

GT-170143

14 June 2017

Quality Assurance of Rework Meters

Support of network operators to the rework process



**Trust
Quality
Progress**



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Kiwa Technology B.V.
Wilmersdorf 50
Postbus 137
7300 AC Apeldoorn
The Netherlands

Tel. +31 88 998 33 93
Fax +31 88 998 34 94
www.kiwatechnology.nl

Colophon

Title	Quality Assurance of Rework Meters
Project Number	004P000658-01
Project Manager	H. de Laat
Contractor	Netbeheer Nederland
Quality Assurance	W. Brouwer
Author(s)	H. de Laat

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Summary

A rework process for L+G Ultrasonic Gas meters with insufficient screw threads on the meter bosses has been realized in the factory of the meter supplier in the UK.

The meters are fitted with an adapter that allows a connection to the meter manifold with sufficient engaging full revolutions of the screw thread. Two different processes are running.

During the first process, two adapters are screwed onto meters that were not fitted with adapters previously. A new type of thread locking agent prevents accidental loosening of an adapter from the meter boss during installation.

The second process is the removal of adapters from meters that were screwed on using the wrong type of thread locking agent. The process ensures removing the adapters without damaging the meters and preparing the meter boss screw threads for mounting new adapters according to the first process.

The choice of the new thread locking agent was made after definition of the root cause of the poor connection. The new thread locking agent is capable of bridging the maximum gap between the male and female thread.

The durability of the solution has been tested with a Highly Accelerated Lifetime Test (HALT test) and several other duration tests derived from the HALT test. The test criteria are gas tightness and resistance to torque, both clockwise and anti-clockwise. The applied materials are verified for compatibility with natural gas.

The quality assurance has been realized by evaluating the method sheets of L+G and auditing the processes several times. The progress of the rework is monitored by the daily first passed yield of the process. The process quality is assured by daily checks of the tools and the testing equipment. The product quality is maintained by a check of all quality parameters for every meter produced.

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Introduction

Commissioned by Netbeheer Nederland, Kiwa Technology has supported the grid operators Enexis and Alliander on the quality assurance of the repair work for Landis+Gyr ultrasonic smart gas meters, that are manufactured with an off-spec screw thread on the connection bosses.

During the installation of the meters in Dutch dwellings in 2016 it was discovered that the screw threads started several millimeters below the boss end, leaving only one or two full engaging revolutions of the nuts for the connection to the meter bracket. Alliander and Enexis decided to repair the meters in order to maintain the pace of the Large Scale Roll-Out of smart meters in The Netherlands.

An adapter was introduced which screws onto the meter boss without being hindered by the protruding boss end, thus engaging sufficient full revolutions of thread. To prevent accidental loosening of the adapter from the meter by the installer, Landis+Gyr proposed to apply a screw thread locking agent.

When the repaired meters were installed for the second time, it turned out that in many cases the adapter could be unscrewed from the meter boss without applying much torque. Apparently, the connection made by the thread locking agent was poor.

Landis+Gyr was asked to repair the meters again, but this time under close supervision of Kiwa Technology, MKB In Control and both network operators. The quality assurance work that resulted in a gas meter suitable for installation is summarized in this report.

Chapter one describes the root cause of the failing thread locking agent and the solution to the problem. The evaluation of the design solution is described in Chapter two. The test program to ensure the functions of the adapter are described in chapter three. The improvements of the production process by auditing from the grid operators are described in chapter four.

1 The poor thread lock problem

1.1 Root cause analysis

The Permabond HM 129 can bridge a gap of maximum 0,15¹ mm. L+G² performed a calculation of the maximum gap width that can occur as a result of manufacturing tolerances. The gap between the female and male thread can be as high as 0,15 mm when the male thread has minimal material (see Figure 1).

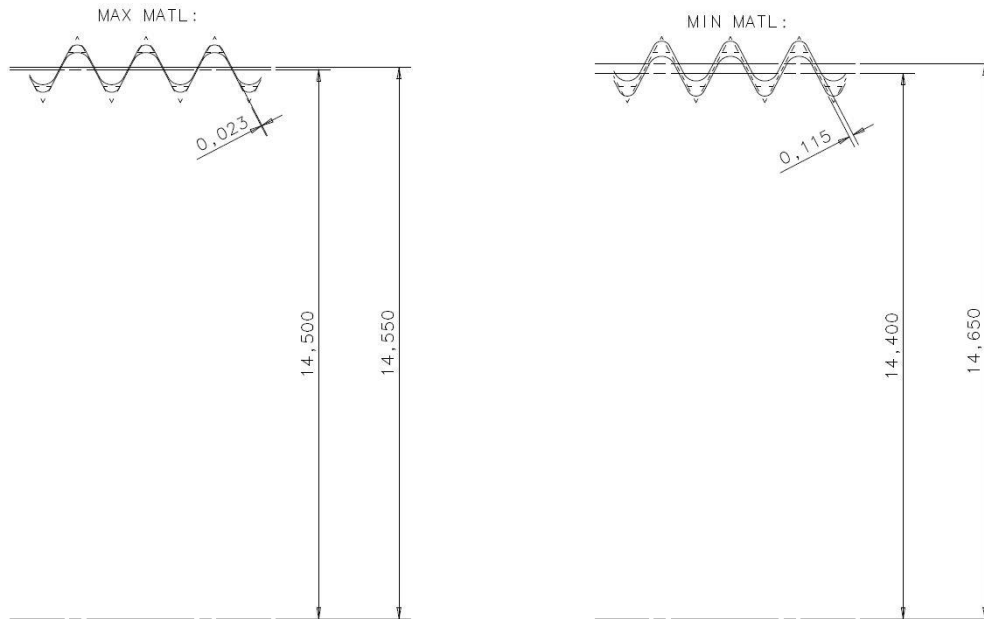


Figure 1 The construction of the gap between the female and male thread (L+G)

The calculation was performed with the male and female thread in the centre. The maximum occurring gap is twice the calculated value, equal to $2 \times 0,115 = 0,23$ mm. This is more than Permabond HM 129 can bridge.

1.2 Solution for the problem

L+G proposed a new Permabond type F202 that is able to bridge a gap of 0,5 mm width³. This product is able to bridge a gap over twice the expected maximum of the gap width between the adapter and the meter boss. The network operators decided to verify the application of F202 by a test program.

1.2.1 Laboratory torque test in Stockport

L+G performed torque tests on 20 samples that were mounted with F202 and cured for 36 hours in the laboratory at Stockport. After curing, the adapters were tested with 45 Nm clockwise and anticlockwise torque. All samples could resist to 45 Nm of

¹ Permabond Engineering Adhesives, Lubribond Benelux brochure (in Dutch)

² Mic Norbury, L+G, e-mail of 7-2-2017

³ Permabond Engineering Adhesives, Lubribond Benelux brochure (in Dutch)

torque without rotation of the adapter relative to the meter housing. The results were judged OK and manufacture could proceed in Waddinxveen.

1.2.2 *Production samples test in Waddinxveen*

The assembly and torque tests of ten samples at Waddinxveen were witnessed by the Network operators. Three out of ten samples failed the torque test. L+G confirmed that other samples manufactured some days earlier at Waddinxveen also failed to pass the test. Together with Permabond, L+G assessed the cause for failure and concluded that the low temperature in the warehouse at Waddinxveen slows the curing process down.

The solution for the curing problem proposed by L+G is to double the curing time from 36 hours to 72 hours.

2 Design evaluation

2.1 Sealing ring material

The sealing ring material shall comply with Gastec QA 165. L+ G produced a certificate from the sealing ring supplier that stated the compliance with BS 746 for the material composition. Kiwa Technology verified whether BS 746 complies with Gastec QA 165. This is the case, the sealing ring material is suitable for the application.

2.2 Torque performance

The laboratory tests of L+G show that all samples resist a 45 Nm torque, both in clockwise and anti-clockwise direction.

2.3 Suitability of Permabond F202 for natural gas

According to the brochure of Permabond F202, the agent is compatible with natural gas.

3 Test program

3.1 Resistance to tighten and loosen

The bosses shall have resistance to tighten and loosen. The minimal required torque is 45 Nm in both directions.

3.2 Gas tightness

The standard tightness test for a gas meter is designed to fit the speed of the automatic assembly line. The test is based on counting helium atoms that leak from the meter to a surrounding vacuum gas chamber. The accuracy of the test meets the requirement set in EN 14236.

The requirement on EN 14236 is described by a test pressure and the immersion of the meter in water. The test pressure is 1,5 times the operation pressure. No bubbles shall be visible within 30 seconds after immersion.

3.2.1 Proposal of L+G

Initially, L+G proposed a gas tightness requirement based on the field test executed by the installer. The chosen test principle is a pressure decay test. This test is adaptable to match the rework operations and the required test hardware is easy to assemble from standard components.

The field test, however, is much less severe than the standard test. The proposed tightness requirement for the meter leakage equals 23% of the allowable leakage of a typical Dutch domestic gas installation.

In terms of the requirement in EN 14236, the proposal of L+G would release an air bubble of 24 mm after 30 seconds. This requirement was rejected since it is much less severe than the standard test and its' magnitude would force the installer to start a leakage finding procedure.

3.2.2 Improved tightness test by Kiwa Technology

The tightness test was improved after it became clear that the actual meter volume is much bigger than assumed (unlike diaphragm meters, the meter volume is not mentioned on the ultrasonic meter housing). The improvements to the initially proposed test are in the Table 1.

Table 1 Comparison of the proposed and improved test

Test type	Proposed	Improved
Test pressure (mbar)	300	300
Test time (s)	30	60
Meter accuracy (mbar)	1	0,1
Reject pressure decay (mbar)	3	1
Leakage limit relative to the leakage of the complete domestic gas installation	23%	4%

The improved parameters scale the leakage limit six times down. The longer test time is compensated for by using multiple test installations in parallel. The calculation of the leakage limits is included in appendix I.

3.2.3 5 meters for foam tightness test

A discussion with Enexis (Ton Rovers, Maikel van Helvoort) was started to assess the probability of detection of very small leaks of the adapter by the installer. The installer uses a foam to detect leaks. Even the slightest leak can be detected using foam, which could cause concern about the tightness of the meters.

A foam test was proposed, using 5 meters that showed over 0,6 mbar pressure decay in the tightness test of L+G. Although some meters with this leak rate were isolated initially from the production process output, a second test to confirm the first test results showed a lower leak rate for each meter. Apparently, the connection between the meters and the test equipment was better during the second test.

It was decided that rejection by the installer is not expected because:

- The connection between the adapter and the meter is not inspected primarily during installation
- The leak rate of the meters is well below the rework rejection criterium of the meter
- The leak rate of the meters is well below the rejection criterium of the complete domestic gas installation.

As a result of this discussion, the foam tightness test was discarded.

3.3 Lifetime tests

3.3.1 Highly accelerated lifetime test (HALT)

The HALT test for the adapter is a combination of vibration and temperature cycling. Since the strength of Permabond is reduced at elevated temperatures, it was expected that failures would result from the HALT test.

The HALT test showed 9 out of 16 sample meter failing to pass the torque test. All samples passed the tightness test. Three other tests were carried out to explain this behaviour.

3.3.2 Thermal cycling

A test with thermal cycling only was performed on 20 samples. 11 of these did not pass the torque test, but all passed the tightness test.

3.3.3 High temperature storage (HTS)

A high temperature storage test was performed on 15 samples for 500 hours at 60°C constant temperature. All samples passed both the tightness and torque tests.

3.3.4 Ongoing reliability tests (ORT)

ORT tests at 65 °C and 85% RH are in progress. Sixteen samples are tested until now without failures. From the results of the HTS and ORT tests it was concluded by L+G that the thermal cycling was the failure mechanism and that the Permabond would provide at least 20 years of field use.

3.3.5 Accelerated lifetime test (ALT)

The results of the ALT test are expected from 18th of June. It was decided not to include the results of the ALT-test in this report.

4 Production

4.1 Environment Waddinxveen

The production environment at Waddinxveen (The Netherlands) is a logistics warehouse for storage of various products. The products to be stored are delivered by lorries and transported internally by forklifts. The possible working hours for L+G is during the day (one shift).

The warehouse temperature was logged by L+G. The space is heated to about 14 degrees, which is lower than the laboratory temperature. This slowed the curing of the Permabond down. Variations in temperature are caused by the opening of doors for lorries. The ambient temperature in March was lower than the warehouse temperature, causing the temperature of the manufacturing environment to fall for short periods.

Another problem for the rework in Waddinxveen is the time-lag between the request for support from the Dutch based L+G team to the home base in Stockport and the actual delivery of the support.

4.2 Environment Stockport (UK)

It was decided by L+G to transfer the production to Stockport after it was clear that production numbers were not feasible in Waddinxveen. In Stockport three shifts are possible. The environment production is intended for manufacturing processes and assistance from technicians for any problem is readily available.

The location was visited by auditors from the network operators. The temperature of the environment is pleasant to work in and is not affected by doors opening and closing. The space available for production is much bigger than in Waddinxveen.

A supporting staff is present and is able to test ideas for the rework process directly in co-operation with the rework staff (the cleaning of meters fitted with an adapter was not started at the time).

4.3 Production processes

This paragraph describes the routine checks to verify the quality of the necessary production processes.

4.3.1 *Process clean meters*

In this process, two adapters are fitted on meters with clean bosses. Clean bosses are either unused (new meter without adapters) or have old Permabond removed (meter from Grid Operator warehouse with adapters fitted).

The method sheets of operations from L+G [2] are described in Table 2.

Table 2 Method sheets for clean meter rework

Method sheet number	Title	Quality topics
OP 10	Load meter	Damage assessment of the meter, dust caps present, correct labels, bar code verification. Adapters and washers free from burrs, contamination or damage.
OP 20	Apply Permabond to bosses	Description of the workmanship for the application of Permabond.
OP 30	Fit adapters to bosses	Check of the torque wrench settings. Quality check of the Permabond application. Smooth turning of the adapters. Torqueing the adapters. Adapter alignment check.
Op 35	Pack meter for holding area (for curing of the Permabond)	Remove excess Permabond and apply the witness mark. Place the dust caps. Pack the meters on the pallet and fill out the time/date card.
OP 40	Load for torque check	Check of the curing time. Presence of dust caps and witness marks. Check of the torque wrench settings. and.
OP 45	Torque check tighten	Torqueing clockwise
OP 50	Torque check loosen	Torqueing anti-clockwise
OP 55	Leak test	Check of the compressed air supply pressure. Correct connection of the meter to the test rig. Check the stability of the test pressure. Close the supply valve. Record the begin and end pressure. Calculate the pressure decay. Stick a label for proof of the leak test.
OP 60	Quality check and Packaging	External check of the meter. Place the dust caps. Record the meter data and the pallet data. Stack the meters on the pallet. One meter per pallet is over-checked by the supervisor.
OP 70	Supervisor checks	Checks done by the supervisor at the start and end of the shift.

The following checks are made to assure the quality of the process.

4.3.1.1 Destructive test

After 72 hours of curing, five meters per day are tested destructively to verify the breakaway torque of the adapters. The test is regarded destructive because the breakaway torque is of the same magnitude of the strength of the boss fixation to the meter housing. The two adapters are used for the two torque directions. The inlet tighten and outlet loosen torques are recorded. The meters that are subjected to the destructive test are discarded.

4.3.1.2 *Torque wrench validation check*

Each day (24 hrs), the setting of a torque wrench is verified by testing the tool five times in a row. All five readings shall be inside the indicated tolerance field. The cell in the data sheet shows red text whenever a value is outside the tolerance.

During the activities it became clear that the torque wrenches wear. By the beginning of June, already 3 out of 24 torque wrenches were replaced based on the results of the daily torque checks.

4.3.1.3 *Leak test validation check*

The leak test rigs are validated each day (24 hrs) by three tests:

- Test the rig for external leaks. This is done by measuring the pressure decay using the “pass” meter.
- Test the rig for reading small leakages. This is done by measuring the pressure decay using the “fail” meter.
- Test the rig for internal leaks. This is done by measuring the pressure increase with the “pass” meter non-pressurized and the feed pressure of 300 mbar present, but the pressurizing valve closed.

The tests are performed twice per double rig, one for each of the two rigs connected to one and the same pressure regulator.

The recorded parameters are the pressure indication at the beginning and at the end of the test duration of 1 minute. The pressure decay or pressure increase is calculated by subtracting the start value from the end value. If the pressure difference is outside the tolerance field, the rig is blocked and maintained.

4.3.1.4 *Swing gauge daily check*

The swing gauges for verifying the alignment of the adapters are checked daily against a pass/fail jig. The recorded information is pass or fail.

4.3.1.5 *Meter over-check*

After production and packaging, one meter is taken from each finalized pallet and checked fully on all the quality topics.

4.3.1.6 *First pass yield (FPY)*

This is the number of finished products divided by the production input. The FPY is recorded daily.

4.3.2 *Clean process adapter fitted*

In this process adapters that are fitted with the old Permabond are removed from meters in case they fail the torque test. The list of method sheets [3] is shown in Table 3.

Table 3 Method sheets of clean process adapter fitted.

Method sheet number	Title	Quality topics
OP 10	Load meter	Check the meter type. Damage of the meter, dust caps present, correct labels, bar code verification. Check for strength of the adapter fitting with a torque wrench (45 Nm). When the fitting is strong enough, put a pass sticker. Place dust caps. Fail meters are marked.
OP 40	Adapter removal (from failed meters)	Check the torque wrench setting (78,4 Nm). When the torque wrench clicks during turning, the meter is discarded. If not, record the maximum torque during unscrewing. Put dust protective plugs in the meter bosses.
OP 50	Clean bosses	Remove loose Permabond using a dry cloth. Place a protective plate over the bosses. Remove Permabond from the threads using a wire brush. Vacuum remaining debris from the bosses. Visual inspection of the clean threads.
OP 60	Check & Pack	Cleaning the meter exterior with a wet cloth. Check the thread geometry by screwing on a thread gauge. Vacuuming of the meter bosses. Cleaning of reusable protective plugs. Check on the witness mark of the boss that has been left on. Packing / stacking of the meters. Fill out the travel card.

The meters that have passed the cleaning process are fitted with new adapters according to 4.3.1.

4.4 Process quality topics

These topics are selected and grouped come from observations made during auditing of the Grid Operators. The purpose of the audits is to acquire confidence in the quality of the production process. Audits were performed at the beginning of new processes and shortly before release of processes. The operation instructions were adapted to these findings of the audits.

This paragraph shows Table 4 with a selection of topics that were addressed during audits of the process, one of which is [4].

Table 4 Process quality topics from audits

Topic	Description	Action
Torque tester in Waddinxveen	Initially, the torque tester was mounted on a cart with swivelling wheels that were rolling freely. This made it difficult to apply a torque.	The cart was made stable.
Vibrations from torqueing the bosses	The application of Permabond was done on the same table as the	The fixture of the torque jig to the table was damped using rubber

Topic	Description	Action
	torqueing of the bosses. The release of the torque wrench made the table vibrate, making the application of Permabond difficult.	mats. Also process actions were separated using more tables.
Wrong use of the torque wrench	An operator cranked the torque wrench beyond the release click.	The operators were trained extra for correct use of the torque wrench
The witness marking does not solidify	The marking that indicates rotation of the adapter after the torque test was expected to show a brittle fracture.	The torque tests are evaluated from the value on the display of the torque wrench. The marking is used only as a proof of mounting the boss during assembly.
Grease and burrs on adapters	Some adapters show grease and burrs upon opening the cardboard box.	The adapters are checked for the presence of grease and burrs upon opening the box.
People work very relaxed in the Stockport environment	The conditions in the surroundings of the work benches are much better than in Waddinxveen and any support needed is close at hand.	
Meter number registration	One digit short	Directly corrected
Missing dust caps	Meter bosses are not covered by dust caps upon opening the cardboard box.	Meters are quarantined.
Meters that show a reading above 1 m ³	Meters are stored without caps and subject to draught	Meters shall be metrologically test by L+G
Measurement of missing threads	The amount of engaging threads cannot be determined analytically.	The number of engaging threads is measured for every meter
Exchange of shutoff valve in the tightness test equipment	The ball valves have no fixed end positions. In the process FMEA, the use of valves with clearly defined end positions of the valve handle were recommended. Valves with clicking operation however, did not seal the test volume well enough.	The initial valves were reclaimed and the method sheet was updated with a detailed valve setting explanation.
Tightness test is running without valve shut	The operator starts the timer but closes the supply valve shortly afterwards.	Explanation to operators. Update method sheet.
Expiration date of Permabond	The expiration date is not mentioned on the Permabond vials.	The expiration date is mentioned on the delivery note of the Permabond cardboard box. The Permabond is usable for

Topic	Description	Action
		the project.
Calibration certificates of the pressure gauges	The calibration laboratory shall have an ISO 17025 certificate.	Calibrate accordingly.
Compressed air for the tightness test	On the location of Waddinxveen, a small air compressor was installed for compressed air supply to the tightness test rigs.	The use of this compressor was continued in Stockport because the factory compressed air system was not stable enough to maintain the supply pressure within the required tolerances
Compressed air for the tightness test	Initially, the compressor was fitted with one liquid trap to prevent oil (and other liquids) from entering the compressed air line	A second liquid trap was installed in series to the first one. At the end of each shift both liquid traps are drained.
Touching the metal parts of the meter during the tightness test	The improved parameters for the tightness test put the test close to its maximum possible accuracy in the production environment. In other words, the test becomes more sensitive to external influences. One influence to avoid is touching the metal parts of the meter since body heat will heat the gas inside. This will affect the pressure reading.	Instructions to avoid touching the metal parts of the meter were added to the leak test operation statement.

I Leak rate calculations

Leak rate of the meter as part of the domestic installation

current test

LG Waddinxveen

meter volume	1,89 l
pressure initial	0,3 bar
decrease	0,001 bar
time	60 s
	0,00004
leak	095 l/s
leak	0,14742 l/h

Old test

LG Waddinxveen

meter volume	1,89 l
pressure initial	0,3 bar
decrease	0,003 bar
time	30 s
	0,0002
leak	457 l/s
leak	0,8845 l/h
	2 l/h

Situation during installation

test pressure	0,03 bar
	because of lower
factor	0,1 pressure
	0,01474
leak at installing	2 l/h

Situation during installation

test pressure	0,03 bar
	because of lower
factor	0,1 pressure
	0,0884
leak at installing	52 l/h

system volume	7,56 l (LG factor 5)
meter volume	1,89 l
total volume	9,45 l

system volume	7,56 l (LG factor 5)
meter volume	1,89 l
total volume	9,45 l

NPR 3378 leak test

allowed pressure decay	0,003 bar
allowed leak volume	0,0292005 l, total system

NPR 3378 leak test

allowed pressure decay	0,003 bar
allowed leak volume	0,0292005 l, total system

minimum time for decay	270 s
meter leakage during test	0,0011 l
part by meter	4%

minimum time for decay	270 s
meter leakage during test	0,0066 l
part by meter	23%

(see the next page)

Comparison of the leak requirement with the DIN-ISO 14236 requirement

din iso 14236

bubble diameter	1,5 mm	the factory helium test would produce the equivalent of a 1,5 mm air bubble.
bubble volume	1,7671458 mm ³	
	68 3	
	1,76715E-06 l	
time	31 s	
	0,0086111 h	
	11 h	
	0,0002052	
rate	17 l/h	
water column	10 cm	
pressure	mba	
correction	1 r	
volume		
correction	1,001	
rate	0,0002 l/h	

current test

din iso 14236

bubble diameter	13,5 mm
	1288,2493 mm ³
bubble volume	38 3
	0,0012882
	49 l
time	31 s
	0,0086111 h
	11 h
	0,1496031
rate	49 l/h
water column	10 cm
pressure	mba
correction	1 r
volume	
correction	1,001
rate	0,1498 l/h

Old test

din iso 14236

bubble diameter	24,4 mm
bubble volume	7606,206316 mm ³
	0,007606206 l
time	31 s
	0,008611111 h
	11 h
	0,883301379
rate	49 l/h
water column	10 cm
pressure	mba
correction	1 mbar
volume	
correction	1,001
rate	0,8842 l/h

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