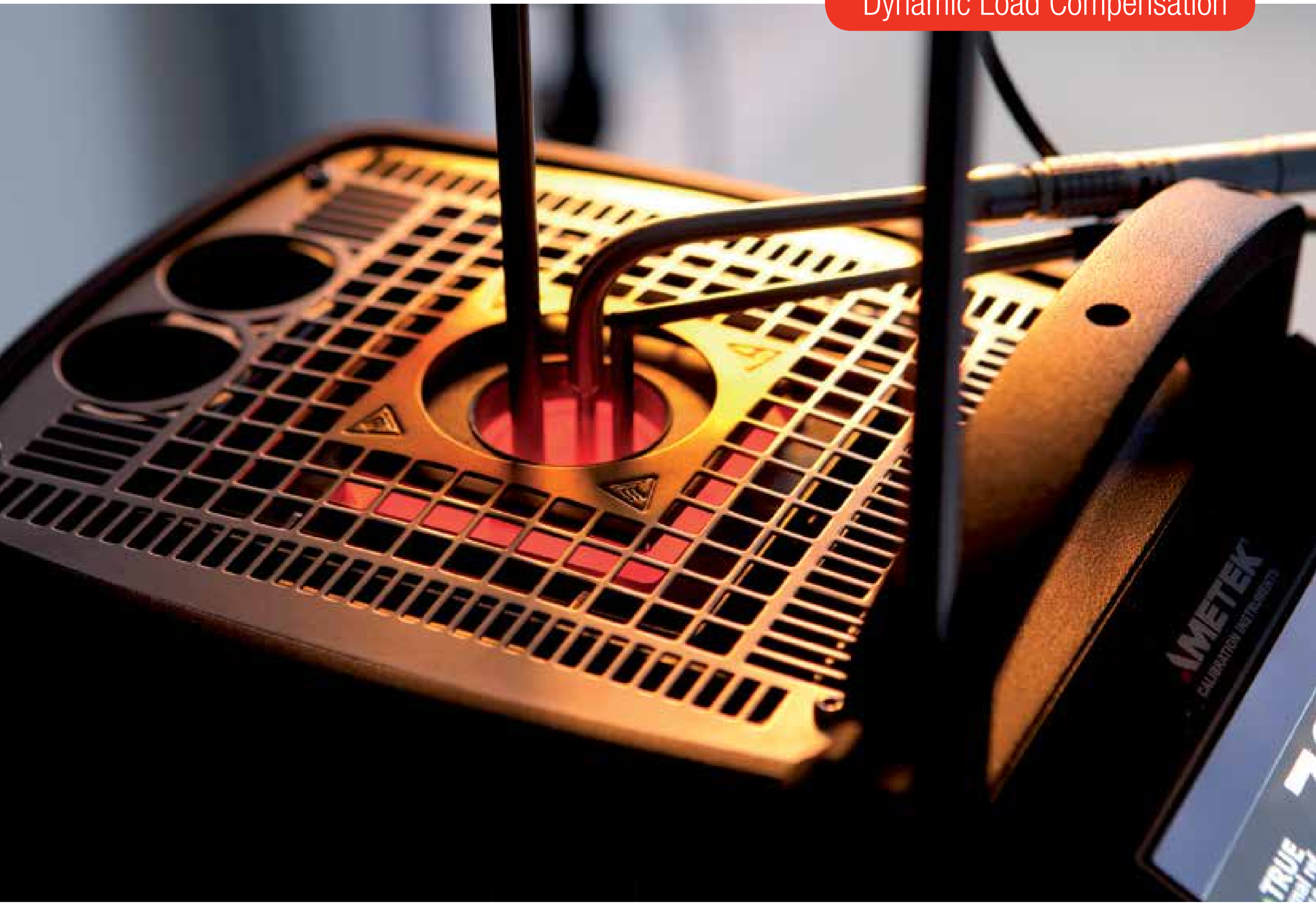
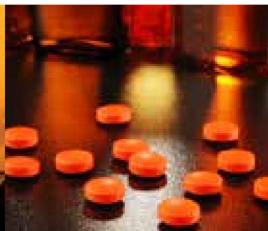
Technical Note

Dynamic Load Compensation





Technical Note - DLC

- Calibrate multiple, odd sized or large sensors without compromising the accuracy
- Improved and documented uncertainty budget calculations
- Accuracy improved by a factor of 3 compared to normal dry-block calibration

AMETEK®
TEST & CALIBRATION INSTRUMENTS

JOFRA is continuously seeking new ways of improving temperature calibration. The DLC calibration correction technology is yet another state of the art innovation within temperature calibration. DLC is short for Dynamic Load Compensation: the principle is innovative and patent pending.

What is the Dynamic Load Compensation system?

The Dynamic Load Compensation system combines a measuring/control system with a newly developed Dynamic Load sensor.

DLC Sensor

What is the purpose of the Dynamic Load Compensation?

The DLC system has been developed to deal with a major contributor to calibration errors.

A dry-block used as a calibration instrument has some inherent error mechanisms. It is a fact that the sensor under test will affect the calibration accuracy during calibration. The sensor transmits energy to and from the calibrator. This heat exchange between the calibrator and the environment has a considerable negative impact on the calibration accuracy. The extent of the error depends on many factors: sensor size (diameter and length), number of sensors in the well and the difference between calibration temperature and ambient temperature.

In other words, calibration accuracy is actually influenced by the actual load of the calibrator.

Patent pending!

How does the DLC system work?

JOFRA temperature calibrators are already famous for their active dual-zone calibration principle.

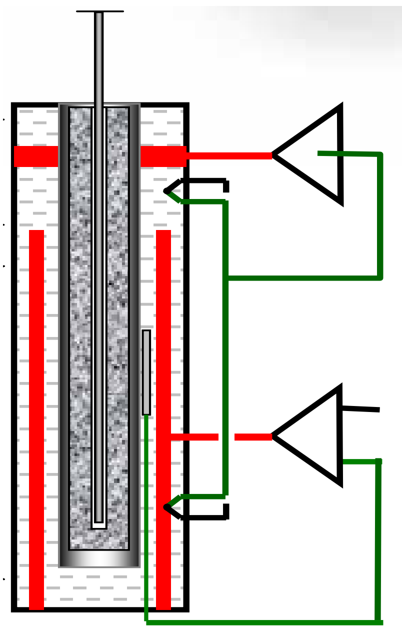
With the DLC system, we have taken this well-proven and acknowledged dual-zone principle one step further. The load compensation is now active both within the heating block and inside the insert during calibration.

The DLC sensor measures the actual temperature difference between two defined points inside the insert. See the purple dots.

The DLC sensor is designed to process input to the heat control system of the calibrator to ensure that the axial gradient deviations in the lower 60 mm of the insert are kept to a minimum. The temperature difference between the bottom and the zone at 60 mm from the bottom is controlled within a few hundreds of a degree.

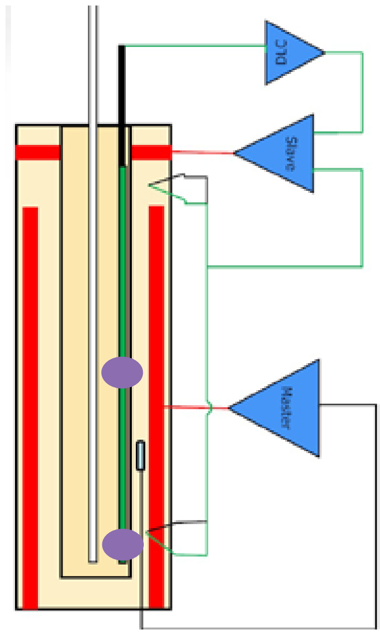
The DLC system reacts immediately to changes in the load of the insert and controls the heat distribution to achieve the minimum axial gradient.

The display value of the DLC shows 0.00 (or very close to this value) when the above mentioned minimum axial gradient has been achieved.



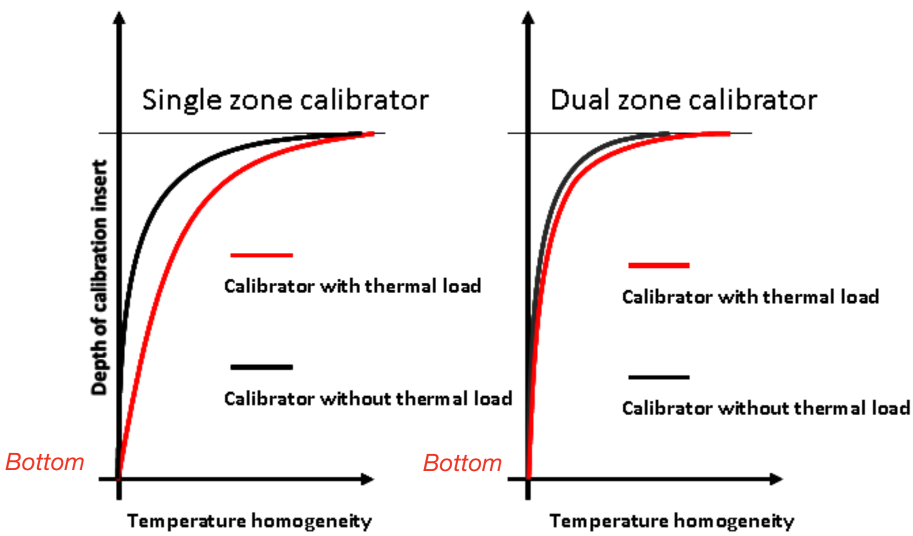
ATC

Dual-zone active block.
Adaptive load compensation in block.



RTC

Dynamic Load Compensation.
Adaptive load compensation in insert.



How much does the DLC system improve your calibration results?

The DLC system improves the calibration accuracy significantly. This may be illustrated and proven by two different test scenarios.

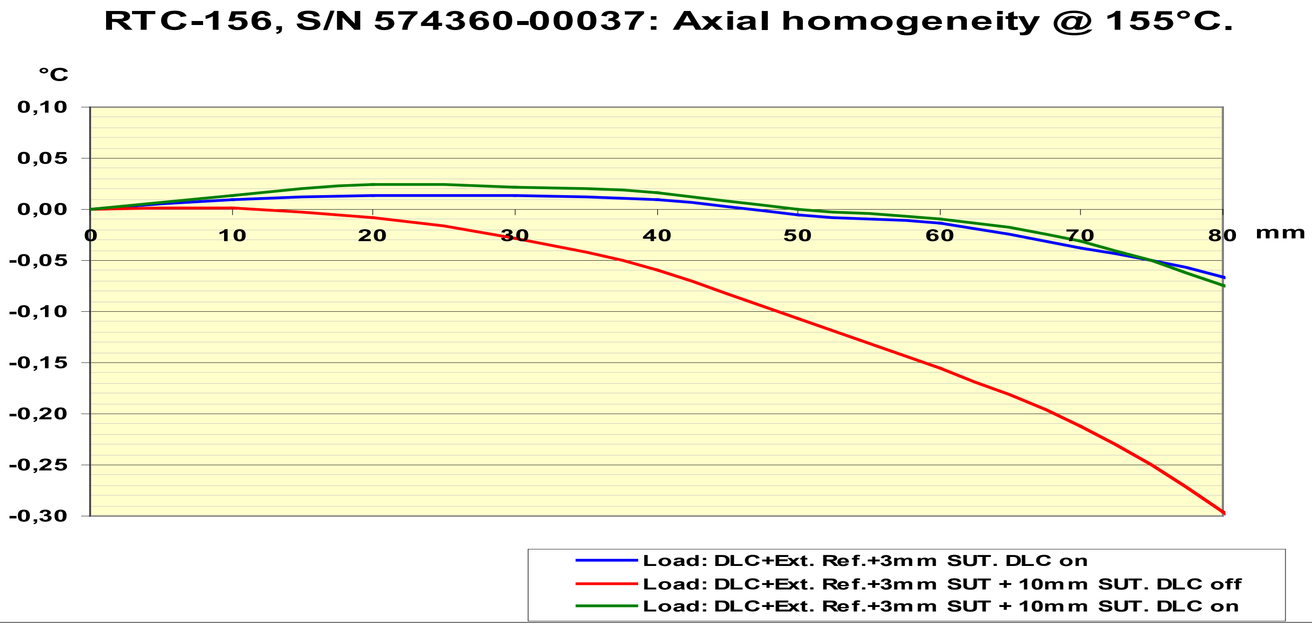
The first scenario shows the improvements when measuring in the insert.
The graph below illustrates the temperature change in the insert as a function of the distance from the bottom. Ideally this should be a straight line with no temperature variation vertically in the insert. If so, the axial gradient would be zero. However, this is not the case in practice.

To prove that the DLC functionality will improve the axial gradient, three tests have been performed.

The first test is to put a very light load on the RTC calibrator, which should produce a very little axial gradient (blue line). The load is a 4 mm external reference sensor, a 3 mm sensor and the DLC sensor. The maximum deviation from the ideal straight line is 0.015°C.

The next test is to load the RTC calibrator more heavily (red line). A thicker, 10 mm, sensor is added to the configuration detailed in the previous test. The DLC functionallity is not activated. The heavier loading of the calibrator causes a nonlinear axial gradient. The maximum deviation from the ideal straight line is 0.160°C.

The last test is carried out with exactly the same load as above, but we will now activate the DLC functionallity to see how efficiently the DLC will straighten the gradient (green line). The maximum deviation from the ideal straight line is 0.025°C.



The effect of using the patent pending DLC system can be expressed in two ways:

1) A heavily loaded RTC calibrator can perform a close to ideal straight line gradient by activating the DLC functionallity.

2) The maximum deviation from the ideal straight line is, in this example, improved by a factor 6 by activating the DLC.

Improvement factor = ratio 0.160 : 0.025 > 6

The second scenario shows the improvement when comparing with an ideal bath calibration.
The principle of this test is to calibrate a sensor in a calibration bath (ideal calibration represented in line 1) and compare the result with the results of the same sensor in an RTC calibrator with and without the DLC function (see table below). In addition to the original sensor, a 10 mm sensor is added to the RTC (lines 2 & 3).

This extra load on the calibrator has a large impact on the calibration result of the 3 mm sensor (line 2). The DLC functionallity is *not* activated.

With the exact same load on the RTC calibrator, we now activate the DLC functionallity and the accuracy is consequently improved.

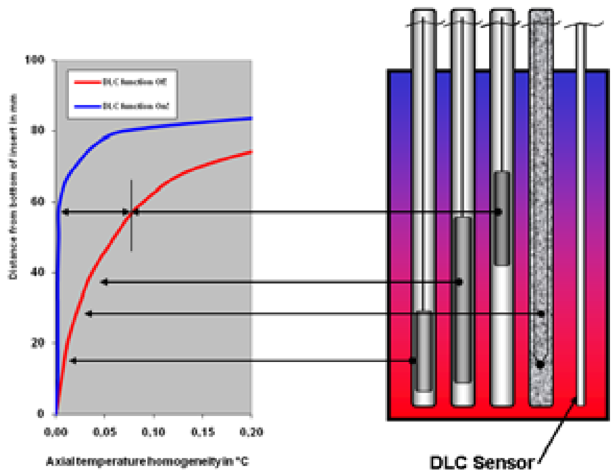
This test shows the following effect when using the DLC:
1: Uncertainty due to thermal load is reduced by a factor 3 when using the DLC (ratio 0.024 : 0.008 = 3)
2: DLC provides optimum accuracy under any thermal loads

	Test setup	SET (°C)	TRUE (°C)	SUT1 (°C)	SUT1 Deviation (°C)	Deviation from bath calibration (°C)
1	Bath Calibration	155,000	154,973	154,923	-0,050	--
2	RTC-156, DLC=off, SUT1 + SUT2	155,000	155,000	154,974	-0,026	0,024
3	RTC-156, DLC=on, SUT1 + SUT2	155,000	155,000	154,958	-0,042	0,008

Example: Calibration of a OD 3mm (SUT1) and OD 10mm (SUT2) at the same time.

What are the advantages of the patent pending DLC system?

- Calibration of several sensors simultaneously
- Calibration of large diameter sensors
- Since no standard temperature sensors have a thermo sensitive lenght beyond 60 mm, it is no longer necessary to know the length of the thermo-sensitive part of the sensor. Just plug it in!
- The DLC indicator shows that the dual-zone is active and working
- A perfectly working calibrator. The DLC value is very close to 0.00 when the calibrator is loaded or not loaded
- Calibration value indication. The DLC indicator shows when the temperature homogeneity in the lower 60 mm part is achieved



What are the important benefits for the user?

- Saves time by calibrating more sensors simultaneously
- Calibrating big diameter sensors without loosing accuracy due to heat conduction
- TSL (Thermo Sensitive Length) independency. Safe, secure and accurate calibration results without spending time to get sensor specifications from your supplier
- The DLC function minimizes the influence from sensor production tolerances like the Pt100 element being mounted in various positions in the sensor
- All temperature sensors that can be placed in the bottom of the calibrator will be calibrated without error
- The displayed DLC value indicates when the optimum temperature homogeneity is achieved
- The displayed DLC value shows when the load has no influence on the calibration result
- When the DLC value is close to zero, the calibration technician knows that the calibration results are reliable
- The DLC indicator proves that the dual-zone is active and well-functioning
- The DLC in conjunction with the stability indicaton show when the calibration value is ready. The green-zero rule (see page 7)

Why does the DLC have a possitive impact on the uncertainty budget?

Our customers often want to make uncertainty budgets for their calibrations. This is usually done by entering the values from the supplier's datasheet. These values are normally rather conservative to ensure that specifications are valid for all calibrators.

The uncertainty budget results are consequently very high. Through the DLC measurement, some of the specifications can be changed with the actual values of the instrument thus providing a far better measuring capability of the calibrator.

The advantage of the DLC system is illustrated by comparing of two uncertainty budgets.

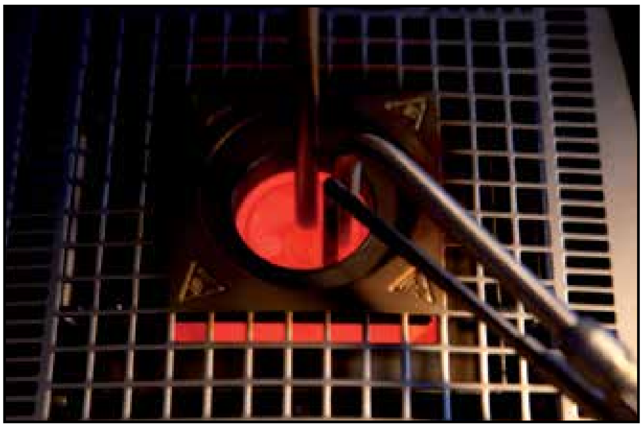
Uncertainty budget RTC calibrator loaded with Ø 10 mm sensor					
DLC off	10 mm load				
1	Temperature of reference thermometer	155.002			
2	Uncertainty reference thermometer (k=2)		0.015	Normal	0.0075
3	Resolution of RTC temperature indicator		0.001	Square	0.0003
4	Hysteresis effect		0.008	Square	0.0046
5	**Axial temperature homogeneity**		**0.159**	**Square**	**0.0918**
6	Radial temperature homogeneity		0.004	Square	0.0023
7	Loading effect		0.004	Square	0.0023
8	Stability in time		0.003	Square	0.0017
		155.002		k=1	**0.092**
	Geometrical sum*			k=2	**0.185**

Uncertainty budget RTC calibrator loaded with Ø 10 mm sensor					
DLC on	10 mm load				
1	Temperature of reference thermometer	155.002			
2	Uncertainty reference thermometer (k=2)		0.015	Normal	0.0075
3	Resolution of RTC temperature indicator		0.001	Square	0.0003
4	Hysteresis effect		0.008	Square	0.0046
5	**Axial temperature homogeneity**		**0.024**	**Square**	**0.0139**
6	Radial temperature homogeneity		0.004	Square	0.0023
7	Loading effect		0.004	Square	0.0023
8	Stability in time		0.003	Square	0.0017
		155.002		k=1	**0.017**
	Geometrical sum*			k=2	**0.034**

* Geometrical sum: Square root of the sum of the squares

1. The uncertainty of the axial gradient has been reduced by 85% when using the DLC system.
2. The RTC calibrator is performing within specifications even while heavily loaded.
3. The total uncertainty is improved by a factor 5 when using the DLC function.

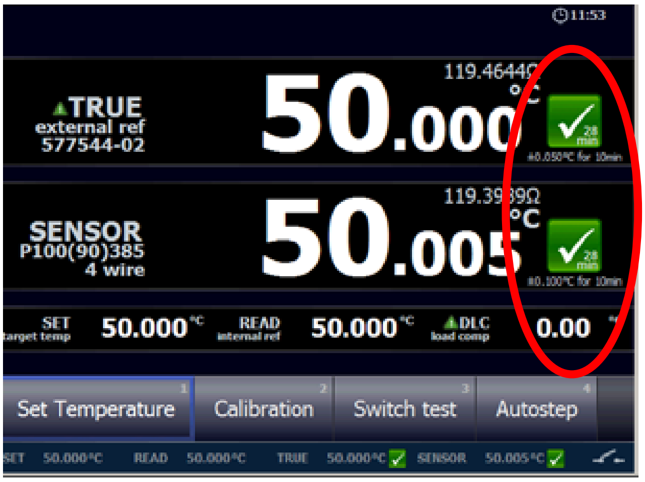
Improvement factor = ratio 0.185 : 0.034 > 5



How can the calibration technician easily see when the calibrator is ready?

The RTC calibrator shows and proves when the optimum gradient and stabilization has been achieved (Green-Zero illustration).

No other calibrators worldwide, are able to provide this essential status information.



The green-zero rule as shown on a type B of the RTC calibrator series.

What are the most frequent questions in connection with the DLC?

Does the DLC sensor have any negative impact on the calibration accuracy?

Since the diameter of the DLC sensor is only 3 mm, it does not impact the measurements.

What is the significance of the sign in the DLC display value?

A positive display value of the DLC means that the top of the 60 mm measuring zone is hotter than the bottom and vice versa.

What are the major conclusions related to the DLC system?

1 The RTC calibrator with the DLC system is the only dry-block in the world that fully compensates for the actual load.

2 Compared with an ideal bath calibration, the achieved accuracy with the DLC is improved by a factor 3.

3 With reference to a load test with a 10 mm load sensor, the axial gradient over a 60 mm length is improved by a factor 6 by activating the DLC system.

4 All temperature sensors can be calibrated without first spending costly time on investigating sensor details, such as Thermo Sensitive Lengths, production tolerances, etc.

5 The DLC display supports your effort to make a more qualified and realistic uncertainty budget.

6 Typically you just have to trust datasheet specifications. With the DLC system, you have the first temperature calibrator where the display shows and proves its own datasheet specifications.

Calibrators with DLC

RTC-156
Temperature range from -30 to 155°C (-22 to 311°F)
General purpose light-weight and high performance dry-block.

RTC-157
Temperature range from -45 to 155°C (-49 to 311°F)
General purpose light-weight and high performance dry-block with superior low temperature performance.

RTC-158
Temperature range from -22 to 155°C (-8 to 311°F)
Combined liquid bath and dry-block with a large diameter insert, designed for calibration of odd sizes or shapes of sensors or when calibrating multiple sensors at a time.

RTC-159
Temperature range from -100 to 155°C (-148 to 311°F)
The most versatile temperature calibrator available with a temperature range that makes it especially ideal for use in the health care, medical, pharmaceutical, biotechnology and food industries.

RTC-250
Temperature range from 28 to 250°C (82 to 482°F)
Combined liquid bath and dry-block with a large diameter insert, designed for calibration of odd sizes or shapes of sensors or when calibrating multiple sensors at a time.

RTC-700
Temperature range from 33 to 700°C (91 to 1292°F)
A unique combination of speed and accuracy at very high temperatures based on our new patent pending heating block.

AMETEK Calibration Instruments
is one of the world's leading manufacturers and developers of calibration instruments for temperature, pressure and process signals as well as for temperature sensors both from a commercial and a technological point of view.

JOFRA Temperature Instruments
Portable precision thermometers. Dry-block and liquid bath calibrators: 5 series, with more than 25 models and temperature ranges from -90° to 1205°C / -130° to 2200°F. All featuring speed, portability, accuracy and advanced documenting functions with JOFRACAL calibration software.

JOFRA Pressure Instruments
Convenient electronic systems ranging from -25 mbar to 1000 bar (0.4 to 15,000 psi) - multiple choices of pressure ranges, pumps and accuracies, fully temperature-compensated for problem-free and accurate field use.

JOFRA Signal Instruments
Process signal measurement and simulation for easy control loop calibration and measurement tasks - from handheld field instruments to laboratory reference level bench top instruments.

JOFRA / JF Marine Instruments
A complete range of calibration equipment for temperature, pressure and signal, approved for marine use.

FP Temperature Sensors
A complete range of temperature sensors for industrial and marine use.

M&G Pressure Testers
Pneumatic floating-ball or hydraulic piston dead weight testers with accuracies to 0.015% of reading.

M&G Pumps
Pressure generators from small pneumatic "bicycle" style pumps to hydraulic pumps generating up to 1,000 bar (15,000 psi).

AMETEK®
TEST & CALIBRATION INSTRUMENTS

www.jofra.com

UK
AMETEK Calibration Instruments
Tel +44 (0)1243 833 302
jofra@ametek.co.uk

France
AMETEK S.A.S.
Tel +33 (0)1 30 68 89 40
general.lloyd-instruments@ametek.fr

Germany
AMETEK GmbH
Tel +49 (0)2159 9136 510
info.mct-de@ametek.de

Denmark
AMETEK Denmark
Tel +45 4816 8000
jofra@ametek.com

USA
AMETEK Mansfield & Green
Tel +1 (800) 527 9999
cal.info@ametek.com

India
AMETEK Instruments India Pvt Ltd.
Tel +91 22 2836 4750
jofra@ametek.com

Singapore
AMETEK Singapore Pte Ltd
Tel +65 6484 2388
jofra@ametek.com

China
AMETEK Inc. - Shanghai
Tel +86 21 5868 5111

AMETEK Inc. - Beijing
Tel +86 10 8526 2111

AMETEK Inc. - Guangzhou
Tel +86 20 8363 4768
jofra.sales@ametek.com.cn

Pub code TN-DLC Issue 1101