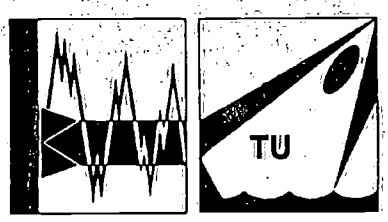
SSL 327

REPORT Nº 327
DATE: 3 JULY 1990
PROJECT: SC 90.02

MATERIAL TESTING

CTOD.TESTS ON 35mm WELDED API.5L.X60

DELFT-3 JULY '90 ING. R.VONK



SHIP STUCTURES LABORATORY.

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Technische Universiteit Delft

CONTENTS

1. INTRODUCTION

This report gives CTOD-values for two sets of specimens tested at -10°C in accordance with BS 5762:1979.
The tests have been carried out on request of the Apparaten- en Ketelfabriek AKF BV in Goes as part of the tests for a welding procedure qualification:
WPQ: NOC 11/90. Single-vee-45°. OD: 406 mm.
WT : 34.9 mm. Position: 6G. Material: API 5L. Grade X60.

2. MATERIAL AND SPECIMENS

Two sets of specimens have been tested.

Set 156W includes 3 specimens, through thickness notched with the notch located on the centre line of the weld (B * 2B specimen).

Set 156F includes 3 specimens, the weld metal notched with the pre-cracked front as close to the fusion line as possible (B * B specimen).

The yield stress is assumed to be:
base material: σ_y = 413 N/mm^2;
weld metal : σ_y = 440 N/mm^2.

The initiating notches have all been provided with integral type knife edges. The distance between the knife edges has been 5 mm.

3. PRECRACKING AND BEND TESTS

Precracking and bend tests have been carried out in 3-point bending, in accordance to BS 5762:1979.

A 100 kN load-controlled servo-hydraulic testing machine has been used for the realisation of the fatigue precracking under constant amplitude loading at room temperature.

The CTOD-tests have been carried out in a 350 kN load-controlled servo-hydraulic testing machine with a cryogene box.
Cooling and stabilisation on the test temperature is obtained by accurately controlled liquid nitrogen injection through a solinoid valve. Via a ducting system the nitrogen is distributed homogeneously in the cryogene box, without influencing the measuring devices.
The temperature is measured using thermocouples in contact with the test piece surface at the crack tip location in front and at the back side of the test piece.

The test temperature for all specimens has been -10°C. The tests were started at a temperature of about 1°C below the test temperature. Depending on the amount of plastic deformation the measured temperatures rose to a value between -10°C and -8.5°C at the moment of failure.

The COD's have been measured with a MTS clip gauge, type 632.020-20, serial no. 675. The calibration values over ranges of 0.5 and 2.6 mm are given in the tables and graphs on page 11 up to 15.

4. RESULTS

The results are presented in the tables and graphs on page 3 up to 10.
All tests are valid according to BS 5762:1979.
Except for specimen 156W1 all fracture surfaces show a normal appearance. However, in specimen 156W1 the unstable crack propagation during the COD-test has started partly on the fatigue crack surface at a distance of about .5 mm from the crack tip in a plane perpendicular to the plane of the notch. Determination of the cause of this initiation requires a further detailed examination of the local crack surfaces.

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Ing. R. Vonk

ir. H.G. Scholte
Head of the Laboratory

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FRACTURE MECHANICS TEST (CTOD-test) cf. BS-5762/1979

PROJECT SC 90 02 Date: 03.07.1990

CLIENT: APPARATEN- EN KETELFABRIEK AKF - BV

Specimen data

Specimen nr.		156W1	156W2	156W3
W (height)	(mm)	61.1	61.2	61.3
B (thickness)	(mm)	30.7	30.6	30.6

Fatigue precracking data — 3 point bending

Testing machine	(kN)	100	100	100
Test temperature	(°C)	20	20	20
Span	(mm)	240	240	240
Loading	(kN)	33	33	33
R (stress ratio)		.1	.1	.1
Kf	(Nmm-3/2)	1604	1567	1525
Number of cycles	(*10^3)	16.62	15.09	14.85
a0	(mm)	30.5	31.2	31.0
a4	(mm)	31.2	30.4	30.1
a1	(mm)	32.8	32.3	32.0
a2	(mm)	32.7	32.4	31.5
a3	(mm)	31.4	31.0	30.8
a average / W		.529	.521	.513

COD-test data — 3 point bending

Testing machine	(kN)	350	350	350
Test temperature	(°C)	-10	-10	-10
Span	(mm)	240	240	240
dK/dt	(Nmm-3/2 s-1)	55.0	54.8	53.6
Vi	(mm)			
Vc plastic	(mm)			.22
Vu component	(mm)		1.79	
Vmax	(mm)	3.00		
Pi	(kN)			
Pc	(kN)			74.5
Pu	(kN)		84.5	
Pmax	(kN)	84.5		

Calculated results

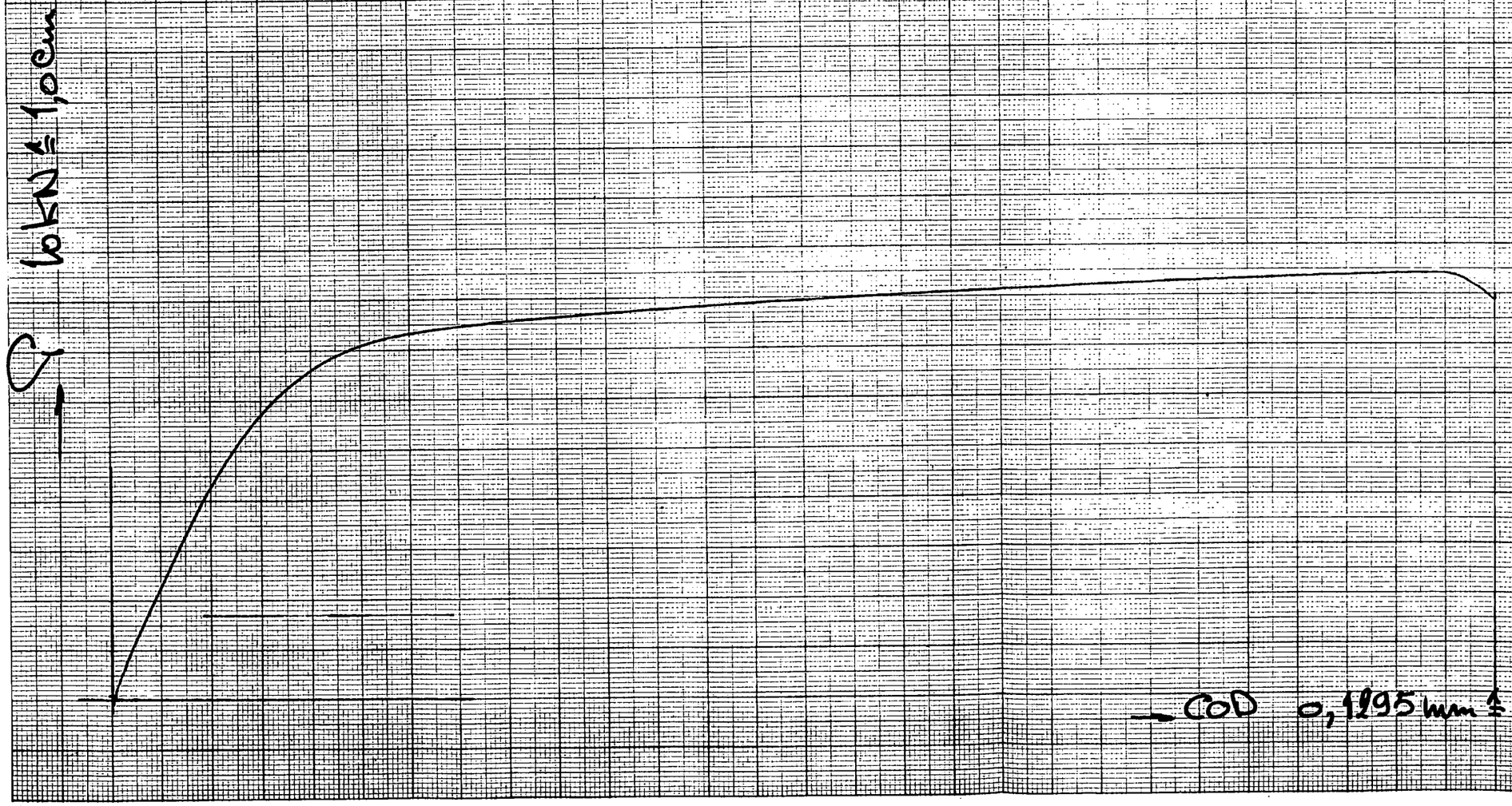
CTODi	(mm)			
CTODc	(mm)			.12
CTODu	(mm)		.56	
CTODmax	(mm)	.87		

Yield strength used in calculations: 440 N/mm2

REMARKS valid valid valid

NOC-11-90

Test Specimen: 156 W 1
date: 3 July '90
test temp. Tweet: -9,8°C



→ COD 0,1295 mm ± 1,0 cm

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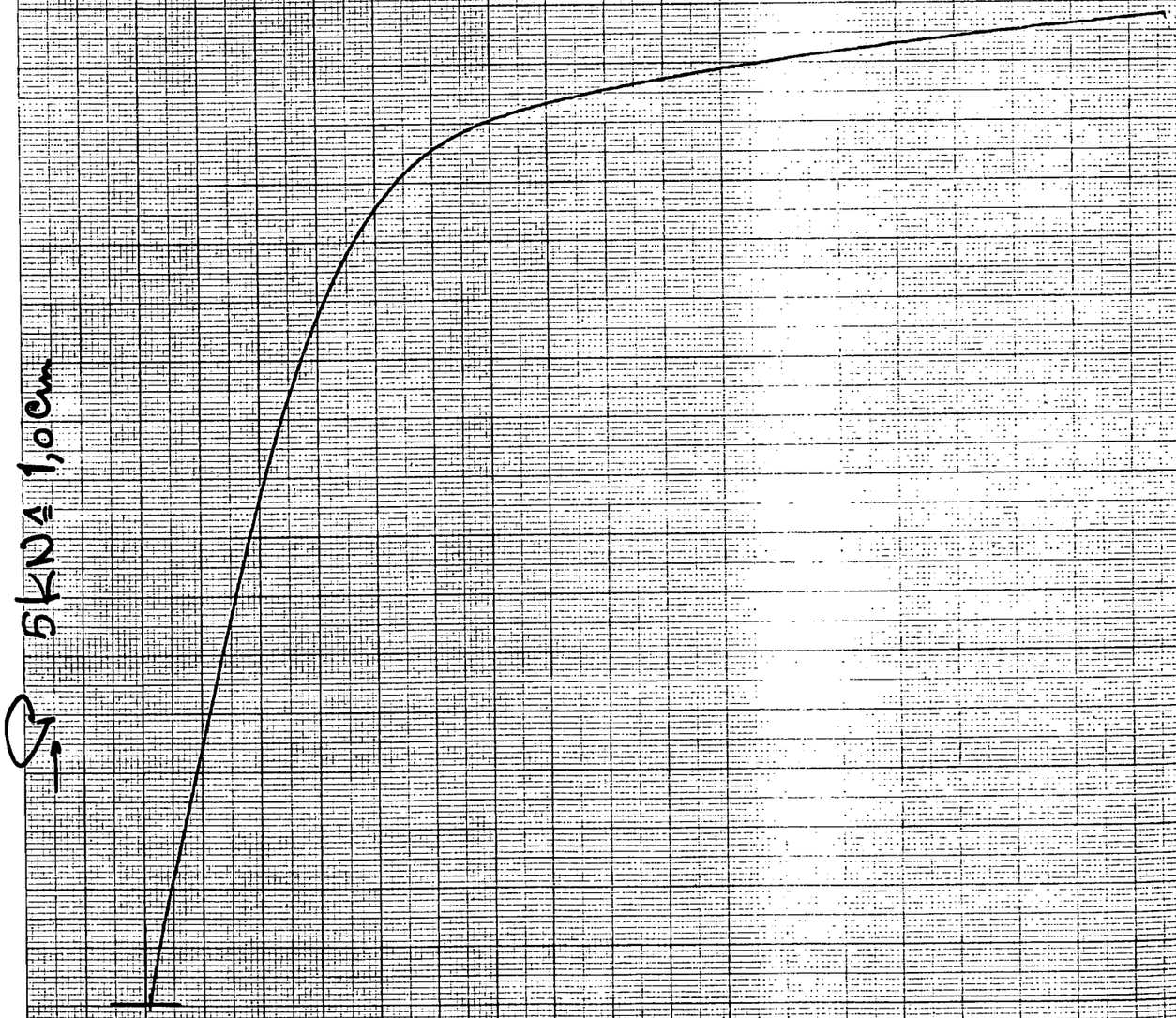
A. J. v.d. Boon
03-07-90

NOC_11-90

testspecimen: 156 W2.
date: 3 July '90
test temp. freeze: -9,8 °C.



COD 0,1293 mm ≙ 1,0 cm

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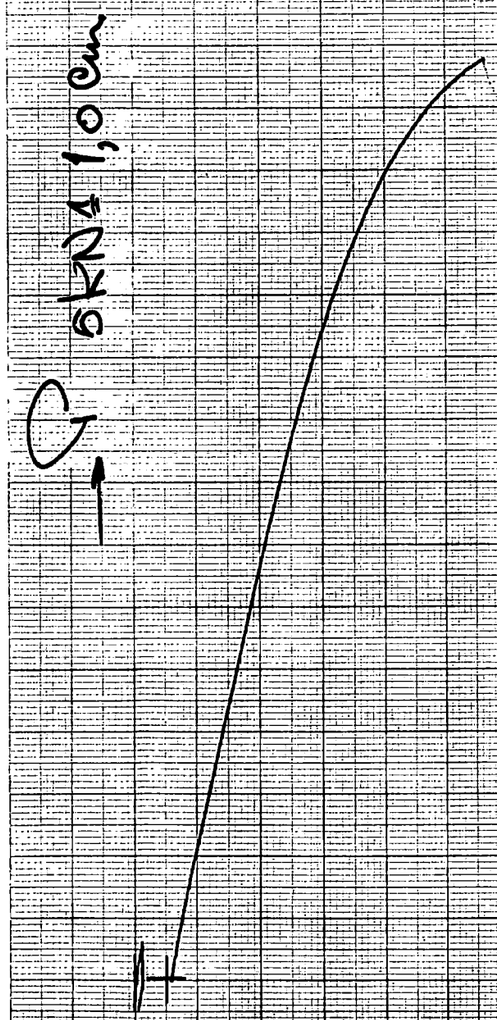
A. J. v.d. Boon
03-07-90

NOC_11.90

test specimen nr. 156W3
date: 3 july '90
test. temp/kwal. −10,1°C



→ COD 0,1295 mm ≙ 1,0 cm

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FRACTURE MECHANICS TEST (CTOD-test) cf. BS-5762/1979

PROJECT SC 90 02 — Date: 03.07.1990

CLIENT: APPARATEN- EN KETELFABRIEK AKF - BV

Specimen data

Specimen nr.		156F1	156F2	156F3
W (height)	(mm)	30.0	30.0	30.0
B (thickness)	(mm)	29.9	29.9	29.9

Fatigue precracking data — 3 point bending

Testing machine	(kN)	100	100	100
Test temperature	(°C)	20	20	20
Span	(mm)	120	120	120
Loading	(kN)	*	29	29
R (stress ratio)		.1	.1	.1
Kf	(Nmm-3/2)	1397	1296	1321
Number of cycles	(*10^3)	*	25.3	28.8
a0	(mm)	11.1	9.9	9.5
a4	(mm)	11.4	10.8	10.4
a1	(mm)	11.9	11.2	11.1
a2	(mm)	12.1	11.3	11.9
a3	(mm)	12.0	11.0	11.1
a average / W		.400	.372	.379

COD-test data — 3 point bending

Testing machine	(kN)	350	350	350
Test temperature	(°C)	-10	-10	-10
Span	(mm)	120	120	120
dK/dt	(Nmm-3/2 s-1)	54.9	55.4	60.0
Vi (plastic component)	(mm)			
Vc (plastic component)	(mm)			
Vu (plastic component)	(mm)			2.90
Vmax	(mm)	3.16	3.10	
Pi	(kN)			
Pc	(kN)			
Pu	(kN)			90.5
Pmax	(kN)	81.5	88.0	

Calculated results

CTODi	(mm)			
CTODc	(mm)			
CTODu	(mm)			1.24
CTODmax	(mm)	1.27	1.33	

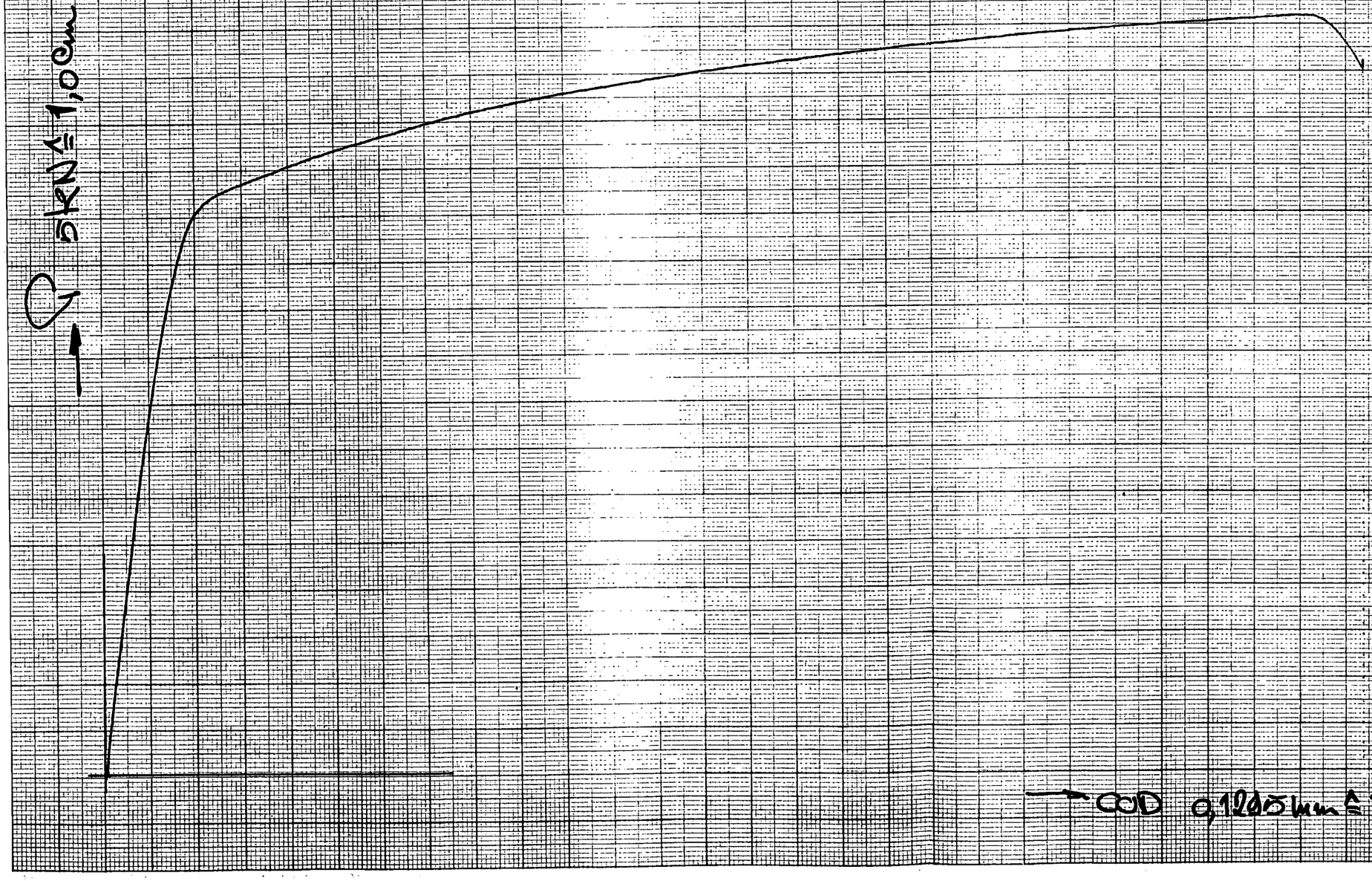
Yield strength used in calculations: 413 N/mm2

REMARKS	valid	valid	valid

* Specimen 156F1 fatigue loading 22.0 kN, R = 0.1, 40 000 cycles and 29.0 kN, R = 0.1, 11 150 cycles.

NOC_11.90

test specimen VS 156 F1
date: 3 jan '90
test temp. [illegible]: −8,9°C



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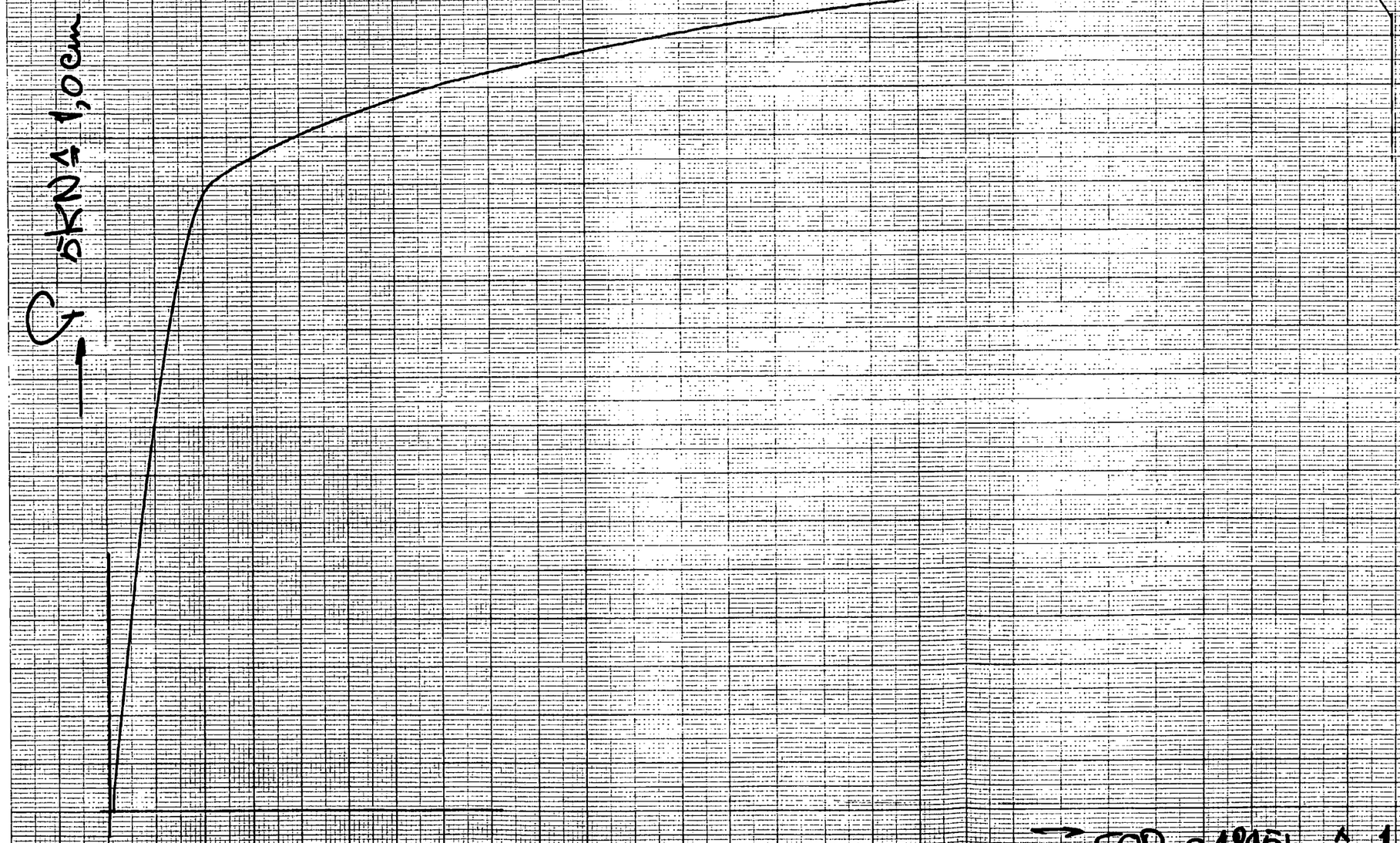
Lloyd's Register
A.J. van Boon
08.01.90

NOC_11_90

test specimen no 156F2
date: 3 july '90
test temp. fract.: -8,4°C



→ COD 0,1285 mm ≙ 1,0 cm

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03 07 90

NOC - 11.09

test specimen nr: 1568 3
date: 3 july '90
test temp. fract.: -9,4°C

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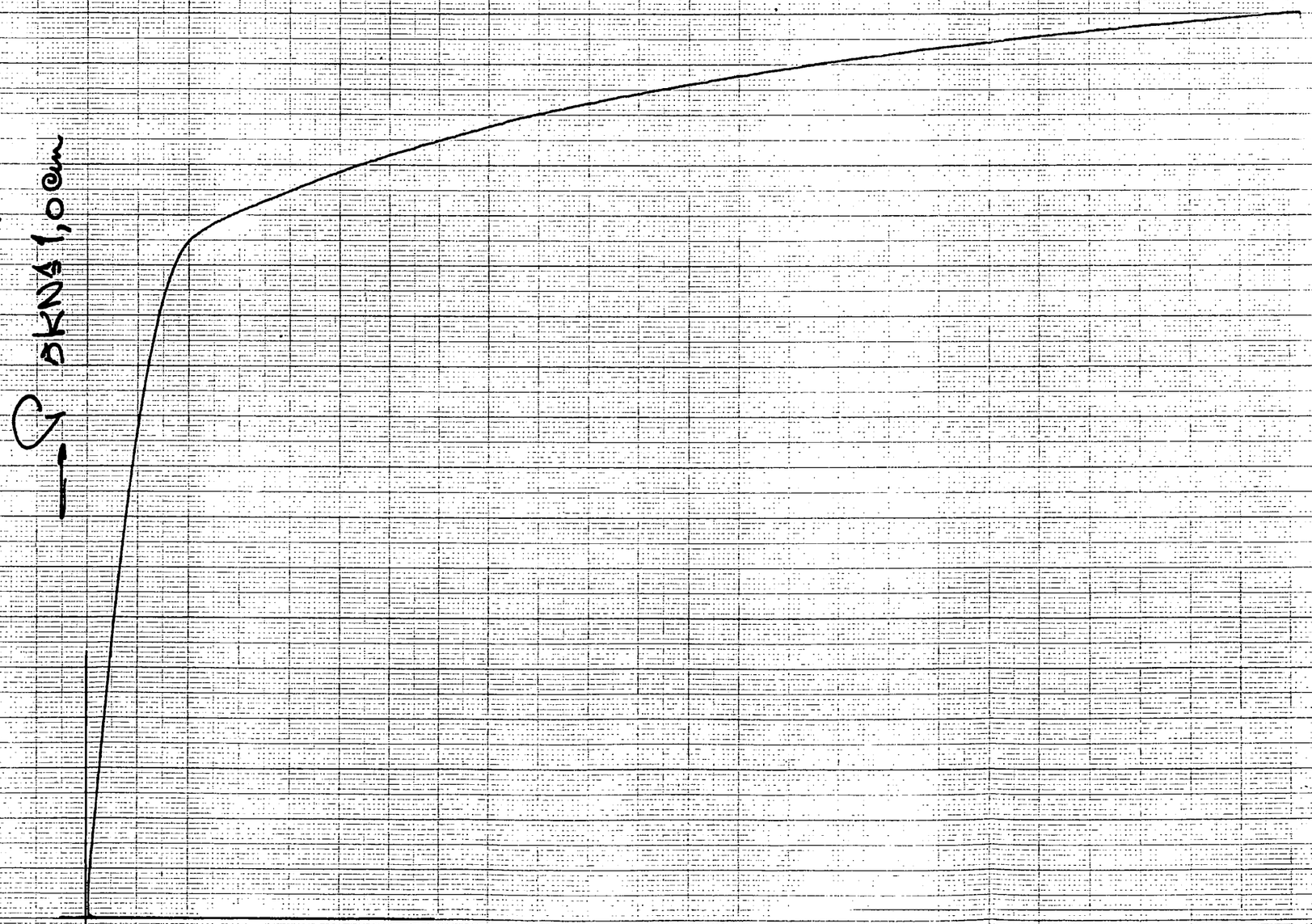

→ COD 0,1295 mm ≙ 1,0 cm

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HEEREMA GROUP QUALITY CONTROL DEPT A. JONGEN

Lloyds Register Offshore Division Rotterdam A.J. v.d. Boon 03-07-90

Calibration of MTS clip gauge 2.5 mm

Clip gauge type: MTS 632-02C-20
Measuring range: 2.5 mm
Gauge conditioner: Peekel MCA100 in 2500 microV/V range (f.s. 10V)

Calibration device: LSC microspan
Clock gauges: 0 - 0.5 mm with 0.001 mm accuracy
0 - 2.5 mm with 0.01 mm accuracy

Measurements (see tables and figures on next pages)

The clip gauge/conditioner combination has been calibrated on the 2nd and 4th of July 1990 (before and after COD-tests).

The results are:

On July 2, 1990	0-0.5 mm	3.84 Volts/mm +/- 0.35%
	0-2.5 mm	3.87 Volts/mm +/- 0.15%
On July 4, 1990	0-0.5 mm	3.84 Volts/mm +/- 0.35%
	0-2.5 mm	3.87 Volts/mm +/- 0.15%

The maximum deviation in the range of 0.5 mm is 0.003 mm and in the range of 2.5 mm the maximum deviation is 0.005 mm.

Delft, July 5, 1990

Ir. B.C. Buisman

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MTS 632-02C-20 Ijking 0-0.5 mm

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Function obtained:
Y = +(3.836 +- 0.013)*(X)
+(1.25 +- 0.37)*E-02*(1)

Analysis of Variance

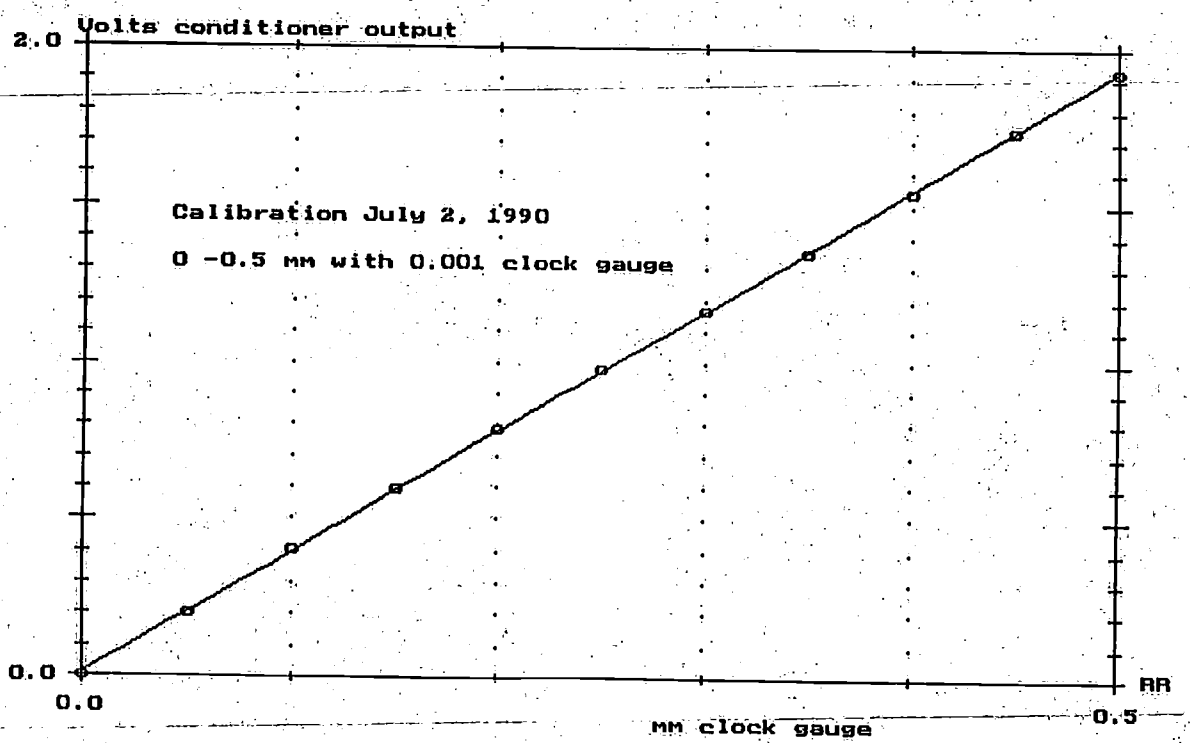
Sum of Squares	Value	Degr. Freedom	Variance
Total	1.4431E+01	11	
Due to regression	1.4430E+01	2	7.2151E+00
Residual	3.9509E-04	9	4.3899E-05

If the model is assumed to be correct, the estimated standard deviation of Y is 6.6256E-03 (absolute)

RelErr = (Yreg - Y)/(Yreg)

Point	X	Y	Yreg	Yreg-Y	RelErr(%)
1	0.000	0.000	0.012	0.012	100.000
2	0.050	0.201	0.204	0.003	1.602
3	0.100	0.403	0.396	-0.007	-1.744
4	0.150	0.593	0.588	-0.005	-0.866
5	0.200	0.784	0.780	-0.004	-0.548
6	0.250	0.977	0.972	-0.005	-0.561
7	0.300	1.171	1.163	-0.008	-0.656
8	0.350	1.352	1.355	0.003	0.235
9	0.400	1.544	1.547	0.003	0.194
10	0.450	1.734	1.739	0.005	0.277
11	0.500	1.928	1.931	0.003	0.137

RR-



MTS 632-02C-20 Ijking 0-2.5 mm

Function obtained:
Y = +(3.8711 +- 0.0044)*(X)
+(1.92 +- 0.67)*E-02*(1)

Analysis of Variance

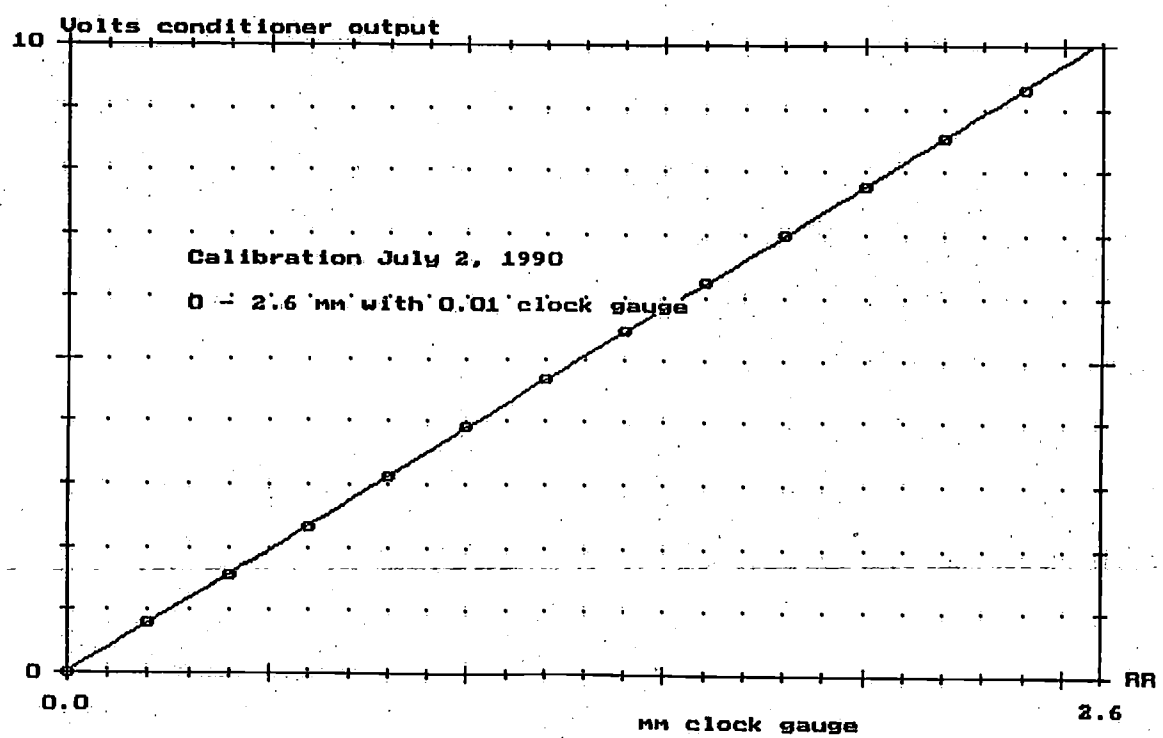
Sum of Squares	Value	Degr.Freedom	Variance
Total	4.9365E+02	14	
Due to regression	4.9365E+02	2	2.4682E+02
Residual	2.1010E-03	12	1.7508E-04

If the model is assumed to be correct, the estimated standard deviation of Y is 1.3232E-02 (absolute)

RelErr = (Yreg - Y)/(Yreg)

Point	X	Y	Yreg	Yreg-Y	RelErr(%)
1	0.000	0.000	0.019	0.019	100.000
2	0.200	0.794	0.793	-0.001	-0.068
3	0.400	1.562	1.568	0.006	0.363
4	0.600	2.335	2.342	0.007	0.295
5	0.800	3.128	3.116	-0.012	-0.381
6	1.000	3.911	3.890	-0.021	-0.530
7	1.200	4.666	4.665	-0.001	-0.030
8	1.400	5.437	5.439	0.002	0.034
9	1.600	6.228	6.213	-0.015	-0.241
10	1.800	7.000	6.987	-0.013	-0.182
11	2.000	7.763	7.762	-0.001	-0.019
12	2.200	8.536	8.536	-0.000	-0.003
13	2.400	9.284	9.310	0.026	0.279
14	2.600	10.080	10.084	0.004	0.042

RR-



MTS 632-02C-20 Ijking 0-0.5 mm

Function obtained:
Y = +(3.841 +- 0.013)*(X)
+(1.20 +- 0.40)*E-02*(1)

Analysis of Variance

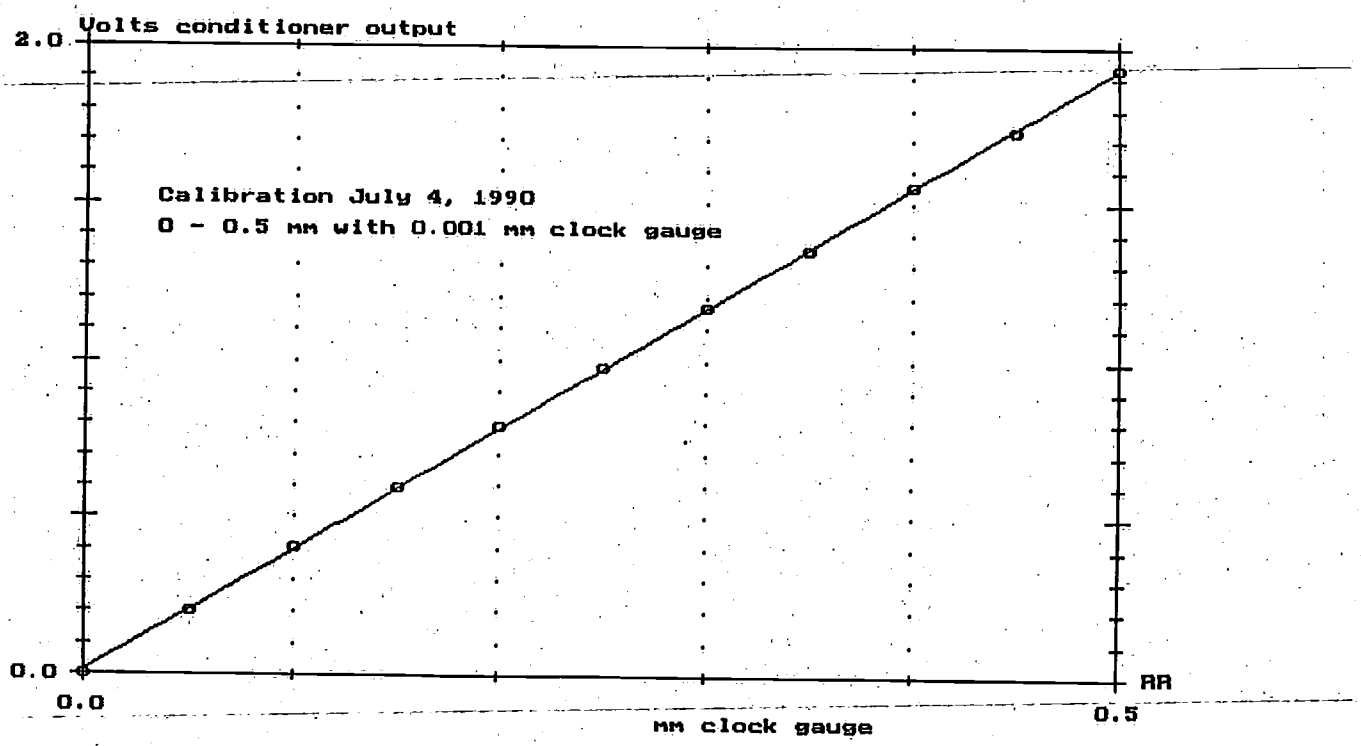
Sum of Squares	Value	Degr.Freedom	Variance
Total	1.4454E+01	11	
Due to regression	1.4453E+01	2	7.2267E+00
Residual	4.4141E-04	9	4.9045E-05

If the model is assumed to be correct, the estimated standard deviation of Y is 7.0032E-03 (absolute)

RelErr = (Yreg - Y)/(Yreg)

Point	X	Y	Yreg	Yreg-Y	RelErr(%)
1	0.000	0.000	0.012	0.012	100.000
2	0.050	0.201	0.204	0.003	1.471
3	0.100	0.402	0.396	-0.006	-1.504
4	0.150	0.591	0.588	-0.003	-0.495
5	0.200	0.789	0.780	-0.009	-1.136
6	0.250	0.976	0.972	-0.004	-0.393
7	0.300	1.171	1.164	-0.007	-0.582
8	0.350	1.350	1.356	0.006	0.462
9	0.400	1.551	1.548	-0.003	-0.173
10	0.450	1.733	1.740	0.007	0.423
11	0.500	1.930	1.932	0.002	0.125

-RR-



MTS 632-02C-20 Ijking 0-2.5 mm

Function obtained:
Y = +(3.8744 +- 0.0040)*(X)
+(1.39 +- 0.61)*E-02*(1)

Analysis of Variance

Sum of Squares	Value	Degr.Freedom	Variance
Total	4.9374E+02	14	
Due to regression	4.9374E+02	2	2.4687E+02
Residual	1.7355E-03	12	1.4462E-04

If the model is assumed to be correct, the estimated standard deviation of Y is 1.2026E-02 (absolute)

RelErr = (Yreg - Y)/(Yreg)

Point	X	Y	Yreg	Yreg-Y	RelErr(%)
1	0.000	0.000	0.014	0.014	100.000
2	0.200	0.786	0.789	0.003	0.359
3	0.400	1.560	1.564	0.004	0.238
4	0.600	2.330	2.339	0.009	0.368
5	0.800	3.122	3.113	-0.009	-0.273
6	1.000	3.903	3.888	-0.015	-0.376
7	1.200	4.666	4.663	-0.003	-0.059
8	1.400	5.440	5.438	-0.002	-0.034
9	1.600	6.229	6.213	-0.016	-0.257
10	1.800	7.002	6.988	-0.014	-0.201
11	2.000	7.766	7.763	-0.003	-0.041
12	2.200	8.537	8.538	0.001	0.008
13	2.400	9.287	9.313	0.026	0.275
14	2.600	10.082	10.087	0.005	0.054

RR-