RESEARCH AND DEVELOPMENT REPORT
REPORT 784
6 MAY 1957

NEL/Report 784

A TEMPERATURE-CONTROLLED TANK FOR CALIBRATING REVERSING THERMOMETERS

J. S. BLACK

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA
A BUREAU OF SHIPS LABORATORY

THE PROBLEM

Develop a controlled-temperature tank for calibrating deep-sea reversing thermometers and other precise temperature-measuring instruments.

RESULTS

A 70-gallon controlled-temperature tank has been constructed and tested. The temperature can be reproduced and held to ±0.002°C over the range —3°C to 40°C. The tank's large size and remote operation permit calibration of 24 reversing thermometers at one time. It eliminates tedious calibration data reduction, since both main and auxiliary thermometer stems are read at temperature of reversal.

RECOMMENDATIONS

1. Continue development to include installation of electronic time-proportioning switches in metering of heat transfer.

2. Study the possibility of an instrument to record temperatures at two points in the tank, throughout any operation.

ADMINISTRATIVE INFORMATION

The work was done under IO 15401, NE 120221-13 (NEL L4-1, part 1). This report covers work from January 1952 to November 1956 and was approved for publication 6 May 1957.

The author wishes to acknowledge the valuable help of J. C. Roque and B. E. Holtsmark in functional design of the equipment. Thanks are also extended to A. A. Arnold, Ronald Jones, S. L. Polansky, and S. Houseknecht for assistance in the technical design and construction.

CONTENTS

ILLUSTRATIONS

INTRODUCTION

The NEL Controlled-Temperature Calibration Tank was designed to fill the Laboratory's need for a reliable and accurate temperature calibration facility for use primarily with deep-sea reversing thermometers. These thermometers are customarily read to 0.01°C and, consequently, must be calibrated to at least that order of accuracy. A secondary use of the tank is the calibration of other temperature-measuring instruments such as thermistor beads and thermocouples, which may require calibration accuracies approaching 0.001°C.

Accurate calibration tanks have been produced in the past. The Dahl-Mosby tank[1] which has been in operation at the Chr. Michelsen Institutt, Bergen, Norway, since 1945, consists essentially of an insulated cylinder which can be reversed end for end. Ten thermometers can be calibrated at a time against the readings obtained on four standard thermometers. Woods Hole Oceanographic Institution produced a more elaborate twelve-thermometer tank in 1947 which has heating and cooling elements controlled by Bourdon tube activated contacts.[2] A glass window and a movable telescope arrangement permit the thermometers to be read while submerged and compared against standard thermometers calibrated in 0.01°C steps. Other tanks similar to the WHOI design are in use at the Pacific Oceanic Fisheries Investigation, Honolulu, T. H.,[3] and at the U. S. Bureau of Standards, Washington, D. C.

---

[1] O. Dahl and H. Mosby *Calibration Tank for Reversing Thermometers* (Christian Michelsen Institutt for Videnskap og Åndsfrihet, Beretninger XI, 3) Griegs, 1945.

[2] D. F. Bumpus and E. T. Penrose *Equipment for Calibrating Deep Sea Reversing Thermometers* (Woods Hole Oceanographic Institution, Completion Report No. 7) 1947.

[3] H. Mann *Plans and Specifications for a Constant Temperature Tank for the Calibration of Deep Sea Reversing Thermometers* (U. S. Fish and Wildlife Service, Pacific Ocean Fishing Investigations) (Unpublished manuscript) 23 May 1950.

DESCRIPTION OF EQUIPMENT

The new NEL calibration tank (fig. 1) represents an improvement over the earlier designs in that it provides automatic temperature control, very high accuracy, rapid operation, and a simplified method of taking readings. The NEL tank will also calibrate twenty-four thermometers at a time, or twice as many as possible in previous models. These thermometers may be moved into position after their temperature has equalized with that of the tank and read *in situ* by means of a reading telescope. The tank is well insulated from ambient temperatures so that little addition or subtraction of heat is necessary to maintain temperatures within the desired limits of accuracy. The rate of heating and cooling is controlled precisely, permitting rapid large changes of temperature, accurate microchanges of temperature, and maintenance of temperature within very small limits.

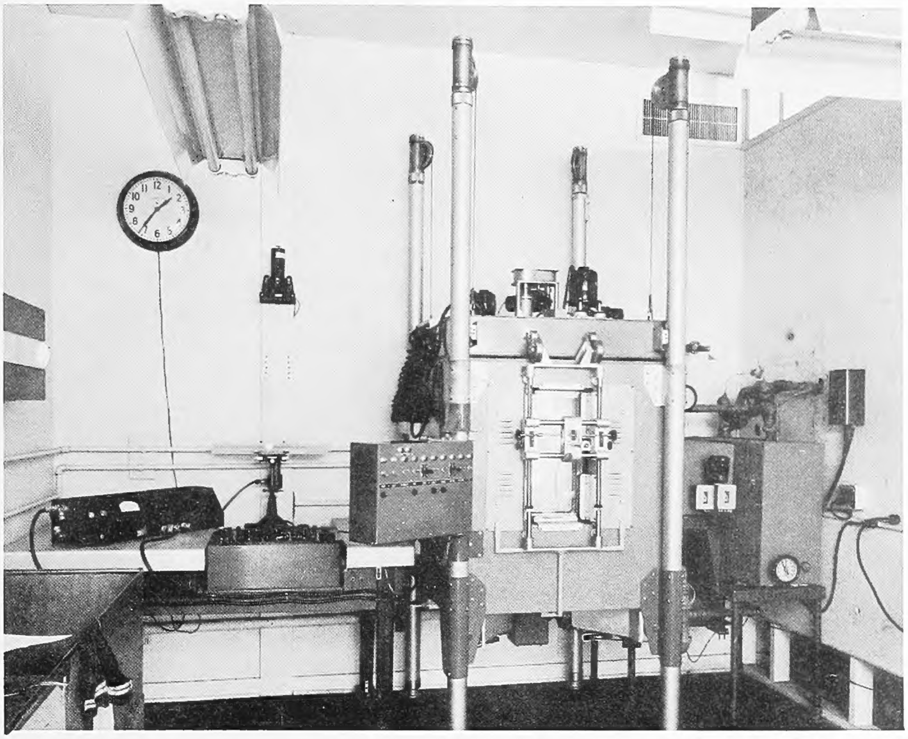


Figure 1. Controlled-temperature calibration facility.

Thermal System

The calibration tank uses external hot and cold tanks, the former maintained well above and the latter well below operating temperature. The transfer of heat is accomplished by pumping liquid from either tank to the calibration tank, with a return path furnished to provide a closed circulating system (fig. 2). The choice of hot or cold is made by the thermostat, which controls electrically operated solenoid valves on the two systems and the pumping motors. In addition, there is a metering valve in each system to control the rate of flow of hot or cold liquid so as to maintain constant tank temperature despite unavoidable transfers of heat to the surroundings. When a macrochange of temperature is desired, the metering valves are opened fully to permit rapid transfer of a considerable volume of liquid from either the hot or cold external tanks. The use of external tanks avoids the thermal lags which would occur if the heating and cooling systems were installed in the actual body of the calibrating tank itself. In the initial installation one pump was used for both hot and cold tanks, but on the first trial run it was found that because of the residual hot or cold liquid in the pump itself and despite the very short piping system from it to the tank, there was too much overshooting. A pump and metering valve have now been installed on each tank so that when the thermostat demands hot or cold it is provided instantly at the requisite rate of flow to allow full mixing, with minimum of overshoot.

Hot Tank

The hot tank measures 8 by 10 by 20 inches and is made of brass sheet ⅛-inch thick, brazed at all edges (fig. 3). It is thermally insulated with 1-inch cork board held in place and surfaced by 3-inch Permacel industrial tape which is painted to form a strong continuous surface. Water is piped into the whole system through the rear end of this tank. Two 1500-watt, 110-volt heating elements are mounted in it through the front, together with a thermometer

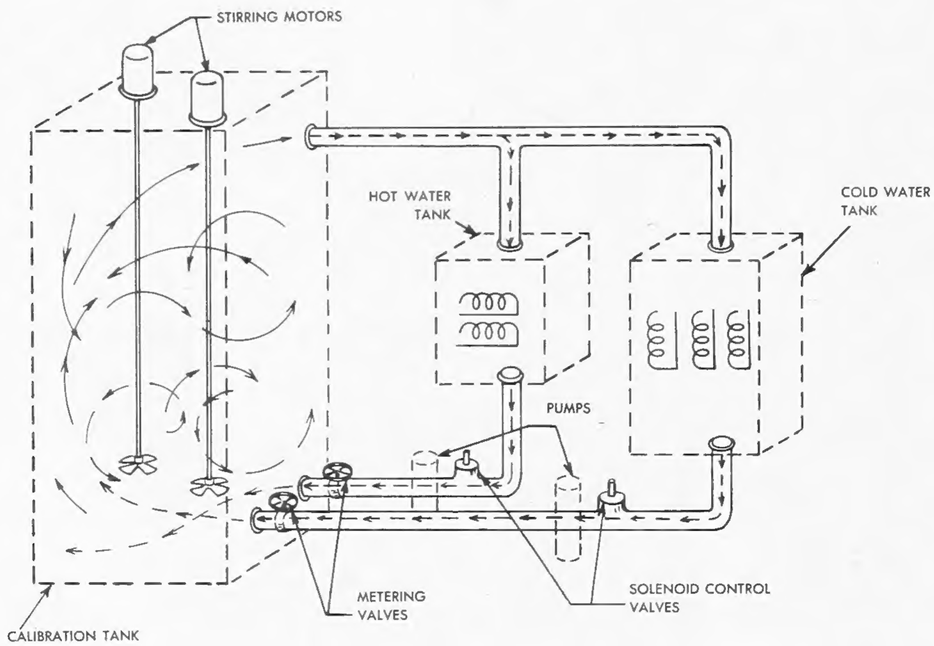


Figure 2. Circulating system.

and a Bourdon tube thermostat to hold the tank temperature to within 2° of any desired value. The water is drawn from the center of the bottom of this tank to the circulating pump and returns from the calibration tank to the top, thereby maintaining a constant circulation as long as the solenoid value between the tank and the pump is open. The metering valve is mounted in the pipeline between the pump and the calibration tank, as near the latter as feasible. The two heating elements are connected in series to enable the use of 220 volts for this 3000-watt heating system.

Cold Tank

The cold tank is also of brazed sheet brass construction, measuring 28½ by 9½ by 22 inches (fig. 3). The dimensions were dictated by the size requirements of a bank of three refrigerating coils known as needle coils, mounted in parallel to the expansion valves for speed of heat transfer. This tank is insulated in the same manner as the hot tank and mounted a few inches to the right of it, sharing the common circulation return with the hot tank. The cold liquid is drawn off the bottom of the tank, which is in the shape of a shallow pyramid. Circulation is controlled by the thermostat-operated solenoid valve and the manually controlled metering valve, both arranged as for the hot tank.

All external piping, pumps, and valves are insulated with Prestite insulation which can be molded to fit any irregularities of form. A thermometer is mounted at the base of this tank and the compressor is controlled by a thermostat that can be set to hold the temperature of the liquid to within 2° from that of the room to —3°C. The compressor used is rated at 1.2 tons, and is mounted outside the building to provide sufficient air circulation for cooling.

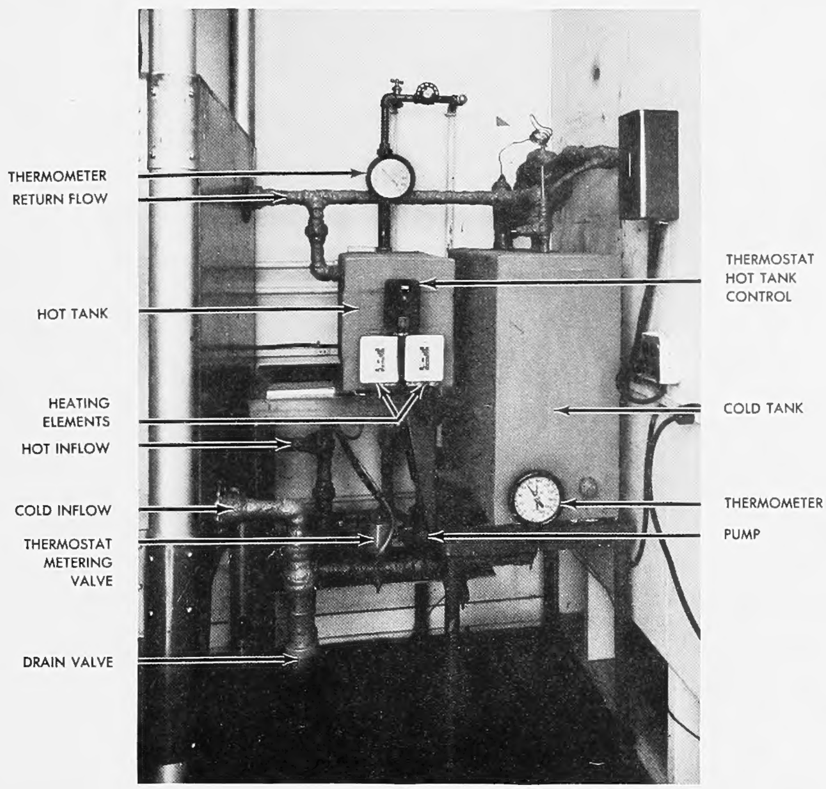
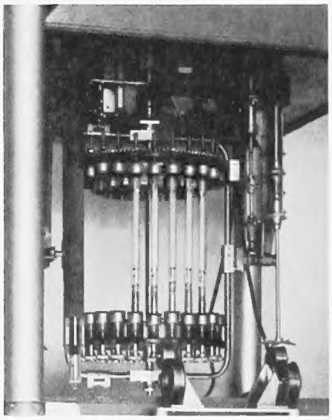


Figure 3. Thermal system.

Calibration Tank

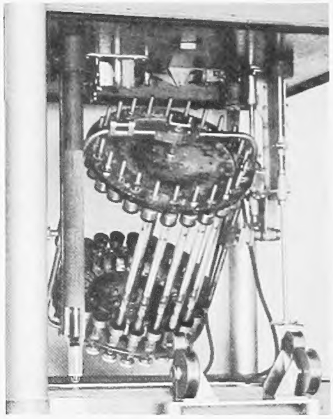
The calibration tank is made with an inner lining of ½-inch lucite, measuring 28 by 23½ by 30 inches, backed by an aluminum foil for radiation insulation (fig. 4). Further heat insulation is provided by a 4½-inch layer of tar-coated cork-board surrounding the inner lucite shell on all sides and at the top and bottom. This inner tank of lucite is supported evenly along its bottom on a grid of 2 × 4's to prevent deformation and possible rupture by the weight of water (approximately 600 lb) it contains when in operation. The outer shell is of ½-inch plywood reinforced at all angles by strength members.

The whole tank is supported at the corners by tubular aluminum uprights, 3 inches in diameter with ¼ inch wall thickness. These are equipped with screw-adjustable feet for levelling purposes and extend to a height of 8 feet above the floor. Mounted on the top of each upright is a pulley assembly for the wire that raises and lowers the lid.

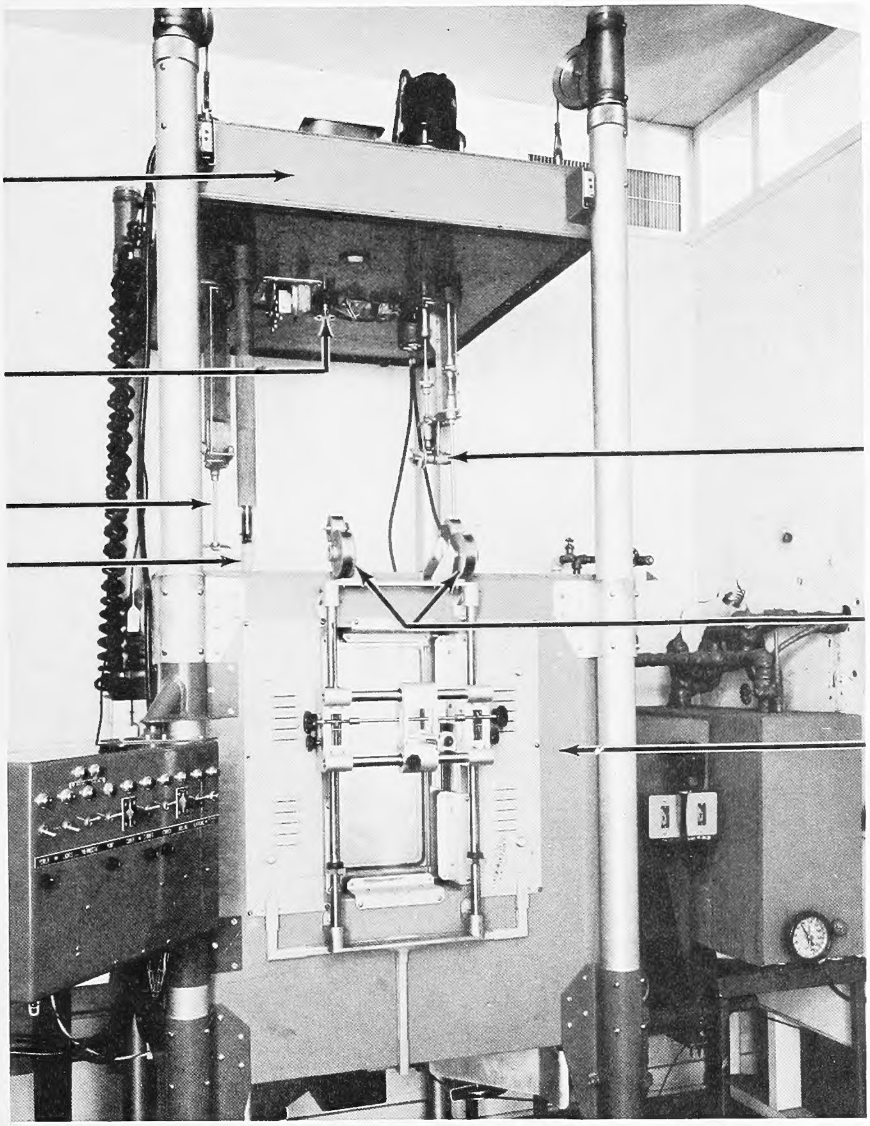


A. RACK BEFORE REVERSAL

Figure 4. Calibration tank, shown (A) before reversal of rack, (B) during reversal of rack, and (C) with rack removed.



B. RACK BEING REVERSED



C. TANK WITH RACK REMOVED

Figure 4. *(continued)*

Tank Lid

The lid is built separately from the tank proper, though of similar construction as to insulation (fig. 5). On it are two shock-mounted 1/20-hp motors connected by V-belt drive to two shafts, each passing into the tank through Micarta insulating inserts 1½ inches in diameter. A stainless steel four-bladed propeller is mounted on each shaft at diagonal corners of the tank to provide thorough cross-stirring of the tank liquid. Apertures in the lid are provided for a standard platinum resistance thermometer and for the thermostat sensing element. Two apertures are also provided for inserting leads for any other element that may be undergoing calibration.

A motor and its accessory drive are mounted on the tank lid to permit reversing the thermometer rack with the lid closed. A motor is also provided for indexing the rack so that the thermometers may be read successively at the telescope. This latter drive includes a solenoid-controlled disengaging lock to enable the rack to be reversed.

The under edge of the lid is fitted with a round soft rubber strip to form a seal between it and the upper lip of the tank proper, which is of ½-inch Micarta. As can be seen, all controls are mounted on the lid of the tank, so that the only apertures beneath the surface of the liquid are those necessary for liquid transfer.

The lid is raised and lowered by four 5/32-inch stainless-steel cables, one attached to each corner, passing over a pulley mounted on top of each upright and down through its center. The cable is led by another pulley to two doubly grooved spiral drums mounted on the bottom of the tank, each of the two drums handling two of the cables. One drum is mounted on each end of the shaft of a reduction gear driven through a friction-slip clutch by a 1/6-hp motor. The direction of rotation of the motor is reversed for raising or lowering the lid. Limit switches are mounted at the top and bottom of the lid's travel to prevent overrunning. Sets of rollers at each corner guide the lid and maintain it in strict alignment with the four supporting uprights.

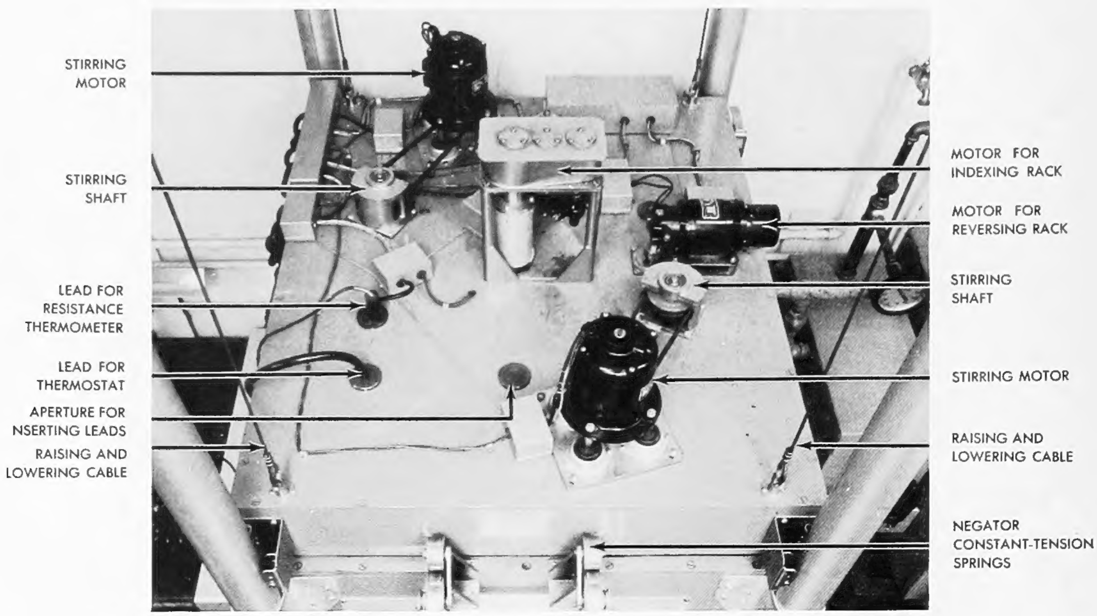


Figure 5. Tank lid.

Thermometer Rack

The thermometer rack is circular. It is designed to hold 24 deep-sea reversing thermometers about its perimeter, each secured by a screw-adjustable rubber-faced cup at one end and a similar, spring-loaded cup at the other end (fig. 4). This is for speed and ease of mounting thermometers of various lengths. Provision is also made for mounting 24 surface thermometers between the deep-sea mounts. These fittings are attached to two Micarta disks, supported by a central shaft which can be rotated to bring each thermometer in front of the reading telescope by means of two vertical fingers projecting from circular plates mounted one on either end of the shaft. These are designed to engage a plate on the end of a drive shaft coming through the lid, which can be retracted by a solenoid to permit reversal of the rack. Rack reversal is accomplished by mounting the rotating shaft in a framework supported at the outer of its two vertical sides by ball and socket shafts, and by using bevel gears to drive the right-hand shaft. Power is supplied through the lid by a 1/20-hp reduction-gear motor on the top of the lid. The rack is supported by two vertical arms attached to the underside of the lid, the right one fitted with bearings for the reversing drive shaft and the left one with a limit switch to cut the drive motor when the rack is in a vertical position for locking onto the indexing drive. As can be seen, all gear in the tank is raised and lowered with the lid, making the rack easily accessible for loading or changing thermometers or for removal of the rack entirely when other apparatus is to be used in the tank. All fittings in the tank are of stainless steel.

Tank Window

The thermometers are read through a window mounted in the front side of the tank (fig. 6). This

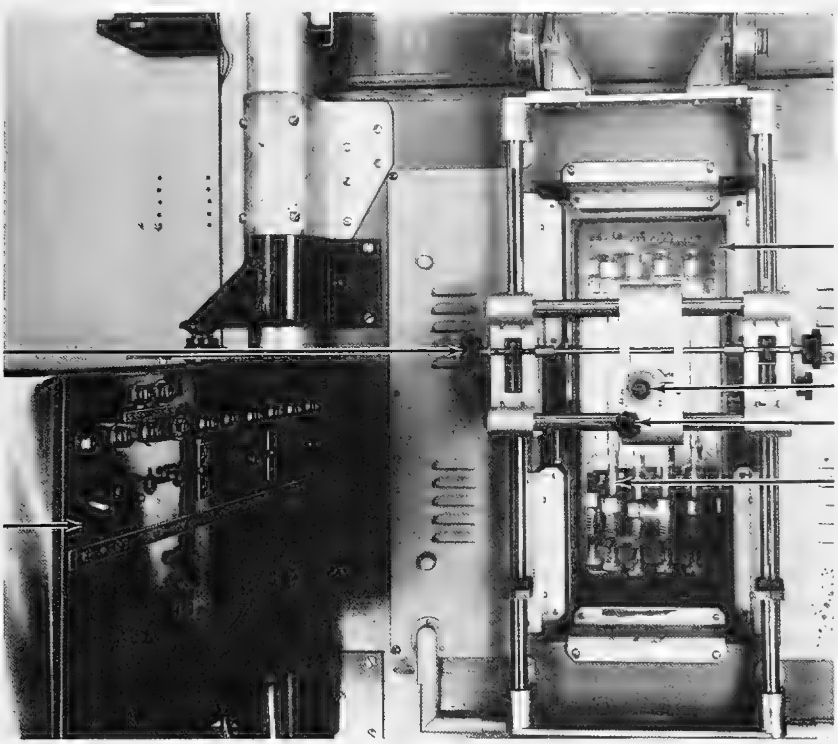


Figure 6. Tank window, reading telescope, and control panel.

window, which measures 9 by 19 inches, is a thermopane unit made to order by the Libby Owens Ford Glass Company and consists of four panes of ¼-inch, optically plane glass, opaque to infrared, mounted parallel in a metal-sealed frame. The three dead-air spaces between the panes give undistorted visibility with extremely low heat transfer. Twelve rubber-faced pressure screws hold the unit in place against an O-ring seated around a suitable aperture cut in the inner lucite shell of the tank. These screws are spaced evenly along its sides and upper and lower edges, and are mounted in aluminum brackets screwed to the frame of the tank. The frame for this window, which extends through the tank insulation, is made of wood with a removable rubber-lined inner frame, to give a snug positive fit for the thermopane.

Reading Telescope

To read the thermometers accurately, a reading telescope is provided. This is a 20X erecting instrument with horizontal hair at the principal focus of its eyepiece systems. It can focus to a minimum distance of 10 inches, and at the 13-inch distance to the mounted thermometers its field is about 1 inch, which makes it possible to read the main and auxiliary thermometers without moving it laterally. To assure accuracy, this telescope is held by a heavy frame, which moves laterally on ball bearings on two horizontal steel tubes pinned rigidly at either end to aluminum travelers. The telescope thus has a 4½-inch lateral traverse. The supporting travelers are in turn mounted on vertical steel rods on which they can be moved 18 inches vertically by means of rack and pinion gears. The mount may be locked in position in either of these movements by set screws actuated by means of knurled knobs. The supporting vertical rods are seated top and bottom in steel frames bolted to the front of the tank. This whole assembly is very carefully aligned so that the telescope is exactly perpendicular to the axis of the thermometers in all positions, thus eliminating error due to parallax, which is ordinarily the greatest single cause of error in reading thermometers from a distance. The thermometers themselves are held rigidly vertical when their rack is locked in reading position. The 7-pound weight of the telescope assembly is counterbalanced by two constant-tension negator springs so that it will remain in any desired position.

TEMPERATURE CONTROL UNIT

Thermostat

Temperature control is attained by means of a thermostat using two thermistor beads, one on each side of a resistance bridge (fig. 7). The other two sides of the bridge consist of a fixed resistor and a Helipot. The thermistor beads are mounted 3 inches to the left and at the same level as the thermometers to be calibrated. As temperature change occurs the resistance of the thermistors varies, throwing the bridge out of balance. This imbalance is fed to a dc amplifier. The amplified voltage drives a servo motor either clockwise or counterclockwise, depending on the sign of imbalance. The servo, in turn, drives a cam mounted on a slip clutch that closes either of two microswitches. However, when exact balance is attained neither of the two switches (one controlling the hot and the other the cold transfer pumping system) is actuated.

At full gain, this temperature-control system responds more rapidly than can be measured with either the platinum or mercury thermometers.

Control Panel

The control panel is mounted on the left front supporting member of the tank. It can be swung into position for operation either by the thermometer reader at the telescope or by the operator at the temperature controls on the left (fig. 6). The panel contains the main power switch and controls for tank illumination, thermostat, pump, lid raise and lower, front and back stirrers, indexing and reversing. The temperature controls are necessarily on the panel of the thermostat, accessible to the operator of the temperature-measuring bridge. Illumination of the tank through the lucite inner wall is supplied by two fluorescent tubes mounted in recesses, one on each side of the thermopane.

The final standard of temperature is obtained by means of a Leeds and Northrup platinum resistance thermometer and associated Muller Bridge, Type G-2, calibrated by the U. S. Bureau of Standards. This bridge measures resistance to 0.0001 ohm, the maximum correction given by the U. S. Bureau of Standards, thus enabling temperatures to be read to 0.001°C absolute. The manufacturer of the bridge claims an over-all accuracy only within several thousandths of a degree centigrade. However, in the

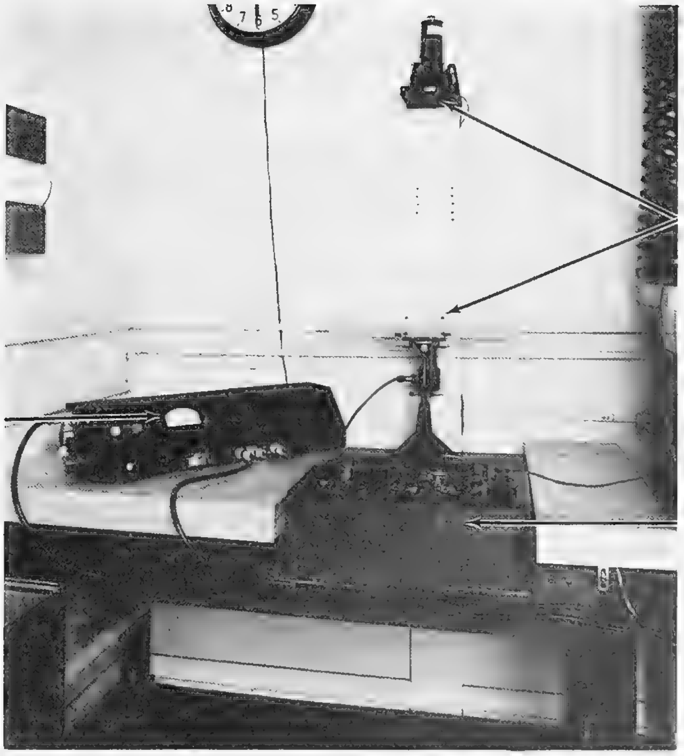


Figure 7. Thermostat and resistance bridge.

uses for which the tank was designed the bridge will be used only between 25 and 30 ohms and it is safe to assume that temperatures can be measured to an accuracy of ± 0.002. The bridge is periodically checked against a standard 10.0100-ohm resistor, certified by the Bureau of Standards, and over a period of three years there has been no measurable divergence from this standard.

In addition the standard thermometer is checked periodically against the ice point provided by distilled water ice.

CALIBRATION OF REVERSING THERMOMETERS

Although the tank can be used to calibrate any instrument capable of being inserted into it, it is largely used for reversing thermometers. The step-by-step procedure used in reversing-thermometer calibration is presented here.

Step 1: Fill Tanks

The system is first filled with water to which is added 15 gallons of alcohol. This amount of alcohol permits temperatures to be lowered to —3°C without ice forming on the refrigerating coils. The solution is checked periodically with an alcohol hydrometer and more is added as needed to replace that lost by evaporation. Alcohol was chosen as being the simplest and cleanest antifreeze to use, as well as the least expensive.

Step 2: Set Temperature

Ordinarily the desired temperature is dialed on the thermostat the night before calibration work is to start. The whole system is then put on a time switch, so that it will be at working temperature in the morning.

For the highest speed of operation, the calibrating run is usually started at the lowest temperature desired and then increased through the necessary range.

The change is very rapid for calibration steps of 1 to 5 degrees because of the large reserves of hot and cold water available instantly on demand. The hot tank contains 7 gallons maintained at 80°C, and the cold tank 25 gallons maintained at —3°C.

Step 3: Insert Thermometers

Twenty-four thermometers are mounted in the circular rack and the whole lid is lowered, so that the thermometers are wholly immersed and the aperture sealed. The stirrers are then placed in operation to give very rapid mixing of the water mass and as nearly homogeneous a temperature structure as is possible.

When the desired temperature has been attained, the metering valves are adjusted to make the flow of water from the hot or cold tanks exactly compensate for unavoidable transfer of heat from the tank because of ambient differences of temperature. An extremely small aperture is needed to avoid overshooting because of the slight lag in the thorough mixing of the incoming water with the whole water mass. Metering is made possible by the use of centrifugal pumps which act as their own bypasses when the flow is shut down. This system was found to be simpler and more readily controlled than that of varying the speed of the motors driving the pumps, which was tried at one stage of construction.

Step 4: Reverse Thermometers

Ordinarily the thermometers are left for 10 minutes at a given temperature to assure full equalization. During this period the bridge operator constantly watches the galvanometer spot. If the spot varies more than 1 mm (*i. e.*, 0.001°C) from its null, the operator makes the necessary adjustments of the metering valves. Several minutes of stabilization are required after each temperature change.

After the temperature has remained constant for the required period, the operator at the controls reverses the rack so that it locks in the reading position. If the mercury columns in any of the thermometers are found not to have broken, the lid may be raised a few inches and the rack tapped sharply without changing the temperature appreciably.

Step 5: Read Thermometers

The operator at the telescope can now read the main thermometer of each unit successively by operating the indexing mechanism which rotates the rack to move successive thermometers into reading position, either clockwise or counterclockwise. There is a 7-second pause between moves, which is usually sufficient for reading.

There ordinarily is no need to read the auxiliary thermometer because the surrounding bath is maintained at constant temperature by the operator at the temperature controls. Of course, if required, calibration can be established for auxiliary thermometers at the same time. This is done by having both operators read the thermometers. Then the whole process is repeated twice at the same temperature, resulting in three double checks at each temperature check. This is not only a check on accuracy, but also gives a very good evaluation of the dependability of the individual thermometers.

Since the thermometers are read at the same temperature at which they were reversed there is no need to go through the tedious temperature correction required when they have to be removed from the bath and allowed to reach a steady room temperature, which in itself usually takes at least 30 minutes.

No time is lost waiting for thermometers to equalize after they have been reversed. And, of course, there is no correction for thermal expansion of the mercury. The index correction is read directly, thus saving time and possible errors.

It is estimated that with two experienced operators it is possible to calibrate a set of twenty-four thermometers in two days, depending upon the range of the thermometers and the number of points (usually every 2°C) to be read. Thus, the tank enables thermometers to be calibrated accurately and surely against a known standard in about one-fifth the time previously required and with about one-fifth of the labor.

CONCLUSIONS

Preliminary use and evaluation of the temperature-controlled tank indicate that it gives an accuracy of ±0.002°C over a range of temperatures from —3°C to 40°C and provides great savings of time and effort in calibration of reversing thermometers.

The accuracy is dependent upon the reliability of the Leeds and Northrup platinum resistance thermometer, the Muller bridge, and the thermostat. The system is checked periodically for ice point and the bridge is checked against a standard 10-ohm resistance.

The main time consumed is in allowing the thermometers to come to equilibrium at each new temperature at which a calibration is required. In making macrotemperature changes, a constant increase of 12°C/hr with 3000 watts in the heating element and a decrease of 8°C to 12°C/hr are possible. This latter change becomes slower as the tank temperature approaches that of the external tank.

Thermometers may be aligned and read rapidly.

RECOMMENDATIONS

1. Continue development to include installation of electronic time-proportioning switches in metering of heat transfer.

2. Study the possibility of an instrument to record temperatures at two points in the tank, throughout any operation.

Navy Electronics Laboratory
Report 784

A TEMPERATURE-CONTROLLED TANK FOR CALIBRATING REVERSING THERMOMETERS, by J. S. Black. 13 p., 6 May 1957. UNCLASSIFIED

A controlled-temperature tank for calibrating deep-sea reversing thermometers and other precise temperature-measuring instruments was developed and tested. The tank's 70-gallon capacity and remote operation permit calibration of 24 reversing thermometers at one time. Temperature can be reproduced and held at $\pm 0.002°C$ over the range $-3°C$ to $40°C$.

1. Thermometers — Calibration
2. Water tanks — Applications

I. Black, J. S.

IO 15401
NE 120221-13 (NEL L4-1)

This card is UNCLASSIFIED

Navy Electronics Laboratory
Report 784

A TEMPERATURE-CONTROLLED TANK FOR CALIBRATING REVERSING THERMOMETERS, by J. S. Black. 13 p., 6 May 1957. UNCLASSIFIED

A controlled-temperature tank for calibrating deep-sea reversing thermometers and other precise temperature-measuring instruments was developed and tested. The tank's 70-gallon capacity and remote operation permit calibration of 24 reversing thermometers at one time. Temperature can be reproduced and held at $\pm 0.002°C$ over the range $-3°C$ to $40°C$.

1. Thermometers — Calibration
2. Water tanks — Applications

I. Black, J. S.

IO 15401
NE 120221-13 (NEL L4-1)

This card is UNCLASSIFIED

Navy Electronics Laboratory
Report 784

A TEMPERATURE-CONTROLLED TANK FOR CALIBRATING REVERSING THERMOMETERS, by J. S. Black. 13 p., 6 May 1957. UNCLASSIFIED

A controlled-temperature tank for calibrating deep-sea reversing thermometers and other precise temperature-measuring instruments was developed and tested. The tank's 70-gallon capacity and remote operation permit calibration of 24 reversing thermometers at one time. Temperature can be reproduced and held at $\pm 0.002°C$ over the range $-3°C$ to $40°C$.

1. Thermometers — Calibration
2. Water tanks — Applications

I. Black, J. S.

IO 15401
NE 120221-13 (NEL L4-1)

This card is UNCLASSIFIED

Navy Electronics Laboratory
Report 784

A TEMPERATURE-CONTROLLED TANK FOR CALIBRATING REVERSING THERMOMETERS, by J. S. Black. 13 p., 6 May 1957. UNCLASSIFIED

A controlled-temperature tank for calibrating deep-sea reversing thermometers and other precise temperature-measuring instruments was developed and tested. The tank's 70-gallon capacity and remote operation permit calibration of 24 reversing thermometers at one time. Temperature can be reproduced and held at $\pm 0.002°C$ over the range $-3°C$ to $40°C$.

1. Thermometers — Calibration
2. Water tanks — Applications

I. Black, J. S.

IO 15401
NE 120221-13 (NEL L4-1)

This card is UNCLASSIFIED

INITIAL DISTRIBUTION LIST

(One copy to each addressee unless otherwise specified)

Chief, Bureau of Ships (Code 312) (12 copies)
Chief, Bureau of Ordnance (Re6) (Ad3) (2)
Chief, Bureau of Aeronautics (TD-414)
Chief of Naval Operations (Op-37) (2)
Chief of Naval Research
(Code 416) (Code 466)
Commander in Chief, U. S. Pacific Fleet
Commander in Chief, U. S. Atlantic Fleet
Commander Operational Development Force, U. S. Atlantic Fleet
Commander, U. S. Naval Air Development Center (Library)
Commander, U. S. Naval Air Missile Test Center (Technical Library)
Commander, U. S. Naval Air Test Center (NANEP) (2)
Commander, U. S. Naval Ordnance Laboratory (Library) (2)
Commander, U. S. Naval Ordnance Test Station (Pasadena Annex Library)
Commanding Officer and Director, David Taylor Model Basin (Library) (2)
Commanding Officer and Director, U. S. Navy Underwater Sound Laboratory (Code 1450) (3)
Director, U. S. Naval Engineering Experiment Station (Library)
Director, U. S. Naval Research Laboratory (Code 2021) (2)
Director, U. S. Navy Underwater Sound Reference Laboratory (Library)
Commanding Officer, Office of Naval Research, Pasadena Branch
Hydrographer, U. S. Navy Hydrographic Office (1)
(Air Weather Service Liaison Office) (1)
(Division of Oceanography) (1)
Senior Navy Liaison Officer, U. S. Navy Electronics Liaison Office
Superintendent, U. S. Naval Postgraduate School (Library) (2)
Assistant Secretary of Defense (Research and Development) (Technical Library Branch)

Assistant Chief of Staff, G-2, U. S. Army (Document Library Branch) (3)
Chief of Engineers, U. S. Army (Engineer Research and Development Division, Field Engineering Branch)
The Quartermaster General, U. S. Army (Research and Development Division, CBR Liaison Officer)
Commanding General, Redstone Arsenal (Technical Library)
Commanding Officer, Transportation Research and Development Command (TCRAD-TO-1)
Chief, Army Field Forces (ATDEV-8)
Resident Member, Beach Erosion Board, Corps of Engineers, U. S. Army
Commander, Air Defense Command
(Office of Operations Analysis, John J. Crowley)
Commander, Air University (Air University Library, CR-5028)
Commander, Strategic Air Command (Operations Analysis)
Commander, Air Force Armament Center (ACGL)
Commander, Air Force Cambridge Research Center (CRQST-2)
Executive Secretary (John S. Coleman), Committee on Undersea Warfare, National Research Council
Commandant, U. S. Coast Guard (Aerology and Oceanography Section)
Commander, International Ice Patrol, U. S. Coast Guard
Director, U. S. Coast and Geodetic Survey
U. S. Fish and Wildlife Service, Pacific Oceanic Fishery Investigations (Library), Honolulu
U. S. Fish and Wildlife Service, La Jolla, California
(Dr. E. H. Ahlstrom)
(South Pacific Fishery Investigations, John C. Marr)
Brown University, Director, Research Analysis Group
University of California, Director, Marine Physical Laboratory, San Diego, California

University of California, Director, Scripps Institution of Oceanography (Library), LaJolla, California
The Johns Hopkins University, Director, Chesapeake Bay Institute (Library), Annapolis, Maryland
Massachusetts Institute of Technology
Director, Acoustics Laboratory (John A. Kessler)
University of Miami, Director, Marine Laboratory
University of Southern California, Department of Geology (K. O. Emery)
Agricultural and Mechanical College of Texas, Head, Department of Oceanography (Dr. D. F. Leipper)
The University of Texas
Director, Defense Research Laboratory
University of Washington, Department of Oceanography (Dr. R. H. Fleming, Executive Officer)
(Fisheries-Oceanography Library)
Yale University
Director, Bingham Oceanographic Laboratory
Director, Lamont Geological Observatory (M. Ewing)
The Director, Woods Hole Oceanographic Institution
Vitro Corporation of America, Silver Spring Laboratory (Library)

NAVY — NEL San Diego, Calif.