# Report Number: 0550

# Corrosion performance of Endotherm Water Treatment with and without Fernox MB-1

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Date: 4 September 2014

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**Introduction**

Midland Corrosion Services Ltd. has been certified by BuildCert Ltd. as an approved laboratory for carrying out the DWTA industry standard performance test for chemical inhibitors for use in central heating systems.

Endo Enterprises supplied samples of Endotherm, Fernox MB-1 and Endotherm + Fernox MB-1 for evaluation of corrosion inhibiting performance. The tests carried out were a modification of the BuildCert industry standard specification for the performance of chemical inhibitors for use in domestic hot water central heating systems .

## 1. Tests Carried Out

Corrosion tests were carried out in inhibitor solutions made up in both standard hard and standard soft water as given in Table 1. The standard hard water was made using Evian Spring Water together with added analytical grade reagents. The standard soft water was made using Aqua Pura together with added analytical grade reagents. The compositions of both waters were as shown in Table 2.

| Cell No. | Inhibitor | Water |
|---|---|---|
| 1 | 4% Fernox MB-1 | Hard |
| 2 | 4% Fernox MB-1 | Soft |
| 3 | 1% Endotherm | Hard |
| 4 | 1% Endotherm | Soft |
| 5 | 4% Fernox MB-1 + 1% Endotherm | Hard |
| 6 | 4% Fernox MB-1 + 1% Endotherm | Soft |

**Table 1 Test Solutions**

| | Standard Hard Water | Standard Soft Water |
|---|---|---|
| Total Hardness (mg/L CaCO3) | 350 +/-10 | 35 +/- 10 |
| Alkalinity (mg/L CaC03) | 250 +/-10 | 25 +/-10 |
| Chloride (mg/L) | 60 +/-10 | 60 +/-10 |
| Sulphate (mg/L) | 60 +/-10 | 15 +/-10 |

**Table 2 Specification of Standard Waters Used**

Metal coupons of dimensions 50x 25mm with bead blast finish of mild steel, copper and aluminium were obtained from European Corrosion Supplies. Each coupon used was weighed before the test using a 5 figure Mettler Toledo analytical balance. Two coupons of each metal were assembled using central holes into a coupon bundle with PTFE spacers and PTFE sleeve so that each coupon was electrically isolated from each other. Each coupon bundle was attached to a stainless steel spindle and placed in a 1 litre jacketed glass cell containing the prepared test solution. The spindles were fitted to an overhead stirrer so that they could be rotated at 200rpm. The coupon arrangement was as follows:

**Al:Steel:Cu – spindle – Al:Steel:Cu**

Test solutions were heated by passing water from a Grant temperature controlled water bath through the glass jackets surrounding the 1 litre cells. The temperature was cycled between 25 deg C and 82 deg C in a 4 hour on 4 hour off cycle. Monitoring of stirrer speeds (Vos 14 overhead stirrers) and cell temperatures was carried out regularly during the tests. The tests were run concurrently for 336 hours (2 weeks).

At the end of the tests, the coupons bundles were immediately rinsed in demineralised water and methanol and dried in warm air. The coupons were then weighed using the analytical balance before and after cleaning according to ASTM G-1. By cleaning and weighing the coupons 4 or 5 times, a corrected weight loss was obtained from which a corrosion rate could be derived.

CORROSION TEST SET UP

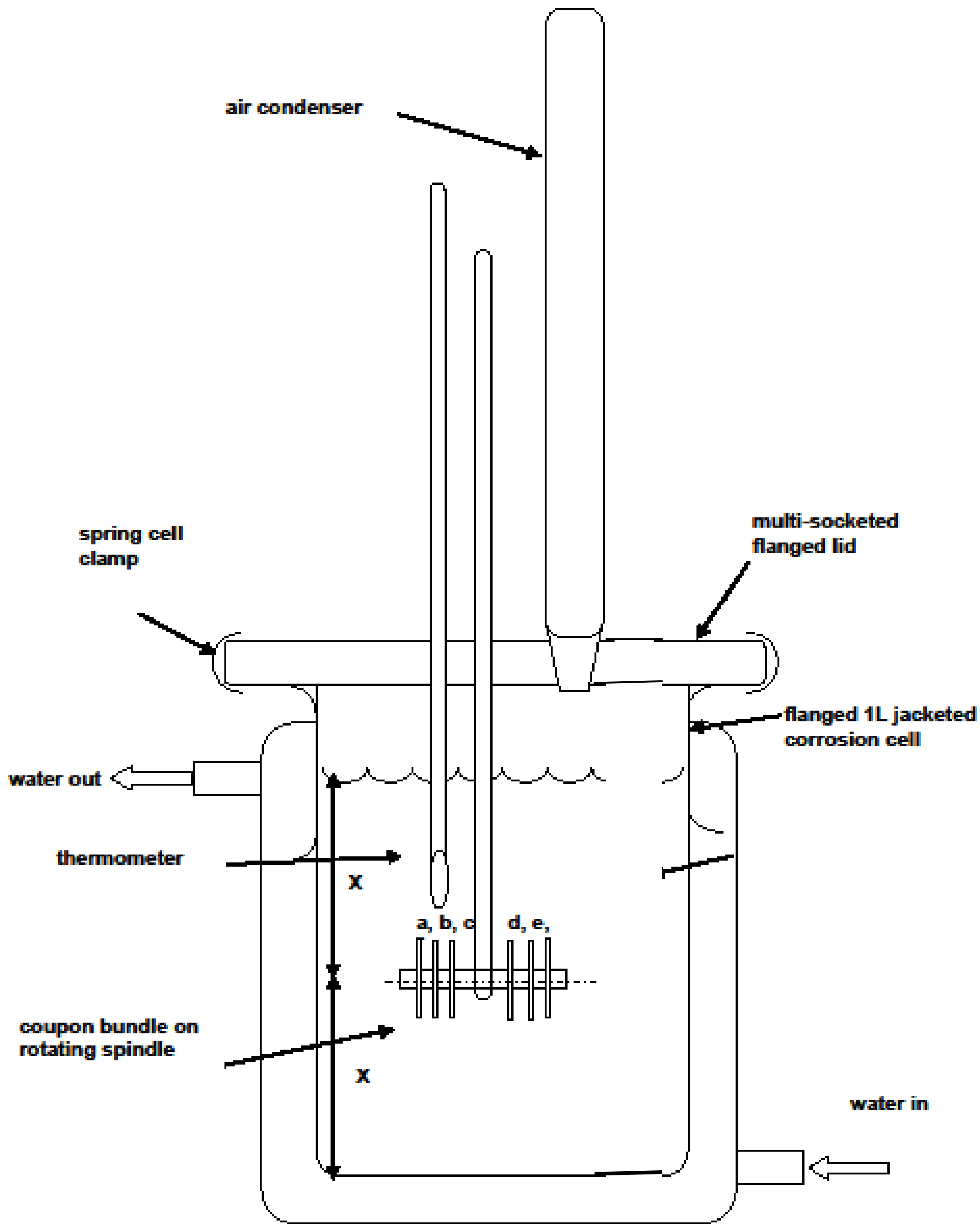


**Fig. 1** **Test Cell**

## 2. Results

Each coupon was weighed after the test and after cleaning 4 times in the recommended acidic cleaning solutions using the 5-figure Mettler Toledo analytical balance. By plotting the results on a graph, corrected weight losses adjusting for any metal losses due to cleaning were obtained.

The mean corrosion rates for the 3 metals, derived from the corrected weight losses are shown in table 2. The last column gives the limits for the corrosion rates according to the BuildCert Test. It is clear that for MB-1 on its own and MB-1 with Endotherm in both hard and soft water, that the corrosion rates for mild steel, aluminium and copper are well below these limits. The addition of Endotherm does not appear to adversely affect the corrosion inhibition of Fernox MB-1. However, for Endotherm on its own, the mean corrosion rates are well above these limits.

The appearance of the coupons after testing is shown in the plates at the end of the report. As can be seen, the coupons from bundles 3 and 4, Endotherm alone appear to be heavily corroded, in contrast to the appearance of coupons from the other bundles. The mild steel coupons in Endotherm were covered with a thick reddish iron oxide layer. The aluminium coupons in this solution appeared to be copper coloured and pitted (especially in the hard water), indicating that copper deposition had occurred on these coupons. The copper coupons were quite dark indicating that some general corrosion had occurred. In the Fernox MB-1 containing solutions (with and without Endotherm), the metal coupons appeared darkened or slightly tarnished but there was no sign of pitting on any coupon or copper deposition on the aluminium coupons.

## 3. Conclusions

When tested in glassware over 2 weeks, the addition of 1% Endotherm to MB-1 in both hard and soft waters does not affect the corrosion inhibition on mild steel, aluminium and copper. Endotherm on its own does not provide any corrosion inhibition on these metals.

Signed…………………………… Phillip Munn

Date…………………………04/09/2014

Phillip Munn
Director

| Metal | Solution | Water | Mean Wt. Loss (mg) | Corr. Rate mm/yr | BuildCert Limit mm/yr |
|---|---|---|---|---|---|
| mild steel | MB-1 | Hard | 3.3 | **0.0037** | **0.04** |
| mild steel | MB-1 | Soft | 8.8 | **0.0114** | **0.04** |
| mild steel | Endotherm | Hard | 510.0 | **0.6390** | **0.04** |
| mild steel | Endotherm | Soft | 697.5 | **0.8871** | **0.04** |
| mild steel | MB-1 + Endotherm | Hard | 4.0 | **0.0055** | **0.04** |
| mild steel | MB-1 + Endotherm | Soft | 4.5 | **0.0067** | **0.04** |
| | | | | | |
| Aluminium | MB-1 | Hard | 4.8 | **0.0179** | **0.100** |
| Aluminium | MB-1 | Soft | 3.3 | **0.0169** | **0.100** |
| Aluminium | Endotherm | Hard | 32.0 | **0.1509** | **0.100** |
| Aluminium | Endotherm | Soft | 39.4 | **0.1564** | **0.100** |
| Aluminium | MB-1 + Endotherm | Hard | 5.1 | **0.0173** | **0.100** |
| Aluminium | MB-1 + Endotherm | Soft | 7.6 | **0.0478** | **0.100** |
| | | | | | |
| Copper | MB-1 | Hard | 1.4 | **0.0022** | **0.005** |
| Copper | MB-1 | Soft | 2.1 | **0.0014** | **0.005** |
| Copper | Endotherm | Hard | 14.1 | **0.0151** | **0.005** |
| Copper | Endotherm | Soft | 12.6 | **0.0133** | **0.005** |
| Copper | MB-1 + Endotherm | Hard | 1.7 | **0.0014** | **0.005** |
| Copper | MB-1 + Endotherm | Soft | 1.2 | **0.0013** | **0.005** |

**Table 2 Mean Weight Losses and Derived Corrosion Rates**


Project 2014-51 (FMB-1, in HW & SW)
MCS
Midland Corrosion Services Ltd.
Bundle 1(HW): Mild Steel
Mild Steel 2
Aluminium
Aluminium 2
Copper
Copper 2
Bundle 2(SW): Mild Steel
Mild Steel 2
Aluminium
Aluminium 2
Copper
Copper 2


Project 2014-51 (ET, in HW & SW)
MCS
Midland Corrosion Services Ltd.
Bundle 3(HW): Mild Steel
Mild Steel 2
Aluminium
Aluminium 2
Copper
Copper 2
Bundle 4(SW): Mild Steel
Mild Steel 2
Aluminium
Aluminium 2
Copper
Copper 2

**Close-up of mild steel coupon from bundle 3**

**Bundle 5(HW): Mild Steel** | **Mild Steel 2** | **Aluminium** | **Aluminium 2** | **Copper** | **Copper 2**

**Bundle 6(SW): Mild Steel** | **Mild Steel 2** | **Aluminium** | **Aluminium 2** | **Copper** | **Copper 2**

# ENDO ENTERPRISES

# AN UNBIASED, THIRD PARTY STUDY OF THE CORROSIVE EFFECT OF

# EndoTherm™

# ON THE MATERIALS FOUND WITHIN CENTRAL HEATING SYSTEMS

BY

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EndoTherm™

Meadowhead Consultancy Ltd.

# A Study of the Corrosive Effect of Endotherm Water Treatment Chemical on Various Metals and Compatibility with Rubbers found within Central Heating Systems.


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Experimental Work Carried Out by:

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Date: 18th of June 2013

**Contents**

## 1. Executive Summary

Endo Enterprises Ltd market a product called Endotherm which is claimed to improve heat transfer when added to the water circulating in a commercial or domestic heating system.

The product is based on a proprietary blend of glucoses and fatty alcohols, a biodegradable surfactant which would not be expected to be particularly aggressive to the materials of construction of a heating system.

This report confirms that the corrosion rate of the materials likely to be found in a commercial heating system is less in a system filled with water treated with 1200 ppm Endotherm than if the system were filled with untreated water.

Tests were conducted using a Buildcert test rig over 14 days in both hard and soft waters.

Tests on metals and seal materials confirm previous tests carried out on this material by Midland corrosion and by Carshalton College. The Midland Corrosion test was conducted on water containing the equivalent of 600 ppm Endotherm.

The Carshalton test was a field test carried out over a 21 month period prior to removal of all system components for examination.

## 2. Introduction

Meadowhead Consultancy carried out laboratory experiments to determine the effect of Endotherm (a proprietary blend of glucoses and fatty alcohols) on the construction materials of heating systems.

A short term laboratory evaluation was undertaken to determine the corrosion rate and pitting of standard metal coupons by Endotherm when dosed at the recommended rate of 1200ppm.

In addition the corrosion rate of hard and soft water, without any added chemicals, was also determined to use as a comparison.

The metals coupons which are used in the tests include Aluminium, Mild Steel, Stainless Steel, Brass and Copper. These metals are representative of the range of alloys which would be found within a domestic heating system. The test metal specimens used are those used in the BuildCert corrosion inhibitor testing

The corrosion rate C is calculated using the corrected weight loss multiplied by the factor K (K incorporates coupon density, area and units) divided by the exposure time which is expressed in mm per year.

This work was carried out in accordance with the BuildCert Chemical Approval Scheme (CIAS) test methods.

This report also contains information on the compatibility of Endotherm with various rubbers within the heating system. The chemical was tested using 4 different rubbers which are found in central heating systems.

The test involved measuring the volume swell of the rubber in double concentration of Endotherm in soft water.

## 3. Experimental Set-Up

a) Corrosion Testing

Test were carried out in one litre flanged glass vessels with multi socketed flanged lids. The corrosion coupons were placed on a central rotation, plastic shaft within the test vessel and the test vessel was filled with a 1000ml of the Endotherm solution. Endotherm was added to give a concentration of 1200ppm (0.12%w/v) in each container, which is the recommended concentration for addition to heating systems.

The coupons used in the experiment were mild steel, copper, brass, extruded aluminium and stainless steel. The coupons were rinsed with demineralised water, then methanol, dried in warm air and then weighed to the nearest 0.1mg in accordance with BS5117 Section 2.1 1985 prior to starting the test procedure.

The one litre vessel was then placed into a water bath which was used to control the temperature at 82°C +/- 2°C. The rotation speed of the overhead stirrers in the vessel was 200rpm +/- 10rpm. Each test was then run for 336 hours.

The coupon bundle was removed from each vessel at the end of the test, and dismantled. Then each coupon was rinsed in demineralised water and then methanol, prior to being dried in warm air. The coupons were then reweighted to the nearest 0.1mg.

b) Rubber Compatibility

Rubber test pieces were cut from certified test sheets obtained from Clwyd Compounders Ltd. The volume of each rubber test piece was determined before and after immersion in the test solution by weighing the pieces in air and in demineralised water using the Mettler Toledo analytical balance.

The compatibility of the Endotherm additive with 4 different rubbers used in central heating systems, was tested by measuring the volume swell of the rubbers in double the concentration of the additive in soft water.

The eight rubber test pieces (4 of each rubber) were immersed individually in glass bottles containing 100ml of 0.2% Endotherm concentrate (2 x recommended strength) in standard soft water. The bottles were placed in a calibrated recirculating oven at 82 +/- 1°C for 96 hours. At the end of the test, the rubbers were inspected for any signs of deterioration using a stereo zoom microscope.

The natural soft water was based on Aqua Pure mineral water as described in section 3. For the corrosion tests, Endotherm was added to the test waters at a concentration of 1,200 mg/L (0.12 %v/v). For the rubber compatibility tests, Endotherm was added to the soft water at a concentration of 2000mg/L (0.2%v/v).

Test Waters

The hard and the soft waters used conformed to the CIAS (Chemical Inhibitor Approval Scheme) specification.
The hard water, based on Evian mineral water had a total hardness of 342mg/l $CaCO_3$, a carbonate hardness of 257mg/l $CaCO_3$ and a chloride and sulphate level of 60 mg/l respectively.

The soft water was based on Aqua-Pura mineral water with added chloride and sulphate. The total hardness was 36mg/l $CaCO_3$, carbonate hardness of 25mg/l $CaCO_3$ and chloride and sulphate levels as before at 60 mg/l

## 4. Results:

a) Corrosion Assessment

The results of the experiment indicate the following.
There is less corrosion in the hard and soft waters where they have been dosed with Endotherm. The results from the untreated hard and soft water caused the coupons to corrode more than the water dosed with the Endotherm.
From the results soft water shows a higher rate of corrosion than hard water. This is to be expected due to the more acidic nature of soft water. However the soft water dosed with Endotherm showed a lower rate of corrosion than of that without.
The mild steel showed the most amount of corrosion in the hard water dosed with Endotherm. However this was about 50% the amount of corrosion experienced in the untreated water. The other metals did not exhibit any corrosion all at in the dosed hard water.
The mild steel again showed the most amount of corrosion in the soft water dosed with Endotherm with the corrosion on the aluminium

coupon being the 2nd most significant. There was approximately 25% less corrosion of the mild steel in the dosed soft water compared with the untreated water. The aluminium showed 80% less corrosion in the dosed water compared to the untreated water. The other metals showed minimal amounts of corrosion in the soft water dosed with Endotherm. See Table 1 and 2

**Table 1 Comparison of Corrosion rates in 1200 ppm Endotherm in Hard water with untreated Hard water**

| | | Material | Weight Difference (mg) Endotherm 600APG | Corrosion Rate C Endotherm mm/year | Weight Difference (mg) untreated Hard Water | Corrosion Rate C untreated Hard Water mm/year | Corrosion Limit mm/year |
|---|---|---|---|---|---|---|---|
| A | Mild steel | DC 01 | 46.3 | 0.057 | 78.15 | 0.097 | 0.040 |
| B | Copper | Cu CW024 | 0 | 0 | 11.37 | 0.012 | 0.005 |
| C | Aluminium | AL6082 | 0 | 0 | 1.98 | 0.007 | 0.100 |
| D | Brass | CW505L | 0 | 0 | 22.29 | 0.025 | 0.005 |
| E | Stainless steel | 1.4307 | 0 | 0 | 2.77 | 0.003 | 0.002 |
| F | Balance | 1.4307 | 0 | 0 | 2.74 | 0.003 | 0.002 |
| | (Stainless steel) | | | | | | |

**Table 2 Comparison of Corrosion Rates in 1200 ppm Endotherm in Soft water with untreated Soft Water**

| | | Material | Weight Difference (mg) Endotherm 600APG | Corrosion Rate C Endotherm 600APG mm/year | Weight Difference (mg) untreated soft water | Corrosion Rate C untreated Soft water mm/year | Corrosion Limit mm/year |
|---|---|---|---|---|---|---|---|
| A | Mild Steel | DC 01 | 125.6 | 0.156 | 153.32 | 0.190 | 0.040 |
| B | Copper | Cu CW024 | 0.1 | 0.0001 | 10.54 | 0.011 | 0.005 |
| C | Aluminium | AL6082 | 15.2 | 0.055 | 71.25 | 0.256 | 0.100 |
| D | Brass | CW505L | 2.9 | 0.003 | 18.55 | 0.021 | 0.005 |
| E | Stainless steel | 1.4307 | 0 | 0 | 2.92 | 0.003 | 0.002 |
| F | Balance | 1.4307 | 0.6 | 0.0007 | 2.66 | 0.003 | |
| | (Stainless steel) | | | | | | |

Notes 1. Corrosion tests indicate that Endotherm has a slight inhibitory effect – Rates in Endotherm are less than in untreated water.

2. Corrosion rate for Endotherm are slightly higher in 1200 ppm than at 600 ppm ( test conducted by Midland Corrosion )

## Seal Material Compatibility

The volume swelling on the 3 different types of EPDM rubbers and the NBR rubber after 100 hours immersion in Endotherm at 2 x recommended concentration in the soft water is given in Table 3. This also shows the volume swells in untreated soft water. It can be seen that the % volume swells were higher in all cases in the Endotherm solution than in untreated soft water. However, the volume swells were relatively slight with the maximum swell of 6.8% with NBR 70 peroxide cured. This swell is below the limit of 10% difference in volume swells between treated and untreated soft water in the DWTA test.

Following the immersion period, the test pieces were removed and inspected at low magnification under a stereo zoom microscope. There was no discernible change in the rubbers.

# Table 3 Volume Swell Measurements in Endotherm treated and untreated soft water

| Rubber Type | Solution | Weight before Immersion<br>AIR<br>WET | Volume Before<br>$cm^3$ | Weight after Immersion<br>AIR<br>WET | Volume after<br>$cm^3$ | Volume of Swell<br>% | Mean volume swell<br>% |
|---|---|---|---|---|---|---|---|
| EPDM -70 resin cured 1 | Soft Water | 1.09591<br>0.08916 | 1.00675 | 1.11460<br>0.09310 | **1.02150** | **1.47** | **1.47** |
| EPDM -70 resin cured 2 | Soft Water | 1.05415<br>0.08590 | 0.96825 | **1.07210**<br>**0.08960** | **0.98250** | **1.47** | |
| EPDM -70 resin cured 3 | Endotherm treated | 1.10625<br>1.01608 | 1.01608 | **1.12889**<br>**1.12889** | **1.03711** | **2.07** | **2.04** |
| EPDM -70 resin cured 4 | Endotherm treated | 1.09386<br>0.08876 | 1.00510 | **1.11590**<br>**0.09063** | **1.02527** | **2.01** | |
| EPDM -70 perox cured 1 | Soft Water | 1.09257<br>0.13150 | 0.96107 | 1.11460<br>0.09310 | **1.02150** | **1.47** | **1.47** |
| EPDM -70 perox cured 2 | Soft Water | 1.05415<br>0.95120 | 0.95120 | **1.07210**<br>**0.08960** | **0.98250** | **1.47** | |
| EPDM -70 perox cured 3 | Endotherm treated | 1.10625<br>0.93306 | 0.93306 | **1.12889**<br>**1.12889** | **1.03711** | **2.07** | **2.04** |
| EPDM -70 perox cured 4 | Endotherm treated | 1.09386<br>094586 | | **1.11590**<br>**0.09063** | **1.02527** | **2.01** | |
| EPDM -70 sulph cured 1 | Soft Water | 1.09591<br>0.88466 | 1.00675 | 1.11460<br>0.09310 | **1.02150** | **1.47** | **1.47** |
| EPDM -70 sulph cured 2 | Soft Water | 1.05415<br>0.86680 | 0.96825 | **1.07210**<br>**0.08960** | **0.98250** | **1.47** | |
| EPDM -70 sulph cured 3 | Endotherm treated | 1.10625<br>0.84237 | 1.12889 | **1.12889**<br>**1.12889** | **1.03711** | **2.07** | **2.04** |
| EPDM -70 sulph cured 4 | Endotherm treated | 1.09386<br>0.10941 | 1.11590 | **1.11590**<br>**0.09063** | **1.02527** | **2.01** | |
| NBR – 70 perox. Cured 1 | Soft Water | **0.93909**<br>**0.14240** | **0.79969** | **0.97230**<br>**0.14670** | **0.82350** | **3.63** | **3.71** |
| NBR – 70 perox. Cured 1 | Soft Water | **0.95764**<br>**0.14480** | **0,81284** | **0.99280**<br>**0.14920** | **0.84360** | **3.78** | |
| NBR – 70 perox. Cured 1 | Endotherm treated | **0.95618**<br>**0.14493** | **0.81125** | **1.01425**<br>**0.1428** | **0.86597** | **6.75** | **6.57** |
| NBR – 70 perox. Cured 1 | Endotherm treated | **0.92711**<br>**0.13999** | **0.78712** | **0.98256**<br>**0.14509** | **0.83747** | **6.4** | |

# References

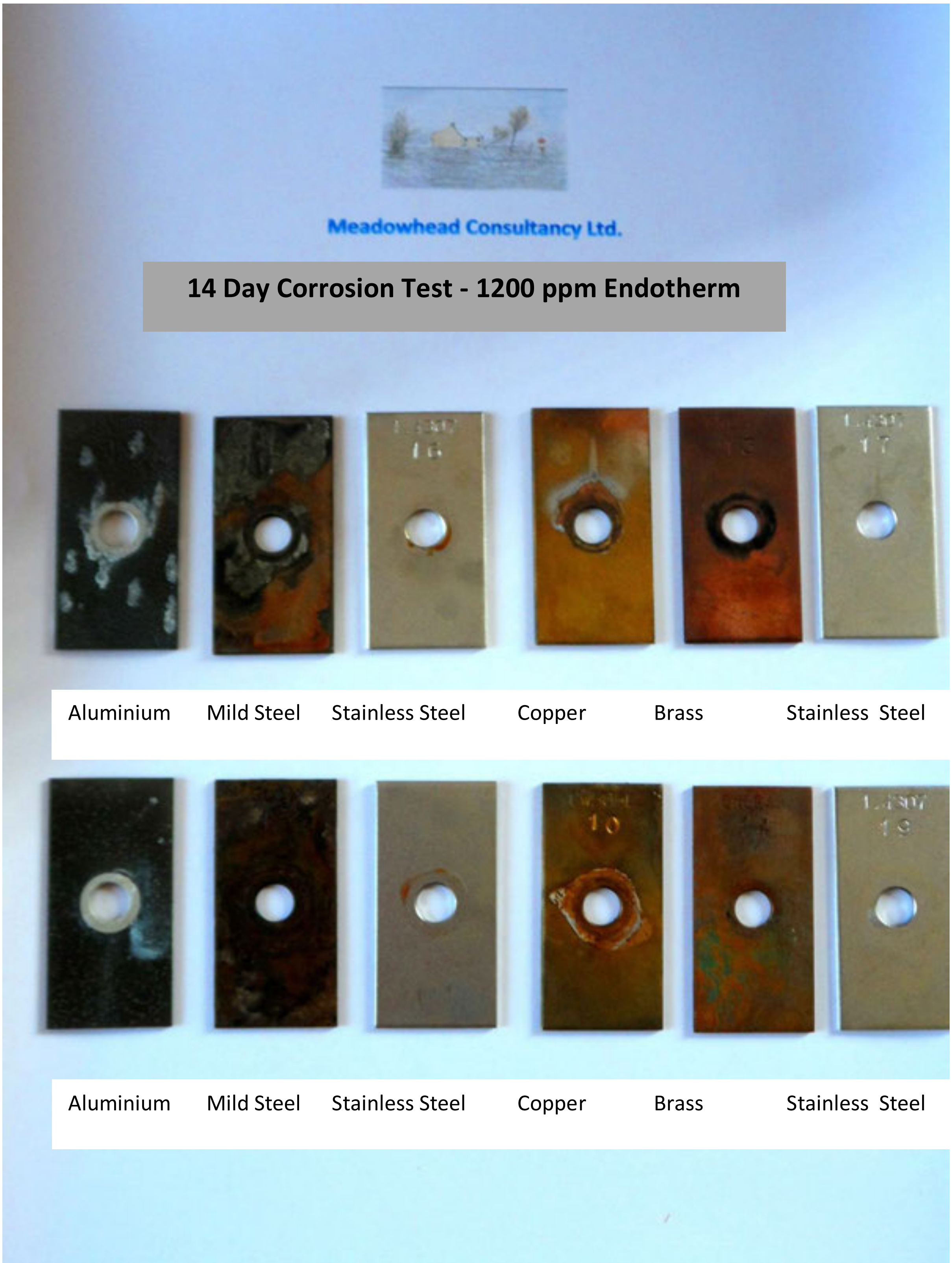

1. **System Inspection following Endotherm Treatment ,A Harris Report CAR /PC/1105 11/01 2012**

Meadowhead Consultancy Ltd.

## 14 Day Corrosion Test - Water only – no treatment


Aluminium | Mild Steel | Stainless Steel | Copper | Brass | Stainless Steel


Aluminium | Mild Steel | Stainless Steel | Copper | Brass | Stainless Steel


Meadowhead Consultancy Ltd.
14 Day Corrosion Test - 1200 ppm Endotherm
Aluminium
Mild Steel
Stainless Steel
Copper
Brass
Stainless Steel
Aluminium
Mild Steel
Stainless Steel
Copper
Brass
Stainless Steel

Typical Testing Apparatus – Reactor Flasks with Corrosion test piece holder , thermometer , air condenser and stirrer.