Cooling Components With Chilled Tap Water

Laboratories and research groups constantly develop devices which need to be cooled, but rarely spend time on effective cooling equipment for them. The following is a relatively inexpensive method to cool instruments using tap water.

Scott D. Wohlstein
SD Labs—Laser Systems Division
Lavelle Rd. Box 512
Athens, OH 45701

In the past, electro-optic firms have concentrated primarily on the development of electro-optic devices and laser equipment, often leaving the design and production of adequate cooling equipment for other firms to complete. In some cases very low temperatures must be maintained; here, thermoelectric cooling or cryogenic dewars must be used. In many cases, however, maintaining a specific low temperature is not the object; rather, the object is to remove thermal energy from a device under thermal stress (e.g., laser mirrors, flashlamps, etc.). In these cases flowing water can be used to remove excess heat.

With flowing water, the logical trade-off concerns the rate of heat removal—should you use a high-velocity flow of water at tap temperature or a low-velocity flow of pre-cooled water? Recently, researchers at SD Labs have developed a simple, compact device for cooling using a technique which involves a low-velocity flow of supercooled tap water.

How It Works

The following equations constitute a rough approximation of the heat-handling capabilities of the system.

To determine the heat dissipated by the device to be cooled:

$$Q_1 = \frac{m_1 \, c_1 \, \Delta t_1}{\tau_1}$$

Where: Q_1 is the heat capacity (BTU/hr).
m_1 is the mass (lb.)
c_1 is the specific heat averaged over all the components in the device (BTU/lb °F).
Δt_1 is the absolute value in the change in temperature (°F), and
τ_1 is the time (hr).

Similarly, to determine the cooling ability of the cooling unit:

$$Q_2 = \frac{m_2 \, c_2 \, \Delta t_2}{\tau_2} (\eta)$$

Where: Q_2 is the heat capacity (BTU/hr).
m_2 is the mass (lb).
c_2 is the specific heat averaged over all the components in the device (BTU/lb °F).
Δt_2 is the absolute value in the change in temperature (°F).
τ_2 is the time (hr), and
η is the refrigeration factor and has no units.

η is a function of refrigerant control (RC) and depends on the coolant used.

(Ed. note: Yes, we know, this could just as easily be done in SI units of degrees Celsius, kilograms and joules, at least in terms of these general equations. But if you buy refrigeration components in the United States, their specifications will be quoted in English units. So we decided to maintain those units in this discussion.)

To determine system heat handling, and to find the refrigeration factor (η), set eq. 1 to eq. 2 and solve for η:

$$\frac{m_1 \, c_1 \, \Delta t_1}{\tau_1} = \frac{m_2 \, c_2 \, \Delta t_2}{\tau_2} \eta$$

Remember that η is a function of refrigerant control (RC), and that although the numbers are of no immediate value, they are directly scaled on the control surface itself to provide a method of comparison when using different coolants.

The flow rate is the same throughout the system; a constant 3 gal/min or 180 gal/hr is assumed, assuring that most cooling needs are met through the control of RC (η).

Following the Flow

The RWCU (refrigerated water cooling unit) functions by circulating two to five gallons of refrigerated tap water through the device to be cooled. The refrigerant, dichlorodifluoromethane, combined with a 500 cubic foot per minute blower, keeps the water at about 35° F. A current sensing device activates the RWCU as soon as the device to be cooled is turned on, and a low level sensor signals when the tank needs refilling. Almost any fluid that can remove heat in any way can replace the water in this system, provided that it does not corrode or cause mineral or chemical deposits to collect on pipes, pumps and their fittings and valves. Alternate cooling fluids include methanol, methanol/water, or ethylene glycol.

Fig. 1 depicts a series of system flow diagrams. In normal operation, **Fig. 1a,** cooled water from the tank (T) is pumped through the pump (P), the solenoid valve, (SV_1) and the I/O_1 valve and into the hot device. The

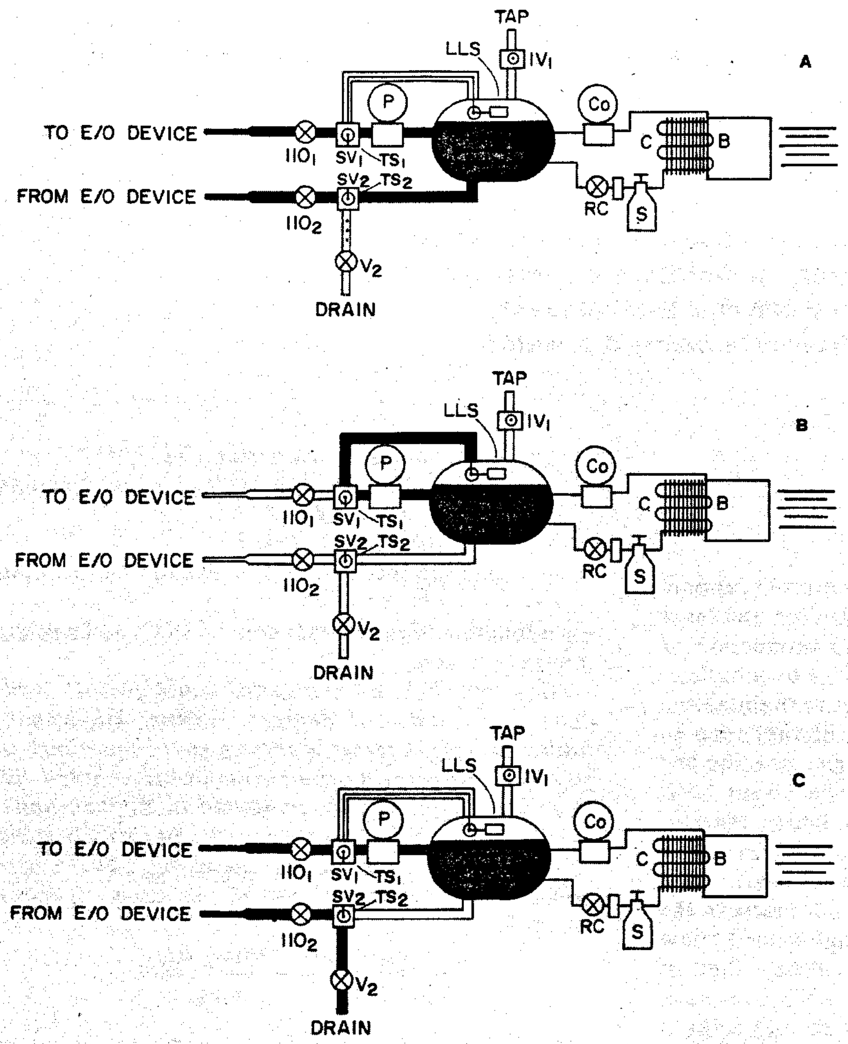

Fig. 1. System flow diagram
a. Full flow (normal operation)
b. In case of high tank temperature
c. In case of high I/O_2 temperature

water is flushed through the device, and the heated cooling water emerges from the output of the cavity. The coolant enters RWCU via insulated water tubing, past the I/O_2 valve and a solenoid valve (SV_2) to refill the tank.

Fig. 1b illustrates the flow of water in RWCU when the water in the tank is too hot. A thermistor (TS_1) gauges the temperature of the water and activates SV_1 if the temperature is above a certain point. The water is then diverted back into the tank for further cooling. When the water temperature falls below the point at which TS_1 is set, the valve re-opens the lines and the water flows into the hot instrument.

When the temperature of the used cooling water leaving the electro-optic device is higher than the setpoint of a second thermistor (TS_2), as in **Fig. 1c**, then SV_2 cuts off access to the tank and directs the hot water out of the system through a valve (V_2) and into a drain. When this happens, the low level sensor in the tank activates IV_1, allowing coolant to refill the tank.

Input valve (IV_1) is a solenoid-controlled valve that is normally closed. I/O_1, I/O_2 and V_2 are manually operated valves that are normally open. If these are manually closed, the RWCU may be moved without draining the tank.

The RWCU uses R-12 (dichlorodifluoromethane) as the refrigerant. A refrigerant control (RC) maintains the pressure difference between the high and low side of the refrigerant storage bottle (S), while allowing the refrigerant to flow from S to the cooled evaporator coil (E). Because of the pressure difference, the R-12 will boil rapidly, cooling E. A compressor (C_o) draws the R-12, now evaporated gas, from E and compresses it to high-pressure gas. This high-temperature, high-pressure gas flows into the forced-air cooled condenser (C), where it expands into its original liquid form, while releasing heat energy. The 500 CFM blower (B) blows air across the coils of C to speed up the cooling process. The R-12 flows back into S, and the process can begin again.

An ordinary single phase 108-125 Vac at 60 Hz service powers the RWCU system. At 11 amps, its maximum power consumption is 1375 watts. The pump, compressor, blower, and meter/controllers, which control the solenoid valves, are all separately fused and switched (**Fig. 2**). Thermistor bias is supplied by the meter/controllers. The low level sensor is a simple float switch

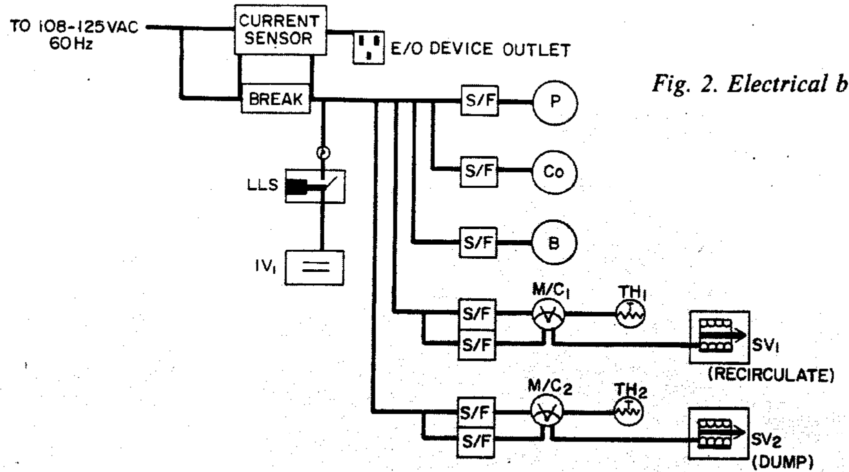

Fig. 2. Electrical block diagram

which activates both a panel lamp and the input valve (IV_1).

RWCU is mounted in a rack, with support sleeves to help sustain its weight. It is 19″ wide (EIA standard), 12″ long with 2″ of overhang for condenser and fins, and 14″ high. It weighs 89 lbs. ☐

References

1. A.D. Althouse, C.H. Turnquist, A.F. Bracciano, *Modern Refrigeration and Air Conditioning* (Goodhart-Wilcox Co., Homewood, Ill. 1968), pp 31-32.
2. N.C. Harris, E.M. Hemmerling, *Introductory Applied Physics*, 4th ed. (McGraw-Hill, Inc., New York, 1980) pp. 337-352.
3. H.M. Muncheryan, *Laser Technology*, (Howard W. Sams and Co., Inc., (Indianapolis, Ind., 1979) pp. 56-57.

Reader Interest Review

Please help our editors evaluate your interest in this article. Circle number indicated on the reader Service card.

High 391 **Medium 392** **Low 393**