

TYPICAL REPORT

PRIMARY SUPERHEATER TUBE



SAFE CONTROL

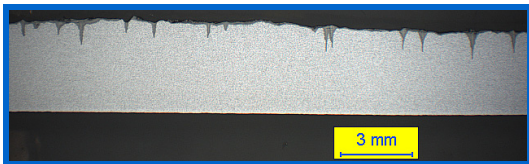
M A T E R I A L T E K N I K

Member of Safe Control Group



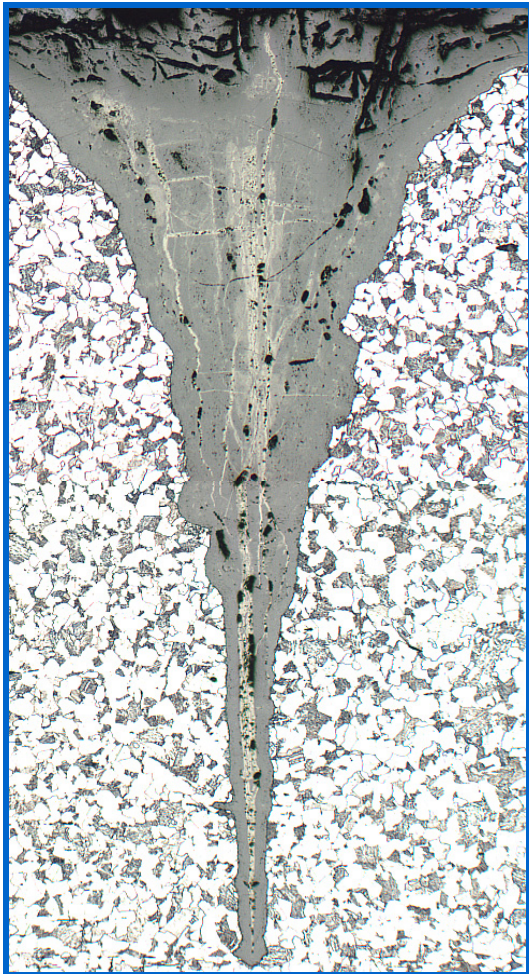
INVESTIGATION REPORT:

Metallographic examination of tube sample from
Primary Superheater II



REGISTRATION NUMBER: M014666

DATE: 2006-11-08



DEPARTMENT: METALLOGRAPHY



RAPPORT

utfärdad av ackrediterat laboratorium
REPORT issued by an Accredited Laboratory



Beställare / Ordered by Safe Control Boiler Service AB Tillgängligheten 1 417 01 Göteborg	Orderdatum / Date of order 2006-10-27	Reg. nr. / Reg.No M014666
Er referens / Your reference Paul Praszquier	Inlämningsdatum / Object (s) received 2006-10-27	Sidnr. / Page 1(12)
Ordernr. / Order number -	Rapportdatum / Date of report 2006-11-08	Vår referens / Our reference Lars Andersson

Investigation:	Metallographic examination
Object(-s):	Tube sample from primary superheater II
Analysis, testing and examination:	Ocular examination of received object. See below. Macroscopic and microscopic examination of cross sections. See page 2. Baumann test. See page 3. Hardness test. See page 3.
Photo pages:	Pages 4 to 12.

Ocular examination:

Received tube sample had a length of 285 mm. Results from dimension measurements, in cross section marked A-A, are shown in fig.2 on page 4. On gas-side on soot-blower side we observed an area which was ground and polished. Replica testing had been performed, at site, in this area (by other company). In this area we observed transversal (circumferential) indications. In areas where the surface had not been ground and polished, we observed transversal linear "elevations" of the surface (in the oxide/deposit layer) on gas-side towards soot-blower side. The amount, spacing and width/length of the "elevations" was similar to the linear indications observed in ground and polished area.

Tube surface on gas-side on leeward side had a dark black/red-coloured appearance.

Tube surface on steam-side was covered by a thin grey-coloured deposit/oxide.

See over-view pictures in fig.1 to 6 on page 4 to 6.

"Laboratorier ackrediteras av Styrelsen för ackreditering och teknisk kontroll (SWEDAC) enligt svensk lag. Den ackrediterade verksamheten vid laboratoriet uppfyller kraven i SS-EN ISO/IEC 17 025 (2005). Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänner annat"

*Provningsresultaten i denna rapport avser endast provade objekt. Icke ackrediterade uppdrag markeras *.*

"Laboratories are accredited by the Swedish Board for Accreditation and Conformity Assessment (SWEDAC) under the terms of Swedish legislation. The accredited laboratory activities meet the requirements in SS-EN ISO/IEC 17 025 (2005). This report may not be reproduced other than in its full, except with the prior written approval of the issuing laboratory"

*The test results in this report refer only to tested objects. Investigations performed un-accredited is marked *.*



RAPPORT

utfärdad av ackrediterat laboratorium
REPORT issued by an Accredited Laboratory



Teknisk instruktion / Technical instruction
Macroscopic and microscopic
examination

Objekt / Object
Cross sections

Reg. nr. / Reg.No
M014666

TI Dokumentnr. / TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM9, SCM10, SCM47, SCM48

Sidnr. / Page
2(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-10-02 -- 2006-10-29

Utfört av / Performed by
Lars Andersson

Macroscopic and microscopic examination:

Cross sections were cut out from the received tube sample, for macroscopic and microscopic examination. The cross sections were prepared and investigated in not etched and etched condition at magnification up to 1000×. The cross sections were etched with nital (etchant A.1 according to SIS-CEN/CR 12361:1996, similar to etchant 74 according to ASTM E 407-99).

Note: During preparation of the cross section, some of the easy removable oxides/deposits on gas-side and steam-side are likely to be removed.

Cross section 1 (fig.7 on page 6 and fig.10 to 13 on page 7)

Structure The structure consisted of nearly normal pearlite in a matrix of ferrite. Some spheroidized carbides could be observed in the pearlite.

Oxides/deposits We observed oxides/deposits, on steam-side, with thickness of about 10 - 15 µm.

Tube surface towards gas-side was free from oxides/deposits (because the gas-side surface in this area was in ground and polished condition because of replica testing at site).

Cracks We observed several wedge-like cracks starting from gas-side. The cracks were filled with oxides/corrosion products. We also noticed a clear difference in coloration within the oxides/corrosion products, towards the centre line of the cracks.

Intergranular corrosion We observed occurrence of intergranular corrosion within the cracks (at crack surfaces).

Cross section 2 (fig.8 on page 6 and fig.14 to 23 on page 8 to 11)

Structure Similar structure as in cross section 1. No sign of carburization towards tube surface on gas-side.

Oxides/deposits We observed oxides/deposits, on steam-side, with thickness of about 10 - 17 µm.

Tube surface towards gas-side was covered by a deposit with thickness up to 120 µm.

Cracks We observed several wedge-like cracks starting from gas-side, similar to the cracks observed in cross section 1. The cracks had a propagation perpendicular to the tube surface. The cracks were filled with oxides/corrosion products. The cracks had a depth up to 1.07 mm.

The width of the deepest crack was measured to 0.62 mm (at tube surface) and 40 µm (at crack tip).

Intergranular corrosion We observed occurrence of intergranular corrosion towards tube surface on gas-side and within the cracks (at crack surfaces).

Cross section 3 (fig.9 on page 5 and fig.24, 25 on page 11)

Structure Similar structure as in cross section 1 and 2.

Oxides/deposits We observed oxides/deposits, on steam-side, with thickness of up to 20 µm.

Tube surface towards gas-side was mainly free from deposit. In some area we observed a deposit with thickness up to 90 µm.

Intergranular corrosion We observed occurrence of intergranular corrosion towards tube surface on gas-side.

Signatur / Signature:



RAPPORT

utfärdad av ackrediterat laboratorium
REPORT issued by an Accredited Laboratory



Teknisk instruktion / Technical instruction
Hardness test. Baumann test

Objekt / Object
Cross sections

Uppdr. nr. / Order No
M014666

TI Dokumentnr./ TI Document no.
SCHÅ1

Provingsutrustning / Testing equipment
SCM 5, SCM 10, SCM 45, SCM 47

Sidnr. / Page
3(12)

Provning enligt / Testing according to
SS-EN ISO 6507-1
ISO 4968

Provningsdatum / Testing date
2006-11-08
2006-11-06

Utfört av / Performed by
Lars Andersson
Lars Andersson

Hardness test: HV10

Hardness test was performed on cross section 1, 2 and 3. Towards gas-side surface, at centre and towards steam-side surface with results as follows.

Cross section	Towards gas-side surface	At centre	Towards steam-side surface
1	-	169	171
2	179	179	162
3	158	159	163

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor, $k=2$, which for a normal distribution corresponds to a coverage probability of approximately 95%. The uncertainty evaluation was carried out in accordance with EAL-G23,1996, GUM-ISO,1995 and EA4/02 rev 00, 2000.

Hardness HV: 3.1 %

Baumann test:*

Baumann test was performed on cross section 1, 2 and 3. We observed high amount of sulphur on gas-side surfaces, in cross section 2 and 3, and within the cracks in cross section 1 and 2. Macro photographs of photographic paper, after Baumann test, of cross section 2 and 3 are shown in fig.27 and 28 on page 12.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Overview pictures

Objekt / Object
Tube sample

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
-

Provningsutrustning / Testing equipment
SCM 54

Sidnr. / Page
4(12)

Provning enligt / Testing according to
-

Provningsdatum / Testing date
2006-10-30 -- 2006-11-03

Utfört av / Performed by
Lars Andersson



Fig.1: Tube no.1 towards soot-blower side. Part of the tube was ground and polished (due to replica testing at site). Transversal linear indications was observed in this area. Location of cross section 1, 2 and A-A as in fig. above.



ID _{12/6}	= 53.4 mm
ID _{3/9}	= 53.4 mm
t ₁₂	= 3.45 mm
t ₃	= 4.40 mm
t ₆	= 4.85 mm
t ₉	= 4.70 mm

Fig.2: Cross section A-A (see fig. above), for dimension survey. Measurements as in table above.



Fig.3: After longitudinal cutting. Steam-side. The surface was covered by a thin layer of grey-coloured deposit/oxide.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Overview pictures

Objekt / Object
Tube sample

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
-

Provningsutrustning / Testing equipment
SCM 54

Sidnr. / Page
5(12)

Provning enligt / Testing according to
-

Provningsdatum / Testing date
2006-10-30 -- 2006-11-03

Utfört av / Performed by
Lars Andersson

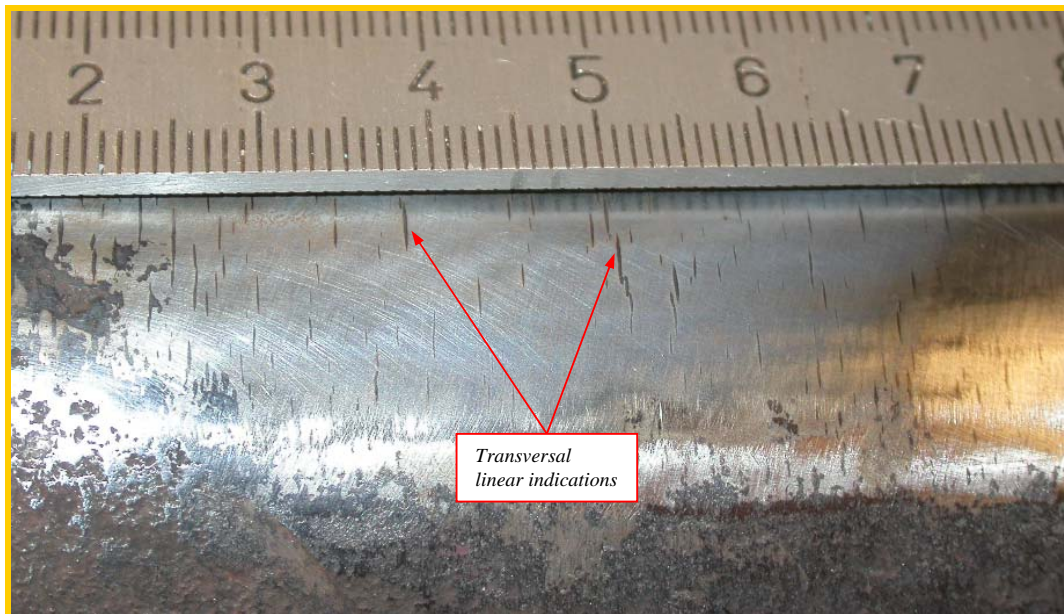


Fig.4: Close-up view of area with transversal indications.

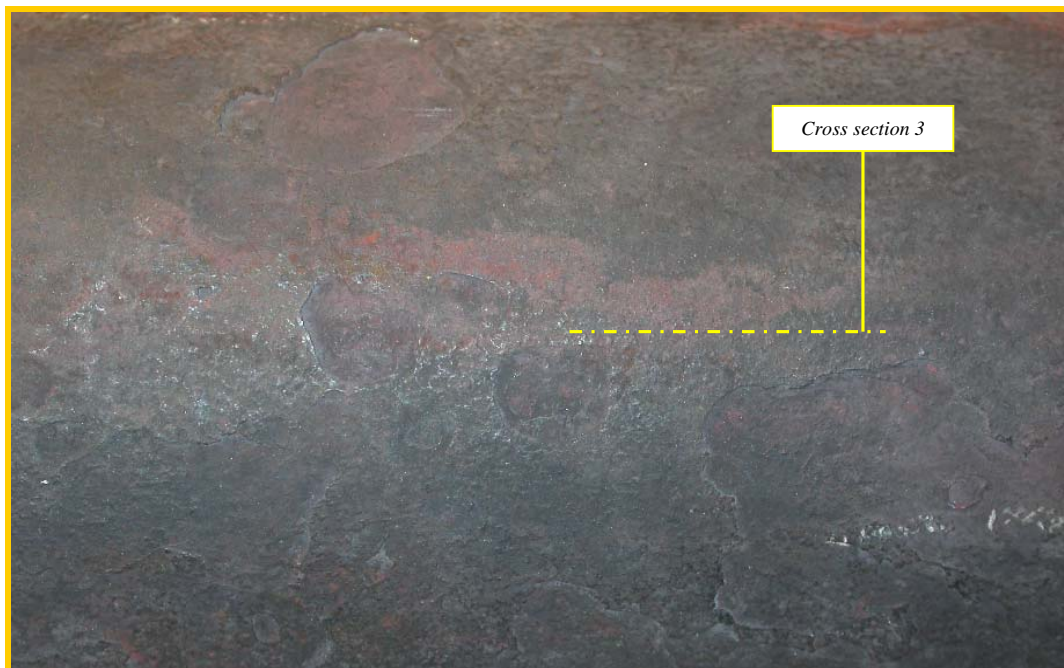


Fig.5: Leeward side. Location of cross section 3 as in fig. above.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Overview pictures. Macroscopic and microscopic examination

Objekt / Object
Tube sample. Cross section 1, 2 and 3

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM 9, SCM 48, SCM 54

Sidnr. / Page
6(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-10-30 -- 2006-11-03

Utfört av / Performed by
Lars Andersson



Fig.6: Gas-side towards soot-blower side. We observed transversal linear "elevations" of the surface (in the oxide/deposit layer). The amount, spacing and width of the "elevations" was similar to the linear indications that we observed in the ground and polished area.



Fig.7: Cross section 1 (cut out from ground and polished area). Several wedge-like cracks, starting from outside/gas-side, could be observed. The cracks were filled with oxides/corrosion products. Etched with nital.

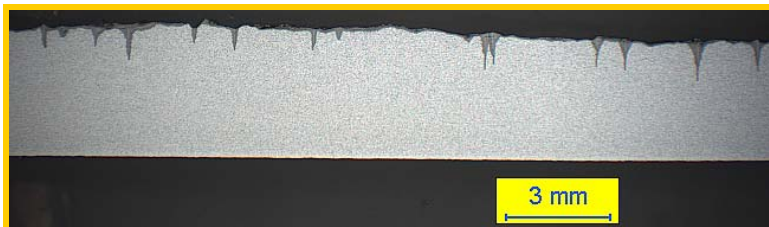


Fig.8: Cross section 2. Several cracks, with depth up to 1.07 mm. Wall thickness was measured to about 3.4 mm. Etched with nital.



Fig.9: Cross section 3. No cracks could be observed. Wall thickness was measured to about 4.8 mm. Etched with nital.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Macroscopic and microscopic examination

Objekt / Object
Cross section 1

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM 9, SCM 10, SCM 47, SCM 48

Sidnr. / Page
7(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-11-03

Utfört av / Performed by
Lars Andersson

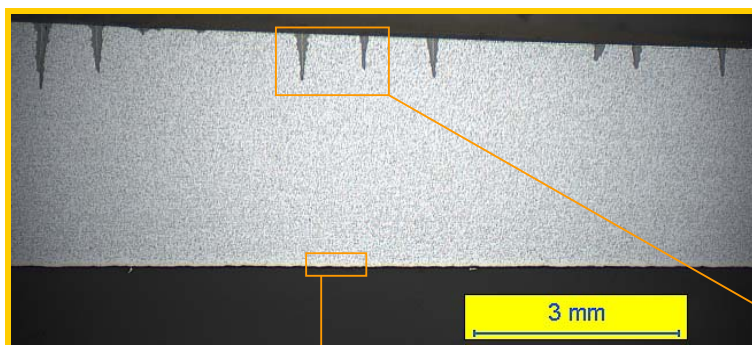


Fig.10: Cross section 1. Same macro as in fig.7 at higher magnification. Several cracks, filled with oxides/corrosion products, initiated from gas-side. The cracks were wedge-like with a direction perpendicular to the tube surface.

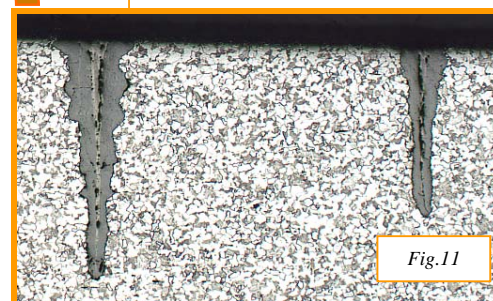
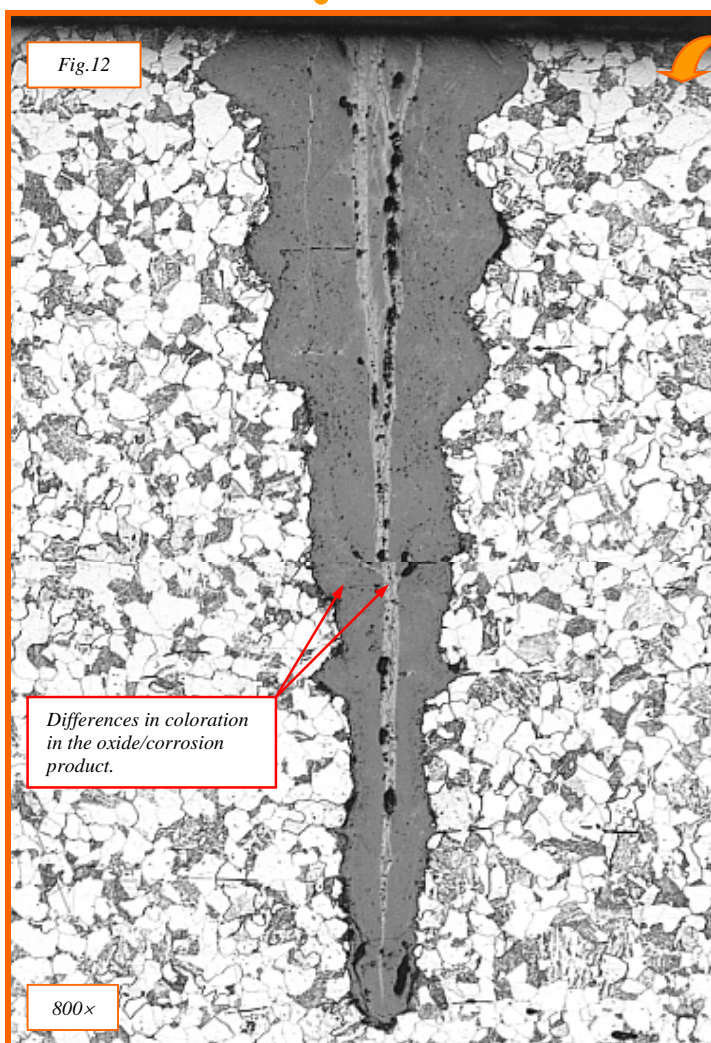


Fig.11: Cracks at higher magnification. The cracks were filled with oxides/corrosion products. Magnification: 50x.



Fig.13: Towards steam-side. The surface was covered by a protective oxide with a thickness of about 10 - 15 µm. 400x.

Fig.12: Left crack in fig.11, at higher magnification. Differences in coloration in the oxide/corrosion product.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Macroscopic and microscopic
examination

Objekt / Object
Cross section 2

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM 9, SCM 10, SCM 47, SCM 48

Sidnr. / Page
8(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-11-03

Utfört av / Performed by
Lars Andersson

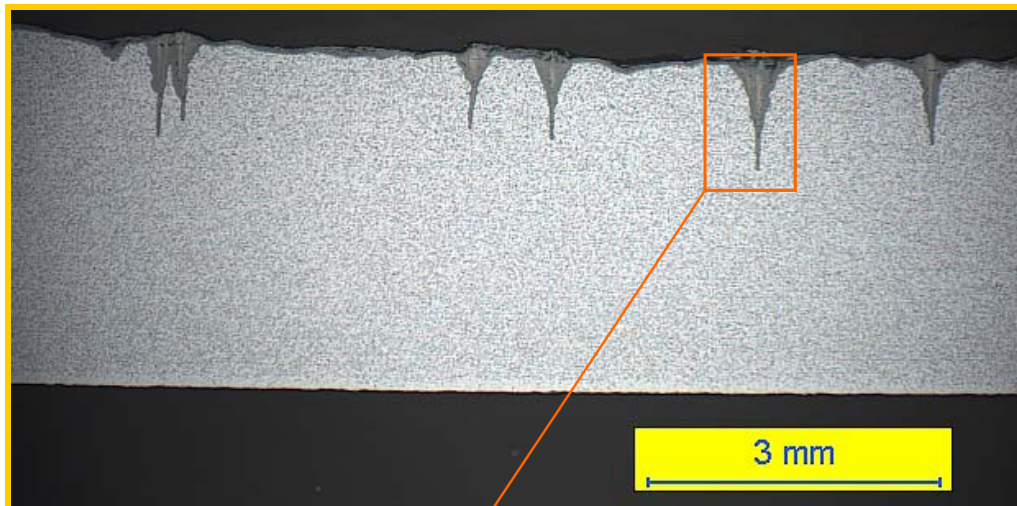


Fig.14: Same macro as in fig.8, at higher magnification.
The cracks were filled with oxides/corrosion products.

Nital.

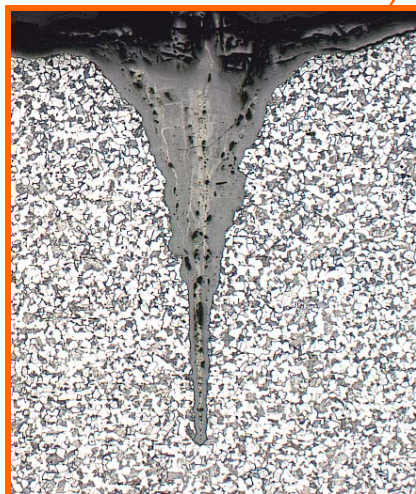


Fig.15: Wedge-shaped crack, filled with oxides/corrosion
products. Nital. 50 \times .

Signatur / Signature:

Teknisk instruktion / Technical instruction
 Macroscopic and microscopic examination

Objekt / Object
 Cross section 2

Reg. nr. / Reg.No
 M014666

TI Dokumentnr./ TI Document no.
 SCMM1

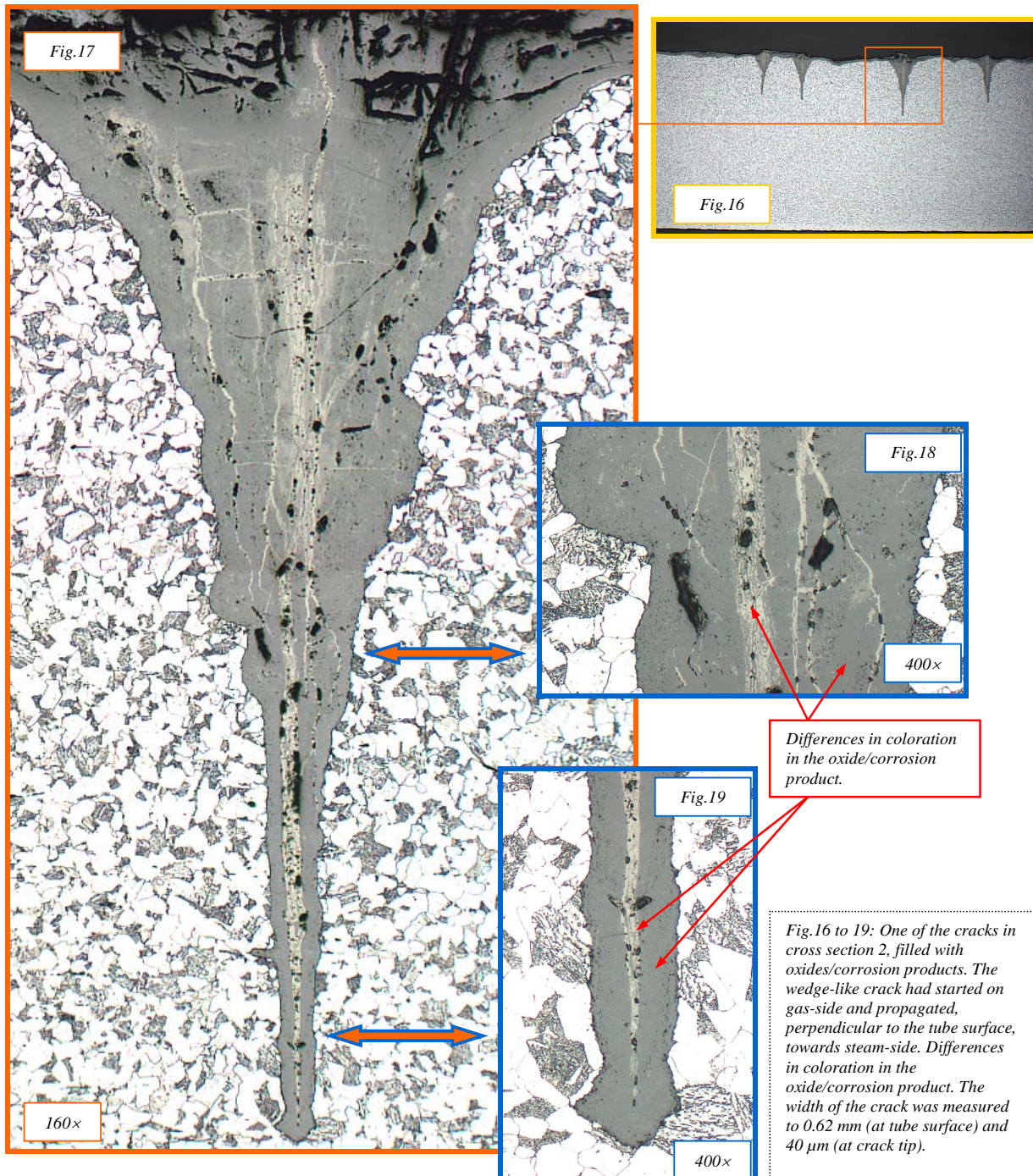
Provningsutrustning / Testing equipment
 SCM 9, SCM 10, SCM 47, SCM 48

Sidnr. / Page
 9(12)

Provning enligt / Testing according to
 SS-EN 1321

Provningsdatum / Testing date
 2006-11-03

Utfört av / Performed by
 Lars Andersson



Signatur / Signature:

Teknisk instruktion / Technical instruction
Macroscopic and microscopic
examination

Objekt / Object
Cross section 2

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM 10, SCM 47

Sidnr. / Page
10(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-11-03

Utfört av / Performed by
Lars Andersson

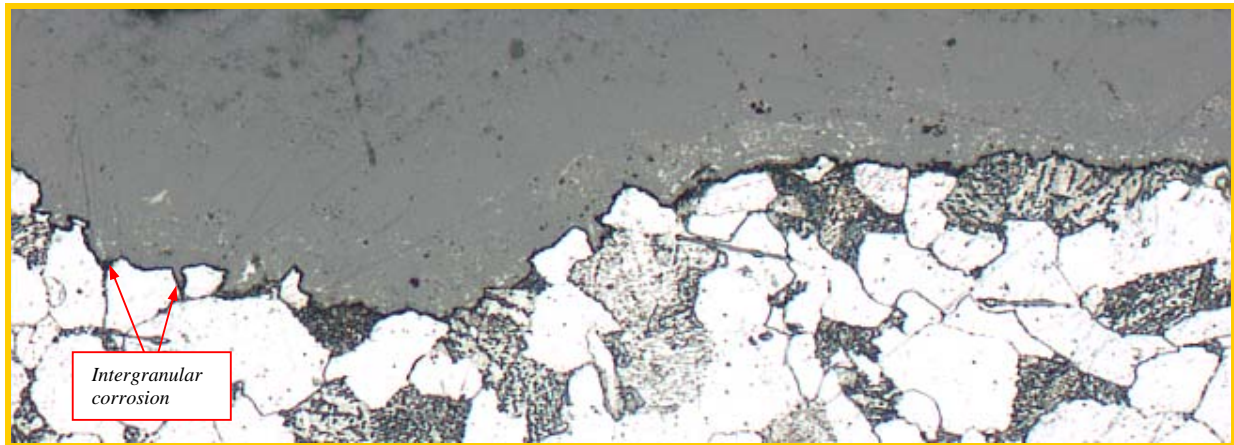


Fig.20: Towards tube surface, on gas-side. Some intergranular corrosion could be observed. Nital. 800x

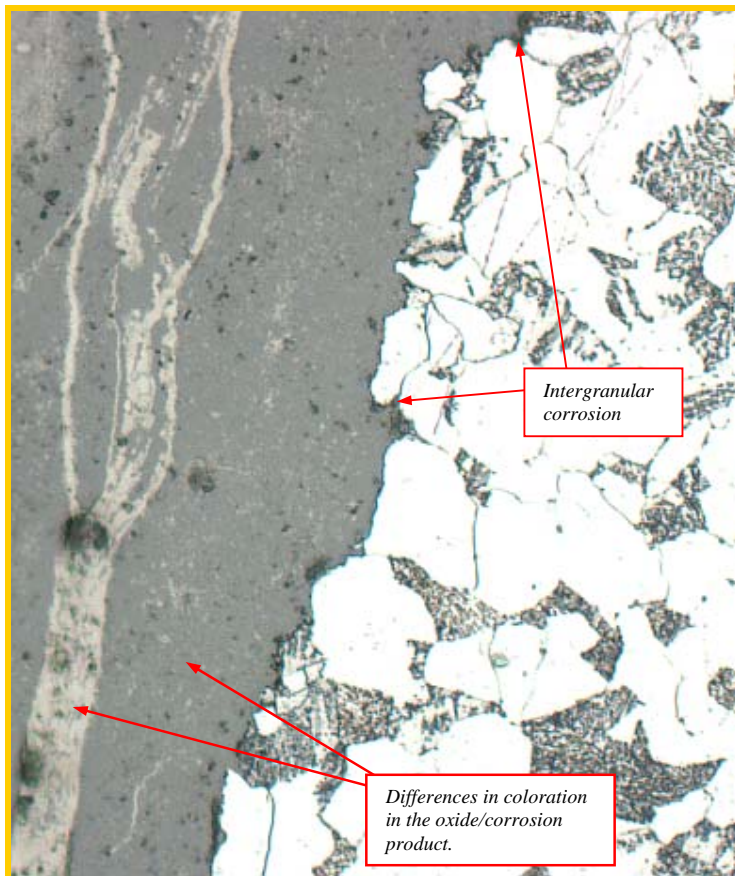


Fig.21: Towards one "crack surface". Similar intergranular corrosion as we observed towards tube surface. Nital. 800x

Signatur / Signature:

Teknisk instruktion / Technical instruction
Macroscopic and microscopic examination

Objekt / Object
Cross section 2. Cross section 3

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
SCMM1

Provningsutrustning / Testing equipment
SCM 10, SCM 47

Sidnr. / Page
11(12)

Provning enligt / Testing according to
SS-EN 1321

Provningsdatum / Testing date
2006-11-03

Utfört av / Performed by
Lars Andersson

Cross section 2

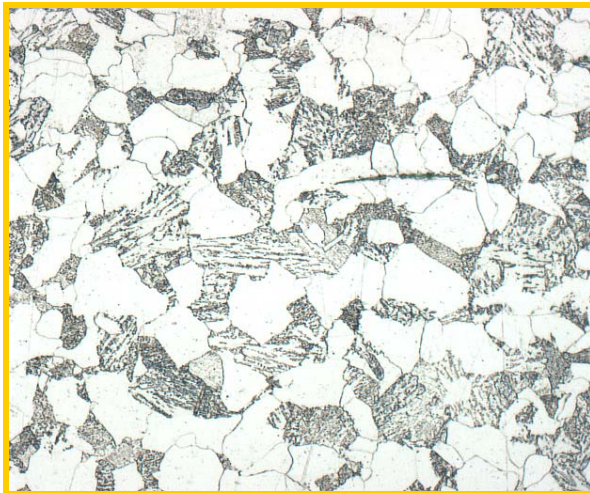


Fig.22: Base metal. Nearly normal pearlite in a matrix of ferrite. Some spheroidized carbides could be observed in the pearlite. Nital. 400x.

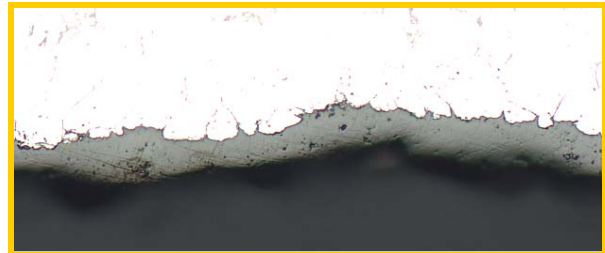


Fig.23: Towards steam-side. The surface was covered by a protective oxide with a thickness of about 10 - 17 μm . 400x.

Cross section 3

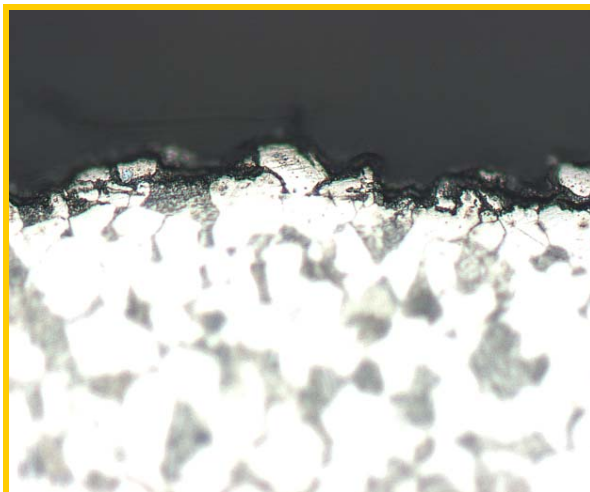


Fig.24: Towards tube surface on gas-side. Some intergranular corrosion. Nital. 400x.

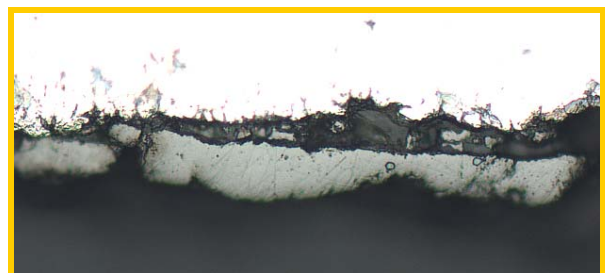


Fig.25: Towards steam-side. The surface was covered by an oxide, detached from the surface, with a thickness of up to 20 μm . 400x.

Signatur / Signature:

Teknisk instruktion / Technical instruction
Baumann test*

Objekt / Object
Cross section 2. Cross section 3

Reg. nr. / Reg.No
M014666

TI Dokumentnr./ TI Document no.
-

Provningstrustning / Testing equipment
SCM 9, SCM 48

Sidnr. / Page
12(12)

Provning enligt / Testing according to
ISO 4968

Provningsdatum / Testing date
2006-11-07

Utfört av / Performed by
Lars Andersson

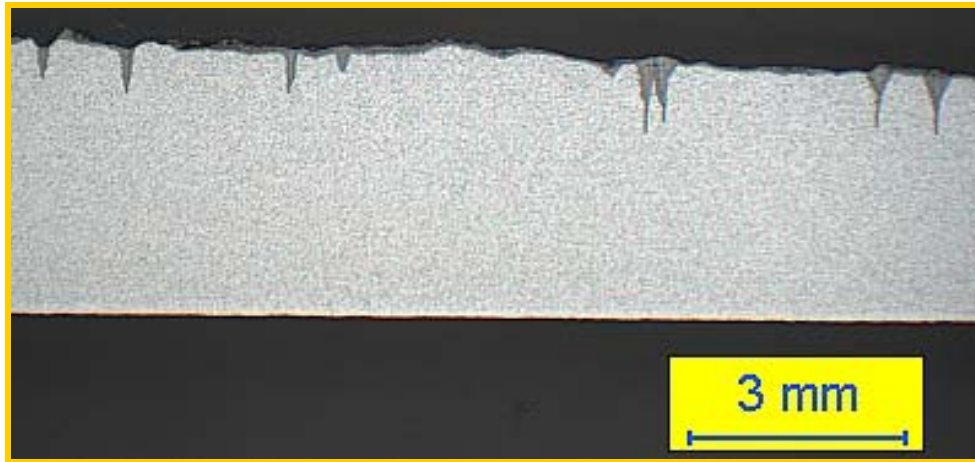


Fig.26: Same macro as in fig.8 (at another magnification).



Fig.27: Macro photo of photographic paper after Baumann test of cross section 2. We observed occurrence of sulphur on tube surface towards gas-side and within in the cracks (see *arrows*).

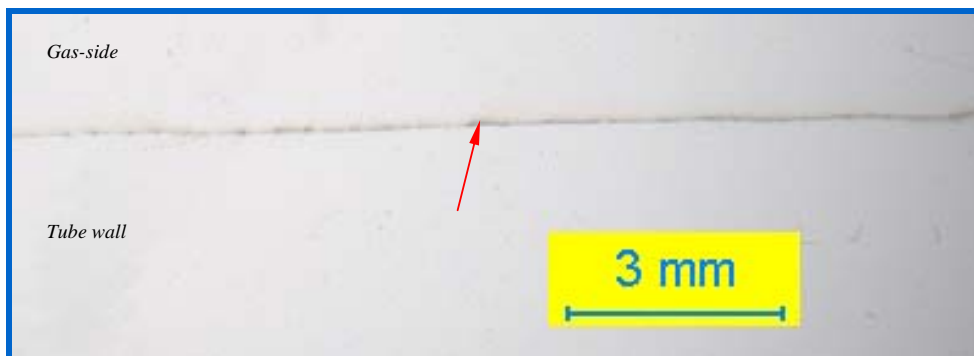


Fig.28: Macro photo of photographic paper after Baumann test of cross section 3. We observed occurrence of sulphur on tube surface towards gas-side (see *arrow*).

Signatur / Signature: