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Engineering and Design Considerations for Service Water Chemical Addition Systems

Engineering and Design Considerations for Service Water Chemical Addition Systems

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PRODUCT DESCRIPTION

Service water systems in nuclear plants often require chemical treatment to control microbiological growth, macrobiological growth, corrosion, mineral scale formation, and the fouling of water-contacted equipment and piping. The chemical feed system is the vehicle for consistently injecting the required chemicals (that is, sodium hypochlorite [bleach] and others) into the service water and maintaining them. Service water chemical feed systems have been a source of numerous difficulties, such as corrosion of the injection piping and tanks, inadequate chemical feed, and accidental placement of the wrong chemical in the wrong storage tank. This report covers these issues; provides current information on chemical storage, transport, and feed; identifies potential problem areas; and captures some industry best practices.

Background

This report provides detailed information on material/chemical compatibility and describes the components that can effectively be used to construct a service water chemical feed system.

Objective

The objective of this report is to supply information to nuclear power plant personnel that will assist with component selection and component arrangements for service water chemical feed systems.

Approach

This report was developed based on case studies of different plants' additions and modifications to their own service water chemical addition systems as well as the experience and information from members of the technical advisory group (TAG) that had been assembled for this project. It covers the compatibility of tank, chemical feed, and chemical transport materials with the types of chemicals that are typically used to treat service water systems. It also covers the types of chemical feed devices and their applicability, advantages, and disadvantages.

Results

This report provides the basis for selecting chemical feed system design features and components that are compatible with the chemicals being fed. Using successful and unsuccessful experiences, the report offers clear guidance on well-engineered chemical feed designs that are effective.

Application, Value and Use

Service water and other open loop cooling water system engineers and design engineers, as well as the plant chemistry staff responsible for the associated chemical additions, can use this report to improve the design and functionality of their plants' service water chemical feed system.

Keywords
Chemical compatibility
Chemical feed
Chemical storage
Chemical treatment
Treatment level control

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

Service water systems are subject to a range of degradation mechanisms. These include microbiological growth, macrobiological growth, microbiologically influenced corrosion, other corrosion mechanisms, mineral scale deposition, and suspended solids fouling (siltation). These mechanisms can lead to the failure or fouling of components such as service water piping (both buried and aboveground), heat exchangers, and pumps. Failure or fouling can lead to the loss of functionality of key systems, both safety-related and non-safety-related.

In order to protect service water system components, water treatment chemicals are often required. The chemical feed system is the vehicle for consistently injecting the required chemicals into the service water. The entire water treatment chemical feed system should include the following:

- Delivery of the chemical
- Storage of the chemical
- Transporting the chemical
- Chemical feed devices that operate effectively
- Maintenance of the required chemical residuals

Over the years, service water chemical feed systems have been a source of many difficulties, such as the following:

- Problems getting the correct chemical delivered into the correct storage tank
- Storage tank size and integrity
- Problems with chemical transport piping integrity
- Problems with chemical feed pumps and pumping issues
- Verification of chemical feed and feed rate
- Proper control of chemical residuals
- Poor reliability of chemical feed systems resulting from lack of maintenance

Each water treatment chemical delivered to the plant must be accompanied by, or have on file, a safety data sheet (SDS), formerly called a *material safety data sheet*.

The SDS provides instructions on handling, spillage abatement, first-aid measures, compatibility, and personal protective equipment (PPE). The product label is also important. This is particularly true for biocides because the label lists the chemical name, applications for which the biocide is approved, the maximum approved dosage, and emergency contact information.

The two chemicals that have created the greatest problems in transfer, storage, and feeding are sodium hypochlorite (bleach, NaOCl) and sulfuric acid (H_2SO_4). Sodium hypochlorite (usually 12%–13% NaOCl) is a very aggressive chemical because of its strong oxidizing potential, corrosiveness, and tendency to vaporize, or off-gas. Sulfuric acid (93%–98% H_2SO_4) and other acids are corrosive and attack many materials. These materials can be very hazardous to personnel.

Many of the chemicals used for chemical treatment of service water systems are incompatible if they are mixed together. For example, sulfuric acid and sodium hypochlorite will react violently if they are mixed together. The reaction between the two generates significant amounts of heat and emits toxic chlorine gas.

Water treatment chemicals used for corrosion control, mineral scale control, and microbiological control are often proprietary blends of chemicals. Each has its own characteristics. Some may be strongly acidic and others strongly basic.

Each chemical, or blend of chemicals, must be stored in containers constructed of appropriate materials. If not, there is a risk of chemical leaks and serious personnel exposure.

There are many types of systems for injecting the chemical into the process. These include various types of pumps, eductors, and gravity feed systems. Each type of feed system must take into account the individual chemical characteristics, such as corrosivity, viscosity, and volatility. The system must be capable of delivering the correct amount of the chemical to the process at the correct rate. This is governed by some type of process control system.

There is significant operating experience in the industry, both good and bad. This operating experience can provide valuable information on best practices and practices to avoid.

There are two basic approaches to chemical feed skids/systems in nuclear power plants: systems that are owned and operated by the plant and systems that are owned, operated, and maintained by an outside third party.

In the systems that are owned, operated, and maintained by the plant, the plant would either design and build the system or would issue design guidelines and purchase specifications for either the materials or an assembled skid. The plant would then operate and maintain the system with plant personnel.

In the systems owned and operated by an outside third party (so-called *black box* systems), the plant would contract with an outside third party (for example, a water treatment service company) to design, build, supply, and start up the system. The outside third party would then operate the system, monitor operations, and provide necessary maintenance. This approach can facilitate rapid repairs/maintenance and upgrades.

This report provides information that applies to both approaches.

2
DESCRIPTION OF TYPICAL PROBLEMS IN CHEMICAL FEED AND CONTROL

Introduction

A typical nuclear power plant might use a broad range of chemicals for treating its service water systems, both safety-related and non-safety-related. The type of chemical treatment required is governed by the design of the system, the metallurgy in the system, and the source and characteristics of the raw water.

Transfer to Storage Facilities

There are many types of chemical deliveries at a typical nuclear power plant. Chemicals are used in many power plant systems, whether service water, circulating water, closed cooling, reactor coolant, or steam generator systems. These chemicals must be delivered to the correct location in the plant and safely transferred to the appropriate storage container. Many problems with chemical delivery and transport have arisen over the years. Some of these have resulted in spills, product contamination/spoilage, equipment damage, injury, and loss of life.

Delivery of a chemical to the correct storage tank is critical. There have been instances where caustic soda has been added to sulfuric acid storage tanks, incompatible water treatment chemicals have been mixed, and so forth. The mixing of chemicals can cause a violent reaction and result in equipment damage and injury.

Case histories related to improper chemical transfer are included in Appendix B of this report.

Transport to Chemical Feed Equipment

After the chemical is in the correct storage tank, it must be transported to the chemical feed equipment. Potential problems with chemical transport include the following:

- Piping or tubing that is attacked by the chemical being transported
- Connections that are attacked by the chemical
- Connections that do not hold up to mechanical or thermal stresses
- Incompatible adaptors or connectors
- Gradient, distance, and traffic considerations
- Mechanical damage from personnel

Chemical Feed Pump and Eductor Reliability

Many of the chemicals being fed have characteristics that make them difficult to feed, whether by pumps or eductors. These characteristics include the following:

- The chemical could be highly corrosive and might attack feed system components.
- The chemical could be viscous.
- The chemical could vaporize (off-gas) and cause pump air binding.
- The chemical could react with a carrier water and form deposits that can plug injection quills or piping.

Chemical Transport to Process

Transporting the chemicals from the chemical feed system to the point where they are injected into the service water system can involve the same problems as transporting the chemical to the chemical feed system. The process of chemical addition needs to ensure that service water system materials are not exposed to concentrations of the added chemical that are in excess of what the service water system materials can tolerate.

Control of Chemical Residuals

When the chemicals are being fed into the service water system, in most cases it is necessary to control the injection rate based on some parameter. The level of control is based on factors such as variations in flow and variations in demand. Instruments used for control of the injection rate can be subject to fouling, instrument drift, and interferences that can cause the system to call for the incorrect amount of chemical.

There are numerous methods that can be used to control the process. These are often used in combination. Control methods include the following:

- Online tracking of storage tank drawdown
- The actual flow of the chemical from a chemical feed pump to the process
- The measurement of a parameter controlled by the injected chemical, such as pH, chlorine concentration, or other measured parameter

3
CHEMICAL RESISTANCE OVERVIEW

Introduction

The materials of construction of any chemical storage and feed system must have adequate chemical resistance to the materials being stored and transported. However, there are other important aspects. These include the following:

- The material must have adequate physical strength for the application.
- The material must be compatible with the environment to which it will be exposed (for example, temperatures and pressures).
- The material must have the ability to be fabricated and joined to meet the needs of the process.

Chemical Resistance

The chemical resistance of materials is a complex issue. The environment can have a significant impact on the chemical resistance of a material. This impact can include temperature conditions, humidity conditions, exposure to sunlight, and exposure to fumes.

Table 3-1 is an overview of the chemical resistance of many of the materials that might be used in a chemical feed system versus many of the chemicals that are typically used in water treatment applications. **Table 3-1 should be used only as a general guide. The chemical and materials suppliers should be consulted during the design phase regarding specific material compatibility.** Table 3-1 was compiled from several sources. In some cases the sources did not completely agree on the compatibility of a specific material with a particular chemical. For example, high-density cross-linked polyethylene (XLPE) was listed as acceptable in one guide and unacceptable in another guide. Another example is the use of Hastelloy[1] C components for sodium hypochlorite. According to the Powell sodium hypochlorite handbook [1], the high nickel content of this alloy will accelerate decomposition of the sodium hypochlorite resulting in off-gassing.

Table 3-1 does not include tantalum-lined components. Tantalum is a corrosion-resistant material. These components are commercially available and can be cost-effective in some situations.

[1] *Hastelloy* is a registered trademark of Haynes International, Inc.

Table 3-1
General chemical resistance chart

	304 SS	316 SS	Aluminum	Titanium	Hastelloy C	Brass	Cast Iron	Carbon Steel	PVDF (Kynar)	PVC/CPVC	Tygon	Teflon	Nylon	Polyethylene	Polypropylene	Viton	Buna N	EPDM	Silicon	Neoprene	Rubber	Ceramic Seals	Carbon Seals
Acetic Acid, 20%	B	A	--	A	A	C	--	--	A	B	--	A	D	--	A	A	C	A	--	C	--	--	A
Alcohol, Isopropyl	A	A	B	A	A	C	C	A	--	--	--	--	A	--	A	A	C	A	C	B	A	A	A
Aluminum Sulfate	C	C	A	A	A	C	D	A	A	A	B	A	A	B	A	A	A	A	--	A	A	--	A
Calcium Hypochlorite, Bleach	D	C	C	A	B	--	D	--	A	D	--	A	D	B	A	A	B		C	D	C	A	A
Ferric Chloride	D	D	D	A	B	D	D	D	--	A	B	A	D	B	A	A	D	A	C	B	A	A	A
Ferrous Sulfate	A	C	D	A	B	--	D	D	A	A	B	A	D	B	A	A	B	A	--	A	A	A	A
Hydrochloric Acid, 20%	D	D	D	C	B	--	D	--	A	A	B	A	D	A	A	A	C	A	--	C	C	D	--
Hydrochloric Acid, 37%	D	D	D	C	B	--	D	--	A	A	B	A	D	A	A	A	C	C	--	C	D	D	--
Hydrogen Peroxide, 30%	--	B	--	B	A	D	--	--	A	B	--	A	D	A	C	A	D	C	--	D	--	A	A
Nitric Acid, 20%	A	A	D	A	A	--	D	--	B	A	B	A	D	B	A	A	D	D	--	D	D	A	A
Nitric Acid, 50%	A	A	D	A	A	--	D	--	B	A	B	A	D	C	D	A	D	D	--	D	D	A	A
Phosphoric Acid, 40%	B	A	D	A	A	D	D	--	A	A	B	A	D	B	A	A	D	B	--	D	C	A	A
Phosphoric Acid, 40-100%	C	B	D	B	A	D	D	--	--	A	B	A	D	C	A	A	D	B	--	D	C	A	A
Potassium Hydroxide, 50%	B	B	D	C	A	D	C	A	D	A	B	A	A	B	A	D	B	A	C	A	C	--	D
Sodium Bisulfite	A	A	A	A	A	--	D	--	A	A	B	A	D	B	A	A	A	--	C	A	A	A	A
Sodium Chloride	A	A	C	A	A	C	B	C	A	A	B	A	A	B	A	A	A	A	C	A	B	A	A
Sodium Hydroxide, 50%	A	A	D	A	A	D	B	--	D	A	B	A	C	C	A	D	D	--	D	B	A	D	D
Sodium Hypochlorite, to 20%	C	C	C	A	-3	D	D	--	A	A	B	A	A	B	D	A	D	B	D	D	C	A	--
Sodium Phosphate, Tribasic	--	A	--	A	--	--	--	--	A	A	--	A	--	A	A	A	A	A	--	A	--	A	A
Sodium Polyphosphate (Mono, Di, Tribasic)	A	A	D	A	A	--	--	--	A	A	--	A	--	B	A	A	A	C	--	D	A	A	A
Sodium Tetraborate	--	A	A		A	--	--	--	A	A	--	A	--	A	A	A	A	C	--	A	--	--	--
Sulfuric Acid (75-100%)	--	D	--	D	B	D	--	(1)	A	B	--	A	D	--	B	A	D	--	--	D	--	--	--
Sulfuric Acid, 70%	-	D	-	-	B	-	D	D	A	A	A	A	-	(2)	B	A	A	B	-	D	-	--	--
Sulfuric Acid, 95%	A	-	-	A	-	-	-	B	A	C	-	D	-	(2)	D	D	-	D	-	D	-	--	--
Zinc Sulfate	A	A	D	A	B	C	C	D	A	C	B	A	A	B	A	A	A	A	--	A	C	A	A

(A=No effect, Excellent) (B=Minor Effect, Good) (C=Moderate Effect, Fair) (D= Severe Effect, Poor, Not Recommended) (--=No test data) (1) Show n as "No Test Data" in Grainger chart but commonly used for concentrated sulfuric acid storage. (2) Listed as "A" in Assmann literature (commonly used) and "D" in Harrington literature. (3) Listed as "B" in Assmann literature but high nickel causes sodium hypochlorite decomposition per Pow ell Sodium Hypochlorite Handbook.

Compiled from information from Grainger (from Little Giant Pump Company), Harrington Industrial Plastics, and Assmann Corp.

Table 3-1 does not cover the materials that are often used as tank linings or interior coatings. A summary of these materials and general applications is shown in Table 3-2.

Table 3-2
Tank lining resin general suitability

	Water and Wastewater	Solvents	Caustics	Mineral Acids	Organic Acids	Vegetable Oils/Fatty Acids
Epoxy	A	B	A	C	C	C
Phenolic epoxy	A	B	A	B	C	B
Novolac epoxy	A	A	A	B	B	A
Polycyclamine-cured novolac	A	A	A	A	B	A
Vinyl ester	A	B	B	A	A	A
Novolac vinyl ester	A	B	B	A	A	A

Compiled from information from International Paint website

Notes:
A = generally suitable
B = sometimes suitable
C = generally unsuitable

4
CHEMICAL STORAGE

Each chemical storage option has advantages and disadvantages. The material chosen for chemical storage must be compatible with the chemical under the environmental conditions that will be encountered. These environmental conditions include variations in ambient temperature and exposure to sunlight. One of the most important things is to have the correct chemical in the correct storage vessel.

Delivery Integrity Issues

There have been numerous instances of a chemical being delivered to the wrong bulk storage tank. This has resulted in serious consequences. Numerous cases have been documented, and some case histories are noted in Appendix B of this report.

Power plants receive many shipments of different chemicals over the course of the year. Ensuring delivery integrity involves clear task assignments, clear procedures, training, and peer review, as needed. Many of the chemicals can have similar sounding names on their shipment paperwork. Many plants have found out that delivery integrity starts with the contract, with the supplier being a key component in the overall safety and reliability of the process. The contract should detail delivery protocol, driver training, and safety requirements (for example, PPE). The plant should refuse delivery if the driver does not follow the required protocol.

Of course, it is the plant's responsibility to provide direction to the correct storage tank and confirm that the unloading is made to the correct tank. Serious accidents have resulted from the driver not being properly supervised and then connecting to the wrong tank. There have also been incidents where the wrong truck was sent to a site with the paperwork for a different shipment. The tanker number and the number on the paperwork must match.

Storage tanks for different chemicals are often fitted with different types of connections. Although this is a good practice, it is not always foolproof. Truck drivers often carry numerous adapters that will allow them to connect to a storage tank regardless of the type of fill connection on the tank.

Matching United Nations Committee of Experts on the Transport of Dangerous Goods (UN) numbers does not always provide adequate delivery integrity. UN numbers identify the hazardous materials in the shipment. Some chemicals have common UN numbers. For example, caustic soda and a corrosion inhibitor in a caustic solution base can have the same UN numbers. Matching the complete chemical listing on a bill of lading with the contents in its intended tank is a better practice. It should be possible to use digital scanning technology for this task at all steps (truck paperwork, storage tank identification, and so forth). In addition, the trailer number on the bill of lading and the actual trailer number should match. There have been instances where the driver hooked up to the wrong trailer.

Good practices include the following:

- Having a clearly visible label mounted on the tank and a tank fill line identifying the chemical name or chemical product number, preferably with a tank number that must be matched with the tank number on the bill of lading
- Offloading done by a procedure that identifies valves by number
- Implementing procedural aids, such as locks with different keys or combinations, that are identified in the procedure to ensure that the proper connection is selected

Bulk Chemical Tanks

The selection of a tank type and material of construction is dependent on the chemical being stored, the environmental conditions at the plant, and the location of the tank (indoors versus outdoors). This report focuses on tanks to store the common water treatment chemicals, including concentrated sulfuric acid, caustic soda, sodium hypochlorite, scale- and corrosion-control chemicals in acidic media, and scale- and corrosion-control chemicals in caustic media.

Before ordering a bulk chemical tank, particularly a nonmetallic tank, it is important to identify the specific gravity of the chemical to be stored. The tank must be designed with a wall thickness that will withstand the stresses created by the weight of chemical in the tank. Because of the life expectancy of a nonmetallic tank, it is important that the tank be located in such a way that it can be removed and replaced with relative ease.

It is common practice to have a single bulk chemical tank for each chemical. In the case of sodium hypochlorite, it can be beneficial to have two bulk storage tanks. This is so that a tank can be almost completely drained before it is refilled. The reason for this is that as sodium hypochlorite degrades during storage, the sodium chlorate content in the solution increases. Adding fresh sodium hypochlorite to a partially full tank can allow the sodium chlorate level to increase to undesirable levels [1].

General guides to chemical resistance of materials versus specific chemicals were shown in Tables 3-1 and 3-2.

Unlined Carbon Steel

Concentrated sulfuric acid (93%–98%) is often stored in unlined carbon steel. The sulfuric acid reacts with the steel surface and forms a dense protective layer of ferrous sulfate.

$$Fe^0 + H_2SO_4 \rightarrow H_2\uparrow + FeSO_4$$

Note that the preceding reaction involves the liberation of hydrogen. Although the amount of hydrogen generated is small and occurs mainly during the initial filling of the tank, it will be discharged from the tank vent and should not be exposed to conditions where it could ignite.

The corrosion rate of the steel is affected by the moisture in the sulfuric acid. The protective ferrous sulfate becomes more soluble as the sulfuric acid becomes more dilute. Concentrated sulfuric acid is naturally hygroscopic (absorbs water). Therefore, water vapor from the air can be absorbed into the sulfuric acid, thereby diluting it. It is strongly recommended that sulfuric acid tanks constructed of unlined carbon steel be fitted with an air dryer (desiccator) arrangement to remove moisture from the air that is drawn into the tank as it is emptied. Desiccators must be monitored, and desiccant media must be replaced or recharged periodically. Some tanks may have separate vent valves that permit air to escape when the tank is filling. All vent valves must be inspected periodically to ensure that the tank draws in only dry air through the desiccator.

Unlined carbon steel tanks for sulfuric acid storage are periodically inspected to identify general or localized wall thinning. Because sulfuric acid absorbs moisture from the atmosphere at the liquid surface, wall thickness reduction is often found in a band around the tank that corresponds to the liquid level. Inspections are often performed by making ultrasonic thickness measurements in a grid pattern around the tank. Inspections can also be performed by draining and cleaning the tank and inspecting internally. There is no established frequency for such inspections, but many plants operate on a five- to seven-year frequency.

Lined Carbon Steel

The lining for a carbon steel tank must be chosen to be chemically resistant to the chemical being stored. With the selection of the appropriate lining material, all of the typical water treatment chemicals can be stored in lined carbon steel tanks. Because of the prevalence of nonmetallic tanks, lined carbon steel tanks are seldom used in the power industry today.

Linings are subject to the formation of holidays (localized failure of the lining). The holidays then allow the chemical to come in contact with the carbon steel. This can lead to pits in the tank wall. The pits can grow rapidly and penetrate the wall.

Periodic inspections are necessary to locate holidays and allow for repair. The inspection consists of removing the chemical from the tank, cleaning the tank so that it is safe to enter, and visually inspecting the lining. New coatings are often inspected using an electrical spark test to locate holidays. The spark test consists of surveying the lining surface with a high-impedance electrical instrument that will discharge and create a visible spark when it comes into the proximity of a holiday in the lining. Spark testing of coatings that have been in service and absorbing fluid during service can produce holidays.

A general guide to tank lining and interior coating material is shown in Table 3-2. Chlorobutyl rubber lined steel is not shown in Table 3-2, but it has successfully been used for sodium hypochlorite [1].

Stainless Steel

For some chemical storage needs, 300-series stainless steel is used. Table 3-1 is a summary of chemical compatibility of many tank materials. As noted, Types 304 and 316 stainless steels have poor resistance to chemicals such as ferric chloride, hydrochloric acid, and sodium hypochlorite. Compatibility with most other common water treatment chemicals is good to excellent. Each potential application should be evaluated on an individual basis.

High-Density XLPE

High-density XLPE is a thermoset resin that is cross-linked with a peroxide catalyst during its manufacture. The resin is suitable for holding many of the chemicals used in water treatment applications. XLPE tanks cannot be used for potable water service but can be used to store chemicals that will be used in potable water applications if certified by NSF International [2]. XLPE tanks are available in capacities ranging from 20 gal (74 l) to 12,000 gal (45,000 l).

XLPE has superior stress crack resistance to high-density linear polyethylene (HDLPE) or fiberglass-reinforced plastic (FRP). In drop-impact tests, XLPE tanks do not split completely open but fail through small localized failures. Tanks should be constructed in accordance with the specifications outlined in ASTM D-1998 [3].

Temperature limits for XLPE range from 140°F to 150°F (60°C to 65°C) based on supplier recommendations. This might limit outdoor use in some parts of the country. The combination of warm ambient air temperatures and direct sunlight can produce limiting temperatures if the tank is installed outdoors and not under a shelter. In addition, XLPE tanks installed in outdoor locations are subject to degradation by ultraviolet (UV) light. These tanks should be manufactured with a UV stabilizer to protect against UV light. They can also be colored and/or sheltered for additional protection.

XLPE is used for single-wall and double-wall tanks. In many cases, the double-wall tanks eliminate the need for a separate containment. Having the outlet penetration is at the bottom of both tank walls can compromise the integrity of the containment and might not be permissible in accordance with local standards. In some cases, double-wall storage tanks can be fitted with a top discharge arrangement using a dip tube with a foot valve. Double-wall XLPE tanks are available with interstitial leak detection systems to detect leaks in the inner tank wall.

Tank installation is very important in order to protect the tank from mechanical stresses. This includes preparation of the base upon which the tank is to sit and protecting tank penetrations from pump vibration. Following the tank manufacturer’s installation instructions is important.

Many factors can impact the life of these tanks. The manufacturer should be consulted on the life expectancy of the tank, given the mechanical, environmental, and operating conditions to which it is subjected.

Unloading a chemical from a tanker to the storage tank is usually done with air pressure. This results in a surge of air into the tank when the transfer is complete. One manufacturer cautions that air pressure used for clearing fill lines should be limited to 7 psig (48 kPag). This could be a difficult limit to achieve because most chemical transport companies use an air compressor that develops 15 psig (103 kPag). The use of air pressure to unload a trailer is not recommended for chemicals, such as surfactants or biodetergents, that can foam. In these cases, a trailer with a gear pump would be needed.

Tank inspections should be based on the manufacturer’s recommendations, the environmental conditions, and plant experience with that particular type of tank.

Table 3-1 contains a listing for only polyethylene. The chemical compatibilities of XLPE and HDLPE (see the following section) are similar, but there can be some differences in specific applications. Each potential application should be evaluated individually.

High-Density Linear Polyethylene

HDLPE also has good chemical resistance to many of the chemicals used in water treatment applications. HDLPE tanks can be used for potable water service or to store chemicals that will be used in potable water applications.

HDLPE tanks have lower impact resistance than XLPE tanks, and they can fail with the sidewall splitting completely open.

Temperature limits for HDLPE range from 120°F to 130°F (49°C to 54°C) based on supplier recommendations. This can limit outdoor use in some parts of the country.

As is the case with XLPE, tank installation is very important in order to protect the tank from mechanical stresses. This includes preparation of the base upon which the tank is to sit and protecting tank penetrations from pump vibration. Following the tank manufacturer's installation instructions is very important.

HDLPE tanks installed in outdoor locations are subject to degradation by UV light. They can be colored or sheltered for protection against UV light.

Many factors can impact the life of these tanks. The manufacturer should be consulted on the life expectancy of the tank, given the mechanical, environmental, and operating conditions to which it is subjected.

Tank inspections should be based on the manufacturer's recommendations, the environmental conditions, and plant experience with that particular type of tank.

Fiberglass-Reinforced Plastic

FRP tanks are constructed with a range of resins and materials. FRP tanks have a laminate structure using fiberglass and a binding resin. Chemical resistance is a function of the binding resin selected. FRP tanks need to be selected based on the chemical to be handled, the environmental conditions, and the physical conditions. FRP tanks are not included in Table 3-1 because there is no single FRP material. The resin and other materials used to construct FRP tanks are selected based on the application. Information on compatibility should be sought from the chemical supplier and tank manufacturer.

Temperature limits for FRP tanks vary depending on the type of resin and construction. The manufacturer should be consulted for details on temperature limits.

As is the case with XLPE and HDLPE, tank installation is very important in order to protect the tank from physical stresses. This includes preparation of the base upon which the tank is to sit and protecting tank penetrations from pump vibration. Following the tank manufacturer's installation instructions is very important.

FRP tanks installed in outdoor locations are subject to degradation by UV light. They can be colored or sheltered for protection against UV light.

Many factors can impact the life of these tanks. The manufacturer should be consulted on the life expectancy of the tank, given the mechanical, environmental, and operating conditions to which it is subjected.

Tank inspections should be based on the manufacturer's recommendations, the environmental conditions, and plant experience with that particular type of tank.

Intermediate Bulk Containers

Intermediate bulk containers (IBCs), or totes, are used for both transporting chemicals and storing chemicals on site. There are numerous designs available. Common sizes are 275 gal (1040 l) and 330 gal (1250 l), but they can range from 120 gal (454 l) to almost 800 gal (3028 l). They are constructed of carbon steel (unlined and lined), stainless steel (unlined and lined), polyethylene inside a steel cage, or heavy-wall polyethylene.

The guidelines for chemical compatibility covered previously and detailed in Tables 3-1 and 3-2 should be applied to IBCs.

Secondary Containment

Bulk storage requires some type of a containment system to prevent the chemical from reaching the environment in case the storage vessel or a connection fails. The design of and materials used for the containment system will vary depending on the size of the storage vessel and the characteristics of the chemical involved. Important aspects of containment design and selection include the following:

- The containment must be able to hold the largest potential spill volume. Some states could require that the containment be sized to hold more than the largest potential spill volume.
- The containment must be constructed or lined with a material compatible with the product being stored.
- Incompatible chemicals (for example, bleach and acid) should not be stored within a common containment basin.
- Any drains from the containment should be valved and locked to prevent opening by unauthorized personnel. Some containments are designed without a drain, and their contents must be pumped out.
- Administrative procedures should be in place to control the opening/closing of the valve. If the containment is exposed to weather, there should be provisions for verifying and draining the rainwater.
- The drain should be routed to an appropriate sump.
- The drain should be able to be opened from outside the containment.
- The drain line should be designed so that it can be flushed after a spill.

Containment design should also take into account factors such as odors and flammability. Secondary containment should also be provided for the bulk carrier unloading area.

5
CHEMICAL TRANSPORT MATERIALS

Chemical transport involves the transport of the chemical from the storage tank to the feed system or from the feed system to the process. Historically, chemical transport has been a problem area for service water system chemical feed. This is because of the following:

- The physical strength of the transport piping
- Chemical attack of the transport piping
- Leaks at connections
- Plugging of injection quills or piping

Materials

A wide range of materials are available for chemical transport. Material selection must be based on chemical resistance (see Table 3-1) but must take into account factors such as the physical strength of the material, machinability, availability in appropriate configurations, the thermal expansion characteristics, the applicability of connection options, and the cost.

Carbon Steel

Carbon steel has very limited application except for transport of concentrated sulfuric acid. Most other chemical solutions used in service-water chemical treatment will rapidly attack bare carbon steel. Carbon steel might or might not be compatible with full-strength water treatment chemicals because of the corrosive characteristics of the concentrated chemicals.

Lined Carbon Steel

Carbon steel can be lined with appropriate materials to improve corrosion resistance (see Tables 3-1 and 3-2). The key factors are the following:

- The chemical resistance of the lining material
- The permeability of the lining material
- Whether the lining is susceptible to forming holidays (small penetrations)
- Connection options

300-Series Stainless Steel

The 300-series stainless steel piping and tubing is compatible with many of the chemicals used in water treatment, but 300-series stainless steel is definitely not compatible with hydrochloric acid, sodium hypochlorite, ferric chloride, and some acidic water treatment chemical blends.

Corrosion-Resistant Alloys

The corrosion-resistant alloys (CRA) such as titanium and Hastelloy C-276 are compatible with most chemicals, except for sodium hypochlorite because of the high nickel content. Titanium is not compatible with ferric chloride.

Polyvinyl Chloride

Polyvinyl chloride (PVC) is compatible with most of the chemicals used in water treatment, except for concentrated sulfuric acid (see Table 3-1). The maximum service temperature for PVC piping is 140°F (65°C). An increase in temperature results in a decrease in tensile strength and pipe stiffness. This impacts the maximum working pressure.

PVC is degraded by sunlight. In outdoor applications, it should be sheltered or protected by painting it with a heavily pigmented water-based latex paint.

Although PVC and chlorinated PVC (CPVC) are compatible with sodium hypochlorite, these materials often turn brittle within one or two years and start to leak at the joints. Experience in the past 10 years has shown that polyvinylidene fluoride (PVDF), although more expensive, is much more robust and less prone to leakage over time when conveying sodium hypochlorite.

Chlorinated PVC

Chlorinated polyvinyl chloride (CPVC) has the same chemical compatibility as PVC. It has a higher temperature tolerance and can handle up to 200°F (93°C). As is the case with PVC, an increase in temperature results in a decrease in tensile strength and pipe stiffness. This impacts the maximum working pressure. CPVC is degraded by sunlight. In outdoor applications, it should be sheltered or protected by painting it with a heavily pigmented water-based latex paint.

Polyvinylidene Fluoride

Polyvinylidene fluoride (PVDF) is a partially fluorinated polymer. It is a strong and abrasion-resistant fluoroplastic material. PVDF is sold under several trade names, including Kynar,[2] Hylar,[3] and Solef.[4] PVDF has good temperature resistance and retains most of its strength to 280°F (138°C). It is resistant to most oxidants (hypochlorite, bromine, and so forth), acids, mild bases, and organic solvents. It is not recommended for strong bases, such as 50% sodium hydroxide. PVDF is a material of choice for high-purity water applications.

Polytetrafluoroethylene

Polytetrafluoroethylene (PTFE) is the original Teflon[5] resin developed in 1938 by DuPont. It is a fully fluorinated fluoropolymer and has broad chemical resistance and high thermal stability. It has lower permeability than PVDF. PTFE is resistant to all of the chemicals used in water treatment applications. PTFE has good temperature resistance and can handle fluids with temperatures ranging from -60°F to +400°F (-51°C to +121°C).

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[2] *Kynar* is a registered trademark of Arkema, Inc.
[3] *Hylar* is a registered trade mark of Solvay Solexis, Inc.
[4] *Solef* is a registered trade mark of Solvay Solexis, Inc.
[5] *Teflon* is a registered trademark of E. I. du Pont de Nemours and Company.

Perfluoroalkoxy

Perfluoroalkoxy (PFA) is chemically similar to PTFE but has different machinability characteristics. It has good mechanical properties up to 500°F (260°C). The physical characteristics of PFA give it good stress and crack resistance and good flex life in tubing. PFA can be purchased in long runs of tubing. This minimizes the number of connections that are needed in a given chemical transport situation.

Connections

The chemical compatibility of the tubing/piping material is one aspect of material selection for water treatment chemicals. Just as important, however, is how the piping/tubing material is joined. As a rule, connections should be minimized where possible. Connections are a likely source of leaks. Appendix A describes a situation where long lengths of tubing were used, which eliminated all joints in piping runs, thereby minimizing the chance for leaks.

Carbon Steel

Threaded connections, socket welds, and butt welds are common in bare carbon steel.

Lined Carbon Steel

Lined carbon steel must use flanged connections to maintain the integrity of the lining.

300-Series Stainless Steel

Threaded connections, socket welds, and butt welds are common with stainless steel pipe. Threaded connections are sometimes difficult to tighten properly because of galling. Stainless steel tubing is commonly connected with compression fittings.

CRA

Compression fittings are usually available in the same CRA as the tubing being used. Alternately, CRA tubing can be butt welded or socket welded. Ginna opted to butt weld the titanium tubing (as opposed to compression fittings) and butt weld the titanium pipe when they installed their open cooling water chemical injection system in 2003. Corrosion-resistant alloys often require special welding techniques.

PVC and CPVC

PVC and CPVC are joined by solvent welding (solvent cementing), threading (Schedule 80 only), or flanging.

Successful solvent welding is a function of materials selection and technique. Solvent welding is a two-step process, using a primer to begin softening the materials in the pipe and fitting and using cement to finish softening and bond the two pieces together.

One problem that can occur is allowing excess cement to run down inside the pipe. This causes penetration of too much of the pipe and can initiate environmental stress cracking of the pipe.

A detailed description of the primer selection, the cement selection, and the proper techniques associated with solvent welding are beyond the scope of this report. These are available in publications such as the Harrington Engineering Handbook for Industrial Plastic Piping Systems [4].

PVDF

PVDF is typically joined by threaded connections (Schedule 80 or heavier), thermal electrofusion, thermal socket, or thermal butt.

PTFE

PTFE is similar to PVDF and is joined by threaded connections (Schedule 80 or heavier), thermal electrofusion, thermal socket, or thermal butt connections.

PFA

Compression fittings are used to join PFA sections and to join PFA tubing to fittings.

Tank Connections

Connections between chemical storage tanks and chemical feed piping must take the following into account:

- The chemical compatibility of all materials, such as storage tank, chemical feed piping, gasket, and expansion joint materials
- Mechanical stresses caused by the thermal expansion characteristics of storage tank and chemical feed piping
- Mechanical stresses caused by pump vibration

Figure 5-1 illustrates some of these issues.

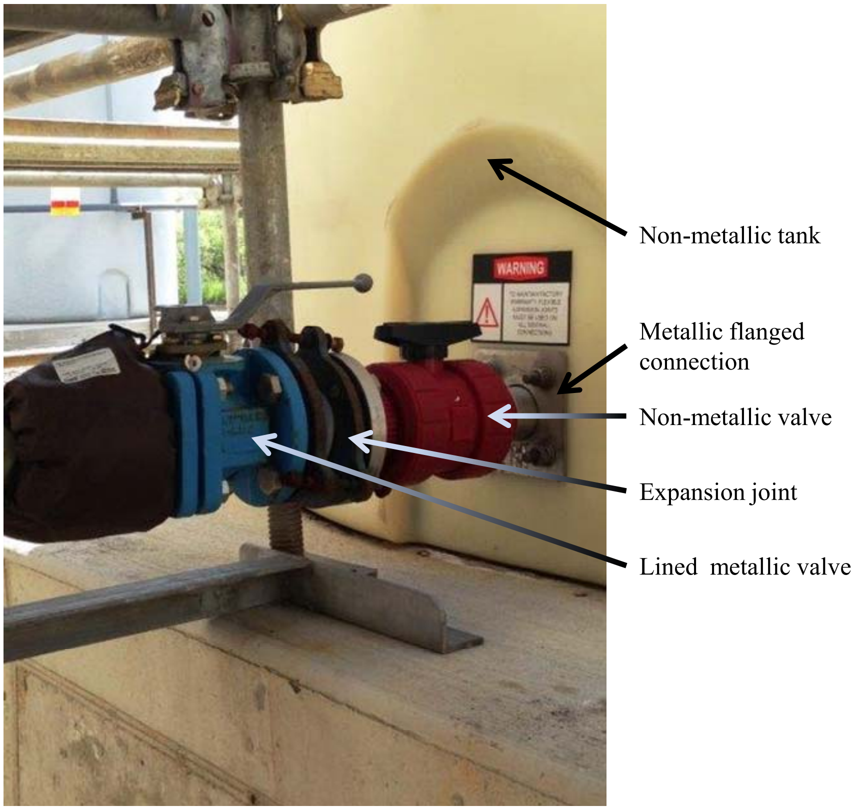

Figure 5-1
Tank connection materials considerations
Used with permission from Water Technology Consultants, Inc.

Another example of a discharge connection is shown in Figure 5-2.

Figure 5-2
A tank discharge connection, stress relief
Used with permission from Exelon, Ginna

Connections from nonmetallic tanks are often bulkhead fittings. Gasket integrity can be an issue with bulkhead fittings. One nonmetallic tank manufacturer provides a titanium female threaded coupling that is part of the tank. It is reported to be stronger than a bulkhead fitting and allows the tank to be drained fully.

6
CHEMICAL DELIVERY TO PROCESS

There are numerous factors that will influence the choice of a chemical feed method. The primary methods are chemical feed pumps, eductor systems, and gravity feed. There are options within each category, particularly with respect to chemical feed pumps.

Chemical Feed Pumps

The choice of chemical feed pumps is a function of the following:

- The chemical being fed and its concentration (chemical compatibility)
- The viscosity of the chemical being fed
- The quantity/volume that is needed
- The process pressure

The chemical resistance of pump materials is shown in Table 3-1.

Diaphragm Pumps

Description

Diaphragm pumps use a flexible diaphragm to displace a set volume of liquid with each stroke. A diaphragm pump uses a drive plunger or piston to move the flexible diaphragm. The flexible diaphragm then transmits pressure to the process fluid. This is done either by directly coupling the plunger/piston to the diaphragm or through a hydraulic arrangement where the plunger/piston pressurizes a hydraulic fluid. There are also double diaphragm pumps where the two diaphragms have an inert liquid or gel between them. This action, coupled with suction and discharge check valves, moves the process fluid in one direction. The process flow rate can be changed either by adjusting the stroke length or the stroke frequency. Diagrams showing a diaphragm pump during the suction and discharge strokes are shown in Figures 6-1 and 6-2.

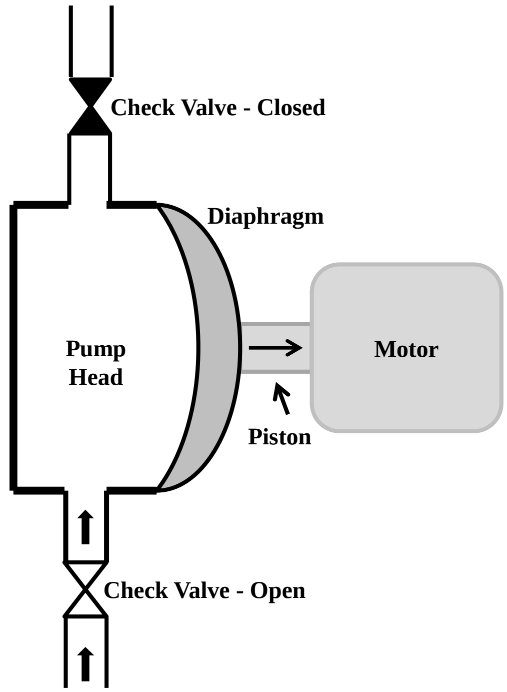

Figure 6-1
A diaphragm pump during a suction stroke
Used with permission from Water Technology Consultants, Inc.

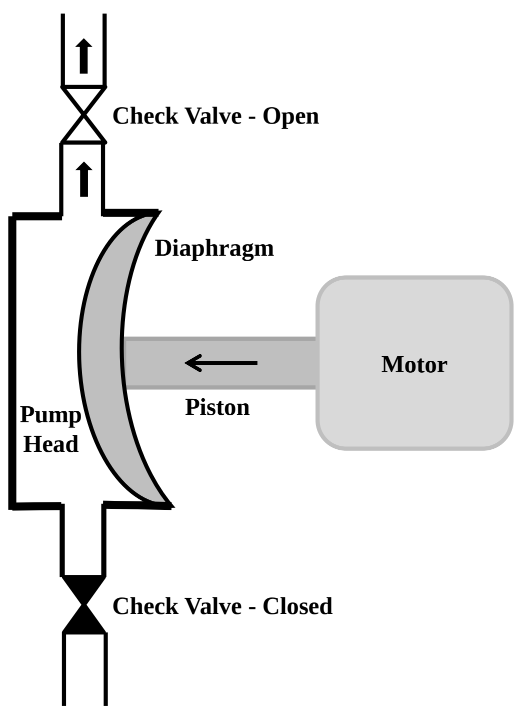

Figure 6-2
A diaphragm pump during a discharge stroke
Used with permission from Water Technology Consultants, Inc.

Diaphragm pumps are available in both motor-driven and air-driven configurations. Motor-driven configurations are most common when operating in the gallons per day (liters per day) or gallons per hour (liters per hour) range. Air-driven diaphragm pumps are often the most economical when operating in the gallons per minute (liters per minute) range.

Variable frequency drive (VFD) motors allow a secondary level of adjustment because the speed of the pump can be varied as well as the stroke.

Applications

Diaphragm pumps are suitable for pumping the following service water system treatment chemicals if suitable materials for wetted parts, such as a diaphragm, pump head, check valves, supply tubing/piping, and discharge tubing/piping, are used.

- Sodium hypochlorite (typically 12.5%)
- Sodium bromide (typically 40%)
- Sulfuric acid (typically up to 93%–98%)
- Scale/corrosion inhibitors in acidic solution
- Scale/corrosion inhibitors in basic (caustic) solution

Advantages

Diaphragm pumps are the most widely used chemical injection systems for water treatment chemical feed applications. They are available with a wide range of capacities and materials of construction. Appropriate materials are available for pump wetted parts, such as heads, diaphragms, and check valves, to feed most water treatment chemicals.

Because they are positive displacement pumps, diaphragm pumps deliver a consistent volume of liquid per stroke.

Diaphragm pumps do not have the same net positive suction head requirements as do centrifugal pumps. Because of this, they can be mounted above the liquid level in the storage tank.

Disadvantages and Cautions

Product-specific gravity and viscosity can interfere with the action of the ball check valves in the pump.

Depending on their design, diaphragm pumps can require manual priming after the loss of prime.

Air or other gas that accumulates in the pump head can interfere with check valve operation. This is referred to as *air binding* or *gas binding*. This is especially common when trying to pump ~12% sodium hypochlorite, but it could also apply to a chemical such as hydrogen peroxide. Chlorine gas is pulled from solution (off-gassing) and accumulates in the pump head. This causes the pump to lose prime. Each pump manufacturer has some way of attempting to prevent gas binding. Some use special degassing heads, and others slow the suction stroke to reduce the off-gassing.

Chlorine gas can also accumulate in the supply piping to pumps, causing them to lose prime. Pipes exposed to heat, such as from sunlight, are prone to off-gassing. There are cases where venting the suction line back to the bulk storage tank vented off gas pockets while still supplying sufficient suction head to the pumps.

The action of positive displacement diaphragm pumps will cause physical pulsing during the discharge stroke. This can cause damage to transport lines or to the pump itself. Pulsation dampers can be used to mitigate this problem.

Gear Pumps

Description

Gear pumps consist of a drive mechanism with two rotating spur gears. There is a drive gear and an idler gear.

Applications

Gear pumps are used for chemicals such as sulfuric acid, sodium hydroxide, and sodium hypochlorite. Pump casing and impeller material that are compatible with the materials being pumped are required. Gear pumps are often better suited for higher volume applications in the gallons per minute (liters per minute) range.

Advantages

Gear pumps handle viscous liquids well. There is positive experience with materials such as sodium hypochlorite because off-gassing does not impact pump output. There are also magnetically driven gear pumps where only the housing and gears are wetted by the chemical and not shafts, seals, and so forth.

Disadvantages and Cautions

The gear pump discharge flow rate decreases with increasing backpressure. Gear pumps work best under conditions of constant backpressure. There will always be wear to the gears in a gear pump. Abrasives will accelerate this wear. This wear will cause the discharge flow rate to decrease over time.

Progressive Cavity Pumps

Description

The pumping principle consists of a metal rotor that rotates inside an elastomer stator. Cavities are formed, which progresses the pumped liquid toward the discharge end of the pump as the metal rotor rotates. An example of the drive mechanism is shown in Figure 6-3.

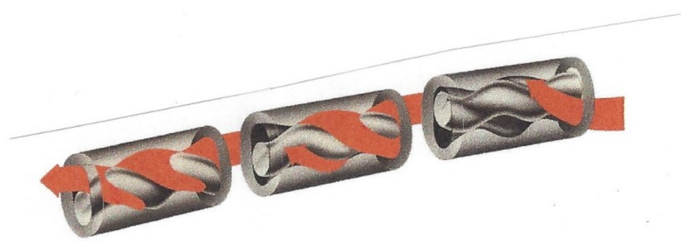

Figure 6-3
A progressive cavity pump
Used with permission from Moyno Pumps

Applications

Progressive cavity pumps are not normally used for chemicals such as concentrated sulfuric acid and sodium hypochlorite, but their applicability depends on the selection of the materials for the rotor and stator elastomer. With the appropriate materials, progressive cavity pumps can be used for many of the typical chemicals that are used in water treatment applications. Pump rotor and stator materials that are compatible with the chemicals being pumped are required.

Advantages

Progressive cavity pumps provide a steady output pressure and nonpulsing flow. In most applications, the pumps are self-priming. Progressive cavity pumps can handle viscous fluids. They do not require backpressure valves as do diaphragm pumps. The limited number of moving parts can be an advantage from a maintenance standpoint.

Disadvantages and Cautions

The rotor and stator can be subject to wear by abrasives in chemicals. Rotor or stator wear will impact pump output.

Peristaltic Pumps

Peristaltic pumps are also known as *tube pumps*. They operate by progressively squeezing a piece of flexible tubing against the casing with rotating rollers, as shown in Figure 6-4.

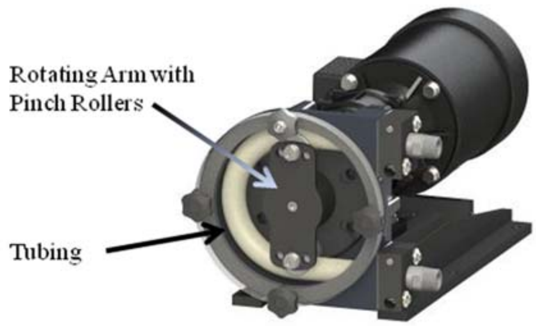

Figure 6-4
A peristaltic pump annotated
Used with permission of Pulsafeeder Incorporated.

Applications

Depending on the tubing material selected, peristaltic pumps can handle any of the common water treatment chemicals and blends.

Advantages

The chemical being pumped touches only the tubing in the pump and not the pump itself. Accurate flow control can be achieved with a peristaltic pump. In sodium hypochlorite service, peristaltic pumps are resistant to gas binding. Peristaltic pumps are self-priming. They can be sized to handle anywhere from a few milliliters per minute to large volumes (for example, 100 gal per min [378 l per min]). However, most peristaltic pumps are designed for fairly low flows such as 6 gal per min (23 l per min) or less.

Disadvantages and Cautions

There is constant wear on the pump tubing. Tubing must be replaced at regular and appropriate intervals.

Eductor Systems

Chemical feed using eductors has been used in several locations.

Description

Eductors are venturi jet devices that use a pressurized liquid (most often water) to create a vacuum and entrain other liquids, gases, or slurries of solids. Eductors come in a wide range of sizes. The flow of drive water in the device creates a vacuum in the suction chamber and pulls the liquid to be fed into the device. A diagram of a chemical feed eductor is shown in Figure 6-5.

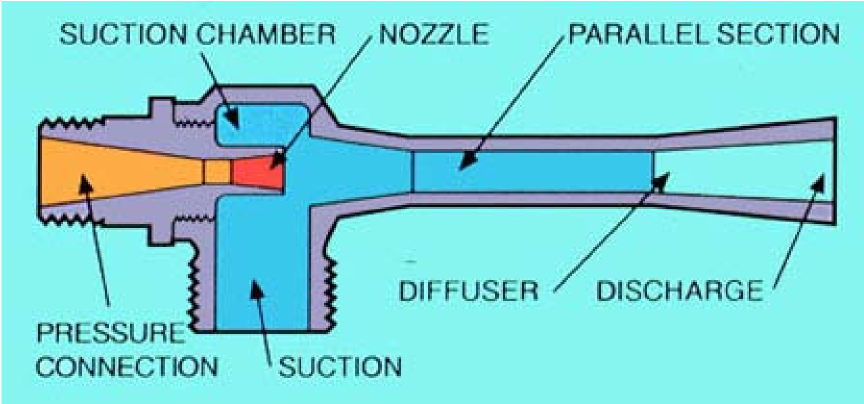

Figure 6-5
A chemical feed educator

Applications

In nuclear service water systems, eductor systems have been most frequently used to feed sodium hypochlorite.

Advantages

A primary advantage of eductors is reliability. Eductors have no seals or packing and are, therefore, relatively maintenance-free. Eductors are powered by the motive force of water and, therefore, have no moving parts. Eductors are good for injecting sodium hypochlorite because they are not subject to air binding as are diaphragm pumps.

Disadvantages and Cautions

The suction produced by an eductor is proportional to the flow rate of the motive fluid. Therefore, consistent flow is required for the consistent delivery of the chemical. The delivery rate of the chemical to the eductor is impacted by the level of the chemical in the storage tank. As the head pressure decreases, the flow rate of the chemical to the eductor decreases.

In hypochlorite service, scale can form as a result of the reaction of the calcium hardness in the motive water and the high pH of the hypochlorite solution. One fossil plant has resolved this by injecting carbon dioxide gas into the motive water at the end of each chlorination cycle. Another plant removes the eductor on an annual basis to clean accumulated scale. Two nuclear plants have eliminated this scale-forming issue by feeding a scale inhibitor (phosphonate) to the drive water during chlorination.

Eductors are generally not suitable for use with concentrated sulfuric acid. Significant heat would be generated at the point of acid–water interface. Most of the materials that are used to construct eductors are not suitable for sulfuric acid service.

Gravity Feed

Description

Gravity feed allows the treatment chemical to flow into the process stream by virtue of the tank head. The gravity acid feed system at one plant is shown in Figure 6-6. In this installation, acid drains by gravity into a header with numerous flexible quills that discharge sulfuric acid into the cooling tower flume.

Figure 6-6
A gravity acid feed system
Used with permission from Exelon Corporation

Applications

Gravity feed has been used primarily for sulfuric acid feed and sodium hypochlorite feed.

Advantages

Valves are the only moving parts, which means that the problems often experienced with pumps are eliminated. In sodium hypochlorite service, gravity feed is not subject to gas binding.

Disadvantages and Cautions

The main disadvantages and cautions of gravity feed systems are as follows:

- Valve failure can allow the uncontrolled flow of the chemical to the process. This risk can be reduced by installing redundant shutoff valves. One plant equips the supply tank with ultrasonic level indicators that alarm if the tank usage is higher than the highest historical usage.
- Failure of a pH meter-based acid controller can cause overfeed or underfeed of acid. One way to prevent this is through the use of dual pH controllers. Another approach is a timer that will allow the feed valve to be open only for a set amount of time even if the controller is calling for acid feed.
- Flow varies with a drop in storage tank level, which means that feed rate is not constant. The flow rate of the chemical can be controlled by a control valve that opens more as the tank head level drops. Another approach is to use an on/off control that is set so that the control valve stays on longer as the tank level drops.
- For bleach feed, scale can build up where the concentrated bleach is injected into the cooling water. Some plants have the discharge point above the water level to prevent scale buildup at the discharge/cooling water interface.

Chemical Injection Points and Equipment

In cooling tower service, sulfuric acid is normally fed into the lower basin of the cooling tower. Concentrated sulfuric acid has a high specific gravity and can easily pool in the bottom of the basin and attack the concrete. For this reason, the sulfuric acid should be added into an acid-resistant trough discharging into an area of the cooling tower basin with turbulent flow to promote mixing.

Chemicals can be injected into a bypass stream that serves to dilute the chemical before sending it to the main process stream. This process is shown in Figure 6-7.

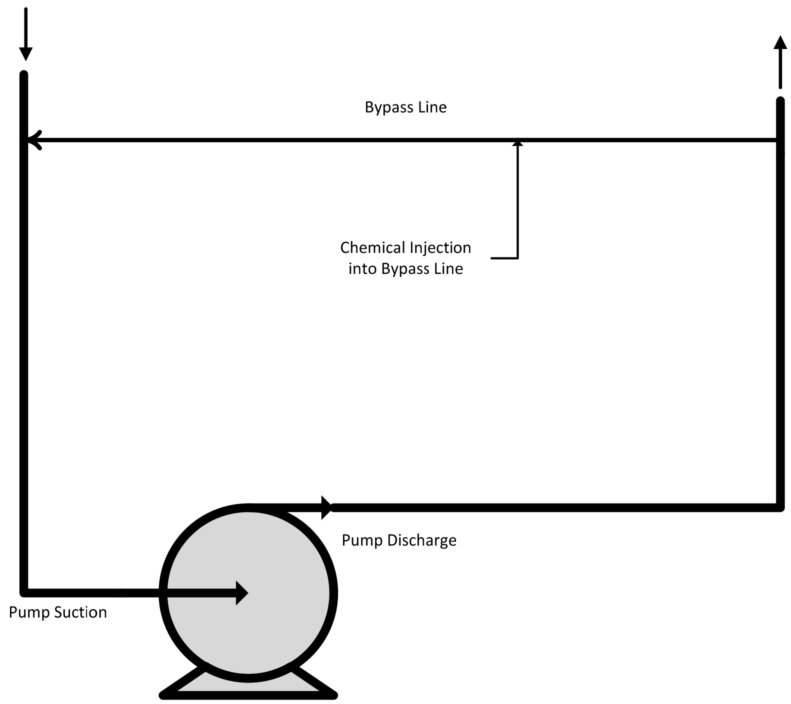

Figure 6-7
Chemical injection into a bypass line
Used with permission of Water Technology Consultants, Inc.

If the chemical is to be injected directly into the process stream, an appropriate injection quill or corporation stop/quill assembly should be used. The purpose of the injection quill or corporation stop is to inject the chemical into the moving stream of water and away from the pipe wall. Injecting the chemical into a tap in the pipe wall can lead to localized corrosion of the pipe wall immediately downstream of the injection point.

Injection quills are used to inject chemicals into high-pressure or high-temperature lines. An example is shown in Figure 6-8. Corporation stops are used to inject chemicals into larger lines. They allow the removal of the injector for servicing with the process line in service.

Figure 6-8
A chemical injection quill
Used with permission from Missouri Filter & Process Equipment Company

The quill is threaded directly into a Weldolet[6] attached to the pipe. The direction of flow is from bottom to top. A corporation stop is shown in Figure 6-9.

Figure 6-9
A corporation stop assembly
Used with permission from Missouri Filter & Process Equipment Company

The chain on the corporation stop allows the quill to be withdrawn and the ball valve closed. In this way, the quill assembly can be cleaned or changed with the process line in service. A low-pressure corporation stop installation is shown in Figure 6-10.

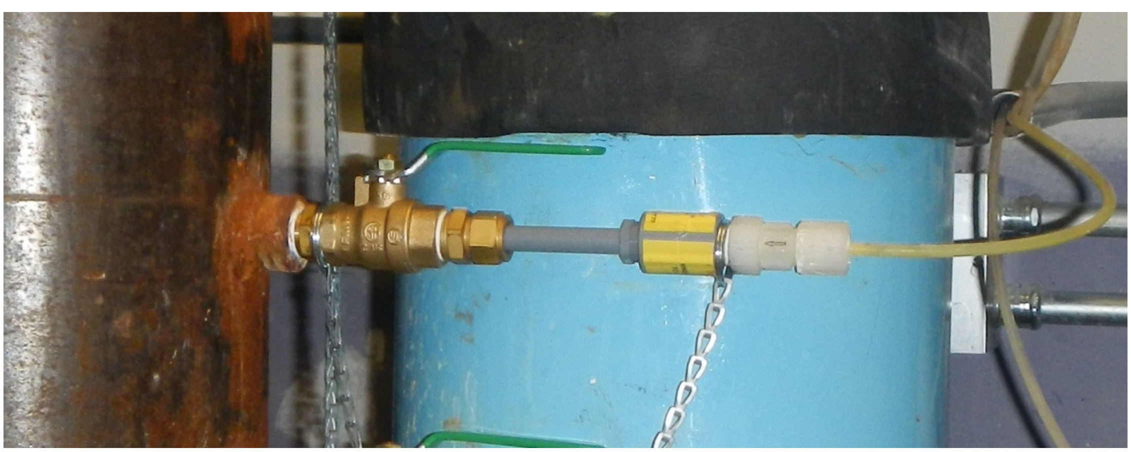

Figure 6-10
A low-pressure corporation stop installation
Used with permission from Water Technology Consultants, Inc.

Quills should be periodically removed and inspected for corrosion or breakage. It is good practice to also use nondestructive evaluation techniques to inspect the piping area around the quill for excess corrosion from concentrated chemicals.

[6] *Weldolet* is a registered trademark of Bonney Forge Corporation.

7
PROCESS CONTROL

Feed Verification

There needs to be verification that the chemical is being fed into the process stream at the correct rate. Some methods are applicable to some situations but not to others. Some are proprietary to individual water treatment service companies.

Calibration Cylinders

Calibration cylinders are low tech, but they are a tried-and-true method of verifying the pumping rate. A schematic is shown in Figure 7-1.

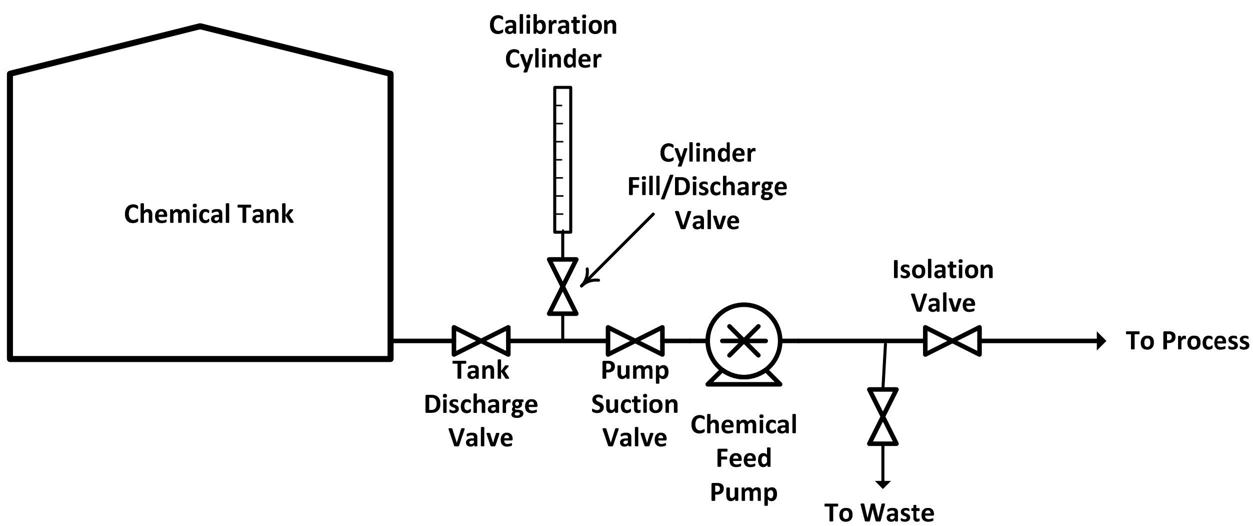

Figure 7-1
A calibration cylinder arrangement
Used with permission from Water Technology Consultants, Inc.

Operation consists of filling the cylinder by opening the cylinder fill/discharge valve to fill the calibration cylinder, closing the chemical tank discharge valve to provide the pump suction with only the chemical in the calibration cylinder, and determining the amount of time it takes the chemical feed pump to discharge a given amount of the chemical. This method serves as a manual check on pump discharge rate or is used to adjust chemical flow. It does not provide any indication of loss of chemical flow.

A written procedure is recommended when using a calibration cylinder to ensure that the valves are set to their original position to allow flow from the storage tank so that the pump does not run dry from leaving the valves in the calibration position.

Flow Sensors

Several types of flow sensors on the market provide a continuous indication of the chemical feed flow. These are set up to signal if the flow is lost. Some of the flow sensors have a moving part, such as a paddle wheel, but others sense the flow electronically or acoustically. Several chemical feed pump manufacturers incorporate flow sensors into their design and integrate the sensor output with the pump electronics. In this way, pump operation can be stopped if the pump loses suction or if the discharge line becomes blocked. The pump can also alarm under these conditions or if it senses excessive flow.

There are proprietary feed verification systems, such as the General Electric PaceSetter[7] VeriFeed,[8] Vericon (EquipSolutions), Micro-Flow (Blue-White Industries), and PosiFlow[9] (Walchem).

Still others use online process control as the means to verify and control chemical feed. These include On-Guard[10] (Ashland), 3D Trasar[11] (Nalco Company), and OnSite[12] (Buckman).

Online Process Control

Injecting a chemical into the system consistently is half of the battle. Injecting it at the right rate as conditions change is the other half. Injecting a chemical at the proper rate is accomplished through online process control. Consistent online process control requires the selection of the appropriate instruments linked with appropriate software, provisions for adequate sample flow to the instruments, appropriate calibration, and provisions for the required maintenance.

Online process control is accomplished by combining the appropriate software with the outputs of the types of instruments described in the following sections of this report.

Electrochemical Analyzers

There are several electrochemical techniques that are used alone or together for process control.

Conductivity

Conductivity is the basic method for control of cooling tower cycles of concentration. It is a simple and reliable method based on measuring the electrical resistance of the water. Conductivity is the mathematical inverse of resistance. The method is based on the fact that, as the concentration of dissolved salts in water increases, conductivity increases (resistivity decreases).

Conductivity instruments are reliable and require little calibration. Fouling of the cells with debris, suspended material, oil, or microbiological growth can impact accuracy.

[7] *PaceSetter* is a registered trademark of General Electric Company.
[8] *VeriFeed* is a registered trademark of General Electric Company.
[9] *PosiFlow* is a registered trademark of Walchem, Iwaki America, Inc.
[10] *On-Guard* is a registered trademark of Ashland, Inc.
[11] *3D Trasar* is a registered trademark of Nalco Company.
[12] *OnSite* is a registered trademark of Buckman Laboratories International, Inc.

pH

Online pH measurement is used to control acid feed to a cooling water system. pH measurement involves two electrodes, a measuring electrode (glass electrode) and a reference electrode. The reference electrode provides a reference voltage and has a flowing junction to create a salt bridge between the electrode and the sample stream.

pH instruments will drift and can provide inaccurate readings if the electrodes become coated with suspended material, oil, or microbiological growth. Regular calibration is required.

Oxidation Reduction Potential

Oxidation reduction potential (ORP) instruments are very similar in design to pH instruments with a measuring electrode and a reference electrode. They are used for direct or indirect control of oxidizing biocide feed. Because ORP measurements are pH sensitive, accuracy can be limited when the ORP instruments are used for direct control of oxidizing biocide feed. For this reason, ORP instruments are more often used as indirect indicators of oxidizing biocide feed.

ORP is also a valuable tool for confirming the adequate feed of a dechlorination chemical when it is used to remove an oxidizing biocide residual prior to discharge.

Chlorine

There are electrochemical chlorine analyzers for monitoring oxidizing biocide (for example, sodium hypochlorite) concentration in cooling water.

Biological

There are electrochemical methods for detecting the accumulation of biofilm. They can be valuable in detecting the initiation of biofilm growth and confirming that a microbiological control program is effective. Online biofilm monitors include ALVIM (ALVIM Srl), BioGEORGE,[13] Kiwa (Kiwa NV Water Research), Neosens (Orchids Laboratory), and BioSense (Chemtrac).

Colorimetric Analyzers

Colorimetric methods operate by adding a reagent to water that reacts with the compound of interest and produces a color, the intensity of which is directly proportional to the concentration of the compound in the water.

Chlorine

There are online colorimetric methods for free available chlorine and total residual chlorine.

Other Colorimetric Analyzers

There are numerous online colorimetric analyzers on the market. These include analyzers for phosphate, silica, and molybdate. Phosphate and silica analyzers are more useful for boiler water chemistry determinations than for cooling water. Molybdate analyzers are not frequently used.

[13] *BioGEORGE* is a trademark of Structural Integrity Associates, Inc.

Indirect Tracers

An *indirect tracer* is a detectible substance that is added to the water treatment product in a given proportion to the active ingredient in the product and used to control product dosage. The tracer usually does not play an active role in corrosion, scale, or deposition control. Some tracers consist of colored fluorescent dyes with colors in either the visible light spectrum or in the UV light spectrum. The tracers in the UV light spectrum require very low concentrations of the tracer. Other tracers consist of an inorganic material, such as molybdate. It is added at concentrations too low to act as a corrosion inhibitor but still in a measurable range.

The advantages of tracer technology are that it can provide rapid detection of product overfeed or underfeed and can be used to control the product injection rate. A disadvantage is that the active ingredient in the water treatment product can be consumed at a different rate in the system from that of the tracer. An example of this is a plant that used a molybdate tracer to control dispersant feed to its spray ponds. The molybdate tracer showed an adequate level of product, but the dispersant had been consumed and was no longer available to perform its intended function.

Direct Tracers

Direct tracers are used with some polymeric water treatment materials where a UV tag is attached to the polymer structure (tagged polymer). The tag can be directly read with an instrument (fluorometer). This provides a means of directly measuring the concentration of the polymer of interest. By combining this with an indirect tracer, the consumption of active ingredient can be followed. The tagged polymer technology is currently a proprietary technology.

Online Tank Level Monitoring

This can also be an effective means of confirming the consistent flow of a chemical feed. It can detect and alarm loss of flow. It is particularly suited for chemicals being fed at a significant rate, such as sodium hypochlorite. Methods of tank level monitoring include mechanical, pressure, ultrasonic, and microwave radiation.

8
REFERENCES

1. Powell Fabrication and Manufacturing, Sodium Hypochlorite General Information Handbook, 2002.
2. NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI, 48105.
3. Standard Specification for Polyethylene Upright Storage Tanks, Designation D-1998, ASTM International, 1988.
4. Harrington Industrial Plastics, Inc., Harrington Engineering Handbook for Industrial Plastic Piping Systems, Chino, CA, 2011.

A
SUCCESSFUL OPERATING EXPERIENCE

Sodium Hypochlorite Injection into Service Water Systems at Calvert Cliffs Nuclear Power Plant

Background

The source of open cooling water at Calvert Cliffs Nuclear Power Plant (CCNPP) in Maryland is Chesapeake Bay, an estuarial body of water. The salinity and other characteristics of the water are highly variable, seasonally and from one year to the next. Salinity varies from 5 to 20 parts per thousand (ppt), pH varies from 7.5 to 9.0, and the suspended solids levels are highly variable. Macrofouling species include hydroids, barnacles, oysters, blue crabs, horseshoe crabs, clams, mussels, jellyfish, tunicates, and assorted fish.

Service Water Chemical Addition System History

There have been five unsuccessful service water chemical addition systems installed since construction. They are as follows:

- Gaseous chlorine, which never operated, because of licensing issues
- Sodium hypochlorite (early operation), which involved a carbon steel piped central pump and was abandoned because of excessive leaks and maintenance
- Sodium hypochlorite (early 1990s), for which the following should be noted:
  - Had threaded PVC pipe and local positive displacement pumps
  - Operated less than two weeks over a two-year year period
  - Abandoned because of excessive leaks and maintenance
- Chloro bromo isocyanurate system, for which the following should be noted:
  - Had dry powder drive-water system
  - Abandoned because of the cost of materials and operation
  - Could not support continuous chlorination
- Sodium hypochlorite (2007–2008), which had a Kynar pipe and drive water system and was highly redundant and designed for continuous or intermittent injection, and was abandoned because of leaks, complexity, and other issues, including calcium buildup, excessive maintenance, control cabinet overheating, rupture of control valves, excessive use of well water, and overall unreliable operation

Chemical Injection Basics at Calvert Cliffs (Old and New Systems)

The following should be considered:

- A permit change to allow continuous chlorination was completed in 2006. The total residual chlorine was limited to 0.1 parts per million (ppm) as Cl_2.
- A 12% sodium hypochlorite solution was used.
- Peak feed rates reach approximately 700 gal per day (2650 l per day) to maintain 0.2 ppm residual just prior to plate-and-frame heat exchangers.
- Chemical storage is approximately 350 ft (107 m) from the injection locations.

New Service Water Chemical Addition System at CCNPP

The new service water chemical addition system was installed in late April 2009. It is designed to inject continuously or intermittently. Continuous injection is the most efficient. The features of this system include the following:

- The self-contained skid is designed to contain spills.
- The system uses continuous 350-ft (107-m) runs of PFA tubing. The lack of joints and fittings prevents leaks.
- The tubing is run in a guard pipe (conduit) that contains any leaks and provides a visual indication of leaks.
- Four spare tubing runs are installed within the guard pipe.
- Simplified controls involve fewer valves and potential leak points.
- The direct injection of sodium hypochlorite into a header does not require carrier water. This reduces water consumption and minimizes calcium buildup. Injection is through titanium injection quills (existing) to protect process piping from the corrosive sodium hypochlorite.

Some of these details are shown in Figure A-1.

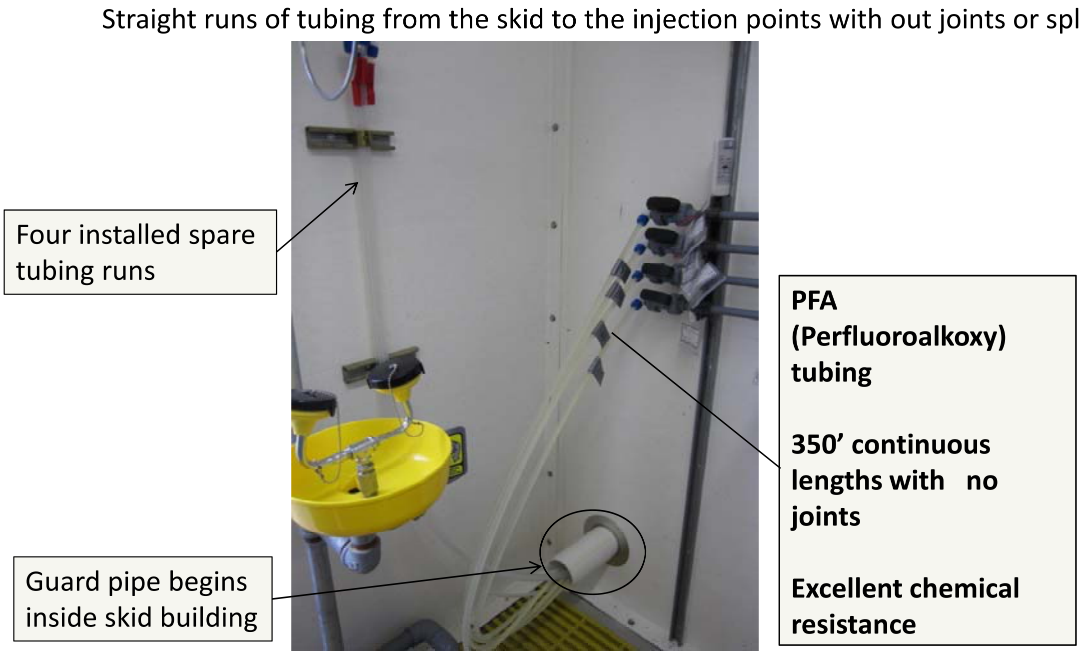

Figure A-1
CCNPP chemical feed details
Used with permission from Constellation Energy

The availability of the service water chemical addition system has been greater than 99% since installation. The overall system was designed by an engineering firm and is maintained by CCNPP. The skid itself was designed by a vendor, and the vendor is responsible for its operation under contract.

Since initial installation, some issues have been corrected. These include the following:

- There was excessive wear to gear pumps. This has been largely resolved by tighter suspended solids limits in sodium hypochlorite specifications.
- Pressure loss in the feed pump suction line has led to net positive suction head issues. The system would have benefited from a larger diameter supply line. This problem is compounded by the fact that the spare pump is farthest from the storage tank.
- The Y-strainer between the storage tank and the pumps requires the system to be taken out of service to clean. The system would have benefited from a duplex strainer that could be cleaned with the feed system in service.

Sodium Hypochlorite Injection into Service Water and Circulating Water at Brunswick Nuclear Plant

Background

The source of open cooling water at Brunswick Nuclear Plant (BNP) is the Cape Fear River, a brackish and tidal river. The salinity and other characteristics of the water are highly variable, depending on the time of year, the amount of rainfall on site and in North Carolina, and the tides. Average salinity ranges from 25 to 30 ppt during the summer months and from 15 to 20 ppt during winter months. Salinity as low as 8–12 ppt can be seen during heavy rains and increased river flows. Macrobiological fouling is caused by seaweed, gracilaria (red algae), tunicates, hydroids, marsh grass, algae, detritus, ctenophores, and jellyfish, barnacles, oysters, clams, assorted shellfish, and fish species. The largest macrofouling threat inside plant systems at BNP is barnacles, oysters, and other shellfish.

Chemical Addition System History

The service water and circulating water systems at BNP were originally treated with gaseous chlorine. This method was effective for controlling macrofouling, but, because of safety issues, the gaseous chlorine system was abandoned.

While a permanent sodium hypochlorite (NaOCl) Injection system was being designed and constructed, BNP employed a temporary injection skid for the service water and circulating water systems. PVC injection piping was installed to gravity feed the NaOCl into the service-water and circulating-water bays from tanker trucks. A flow meter was installed in-line to determine the flow rates from the tanker trucks. This method was somewhat effective, yet very labor intensive. Also, fouling issues arose as a result of inconsistent application of NaOCl.

Sodium Hypochlorite Injection Basics at Brunswick

The following should be considered:

- A 5-mile-long (8.05-km-long) discharge canal allows time for the NaOCl to be consumed before it is discharged to the Atlantic Ocean (the National Pollutant Discharge Elimination System [NPDES] -permitted outfall). The NPDES permit requires no free residual chlorine at the outfall. This length of the discharge canal makes it possible to continuously chlorinate the service water system with no NPDES permit violations.
- A 12.5% NaOCl solution with a proprietary bromine solution (ActiBrom[14]) is injected into circulating water and service water systems.
- Peak feed rates for service-water reach approximately 120 gal per hour (454 l per hour). This can range from approximately 100 gal per hour (380 l per hour) in summer to as low as 25 gal per hour (95 l per hour) in winter to maintain a 0.25-ppm residual just prior to the closed cooling water heat exchangers. An upper limit of 3 ppm is employed to prevent the corrosion of stainless steel service-water components.
- The peak feed rates for circulating water reach approximately 675 gal per hour (2555 l per hour) per unit. The normal summer rates are 630 gal per hour (2385 l per hour). Winter rates are as low as 300 gal per hour (1136 l per hour), which is injected for 25 min, six times a day. A lower limit of 0.1 ppm residual is needed for circulating water treatment.

[14] *ActiBrom* is a registered trademark of Nalco Company.

Sodium Hypochlorite Injection System at Brunswick

The sodium hypochlorite injection system was installed in December 2007. The system is designed to inject continuously or intermittently into service water and circulating water systems. Information about the system includes the following:

- The self-contained skid is designed to contain spills.
- The skid is located outside of the plant's protected area, which eases chemical delivery and maintenance activities.
- There is a 20,000-gal (75,700-l) NaOCl double-walled FRP tank, which includes level indication and leak detection systems.
- There is a 6000-gal (22,710-l) ActiBrom double-walled FRP tank, which includes level indication and leak detection systems.
- The service water injection system has the following characteristics:
  - Four 38-gal-per-hour (144-l-per-hour) capacity diaphragm pumps for NaOCl
  - Four 3.2-gal-per-hour (12.1-l-per-hour) capacity diaphragm pumps for ActiBrom
  - NaOCl and ActiBrom combined in a common Teflon PTFE tubing injection line that is routed in a PVC guard pipe to the four service-water bays (Tubing length is approximately 920 ft [280 m].)
  - An injection line that has four isolation valves, two at the skid and two at the intake structure
  - Chemical tubing that is routed underwater in a guard pipe for better mixing in the low service-water flow
- The circulating water injection system has the following characteristics:
  - Eight 3.7-gal-per-min (14.0-l-per-min) capacity gear pumps for NaOCl
  - Eight 17-gal-per-hour (64.3-l-per-min) capacity diaphragm pumps for ActiBrom
  - NaOCl and ActiBrom combined in a common Teflon PTFE tubing injection line that is routed in a PVC guard pipe to the eight circulating-water intake pump bays (Tubing length is approximately 920 feet [280 m].)
  - An injection line that has four isolation valves, two at the skid and two at the intake structure
  - Chemical tubing that is routed to each circulating-water bay, where it is fed above the waterline when the pump is running
- Circulating-water and service-water chemical pumps are controlled by a programmable logic controller, and manual and automatic modes control the pump injection rates using VFD motor controllers.

The availability of the NaOCl system at BNP has been excellent, averaging above 99%. The overall system was designed by BNP and an outside engineering firm with support from the chemical supply vendor. The chemical injection pump skid is maintained by the chemical supply vendor. Pump injection rates are controlled by site chemistry with vendor input.

Since initial installation, there have been some issues that have been corrected. The majority of these issues were resolved when BNP installed redesigned circulating-water bleach pumps to reduce leaks from the pump heads (safety and reduced maintenance cost).

A project is currently in the design phase at BNP to install continuous chlorination analyzers in the service water and circulating water systems to improve the chemical treatment effectiveness and potentially allow for reduced chemical injection rates. BNP currently takes daily samples of service water at the closed cooling-water heat exchangers and adjusts injection rates accordingly.

B
TRANSPORT AND DELIVERY ISSUES

There have been numerous incidents of chemical delivery mistakes.

Case Study of Caustic to Acid Tank Incident

System

This power plant had an external water treatment building with a makeup demineralizing system. The tanks for 93% sulfuric acid and 50% caustic (sodium hydroxide) were located adjacent to the building.

Incident

A truck driver delivering 50% caustic soda connected to the fill connection for the 93% sulfuric acid tank and began transferring caustic to the acid tank. The caustic and acid quickly reacted, producing large volumes of steam. The entire 5000-gal (18,927-l) acid tank flew up onto the roof of the water treatment building where it remained. The acid and caustic mixture flowed into the ground floor of the water treatment building.

Injuries

One plant person was on duty in the water treatment building. He escaped from the building through a back door without injury. The truck driver sustained some chemical burns that were not fatal.

Equipment Damage

The event put the entire water treatment plant out of service because of chemical damage to wiring, panels, and so forth. The plant was out of service for approximately one year. Rental systems were used during that time to provide makeup water to the plant.

Costs

The rental water systems cost approximately $100,000 per month. The replacement of the water treatment equipment cost approximately $7 million. The total cost was approximately $8 million to $8.5 million.

Cause of Accident and Contributing Factors

Lack of supervision at the plant level and inadequate knowledge/training on the part of the driver contributed to the cause of the accident.

Lessons Learned

Lessons learned included that there is no substitute for the following:

- Direct supervision by appropriate plant personnel
- Satisfactory training
- Procedures
- Checklists

Case Study of Caustic to Acid Tank Near Miss

System

This power plant received frequent deliveries of 66˚ Baumé sulfuric acid (~93%) and 50% sodium hydroxide (caustic soda).

Incident

The acid and caustic tanks were fitted with four-bolt flanges. The third-party trucking firm that normally delivered sulfuric acid to the site was instead bringing a load of caustic on that day. The delivery sheet was filled out, but the operations personnel responsible for overseeing the offloading assumed that the delivery was sulfuric acid. The driver was directed to the sulfuric acid tank and proceeded to connect to the four-bolt flange. A security guard walked by and asked a question about caustic acid. This caused the operations personnel to take a second look and catch the mistake before any product was transferred.

Injuries

Fortunately, there were no injuries in this incident.

Equipment Damage

There was no equipment damage.

Costs

The costs included the labor cost of the stand-down to assess the incident and the management time to oversee all deliveries for the next three to four months.

Cause of Accident and Contributing Factors

The following contributed to the cause of the accident:

- Inadequate supervision at the plant level (directing the driver to the wrong tank)
- Inadequate procedures and checklists to ensure that the tanker was connected to the correct tank
- Identical connections for acid and caustic

Lessons Learned/Corrective Actions

The following are lessons learned and corrective actions:

- The need for additional training for operations personnel
- Improved procedures, for example, to match product UN identification number in the procedure to the product UN identification number on truck (**Note**: This was a site-specific corrective action. UN numbers only identify hazardous materials. Different chemicals can have the same UN number. The chemical ID on the bill of lading and the chemical ID on the tank and truck must be matched.)
- Fill connection on caustic tank switched to stainless steel cam-lock fitting (**Note**: Truck drivers carry many adapters; so, this will not guarantee that a connection to the wrong tank can be avoided.)

Case Study Connection of Sulfuric Acid Tote to Ammonia System

This fossil plant feeds aqueous ammonia for boiler pH control. The totes used for this are blue. The plant also use totes of concentrated sulfuric acid for pH control in the makeup treatment system. The sulfuric totes are also blue and are similar in appearance. Aqueous ammonia and sulfuric acid totes have the same type of outlet connection.

In this case, a chemical technician went to change the ammonia tote and brought in another blue tote without reading the label on the tote. The second tote contained sulfuric acid instead of ammonia. The chemical technician did not realize his error until he valved the tote in and the acid began reacting with the water in the line, creating considerable rumbling and popping sounds as the water was flashing to steam. Fortunately, the technician managed to get the tank isolated and broke the connection without being injured. The pumps were turned off, and no acid was pumped to the unit. It was necessary to then flush the piping and, after an ammonia tote was attached, run the pumps to waste until the acid cleared.

Causes

The following should be considered:

- A possible lack of training
- Inattention on the part of the operator
- An apparent lack of written procedures and checklists

Case Study of Sulfuric Acid Driver Fatality

In the early 1970s, a truck driver was killed when he opened the dome of his trailer full of sulfuric acid thinking that the tank was not pressurized. The gauge on his trailer showed *no pressure*, and the shipment was not unloading. What had actually happened was that the hydraulic unloading valve on the back of the truck had not opened as the driver had thought and the pressure gauge had failed. Thinking his dome gasket was leaking and preventing the trailer from building pressure, the driver opened the dome. When he knocked the last connecting bolt loose, the trailer instantly depressurized, causing the trailer to move. In the process, a full column of acid was sloshed out the dome opening and came down right on top of the truck driver.

Many new safety rules regarding chemical unloading were instituted by the plant following this incident. Safety requirements were built into contracts to require the suppliers to ensure that their drivers followed the proper procedures, and contracts went only to suppliers that delivered with their own trucks.

C
OTHER PLANT CHEMICAL FEED ISSUES

Recent Chemical Feed Equipment Issues at Palo Verde

Background

In 2009, a plant modification to install five chemical addition skids in each Palo Verde Unit (15 total) was completed. The function of these skids was to feed specialty chemicals and sulfuric acid into the essential spray ponds. Each skid includes a chemical storage tank, two diaphragm pumps, two pulsation dampeners, valves, instruments, and piping. Delivery of the chemicals is orchestrated by a programmable logic controller (human-machine interface [HMI]), which starts and stops the chemical feed pumps according to a predetermined schedule. The chemicals are as follows:

- Copper corrosion inhibitor (tolyltriazole)
- Dispersant
- Non-oxidizing biocide
- Mild steel corrosion inhibitor
- 93% sulfuric acid

Sulfuric acid is fed directly into each spray pond, and the other four chemicals are fed into a recirculation header that dilutes the chemicals and transports them to the associated spray pond.

Figure C-1 depicts a simplified layout of the chemical feed equipment.

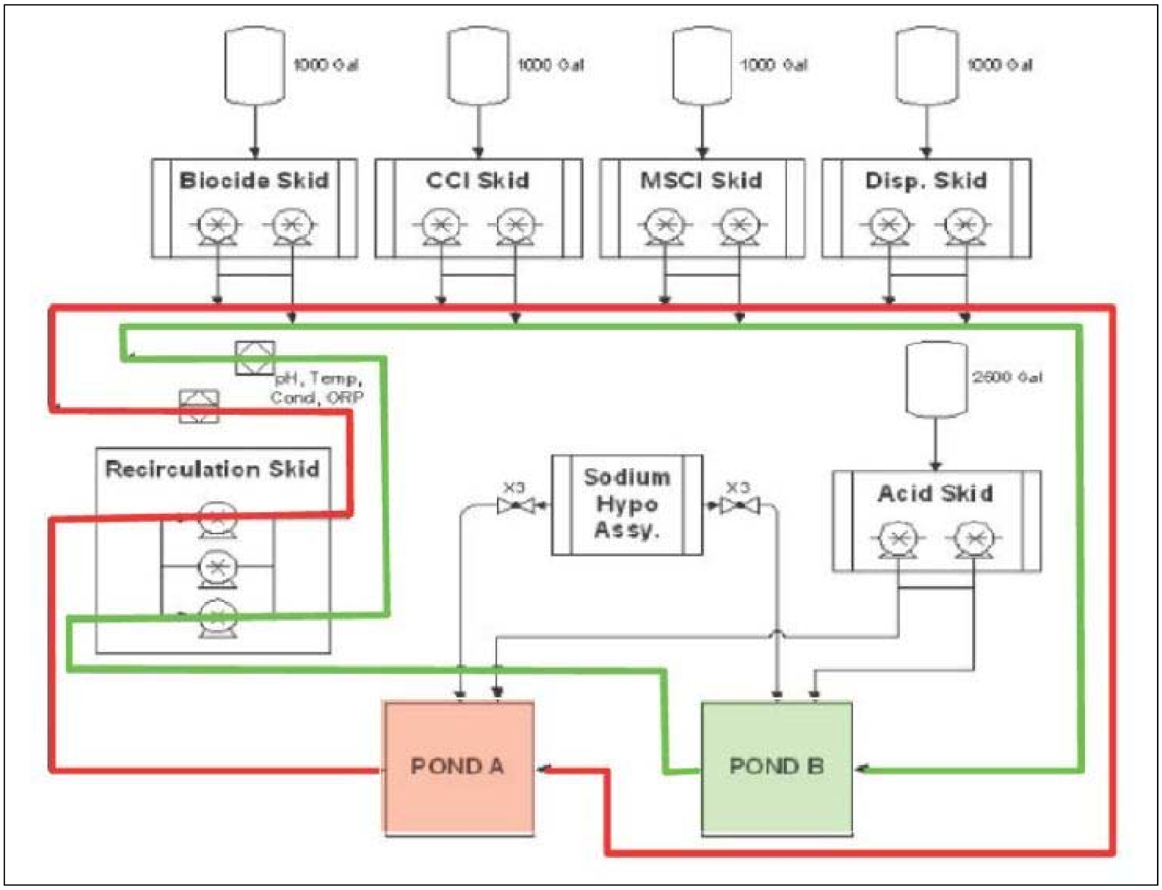

Figure C-1
The chemical feed skid layout at Palo Verde
Used with permission from Arizona Public Service Company

The modification also installed three air-operated valves per pond to facilitate control of sodium hypochlorite addition through the HMI. The hypochlorite equipment has experienced relatively few issues and will not be included in this report.

Materials

Each chemical is stored in a double-walled cross-linked high-density polyethylene (HDPE) tank.

Specialty chemical, piping, valves, pulsation dampers, and associated equipment are fabricated of a combination of PVC and CPVC.

Sulfuric acid piping, valves, pulsation dampeners, and associated equipment are fabricated of PVDF, or Kynar.

Equipment Issues

Pump failures. During the first 15 months of service, the chemical feed pumps experienced numerous diaphragm failures. It was determined that the pump internal relief setting was factory-set to more than three times the pressure of the recirculation header. The relief setting was changed to 10%–20% above the expected discharge pressure, and no diaphragm failures have been reported in the two-plus years since.

Leaks. Numerous leaks have occurred, and continue to occur, at threaded pump/valve fittings throughout the skids. The following should be noted:

- Through-wall leaks have occurred in CPVC piping containing copper corrosion inhibitors. This was caused by the chemical attack of localized areas featuring glue dribbles that occurred during the pipe assembly. The sections of piping that experienced excessive glue application were replaced. It was also determined that CPVC was not compatible with the copper corrosion inhibitor, and the affected pump discharge piping was replaced with stainless steel.
- Following the replacement of the CPVC piping with stainless steel, an adjacent section of PVC piping failed catastrophically because of the stress from the distortion of the adjacent steel piping that occurred when it was welded.
- A copper corrosion inhibitor pulsation dampener failed catastrophically. The fragments were sent offsite for analysis, and the cause was determined to be fatigue-induced cracking. Based on the input from the vendor and the operating conditions, the fatigue was believed to be the result of pressure surging from the loss of pre-charge pressure and/or the blockage of downstream injection quills.
- Two of the three sulfuric acid tanks experienced leakage resulting from the cracking of the inner tank wall at the bolted connection for the outlet pipe. The outer tank contained the leakage until the acid in the annulus filled the outlet pipe transition fitting and leaked past the grommet between the fitting and the pipe. The leakage of the inner tanks was not apparent until acid was discovered dripping onto the ground. Both tanks were replaced, and one of the new tanks experienced a leak after approximately six months in service.
- Bolted bulkhead fittings associated with outlet piping for the specialty chemical tanks have experienced minor leakage. Unlike the issue with the acid tanks, no tank failure has occurred.
- Numerous occurrences of leakage and/or blockage of injection quills have occurred. Based on the configuration of the skids and recirculation header, as well as the chemical addition sequence, it has been determined that injection quills are not necessary and should not have been included in the design.

Path Forward

Threaded fitting leaks have been most prevalent on the copper corrosion inhibitor skids, and an evaluation of this trend has revealed that the O-ring material might not be compatible with this chemical. A material change is being pursued to reduce the frequency and severity of leaks on the copper corrosion inhibitor skids.

The long-term strategy is to replace the skids. A new modification has been proposed to replace the skids with a similar equipment layout using chemically compatible metal alloys. The high-density polyethylene tanks would be replaced by either metal tanks or a containment structure that would allow the delivery of chemicals directly from vendor-supplied totes. The intent is to use materials, equipment, and fitting connection types (that is, welded or bolted) that will virtually eliminate leaks. The skids will be simplified where possible, and the use of metal piping and components will provide greater assurance that the equipment will remain functional for the remainder of plant life.

D
RELATED INFORMATION

Chemical Label

The label on a chemical container is a valuable source of information. Figure D-1 shows a copy of a label for a non-oxidizing biocide. The label shows informations on ingredients, precautions, storage, disposal, permitted uses, and permitted dosages.

PRECAUTIONARY STATEMENTS: HAZARDS TO HUMANS AND DOMESTIC ANIMALS

DANGER. CORROSIVE. CAUSES IRREVERSIBLE EYE DAMAGE OR SKIN BURNS. HARMFUL IF INHALED, SWALLOWED OR ABSORBED THROUGH SKIN. Do not get in eyes, on skin or on clothing. Prolonged or frequently repeated skin contact may cause allergic reaction in some individuals. Mixers, loaders, and others exposed to this product must wear: long-sleeved shirt and long pants; chemical resistant gloves such as nitrile or butyl rubber; shoes plus socks; goggles and face shield; and chemical resistant apron. Discard clothing or other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them. Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry. Users should wash hands before eating, drinking, chewing gum, using tobacco or using the toilet. Users should remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing. Users should remove PPE immediately after handling the product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly. Do not apply this product in a way that will contact workers or other persons.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to fish and wildlife. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of the EPA. Do not contaminate water by cleaning of equipment or disposal of waste. Apply this pesticide only as specified on this label.

PHYSICAL AND CHEMICAL HAZARDS

This product is corrosive to mild steel. Do not store or transport in unlined metal containers.

STORAGE AND DISPOSAL

STORAGE: Do not contaminate water, food, or feed by storage or disposal. Open dumping is prohibited.

DISPOSAL: Pesticide wastes are toxic. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal Law. If these wastes cannot be disposed of by use according to label instructions contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

(Instructions for non-refillable containers 5 gallons or less:)

Container Handling: Non-refillable container. Do not reuse or refill this container. Offer for recycling, if available. Triple rinse (or equivalent) container promptly after emptying. Triple rinse as follows: Empty remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container ¼ full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times. Then offer for recycling, if available, or reconditioning, or puncture and dispose of in a sanitary landfill, or incinerate or burn, if allowed by state and local authorities. If burned, stay out of smoke.

Net Contents Shown Elsewhere on Container

NALCO

Nalco 7330

A MICROBIOCIDE FOR CONTROL OF BACTERIA, FUNGI AND ALGAE IN INDUSTRIAL RECIRCULATING WATER COOLING TOWERS, INDUSTRIAL PROCESS WATER SYSTEMS, AIR WASHER SYSTEMS, BREWERY PASTEURIZERS, AND ELECTRODEPOSITION SYSTEMS.

ACTIVE INGREDIENTS:	
5-Chloro-2-methyl-4-isothiazolin-3-one	1.1%
2-Methyl-4-isothiazolin-3-one	0.4%
INERT INGREDIENTS:	98.5%
TOTAL	100.0%

This product contains the active ingredients at 0.127 pounds per gallon

KEEP OUT OF REACH OF CHILDREN

DANGER PELIGRO

FIRST AID

If swallowed:
· Call a poison control center or a doctor immediately for treatment advice.
· DO NOT INDUCE VOMITING.
· Do not give anything to drink.

If in eyes:
· Hold eye open and rinse slowly and gently with water for 15-20 minutes.
· Remove contact lenses, if present, after the first 5 minutes, then continue rinsing for at least 15 minutes or until it is judged that nearly all of the contamination has been removed.
· Call a poison control center or a doctor immediately for treatment advice.

If on skin or clothing:
· Take off contaminated clothing.
· Rinse skin immediately with plenty of water for 15-20 minutes.
· Call a poison control center or a doctor for treatment advice.

If inhaled:
· Move person to fresh air.
· If person is not breathing, call 911 or an ambulance, and then give artificial respiration, preferably mouth-to- mouth if possible.
· Call a poison control center or a doctor for further treatment advice.

NOTE TO PHYSICIAN:
Aspiration may cause lung damage. Probable mucosal damage may contraindicate the use of gastric lavage.
Have the MSDS and, if available, the product container or label with you when calling a poison control center or a doctor, or going for treatment.

SEE SIDE PANEL FOR ADDITIONAL PRECAUTIONARY STATEMENTS.

Nalco Company
1601 West Diehl Road
Naperville, IL 60563-1198
EMERGENCY PHONE NO. (800) 424-9300

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

INDUSTRIAL COOLING TOWER SYSTEMS AND PROCESS WATER SYSTEMS

(Such as pretreatment systems and process waters used for washing metal or plastic parts and/or paint reduction.) For control of bacteria, fungi and algae, add NALCO 7330 to the tower basin, distribution box or some other point in the system to insure uniform mixing. Badly fouled systems must be precleaned before treatment is begun.

INITIAL DOSE: When the system is noticeably fouled apply 2.46 to 7.46 lbs. (37 to 113 fluid ounces) of NALCO 7330 per 1000 gallons of water in the system. Repeat until control is achieved.

SUBSEQUENT DOSE: When microbial control is evident, add 1.26 to 1.86 lbs. (19 to 28 fluid ounces) of NALCO 7330 per 1000 gallons of water in the system weekly or as needed to maintain control.

INDUSTRIAL RECIRCULATING CLOSED LOOP WATER COOLING SYSTEMS

For the control of bacteria, algae and fungi add NALCO 7330 to the reservoir, recirculating line or some other point in the system to insure uniform mixing.

INITIAL DOSE: When the system is noticeably fouled, apply 1.26 to 7.46 lbs. (19 to 113 fluid ounces) of NALCO 7330 per 1000 gallons of water in the system. Repeat until control is achieved.

SUBSEQUENT DOSE: When microbial control is evident, add 35 to 219 ppm NALCO 7330 (0.3 to 1.86 pounds or 4.5 to 28 fluid ounces of NALCO 7330 per 1000 gallons of in the system) weekly or as needed to maintain control. Badly fouled systems must be cleaned before treatment is begun.

AIR WASHER SYSTEMS AND BREWERY PASTEURIZERS

For control of bacteria, algae and fungi, add NALCO 7330 to a point in the system where uniform mixing can occur such as the basin. FOR USE IN INDUSTRIAL AIR WASHER SYSTEMS THAT MAINTAIN EFFECTIVE MIST ELIMINATING COMPONENTS. Badly fouled systems must be precleaned before treatment is begun.

INITIAL DOSE: When the system is noticeably fouled, add 1.26 to 7.46 lbs. (19 to 113 fluid ounces) of NALCO 7330 per 1000 gallons of system water. Repeat until control is achieved.

SUBSEQUENT DOSE: When microbial control is evident, add 0.3 to 1.86 lbs. (4.5 to 28 fluid ounces) of NALCO 7330 per 1000 gallons system water weekly or as needed to maintain control.

ELECTRODEPOSITION SYSTEMS
(NOTE: THIS USE NOT CURRENTLY AUTHORIZED IN CALIFORNIA)

For control of bacteria, and fungi in Electrodeposition Systems (such as automotive or industrial equipment systems) slug feed NALCO 7330 at a rate of 1 gallon per 1000 gallons of paint in the system (1000 ppm) as needed, depending upon results of cultures taken from the system.

INTERMITTENT OR SLUG METHOD

INITIAL DOSE: When the system is noticeably fouled, apply 148 to 883 ppm NALCO 7330 (1.26 to 7.46 pounds or 19 to 113 fluid ounces of NALCO 7330 per 1000 gallons of water in the system). Repeat until control is achieved.

SUBSEQUENT DOSE: When microbial control is evident, add 35 to 219 ppm NALCO 7330 (0.3 to 1.86 pounds or 4.5 to 28 fluid ounces per 1000 gallons of water in the system). Weekly or as needed to maintain control. Badly fouled systems must be cleaned before treatment is begun.

CONTINUOUS FEED METHOD

INITIAL DOSE: When the system is noticeably fouled, apply 148 to 883 ppm NALCO 7330 (1.26 to 7.46 pounds or 19 to 113 fluid ounces of NALCO 7330 per 1000 gallons of water in the system).

SUBSEQUENT DOSE: Maintain this treatment level by adding a continuous feed of 35 to 219 ppm NALCO 7330 (0.3 to 1.86 pounds or 4.5 to 28 fluid ounces per 1000 gallons of makeup water). Badly fouled systems must be cleaned before initial treatment.

EPA REG. NO. 1706-153

EPA Establishment numbers may include the following. (Letters in () that match the prefix in batch number identify the establishment number.)

1706-CA-1 (CR); 1706-CN-1 (BU);
1706-IL-1 (BP); 1706-LA-1 (GV); 1706-PA-1 (EL);
1706-WA-1 (VW); 68708-OK-1 (TU);
68708-TX-1 (SL); 68708-TX-2 (FP);
68708-TX-3 (DS)

NR5 Revised: 01/25/2011 UN 3265, Corrosive Liquid, Acidic, Organic, N.O.S. (Isothiazolinone Microbiocide), 8, II

Figure D-1
A label for a non-oxidizing biocide
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