A Mobile Laboratory With Flow-Through Capability for Thermal Tolerance Studies of Aquatic Organisms

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ABSTRACT—A mobile laboratory, designed for studies to determine the temperature tolerance of certain aquatic animals, is described. The laboratory is equipped with the apparatus and control systems necessary to supply water of controlled temperature for flow-through bioassay tests. The laboratory has been used to determine the upper lethal temperature levels for crab and flatfish at one site on Puget Sound in northwestern Washington State. It could be used at other sites in studies to determine the effect of either existing or proposed discharges of waste heat on resident species of fish and shellfish.

INTRODUCTION

The current energy crisis demonstrates the urgent need for additional sources of economical electric power for domestic and commercial use. Electrical generating plants operated by thermal nuclear energy eventually may be located on the shores of Puget Sound to help satisfy the growing demand for power.

Nuclear plants employing "once through cooling" can raise the temperature of the cooling water approximately 18°F above the ambient temperature of the intake water (Coutant, 1970). The average 1,000 megawatt nuclear plant uses about 2,000 cubic feet of cooling water per second (Sorge, 1969). This volume of heated water can have a tremendous impact on the marine environment and biota. Animals transported with the cooling water through the plant could be subjected to the total temperature increase, while animals in the heated discharge plume could be subjected to temperature increases as high as the maximum 18°F above ambient, depending upon their proximity to the discharge outfall.

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If thermal nuclear power plants are located around Puget Sound their effects on the natural resources must be minimized. As a prerequisite, we should determine the effects of thermal increases on the animals inhabiting the aquatic environment where the plants may be located. Because the species of animals in different areas of Puget Sound vary considerably, thermal tests should be conducted at each site where a thermal nuclear plant is proposed.

This paper describes a mobile laboratory equipped with the necessary research apparatus to conduct thermal tolerance tests on selected aquatic organisms at field sites. The laboratory has already been used to test the upper thermal tolerance levels of Dungeness crab, *Cancer magister*, and two species of flatfish, English sole, *Parophrys vetulus*, and rock sole, *Lepidopsetta bilineata*, at one location on Puget Sound. It could be used at other locations for future studies.

DESCRIPTION OF APPARATUS

Both the towing tractor and the mobile van used to house the test apparatus (Fig. 1) were acquired from Federal surplus supplies. The tractor is fitted with a conventional semitrailer hitch (fifth wheel); any similarly equipped tractor could be used to move the van.

The van is 24 feet long and 7.5 feet wide; the interior is 6.5 feet high. It contains 12 wooden test tanks constructed of ¾-inch thick plywood, painted with a nontoxic material and mounted in metal stands welded to each side of the van (Fig. 2). There are seven tanks on the left side and five on the right. Each test tank is 24 inches long, 18 inches wide, 18 inches deep, and holds approximately 20 gallons of water. A 12 × 18-inch viewing window is in the front of each

Figure 1.—Mobile laboratory with flow-through capability for thermal tolerance studies of aquatic animals.

tank. The tanks are supported approximately 1 foot above the floor by the metal stands. Constructed as an integral part of the stands above the tanks are counter tops that provide convenient work surfaces for measuring, weighing, and marking the test animals (Fig. 3). The counter tops also provide a convenient location for the equipment used to control and monitor water temperatures. Installed in the forward end of the right counter is a stainless steel sink that can be plumbed with freshwater for cleaning test equipment.

The pipes that supply water to the test tanks and the valves that control water flow to and temperature in the tanks are constructed of polyvinyl chloride; they are located on the underside of the counter tops. The main supply lines are 1.25 inches in diameter reduced to 0.5 inch at the control valves. The control valves and the flexible tubing from the valves to each test tank are 0.5-inch inside diameter. The level of water in the test tanks is controlled by 1.25-inch standpipes; 2-inch drain pipes run the length of the van on each side under the test tanks.

Two reservoirs, each 3 × 3 × 3 feet and constructed of 0.19-inch thick fiber glass, are located on metal stands at the front of the van approximately 3 feet above the floor. The reservoir on the left is equipped with three submersible electric water heaters, each rated at 10,000 watts. Each heater is comprised of two electrodes. The electrodes of one heater are electrically divided and operated manually so either one or both of the electrodes can be used at one time producing either 5,000 or 10,000 watts of energy for constant heating. The remaining two heaters are connected through relays to a thermostat that automatically controls the duty cycle (either individually or simultaneously, depending on the amount of water being heated) to maintain the water temperature in the heated reservoir at a preselected temperature. The electrodes of the heaters can be electrically selected to work in 5,000-watt increments to a maximum of 30,000 watts, depending on the volume of water heated. The heaters have the total capacity to heat approximately 6 gallons of water a minute from an ambient temperature of 50°F to 86°F. A rotary pump on the floor below the heated water reservoir circulates water through the reservoir to prevent thermal stratification.

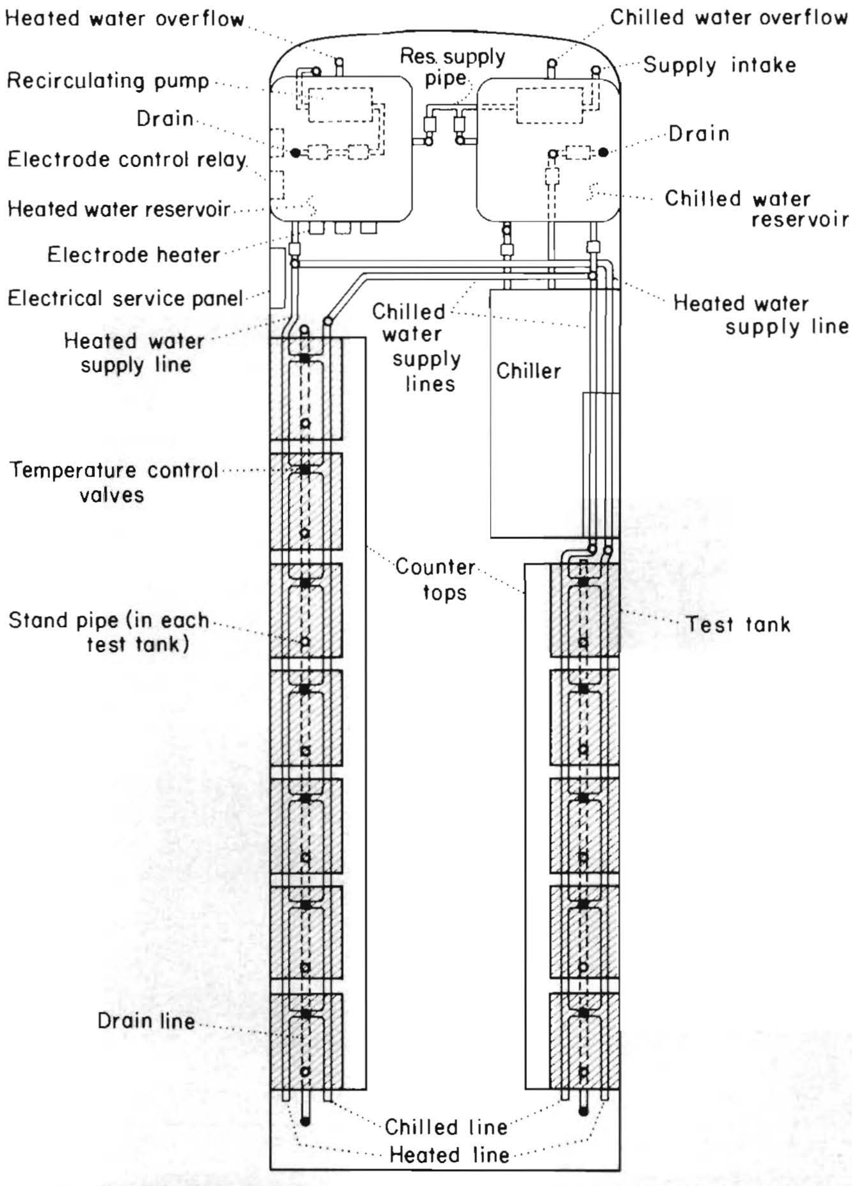

Figure 2.—Plan view of mobile laboratory. Pump supplies water to reservoirs where it is either heated (left) or chilled (right). Treated water flows by gravity through supply lines and temperature control valves to test tanks. Excess water flows out of test tanks through stand pipes to drains that carry it back to the source.

Behind the right reservoir (chilled water) and interconnected with it is a 3-ton chiller. This chiller has the rated capacity of cooling approximately 7.2 gallons of water per minute from 50°F to 40°F. A pump in the chiller circulates water from the reservoir through the chiller, preventing thermal stratification in the reservoir.

Water is supplied to the two reservoirs by a rotary pump located on the floor below the reservoir for the chilled water. The pump is capable of delivering approximately 50 gallons of water per minute with 20 feet of head. Intake water can be routed to either or both of the reservoirs by adjusting valves located between the pump and the reservoirs. A constant water level is maintained in the reservoirs by supplying more water than is being used in the test tanks. An overflow drain near the top of each reservoir carries the excess water out of the van, and back to the water source through drain hoses.

A 200-ampere, 240-volt, single phase, electrical service panel and a bank of electrical relays mounted near the

Figure 3.—Interior of mobile water temperature laboratory. Fishery biologist records observations as experiment progresses. Reservoirs for heated and chilled water are at forward end of van. Test tanks, supply lines, and temperature control valves are under counter tops. Drain lines are on floor under test tanks.

heated water reservoir comprise the electrical apparatus necessary to distribute electricity throughout the van for the heaters, chiller, pumps, temperature control equipment, lights, wall receptacles, etc.

PROCEDURE

Preparing the van for a series of thermal tests requires about 1 hour. A description of the procedures that are followed is presented below. First, the pump that supplies water is started and the two reservoirs are filled. The pump runs continuously; excess water is returned to the supply source through overflow drains. The heaters in the heated water reservoir and the chiller connected to the cold-water reservoir are started. When the water in each reservoir reaches the approximate desired temperature, the appropriate valves are opened and the water flows by gravity from the reservoirs through the supply lines to the test tanks. Individual valves are adjusted to supply the correct volume of heated and chilled water to maintain the desired temperature in each test tank. Assuming an ambient temperature of 50°F, the range of temperatures in the tanks can be controlled from about 40°F, using chilled water only, to as high as 86°F with heated water only.

The valves at each tank are adjusted to control not only the water temperature but also the volume of flow. An attempt is made to have approximately the same water volume flowing into each tank regardless of the temperature.

The temperature of the water flowing into each test tank is monitored by individual sensing probes placed in the tube that brings the water from the control valves to the tanks. The water temperature in the individual test tanks is periodically checked with a thermometer.

When the valves are properly adjusted at the test tanks and the water in the heated and in the chilled water reservoirs is stabilized at the desired maximum and minimum temperatures, the tests are started. Heated water used in some of the test tanks mixes in the drains with the chilled water used in other test tanks. The total volume of water can be discharged without further treatment and at approximately ambient temperature.

In our tests, the test animals were brought from holding tanks located outside the van and placed immediately in the test tanks. The number of animals tested in any one tank varied depending on the size of the animals. We usually tested only 4 or 5 Dungeness crabs in each tank, whereas as many as 8 or 10 small flatfish were tested in one tank. We also made periodic checks of the dissolved oxygen in the tanks to assure that the level did not fall below accepted minimum standards for the species being tested. Our test duration varied from 10 minutes for the higher temperatures to 48 hours for the lower temperatures.

COST

Our total cost of assembling the mobile water temperature test laboratory does not include the cost of either the towing tractor or the van because both were acquired through government surplus channels at no expense to our agency. An approximate cost of the various components is given in Table 1.

Table 1.—Approximate cost breakdown of the various components of the mobile water temperature testing laboratory.

Components	Price
Stands for test tanks and reservoirs: 3 @ $150 ea.	$450
Test tanks: 12 @ $50 ea.	600
Reservoirs: 2 @ $350	700
Submersible heaters: 3 @ $150	450
Chiller: 1 @ $7,500	7,500
Electrical components (service box, relays, wiring, lights, receptacles, etc.)	500
Plumbing (pipe, valves, hoses)	500
Pumps: 2 @ $275 ea.	550
Total	$11,250

APPLICATION

The mobile laboratory has been used in tests to determine the upper lethal temperature limits for the Dungeness crab and two species of flatfish, English sole and rock sole. The primary purposes of the experiments conducted thus far were to test the operation of the systems designed into the van and to determine the feasibility of using it as an on-site laboratory. Under test conditions, the various systems functioned well. It would be possible to move the laboratory to any site on Puget Sound accessible by road, to set it up and have it operating within 2 or 3 days with a crew of 3 or 4. If commercial electricity were not available at the test site an alternate source, such as a portable motor generator, would have to be provided.

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