GALLIUM APPARATUS
MODEL 17402B
INCLUDES
GALLIUM CELL
MODEL 17401

Isotech North America
158 Brentwood Drive, Unit 4
Colchester, VT 05446

Phone: (802)-863-8050
Fax: (802)-863-8125

www.isotechna.com
sales@isotechna.com

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EMC INFORMATION

This product meets the requirements of the European Directive on Electromagnetic Compatibility (EMC) 89/336/EEC as amended by EC Directive 92/31/EEC.

The product meets the susceptibility requirements of EN 50082-1, criterion B.

ELECTRICAL SAFETY

This equipment must be correctly earthed.

This equipment is a Class 1 Appliance. A protective earth is used to ensure the conductive parts cannot become live in the event of a failure of the insulation.

The protective conductor of the flexible mains cable which is coloured green/yellow MUST be connected to a suitable earth.

The Blue conductor should be connected to Neutral and the Brown conductor to Live (Line).

Warning: Internal mains voltage hazard. Do not remove the panels.

There are no user serviceable parts inside. Contact your nearest Isotech agent for repair.

Voltage transients on the supply must not exceed 2.5kV.

HEALTH AND SAFETY INSTRUCTIONS

1. Read all of this handbook before use.

2. Wear appropriate protective clothing.

3. Operators of this equipment should be adequately trained in the handling of hot and cold items and liquids.

4. Do not use the apparatus for jobs other than those for which it was designed, ie. the calibration of thermometers.

5. Do not handle the apparatus when it is hot (or cold), unless wearing the appropriate protective clothing and having the necessary training.

6. Do not drill, modify or otherwise change the shape of the apparatus.

7. Do not dismantle the apparatus without disconnecting it from the supply and leaving time for it to reach ambient temperature.

8. Do not use the apparatus outside its recommended temperature range.

9. If cased, do not return the apparatus to its carrying case until the unit has cooled.

10. There are no user serviceable parts inside. Contact your nearest Isotech agent for repair.

11. Ensure materials, especially flammable materials are kept away from hot parts of the apparatus, to prevent fire risk.

12. Ensure adequate ventilation when using oils at high temperatures.

13. Each apparatus is protected by an over temperature circuit. Please consult handbook for details.

Product covered by this document are described in our manual attached.

GUARANTEE

This instrument has been manufactured to exacting standards and is guaranteed for twelve months against electrical break-down or mechanical failure caused through defective material or workmanship. Failure caused by misuse is not covered. In the event of failure covered by this guarantee, the instrument must be returned, carriage paid, to the supplier for examination, and will be replaced or repaired at our option.

FRAGILE CERAMIC AND/OR GLASS PARTS ARE NOT COVERED BY THIS GUARANTEE

INTERFERENCE WITH, OR FAILURE PROPERLY TO MAINTAIN, THIS INSTRUMENT MAY INVALIDATE THIS GUARANTEE

RECOMMENDATION

The life of your **ISOTECH** Instrument will be prolonged if regular maintenance and cleaning to remove general dust and debris is carried out.

Serial No:..

Date:...

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The Company is always willing to give technical advice and assistance where appropriate. Equally, because of the programme of continual development and improvement, we reserve the right to amend or alter characteristics and design without prior notice. This publication is for information only.

INTRODUCTION TO THE PRODUCTS

The ITL Model 17401 Gallium Cell is a cell containing 425 grams of the metallic element gallium of 99.99999+% ("seven nines"+) purity. The cell is intended for use in realising a thermometric fixed point for the calibration of thermometers. It is designed to be used in the ITL Model 17402B Gallium Temperature Standard apparatus, but can also be used in a liquid calibration bath that is equipped with an accurate temperature control facility.

The Gallium Cell is composed of a closed tube machined from "Teflon" rod, which contains the gallium, and a thermometer-well also machined from Teflon rod, which extends into the gallium. The well is lined with thin-wall stainless steel tubing in its lower 12 inches and is extended upwards to form a convenient handle for the cell and guide tube for the thermometer to be calibrated. A shell of anodized aluminium surrounds the tube to help equalise temperature along its length, and to stabilise mechanically the Teflon, particularly during the freezing-expansion of the gallium which is about 3%. A jacket of plastic tubing is shrunk over the aluminium shell to reduce electrolytic corrosion when the cell is in contact with the metal parts of its melt environment, and to provide a more uniform thermal resistance between the cell and its environment. Dimensions and a cross-section of the cell are shown in Figure 1.

The ITL Model 17402B Gallium Temperature Standard apparatus is completely automated and with a Model 17401 Gallium Cell, provides a complete temperature standard system. The 17402B is a bench-top unit which provides a controlled environment for melting and refreezing the gallium in the cell. The control unit is designed to provide an environment in which the gallium melt plateau is realised for a period of approximately 12 to 16 hours, and also to provide an environment in which the gallium in the cell is refrozen in such a way as to minimize the risk of damage due to freezing-expansion. Its functional features include a temperature-controlled well for the cell and a control panel with a timer. On plugging the Automated Gallium Melter into the supply a 24 hour timer is energized. (This is with the control knob in the auto position). It has been pre-programmed to slowly melt the cell over 20 hours and to refreeze it for 4 hours after which the process is automatically repeated. The control unit requires neither external adjustments nor periodic recalibration (it has several internal adjustments which affect the timing of the operating sequence only). If repair is necessary, adjustment requires a DMM, a laboratory oscilloscope and a thermometer capable of indicating temperatures of the order of 30°C to within ±0.1°C. (Contact the factory for additional information.)

A brief description of the system start-up sequence is as follows (see unpacking and setup section for a detailed procedure): The cell is placed in the control-unit well and the control unit is set to "MELT" mode for 24 hours to ensure that all of the gallium in the cell is liquid. The axis of the cell is disposed vertically to give radially uniform contact between gallium and thermometer pocket.

The control unit is then switched to "FREEZE" mode, which causes the gallium to freeze upwards from the bottom of the cell to minimize stress due to freezing-expansion. The "FREEZING" indicator will remain lit until all of the gallium in the cell is frozen, at which time the system is ready for initiation of a melt sequence for thermometer calibration. The control unit is designed to be left switched on during periods of frequent use, although, without power, it still provides a proper freezing environment for the cell. The normal melt sequence is initiated by switching the mode-switch to "MELT".

When the "WARM UP" indicator goes off, the gallium in the cell is on its melt-plateau and a thermometer in the well of the cell may be calibrated as soon as it has had time to equilibrate with the cell temperature. 17cc of water should be introduced into the well to ensure good thermal contact.

PRODUCT SPECIFICATIONS

MODEL 17401 GALLIUM CELL AND MODEL 17402B GALLIUM TEMPERATURE STANDARD

Temperature (as defined by ITS-90) of the solid-liquid equilibrium of gallium at 1 standard atmosphere pressure is 29.7646°C ±0.0002°C. It is expected that the uncertainty will be reduced by continuing investigation.

GALLIUM PURITY
7N+ (99.99999+%) (semiconductor grade)

CERTIFICATION
Each cell is accompanied by a certificate of traceability to the ITS-90. The certificate will state the mean and standard deviation of a number of measurements of the equilibrium temperature of the cell. Since this temperature is a constant of nature, recertification is normally never required. However some approval schemes require intercomparisons on a 4 yearly basis.

PLATEAU DURATION
Under the specified ambient conditions, not less than 12 hours (15 hours is typical).

CYCLE TIME
With the cell starting at 20°C, the time taken to reach the melt plateau in Model 17402B should not exceed 45 minutes and is typically 32 minutes. A panel lamp indicates when this condition has been reached. Time to recycle, including time to refreeze the cell, is typically 3 to 4 hours.

THERMOMETER WELL DIMENSION
The thermometer well will accommodate any thermometer with diameter less than 11.65mm (0.460"), requiring less than 230mm (9.0") of active stem immersion, and with total stem length not less than 370mm(14.5"). Such thermometers include Hewlett Packard Models 18111A and 18112A Quartz Crystal Thermometers and laboratory standard platinum resistance thermometers such as ITL Models 909 & 962.

POWER REQUIREMENTS
50 W maximum for 115VAC, 50-60 Hz or 230VAC, 50-60 Hz supplies.

AMBIENT TEMPERATURE LIMITS
Storage, -20 to +55°C; operating, 15 to 28°C.

AMBIENT HUMIDITY UPPER LIMIT
70% RH.

UNPACKING AND SETTING UP OF ITL MODEL 17402B GALLIUM TEMPERATURE STANDARD

Unpack the control unit carefully. Look for the detachable power cable.

Unpack the Model 17401 Gallium Cell. Note that this cell has been shipped in a refrigerated container. Gallium is not highly reactive chemically, but, because it can weaken the grain boundaries of aluminium, it is classified and, consequently, there is a requirement that the cell be packed in such a way as to ensure that the gallium remains in the solid state during shipment. It is suggested that the packing container be retained, in case later shipment by common carrier is required.

Place the control unit on a relatively level surface to avoid accidental overturn. Connect the power cable to the module and then to an appropriate power source. Check the indicated voltage on the power-connector fuse-block. If the voltage is not correct, open the fuse door, replace the fuse (500mA anti-surge), if necessary, and rotate the drum to the correct position. Once connected the 24 hour pre-programmed cycle is initiated. (With the control knob in auto position).

The system is now ready for use as a temperature standard after 1 hour.

AUTOMATIC TIMER

The equipment incorporates a timer which can switch between MELT and FREEZE modes. Once initiated the cell can be arranged to be on the melt plateau during the day and automatically frozen and brought back to the melt plateau overnight.

Alternatively the front panel switch can select MELT and FREEZE modes manually in which case the timer continues running through the cycle but no automatic switching occurs,

OPERATION OF THE 17402B GALLIUM TEMPERATURE STANDARD

To initiate a melt sequence, just plug the unit into the supply. The "WARM UP" indicator will light for 30 to 35 minutes.

When the "WARM UP" light goes off, the gallium is in solid-liquid phase equilibrium and is ready for use in the calibration of thermometers (note, however, that the thermometer and any heat transfer fluid in the thermometer well may not be in equilibrium with the gallium, depending upon the thermal mass in the well). For most accurate measurements, it is recommended that measurement be deferred until the "WARM UP" light has been off for at least 15 minutes. The module is designed to hold the cell on the melt plateau for a minimum of 12 hours (when ambient temperature is 15-30°C) with most thermometers. For thermometers with stems having high heat transfer rates to ambient, longer plateau duration times may occur or, in extreme cases, melting may not occur. A typical plateau duration with a quartz-sheathed Standard Platinum Resistance Thermometer is about 15 hours.

To calibrate a thermometer, place the thermometer in the well of the gallium cell. If a heat-transfer fluid is used, limit the fluid contact to the lower 175mm (7 inches) of the thermometer stem. If more transfer fluid is used, it may pipe ambient heat to the sensing element of the thermometer and this may result in erroneous measurements.

If a number of thermometers are to be calibrated, the quantity of heat extracted from the cell can be reduced, and the equilibrium plateau maintained, by bringing each thermometer approximately to temperature (for example, in a water bath) before transferring it to the gallium cell. In a long series of calibrations it may be advisable to monitor the cell occasionally with one of the first thermometers calibrated to ensure that the plateau is still in existence.

After a period of 20 hours the unit automatically refreezes the Gallium and recommences the melt cycle after 24 hours from the initial start up. (Auto Mode).

THEORY OF OPERATION/CIRCUIT DESCRIPTION, 17402B CONTROL UNIT

The 17402B control unit with a 17401 gallium cell is designed to be a complete, automated temperature standard system for realizing the melting point of gallium. To accomplish this, the control unit must provide an environment in which the gallium in the cell will maintain its melting phase transition for a useful period of time, and then allow the gallium in the cell to be frozen without damaging the cell as expansion takes place. The control unit heater well assembly is a copper tube surrounded by a heater, and having a thermoelectric heat pump module (TEHP) attached to its base. It has two precision, high-stability, thermistor temperature sensors, one near the top, and the other near the bottom. The temperature control circuit has two main operating modes, each of which can be devided into phases. The "MELT" mode has two phases. The "WARM UP" phase provides a well temperature of 31.6°C to bring the cell to operating temperature, after which the "WARM UP" light goes off and the well temperature is reduced to 30.4°C to maintain the melt plateau. The "FREEZE" mode also has two phases. The "FREEZING" phase applies full power to the TEHP until the temperature at the top of the well drops below 26°C, at which time the "FREEZING" indicator goes off and the well temperature will be constrained to remain not greater than 26°C by the cooling function of the TEHP. In addition to the active "FREEZE" mode, the control unit is designed to allow safe passive (power off) freezing of the gallium in the cell by ensuring that the thermal resistance from the gallium to ambient is lower at the bottom of the cell than at the top. This is possible because of the relatively low thermal resistance of the TEHP with power off.

Temperature control in the "MELT" mode is accomplished by two interconnected proportional control circuits with, additionally, sensing timing, and logic for automatic switching of the setpoint at the end of the "WARM UP" phase. The sensor input circuit is a "three legged" wheatstone bridge with two identical sensor legs. The main control loop uses R6 and the top thermistor (RT1), while the differential loop uses R7 and the bottom thermistor (RT2). The third leg of the bridge is made up of fixed resistors R8, R9, R10, R12 and R19 with "setpoint" potentiometer R11, and a quad analog gate (U6) for warm-up offset and mode selection. Current is supplied through R5 to give a bridge voltage of about 3V. Amplifier U3 serves as a unity-gain buffer for the output of the top-thermistor leg of the bridge, while U4 compares the output of the bottom-thermistor leg to the output of U3. Component tolerances in the differential circuit are compensated by the "offset" potentiometer R15 and summing resistor R16. Main-error amplifier U5 compares the output of buffer U3 to the setpoint, producing a main-error signal of about 24V/°C. The main-error signal is fed to pulse-width modulator U8b which drives the base of heater switching transistor Q1, producing a final proportional band of about 0.2°C. The differential error signal at the output of U4 represents the vertical temperature gradient of the heater-well at a sensitivity of about 10V/°C with integral feedback provided by C7.

This error signal is pulse-width-modulated by U8c to drive the TEHP in the heating direction through output amplifier U8a, Q2 and Q3. This "reverse" drive applied to the TEHP forces it actively to simulate an ideal thermal insulator by eliminating vertical temperature gradients in the heater well. The general goal of the "MELT" mode is to minimise "WARM UP" time and maximise melt plateau duration. This is accomplished by sensing the thermal condition of the cell at the beginning of the "MELT" mode, and adding heat to the cell accordingly. The main-error signal (U5 output) is a good indicator of the cell's thermal condition since it is directly proportional to the thermal load on the heater-well.

The load on the heater decreases rapidly as the aluminium shell of the cell approaches the temperature of the well.

The main-error signal is compared to the slider of R37 by U8d, which controls the "reset" input of counter/frequency divider U9. The output of U9 will be low as long as its "reset" input is high, and for 2048 clock-cycles thereafter. The system clock, U10, operates with a period of 0.732 seconds, thus producing a delay of 25 minutes. The output of U9 drives the "WARM UP" indicator via Q6, and keeps U6c closed via U7d & U6d, which keeps the control circuit operating at the higher of its two setpoints. Maintaining "WARM UP" temperature for 25 minutes allows for the effect of the thermal inertia (time constant) of the cell contents and the Teflon structure surrounding the gallium.

After 20 hours when the timer switches to ‘freeze’ mode the function of linear, proportional, cooling-only temperature control with a setpoint of approximately 26°C. When the "MELT" control signal goes low, and the "FREEZE" control signal goes high, analog gates U7a, U7c & U7d are opened, disabling all of the heating circuits, while U7b enables the cooling circuit. The setpoint is lowered by opening U6b and closing U6a. The "FREEZE" mode control loop uses the main-error signal to drive the TEHP directly through the output-amplifier. Since the top thermistor is used to control the TEHP, which is attached to the base of the well, the control circuit produces considerable overshoot, which is desirable in this case since it reduces the possibility of leaving the gallium in the cell in an supercooled state.

As in the "MELT" mode, the thermal load on the TEHP (and thus the main-error signal voltage) is an indication of the cell's approach to thermal equilibrium with the well. The main error signal will be near the +12V supply until the controller enters its linear range, indicating that all of the gallium in the cell is frozen. After the temperature at the top of the cell has dropped to 26°C, the main-error signal will fall below 4V at high ambient temperatures, or go to the negative rail at low ambient temperatures. The main error signal, via Q4 & Q5, also drives the "FREEZING" indicator, causing it to stay on until all of the gallium in the cell is frozen.

MAINTENANCE

The only required periodic maintenance of the control unit is occasional inspection and cleaning of the interior of the heater well. Look for foreign material or fluid which may alter heat transfer to the cell. Cleaning may be accomplished with water, alcohol or other materials compatible with copper and polyethylene.

CAUTION

DO NOT USE CORROSIVE SOLUTIONS TO CLEAN THE WELL; ANY RESIDUE MAY CAUSE RAPID DETERIORATION OF THE ALUMINIUM JACKET OF THE GALLIUM CELL

TROUBLE SHOOTING AND REPAIR

If the module fails to operate properly, it may be returned to the factory for repair, or may be serviced by any competent electronics technician. If the module is to be repaired by the user, observe the condition of the indicator lights and the temperature of the heater well, and then refer to the theory of operation and the drawings to locate the defective component.

CAUTION

HAZARDOUS VOLTAGES ARE PRESENT INSIDE THE MODULE CABINET. DISCONNECT THE POWER CABLE BEFORE REMOVING ANY PART OF THE CASE - REFER TO CASE REMOVAL PROCEDURE.

CASE REMOVAL PROCEDURE (to gain access to the circuitry):

1. Remove the 4 screws at the corners of the control panel and unplug the panel connector.
   Disconnect timer and remove retaining clip.

2. Remove the cabinet after extracting the 4 screws from the back. Be careful to avoid undue sideward pressure on the heater well.

3. Place the module on its left side and remove the 2 screws at the top of the bottom panel.

4. Return the module to an upright position and remove the remaining 7 screws which attach the right side to the front, top and back panels (the right side is the side which is further from the well).

If the heater-well is defective it must be returned to the factory for repair or replacement. By detaching the top panel and then extracting the four flat-head screws that attach the cooler block to the bottom panel, the well and insulation may be removed as a unit.

ADJUSTMENT PROCEDURE

Adjustment should be performed whenever a component is replaced in the system clock or controller input circuits or in the event that warm-up time or plateau time becomes unreasonable.

CAUTION

HAZARDOUS VOLTAGES ARE PRESENT INSIDE THE MODULE CABINET. DISCONNECT THE POWER CABLE BEFORE REMOVING ANY PART OF THE CASE.

1. Remove the power cable and open the case as described under "CASE REMOVAL PROCEDURE".

2. Using due caution, reconnect the control panel and then the power cable.

3. Set an oscilloscope for 5V/division, 0.1 second/division and connect it from the chassis to R44 (see component layout diagram P11). The clock period should be 0.73 ±0.02 seconds. Adjust R46 if necessary to obtain this value.

4. With the control unit in "MELT" mode, place a temperature-measuring probe against the inside of the well 280mm (11 inches) above the bottom. After the "WARM UP" light has been off for 10 minutes, the temperature should be 30.30 ±0.05°C. If the temperature is out of tolerance, disable the warm-up circuit by connecting a jumper across R39 and then adjust R11 to correct. Temperature stability should be obtained within a few minutes.

5. Move the probe down to the bottom of the well. The temperature should be 30.30 ±0.05°C. Adjust R15 if necessary to correct.

6. Remove the warm-up jumper.

7. Connect a DMM to the slider of R37. The voltage should be 7.0 ±0.05. Adjust R37, if necessary, to obtain this value.

ADJUSTING THE TIMER

Programming the Timer

(01) Remove the Power Supply from the Unit.

(02) Press down and hold the SET button for five seconds, until the timing mode currently selected begins to flash.

(03) Press the Up Arrow button until ICY+ is flashing and press SET to select.

(04) The decimal place and timing ranges should now be flashing, with the ICY+ symbol showing in timing mode area. Use the Up Arrow until the timing range is set to HRS (hours) and the Set Time is set for a single decimal place. Press the SET button to proceed.

(05) The decimal place and timing ranges should now be flashing, with the ICY- symbol showing in timing mode area. Use the Up Arrow until the timing range is set to HRS (hours) and the Set Time is set for a single decimal place. Press the SET button to proceed.

(06) The display will now flash the ∧ or the ∨ symbol in the top left corner. Use the Up Arrow button to alternate between the two. Press SET to select. The ∧ means that when operating the display will show the time elapsed, and ∨ means that the display will show the time remaining.

(07) Now with ICY+ showing the first digit will be flashing. To set the time spent freezing use the Up Arrow button to select the required value. Press SET. The Second digit will now flash, use the Up Arrow button to select the required value. Press SET. The last digit will now flash, set the final digit with the Up Arrow button and press SET to proceed.

(08) Now with ICY- showing the first digit will be flashing. To set the time spent melting use the Up Arrow button to select the required value. Press SET. The Second digit will now flash, use the Up Arrow button to select the required value. Press SET. The last digit will now flash, set the final digit with the Up Arrow button and press SET.

(09) The display will now become blank. The setup is complete and the unit is now ready for use.

(10) Upon powering up the unit will begin to freeze.

APPENDIX A

THERMOMETRIC FIXED POINTS (a tutorial note)

Temperature scales used in science and industry are defined by a series of "fixed points", which are realised by establishing thermal conditions under which pure materials exhibit equilibrium between two or three phases. A scale assigns numerical values to the temperatures at which these phase equilibria exist. For example, the temperature at which pure water exists simultaneously in its liquid, solid and gas phases (triple point) has been assigned the numerical value of 0.01°C on the International Temperature Scale, and the value of 273.16K on the Kelvin Thermodynamic Temperature Scale. Examples of other defining fixed points of the International Temperature Scale of 1990 are the respective liquid-solid equilibria of tin, zinc and silver under 1 standard atmosphere pressure.

In some important disciplines it is desirable to realise a thermometric fixed point between 0 and 100°C, frequently in the vicinity of body or environmental-temperature. The melting temperature of high purity gallium, 29.7646°C, is a fixed point that can be useful in this context.

The solid-liquid equilibrium point of gallium is realised in cells such as those shown in figure 1 or reference 2. A quantity of pure gallium is contained in a vessel which provides, also, a re-entrant well for insertion of a thermometer. The cycle for realising the melt equilibrium is as follows:

The gallium starts in a single phase, assumed for present purposes to be liquid. The cell is placed in a cold environment until the gallium has solidified. The phase-change of the metal can be determined by tracing the temperature of the well. As the metal cools from the liquid phase, the temperature will begin to fall. An initial smooth drop in temperature will be observed, and then at some temperature below the freezing temperature there will be seen a reversal and a subsequent rise in temperature. This "undercool" phenomenon is characteristic of many pure materials, most of which can remain liquid at temperatures below their normal freezing points (if the metal were initially solid, the temperature would fall uninterruptedly to that of the cold environment).

The reversal takes place as the first crystalline solid forms in the liquid; the temperature rises to the liquid-solid equilibrium plateau temperature as the metal gives up latent heat on freezing, remaining thereafter at this temperature until the metal is completely solid. Beyond this stage there will be a smooth drop in temperature to that of surrounding environment.

To establish the melting condition, the cell is then transferred to an environment maintained at a temperature slightly above the melt temperature of gallium. This environment may be a stirred fluid bath of sufficient heat capacity and control capability, or may be the module of the ITL Model 17402B Gallium Temperature Standard apparatus, which is designed automatically to raise the temperature of the cell to initiate melting of the metal and then to maintain it at a correct level. The temperature to which the cell is exposed to melt the metal does not determine the solid-liquid equilibrium temperature, but it can have a substantial effect on the duration of the (constant-temperature) melt plateau.

The monitoring thermometer will indicate a rise in temperature in the well as the solid gallium approaches the melt temperature. Then, beyond the instant at which liquid first begins to form, the temperature will remain constant until all the metal has melted. The end of the melt plateau is signalled by a rise in well temperature to the temperature of the surrounding environment. An ITL 17401 gallium cell used in the Model 17402B system can give a plateau duration of at least 12 hours.

The melting cycle is now complete. The material in the cell is entirely in the liquid phase. Another cycle may be started immediately, if desired.

17cc of water should be poured into the re-entrant tube to allow proper conduction between cell and thermometer.

For the highest accuracy measurements (to less than 0.1mK of the ITS-90 value) an hour should elapse between switching to melt and commencing measurements. Alternatively, once the melt has began the water in the well can be replaced by warm water at say 40°C to initiate a melt round the re-entrant tube. See CCT96/8 for additional guidance.

APPENDIX B

USE OF THE ITL MODEL 17401 GALLIUM CELL WITHOUT THE 17402B CONTROL UNIT

Model 17401 Gallium Cell may be used without the 17402B control unit if another means is provided for raising the temperature of the cell environment to the melt plateau and maintaining it for a reasonable period of time. Such a means may be a stirred bath, containing water or another fluid, of sufficient depth and heat capacity, and adequately controlled. The bath temperature should be approximately 30°C with a control tolerance of approximately ±0.05°C.

Some degree of experimentation is required to obtain longest plateaux for any particular type of thermometer. For any real thermometer with its sensing element not at ambient temperature, heat will be conducted along the thermometer stem. At a bath temperature very close to the gallium melt temperature, in the presence of a low ambient temperature, a highly conductive thermometer stem may prevent the attainment of melt temperature in the gallium. Conversely, plateau durations in excess of 72 hours have been obtained under a superior thermal regime.

Since gallium expands as it freezes, it is important to freeze the cell from the bottom upwards in order to avoid irreversible damage (note that ITL Model 17402B automatically does this).

REFERENCES GIVING FURTHER DETAIL

1. H.E. Sostmann, The Melting Point of Gallium as a Temperature Calibration Standard, Review of Scientific Instruments, 48 2, p. 217.

2. H.E. Sostmann, Temperature Measurement, Kirk-Other Encyclopaedia of Chemical Technology, Vol. 23, John Wiley & Sons, 1983.

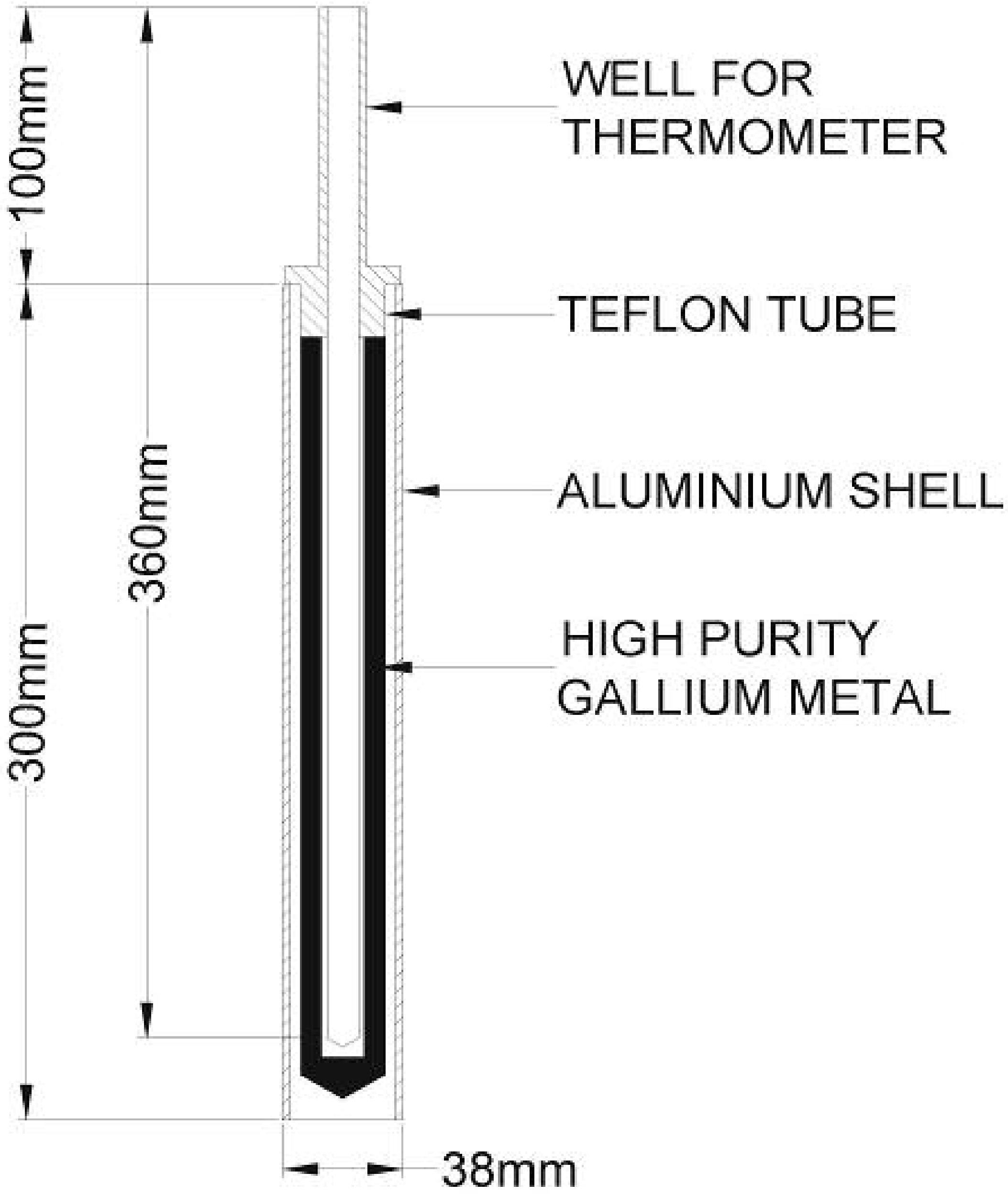

figure 1. GALLIUM CELL