Statens vegvesen

Fedafjord bru - rapport fra utmattingsprøving av bærekabel

RAPPORT

Teknologiavdelingen

Nr: 2400

Seksjon for bruteknikk: 2005-07-15

Statens vegvesen

Vegdirektoratet
Teknologiavdelingen

Postadr.: Postboks 8142 Dep
0033 Oslo
Telefon: 22 07 35 00

www.vegvesen.no

TEKNOLOGI-RAPPORT nr. 2400

Tittel

Fedafjord bru - rapport fra utmattingsprøving av bærekabel

Utarbeidet av

Gunnar Gundersen

Dato:	Saksbehandler	Prosjektnr:
2005-07-15	Gunnar Gundersen	
	Kontrollert av	**Antall sider og vedlegg:**

Sammendrag

Utmattingsprøving av bærekabel for Fedafjord bru er utført av Deutsche Montan Technologie (DMT) i Bochum, Tyskland i perioden 2. til 15. juni 2005.

I løpet av utmattingstesten ble det registrert 19 trådbrudd, hvorav 13 i ytre lag.
Strekkprøving av kabelen etter utført utmatting viste en bruddlast på 10100 kN, som er 95 % av spesifisert bruddlast.
Kravet på 75 % av spesifisert bruddlast etter utmatting er dermed oppfylt.

Summary

Emneord:

Hengebruer, kabel

Generelt

Det er bestemt å utføre utmattingstest av en prøve av bærekablene for Fedafjord bru. Testen utføres av Deutsche Montan Technoligie GmbH (DMT) i Bochum, Tyskland.

Testen utføres iht. Håndbok-122; Kabler til hengebruer og skråstagbruer Tekniske leveringsbetingelser, 1994-utgaven. Denne utgaven av håndboken viser til DIN 18809, som igjen viser til TL-Seile, hvor testen spesifikasjoner er gitt.

Testen startet 2. juni 2005. Forut for oppstart ble det holdt et møte hos DMT, hvor opplegget for testen ble gjennomgått. På møtet deltok Manfred Vorholt og Friedrich Dürrer fra DMT, Knut Gjerding-Smith fra Haug og Blom-Bakke as og Gunnar Gundersen fra Statens vegvesen. Bridon hadde lagt fram en prosedyre for testen. Den var stenplet ”Uncontrolled copy”. Gjennomgang av opplegget for testen viste at dette var i samsvar med spesifikasjonen.

Kabeldata

Kabelen er en spiralslått, lukket, galvanisert kabel.
Spesifisert bruddlast er 10600 kN.
Kabeldiameter er beregnet til 103 mm.

Trådenes strekkfasthet er spesifisert til min. 1570 MPa.
Tverrsnittsareal er spesifisert til 7384 mm^2.
Vekten av kabelen er beregnet til 64.1 kg/m.

Testdata

Lasten i kabelen under utmattingstesten varierer mellom 4867 kN og 3759 kN.
Det vil si at øvre lastnivå er 42 % av spesifisert bruddlast.
Senningsvidden er 150 MPa.
Det skal gjennomføres 2 millioner lastvekslinger.
Frekvensen er 2 Hz. Kravet er mellom 1.5 og 3.8 Hz.
Lengden av prøvestykket skal være min. 5 m. Det aktuelle prøvestykket var 5.38 m.
Det var ikke benyttet kabelhoder av den type som skal benyttes på kabelen. Dette er akseptert fordi hodene er ikke utmattingsømfintlige.

Oppstart av testen

Kabelen var montert i utmattingsprøvemaskinen da vi ankom bedriften.
Etter møtet ble testen igangsatt.

Det benyttes akustisk måleutstyr for å registrere trådbrudd.
Temperaturen registreres. Den var 19 °C ved oppstart.

Kl. 12.15 den 2. juni var testen i gang.

3. juni ble det avlagt et nytt besøk i laboratoriet i anledning en annen sak (strekkprøving). Kl. 12 den 3. juni var antall lastvekslinger kommet opp i 180000. Hele testen vil ta 11.5 døgn ved den valgte frekvens. Temperaturen i kabelen var nå kommet opp i 27 °C.

Utmatting
2 millioner lastvekslinger ble nådd 13. juni. Ved akustisk registrering var det registrert 19 trådbrudd. 13 av disse bruddene ble visuelt registrert i ytre trådlag.

Strekkprøving

15. juni ble det foretatt nytt besøk i laboratoriet i anledning strekktest av kabelen for å finne bruddlast etter utført utmatting. Fra DMT var Friedrich Dürrer tilstede. Fra Bridon Gelsenkirchen deltok Friedhelm Eric Rentmeister, fra DNV Essen deltok André Pfahlert, fra Statens vegvesen deltok Gunnar Gundersen.

Kabelen var montert i strekkprøvemaskinen ved ankomst. Kabelen ble så strukket til brudd ved en langsom kontinuerlig pålastning (mer en 5 minutttert forløp). Brudd oppstod ved 10100 kN. Dette er 95 % av foreskrevet bruddlast. Kravet er at kabelen etter utmatting skal holde minimum 75 % av foreskrevet bruddlast.

Konklusjon
Kabelen oppfylte kravet til utmatting.

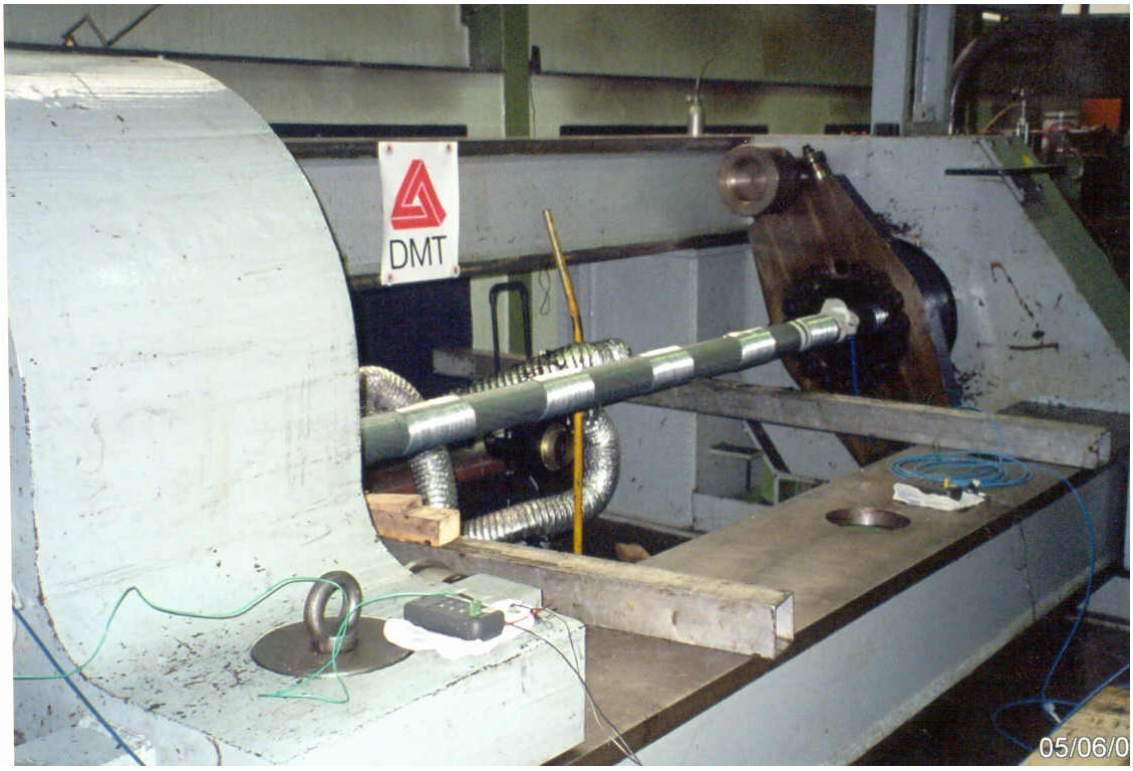


Foto 1. Kabelen montert i utmattingsprøvemaskinen

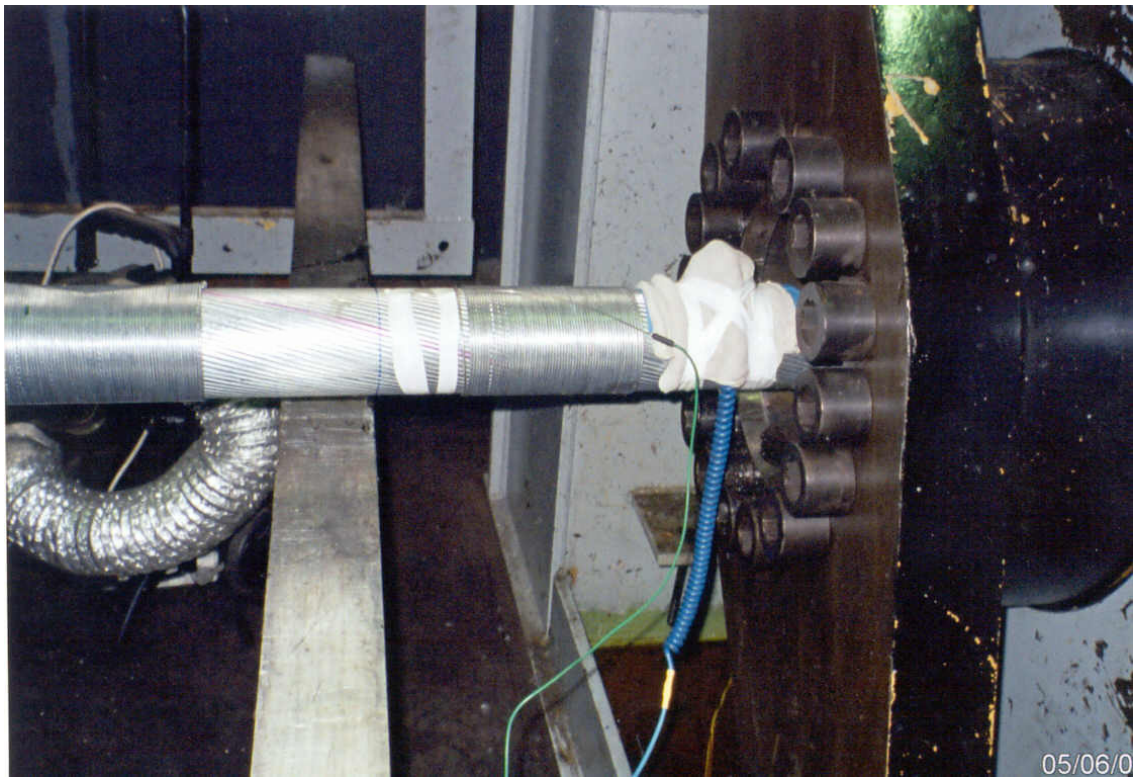


Foto 2. Sensor for akustisk registrering av trådbrudd er tilkoblet.

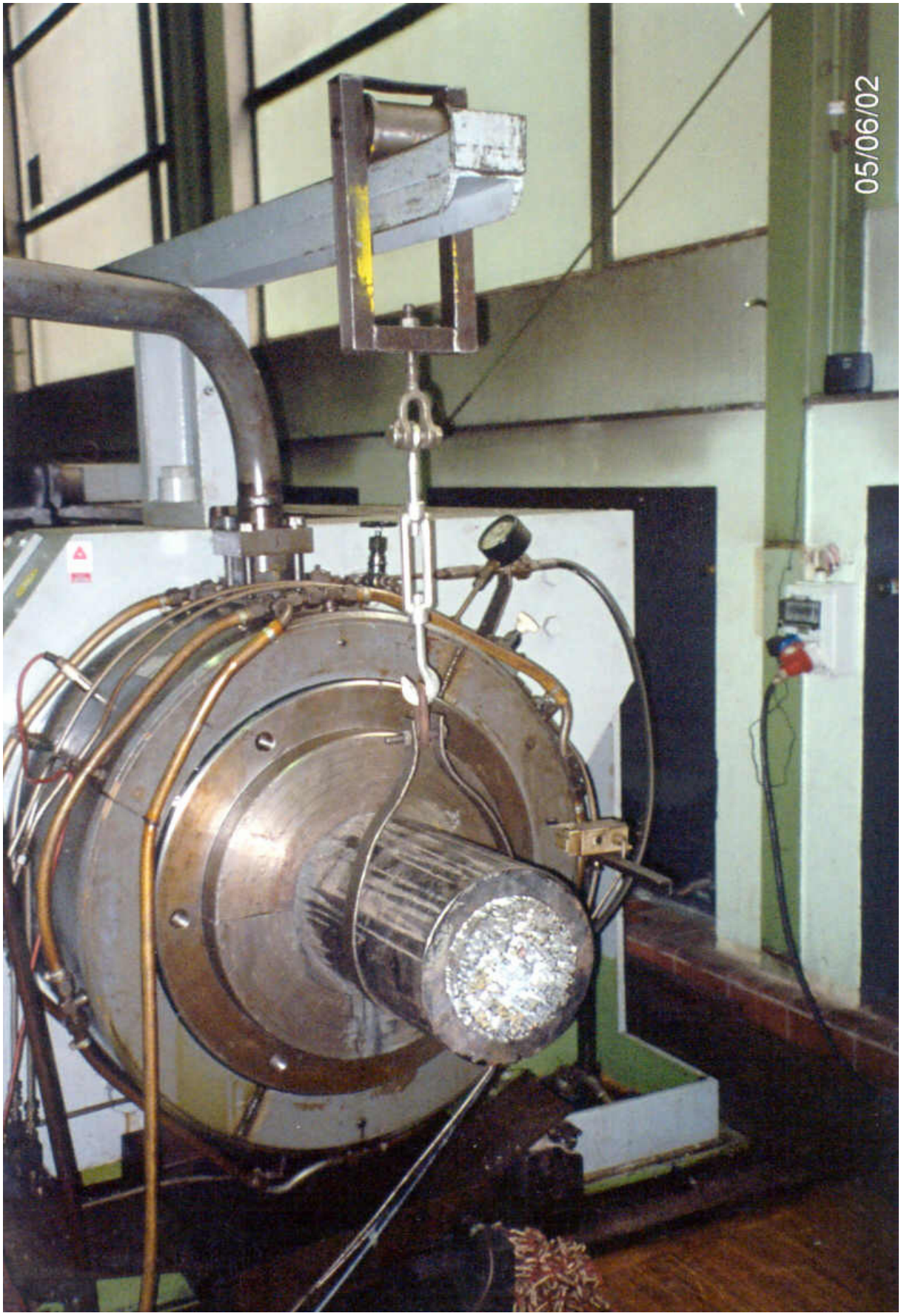


Foto 3. Kabelhode i den ende hvor på- og avlastning foretas.

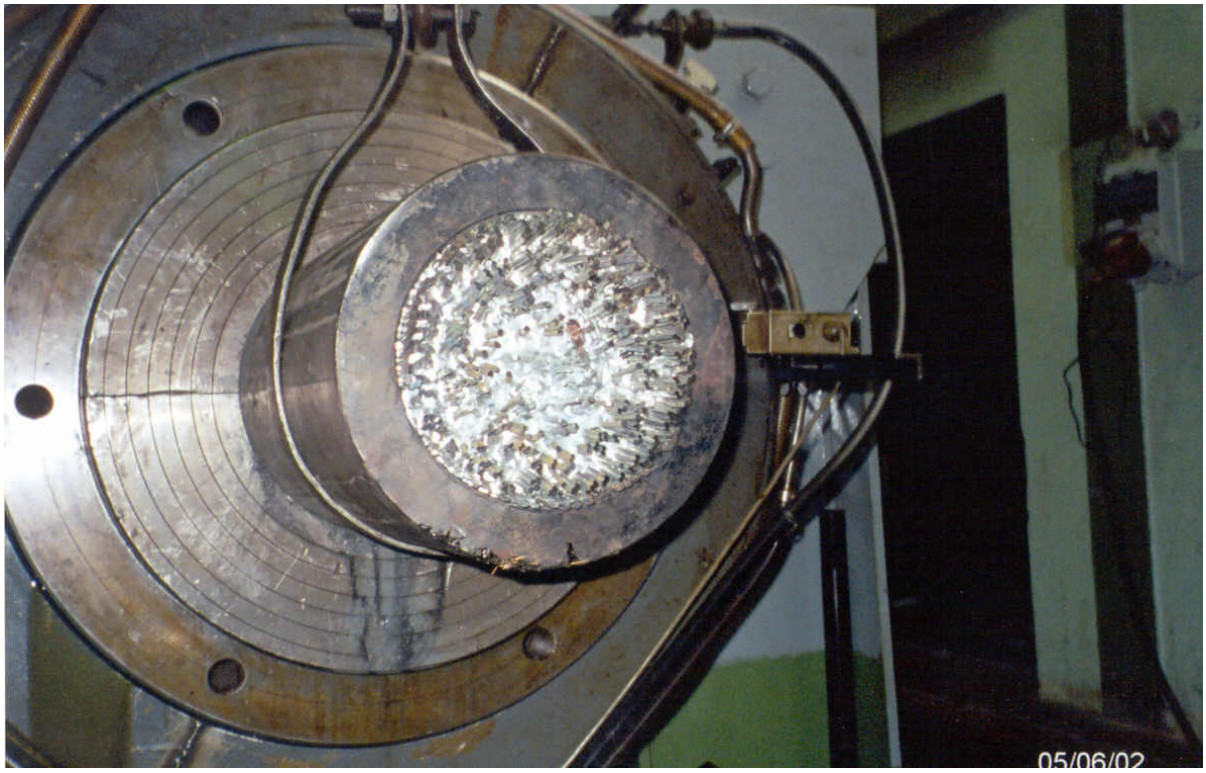


Foto 4. Samme som forrige. God trådfordeling.

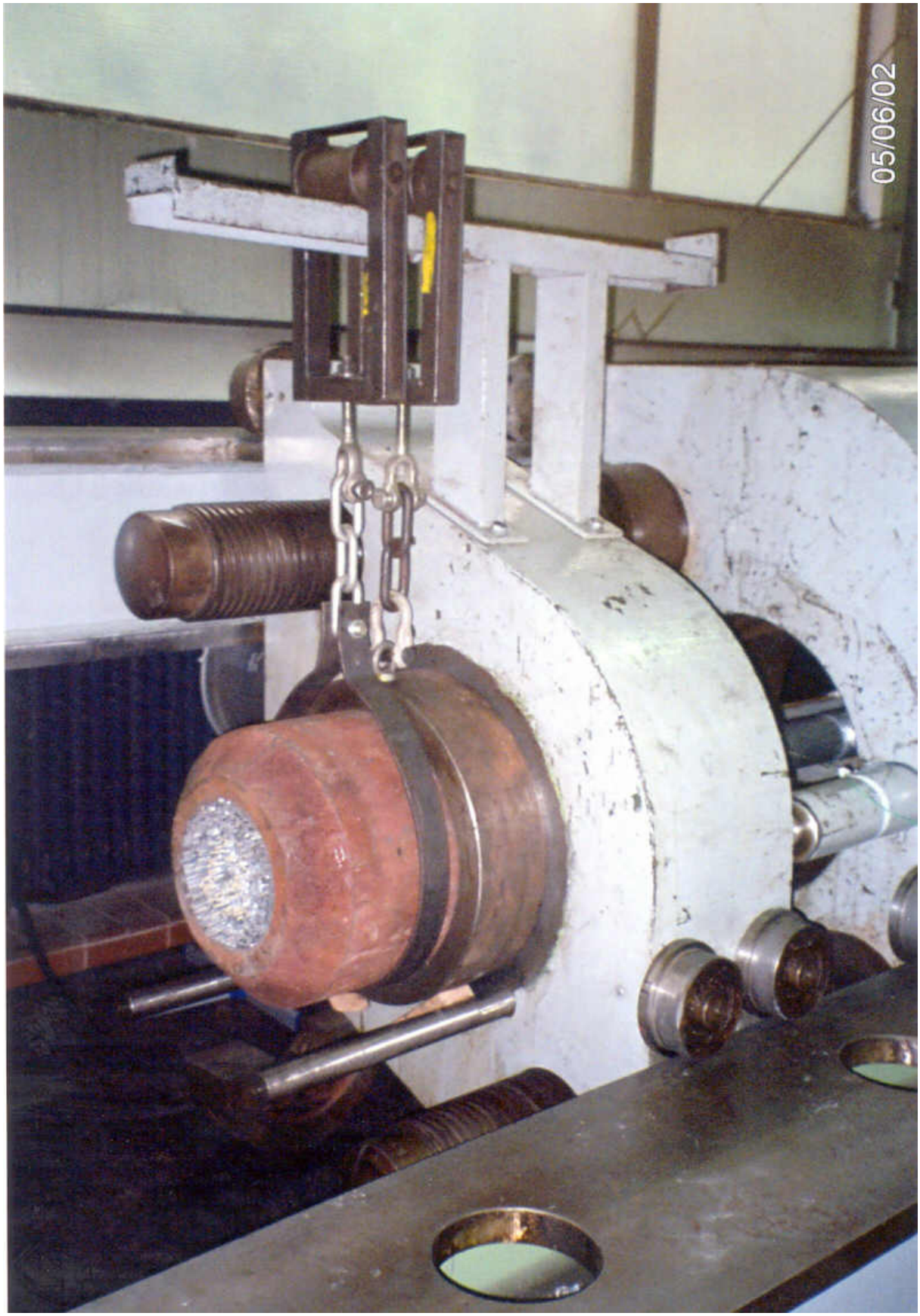


Foto 5. Kabelhode i motsatt ende.

Foto 6. Samme som forrige. Ikke optimal trådfordeling.

Foto 7. Maskin som styrer utmattingstesten.

Foto 8. Maks. og min. last under utmattingen.

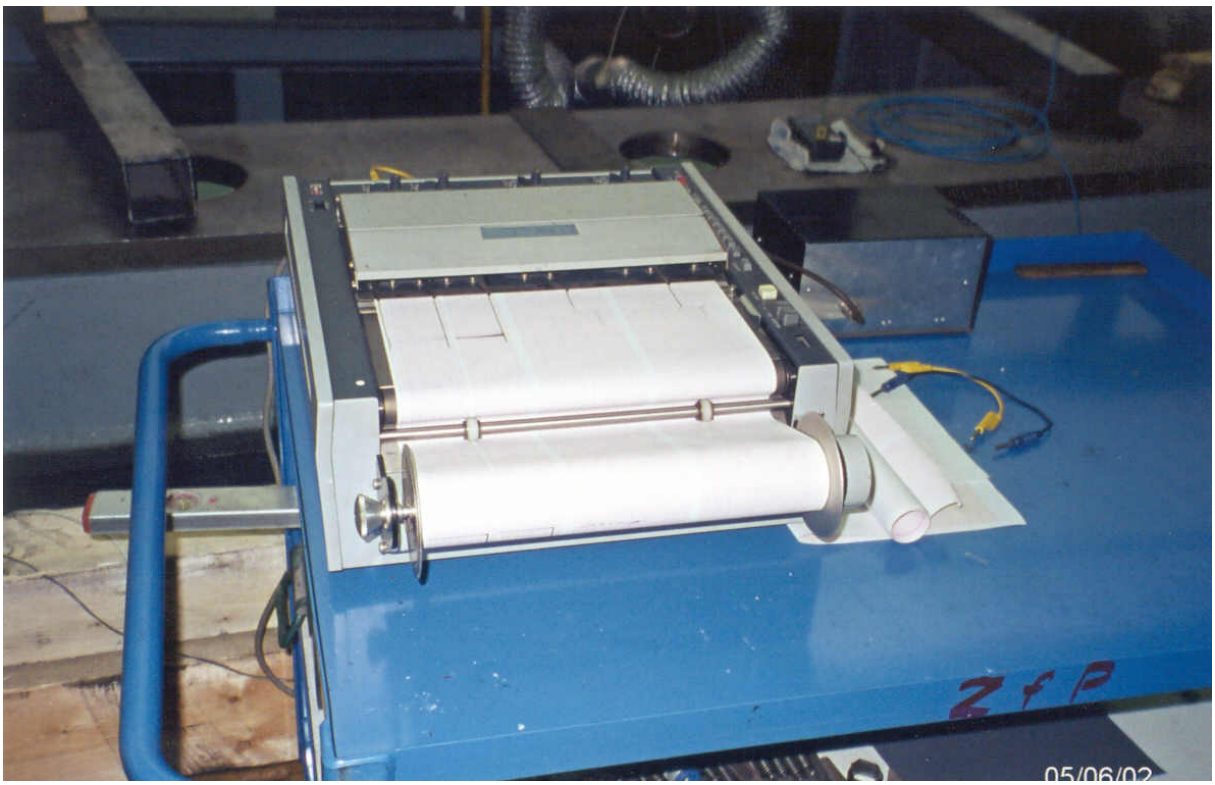


Foto 9. Registrering av tråddbrudd.

Foto 10. Merke som viser at maskinen er kalibrert.

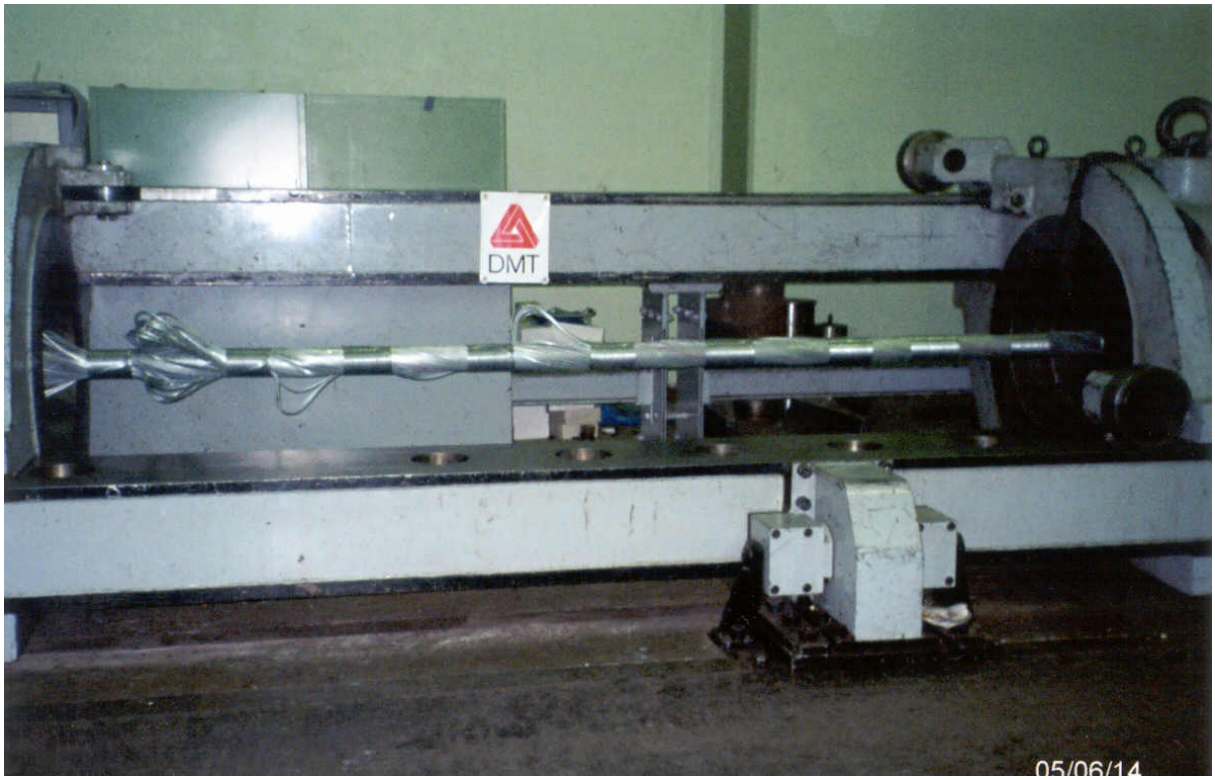


Foto 11. Kabelen etter strekkprøving, brudd i en god del tråder, bruddlast 10100 kN.

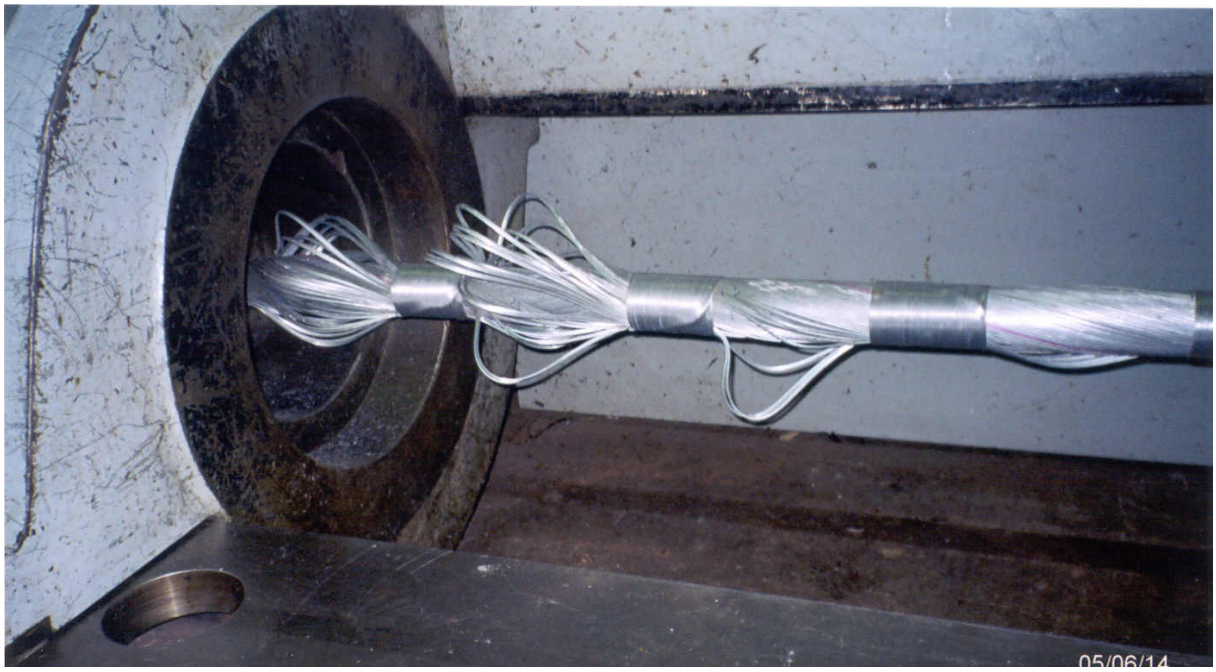


Foto 12. Brudd i kabelen.

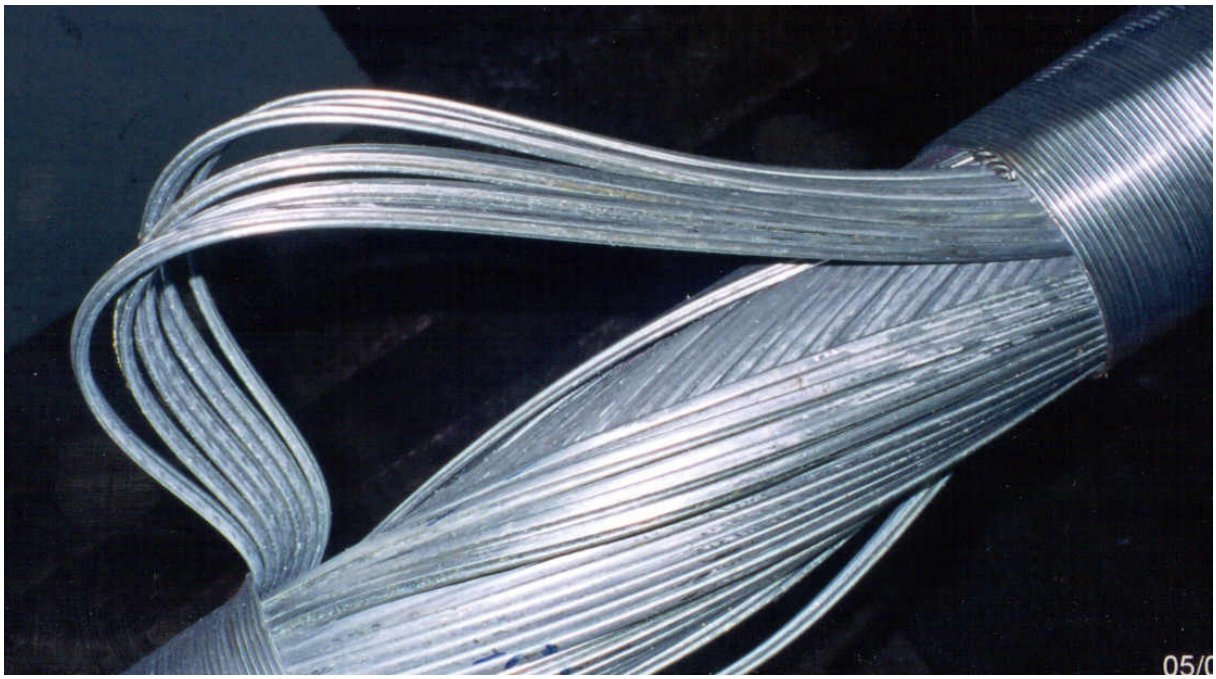


Foto 13. Det er spinnemiddel på trådene i 2 lag, men ikke på trådene i ytre lag.

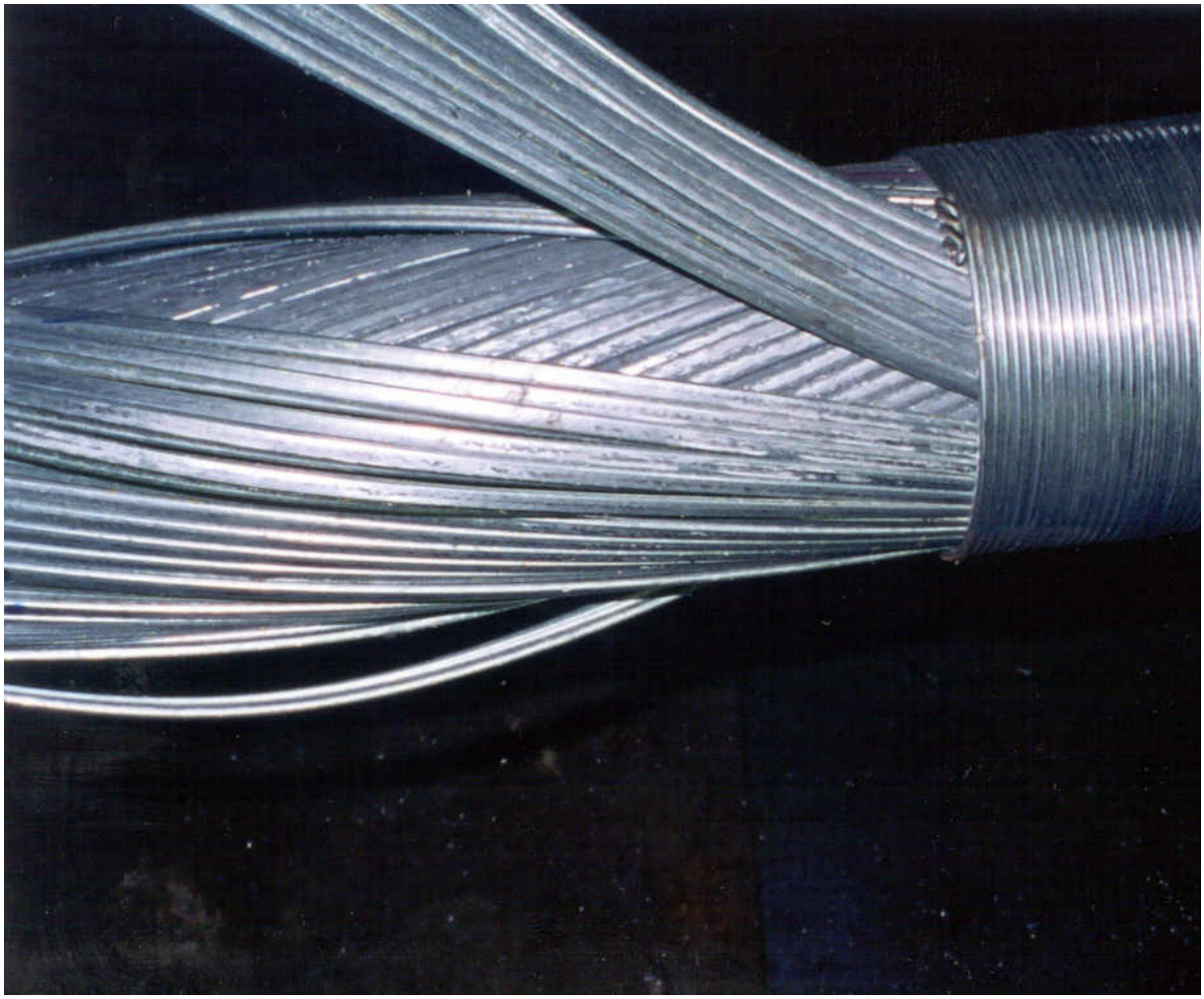


Foto 14. Ikke spinnemiddel i ytre lag

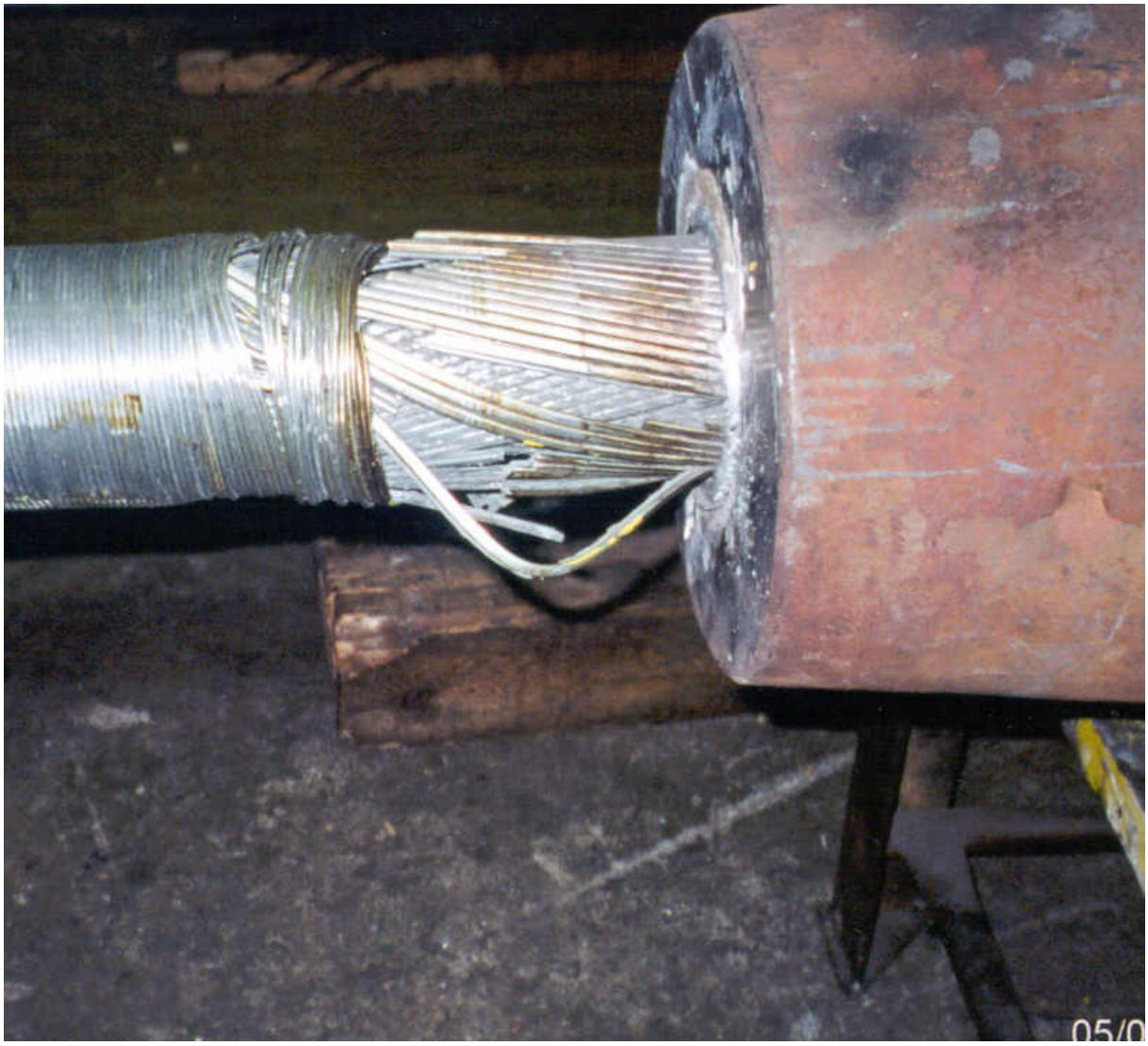


Foto 15. Trådbrudd ved kabelhodet.

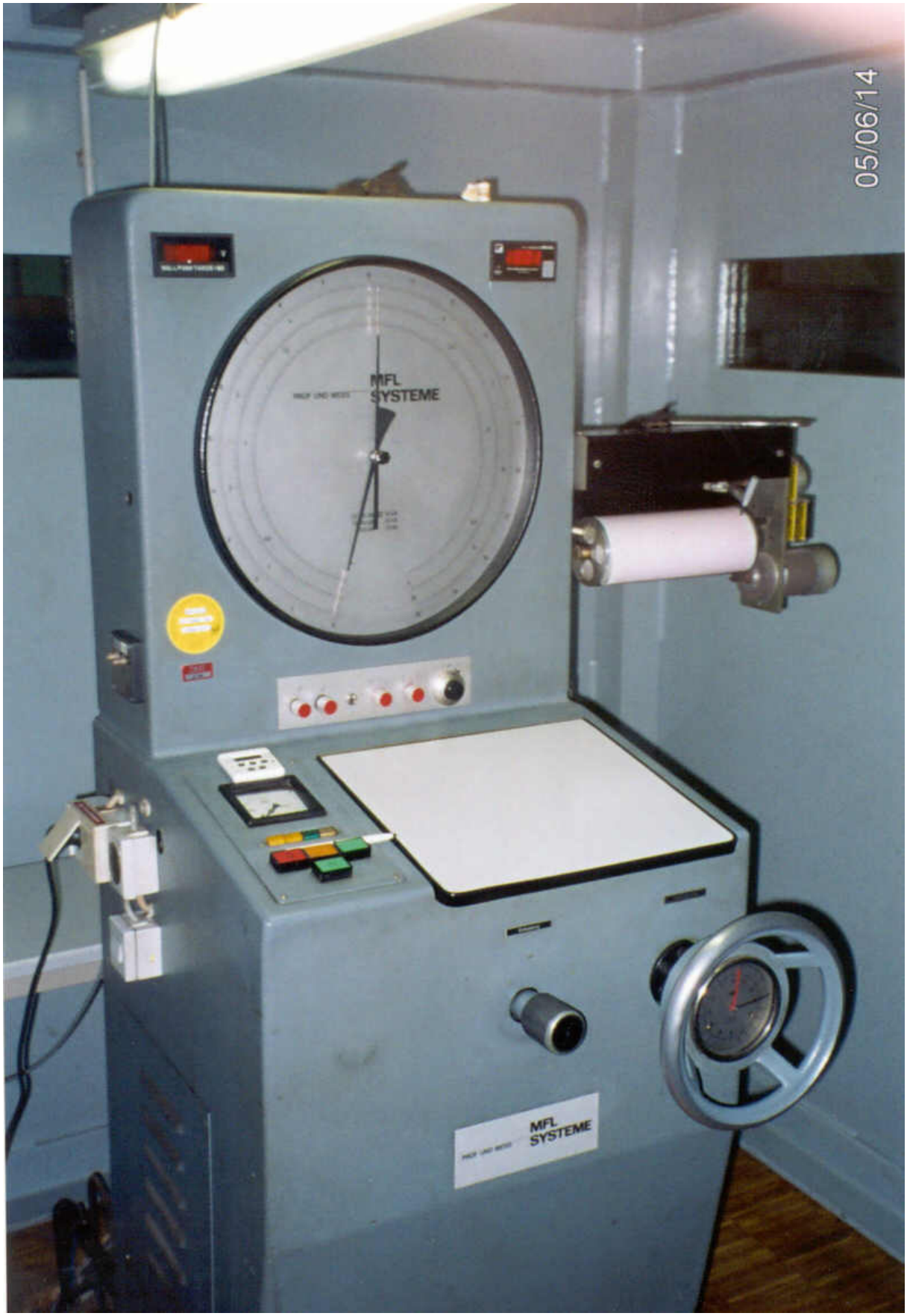


Foto 16. Styringsenheten

Foto 17. Merke som viser at maskinen er kalibrert.

Vedlegg 1. Prosedyre for utmattingstest (**uncontrolled copy**).

STANDARD NO	:	**PST.10111**		
EDITION	:	**Ed.1.**	REVISION :	**Rev.0.**
PAGES	:	**6**	DATE :	**May 2005**
TITLE	:	**FATIGUE TESTING PROCEDURE FOR 103MM LOCKED COIL CABLES FOR THE FEDA FJORD BRIDGE**		

CREATED BY : P. A. SAYER DATE : 24/05/2005

APPROVED BY : M. J. WARNER DATE : 24/05/2005

CONTENTS

1.0 SCOPE

This standard covers the procedure for fatigue testing of the 103 mm locked coil ropes for the Feda Fjord bridge. This testing is in accordance with the requirements of Norwegian Public Roads Department Handbook 122, 1994.

103mm diameter rope

Minimum breaking load (M.B.L): ..... 10600 kN

Steel cross sectional area of rope :.....7386 mm^2

Number of wires in rope:..... 322

Tensile strength:..... 1570 N/mm^2

Maximum stress:..... 0.42 x 1570 = 659 N/mm^2

Maximum load:.....4867 kN

Stress range:.....150 N/mm^2

Minimum stress: .....509 N/mm^2

Minimum load:.....3759 kN

2.0 GENERAL REQUIREMENTS

This Standard is the property of Bridon International and shall not be issued to a third party without prior written authorisation from Bridon International.

3.0 SAMPLE PREPARATION

3.01 The test sample shall be fitted both ends with dummy sockets. Both sockets will be poured with zinc alloy GB-ZnAl6CuI (Z610) as used for production socketing.

3.02 The cylindrical socket shall have an outer diameter not greater than 310mm to facilitate loading into the test machine. The dynamic head of the test machine has a bore of 315mm.

3.03 Care shall be taken during handling and transport of the sample to avoid any damage to the wire surface which could lead to premature wire failure.

3.04 Samples for fatigue testing shall be supplied to the test house on a support beam to prevent bending or twisting of the sample.

3.05 The sample length shall be 5565 mm, measured from the inboard face of each socket.

3.06 A clamp shall be fitted to the inboard side of the sockets to prevent the sockets from being dislodged in transit.

4.0 FATIGUE TESTING

4.01 The sample shall be carefully loaded into the fatigue test machine avoiding any twisting or bending of the sample.

4.02 Temperature of the sample will be checked continuously.

4.03 The load shall be cycled at a frequency of 2 Hz between the following values:

Minimum load (kN)	3759
Maximum load (kN)	4867

4.04 Rope temperature shall be monitored throughout fatigue testing.

4.05 An acoustic detection system shall be used to log any wire breaks occurring during testing.

4.06 The test shall be terminated after 2million load cycles.

4.07 On completion of testing the sample shall be loaded to failure at a rate of approx 1000 kN / minute.

4.08 The test shall be considered satisfactory if the breaking load after the completion of 2 million cycles in the fatigue test is equal to 2.2 x the assumed maximum load in the structure but is not more than 25% below the minimum breaking load i.e. the minimum breaking load after the fatigue test shall be 7950 kN.

5.0 REPORTING

Five copies of the test report shall be supplied.

The report shall include as a minimum, the following:

- The rope identification number
- Reference to this test procedure; PST.10111
- The test results showing the number of load cycles completed , the temperatures recorded, the number of wire breaks and the actual breaking load after fatigue testing.
- Calibration certificates for all test and measuring equipment used.

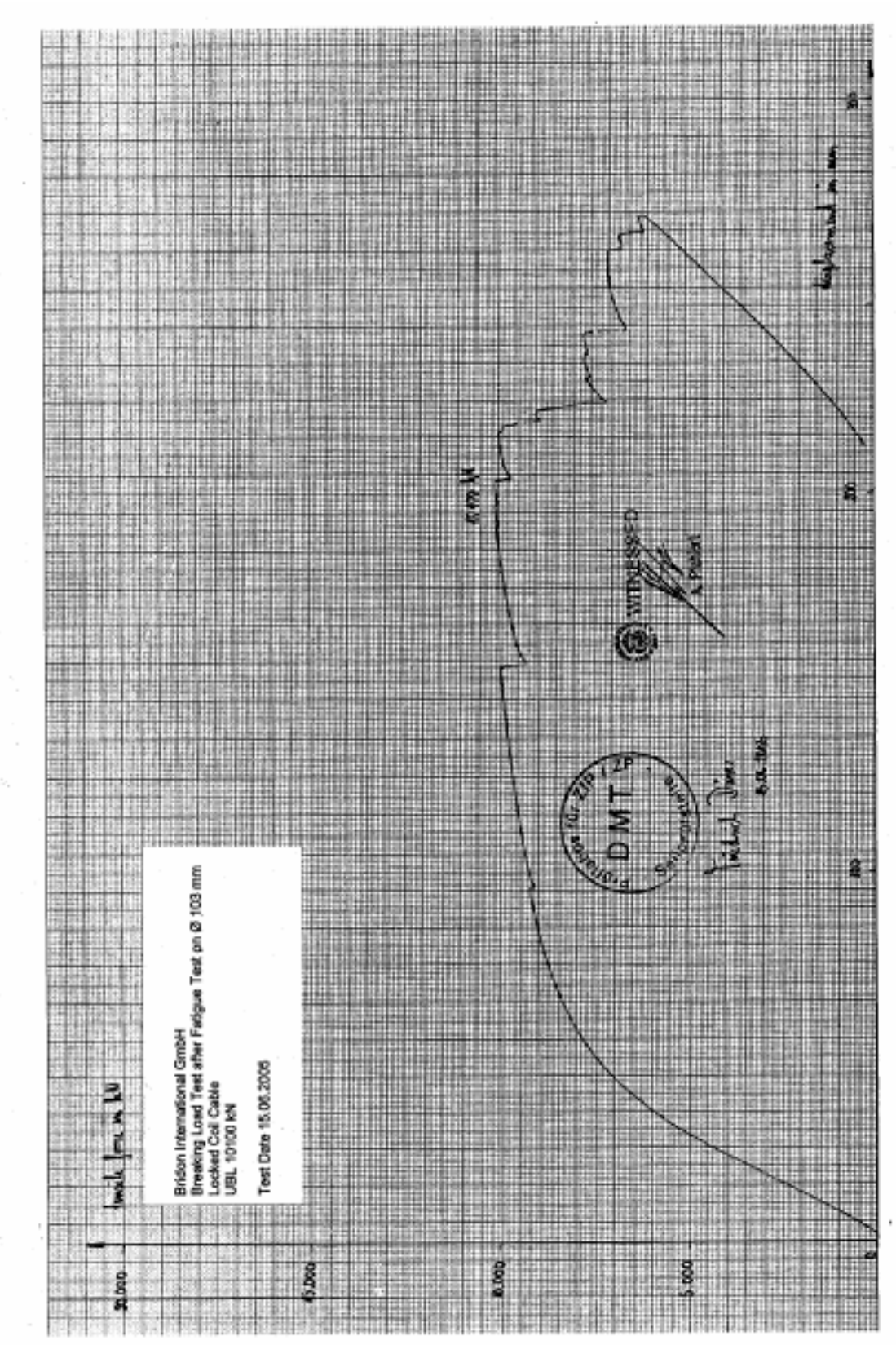
The report shall also be supported with photographs of the test assembly before and after the test.

6.0 DOCUMENT HISTORY

Edition 1, Revision 0 **24th May 2005**

Created by P.A.Sayer

Vedlegg 2. Utskrift av forløpet av strekkprøvingen.



Vedlegg 3: Kopi av kalibreringssertifikat for uttmattingsprøvemaskin

MPA NRW.
Materialprüfungsamt Nordrhein-Westfalen
PRÜFEN · ÜBERWACHEN · ZERTIFIZIEREN

Marsbruchstraße 186 - 44287 Dortmund - Telefon (0231) 4502-433 - Telefax (0231) 4502-589 - E-Mail: Dez43@mpanrw.de

Amtliche Prüfstelle Werkstoffprüfmaschinen

ZEUGNIS

über die Prüfung und Kalibrierung einer Werkstoffprüfmaschine nach DIN 51220 durch einen vom Verband der Materialprüfungsämter e.V. (VMPA) zertifizierten Prüfingenieur

DKD

DKD - K - 06301 Elektrische Größen, Härtevergleichsplatten, Eindringkörper, Kraft, Spannungsverhältnis, Härteprüfmaschinen

DAP - PL - 2600.34
Prüfung und Kalibrierung von Werkstoffprüfmaschinen

Die Akkreditierungen gelten für die in den Urkunden aufgeführten Messgrößen bzw. Prüfverfahren.

Deutscher Akkreditierungs Rat
DAR
DAP-PL-2600.34

MPA NRW.
Materialprüfungsamt Nordrhein-Westfalen
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- Official Calibration Laboratory for Testing Machines -

Verification Report N°: 43 0668 05 - 2
Verification and Calibration of a Testing Machine according to DIN 51220
(D-N°: 0668_W_600_03_05_engl)

Company	: DMT Geschäftsfeld Bergbau Service, Seil- und Fördertechnik : 44809 Bochum
Location of the machine	: Prüfhalle-Seilprüfstelle
Model/Type	: Differential-Prüfzylinder, liegend / RD HO
Manufacturer	: M.B. Trebel GmbH; Ratingen
Serial Number	: HO 600/1 year of Construction: 1976
Direction of the improving Force/drive mechanism	: Hydraulisch, Motorpumpe
Force-proving device	: Elektr. Kraftaufnehmer (DMS)
Force-proving display	: Ziffernanzeige
Additional Instrument	: Spitzenwertspeicher
Ranges of Force Measurement	: 6000 kN
Dimensions of anvil	: -
Max. height	: -
Masse of pendulum	: -

Date of Verification: 03-24-2005 and 03-23/19-2005

1. Results of Verification: The Testing machine was calibrated and verificated in 4 range(s) according to **DIN EN ISO/IEC 7500-1.** The machine fulfils the requirements of **DIN EN ISO/IEC 7500-1** and was classified as follows:

Range of the force	from	To	Class	Calibration value
6000 kN Tension	600 kN	6000 kN	2	Oberlast
6000 kN Tension	600 kN	6000 kN	2	Unterlast
The testing machine may be used for spezial requirements (maßgebliche Untersuchungen).				

Results of calibration see page 2 and 3

Dortmund, 03-24-2005
By order

gez. Schiffer
VMPA-Prüfingenieur

Materialprüfungsamt MPA 101 Nordrhein-Westfalen

This certificate is valid as Quality Insurance according to DIN EN ISO 9001. The laboratories of MPA NRW are accredited on DIN EN ISO/IEC 17025.

This certificate was produced by EPD and is valid without signature.
It consist out of 3 pages one explanation shed and 5 data table(s).
Time of validity: According to DIN 51220 this certificate is no more valid after each fit up (for standing machines), when deviations are suspected in application of the test force, extension-, working- or force-proving device, after each change, addition or repair, which can affect the working of the machine. Unless otherwise specified the verification and the certificate are valid one year.

Because of translation from German to English language, in case of controversy German text is valid.

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2. Results of the Calibration

2.1 General inspection of the testing machine

a) Behaviour and function

- Crosshead
- Mounting of the machine
- Guiding rolls
- Parts of the drive mechanism
- Fasteners on columns and crossheads
- Uniform variation of the force
- Identification of the masses of pendulum

b) Influences of the environmental conditions

- Vibration
- Aggressive media
- Temperature influences from one side

c) Anvil

- Evenness
- Hardness
- Mobility/stroke
- Bend under max. force

d) Verification of relative Influence of bending f_e

Verificated Positions: a, b, d

The verification did not lead to any objection.

MPA NRW.
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Page 3 of certificate N°. 43 0668 05 – 2 dated 03-24-2005

2.2 Verification of force proving device

a) Verificated ranges and there resolution

Range of force F_N	Indicated Force F_i from	to	Resolution r*)	Relative Resolution a ≤ % von F_i	Used force proving device
600 kN	300 kN	6000 kN	1 kN	0,33	Nr. 72622

*) Resolution r = 1 digital step or
r = 1 partition of scale/estimable part of the partition of scale
If the display is moving: r = half of the moving range (see remark)

b) The relative deviation of the zero point f_o fulfils for the different ranges the requirements of the admitted classes.

c) Determination of
the relative accuracy error q,
the relative repeatability error b,
the relative reversibility error u,
the influence of the additional instrument

d) The uncertainty of measurement of the several measured values was determined with a guideline of dedaration the uncertainty of measurement. While measuring – GUM – TSO 1995-

Results see tables

Remarks:

The measured values were determined in the switch setting "Stat." .
The peak value storage will be enabled by the switch setting "dyn.".
The measured value of the reversal error portents to friction
The adjustment equipment, with which the characteristic curve of the different measurement ranges can be changed, was sealed with the MPA NRW button No 856 and No 859
The length of the measurement cable from compression proving instrument to the digital indicator was at about 20 m

3. **Used instruments:** ZST 10000/1; CMS 32-88

The used measuring-, test control units and reference materials are attributed to the national normal.

Because of translation from German to English language, in case of controversy German text is valid.

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Erläuterungsblatt W

Formelzeichen und Definitionen

F_N	Nennkraft eines Kraftanzeigebereiches der Prüfmaschine (Höchstkraft)	
F_i	Bei zunehmender Prüfkraft	an der Prüfmaschine angezeigte Kraft
F'_i	Bei abnehmender Prüfkraft	
F	Bei zunehmender Prüfkraft	am Kraftmessgerät angezeigte oder von Belastungskörpern ausgeübte richtige Kraft
F'	Bei abnehmender Prüfkraft	
F_c	Bei zunehmender Prüfkraft am Kraftmessgerät angezeigte oder von Belastungskörpern ausgeübte richtige Kraft	während der ergänzenden Messreihe im kleinsten benutzten Kraftanzeigebereich für den Fall, dass mit Zusatzeinrichtungen gearbeitet wird
F_{ic}	Bei zunehmender Prüfkraft an der Prüfmaschine angezeigte Kraft	
$\overline{F_i}$, $\overline{F}$	Arithmetische Mittelwerte aus mehreren Messungen von F_i bzw. F bei gleicher Prüfkraftstufe	
$F_{i\,max}$, $F_{i\,min}$ F_{max}, F_{min}	Größter bzw. kleinster Einzelmesswert von F_i bzw. F bei gleicher Kraftstufe	
F_{io}	Restanzeige an der Kraftanzeigeeinrichtung der Prüfmaschine nach Entlastung	
b_3, b_4	Relative Wiederholpräzision aus 3 bzw. 4 Messreihen	der Kraftmesseinrichtung der Prüfmaschine
f_0	Relative Nullpunktabweichung	
q	Relative Anzeigeabweichung	
u	Relative Umkehrspanne	
r	auflösungsbedingte absolute Ableseunsicherheit	der Kraftanzeigeeinrichtung
a	auflösungsbedingte relative Ableseunsicherheit	
F_S	Prüfkraft im betrachteten Skalenpunkt (Untere Messbereichsgrenze bzw. Punkt der Änderung der absoluten Ableseunsicherheit)	
q_z	relative Anzeigeabweichung der Zusatzreihe	

MPA NRW.
Materialprüfungsamt Nordrhein-Westfalen

Marsbruchstraße 186 - 44287 Dortmund - Telefon (0231) 4502-433 - Telefax (0231) 4502-589 - E-Mail: Dez43@mpanrw.de

Bearbeitungsnummer 43 0668 05
Herstellnummer : HO 600/1
Messbereich : 6000 kN Zug
Zusatzeinrichtung : -
Prüfdatum : 16.03.2005
Temperatur : 21 °C
Weitere Angaben: -

			Hauptmessreihen			ergänzende Messreihe		
Fi	F	r	q	b	u	q	b	U
Maschinen-anzeige kN	richtige Kraft kN	Auflösung kN	Anzeige-abweichung %	Wiederhol-präzision %	Umkehr-spanne %	Anzeige-abweichung %	Wiederhol-präzision %	Messunsicherheit (k=2) %
300	303,16	1	-1,0	0,4	-2,2	-	-	0,34
600	602,19	1	-0,4	0,1	-1,4	-	-	0,26
1200	1198,49	1	0,1	0,1	-1,0	-	-	0,25
2400	2390,82	1	0,4	0,1	-0,9	-	-	0,24
3600	3586,30	1	0,4	0,1	-0,7	-	-	0,24
4800	4780,69	1	0,4	0,0	-0,8	-	-	0,24
6000	5981,66	1	0,3	0,1	-	-	-	0,24

0668_W_HO 6_M01_03_05

MPA NRW.
Materialprüfungsamt Nordrhein-Westfalen

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Bearbeitungsnummer 43 0668 05
Herstellnummer : HO 600/1
Messbereich : 6000 kN Zug
Zusatzeinrichtung : mit Spitzenwertspeicher
Prüfdatum : 17.03.2005
Temperatur : 21 °C
Weitere Angaben: -

			Hauptmessreihen			ergänzende Messreihe		
Fi	F	r	q	b	u	q	b	U
Maschinen-anzeige kN	richtige Kraft kN	Auflösung kN	Anzeige-abweichung %	Wiederhol-präzision %	Umkehr-spanne %	Anzeige-abweichung %	Wiederhol-präzision %	Messunsicherheit (k=2) %
300	305,90	1	-1,9	0,8	0,8	1,2	1,1	0,41
600	605,21	1	-0,9	0,1	1,1	0,4	0,5	0,26
1200	1205,07	1	-0,4	0,3	-0,4	0,1	0,7	0,26
2400	2397,12	1	0,1	0,2	-0,9	0,3	0,4	0,25
3600	3591,10	1	0,2	0,0	-0,8	0,4	0,2	0,24
4800	4787,40	1	0,3	0,0	-0,7	0,3	0,1	0,24
6000	5987,14	1	0,2	0,0	-	0,3	0,1	0,24

0668_W_HO 6_M02_03_05

Vedlegg 4: Kopi av kalibreringssertifikat for strekkprøvemaskin

DMT

MPA NRW.
Materialprüfungsamt Nordrhein-Westfalen
Marsbruchstraße 186 - 44287 Dortmund - Telefon (0231) 4502-433 - Telefax (0231) 4502-589 - E-Mail: Dez43@mpanrw.de

Amtliche Prüfstelle Werkstoffprüfmaschinen

ZEUGNIS

über die Prüfung und Kalibrierung einer
Werkstoffprüfmaschine nach DIN 51220
durch einen vom Verband der Materialprüfungsämter e.V.
(VMPA) zertifizierten Prüfingenieur

DKD

DKD - K - 06301 Elektrische Größen,
Härtevergleichsplatten, Eindringkörper,
Kraft, Spannungsverhältnis,
Härteprüfmaschinen

DAP - PL - 2600.34
Prüfung und Kalibrierung von Werkstoffprüfmaschinen

Die Akkreditierungen gelten für die in den Urkunden aufgeführten Messgrößen bzw. Prüfverfahren.

Deutscher Akkreditierungs Rat
DAR
DAP-PL-2600.34

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- Official Calibration Laboratory for Testing Machines -

Verification Report N°: 43 0668 04 - 3
Verification and Calibration of a Testing Machine according to DIN 51220
(D-N°: 0668-8858-12-04-engl.)

Company	: DMT Geschäftsfeld Bergbau Service, Seil- und Fördertechnik : 44809 Bochum
Location of the machine	: Prüfraum-Seilprüfstelle
Bauart/Type	: Zugprüfmaschine, liegend / MHE
Manufacturer	: MFL Prüf- und Messsysteme GmbH, Mannheim
Serial Number	: 8858 Baujahr: 1977
Direction of the improving Force/drive mechanism	: Hydraulisch, Motorpumpe
Force-proving device	: Elektr. Kraftaufnehmer (DMS)
Force-proving display	: Skalenanzeige
Additional Instrument	: Schleppzeiger und Diagrammschreiber
Ranges of Force Measurement	: 4000- 10000 – 20000 kN
Dimensions of anvil	: -
Max. height	: -
Masse of pendulum	: -

Date of Verification: 2005-01-22/23/25/26

1. Results of Verification: The Testing machine was calibrated and verificated in 4 range(s) according to **DIN EN ISO/IEC 7500-1.** The machine fulfils the requirements of **DIN EN ISO/IEC 7500-1** and was classified as follows:

Range of the force	From	to	Class	Calibration value
4000 kN Tension	400 kN	4000 kN	1	}
10000 kN Tension	1000 kN	10000 kN	1	} Messstelle 1
20000 kN Tension	2000 kN	20000 kN	1	}
The testing machine may be used for spezial requirements (maßgebliche Untersuchungen).				

Results of calibration see page 2 and 3

Dortmund, 2005-01-27
By order

gez. Schiffer
VMPA-Prüfingenieur

Materialprüfungsamt MPA NRW 101 Nordrhein-Westfalen

This certificate is valid as Quality Insurance according to DIN EN ISO 9001.
The MPA NRW laboratories are accredited after DIN EN ISO/IEC 17025
This certificate was produced by EPD and is valid without signature.
It consist out of 3 pages one explanation shed and 5 data table(s).
Time of validity: According to DIN 51220 this certificate is no more valid after each fit up (for standing machines), when deviations are suspected in application of the test force, extension-, working- or force-proving device, after each change, addition or repair, which can affect the working of the machine. Unless otherwise specified the verification and the certificate are valid one year.

Because of translation from German to English language, in case of controversy German text is valid.

DMT

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2. Results of the Calibration

2.1 General inspection of the testing machine

a) Behaviour and function

- Crosshead
- Mounting of the machine
- Guiding rolls
- Parts of the drive mechanism
- Fasteners on columns and crossheads
- Uniform variation of the force
- Identification of the masses of pendulum

b) Influences of the environmental conditions

- Vibration
- Aggressive media
- Temperature influences from one side

c) Anvil

- Evenness
- Hardness
- Mobility/stroke
- Bend under max. force

d) Verification of relative influence of bending f_e

Verificated Positions: a, b, d

The verification did not lead to any objection.

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2.2 Verification of force proving device

a) Verificated ranges and there resolution

Range of force F_N	Indicated Force F_i from	to	Resolution r*)	Relative Resolution a ≤ % von F_i	Used force proving device
4000 kN	400 kN	4000 kN	2 kN	0,5	
10000 kN	1000 kN	10000 kN	4 kN	0,4	
20000 kN	2000 kN	20000 kN	10 kN	0,5	

*) Resolution r = 1 digital step or
r = 1 partition of scale/estimable part of the partition of scale
If the display is moving: r = half of the moving range (see remark)

b) The relative deviation of the zero point f_0 fulfils for the different ranges the requirements of the admitted classes.

c) Determination of
the relative accuracy error q,
the relative repeatability error b,
the relative reversibility error u,
the influence of the additional instrument

d) The uncertainty of the single measurement values was determined according to the "Guide to the Expression of Uncertainty in Measurement (1995) " (GUM).

Results see tables

Remarks:

The needle is very slow, when heading the zero point
That why for alignment of the zero point an external digital-Volt-meter was added. The digital-Volt-meter is attached with the control equipment of the testing machine.
As to the request of the customer only the range of the Measurement point 1 (Messstelle 1) was calibrated.
With Measurement point 1 the Measurement point was defined which is near to the crossbar. The measurement point 2 is near to the working piston.
Between feed rod and chuck head is at about 1mm of clearance
Between gear rod and pinion gear of the force-proving instrument there is a clearance.
The adjustment equipment, with which the characteristic curve of the different measurement ranges can be changed, was sealed with the MPA NRW button No 0176 and No 60

3. **Used instruments:** ZST 25000/1; CMS 32-88

The used measuring equipment, the test control unit and the reference materials are arised from the national standards.

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Bearbeitungsnummer 43 0668 04
Herstellnummer : 8858
Messbereich : 4000 kN Zug
Zusatzeinrichtung : mit Schleppz,u.Diagr.schr.
Prüfdatum : 21.12.2004
Temperatur : 20 °C
Weitere Angaben: -

			Hauptmessreihen			ergänzende Messreihe		
Fi	F	r	q	b	u	q	b	U
Maschinen-anzeige kN	richtige Kraft kN	Auflösung kN	Anzeige-abweichung %	Wiederhol-präzision %	Umkehr-spanne %	Anzeige-abweichung %	Wiederhol-präzision %	Messunsicherheit (k=2) %
200	198,66	2	0,7	1,1	-0,6	0,9	1,1	0,74
400	398,04	2	0,5	0,4	-0,6	0,5	0,4	0,40
800	797,19	2	0,4	0,1	0,0	0,3	0,1	0,28
1200	1196,82	2	0,3	0,1	0,0	0,2	0,1	0,26
1600	1596,09	2	0,2	0,0	0,0	0,3	0,0	0,25
2000	1993,64	2	0,3	0,0	0,0	0,4	0,1	0,25
2400	2393,03	2	0,3	0,0	0,1	0,3	0,0	0,25
2800	2792,91	2	0,3	0,0	0,0	0,3	0,1	0,24
3200	3192,18	2	0,2	0,0	0,0	0,2	0,1	0,24
3600	3592,79	2	0,2	0,0	0,1	0,2	0,0	0,24
4000	3992,42	2	0,2	0,0	-	0,2	0,0	0,24

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Bearbeitungsnummer 43 0668 04
Herstellnummer : 8858
Messbereich : 10000 kN Zug
Zusatzeinrichtung : -
Prüfdatum : 23.12.2004
Temperatur : 20 °C
Weitere Angaben: -

			Hauptmessreihen			ergänzende Messreihe		
Fi	F	r	q	b	u	q	b	U
Maschinen-anzeige kN	richtige Kraft kN	Auflösung kN	Anzeige-abweichung %	Wiederhol-präzision %	Umkehr-spanne %	Anzeige-abweichung %	Wiederhol-präzision %	Messunsicherheit (k=2) %
1000	992,97	4	0,7	0,3	-	-	-	0,35
2000	1989,91	4	0,5	0,1	-	-	-	0,27
3000	2987,47	4	0,4	0,1	-	-	-	0,26
4000	3982,89	4	0,4	0,0	-	-	-	0,25
5000	4980,46	4	0,4	0,0	-	-	-	0,24
6000	5967,07	4	0,6	0,0	-	-	-	0,24
7000	6967,07	4	0,5	0,1	-	-	-	0,24
8000	7963,41	4	0,5	0,0	-	-	-	0,24
9000	8962,80	4	0,4	0,0	-	-	-	0,24
10000	9960,36	4	0,4	0,0	-	-	-	0,24

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Bearbeitungsnummer 43 0668 04
Herstellnummer : 8858
Messbereich : 20000 kN Zug
Zusatzeinrichtung : -
Prüfdatum : 03.01.2005
Temperatur : 20 °C
Weitere Angaben: -

Fi	F	r	Hauptmessreihen q	b	u	ergänzende Messreihe q	b	U
Maschinen-anzeige kN	richtige Kraft kN	Auflösung kN	Anzeige-abweichung %	Wiederhol-präzision %	Umkehr-spanne %	Anzeige-abweichung %	Wiederhol-präzision %	Messunsicherheit (k=2) %
2000	1987,16	10	0,6	0,6	-0,6	-	-	0,43
4000	3990,83	10	0,2	0,3	0,7	-	-	0,30
6000	5984,74	10	0,3	0,2	0,1	-	-	0,27
8000	7978,64	10	0,3	0,2	0,2	-	-	0,26
10000	9971,03	10	0,3	0,1	0,1	-	-	0,25
12000	11960,99	10	0,3	0,1	0,0	-	-	0,25
14000	13963,14	10	0,3	0,1	0,2	-	-	0,25
16000	15948,84	10	0,3	0,2	-0,1	-	-	0,25
18000	17936,38	10	0,4	0,0	0,0	-	-	0,24
20000	19925,75	10	0,4	0,1	-	-	-	0,24

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Statens vegvesen

Statens vegvesen Vegdirektoratet
Postboks 8142 Dep
N - 0033 Oslo

Tlf. (47) 22 07 35 00
E-post: publvd@vegvesen.no

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