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Portable Field Temperature Calibration System

Metropolia University of Applied Sciences

Bachelor of Engineering

Electrical and Automation Engineering

Thesis

26.4.2020

Author Title	Mikko Tervala Portable Field Temperature Calibration System
Number of Pages Date	17 pages + 2 appendices 26 April 2020
Degree	Bachelor of Engineering
Degree Programme	Electrical and Automation Engineering
Specialisation option	Electronics
Instructors	Ville Alasmaa Service Development Manager, Tuukka Korkea-aho Testing and Calibration Manager, Anssi Ikonen Senior Lecturer

This thesis work discusses the design for a new portable temperature calibration system. The system is used by field technicians to perform calibrations at a customers site. A new system recommendation is needed to replace current older systems. This work focuses on temperature calibrators and usability requirements.

This thesis begins by studying the required specifications and discussing feedback acquired from users of the current system. Then multiple possible units are specified using manufacturer information. By comparing these specifications, a recommendation for a unit is made.

The resulting comparison shows that most units have very similar specifications. The most significant features are the ones affecting usability and versatility.

Keywords	Temperature calibration, calibration

Contents

1 Introduction

This study was carried out in cooperation with Metropolia University of Applied Sciences and Vaisala Oyj. Purpose for the study was to research and plan a portable temperature calibration system. There are multiple specifications about features that need to be achieved.

Vaisala is a Finnish company founded in 1936. Vaisala produces some of the leading technologies in environmental and industrial measurement. A big part of maintaining accurate measurements is calibration for the instruments. For this reason, Vaisala provides calibration and repair services for its devices. Most calibrations are done in Vaisala's calibration centers, in a measurement laboratory. Vaisala also offers on-site calibrations. In on-site calibrations measurement references and calibration equipment is taken to customer's site, and calibration is performed there.

Objective was to plan a calibration system, which can be easily transported to customer's site, and still be capable of high accuracy calibrations. The system's focus was on temperature calibrations Humidity calibration will be performed with a separate unit.

2 Specifications and Features

Specifications were created to list needed functionality for the station. The specifications include speed and capacity, as well as features. These specifications were considered as preliminary, as there might be no unit that achieves them all.

2.1 Device Capability

Calibration capability for the following devices:

- DL1000 series data loggers
- HMP110, HMP113 and HMP115 humidity and temperature probes
- HMP7 and TMP1 humidity and temperature probes
- HMT330 series humidity and temperature transmitters

Figure 1 Vaisala HMP110 humidity and temperature probe

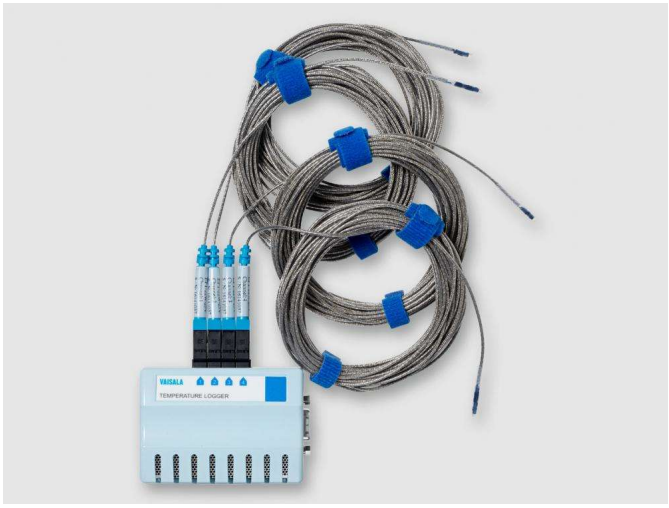

Figure 2 Vaisala DL1416 temperature data logger

2.2 Calibration Range

Calibration range is from -25 °C to +60 °C. This range covers most calibration needs for warehouses, cold storage and freezers. Low and ultra-low temperature freezers are excluded from this range, as reaching them will require considerably more time. In case a customer requires a calibration with a larger range and/or lower uncertainties, it is recommended they send the unit to a calibration center.

2.3 Calibration Capacity

The system should be able to do at least three calibrations with three temperature points in a workday. Each calibration should last less than two hours and have room for four devices. This results in a minimum of 14 calibrated units a day.

2.4 Temperature Reference

Most previous similar stations use manufacturer provided temperature references. These have excellent specifications and ease of use. To calibrate these references, the entire unit needs to be sent to the manufacturer along with the references. The unit has integrated measurement electronics for the sensor, so often a reference is tied to one system.

The new system should use a reference, which is not tied to the system and can be calibrated more easily. Spare references must always be available, that can be quickly swapped if there is any suspect of reference problems such as sensor damage and measurement drift.

2.5 Portability

The entire system needs to be small enough, to transport it in an airplane along with a technician. This also imposes limits on weight. The system must not have any fluids, gases or other hazardous materials so that it would need special documentation or clearing before transport.

2.6 Capability and Support

The generator must have universal power input so that it can be used on both 110 V AC and 230 V AC, 50 or 60 Hz mains power. It must have global support, so that it can be serviced in all areas it is used.

3 Solving Problems

3.1 Device Capability

Vaisala devices use multiple probe sizes. Most common is a 12mm probe, which houses humidity and temperature sensors. Older external temperature sensors are 6mm, new data logging systems use 5mm or 3mm. These devices create a difficult low volume high mix situation.

Most calibrators use a 30mm diameter insert. These are also in field use now. It will fit plenty of 5mm or 3mm temperature probes, but only fits one or two larger probes. To fit an adequate amount, the unit must have a 60mm insert. This rules out almost all units from Ametek that have been used before.

3.2 Dry Block Versus Oil Bath

There are two common ways to do temperature calibrations, dry block or oil bath.

Dry block calibrations use a metal block that is often made of aluminum due to its high thermal conductivity and ease of machining. This block is drilled with holes that fit the used temperature sensors. Dry blocks offer fast stabilization, and simple usage. Down sides are that they are expensive. A new block needs to be manufactured for all configurations of different sized sensors that will be calibrated.

Dry blocks are expensive due to the high accuracy needed in machining. Surface finish and manufacturing tolerances affect thermal transfer speeds. If the insert and temperature sensors have gaps, the sensors will take a lot longer to stabilize as there is no other thermal transfer material. Due to this reason, calibration inserts need to be manufactured for different sized sensors. For example, 3mm sensors cannot be calibrated in 5mm holes.

Oil baths use a temperature controlled container of oil. As there are no fixed holes for the sensors, it can be used with all sensor sizes and shapes. Downside of using oil is

that measurement probes need to be protected to keep them clean. This can be achieved with plastic sleeves. Everything that touches oil, must be stored carefully as the oil will contaminate all surfaces it touches. Calibration oil also has a higher thermal capacity than aluminum, so reaching set temperatures will take longer.

Both ways have advantages and disadvantages. Best case would have both. Dry blocks for most common configurations, and an oil bath for high mix calibrations.

Figure 4 Machined dry block model

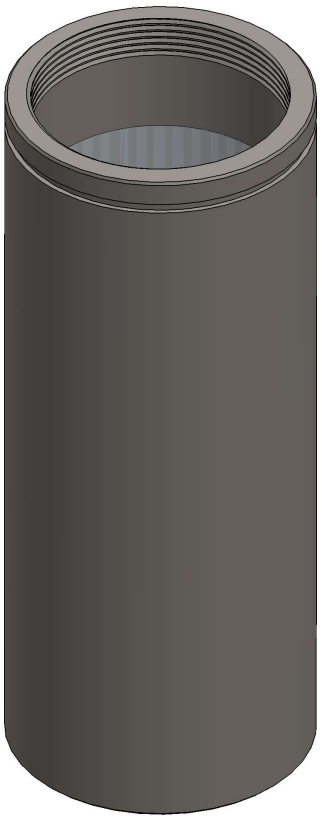

Figure 3 Machined oil block model

3.3 Selecting the Temperature Reference

The previous portable temperature calibrator uses a reference provided by the manufacturer. These references have excellent specifications and are easily connected to the system. Downside is that calibration for these sensors is expensive and slow.

The new system will utilize the Vaisala TMP1 digital temperature probe as the reference. TMP1 uses a stable PT100 platinum resistance thermometer as the sensor. TMP1 can be quickly calibrated in Vaisala's own measurement standards laboratory. The nominal accuracy for the sensor at +23 °C is ±0.1 °C, including non-linearity and repeatability. This, however, can be improved with a multipoint calibration that is always performed for references. This calibration provides a calibration with low calibration uncertainty.

The TMP1 can be easily connected to a PC with a USB serial converter, also providing power for the unit. Power consumption is low because sensor heating and other power intensive functions are not needed. The unit does not need a separate power supply. As Vaisala devices are widely used at the Vaisala factory calibration stations, a lot of the needed software is already written.

The new generation of Vaisala devices communicates with Modbus over RS485. This simplifies cabling considerably as we can have all of the needed references on the same RS485 bus. The station will need a reference for temperature, and a device to measure ambient humidity and temperature. Ambient measurements are not used in the calibration, but they are always listed on the certificate.

3.4 Portability and Transportation

Some manufacturers sell transport cases for devices, but in previous experience these are not always the best option. For example the cases sold by Ametek start to loosen up after some use. After that, the locks no longer function reliably, and the lid needs to be secured otherwise.

A non functioning transport case will cause frustration in the field. In the worst case it can also prevent shipping of the unit.

Figure 5 Ametek case locks damaged in use

Another option is to get a universal transport case. Transport cases made by Pelican have worked excellently before. They feature a tough plastic casing, weather and moisture protection, shock proofing and carrying handles. Pelican cases have gotten good feedback from field techs before, so it is the clear winner for this as well.

Figure 6 Pelican universal transport case

4 Researched Units

For this work, five manufacturers were researched:

- Ametek
- Fluke
- Sika (Druck)
- Michell Instruments
- Thunder Scientific

Most units available are too heavy and large. All manufacturers did nor have any units for this category.

The following devices were considered for the system. Main features are written, and common features are compared between the units.

4.1 Fluke 7103 Micro-Bath

The Fluke 7103 is a small portable oil bath. It is the lightest of all units compared, making it easy to transport. It has an oil bath with a diameter of 48mm.

4.2 Sika TP 3M165E.3

The Sika TP 3M165E.3 is a larger but still portable temperature calibrator with a 60mm insert. It can be used with a dry block, or oil bath. It promises best speeds and versatility in its class. This generator supports a removable oil bath, offering a great compromise. It can be easily changed without any cleaning.

4.3 Ametek Jofra RTC-158

The Jofra RTC-158 is a new unit with a 60mm insert by Ametek. It is the most expensive, and has small temperature range compared to other units. Jofra units have proven reliable in use, and they have excellent temperature stability due to their Dynamic Load Compensation (DLC) System. It does support oil calibrations, but it cannot be transported with oil inside. The oil must be cleaned out every time the type is changed.

5 Comparison Between Units

Table 1 Feature comparison

	Fluke 7103 Micro-Bath	Sika TP 3M165E.2	Jofra RTC-158
Type	Oil	Oil and dry block	Oil or dry block
Universal power			
–25°C to 60°C	–30°C to 125°C	–35°C to 165°C	-22°C to 125°C
Airplane transport			
At least 6 probes	48mm oil well	60mm	63mm
Computer control			
Price	≈ 8k€	≈ 10k€	≈ 17k€
3 point calibration	2h 15min	2h 20min (Oil) 1h 50min (Dry block)	2h

Table 1 includes the most important specifications for the units. Green fields indicate better than average properties, and red fields below average properties. Full specifications are listed in appendix 1. Full speeds are listed in appendix 2.

5.1 Similarities Between Devices

All of the compared devices are very similar in features. All of them are designed for the same use case. They support universal power input and have full computer control interface available. Both dry block models have a very similar block size. The Fluke and Sika oil blocks are similar in size.

Calibration time for all systems is very similar. These calibration speeds have been calculated using manufacturer provided speeds in the datasheets. In general, oil calibrations take a little longer due to higher thermal capacity of the oil.

5.2 Calibration Range

Ametek Jofra does not quite reach our desired temperature range. Sika generator would go considerably higher than the others. This would allow adding high temperature calibrations to the offering. Sika also offers the lowest temperature of these units, but it is still not cold enough for ultra-low temperature freezers.

5.3 Pricing

Ametek Jofra is the most expensive unit, and the price will be even higher due to the multiple calibration inserts needed. Fluke is clearly the most inexpensive unit, due to its price and use of oil. The oil is relatively inexpensive and this unit does not need any custom manufactured parts. Sika fits in the middle. It is more expensive than Fluke, but it will also need some calibration inserts manufactured.

When considering business decisions, all of the units are very affordable. Price would not be the deciding factor in any of these units.

6 Full System Recommendation

Based on the study, the following recommendations can be given for a complete system.

6.1 Generator and Reference

Recommendation is the Sika TP 3M165E.3. This is due to its high versatility, and portability. The unit would allow easy dry block calibrations for big batches, and oil calibrations for occasional high mix situations.

As the temperature reference, a Vaisala TMP1 transmitter should be used. This is due to its very small size, as well as light weight. Still it is capable of offering good calibration accuracies that can be achieved with the current system. The transmitter is also inexpensive so that we can have spare references for calibration rotation as well as spared.

6.2 Test Equipment

As all devices to be calibrated on the system are digital, there is no need for bulky analog measurement devices or multiplexing. All instruments can be directly connected to a laptop using serial communication. These cables are also capable of powering the devices, making external power supplies unnecessary. This system is extremely easy to build and very light weight. Due to this the existing cabling is recommended.

6.3 Mechanical Build

The system should be built inside a Pelican transport case. These cases are currently in use for some systems, and they have received good feedback on usability and durability. The same case can fit the calibrator, as well as needed test cabling and a laptop. This also highly resembles the current systems.

7 Consideration for Humidity Capability

Originally, the system was specified to include temperature measurement only. During discussion with field technicians, they raised concerns about the old portable humidity generator. The old generator does not support computer control, and thus has to be controlled manually. This makes the calibrations more time consuming, and the system cannot perform calibrations while the technician is elsewhere.

Range of the study was extended to consider humidity calibration. Unfortunately, these units were not suitable for the use. Most of them are too bulky, and they lack the needed temperature range. Most humidity calibrators do not support temperature change at all; they only do calibrations in the ambient temperature. Some of the designs were so obsolete, they do not support computer control.

Taking into account the extended stabilization period caused by air as the medium, the calibration would take much longer compared to a dry block, or oil bath.

A combined humidity and temperature calibrator would make field calibrations easier, but only one unit comes close to the needed specifications. Problem with that unit is that the temperature range starts from +5°C. That unit could be used for humidity and some temperature calibrations, but the technician would still need a temperature calibrator for the lower temperature points.

As there is no unit that could handle the large temperature range, a combination unit cannot handle the calibrations. At the moment the main focus is to provide faster temperature calibrations. This cannot be achieved with air chambers. Due to that humidity calibration capability will be tackled later.

8 Conclusion

8.1 Data Reliability

Estimated calibration times were calculated using manufacturer provided data for each device. These times were very consistent. For example, units using the same thermal medium have very similar speeds when electrical power is considered. It is possible to conclude that the times are accurate estimations.

8.2 Conclusion

Unfortunately, during the work real world tests were not carried out. The Ametek unit is not yet sold in Europe, and delivery time for the Sika unit was longer than time I had available.

All determinations about the units researched were made using data available from manufacturers, and previous experiences with similar units.

Using the data available, it was possible to give a good recommendation on what device the new calibration system should be based on.

References

1 Ametek SS-RTC-158/250 Technical Datasheet https://www.ametekcalibration.com/-/media/ametekcalibration/download_links/temperature/rtc/reference-temperature-calibrator-rtc-158-250-datasheet-us.pdf

2 Sika TP 3M Technical Datasheet https://www.sika.net/services/downloads/send/345-temperature-calibrators/2142-data-sheet-tp-3m-premium.html

3 Fluke 7103 Technical Datasheet https://us.flukecal.com/products/process-calibration-tools/temperature-calibrators/dry-block-calibrators/6102-7102-7103-micr?quicktabs_product_details=2

Appendix 1: Full Feature Comparison of Generators

Data acquired from manufacturer datasheets, Ametek[1], Sika[2], Fluke[3].

	Fluke 7103 Micro-Bath	Sika TP 3M165E.2	Jofra RTC-158
Type	Oil	Oil or dry block	Oil or dry block
Range	–30°C to 125°C	–35°C to 165°C	-22°C to 125°C
Weight	9.8 kg	13 kg	11 kg
Power	94–234 V AC, 50/60 Hz, 400 W	100–240 V AC, 50/60 Hz, 375 W	115V or 230V 400 W
Other	Lid for portability	Dry and wet blocks	Too big as luggage
Price	≈ 8k€	≈ 10k€	≈ 15k€ + 2k€
Capacity	48mm oil well, 7x HMP115	60mm, 7x HMP115	63mm, 7x HMP115
Stability	±0.03 °C	±0.01 °C	±0.01 °C

Appendix 2: Calibration Speed Estimates

*Three point calibration: 25°C -> -25°C -> 40°C
20 min at each point

	Fluke 7103 Micro-Bath	Sika TP 3M165E.2 (Oil)	Sika TP 3M165E.2 (Dry block)	Jofra RTC-158 (Dry block)
Cooling	1.1 °C/min	0.8 °C/min	1.4 °C/min	1.1 °C/min
Heating	2.1 °C/min	3.6 °C/min	5.4 °C/min	5.0 °C/min
Stabilisation time	-	From 5 min	From 5 min	Approx. 15 min
Calibration run*	2h 15min	2h 20min	1h 50min	2h