

**DRY BLOCK CALIBRATOR
MODEL JUPITER^{PLUS} 650**
User Maintenance Manual/Handbook

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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.

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CE 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 and the European Low Voltage Directive 73/25/EEC, amended by 93/68/EEC. To ensure emission compliance please ensure that any serial communications connecting leads are fully screened.

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

| Symbol Identification | Publication | Description |
|---|-------------|-----------------------------|
|  | ISO3864 | Caution (refer to handbook) |
|  | IEC 417 | Caution: Hot Surface |

ELECTRICAL SAFETY

This equipment must be correctly earthed.

This equipment is a Class I Appliance. A protective earth is used to ensure the conductive parts can not 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.

Conductive pollution, e.g. Carbon dust, must be excluded from the apparatus. EN61010 pollution degrees 2.

The apparatus has two input connectors for temperature sensors; see Figure 1 (page 36). These inputs are only suitable for either a thermocouple or resistance thermometer. No other sensor or signal may be connected.

Environmental Ratings

Operating Temperature 0-50°C

Relative Humidity 5-95%, non condensing

HEALTH AND SAFETY INSTRUCTIONS

1. Read this entire 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, i.e. 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.
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.

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, provided the failure is not the result of misuse. 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 TO PROPERLY 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.

We recommend that this instrument to be re-calibrated annually.

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Insert Warning

The inserts are specially processed for use with the Jupiter^{PLUS}. It is important that only inserts supplied by Isothermal Technology Ltd are used. Failure to comply with this information may result to damage the Jupiter which would not be covered under warranty.

CAUTIONARY NOTE

ISOTECH PRODUCTS ARE INTENDED FOR USE BY TECHNICALLY TRAINED AND COMPETENT PERSONNEL FAMILIAR WITH GOOD MEASUREMENT PRACTICES.

IT IS EXPECTED THAT PERSONNEL USING THIS EQUIPMENT WILL BE COMPETENT WITH THE MANAGEMENT OF APPARATUS WHICH MAY BE POWERED OR UNDER EXTREMES OF TEMPERATURE, AND ARE ABLE TO APPRECIATE THE HAZARDS WHICH MAY BE ASSOCIATED WITH, AND THE PRECAUTIONS TO BE TAKEN WITH, SUCH EQUIPMENT.

INTRODUCTION

The Jupiter^{PLUS} 650 series consists of two models, the Basic (B) and Site (S). Both models have been designed to be rugged and easily maintained.

By using a proprietary plug-in controller the total electronics package can be replaced in a few minutes. As can be seen from the parts list, remarkably few components have been used, each of which are easily removed and replaced. All models have a temperature range of 35 to 650°C.

Jupiter 650^{PLUS} Basic (B)

This model provides an isothermal enclosure (metal block) in which thermometers and thermostats can be checked against the temperature indicated on the temperature controller.

For traceable calibration a standard (reference) probe should be placed into the metal blocks alongside the units under test.

The probe under test should be calibrated by comparison to the standard probe.

Jupiter 650^{PLUS} Site (S)

The S is again similar to the B but this unit has the addition of a digital temperature indicator. The indicator is independent from the controller and can be programmed to work with a thermocouple or industrial Pt 100 resistance thermometer.

This combination of sensor and probe can be calibrated. Then the units under test can be compared to the independent calibrated measuring systems allowing for traceable calibration.

The Jupiter 650^{PLUS} Series represents the third generation of a ten year development program. During which many customer improvement suggestions have been incorporated into the models. Such suggestions have generally arisen from technical queries posed by equipment users, therefore please consult with us if at all unsure with any aspect of our equipment.

The Jupiter^{PLUS} 650 models are part of a range of portable calibrators designed and made by ourselves. Please contact us if you require more information about our other products.

UNPACKING AND INITIAL INSPECTION

Our Packing Department uses custom designed packaging to send out your unit, but as accidents can still happen in transit, you are advised, after unpacking the unit, to inspect it for any sign of shipping damage, and confirm that your delivery is in accordance with the packing note. If you find any damage or that part of the delivery is missing notify us or our agent, and the carrier immediately. If the unit is damaged you should keep the packing for possible insurance assessment.

ELECTRICITY SUPPLY

Before connecting to the electricity supply please familiarise yourself with the parts of the handbook relevant to your model.

Your unit's supply voltage requirement is specified on a plate on the instrument along with the serial number. All Jupiter units will work on an electricity supply frequency of 50Hz or 60Hz. The apparatus is provided with an approved power cord. If the plug is not suitable for your location then the plug should be removed and replaced with an appropriate plug.



Take care to ensure the old plug is disposed safely.

The cable is colour coded as follows:

| COLOUR | FUNCTION |
|--------------|----------------|
| Green/yellow | Earth (Ground) |
| Brown | Live (line) |
| Blue | Neutral |

Please ensure that your unit is correctly connected to the electricity supply.

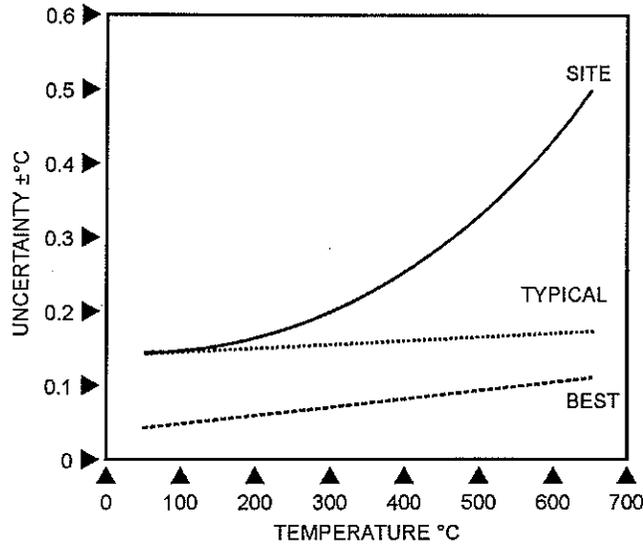
THE APPARATUS MUST BE CORRECTLY EARTHED (GROUNDED)

The units' on/off switch is located on the power inlet. Take care NOT to switch the unit off when it is hot - allow to cool first.

SPECIFICATION

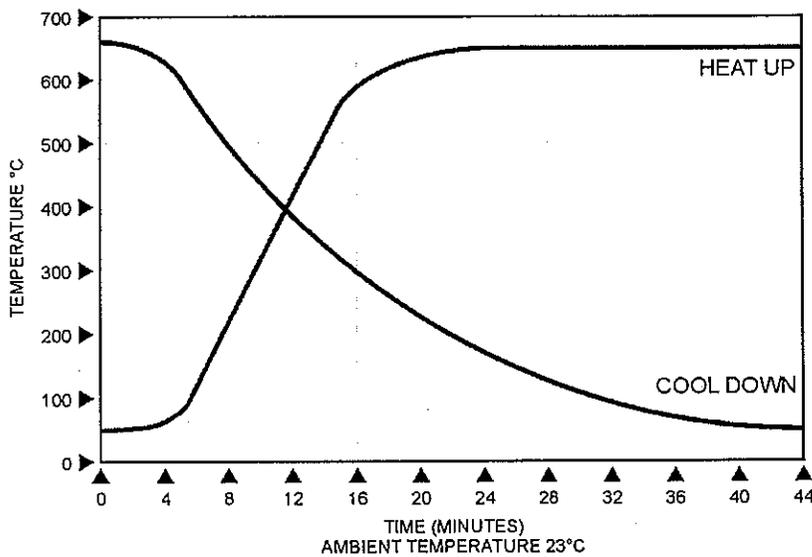
| | |
|-----------------------------------|--|
| Voltage | 230VAC (or 115VAC) see ratings plate |
| Power | 1kW |
| Supply Frequency | 50/60Hz |
| Maximum Operating Temperature | 650°C |
| Minimum Operating Temperature | 35°C (Ambient = 20°C) |
| Stability | 50°C ±0.02°C 250°C ±0.02°C 650°C ±0.03°C (Absolute over 30 Minutes) |
| Calibration Volume | 35mm dia by 148mm |
| Standard Insert Hole Dimensions | 2 x 6.4mm dia + 1 x 9.5mm dia + 1 x 8mm dia |
| Insert Options | Drillings available to customer requirements |
| Dimensions (not including handle) | Height 302mm Width 176mm Depth 262mm |
| Weight | 8.50Kg |

Jupiter^{PLUS} 650 Uncertainty



BEST UNCERTAINTY - USING JUPITER BASIC WITH A TTI2 AND A 935-14-72 CALIBRATION SYSTEM
 TYPICAL UNCERTAINTY - USING JUPITER BASIC WITH A TTI AND A 935-14-72
 SITE VERSION UNCERTAINTY - JUPITER SITE USING BUILT IN INDICATOR AT THE TIME OF CALIBRATION

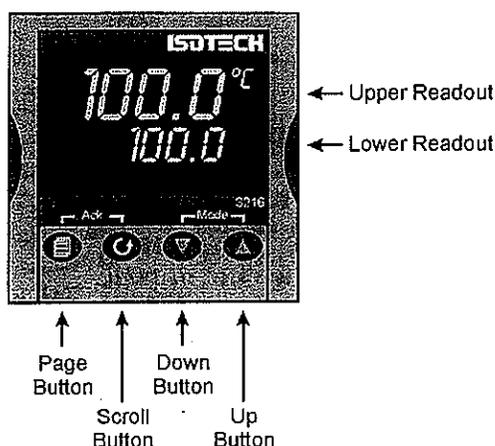
Jupiter^{PLUS} 650 Heat Up/Cool Down



A full evaluation of the Jupiter 650 is available contact the factory for availability

OPERATING THE PLUS MODEL

FRONT PANEL LAYOUT



The Temperature Controller

The controller has a dual display, the upper display indicates the nominal block temperature, and the lower display indicates the desired temperature or setpoint.

Altering the Setpoint

To change the setpoint of the controller simply use the UP and DOWN keys to raise and lower the setpoint to the required value. The lower display changes to indicate the new setpoint.

Advanced Controller Features

Setpoint Ramp Rate

By default the Dry Blocks are configured to heat and cool as quickly as possible. There may be some calibration applications where it is advantageous to limit the heating or cooling rate.

An example might be when testing bimetallic thermostats; by forcing the Dry Block to heat at a controlled rate it is easier to determine the temperature at which the thermostat changes state.

The Dry Block can have its heating rate limited with the Setpoint Ramp Rate feature. This feature is accessed from the Scroll key. Depress the key until the display shows,

SP.RAT

The upper display will show the current value, and is adjustable from OFF to 999.9. The units are °C/min and are adjustable via the UP/DOWN keys.

When the SP.RAT is active the lower setpoint display will now automatically update with the current value, known as the working setpoint. The setpoint can be seen by pressing either the UP and DOWN key.

The Setpoint ramp rate operates when the bath is heating and cooling.

Instrument Address

The controller has a configurable "address" which is used for PC communications. Each instrument has an address; this allows several instruments to be connected in parallel on the same communications bus. The default value is 1. This address would only need to be changed if more than one Dry Block is connected to the same PC port.

To check the Address value press the scroll key until the lower display indicates,

ADDR

The upper display will show the current value that can be modified with the UP and DOWN keys.

Monitoring the Controller Status

A row of beacons indicate the controllers status as follows,

| | |
|-----|---|
| OPI | Heat Output |
| OP2 | Cool Output (only for models which operate below 0°C) |
| REM | This beacon indicates activity on the PC interface |

For models fitted with cool down fans, such as the Calisto and Jupiter, the lower display will alternate between the setpoint and the message, cooling to temperature. This message is not an error but is showing that the cooling fan is operating. It will automatically switch off when the temperature is within 5°C of the setpoint.

Units

Momentary pressing of the Scroll key will show the controller units °C or °F.

The Temperature Indicator (Site (S) Models Only)

The site models include an electronic temperature indicator. The indicator can be configured for the desired sensor type, and for custom calibration data. The customer calibration data can be set ON or OFF.

Setting the Input Type

A 100 Ohm resistance thermometer can be connected to the PRT Connector or a thermocouple may be connected to the miniature TC Connector.

Ensure that only a PRT or a TC is connected at any one time. If a PRT and TC are connected simultaneously the indicator will read in error.

Check that any sensor placed into the equipment is suitable for the temperature range. Sensors can be damaged if taken outside their normal operating limits.

The desired sensor type is easily set, press the Scroll key until the lower display indicates,

In.Type

The upper display will show the current set sensor type,

| | |
|------|--|
| J.tc | J thermocouple |
| K.tc | K thermocouple |
| L.tc | L thermocouple |
| r.tc | R thermocouple (Pt/Pt13%Rh) |
| b.tc | B thermocouple (Pt30%Rh/Pt6%Rh) |
| n.tc | N thermocouple |
| t.tc | T thermocouple |
| S.tc | S thermocouple (Pt/Pt10%Rh) |
| PL.2 | PL 2 thermocouple |
| rtd | 100 Ohm platinum resistance thermometer. |
| T012 | E thermocouple |

Again the value can be modified with the UP and DOWN keys.

Enabling/Disabling Custom Calibration

Custom calibration allows the indicator to be programmed to suit a particular temperature sensor. This allows the indicator to automatically show the true temperature, without having to manually apply a correction.

When the Custom or User Calibration is active the indicator will show the REM beacon lit continuously. The use of User calibration can make a significant difference to the accuracy of the instrument, and this REM beacon provides a clear and continuous indication of the calibration status. Isotech will configure and set user calibration when the Dry Block is ordered with a temperature sensor.

To alter the calibration status press the Scroll key until the lower display shows,

UCAL

The upper display will indicate either,

ON for user calibration

Or

OFF for factory calibration of the indicator

Use the UP and DOWN keys to toggle between the two values.

When calibrating an unknown sensor against a calibrated probe it may be necessary to switch the calibration off for the unknown, and on for the calibrated probe.

Instrument Address

Like the controller, the indicator has a configurable "address" which is used for PC communications. Each instrument has an address; this allows several instruments to be connected in parallel on the same communications bus. The default value is 2 (The controller defaults to 1). This address would only need to be changed if more than one Dry Block is connected to the same PC port.

To check the Address value press the scroll key until the lower display indicates,

ADDR

The upper display will show the current value that can be modified with the UP and DOWN keys.

Monitoring the Indicator Status

For the indicator the REM beacon is lit continuously when the user calibration is active, the REM beacon flashes when the PC communications port is active.

Units

Momentary pressing of the Scroll key will show the controller units °C or °F.

Advanced Indicator Operation

The indicator can be configured with up to five custom calibration points; the points contain "data pairs". First the temperature (point) and secondly the Error (offset) at this temperature point. Isotech Dry Block calibration certificates will show the values to suit a particular sensor.

These values can be inspected, and modified with the following procedure,

Hold the PAGE key down until the display indicates,

CONF
GOTO

then

0
CODE

Set the Code to 2 with the UP key

The display reads,

CONF

Press the Page Key until the controller shows

CAL

Now use the Scroll key to examine the data pairs. The values Pnt 1 - Pnt 5 and Ofs 1 to Ofs 5 can be modified with the UP and DOWN keys.

To exit this mode hold the Page key until the top display shows,

CONF
GOTO

And then set the upper display to Lev 1. While in this mode take care not to modify other parameters.

CALIBRATION DATA EXAMPLE

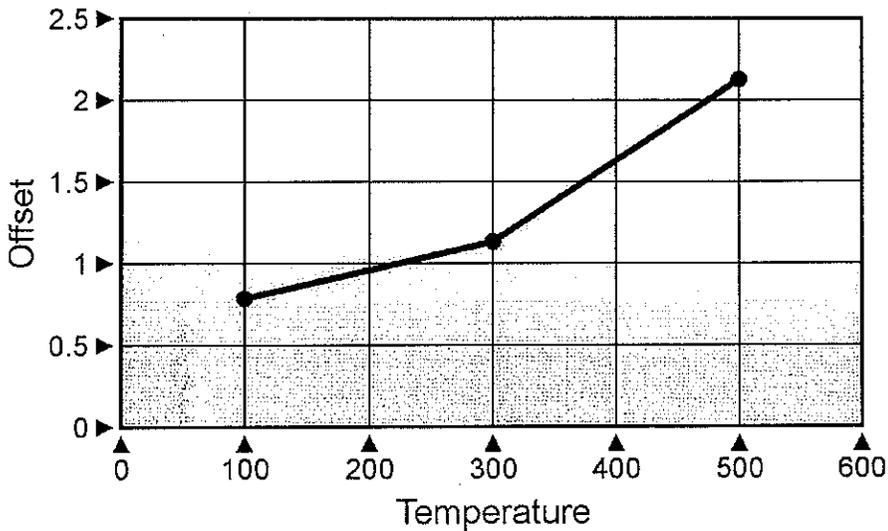
A maximum of five points may be entered, shown as Pnt 1 to Pnt 5 for the temperature point and Ofs 1 to Ofs 5 for the offset values.

The Pnt values must be entered in ascending order.

Set a Pnt to a value lower than the previous point to disable it.

The indicator would be programmed with the following data:

| | | | |
|-------|------|-------|-----|
| Pnt 1 | 100 | Ofs 1 | 0.8 |
| Pnt 2 | 300 | Ofs 2 | 1.1 |
| Pnt 3 | 500 | Ofs 3 | 2.1 |
| Pnt 4 | -999 | Ofs 4 | 0 |
| Pnt 5 | -999 | Ofs 5 | 0 |



Connecting a current transmitter (up to 20mA)

The transmitter should be powered externally, a 2.49Ohm current sense resistor is fitted internally and this allows the indicator to read mA.

- 1 From the input type menu select "mV".
- 2 The scaling can be configured in the CAL menu, accessed as described above.

Selecting Input Type

'HOME'
display



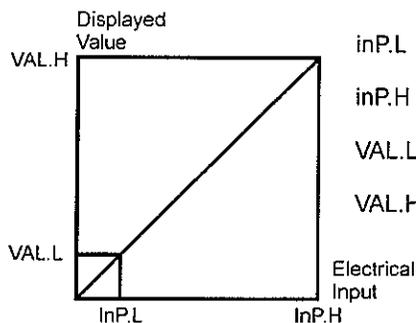
↓
Press scroll key
until in.typ appears

↓
Press 'Up/Down'
key to required
input.

From the input menu iP set the inP.L, inP.H, VAL.L and VAL.H parameters to suit see table below:

Linear Input Scaling - The next 4 parameters only appear if a linear input is chosen

e.g. 4 to 20mA = 0 to 100°C

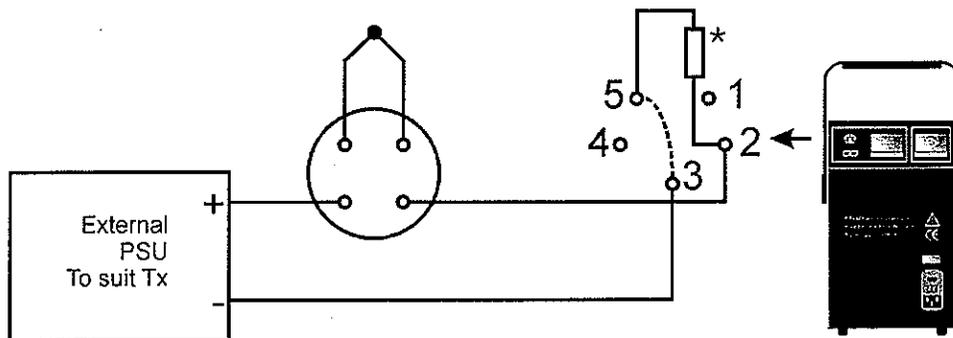


| | | |
|-------|------------------------|--------------------|
| inP.L | Input value low | i.e. 4mA set 9.96 |
| inP.H | Input value high | i.e. 20mA set 49.8 |
| VAL.L | Displayed reading low | 0°C |
| VAL.H | Displayed reading high | 100°C |

E.g. 4-20mA = 0 to 100°C

| | | | |
|-------|---|-----------|----------------|
| inP.L | = | 9.96 (mV) | (4mA x 2.49Ω) |
| inP.H | = | 49.8 (mV) | (20mA x 2.49Ω) |
| VAL.L | = | 0 (°C) | |
| VAL.H | = | 100 (°C) | |

Exit config level by pressing PAGE key until the top display shows Exit, use the UP key to select YES, after two seconds the instrument will reset.



*2.49Ω resistor fitted internally (Pins 2 and 5).

Link Pins 3 and 5 for transmitter inputs.

Remove link for T/C's and PRT's.

Socket Pins shown from Panel View

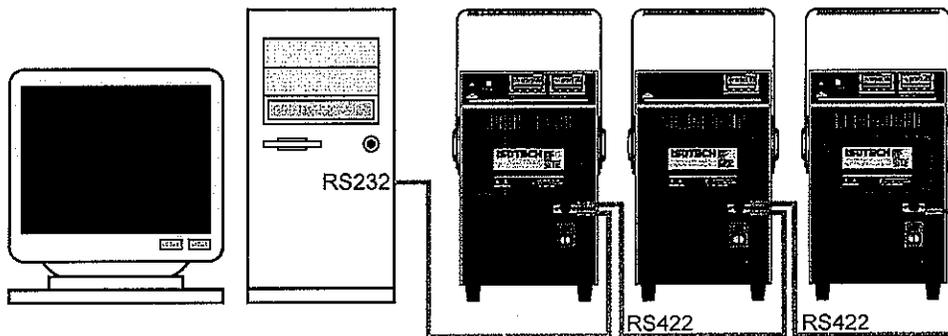
Testing Thermal Switches

The site Model Jupiter's include a switch test facility which is used in conjunction with the supplied Cal Notepad Software. See Cal NotePad manual or instructions on how to use this.

Using the PC Interface

The PLUS models include an RS422 PC interface and a special converter cable that allows use with the standard RS232 port. When using the bath with an RS232 port it is essential that this converter cable is used. Replacement cables are available from Isotech, part number ISO-232-432. A further lead is available as an option, Part Number ISO-422-422 lead which permits up to 5 instruments to be daisy chained together.

The benefit of this approach is that a number of calibration baths may be connected together in a "daisy chain" configuration - and then linked to a single RS232, see diagram.



Note: The RS 422 standard specifies a maximum lead length of 1200M (4000ft). A true RS422 port will be required to realise such lead lengths. The Isotech conversion leads are suitable for maximum combined lead lengths of 10M that is adequate for most applications.

Connections

For RS232 use simply connect the Isotech cable, a 9 to 25 pin converter is included to suit PCs with a 25 pin serial converter.

RS422 Connections

| Pin | Connection |
|-----|------------|
| 4 | Tx+ A |
| 5 | Tx- B |
| 8 | Rx+ A |
| 9 | Rx- B |
| 1 | Common |

Using the Interface

The models are supplied with Cal NotePad as standard. This easy to use package is compatible with MS Windows 9X, XP. A handbook for Cal NotePad can be found on the first installation disk in Adobe PDF format. If required a free Adobe PDF reader can be downloaded from, www.adobe.com.

CAL NOTEPAD

Cal Notepad can be used to log and display values from the Dry Blocks and an optional temperature indicator.

Minimum System Requirements

CNP requires Windows 9X, XP, a minimum of 5Mb of free hard drive space and free serial ports for the instruments to be connected.

Development

CNP was developed by Isothermal Technology using LabVIEW from National Instruments.

License

Use of the Cal NotePad software program "CNP" is as granted in this license agreement. In using the CNP software the user "licensee" is agreeing to the terms of the license. You must read and understand the terms of this license before using CNP.

- 1, This license permits licensee to use CNP software on a single computer. The user may make copies for back up and archival purposes freely as long as the software is only ever in use on a single computer at any one time. Please enquire about multi-user licenses.
- 2, CNP is protected by international copyright laws and treaties. CNP must not be distributed to third parties.
- 3, CNP must not be reversed engineered, disassembled or de-compiled. Licensee may transfer the software to a third party provided that no copies or upgrades of CNP are retained.
- 4, It is the responsibility of the user to ensure the validity of all stored results and printed certificates. Isothermal Technology Ltd accept no responsibility for any errors caused by inappropriate use, incorrect set up or any other cause; including defects in the software.
- 5, Limited Warranty. Isothermal Technology warrants that CNP will perform substantially as described in this manual for a period of 90 days from receipt. Any distribution media will under normal used be guaranteed for a period of 90 days.

NO OTHER WARRANTIES, EXCEPT AS STATED ABOVE. The software and documentation is provided "as is" without warranty of any kind and no other warranties (either expressed or implied) are made with regard to CNP. Isothermal Technology does not warrant, guarantee or make any representations regarding the use or results of the use of the software or documentation and does not warrant that the operation of CNP will be error free.

In no event will Isothermal Technology, its employees, agents or other associated people be liable for direct, indirect, incidental or consequential damages, expenses, lost profits, business interruption, lost business information or other damages arising out the use or inability to use CNP. The license fee reflects this allocation of risk.

CNP is not designed for situations where the results can threaten or cause injury to humans.

Installing Cal NotePad

1. Insert Isotech Support CD into the CD drive.
2. Allow CD browser to open and install version of Cal NotePad required.
3. Follow the prompts which will install the application and necessary LabVIEW run time support files.
4. Should you ever need to uninstall the software then use the Add/Remove Programs option from the Control Panel.

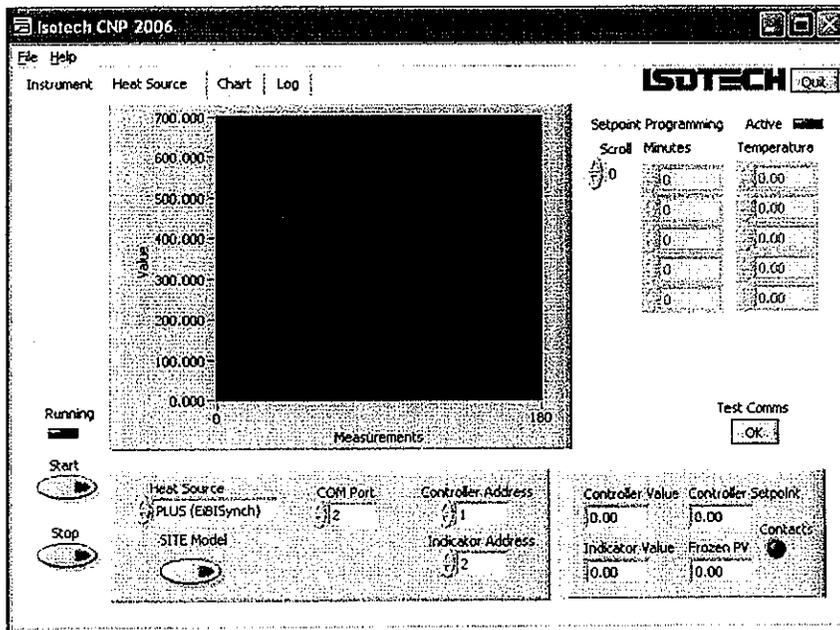
Starting Cal NotePad

From a Standard Installation:

Click the START button

Highlight PROGRAMS

Select Isotech - Select Calpad



Protocol

The instruments use the "Modbus Protocol"

If required, e.g. for writing custom software the technical details are available from our website at www.isotech.co.uk/refer.html

Diagnostic alarms

Diagnostic alarms indicate a possible fault within the controller or connected devices.

| Display shows | What it means | What to do about it |
|---------------|---|---|
| E.ConF | A change made to a parameter takes a finite time to be entered. If the power to the controller is turned off before the change has been entered then this alarm will occur. Do not turn the power off to the controller while ConF is flashing | Enter configuration mode then return to the required operating mode. It may be necessary to re-enter the parameter change since it will not have been entered in the previous configuration. |
| E.CAL | Calibration error | Re-instate Factory calibration, refer to Isotech |
| E2.E | EEPROM error | Return to Isotech for repair |
| EE.E | Non-vol memory error | Note the error and contact Isotech. |
| E.Lin | Invalid input type. This refers to custom linearisation which may not have been applied correctly or may have been corrupted. | Go to the INPUT list in configuration level and set a valid thermocouple or input type |
| E.mod | IO1, OP2, or OP3 has been changed | If this has been field changed by the installation of a new board, enter config level, then exit back to operator level. If the message occurs at any other time return to factory for repair. |

Additional Information;

1. If the input is too high HHHHH will be displayed.
2. If the input is too low LLLLL will be displayed.

JUPITER^{PLUS} 650 B, 650 S - INITIAL TESTING

This unit was fully tested before despatch to you but please check its operation as outlined below.

After connecting the Jupiter^{PLUS} 650 to the electricity supply, the temperature controller display will show the temperature of the block and the last set-point value. The S controller and indicator both go through a self-test sequence first. The fan on the front panel should be heard running.

Change the set-point to 100°C and observe that the block temperature rises and settles to this value. For the S; place a thermometer in an insert in the block and connect it to the suitably configured indicator. Confirm that the indicator agrees within $\pm 2^{\circ}\text{C}$ of the controller.

Change the set-point to 70°C; this should cause the second cooling fan to operate until the temperature falls to below 75°C when it will turn off.

Your unit should have performed as described above and can now be used for calibration.

If any problems or faults arise during these tests please contact us or our agents for help and advice.

IMPORTANT NOTICE

The controller's function settings are preset and will not require adjustment.

FAST COOL DOWN PROBE (OPTION)

The fast cool down probe can be attached to a suitable air supply and then placed into the Jupiter^{Plus} insert for rapid cooling.



Take care when placing the probe into the hot block.

Ensure the air supply is set to give an appropriate flow rate. Guard against setting so high that the probe may be blown from the insert.

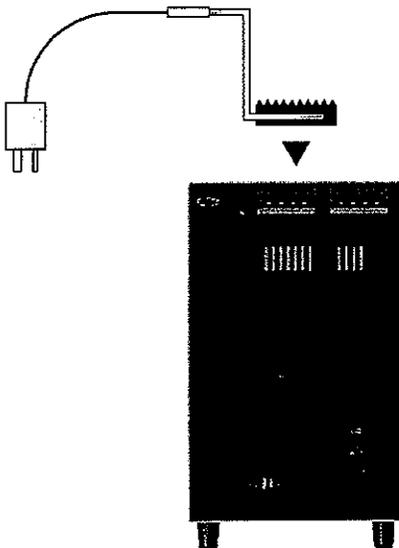
USING THE JUPITER^{PLUS} 650 WITH THE BLACK BODY TARGET KIT (OPTION)

The black body function of the Jupiter^{PLUS} 650 is well suited for the fast, convenient, mess free calibration of infra-red temperature sensors.

The black body target and insulators are placed into the calibration well. For the S models the reference probe, a Type N thermocouple, is placed into the black body target and the actual temperature can be read from the temperature indicator to which the infra-red thermometer(s) are compared. For the B models an external temperature indicator should be used.

Assembly

The target and thermocouple are placed into the well as shown.



The Type N thermocouple is arranged as shown and connected most usually to the inbuilt indicator of the Jupiter^{PLUS} 650S.

Set the input type and indicator calibration to suit - see page 15.

JUPITER^{PLUS} 650 B, 650 S - MAINTENANCE

Turn the electricity supply off before attempting any cleaning operation.

The only moving parts are the fans. They have sealed-for-life bearings. Depending on the environment in which it is used, periodic cleaning is recommended. Cleaning may be accomplished by the use of a small dry paint brush.

The instrument should be periodically checked to ensure it is in good order both mechanically and electrically.

The Basic Workings of the Jupiter^{PLUS} 650

The purpose of the Jupiter^{PLUS} 650 models is to provide an adjustable isothermal enclosure for calibration purposes.

The isothermal enclosure consists of a fixed heater block into which an insert can be placed. Items for calibration are placed in suitably drilled holes in the insert. The replaceable inserts enable a variety of items to be calibrated.

The heater block houses a heater and the control sensor used by the temperature controller to sense the block temperature. To obtain and maintain a required temperature the controller varies the power to the heaters via a solid state relay.

There are two electrically driven fans in the unit. One runs continuously and cools the electronics in the instrument and the other fan cools the heater block when called upon to do so by the temperature controller. This second fan is operated by the controller to cool the heater block when the set point is 5°C or more lower than the block temperature, when this second fan is on cooling to temperature appears on the controller to signify this.

Operating Procedures

The following operating procedures have been written for one of the two models as indicated by the Procedures heading. However the procedure may be common to the other models and in such cases the relevant models are indicated in brackets.

Please note: No oils, greases or powders should be introduced into the Jupiter^{PLUS} 650 or its inserts.

Only use Isotech supplied inserts.

The inserts are specially plated for use in the block. Using non-Isotech inserts may lead to failure of the block and cause the insert to seize in the block.

JUPITER^{PLUS} 650B, 650S - CHECKING USING THE TEMPERATURE INDICATED ON THE CONTROLLER

1. Remove the Jupiter^{PLUS} 650 from its case and visually inspect it for any damage it may have sustained since it was last used. Insert the required metal insert into the furnace block using the tool supplied to avoid damage to the heater assembly.
2. Connect the Jupiter^{PLUS} 650 to a suitable power supply and set the controller to the required temperature.
3. Place the thermometer for calibration into a suitable hole in the metal insert and wait for the temperature to stabilise.
4. When the temperature indicated by the controller and the output of the thermometer are both stable (see specification for typical values) record three sets of readings over a period of about six minutes. Check that these readings are consistent and then calculate their average values.
5. If the Jupiter^{PLUS} 650 has itself been calibrated, correct the average values accordingly.
6. Reset the controller and/or repeat the calibration for another thermometer.
7. When the calibration is complete, reset the controller to 0°C and wait until the unit has cooled to below 400°C before moving the Jupiter^{PLUS} 650 to a new location. The Jupiter^{PLUS} 650 must be cooled below 100°C before it can be put back into its carrying case.

JUPITER^{PLUS} 650 B, 650 S - CALIBRATION USING A STANDARD THERMOMETER WITH EXTERNAL INDICATION

1. Remove the Jupiter^{PLUS} 650 from its case and visually inspect it for any damage it may have sustained since it was last used. Insert the required metal insert into the furnace block using the tool supplied to avoid damage to the heater assembly.
2. Connect the Jupiter^{PLUS} 650 to a suitable power supply and set the controller to the required temperature.
3. Place the thermometer(s) for calibration and the standard thermometer into suitable holes in the metal insert; wait for the temperature to stabilise.
4. When the temperature indicated by the controller and that of the other thermometers are stable (see specification for typical values) record three sets of readings over a period of about six minutes. Check that these readings are consistent and use their average values for the final calibration figures.

Compare the units under test to the standard thermometer.

5. Reset the controller and/or repeat the calibration for another thermometer.
6. When the calibration is complete, reset the controller to 0°C and wait until the unit has cooled to below 400°C before moving the Jupiter^{PLUS} 650 to a new location. The Jupiter^{PLUS} 650 must be cooled below 100°C before it can be put back into its carrying case.

JUPITER^{PLUS} 650 S - CALIBRATION USING A STANDARD THERMOMETER AND THE INTERNAL INDICATOR

1. Remove the Jupiter^{PLUS} 650 from its case and visually inspect it for any damage it may have sustained since it was last used. Insert the required metal insert into the furnace block using the tool supplied to avoid damage to the heater assembly.
2. Connect the Jupiter^{PLUS} 650 to a suitable power supply and set the controller to the required temperature.
3. Place the thermometer(s) for calibration into a suitable insert(s) in the metal block and wait for the temperature to stabilise, connect the standard thermometer to the indicator.

Ensure the indicator is configured for the correct sensor and where applicable the calibration data has been entered and user calibration enable.

4. When the temperature indicated by the controller and that of the other thermometers are stable (see specification for typical values) record three sets of readings over a period of about six minutes. Check that these readings are consistent and use their average values for the final calibration figures.
5. If the Jupiter^{Plus} 650 has been calibrated, correct the figures accordingly.
6. Reset the controller and/or repeat the calibration for another thermometer.
7. When the calibration is complete, reset the controller to 0°C and wait until the unit has cooled to below 400°C before moving the Jupiter^{PLUS} 650 to a new location. The Jupiter^{PLUS} 650 must be cooled to below 100°C before it can be put back into its carrying case.

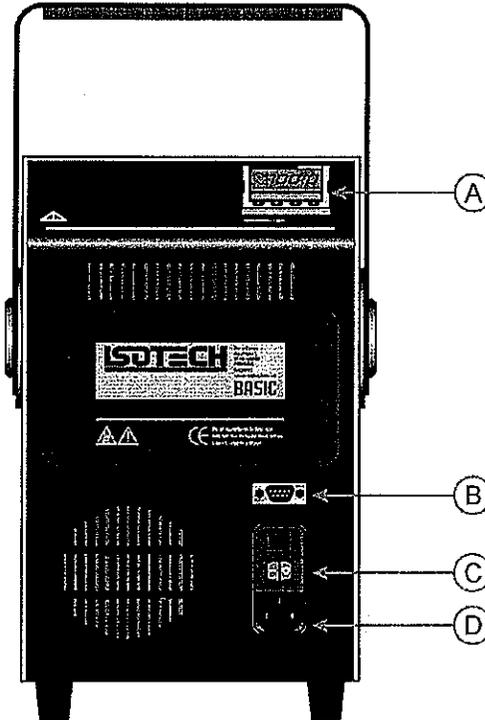
JUPITER^{PLUS} 650 S - CALIBRATION USING THE INTERNAL INDICATOR TO READ A STANDARD AND UNKNOWN THERMOMETERS

1. Remove the Jupiter^{PLUS} 650 from its case and visually inspect it for any damage it may have sustained since it was last used. Insert the required metal insert into the furnace block using the tool supplied to avoid damage to the heater assembly.
2. Connect the Jupiter^{PLUS} 650 to a suitable power supply and set the controller to the required temperature.
3. Place the thermometer(s) for calibration and the standard thermometer into suitable holes in the metal insert; wait for the temperature to stabilise.
4. When the temperature indicated by the controller and the standard are stable (see specification for typical values) record the reading of the standard. Connect the thermometer under test, in place of the standard, to the indicator and re-configure the indicator for the new sensor type as necessary if user calibration is enable for the standard it will need to be turned off or modified for the unit under test. Record the temperature of the thermometer under test. For security reconnect the standard thermometer, reconfigure the indicator and make sure the temperature has not changed from the first reading.
5. If the Jupiter^{PLUS} 650 has itself been calibrated, correct the average values accordingly. If there is no calibration, use an uncertainty figure of $\pm 1\%$ for the temperature indicated by the standard thermometer and indicator.
6. Reset the controller and/or repeat the calibration for another thermometer.
7. When the calibration is complete, reset the controller to 0°C and wait until the unit has cooled to below 400°C before moving the Jupiter^{PLUS} 650 to a new location. The Jupiter^{PLUS} 650 must be cooled to below 100°C before it can be put back into its carrying case.

JUPITER^{PLUS} 650 S - USING THE INDICATOR TO MEASURE TEMPERATURES REMOTE FROM THE FURNACE

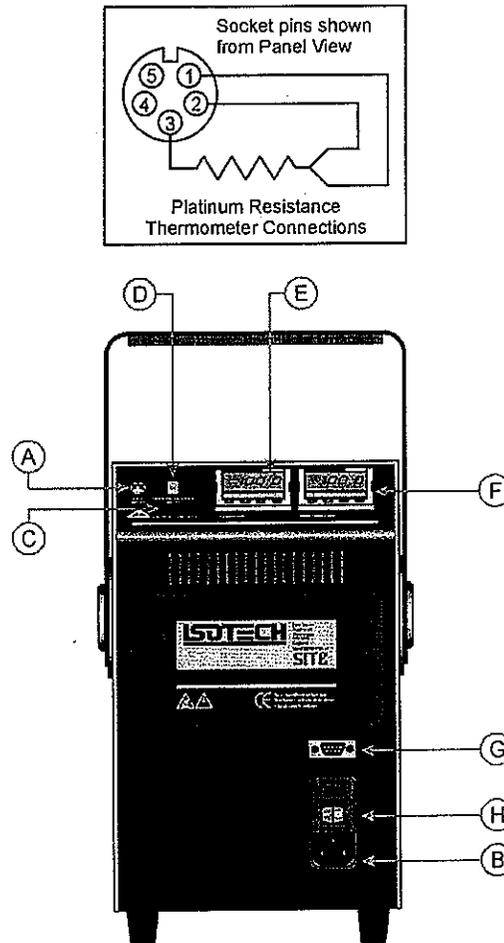
1. Remove the Jupiter^{PLUS} 650 from its case and visually inspect it for any damage it may have sustained since it was last used. Insert the required metal insert into the furnace block.
2. Connect the Jupiter^{PLUS} 650 to a suitable power supply and set the controller to either 0°C if the furnace is not to be used or to the required temperature if it is going to be used to calibrate thermometers.
3. If the standard thermometer is going to be used to measure a temperature other than the metal block, reconfigure and set the offset of the indicator accordingly. Connect the standard thermometer to the indicator which will now display its temperature.
4. If the indicator is going to be used to measure the temperature of a remote thermometer, reconfigure and set the user calibration of the indicator to correspond to that type of thermometer, connect the thermometer to the indicator and the corresponding temperature will be displayed.
5. If the Jupiter^{PLUS} 650 has itself been calibrated, correct the average values accordingly. If there is no calibration use an uncertainty figure of $\pm 1\%$ for the temperature indicated by the standard thermometer and indicator.
6. Reset the controller and/or repeat the calibration for another thermometer.
7. When the calibration is complete, reset the controller to 0°C and wait until the unit has cooled to below 400°C before moving the Jupiter^{PLUS} 650 to a new location. The Jupiter^{PLUS} 650 must be cooled to below 100°C before it can be put back into its carrying case.

Figure 1 – Jupiter^{PLUS} 650 Basic (B)



- (A) Temperature Controller
- (B) PC Interface
- (C) On/Off Switch
- (D) Power Entry and Fuse

Figure 2 - Jupiter^{PLUS} 650 Site (S)



- (A) Platinum Resistance Thermometer Connector
- (B) Power Entry and Fuse
- (C) Switch Contact (Thermostat)
- (D) Thermocouple Connector
- (E) Temperature Indicator
- (F) Temperature Controller
- (G) PC Interface
- (H) On/Off Switch



Note: Only connect a thermocouple or platinum resistance thermometer to the input connectors. Ensure that only one sensor is connected at any time.

APPENDIX I

Jupiter^{Plus} 650 Trouble Shooting

1. **Unit fails to operate**

Check fuse, Figure 1. If fuse blows repeatedly consult Isotech or local agent.

2. **Will not control at 35°C**

Check room temperature. Minimum operating temperature of 35°C is for a room temperature of 20°C.

3. **Indicator reads incorrectly**

Two sensors connected simultaneously,
Indicator incorrectly configured.

4. **Unit unstable**

Control parameters have been interfered with - consult your local agent.

5. **Cannot establish PC Communications**

For RS232 you must use the Isotech adaptor cable.
Ensure the addresses of the controller and indicator match those set in Cal Notepad.
Ensure each controller and indicator are set to a unique address.
Refer to 'Using the PC Interface' section and the Cal Notepad manual for further details.

APPENDIX 2

Accessories Parts List

| | |
|---|---|
| Semi Standard Platinum Resistance Thermometer | 935-14-72 |
| Type N Thermocouple | 935-14-63 |
| Undrilled Insert | 852-07-07 |
| Standard Insert | 852-07-11 |
| Special Insert | Consult Factory |
| Fuse 230VAC Models | 20mm 5 AMP Quick Blow RS Components 416-376 |
| 115VAC Models | 20mm 10 AMP Quick Blow RS Components 416-405 |
| PRT Plug | 935-16-75 |
| T/C Plug (Type N) | 935-35-101 |
| Fast Cool Down Probe | 853-04-02 |

APPENDIX 3

Indicator Configuration (Reference Only)

Config.INST

| Name | Description | Value |
|------|---------------------------------|-----------|
| unit | Instrument Units | C (0) |
| dEcP | Decimal Places in Display | NN.NN |
| Ctrl | Control Type | PID (0) |
| Act | Control Action | REV (0) |
| COOL | Cooling Type | LIN (0) |
| PwrF | Power Feedback Enable | OFF (0) |
| Patr | Manual/Auto-Transfer PD Control | NO (0) |
| FoP | Forced Output Enable | NO (0) |
| Sbrt | Sensor Break Type | SB.OP (0) |
| rnGH | Process Value High Limit | 670 |
| rnGL | Process Value Low Limit | 0.00 |

Config.IP

| Name | Description | Value |
|------|------------------------|----------|
| inPt | Linearisation Type | RTD |
| CJC | CJC Type | (EXT) |
| imP | Sensor break impedance | AUTO (I) |

Config.CAL

| Name | Description | Value |
|------|-------------------------|---------|
| UCAL | User Calibration Enable | YES (I) |
| Pnt1 | User Cal Point 1 | 0 |
| Pnt5 | User Cal Point 5 | -99.00 |
| OFS1 | User Cal Offset 1 | 0.00 |
| Pnt2 | User Cal Point 2 | .99 |
| OFS2 | User Cal Offset 2 | 0.00 |
| Pnt3 | User Cal Point 3 | .99 |
| OFS3 | User Cal Offset 3 | 0.00 |
| Pnt4 | User Cal Point 4 | -99.00 |
| OFS4 | User Cal Offset 4 | 0.00 |
| OFS5 | User Cal Offset 5 | -99.00 |

Note: User Cal values are unique to each instrument. If available set values to those from calibration certificate

Config.AL

| Name | Description | Value |
|-------|------------------|---------|
| AL_1 | Alarm 1 Type | OFF (0) |
| Ltch1 | Alarm 1 Latching | NO (0) |
| AL_2 | Alarm 2 Type | OFF (0) |
| Ltch2 | Alarm 2 Latching | NO (0) |
| AL_3 | Alarm 3 Type | OFF (0) |
| Ltch3 | Alarm 3 Latching | NO (0) |
| AL_4 | Alarm 4 Type | OFF (0) |
| Ltch4 | Alarm 4 Latching | NO (0) |

Config.HA

| Name | Description | Value |
|------|------------------|----------|
| id | Module Identity | CMS (7) |
| Func | Module Function | CMS (65) |
| bAud | Baud Rate | 9600 (0) |
| PrtY | Comms Parity | NONE (0) |
| rES | Comms Resolution | FUL (0) |

Config.1A

| Name | Description | Value |
|------|-----------------|----------|
| id | Module Identity | LOG (3) |
| Func | Module function | NONE (0) |
| SEnS | Sense of Output | NOR (0) |

Config.2A

| Name | Description | Value |
|------|-----------------|----------|
| id | Module Identity | LOG (3) |
| Func | Module function | NONE (0) |
| SEnS | Sense of Output | NOR (0) |

TEMPERATURE CALIBRATION USING METAL BLOCK CALIBRATORS

OPENING REMARKS

Practical thermometry is derived by relating the gas laws (Boyle, Charles, Avagadro) to practically realisable devices such as triple-, freeze- and melt-point cells of various very pure substances.

Calibration is carried out after heat transfer processes have produced thermal equilibrium between apparatus containing the cell and temperature sensors placed in them.

Energy exchange is governed by the laws of thermodynamics. Such has been the difficulty of understanding this area of science that only after the first three laws were discovered was the most fundamental property defined. Consequently, this was called, somewhat incongruously, the zeroth law. It states: "If two systems, in equilibrium, each have the same temperature as a third, then they also have the same temperature as each other".

Read the zeroth law a few times and think about it; it is the key factor in being able to make comparison calibrations. Translated, it says that if a calibrated standard thermometer is at the same temperature as a calibration bath and an industrial temperature sensor is also at the same temperature as the bath, then the calibrated standard and the industrial sensor will be at the same temperature as each other.

An intriguing truism also to bear in mind is: "A thermometer measures its own temperature". This, of course, applies to a contact-type thermometer and refers quite specifically to the sensing element within it. Immediately called into question is the manner of application of the thermometer to ensure establishment of thermal equilibrium as defined by the zeroth law. Factors that introduce errors and uncertainties will be discussed later.

TEMPERATURE CALIBRATION WITH METAL BLOCK CALIBRATORS

Calibrating thermometers is done at many levels of accuracy. For highest accuracies, freeze-point cells have been designed, together with Standard Platinum Resistance Thermometers (S.P.R.T.'s) to realize temperatures defined by the gas laws (upon which laws practical temperature scales are based).

Personnel involved at this level of measurement can easily become dismissive of the problems faced daily by plant maintenance engineers whose job it is to ensure that temperature sensors, indicators and controllers are reading correctly. We neglect this area at our peril since it represents the majority of calibrations performed daily and is one of the most important reasons for introducing temperature sales in the first place.

This tutorial acknowledges, and attempts to redress, the omission, albeit in a simplified and generalised manner.

During the past decade there has been an increase in the use of metal block calibrators for industrial calibration work. It is to the users and would-be users of these products that this tutorial is addressed.

INFERENCES OF USING SENSORS "NOT DESIGNED FOR CALIBRATION"

Unlike S.P.R.T.'s, which are designed solely for calibration purposes, the great majority of industrial temperature sensors are designed with insufficient consideration of their suitability for calibration.

For example, an engineer wished to measure ambient temperature to an accuracy of $\pm 0.001^{\circ}\text{C}$. He proposed the use of a temperature sensor 40mm long. When asked how he proposed to calibrate his sensor, he confessed not have considered this aspect of his measurement.

Most industrial temperature sensors are designed to penetrate a pipe, or to strap onto a surface, or even to fit into the wall of a vessel or into a thermowell attached to it.

In a perfect world the industrial temperature sensor would be long enough to calibrate without errors caused by heat transfer along the stem. Thermocouples and bead thermistors, because of their small size, not only measure temperature essentially at a point but, also, can be contained in a thermometer tube of small diameter. On the other hand, sensing elements of industrial platinum resistance thermometers have a length of, typically, 25mm and require envelopes of relatively large (eg. 6mm) diameter to contain them; both dimensions constrain the magnitude of minimum acceptable immersion length to enable a given level of temperature measurement accuracy to be attained.

In practice, sensors can be short as 40mm, or can even be surface-mounted, with no immersion. These devices do not fulfil the zeroth law's requirement that they be in thermal equilibrium with no nett heat transfer occurring when readings are steady.

At some shortness, the sensor ceases to be a thermometer in the normally accepted sense of the word. This applies to many industrial temperature sensors.

The short sensor assumes a temperature somewhere between that of the process it is supposed to measure and ambient temperature.

Our works engineer faces a true dilemma with such a device. Should he calibrate the sensor according to traditional practice by immersing it sufficiently into a medium for it to assume the medium's temperature? Should he, more controversially, immerse it only to the same length as it was in normal use? Or, should he calibrate it in situ?

The last solution is the correct one, if some way can be found to measure the true process temperature (once or twice a year, say), with a calibrated and properly-immersed sensor, whilst recording the reading of the normal measuring instrument. This will give the most representative results. Commonly, it is not possible to carry out this procedure. Removal of the sensor and immersion in a calibrator to a similar length as that in use is the next best solution.

SOME THOUGHTS ABOUT CALIBRATORS

Ideally, the calibrator's heat transfer characteristics should match those of the normal measuring situation.

One important factor affecting calibration accuracy is the contact between the sensor and the calibrator.

For example, most removable temperature sensors fit into a pocket or thermowell; hence, there is an air gap, however small, between sensor and inside wall of the pocket. The calibration of such a sensor in a metal block calibrator can provide conditions that simulate those of the sensor in its pocket.

Conversely, a very short sensor normally directly immersed into a liquid will not give the same results in a metal block calibrator. It should be calibrated in a stirred liquid bath.

SUMMARISING PART 1 OF THIS TUTORIAL:-

Ideally, an industrial temperature sensor should be long enough so that, when immersed in a calibration bath, errors due to stem conduction can be ignored. (A means of evaluating stem conduction error is given in the Appendix.)

If the sensor is unlikely to meet this criterion (and it cannot be calibrated in situ) it should be calibrated in a system which, as nearly as possible, simulates the sensor in its working environment.

TWO CALIBRATION TECHNIQUES USING METAL BLOCK CALIBRATORS

The two main methods of calibration using metal block calibrators are (i) using the calibrator itself as a standard, (ii) using an externally-calibrated standard in conjunction with the calibrator.

(i) Using the calibrator as a standard

A calibrator (such as the "Apollo") may be purchased with a discrete number of pre-programmed fixed temperatures available to the user.

Before despatch, and at annual intervals, a certificate (traceable to national standards) is prepared for the calibrator, giving the actual temperatures at the set points as indicated by an S.P.R.T.

The calibrator may then be loaded with industrial sensors and calibration made by assuming the sensors are at the temperatures indicated on the calibration sheet.

A calibrator such as the "Gemini" is supplied with a controller which can be set to any temperature (within the limits stated). It, too, can be supplied with a calibration certificate showing the deviation (usually at 5 points) of the indicated temperature on the controller of the calibrator from the actual temperature as indicated by an S.P.R.T.

The calibrator may be loaded with industrial sensors, their temperature being calculated by applying a correction factor to the temperature indicated on the controller. The calibrator must be returned annually for a new calibration certificate.

The thermal properties of Apollo and Gemini have been designed to provide a constant temperature (isothermal) environment for the sensors.

Caution must be exercised when using the above philosophy, once inserts become involved. Inserts introduce convenience and flexibility for the user, but add an extra air-gap in the system. When using metal block baths with inserts, extra errors may be introduced; for best results an independent standard should be used to gauge the magnitude of the error.

(ii) Metal block baths with inserts that will accommodate a standard thermometer

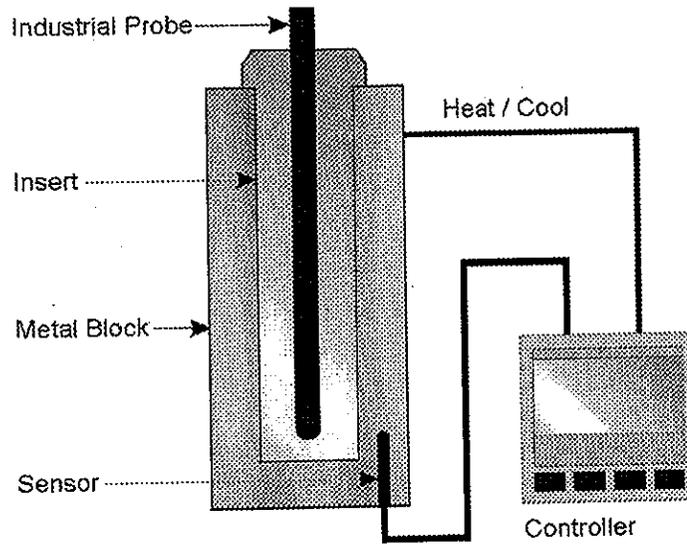
Baths, such as the Isotech "Jupiter" and "Pegasus" products, have been designed for flexibility, fast response and lightness. They have removable inserts that accept different diameter sensors BUT, the inserts have also a hole to accommodate a standard thermometer.

In some designs of metal block baths, the industrial sensor measurement is related to the controller indication of temperature. This is not good practice and can give rise to large errors.

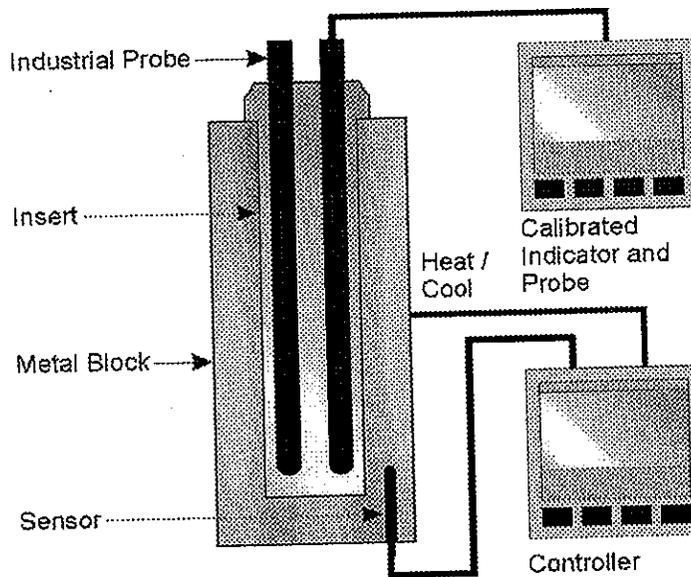
The two figures overleaf show the differences between a poor design and a professionally-designed metal block bath.

The calibrated indicator and probe may be either separate from the metal block bath, or, more conveniently, incorporated in the calibrator for on-site work, making the calibrator a truly self-contained calibration facility.

Metal Block Calibrator of Poor Design



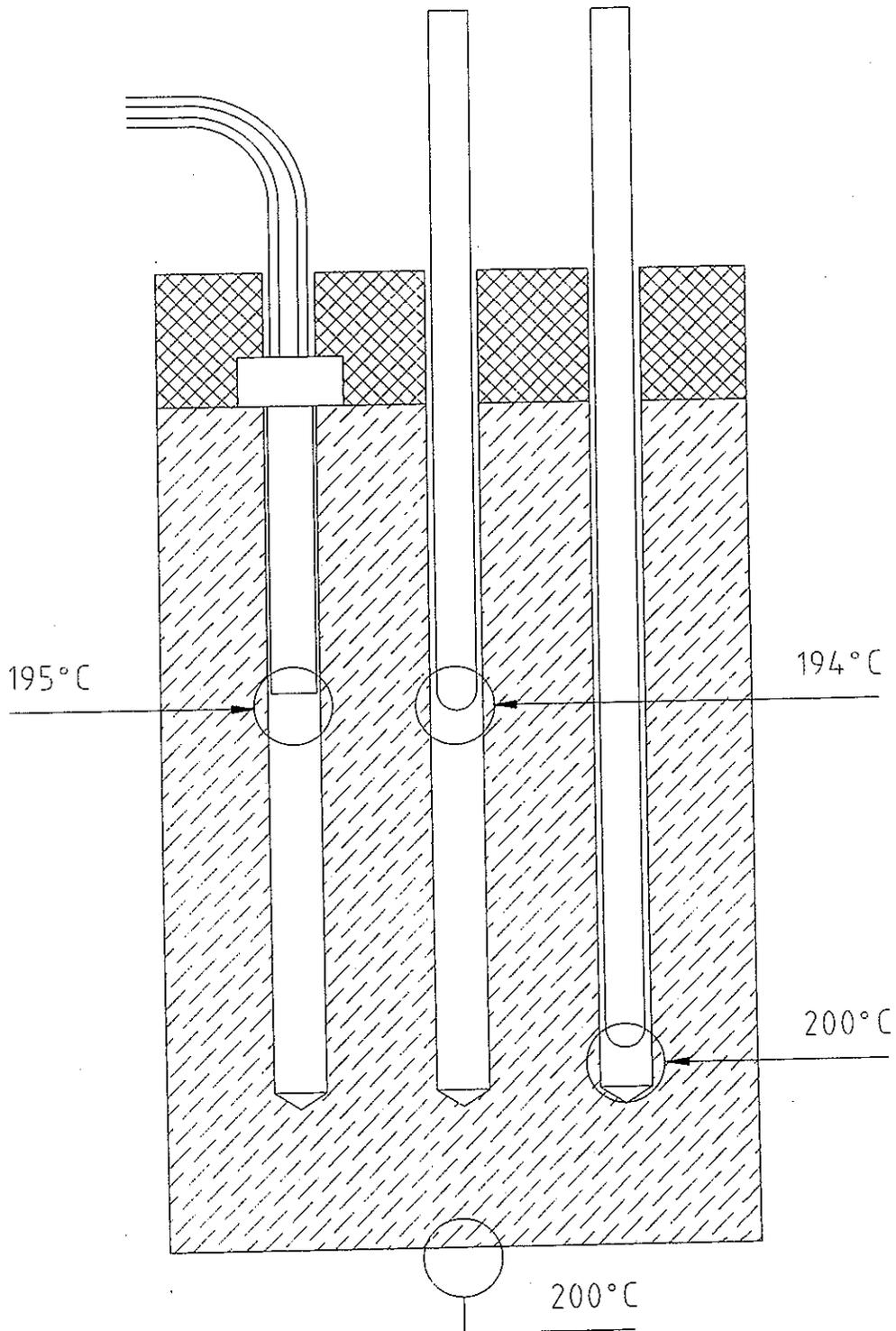
Metal Block Calibrator Meeting ISO9000 Requirements



TWO WRONGS CAN MAKE A RIGHT (APPROXIMATELY)

Many industrial temperature sensors are too short to be calibrated satisfactorily because of stem conduction errors. The figure overleaf shows a short sensor with sufficient stem conduction to give a 5°C differential with respect to the insert. However, displacing the standard so that its sensing element is at the same level as that of the short industrial sensor subjects the standard to more nearly equal stem conduction errors and thus provides a measure of compensation that enables a more realistic appraisal to be made of the short sensor's characteristics.

Calibrating using external standards offers many advantages.



- G -

ON-SITE CALIBRATORS

These products - like Jupiter and Pegasus - need a few more words of explanation.

On-site portable calibrators have one extra requirement: the calibrator should be able to cool down quickly. This requirement imposes a number of constraints on their construction and extra care is necessary when using them.

In order to provide fast cool-down, there is no insulation around the calibration block. This gives rise to larger thermal gradients than in Apollo and Gemini. To calibrate using on-site calibrators, the following information is relevant:-

THE JUPITER

The volume having uniform temperature is the insert in the centre of the metal block. It is drilled to accept not only industrial sensors, but has also a separate hole for a calibrated standard. The calibrated standard will indicate the temperature of the insert, which is at the same temperature as the industrial sensor.

It should be noted that the insert will not necessarily be at the same temperature as that indicated on the controller.

For faster cool-down, the insert should be removed.

The Jupiter may be switched off and moved provided the metal block is at 400°C or below; however, it should not be put into its carrying case until its temperature has reached 100°C or below.

THE PEGASUS

This small electric tube furnace has been specially wound to provide extra heating at top and bottom of the furnace where most losses occur. The tube is made of ceramic. In this type of furnace, unlike metal block baths, there is really no constant temperature zone. This is of little consequence provided that a metal insert is used and the standard and industrial thermometers are immersed to the same length (100 to 140mm is ideal).

Having placed the calibrated standard in the insert at the appropriate position, it will indicate the temperature of the insert at that level, which will be the same as that of the industrial sensor.

It should be noted that the insert will not necessarily be at the same temperature as that indicated on the controller.

For faster cool-down, the insert and insulation blocks should be removed.

The Pegasus may be switched off and moved provided the metal block is at 400°C or below; however, it should not be put into its carrying case until its temperature has reached 100°C or below.

ON-SITE PORTABLES - THE CALIBRATED STANDARD

The calibrated standard may be an independent S.P.R.T. and indicator, or more conveniently for site work, the standard can be supplied as part of the calibrator. In the latter case, the thermometer is calibrated with its indicator and a calibration certificate (which requires updating annually) is issued.

EVALUATING THE "UNCALIBRATABLE"

The sensors that are most difficult to evaluate (the word is used in preference to calibrate) are surface mounted sensors.

In theory, if a sensor is small enough and thermally attached to a surface well enough and the leads are thin enough and the surface is insulated well enough, a good approximation to the surface temperature can be obtained.

In practice, such devices - with the possible exception of very fine wire thermocouples - fail to meet these criteria.

To evaluate the sensor's performance, the best option (if possible) is to leave the sensor in place and compare its readout to known process temperatures.

CONCLUSION

In the above, brief, tutorial an attempt has been made to help works engineers more closely identify their thermal calibration problems in order to enable them more easily to define what type of calibrator they require and how to use it.

More operational guidance is provided in the individual handbooks.

APPENDIX

THERMOMETER IMMERSION

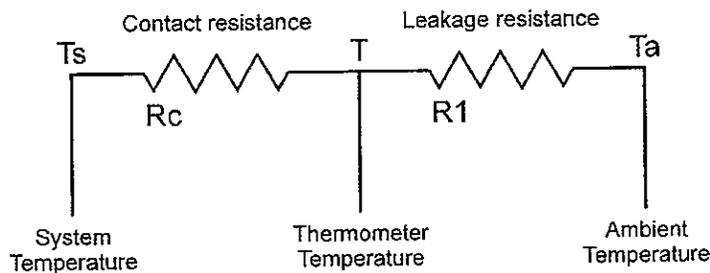
A Definition:

"A thermometer is sufficiently immersed in a system when there is no heat flow between the sensing element and its environment through the leads or sheath that extend to the ambient environment".

Heat flowing through the thermometer from or to ambient temperature is absorbed or replaced by the system in the form of conduction, convection and radiation. The simple heat flow equation:

$$\Delta T = qR$$

(temperature difference = rate of flow x thermal resistance) can be interpreted by comparison with Ohm's law, which relates potential difference to current and electrical resistance in a perfectly analogous fashion.



- i) The greater the immersion length, the greater is the leakage resistance; therefore, the thermometer should be immersed as far as is practicable.
- ii) The greater the immersion length, the smaller the contact resistance is likely to be.
- iii) The contact resistance depends also on the thermal conductivity of the system and if a fluid is present, on how fast it is flowing.

A simple formula giving the measurement error caused by finite immersion length is:

$$T_e = T - T_s = (T_a - T_s)k \exp(-L/D_e)$$

where: T_e = Temperature Error T_a = Ambient Temperature

T_s = System Temperature

k = Constant (approximately equal to, but less than, unity)

L = Immersion Length of the thermometer

D_e = Constant, called the effective diameter of the thermometer

The over-riding influence on T_e is L ; by making L large enough, T_e can be reduced to an insignificant value.

The length of the sensing element (assumed to be inserted to the bottom of the thermometer sheath) must be added to the calculated minimum immersion length to give the total immersion length required for the thermometer tip.

As a rule of thumb, for immersion in a liquid, if the accuracy of temperature measurement required is expressed as the percentage p of the deviation of the system temperature from ambient, the total immersion length required is n thermometer-diameters plus the sensing element length, where:

$$n = 2.3 \times (2 - \log_{10} p)$$

e.g. for $p = 0.01$, $n = 9.2$ (10, say)
for $p = 1$, $n = 4.6$ (5, say)

It is prudent to add a further 3cm to the immersion length if the thermometer is to be sited in a well (implying the presence of an air-gap) rather than being exposed to liquid-contact.

Practical applications

In instances where the conductivity of the system is poor, or where high precision in the measurement is desired, a simple exercise can be carried out to determine D_e and T_s . At least 3 measurements must be made.

Suppose measurements are made at each of the immersion lengths L_1, L_2, L_3 , where $L_1 - L_2 = L_2 - L_3 = \Delta L$ and the resulting temperature are T_1, T_2, T_3 respectively. It follows that:-

$$T_s = T_1 + \frac{(T_2 - T_1)^2}{2(T_2 - T_1) - (T_3 - T_1)}$$

and

$$D_e = \Delta L / \ln \frac{(T_s - T_1)}{(T_s - T_2)}$$

Example

Suppose 3 measurements made at immersion lengths of 3, 4, and 5cm give measured temperatures of 115°C, 119°C and 121°C. What is the value of system temperature and of the effective diameter of the thermometer?

$$T_s = 115^\circ\text{C} + \frac{(119 - 115)^2}{2(119 - 115) - (121 - 115)} \text{ } ^\circ\text{C} = 123^\circ\text{C}$$

and

$$D_e = (4 - 3) / \ln \frac{(123 - 115)}{(123 - 119)} \text{ cm} = 1 / \ln(2) \text{ cm} = 1.4 \text{ cm}$$

