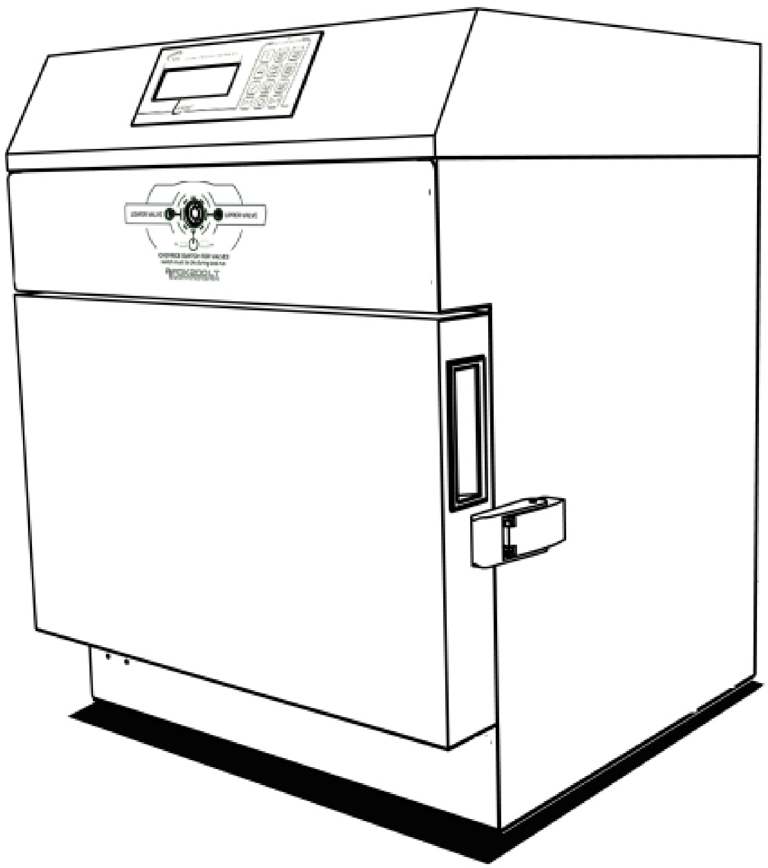
FOX200LT Instrument Manual



107 Audubon Rd Building 1 Suite 40 Wakefield, Massachusetts 01880-1245 U.S.A.

Phone (781) 233-1717 Fax (781) 941-2484

Website: www.tainstruments.com E-mail: lasercomp@lasercomp.com

Table of Contents

. Introduction

Thank you for purchasing one of LaserComp's FOX line heat flow meter instruments.

The FOX instruments are the most advanced and easiest to use instruments for measurement of the apparent thermal conductivity of thermal insulation. They were designed according to ASTM C518-04 "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus", and correctly used, provide very accurate results.

The heat flux transducers were calibrated at LaserComp prior to shipment using 1450b SRM (Standard Reference Material) issued and certified by NIST (the National Institute of Standards and Technology) at 20^{0}C (36^{0}F) plates' temperature difference (delta T) and upward heat flow. For more information on calibration procedure please refer to Sections 3 and 4. To start a test without reading this Manual refer to section 1.1 "Quick Start". Nevertheless it is advisable to read this short Manual for a better understanding of this instrument.

1.1.Quick Start

Remember that pressing the "ESC" key once, before the actual test is started, will cancel the last mistake entry and correct it. Pressing the "ESC" key several times will bring the user back to any step in the program, canceling every entry it passes.
IMPORTANT: Make sure that liquid nitrogen is connected to the instrument and flow valve is open. Running the instrument without liquid nitrogen can cause serious damage to the test plates and shorten life of the solenoid valve. It is equally important to purge to instrument with Nitrogen gas. Typical liquid nitrogen pressure from Dewar is 340 kPa (50 lb_f /in^2) (see Section 6).

1. Turn on the power to the instrument.
2. On the first screen press either "1" to select English (British) units or "2" to select SI (metric) units.
3. Open the outer test chamber door from its top sides with both – left and right hands evenly. Then open the inner door. **WARNING: Do not open test chamber during or immediately after the low temperature runs under any circumstances – in order to prevent moisture condensation! Instrument plate temperatures should be brought to about 30°C for at least 30 minutes before the chamber is opened.**

4. Remove the sample from the test chamber (if present), make sure that plates are clean, press “2”, and wait until the instrument’s motors stop.

5. Once the upper plate has stopped moving and the “SRM Type Select” screen appears press “1” to select NIST 1450b.

6. On the next screen press “1” to run a test.

7. Press 2 on the following screen.

8. Next enter pairs of the plates’ temperatures:

e.g. in degrees Centigrade:

U1=-140^0 and L1=-160^0;

U2=-120^0 and L2=-140^0; etc. - up to 9 pairs.

To enter a negative temperature press “0” instead of “ - “. When the next digit is pressed the “0” will change to” - “.

Keep in mind that the FOX200LT instrument is calibrated at LaserComp with an over a range from -175^{0}C to 40^{0}C for the upper plate, and from -155^{0}C to 20^{0}C for the lower plate (at 20^{0}C temperature difference and heat flow down). If a temperature is not accepted by the instrument (i.e. after entering the number and pressing the “ENT” key the number is erased) this means that the entered temperature is out of range of the instrument’s calibration.

The first temperature set should be the coldest of the test, with each successive pair having a warmer average temperature. The last temperature set should be above room temperature (+30 and +50 for example) to warm the instrument. If the last point has a very low temperature, it will take many hours for the test chamber of the instrument to reach room temperature.

9. To end setpoint entry press “ENT” two times. The next screen will appear.

10. Insert the test specimen into the chamber and press 1. The stack will close and the sample thickness will be displayed.

11. Input the sample ID and press “ENT”. The test will start.

12. Normally it takes about 2 hours for each setpoint (~3 hours for the first setpoint) for 1”-thick (25.4 mm) thermal insulation foam material like Expanded Polystyrene) When test is completed values of thermal conductivity calculated for each plates can be read (in mW m^{-1} K^{-1} or in 10^{-3} x Btu hr^{-1} ft^{-2} in $^0F^{-1}$). Calculate and use the average value (fourth digit is out of instrument’s accuracy). Press “ENT” to see results of the next pair of temperature setpoints.

13. To repeat test at the same temperature setpoints press “1”. To enter new pairs of temperatures press “2”.

14. Dry Instrument for at least 1 hour before starting next test (See section 6.1).

2. Description of FOX200LT Instrument

The FOX200LT instrument consists of two basic sections: the top and the base. All the electronics are housed in the top section. The base section of the instrument is the actual test chamber. Once the outer and inner doors are opened, the sample can be placed between two plates in the test stack. The lower plate is stationary. The upper plate can move up and down. It is powered by four independently controlled stepping motors. The position of each corner of the upper plate is monitored by sophisticated digital thickness readout systems. Each time a sample is inserted into the instrument and the stack is closed, the thickness of the sample will be determined to within ~0.025 mm (~0.001") resolution.

High output Heat Flow Meters (transducers), developed by LaserComp are permanently bonded to the surface of each plate. The transducers are of the integrating type and have a 3" x 3" metering area in the centers of the plates. Their thickness is 0.063" (~1.6 mm). In the center of each transducer a type E thermocouple is bonded within 0.005" (0.127 mm) of its surface (as close as possible to sample). Because the thermocouple is positioned next to the sample, it provides accurate readings of the sample's surface temperature. The same thermocouples are used to control the plate's temperatures.

Each plate is outfitted with a resistance heating/LIQUID NITROGEN cooling system. With an electronically controlled Liquid Nitrogen flow (–195.8^{0}C or -320.5^{0}F) the plates' temperatures can be as low as -175^{0}C. The plates' temperatures can be controlled accurately between -175^{0}C and +50^{0}C (i.e. -283^{0}F and +104^{0}F).

In addition to the upper and lower plate control, there is also liquid nitrogen cooling guard and a resistance heater surrounding the sample and the upper and lower plates. Its purpose is to reduce any lateral heat losses (gains), especially at the extreme temperatures, but they are used throughout the temperature range of the FOX200LT.

The "brain" of the FOX 200LT instrument is a very powerful Digital Signal Processor equipped with a 24 Bit Analog to Digital (A/D) Converter. The A/D Converter converts the signals from the thermocouples and heat flow transducers to the digital domain. The resolution of the conversion is ~0.6 μV. This translates to a 0.01^{0}C temperature resolution.

The DSP controls all aspects of the instrument's operation, from the user interface to sending data to the host computer and calculating the results. The DSP's most important task is to monitor the temperatures of the plates and to perform a multistage PID algorithm to control the plates setpoint temperatures. Based on the outcome of the algorithm, new control signals are sent to the Power Output Board in each acquisition cycle (every ~0.7 sec.), and to the liquid nitrogen control valves.

3. Pre-Saved Calibration

The heat flux transducers in each plate must be calibrated before tests can be performed. Two independant calibrations have been performed and are saved on the instrument's non-volitile memory- a "NIST 1450b type" (SRM, fiberglass) and a "User Type". The following set of temperatures are used (degrees ^{0}C) for the calibrations:

"NIST 1450b Type" Calibration

T_U=-175°C	T_L=-155°C	T_{mean}=-165^{0}C
T_U=-160°C	T_L=-140°C	T_{mean}=-150^{0}C
T_U=-135°C	T_L=-115°C	T_{mean}=-125^{0}C
T_U= -110°C	T_L= -90°C	T_{mean}=-100^{0}C
T_U= -85°C	T_L= -65°C	T_{mean}=-75^{0}C
T_U= -60°C	T_L= -40°C	T_{mean}=-50^{0}C
T_U= -10°C	T_L= +10°C	T_{mean}=0^{0}C
T_U= +15°C	T_L= +35°C	T_{mean}=+25^{0}C
T_U= +30°C	T_L= +50°C	T_{mean}=+40^{0}C

"User type" Calibration

T_U=-10°C	T_L=+10°C	T_{mean}=0˚C
T_U=0C	T_L=+20°C	T_{mean}=+10˚C
T_U=+10°C	T_L=+30°C	T_{mean}=+20˚C
T_U=+20°C	T_L=+40°C	T_{mean}=+30˚C

To calibrate the transducers a sample of known conductivity is placed in the instrument and calibration mode is selected. A calibration can be performed with a single set of temperatures or with several sets. Usually the calibration is performed with several sets of temperatures covering the temperature range over which tests on unknown samples will be performed. During a calibration run the instrument calculates calibration constants (S) at each temperature for each plate's transducer (S_U at T_U and S_L at T_L):

$$S_U(T_U)= [\lambda_{(standard)} * (T_U - T_L)] / (L^* Q_U)$$
$$S_L(T_L) = [\lambda_{(standard)} * (T_U - T_L)] / (L^* Q_L)$$

where:

- $S_U(T_U)$ is the upper plate's calibration constant at temperature T_U
- $S_L(T_L)$ is the lower plate's calibration constant at temperature T_L
- Q_U is the output of the upper heat flux transducer at T_U
- Q_L is the output of the lower heat flux transducer at T_L
- $\lambda_{(standard)}$ is the calibration standard's conductivity at mean temperature
- L is the standard's thickness

Calibration data are stored in the instrument's non-volatile memory. Tests can be run at any temperature between the lowest and highest calibration temperature. The calibration constants are calculated at the actual test temperatures by interpolating the stored calibration data. If a calibration was performed only at one temperature, then the test plates' temperatures must be within 2^{0}C of the calibration plates' temperatures.

The temperature difference T_U-T_L should be the same for all calibration temperature sets. To obtain the most accurate results, the temperature difference T_U-T_L and direction of the heat flow in a test should be the same as in the calibration. In general, a 20°C temperature difference is recommended.

The FOX 200LT has two types of calibration modes and can store two calibrations. The first mode is when a 1450b NIST SRM was used as the calibration standard. The equation for this standard's conductivity dependence on temperature and density (taken from the 1450b NIST certificate) is stored in the instrument. When this mode is selected, the user must input the weight and area of the 1450b standard. The instrument automatically calculates the standard's conductivity $\lambda_{(standard)}$ at each of the temperatures. This calibration mode is used most of the time. The 1450b NIST SRM data is given by NIST with +/- 2% accuracy (3% at -173°C).

The "User type" calibration was obtained using one of two Special High Accuracy (0.5%) NIST-traceable Standards. Their thermal conductivity is:

$\lambda(12.5^0C)=32.53\ mW\ m^{-1}\ K^{-1}$

$\lambda(22.5^0C)=33.64\ mW\ m^{-1}\ K^{-1}$

$\lambda(32.5^0C)=34.80\ mW\ m^{-1}\ K^{-1-1}$

$\lambda(42.5^0C)=35.95$ mW m^{-1} K^{-1}

4. Program Flow

This section explains the operation of the FOX instruments by presenting each screen of the instrument in the order they appear.

When the instrument is turned on, it performs a test of the internal electronics and the thermocouples. If no malfunctions are detected, the first screen appears.

Screen 1

```
  LASERCOMP FOX200LT
Select Units:
1. English
2. S.I.
```

By pressing 1 the English units will be used for all tests. Temperatures will be entered and displayed in degrees Fahrenheit and the results calculated in Btu in/h ft^2F.

By pressing 2 the metric set of units will be used for all tests. Temperatures will be entered and displayed in degrees Centigrade and results calculated in W/mK.

After selecting units, the instrument will move the upper plate up to facilitate sample removal, and the following screen will appear:

Screen 2

```
 LASERCOMP FOX200LT
1.Open Stack
  Remove Sample and
2.Calibrate Delta X
```

Remove the sample from the test chamber and press "2". The instrument will move the upper plate down to the lower plate in order to calibrate zero thickness of the digital thickness measurement system. After calibration is performed, the upper plate will move up to its highest position. From this point on and until the power is turned off, the instrument will know the position of each corner of the upper plate with respect to the bottom plate with 0.025 mm (0.001") resolution.

Screen 3

```
SRM Type
Select:
1. NIST 1450b
2. User Type
```

Press 1 in order to: a. run test based on a calibration with SRM 1450b; b. run a calibration with SRM 1450b. Normally 1 is selected (i.e. NIST 1450b)
Press 2 in order to: a. run a test based on a user provided calibration sample (a calibration in this mode must be run first); b. run a calibration with a user provided calibration sample.
If 1 is selected, the following screen will appear. If 2 is selected - go to subsection 4.3 "Running a User Type Calibration" on page 15.

Screen 4

```
Select Run Mode
SRM Type 1450b
1. Test
2. Calibration
```

Pressing 1 will indicate that a test on an unknown sample will be performed next.

Pressing 2 will indicate that a calibration will be performed next.

4.1.Running a Test

If 2 (Calibration) was selected, go to subsection 4.2 "Running a 1450b SRM Calibration" on page 14. If 1 (Test) was selected the following screen will appear:

Screen 5

```
Maintain Temperature
between Tests?
1. Yes
2. No
```

Pressing 1 will cause the instrument to maintain the temperatures of the plates at the **last** setpoint after the test is over. Do not select this mode on the FOX200LT or you may waste all your liquid nitrogen!

Pressing 2 will cause the instrument to turn off the power to the plates after the test when the last setpoint is finished.

Screen 6

```
Enter Test Temp.1450
U1=    _°C   L1= XXX°C
U2= XXX°C  L2= XXX°C
U3= XXX°C  L3= XXX°C
```

The desired test temperatures should be entered at this screen. "U" stands for Upper plate and "L" stands for Lower plate. To enter a negative setpoint, press 0 first, followed by the desired number and then "ENT". To enter 0 as the setpoint, press 0 and "ENT". Once "ENT" is pressed, the cursor will advance to the next position. To end entry of setpoints press "ENT". If a mistake is made during setpoint entry, pressing the "ESC" key will bring the cursor back to any position and corrected data can be re-entered. This is true not only for the setpoint entry screens, but for the whole program. Pressing the "ESC" key will bring the user step by step back through each entry or selection you made, canceling each.

After the lower temperature for the third setpoint is entered, the next screen appears. Up to a total of nine setpoint pairs can be entered (i.e. three screens).

The direction of heat flow should be upward in all tests, as in the calibration. For best results the temperature difference across the sample should be the same as during the calibration. The FOX200LT instrument is supplied with a calibration based on a 1450b NIST SRM with heat flow up and a 20°C temperature difference.

Temperatures more than 2^0degree C outside the range of the calibration, or outside the range of the instrument, will not be accepted.

The calibration is indicated in the upper right corner on screen 6. In the case shown it is 1450, indicating a calibration based on NIST SRM 1450b. If a User Type was selected earlier, then its number would be displayed instead.

WARNING: To prolong the life of the instrument you should finish tests and calibrations at room temperature. Finishing runs at severe low temperatures may cause a damage of components. The wiring and plumbing may be extremely brittle at low temperatures and this may cause them to crack if moved.

Press "ENT" twice to finish the setpoints entry. The following screen appears.

Screen 7

Insert Sample and
Select:
1. Auto Thickness
2. User Def. Thick.

Pressing 1 (Auto Thickness), after inserting the sample, will cause the upper plate to raise and close on the sample and determine the samples thickness. This mode is used for rigid samples.

Pressing 2 (User Defined Thickness) will allow the user to enter the desired sample test thickness. This mode is used for compressible samples.

Screen 8

Sample Thickness is
dX =   _cm
Sample ID = xxxx
Press ENT to Accept

If Auto Thickness is selected on the previous screen, the sample's thickness will be displayed on the second line and the cursor will be at the sample ID entry point.

If User Defined Thickness is selected on the previous screen, the cursor will be as shown above waiting for the user to enter the desired thickness. The instrument will attempt to achieve the entered thickness. If the sample will not compress to that thickness, the plates will stop.

In either case the actual achieved plate spacing (sample thickness) will be displayed and the cursor will be at the sample ID entry point.

Up to 4 digits can be entered for the sample ID. Once the “ENT” key is pressed the test will start.

NOTE. Pressing the “ESC” key during a test aborts the test at that setpoint and the program advances to the next setpoint (if more than one setpoint were entered), or displays the results screen 10 (pg.12) (if all the setpoints have been aborted). The results for the aborted setpoint will probably be invalid.

Screen 9

```
-157.11    1234    -177.11
U=-159.86C L=-139.86C
QU=-1300   QL= 1200
Test 1 of 3  2*  511
```

This screen appears during a test. The sample ID is displayed in the middle of the first line (e.g. 1234).

The Guard temperature readout is in the upper left corner of the screen, and the Heat Sink temperature readout is in the upper right corner of the screen.

The second line displays the current temperatures of the upper surface of the sample (U=) and the lower surface of the sample (L=). The units displayed are based on the selection made on Screen 1.

The third line displays the output of the upper heat flow transducer (QU=) and the lower (QL=) in microVolts.

The fourth line displays status information.

First “Test X of Y” indicates the setpoint number currently being performed (X) and the total number of set points entered (Y). In the example above, the first setpoint out of a total of 3 setpoints is underway.

Next, the current block number for this setpoint is displayed. The block number starts at 0 at the beginning of each setpoint and counts up. In the space following the block number several codes are displayed indicating the currently met Equilibrium Criteria:

“ “ (blank space) indicates that none of the criteria has been met;
“$” indicates that the temperature equilibrium (T.E.) criterion has been met;
“*” indicates that the semi-equilibrium (S.E.) criterion has been met;
“%” indicates that the percent equilibrium (P.E.) criterion has been met;

For explanation of the equilibrium criteria, see section 5 (pg.17).

The block counter is displayed in the lower right corner of the screen. The counter starts at 511 at the beginning of each block and decrements by 1 each time a complete set of data is taken. When the counter reaches zero a new block is started.

Once a test at a setpoint is finished, the program automatically advances to the next setpoint. At the end of all the setpoints, for a given sample, the results screen appears.

Screen 10

```
Test 1 of 3 Results:
U=-159.86C L=-139.86C
λU= 30.23  λL= 30.22
Press Enter
```

This screen displays the results. Each setpoint's results are displayed on separate screens.

The first line indicates the setpoint number and the total number of setpoints. In the example above the results are for the first setpoint out of a total of three.

The second line displays the sample's upper surface temperature (U=) and the sample's lower surface temperature (L=).

The third line displays two thermal conductivity results. One result is calculated based on the output of the upper plate heat flux transducer (λU=) and the second is based on the lower plate heat flux transducer (λL=). The results are in 10^{-3} W/mK in SI Units Mode and in 10^{-3} Btu*in/h ft^2F in English Units Mode. The final test results should be the average of the upper and lower plate results.

Pressing "ENT" will display the next setpoint's results. The "ESC" key will bring back the screen for the previous setpoint until ENT is pressed on the last setpoint's results. **After pressing "ENT" on the last setpoint's results screen the results are ERASED from memory** and the upper plate moves to its top position to facilitate sample removal. The following screen appears:

Screen 11

```
Repeat Test at Same
Temperatures?
1. Yes
2. No
```

Pressing 1 will result in bypassing temperature entry, Screen 6 (pg.10), and returns the user to Screen 7 (pg.11) allowing the start of a new test at the same temperatures as the previous test.

Pressing 2 will return the user to Screen 6 (pg.10) to enter the temperatures for the next test.

This process will continue until the user wishes to run a calibration or a test based on the alternate calibration. If that is the case, the user must press the "ESC" key several times to go back to the point were that selection can be made.

4.2.Running a 1450b SRM calibration

Refer to the beginning of section 4 (pg.8) for instructions on how to get to Screen 3.

NOTE: Calibrations are always performed in SI units, regardless of what is selected. If English Units are entered they will be converted to SI units.

Screen 3

```
SRM Type
Select:
1. NIST 1450b
2. User Type
```

Press 1 to select NIST 1450b SRM

Screen 4

```
Select Run Mode
SRM Type 1450b
1. Test
2. Calibration
```

Press 2 to select a calibration run.

Screen 5A

```
Show Calibration or
Start a New One?
1. Show Constants
2. Start New
```

Press 1 to view the current 1450b NIST calibration's constants and calibration temperatures.
Press 2 to start a new calibration. The following screen will appear.

Screen 5B

```
 Calibration const.
SRM Sample Type 1450b
  Weight:    _ kg
Base Area:XXXXX m2
```

A calibration is performed in SI units. Enter the weight of the SRM sample in kg and the area in m^2. The decimal point will appear automatically.

Screen 6

```
Enter Cal. Temp.1450
U1=   _°C    L1= xxx°C
U2= xxx°C  L2= xxx°C
U3= xxx°C  L3= xxx°C
```

Enter the temperatures for the calibration. Calibrations must be performed from the lowest to the highest temperature. Heat flow is recommended to be in the upward direction for all calibrations as well as tests. Press "ENT" twice to end temperature entry. Screen 7 (pg.11) will appear, followed by Screen 8 (pg.11). After the user enters the ID number the calibration will start. Screen 9 (pg.11) will be displayed with "Cal.: in place of "Test" to indicate that a calibration is being performed. When the calibration is completed the following screen will appear:

Screen 10A

```
Cal. X of Y Results
U=-10.01C  L= 10.01C
sU= 14.25  sL= 14.28
Press Enter
```

This screen displays the calibration results. The explanation is the same as for Screen 10 (pg.12) except in place of thermal conductivity the calibration factors results are displayed. After pressing "ENT" at the last setpoint's screen the stack is opened and the following screen is displayed:

Screen 11

```
Save new Calibration
Permanently?
1. Yes
2. No
```

Press 1 to save the calibration in the instrument's non volatile memory **(original 1450b calibration will be erased!).**

Press 2 if you do not wish to save the calibration permanently. If 2 is selected the instrument reverts to the calibration stored on the instrument.

4.3.Running a "User Type" calibration

NOTE: Calibrations are always performed in SI units, regardless of what is selected. If English Units are entered they will be converted to SI units.

This calibration mode is intended for users with calibration samples other than NIST 1450b. The user must have conductivity data for his calibration sample.
To enter this mode the user must press 2 on Screen 3 (pp. 7 & 11). On Screen 4 (pp. 7 & 11) "Calibration" must be selected by pressing 2. Screen 5A (pg.14) will appear. Select 2 in order to start a new calibration. The following screen will appear.

Screen 12

```
Enter New User Type
     Number   _
or Press Enter
     to leave XXXX
```

The "User Type" number is the number used to identify a set of temperature vs. conductivity data. <u>When running this mode for the first time enter</u> <u>a number different than the number XXXX displayed</u> in the bottom right corner of the screen. This new number will identify the data that the user must enter on the next screen.

Screen 13

```
Cal. Standard Data
T1=     _.xxC  λ1=xx.xx
T2= xxx.xxC  λ2=xx.xx
T3= xxx.xxC  λ3=xx.xx
```

The conductivity vs. mean temperature data for the user provided calibration standard must be entered on this screen. To enter the mean temperature enter the integer portion first, press "ENT" and then enter the fraction. The conductivity must be entered in mW/m K (W/m K $*10^{-3}$). To end data entry press "ENT". The next screen will appear

Screen 6

```
Enter Cal. Temp.xxxx
U1=     _°C   L1= xxx°C
```

U2= xxx°C L2= xxx°C
U3= xxx°C L3= xxx°C

The number identifying the conductivity vs. temperature data set will be displayed in the upper right corner (xxxx). Enter the plates' temperatures for the calibration. After the lower plate temperature is entered the instrument calculates the mean temperature. The mean temperature must be within the range of the entered mean temperatures for the standard's thermal conductivity +/- 2°C. The rest of the calibration instructions are the same as for a 1450b standard calibration. Go to subsection 4.2 (pg.14) after Screen 6.

User Type calibrations can be saved in non volatile memory by selecting 1 on Screen 11 (pg.15).

5. <u>Data Organization and Equilibrium Criteria</u>

During the run a set of 512 successive data acquisition cycles is organized in one block. Duration of the cycle is about 0.7 seconds, so duration of one block is about 6 minutes. The data consist of the upper and lower plates' temperatures (T_U and T_L), and the upper and the lower plates transducers signals (Q_U and Q_L.), and temperatures of the guard and the heat sink. Once the block is taken the data are averaged to obtain the average values of T_U, T_L, Q_U and Q_L.

These former 4 values are compared to the respective average values of the previous block. Once this comparison satisfies all the equilibrium criteria explained later, the sample is declared to be in thermal equilibrium, and the test (or calibration) is ended for the current temperature setpoint. Each plate must meet each criterion independently. The equilibrium criteria, their default values and their symbols (on the Screen 9, section 5) are:

(i) Temperature Equilibrium (T.E.) Criterion. The default value is 0.2°C. Symbol is "$". This criterion is evaluated before any other one. The average temperature of each plate in the block must be equal to the plate's setpoint temperature within +/- T.E. criterion value:
$|T_{U\,avrg} - T_{U\,stp}|$ < T.E. criterion value
$|T_{L\,avrg} - T_{L\,stp}|$ < T.E. criterion value

(ii) Semi-Equilibrium (S.E.) Criterion. The default value is 49 μV. Symbol is " * ". To meet this criterion, transducers average signals of two successive blocks (block "n" and block "n-1") must be equal within the S.E. criterion:

$|Q_{U\,avrg}\,(n) - Q_{U\,avrg}\,(n\text{-}1)|$ < S.E. criterion value

$|Q_{L\,avrg}\,(n) - Q_{L\,avrg}\,(n\text{-}1)|$ <S.E. criterion value

(iii) Percent Equilibrium (P.E.) Criterion. The default value is 2%. Symbol is "%". To meet this equilibrium criterion the transducers average signals of two successive blocks (block "n" and block "n+1") must be equal within the value of the P.E. criterion:

$|Q_{U\,avrg}\,(n) - Q_{U\,avrg}\,(n\text{-}1)|\ /\ Q_{U\,avrg}\,(n) \times 100\%$ < P.E. criterion value

$|Q_{L\,avrg}\,(n) - Q_{L\,avrg}\,(n\text{-}1)|\ /\ Q_{L\,avrg}\,(n) \times 100\%$ < P.E. criterion value

(iv) Number of Blocks of Percent Equilibrium. The default value is 4 blocks for tests and 8 blocks for calibrations. No symbols on the screen. This is the number of successive blocks satisfying the P.E. criterion required to declare that thermal equilibrium has been reached and results can be calculated.

(v) Inflexion Criterion. No default values or symbols on screen. This is the last criterion that must be met. It requires that Q_{avrg} for successive blocks that meet the P.E. criterion can not be changing only in one direction. The difference between block "n" and block "n-1" must change its sign or be equal to zero. If this criterion is not met, then even if the criterion (iv) is satisfied, the test is prolonged and more blocks are collected. Only then the final equilibrium can be declared and the results can be calculated.

(vi) Number of Blocks Used to Calculate Results. The default value is 3 blocks for tests and 6 blocks for calibrations. No symbols on the screen. This is the number of last blocks used to calculate the results. For example, if 6 blocks satisfy the P.E. criterion, the last 3 blocks will be used to calculate the results.

6. <u>Low Temperature Operation</u>

Typically, the line pressure for a standard Dewar is approximately 50 Lb/in^2 (~340 kPa).

A Dewar with a capacity of 230 Liters will supply enough liquid nitrogen for 2 typical full range tests of 9 temperature points.

There are two plumbing ports to connect to (diagram on next page):

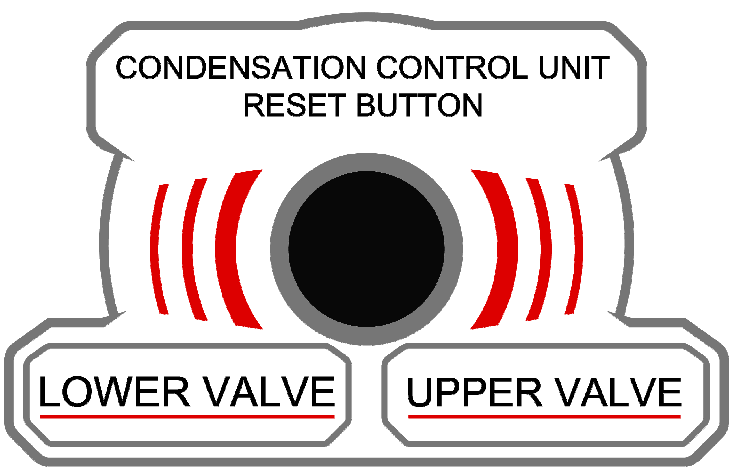
<u>1. Liquid Nitrogen In</u> – is connected to the liquid nitrogen supply tank – Dewar – and is connected to the inlet side of the solenoid flow control valve. Consult your local liquid nitrogen supplier about an adaptor to connect the Dewar transfer hose to this port.

2. Liquid Nitrogen Out (Exhaust) –The Dewar's valve should be adjusted so that no liquid nitrogen is present in the exhaust, i.e. it is desirable to see only the gas exit out of the instrument. Instrument should be operated in a well ventilated room. If the room is small or poorly ventilated, the nitrogen gas exhaust should be re-routed to an area of better ventilation.

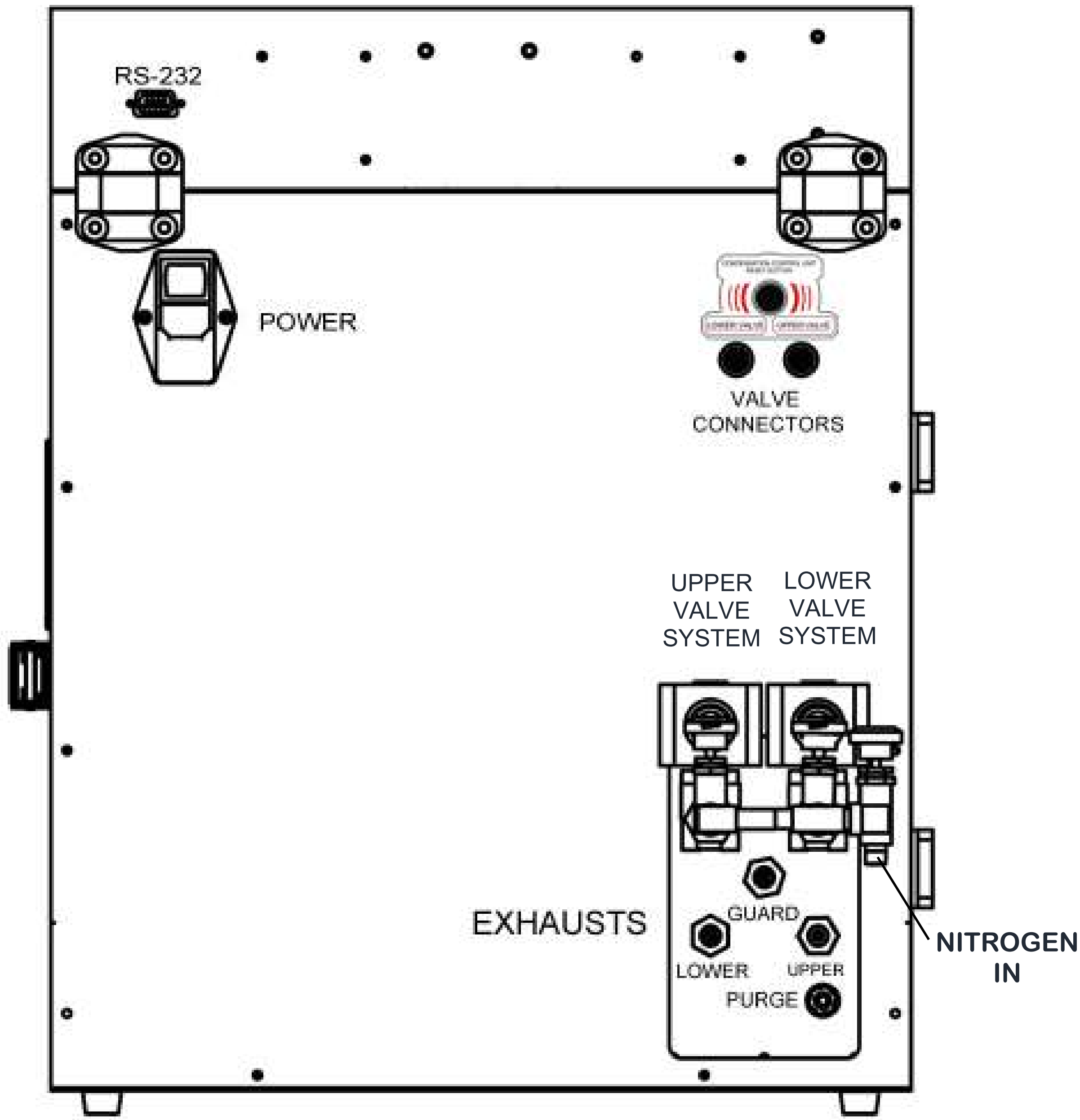
3. Dry gas purge input –used to purge and dry the instrument's chamber with dry gas. Typically, the "gas" output from the liquid nitrogen Dewar can be connected to the purge input at a very low positive pressure via a flow control valve (similar to those used for TIG welding).

4. Condensation Reset Button –This button would allow to reset the **Condesation Control Unit** in case of any evidence of condensation/ ice built around the unit. After pressing the button the heaters get active and will raise the temperature of the Chassy to room temperature conditions.

It is located at the back of the unit above the solenoid connections. See the illustration down below.



FOX 200LT PORT CONNECTIONS IN REAR OF INSTRUMENT

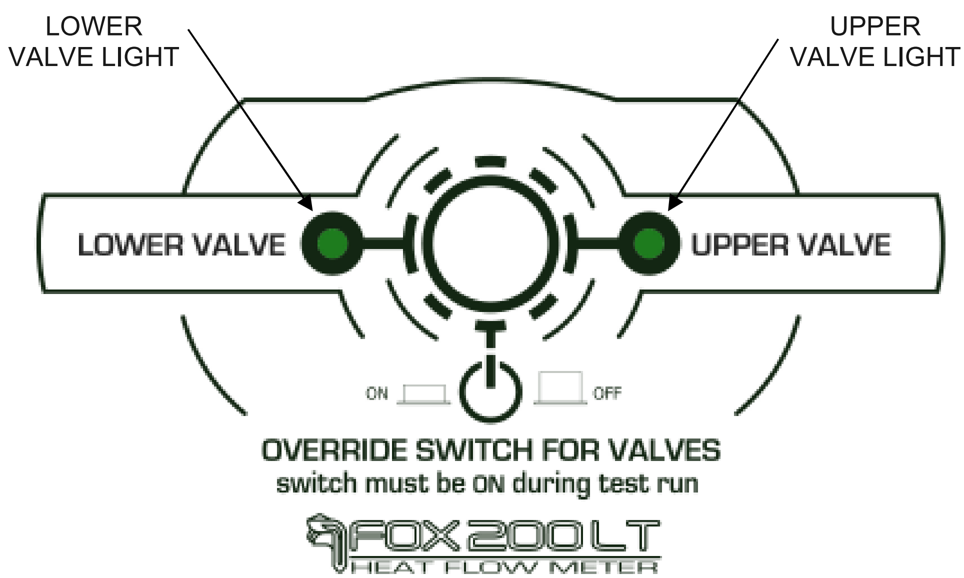


6.1.Drying the Instrument

Although the nitrogen purge should prevent any moisture from entering the instrument, it is important to dry the instrument between tests. To do this, first turn off the valves by pressing the button located in the rear of the instrument. Then run either a calibration or test with the upper plate at +50^{0}C and the lower plate +30^{0}C. The plate opening should be such that there is an air gap of at least 2mm. The instrument should be dried for at least a couple of hours. Remember to switch the valves on before starting the next test.

6.2. Override Switch For Valves.

The Override switch located at the front of the instrument, must be on during the test and should be turn off during service.



<u>CAUTION:</u> ALTHOUGH NITROGEN IS AN INERT GAS ABUNDANT IN OUR ATMOSPHERE, IT CAN BE DEADLY IF IT REPLACES THE OXYGEN!