A PRACTICLE CONCEPT OF PLUMBING CROSS-CONNECTIONS

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

James Ruiter

1948

A Practicle Concept of Plumbing Cross-Connections

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

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Bachelor of Science

June 1948

6/11/48
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PRACTICLE CONCEPT OF CROSS CONNECTIONS

The purpose of this report or thesis is to put this subject to the people in a form that can be easily understood. This report for that reason is written for the plumber, the janitor, owners of buildings and plumbing inspectors. The majority of reports that have been written on the subject of cross connections have been in such a technical form, that it takes a hydraulic engineer to decipher them. Yes it is quite necessary for a person to understand a few of the basic principles of hydraulics to read and understand this report, but in the pages to follow, they will be explained in words of the average citizen.

The evils of cross connections must be eliminated. If this subject can be so presented that the average citizen realizes the possibility and dangers of cross connections it will not be difficult to have plumbing supervisors enforce regulations regarding cross connections.

During the past 50 years, a great decrease in the number and extent of water-borne epidemics have been accomlished. This is mainly due to the improvement of the quality of water supplies. It has taken many years and at the cost of millions of dollars to furnish you with this safer water supply. In the fight of reducing the water-borne epidemics, man has the advantage that the typhoid germ is relatively easy to kill. However, other types of water-borne disease germs are not so easily eliminated, this is especially true of the different types

of dysentery producing bacteria. And it is therefore unfortunate that the supervision of water supply, alone doesn't end our fight of these epidemics. Therefore, we should not be lulled into the false sence of security by past general improvements in our water supplies. Lack of vigilance in safe guarding public water supplies takes its toll of human lives and suffering, to say nothing of the extensive economic losses to the community affected.

Unfortunately, as a result of the general decreasing typhoid fever rate in the United States, there has arisen the false impression, in the minds of the general public and to a lesser degree among health and water works officials, that water-borne epidemics are no longer to be feared as they were in the past. With the construction of the modern water purification plants, there has developed among public officials a feeling that vigilance can be relaxed in matters pertaining to pollution of the source of supply and supervision over the health aspects of the water works systems.

Before any of us get the impression that this, faulse safety, is easy to talk about, but no concrete evidence can be shown, let us site a few examples of what has happened.

In the Engineer News Record, May 1930 this article appears:

Leaky Cross-Connection Kills 15

No news article written in Bloomington, Illinois, but 15 died of typhoid fever-If it had been loss due to cyclone, Mexican Raid, or race riot, the papers

would have had it in head lines!

Unfortunately there are still some engineers, especially those in the employ of the fire insurance companys, who see no harm in cross connections, or who put property risks above life. Some day sanitarians will ask organized labor to help rid the nation, under drastic penalties.

The historic widespread epidemic of dysentery which occurred in Detroit, Michigan,*in February 1926, which resulted in a least 4500 cases, should be mentioned here. This epidemic, is the most extensive outbreak of dysentary on record. Yet the city of Detroit has the most modern and best rapid sand filter plant for water purification, so it is quite apparent this outbreak was due to laxity in control.

And the shinning example, of 1933 in Chicago during the Worlds Fair. A dysentery epidemic was traced directly to faulty hotel plumbing, and this, more than any other single incident, arroused the interest of health authorities on the health menace of plumbing.

Examples such as the typhoid epidemic at Hanover, Germany in 1929, there were over 2400 cases reported; at Lyon, France in 1929 there were over 2100 cases. Of which the majority were caused by cross connections of one type or another!

The following graph appeared in the book, "The

* Wolman-Gorman, Water-Borne Outbreaks

Significance of Waterborne Typhoid fever outbreaks" by Wolman & Gorman. This may give a very good indication of where most of the cases of typhoid fever and dysentery originate.

Miscellaneous	1.7 %
Contamination of Reservoirs	1.4 %
Untreated Surface Supplies	2.3 %
Contamination in Distribution Systems	9.2 %
Contamination in Collection Systems	14.7 %
Inadequate Control Over Purification Methods	54.1 %
Untreated Ground Water Supplies	16.6 %

Any person who has fallen into false idea of safety and lack of vigilance should again be reminded, that one who holds such a viewpoint should heed the facts of the few examples just stated!

Now that we are quite sure cross connections do exist, and they do, even today in our modern world; just what is a cross connection? Cross connections have been defined in many different ways, but all their meanings are the same. Can a definition of a cross connection be pinned

down and a general statement be made? Are all cross connections based upon one principle? No, they can't and that seems to be one of the main difficulties in eliminating them. Cross connections may exist and no tangeable trouble or disaster arise from them. But when ever such a connection does exist the danger, or possible source of trouble is there. It has often been said that an ounce of prevention is worth a pound of cure, and in this case that statement is no exception. Why spend millions of dollars to make our water supplies safe and for the sake of a three dollar check valve, or a days labor, should we jeopardize the health of each and every one of us? To a business man, housewife, or property owner this does not make sence. If a business man were to invest, say $1000 in some sort of transaction, and at a later date it would take $3.00 to insure him a greater profit on his investment, he would not give the $3.00 a second thought, but would readily spend it. But yet today, with even higher profits or losses, sickness and death, at stake, the general public will hesitate to spend that three dollars to eliminate a cross connection possibility.

In order for a cross connection to cause any damage, one of two conditions must be statisfied. There must be a leak, and or a stoppage. Yes that is pinning it down pretty finely, but I believe this statement can be safely made.

By a leak I mean, a faucet that doesn't close tightly, a check valve that doesn't hold, a crack or flaw in a

contaminated pipe or a valve that has been opened by mistake and left that way, there by being a leak through the valve.

A stoppage consists of a sewer line, waste line or a unsafe water line, that has been stopped or plugged by one of various reasons to numerous to mention. Stoppage can also mean the closing of a valve.

The Wisconsin State Board of Health*has adopted the following definition of cross-connections:

> A cross-connection may be defined as any connection between a safe water supply and unsafe water source through which it is possible to contaminate the safe water supply.

Cross connection may be divided into two groups: (1) Direct cross-connections: A connection in the plumbing system in which the safe and unsafe water supplies are connected directly by means of pipes and valves. (2) Indirect cross-connection: A point in the plumbing system through which a safe water supply could be contaminated by a conceivable and probable change in existing conditions. These changes of conditions will be discussed in a later section of this report!

Are there any laws set up in the State of Michigan, pertaining to cross connections? In the State Plumbing Code, as approved by the State Plumbing Board with the Concurrence of the Advisory Council of Health, June 28, 1935, page 22 section 52, it states:

* Cross Connections in Plumbing and Water-Supply Systems, July 1941, by Wisconsin State Board of Health

A distributing system for a water supply for drinking and domestic purposes shall not be connected with the distributing system of another water supply unless such connection is approved by the health authority having jurisdiction.

In a recently adopted Plumbing Code of the City of Detroit; March 26, 1946; page 10 section 208, it states:

A cross connection or interconnection is any physical connection between a city water supply and any waste pipe, sewer drain, or any private or uncertified water supply. Furthermore, it is any potable water supply outlet which is submerzed or can be submerzed in waste water, and or any other source of contamination.

In section 701.2 pg 36, the above mentioned code goes on to state:

Cross connections or inter-connections between the potable water distribution system and any portion of the waste or soil system, or with fixtures and or devices whose usage may contaminate, pollute or otherwise render unfit for drinking purposes the water used therein, shall be prohibited. Those fixtures or devices, whose proper functioning will not permit of an air gap adequate to prevent back-siphonage, shall be equipped with vacuum breakers and or other safety devices which are acceptable to the Department of Buildings and Safety Engineering.

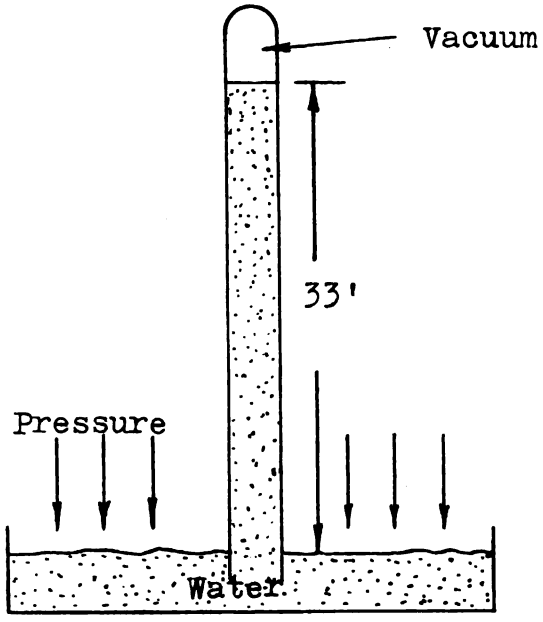
The above codes are enforceable by law, under the penalty of fine and or imprisonment, for the violation thereof.

As was stated in a previous section of this report, cross connections are dangerous at all times, but certain conditions must be satisfied before they are harmful. There must be a leak and or a stoppage, before these conditions are satisfied. We are all to aware, that these conditions are statisfied in every plumbing system, very frequently! It is a commonly known fact that when ever a fluid flows through a conductor, leaks and stoppage occur at any and all times!

Now let us look into a few of the principles of hydraulics that must be understood in order to thoroughly understand the principles and conditions of a cross connection.

Pressure: The earth is surrounded by a layer of air, and is held to the earth by gravitational attraction. The body of air, like all fluids, exerts a pressure determined by its height and density. The density of water being 62.4#/cu' as compaired to that of air of .081#/cu'. The pressure of the air on the earth is called atmospheric pressure and in this locality is equal to 33 feet of water or 29 inches of mercury. The measurement of this pressure can be demonstrated by setting up a barometer. In setting up this apparatus, a long glass tube sealed at one end is completely filled with water or mercury, and than placed in

a vessel as shown.



When ever pressure is spoken of it is either in pounds per square inch or in feet of water. Atmospheric pressure being taken as zero, and any thing below zero is a vacuum. When ever a gage is read, the gage pressure is read as the actual pressure the substance is under, not including atmospheric. In other words absolute pressure is equal, gage pressure plus atmospheric pressure.

Water has a density of 62.4#/cu', therefore the pressure exerted by a column of water one foot high on an area of one square inch is 62.4/144 = .433 lbs. It would take a column of water 2.31 feet high in order to exert a pressure of 1#/ square inch. Or as I remember it approx. 27" of water will exert a pressure of 1#/ sq", regardless of the area of water. That is to say 27" (approx.) of

water in a 4" pipe or a 2" pipe, would exert a pressure of 1#/ sq" on a table surface. Now, knowing this, what is the pressure exerted by atmospheric pressure? It is figured 33"x.433 = 14.29#/ sq". Whenever pressure is expressed in lbs. it is generally understood to mean lbs. per square inch, and it can be converted into feet of water by multiplying by 2.31.

A vacuum is what might be called a negative pressure, or lack of pressure. As in the example used to explain atmospheric pressure, the space in the column above the water surface is a partial vacuum. Vacuums, (pressures below atmospheric pressure, which is called zero), are usually expressed in inches of mercury. As stated before, atmospheric pressure in this locality can sustain approximately 29 inches of mercury, when a perfect vacuum exists at the top of the mercury column. Therefore a perfect vacuum is said to be 29 inches of mercury. Partial vacuums are therefore expressed as 5, 10, 20 inches of mercury. Actually there is no such thing as a perfect vacuum.

A report written in the "Municipal Sanitarian" November 1934, on test run in New Orleans, stated; "Actual and repeated tests have proven to us that every time a water main is shut off a vacuum is created therein which may be anything from 5 or 6 inches of mercury depending upon the topography. Actual experience proved that in many installations it is not even necessary to shut off the

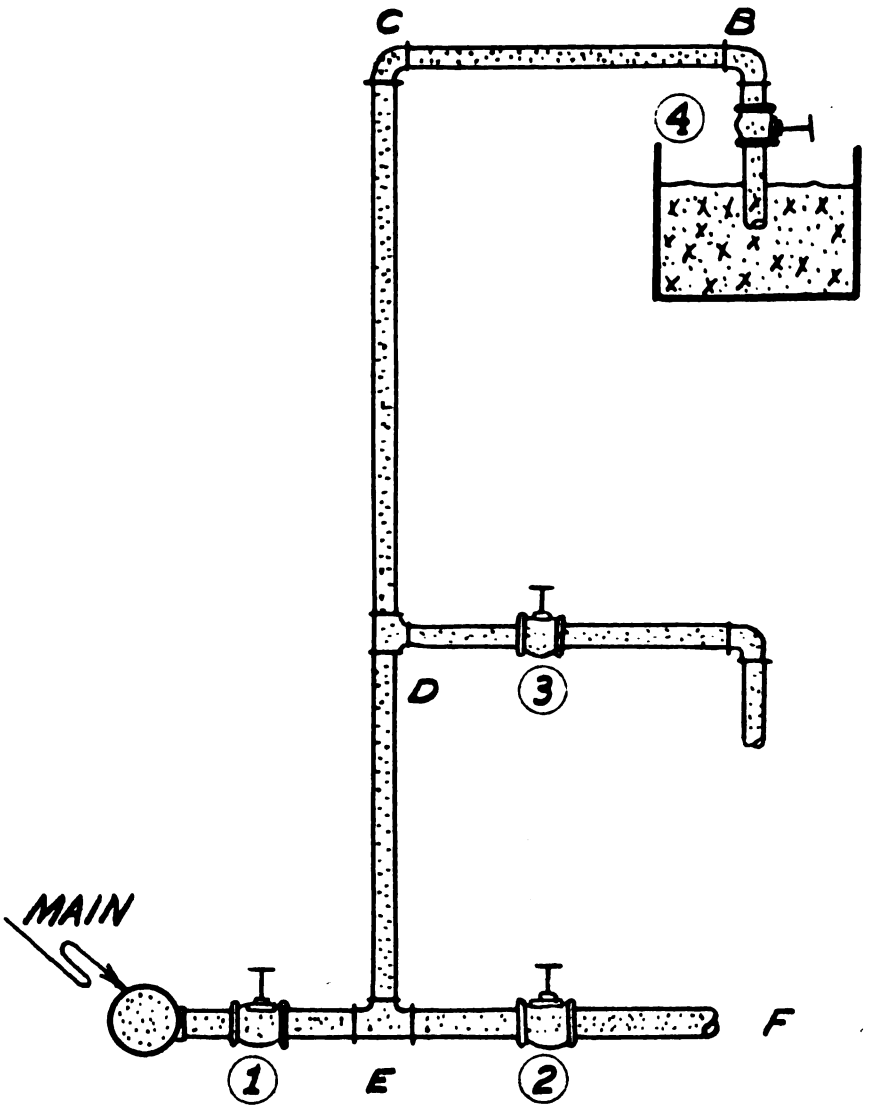
water in order to produce a vacuum on the water supply pipes in a building"!

Siphons, as a phenomina of hydraulics are both useful and detrimental. In sewerage works the term inverted siphon is applied to a portion of a sewer which dips below the hydraulic grade line, to avoid such an abstruction as a railway cut, a subway, or a stream. Siphons are also used in flushing devices, in regular street catch basins, and in intermittent sand filters in sewage disposal plants. All these cases are of the beneficial type of siphon. In the case of cross connections, siphons are detrimental and cause a considerable amount of trouble.

In order for a siphon to exist there must be a short and a long leg. Lets take for example a bucket of water standing on a table, and we want to siphon the water from this bucket to one on the floor. It is necessary first to have a connection between the two, say a flexible hose, a short leg and a long leg must exist. The short leg being the portion of the tube in the bucket on the table and the long leg the one running to the bucket on the floor. Now to start the flow all the air must be expelled from the tube, when this has been accomplished a siphon exists. When the fluid starts to flow through the tube, it will continue until the upper bucket is drained or until air enters the hose and breaks the siphon.

It might be easier to understand, the how and why of a siphon if it is applied to a general skematic drawing of

a water distribution system of a plumbing system. Siphons can and do occur in both up feed and down feed systems. The author has seen cases of where, in a down feed system, a complete office building has depended on one check valve to hold, and prevent siphonage of its distribution system.



SIPHONAGE IN UP FEED PIPE SYSTEM

a. IF VALVE 1 IS CLOSED AND VALVE 2 OR 3 IS OPENED AND VALVE 4 LEAKS OR IS OPENED, WATER FROM TANK WILL ENTER SUPPLY LINE.

b. HEAVY DISCHARGE THROUGH LINE E-F MAY REDUCE PRESSURE SUFFICIENTLY TO CAUSE SIPHONAGE IF VALVE 4 LEAKS OR IS OPENED.

c. SUFFICIENT REDUCTION OF MAIN PRESSURE AND RESULTANT DRAINAGE OF RISER WILL CAUSE SIPHONAGE OF THE TANK.

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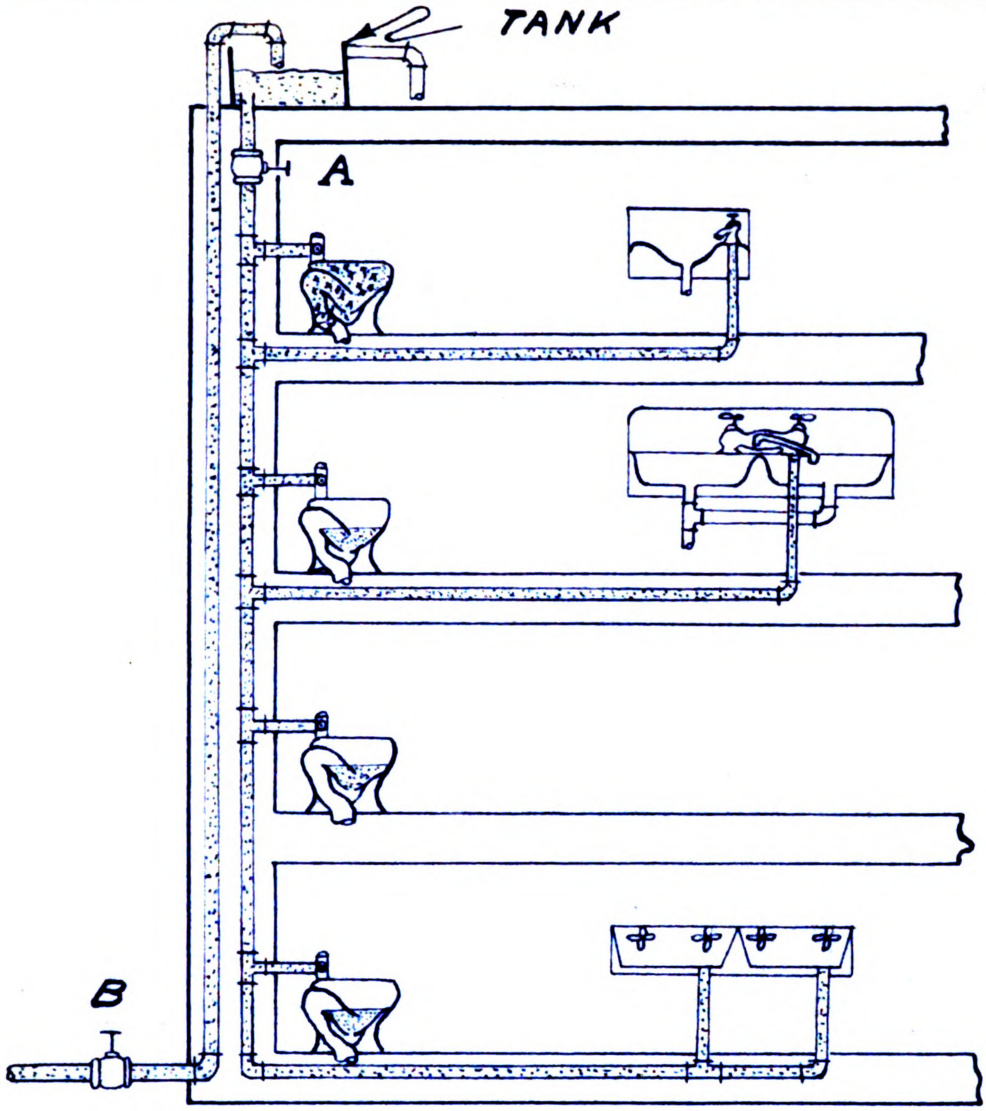


SIPHONAGE IN DOWN FEED SYSTEM

a. CLOSING VALVE "A" AND OPENING ANY FIXTURE BELOW TOP FLOOR WILL BACK-SIPHON CLOSET BOWL ON TOP FLOOR, IF VACUUM BREAKER IS DEFECTIVE.

b. WITH VALVE "A" OPEN, A HEAVY DRAUGHT OF WATER ON LOWER FLOOR MAY CREATE A VACUUM IN UPPER PART OF DOWN FEED RISER, THEREBY SIPHONING CLOSET BOWL ON TOP FLOOR.

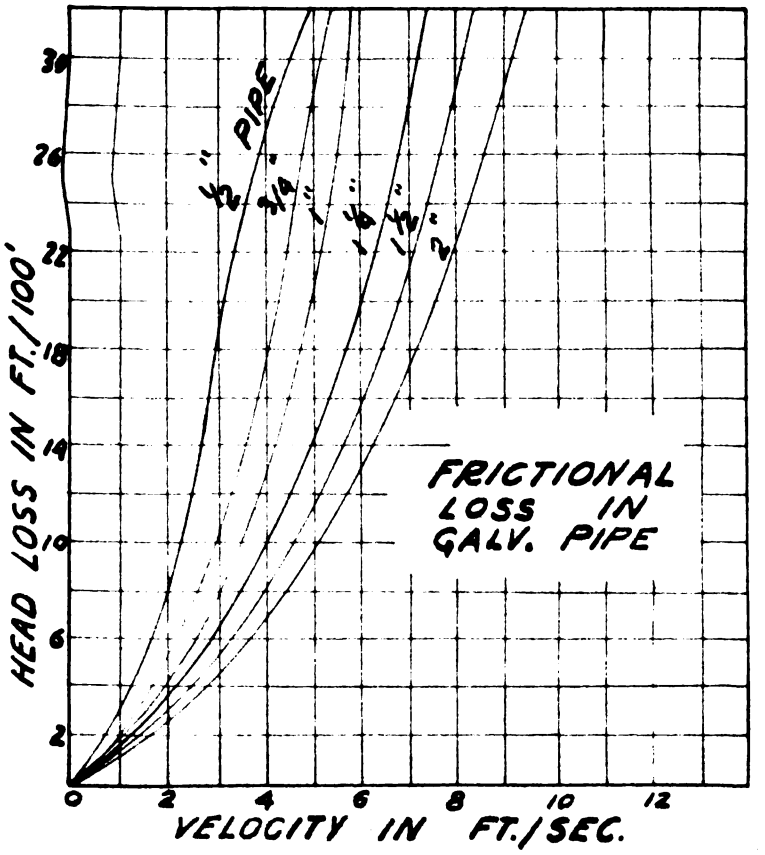
Water or sewage, flowing in a pipe loses pressure, if flowing horizontaly, due to frictional loss. This loss is due to the water particles as they rub against the walls of the pipe and over each other. If in a horizontal pipe the pressure is read at different points, it will be seen that the pressure decreases, according to the length it has flowed, velocity with which it flows, roughness of the pipe, and the diameter of the pipe. On the following page a chart is given, on which pressure loss in gavalnized pipe, can be read directly. The author through direct experiment has recorded, losses of 1" of water over a length of 18' of 2" pipe, and flow through fittings losses as indicated on the following sheet.

The vacuum frequency chart on the following page is from data obtained from 6 buildings in Detroit. This chart is not a general, but a specific, case. To me this chart indicates the wide variation, and possible danger, of pressure in different buildings. Is your home in accordance with Building "C" or Building "B"?

VACUUM FREQUENCY

BUILDING	Nº OF READINGS	FREQUENCY %	LOW READING
A	3582	.013	2 PSI
B	3495	25.0	15" H_g VAC.
C	697	NEGLIGIBLE	24 PSI
D	3854	.24	1" H_g VAC.
E	1944	.0051	2 PSI
F	2570	.015	1 PSI

FOR EXAMPLE; "B" CAN EXPECT A PRESSURE OF LESS THAN 1 PSI, 25 % OF THE TIME, RUNNING AS LOW AS 15" H_g VACUUM. CROSS CONNECTION IN "B" IS FAR MORE DANGEROUS THAN IN "C"



THE GALLONS PER MINUTE WHICH A PIPE WILL DISCHARGE EQUALS .0408 × DIAMETER, IN INCHES, SQUARED × VELOCITY, IN FT. PER SECOND, × 60

FRICTION LOSS IN EQUIVALENT FT OF PIPE

FITTING — SIZE	½"	¾"	1"	1¼" TO 2"	3"
90° ELBOW	5	6	6	8	15
TEE-USED AS ELBOW	7	8	9	11	17
GLOBE VALVE	8	9	10	13	23

Now to summarize a few of the principles of hydraulics, lets list a few conversions that may come in handy to the plumber!

To reduce pounds pressure to feet of head, multiply by 2.31.

To reduce heads in feet to pressure in pounds multiply by .434.

Friction of liquids in pipes increases as the square of the velocity.

Doubling the diameter of a pipe increases its capacity four times.

From the discussion of hydraulics, it leads one to believe there are certain conditions that cause a cross connection to be danger. This is the case, and as stated before there are two types of cross connections. The direct and indirect connection.

Very little if any discussion is necessary for the case of a direct cross connection, because when they exist no conditions have to change in order for them to cause damage and trouble. Direct cross connections are most likely to occur where there is a dual water supply in a building. This is especially true in factory buildings where an unsafe water supply is used for the sprinkling system. A recommend connection is illustrated on the following pages of direct connections. Another example of a direct cross connection is where, to economize, an owner took particular pains to have seperate suction lines, but

a common pump, of two different water supplies, one polluted the other supposedly safe. Another example might be, running a cooling system directly, into a waste line, that is not into an open receptacle. The cooling system being feed by well water, also with tight connection.

The direct cross connection is rather easily understood, but not so with the indirect cross connection. Yes there must be a stoppage and or a leak, but also a change in pressure, siphon, or a vacuum must occure to cause pollution of safe supply. This by no means indicates that indirect cross connections are not dangerous. Because so many conditions must be satisfied, makes them more dangerous than before, they may exist for years, and cause no trouble.

What can cause a change in pressure, in a distributing system?

Water Pressure Failure, are caused by.

a. Breaks in water mains.
b. Improperly designed water piping in houses, excessive frictional loss!
c. Isolated districts where developements have caused reduced pressures.
d. Heavy demands in extended dry periods causing reduced main pressure.
e. Fire pump connections "Hogging" of all the water.
f. Booster Pumps.

g. Connections to heating plants.

h. Air compressor, attached to meter to run it backwards.

i. Back pressure from circulating pumps in air conditioning apparatus.

Any one of these things might happen to cause a change of pressure in your distribution system and make a cross connection dangerous.

It is quite evident that a cross connection is where the water from a polluted supply gets back into the sanitary supply system. First there must be a path for the flow, and than a decrease in pressure. Water as does all fluids, flows from an area of higher pressure to one of lower pressure. And for a cross connection to become active this must be the case. The majority of people are of the opinion that when waste water is put into a lavatory, sink, or toilet, the waste will flow away. This is the case generally, but it is also quite frequent that a stoppage has occured. It is also common practice to expect water to flow out of your faucets when you turn them on, but how often have you turned your faucet on and heard a "Woosh" or air and spurts of water come out? When this happens, one of the above conditions have been satisfied.

Lets now look at a few specific cases of cross connections. The numbers before each example indicate and correspond to the numbers on the drawings, on the following

pages. Not all the examples here given are followed by drawings.

1. As was stated before, where two systems enter a building, polluted and sanitary, there is always the possibility of direct cross connection. In the drawing, it can be seen where the safety of the employees depends upon one check valve to hold. The polluted supply is used for fire prevention while the safe supply is used for drinking purposes. The correct method to hook up a dual system is also shown.
2. These two types of cross connections are quite different from the ordinary ones, but never the less are possibilities of pollution. The well, and sprinkling system, may receive ground run off, and due to a vacuum, siphon or gravity flow, cause pollution of the sanitary water supply.
3. These three cases of cross connections are very common ones, although in recent years the fixture manufactures have remedied these connections. The air gap of 1" is recommended because, it has been found through experiment that water, with sufficient vacuum in the line, can be drawn into the faucet as high as 1".
4. The vacuum breaker shown here is a typical one. It is my opinion that, this device, as well as the open receptical will save more trouble than any

other device used. A vacuum breaker will stop siphon action before it starts, and the flowing of waste into an open receptical rather than a direct connection with a sewage line, will not allow back up of sewage.

5. It seems that the toilet bowl and its mechanism is a great cause of cross connections. Generally water is supplied to toilet bowls either by a flush box or a directly connected valve. It is rather difficult for the water from a bowl to get into the box, except in the case shown. But it has happened, where the water or sewage was siphoned out of the bowl! It has been my experience, to be called to remove a siphon breaker from the flush valve of a toilet tank. Yes it is agreed they do cause a little noise, but it must be remembered, they are put there for a purpose. And to me that purpose is a very sound one, "Safety of our lives."

6. This plate, does not indicate a cross connection, but does show a ease of laxity. This drawing is probably the most common example of unsanitation available. This drawing indicates essencially what happened in the 1933 epidemic in Chicago. There, a leaky sewage line dripped into a soft water tank, that distributed water to the hotel for consumption.

7. Cross connections that exist:

Submerged inlets of all kinds.

Cellar drainers with primer connections.

Combination faucets with one unsafe and one safe water supply.

Dish Washers.

Hydraulic elevators with direct connection to waste line.

Ice box or Refrigerator connections.

Swimming pools.

Cattle drinking basin.

Pump connections.

Water Softeners.

At times it is rather difficult to locate a cross connection, and as far as there being any standard way for finding them, there is none. It is very possible to check valves for leaks and thereby assuring a certain amount of safety, but to locate a cross connection, it takes a considerable amount of practice, and ability to sence a possibility. In the June, 1920 issue, of the Engr. News Record, there appears quite an interesting article on an ingenious way, a cross connection was located, with the use of alkali. This test amounts to, pouring caustic soda into the line under observation. Than putting a spigot in the line any where and pump the alkali water to the spigot. Than at the other end attach a meter. Now when the soda is detected at the spigot, read the meter, and continue to pump.

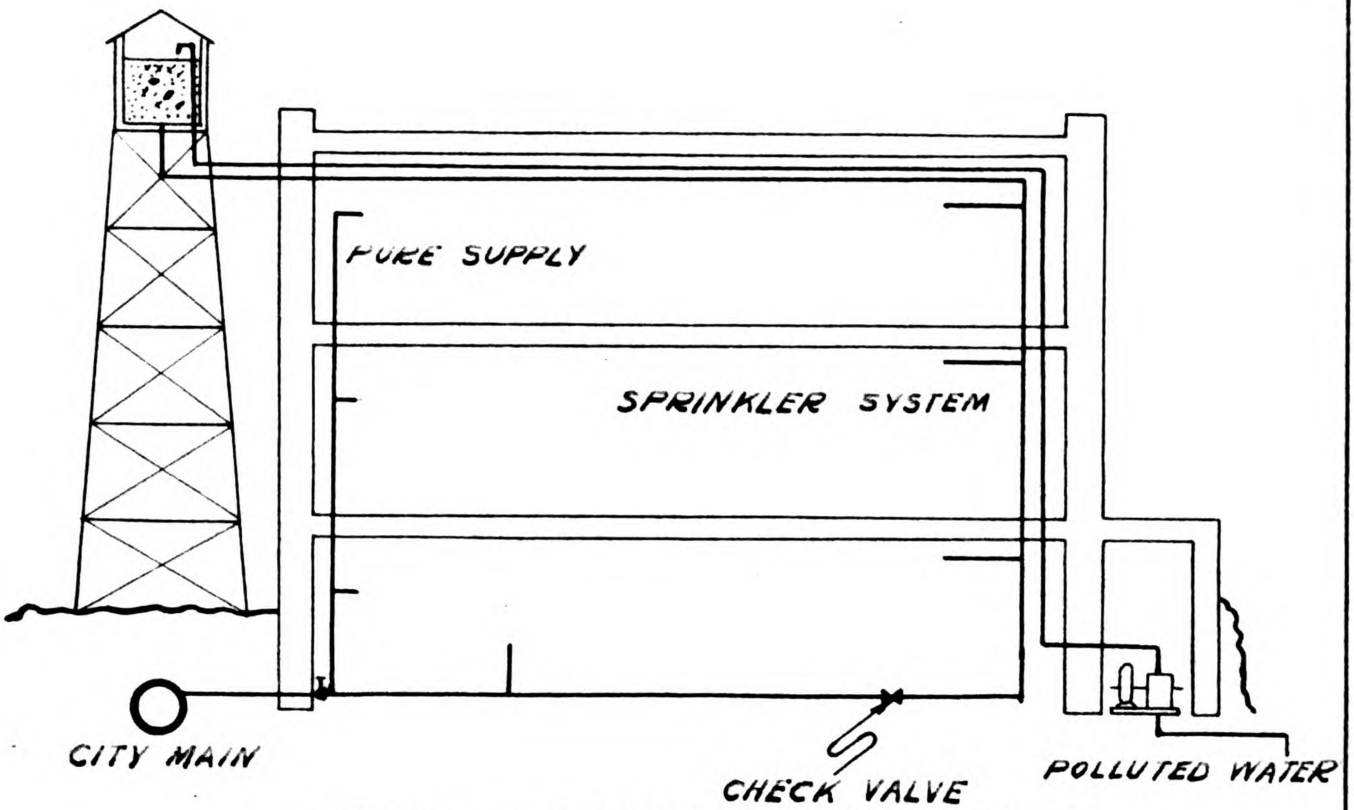
When alkali is detected at the meter read it again. The difference in meter readings will give you the volume of water in the known size pipe, to the cross connection.

In 1943 President Roosevelt appointed a subcommittee on Sanitary Engineering to study and recommend means of preventing back flow into Portable Water systems. Here is a list of their recommendations-

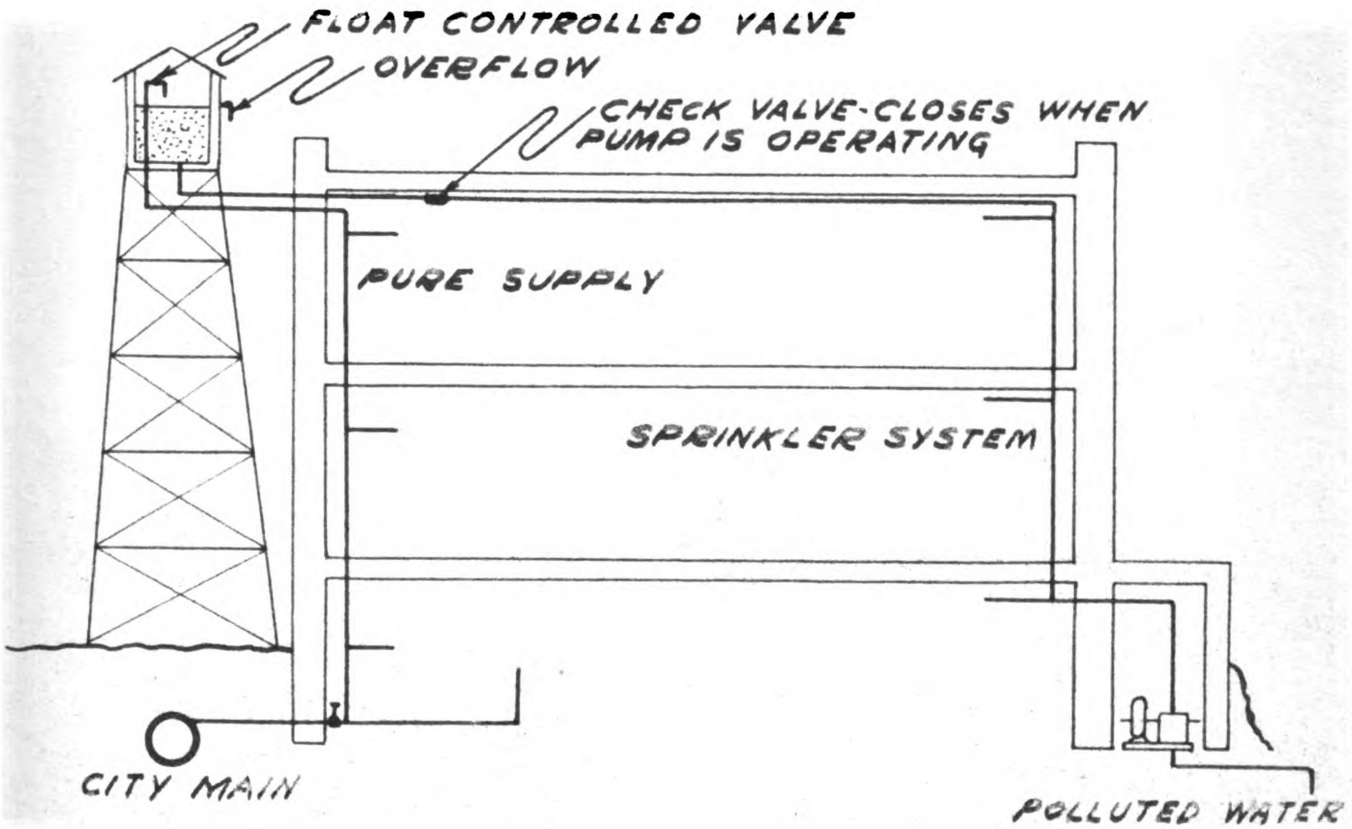
1. Physical Seperation with a safe air gap.
2. Use of vacuum breakers installed on the discharge side of the last separating control valve and so placed that there is no back-pressure when the normal flow ceases.
3. Use of a back-flow preventer which operates under pressure.
4. Use of double check valves of 6" or larger.
5. Use single check valves on 2" to 6".

"To drink water from a recently used water closet, to bathe in the waste liquids discharged from a urinal, to plunge into the diluted contents of a bed pan, to purge a wound with the drainage from an operating table, is worse than disgusting. Such conditions may result from the existence of a plumbing cross-connection. Irrefutable records of tragedies stand ready to testify as to the frequency of occurrence of these revolting dangers to the health of the public."*

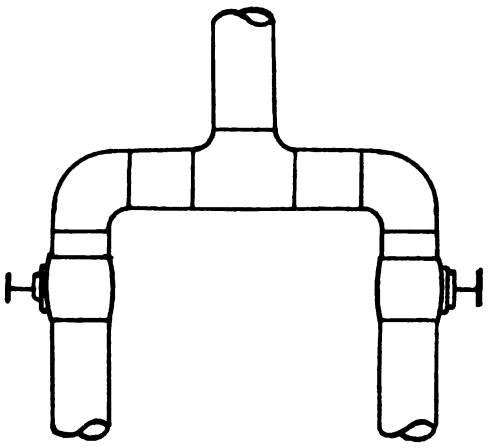
* "What is a Cross-Connection"? Domestic Engineering Vol. 154.



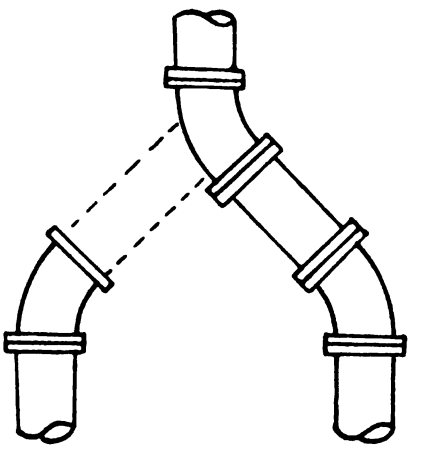
CROSS-CONNECTION; DUAL SUPPLY



SAFE METHOD ; DUAL SUPPLY

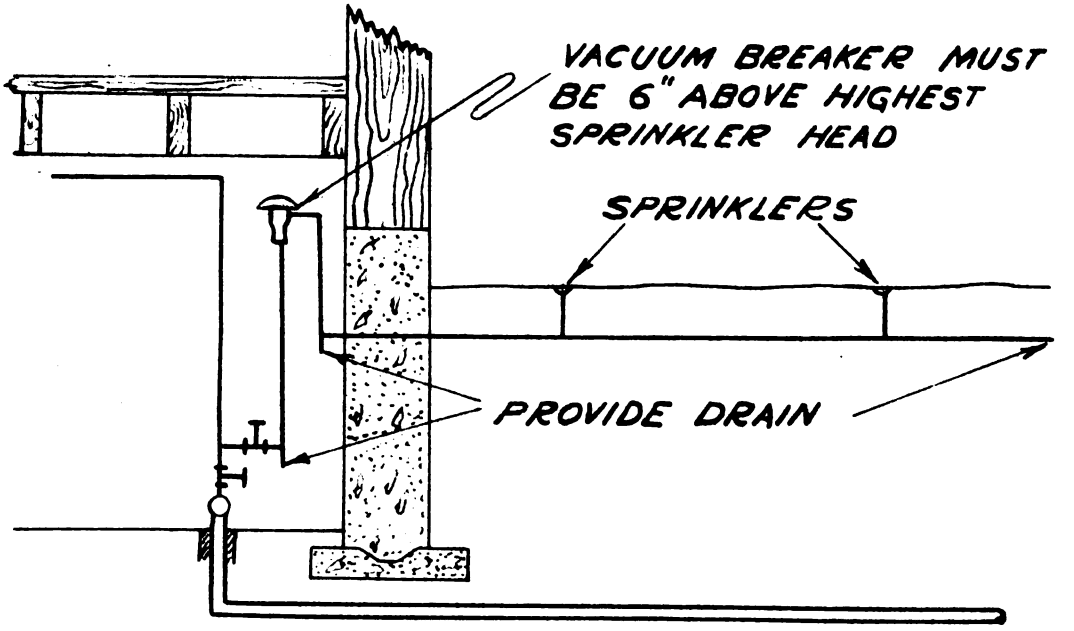


WRONG

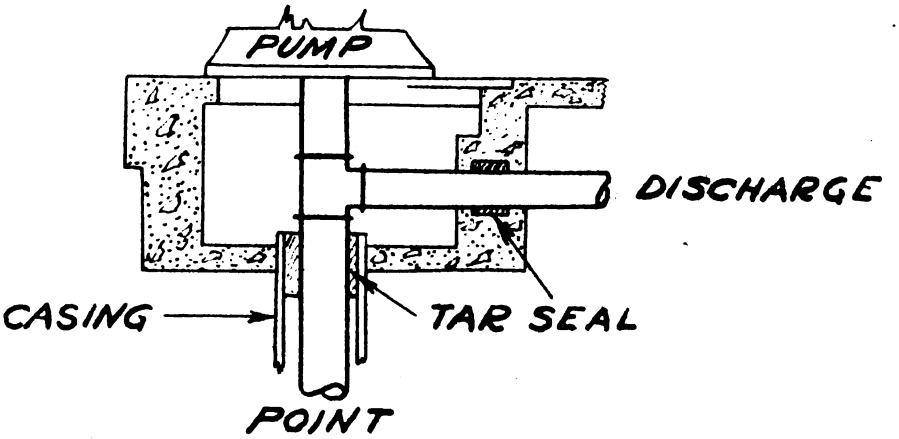


RIGHT

DUAL SUPPLY



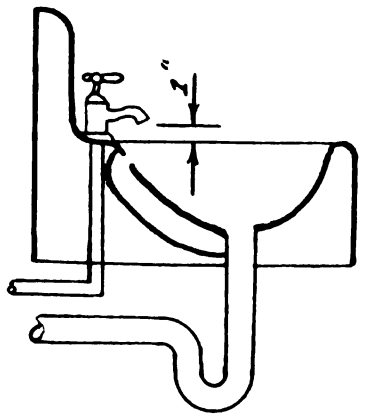
CITY OF CHICAGO ACCEPTED INSTALLATION

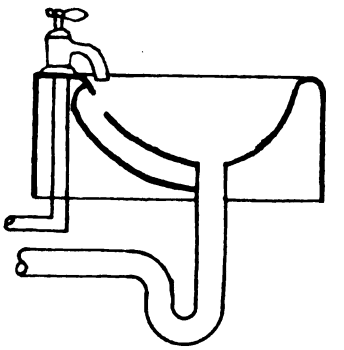


WELL PROTECTION

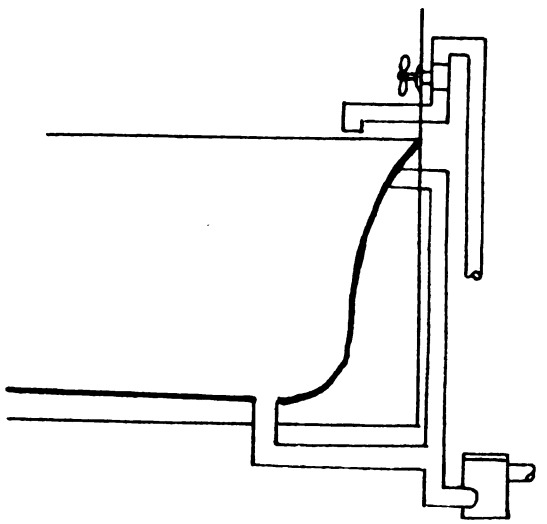
SAFE

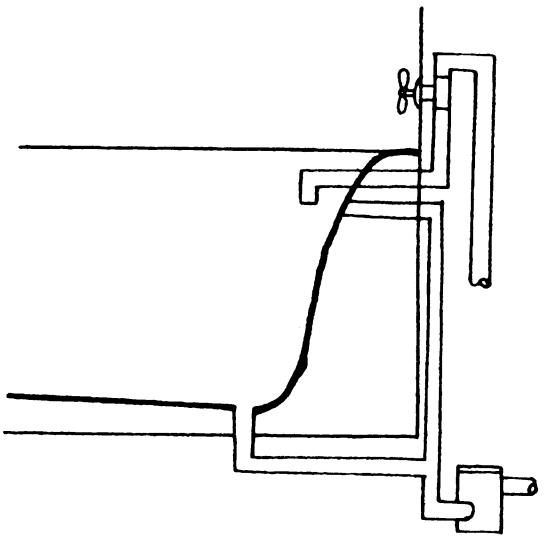
UNSAFE



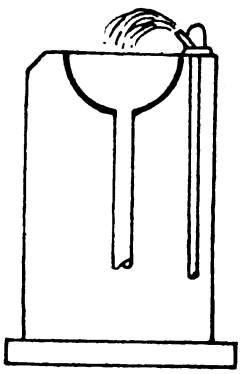


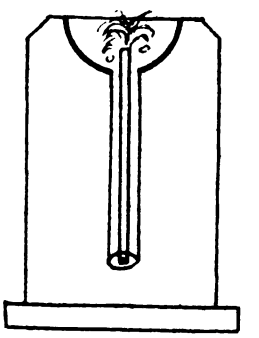
LAVATORY



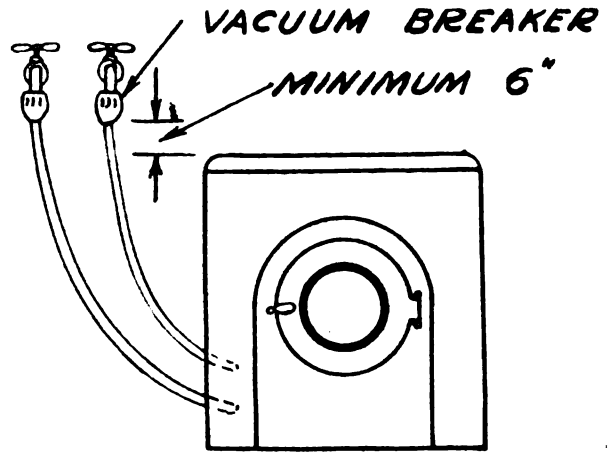


BATH TUB

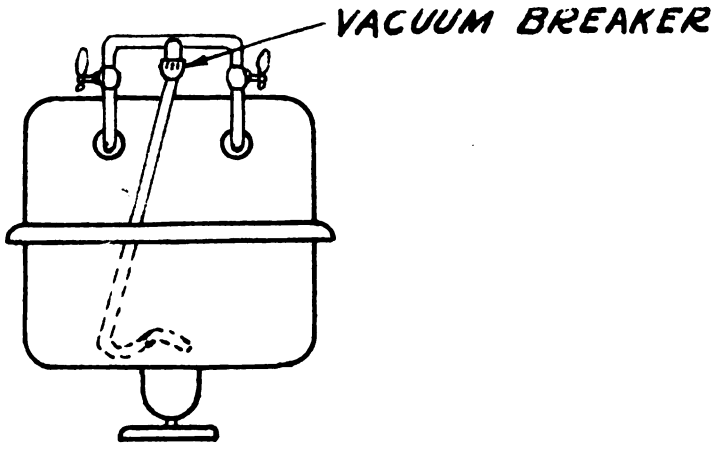




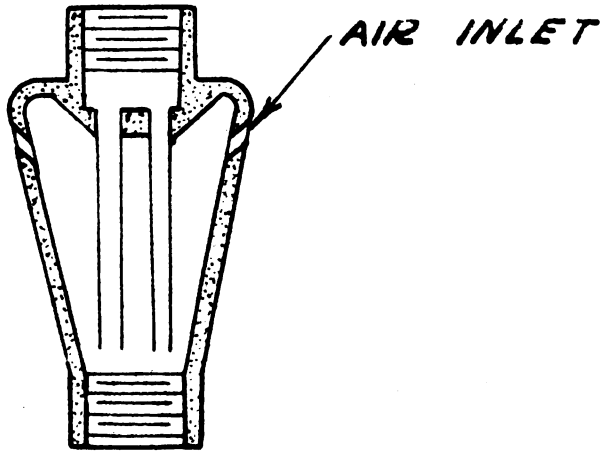
DRINKING FOUNTAIN



AUTOMATIC WASHING MACHINE

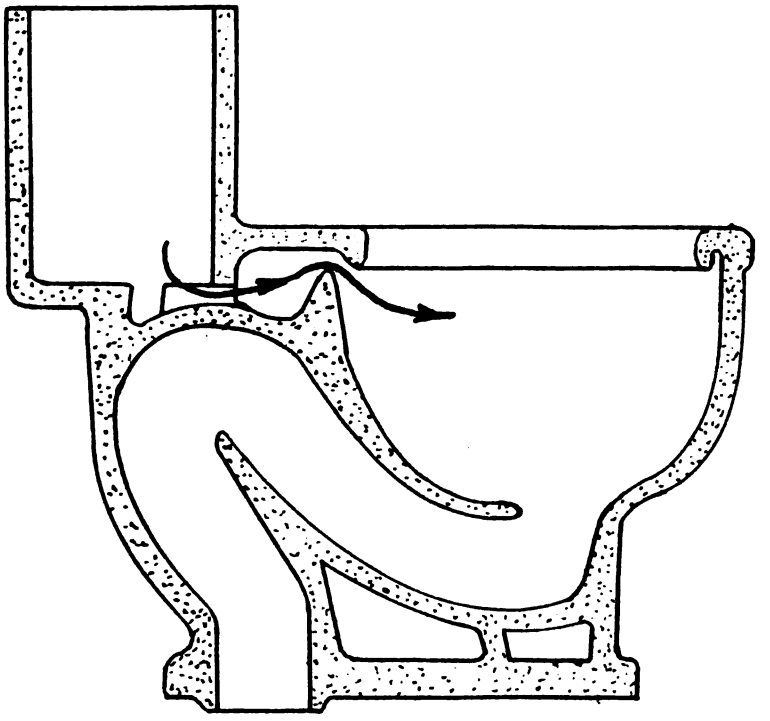


SLOP SINK



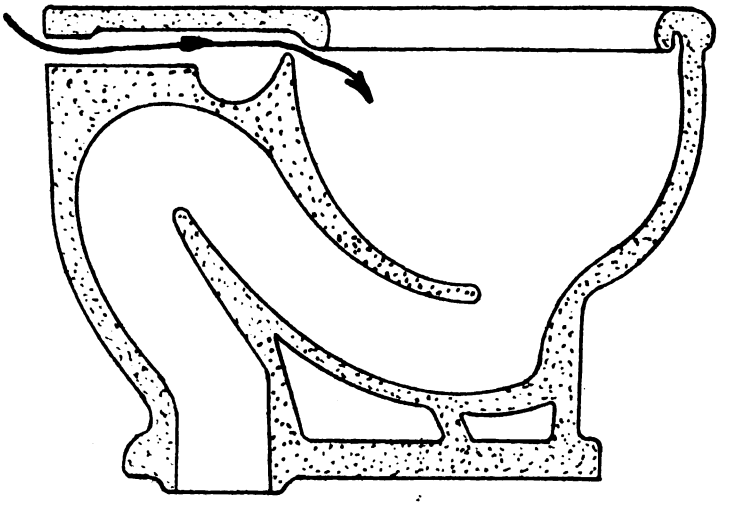
TYPICAL VACUUM BREAKER

INTEGRAL FLUSH BOX & BOWL

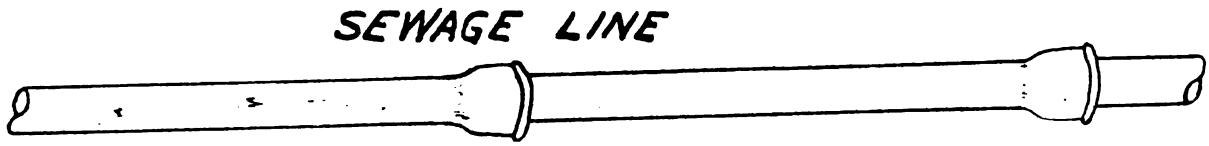


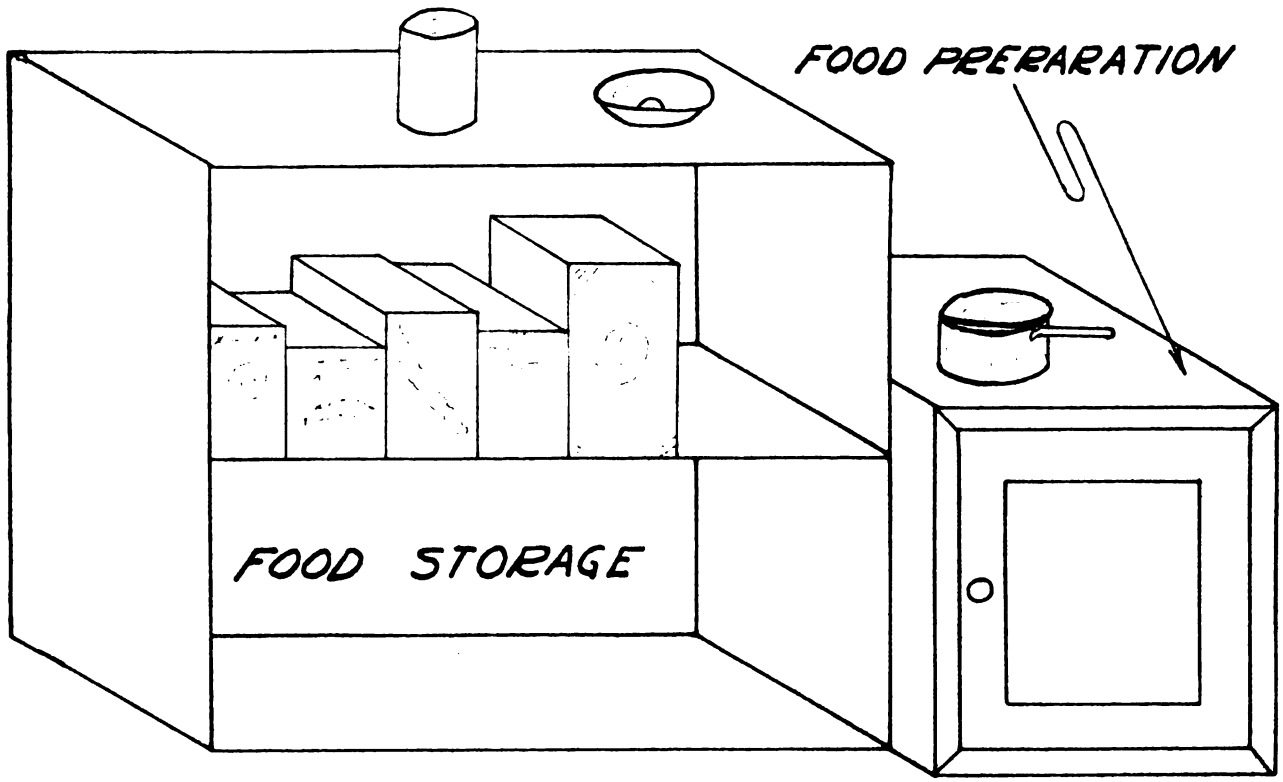
ANY STOPPAGE IN THE BOWL THAT CAUSES WATER TO RISE TO OVERFLOW, WILL ALLOW CONTAMINATION OF THE FLUSH BOX

WASH DOWN TOILET BOWL



THERE IS LITTLE CHANCE FOR POLLUTED WATER TO GET FROM BOWL TO TANK, BUT BALL COCK SHOULD STILL BE VACUUM BREAKER TYPE


SEWAGE LINE


FOOD PREPARATION
FOOD STORAGE

Mr. Dawson of State Plumbing Board suggested that mention of the classic case of brucellosis contamination in the bacteriological building at M.S.C (from slop sink) be ommitted, on the principle that it is better to "let sleeping dogs lie." This is typical of the unscientific approach. This case should be included.

C.M. Cade