Chlorination in Food Processing Plants

SEVERN TRENT SERVICES

CAPITAL CONTROLS

Chlorination of domestic, public, and private water supplies has been carried on for many years as a safeguard against water-borne diseases. In recent years chlorination of industrial water has become a common practice in food processing plants as a means of improving plant sanitation.

The Controlled Application of Chlorine

When used in a food plant, chlorine must be applied under controlled conditions if the desired germicidal effects are to be obtained without adverse results.

Survey of Water to be Chlorinated

To use chlorine effectively and efficiently, the chemical and physical nature of the water must be known. The following facts should be obtained: the average pH of the water, the temperature range, the chlorine demand, the concentration of organic matter, the volume to be chlorinated, and the presence in the water of phenols or other materials which might lead to off flavors.

Selection of the Chlorine Compound to Use

The selection of a chlorine compound to use will depend to a great extent on the volume of water to be chlorinated, the level desired, and especially the use that will be made of the water.

Chlorine Gas

Chlorine gas is generally considered the best source for in-plant chlorination where large volumes of water are to be chlorinated to high levels (4-5 ppm), because

1. It is a pure substance, and no other materials are added.
2. It lowers the pH slightly.
3. It is easy to control and apply.
4. It is the cheapest source on the basis of pounds of available chlorine.

The main objection to chlorine gas is the cost of chlorination equipment: However, this cost is eventually balanced by the lower cost of the chlorine.

*Script and tables extracted from National Canners Association Publication, “The Chlorination of Water”, and reprinted courtesy of National Canners Association.

Hypochlorites are the second choice for in-plant chlorination for the following reasons:

1. When they are added, other chemicals such as $CaCL_2$ and NaCL are produced which may have an adverse effect on the quality of the product.
2. The amount added is difficult to control.
3. They raise the pH of the water, and in hard water this may contribute to a deposit on equipment and cans.
4. They are more sensitive to organic matter in the water and thus lose their germicidal powers faster.
5. Being unstable they are difficult to store and deterioration results on long standing.
6. Their cost is high in terms of available chlorine content.

Hypochlorites are a good source when only small amounts of chlorine are needed, such as in can cooling systems, in a localized germicidal application for cleanup purposes and in preventing slime formation on belts and other equipment.

When a calcium hypochlorite is used, only the amount needed should be made up into a solution because it deteriorates on standing.

Salts of heavy metals, even in small amounts, catalyze the disintegration of hypochlorites.

Chloramines

Chloramines are not suited for in-plant chlorination due to their slow action. However, because of their stability they are well suited for use when a long contact time is needed. For example, they may be used in wood holding tanks held full of water during an off season.

In-plant Chlorination

In-plant chlorination provides a continuous application of germicidal chlorine to the food preparation equipment, with the result that bacterial counts are reduced, slime formation is prevented, odors are avoided, and the time required to accomplish a satisfactory cleanup is shortened. Also, if the water is used in can coolers, chlorination helps to prevent spoilage from recontamination.

Recommended Chlorine Levels

Free chlorine residuals of 4-7 ppm at the point of water application to equipment are recommended. If the operations are light, with only one shift, satisfactory control may be maintained by the lower concentrations, whereas during heavy or continuous operation 5 ppm may be required.

An increase to chlorine residuals of 10-20 ppm is recommended for cleanup purposes. This serves to give an effective germicidal treatment to all equipment in the plant.

Effect of In-Plant Chlorination on Food Quality

The effects of chlorine on the flavor of 29 fruits and vegetables are shown in Table 1. Of the products tested it is evident that apples, pears, cling peaches, figs, strawberries and yams are the most susceptible to chlorine flavor. However, when unchlorinated water was used for syrups and brines, off flavors did not develop with the chlorine concentrations recommended for in-plant chlorination.

Tests on these products showed that a chlorine concentration of 5 ppm has no effect on the color or ascorbic acid content.

Effect of In-Plant Chlorination on Cans and Equipment

Chlorine is corrosive to the common metals as shown in Table 2. However, in low concentrations such as are used for in-plant chlorination (2-5 ppm), it does not noticeably corrode either cans or equipment under ordinary conditions. This conclusion is based on years of experience by many canners using in-plant chlorination. Some packers have reported that less corrosion takes place when chlorine is used because corrosion is most severe under slime deposits and the chlorine prevents slime formation. Even the high concentrations (10-20 ppm) used for clean-up do not generally produce significant corrosion because the contact time is too short. However, while corrosion attributable to chlorination is not normally a problem, its possibility should not be completely ignored, and it must be used with care. If the can cooling water contains sulfates or chlorides, the addition of chlorine increases the tendency toward can corrosion, and the addition of a corrosion inhibitor such as sodium chromate may be necessary to counteract this.

TABLE 1

Effect of Chlorine Treatment on Flavor of Canned Foods
(Somers, 1951)

	Lowest concentration which produced off-flavor when 2, 5, 10 and 50 ppm of chlorine were added.	
PRODUCT	**Partial treatment. Chlorination of all water except brines & sirups.**	**Complete treatment. Chlorination of all water including brines & sirups.**
	Chlorine, ppm	Chlorine, ppm
Applesauce. Rome Beauty +	10	5
Applesauce, Gravensteint +	(None at 50)	10
Apricots, halves unpeeled	(None at 50)	50
Apricots, whole peeled	(None at 50)	50
Asparagus. all green	50	50
Beans, green cut	50	10
Beans, green limas	50	10
Beans, with pork (recanned)+	---	50
Beets. red sliced	50	10
Carrots, sliced	(None at 50)	10
Carrots, pureed +	(None at 50)	50
Cherries, Royal Anne	(None at 50)	50
Corn	---	(None with 15)
Figs, whole Kadota	50	5
Grapefruit juice (recanned)+	---	50
Orange juice (recanned)+	---	50
Peaches, clingstone halves	(None at 50)	5
Peaches, Elberta halves	(None at 50)	10
Peas	---	(None with I0)
Pears	50	2 to 5
Pineapple juice (recanned)+	---	10
Potatoes, sweet, solid pack +	(None at 50)	50
Pumpkin, solid pack+	(None at 50)	50
Prunes, Italian	(None at 50)	10
Spinach	50	10
Strawberries, whole	(None at 50)	5 to 10
Tomato juice +	---	10
Vegetable juice cocktail (recanned)+	---	5
Yams, sirup pack	---	5

+Chlorine added directly to the product.

TABLE 2

Effect of Chlorine on Metal and Other Surfaces

Material	Effect of Chlorine Solutions 5 ppm	100 ppm	1000 ppm
Glass, earthenware, silver +, tantalum, most precious metals, bitumastics (tar), hard rubber.	None	None	None
Soft gum rubber, fabrics, concrete	None	None	Disintegrates
Wood	None	None	
Iron, steel, stainless steel, copper, brass, aluminum, tin.	None	Corrodes ++	Corrodes

\+ Protection of silver is due to formation of silver chloride and if this is removed by abrasion corrosion will result.

++ Corrosion occurs if application is continuous. A periodic application of a few minutes contact may have very little effect. The lower the pH the more corrosion will result.

Installation for In-Plant Chlorination

For reasons explained previously, chlorine gas is preferred to hypochlorites for in-plant chlorination; however, both may be used.

Various types of chlorinators are employed, depending on the source of chlorine. Gaseous chlorine is ordinarily added to water by means of equipment which mixes the gas with water and then injects this water back into the supply line. “Homemade” gas chlorinators are not advisable where accurate control is necessary. Cylinders of chlorine should preferably stand on platform scales while being discharged. This provides a means for measuring the rate of discharge and indicates when the cylinders are empty. Hypochlorites are added by pumping or aspirating a solution of the material into the water line. Some very satisfactory hypochlorinators are on the market.

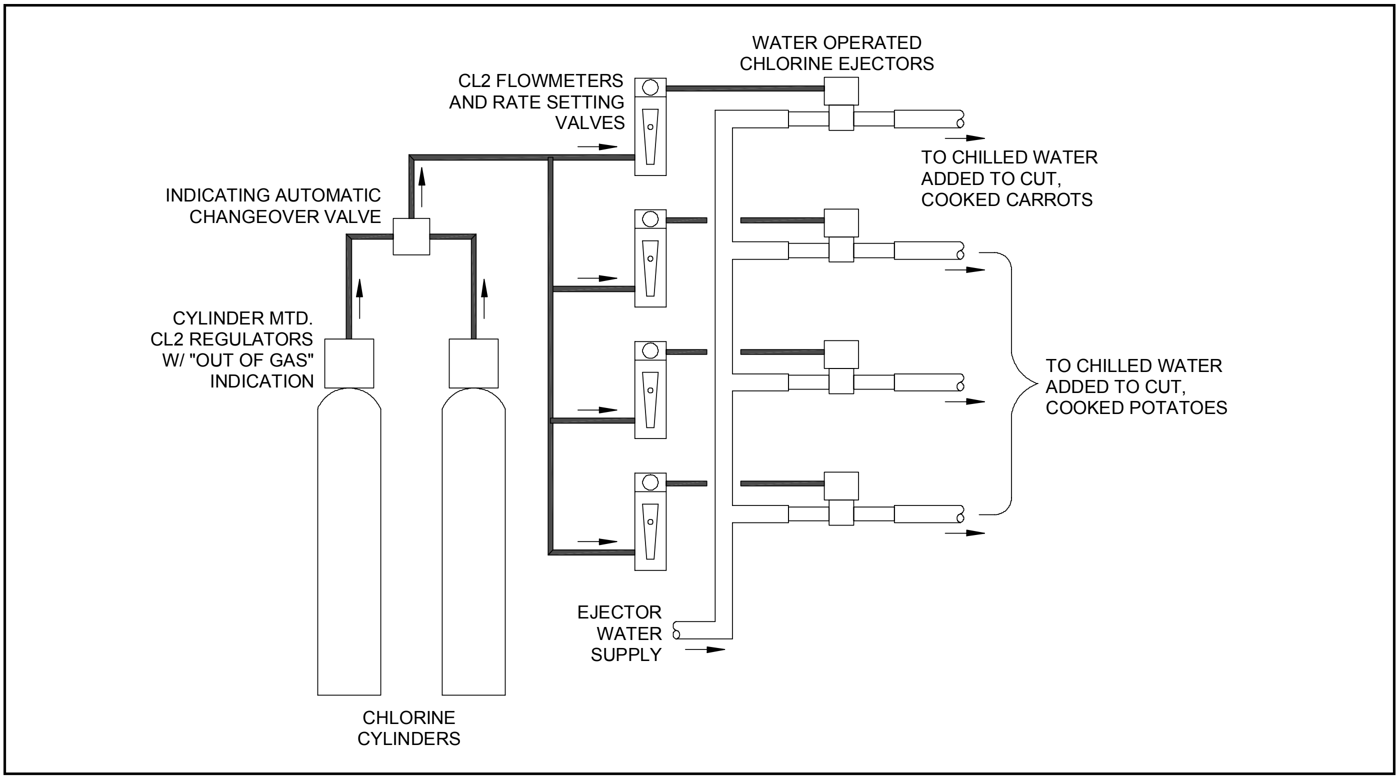
Pump hypochlorinators can be used for chlorinating either closed or open water systems. In closed systems the solution is pumped directly into the line. These pump chlorinators are made of non-corrodible material and may be equipped to add hypochlorite solution in proportion to the water flow. A simple method for chlorinating well water is to connect the solution feed pump motor to the same switch as the pump motor in such a way that the chlorinator operates when the well pump is on. Aspirator type hypochlorinators are available which add the solution in proportion to the flow of water through the line. These have been employed successfully for in-plant chlorination with sodium hypochlorite solutions.

Regardless of the source of chlorine, only automatic equipment which feeds the chlorine in proportion to the water flow should be used. This is necessary to avoid fluctuations in the chlorine level which, if too low, would be ineffective, or, if too high, might produce off-flavors and corrosion.

For in-plant chlorination to be most effective there should be a continuous application of chlorinated water to all surfaces where bacteria are likely to grow and slime to form. This may involve additional piping. For belts, bucket elevators, reel washers and similar equipment, the chlorine may be applied by installing sprays of chlorinated water in such a way that they will constantly bathe the moving surfaces. Best results are obtained on belts when the chlorinated water is sprayed on both sides of the belt.

For equipment (such as fillers, dicers, peelers, etc.) where a continuous application of chlorinated water is not possible, water lines with short hoses should be installed near each machine to be used for washing the equipment each time operations cease.

As a precaution against off flavors, and to avoid any employee objection, it is advisable to install lines of unchlorinated water for syrup or brine making, for boiler water, and for drinking purposes.



Typical Chlorination System for a Food Processing Plant

Precautions When In-Plant Chlorination is Used.

After the installation has been made, the chlorine should be turned on for at least a week before canning operations are commenced to “burn out” all organic matter in the lines. This helps to assure safety from off flavor and will reduce the chances of objection from employees, because the flavor of the water is usually unpleasant until the lines are clean. If there has been no previous experience with the products being canned, an experimental pack using chlorinated water should be made prior to the start of operations to determine the possibilities of off flavor. In the tests chlorine is added directly to the canned product in the approximate concentrations of 2, 5, 10, and 25 ppm, and the level at which any flavor change occurs noted (see Table 1).

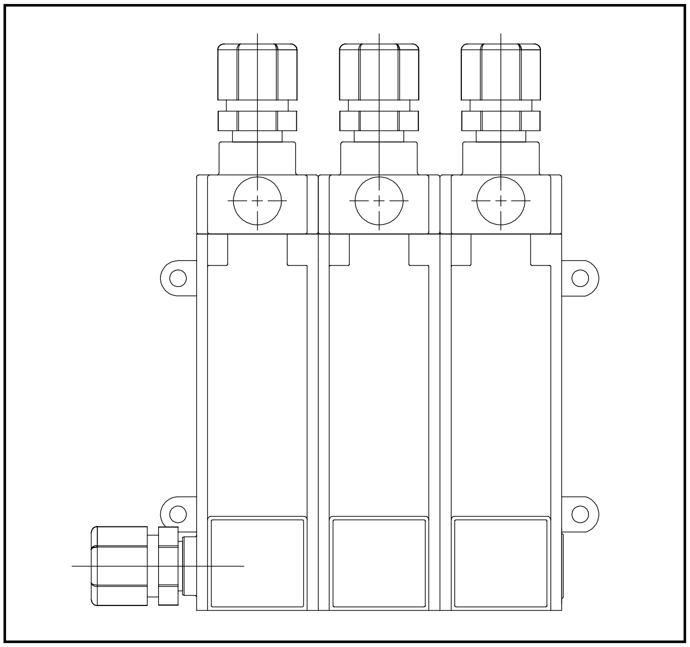
All cresols, phenols or phenol-like compound should be removed from the plant, because chlorine in combination with such materials produces compounds which have a very strong flavor even when present in minute quantities. Material which may contain phenols and cresols are marking inks, paints, fly sprays, special wood sealers, hand lotions, boiler feed water compounds, etc.

When using chlorine gas, every precaution should be taken to avoid personal injury, because chlorine gas, even in low concentrations, will cause skin irritation, serious injury to the lungs and throat, and in high concentrations is poisonous. Chlorine cylinders should be handled carefully, never dropped or rolled, and should be stored in an upright position in a well ventilated area readily accessible for inspection.

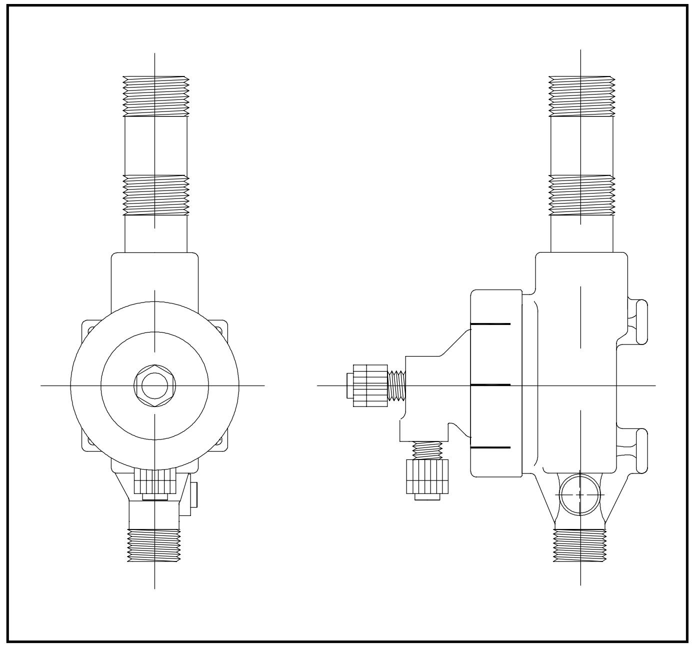
A chlorinator installation should be located in an above ground room with good ventilation and never in a basement, because if any leaks occur, chlorine, being heavier than air, will accumulate in a basement room and toxic concentrations may develop. Since liquid chlorine expands very rapidly when heated, the cylinders are equipped with fusible plugs which melt at about 158°F and release the gas as a precaution against explosion. It is desirable therefore to have the chlorinator room and the chlorine storage area of fireproof construction and to keep the cylinders away from heat. In case of fire, chlorine cylinders should be removed from the building, or if this is not possible, firemen should be informed of their presence.

If a leak occurs in a chlorine cylinder, steps should be taken to correct the condition immediately because chlorine leaks always become worse. Never spray leaking cylinders with water because chlorine reacts with water to produce heat, which increases the pressure and, in turn, increases the escape of chlorine. Gas evolution from chlorine spilled on the floor or ground can be reduced by spraying with cold water.

Keep to the windward side and higher than the leak. If a chlorine container is leaking and is in a position that would cause liquid chlorine to escape, it should be turned so that gas escapes. The quantity of chlorine escaping from a gas leak is about 1/15 the amount that escapes from a liquid leak through the same size hole.



Chlorine Flowmeters with Rate Setting Valves



Water Operated Chlorine Ejector

If a leak occurs in chlorination equipment, close the cylinder valve immediately.

A bottle of ammonia should be kept in the chlorinator room for use in checking for gas leaks. The open bottle of ammonia or a rag wrapped on a stick and soaked in ammonia is placed near places which are likely to leak. If chlorine is present, a white cloud will appear. A chlorine gas mask (U. S. Bureau of Mines approved; the common industrial type is not satisfactory) should be provided for each employee who might be exposed to chlorine.

Chlorine may be absorbed in caustic soda, soda ash or hydrated lime solutions. Caustic soda is recommended. The amounts of alkalis are recommended by The Chlorine Institute.

One man should be responsible for the repair, care, and maintenance of chlorination equipment, and if a leak is suspected or anything else goes wrong, he should be called and everyone else should leave the area.

It is desirable to hang a chart of instructions near where chlorine is being used to inform employees what to do in case of an accident. These charts may be obtained from the chlorine manufacturers.

Laboratory Control of In-Plant Chlorination

Continuous laboratory control is essential for safe application of in-plant chlorination, and the following schedule is recommended:

1. Check the chlorine residual every 2 hours for the first week using the orthotolidine flash test. This will help to establish what variations are likely to be encountered.
2. After the first week check the chlorine residual at several points in the plant at least twice a day. Always sample at the same places each day.
3. If possible, take the sample from a tap that has been running for several minutes. A sample taken from a tank, flume, etc., may not give true values.
4. Keep a record of all residuals observed.
5. Taste the water (if it is potable) every time a residual is taken, as a check on possible off flavors.
6. Record the chlorinator setting each time the residual is taken. After a few days it may be possible to correlate residuals with chlorinator settings, and wide discrepancies would indicate that something was wrong. Also, the chlorine demand of the water may be estimated by calculating the theoretical residual, and subtracting from this the observed residual.
7. Weigh the chlorine cylinder each day at the same time, and record the loss in weight. This is a check on the accuracy of the chlorinator feed setting and the results indicate when a new cylinder is needed.
8. Check the chlorinator operations, and at least once a day inspect for leaks using an ammonia bottle as described previously.
9. For hypochlorinators, check and record the volume of chlorine solution in the supply tank and each day calculate the gallons of solution that have been fed per hour during the previous day.

Chlorination of Cooling Water

When cooling water is reused or has a high bacterial content, chlorination is advisable. When cans are to be processed in retorts or continuous cookers, chlorination of cooling water should always be accompanied by washing the cans after filling to reduce the amount of organic matter which might find its way to the cooling system and increase the chlorine demand.

Cooling Towers

Water that is cooled for reuse by passing over a cooling tower may be highly contaminated with microorganisms, and chlorination is usually necessary. Sufficient chlorine should be added as the water leaves the tower for use in the plant to maintain a free residual of approximately 0.5 ppm in the water as it drips from the tower at the end of the cycle. This treatment should be accompanied by screening of the water to remove large foreign objects. The chlorine residual after cooling should be increased from 0.5 to 4-5 ppm for a few hours every week or two to eliminate more resistant microorganisms which gradually build up in towers.

Tank, Canal, and Rotary Continuous Coolers

Bacterial counts may rapidly build up to high levels in water in tank, canal or continuous rotary coolers unless the water is chlorinated. A free chlorine residual of from 0.5 to 1.0 ppm at the discharge end of the cooler is recommended. When in-plant chlorination is practiced, the 5 ppm residual carried in the cooler inlet water is often sufficient to maintain the necessary 0.5 ppm at the discharge end of the cooler without additional chlorination.

Chlorine Compounds and Chlorinator Equipment

Chlorination of cooling water may be accomplished with either gaseous chlorine or hypochlorites. Either automatic or manual feed equipment may be used, but it is sometimes more difficult to get accurate control with a manual feed. The same precautions apply for these installations as are described under in-plant chlorination for using gaseous chlorine.

For cooling canals and open coolers, hypochlorites are generally used, and these may be fed by means of a chemical solution feed pump, or, if no other means is available, by a drip feed mechanism. This drip feed equipment is satisfactory for applying sodium hypochlorite solutions, but with calcium hypochlorite it may soon clog and be difficult to control due to the formation of calcium carbonate deposits. Calcium hypochlorite solutions are best added with pumps, and they should be made up several hours before use to give them a chance to settle.

Laboratory Control

The following checking routine is recommended for cooling water chlorination:

1. Chlorine residuals and the operation of the chlorinator should be checked at least every two hours when chlorination first starts, and at least every four hours after the first week.
2. The solution tank should be calibrated so that the gallons fed per hour can be calculated each time a check is made.

Chlorination of Water Reused for Purposes Other than Cooling

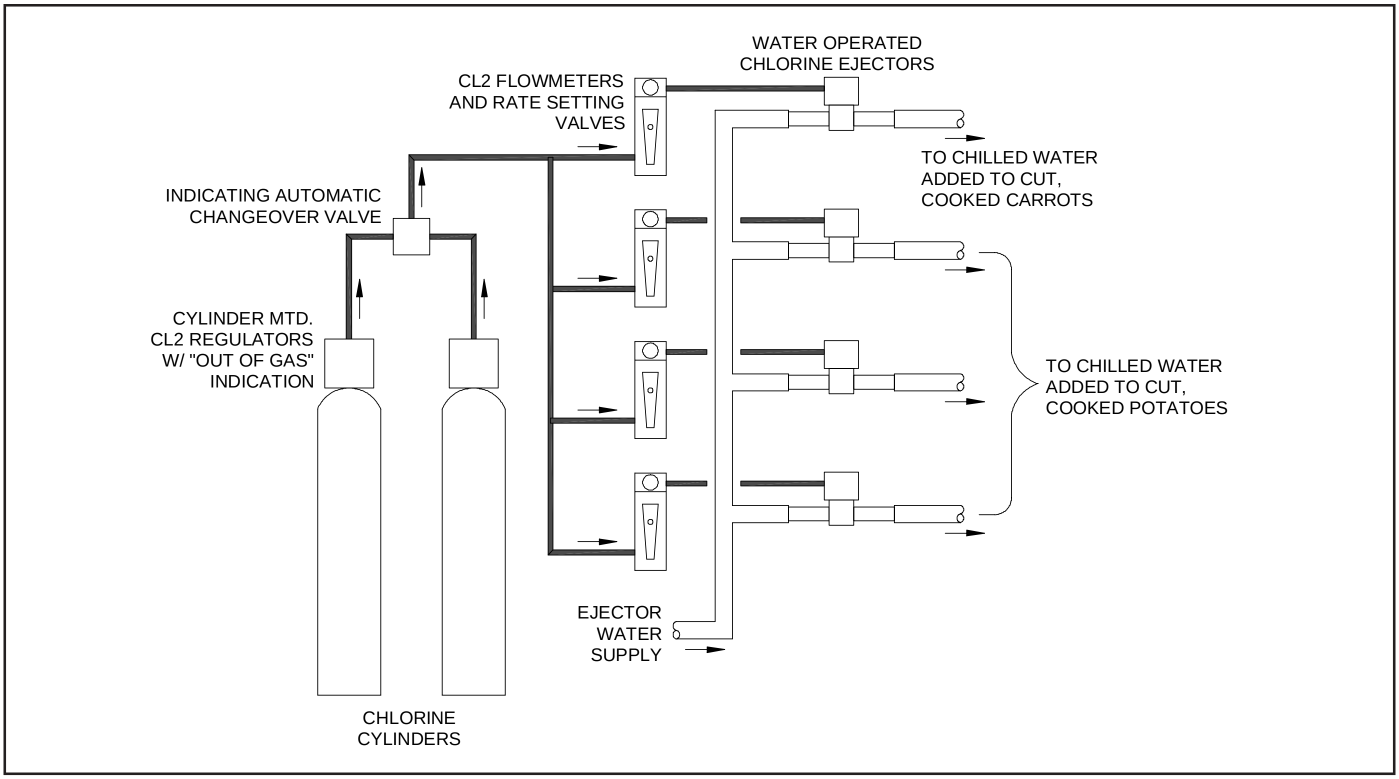
When it is necessary to reuse water in food preparation departments, the best and safest method is the counter-flow principle, with successive uses of the water in reverse order to the flow of product through the lines. The fresh water is used for the final washing or fluming of the product prior to canning. The second or third uses may be for fluming or washing at intermediate stages in the preparation, and the last use for washing or pumping the raw product as it enters the preparation lines, after which the water is discarded or used for fluming waste. The exact details of such a system must be worked out for each cannery because no two plants handle a given product in exactly the same manner.

With the counterflow system, the water is collected in a separate tank after each use and rechlorinated. A gaseous chlorinator other than the in-plant chlorinator is used for this purpose. The concentrated chlorine solution is fed into a header with a valve controlled outlet for each tank. Special rubber hoses from these outlets carry the chlorine solution to the collection tanks. Sufficient concentrated chlorine solution is added to the water in the tank to give a trace of free residual at the end of the next use. This completely satisfies the chlorine demand of the water and, because of the organic matter present, results in a fairly high combined residual. Because of the long contact time, this residual exerts enough germicidal power to prevent the multiplication of microorganisms.

When water is reused according to the counter-flow principle, the following considerations are important:

1. Water used for the first wash of the product as it enters the plant, or for the first wash of the product after blanching should be discarded.
2. The water which is being reused should be kept cool (below 85°F) by adding fresh cold water to the various collection tanks as the need indicates.
3. Reuse of water must be accompanied by a good daily clean-up of the plant.
4. In addition to chlorination of the reused water, in-plant chlorination to a level of at least 5 ppm free residual is essential.
5. Only gaseous chlorine should be used, because successive rechlorination with hypochlorites would result in the accumulation of a large amount of chemicals other than chlorine compounds which might affect the quality of the product.

The reuse of water 4 times by the counter-flow system has resulted in a saving of 50% in water consumption in pea canneries, without any spoilage hazard or lessening of plant sanitation (Mercer and York, 1953). Reuse of water by circulation within one operation and with discharge only by over-flow is not recommended. The temperature tends to rise, and after recirculation over a long period of time, the water becomes so filled with soluble and suspended organic matter that even with chlorination it is difficult to maintain bacterial populations at a low level. The build-up in organic matter may also result in contamination of the product. A canner has no way of making certain that fresh water will always be added in the amount needed to keep the recirculated water from becoming foul. A shortage of water may result in the operator shutting off the valves.



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