kamstrup

Technical description

Calibration unit for MULTICAL® 303

Glossary, formulas and abbreviations

Letter/Symbol	Meaning / Formula	Unit
t1	Inlet temperature (also called Tf)	°C
t2	Outlet temperature (also called Tr)	°C
$\Delta\Theta$	Temperature difference t1-t2	K
$\Delta\Theta$min	Minimum temperature difference = 3K according to MID	K
TrueV	Simulated volume during auto integration	litres
k	Heat coefficient from EN1434-1	kWh/m³/K MJ/m³/K
True E	Calculated true energy	kWh
Measured E	Measured energy	kWh, MWh, GJ
Deviation	(Measured Energy - True Energy) x 100/True Energy	%
U	Uncertainty	%
MPE	Maximum Permissible Error	%
EN 1434	European standard for thermal energy meters	
Auto integration	Energy calculation based on volume simulation via serial data communication	

Contents

Calibration unit for MULTICAL® 303

1 General description

Calibration unit, 6699-303, is designed to perform a calculator calibration of Kamstrup's heat and/or cooling meters of the type MULTICAL® 303 with Pt500 temperature sensors.

1.1 Introduction

Kamstrup's calibration unit (6699-303) is, together with software product "METERTOOL HCW" (6699-724), used for the calibration. Various inlet and outlet temperatures are simulated which, together with volume simulation, form the basis for verifying the energy calculation. The test does not include the temperature sensors or the flow part.

1.2 Equipment

The calibration unit is primarily designed for use by laboratories, calibrating heat and/or cooling meters. Due to the compact construction of MULTICAL® 303, separation of the cabinet requires breaking the "Security Seals" and therefore, on-site calibration is not recommended.
The calibration unit is housed into a standard MULTICAL® 603 base, containing calibration PCB with microprocessor, control relays, precision resistors, etc.
The calibration unit interacts with MULTICAL® 303 through the optical read-out head and with the PC through the USB connection.
During the test, the calibration unit is supplied via the USB connection. The microprocessor simulates the volume with the use of auto integration. Temperature simulation is achieved by means of fixed precision resistors, which change automatically via relays that are controlled by the microprocessor.
After the test, the PC reads all the registers in the meter and compares the values with the true values calculated. The deviation determined for each test point, shown in percent, can be printed on a test certificate and/or stored in the PC (using METERTOOL HCW) under the serial number of the meter tested.


System requirements and installation guidelines for METERTOOL can be found in the technical description of METERTOOL HCW, 5512-2097.

1.3   Functional diagram

A functional diagram of the needed equipment to calibrate MULTICAL® 303 is seen below. It consists of the calibration unit, the calculator, the optical read-out head and a PC running METERTOOL HCW.
The microprocessor controls the temperature simulation of t1 and t2 by controlling the relays with different resistor values. Moreover, the microprocessor simulates the volume as well as uses autointegration.
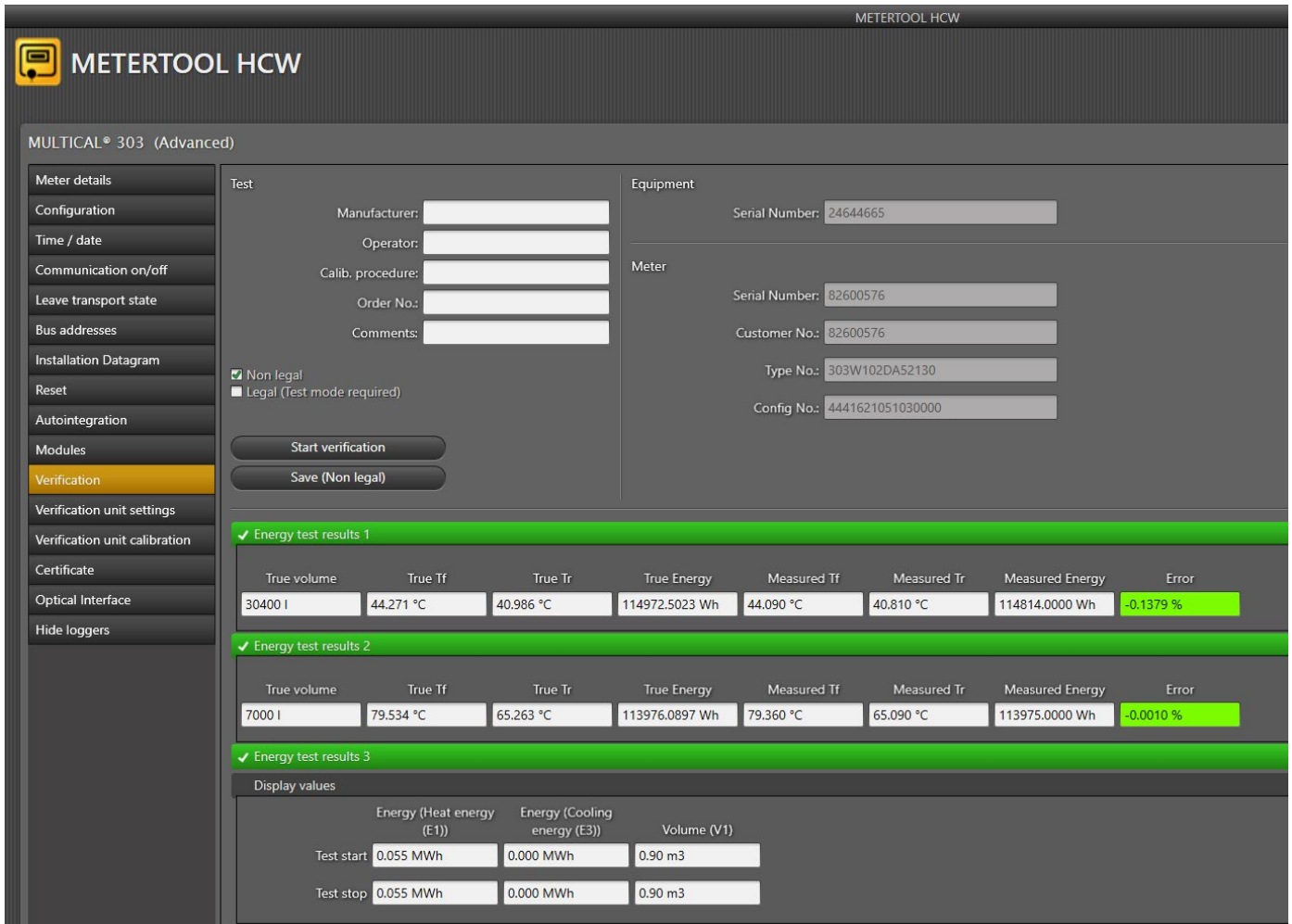Data is sent to and from METERTOOL HCW through the USB cable.
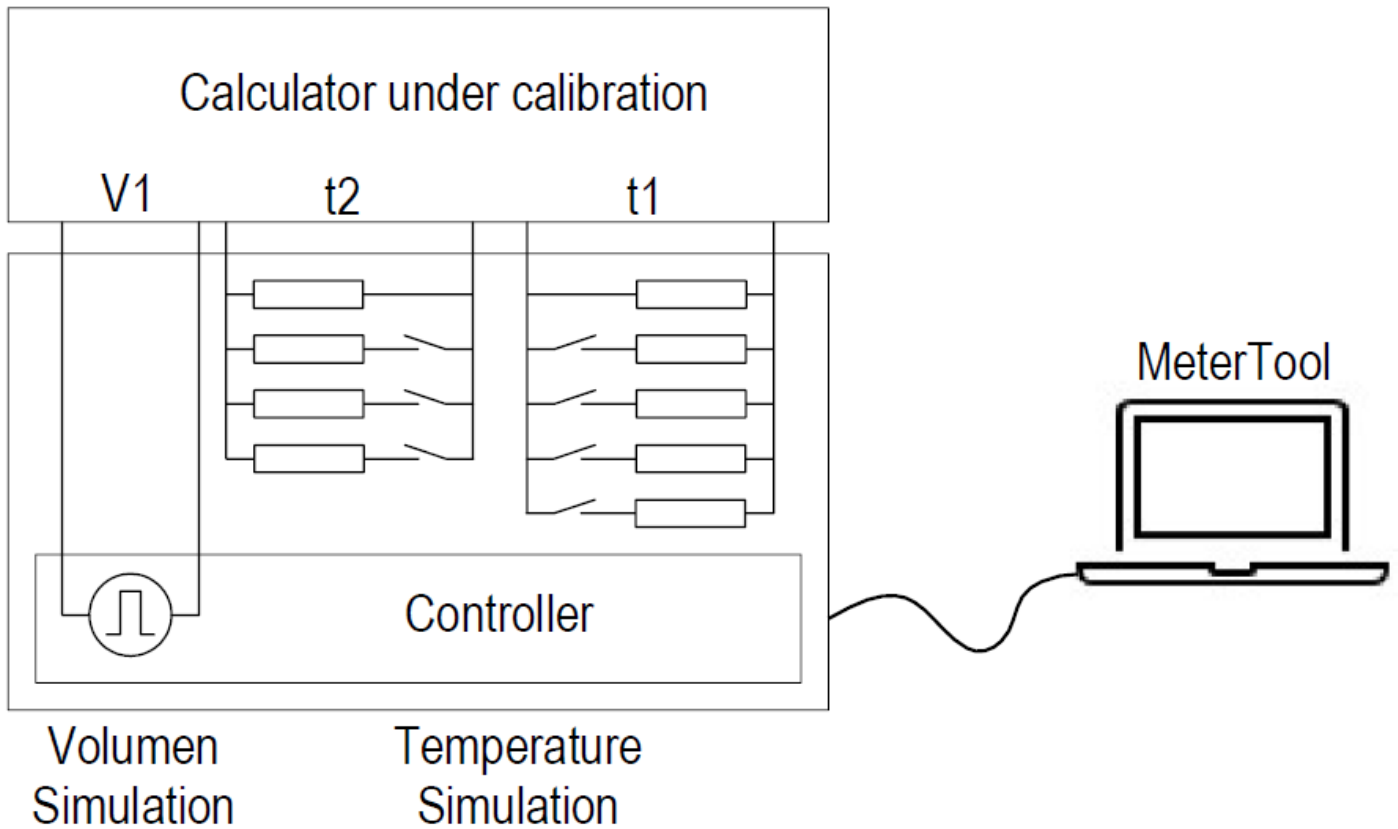
The optical read-out head is to be connected to MULTICAL® 303 through the wires as seen on the picture below (brown (Pin 5), yellow (Pin 6), green (Pin 7), white (Pin 8)).

2 Calibration

To calibrate MULTICAL® 303, the "Verification" tab in METERTOOL HCW is used, which is shown below:

2.1 Calibrating MULTICAL® 303

Clicking "Start verification" loads all necessary meter data from MULTICAL® 303 and starts the calibration. Beforehand, it is possible to either tick off the "non legal" (recommended for on-site use. Requires setup mode. The volume and energy simulated during the calibration will not be accumulated) or "legal" (recommended for laboratory use. Requires test mode. The volume and energy simulated during the calibration will be accumulated) verification. The legal verification can only be done by a certified laboratory with authorized personnel. If the "non-legal" test is selected, you receive a test report as described in section 2.3. If, however, the option "legal" is selected, you receive a calibration certificate.

The results for each test point show the true (simulated) values and the measured values as well as the error between them. As long as the error is within the MPE according to EN1434-1, the field is green. If not, the field is marked red. See section 2.2.4 for a description of the test points.

The amount of test points used depends on the type of meter. A heat meter is calibrated by the first 3 test points while a cooling meter is calibrated by test point 4 and 5. For heat/cooling meters, all 5 of the test points are used.

When the test is completed, the results are displayed in METERTOOL HCW. If the results are acceptable, choose "Save". The energy test results are then stored in the database under the serial number of the meter.

2.2 Verification unit settings

To show data from the calibration unit in METERTOOL, select "Read" under "Verification unit settings". All the data seen below is then read by the unit.

It is possible to edit these values. But as this data is crucial to the calibration result, it is protected by a password and should only be changed during reverification of the equipment.

Kamstrup can disclose this password upon request.

2.2.1 Permissible error and Uncertainty

The permissible error, expressed as a percentage, as well as the measuring uncertainty of the equipment can be seen under each of the five calibration points 1st, 2nd, 3rd, 4th and 5th. The "permissible error" minus "uncertainty" is stated as the MPE on the calibration certificate. According to EN1434-1, the MPE is $E_C = \pm(0,5 + \Delta\Theta min/\Delta\Theta)$ %.

2.2.2 Heat coefficients in inlet and outlet pipes

The heat coefficients used during the computer calculation of the "true" energy are also automatically filled after the use of "Read". As MULTICAL® 303 uses the heat coefficient from EN1434-1, the same table is naturally used during calibration. Please note that in accordance with EN1434-1, only values from the 16 bar table are used.

2.2.3 Number of integrations

The number of energy integrations for each test point is also set automatically and the suitable numbers have been determined for each specific calibration unit type.

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2.2.4 Nominal test points

Test point	t1/t2	ΔΘ [K]
1:	44,3/41°C	3,3
2:	80/65°C	15
3:	160/20°C	140
4:	15/18,3°C	-3,3
5:	6/20°C	-14

Test points are determined by the value of the temperature simulation resistors fitted in the test equipment. Type no. 6699-303 has the test points shown to the left.
The "true" temperatures are calculated automatically by METERTOOL HCW based on the "Measured resistance" values stored in E²prom in the calibration unit.
The negative symbol (-) used for the differential temperature shows the cooling meter usage.

2.2.5 Measured resistance

To update the calibration of the built-in temperature simulation resistors, type in the new measured values. A calibration sheet listing measured resistance values for all simulation resistors is supplied with the calibration unit by Kamstrup A/S. The temperature simulation resistors should be calibrated once a year when used in certified laboratories. Please refer to section 2.4 for details concerning the calibration procedure of the equipment.

2.3   Test report

This menu is used to print test reports or calibration certificates. A calibration certificate can only be made by verification laboratories with authorized personnel. This document is signed by the authorized person and indicates that the unit is verified. The test report can, however, be made by everyone and shows if the unit is accurate in a non-legal manner.

To make a report, type in the serial number of MULTICAL® 303 for which the report is needed. This requires a saved calibration as described in section 2.1.

You can type in any comment before printing. Click "Print".

An example of the test report and an example of the calibration certificate are shown below:

Test Report
for MULTICAL® 303

Ordered by:
Address:

Make:	Kamstrup A/S	Ambient temperature:	23 °C ± 5 °C
Type:	303W102DA52130	Type of test:	
Serial No.:	82600576	Calibration date:	14/10/2021
Config No.:	4441621051030000	Calibrated by:	

	True tf [°C]	True tr [°C]	True V [l]	True E [kWh]	Measured E [kWh]	Error [%]	Accept limit	Uncertainty [±%]	MPE [±%]
Test 1	44.27	40.99	30,400.00	114.97	114.81	-0.14	1.16	0.25	1.41
Test 2	79.53	65.26	7,000.00	113.98	113.98	0.00	0.61	0.09	0.70
Test 3	159.86	20.25	700.00	114.41	114.45	0.03	0.50	0.02	0.52

Reference equipment S/N: 24644665

The true values of temperature and volume are simulated values.

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95 %.

The verification equipment used is calibrated with traceability of measurement to recognized national or international standards.

Date: 14/10/2021   Approved by: _____

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Calibration Certificate
for MULTICAL® 303

Ordered by:
Address:

Make: Kamstrup A/S   Ambient temperature: 23 °C ± 5 °C
Type: 303W102DA52130   Type of test:
Serial No.:   82600576   Calibration date: 16/11/2021
Config No.:   44416210510300000   Calibrated by:

	True tf [°C]	True tr [°C]	True V [l]	True E [kWh]	Measured E [kWh]	Error [%]	Accept limit	Uncertainty [±%]	MPE [±%]
Test 1	44.27	40.99	100.00	0.38	0.38	-0.52	1.16	0.25	1.41
Test 2	79.53	65.26	100.00	1.63	1.63	0.06	0.61	0.09	0.70
Test 3	159.86	20.25	100.00	16.34	16.35	0.05	0.50	0.02	0.52

Reference equipment S/N: 24644665

The true values of temperature and volume are simulated values.

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95 %.

The verification equipment used is calibrated with traceability of measurement to recognized national or international standards.

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2.4   Calibration of the equipment

The calibration equipment consists of long-term stable resistance references. Under normal conditions, these require calibration just once a year if used in certified laboratories.

During calibration, use a six- or seven-digit precision ohmmeter with 4-wire connection and traceable calibration. **We recommend that a recognized institute or laboratory calibrates the equipment. Kamstrup also offers traceable re-calibration.**

2.4.1   Measuring t1 and t2

t1 and t2 can be measured through the connector J1 of the calibration base with a precision ohmmeter.

t1: Measured between J1 brown and yellow wires.
t2: Measured between J1 green and white wires.

2.4.2   Procedure

1. First, connect the USB plug to the PC.

2. Connect the precision ohmmeter between the brown and yellow wires. This will measure the resistance of the inlet temperature (t1).

3. Use "Verification unit calibration" in METERTOOL HCW and tick "Set test point 1". Now, the relays will connect the resistors to test point 1 and a measurement can be made with the ohmmeter.

    Figures below are examples of Pt500 values.
    Test point 1 = True 1st Tf = 586,002 Ω at t1 = 44,3 °C. Make a note of the measured 1st Tf _44.3.

4. Now tick "Set test point 2". It is possible to hear the calibration unit shift its relays when choosing the different test points.

    Test point 2 = True 2nd Tf = 654,484 Ω at t1 = 80,0 °C. Make a note of the measured 2nd Tf _80.0.

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Do the same for test points 3, 4 and 5:

Test point 3 = True 3rd Tf = 805,272 Ω at t1 = 160,0 °C. Make a note of the measured 3rd Tf _160.0.

Test point 4 = True 4th Tf = 529,247 Ω at t1 = 15,0 °C. Make a note of the measured 4th Tf _15.0.

Test point 5 = True 5th Tf = 511,715 Ω at t1 = 6,0 °C. Make a note of the measured 5th Tf _6.0.

The same procedure is used to measure the outlet temperature (t2). Connect the precision ohmmeter between the green and white wires.

Test point 1 = True 1st Tr = 579,635 Ω at t2 = 41 °C. Make a note of the measured 1st Tr _41.0.

Test point 2 = True 2nd Tr = 625,800 Ω at t2 = 65,0 °C. Make a note of the measured 2nd Tr _65.0.

Test point 3 = True 3rd Tr = 538,968 Ω at t2 = 20,0 °C. Make a note of the measured 3rd Tr _20.0.

Test point 4 = True 4th Tr = 535,664 Ω at t2 = 18,3 °C. Make a note of the measured 4th Tr _18.3.

Test point 5 = True 5th Tr = 538,968 Ω at t2 = 20,0 °C. Make a note of the measured 5th Tr _20.0.

Using the "Verification unit settings", click "Edit" and enter the measured resistance values in the corresponding fields. The true temperature is hereby calculated by the program using the formulas shown in section 2.5.1.

Please note that a password from Kamstrup is needed to edit the settings in "Verification unit settings".

2.5   Calculations

During calibration, a series of calculations are continuously carried out. These calculations are used to determine the measured error and are based on the following:

Volume: TrueV = Simulated volume during the auto integration, e.g. 100 litres

Temperature difference:
$$\Delta\Theta = t1 - t2 \ [K]$$

The formula and method of calculating t1 and t2 can be seen in the next section.

Heat coefficient:
Heat coefficient "k" in accordance with EN1434-1.

Flow sensor in inlet:

Test point	Test point:		k [MJ/m³/K]	k [kWh/m³/K]
	t1	t2		
1	44,3 °C	41 °C	4,1381	1,1495
2	80 °C	65 °C	4,0714	1,1310
3	160 °C	20 °C	3,8314	1,0643
4	15 °C	18,3 °C	4,1818	1,1616
5	6 °C	20 °C	4,1896	1,1638

Flow sensor in outlet:

Test point	Test point:		k [MJ/m³/K]	k [kWh/m³/K]
	t1	t2		
1	44,3 °C	41 °C	4,1437	1,1510
2	80 °C	65 °C	4,1081	1,1411
3	160 °C	20 °C	4,2148	1,1708
4	15 °C	18,3 °C	4,1794	1,1609
5	6 °C	20 °C	4,1822	1,1617

Energy:
k from column k [MJ/m³/K] is used and the TrueV in litres is used:

$$True\ E = \Delta\Theta\ TrueV \times k$$

Deviation: Error = (Measured Energy – True Energy)100/True Energy   [%]

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2.5.1 Calculating t1 and t2

The example below shows how t1 and t2 are calculated by the program: In this example, 1st Tf _44,3 is measured at 586,032 Ω.

Pt500 sensors comply with standard EN 60751

$$R_T = R_0 (1 + A \times T + B \times T^2)$$

R_T: Resistance at a given temperature T

R_0: Resistance at 0 °C   for Pt500: R0 = 500 Ω

A = 0,0039083 °C^{-1}
B = -0,5775 x 10^{-6} °C^{-2}

T can be calculated as follows:

$$T = \frac{(-R_0 \times A) + \surd((R_0 \times A)^{-2} - 4 \times R_0 \times B \times (R_0 - R_T))}{\times R_0 \times B}$$

With RT = 1st Tf _44,3 = 586,032 Ω inserted in the above formula, T = 44,316 °C

The same method can be used to determine other values.

3 Uncertainty

3.1 Calculating equipment uncertainty

The following uncertainty calculations are only guiding and based on the equipment being calibrated once a year. It is the choice and responsibility of each verification laboratory.

Uncertainty is calculated according to EA-4/02 M:2013 (Evaluation of the Uncertainty of Measurement In Calibration).

$E = V \times \Delta\Theta \times k$

E: Energy

V: Volume

$\Delta\Theta$: Temperature difference between inlet and outlet pipes

k: Heat coefficient

The uncertainty of $\Delta\Theta$ (variances of reference resistors type VISHAY S102C) is found. Furthermore, reading of the meter brings about an uncertainty which is included.

Specification on resistors:

TCR Temperature coefficient: ±2,0 ppm/°C

1 year's stability: ±0,005 %

Thermal EMF: 0,05 μV/°C (0,1 ppm/°C at U_{RT} =1 Volt. This point is thus without importance)

MULTICAL® 303 is a compact meter where the calculator and flow sensor are inseparable. Therefore, the volume simulation under calibration is made as "auto integration". During the calibration of the meter, the volume is here a constant, for example 100 l, and therefore, the uncertainty regarding the flow is zero. The number of integrations is solely used for determining how many temperature measurements are to be made.

3.2   Examples of uncertainty calculated for Pt500 type

3.2.1   Points t1 and t2: 15 °C and 18,3 °C

The uncertainty budget calculates the uncertainty at $\Delta\Theta$ = -3,3 °C to be 0,013 K.
The relative measuring ability is calculated as follows:

$$U_{\%} = \frac{U}{\Delta\Theta} \text{ x } 100 \text{ [\%]}$$

$$U_{\%} = \frac{0,013}{3,3} \text{ x } 100 \text{ [\%]} = 0,39 \text{ \%}$$

To this, the reading uncertainty of the meter must be added. A standard deviation of s = 0,25 % has been found by repetition tests. The expanded coverage factor k=2 makes U=0,5 %.

Thus, combined uncertainty is = % $\sqrt{0,39^2 + 0,50^2}$ %   <u>U = 0,64 %</u>

3.2.2   Points t1 and t2: 160 °C and 20 °C

The uncertainty budget calculates the uncertainty at $\Delta\Theta$ = 140 °C to be 0,016 K.
The relative measuring ability is calculated as follows:

$$U_{\%} = \frac{U}{\Delta\Theta} \text{ x } 100 \text{ [\%]}$$

$$U_{\%} = \frac{0,016}{140} \text{ x } 100 \text{ [\%]} = 0,012 \text{ \%}$$

To this, the reading uncertainty of the meter must be added. It is recommended to use 1 integration.
A standard deviation of s = 0,01 % has been found by repetition tests. k=2 makes U=0,02 %.

Thus, combined uncertainty is = % $\sqrt{0,012^2 + 0,02^2}$ %   <u>U = 0,023 %</u>