

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 1 of 50
		December, 2003	

Changes shown by ↗

CONTENTS

Section	Page
SCOPE	3
REFERENCES.....	3
DESIGN PRACTICES	3
ENVIRONMENTAL DESIGN PRACTICE	3
OFFSITES DESIGN PRACTICE	3
INTERNATIONAL PRACTICES	3
OTHER LITERATURE.....	3
BACKGROUND.....	4
DEFINITIONS	4
SYSTEM TYPES AND APPLICATIONS	6
BASIC DESIGN CONSIDERATIONS.....	6
RELIABILITY	6
FLEXIBILITY.....	6
ENVIRONMENTAL AND SAFETY CONCERNS.....	7
SYSTEM SELECTION	7
COOLING WATER REQUIREMENTS	8
LOAD GROWTH AND RESERVE CAPACITY	8
COOLING TOWER TYPES.....	8
COOLING TOWER BASIN.....	9
MATERIALS OF CONSTRUCTION	10
WATER TREATMENT FOR ONCE-THROUGH SYSTEMS.....	10
WATER TREATMENT FOR SALT WATER COOLING TOWER SYSTEMS.....	10
WATER TREATMENT FOR FRESH WATER COOLING TOWER SYSTEMS	10
EXTERNAL TREATMENT.....	11
INTERNAL TREATMENT.....	11
ALKALINITY (PH) CONTROL	11
Corrosion Control	11
SCALE AND SLUDGE CONTROL	12
BIOLOGICAL CONTROL	13
BLOWDOWN	14
CONTROLS AND MONITORS.....	14
WASTEWATER REUSE POSSIBILITIES	14
DESIGN PROCEDURE FOR ONCE-THROUGH SYSTEMS	15
DESIGN PROCEDURE FOR RECIRCULATING SYSTEMS	19
REVAMP AND EXPANSION PROJECTS.....	27


Documents

Document Sharing Hub

Section XXVII	Page 2 of 50	COOLING WATER SYSTEMS	 DESIGN PRACTICES
December, 2003			

CONTENT (CONT)

COMPUTER PROGRAMS	29
NOMENCLATURE	29
APPENDIX A Reliability Check List.....	30

TABLES

Table 1 Impurities Found in Cooling Water.....	32
Table 2 Allowable Concentration of Impurities in Recirculated Fresh Cooling Water	33
Table 3 Method of Chemical Receipt.....	34
Table 4 Water Treatment Analysis Worksheet.....	35

FIGURES

Figure 1 Typical Once-Through Cooling Water System.....	36
Figure 2 Typical Recirculated Cooling Water System.....	37
Figure 3 Cooling Tower Types.....	38
Figure 4 Support Structure for Water Intake Crib.....	39
Figure 5 Water Intake Pipe	40
Figure 6 Water Intake Bay	41
Figure 7 Sump Dimensions vs. Flow Rate* Customary Units	42
Figure 8 Configurations for Multiple-Pump Pits.....	45
Figure 9 Fan Horsepower Requirements* Customary Units	46
Figure 10 Cooling Tower Orientation	48
Figure 11 Water Treatment Flow Plan for Recirculating Cooling Water Systems	49
Figure 12 COOLING TOWER DISENGAGING STACK.....	50

Revision Memo

12/03 Reliability Check List Appendix A

EMRE COOLING WATER SYSTEM SPECIALISTS

TECHNOLOGY AREA	CONTACT	PHONE NO. (703) 846-	E-MAIL (AMERICAS)
Water Treatment	R. G. Balmer	3640	RGBALME
	C. M. Havran	3806	CMHAVRA
System Planning and Design	R. A. Lieberwirth	7378	RALIEB2
	G. E. Stover	(281) 834-7599	GESTOVE

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section	Page
		XXVII	3 of 50
		December, 2003	

SCOPE

This section presents the criteria and general procedures for the selection and design of cooling water systems in process plants. Major components are described for both once-through and recirculated type cooling systems using either fresh or salt water. This section also includes information on the chemical treatment required to control corrosion, scaling and biological fouling in cooling water systems. Information on automatic equipment used to monitor water condition and to make the necessary adjustment in chemical treatment is also included.

REFERENCES

DESIGN PRACTICES

Section II	Design Temperature, Design Pressure and Flange Rating
Section IX	Heat Exchange Equipment
Section X	Pumps
Section XII	Instrumentation
Section XIV	Fluid Flow
Section XV	Safety in Plant Design

ENVIRONMENTAL DESIGN PRACTICE

Section XIX-B	Water Reuse
-------------------------------	-------------

OFFSITES DESIGN PRACTICE

Section XXVI-A	Boiler Feedwater Treating Systems
--------------------------------	-----------------------------------

INTERNATIONAL PRACTICES

IP 1-1-1	Drawings, Diagrams and Line Lists
IP 3-10-3	Cement Lined Pipe and Fittings
IP 3-10-4	Plastic and Plastic-Lined Piping
IP 8-1-1	Cooling Towers
IP 10-11-1	Sizing of Drivers and Transmissions for Compressors, Fans, and Pumps
IP 16-1-1	Area Classification and Related Electrical Design for Flammable Liquids, Gases, or Vapors
IP 16-4-1	Grounding and Overvoltage Protection
IP 19-6-1	Facilities for Corrosion Monitoring in Process Equipment

OTHER LITERATURE

Cooling Tower Water Treatment Guidelines, ER&E Report No. EE.102E.78.
Exxon Cooling System Handbook, January, 1986.
Environmentally Acceptable Cooling Water Treatments, ER&E Report No. EE.34E.86.
Karlsruhe Cooling Water System Reliability Study, ER&E Report No. 85EEEL.3268.
Reuse of Wastewater as Cooling Tower Makeup, ER&E Report No. EE.58E.85.
Guidelines for the Inspection, Preventative Maintenance and Rehabilitation of Cooling Towers, ER&E Report No. EE.47E.89.
Guidelines for Safety Evaluation of Chemical Injection Facilities, ER&E Report No. EE.92E.94.
EMRE *Water and Wastewater Design Guide*, TMEE 080, DG 11-3-1, Gas Chlorinators for Water Treating Service.
EMRE *Water and Wastewater Design Guide*, TMEE 080, DG 11-6-2, Chemical Feeders for Cooling Towers (Leased or Purchased).
EMRE *Refinery Construction Materials Manual*, Manual No. EETD 028
Cooling Tower Institute (CTI) Acceptance Test Codes for Water Cooling Towers (ATC-105).
Cooling Tower Institute (CTI) Cooling Tower Performance Curves.

Section XXVII	Page 4 of 50	COOLING WATER SYSTEMS	ExxonMobil DESIGN PRACTICES
December, 2003			

BACKGROUND

Rejection of heat is a requirement of a great many processes and utility systems. Coolers and condensers reject much of this heat to water. The main purpose of a cooling water system is to absorb the heat rejected and dispose of it. The system must be safe, reliable, and flexible, and it must have a minimum impact on the environment.

Cooling system selection and design is very site specific and cannot be generalized. The EMRE COOLING SYSTEM SPECIALISTS are available for consultation on specific requirements.

DEFINITIONS

Ambient Wet Bulb Temperature

The wet bulb temperature that exists in the cooling tower area. It is the temperature specified in the Design Specification for the design and guarantee basis. Note the actual tower inlet wet bulb temperature may be higher than the ambient wet bulb temperature due to hot air recirculation.

Approach

The difference in temperature between cold water leaving the tower and ambient wet bulb temperature.

Battery Limits

A boundary which is normally assumed to be at the physical edge of the block in which the facility is located.

Blowdown

The continuous or intermittent discharge of a small amount of the circulating water. Its purpose is to limit the increase in the concentration of solids in the water due to evaporation. It is expressed in percent of water circulated.

Brackish Water

Water which contains 3,000 to 5,000 wppm of dissolved salts.

Cell

The smallest tower subdivision which can function as an independent unit with regard to air and water flow.

Cooling Tower Pumping Head

The total pressure at the centerline of the tower inlet to its hot water distribution system plus the difference in elevation between the centerline of the inlet and the top of the cold water basin curb. It does not include friction pressure drop in the riser pipe. This is a parameter representing the head required for the cooling tower only. It excludes the cooling water distribution system.

Counterflow Tower

A cooling tower in which air induced at the bottom of the tower flows up through the fill against the falling water.

Crossflow Tower

A cooling tower in which air induced at the sides of the tower flows horizontally across the fill and the falling water.

Cycles of Concentration

The ratio of dissolved solids in circulating water to dissolved solids in makeup water.

Dissolved Solids

A measure of the total quantity of dissolved salts in water. It can be determined by conductivity measurements.

Drift

The entrained water carried from the tower by exhaust air, expressed in percent of water circulated.

Dry Bulb Temperature

The temperature of ambient air read on an ordinary thermometer.

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 5 of 50
		December, 2003	

DEFINITIONS (Cont)

Fill

Packing within the cooling tower to provide the required surface area for heat transfer between ambient air and the return cooling water. **Splash fill** breaks the water into small drops by causing it to cascade through successive offset levels of parallel, level splash bars. **Cellular or film fill** causes the water to spread into thin films over large vertical areas.

Heat Load

Heat removed from the circulation water within the tower. It may be calculated from the range and the circulating water flow rate.

Interference

The mixing of tower inlet air with the discharge vapors from another tower or other heat source. This results in reduced thermal performance.

Makeup

The water required to replace circulating water which is lost by evaporation, drift, blowdown, and leakage. It is expressed in percent of water circulated.

Offsites

Support facilities such as utilities (steam, power, cooling water), tankage, waste treating, etc., for the processing operations.

Once-Through Cooling System

A system in which water passes through the heat exchange equipment once and is then discharged.

Onsites

Facilities that are a part of the processing operations.

Range or Water Cooling Range

The difference in temperature between the hot and cold circulating water, or on-tower temperature minus off-tower temperature.

Recirculated Cooling System

A system in which water is circulated to coolers in a loop and the heat absorbed from this cooling operation is dissipated by a cooling tower or some other type of heat exchanger.

Recirculation

An undesirable condition in which part of the tower discharge vapor stream is recirculated through the tower resulting in increased inlet air wet bulb temperature.

Relative Humidity

The ratio of the quantity of water vapor present in air to the quantity which would saturate the air at the existing temperature.

Salt Water

Water which contains more than 5,000 wppm of dissolved salts.

Wet Bulb Temperature

The equilibrium temperature obtained when ambient air is passed over a continuously wetted thermometer bulb evaporating the water and cooling the bulb. This equilibrium temperature occurs when the heat transferred from the air to the wetted surface equals the heat loss due to latent heat of evaporation.

Wind Rose

A diagram that shows the average frequency and intensity of wind from different directions for a particular location.

Section XXVII	Page 6 of 50	COOLING WATER SYSTEMS	ExxonMobil DESIGN PRACTICES
December, 2003			

SYSTEM TYPES AND APPLICATIONS

Cooling water systems in refineries and chemical plants are generally either the once-through or the recirculated type designed for fresh, salt, or brackish water.

In the once-through system (see [Figure 1](#)), pumps take suction from a source of supply such as a river, or other body of water and deliver the water to process coolers and other consumers. After passing through the cooling exchangers, the hot cooling water is discharged through pressurized piping or a gravity flow system.

In a recirculated system (see [Figure 2](#)), pumps take suction from a cooling tower basin and deliver the water to process coolers and other consumers. After passing through the cooling exchangers, the hot cooling water is discharged through a pressurized return system to a cooling tower.

The choice between a once-through and recirculated cooling water system must be based on: (1) availability of water of satisfactory quality, (2) process temperatures, (3) atmospheric conditions, (4) investment and operating costs, and (5) effluent water quality and temperature limitations.

The cooling water is distributed to individual consumers throughout the plant in piping main supply and return headers and series and parallel branches consisting of laterals and sublaterals. The main cooling water distribution headers are either buried in underground trenches, or are located above grade on ground-level pipe sleepers or on elevated pipe racks. Underground piping has the advantage of minimizing problems associated with thrust loads, thermal expansion, and freezing. Elevated piping is easier and less expensive to install and repair and it makes it easier to locate leaks.

BASIC DESIGN CONSIDERATIONS

RELIABILITY

The cooling water system is an important utility and its reliability is critical to successful plant operation. The typical system provides cooling water to both onsite and offsite consumers. It can have a direct impact on the sizing criteria for the emergency relief (flare) system (refer to [Section XV-C, Safety in Plant Design Pressure Relief](#)). The system, therefore, normally must be capable of continuous operation so that cooling water is always available to critical consumers.

The reliability required to achieve continuous operation is provided in several ways:

- Spare makeup and water circulating pump(s) are provided to assure continuous operation.
- Different types of drivers are specified for the supply or water circulating pumps. Motor-driven pumps are supplied from two different buses on a secondary selective electrical distribution system.
- Cooling tower fan drivers are normally supplied from a secondary selective system.
- Holdup volume is provided in the cooling tower basin to permit an orderly shutdown of process units if the makeup water supply is lost or a failure occurs in any part of the recirculated cooling water system.
- Valves, blinds and bypasses are provided to permit individual components to be removed from the system for maintenance while the system is operating.
- Construction materials provided for cooling water facilities are designed for long-term corrosion resistance, since maintenance work is often difficult (if not impossible) to schedule without a complete refinery shutdown.

FLEXIBILITY

The cooling water system must include sufficient flexibility to cover all present operating requirements plus any future operating requirements that are defined in the design basis document. For example, future operating requirements could be dictated by a near-term increase in plant size.

The type of flexibility features provided in a system may include the following:

- Makeup water treating facilities should be able to deliver the required water assuming the worst conditions of the water source.
- Waste treating facilities should be designed to handle effluent water containing varying concentrations of oil and chemicals over the range of expected ambient temperatures.
- Valves and blind flanges should be provided to permit future tie-ins to the system without a shutdown. An exception would be on lines where a "hot tap" could be made with minimum risk of an emergency shutdown or where the cost of required valves is prohibitive.
- Cooling tower cells should be completely partitioned as described in **IP 8-1-1** to allow personnel entry to any cell for maintenance without affecting the operation or capacity of the other cells. Normally, spare cells are not provided. Maintenance is carried out during cooler periods when the cooler ambient and wet bulb temperatures enable the cooling tower to handle greater heat loads.

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 7 of 50
		December, 2003	

BASIC DESIGN CONSIDERATIONS (Cont)

- Where multiple cooling tower systems exist, consideration should be given to providing valved cross connections between their respective supply mains and between their respective return mains. These would be used only for special operations such as turnarounds or emergencies. The impact on flare sizing should be evaluated if these cross connections are provided.

ENVIRONMENTAL AND SAFETY CONCERNS

Once-through cooling water systems usually require controls to minimize the release of hydrocarbons and free halide residuals to the environment. As a minimum, cooling water discharges should be monitored for free oil, total organic carbon, or hydrocarbon vapors to determine if system coolers are leaking. Free chlorine residuals in the discharge should also be monitored as required to meet local regulations and to detect process leaks. In most cases, once-through cooling water flows are too large to be handled in the plant's wastewater treatment system. However, once-through water that could become contaminated with hydrocarbons is often segregated and treated in a large skim pond or special purpose separator prior to discharge. Local environmental regulations and permit requirements will dictate the extent of treatment required.

Cooling tower blowdown from recirculated systems is normally bypassed around major wastewater treatment and discharged with the treated wastewater. An oil-in-water detector should be provided to detect oil in the blowdown from process leaks. This will enable stopping the blowdown or diverting it to temporary holdup until the leak is corrected. A major rupture in a process heat exchanger tube can also result in the cooling tower being the discharge point for hydrocarbon vapors.

Because of the likely presence of flammable vapors, the areas around cooling towers are subject to electrical classification in accordance with **IP 16-1-1**.

The type and amount of chemicals added to the cooling water should be evaluated as to their effects on the plant's wastewater treatment process. Biocides, corrosion inhibitors, and antifoulants may result in significant problems for the wastewater treatment plant.

Other environmental concerns are:

- Cooling tower noise emissions from fans and from the flow of cooling water over the tower may require suppression if near a local community.
- Cooling tower water mist drift can cause fog and ice formation on nearby roads and promote deterioration of nearby equipment. It may also result in damage to sensitive vegetation in the surrounding area.
- Process gas releases to atmosphere resulting from process gas pickup by cooling water including the venting of toxic gases from exchanger tube ruptures must be considered in locating cooling towers or discharge points from once-through systems.
- Spills and overflows of toxic and hazardous chemicals used in treating the cooling water must be contained.

SYSTEM SELECTION

The selection of a cooling water system is often determined by the availability of water. In regions where water is scarce, once-through systems are obviously eliminated from consideration and recirculated systems are chosen. A once-through cooling system may be the economical choice if the plant is located adjacent to a body of water and consumers are elevated no more than 50 ft (15 m) above the water level. However, once-through system costs may be increased significantly by environmental limitations in many locations. These may limit maximum discharge water temperature and, therefore, will reduce the maximum cooling water ΔT . This will increase the required flow and cost of once-through systems. In addition, regulations may require waste treatment of the large volume of effluent, thus increasing costs.

The choice of a cooling water system must be based on comparisons of initial investment and operating costs. Relative initial costs of a system vary with climatic conditions, distance from pump to users, complexity of inlet structures and corrosive nature of the water. Salt water or brackish water service requires the use of cement mortar lined pipe and alloys for exchangers and pumps. Carbon steel is usually satisfactory for fresh water. Special attention should be given to the impact of bottom silt, mud and seaweed on intake facilities to once-through or makeup to recirculated systems. Cribs, flumes, large bays, screens, trash racks or other extensive facilities may be required.

During the early stages of a project, the designer should review with the planning or design groups the heat level and volume of all process streams which require cooling. The optimum method of cooling should then be determined; i.e., heat exchange and/or rejection of heat to air or water. A break point should be selected above which air cooling is economical and below which trim water cooling is preferred.

Section XXVII	Page 8 of 50	COOLING WATER SYSTEMS	 DESIGN PRACTICES
December, 2003			

BASIC DESIGN CONSIDERATIONS (Cont)

COOLING WATER REQUIREMENTS

Cooling water requirements for each process unit and offsite consumer are obtained from the appropriate design groups. For existing locations, maximum cooling water loads should be based on the design inlet cooling water temperatures given in [Section IX-B, Design Considerations for All Types of Heat Exchangers](#). For new locations, the inlet cooling water temperature must be set based on local water temperature data for once-through systems and wet bulb temperature and selected approach for recirculated systems.

The bulk water temperature at the cooler outlet has been selected as the controllable variable for design and operation of coolers. Although the corrosion rate depends on the metal temperature, this is difficult to determine in the operation of a cooler. Based upon the findings of a Materials Development Section test program, maximum design outlet water temperatures have been set as indicated below:

Fresh Water	130°F	(54°C)
Treated Fresh Water	130°F	(54°C)
Brackish Water	125°F	(52°C)
Salt Water	120°F	(49°C)

When the maximum plant cooling water requirement has been established for new process and utility consumers, appropriate Load Growth and Reserve Capacity Factors (LGF and RCF) should be applied, depending on the development stage of the project. Cooling water loads should be updated and system capacity adjusted periodically as design work progresses.

LOAD GROWTH AND RESERVE CAPACITY

Utility loads tend to increase as the loads become better defined through successive stages of project definition. Therefore, load growth and reserve capacity factors (LGF and RCF) are applied to raw loads as a means of predicting final equipment sizes and capital costs. These load growth factors do not cover basis changes through project development such as project or process unit size/throughput. For revamp or modernization projects, these factors are generally applied only to new loads or changes to existing loads on the basis that existing or unchanged loads are well known.

Recommended Load Growth Factors are as follows:

CONSUMERS	PLANNING (SCREENING THROUGH DBM)	DESIGN SPEC.
Existing Facilities	0 - 10%	0 - 10%
New Facilities	20 - 30%	5 - 10%

Selection of the load growth factor to use should be based on the quality and level of effort associated with development of the raw loads.

Final sizing of the source facility (e.g., the cooling tower and circulation pumps) should include a reserve capacity factor of 10% to cover small post startup changes, minor future projects, and dynamic conditions not predicted by steady state balances. The sizing basis for distribution facilities should not include the RCF.

COOLING TOWER TYPES

The cooling tower is the major piece of equipment specified in recirculating cooling water systems. In effect, it is the heat exchanger which cools the hot water to a suitable temperature for re-use, primarily by evaporation through contact with air. The cooling tower contains fill to break up the water flow into droplets or film on a surface. The fill increases the water/air contact area and enhances heat transfer.

Cooling towers are classified according to the means by which air is supplied to the tower, i.e., induced or forced mechanical draft (fan) vs. natural draft, and according to the relative movement of the air and water, that is, counterflow or crossflow (see [Figure 3](#)). Most of the towers in the ExxonMobil circuit are mechanical induced-draft type. Economics determine whether they are counterflow or crossflow.

 DESIGN PRACTICES	COOLING WATER SYSTEMS	Section	Page
		XXVII	9 of 50
		December, 2003	

BASIC DESIGN CONSIDERATIONS (Cont)

In crossflow towers, the air travels horizontally across the falling water, while in the counterflow design, the air travels vertically up through the falling water. Comparisons of plot space, fan horsepower, and future maintenance costs, determine which design will be more economical. Factors which influence this selection are cooling water rate, range and approach for a particular location. In addition, in some locations, materials of construction and associated labor costs will affect the final selection.

In the past, crossflow towers were usually preferred over counterflow towers for extremely cold locations where ice formation could restrict or block air flow through the louvers. However, this consideration is usually no longer valid due to the increased use of PVC film-type tower fill rather than splash-type fill in counterflow towers.

Mechanical draft designs use one or more fans to provide the air needed for cooling. Induced-draft units have the fans located on top of the tower. Air is pulled through the packing and discharged vertically upward at high velocities. Forced-draft units have the fans located at the base of the tower and push the air through the fill. Forced-draft towers in large industrial sizes experience difficulties with recirculation and in providing a uniform distribution of air. As a result, they have been superseded by induced-draft designs.

Fill may be splash or film type. Splash fill normally consists of horizontal slats in horizontal rows offset to one another to cause the water to break up into droplets as it falls downward through the cooling tower. Splash fill is characterized by reduced air pressure losses. It is also less conducive to clogging and easier to clean after a spill. However, it is very sensitive to inadequate support and must remain horizontal and level. It is made of treated wood or plastics such as PVC or polypropylene. Film fill comes in various designs but they all cause the water to flow in films over the fill surface and provides more cooling capacity within a given amount of space than splash fill. Because of this increased heat transfer efficiency, film fill is generally used in most new cooling towers. However, because of its smaller passages, it is more sensitive to plugging and is difficult to clean if it does become plugged. It may not be appropriate for services cooling mainly heavy fuels or waxy lubes where a leak would cause fill plugging, or for services with a high biological fouling potential. PVC is currently the most widely used material for film fill. The selection of fill type is usually proposed by the vendor and reviewed by the COOLING WATER SYSTEMS SPECIALISTS.

Natural-draft or hyperbolic cooling towers depend on the natural draft created by the difference in the density of the entering and leaving air for movement. Generally, hyperbolic cooling towers have been used in Europe and in the utility industry in the USA for large capacities [250,000 gpm (16,000 L/s)], short ranges, [10 to 15°F (6 to 8°C)] and long approaches [10 to 15°F (6 to 8°C)]. They are most effective where low ambient wet bulb temperatures occur with high relative humidities. These towers normally have diameters in excess of 200 ft (60 m) and are greater than 250 ft (75 m) in height. Their major advantages are:

- No operating or maintenance cost for fans.
- Reduction in problems associated with fogging, drift and recirculation, due to their great height and diameter.

The primary reasons why hyperbolic towers are not used in ExxonMobil projects include:

- High initial cost
- Large plot space requirement and high visual impact
- Complete dependence on atmospheric conditions
- Lack of flexibility for future expansions

COOLING TOWER BASIN

The primary function of the cooling tower basin is to collect the cooled water leaving the tower and to provide a reservoir for the cooling water pumps. Design aspects to be considered are the basin's capacity, cleanability, draining facilities, sump, and screen details. To obtain the necessary time for corrective action during emergency conditions, a minimum storage capacity of 90 minutes based on loss of makeup water flow should be provided in the basin between the basin low level alarm (LLA) and the minimum pump submergence (MPS). When the basin water level reaches the MPS point, loss of recirculation pump suction and cooling water flow is imminent. Typical values for basin water levels are as follows:

- High Level Alarm (HLA): 1 ft (300 mm) below top of the basin wall
- Normal Water Level: 1.5 ft (450 mm) below top of the basin wall
- Low Level Alarm (LLA): 2.5 ft (760 mm) below top of the basin wall
- Distance between LLA and MPS: 3.5 ft (1070 mm)
- Minimum Pump Submergence Depth: 4.5 ft (1370 mm)
- Clearance of Pump Suction off Basin Floor: 1.5 ft (450 mm)

Actual values may vary depending on pump type selected, pump suction line diameter, and cooling tower cell plot area.

Section XXVII	Page 10 of 50	COOLING WATER SYSTEMS	ExxonMobil DESIGN PRACTICES
December, 2003			

BASIC DESIGN CONSIDERATIONS (Cont)

MATERIALS OF CONSTRUCTION

The *EMRE Refinery Construction Materials Manual* and **IP 8-1-1** list acceptable materials for all components in each type of cooling water system (once-through and recirculating). For salt water systems, emphasis must be placed on proper materials selection throughout the system. The external salt water environments in the vicinity of the tower itself and the intake stations must be taken into consideration. Proper siting of the tower is extremely important to avoid salt water corrosion of adjacent units or the need to use expensive materials to operate in such an environment.

WATER TREATMENT FOR ONCE-THROUGH SYSTEMS

Once-through salt and fresh cooling water systems can develop a variety of problems such as fouling due to seaweed or other debris, marine microorganisms such as muscles and shell fish, and biological growth. Corrosion and scaling problems are minimal in fresh water once-through systems because the water is not concentrated by evaporation. In salt water systems, corrosion is minimized by proper materials selection, and scaling problems generally do not occur.

Protection against fouling by seaweed or other debris is provided by careful selection of the water intake location and traveling screens with washing facilities. In some cases, additional steps may be required. These may include an additional secondary set of traveling screens, and possibly battery limit strainers on the cooling water supply lines to individual units.

Protection against fouling by marine microorganisms and biological growths is achieved primarily by injecting chlorine, hypochlorite, chlorine/bromine, or other similar chemicals which kill these growths. Chlorine is commonly used and is injected in sufficient quantities to produce a residual of 1 wppm in the effluent for one hour each day (shock chlorination). Continuous chlorination for 2 - 3 days per month at lower levels (0.3 wppm residual chlorine in the effluent) may also be used in addition to shock chlorination.

The large water volume discharged from once-through systems usually makes chemical treating for corrosion or deposit control too costly. These problems are handled by proper materials selection and by keeping water velocities through exchanger tubes greater than 3 ft/s (0.9 m/s). Occasionally, the water analysis of a fresh water source being considered for a once-through system using carbon steel materials will indicate the need for some corrosion or deposit control. In this case the cost of the threshold treatment with the once-through system should be compared to the costs of a recirculated system before making a final choice.

WATER TREATMENT FOR SALT WATER COOLING TOWER SYSTEMS

A total dissolved salts (TDS) concentration limit of 55,000 wppm for sea water in cooling tower systems requires high blowdown rates since the makeup sea water typically has from 35,000 to 40,000 wppm TDS. Because of cost restraints, the only water treatment normally specified for these systems is for biological control. Chlorine is most commonly used either as direct chlorine injection or hypochlorite produced in electrochlorinators. Care must be taken in selecting the intake location to assure that the suspended solids do not exceed 200 wppm in the recirculated water. If it is not possible to find sea water with sufficient clarity, clarification with polyelectrolytes should be evaluated. Corrosion is one of the major problems with the use of sea water in cooling towers. This requires proper materials selection.

WATER TREATMENT FOR FRESH WATER COOLING TOWER SYSTEMS

Cooling tower water treatment is necessary to minimize or eliminate: corrosion, scale, and biological fouling of process heat transfer surfaces caused by minerals and impurities in the water. The difficulties caused by these impurities and the means of treatment are shown in [Table 1](#).

Water lost by evaporation results in an increase in total dissolved salts in the recirculated water. To indicate the degree of concentration of impurities, the term cycles of concentration is used.

Corrosion is an electrochemical process that deteriorates metals exposed to water in the presence of corrosive agents such as acids, oxygen, or bacteria. A common form of corrosion is pitting. Severe corrosion can lead to equipment failure. Corrosion is caused by many conditions including process leaks into the cooling water, water flow velocity that is too low (causes deposits and fouling leading to corrosion) or too high (causes erosion and corrosion), low pH, and high temperatures. Corrosion is less likely in water with non-acidic pH values (greater than 7) although scaling is more likely in these pH ranges.

Scaling is characterized by the formation of hard, dense deposits on material surfaces. These deposits impact heat transfer and can become a site for localized under-deposit corrosion. Scaling is influenced by many factors including makeup water composition, total dissolved solids in the recirculating water, water temperature and pH, and flow velocity. Calcium carbonate is the main scaling constituent in all waters and it is the least soluble. It forms from the hardness (calcium Ca^{++}) and bicarbonate (HCO_3^-) alkalinity present in most water.

Fouling can be caused either by the settlement of suspended matter or by microbiological growth of algae, bacterial slime or fungi. Fouling will reduce heat transfer, cause plugging, and create corrosion sites.

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 11 of 50
		December, 2003	

BASIC DESIGN CONSIDERATIONS (Cont)

Treatment of the cooling water is broken down into two major categories: external and internal. External treatment encompasses any treatment given to the cooling tower makeup water. Internal treatment is the addition of chemicals directly to the recirculated cooling water.

EXTERNAL TREATMENT

External treatment to remove impurities in order to reduce the amount of blowdown should always be evaluated as to cost effectiveness. The most frequently used techniques for treating makeup water are shown in [Figure 11](#). Details of available treatment processes (see [Table 1](#) for methods available) are covered in [Section XXVI-A, Boiler Feedwater Treatment](#). For cooling tower systems that meet currently required drift limits in refineries and chemical plants, uncontrolled cooling water losses (drift, and miscellaneous process uses) normally amount to about 14% of the cooling water evaporation loss. Under these conditions, the maximum cycles of concentration achievable are 8 with no controlled blowdown. Some cooling towers are operating at up to 10 cycles of concentration. Additional controlled blowdown, required to limit the cycles of concentration per the water quality criteria, is covered later.

INTERNAL TREATMENT

The makeup water analyses, amount of cooling water losses, environmental restraints, potential chemical hazards, materials of construction, and film temperatures of heat transfer surfaces determine the type of internal treatment required for cooling tower systems. The internal water treatment program selected must address corrosion, scale, fouling, biological growth, and chemical attack of cooling tower components.

Numerous chemicals and treatment programs are continuously being developed for addressing the potential problems. The slightly acidic low pH programs of the past, which used chromate based chemicals and usually required acid injection, are being completely phased out because of environmental restrictions on chromate and the higher costs associated with meeting current practices for handling hazardous chemicals such as acid. Non-chromate treatments which use inhibitors such as phosphates, zinc, and organics, along with higher pH, have been developed to replace the earlier programs. Although not as effective as chromate, these inhibitors operate at higher water pH which is a less corrosive environment. The disadvantage of the higher pH is the greater tendency to form scale. This tendency is controlled by the use of dispersants, or scale inhibitors, which are normally organic polymers or phosphonate. A corrosion inhibitor for copper or brass is also normally required if these metals are present in the system.

The following paragraphs describe techniques and chemicals to control alkalinity (pH), corrosion, scale, sludge, and biological growth. The chemicals mentioned are normally purchased as pre-mixes from vendors and dosed in combination. Most corrosion and scale control program chemicals are two drum formulations due to the incompatibility of some chemicals in the concentrated state. Therefore, separate feed systems are generally provided for chemicals for control of corrosion and scale (2 drums), and biological growth (if liquid). If a program includes fixed pH, then an additional feed system is required to add acid. Water treatment programs are site specific and changing. The COOLING WATER SYSTEMS SPECIALISTS should be consulted for recommendations on the internal water treatment programs when an analysis of the available water is known.

ALKALINITY (PH) CONTROL

Cooling water treatment programs presently available fall into two basic categories; those that do not control pH (floating pH or alkaline treatment programs without pH adjustment), and those that control pH within a specified range by adding acid. The programs that do not control pH are gaining favor because of the additional cost, equipment, and precautions required to minimize the risk associated with handling acid, and because of improvements in chemicals to control deposits.

High pH in the recirculating cooling water is a result of the alkalinity of the fresh water due to bicarbonate salts. This combined with carbon dioxide, results in the water having a pH range of 6 to 8.5. When this fresh makeup water is mixed with the recirculated cooling water and passed through the cooling tower, the air flow strips out the carbon dioxide. Bicarbonate ions then convert to carbonate ions raising the pH, which can cause both calcium carbonate and calcium phosphate salts to precipitate out of solution and form deposits. Another debit in allowing the cooling water pH to increase is increased chlorine consumption to control biological growths.

If a program using pH control is justified and chosen, acid addition is used under control of a pH analyzer, to control recirculated cooling water alkalinity and pH to the range required by the treatment program.

Corrosion Control

To reduce corrosion to an acceptable level, chemical corrosion inhibitors which form protective films on heat transfer surfaces are the most effective protection. Inhibiting corrosion is accomplished by phosphates, organics, zinc, nitrites, and molybdate salts. Unfortunately, the use of chromate, which is a reliable corrosion inhibitor, is prohibited by environmental constraints. Nitrite is not practical in an open system due to atmospheric oxygen converting the nitrite to nitrate.

Section XXVII	Page 12 of 50	COOLING WATER SYSTEMS	ExxonMobil DESIGN PRACTICES
December, 2003			

BASIC DESIGN CONSIDERATIONS (Cont)

Phosphate inhibitors (orthophosphate polyphosphate, phosphonate) are the basic treatment for new towers in today's environment. In addition to the phosphate chemistry, salts of zinc, may be added to aid in inhibiting corrosion. These ions combine with the hydroxide ion forming thin protective films. Zinc is used to provide a synergistic effect in combination with the phosphate salts for protecting carbon steel surfaces from corrosion. Finally, all-organic programs are offered by several manufacturers. The use of these treatments has been made possible by the development of polymer dispersants, which give calcium salts a much higher solubility and reduce the tendency to scale.

When a cooling water system contains copper alloys, azole based and azole substitutes are required as copper corrosion inhibitors. There are several effective inhibitors. The most common is tolytriazole (TTA) due to its resistance to chlorine.

The corrosion inhibitors most frequently used in ExxonMobil recirculating cooling water systems are shown below in descending order of preference, provided their use meets all environmental requirements:

- **Stabilized Phosphate** (Ortho/Polyphosphate) - Environmental restrictions on the use of zinc have resulted in ExxonMobil plants in the USA using a blend of orthophosphate and polyphosphate type corrosion inhibitors with good results. This treatment forms a thin protective calcium phosphate film on heat transfer surfaces through the use of orthophosphate concentrations as high as 12 - 17 wppm. The use of calcium phosphate dispersants and Hydroxethylidene Diphosphonate (HEDP) stabilizes the treatment and prevents the formation of calcium phosphate scale. Concentration of the dispersants depends upon the calcium concentration, temperature, and pH. Stabilized Phosphate treatment programs can operate in a pH range of 6.8 to 7.8. Alternatively, an alkaline (floating pH) stabilized phosphate treatment program can be used. This program uses little or no acid addition and is gaining in popularity although not well established yet. It operates with pH values of 8 - 9 and uses higher quantities of dispersants and lower levels of phosphate. A corrosion inhibitor for copper and brass is normally included for all stabilized phosphate programs. Several vendors offer these programs. Two separate chemical feeders are generally required.
- **Zinc Alkaline Phosphate** - Heritage Exxon plants in Europe, where the use of zinc is not restricted, have obtained good control of corrosion and scaling using zinc-polyphosphate treatment programs. Low (6.5 - 7.2) and high (7.3 - 8.0) pH programs have been used. The high pH (zinc alkaline phosphate) programs are the lowest cost and are recommended. As with the Stabilized Phosphate treatment, dispersants such as HEDP and polyacrylates are required to prevent the formation of zinc or calcium phosphate scale on heat transfer surfaces. A corrosion inhibitor for copper or brass is normally used with this program, which is offered by several vendors.
- **Organic Salts** - All-organic (polymer) programs are offered by several manufacturers and have been used successfully within Exxon. In general, these treatments are based on a combination of a phosphonate to control corrosion, polymers (dispersants) to prevent scale deposition, and a corrosion inhibitor for copper or brass. This type of program is most effective in conditions of high hardness, high alkalinity (M alkalinity >300 wppm as CaCO₃), and high pH values (> 8.5). However, some manufacturers have reported success in softer water with alternative polymer component formulations. In general, an inorganic corrosion control program is preferred to the all-organic programs which are sensitive to alkalinity and more costly.

Detailed control limits for effective use of each of the above inhibitors and materials selection are covered in Report No. EE.34E.86, *Environmentally Acceptable Cooling Water Treatments*, Report No. EE.102E.78, *Cooling Tower Water Treatment Guidelines*, and in the EMRE Refinery Construction Materials Manual.

SCALE AND SLUDGE CONTROL

Scale and sludge deposits in cooling water systems cause loss of heat transfer and provide the conditions for pitting corrosion. Scale consists of inorganic salts which have precipitated from the cooling water forming a coating on heat transfer surfaces. Sludge consists of organic and inorganic suspended matter that settles in quiescent areas and in heat exchangers. The key to prevention of both scale and sludge formation in a cooling system is keeping water velocities greater than 3 ft/s (0.9 m/s), and the use of chemical additives in combination with a blowdown rate that keeps the impurity concentration below the level which causes deposits. (See [Table 2](#) for limits on impurities.) Scale control has become increasingly important in higher alkalinity "floating pH" water treatment programs.

Salts most commonly found in scale deposits are calcium carbonate, calcium sulfate, tricalcium phosphate, zinc phosphate, magnesium silicate, and silica. The control method for preventing scale from each of these salts is discussed below:

- **Calcium Carbonate** - Where justified, using pH/alkalinity control in the range of 7.0 to 7.5 will normally inhibit the formation of calcium carbonate scale if anti-scalent chemicals (phosphonates, acrylates, copolymers) are part of the chemical treatment. (See Report No. EE.102E.78, *Cooling Tower Water Treatment Guidelines*.) Higher pH water treatment programs require greater concentrations of these chemicals along with dispersants and flocculants to inhibit the formation of scale and precipitation of other salts.

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 13 of 50
		December, 2003	

BASIC DESIGN CONSIDERATIONS (Cont)

- **Calcium Sulfate** - When heat transfer skin temperatures are below 250°F (120°C) and the cooling water bulk temperatures are under 130°F (54°C), gypsum scale ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) will form if the product of the calcium and sulfate ions concentrations, each expressed as wppm CaCO_3 equivalent, exceeds 500,000. Gypsum scale is prevented by maintaining bulk water temperature below the indicated limits, and controlling calcium and sulfate ions through blowdown or through the use of newer dispersants on the market.
- **Tri-Calcium and Zinc Phosphate** - Almost all chemical additives for corrosion control contain some type of phosphate salt. These have a tendency to form the orthophosphate ion depending on time, pH, and temperature. Cooling waters using these corrosion inhibitors may have an orthophosphate concentration in excess of 5 wppm as PO_4^{3-} . To prevent calcium phosphate scale, [Table 2](#) shows a limit of 1000 wppm of calcium as CaCO_3 equivalent when using a phosphate inhibitor in combination with a chemical dispersant. (See Report No. EE.102E.78, *Cooling Tower Water Treatment Guidelines*, for solubility of calcium phosphate.) These inhibitors and dispersants generally fall into one of the following categories:
 - Sequestrants, antiprecipitants, and inhibitors such as hydroxyethylidene diphosphonate (HEDP), phosphate esters and aminomethylene phosphonate (AMP) function by defying/distorting the crystal structure of the scale formations to prevent nucleation and growth of the scale.
 - Dispersants, based on either anionic or nonionic polymers, such as polyacrylamide, polyacrylate, or polymaleic acid, function to stabilize colloidal and scale-forming particles in suspension. Anionic polymers prevent agglomeration of suspended particles, by either charge repulsion or crystal distortion, while nonionic polymers reduce the surface tension of particles.
- **Silica Deposits** - Quantitative indices for determining limits for silica in combination with other ions are not available due to the formation of complex polymers. Instead, the rule of thumb limit of keeping reactive silica concentrations in the cooling water below 150 wppm as SiO_2 has been successful.

Possible alternatives for controlling sludge are:

- **Chemical Dispersants** - Water treating chemical suppliers now offer many types of dispersants. These are mostly polyelectrolytes. Claims for removal of slime, silt, and mud from cooling tower basins and exchangers are made. However, satisfactory results using these chemicals as a coagulant aid require very accurate control of the amount fed to the water and stable operation of the water system. Also, suspended solids should be kept below 200 wppm for particles larger than 0.45 microns. Dispersants are used in virtually all fresh water cooling tower systems despite their high cost.
- **Sidestream Filtration** - The use of a sand pressure filter is the most reliable method for sludge removal. Operating and maintenance costs are minimal for this equipment.
- **Higher Blowdown Rates** - This may be an economical alternative, depending on the cost of makeup water. Additional chemical costs must be included in any evaluation of this method.
- **Makeup Clarification** - This alternative may require additional raw water treatment facilities to handle seasonal variations in turbidity and/or suspended solids. This method is applicable only where suspended solids come from makeup water.

BIOLOGICAL CONTROL

Operating conditions in recirculated cooling water are ideal for the growth of biological matter. Water temperatures from 70 to 120°F (20 to 50°C); favorable water pH; continuous supply of nutrients including carbon, nitrogen, and phosphorus; inorganic salts; and sunlight all lend themselves to environmental conditions encouraging microbiological growth and plant life.

If biological growths get out of control and form large sticky agglomerations, some of the following operating problems will result:

- Fouling of heat transfer surfaces by bacterial slimes, resulting in flow restrictions and high process temperatures.
- Reduced cooling tower efficiency resulting from algae, fungi, and bacterial slime growths in the water distribution basin and fill area of the cooling tower.
- Excessive plugging of screens and filters.
- Corrosion.
- Wood destruction by fungi.
- Clogging of water distribution nozzles.
- Excessive sludge accumulation in the cooling tower basin.

An important part of the water treatment program is to control biological activity by feeding a biocide chemical. Oxidizing biocides such as chlorine, sodium hypochlorite, chlorine dioxide, or bromine-associated compounds are most commonly used with good results. Plate counts should be maintained below 50,000 counts/ml (bacterial).



Section XXVII	Page 14 of 50	COOLING WATER SYSTEMS	ExxonMobil DESIGN PRACTICES
December, 2003			

BASIC DESIGN CONSIDERATIONS (Cont)

Chlorine is the most effective biocide for cooling water because of its low cost, extensive period of successful use, ease of application, and minimum environmental effects if applied under controlled conditions. Either a liquid feed (sodium hypochlorite) or a gas feed (100% chlorine) is added to the cooling tower basin. A sufficient dosage is that which obtains a 0.1 to 0.3 wppm continuous free residual in the hot return water to the cooling tower.

Advantages to continuous chlorination over shock treatment based on ExxonMobil experience are:

- Minimizes chlorine degradation of polymers.
- Better reduction in total aerobic bacteria plate count resulting in cleaner heat transfer surfaces.
- Does not cause significant pH depressions.
- Better control results, with less chlorine consumption.

Details concerning chlorine addition, as well as the other alternative biocides, are given in Report No. EE.102E.78, *Cooling Tower Water Treatment Guidelines* and in EMRE *Engineering Water and Wastewater Design Guide*, TMEE 080, DG 11-3-1, *Gas Chlorinators for Water Treating Service* and DG 11-6-2, *Chemical Feeders for Cooling Towers (Leased or Purchased)*.

Gaseous chlorine systems have become more costly in recent years because of the additional precautions, equipment and procedures required to minimize the risk associated with handling this gas. Alternatives to gaseous chlorine are available but require more attention and have a higher operating cost. Sodium hypochlorite (either purchased or generated), and sodium bromide, stabilized solid halide (chlorine/bromine) products, chlorine dioxide and ozone are all alternatives which may have applications. Contact the COOLING WATER SYSTEMS SPECIALISTS for guidance in the use of these alternative treatment schemes.

BLOWDOWN

Blowdown control is required to maintain the proper cycles of concentration in the system. The most reliable and simplest type of control for blowdown is specific conductance measurement of the cooling water. Electrical signals from the specific conductance measurements of some impurity in the cooling water are used to actuate an automatic blowdown valve. Impurities normally used for blowdown control are dissolved solids, chloride, calcium, magnesium and silica.

CONTROLS AND MONITORS

Any chemical treatment used to control problems in a cooling water system must be carefully monitored to be completely effective.

The installation of automatic controls should be considered for recirculated cooling water systems in all plants. Designs should include pH, conductivity, corrosivity, inhibitor and biocide control. Automatic controllers are available which continuously monitor the condition of the water and automatically make chemical additions to keep the water within compositional limits. Test exchangers and corrosion coupons are also useful in monitoring the effectiveness of the water treatment program.

An oil-in-water monitor should be considered to provide early detection of oil leaks into the cooling water. This will enable corrective action to be taken before extensive contamination of the cooling water circuit occurs. This is especially important in cooling towers with high efficiency cellular fill which can be difficult to clean if significantly fouled.

Manual control systems may be used in locations that have adequate technical personnel to perform routine water analyses and to modify chemical treatment necessitated by sudden variations in water composition, process contamination, etc.

WASTEWATER REUSE POSSIBILITIES

Recirculating cooling water systems normally have the highest plant raw water demand. A potential alternative is to use treated wastewater to supply part or all of the makeup water requirement. The treatment required must be determined, but will typically include primary oil removal (e.g., API Separator), secondary oil and suspended solids removal (e.g., filtration, dissolved or induced air flotation), and soluble carbon removal utilizing biological treatment.

The reuse of treated wastewater as makeup currently exists at only a few locations. If this alternative is being considered, refer to Report No. EE.58E.85, *Reuse of Wastewater as Cooling Tower Makeup* and [Section XIX-B, Water Reuse](#).

ExxonMobil DESIGN PRACTICES	COOLING WATER SYSTEMS	Section XXVII	Page 15 of 50
		December, 2003	

DESIGN PROCEDURE FOR ONCE-THROUGH SYSTEMS

STEP 1 - Select a location for the intake station and pumps.

Factors which influence this selection are as follows:

- Depth of water and tidal variations
- Relative location of intake and outfall, direction of current
- Length and size of intake suction piping vs. pump discharge piping

STEP 2 - Determine cooling water requirements.

Determine the design cold water inlet temperature based on site data covering seasonal water temperature as a function of inlet location and depth (for existing locations refer to [Table 2 in Section IX-B](#)).

Tabulate the cooling water requirements for each process unit and offsite consumer. Apply the proper LGFs to all cooling loads, depending on the stage of the project and whether the new units are exact duplicates of existing units.

It should be pointed out that process cooler outlet temperatures are highly dependent on the heat levels and volumes of the process streams. The designer should investigate methods to increase effluent water temperature to the maximum recommended limit for the particular type of water used. One common method is to reuse water from a light ends cooler in a heavy fuel oil cooler. This increases the effluent water temperature by 10 to 15°F (5 to 8°C), but the bulk temperature is still within allowable limits. The designer should determine whether all cooler outlet temperatures have been optimized before proceeding with the cooling water system design.

STEP 3 - Determine the total required capacity for water intake facilities.

Process Coolers - The total requirements determined in Step 2, including LGFs.

Firewater - This is often supplied from the intake bay of a once-through system.

Future Expansions - These should be considered in sizing intake facilities.

Total Required Capacity - The sum of the above three items.

STEP 4 - Provide water intake facilities.

Intake Crib - The intake crib with its support structure is located at the extreme end of the water intake line. (See [Figure 4](#).) The intake is usually located 200 to 300 ft (60 to 90 m) offshore and at a sufficient depth below the lowest water level to preclude vortex formation and subsequent pump cavitation during storm conditions. Additionally, the crib should have 3 to 5 ft (1 to 1.5 m) clearance above the sea floor to minimize sand and silt pickup.

A concrete velocity cap should be specified to cover the inlet crib. This will minimize the incidence of fish and other foreign matter entering the system. A horizontal inlet flow pattern should be designed with a maximum entrance velocity of 1 ft/s (0.3 m/s). Experience shows that vertical velocity flow confuses fish and they are drawn into the intake line.

The intake crib support structure protects the crib from adverse effects of storms and tidal motions, as well as protecting it from impact of floating and submerged objects. A self-cleaning screen can be specified to prevent entrance of large objects into the system at the crib.

Intake Line ([Figure 5](#)) - An intake line is required if the water depth along the shore does not permit water to flow directly into the intake bay. The intake line is usually buried in the sea floor and covered with a minimum required overburden. Consult with the COOLING WATER SYSTEMS SPECIALISTS for required coverage at a specific site.

Chlorine or sodium hypochlorite is injected at the intake crib to prevent marine growth in the line.

Note that an intake crib and line will not be required if water of sufficient depth is available at the supply pump station.

Intake Bay ([Figure 6](#)) - The intake bay is an enclosure which houses the pumps and screens. Depending on a particular design, a series of screens is used to ensure the supply of clean water. Trash racks comprise the first element of the filter system. These remove only very coarse material from the water, such as bulk seaweed. They can be supplied with a traversing raking mechanism.

Lift screens provide secondary cleanup. These screens can be lifted out of the intake bay for periodic cleaning. Double lift screens can be used if it is deemed necessary to have one in service at all times.

Final water filtering is usually done by traveling screens. Details of the screen dimensions and the mounting are usually determined during detailed engineering. Screen net open area is typically approximately 50% of total screen area. The screens should be sized for a normal water velocity of 1.2 ft/s (0.4 m/s) through the open screen area. Maximum velocity should be limited to 2.4 ft/s (0.8 m/s) with 50% of the screen area plugged. This is the upper velocity limit for efficient screening.