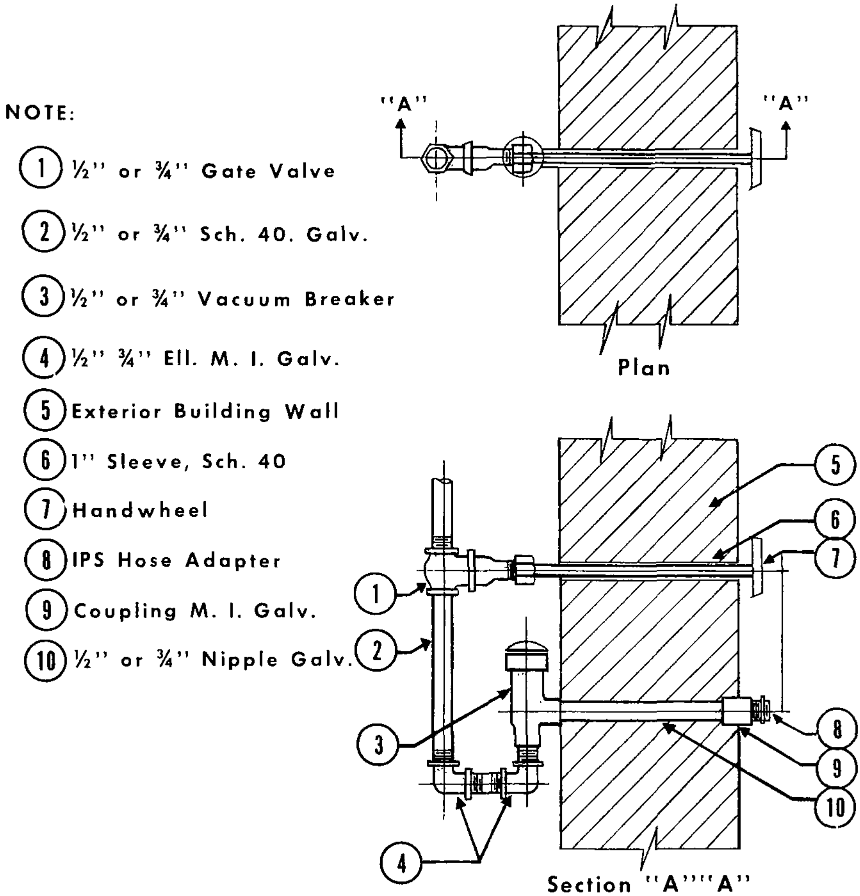

FIGURE 35. Vacuum breaker arrangement for an outside hose hydrant. (By permission of Mr. Gustave J. Angele Sr., P.E. Formerly Plant Sanitary Engineer, Union Carbide Nuclear Division, Oak Ridge, Tenn.)

APPENDIX F—GLOSSARY

Airgap

The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture, or other device and the flood-level rim of the receptacle.

Backflow

The flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable supply of water from any source or sources other than its intended source. Backsiphonage is one type of backflow.

Backflow Connection

Any arrangement whereby backflow can occur.

Backflow Preventer

A device or means to prevent backflow.

Backflow Preventer, Reduced Pressure Principle Type

An assembly of differential valves and check valves including an automatically opened spillage port to the atmosphere.

Backsiphonage

Backflow resulting from negative pressures in the distributing pipes of a potable water supply.

Cross-Connection

Any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water, and the other, water of unknown or questionable safety, or steam, gases, or chemicals, whereby there may be a flow from one system to the other. No physical cross-connection should be permitted between public or private water distribution systems containing potable water and any other system containing water of questionable quality or containing contaminating or polluting substances.

Effective Opening

The minimum cross-sectional area at the point of water supply discharge, measured or expressed in terms of (1) diameter of a circle, or (2) if the opening is not circular, the diameter of a circle of equivalent cross-sectional area.

Flood-Level Rim

The edge of the receptacle from which water overflows.

Flushometer Valve

A device which discharges a predetermined quantity of water to fixtures for flushing purposes and is actuated by direct water pressure.

Free Water Surface

A water surface that is at atmospheric pressure.

Frostproof Closet

A hopper with no water in the bowl and with the trap and water supply control valve located below frost line.

Indirect Waste Pipe

A drain pipe used to convey liquid wastes that does not connect directly with the drainage system, but which discharges into the drainage system through an airbreak into a vented trap or a properly vented and trapped fixture, receptacle, or interceptor.

Plumbing

The practice, materials, and fixtures used in the installation, maintenance, extension, and alteration of all piping, fixtures, appliances, and appurtenances in connection with any of the following: sanitary drainage or storm drainage facilities, the venting system and the public or private water-supply systems, within or adjacent to any building, structure, or conveyance; also the practice and materials used in the installation, maintenance, extension, or alteration of storm water, liquid waste, or sewerage, and water-supply systems of any premises to their connection with any point of public disposal or other acceptable terminal.

Potable Water

Water free from impurities present in amounts sufficient to cause disease or harmful physiological effects. Its bacteriological and chemical quality shall conform to the requirements of the Public Health Service Drinking Water Standards or the regulation of the public health authority having jurisdiction.

Vacuum

Any absolute pressure less than that exerted by the atmosphere.

Vacuum Breaker

A device that permits air into a water supply distribution line to prevent backsiphonage.

Water Outlet

A discharge opening through which water is supplied to a fixture, into the atmosphere (except into an open tank which is part of the water supply system), to a boiler or heating system, to any devices or equipment requiring water to operate but which are not part of the plumbing system.

Water Supply System

The water service pipe, the water-distributing pipes, and the necessary connecting pipes, fittings, control valves, and all appurtenances in or adjacent to the building or premises. The water supply system is part of the plumbing system.

APPENDIX G—BIBLIOGRAPHY

A Revision of The National Plumbing Code, ASA A40.8-1955, Report of the Public Health Service Technical Committee on Plumbing Standards. Sept. 15, 1962, Public Health Service, Washington 25, D.C.

Accepted Procedure and Practice in Cross-Connection Control, Pacific Northwest Section, American Water Works Association, Oct. 1971.

Angele, Gustave J., *Cross-Connection and Backflow Prevention,* American Water Works Association. Supplementary Reading Library Series - No. S106, New York 10016.

Control and Elimination of Cross-Connections, Panel Discussion, *Journal American Water Works Association,* Vol. 50, No. 1, 1960.

Cross-Connection Complications, *The Capital's Health,* Vol. II, No. 9, Dec. 1953, D.C. Dept. of Public Health, Washington, D.C.

Dawson, F. M., and Kalinske, A. A., *Report on Cross-Connections and Backsiphonage Research,* Technical Bulletin No. 1, National Association of Plumbing, Heating, Cooling Contractors, Washington, D.C.

How To Prevent Industrial Cross-Connection Dangers, *Water Works Engineering,* Feb. 1962.

Manual of Cross-Connection Control, Foundation for Cross-Connection Control Research, University of Southern California, Los Angeles, Calif. 90007, Mar. 1969.

Regulations Relating To Cross-Connections, except from the California Administrative Code, Title 17, Public Health, 1956.

Springer, E. K., and Reynolds, K. C., *Definitions and Specifications of Double Check Valve Assemblies and Reduced Pressure Principle Backflow Prevention Devices,* University of Southern California, School of Engineering Rept. 48-101, Jan. 30, 1959.

Taylor, F. B., and Skodje, M. T., *Cross-Connections, A Hazard in All Buildings, Modern Sanitation and Building Maintenance,* Vol. 14, No. 8, Aug. 1962.

Use of Backflow Preventers for Cross-Connection Control, Joint Committee Report, *Journal American Water Works Association,* Vol. 50, No. 12, Dec. 1958.

Van Meter, R. O., Backflow Prevention Hardware, *Water and Wastes Engineering,* Pt. 1, Sept. 1970; Pt. 2, Oct. 1970.

APPENDIX H

CROSS-CONNECTION SURVEY FORM

Place: ______________________________ Date: ____________

Location: ______________________ Investigator(s): ____________

Building Representative(s) and Title(s):

____

____

Water Source(s): ______________________________

____

____

Piping System(s): _____________________________

____

____

Points of Interconnection: _______________________

____

____

____

____

Special Equipment Supplied with Water & Source:

____

____

____

Remarks or Recommendations: ____________________

____

____

____

____

____

NOTE: Attach sketches of cross-connections found where necessary for clarity of description. Attach additional sheets for room by room survey under headings

Room Number | *Description of Cross-Connection(s)*

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