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Semiclosed Seawater System With Automatic Salinity, Temperature, and Turbidity Control

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Semiclosed Seawater System With Automatic Salinity, Temperature, and Turbidity Control

SID KORN[1]

ABSTRACT

The new seawater system at the Southwest Fishery Center, Tiburon Laboratory, is described. The system delivers up to 450 l/min of filtered, ultraviolet sterilized, temperature- and salinity-controlled seawater suitable for extended holding of marine fish and invertebrates. Unique aspects of the system including provisions for open and/or closed circulation, and the pneumatic salinity control components are described in detail. The design of this facility may offer ideas to others desiring near-oceanic quality seawater from marginal sources.

INTRODUCTION

The purpose of this paper is to describe the new seawater facility of the National Marine Fisheries Service (NMFS), Southwest Fisheries Center, Tiburon Laboratory. Special emphasis is placed on the salinity control components and design features that allow for either open or closed circulation. I hope this information will assist other facilities with water supplies varying in temperature, salinity, and turbidity, in their effort to obtain near-oceanic quality water.

This facility is located on San Francisco Bay where water conditions vary considerably in temperature, salinity, and turbidity, partially caused by runoff from the Sacramento-San Joaquin rivers. The former seawater system, operating from 1967 to 1971, did not control temperature or salinity and had a limited filtering capacity. Fouling of waterlines and tanks, wide fluctuations in temperature (range 9°-20°C) and salinity (range 2-30‰), and bacterial disease problems made research impossible during certain times of the year. This facility is used for physiological research and needs a system that supplies water of near-oceanic quality with constant physical conditions.

Final specifications and design work were completed by consulting engineers. The system was constructed from November 1972 to April 1973.

The new seawater system (Fig. 1) is a semiclosed system which can circulate 450 l/min of filtered, sterilized, temperature- and salinity-controlled water. Most of the system is duplicated to facilitate repairs and cleaning without disruption of the waterflow.

Due to the high cost of salinity and temperature control, most of the water is recirculated. However, some open circulation is required when toxic effluents from experiments are involved and to insure that problems associated with recirculating water do not occur. After water has been recirculated for extended periods through tanks containing a biomass, nitrates accumulate, trace elements may be lost, and pH may change. Therefore, we always maintain at least 10% of the total flow to open circulation. Toxic effluents are filtered through activated charcoal before being discharged.

FLOW DESCRIPTION

Seawater is pumped by one of two centrifugal pumps (Ace 3 horsepower, hard rubber [Fig. 2]), through a two-stage, automatically backflushing, high-rate sand filter (Baker Model HRB-30). From the filter, the flow is directed to either the sump tank or back into the bay by an electrically actuated valve, which is controlled by a level indicator in the reservoir (Fig. 1). This is done to prevent excess water from entering the system. Dual 3-inch PVC (polyvinyl chloride) lines allow for cleaning of lines and changing of the pump.

The 600-liter epoxy-lined concrete sump tank collects new filtered water and water that has been recirculated through the laboratories. As the water level rises, one of two 10-horsepower centrifugal pumps (Allis Chalmers Model F-4, 316 stainless steel) is activated by a float valve. Water is pumped through a second single-stage sand filter (Baker Model HRB-36) to the 53,000-liter reservoir (Fig. 3). The water enters the reservoir through a redwood splash tray aerator patterned after a similar design at the Southwest Fisheries Center, La Jolla, Calif. (Lasker and Vlymen 1969).

The concrete reservoir is epoxy-lined and is divided by a concrete wall into two sections. Water can be valved to enter and leave one or both sides. This allows for the cleaning of one half of the reservoir without disrupting the flow through the system. The capacity of the tank allows for a 2-h full flow reserve in the event of a failure. By reducing flow rates to 112 l/min this reserve can be extended to 8 h.

Water flows (up to 450 l/min) by gravity from the reservoir to the wet laboratories passing through: an ultraviolet (UV) sterilizer; a heat exchanger; and temperature- and salinity-measuring probes. The flow is then directed into tanks and aquaria as needed (Fig. 4). Depending on the need for open or closed circulation, the effluent line is valved to direct flow into concrete trenches

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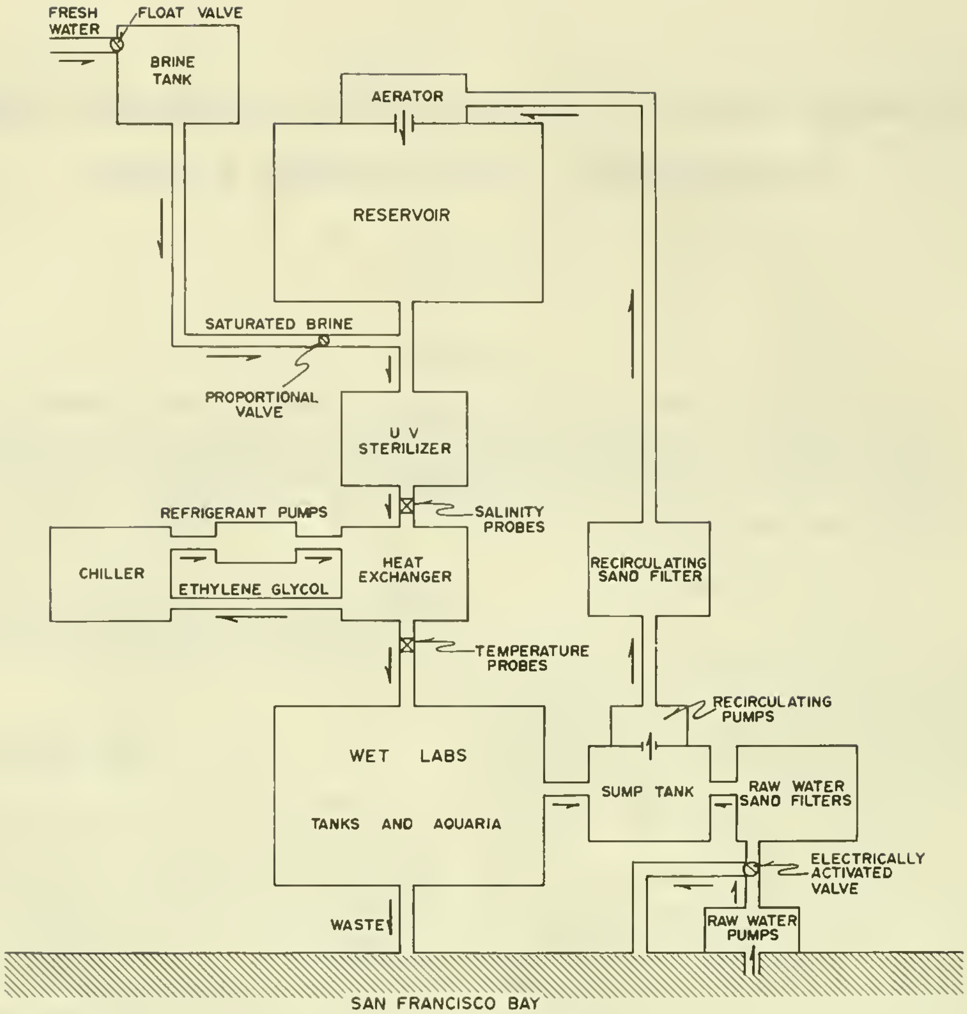

Figure 1.—Schematic of Tiburon seawater system.

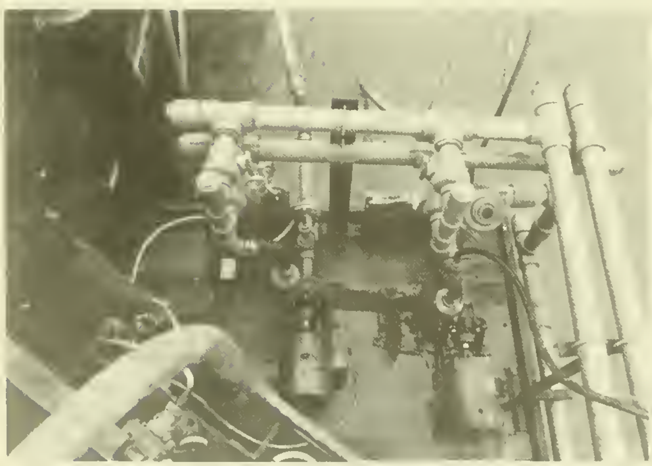

Figure 2.—Intake pumps, showing cleanouts and dual piping.

Figure 3.—Reservoir, aerator, brine tank, and pneumatic salt delivery line.

Figure 4.—Part of main wet laboratory. Plastic sheeting isolates tanks at rear for behavioral observations.

where it flows out a 6-inch cast iron line into the bay, or into 3-inch PVC recirculating pipes which deliver the water to the sump tank for recirculation (Fig. 5). Three-inch caps on Y fittings are located every few feet to allow entry to the recirculating lines.

All piping and valves in the system are schedule 80-PVC. Piping is in straight runs with threaded caps serving as cleanouts at each end. All seawater lines are dual to allow for maintenance, except for piping downstream from the UV sterilizer, where cleaning is minimal.

TEMPERATURE CONTROL

The seawater can be cooled to a set temperature (± 2° C). Although this temperature can be adjusted for the entire system, investigators must vary temperature in their tanks by individual cooling and heating devices.

A 750,000 BTU (British thermal unit) air-cooled compressor (Trane Model CGAA-6004-MA) cools ethylene glycol, which is circulated by one of two centrifugal pumps (Allis Chalmers Model F2L1, cast iron) through an all glass heat exchanger (Corning Model 600-GRB). An air-operated temperature probe in the seawater effluent line from the heat exchanger controls the compressor through five steps of capacity. At the maximum step of capacity, 450 l/min can be cooled 10°C. The Corning heat exchanger is similar to that described by Lasker and Vlymen (1969).

Figure 5.—Recirculating line in trench. Y fittings serve as entry points.

SALINITY CONTROL

The salinity can be adjusted to any level above ambient (±0.5‰). A 41,600-liter fiber glass brine tank is filled pneumatically with 31,745 kg of rock salt (Fig. 3). This salt is the unrefined product of a salt company located in the San Francisco Bay area. A typical analysis is given below:

Component	*Percent*
Calcium sulfate	0.09
Magnesium chloride	0.03
Magnesium sulfate	0.01
Moisture (H_2O)	3.45
Water Insolubles	0.01
Sodium chloride	96.41

Freshwater enters the tank, controlled by a float valve, and becomes saturated brine solution. This is metered into the seawater line by gravity flow through a stainless steel air-operated proportional valve, controlled by a conductivity meter pneumatic control system (Fig. 6). This system, patterned after Hettler et al. (1971), features conductivity meters with platinum probes mounted in the seawater line, a pneumatic controller, and chart recorder (Fig. 7). The temperature-compensated conductivity signal is converted to salinity, then recorded on a 7-day chart and fed into the pneumatic controller. The salinity is dialed on the controller, the instrument measures the difference between measured salinity and the set point, and sends a variable air pressure (4-15 pounds) to adjust the proportional valve. Variation in the salinity has been controlled to ±0.5‰. By adding another proportional valve connected to a freshwater source, one could lower the salinity if needed.

ALARM SYSTEM

An alarm has been incorporated into this system to avoid loss of fish and research time from component failures (Fig. 7). Specifically, the system alarms if: 1) water temperature exceeds high or low set points; 2) salinity exceeds high or low set points; 3) the water level is too high in sump tank; 4) the water level becomes too low in the reservoir; or 5) the electric power fails. An alarm signal activates a bell and timer. If the alarm persists past a preset time interval (30-300 s), a telephone dialer is activated, sending a signal to a local alarm company that has 24-h service (they have a list of people to call for corrective maintenance).

PERFORMANCE AND MAINTENANCE

The Tiburon Laboratory seawater system has been operating since April 1973. As of October 1974, after some modifications, the system is meeting the objectives of high water quality year-round.

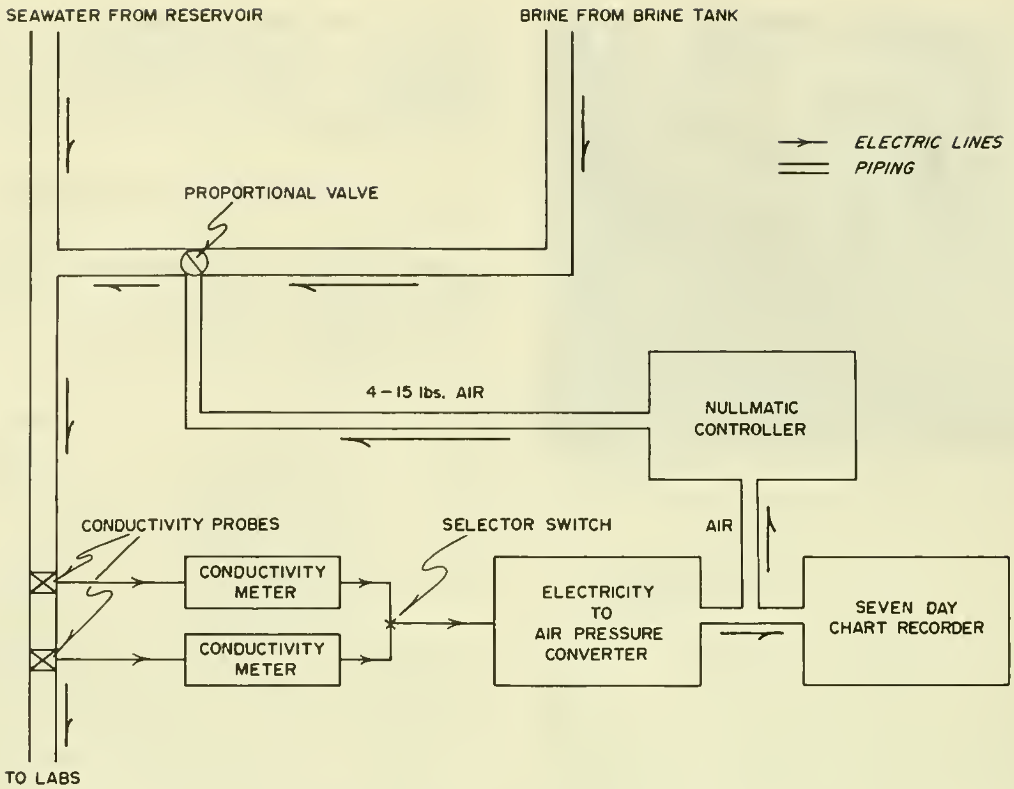

Figure 6.—Schematic of salinity control system.

During September-December 1974, two filtered raw water samples and two recirculating water samples (entering the wet laboratories) were taken to determine water quality changes caused by recirculation with changing biomass. Samples were analyzed for nitrate, nitrite, and phosphate by a state-certified water quality laboratory. Temperature, pH, and salinity were measured at this facility (Table 1).

The results show no significant increase in nitrite, phosphate, and pH with recirculated water. Nitrate does accumulate at low levels but adjustment of the open flow will keep nutrients at acceptable levels. The December 9 condition indicates the seawater system water quality at near maximum biomass and flow rates.

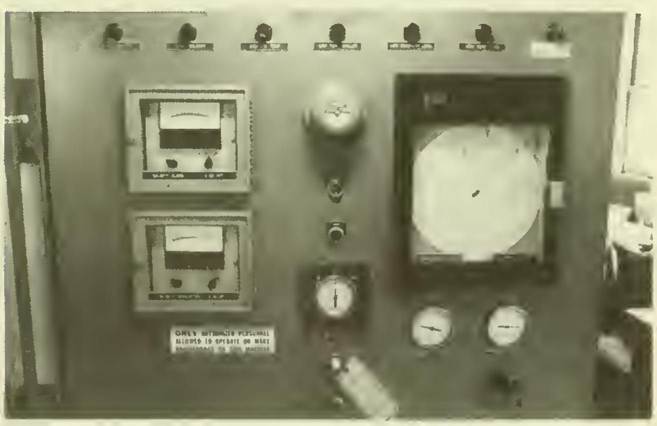

Figure 7.—Control and alarm panel showing alarm indicators (top), conductivity meters (left), nullmatic controller (bottom center), and chart recorder (right).

At this biomass the oxygen content measured in the effluent of the tanks was 1-3 mg/l below saturation. The actual maximum biomass the system will maintain depends on the species held, temperature, and stress factors.

For the past year, although bay turbidities sometimes exceeded 100 Jackson Turbidity Units (JTU, Hach 2100 Turbidometer), values in the laboratories never exceeded 5 JTU. Because of this, cleaning of lines containing filtered water has been unnecessary. The absolute water clarity is important for the efficient functioning of the UV system (Herald et al. 1970).

The built-in UV output meter in our model (Refco Model EP-120, 316 stainless steel) indicates whether the unit needs cleaning or lamp replacement. To date, one cleaning has been needed (20% acetic acid soak for 1 h) and several lamps have needed replacement.

The temperature control has been less than satisfactory and will be modified. The high temperature variation of ±2°C is due to the cycling of the compressor through five stages of capacity to maintain the set temperature. A modification is planned whereby a two-way proportional valve controlled by an air-operated temperature controller will direct the ethylene glycol flow into the heat exchanger or a bypass line. This arrangement should allow for precise temperature control (±0.5°C). Plans also call for addition of heating capacity via a large-capacity water heater in the ethylene glycol line.

Salinity control has been precise (±0.5‰) and has been maintained, although bay salinities varied from 12 to

Table 1. —Comparison of raw and recirculated water in the Tiburon seawater system.[1]

Sample	Salinity (‰)	Temperature (°C)	pH	Total phosphate (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Recirculating flow (l/min)	Open flow (l/min)	Biomass (kg)
Sept. 10							300	60	20
Raw	26	18	7.8	0.80	0.44	0.02			
Recirc.	26	16	7.8	0.62	0.70	0.02			
Oct. 29							240	55	30
Raw	27	17	7.8	2.5	0.62	<0.01			
Recirc.	26	17	7.8	2.8	0.61	<0.01			
Nov. 14							320	45	40
Raw	23	13	7.8	0.5	0.31	<0.01			
Recirc.	26	14	7.7	0.6	0.43	<0.01			
Dec. 9							400	200	340
Raw	22	12	7.8	0.6	0.37	<0.01			
Recirc.	24	11	7.8	0.6	0.52	0.02			

[1]Mean values, $N = 2$. Total system volume = 65,000 liters.

30‰. Control can be maintained with up to 150 l/min open flow. With an average bay salinity of 18‰ and open circulation of 75 l/min, a level 10‰ higher can be maintained for $270.00/week (salt cost $30.00/ton, delivered). The cost of salt makes it mandatory to recirculate most of the flow and to monitor open circulation during periods of low bay salinities. It is recognized that the unnatural ionic balance of the salt used to increase salinity could cause problems with sensitive invertebrates or fish larvae, although no problems have been encountered to date.

No maintenance has been required except routine calibration. It is expected that the conductivity probes will need cleaning and replatinization every 2 yr, and the brine tank will need cleaning every 2-3 yr.

This seawater system has allowed us to hold and maintain a wide variety of organisms including adult and larval Pacific herring, adult and larval northern anchovy, juvenile striped bass, juvenile chinook salmon, and other bay fish and invertebrates. Organisms have been held for up to 8 mo and used for determining effects of petroleum components on their physiology. Pacific herring and northern anchovy have been reared from eggs to juveniles. We have achieved our goal of year-round research with near-oceanic quality water.

ACKNOWLEDGMENTS

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