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THERMAL CONDUCTIVITY TESTS OF LIQUIDS USING FOX50 HEAT FLOW METER INSTRUMENT

(Amendment the FOX50 Instrument Manual)

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INTRODUCTION

To measure thermal conductivity of liquids using the FOX50 Instrument a special cell described here should be used. The cell is made of two flat Pyrex glasses framed into the Polyethylene Terephthalate (PET) spacer ring. The cell should be filled up by the liquid and placed between the two plates of the Instrument.

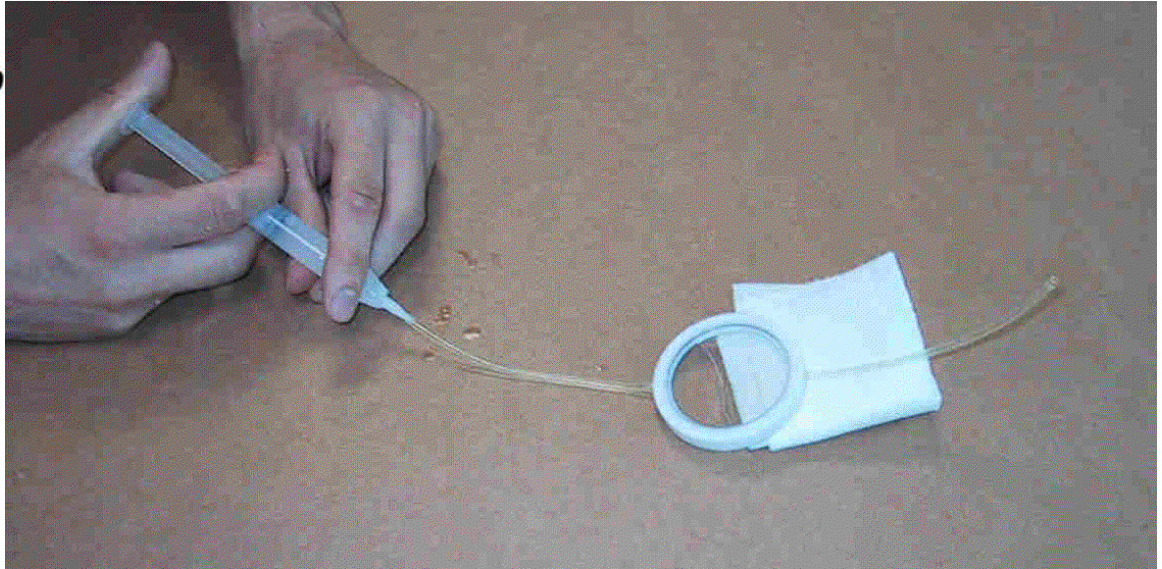
The plates of the FOX50 Instrument are made of copper – material having very high thermal conductivity to create uniform heat flow through the sample. Each plate has a heat flow transducer to convert the heat flow into the electric signal. Temperatures of the plates are measured by thermocouples and are automatically controlled to create and maintain the constant temperature difference between the plates, and, consequently, to create the constant heat flow (after reaching thermal equilibrium) through the cell (or sample).

Automatic thickness measurement system measures total thickness of the cell. Thickness of the Pyrex glasses Δx_{glass} is known (comes with the cell), so the software calculates thickness of the liquid layer.

CELL

The cell has two holes on the sides of its spacer ring – one to fill the cell, and second one - to let air out of the cell during the filling. Each of the holes has flexible Ether-based Polyurethane tubing. Use a syringe to fill the cell (see photograph on the next page). Place the cell at an angle and fill it slowly from the bottom. Be careful to let all the air out of the cell, and do not allow any bubbles to form. The outer ends of the tubes should be kept in position higher than the cell to avoid leakage of the liquid. Two O-rings (033 Buna-N, 2" ID and 2 1/8" OD) are used to seal the cell.

You can disassemble the cell (if you need to wash it) by carefully applying some water pressure inside it using syringe. The easiest way is to put both the cell and the syringe under water. Do not use sharp tools to open the cell!



After assembling the cell back please make sure that its Pyrex glasses are properly placed (parallel to each other) and have good contact with inner part of the spacer ring.

TESTS

Before starting the liquid cell tests a Two-Thickness Pyrex calibration with downward heat flow should be performed. Also thickness of the cell's Pyrex glasses should be known (0.33 cm each).

Warning: For tests of liquids use only downward heat flow to avoid free convection. This is especially important in case of liquids of low viscosity and at elevated temperatures.

- Open "WinTherm50" software and establish communication with the FOX50 Instrument (see FOX50 Instrument's Manual). Re-zero the plates' thickness measurements system. Click "Start".
- Put the cell on the center of the Instrument's plate.
- Make sure that the FOX50 upper insulation is in contact with the lower insulation, and the liquid cell hoses that extend beyond have their ends up to prevent liquid draining out.
- Select the Test Mode: "Liquid Cell", using "Filed Calibration, click "Run".
- Next the "Sample Information" window appears. Enter name of the file, thicknesses of the cell's Pyrex glasses in centimeters (0.33 cm), and any additional information about the liquid and conditions of the run into "Aux Info". Click "OK".



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- Next “Enter Test Set point” window appears. Enter the set points’ temperatures. Remember that the upper plate should have HIGHER temperature than the lower one! Click OK”.
- Next select the double-thickness (i.e. with “.dcal” extension) Pyrex calibration file with downward heat flow to be used for calculations. Click “OK”. Change, if necessary, the “Equilibrium Criteria” (see Manual).

After finishing each of the set points the modified “WinTherm50” software calculates the liquid’s thermal conductivity using values of the heat flow transducers’ signals, calibration factor, temperature difference, thickness of the liquid layer. Calibration factors and Pyrex/Instrument’s thermal contact resistances are taken from the calibration file to calculate the heat flux and thermal resistance of the liquid layer (see next “Theory” Section).

THEORY

Thermal resistance is resistance to the flow of heat. Thermal resistance R of a layer is equal to its thickness Δx [m] divided by its thermal conductivity λ [W/mK]:

$$R_{liquid} = \Delta x_{liquid} / \lambda_{liquid} \quad [m^2K/W] \quad (1)$$

$$R_{glass} = \Delta x_{glass} / \lambda_{glass} \quad [m^2K/W] \quad (2)$$

Thermal contact resistance R is equal to temperature difference δT [K] between two contacting surfaces divided by heat flux q [W/m²]:

$$R = \delta T / q \quad [m^2K/W] \quad (3)$$

and depends on the types of adjoining materials, their surface roughness, and the interface pressure.

There is no thermal contact resistance between liquid and the cell’s glasses, so the total thermal resistance is equal to:

$$R_{total} = 2R_{glass} + R_{liquid} + 2R_{contact} \quad (4)$$

Heat Flow Meter instruments can measure only the total thermal resistance - sum of the cell’s thermal resistance (liquid and two Pyrex glasses), and sample/instrument’s thermal contact resistances $2R$ of both surfaces. The FOX50 instrument, using modified “WinTherm50” software developed by LaserComp, is able to determine pure thermal conductivity



of the liquid excluding the Pyrex glasses' and contacts' thermal resistances.

Electric signal Q [μV] in Heat Flow Meter instruments is proportional to the heat flux q [W/m^2], which is equal to temperature difference ΔT divided by the total thermal resistance:

$$Q = q / S_{cal} = \Delta T / [(\Delta x / \lambda + 2R_{contact} + 2R_{glass}) S_{cal}] \quad [\mu\text{V}] \quad (5)$$

The calibration factor S_{cal} is particular instrument's characteristics, which should be determined beforehand during Two-Thickness calibration run (to determine and exclude thermal contact resistance) using Pyrex as standard material with well-known thermal conductivity. Physically, the calibration factor S_{cal} is equal to the heat flux q necessary to create 1 microVolt signal on the transducer.

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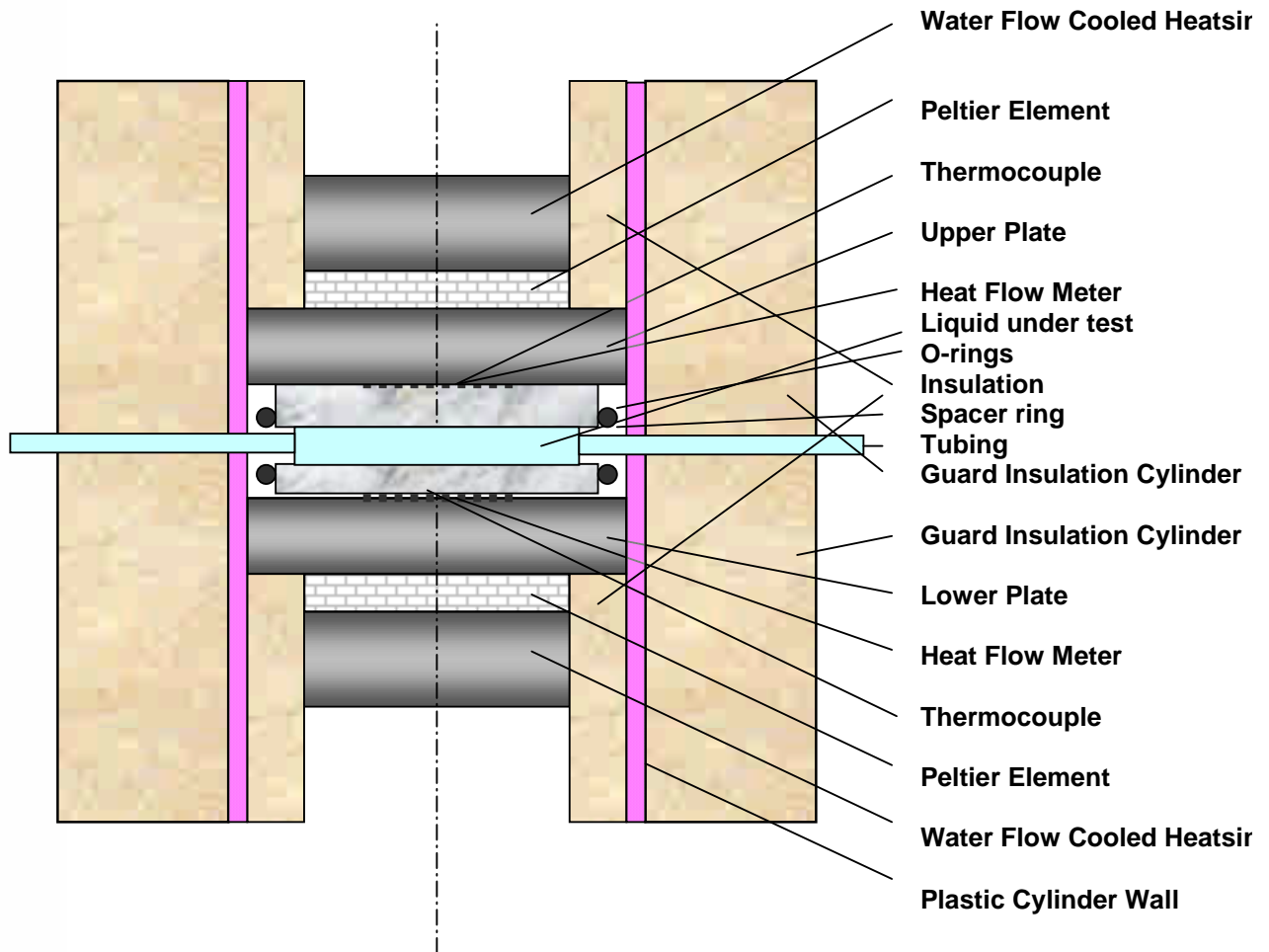


Fig. 1. Schematic diagram of FOX50 Heat Flow Meter Instrument with cell to test thermal conductivity liquids (not all parts are shown). *LaserComp, Inc.*



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Thermal resistance of the glasses $2R_{glass}$ can be calculated using Eq. (3) where the heat flux

$$q = Q S_{cal} \quad (6)$$

is the same for all layers of the stack – layer of the liquid, both of the glasses and contacts between the glasses and the Instrument plates. Thermal contact resistance $2R_{contact}$ is taken from Pyrex calibration file.

So, the value of the liquid's thermal conductivity λ is equal to thickness of the liquid's layer divided by the liquid's thermal resistance, which is equal to total thermal resistance **minus** thermal contact resistance and Pyrex' glasses' thermal resistances:

$$\lambda = \Delta x_{liquid} / R_{liquid} = \Delta x_{liquid} / (R_{total} - 2R_{glass} - 2R_{thermal\ contact}); \quad (7)$$

The modified "WinTherm50" software developed by LaserComp, Inc calculates all results automatically.

If you have questions – feel free to call, fax or e-mail to LaserComp:
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