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Improving Yield on Testing Stations

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The purpose of this study was to find root causes for a bad yield on two identical testing stations that are used for dew point calibration. This study shows the process and the steps to achieve this goal.

Vaisala's devices were used for gathering data of the testing stations. The data was monitored, and actions were taken according to the data. These actions included making changes to the testing process, improving instructions, and improving tools for the users to detect fault in the tests.

These actions resulted in reduction of lost run time, exceeding the wanted result, thus improving the yield on the stations.

Keywords:	Dew point, Humidity, Calibration station, Vaisala

Tekijä: Otsikko: Sivumäärä: Päivämäärä:	Henri Peltonen Saannon parannus testiasemilla 23 sivua
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Tämän työn tarkoitus oli löytää juurisyitä kahden identtisen testiaseman saantoon. Työssä käy ilmi eri prosessit ja työ vaiheet, joiden avulla tavoite saavutettiin.

Kaikki datan keräyksessä käytetyt laitteet ovat Vaisalan laitteita. Laitteiden avulla monitoroitiin dataa, jonka perusteella tehtiin parannuksia prosesseihin. Näihin parannuksiin kuului testaus prosessin parantaminen, ohjeistuksen parantaminen sekä parannuksia työvälineisiin, joiden avulla käyttäjä pystyy havaitsemaan ongelmia testiasemissa.

Näiden vaiheiden avulla aseman saantoa saatiin parannettua pienentämällä hukka-ajojen aikaa yli annetun tavoitteen.

Avainsanat:	Kastepiste, Kosteus, Kalibrointiasema, Vaisala

Contents

List of Abbreviations

JIB:	Job instruction breakdown
PDCA:	Plan-Do-Check-Act
PoE:	Power over Ethernet
Pv:	Partial pressure
Pvs:	Vapor pressure
RH:	Relative humidity
Td:	Dew point
Tdf:	Frost point
TWI:	Training within industry
UUT:	Unit under testing

1 Introduction

This thesis work was made for Vaisala Oyj, which is Finnish company founded in 1944. Vaisala was founded by Vilho Väisälä under the name of Mittari Oy.

The purpose of this thesis work was to find solutions for a bad yield in two testing stations, where multiple Vaisala's devices are tested. This study was done using Lean A3 problem solving approach to find root causes for the yield problems and developing counter measures to fix them and monitoring the effects.

Methods for finding the root causes included monitoring the testing stations with Vaisala's own devices. The devices used in this project were dew point transmitters and pressure transmitters which monitored the environment of the testing chambers of the stations.

From the data gathered by the transmitters different actions were made for improving the yield. These actions included changes to the process and instruction and making tools to ensure the working of the stations.

2 Theory

The theory part of this project focused on humidity, since the two testing stations are used for calibrating dew point transmitters.

2.1 Relative Humidity

Relative humidity represents the amount of concentrated water vapor in the air as a percentage. Pv represents the amount of water vapor in the air and Pvs represents the amount of water there could be at a given temperature. [1.] RH ranges from 0% to 100%, where 0% means extremely dry environment and 100% means extremely humid environment.

$$RH = \frac{Pv}{Pvs} * 100\% \tag{1}$$

2.2 Dewpoint Temperature

Another humidity parameter is dew point. It is used in industrial applications for measuring dryness.

Dewpoint temperature is a temperature, where condensation begins. In other words, it is the temperature where surrounding air cannot hold its humidity in gaseous form. Good example of dew point is a cold drink in a glass.

If the temperature of the glass is lower than the dew point, condensation will happen. This will appear as compensated water forming on the glass' surface. If dewpoint is below 0°C it is called frost point. Tdf means the temperature where frost starts to form on a surface of an object. [2.]

$$Td = T - \frac{100 - RH}{5} \tag{2}$$

3 Testing Stations

The testing stations are two identical stations used for dew point calibration. They create a measuring environment into their measuring chambers, where multiple Vaisala's dew point transmitters are calibrated.

The stations are capable creating dew and frost points by mixing nitrogen and gas from humidity generators made by Vaisala. Each calibration point has a different kind of mixture of moist and dry gases.

After the environment for calibration point has been created by the environment mixer, the mixture goes to the measurement chamber where UUTs get calibrated. For making sure the environment is correct, 373LX dewpoint mirror made by a company called MBW works as a dewpoint reference.

4 Equipment Used in the Study

All the devices used in this study are Vaisala's products. The study was done with two dewpoint transmitters, one combined humidity, pressure, and temperature transmitter and two differential pressure transmitters.

4.1 Vaisala's DRYCAP Technology

DRYCAP technology was introduced in mid-1990s because traditional instruments made for measuring humidity were not accurate at low humidity and sensors made from aluminum oxide started to drift while being in long term use. For removing these weaknesses Vaisala came up with a solution to combine quality polymer technology with auto calibration feature, which eliminates the sensor drift in very dry conditions.

DRYCAP uses capacitive thin-film polymer sensor, where capacitance changes while the sensor absorbs or releases water vapor as the surrounding humidity decreases or increases. The capacitive sensor is put together with a PT-100, which is a temperature sensor, and the dew point is calculated based on the readings of humidity and temperature.

Vaisala's auto calibration feature optimizes the measurement stability by heating the sensor at regular intervals. This calls for offset compensating, which is achieved by monitoring the temperature and humidity sensor while they cool down to an ambient temperature. After the cooling an offset compensation is given for the sensor to prevent potential drift. [3.]

4.1.1 DMT143

Vaisala's DMT143 is a dew point transmitter suitable for measuring wide range of industrial applications. Its measuring range is from -70°C to +60°C. This device was selected because it can reach all calibration points on multiple Vaisala's dew point transmitter calibration runs, and it was mounted on the other testing station which is the usual testing station for these devices. [4.]

Figure 1 DMT143 [14.]

4.1.2 DMT152

Vaisala's DMT152 is a dewpoint transmitter designed for low dew points down to -80°C. The device was selected because one of the testing stations is mostly used for calibrating DMT152 devices, and lower dewpoint transmitter was needed since DMT143 can only reach -70°C. [5.]

Figure 2 DMT152 [14.]

4.2 Vaisala's BAROCAP Technology

Vaisala's BAROCAP technology was introduced in 1985 and it is a micromechanical pressure sensor made from single-crystal silicon material. BAROCAP measures pressure from the dimensional changes in its silicon membrane. The membrane bends according to surrounding pressure changes causing the height of the vacuum gap inside the sensor to decrease or increase. As the vacuum gap changes, the capacitance of the sensor changes since the opposite sides work as electrodes. The capacitance is then converted into a pressure reading. [6.]

4.2.1 PTU300

Vaisala's PTU300 series devices are a pressure, temperature, and humidity transmitters. PTU301 was used in this project to measure pressure, though it is capable of three different measurements. [7.]

Figure 3 PTU300 [14.]

4.2.2 PDT101

Vaisala's PDT101 is a differential pressure transmitter. It can measure precise difference between two pressures using its high and low inputs. It is ideal for ViewLinc applications. [8.]

Figure 4 PDT101 [15.]

4.3 Vaisala ViewLinc

Vaisala's ViewLinc is a software for alarming, monitoring, and reporting continuously parameters such as temperature, pressure, dewpoint, and humidity.

As seen in figure 5, ViewLinc operates by gathering data from data loggers, such as DL-4000, which was used in this study, and sending the data to ViewLinc server where the parameters can be monitored in real-time. [9.]

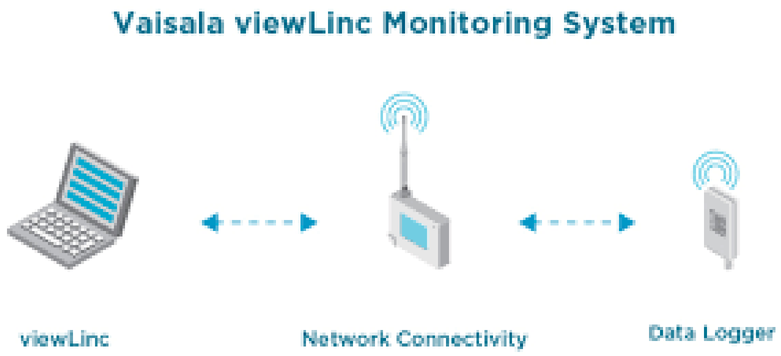


Figure 5 ViewLinc [9.]

4.3.1 DL4000

Vaisala's DL4000 is a data logger which can be connected into ViewLinc thought vNet device. This data logger has four channels meaning that four different transmitters can be connected to it. It can provide historical and real-time data. [10.]

Figure 6 DL4000 [15.]

4.3.2 vNet logger interface

Vaisala’s vNet PoE data logger interface is a device which can connect DL-series data loggers into ViewLinc through ethernet. [11.]

Figure 7 vNet data logger [15.]

5 Lean Approach and the Project

This study followed Lean’s A3 approach to find root causes and solutions for the bad yield. The A3 approach is a standardized and structured tool for continuous improvement and problem solving which is based on PDCA thinking. [12.]

Next sections describe different parts of A3 approach, and each picture at the beginning of each chapter is from the A3 plan which this project followed.

5.1 Describe the Problem

At the beginning of this project there were known problems with the mirror's stabilization on two different calibration points. This caused the testing time to variate heavily. For this station an average run time was 120% higher than optimal run time.

For the other testing station, the situation was much worse. For that station average run time was couple of hours higher than good run time. This caused the run time to be 150% higher than optimal run time.

At the beginning of this project, a plan was made to improve the yield and reduce variation on the testing stations. At first, the current situation was described as well as the problem and the goal. Figure 8 describes the simplified version of the plan.

As seen in figure 8, the goal was to improve the yield by reducing the lost run time by fixing the known issues, which were stabilization problems on two frost point calibration points and thus fixing the "current situation".

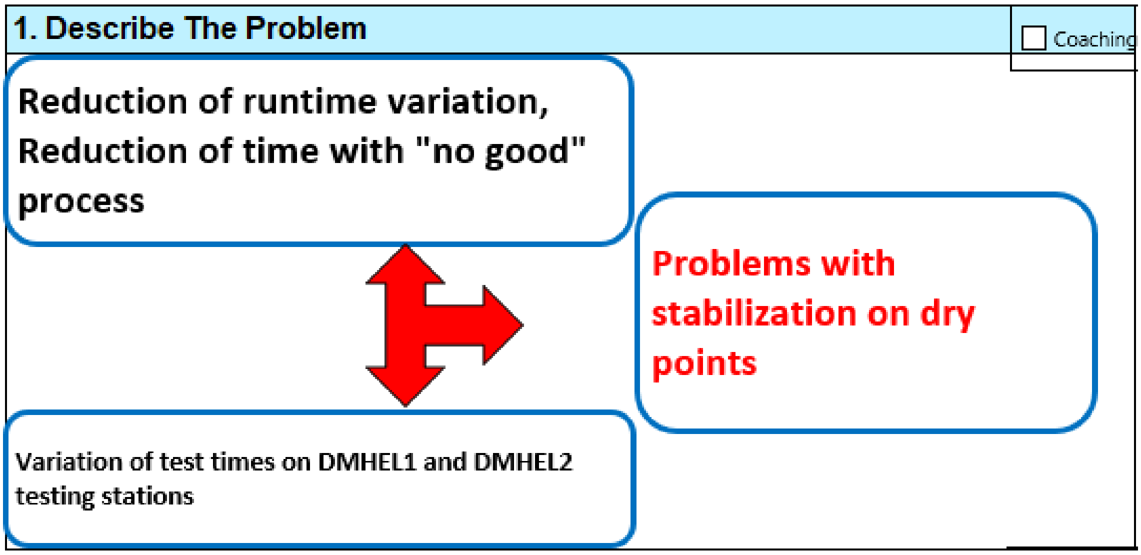


Figure 8 Part 1 of the A3 approach, Describe The Problem

5.2 Break Down the Problem

This chapter describes the found root causes of the bad yield. After finding out what causes the problems, a rough division was made to two main causes to simplify the problem. These causes were humidity and leakage, as seen on figure 9.

With these stations the leakage means, that the ambient humidity gets inside of the testing chamber. The ambient humidity is the RH in room temperature, which can vary from 30% to 40% RH, which means from 4 to 8 Td. The Td in the testing chamber varies from extremely dry frost point to wet dew point, and so the ambient humidity causes problems in the drier end of the wanted Tdf.

Humidity problems in these stations means the humidity which is stored in the UUTs before the test runs. At the beginning of this project the UUTs were waiting for the test runs in open factory air, and the filters of the UUTs absorbed ambient RH in them. This caused the run times to get longer since the humidity had to be dried inside of the testing chamber before the Tdf was good for testing.

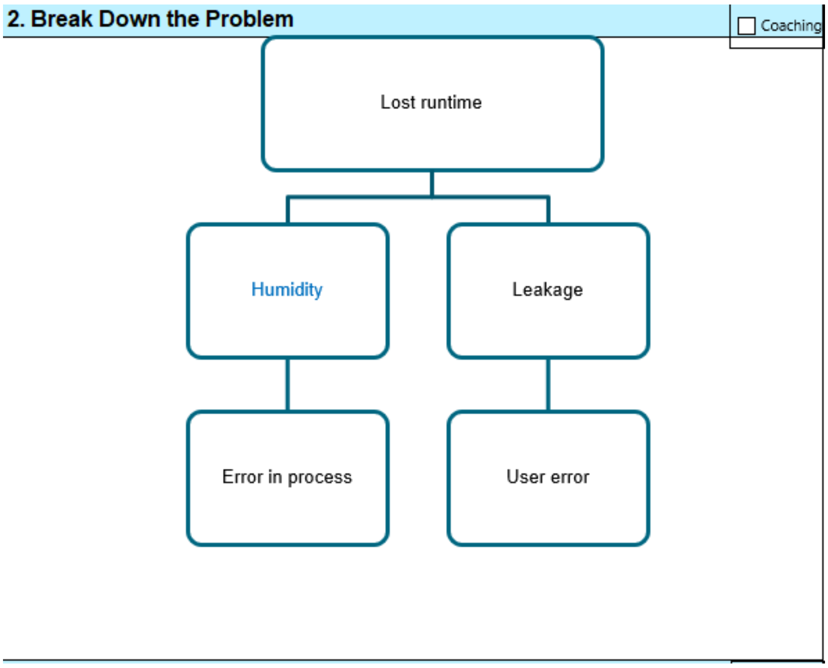


Figure 9 Part 2 of the A3 approach, Break Down The Problem

5.3 Set a Target

Since the problem of the stations was variation of the test runs and a lot of lost run time, it was clear that the average runtime must be reduced close to the time of good run. To achieve this, different methods were created such as monitoring measurement chambers of the stations and standardizing the process. Figure 10 describes the set goal where lost run time for both testing stations is cut by 50%, still leaving room for some user errors happened by accidents.

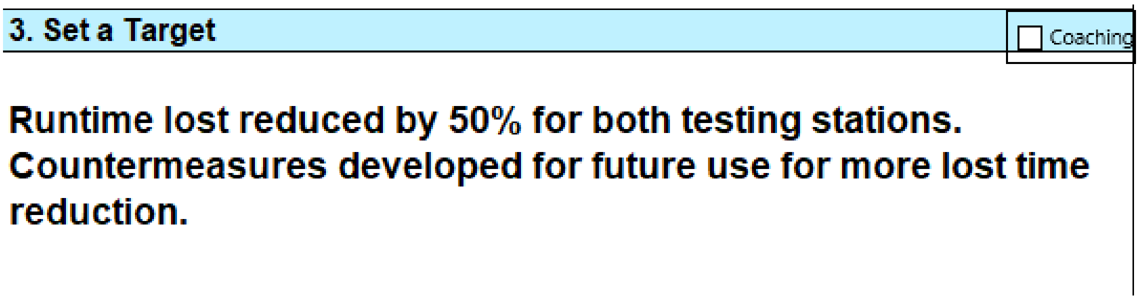


Figure 10 Part 3 of the A3 approach, Set a Target

5.4 Analyzing the Root Cause

The different root causes were found by using Lean thinking's 5 whys, which is a problem-solving technique developed by Sakichi Toyoda, the founder of Toyota, made for helping companies find the root causes of problems.

This approach proved to be extremely useful guidance on this project as it provided clear path to follow and to make improvements for this project by asking "why?" after each problem was discovered until the root cause came clear.

Figure 11 describes the flow chart of the 5 whys with the starting point of two known issues, leakage, and humidity.

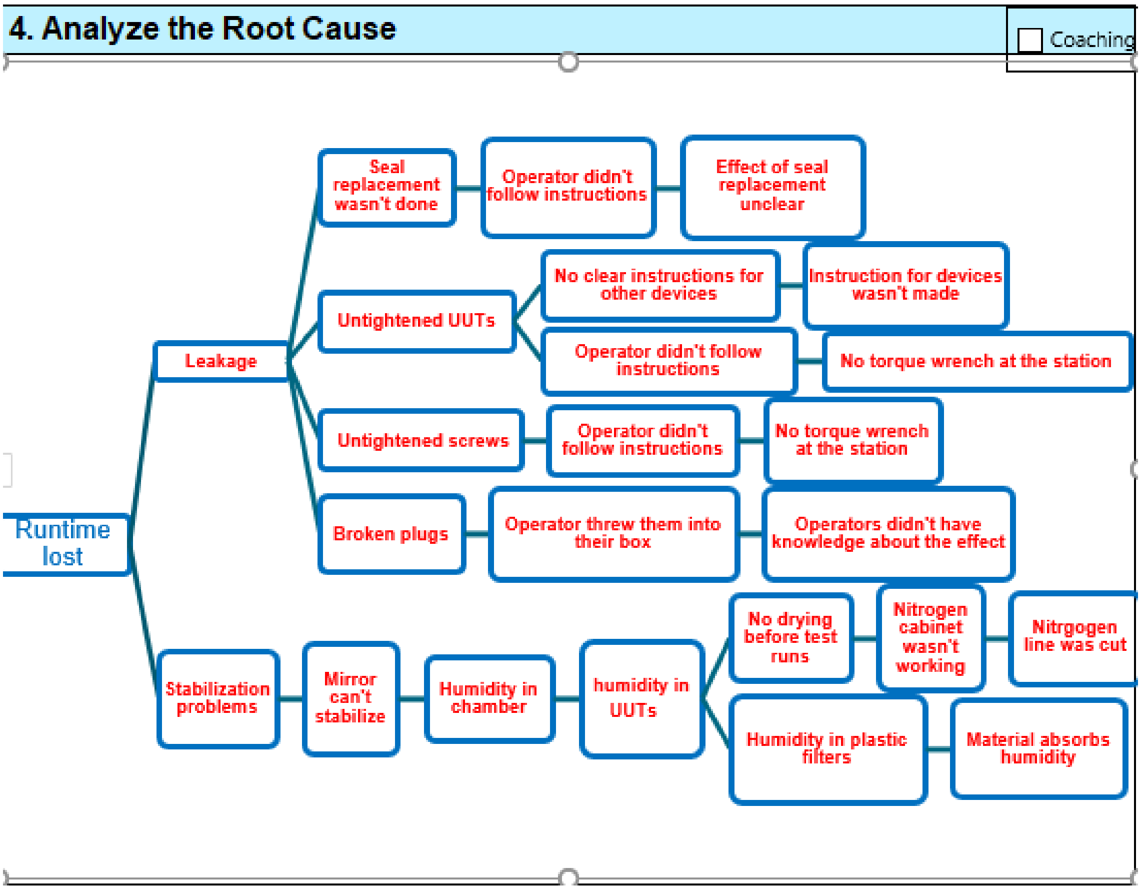


Figure 11 Part 4 of the A3 approach, Analyze The Root Cause

5.4.1 Leakage

Since the stations did not have a check for possible leakage it was clear that preventing them must be done before the test runs. Easiest and quickest way to make this happen was to change the sealings of every device before starting the test. This way the effect of bad sealings could be ruled out as a source of leakage.

Now that the sealings were not a possible reason, it was time to look at the sealing plugs of the stations. Many of the plugs were scratched, thus preventing the sealing between the plug and the seal itself from working. To get rid of this effect the plugs were fixed using sandpaper and making sure that the plugs were scraped if any scratches were found. It was also made clear for operators using these stations, that the tasks were necessary for the stations to work properly. After these tasks were done, it came clear that the stations have need for torque wrench to standardize the momentum of the UUTs

5.4.2 Stabilization Problems

For understanding the cause of the stabilization problems, a method was needed for monitoring the environment in the chamber. This was made by mounting DMT143 on the other testing station, since devices such as DMT143, DMT340 and DMP74 were usually tested on that station, and DMT152 on the other testing station because DMT152 products are usually tested on that station. Both devices were mounted on the last places on the chamber for monitoring the environment right before the dew point reference mirror.

Both monitoring devices were installed into DL-4000, which gathered the data onto ViewLinc server thought vNet device where data was monitored in real-time.

After monitoring the test runs it came clear that UUTs have humidity in them, which caused mirror not being able to stabilize. It was detected by looking the raw dewpoint data from monitoring devices and the mirror, and data suggested that mirror sees more humidity than the device. Because the measuring system is closed, the humidity must be in UUTs. Figure 12 shows an Excel graph, which was made from the DMT143's and the mirror's data.

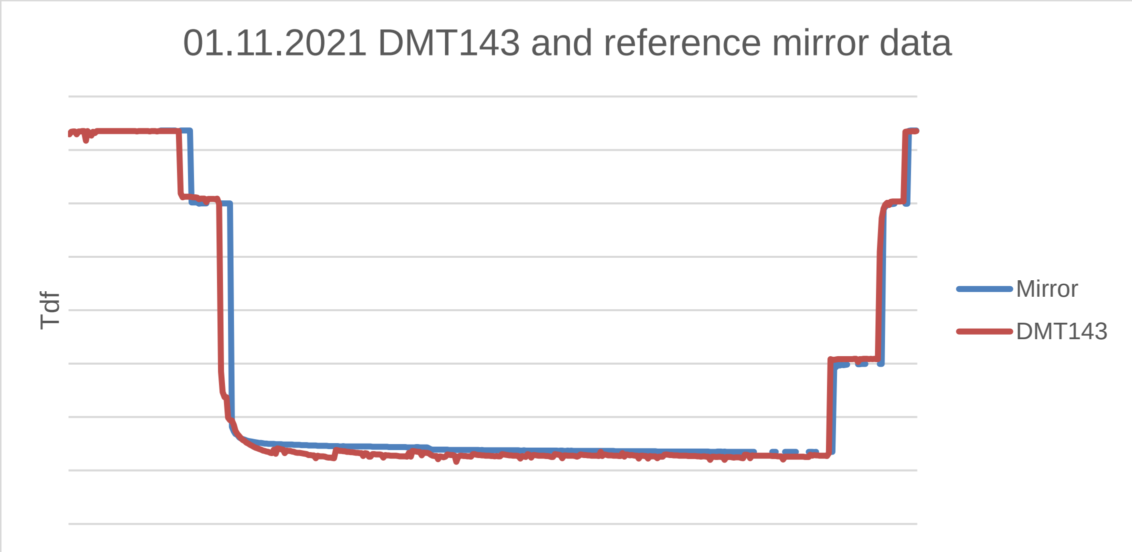


Figure 12 Excel graph from ViewLinc and mirror references data

5.5 Develop Countermeasures

After the root causes had been discovered it was time to plan action for removing them. The actions for removing the problems were created according to last phase where root causes were analyzed.

5. Develop Countermeasures ☐ Coaching

Root Cause	ID	Coutermeasure	Easy	Impact
Nitrogen line was cut	1	New line for nitrogen cabinet installed	+	+
	2	Drying cabinet for added capacity		
No torque wrench at the station	3	Torque wrench brought to the station	+	+
	4	Instruction list brought at the stations	+	+
Effect of seal replacement wasn't clear	5	Data of impact was shown for operators	+	+
Undone seal replacement	6	Instruction list brought at the stations	+	+
	7	Data of impact was shown for operators	+	+
instruction for other devices wasn't made	8	New instruction for operators to read	+	+
Humidity in plastic filter	9	Change filters to metallic ones	-	+

Figure 13 Part 5 of the A3 approach, Develop countermeasures

Developed countermeasures included making changes to the calibration process on the operator level so there was no need for modifying the stations. Countermeasures included improving the instructions and little modifications on the area surrounding the stations.

Figure 13 shows the table of root causes, counter measures and the difficulty of achieving them as well as the impact of their effect.

5.6 Implement Countermeasures

Once the counter measures were developed, it was time to start implementing them. Implementing the counter measures included monitoring the effects and improving them more, as seen in figure 14.

6. Implement Countermeasures ☐ Coaching

ID	Coutermeasure	Resp	Schedule	Status
1	New line for nitrogen cabinet installed	Henri	3.11.2021	Done
2	Drying cabinet for added capacity	Henri	Feb 2022	Ordered
3	Torque wrench brought to the station	Henri	25.10.2021	Done
4	Instruction list brought at the stations	Henri	25.10.2021	Done
5	Data of impact was shown for operators	Henri	25.10.2021	Done
6	Instruction list brought at the stations	Henri	25.10.2021	Done
7	Data of impact was shown for operators	Henri	25.10.2021	Done
8	New instruction for operators to read	nri/Eer	8.12.2021	In progress
9	Change filters to metallic ones	Henri	15.12.2021	Done

Figure 14 Part 5 of the A3 approach, Implement Countermeasures

5.6.1 Countermeasures for Stabilization and Humidity Problems

Once the root cause for stabilization problems was found, the devices were placed in a nitrogen cabinet for drying before the test runs. This proved to be very effective, and the test run times including only the devices placed on the cabinet reduced significantly.

Figure 15 Nitrogen cabinet

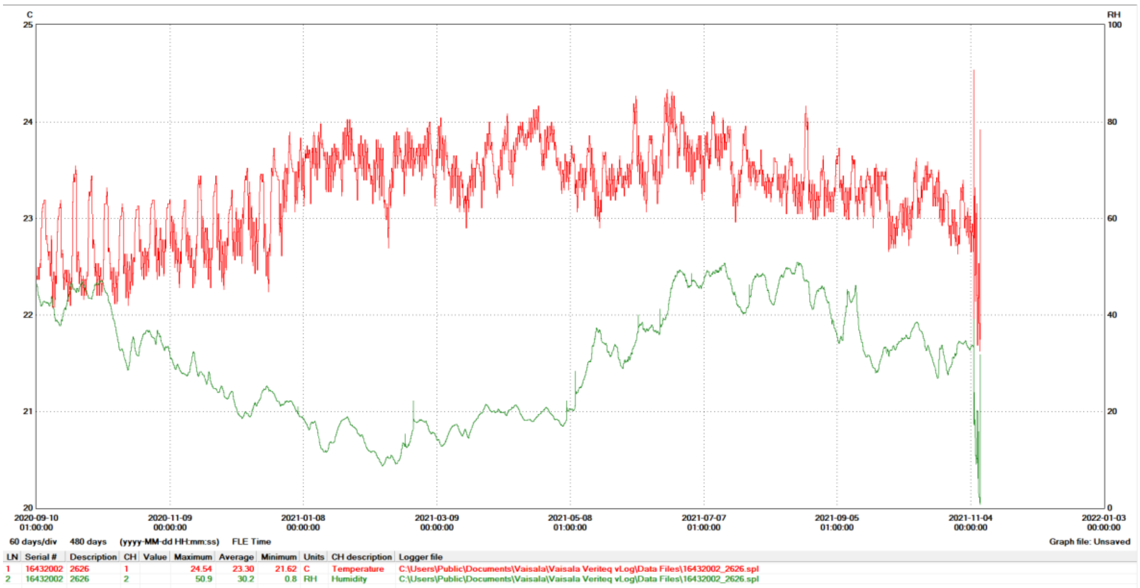


Figure 16 Logger data from cabinet's RH

After monitoring the nitrogen cabinet, it came clear that the cabinet cannot keep RH stable as seen on figure 16, where the green plot is humidity and red plot is temperature. Also, the cabinet isn't as dry as needed since the logged data shows that the humidity is almost the same as the room humidity. That is why decision of replacing it with drying cabinet for extremely low RH was made. Unfortunately, due to long delivery time the cabinet did not arrive in time for this project.

While the yield became better for the devices which were in the nitrogen cabinet, other devices in same runs still had problems which caused the whole run to take longer. To rule out leakage problem, PTU301 was added into one of the testing station's chambers.

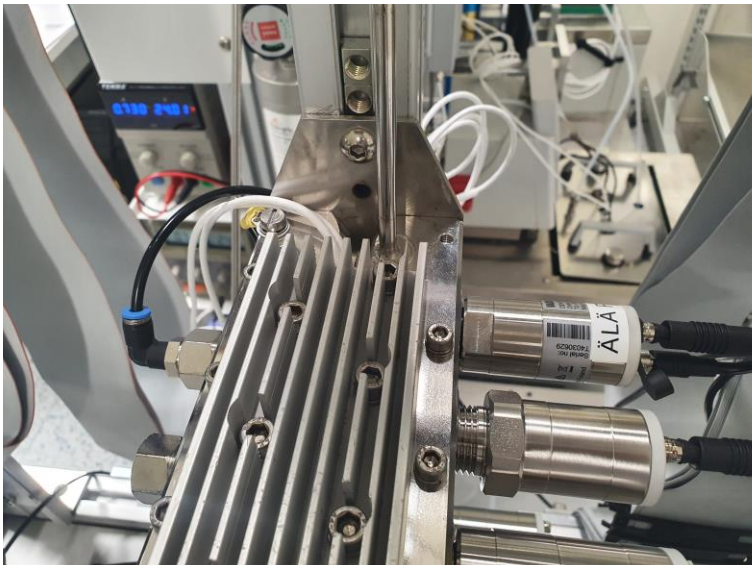


Figure 17 Pressure and dew point transmitters in the testing chamber

PTU301 was added into ViewLinc, and it was compared with the ambient pressure. Because the measurement chamber is a closed system, it has different pressure than the ambient pressure of the room. If the two pressures are the same, there is leakage on the chamber.

Figure 18 PTU301 devices logging ambient and chamber pressure

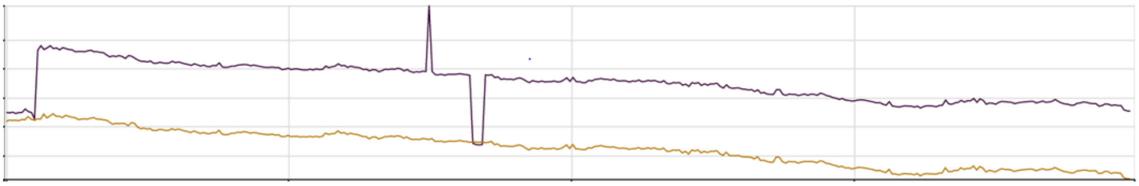


Figure 19 ViewLinc data of ambient and chamber pressures

As we can see in figure 19, there is a difference between ambient and chamber pressure, which means there is no leakage on the chamber. With no leakage, humidity cannot get to the chamber from outside so, it was clear that the humidity was in the UUTs. Since only parts of the UUTs in the chamber were sensor and plastic filter it was clear that the filter caused the problem.

Because of the size of the devices, they could not be put in the nitrogen cabinet for drying, which meant the filters material had to change for something that doesn’t absorb as much humidity. The metallic filters were an answer to this problem, but since there would be a change to the product, the validation had to be done.

The validation happened by placing a device with metallic filter into the measurement chambers first place where the biggest error of measurement happens. After the calibration run was done, the device was sent to Vaisala's measurement laboratory for a recalibration where possible error was measured. The recalibration showed that there was only a small error of 0.4 Tdf, and it was still in the error range and metallic filters could be used in calibration runs.

5.6.2 Countermeasures for Instructional Problems

As the progress on the testing stations improved, there became a need for new instructions. The instructions followed TWI approach, where instructional training is used for standardizing the project, JIB was made for the testing process.

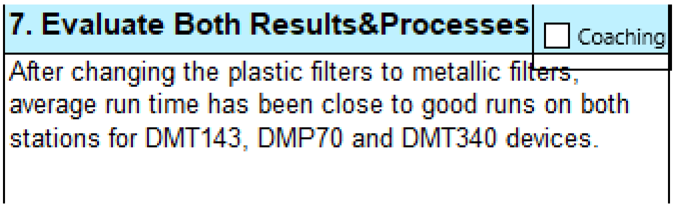
The new JIB included instructions for placing the devices into drying cabinet before the test run, and the order of phases to complete the process to make it function properly. This also included 5S system for the stations to improve efficiency of the work since all the equipment such as plugs, adapters and tools were placed on their own places at the stations, thus reducing waste time of searching the right tools and standardizing the process.

5s stands for five Japanese words, which are Seiri(sort), Seiton(place), Seiso(cleanse), Seketsu(standardize) and Shitsuke(retain), and it is a tool used for keeping working environment in order and clean. [13.]

5.7 Evaluate Both Results & Processes

So far, the results seem good for other than DMT152 devices. With these devices the humidity is still problematic for the test runs, since they are tested on extremely dry Tdf point and the RH where they are dried before test runs varies from 0% to 30% RH in the nitrogen cabinet, which causes the change in dew point being big and devices not to dry properly before the test runs.

With the other devices test data has been mostly good. After the change from plastic filters to metallic filters the average test run time has been close to a good run time in hours, as seen in figure 20, but there still is some variation on the test run times. Reason for this is that a test run with different devices at a same time has more testing points than running only one type of devices. For example, test run of DMT143 devices has its own calibration points, and DMP70 devices have adjustment points added to calibration points making the test run longer.



7. Evaluate Both Results&Processes ☐ Coaching

After changing the plastic filters to metallic filters, average run time has been close to good runs on both stations for DMT143, DMP70 and DMT340 devices.

Figure 20 Part 7 of the A3 approach, Evaluate Both Results & Processes

The measuring system for dew point and pressure was also updated from a prototype to an actual system seen in figure 21. PTU301 was replaced with two PDT101 devices, and pressure measuring capability was added to the other station as well. PDT101 works differently than PTU301, since it is a differential pressure transmitter. This means, there is two inputs that are compared, and the output is sent to ViewLinc. The inputs are measured from the testing chamber and the ambient pressure. If their difference is 0, there is a leakage since the ambient pressure gets inside of the closed measurement chamber. The ViewLinc data of the updated system can be seen in figure 22 where the blue plot is dew point measurement, and purple plot is pressure measurement.

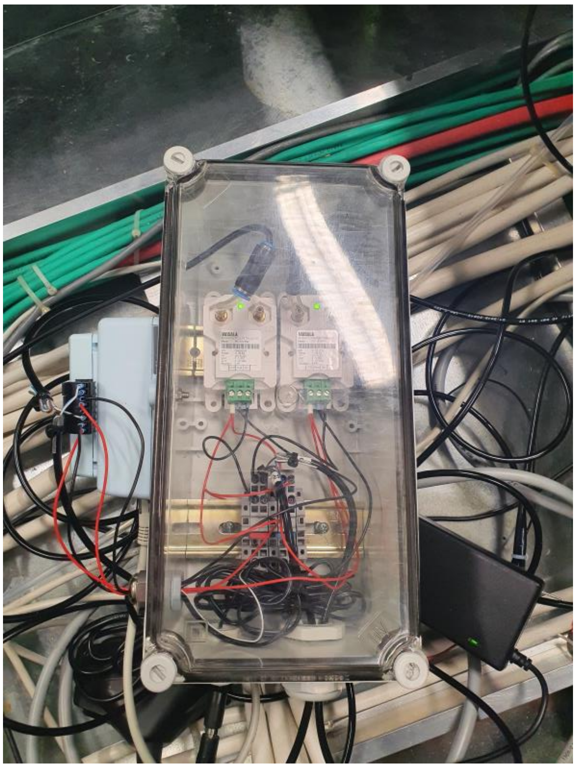


Figure 21 Updated measuring system

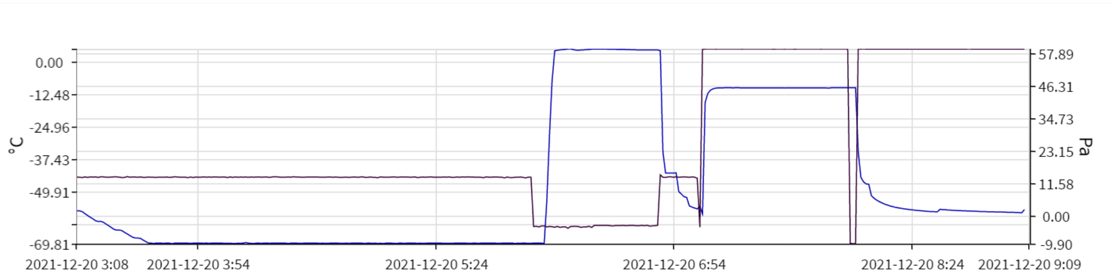


Figure 22 ViewLinc data of updated measurement system

6 Conclusions

This thesis work was about finding and fixing root causes for a bad yield on two identical testing stations where Vaisala's dew point transmitters are calibrated. The goal was to reduce testing run times closer to a good test run of the products which varies from depending on the devices on the test run.

After monitoring the effects of the counter measures for two weeks, it can be said that this project was successful, and the set goal was exceeded based on monitored data from three-month period.

7 Figures

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