Evaluation of metal leaching and food suitability of the Ensitech TIG Brush® weld cleaning method

Requested by: BM Teknik
Completed by: FORCE Technology, Troels Mathiesen, +45 43 26 74 53
Reviewed by: Lisbeth Hilbert, +45 43 26 71 53
Your ref.: ME1011
Our ref.: 110-33524 TRM/jrm (17 pages incl. 4 appendices)

11 February 2011

Materials and Welding
At the request of BM Teknik, FORCE Technology’s Corrosion and Metallurgy Department has evaluated the Ensitech TIG Brush® weld cleaning method with regard to metal leaching and food suitability.

Introduction

The TIG Brush® is a new method for post-treatment of stainless steel welds based on electrolytic cleaning. Heat tint from welding is removed by applying an acidic fluid with a conductive brush and, at the same time, applying a current between the brush and the metal. The objective of this cleaning method is to restore the corrosion resistance of the stainless steel by removing the chromium-depleted layer ("heat tint"). This cleaning principle can be characterised as electrolytic pickling and it does not involve use of the conventional pickling chemicals such as HF and HNO₃.

Compared with other known electrolytic pickling methods, the TIG Brush® method uses a conductive brush rather than an insulating pad soaked in electrolyte, which allows higher currents and temperatures. Occasionally, this arrangement causes small sparks when the released hydrogen gas from the decomposition of the fluid is ignited.

The obtained result in relation to passivation properties has been tested by Gauge in Australia /1/. This study is based on tests according to the ASTM A967-05 and B912-02 standards. The study shows that the TIG Brush® method is capable of removing the chromium-depleted material. Such layers are susceptible to corrosion, as demonstrated by exposing both non-treated and treated specimens to a range of media, i.e. water, potassium ferricyanide in nitric acid, and copper sulphate solution. We have no reason to doubt the obtained results by Gauge. If we had been requested to test the passivation properties, we would have applied much the same approach.

Potential customers of the TIG Brush® technique have requested additional documentation of two issues concerning this cleaning method:
- waste handling (leached metals)
- food suitability

To our knowledge, there are no exact test protocols for evaluating these issues, but general guidelines exist. Neither are we aware of similar studies performed on conventional pickling methods that are used widely, such as paste pickling, electrolytic pickling or dip pickling. On this basis, we have established an approach for examining the Ensitech TIG Brush® weld cleaning method.

Based on our expertise, efforts have been made to fulfil the common guidelines within the area. The amount of leached metals has been correlated with the Danish guideline for discharge of industrial wastewater to public wastewater treatment plants /2/ - see Appendix A.
The study on food suitability has followed the guidelines provided in Bekendtgørelse nr. 167 af 3. marts 2009, Cirkulære nr. 9309 af 1. maj 2008 /3/. In this document, exposure to 3 % acetic acid is mentioned as a possible migration test. The overall migration limit is stated as 60 mg per kg food or 10 mg/dm² surface area of the material surface.

In addition, we have talked to Tove Skaarup at Fødevarestyrelsen (FVST) who found the test approach in accordance with common guidelines. Usually, FVST mainly focus on construction and packaging materials, and not secondary treatment like pickling. It was mentioned that no material or treatment must affect the physical characteristics, smell, taste or appearance of the food product. Reference was made to European Parliament and Council Regulation (EC) No 1935/2004 of 27 October 2004 on materials and articles intended for food contact /4/.

Guideline No. 12114 of 1 January 2001 /5/ indicates that the overall migration limit (10 mg/dm²) specified in the current announcement at that time applies to all materials. The instructions specify limits in food for lead, cadmium, mercury and tin, and migration limits for lead (1 mg/kg) and cadmium (0.1 mg/kg) from ceramics, and tin (50 mg/kg) from cans. In addition, a maximum nickel release from electric kettles and pots is specified as 0.1 mg/kg.

Specific requirements for metals are not part of EU law, but derive from national regulations. Consequently, the best, available knowledge must always be applied to assess possible health risks by incorporating the rules of other countries together with the Danish guideline as basis for the assessment. The Italian rules are very clear and only allow a total migration at 8 mg/dm² for stainless steel, while other European countries that have specific legislation on the issue allow 10 mg/dm².

On this basis, the study has involved the following actions to evaluate metal leaching and food suitability:

**Metal leaching**
1. XRF screening of chemical fluids (for detecting any foreign heavy metals)
2. Preparation of heat-tinted AISI 304 welds
3. TIG Brush® cleaning tests on heat tinted AISI 304 welds using 3 mediums; TB-21, TB-25 and TB-30ND according to the instructions in the TBE-250 TIG Brush® User Manual /6/
4. Collection of wash water samples
5. Determination of heavy metals in the wash water (Fe, Cr, Ni, Mo, Cd and Pb)
6. Correlation with allowable release limits for public wastewater treatment plants in Denmark

**Food suitability**
1. Exposure of TIG Brush® cleaned and non-welded AISI 304 specimens (for reference) in 3 % acetic acid
2. Determination of heavy metals in acid solution (Fe, Cr, Ni, Mo, Cd and Pb)
XRF screening of TB fluids

The Material Safety Data Sheets (MSDS) /7/ of the Ensitech weld cleaning fluids were provided by BM Teknik together with a general description of the fluids. According to this information, the TB-21 and TB-25 fluids contain phosphoric acid with some significant proprietary additives. The TB-30 fluid contains a proprietary blend as the major component with citric acid as a minor component.

In order to evaluate whether the cleaning fluids contain other elements that could affect waste handling or food suitability, each fluid was screened by using XRF (X-ray fluorescence). This technique is capable of detecting elements with an atomic number greater than 17 (Al). The details and results are enclosed in Appendix B.

Phosphorous was detected in all samples (TB-21, TB-25 and TB-30ND), while calcium was detected in TB-30ND as well. Based on these results, the XRF screening showed no signs of heavy metals that could affect waste handling or food suitability.

Cleaning tests

Cleaning tests with the TIG Brush® were performed on TIG-welded specimens of AISI 304 plate (2 mm). The steel certificate of the base metal is attached in Appendix C. The root of the weld was protected by shielding gas during welding. Consequently, heat tinting on this side was limited. The cap of the weld shows severe heat tinting due to limited use of shielding gas. This side was used for detecting leached metals to obtain conservative levels.

Photos of the test set-up and specimens are shown in Figures 1-3.

Both sides of the weld were cleaned using the TBE-250 model TIG Brush® according to the instructions in the TBE-250 User Manual. The settings of the power supply were set in “high power” and “clean” modes, which represent a pickling treatment. In all cases, the heat tint on all samples was easily removed by 1-2 strokes with the wetted conductive brush.

Washing was performed according to the User Manual; first using deionised water, then TB-40 or TB-41 neutraliser, and finally deionised water again. A minimum amount of washing solution (35-55 ml) was applied in order to increase the resolution of the chemical analysis. The entire wash solution from the heat tinted weld cap was collected, and the total volume was determined by weighing.

Leached metal

The collected wash water samples from the cleaning tests were analysed using ICP-OES. The details and obtained results with this technique are enclosed in Appendix D.
Table 1 shows the calculated amount of metal released from cleaning 1 meter of weld.

<table>
<thead>
<tr>
<th>Cleaning fluid</th>
<th>Cr</th>
<th>Fe</th>
<th>Mo</th>
<th>Ni</th>
<th>Cd</th>
<th>Pb</th>
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<tr>
<td></td>
<td>mg/m</td>
<td>mg/m</td>
<td>mg/m</td>
<td>mg/m</td>
<td>mg/m</td>
<td>mg/m</td>
</tr>
<tr>
<td>TB-21</td>
<td>8.4</td>
<td>30.0</td>
<td>0.117</td>
<td>3.604</td>
<td>0.003</td>
<td>0.017</td>
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<tr>
<td>TB-25</td>
<td>6.8</td>
<td>25.5</td>
<td>0.100</td>
<td>2.618</td>
<td>0.003</td>
<td>0.086</td>
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<tr>
<td>TB-30ND</td>
<td>2.9</td>
<td>12.4</td>
<td>0.044</td>
<td>1.110</td>
<td>&lt;0.002</td>
<td>0.160</td>
</tr>
</tbody>
</table>

It appears that the individual amount of leached metals correlates fairly well with the stoichiometric composition of the stainless steel (~ 70 % Fe, 18 % Cr and 8 % Ni) - see Appendix C. This behavior is expected because the TIG Brush® essentially dissolves the stainless steel uniformly by applying acidic fluid and electrical current at the same time.

The minimum amounts of wash water required to fulfil the release limits for industrial wastewater have been calculated, and are shown in Table 2. It appears that the lower limit is determined by the element chromium being 100-300 litres per meter cleaned weld seam. This figure is based on the maximum discharge limit whilst the threshold limit allows 10 times greater concentrations, but only as short non-continuous events.

<table>
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<tr>
<th>Discharge limits</th>
<th>Cr</th>
<th>Fe</th>
<th>Mo</th>
<th>Ni</th>
<th>Cd</th>
<th>Pb</th>
</tr>
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<tr>
<td></td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
<td>µg/l</td>
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<tr>
<td>Maximum</td>
<td>30</td>
<td>-</td>
<td>3</td>
<td>25</td>
<td>0.3</td>
<td>10</td>
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<tr>
<td>Threshold</td>
<td>300</td>
<td>-</td>
<td>30</td>
<td>250</td>
<td>3</td>
<td>100</td>
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<tr>
<td>Treatment</td>
<td>litres/m</td>
<td>litres/m</td>
<td>litres/m</td>
<td>litres/m</td>
<td>litres/m</td>
<td>litres/m</td>
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<tr>
<td>TB-21</td>
<td>280</td>
<td>39</td>
<td>144</td>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>TB-25</td>
<td>227</td>
<td>33</td>
<td>105</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>TB-30ND</td>
<td>98</td>
<td>15</td>
<td>44</td>
<td>7</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

Based on our practical experience from the tests, the calculated amount of wash water to fulfil the discharge limits seems high. As a basis, dilution is not allowed to fulfil such discharge limits. Consequently, it may be necessary to collect and treat the wastewater from the cleaning depending on the extent of work. This applies to any pickling method because the amount of leached metals will be more or less the same. Local authorities may be consulted for an agreement on such issues.
**Migration tests**

The TIG Brush® cleaned weld specimens were used for the migration tests together with non-welded specimens (UW) of the same metal for reference. Each specimen was fully immersed in boiling acetic acid (3 %) three times for 30 minutes. Analytical grade chemicals were used for preparing the solution, and all tests were performed in new glassware.

The solution from the final treatment of each specimen was collected for chemical analysis in accordance with the guideline /3/. ICP-OES was used for this determination according to the details and results enclosed in Appendix D.

Table 3 shows the calculated migration as milligrams per square decimetre (mg/dm²). Apart from iron, most of the determinations were below the detection limit of the individual metals.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Cr (µg/dm²)</th>
<th>Fe (µg/dm²)</th>
<th>Mo (µg/dm²)</th>
<th>Ni (µg/dm²)</th>
<th>Cd (µg/dm²)</th>
<th>Pb (µg/dm²)</th>
<th>Total (mg/dm²)</th>
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<tr>
<td>UW</td>
<td>3</td>
<td>34</td>
<td>&lt;2</td>
<td>2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;0.045</td>
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<tr>
<td>TB-21</td>
<td>&lt;3</td>
<td>24</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;0.037</td>
</tr>
<tr>
<td>TB-25</td>
<td>&lt;3</td>
<td>14</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;0.028</td>
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<tr>
<td>TB-30ND</td>
<td>&lt;3</td>
<td>19</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;0.032</td>
</tr>
</tbody>
</table>

Based on the introduction, two main criteria must be fulfilled to attain food suitability:

- Total migration < 10 mg/dm²
- Nickel migration < 0.1 mg/kg (mass of food)

It appears that the migration of metals is well below the total limit regardless of specimen type or treatment. In fact, the metal release is slightly higher for the non-welded specimen. We ascribe this effect to a slightly higher area of cut faces on these specimens.

In order to correlate nickel migration with the mass of food product, the equipment design must be known. However, when considering a cylindrical tank (Ø 1 x 1 m), the measured nickel release (2 µg/dm²) corresponds to a migration of approximately 1 µg/kg. Consequently, the observed nickel migration for all TIG Brush® cleaning is well below the acceptance limit.

At the same time, the migration test demonstrates that corrosion resistance of the TIG Brush® cleaned specimens is comparable to that of the non-welded material. This view is further supported by the passivation tests performed by Gauge /1/, which confirmed that TIG Brush® cleaning was capable of restoring the corrosion resistance of welds when evaluated according to the ASTM standards.
On this basis, we expect that TIG Brush® cleaned welds will provide the same corrosion resistance as AISI 304 base metal. AISI 304 has a long record of successful use without any known problems with contamination or migration. However, incomplete cleaning of welds may lead to increased migration due to insufficient corrosion resistance, but this aspect applies to all common cleaning or pickling methods.

Conclusion

Three Ensitech fluids were tested with the TIG Brush® weld cleaning method on stainless steel type AISI 304. The tests showed that the TIG Brush® is capable of removing heat tint from welds. Similar to alternative pickling methods, a thin layer of oxides and base metal is dissolved by this process.

The total amount of leached metals was determined by analysing the wash water from subsequent cleaning. Correlation with common discharge limits for public waste water indicates that additional treatment of the wash water may be required before discharge due to the released amount of chromium (and nickel). This applies to any pickling method because the amount of leached metals has to be roughly the same to obtain the required result, i.e. complete removal of heat tint.

Migration of metal from TIG Brush® cleaned welds was compared with that of non-welded specimens by exposure to boiling acetic acid (3 %). The behaviour of the TIG Brush® cleaned welds was comparable to that of non-welded base materials. In all cases, the tests showed a metal migration well below the limits specified in common guidelines for evaluating materials intended for food contact. On this basis, we expect that TIG Brush® cleaned welds will provide the same corrosion resistance and food suitability as that known for the AISI 304 base metal. AISI 304 stainless steel has a long record of successful use in the food and beverage industry without any problems with contamination or migration.

Lisbeth Rischel Hilbert
Specialist, MSc Eng., Ph.D.  
Corrosion and Metallurgy

Troels Mathiesen
Specialist, MSc Eng., Ph.D.  
Corrosion and Metallurgy
References


NOTE: Ensitech® and TIG Brush® are registered Trade Marks of Ensitech Pty Ltd
TB-21, TB-25 and TB-30ND are cleaning fluids manufactured by Ensitech Pty Ltd
TB-40 and TB-41 are neutralising fluids for use with the cleaning fluids
Figures

Figure 1. Set-up used for weld cleaning tests.

Figure 2. Test specimens prior to TIG Brush® weld cleaning.
Figure 3. Test specimens after TIG Brush® weld cleaning.
# Appendix A

## Tabel 2.5.1

Beregnete maksimale tolerable koncentrationer for metallet til renseanlæg samt grænseværdier for afladning af spildevand.

<table>
<thead>
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<th>Metal</th>
<th>Reference vandkvalitet</th>
<th>Reference slammkvalitet</th>
<th>Mest kritiske hensyn</th>
<th>Beregnet maksimal acceptabel tilløbskonz. (µg/l)</th>
<th>Grænseværdi (µg/l)</th>
<th>Reference grænseværdi</th>
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<td>Arsen</td>
<td>(DHI, 2000a)</td>
<td>(Miljøministeriet, 2003)</td>
<td>Fersk- og saltvand</td>
<td>1,3</td>
<td>13</td>
<td>(Miljøstyrelsen, 2002b)</td>
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<tr>
<td>Kobber</td>
<td>(Miljøstyrelsen, 2005)</td>
<td>(Miljøministeriet, 2003)</td>
<td>Fersk- og saltvand</td>
<td>10</td>
<td>100**</td>
<td>(Miljøstyrelsen, 2002,b)</td>
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<tr>
<td>Kobolt</td>
<td>(DHI, 2000a)</td>
<td>(LRF, 1997)</td>
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<td>1,0</td>
<td>10</td>
<td>(Miljøstyrelsen, 2002,b)</td>
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<td>Molybdæn</td>
<td>(Miljøstyrelsen, 1996c &amp; 1997b)</td>
<td>(Miljøstyrelsen, 1998c)</td>
<td>Slam</td>
<td>3</td>
<td>30</td>
<td>(Miljøstyrelsen, 2002,b)</td>
</tr>
<tr>
<td>Selen</td>
<td>(Miljøstyrelsen, 1996c &amp; 1997b)</td>
<td>(Miljøministeriet, 1997a)</td>
<td>Slam</td>
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<td>8</td>
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<td>Tin</td>
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<td>(Miljøstyrelsen, 1997a)</td>
<td>Slam</td>
<td>6</td>
<td>60</td>
<td>(Miljøstyrelsen, 2002,b)</td>
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* Det vandkvalitetskriterium/krav, der er anvendt som grundlag for fastsættelsen af grænseværdien, er under revision fra EU.

** Tilsigtede grænseværdi som udtryk for det langsigtede mål for afladningen.
Appendix B (page 1 of 2)

FORCE Technology
Park Allé 345
2605 Brandby.
Attn.: Troels Mathiesen.

Brandby, 09.12.2010

Report

Job no. 110-33524
Report no. 1
Prepared by OP/SV/AS
Pages 1
Number of pages incl. 0 enclosure 1

Task description
In the specified job a chemical analysis has been performed on three liquid samples with the purpose to detect content of metals. Three liquid samples were received in the laboratory on 07.12.2010. The samples were in plastic containers marked TB21, TB25 and TB40.

Test preparation
The three samples were each poured into a XRF-cup. The three samples were compared with a blind containing demineralised water.

Testing
Testing/determination were carried out by means of energy dispersive X-ray fluorescence by use of our X-LAB 2000 equipment applying our standard Tok-3945-programme. The method makes it possible to determine contents of elements with atomic numbers Z ≥ 13 (Al) with varying detection limits. The measurements were taken on 07.12.2010.

Results
In sample TB21 and TB25 only phosphorus was detected. In sample TB40 phosphorus and sulphur was detected. No metals at all were detected in any of the samples.

Remark
No technical remarks.

FORCE Technology

Sven H. Jørgensen
Technician
Chemical Analysis

Ole Pedersen
Specialist
Chemical Analysis

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Report

Job no. 110-33524
Report no. 2
Prepared by OP/510/mv6
Pages 1
Number of pages incl. 0 enclosure 1

Task description
In the specified job a chemical analysis has been performed on a liquid sample with the purpose to detect content of metals. The liquid sample was received in the laboratory on 20.12.2010. The sample was in a plastic container marked TB30ND.

Test preparation
The sample was poured into a XRF-cup. The sample was compared with a blind containing demineralised water.

Testing
Testing/determination was carried out by means of energy dispersive X-ray fluorescence by use of our X-LAB 2000 equipment applying our standard Tqk-3945-programme. The method makes it possible to determine contents of elements with atomic numbers Z ≥ 13 (Al) with varying detection limits.

The measurement was taken on 20.12.2010.

Results
In sample TB30ND phosphorus was detected and additional trace of calcium was detected.

Remark
No technical remark.

FORCE Technology

Svén H. Jørgensen
Technician
Chemical Analysis

Ole Petersen
Specialist
Chemical Analysis

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**Appendix C (page 1 of 1)**

**REF.NR** SE88-2300  
**INSPCTION CERTIFICATE**  
**ACO TO EN 10204-3.1 B**

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**AVESTA SHEFFIELD NORDIC AB**

**BOX 1134**

**531 80 ESKILSTUNA**

**COLD ROLLED STAINLESS SHEET, FINISH 2B**

**Requirements/Anforderungen**

**TRD 100 AD W2AD W10 & DIN 17441, ASME SA 240 ED 95, SS 219120**

**E+GLU/ACD**

**AVESTA 18-9**

**EXCEPT OF DELIVERY / UMFANG DER LIEFERUNG**

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<th>Qualität/ Stückzahl</th>
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<th>Breite/ Meter</th>
<th>Süden/ mm</th>
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**CHEMICAL COMPOSITION / CHEMISCHE ZUSAMMENSETZUNG %**

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**RESULT OF TESTING / ERGEBNIS DER PRÜFUNG**

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<tr>
<td>01 T</td>
<td>305</td>
<td>326</td>
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<td>56</td>
<td>52 174 GRADE VERIF.(SPECTROSCOP): OK</td>
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<tr>
<td>02 T</td>
<td>297</td>
<td>320</td>
<td>632</td>
<td>56</td>
<td>52 174 HEAT TREATMENT: 1085 C</td>
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**DIN 50914 SATISFACTORY**

**ÜBERPRÜFT NACH AD-MERKBLATT W0/ TRD 100 DURCH DEN TÜV NORD E.V.**

**MIT VERZICHT AUF GEGENZEICHNUNG**

**DERR WERKSSACH-VERSTÄNDIGE**
Appendix D (page 1 of 2)

Report

Job No. Report No. Prep. by Page No of pages incl. 1 enclosure
110-33524.01 1 DP/MKA/mvb 1 2

Job description
In the above-mentioned job chemical analytical testing has been performed on 7 liquid samples with the purpose of determining the content of cadmium (Cd), chromium (Cr), iron (Fe), molybdenum (Mo), nickel (Ni) and lead (Pb). The samples were received in the laboratory on 09-12-2010 plastic tubes with lid and were labeled UW, TB21, TB25 TB30, 21M, 25M and 30M.

Sample preparation
The samples TB21, TB25 TB30, 21M, 25M and 30M were all acidified with hydrochloric acid adding 5 ml conc. HCl per liter liquid.

Testing
Testing was performed in the period 14-12-2010 to 15-12-2010.

Results
Results obtained and sample identification are given in enclosure No. 1

Remarks
No technical remarks.

FORCE Technology

Michael W. Axelsen
Technician
Chemical Analysis

Ole Petersen
Specialist
Chemical Analysis

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### Results

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<th>Lab-No.</th>
<th>Cd</th>
<th>Cr</th>
<th>Fe</th>
<th>Mo</th>
<th>Ni</th>
<th>Pb</th>
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<td>71</td>
<td>0.28</td>
<td>7.3</td>
<td>0.24</td>
</tr>
<tr>
<td>TB30</td>
<td>&lt;0.005</td>
<td>6.5</td>
<td>28</td>
<td>0.099</td>
<td>2.5</td>
<td>0.36</td>
</tr>
<tr>
<td>21M</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.040</td>
<td>&lt;0.005</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>25M</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.024</td>
<td>&lt;0.005</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>30M</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.032</td>
<td>&lt;0.005</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
</tr>
</tbody>
</table>

**Note:**

Wash water samples are identified as: TB21, TB25 and TB30  
Migration test samples are identified as: UW, 21M, 25M, 30M