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Dear Owner

CONGRATULATION WITH YOUR CHOICE OF THE PAT ADHESION TESTER!

You are now in possession of an instrument which is a technological leader in its field and which even supersedes current recognised laboratory test methods.

The instrument is robust and designed to be reliable and easy to use in a wide range of applications.

If you have any queries relating to the use of this equipment e.g. types of coatings, accessories, test elements, calibration, use of glue – in fact any issues in the area of adhesion testing, please do dot hesitate to contact us. We promise to assist you in any way we can!

In order to get maximum satisfaction from the use of the equipment and to avoid complications you should

STUDY THIS INSTRUCTION MANUAL THOROUGHLY!

Good luck with your testing!

Yours sincerely

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CONTENTS

OPERATIONS INSTRUCTIONS

1. SCOPE OF SUPPLY

PAT*handy*™/6.3kN includes:

- Hydraulic pump with tightening wheel, crank and precision gauge
- Hydraulic testing head model 6.3kN
- High Speed Steel coating cutting tool
- 5 standard 3.14 cm^2 (Ø20mm) mild steel test elements
- Instrument carry case with protective interior
- Calibration certificate
- User Instruction Manual

PAT model GM01/6.3kN includes:

- Hydraulic pump with analogue precision gauge, high pressure tube and quick-release coupling
- Hydraulic testing head model GM 0101 6.3kN
- High Speed Steel coating cutting tool
- 5 standard 3.14 cm^2 (Ø20mm) mild steel test elements
- Heating iron for removal of test elements
- Aluminium instrument carry case with protective interior
- Calibration certificate
- User Instruction Manual

PAT model GM04/20kN includes:

- Hydraulic pump with analogue precision gauge, high pressure tube and quick-release coupling
- Hydraulic testing head model 20kN
- Adaptor and test platform
- Aluminium instrument carry case with protective interior
- Calibration certificate
- User Instruction Manual

PAT model GM04/40kN includes:

- Hydraulic pump with analogue precision gauge, high pressure tube and quick-release coupling
- Hydraulic testing head model 40kN
- Adaptor and test platform
- Aluminium instrument carry case with protective interior
- Calibration certificate
- User Instruction Manual

2. IMPORTANT POINTS

The instrument is certified for working loads up to 85% of full scale. There is however, a small safety margin built into the system in cases of accidental overload.

THE INSTRUMENT MUST NOT BE SUBJECTED TO FORCES EXCEEDING 95% OF FULL SCALE.

In case of overload the precision could be affected and the instrument may need to be re-calibrated.

If the instrument is used repeatedly up towards the maximum allowable pressure a test element with a smaller diameter should be used instead. Alternatively a more powerful testing head could be used.

3. CLEANING OF THE TEST ELEMENTS BEFORE TESTING

In order to prevent avoidable glue failure during testing it is important to clean the test elements before testing. The following guidelines should minimise this risk.

Removal of glue and coating remnants from used test elements

The test element can be re-used many times so the coating has to be removed before new testing can commence. This can be done several ways:

- The test elements can be submerged in paint stripper or other solvents which dissolves the coating to such extent that the whole paint flake falls off. The disadvantages with this method are staining of the test elements (cosmetic problem only), availability of chemicals, waiting time before the coating falls off, possible contamination, evaporation, pollution, etc. **NB! Make sure you follow all the handling instructions for the chemicals you are using!**

- The test elements can be gritblasted. The disadvantages are that this is time-consuming and expensive. **NB! Gritblasting must only be carried out by suitably qualified personnel!**

- The test elements can be heated so that the glue interface to the steel fails. The test elements can be placed in an oven, but a much quicker and more economical method is to place them on an electric hob with the coated surface facing up. After a few minutes the heat will weaken the glue and the coating can be peeled off with a knife or a chisel-like object while holding the hot test elements with pliers**. NB! Sufficient ventilation is required as the heated adhesive may emit some gases during heating.**

Final cleaning before testing

Immediately prior to gluing the test elements to the surface they should be abraded with a grit paper (grit size 80 –120). Place the gritpaper on a flat, smooth and hard surface and rub the test surface of the test element firmly against the gritpaper in the same direction several times until the characteristic grey pure steel colour appears. Rub the test elements in the one direction only as this will create many parallel micro-grooves on the test surface with minimal contamination. (The only contamination will be fragments of grit and steel which will be absorbed into the adhesive as individual particles, thereby not reduce the adhesive strength.) With the micro-grooves the effective surface area is now many times larger than the nominal size of the test element, and this will strengthen the effective bond between the adhesive and the test element and reduce glue failure.

Abrasion of this kind is regarded as the ultimate type of cleaning since mechanical removal of the steel this way exposes a 100% bare metal surface. Therefore, do not use any solvents or other cleaning method on the test element *after* this abrasion. Do not touch the surface after abrasion - you do not even have to blow or brush the surface.

4. PREPARING THE COATING BEFORE TESTING

The coating should be degreased, abraded or otherwise cleaned depending on which type it is. Generally, the more fragile a coating is the less dependent you are on a good glue strength since the glue only needs to be *stronger than* the coating, not twice or three times as strong.

Some coatings may be sensitive to certain chemicals, which should be avoided in cleaning the coating. Abrasion of the coating surface (e.g. with a grit paper) may be suitable and necessary when epoxy adhesives are used but not necessarily if cyanoacrylate adhesives are used. Cyanoacrylate adhesives are better on smooth and gloss surfaces.

5. PREPARING AND EXECUTING THE TESTS

Glue the test elements the surface with a suitable adhesive.

Cyanoacrylate adhesives may be used successfully on most painted surfaces, metal and other coatings.

In some cases two-component epoxy adhesives are recommended for porous or uneven coatings such as zinc primers, glass-flake, thermal sprayed coatings, coated concrete materials, etc.

After the adhesive has cured remove all excessive glue using the coating cutter and, if required, cut the coating to the substrate surrounding the test element. Failing this may otherwise interfere with the pull-off action.

Any inaccuracies in connection with the pull-off will almost inevitably result in a premature fracture and therefore a reduced reading.

TESTING HEAD 6.3kN or 20kN

Lift the outer ring of the testing head's quick release coupling with the index finger and mount the coupling over the test element. Release the outside ring and a "click" can be heard, the test element is now locked into the testing head.

TESTING HEAD 40kN
Connect the testing head to the test element by fitting the threads on the testing head into the threads in the test element. This is easiest done if the hydraulic cable is disconnected. Make sure it is completely screwed on by either turning the screw itself by hand or by rotating the whole testing head. Do not use any tools for tightening. Connect the hydraulic cable's spring coupling to the testing head

MANUAL HAND-HELD PUMP

Connect the hydraulic cable's quick release socket onto the testing head's inlet plug.

Open the pump's by-pass valve by turning it a quarter to half turn. Press the testing head's four pistons against an even surface by hand. The oil content of the testing head will return to the pump and the equipment will be ready for testing.

Close the pump bypass valve by turning the handle so it points forward.

Place the pump on a stable, *horizontal* foundation at a comfortable height and position for the test operator. (It is easier to operate the pump if it is placed on a low foundation so that the operator can press the lever with a straight, vertical arm thereby having good control of the force.)

Return the drag pointer on the gauge to zero.

Lift and press slightly the lever of the hydraulic pump so that the hydraulic pistons just touch the coating (without any pressure). Lift the lever again to a comfortable middle position in order to have sufficient distance to complete the test in *one* smooth operation.

PAT*handy*™ WITH TURNING CRANK

Make sure that both the crank on the right hand side and tightening wheel have been returned to start position

Press the testing head's four pistons against an even surface by hand. The oil content of the testing head will return to the pump and the equipment will be ready for testing.
Lift the outer ring of the testing head's quick release coupling with the index finger and mount the coupling over the test element. Release the outside ring and a "click" can be heard, the test element is now locked into the testing head.

Return the drag pointer on the gauge to zero.

Turn the tightening wheel at the bottom of the pump until the four legs of the testing head are fully engaged on the tested surface and the pointer on the gauge begins to move slightly.

Conduct the testing by turning the crank smoothly and successively until desired level has been reached or fracture occurs (see separate section about destructive and non-destructive testing).

6. EXECUTING THE TEST

Destructive Test

Increase the pressure smoothly and successively until fracture occurs.

Read the value on the drag pointer and, if necessary, convert this value to the actual maximum material stress using the tables below:

TESTING HEAD 1kN (MICRO TESTING)

Gauge Reading Ratio	Test Element Diameter	Test Element Area	Max Testing Range	Certified Testing Range
2 : 1	Ø 5.6mm	24 mm^2	0 – 40 MPa	0 – 34 MPa
4 : 1	Ø 4mm	12.6mm^2	0 – 80 MPa	0 – 68 MPa
8 : 1	Ø 2,8 mm	6.28mm^2	0 – 160 MPa	0 – 136 MPa

TESTING HEAD 6.3kN

Gauge Reading Ratio	Test Element Diameter	Test Element Area	Max Testing Range	Certified Testing Range
1 : 12.5	Ø 70.7mm	39.24cm^2	0 - 1.6 MPa	0 – 1.36 MPa
1 : 7.81	50 x 50mm	25 cm^2	0 - 2.5 MPa	0 – 2.17 MPa
1 : 6.25	Ø 50 mm	19.62cm^2	0 - 3.2 MPa	0 – 2.72 MPa
1 : 4	Ø 40 mm	12.56cm^2	0 - 5 MPa	0 – 4.25 MPa
1 : 2	Ø 28.2mm	6.28cm^2	0 – 10 MPa	0 – 8.5 MPa
1 : 1	Ø 20mm	3.14cm^2	0 – 20 MPa	0 – 17.0 MPa
2 : 1	Ø 14.2mm	1.57cm^2	0 – 40 MPa	0 – 34 MPa
6 : 1	Ø 8.16mm	0.52cm^2	0 – 120 MPa	0 – 102 MPa

TESTING HEAD 20kN

Gauge Reading Ratio	Test Element Diameter	Test Element Area	Max Testing Range	Certified Testing Range
1 : 4	Ø 70.7mm	39.24cm^2	0 – 5 MPa	0 – 4.25 MPa
2 : 5	50 x 50mm	25 cm^2	0 – 8 MPa	0 – 6,8 MPa
1 : 2	Ø 50 mm	19.62cm^2	0 – 10 MPa	0 – 8.5 MPa
2 : 1	Ø 25 mm	4.90cm^2	0 – 40 MPa	0 – 34 MPa

TESTING HEAD 40kN

Gauge Reading Ratio	Test Element Diameter	Test Element Area	Max Testing Range	Certified Testing Range
1 : 2	Ø 70.7mm	39.24cm^2	0 – 10 MPa	0 – 8.5 MPa
4 : 5	50 x 50mm	25 cm^2	0 – 16 MPa	0 – 13.6 MPa
1 : 1	Ø 50 mm	19.62cm^2	0 – 20 MPa	0 – 17 MPa
4 : 1	Ø 25 mm	4.90cm^2	0 – 80 MPa	0 – 68 MPa

Example: The 6.3 kN testing head in combination with a 1.57cm^2 test element gives a reading on the gauge dial of 12 MPa (or 1740 psi). The actual test result is calculated by the ratio 2 : 1, i.e. 24 MPa (or 3480 psi).

Non-Destructive Test

The following points are important before choosing this method:

The coating must *not* be cut around the test element, as this would make it a *destructive* test.

Non-destructive testing is not recommended for some decorative coatings as a certain amount of glue may remain on the surface after the completion of the test.

Furthermore, this test is only non-destructive provided the coating does *not* fracture prematurely. Therefore careful professional judgement is needed before choosing this non-destructive method.

Choose the desired minimum strength of the coating and turn the drag pointer of the gauge to this value. This value may be determined by yourselves, a contract specification or any other inputs.

Carry out the test as under the section for Destructive Test. Increase the pressure smoothly and successively until the required force on the test element has been reached (i.e. when the gauge pointer overlaps the drag pointer).

Discontinue the force build-up, release the pressure by opening the pump's by-pass valve and disconnect the testing head from the test element.

Removal of the Test Element using the Heating Iron

Remove the test element from the coating without damaging it the following way:

- Connect the heating iron to the AC supply and, when it is completely hot, position it over the test element and hold the iron over the test element for 1-2 minutes. The heat will transfer via the test element to the glue and weaken this before the coating itself becomes damaged.

- Carefully apply a slight levered tilting force on the test element with the handle of the heating iron until the test element comes off. This force must not exceed the strength of the coating.

7. EXTERNAL FACTORS WHICH MAY AFFECT THE TEST RESULTS

Incorrect use of adhesive

The adhesive layer must be absolutely homogeneous without air pores.

In cases where high values are expected and exact measurements are important it is recommended to use low molecular epoxy adhesives.

Apply a sufficient amount of adhesives in the centre of the test area on the substrate or on the test element.

Place the test element on top of the adhesive and press it down until it is firmly embedded in the adhesive and the adhesive has been squeezed out around *the whole* circumference.

Test results with glue fracture, which read below the average test results of the batch, should be excluded from the test sample.

Even very small air pores in the adhesive (or areas without glue under the test element), particularly near the edge of the test area may affect the test results significantly.

Removal of excess adhesive must be done carefully and consistently with the HSS cutting tool provided with the equipment.

Excess adhesive around the edge of the test area has been known to *reduce* the value of the test result in spite of the fact that the effective test area nominally is bigger. The reason for this is that the test instrument cannot compensate for the unevenness of the edge.

Substrate Thickness

Testing on thicker test panels often give higher pull-off values than on thinner panels. The reason for this is that all materials yield to a certain degree when subjected to a momentous stress, which is the typical stress pattern in the test panel under this type of testing. Because there is a certain distance from the centre of the test element to the hydraulic legs the counter force required will cause the panel to flex. This flexing could typically be less than 1µm but this is often enough to distort the testing. (E.g. if the coating is 10µm thick, 1µm the flexing would represent 10% of its thickness!)

Testing of thick and flexible coatings would generally be less affected by panel flexing than testing on thin and brittle coatings. For a test to be 100% successful the substrate must be made sufficiently rigid to prevent adverse bending of the test panel.

What is regarded a “thin” test panel depends on the following factors:

- *The total force required (kN).* Testing of a strong coating will require more force and therefore develop more flexural stress than testing of a fragile coating.

- *The model size of testing head used.* The larger the testing head the longer the distance from the centre of the test element to the hydraulic legs, hence the greater the momentous stress and flexing.

- *The actual thickness of the substrate.* A substrate may vary in thickness from a less than 1µm (e.g. a coated metal film) up to infinite thickness (e.g. a coated tunnel wall).

How to prevent flexing of a test panel.

To eliminate flexing of the test panel the following procedure is recommended:

- Cut (e.g. with a hacksaw) the test panel into small pieces sufficiently big for one test element to be glued on each piece.
- When gluing the test element to the small pieces, glue the pieces themselves onto a completely rigid surface (e.g. a steel plate more than 10 – 15 mm thick).
- When the glue is cured testing can be carried out as normal. It is recommended to rest the hydraulic legs on a correctly sized support ring to further prevent the test panel itself to delaminate from the rigid surface during testing.

Cutting around the test element

Core cutting concrete substrates must be done with a suitable drill and drill bit in accordance with the instructions for that drill equipment.

Atmospheric Conditions

Even very small temperature variation will affect the cohesive strength of polymer coatings hence give rise to result variation.

8. CHECKING THE ACCURACY OF THE EQUIPMENT

Factory Calibration

It is recommended to check the accuracy of the instrument in the interval between re-calibrations. It is particularly important to check the accuracy regularly if the equipment is:

- used by several people;
- transported extensively;
- used regularly on site testing, etc.
- If the equipment is used for testing of strictly specified requirements, it should be checked, certified and calibrated once a year, otherwise in accordance with your own calibration procedures.

When the equipment is returned to us for factory re-calibration, we do the following:

Check the instrument up against a load cell with accuracy traceable to the Norwegian Directorate of Measurements (NDM). The values at several intervals on the dial are recorded and compared with the corresponding values of the load cell. This comparison represents the actual calibration of the equipment.

If the gauge has drifted outside ±1% of full scale the accuracy the equipment is adjusted accordingly.

After adjustment, if required, the equipment is again checked up against the load cell (i.e. calibrated).

A dated, stamped and signed Certificate of Calibration is issued documenting that the instrument is operating with stipulated accuracy.

Your Own Calibration

The PAT adhesion tester is a very stable instrument *under normal use.* You are therefore able to carry out your own *calibration* of the instrument provided you follow the steps below.

The optional portable calibration unit, **PAT model GM03**, is available as an accessory to provide easy and quick checks of the equipment's accuracy at all times.

PAT model GM03 calibration unit can also be used more extensively as part of your main calibration procedures the following way:

The PAT model GM03 is itself calibrated against the load cell the same way as the PAT adhesion tester and issued with the same type of calibration certificate.

This calibration unit is designed for calibration of adhesion testers in cases when it is desirable to check the testing unit more frequently than annually, in particular when

testing is carried out by several people;

the instrument is frequently transported;

the instrument is used under rough site conditions;

"before testing/after testing" calibration requirements are in force;

you cannot part with the test equipment for longer periods at the time due to constant testing commitments.

Since this calibration unit's own calibration is traceable to NDM via our load cell it is perfectly possible to use this for subsequent "sub-calibration" of your adhesion tester without having to send it for external calibration provided:

- the calibration unit itself carries a current certificate satisfactory to yourselves or your clients;

- the tester, which is calibrated, has not drifted outside its accuracy range since the last certificate was issued. If it has, your sub-calibration" certificate must reflect this.

- you take into account the added uncertainty of the calibration unit itself in your "sub-calibration". Its accuracy is certified within ±1% of its full scale, so this must be added to the normal accuracy of the testers (which also is ±1%).

- you ensure that the "sub-calibration" has been carried out to the satisfaction of the involved parties.

If the adhesion tester is damaged or need adjustment, work in connection with this must be carried out by us.

9. MAINTENANCE AND CARE OF THE INSTRUMENT

Always keep the instrument in the instrument case ***with the lid shut*** when not in use, particularly in dusty and otherwise hostile environments, typically when spraying and surface preparation is in progress.

The equipment is practically maintenance free under normal use.

Even so, situations may arise where it does not function satisfactorily.

Bleeding of the hydraulic system (Only Manual hand-held pump).

This must be done with the greatest care following the instructions below:

- Connect the testing head to the pump.

- Return the oil from the testing head to the by pressing the pistons to the bottom.

- Disconnect the testing head.

- Tilt the pump over sideways (with the glass of the pressure gauge facing up).

- With a sharp object carefully hold in the quick-release valve on the hydraulic cable, and at the same time pump steadily and carefully until an even flow of oil appears in the valve.

- Release the valve and turn the pump to an upright position.

- Press the lever to build up pressure without connecting the testing head to check if the air has been bled.

Check the Dynamic Characteristics of the Testing Head

The hydraulic parts of the testing head have been manufactured with great precision to ensure minimum friction thereby ensuring accurate and consistent adhesion measurements. If, through

serious accident, the hydraulic legs have been damaged through impact this could cause them to become imbalanced in relation to each other. Following such impact accident you can quickly ascertain if indeed the testing head has been damaged the following way:

- Press the four hydraulic pistons on the testing head half way out with the lever on the pump.
- Press in each individual piston whilst pressing against the other three pistons in succession.
- As each piston is pressed in the other pistons should move outwards with a smooth movement without any *mechanical* friction.

10. OTHER POINTS TO REMEMBER

The operator of the instrument will, in connection with the characterisation of materials, need a thorough introduction and training in order to be able to interpret the test results correctly.

It is particularly important to understand the causes and effects of potential sources of error, like “glue failure”, inadequate coating cutting, air pores in the coatings or the adhesive, uneven curing of the coatings, inconsistent stress increase from one test to another.

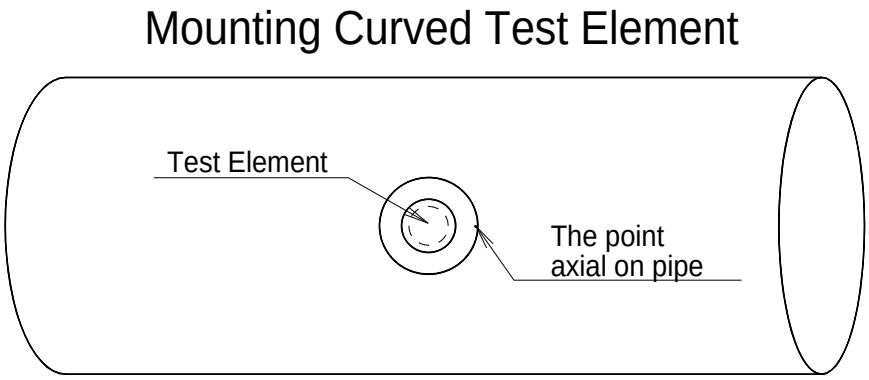
11. TESTING ON CURVED SURFACES

Curved Test Elements

For testing on convex and concave surfaces it is strongly recommended to use purpose-machined test elements with a specified curve diameter.

As cyanoacrylate adhesives require the film thickness to be minimal to be effective, even a small difference in the diameter between the dolly and the surface to be tested may result in this adhesive type being unusable for this application.

Purpose-machined test elements have been marked with a dot on their sides to indicate the axial direction of the curve (particularly useful when the diameter is very large and difficult to see with the naked eye). During testing the test elements must be positioned as indicated in the illustration.



Testing Platform for Curved Surfaces

When testing either concave or convex surfaces, particularly those with small diameters, it is strongly recommended (and sometimes unavoidable) to use a testing platform against which the hydraulic will press. This platform will give a support which is perpendicular to the pull direction, thereby eliminated any radial forces on the hydraulic legs during testing.

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