Figure 15. Salt Passage Correction Factor "J" for B-10

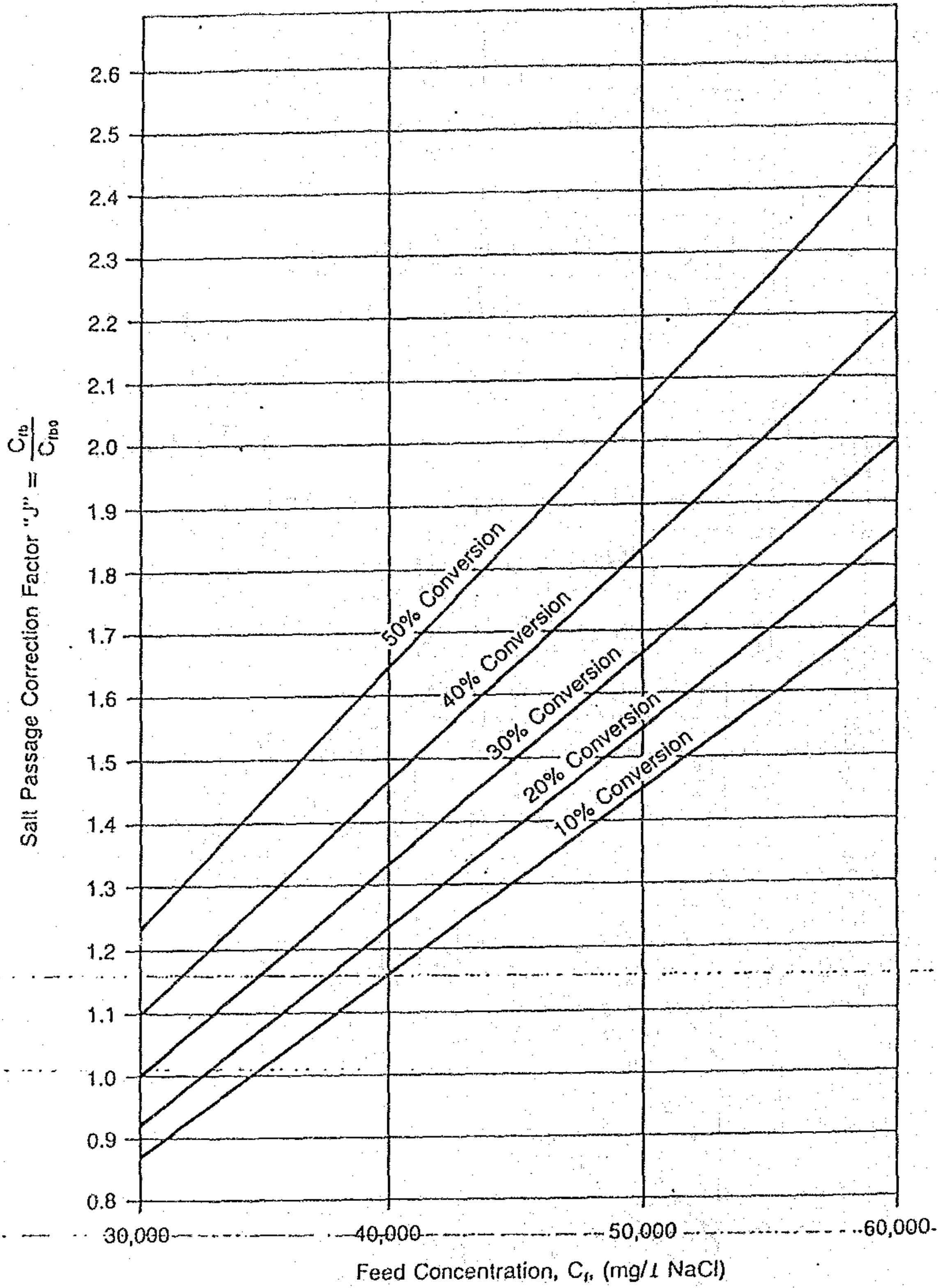
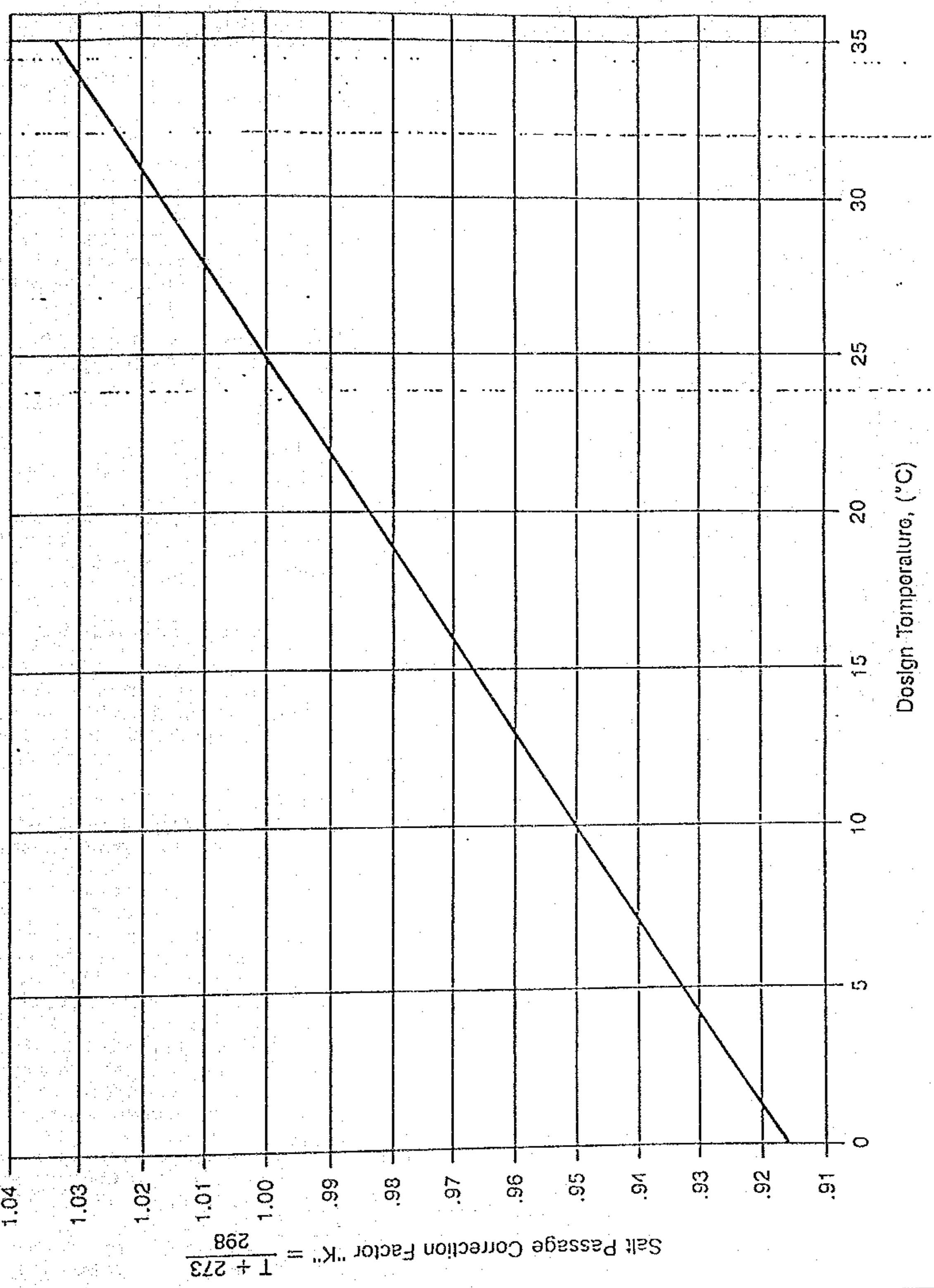


Figure 16. Salt Passage Correction Factor "K" for B-10



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Du Pont Company / Polymer Products Dept. / Permasep* Products / Wilmington, DE 19898

BULLETIN 403

SEAWATER RO SYSTEM DESIGN WITH "PERMASEP" PERMEATORS

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A. INTRODUCTION

To achieve satisfactory performance, each end-use application of B-10 permeators needs individual consideration. The fundamental elements needed to insure satisfactory performance are:

- Complete and accurate information about the feedwater and the operating conditions.
- A well-designed pretreatment system.
- A properly designed RO system.
- Correct plant operation and maintenance.

Seawater reverse osmosis (RO) systems are composed of basic, easily obtainable water-treatment equipment. Selecting the proper components is a key to a successful installation. This bulletin discusses seawater RO system design with "Permasep" B-10 permeators, including:

- Single Permeator Systems
- Multiple Permeator Systems
- Auxiliary Systems
- Energy Recovery Systems
- Materials of Construction
- Large Systems

Seawater RO systems require different design elements than those necessary for brackish water RO systems. Greater emphasis is placed on materials of construction and protecting the membrane during shutdowns. In addition:

- Pretreatment is usually not as extensive.
- Pumps, piping and instrumentation must be capable of greater corrosion resistance.
- Higher operating pressure is used in some portions of the system.
- An adequate supply of product water is required in a draw-back tank to prevent fiber dehydration at shutdown.
- A fresh-water flush that removes highly saline water from stainless steel portions of the system at shutdown is necessary to prevent corrosion.

B. SINGLE PERMEATOR SYSTEMS

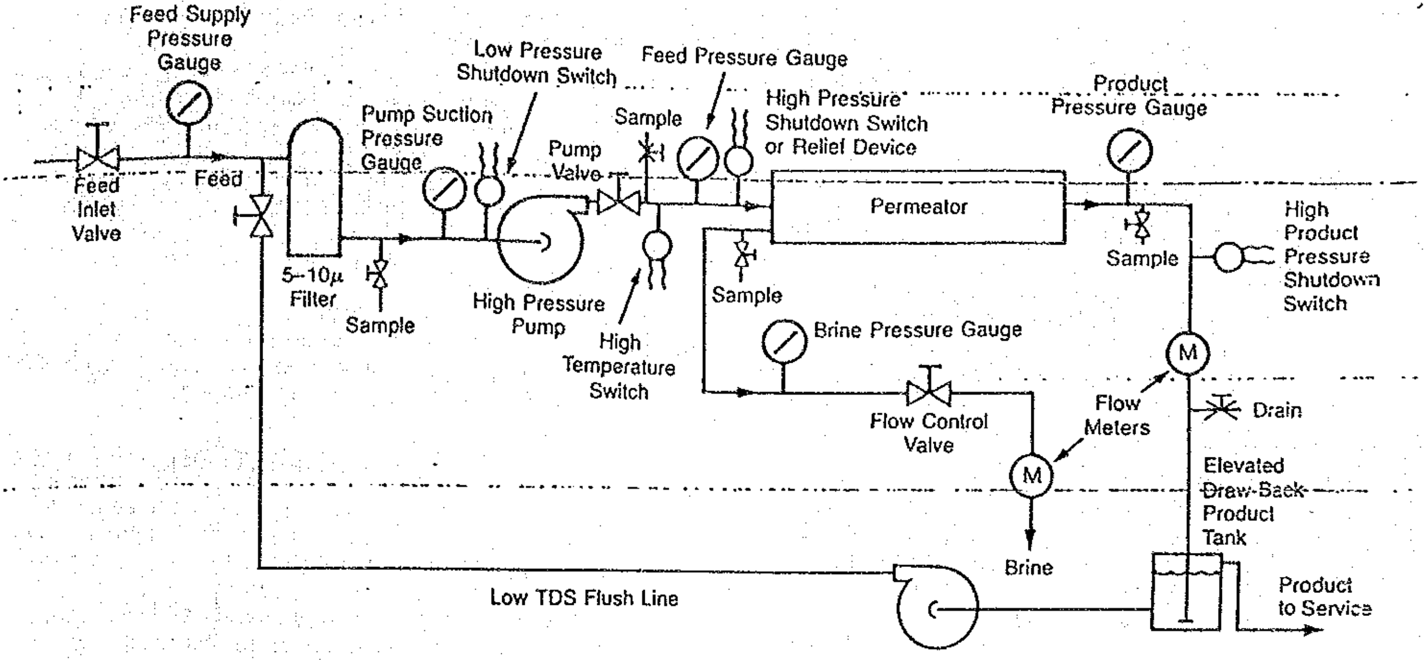
In its simplest design, a reverse osmosis system consists of a pump to pressurize the feedwater, a permeator, and a flow-regulating valve on the brine outlet to control conversion. A typical RO plant uses this basic design in modular form to achieve the desired capacity and water quality.

Figure 1 illustrates a single permeator system. Feedwater enters the system through the inlet valve and flows through the cartridge filter to the high-pressure pump. From the high-pressure pump, the feedwater flows to the feed-inlet connection of the permeator. Two water streams are shown leaving the permeator. The product stream should leave the permeator at essentially atmospheric pressure. Back pressure in the product stream from the permeator will reduce productivity. Brine leaves the brine-outlet connection at a pressure close to the feed pressure. Pressure drop across the permeator from feed inlet to brine outlet will usually be 35 to 138 kPa (5 to 20 psi). Brine flow rate is controlled by the brine flow control valve. An automatic pressure control valve should not be installed in this line. A drop in feed pressure would cause the valve to close and prevent brine flow from the permeator. This would result in operation at 100 percent conversion and would lead to precipitation of the minerals in the feed supply. The components of a basic RO system as shown in Figure 1 are:

1. *Feed-Inlet Valve*—This valve is used to stop the feedwater flow whenever the plant is shut down.
2. *Cartridge Filter*—A five- to ten-micron cartridge filter is used to remove large particulate matter that could damage the high-pressure pump or cause device plugging. The filter should be sized for a flow rate of 5 to 10 $m^3/h \cdot m^2$ (2 to 4 gpm/ft^2) of filter medium surface area.

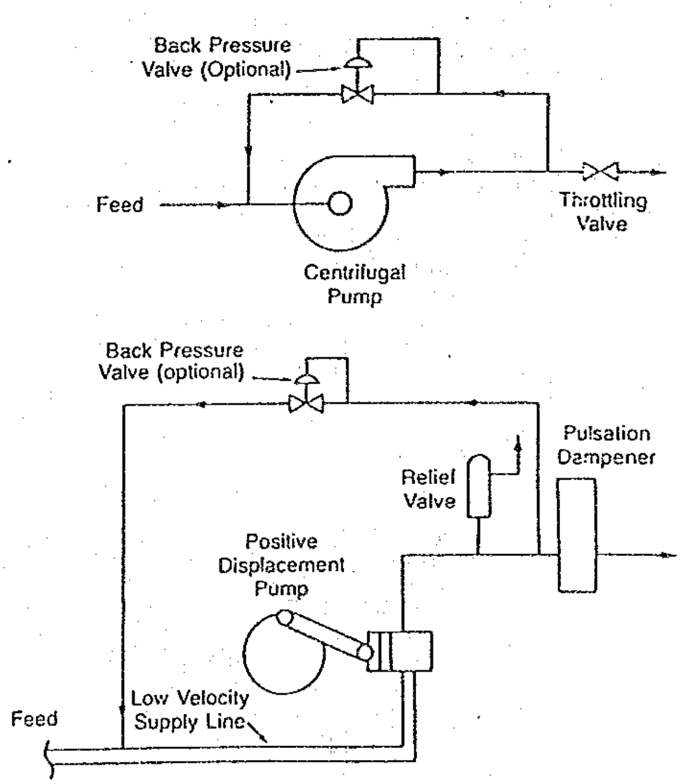
*Reg. U.S. Pat. & Tm. Off. for Du Pont's permeators

Figure 1. One Permeator Plant



3. *High-pressure Pumps*—The two basic types of pumps generally used in RO systems are centrifugal and positive displacement, see Figure 2. The pump choice is at the designer's option.
   - Centrifugal Pumps (CP)—Centrifugal pumps are the nearly universal choice for providing RO feed pressure in large B-10 systems. They are less complex than positive displacement pumps. A throttling valve in the pump discharge line is normally used to control the feed pressure to the permeator, but a variable speed electric motor drive can also be used. A back-pressure valve sized for about 10 percent of the total flow is used to "fine tune" the system by recirculating the excess flow when the pump capacity is greater than that needed to supply the permeator.
   - Positive-displacement Pumps(PD)—Positive displacement pumps are frequently used in small and medium sized B-10 systems. They are also available for large systems. PD pumps are offered by many manufacturers and provide better operating efficiency than centrifugal pumps for the required 5,520 to 6,900 kPa (800 to 1,000 psig) service. Since PD pumps cannot be throttled, a relief valve is required on the discharge line. There must not be any positive flow restrictions such as a shut-off valve between the pump and the relief device. A back-pressure valve located on the recirculation loop can be used to control system pressure when the pump capacity is greater than that needed to supply the permeator. A pulsation dampener, sometimes called an accumulator, is recommended on the pump inlet and discharge lines to dampen pressure variations. If a low-flow velocity (1 to 2 fps) positive-pressure, suction head supply line is used; a pulsation dampener is usually not required on the inlet line.

Figure 2. Centrifugal and Positive Displacement Pumps: Typical Piping Configurations



4. *Shutdown Switches*—The permeator must be protected against high feed pressure, high temperature exposure and high product pressure. The pump must also have sufficient feed volume to prevent cavitation. The following system shutdown switches are recommended to avoid exposing permeators to conditions in excess of design limits:
   - High feedwater pressure shutdown.
   - Low feedwater pressure. Low feed pressure to the pump can cause damage to the pump.
   - High feedwater temperature shutdown.
   - High product pressure shutdown. To insure that the 50 psig product pressure guideline and the pressure rating of the piping are not exceeded, a pressure-relief device should be installed in the product line.
5. *Valves*—A flow-control valve in the brine stream is used to set conversion. An automatic pressure control valve should not be used. If the RO supply pressure were low enough, an automatic valve would close. This would result in operation at 100 percent conversion and thus cause scaling in the permeator.

   Flow measurements should be used to set and control conversion. If needle valves are used in the brine stream, care must be exercised to insure that the valves do not plug.

   Conductivity measurements should not be used to set conversion; this could result in improper brine flow rates and subsequently affect system performance.
6. *Meters and Gauges*—Meters are required to measure brine and product flow rates. Gauges are used to determine the pressure drop across the cartridge filter, the suction pressure at the pump inlet, the feed pressure to the permeator, the pressure drop between the feed and the brine, and the pressure in the product line. Liquid-filled gauges should contain permeator-compatible chemicals such as glycerine or water in place of oils or similar water-immiscible liquids. The accuracy of all meters and gauges is critical. Calibration on a regular maintenance schedule is strongly recommended.
7. *Auxiliary Equipment*—If acid is used to adjust the feed pH, a high and low pH shutdown switch in the feed stream is recommended.
8. *Sample Valves*—Sample valves in the product and brine stream are used to monitor permeator performance. A sample valve is also needed after the cartridge filter to permit sampling for determining the feedwater silt density index (*SDI*).
9. *Optional Equipment*—Various pieces of optional equipment can be useful in monitoring and controlling the RO system. These may include:
   - Continous feedwater temperature recorder after the high-pressure pump.
   - Continuous *SDI* (Silt Density Index) monitor in the feed line before the high-pressure pump.
   - Continuous pH recorder in the feed line in front of the high-pressure pump.
   - Chlorine detection monitor with automatic shutdown before the RO pump.
   - Hour meter connected to the RO pump motor.
   - Differential pressure gauge between the feed and brine outlets of the permeator.
   - High product and brine conductivity alarms.
10. *Piping*—Design of the piping arrangement should include the following aspects:
    - Minimize stresses at connections.
    - Insure resistance to corrosion.
    - Consider cost of materials.
    - Protect plastic piping from vibration and water hammer.
    - Design the racks to minimize the chances of accidental physical abuse of the piping.
11. *Straps*—Permeator mounting or retaining straps must be used. Excessive tightening of permeator mounting straps or retaining "U" bolts can cause distortion of the permeator shell resulting in O-ring seal leaks. Permeators can be mounted in any position. If mounted vertically, however, the product end should be down.
12. *Product Lines*—A drain point in the product-water line for use during the start-up and cleaning is required. Chlorine-free water such as permeate is required for flushing piping, pumps and permeators.

C. MULTIPLE PERMEATOR SYSTEMS

Most RO systems require more than one permeator to produce the desired quantity and quality of product water. Three basic permeator arrangements have been developed to solve most desalting problems. The nature of the feedwater and product quality specifications will usually dictate which arrangement is used. The pumps, valves, gauges, meters, etc., required for multiple permeator systems are the same as those needed for single permeator systems.

1. Parallel Single-staged Systems

Almost all B-10 small seawater designs will call for "single-stage" multi-permeator systems, as shown in Figure 3. A major difference between a single permeator system and the parallel configuration is the connection to common manifolds of feed, product and brine, as shown in Figure 4. Overall system controls are the same as in a single permeator system. Note that conversion for the entire system is controlled by a single valve in the brine manifold (Figure 3).

Flow balancing tubes are used to induce artificial pressure drops in the piping across each permeator that will equalize brine flow rates in any multipermeator parallel array. Slight differences in pressure drop among permeators operating in parallel could otherwise cause significant differences in brine flow rates. The flow-balancing tubes minimize the differences in conversion from permeator to permeator. A minimum pressure drop of 240 kPa (35 psig) for single-stage systems is recommended. Stainless steel tubing is usually used for flow-balancing tubes for B-10 Permasep* permeators. Figure 5 illustrates the expected pressure drop for various sizes and types of tubing.

In addition to the sample valves in the product and brine lines for each single permeator, sample valves are also required on the feed, product and brine manifolds in the parallel configuration for monitoring overall system plant performance.

2. Brine-staged Systems

Brine staging is rarely used for seawater B-10 systems since the TDS level of the first-stage brine is usually too high to make a second stage practical. When staging is necessary, however, design of such a system follows the same general rules as for B-9 systems. See

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*Reg. U.S. Pat. & Tm. Off. for Du Pont's Permeators.

Figure 3. Single Stage Parallel System

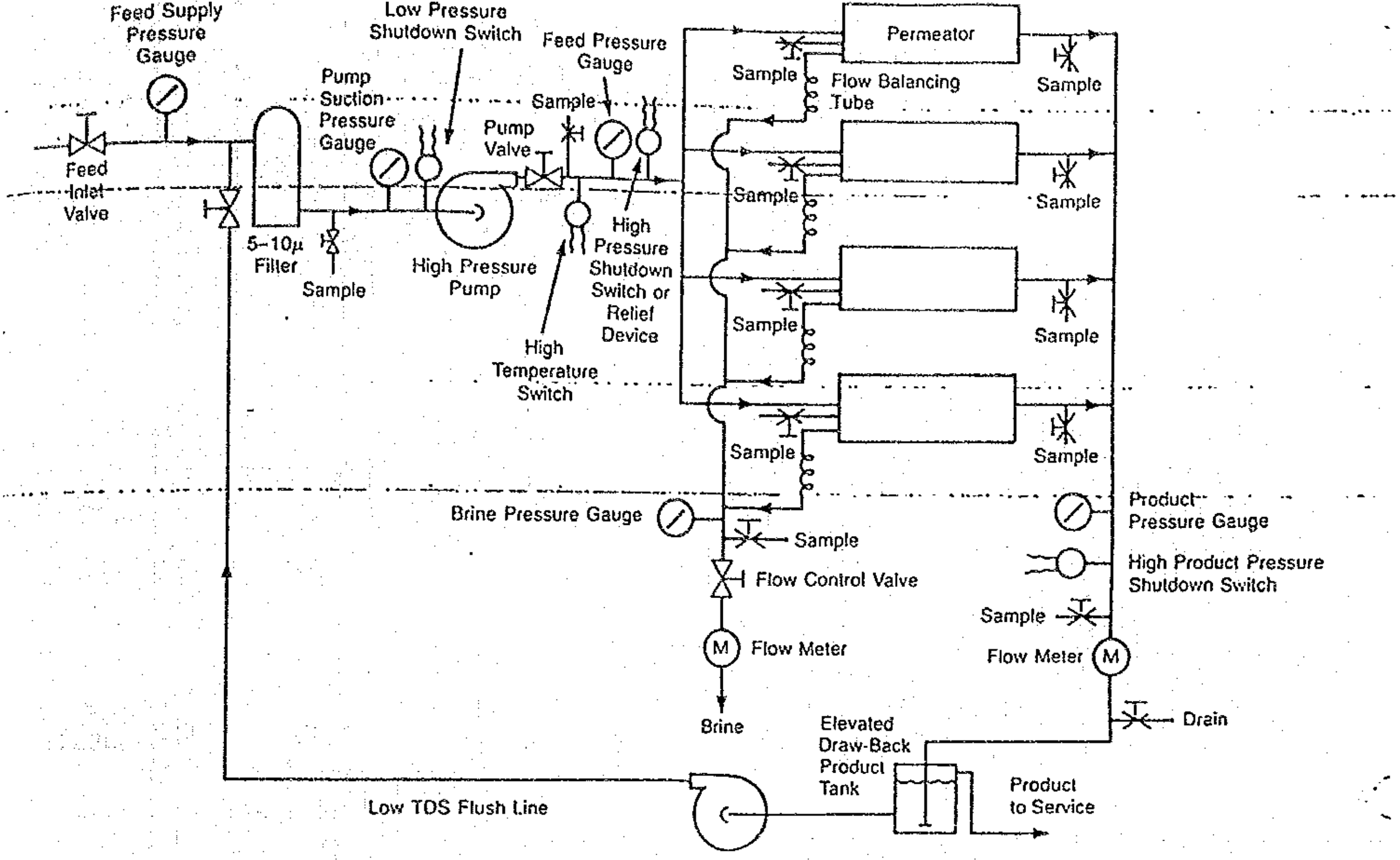


Figure 4. Permeator Manifold Piping Arrangement

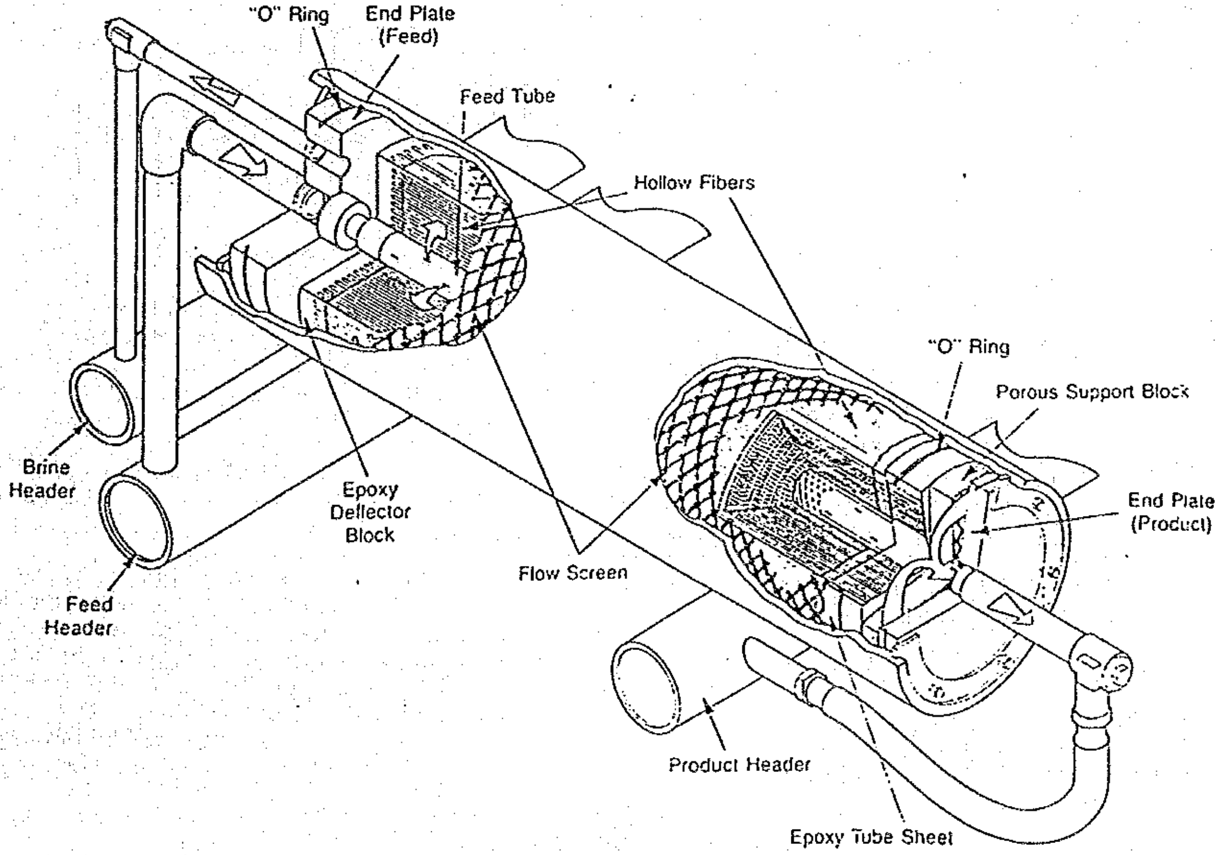
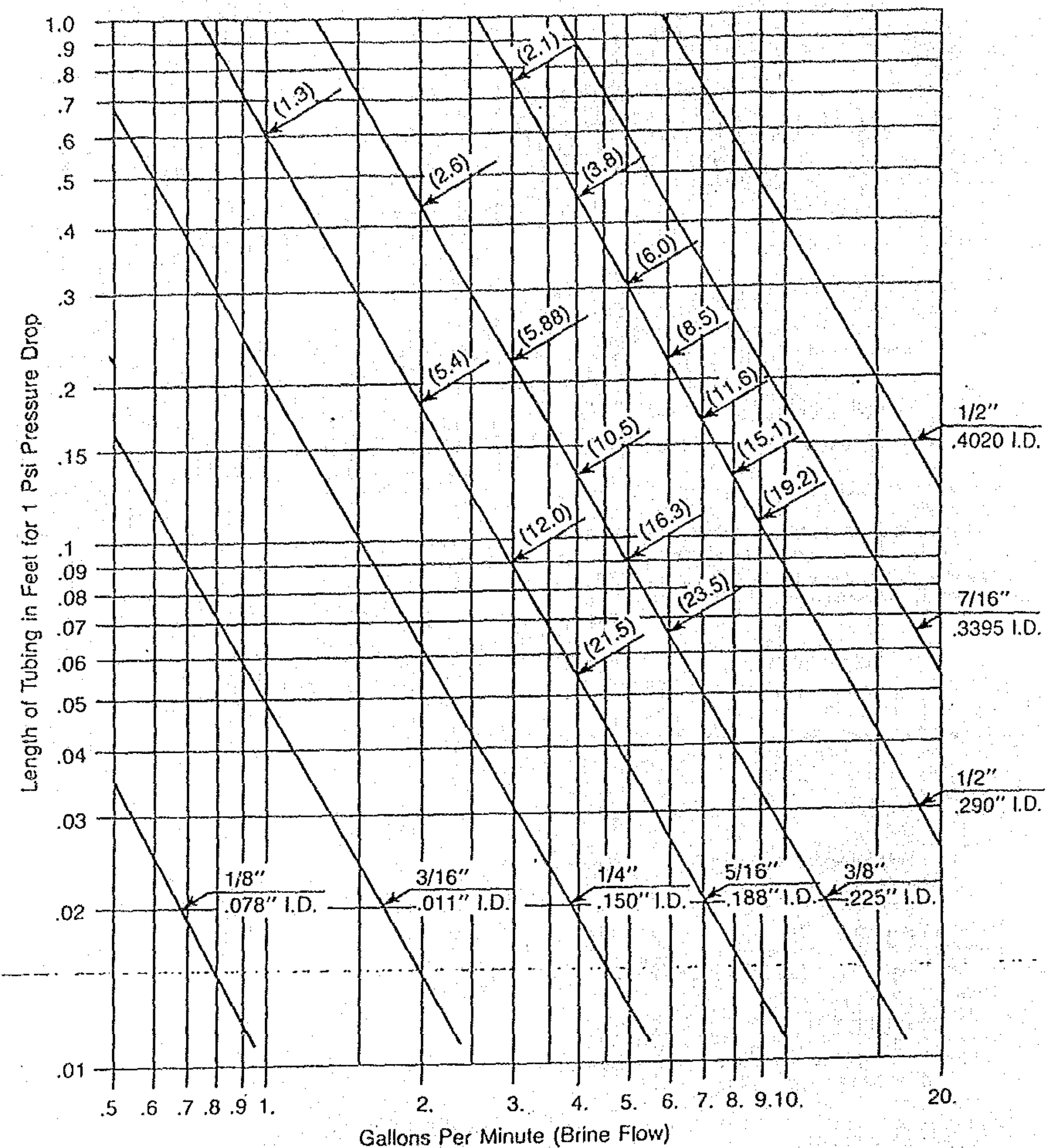


Figure 5. Pressure Drop (ΔP) Through Tubing



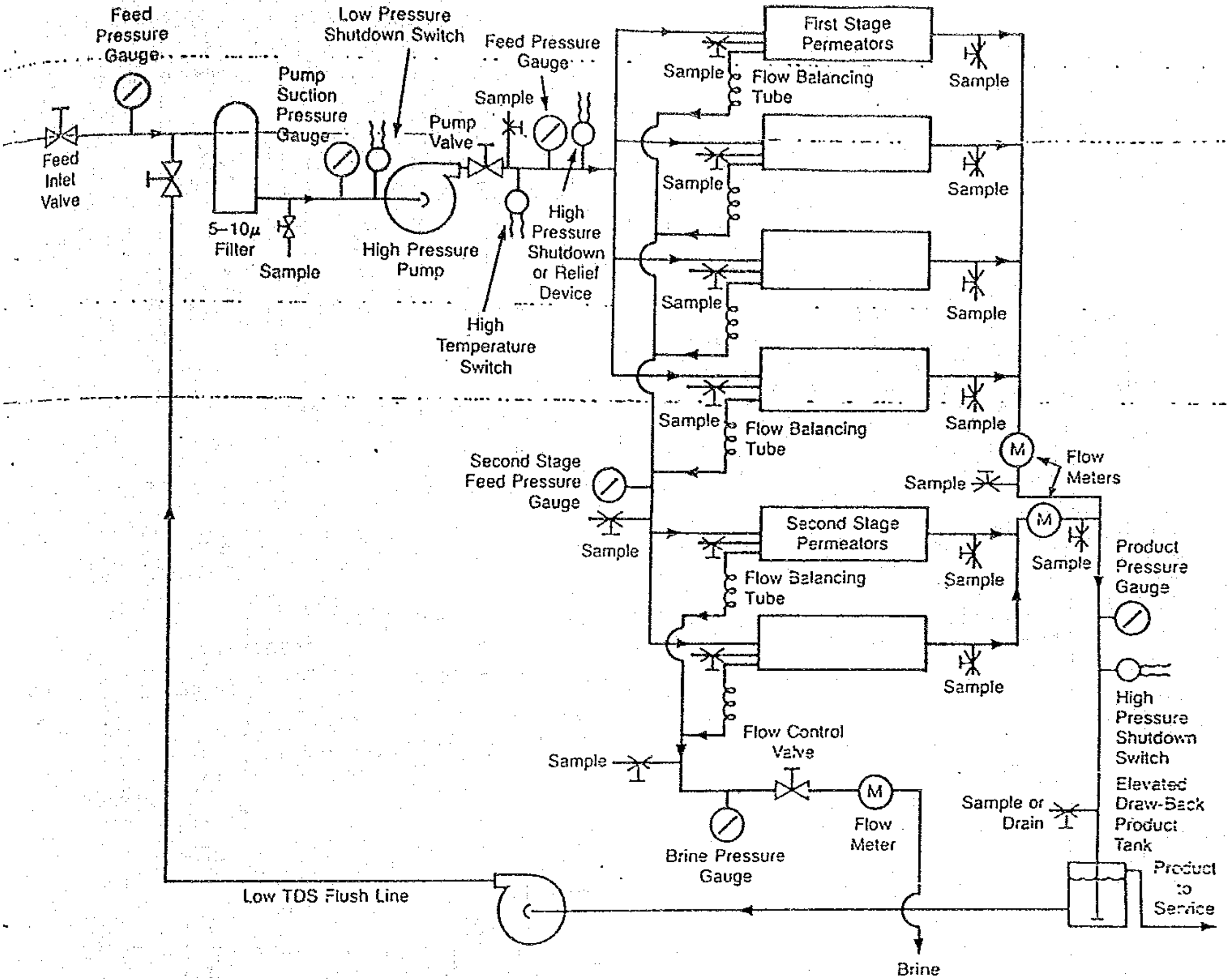
1.) Figures in Parenthesis are Additional Pressure Drops for Entrance and Exit Losses. (In psi)
2a.) Tubing at Less Than .290" I.D. is Type H Nylon—2500 psi Burst Rating.
b.) Tubing of .3395 I.D. and .4020 I. D. is Stainless Steel.

Bulletin 303. B-10 brine staging as shown in Figure 6 could be used in some highly brackish feedwater applications.

3. Product-staged Systems

Product staging can be used when a single-pass RO system does not yield the desired product quality. This design option consists of placing two RO systems in series, as shown in Figure 7. The product water from the first RO system becomes the feedwater for the second system. Each system is a separate RO plant requiring its own high-pressure pump. Each system may be either single-staged or brine-staged. Since the brine from the second system has a lower *TDS* than the raw feed to the first unit, it can be recycled and added to the feedwater of the first system.

Figure 6. Brine Staging



The storage tank between the systems must be covered and vented to prevent contamination by dust or biological organisms. Since B-10 permeators operate at 1.5 percent maximum salt passage (at standard test conditions), the *TDS* of the first stage product is usually less than 1,000 mg/liter. Therefore, a lower pressure 2,760 kPa (400 psig) B-9 system provides a very efficient second stage. The final product water generally contains less than 100 mg/liter (ppm). Second pass conversions with B-9 system often reach 90 percent. If the second stage does operate at high conversions, it will usually be brine-staged in order to meet good hydraulic flow design practice.

D. AUXILIARY SYSTEMS

1. Shutdown Systems

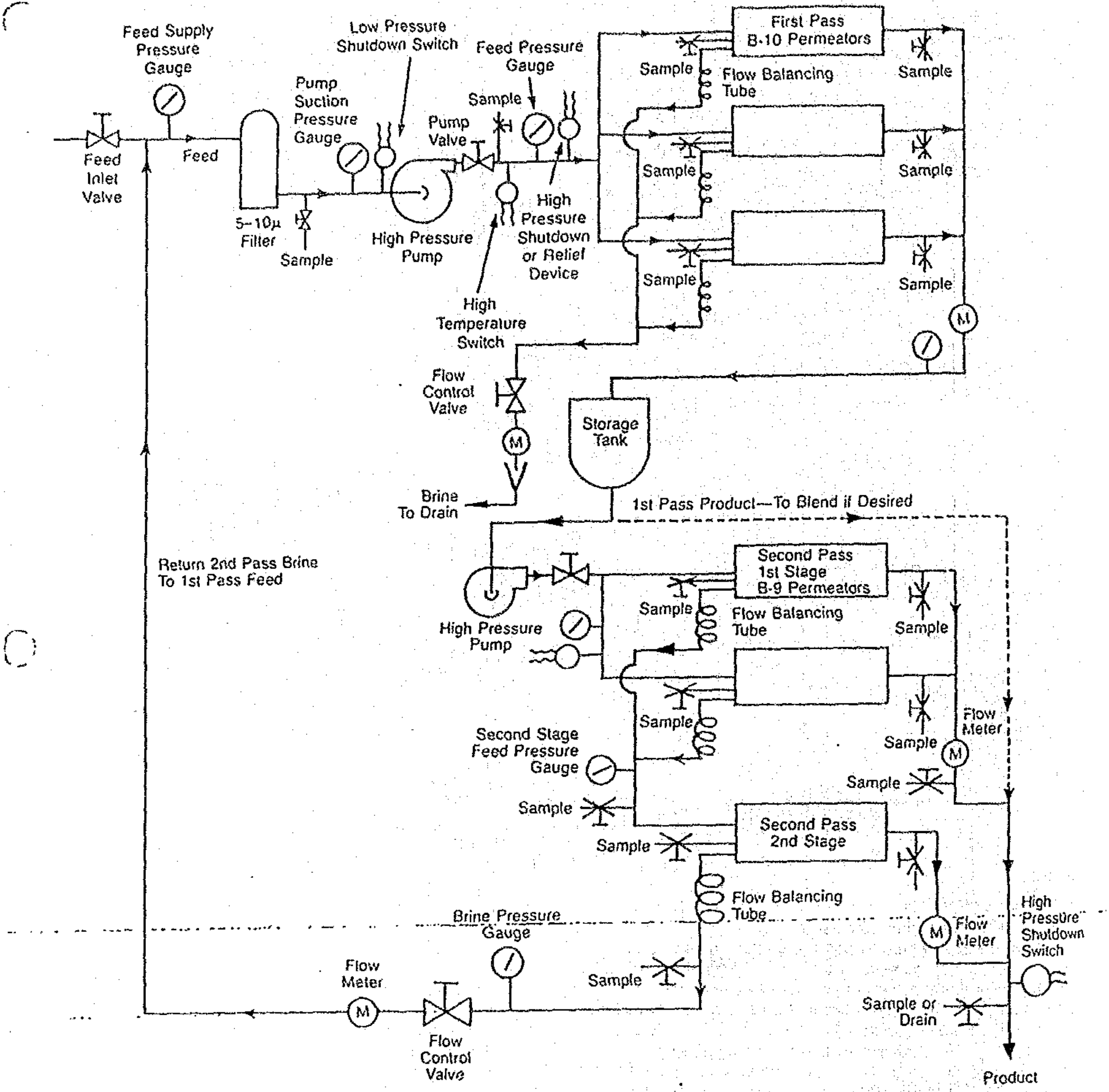
High-salinity feedwater should be flushed from the stainless steel components and permeators after shutting down a B-10 system for the following reasons:

- Corrosion of stainless steel components in stagnant seawater is very high.
- Sequestrants produce a metastable state with respect to precipitation of sparingly soluble salts. Upon shutdown, precipitation can occur within four hours if the permeators are not flushed.
- Upon shutdown, reverse osmosis will cease and natural osmosis will occur. Natural osmosis is a process in which water flows from the fiber bore to the fiber feed-brine side (Figure 8). If an adequate volume of product water at positive pressure (draw-back tank) is not supplied, fiber dehydration could occur.

Flushing the permeators with low TDS water at shutdown will also prevent natural osmosis. However, a draw-back tank is highly recommended as an additional precaution in case of an unexpected shutdown.

Figures 3, 6 and 7 all show the location of a suitably sized product water storage tank that can be used for these purposes. The tank should be elevated above the highest permeator. However, it should not exceed a positive head of 350 kPa (50

Figure 7. Product Staging



psig) on the lowest permeator. The tank must be large enough to provide sufficient water for system flushing and permeator draw-back using the following guidelines:

- About 0.011 m^3 (3 gallons) for a 4-inch B-10 permeator
- About 0.038 m^3 (10 gallons) for a 8-inch B-10 permeator

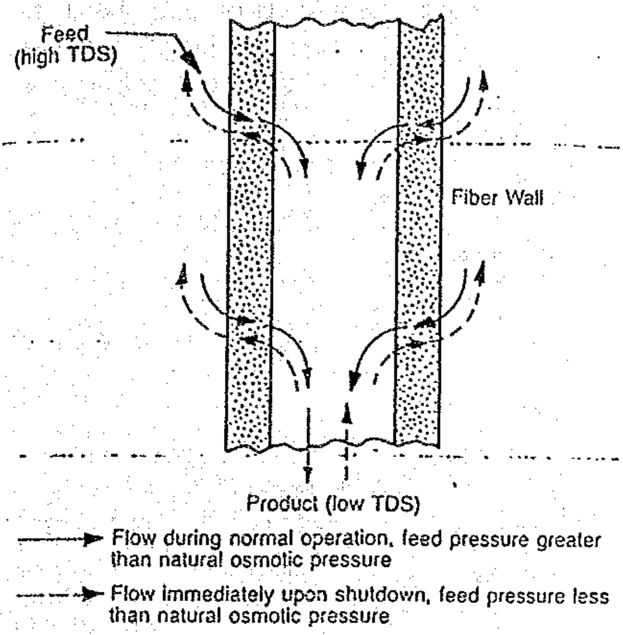
In addition, about 5 times the volume of system piping, filters, etc., will be needed to flush the system.

2. Cleaning, Sterilizing and Flushing Systems

Reverse osmosis systems, like most other water-treatment equipment, occasionally need cleaning, sterilizing or flushing. Permanent equipment, properly sized for the particular system, can handle all of these auxiliary operations. Figure 9 is a schematic of this equipment.

RO systems are generally designed with several control blocks which can be operated independently from other control blocks. RO systems are usually treated one block at a time to minimize plant downtime. For large installations, the treatment equipment is sized

Figure 8. Natural Osmosis and Draw-back at Shutdown of a B-10 System



⟶ Flow during normal operation, feed pressure greater than natural osmotic pressure

- - -> Flow immediately upon shutdown, feed pressure less than natural osmotic pressure

for some fraction of the system capacity.

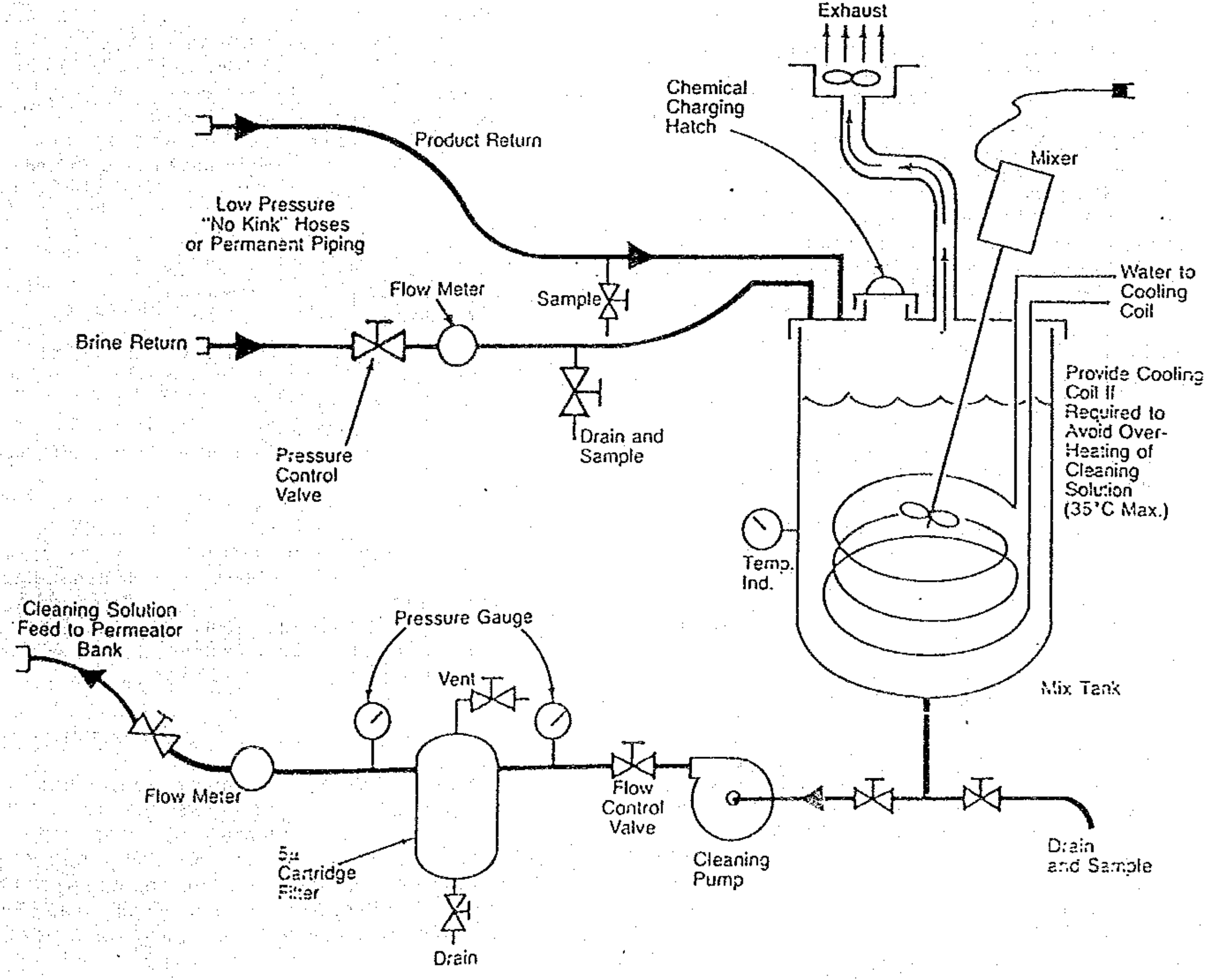
The mix tank should be made of non-corrosive materials such as reinforced plastic. The tank should be sized for at least a three-minute retention time, considering the number of permeators to be cleaned at one time and the volume of liquid in the cleaning pump and piping.

A tank cover, exhaust fan, mixer, and in some cases, a cooling coil should be provided. A temperature indicator and alarm assures that the temperature of the cleaning solution does not exceed 35 degrees C during the closed-circuit circulation of the cleaning fluid. Heat added by pumping will cause a rise in fluid temperature.

The pump should be stainless steel for compatibility with the anticipated fluid reagents. A centrifugal pump is desirable for ease of operation and safety. Thin-walled hoses which have a tendency to kink should be avoided.

A 5- or 10-micron cartridge filter should be installed after the recirculation pump to avoid recirculating sediment which may dislodge from the system during the cleaning operation. Only one stage of a brine-staged system should be cleaned at a time so that material removed does not contaminate another stage.

Figure 9. Equipment for Cleaning, Sterilizating and Flushing



3. Additive Systems, General

a. Pumps
Positive-displacement diaphragm pumps or plunger pumps are generally used for adding acid, sodium hexametaphosphate, etc. Stainless steel (316), plastic or alloy 20 are the minimum acceptable materials of construction. These pumps should be sized to minimize surges in concentration of the additive in the feed stream. High-pressure relief devices must be provided for these pumps. In addition, a sample and drain tap should be provided on the discharge stream of an addition pump to allow for flow-rate calibration and for purging air to prevent vapor locks.

b. Check Valves
These systems should also be equipped with check valves and an anti-siphon device to prevent the additive from flowing into the feed stream on shutdown. A check valve is used to prevent back flow of feedwater into the additive tank. Also, positive-displacement diaphragm pumps and plunger pumps must be electrically interlocked with the RO pump-drive so that injection stops when the RO plant feedstream flow stops. The design should include devices and procedures to assure that the additive is in fact being injected at the designated dosage. The RO feedwater should be periodically analyzed to assure that the additive is present.

c. Mixers
One or more makeup tanks with appropriate mixing devices are needed for any chemical additive which must be diluted or dissolved. Uniform distribution of the additive solution in the feed stream is necessary for additives to be effective. Normal turbulence in the feed stream piping network, even when coupled with a central-stream injection nozzle, may not be sufficient for proper mixing. For this reason, an in-line static mixer is also recommended. Whenever possible, additives should be injected into the low-pressure system prior to the micron filter.

4. Chlorination Systems

Seawater from surface sources is usually chlorinated to control biological growth and then dechlorinated before entering the permeators. An automatic feed stream shutoff or a diversion valve is recommended for chlorinated feed streams to prevent accidental chlorination of the permeators. The feedwater stream supplying the high-pressure RO pump is pressurized by a feedwater supply pump, booster pump, or well pump. Pressurized feedwater can flow through a stopped centrifugal RO pump and into the permeators. Since additive pumps shut off immediately upon RO system shutdown, chlorinated stream flow must also be stopped immediately if dechlorination is by chemical (bisulfite) addition rather than by a carbon filter.

5. Cooling Systems

Seawater temperatures, at a given location, can vary greatly due to seasonal changes. The highest temperature is normally used as the design basis. For example, if a seawater source is assumed to fluctuate between 27 degrees and 35 degrees C, then an RO plant design would generally use 35 degrees C as the conservative design basis. This means that feed pressures for the B-10 permeator would be limited to 5,520 kPa (800 psig) when the temperature is 35°C, at least for specific periods of time. Using the higher temperature often requires a two-pass system. At the lower temperature, however, a single-pass system would suffice since additional feed pressure could be used.

TABLE I
THE EFFECT OF FEEDWATER COOLING
ON PERMEATOR REQUIREMENTS
3,785 m^3/d (1 MILLION GPD) PLANT

	No Cooling	Cooling
Feed *TDS* (mg/ℓ)	39,500	39,500
Feed flow (m^3/d)	16,450	12,630
B-10 Feed pressure (kPa)	5,520 (800 psi)	6,900 (1,000 psi)
B-9 Feed pressure (kPa)	2,760 (400 psi)	B-9 not required
Feed temperature (°C)	27–35	27
B-10 Conversion (%)	25	30
B-9 Conversion (%)	90	B-9 not required
Plant product flow (m^3/d)	3,800	3,800
Plant product *TDS*	500	500
Permeator requirements, approximately	300 B-10 30 B-9	180 B-10

To lower the feedwater temperature and permit RO operation at higher pressures, feedwater coolers (chillers) are often recommended. The cost of cooling must be compared to the additional capital and operating cost of a system designed to operate at lower pressure.

The advantages of an RO system with cooling, operating at a constant feedwater temperature, compared to a fluctuating temperature design are shown in Table I and highlighted below:

- Nearly 4,000 m^3/d less feed flow and therefore, smaller pretreatment equipment and lower chemical consumption.
- Fewer B-10 permeators.
- No B-9 second stage required to meet product quality criteria.

Savings in capital, energy and chemical costs that result must be compared to the cost of the cooler (chiller) and the energy required to operate it. Costs to operate the B-10 section as its optimum pressure of 6,900 kPa (1,000 psig) must also be considered. At many sites the chiller would only operate during the hottest season. This economic balance will vary from case to case.

E. ENERGY RECOVERY SYSTEMS

Hydroturbines and impulse turbines are two devices for recovering energy from high-pressure hydraulic streams. They have been in use for many years in wide ranging applications, particularly in chemical refining and hydroelectric generation industries. Incorporating energy recovery equipment into RO system design is a logical and economically rewarding method for capturing the energy that

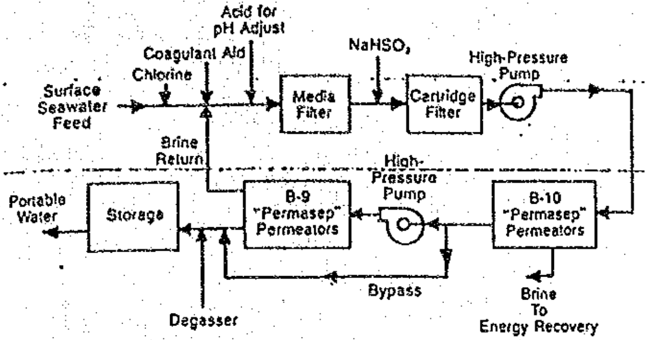


Figure 10. Large Seawater RO Plant Design

otherwise would be discarded with the high-pressure brine. Since seawater reverse osmosis systems operate at generally between 15 and 40 percent conversion, the remaining 60 to 85 percent of the seawater pumped into the permeator is discharged from the permeator as high-pressure brine. A flow diagram for a typical Middle East seawater system with energy recovery equipment is shown in Figure 10.

Seawater reverse osmosis systems such as depicted in Figure 10 usually operate at permeator feed pressures of 5,520 kPa (800 psig) to 6,900 kPa (1,000 psig). The brine stream is discharged from the permeators at pressures ranging from 5,175 kPa (750 psig) to 6,550 kPa (950 psig), carrying with it most of the original pumping energy.

Hydroturbines and impulse turbines are proven techniques for recovering hydraulic energy from liquid streams.

1. Hydroturbine

A process flow sketch for a 3,785 m^3/day (1.0 million GPD) seawater plant incorporating a hydroturbine is shown in Figure 11. A hydroturbine is essentially a horizontal, split-case, multi-stage, centrifugal pump which runs backwards. Hydroturbines can be mounted on a common base plate with the high-pressure reverse osmosis pump. They can be directly connected to one end of the RO pump impeller shaft. The energy recovered by the hydroturbine is shaft energy that is used to help turn the high pressure RO pump. The RO high-pressure pump and the hydroturbine are designed to operate at the same speed. The electric motor that drives the high-pressure pump operates at a constant speed and acts as the control device for the hydroturbine. The design technology for a hydroturbine is nearly identical to that of centrifugal pumps. Consequently, most major centrifugal pump manufacturers can supply this type of equipment.

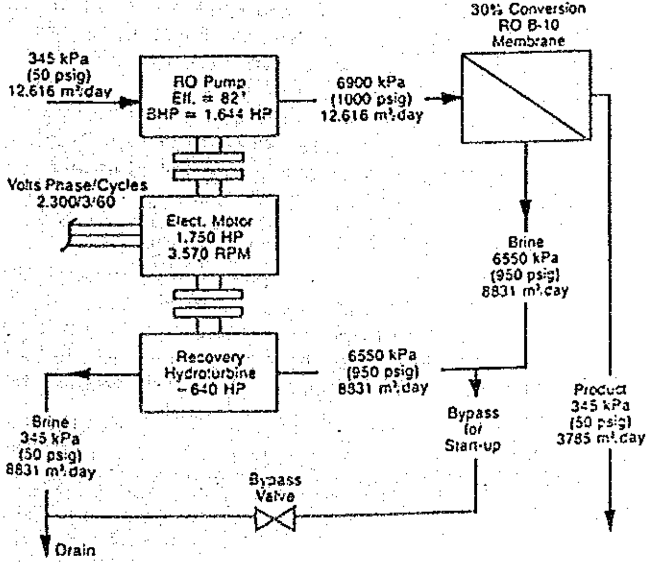


Figure 11. 3,785 m^3/Day (1,000,000 GPD) Permasep* Permeator Seawater RO System Hydraulic Power Recovery Turbine

2. Impulse Turbine

The impulse turbine is the second type of energy recovery device for high-pressure hydraulic streams. It is also known as the "Pelton wheel," a wheel with a series of paddles or buckets attached to its circumference. A high-pressure water stream directed at the buckets on the wheel causes it to turn at high speed, generating mechanical energy. Small impulse turbines usually operate at very high shaft speeds (5,000 to 10,000 rpm), while very large impulse turbines usually operate at relatively low shaft speeds (200 to 1,000 rpm).

Impulse turbines can be connected to induction motor/generators which generate electricity that is returned to the power grid. When driven at slightly above its synchronous speed, an induction motor becomes a generator (in this case, driven by the impulse turbine). This is an unusual characteristic of an induction motor. The induction motor/generator will operate at the proper frequency without a governor or speed control as long as the generator power input to the electric supply grid is only a small part of the power generating capacity for the grid.

The combined efficiency of the impulse turbine/generator package is about equal to the efficiency of the hydroturbine. The impulse turbine/generator system will usually have a higher capital cost than the hydroturbine because the turbine/generator system consists of two pieces of equipment.

3. Energy Consumption

Large seawater RO plants with energy recovery equipment require only one-half to one-third the energy required by the most efficient MSF distillation plant and only two-thirds the energy required by vapor compression (VC) processes.

Energy and power requirements for a 3,785 m^3/day (1.0 million GPD) seawater RO plant are shown in Table II. The energy users for a typical seawater reverse osmosis process are listed below:

- Seawater pump
- Additive pump (injector)
- Filtered water pump
- Reverse osmosis pump (high-pressure pump)
- Second-stage reverse osmosis pump (a second RO stage may be required if feed *TDS* exceeds 40,000 mg/ℓ)
- Product water degassing blower
- Product water distribution pump

About 30 percent of the overall energy input is recovered with energy recovery equipment. As plant sizes increase, this percentage should increase with the generally higher efficiency of larger size pumps and motors.

It should be noted that the power consumption for

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*Reg. U.S. Pat. & Tm. Off. for Du Pont's Permeators.

TABLE II
SEAWATER RO SYSTEM[†]
ENERGY POWER REQUIREMENTS
3,785 m^3/day (1.0 million GPD)

	Pump flow m^3/min.	Pump Eff. %	Pump Head Flow	Motor HP (90%) Eff.	Motor Kw	kWh/m^3 of Product Water
Sea Pump	8.8	80	115	95.9	71.5	.45
Additive Pumps	—	—	—	4.0	3.0	.02
Filter Water Pump	8.8	80	115	95.9	71.5	.45
B-10 RO Pump	8.8	80	2,079	1,726.0	1,287	8.16
Degas	—	—	—	4.0	3.0	.02
Product Pump	2.8	80	115	28.1	21.0	.13
B-9 RO Pump	1.2	80	924	97.6	72.8	.46
Energy Recovery Turbine	6.9	80	1,963	−630.7	−470.3	−2.98
TOTAL				1,420.8	1,059.5	6.71

[†] Basis:
- Conversion of seawater to product water = 30%
- Feedwater *TDS* is 42,000 mg/ℓ
- RO feed pressure is 6,210 kPa (900 psig) for B-10
- Feedwater temperature is 26 to 32 degrees C.

smaller RO seawater desalting systems may be higher than the values given in Table II because centrifugal pump efficiencies tend to decrease as pump size decreases.

F. MATERIALS OF CONSTRUCTION

1. Introduction

Metal corrosion can be a serious problem in many water treatment processes. All RO devices are particularly sensitive to metal corrosion products (see Bulletin 503, Pretreatment for Metal Oxides). If corrosion is not controlled, premature failure of the RO system will result. When designing a plant, the degree of corrosion and the effect it will have on the RO system must be carefully considered. The most effective way to minimize corrosion in an RO plant is to limit the use of metal. Non-metallic materials should be used on all wetted parts wherever they are practical and economical.

2. Metallic Materials of Construction

The corrosion rate of metallic materials is a complex phenomenon depending on the material itself and the environment to which it is exposed. Factors such as dissolved gasses (O_2, CO_2, H_2S), anions (Cl^-, $SO_4^=$), and pH affect the rate and type of corrosion on a particular metal surface. Further, use of dissimilar metals in a connected system can lead to galvanic type corrosion if protective measures are not applied. Experience has shown that corrosion is high at threaded pipe connections. Therefore, this type of connection should be minimized. Where threads are required, the use of chemically compatible materials such as epoxies to fill thread voids when making the joint should be considered. The following precautions should be considered for specific metals:

- *Carbon Steel*—Carbon steel and other similar ferrous materials such as black, cast and wrought irons should be avoided since experience shows that severe corrosion occurs with their use. If these materials are employed upstream of the permeator, proper pretreatment (Bulletin 503) must be used to prevent metal oxide fouling.
- *Stainless Steel*—Stainless steels are generally proven to be more corrosion resistant than carbon steel. In particular, Type 316, 316L and higher alloy stainless steels have been successfully used in many B-10 plants for piping, pumps and vessels. When corrosion of stainless steel does occur, it is usually localized and in stagnant flow zones, i.e., crevices. Crevices should be avoided. When designing and fabricating stainless steel pipe and equipment, a designed water flow of greater than 1.5 m/s (5 fps) should be used. Stainless steel can be corroded by the presence of bacteria which produce slimes that block the flow of water across metal surface and cause high salt concentration regions to form. This can occur during pipe fabrication and testing or when a plant is shut down for an extended time period. Therefore, proper sterilization procedures should be followed (Bulletin 509).
- *Non-ferrous Metals*—Galvanized lining is not recommended for piping or equipment. Experience has shown that the protective layer can be short lived. In general, copper, bronze, brass and aluminum also should be avoided since they can cause metal oxide fouling within RO devices. Nickel-aluminum-bronze alloys have been successfully used in plunger pumps.

3. Non-metallic Materials of Construction

Engineering plastics, plastic composites, glass, concrete, rubber and ceramics are desirable materials of construction which avoid metal corrosion. When these materials are used, they must be properly applied for the intended service. Factors to be considered in the selection and use of non-metals include:

- Pressure rating
- Thermal expansion and contraction
- Temperature rating

- Chemical compatibility
- Mechanical integrity

4. **Non-metallic Liners and Coatings**

Non-metallic liners and coatings such as phenolics, epoxies, rubber, acrylics, and glass are frequently used to protect pipe and equipment from corrosion and chemical attack. In selecting and applying the liner or coating, the following factors must be considered:

- Thermal expansion and contraction
- Chemical compatibility
- Temperature rating
- Mechanical integrity

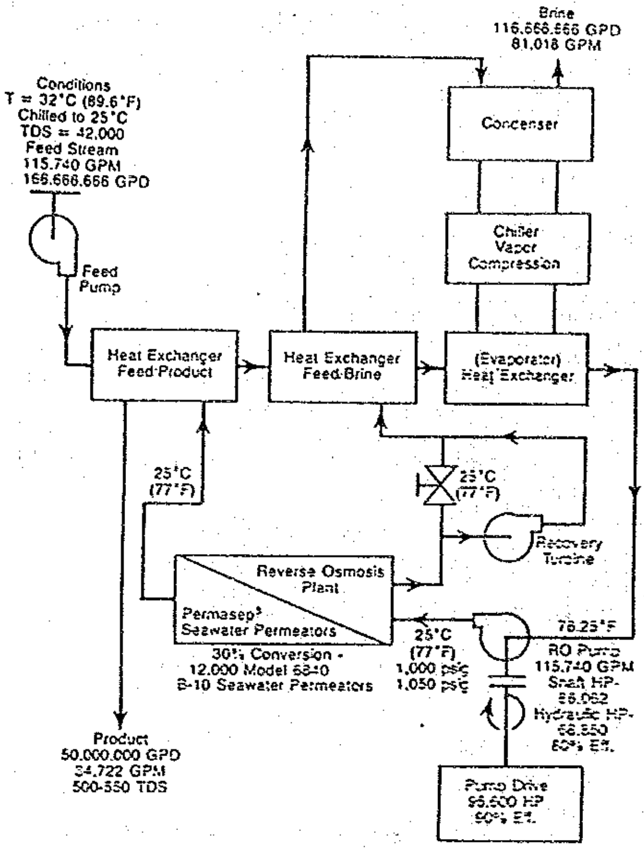
The integrity of the coatings is the key to preventing problems. The base material must be totally (100 percent) covered. Pinhole leaks and unprotected flanges and crevices can result in shortened life for the pipe, equipment and permeators. Because epoxy paint tends to chip and expose the metal, this type of coating is not recommended.

G. LARGE SYSTEMS

RO systems are generally designed with multiple blocks or modules. The modules are self contained and are connected either to an independent feed pump or by pipeline to a feed header. With this configuration a portion of the plant can be shut down via valves without interrupting other blocks. There is no restraint on the size of a single block. The larger the block, the larger and more efficient the pumps and recovery equipment. Five to ten million GPD blocks are conceivable in 40 to 50 million GPD plants.

Today's technology also permits design of an entire 50 million GPD plant in one block. Although this approach is not usually recommended for designing a plant of this size, high-pressure pumps and hydraulic turbines are available in sizes which have been proven reliable in operation of municipal water systems at similar volumes for many years. Figure 12 is a schematic of a 50 million GPD design.

Figure 12. Du Pont Permasep* Products (50 Million GPD)† Seawater Reverse Osmosis Plant



†189,250 m³/D

If feedwater cooling is required, a heat pump system should be considered. These large plants could operate reliably 90 to 95 percent of the time. Equipment capable of handling these flow rates is commercially available.

REFERENCE

1. Landrum, R. J. "Materials of Construction Guide for 'Permasep' Seawater RO Systems," December 31, 1980. Published by E. I. du Pont de Nemours & Co., Inc.

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*Reg. U.S. Pat. & Tm. Off. for Du Pont's Permeators.

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BULLETIN 509

STERILIZING (SANITIZING) PROCEDURE

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A. INTRODUCTION

Treating permeators with a biocide may be required if:

- The RO plant will be out of service for an extended period of time (five days or longer).
- The RO plant will be out of service for a day or more after cleaning with an organic solution such as citric acid.
- Permeator product water is contaminated with bacteria.

For routine storage (items one and two above) a biostat solution of sodium metabisulfite and glycerine may be used. Permasep[*] permeators are routinely treated with a 1/4 wt. percent sodium metabisulfite and 18 wt. percent glycerine solution prior to shipment. If a permeator has become biologically fouled and sterilization is required, only formaldehyde is approved as an effective biocide. Formaldehyde may also be used as a storage solution for permeator and RO systems not in use.

B. SAFETY PRECAUTIONS

- In using any chemical follow accepted safety practice. Consult the manufacturer of the chemicals for detailed information with respect to safety, handling and disposal.
- When preparing chemical solutions for cleaning, be certain that all chemicals are dissolved and well mixed, before introducing them into permeators.
- Before sterilization, flush the permeators thoroughly with good quality chlorine-free water (*TDS* less than 5,000 mg/ℓ). If available, product water is recommended.
- During recirculation, temperatures must not exceed 35 degrees C.

C. EQUIPMENT

The equipment for cleaning, sterilization and posttreatment is shown in Figure 1, Equipment for Cleaning, Sterilizing and Posttreating. The materials of construction must be chemically compatible with all the chemicals employed and corrosion resistant.

The mix tank should be sized for a minimum 3-minute retention time and provided with a cover, exhaust fan, mixer, cooling coil and a temperature indicator. The pump should be 316 stainless steel and sized for the flow and pressure used in the various procedures. A centrifugal pump is most suitable for flexibility and safety. If hoses are used for supply and return lines, be sure the pressure rating is adequate and that kinking will not occur. A 10μ cartridge filter is used to remove any dislodged solids. Appropriate valves must be provided to control system pressure and permit drainage and flushing of tank and lines. All cleaning and flushing must be performed as in normal operation mode, i.e., feed port to brine port. Flow meters are necessary to establish proper rates through the permeators. Sampling ports should be available for monitoring.

The flow requirements for effective permeator cleaning, sterilization and post-treatment vary. In many cases, plants may be treated stage by stage with the flow balancing tubes in place. Procedures which require high brine flows may necessitate a bypass around the flow balancing tubes.

D. STERILIZATION PROCEDURE

1. Flush the permeators with chlorine-free product or good quality water (*TDS* less than 5,000 mg/ℓ) prior to sterilizing. Use a once-through flush (brine and product to drain) of 38 liters (10 gallons) of water per 4-inch permeator.[†]
2. If disinfection is required, prepare a well-mixed 1 to 2 wt. percent (active ingredient) solution of formaldehyde in the brine tank, taking into account the volume of water in piping, hoses and permeators (assume 9.5 liters [2.5 gallons of water] per 4-inch permeator). If the permeator is not biologically fouled and sterilization is required for storage purposes, then a 1/4 wt. percent solution of formaldehyde or sodium metabisulfite can be used. If sodium metabisulfite is used, 18 wt. percent glycerine must be added in order for it to be effective in preventing biological growth.

   Glycerine (18 wt. percent) is also required with formaldehyde if the permeator is to be stored at temperatures less than 0 degrees C (32 degrees F). If storage is to be greater than one month, magnesium chloride (250 mg/ℓ as Mg^{++}) should be added, regardless of which sanitizing solution is used to maintain fiber stability.

   Chlorine-free product or good quality water (*TDS* less

[†] Flows and volumes stated are based on 4-inch diameter permeators (Model 0440, 6440). For 0420 and 0410, flows and volumes are one-half and one-fourth respectively of the 0440 rates. For 6410, flows and volumes are one-fourth of the 6440 rate. For 8-inch diameter permeators (Model 0840, 6840), flows and volumes should be increased by a factor of three. Cleaning 10-inch diameter permeators (Model 0040) flows and volumes are to be increased by a factor of six.

[*] Reg. U.S. Pat. & Tm. Off. for Du Pont's permeators

Printed in U.S.A.

530 mg/ℓ NaCl taking into account the volume of water in piping, hoses, and permeators (assume 9.5 liters [2.5 gals.] of water per 4-inch permeator). Use chlorine-free product water.

c. Recirculate the PT-A solution through the permeator. A brine flow of about 7 ℓ/m (2 gpm) per 4-inch permeator is recommended using a pressure of 345–517 kPa (50–75 psig). The temperature must not exceed 35 degrees C. This temperature maximum protects the permeator and prevents precipitation of PT-A (cloud point equals 37 degrees C).[†]

d. Monitor the conductivity of the product every 15 minutes. Terminate the PT-A posttreatment when product conductivity is constant for 30 minutes. Usually, constant conductivity is obtained after one hour of treatment.

e. When the posttreatment is complete, stop recirculating. Drain the Mix Tank solution to waste. Flush the residual PT-A solution from the permeator with RO product water by operating at 345–517 kPa (50 to 75 psig) and at a brine rate of 17 ℓ/m (4.5 gpm) per 4-inch permeator for five minutes in the normal feed direction. During this flush, the brine and product both go to drain. The units may then be flushed using regular feedwater at a reduced pressure (less than 1,380 kPa [200 psig]) for 15 minutes. Both the brine and product should go to drain.

f. After the system is stabilized, check the performance to determine the effectiveness of PT-A treatment.

E. PT-B POSTTREATMENT

After the initial flush, new B-10 permeators usually must be treated with PT-B before placing them on-stream. B-10 permeators MUST also be retreated with PT-B after any cleaning operation. B-9 permeators can also be treated with PT-B. Permeators are normally treated with PT-B by shutting down the portion of the system requiring treatment, treating the units and returning them to service. However, under certain conditions, permeators can be treated while in operation. These procedures are discussed below.

1. PROCEDURE[††]

a. Flush the permeators with chlorine-free product or good quality water (*TDS* less than 5,000 mg/liter) prior to posttreatment. Use a once-through flush (brine and product to drain) of 38 liters (10 gallons) of water per 4-inch permeator.[††]

b. In the Mix Tank, prepare a solution containing 1 wt. percent citric acid plus 80 mg/liter of PT-B, taking into account the volume of water in piping, hoses and permeators (assume 9.5 liters [2.5 gallons] of water per 4-inch permeator). Use RO product or other good quality water (*TDS* less than 5,000 mg/liter). Since the PT-B is a solid which does not dissolve immediately, the PT-B is best added as a dilute aqueous stock solution containing 3 wt. percent of PT-B.

c. Recirculate the PT-B solution through the permeators. A brine flow of about 7 ℓ/m (2 gpm) per 4-inch permeator is recommended using a pressure of 690 to 1034 kPa (100 to 150 psig). The temperature must not exceed 35 degrees C.

d. After one hour, stop recirculating. Drain the mix tank solution to waste. Flush the residual PT-B solution from the permeators with product water at 345–517 kPa (50–75 psig) and a brine rate of 17 ℓ/m (4.5 gpm) per 4-inch permeator for five minutes in the normal feed direction. During this flush, the brine and product water go to the drain. The units may then be flushed with regular feed water at a reduced pressure (less than 1,379 kPa [200 psig]) for 15 minutes. The brine and product water go to drain.

e. After the system operation has stabilized, check the performance to determine the effectiveness of PT-B treatment.

2. ON-LINE PT-B TREATMENT

B-10 permeators can be PT-B treated while in operation provided the feed pH during treatment is less than 5.0. At a pH greater than 5.0, PT-B is relatively insoluble in seawater and forms a brown precipitate even at a PT-B concentration of only 10 mg/ℓ. However, if the seawater pH is less than 5.0, no precipitate is formed even at PT-B concentrations of 80 mg/ℓ. The on-line PT-B treatment is performed by injecting a PT-B and citric acid solution into the feed stream. A mix tank and injection system are required. If operating conditions permit on-line treatment, "Permasep" Products Licensees can provide design assistance and operating procedures.

[†] At higher concentrations, the cloud point is lower; at 3 wt. percent or above, it is 30 degrees C. Thus, these solutions should be stored at temperatures lower than 30 degrees C.

[††] Flows and volumes stated are based on 4-inch diameter permeators (Model 0440, 6440). For 0420 flow and volumes are one-half and for 0410 flows and volumes are one-fourth of the standard 0440 rates.
For 8-inch diameter permeators (Model 0840, 6840) flows and volumes should be increased by a factor of three. When cleaning 10-inch diameter permeators (Model 0040), flows and volumes are increased by a factor of six.

CAUTION: Follow manufacturers' recommendations on containers or in product bulletins for the safe handling of all chemicals and cleaning agents used with "Permasep" permeators.

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BULLETIN 507

CLEANING PROCEDURES

TABLE OF CONTENTS

A. INTRODUCTION

Each bulletin on potential membrane problems briefly describes the cleaning agents for that particular problem. A summary of these chemical cleaning agents is presented in Table I. A system supplier will typically provide an operating manual with detailed procedures for cleaning the RO system. The procedures included in this section illustrate the simplicity of cleaning an RO system.

Frequent cleaning is not required for properly designed and properly operated RO systems. But if cleaning is required, the synthetic aramid membrane used in B-9 and B-10 "Permasep" permeators permits a broader range of cleaning chemicals than can be tolerated by most other commercial membranes.

Large RO plants are usually designed with more than one control block (independent units). Cleaning is then performed on one block at a time permitting the balance of the plant to continue normal operation.

B. SAFETY PRECAUTIONS

1. In using any of the chemicals listed in Table I, Chemical Cleaning Agents, follow accepted safety practice. Consult the manufacturer of the chemicals for detailed information with respect to safety, handling and disposal.
2. When preparing chemical solutions for cleaning, be certain that all chemicals are dissolved and well mixed, before introducing them into permeators.
3. Before and after each cleaning, flush the permeators thoroughly with good quality chlorine-free water (*TDS* less than 5,000 mg/ℓ). If available, product water is recommended. If cleaning agents are used sequentially, it is mandatory that the permeators be thoroughly flushed between cleanings to prevent possible harmful interaction between different cleaning solutions. Following a "Biz" cleaning, it is desirable to have the flush water at pH 10 to avoid the formation of fatty acids, which will precipitate at low pH.
4. During recirculation, temperatures must not exceed 35 degrees C.

C. EQUIPMENT

The equipment for cleaning, sterilization and posttreatment is shown in Figure 1, Equipment for Cleaning, Sterilization and Posttreatment. The materials of construction must be chemically compatible with all the chemicals employed and corrosion resistant.

The mix tank should be sized for a minimum 3-minute retention time. Provide a cover, exhaust fan, mixer, cooling coil and a temperature indicator. The pump should be 316 stainless steel and sized for the flow and pressure used in the various procedures. A centrifugal pump is most suitable for flexibility and safety. If hoses are used for supply and return lines, be sure the pressure rating is adequate and that kinking will not occur. A 10μ cartridge filter is used to remove any dislodged solids. Appropriate valves must be provided to control system pressure and permit drainage and flushing of tank and lines. All cleaning and flushing must be performed as in normal operation mode; i.e., feed port to brine port. Flow meters are necessary to establish proper rates through the permeators. Sampling ports should be available for monitoring.

The flow requirements for effective permeator cleaning, sterilization and posttreatment vary. In many cases, plants may be treated stage by stage with the flow balancing tubes in place. Procedures which require high brine flows may necessitate a bypass around the flow balancing tubes.

D. DETERGENT FLUSHING PROCEDURES

Cleaning with "Biz"[†] detergent, using the method described below, is effective in removing colloidal foulants.

1. CLEANING PROCEDURE USING "BIZ"[†] (WITH PHOSPHATE)

a. Flush permeators with product water prior to cleaning using a once-through flush (brine and product to drain) of 38ℓ (10 gallons) per 4-inch permeator.[††] The brine pH must be 6.0 or above.
b. In the mix tank, prepare a 0.5 wt. percent "Biz" detergent (with 17.6% phosphorus) solution taking

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[†] Trademark of Proctor and Gamble, U.S.A. for a detergent sold in the U.S.A.

[††] Flows and volumes stated are based on 4-inch diameter permeators (Model 0440, 6440). For 0420 and 0410, flows and volumes are 1/2 and 1/4 respectively of the 0440 rates. For 6410 the flows and volumes are 1/4 of the 6440 rates. For 8-inch diameter permeators (model 0840, 6840) flows and volumes should be increased by a factor of three. Cleaning 10-inch diameter permeators (model 0440) flows and volumes are to be increased by a factor of six.

[*] Reg. U.S. Pat. & Tm. Off. for Du Pont's permeators

TABLE I
CHEMICAL CLEANING AGENTS

Chemicals	Foulants						
	$CaCO_3$	$CaSO_4$ $BaSO_4$ $SrSO_4$ CaF_2	SiO_2	Metal Oxides	Inorganic Colloids	Biological Matter	Organics
Hydrochloric Acid[1] (HCl)(pH 4.0)	X				X		
2.0 wt. % Citric Acid + NH_4OH (pH 4.0)	X			X	X		
5 wt. % Nutek NT-600	X						
2 wt. % Citric Acid + NH_4OH (pH 8)		X					
1.5 wt. % Na_2EDTA[3] + NaOH (pH 7–8) or 1.5 wt. % Na_4EDTA + HCl (pH 7–8)		X					
1.0 wt. % Na Hydrosulfite ($Na_2S_2O_4$)		X		X			
NaOH (pH 11.0)[2]			X		X		X
2.0 wt. % Citric Acid + 2.0 wt. % Na_2EDTA + NH_4OH (pH 4.0)	X			X			
0.5 wt. % "Biz"[4] (with phosphate) + NaOH (pH 11.0)			X		X		X
1 wt. % Drewsperse 738					X		
1 wt. % NaHMP				X	X		X
1/4–2 wt. % Formaldehyde followed by 0.25 wt. % "Biz" (with phosphate)						X	

1. A lower pH may be more effective. If pH is <4.0 the low pH Guideline must be followed.
2. A higher pH may be more effective. If pH is >11.0 the high pH Guideline must be followed.
3. EDTA is ethylenediaminetetracetic acid.
4. "Biz" is a detergent sold by Procter and Gamble, U.S.A.

into account the volume of water in the piping and permeators (assume 9.5 ℓ [2.5 gal.] of water per 4-inch permeator).

c. With agitation add sufficient NaOH solution to increase the pH to 11.0. NOTE: Solid caustic (flake, solid, etc.) is difficult to dissolve and may settle to the bottom of the chemical cleaning tank. This can result in what appears to be acceptable pH measurements taken at the top of the tank and an excessive pH at the bottom of the tank where the pump suction is located. If the solution is not properly mixed, the high pH portion of the solution can be pumped into the permeator causing irreversible damage.

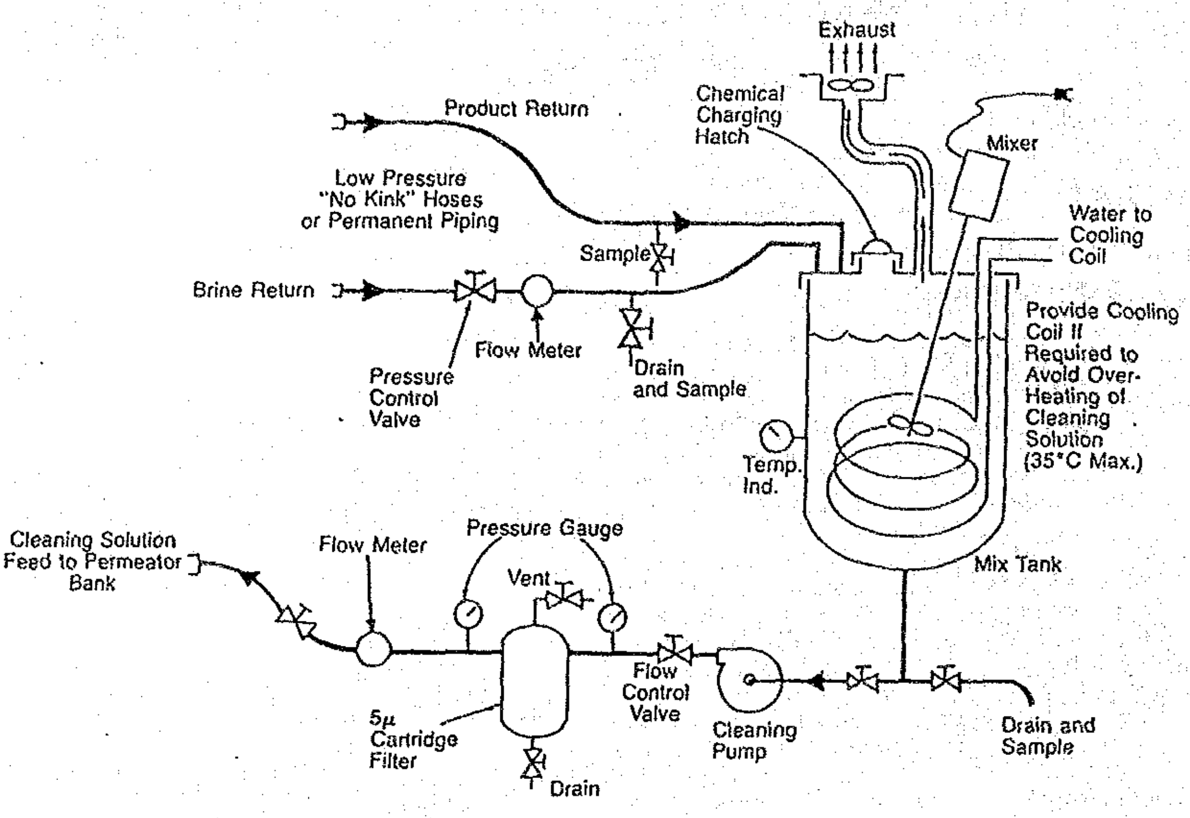
d. Circulate the cleaning solution through the permeator. Take the first 20 percent of the solution to drain via the brine return valve, and then recycle the cleaning solution through the mix tank. A brine flow of about 17 ℓ/m (4.5 gpm) per 4-inch permeator is recommended at a pressure of 345–1,035 kPa (50–150 psig).

e. The effects of the "Biz" cleaning can be monitored by observing the effluent. If the effluent is darker than the feed, colloidal material is being removed. The flushing operation should be conducted for at least 2 hours and/or as dictated by the amount of foulants.

f. In place of continuous recycling as described in Step d, a flush/soak method in 15 minute cycles provides an alternative. With this method, the cleaning cycle is easily monitored by watching the effluent at the beginning of each flush. The effluent usually will be very dark (as compared to the feed) for the first 1 to 2 minutes after starting the flush. Agglomerated colloidal materials may be dispersed and placed in suspension during soak and are then removed more easily from the bundle to the mix tank. The flush/soak cleaning should be continued until the effluent is no longer badly discolored.

g. When cleaning is complete, stop recirculation. Drain mix tank solution to waste. Do not reuse cleaning solution. Flush residual cleaning solution from permeators with product water by operating at 345–518 kPa (50–75 psig) and 17 ℓ/m (4.5 gpm) per

Figure 1. Equipment for Cleaning, Sterilization and Posttreatment



4-inch permeator brine rate in the normal feed direction. During this flush, brine and product go to drain. The units may then be flushed with brine and product to drain using regular feedwater at reduced pressure of less than 1,380 kPa (200 psig) until no foaming occurs. Collect a sample of the brine in a jar and shake it to test for any remaining detergent. If foaming occurs, continue the flushing until foaming is no longer present.

h. After posttreatment (See Bulletin 508), return permeators to normal operation and check the performance to determine cleaning and posttreatment effectiveness.

2. ALTERNATE DETERGENTS

The following detergents have been tested for compatibility with the B-9 and B-10 membranes. No significant change in fiber properties was noted during a three-month exposure to 0.25–0.50 wt. percent concentrations. The materials are not tested for effectiveness. They may be considered as alternates when "Biz" is not available. Note that all detergents should be free of significant amounts of insoluble matter.

COMPATIBLE CLEANING AGENTS

Biz (17.6%, phosphorus)	Procter & Gamble U.S.
Ariel	Procter & Gamble France
Ariel	Procter & Gamble England
Ariel	Procter & Gamble Belgium
Ariel	Procter & Gamble Spain
Ariel	Procter & Gamble Mexico
Terg-A-Zyme	Fisher Scientific
OMO	Lever France
Drive	Lever Australia
Amaze	Lever Canada
Skip	Lever France
Skip	Lever Spain
Lava (60°)	Procter & Gamble France
Dato (60°)	Henkel
Xtra	Henkel
Alconox	Alconox Inc. U.S.
Alcojet	Alconox Inc. U.S.
Nutek NT 600	Nuclear Techn. Corp.
Na_2EDTA	Several Commercial Sources
Na_4EDTA	Several Commercial Sources
Drewsperse 738	Drew Chemical
Decon 90	United Kingdom
Dobanol 91/6	United Kingdom
Tergitol 15/5/7	Union Carbide Co.
Biox	Unibound
Microdetergent	International Product Group
Spee	East Germany
Milwok 71	East Germany
Detergent 28-77	East Germany

E. CLEANING WITH CITRIC ACID

Iron fouling will cause increased pressure drop and associated decrease in flux and increase in salt passage. Permeators should be cleaned if the pressure drop increases more than 50 percent.

1. Flush Permeators—Flush permeators with product water prior to cleaning using a once-through flush

(brine and product water to drain) of 38ℓ (10 gals) of water per 4-inch permeator.[†]

2. In the mix tank, prepare a 2 wt. percent solution of citric acid, taking into account the volume of water in piping, hoses and permeators (assume 9.5ℓ [2.5 gals.] of water per 4-inch permeator). Citric acid is very soluble in water (see Table II). A small volume of concentrate can be made up in a container in which complete dissolution is assured by visual inspection. This concentrate can then be transferred to the mix tank for final adjustment to the proper concentration.

TABLE II

CITRIC ACID SOLUBILITY IN WATER

Temperature (°C)	Citric Acid (% by Weight)
10	54
20	60
30	64
40	69
50	71
60	74
70	76
80	79
90	81
100	89

Source: Technical Files of Chas. Pfizer and Company, Inc.

3. With agitation, add sufficient NH_4OH to increase the pH to 4.0 (about 10 ml of a concentrated NH_2OH [24.4 percent] per liter of 2 wt. percent citric acid solution is required to obtain a pH of 4.0). It is important that the pH be 4.0 ± 0.2 at the end of the NH_4OH addition as well as during the entire cleaning period. Positive ventilation will be needed while adding concentrated ammonia, but odor will be negligible once mixing is complete.
4. Circulate the Cleaning Solution—In large permeator installations, it is desirable that cleaning chemicals be circulated by an auxiliary pump made of corrosion-resistant materials such as stainless steel or plastic. Circulate the cleaning solution through the permeators. Take the first 20 percent of the solution to drain via the brine drain valve, and then recycle the brine through the mix tank. A brine flow of about 7 ℓ/m (2 gpm) per 4-inch permeator is recommended using a pressure of 345 to 518 kPa (50 to 75 psig).
5. Using an iron test kit, monitor the cleaning solution in the mix tank for iron about every 30 minutes. Cleaning is considered complete when three successive analyses agree within 10 percent. This usually requires 1 to 4 hours. Observe the color of the ammoniated citric acid solution in the mix tank. If the citric acid is in excess with respect to iron, a green-yellow color will be observed. If the iron is in excess with respect to citric acid, a red-brown color will be observed, and the cleaning solution should be changed.
6. When cleaning is complete, stop recirculation. Drain mix tank solution to waste. Do not save for reuse. Flush residual cleaning solution from permeators by operating at 276 kPa (40 psig) and 7 to 11 ℓ/m (2 to 3 gpm) per 4-inch permeator brine rate for one hour in the normal feed direction. A four-hour flush at 345 kPa (50 psig) and 4 ℓ/m (1 gpm) per 4-inch permeator brine flow is also satisfactory. Brine and product must be discharged to waste during this period.
7. After posttreatments (See Bulletin 508), return permeators to normal operation and check the RO performance to determine cleaning and posttreatment effectiveness.

F. CLEANING WITH OTHER SOLUTIONS

1. When using other cleaning solutions, as indicated in Table I, Chemical Cleaning Agents, use the flow rates given for the citric acid cleaning procedure when cleaning for $CaCO_3$, $CaSO_4$, $BaSO_4$, $SrSO_4$, CaF_2 and metal oxides.
2. Use the flow rates given for the Cleaning Procedure Using "Biz" when cleaning for SiO_2, inorganic colloids, biological material and organic matter.
3. If metal oxide fouling is suspected as a result of corrosion, the higher flow rates given for the Cleaning Procedure Using "Biz" should be used.

[†] Flows and volumes stated are based on 4-inch diameter permeators (Model 0440, 6440). For 0420 and 0410, flows and volumes are 1/2 and 1/4 respectively of the 0440 rates. For 6410 the flows and volumes are 1/4 of the 6440 rates. For 8-inch diameter permeators (model 0840, 6840) flows and volumes should be increased by a factor of three. Cleaning 10-inch diameter permeators (model 0440) flows and volumes are to be increased by a factor of six.

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CHEMICAL ANALYSIS FOR HAQL PLANT

Description	Feed	Brine
pH	6.14	6.17
Conductivity us/Cm	53800	76400
TDS mg/L	37600	54200
Temperature °C	22.5	21.2
Turbidity NTU	0.37	0.38
SDI	0.80	-
TH as $CaCo_3$ mg/L	6700	10300
Ca as $CaCO_3$ mg/L	1050	1500
Mg as $CaCO_3$ mg/L	5650	9800
Chloride as Cl^- mg/L	20330	30167
Carbonate as CO_3 mg/L	Nil	Nil
Bicarbonate as HCO_3	50	74
Total Alkalinity as $CaCO_3$ mg/L	50	74
Carbon dioxide as CO_2 mg/L	38.72	56.32
Res. Chlorine as Cl_2 mg/L	0.25	0.25

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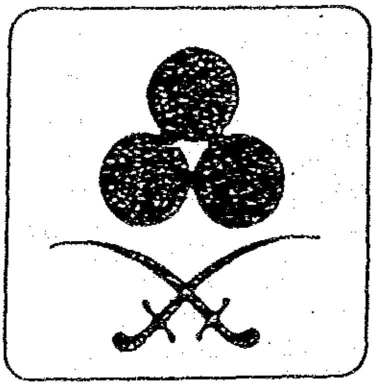
ENVIRONMENTAL PROTECTION STANDARDS

(GENERAL STANDARDS)

DOCUMENT NO. 1409 - 01



Kingdom of Saudi Arabia
Ministry of Defence & Aviation

METEOROLOGY & ENVIRONMENTAL
PROTECTION ADMINISTRATION (MEPA)

TRANSLATED FROM THE OFFICIAL ARABIC VERSION

ENVIRONMENTAL PROTECTION STANDARDS IN THE KINGDOM OF SAUDI ARABIA

(GENERAL STANDARDS)

DOCUMENT NO. 1409 - 01

Meteorology and Environmental Protection
Administration
Jeddah
Kingdom of Saudi Arabia

Translated from the official Arabic version

KINGDOM OF SAUDI ARABIA
MINISTRY OF DEFENCE & AVIATION

METEOROLOGICAL & ENVIRONMENTAL PROTECTION ADMINISTRATION

Pursuant to the Royal Decree No. 7/M/8903 dated 21/4/1401 which assigned the Meteorology and Environmental Protection Administration for the control of pollution and protection of environment in accordance with the arrangement set forth in the decision of the Supreme Commission for administrative reform No. 86 dated 20/8/1399; MEPA has established the following standards.

1 — Title

These standards shall be referred to as the Environmental Protection Standards.

2 — Purpose

The purpose of these standards is to provide appropriate bases for the evaluation and regulation of industrial and urban activities that currently exist in the Kingdom and to help in the planning, design, execution and operation of facilities that will be established in a manner which shall not adversely affect the health, safety and welfare of the people and which shall help in promoting their overall economic and social well-being and in protecting the Kingdom's environment in general.

3 — Effective Date

These standards shall come into force as of the first of D. Qa'dah 1402.

4 — Definitions

Unless the context otherwise requires, terms and expressions stated hereinafter shall have the meanings as defined below.

1 — The Administration
means the Meteorological and Environmental Protection Administration established under the Royal Decree No. 7/M/8903 dated 21/4/1401.

2 — The General Standards of Environmental Protection
means the standards which express the general policy for pollution control in the Kingdom and apply to the design and operation of facilities.

3 — Environmental Quality Standards
means the limits of air, water and land pollution that should not be exceeded.

4 — Source Standards
means pollution control technologies and operational practices which reduce pollution from a facility and include as well the standards for discharge of pollutants from their sources.

5 — Guidelines
they are not standards and are adopted for cases where baseline information is not sufficient for the issuance of specific standards at the respective time.

6 — Facility
means any plant or activity which is expected to be a source of pollution or environmental deterioration.

7 — Major Facility
means a facility with sufficient capacity to cause a substantial impact on the quality of ambient air or water.

8 — Public Facility
means any facility owned or operated by any ministry, department, governmental or semi-governmental unit regardless of its size or function.

9 — Private Facility
means any facility owned or operated by any natural or artificial organization whether corporate or not.

10 — Modification (i.e. of Facilities)
means a change in the design or operation of a facility which has the potential to result in increased pollution from the facility. For the purpose of this definition, any replacement of equivalent kind and capacity is not considered a modification.

11 — Major Modification
means a change in the design or operation of an existing facility with a reasonable likelihood of causing a substantial impact on the quality of air or water. For the purpose of this definition any replacement of equivalent kind and capacity is not considered a modification.

12 — Substantial Impact
means any impact with a reasonable likelihood of causing exceedance of the applicable standards alone or in combination with the impact of other sources.

13 — Moderate Impact
an impact which is likely to cause exceedance of the applicable standards only in combination with the impact of other sources.

14 — Minor Impact
any impact which is not likely to cause exceedance of the applicable standards whether alone or in combination with the impact of other sources.

15 — Toxic Substance
means any substance which causes death, disability or discomfort for man or animal whenever available in sufficient quantities, either by touch, inhaling or entering through the mouth, taking into consideration the possibility of the concentration of this material in the food chain, or such substance that may cause damage or destruction for plants or animal on touch or when entering into its food.

16 — Inhalable Particulates
for the purpose of these standards the inhalable particulates shall be considered as any substance dispersed in the atmosphere in the form of individual solid and liquid particles each of which is less than 15 micron in diameter.

17 — Photochemical Oxidants
are substances produced in the atmosphere where certain active chemical compounds, principally the hydrocarbons and nitrogen oxides, are exposed to sun light. For the purpose of these standards the photochemical oxidants shall include ozone, peroxyacyl, nitrates, organic peroxides and other oxidants which contribute to the increase of the oxidants quantity as measured by the method specified in paragraph C of Article 11.

8 — Receiving Water
means a surface water body into which pollutants are or may be directly discharged.

9 — Waste Water
means any contaminated water resulting from the industrial or agricultural processes, or other activities which are of equivalent environmental effect including sanitary sewage.

0 — Mixing Zone
it is a defined area of water directly adjacent to the area of discharge of contaminants where receiving water quality standards may be exceeded and such area is determined pursuant to paragraph E of Article 13.

21 — Pretreatment
means the stage of application of controls to waste water in the industrial areas prior to its discharge to central treatment facility.

22 — Discharge
means addition of contaminants to the ambient air, receiving water or to a central treatment facility.

23 — Direct Discharge
means a discharge to receiving waters and not to a central treatment facility.

24 — The Best available Technology
means the best available level for controlling pollution in comparison to practices in similar facilities in the Kingdom and other countries.

5 — Applicability

These standards shall apply to all facilities in the Kingdom, existing and newly designed, public and private, except for facilities specifically exempted by MEPA.

6 — Scope and Interpretation

1 — These standards consist of the rules appearing herein, including any detailed description of the environmental protection standards and methods of application as issued by MEPA from time to time.

2 — MEPA shall be the only authority to interpret and determine the meaning and scope of these standards.

3 — MEPA may from time to time amend or supplement these standards as the need arises.

7 — General Environmental Standards Applicable to New Facilities

1 — All major new facilities, or major modifications to existing facilities, shall be designed, operated and maintained so as to avoid exceedances of the ambient environmental standards as promulgated for the Kingdom at the time of approval of the design.

2 — Each major new facility or major modification to an existing facility shall incorporate the best available technology for control of pollutant discharges, and for the disposal of wastes associated with the operation of the facility.

3 — All new facilities and modifications to existing facilities shall be designed and operated so as to avoid the discharge of any toxic substance, whether specifically regulated or not, in quantities sufficient to be harmful to the public health.

8 — General Environmental Standards Applicable to Existing Facilities

1 — All major existing facilities shall be operated and maintained so as to avoid exceedances of the ambient environmental standards promulgated for the Kingdom. Additional control technology shall be installed at major existing facilities where necessary so as to avoid exceedance of the ambient environmental standards.

2 — Each existing facility shall be operated and maintained so as to avoid the discharge of any toxic substance, whether specifically regulated or not, in quantities sufficient to be harmful to the public health.

9 — Exceptions

The Department shall have the power to grant some facilities, under special circumstances, an exception from the application of some sources or performance standards. MEPA shall evaluate the application submitted by the owner of any facility for obtaining an exception from the application of any special standard. MEPA shall make its decision with respect to each case separately after the owner submits all the required information related to said matter and after making sure that such exception shall not result in exceeding the environmental quality standards and is not detrimental to the public health.

10 — Ambient Air Quality Standards

A — Sulfur Dioxide (SO_2)

A-1 Purpose: The purpose of these standards is to prevent adverse health effects and adverse effects upon vegetation.

A-2 Standards:

(a) During any 30 day period, the one-hour average SO_2 concentration shall not exceed 730 $\mu g/m^3$ (0.28 ppm) more than twice at any location.
(b) During any 12-month period, the 24-hour average SO_2 concentration shall not exceed 365 $\mu g/m^3$ (0.14 ppm) more than once at any location.
(c) During any 12-month period, the annual average SO_2 concentration shall not exceed 80 $\mu g/m^3$ (ppm) at any location.

A-3 Measurement Method: The Pararosaniline Method (WHO 1976) shall be the reference method of measurement of SO_2 concentrations. MEPA shall be responsible for approving equivalent measurement methods.

10 — B Inhalable Particulates (IP)

B-1 Purpose: The purpose of these standards is to protect susceptible populations from adverse health effects, taking into account the synergistic effects associated with the presence of other contaminants.

B-2 Standards:

(a) During any 12-month period, the 24-hour maximum inhalable particulate concentration shall not exceed 340 $\mu g/m^3$ more than once at any location.
(b) During any 12-month period, the annual average inhalable particulate concentration shall not exceed 80 $\mu g/m^3$ at any location.
(Note: The exceedance of the 24-hour or annual inhalable particulate standard as a result of abnormal natural background concentrations shall not be considered as a violation of the standard.)

B-3 Measurement Method: The concentration of inhalable particulates shall be determined by the use of a size selective high volume sampler. Specifications for equipment and filter media shall conform to standards acceptable to MEPA.

10 — C Photochemical Oxidants Defined as Ozone (O_3)

C-1 Purpose: The purpose of this standard is to prevent significant human discomfort or damage to vegetation and materials.

C-2 Standard: During any 30-day period, the one-hour average concentration of photochemical oxidants shall not exceed 295 $\mu g/m^3$ (0.15 ppm) more than twice at any location.

C-3 Measurement Method: The chemiluminescence method (WHO 1976) shall be the reference method for measurement of photochemical oxidants as ozone. MEPA will be responsible for approving equivalent measurement methods.

10 — D Nitrogen Oxides Defined as Nitrogen Dioxide (NO_2)

D-1 Purpose: The purpose of these standards is to prevent the development of nitrogen dioxide concentrations which could produce adverse health effects or lead to the production of significant concentrations of photochemical oxidants.

D-2 Standards:

(a) During any 30 day period, the one-hour average NO_2 concentration shall not exceed 660 $\mu g/m^3$ (0.35 ppm) more than twice at any location.
(b) During any 12-month period, the annual average NO_2 concentration shall not exceed 100 $\mu g/m^3$ at any location.

D-3 Measurement Method: An NO_2 analyzer based on the gas phase chemiluminescence measurement principle of NO with O_3 is designated as the reference method. Specifications for measurement equipment shall conform to standards acceptable to MEPA.

10 — E Carbon Monoxide (CO)

E-1 Purpose: The purpose of these standards is to prevent short-term adverse health effects in sensitive population groups and in normal exercising population groups.

E-2 Standards:

(a) During any 30-day period, the one-hour average CO concentration shall not exceed 40 mg/m^3 (35 ppm) more than twice at any location.
(b) During any 30-day period, the 8-hour average CO concentration shall not exceed 10 mg/m^3 (9 ppm) more than twice at any location.

E-3 Measurement Method: The nondispersive infrared (MDIR) technique (WHO 1972) will be the reference method for CO. MEPA will be responsible for approving equivalent measurement methods.

10 — F Hydrogen Sulfide (H_2S)

F-1 Purpose: The purpose of these standards is to protect human and animal health, and to avoid the nuisance caused by exposure to H_2S. (These standards will not completely prevent materials damage; therefore, special materials preservation step should be taken in regions where elevated H_2S levels are expected.)

F-2 Standards:

(a) During any 12 month period, the one-hour average H_2S concentration shall not exceed 200 $\mu g/m^3$ (0.14 ppm) more than once at any location.
(b) During any 12-month period, the 24-hour average H_2S concentration shall not exceed 40 $\mu g/m^3$ (0.03 ppm) more than once at any location.

F-3 Measurement Method: The Gas Bubbler-Methylene Blue method (APHA 1972) shall be the reference method for H_2S. MEPA will be responsible for approving equivalent measurement methods.

10 — G Fluorides ($F-$)

G-1 Purpose: The purpose of this standard is to protect against adverse effects on vegetation and grazing animals.

G-2 Standards: During any 30-day period, the monthly average fluoride concentration shall not exceed 1.0 $\mu g/m^3$ (0.001 ppm) at any location.

G-3 Measurement Method: The specific ion electrode (Thompson et al. 1971) method shall be the reference method for fluoride measurement. MEPA will be responsible for approving equivalent measurement methods.

11. Air Pollution Source Standards

11 — A Combustion Facilities: All fossil fuel fired boilers and furnaces having a heat input capacity equal to or greater than 30 megawatts (100 MBTU/hr.) shall utilize appropriate gas cleaning equipment to limit emissions to the following rates:

(1) 43 ng/j (0.1 1b/MBTU) of total particulates
(2) 1 μg/j (2.3 1b/MBTU) of SO_2
(3) 130 ng/j (0.3 1b/MBTU) of NO_x for oil fired facilities
(4) 86 ng/j (0.2 1b/MBTU) of NOx for gas fired facilities

11 — B Petroleum and Petrochemical Facilities

B-1 Storage Vessels for Petroleum Liquids Storage vessels for volatile organic compounds (VOC) which have a capacity greater than 1000 barrels (5614 cubic feet) shall be equipped for vapor emission control as follows:

(a) Vapor recovery or equivalent systems are required for VOC having a vapor pressure in excess of 570 mm Hg. Floating roof tanks shall be considered adequate for storage of crude oil providing a consistent seal inspection and reporting program is implemented by owner.
(b) Floating roof with double boot seal or equivalent systems are required for VOC having a vapor pressure in excess of 78 mm Hg (1.5 psi) but less than 570 mm Hg (11 psi)

B-2 FCC Unit Catalyst, Regenerators

FCC unit catalyst regenerators shall utilize:
(a) CO boilers or high temperature regeneration to limit CO emissions to 500 ppm and
(b) appropriate air cleaners to limit particulate emissions to 1.0 kg per metric ton of coke burn-off.

B-3 Fuel Gas Combustion Process

Fuel gas combustion process shall utilize amine scrubbing or other appropriate gas cleaning process to limit H_2S content of fuel gases to 230 mg per dry standard cubic meters (150 ppm).

B-4 Claus Sulfur Recovery Plants

Sulfur recovery plants shall utilize a two-or three-stage Claus process to achieve at least 95% recovery of total sulfur.

B-5 Fugitive Emission

Fugitive emission of VOC from Petroleum and Petrochemical process shall be limited through the utilization of good maintenance and inspection procedures as well as monitoring of potential VOC emission points.

11 — C Fertilizer Plants

Fertilizer plant purge gases shall be controlled by incineration or other acceptable cleaning method to ensure 99 percent removal of volatile organic compounds.

11 — D Cement Plants

D-1 Cement Kilns

Emissions from cement kilns shall be controlled by electrostatic precipitators, fabric filters or other suitable means to limit the emission of particulates to no more than 0.15 kg/metric ton.

D-2 Clinker Coolers

Emissions from clinker coolers shall be controlled by fabric filters or other suitable means to limit the emission of particulates to no more than 0.05 kg/metric ton.

11 — E Primary Aluminum Reduction Plants

E-1 Pot Lines

Emission from aluminum reduction pot lines shall be controlled by suitable air cleaning equipment to limit the emission of total fluorides to no more than 1.25 kg/metric ton.

E-2 Anode Bake Plants (plus Pole Heating Plants)

Emissions from anode bake plants (plus pole heating plants) shall be controlled by suitable air cleaning equipment to limit the emission of total fluorides to no more than 0.05 kg/metric ton.

11 — F Iron and Steel Plants: Electric Arc Furnaces

Emissions from electric arc furnaces shall be controlled by suitable gas cleaning equipment to limit the emission of particulates to 12 mg/dscm.

11 — G Lime Manufacturing Plants: Rotary Kilns

Emissions from rotary kilns shall be controlled by suitable gas cleaning equipment to limit the emission of particulates to no more than 0.2 kg/metric ton of limestone feed material.

11 — H Visible Emissions from Industrial Activities

Visible emissions from all industrial activities (except for water vapor) shall be controlled to 20% maximum capacity except for three-minutes during any continuous sixty-minute period.

12. Receiving Water Guidelines

12 — A Purpose: These guidelines for receiving water quality are intended to provide guidance for the location, design and operation of new facilities and modifications to existing facilities, and for the operation of existing facilities, pending development of receiving water standards.

12 — B Guidelines: The following guidelines for receiving water quality apply at the edge of the mixing zone and beyond for the discharge from any facility to the coastal waters. Unless otherwise stated, each interim guideline refers to a thirty-day average.

B — 1 Physio-chemical Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Floatables	Non attributable to the discharge
(b)	PH	0.1 PH units (maximum change from typical local baseline conditions)
(c)	Total suspended solids (TSS)	5% (all references to percentage are maximum changes from typical local baseline conditions) (in this and following paragraphs)
(d)	Temperature	1°C (maximum change from typical local baseline conditions)
(e)	Oil and grease	Management measures required*
(f)	Dissolved Oxygen (DO)	5%
(g)	Turbidity	5%

* Facilities using, transferring or storing oil and petroleum hydrocarbons are required to prepare, maintain and update a spill prevention, control and clean-up plan.

B — 2 Organic Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Chemical Oxygen demand (COD)	5%
(b)	Total organic carbon (TOC)	5%
(c)	Total kjeldahl nitrogen (TKN)	5%
(d)	Chlorinated Hdro carbons	5%
(e)	Oil and Grease	5%
(f)	Phenolics	5%

B — 3 Non-organic Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Amonia	5%
(b)	Arsenic	5%
(c)	Cadmium	5%
(d)	Chloride	5%

(e)	Residual Chlorine	5%
(f)	Total Chromium	5%
(g)	Copper	5%
(h)	Total Cyanide	5%
(i)	Lead	5%
(j)	Mercury	5%
(k)	Nickel	5%
(l)	Total Phosphate	5%
(m)	Zink	5%
(n)	Dissolved Oxygen	5%

B — 4 Biological Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Total Coliform	70 most probable number per 100 ML (average for 30 day period).

13. Performance Standards for Direct Discharge

A — Purpose: Performance standards for direct discharge are intended to require waste water source to adopt best practical controls.

B — Scope: Performance standards for direct discharge apply to sanitary sewage, surface runoff (including fire control waters), cooling water discharges, boiler water conditioning blowdown, process wastewaters, and any other wastewater.

C — General Performance Standards: Wastewaters of different character shall be segregated to the maximum extent possible. Uncontaminated surface runoff and once-through cooling waters may be discharged to receiving waters without treatment.

D — Specific Performance Standards: The following performance standards apply to wastewaters at the end of the outfall and before discharge to coastal waters or to any channel of wastewater.

D — 1 Physio-Chemical Pollutants

	(Pollutants)	(Allowable effluent Level)
(a)	Floatables	None
(b)	PH	6-9 pH units
(c)	Total Suspended solids (TSS)	15 mg/1 (max.)

(d)	Temperature	MEPA determines the thermal properties of discharged water to fit the properties of receiving water and such properties are determined on a case by case basis.
(e)	Turbidity	75 NTU (max.)

D — 2 Organic Pollutants

	(Pollutants)	(Allowable Effluent Level)
(a)	Biochemical Oxygen Demand	25 mg/1
(b)	Chemical Oxygen Demand	150 mg/1
(c)	Total Organic Carbon (TOC)	50 mg/1
(d)	Total kjeldahl nitrogen (TKN)	5 mg/1
(e)	Total Chlorinated Hydrocarbons	0.1 mg/1
(f)	Oil and Grease	8 mg/1 (not to exceed 15 mg/1 in any individual discharge)
(g)	Phenols	0.1 mg/1

D — 3 Non-organic Pollutants

	(Pollutants)	(Allowable Effluent Level 30-day Average)
(a)	Ammonia (as nitrogen)	1.0 mg/1
(b)	Arsenic	0.1 mg/1
(c)	Cadmium	0.02 mg/1
(d)	Chlorine (residual)	0.5 mg/1
(e)	Chromium (total)	0.1 mg/1
(f)	Copper	0.2 mg/1
(g)	Cyanide	0.05 mg/1
(h)	Lead	0.1 mg/1
(i)	Mercury	0.001 mg/1
(j)	Nickel	0.2 mg/1
(k)	Phosphate (Total) (as Phosphorous)	1.0 mg/1
(l)	Zinc	1.0 mg/1

D — 4 Biological Pollutants

	(Pollutant)	(Allowable Effluent Level — 30-day Average)
(a)	Total Coliform	1000 MPN per 100 ml

E — Mixing Zone

Each direct discharge shall be adequately dispersed and mixed with the receiving waters. A mixing zone shall be designed to minimize adverse effects to designated beneficial uses. Adequacy of the mixing zone shall be determined on a case-by-case basis.

14. Pretreatment Guidelines for Discharge to General Treatment Facilities.

A — Purpose: Pretreatment guidelines are intended to provide guidance for the removal of substances that significantly effect the performance of the central treatment facilities, and substances that are not adequately controlled at central treatment facilities.

B — Scope: Pretreatment guidelines and standards apply to all facilities and modifications covered by the environmental standards which discharge to a central industrial or municipal wastewater treatment facility.

C — General Pretreatment Guidelines: Wastewaters of different character shall be segregated to the maximum extent possible. Sanitary wastes may be sent to a central treatment facility without pretreatment. Contaminated wastewaters other than sanitary wastes shall be treated on-site to meet applicable pretreatment requirements.

D — Specific Pretreatment Guidelines: The following pretreatment guidelines apply to wastewater before discharge to a central treatment facility. The pretreatment guidelines provide a range for allowable levels of pollution in the effluent.

D — 1 Physio-chemical Pollutants

	(Pollutants)	(Guidelines)
(a)	Total suspended Solids (TSS)	2,000 mg/1 (max.)
(b)	pH	5-10 pH units
(c)	Temperature	60° C (max.)

D — 2 Organic Pollutants

	(Pollutants)	(Guidelines)
(a)	Chemical Oxygen Demand	1,500 mg/1
(b)	Total organic carbon	1,000 mg/1
(c)	Oil and Grease	120 mg/1
(d)	Phenols	150 mg/1

(e)	Total chlorinated Hydrocarbons	0.5 mg/1

D — 3 Non-organic Pollutants

	(Pollutants)	(Guidelines)
(a)	Arsenic	1.0 mg/1
(b)	Cadmium	0.5 mg/1
(c)	Chromium (Total)	2.0 mg/1
(d)	Copper	1.0 mg/1
(e)	Cyanide (Total)	1.0 mg/1
(f)	Lead	1.0 mg/1
(g)	Mercury	0.01 mg/1
(h)	Nickel	2.0 mg/1
(i)	Zinc	10.0 mg/1

15. Implementation Obligations

1 — It shall be the duty and obligation of the owners, planners and operators of new facilities and modification to existing facilities to ensure that such facilities are located, designed and operated in accordance with these standards.

2 — It shall be the duty and obligation of owners and operators of existing facilities to ensure that such facilities are operated in accordance with these standards.

3 — Subject to other official requirements, owners and operators proposing to build a new facility must contact MEPA and provide specific required data to MEPA including relevant planning and design details indicating the pollution control measures to be taken. MEPA shall review such data and grant written permit within a period not exceeding 3 months after the date of receiving such data from other departments and facilities, prior to execution of such facilities.

4 — Owners and operators of existing facilities are required to supply specific required data to MEPA following notification by MEPA. MEPA may request the carrying out of tests, investigations or analysis to insure compliance with the standards in any existing facility. The owners and operators of existing facilities shall be deemed responsible for submitting data relating to the existing facilities even if they don't receive notification by MEPA requesting such information.

16. Enforcement

1 — It shall be the responsibility of MEPA to ensure that compliance with these standards is enforced.

2 — Every application for a license to construct a new facility or introduce a major modification to an existing facility which is submitted to the competent authority must enclose a certificate stating that MEPA has evaluated the existing facility or the plans for the new facility and ascertained that the subject facility complies with these standards.

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3 — In case where MEPA finds that the design of a planned new facility does not incorporate adequate control measures to comply with the standards, MEPA shall so inform the applicable licensing authority and request that a license not be issued to the facility until it rectifies the specific defects cited by MEPA. The facility owners shall also be informed.

4 — In case where MEPA finds that an existing facility is contravening these standards, MEPA shall so inform that facility and request that it be rectified according to a designated schedule. If the contravention continues, MEPA may address a final warning to the facility. If the warning fails to produce positive results, MEPA shall inform the licensing authority concerned and request that the license of the facility be suspended or withdrawn.

5 — MEPA shall carry out spot inspection of any facility to assess compliance with these standards without prior notice or warning.

添付試料 (7)

المملكة العربية السعودية
وزارة الدفاع والطيران
مصلحة الارصاد وحماية البيئة

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means the stage of application of controls to waste water in the industrial areas prior to its discharge to a central treatment facility.

22 — Discharge
means addition of contaminants to the ambient air, receiving water or to a central treatment facility.

23 — Direct Discharge
means a discharge to receiving waters and not to a central treatment facility.

24 — The Best available Technology
means the best available level for controlling pollution in comparison to practices in similar facilities in the Kingdom and other countries.

5 — Applicability

These standards shall apply to all facilities in the Kingdom, existing and newly designed, public and private, except for facilities specifically exempted by MEPA.

6 — Scope and Interpretation

1 — These standards consist of the rules appearing herein, including any detailed description of the environmental protection standards and methods of application as issued by MEPA from time to time.

2 — MEPA shall be the only authority to interpret and determine the meaning and scope of these standards.

3 — MEPA may from time to time amend or supplement these standards as the need arises.

7 — General Environmental Standards Applicable to New Facilities

1 — All major new facilities, or major modifications to existing facilities, shall be designed, operated and maintained so as to avoid exceedances of the ambient environmental standards as promulgated for the Kingdom at the time of approval of the design.

2 — Each major new facility or major modification to an existing facility shall incorporate the best available technology for control of pollutant discharges, and for the disposal of wastes associated with the operation of the facility.

3 — All new facilities and modifications to existing facilities shall be designed and operated so as to avoid the discharge of any toxic substance, whether specifically regulated or not, in quantities sufficient to be harmful to the public health.

8 — General Environmental Standards Applicable to Existing Facilities

1 — All major existing facilities shall be operated and maintained so as to avoid exceedances of the ambient environmental standards promulgated for the Kingdom. Additional control technology shall be installed at major existing facilities where necessary so as to avoid exceedance of the ambient environmental standards.

2 — Each existing facility shall be operated and maintained so as to avoid the discharge of any toxic substance, whether specifically regulated or not, in quantities sufficient to be harmful to the public health.

9 — Exceptions

The Department shall have the power to grant some facilities, under special circumstances, an exception rom the application of some sources or performance standards. MEPA shall evaluate the application submitted y the owner of any facility for obtaining an exception from the application of any special standard. MEPA shall nake its decision with respect to each case separately after the owner submits all the required information related o said matter and after making sure that such exception shall not result in exceeding the environmental quality tandards and is not detrimental to the public health.

10 — Ambient Air Quality Standards

A — Sulfur Dioxide (SO_2)

A-1 Purpose: The purpose of these standards is to prevent adverse health effects and adverse effects upon vegetation.

A-2 Standards:

(a) During any 30 day period, the one-hour average SO_2 concentration shall not exceed 730 $\mu g/m^3$ (0.28 ppm) more than twice at any location.
(b) During any 12-month period, the 24-hour average SO_2 concentration shall not exceed 365 $\mu g/m^3$ (0.14 ppm) more than once at any location.
(c) During any 12-month period, the annual average SO_2 concentration shall not exceed 80 $\mu g/m^3$ (ppm) at any location.

A-3 Measurement Method: The Pararosaniline Method (WHO 1976) shall be the reference method of measurement of SO_2 concentrations. MEPA shall be responsible for approving equivalent measurement methods.

10 — B Inhalable Particulates (IP)

B-1 Purpose: The purpose of these standards is to protect susceptible populations from adverse health effects, taking into account the synergistic effects associated with the presence of other contaminants.

B-2 Standards:

(a) During any 12-month period, the 24-hour maximum inhalable particulate concentration shall not exceed 340 $\mu g/m^3$ more than once at any location.
(b) During any 12-month period, the annual average inhalable particulate concentration shall not exceed 80 $\mu g/m^3$ at any location.
(Note: The exceedance of the 24-hour or annual inhalable particulate standard as a result of abnormal natural background concentrations shall not be considered as a violation of the standard.)

B-3 Measurement Method: The concentration of inhalable particulates shall be determined by the use of a size selective high volume sampler. Specifications for equipment and filter media shall conform to standards acceptable to MEPA.

10 — C Photochemical Oxidants Defined as Ozone (O_3)

C-1 Purpose: The purpose of this standard is to prevent significant human discomfort or damage to vegetation and materials.

C-2 Standard: During any 30-day period, the one-hour average concentration of photochemical oxidants shall not exceed 295 $\mu g/m^3$ (0.15 ppm) more than twice at any location.

C-3 Measurement Method: The chemiluminescence method (WHO 1976) shall be the reference method for measurement of photochemical oxidants as ozone. MEPA will be responsible for approving equivalent measurement methods.

10 — D Nitrogen Oxides Defined as Nitrogen Dioxide (NO_2)

D-1 Purpose: The purpose of these standards is to prevent the development of nitrogen dioxide concentrations which could produce adverse health effects or lead to the production of significant concentrations of photochemical oxidants.

D-2 Standards:

(a) During any 30 day period, the one-hour average NO_2 concentration shall not exceed 660 µg/m³ (0.35 ppm) more than twice at any location.
(b) During any 12-month period, the annual average NO_2 concentration shall not exceed 100 µg/m³ at any location.

D-3 Measurement Method: An NO_2 analyzer based on the gas phase chemiluminescence measurement principle of NO with O_3 is designated as the reference method. Specifications for measurement equipment shall conform to standards acceptable to MEPA.

10 — E Carbon Monoxide (CO)

E-1 Purpose: The purpose of these standards is to prevent short-term adverse health effects in sensitive population groups and in normal exercising population groups.

E-2 Standards:

(a) During any 30-day period, the one-hour average CO concentration shall not exceed 40 mg/m³ (35 ppm) more than twice at any location.
(b) During any 30-day period, the 8-hour average CO concentration shall not exceed 10 mg/m³ (9 ppm) more than twice at any location.

E-3 Measurement Method: The nondispersive infrared (MDIR) technique (WHO 1972) will be the reference method for CO. MEPA will be responsible for approving equivalent measurement methods.

10 — F Hydrogen Sulfide (H_2S)

F-1 Purpose: The purpose of these standards is to protect human and animal health, and to avoid the nuisance caused by exposure to H_2S. (These standards will not completely prevent materials damage; therefore, special materials preservation step should be taken in regions where elevated H_2S levels are expected.)

F-2 Standards:

(a) During any 12 month period, the one-hour average H_2S concentration shall not exceed 200 µg/m³ (0.14 ppm) more than once at any location.
(b) During any 12-month period, the 24-hour average H_2S concentration shall not exceed 40 µg/m³ (0.03 ppm) more than once at any location.

F-3 Measurement Method: The Gas Bubbler-Methylene Blue method (APHA 1972) shall be the reference method for H_2S. MEPA will be responsible for approving equivalent measurement methods.

0 — G Fluorides (F^-)

G-1 Purpose: The purpose of this standard is to protect against adverse effects on vegetation and grazing animals.

G-2 Standards: During any 30-day period, the monthly average fluoride concentration shall not exceed 1.0 µg/m³ (0.001 ppm) at any location.

G-3 Measurement Method: The specific ion electrode (Thompson et al. 1971) method shall be the reference method for fluoride measurement. MEPA will be responsible for approving equivalent measurement methods.

11. Air Pollution Source Standards

11 — A Combustion Facilities: All fossil fuel fired boilers and furnaces having a heat input capacity equal to or greater than 30 megawatts (100 MBTU/hr.) shall utilize appropriate gas cleaning equipment to limit emissions to the following rates:

(1) 43 ng/j (0.1 1b/MBTU) of total particulates
(2) 1 μg/j (2.3 1b/MBTU) of SO_2
(3) 130 ng/j (0.3 1b/MBTU) of NO_x for oil fired facilities
(4) 86 ng/j (0.2 1b/MBTU) of NOx. for gas fired facilities

11 — B Petroleum and Petrochemical Facilities

B-1 Storage Vessels for Petroleum Liquids Storage vessels for volatile organic compounds (VOC) which have a capacity greater than 1000 barrels (5614 cubic feet) shall be equipped for vapor emission control as follows:

(a) Vapor recovery or equivalent systems are required for VOC having a vapor pressure in excess of 570 mm Hg. Floating roof tanks shall be considered adequate for storage of crude oil providing a consistent seal inspection and reporting program is implemented by owner.
(b) Floating roof with double boot seal or equivalent systems are required for VOC having a vapor pressure in excess of 78 mm Hg (1.5 psi) but less than 570 mm Hg (11 psi)

B-2 FCC Unit Catalyst, Regenerators

FCC unit catalyst regenerators shall utilize:
(a) CO boilers or high temperature regeneration to limit CO emissions to 500 ppm and
(b) appropriate air cleaners to limit particulate emissions to 1.0 kg per metric ton of coke burn-off.

B-3 Fuel Gas Combustion Process

Fuel gas combustion process shall utilize amine scrubbing or other appropriate gas cleaning process to limit H_2S content of fuel gases to 230 mg per dry standard cubic meters (150 ppm).

-4 Claus Sulfur Recovery Plants

Sulfur recovery plants shall utilize a two-or three-stage Claus process to achieve at least 95% recovery of total sulfur.

-5 Fugitive Emission

Fugitive emission of VOC from Petroleum and Petrochemical process shall be limited through the utilization of good maintenance and inspection procedures as well as monitoring of potential VOC emission points.

1 — C Fertilizer Plants

Fertilizer plant purge gases shall be controlled by incineration or other acceptable cleaning method to ensure 99 percent removal of volatile organic compounds.

11 — D Cement Plants

D-1 Cement Kilns

Emissions from cement kilns shall be controlled by electrostatic precipitators, fabric filters or other suitable means to limit the emission of particulates to no more than 0.15 kg/metric ton.

D-2 Clinker Coolers

Emissions from clinker coolers shall be controlled by fabric filters or other suitable means to limit the emission of particulates to no more than 0.05 kg/metric ton.

11 — E Primary Aluminum Reduction Plants

E-1 Pot Lines

Emission from aluminum reduction pot lines shall be controlled by suitable air cleaning equipment to limit the emission of total fluorides to no more than 1.25 kg/metric ton.

E-2 Anode Bake Plants (plus Pole Heating Plants)

Emissions from anode bake plants (plus pole heating plants) shall be controlled by suitable air cleaning equipment to limit the emission of total fluorides to no more than 0.05 kg/metric ton.

11 — F Iron and Steel Plants: Electric Arc Furnaces

Emissions from electric arc furnaces shall be controlled by suitable gas cleaning equipment to limit the emission of particulates to 12 mg/dscm.

11 — G Lime Manufacturing Plants: Rotary Kilns

Emissions from rotary kilns shall be controlled by suitable gas cleaning equipment to limit the emission of particulates to no more than 0.2 kg/metric ton of limestone feed material.

11 — H Visible Emissions from Industrial Activities

Visible emissions from all industrial activities (except for water vapor) shall be controlled to 20% maximum capacity except for three-minutes during any continuous sixty-minute period.

12. Receiving Water Guidelines

12 — A Purpose: These guidelines for receiving water quality are intended to provide guidance for the location, design and operation of new facilities and modifications to existing facilities, and for the operation of existing facilities, pending development of receiving water standards.

12 — B Guidelines: The following guidelines for receiving water quality apply at the edge of the mixing zone and beyond for the discharge from any facility to the coastal waters. Unless otherwise stated, each interim guideline refers to a thirty-day average.

B — 1 Physio-chemical Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Floatables	Non attributable to the discharge
(b)	PH	0.1 PH units (maximum change from typical local baseline conditions)
(c)	Total suspended solids (TSS)	5% (all references to percentage are maximum changes from typical local baseline conditions) (in this and following paragraphs)
(d)	Temperature	1°C (maximum change from typical local baseline conditions)
(e)	Oil and grease	Management measures required*
(f)	Dissolved Oxygen (DO)	5%
(g)	Turbidity	5%

* Facilities using, transferring or storing oil and petroleum hydrocarbons are required to prepare, maintain and update a spill prevention, control and clean-up plan.

B — 2 Organic Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Chemical Oxygen demand (COD)	5%
(b)	Total organic carbon (TOC)	5%
(c)	Total kjeldahl nitrogen (TKN)	5%
(d)	Chlorinated Hdro carbons	5%
(e)	Oil and Grease	5%
(f)	Phenolics	5%

B — 3 Non-organic Pollutants

	(Pollutants)	(Guidelines at edge of mixing zone)
(a)	Amonia	5%
(b)	Arsenic	5%
(c)	Cadmium	5%
(d)	Chloride	5%