TECHNICAL REPORT

METASYSTEMS AS

VERIFICATION OF OPERATION OF SHAFT POWER MEASUREMENT DEVICE "METAPOWER"

REPORT NO. BGN-R2199387

REVISION NO. 01

DET NORSKE VERITAS

TECHNICAL REPORT

Date of first issue: 21 December 1999	Project No.: 550 21 186
Approved by: Bård Espelid Head of Section	Organisational unit: Materials and Inspection Technology
Client: Metasystems AS P.O.B. 2634 N-5026 BERGEN	Client ref.: Marvin Storesund

DET NORSKE VERITAS AS
Division Nordic Countries
Operation & Maintenance Technology
Johan Berentsensvei 109-111,
P.O.Box 7400,
N-5020 BERGEN, Norway
Tel: +47 55 94 95 00
Fax: +47 55 94 95 60
http://www.dnv.com
Org.No: NO 945 748 931 MVA

Summary:

Det Norske Veritas AS has witnessed testing of “MetaPower”, a device used for measurement of power transmitted through rotating shafts.

The tests were carried out 7 and 10 December 1999 at the State College of Higher Education, Faculty of Engineering, in Bergen.

The results showed an very good correlation between the readings made with MetaPower and the reference equipment used by the State College. The readings and linear regression analysis are given in this report.

Report No.: BGN-R2199387	Subject Group:	
Report title: Verification of Operation of Shaft Power Measurement Device "MetaPower"		
Work carried out by: Erling Handal		
Work verified by: Vidar Åhjem		
Date of this revision: 1999-12-21	Rev. No.: 01	Number of pages: 10

Indexing terms

SHAFT POWER
CALIBRATION
SHAFTS

☒ No distribution without permission from the Client or responsible organisational unit

☐ Limited distribution within Det Norske Veritas

☐ Unrestricted distribution

Table of Content *Page*

Reference to part of this report which may lead to misinterpretation is not permissible.

1 CONCLUSIVE SUMMARY

Det Norske Veritas has on behalf of Metasystems AS verified the operation and accuracy of **MetaPower**, in comparison with a reference system delivered by Siemens. It was found statistically to be very good correlation between the measurements undertaken with MetaPower and the reference, covering the torque range from 5 to 40 Nm. Maximum measured deviation between measured value and calculated linear regression on MetaPower results was 1.5 and –1.4 Nm. The system did not show any significant deviations between readings at different rotation speeds ranging from 300 to 1500 RPM. There was also no significant variation between measurement series 1 and 2 taken two hours apart. Small deviations were found between measurements with opposite directions of rotation. This can be caused by variations in the static friction in the reference equipment.

As the G-modulus of the shaft was not actually measured, it is difficult to conclude about the absolute accuracy of the system. However, the measurements indicate that the system is within the same accuracy as the reference equipment.

2 INTRODUCTION

Det Norske Veritas AS was requested by Mr. Marvin Storesund, Metasystems AS, to verify the operation and accuracy of their newly developed system for measurement of shaft power, called MetaPower.

2.1 MetaPower working principle

The system is a digital measuring system using a laser beam for the detection of the shaft torque, the shaft RPM and consequently the transferred power.

The MetaPower basic working principle is shown in Figure 1 /1/.

Reference to part of this report which may lead to misinterpretation is not permissible.

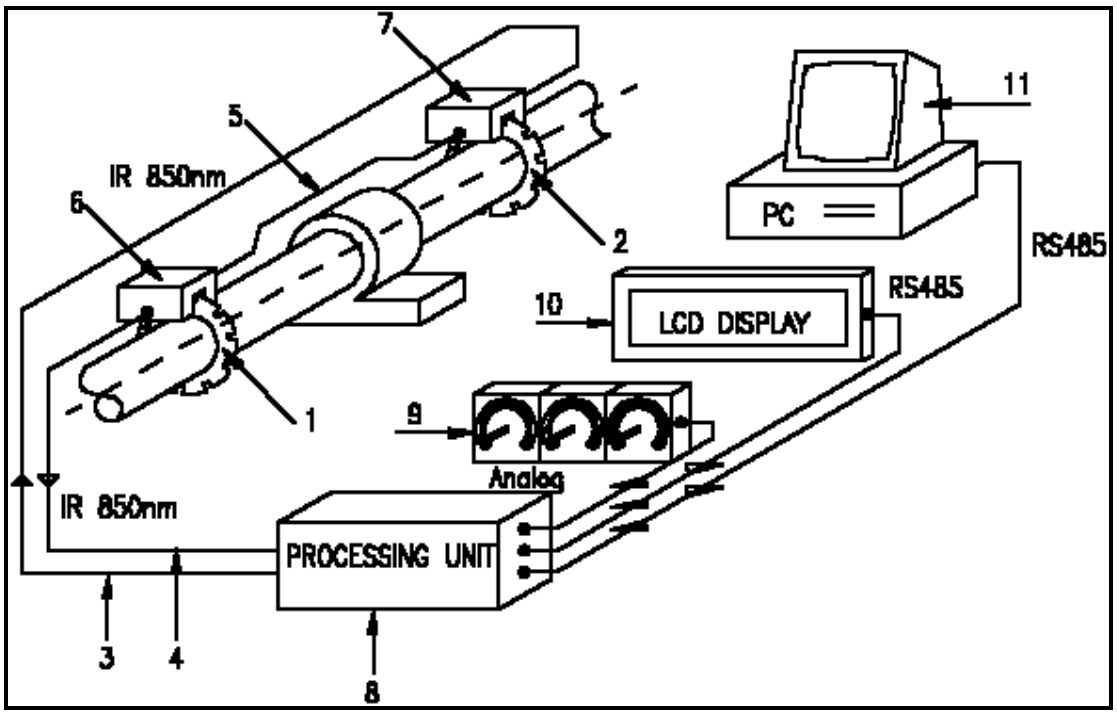

Figure 1 Working principle MetaPower

An IR beam is transmitted through optical fibre (3) from the VCSEL source mounted in the processing unit (8) to a special designed type of an optical fork (7). The IR beam in the air gaps is pulse modulated by the coding wheels (1) and (2) mounted on the rotating shaft at an adequate distance from each other. The generated pulse pattern will depend on the shaft speed. The optical fibre (5) transfer the IR pulses from the air gap in the first fork (7) for the second pulse modulation in the air gap of the next fork (6), coding wheel (1). The resulting IR light signal in the optical fibre (4) contains information of the torsional angle between the two cuts (1) and (2) of the rotating shaft. In addition the IR light signal contains information of the shaft rotation frequency. The IR signal is detected by a single light sensitive sensor in the processing unit (8). The modulated IR pulses are converted to electronic pulses for further processing.

3 REFERENCE EQUIPMENT

The reference equipment used to verify the reading from MetaPower was a system supplied from SIEMENS to the State College of Higher Education, Faculty of Engineering, in Bergen. The torque measurement equipment was marked as follows: *DMS-Hottinger 28/50 kg. No. G23065 Max 98,1 Nm, Eichgew (Standard weight) 46,642 Nm.* The linearity deviation was given as 0.1%, but it is not clear whether this is related to full scale or actual level. Resolution in range 0 – 20 Nm was 0.01 Nm, and 0.1 Nm in range 20 – 200 Nm.

The equipment was operated by Mr. Guttorm Lyngvær, employed by the State College.

An electrical engine, marked *64011, Siemens 3~ Mot. 1 LA5113-4AA70, 4 kW, 1435 ^{1}/mm* was used to run the shaft during measurements.

Reference to part of this report which may lead to misinterpretation is not permissible.

4 TEST SET-UP

The test set-up is shown in Figure 2, with the reference equipment shown to the left. The reference read-out unit is shown in Figure 3. When calculating the torque in the shaft, Metasystems AS used a G-modulus of 80 GPa. Distance between coding wheels was measured to 480 mm. Shaft diameter was 19.99 mm.

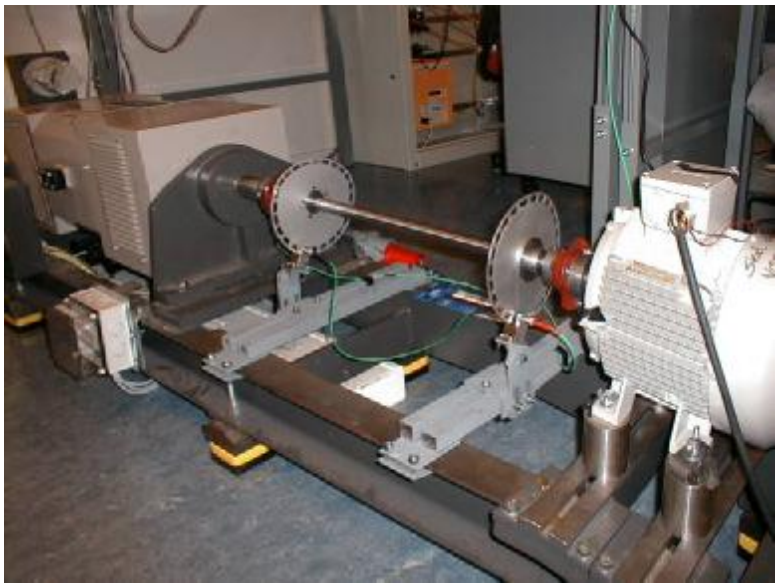

Figure 2 Test set-up

Figure 3 Reference read-out unit.

Reference to part of this report which may lead to misinterpretation is not permissible.

5 PROCEDURE

5.1 Zero-adjustment

The zero reading on the reference equipment was adjusted to within 0.2 Nm with the shaft running at approximately 600 RPM, both directions.

5.2 Calibration

Prior to measurements, the reference equipment was calibrated by means of a calibration lever with standard weight, according to the procedures given in the operating instructions /2/. The standard weight should give a reading of 46.642 Nm. The calibration was carried out whilst the shaft was rotating at approximately 600 RPM. The weight was applied in both directions, (clockwise and counter-clockwise) and the shaft was also run in both directions.

5.3 Zero-offset

While calibrating, the generator in the reference equipment was running the shaft. During measurements, however, the reference unit was used as a brake, giving torque in the shaft. This means that the internal friction in the reference unit was not detected during initial calibration. As shown in the analysis in section 6, there was detected an offset of between 3 and 4 Nm between the MetaPower and the reference equipment, which can be attributed to the internal friction. This was verified by measurements 10 December when the attached motor (to the right in Figure 2) was used to run the shaft, while the reference equipment was un-magnetised. These readings showed an offset of between 3 and 4 Nm.

5.4 Readings

The torque was applied in steps according to the test matrix in Table 1. Due to restriction on torque and rotation speed, some combinations were not applicable (NA). The torque was adjusted by using the reference equipment as a brake. The MetaPower system was set-up to take a reading using average measurements over a period of 5 seconds. When two subsequent MetaPower-readings where within 0.1 Nm (typically within 0.01 – 0.02 Nm) a reading was taken on the reference equipment. As the indicated value showed some variations, an average over a couple of seconds was recorded. The measurements were registered manually.

Table 1 Test matrix

RPM	Torque						
	5 Nm	10 Nm	15 Nm	20 Nm	25 Nm	30 Nm	40 Nm
300 RPM	√	√	√	√	NA	NA	NA
600 RPM	√	√	√	√	√	√	√
900 RPM	√	√	√	√	√	√	√
1200 RPM	√	√	√	√	√	√	√
1500 RPM	√	√	√	√	√	√	NA

Reference to part of this report which may lead to misinterpretation is not permissible.

6 RESULTS

The measurements described in the test matrix (Table 1) were carried out twice for each rotation direction, for a total of 124 readings. All readings are given in Appendix A. Standard linear regression analysis was carried out on the readings using an Excel spreadsheet. The data were either analysed together, or grouped according to rotation direction of the shaft, serial or rotation speed. A summary of the results is given in Table 2. The values in Table 2 can be explained as:

R^2	correlation coefficient (A value of 1 indicates perfect correlation)
A	scale coefficient
B	intercept coefficient
St. dev A	Standard deviation of scale coefficient
St. dev B	Standard deviation of intercept coefficient
n	number of readings used in the analysis

Using the coefficients ***A*** and ***B***, the relation between MetaPower reading and the reference equipment can be given as

MetaPower [Nm] = ***A*** * Reference [Nm] + ***B*** [Nm]

Table 2 Summary of results

Sub-set Analysis	R^2	A	B	St. dev. A	St. dev. B	n
All RPMs, both serials	0.999	1.00	-3.2	0.00	0.05	124
All RPMs, CW	0.997	0.98	-3.7	0.01	0.14	62
All RPMs, CCW	0.997	1.01	-3.4	0.01	0.16	62
All RPMs, serial 1	0.999	1.00	-3.0	0.00	0.07	62
All RPMs, serial 2	0.999	1.00	-3.5	0.00	0.07	62
Both serials 300 RPM	0.998	1.00	-3.6	0.01	0.16	16
Both serials 600 RPM	1.000	1.00	-3.2	0.00	0.10	28
Both serials 900 RPM	1.000	1.00	-3.2	0.00	0.10	28
Both serials 1200 RPM	1.000	1.00	-3.4	0.00	0.09	28
Both serials 1500 RPM	0.999	1.00	-2.8	0.01	0.12	24

As can be seen from the results, there is very good correlation between measurements undertaken with MetaPower and the reference equipment, indicated by a $\boldsymbol{R^2}$ close to 1.0. Also, the ***A*** value is close to 1.0, indicating that the G-modulus chosen (80 GPa) is correct.

This correlation is also evident from Figure 4, which shows all readings (both serials, for all RPMs) adjusted for the zero-offset, ***B***. This zero-offset of about 3 Nm is caused by the friction in

Reference to part of this report which may lead to misinterpretation is not permissible.

the reference equipment, as explained in paragraph 5.3, page 4. Figure 5 shows the same readings **not** adjusted for zero-offset. Maximum deviation between measured value and calculated linear regression was 1.5 and –1.4 Nm.

Readings for each RPM level are given in Figure 6 to Figure 10.

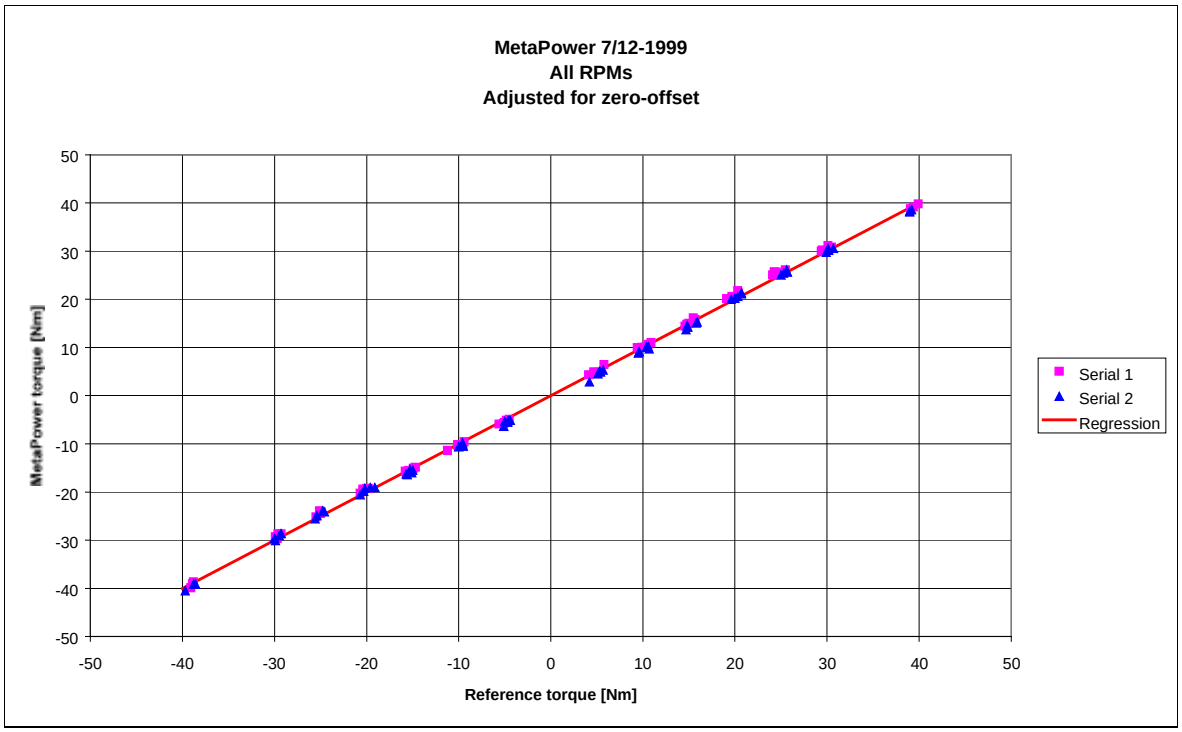

Figure 4 Results, all readings, corrected for zero-offset

Reference to part of this report which may lead to misinterpretation is not permissible.

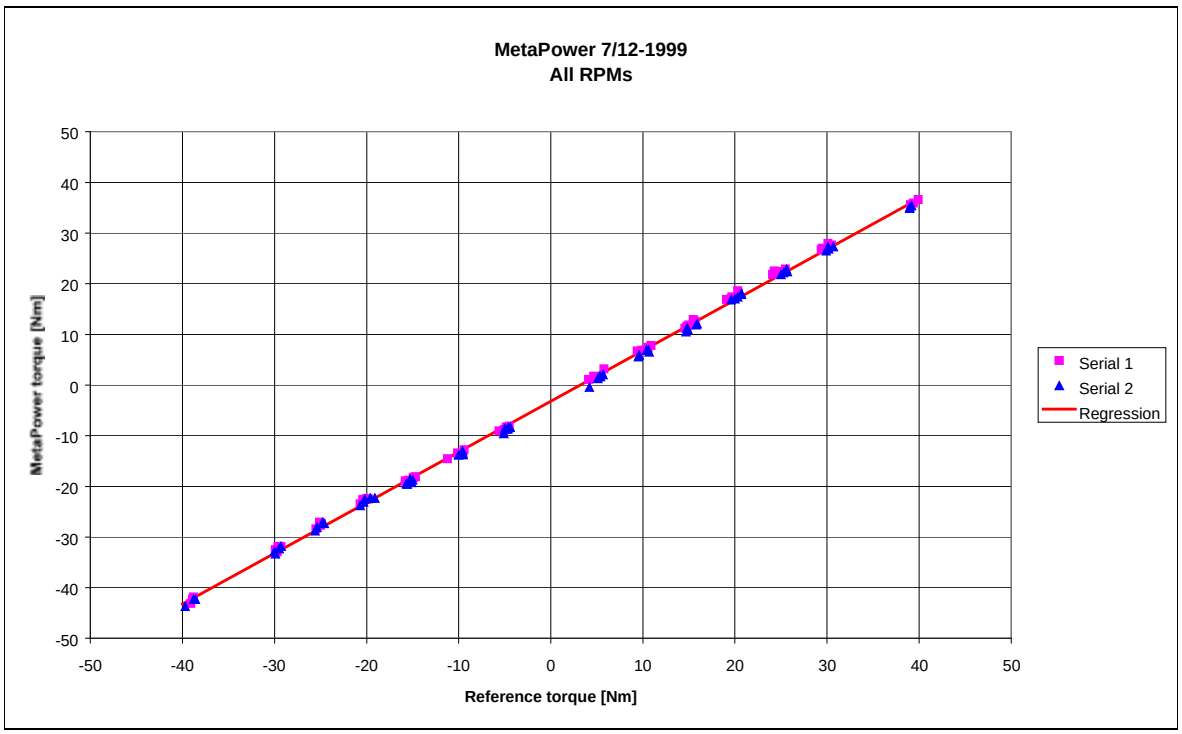

Figure 5 Results, all readings

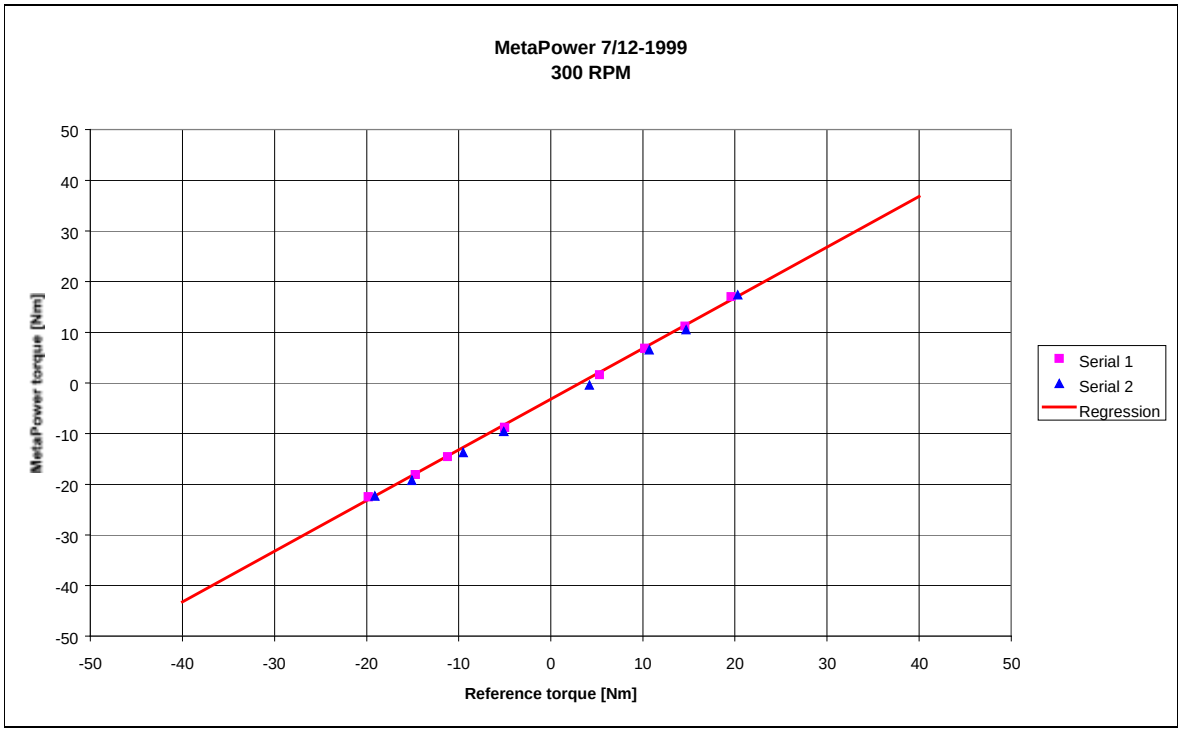

Figure 6 Both serials, 300 RPM

Reference to part of this report which may lead to misinterpretation is not permissible.

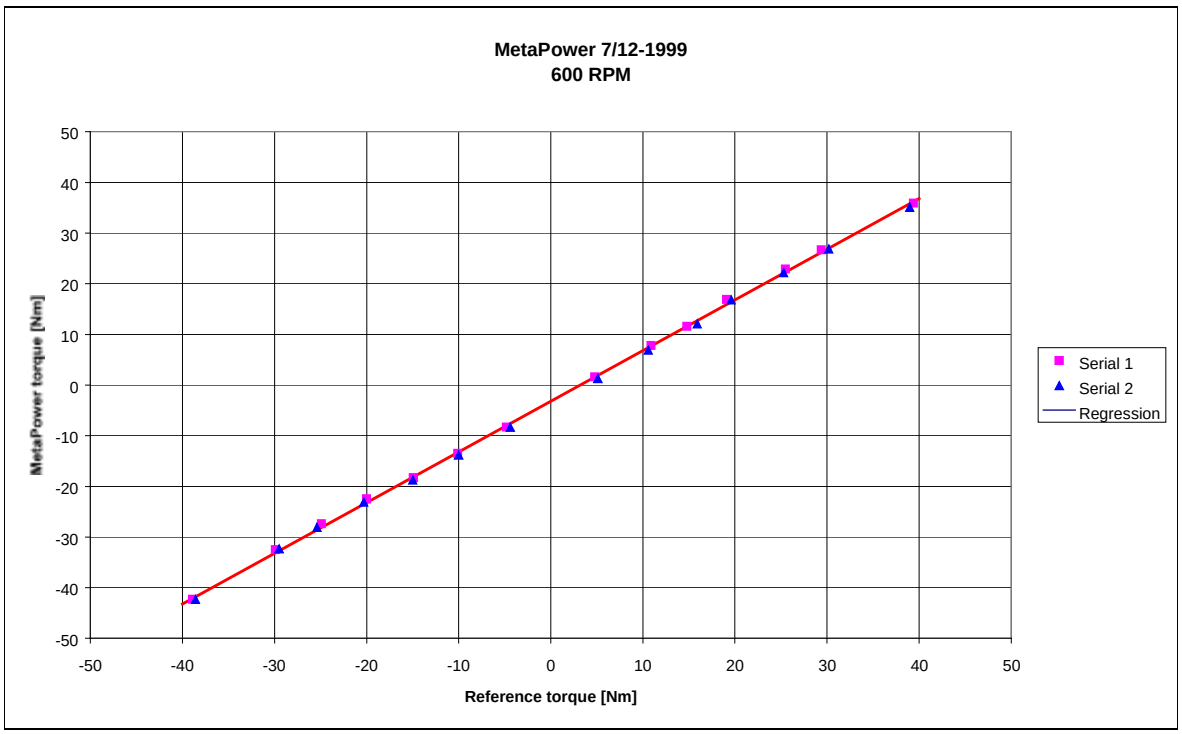

Figure 7 Both serials, 600 RPM

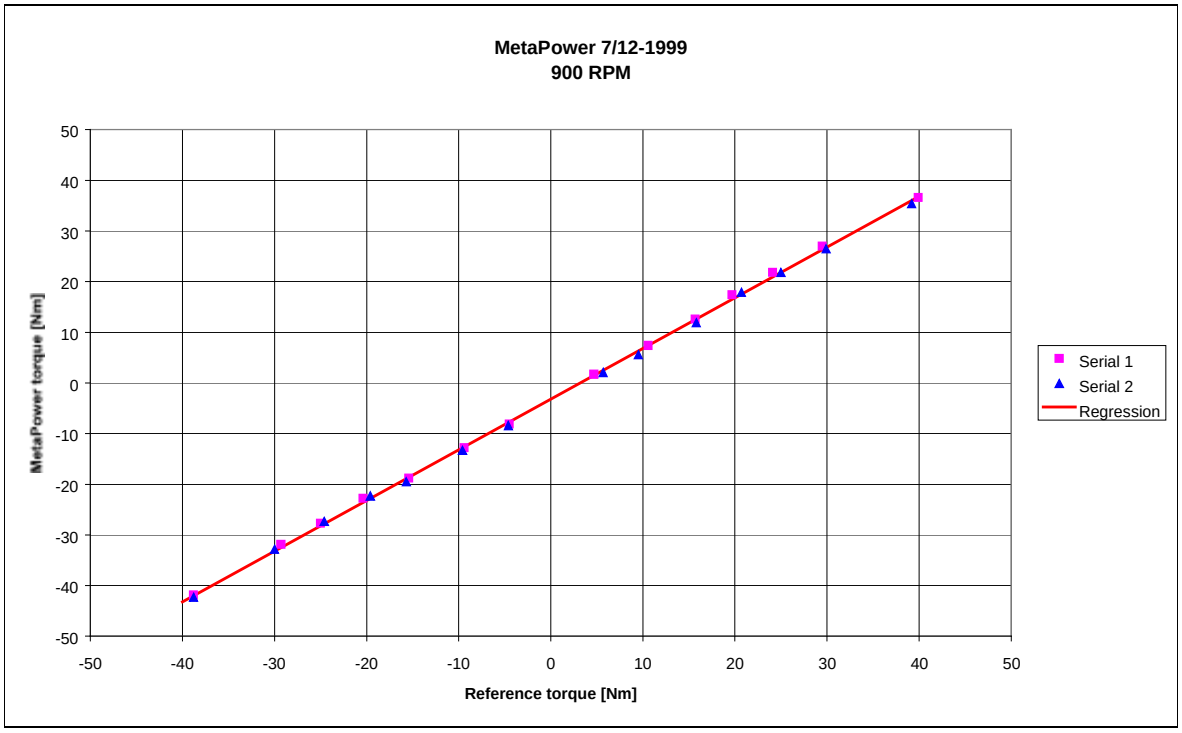

Figure 8 Both serials, 900 RPM

Reference to part of this report which may lead to misinterpretation is not permissible.

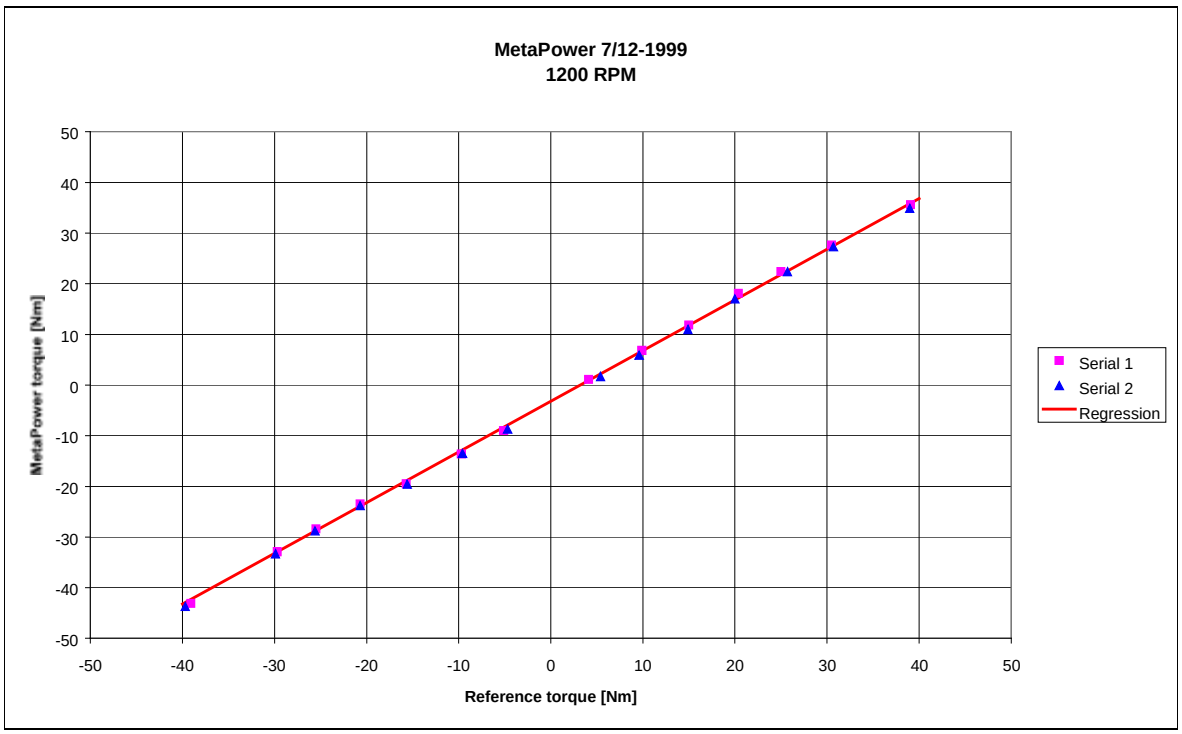

Figure 9 Both serials, 1200 RPM

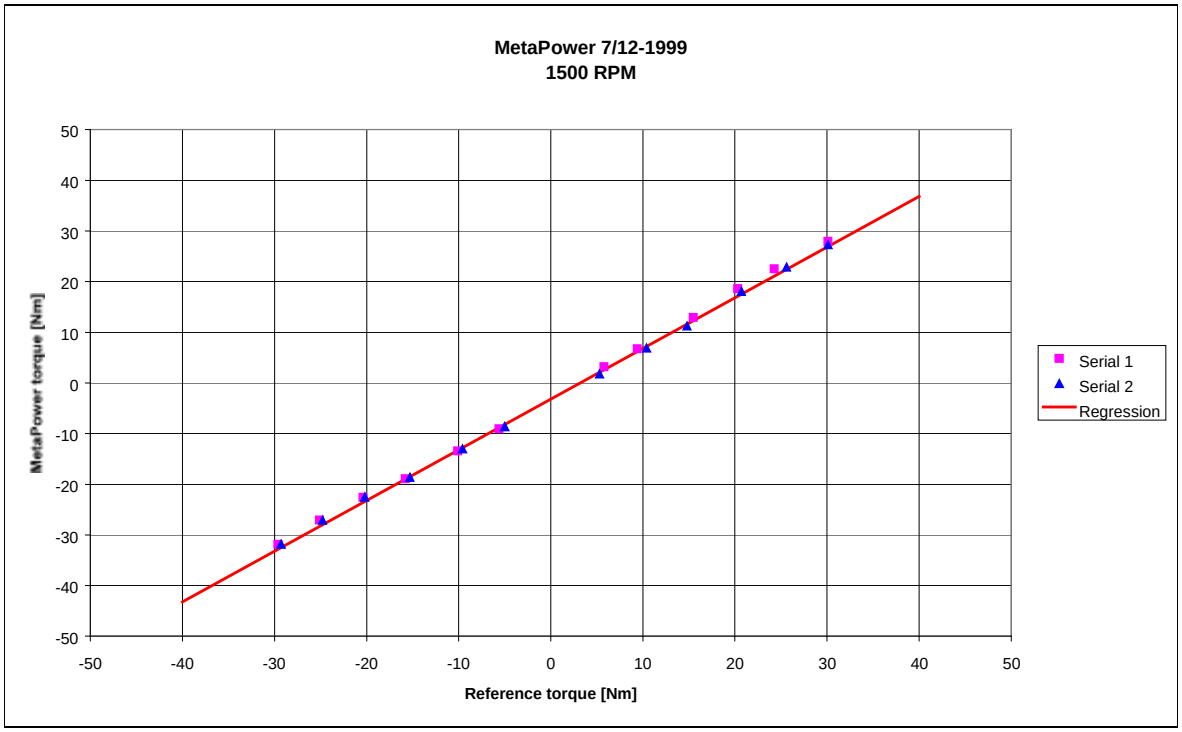

Figure 10 Both serials, 1500 RPM

Reference to part of this report which may lead to misinterpretation is not permissible.

7 REFERENCES

/1/ Metasystems Internet-site: http://www.metasystems-as.com/metapower.htm

/2/ SIEMENS “Operation Instruction Speed/Torque measuring unit Order No. 2GA1910-1/ 2GA1914-1”

- o0o -

Reference to part of this report which may lead to misinterpretation is not permissible.

APPENDIX
A
MEASUREMENT DATA

Table A-1 Measurements serial 1, counter clockwise

Time	Serial	Direction	Reference		MetaPower	
			RPM	Torque [Nm]	RPM	Torque [Nm]
10:44:00	1	CCW	306	5.3	307	1.6
10:45:00	1	CCW	307	10.2	307	6.8
10:48:00	1	CCW	307	14.6	307	11.2
10:50:00	1	CCW	306	19.6	307	17.0
10:52:00	1	CCW	605	4.8	606	1.6
10:53:00	1	CCW	605	10.9	606	7.8
10:53:30	1	CCW	605	14.8	606	11.6
10:54:00	1	CCW	605	19.1	606	16.9
10:55:00	1	CCW	605	25.5	606	22.9
10:57:00	1	CCW	605	29.4	606	26.7
10:57:30	1	CCW	605	39.4	606	35.9
11:00:00	1	CCW	900	4.7	902	1.7
11:00:30	1	CCW	900	10.6	902	7.4
11:01:00	1	CCW	900	15.7	902	12.6
11:01:30	1	CCW	900	19.7	902	17.4
11:02:00	1	CCW	900	24.1	902	21.8
11:02:30	1	CCW	900	29.5	902	27.0
11:03:00	1	CCW	900	39.9	902	36.6
11:05:00	1	CCW	1201	4.1	1203	1.1
11:05:30	1	CCW	1200	9.9	1202	6.8
11:06:00	1	CCW	1200	15.0	1202	11.8
11:06:30	1	CCW	1200	20.4	1202	18.1
11:07:00	1	CCW	1200	25.0	1202	22.4
11:07:30	1	CCW	1200	30.5	1202	27.6
11:08:00	1	CCW	1200	39.1	1202	35.6
11:09:00	1	CCW	1502	5.8	1505	3.2
11:10:00	1	CCW	1502	9.4	1505	6.7
11:10:30	1	CCW	1502	15.5	1505	12.9
11:11:00	1	CCW	1502	20.3	1505	18.6
11:12:00	1	CCW	1502	24.3	1505	22.5
11:13:00	1	CCW	1502	30.1	1505	27.9

Table A-2 Measurements serial 1, clockwise

Time	Serial	Direction	Reference		MetaPower	
			RPM	Torque [Nm]	RPM	Torque [Nm]
11:19:00	1	CW	307	-5.0	307	-8.8
11:20:00	1	CW	307	-11.2	307	-14.6
11:20:30	1	CW	306	-14.7	307	-18.1
11:21:00	1	CW	306	-19.8	307	-22.5
11:23:00	1	CW	605	-4.8	606	-8.3
11:24:00	1	CW	605	-10.1	606	-13.5
11:24:30	1	CW	605	-14.9	606	-18.3
11:25:00	1	CW	605	-20.0	606	-22.5
11:26:00	1	CW	605	-24.9	606	-27.4
11:26:30	1	CW	605	-29.9	606	-32.5
11:28:00	1	CW	605	-38.9	606	-42.3
11:30:00	1	CW	904	-4.5	905	-8.1
11:34:00	1	CW	904	-9.4	905	-12.8
11:34:30	1	CW	904	-15.4	905	-18.8
11:35:00	1	CW	904	-20.4	905	-22.8
11:36:00	1	CW	904	-25.0	905	-27.7
11:36:30	1	CW	904	-29.3	905	-31.9
11:37:00	1	CW	904	-38.8	905	-41.9
11:40:00	1	CW	1200	-5.1	1202	-9.0
11:40:30	1	CW	1201	-9.7	1202	-13.6
11:41:00	1	CW	1201	-15.7	1203	-19.5
11:42:00	1	CW	1201	-20.7	1203	-23.5
11:42:30	1	CW	1201	-25.5	1203	-28.4
11:43:00	1	CW	1201	-29.7	1203	-32.9
11:43:30	1	CW	1200	-39.1	1202	-43.1
11:46:00	1	CW	1499	-5.6	1502	-9.1
11:46:30	1	CW	1500	-10.1	1502	-13.4
11:47:00	1	CW	1499	-15.8	1502	-18.9
11:47:30	1	CW	1500	-20.4	1502	-22.6
11:48:00	1	CW	1500	-25.1	1502	-27.1
11:48:30	1	CW	1500	-29.6	1502	-31.9

Table A-3 Measurements serial 2, clockwise

Time	Serial	Direction	Reference		MetaPower	
			RPM	Torque [Nm]	RPM	Torque [Nm]
12:44:00	2	CW	303	5.1	303	-9.6
12:45:00	2	CW	303	-9.5	303	-13.7
12:45:30	2	CW	303	-15.1	303	-19.2
12:46:00	2	CW	303	-19.1	303	-22.3
12:49:00	2	CW	599	-4.4	600	-8.3
12:50:00	2	CW	599	-10.0	600	-13.8
12:50:30	2	CW	600	-15.0	600	-18.7
12:51:00	2	CW	599	-20.3	600	-23.1
12:51:30	2	CW	600	-25.4	600	-28.1
12:52:00	2	CW	599	-29.5	600	-32.3
12:52:30	2	CW	599	-38.6	600	-42.3
12:55:00	2	CW	903	-4.6	904	-8.4
12:56:00	2	CW	903	-9.6	905	-13.3
12:56:30	2	CW	903	-15.7	905	-19.5
12:57:00	2	CW	903	-19.6	905	-22.3
12:57:30	2	CW	903	-24.6	905	-27.3
12:58:00	2	CW	903	-30.0	905	-32.8
12:58:30	2	CW	903	-38.8	905	-42.3
13:00:00	2	CW	1201	-4.7	1203	-8.7
13:00:30	2	CW	1201	-9.6	1204	-13.5
13:01:00	2	CW	1201	-15.6	1204	-19.6
13:01:30	2	CW	1201	-20.7	1204	-23.8
13:02:00	2	CW	1201	-25.6	1204	-28.8
13:02:30	2	CW	1201	-29.9	1204	-33.3
13:03:00	2	CW	1201	-39.7	1204	-43.7
13:05:00	2	CW	1500	-5.0	1503	-8.6
13:05:30	2	CW	1500	-9.6	1503	-13.0
13:06:00	2	CW	1500	-15.3	1503	-18.6
13:06:30	2	CW	1500	-20.2	1503	-22.5
13:07:00	2	CW	1500	-24.8	1503	-27.1
13:07:30	2	CW	1500	-29.3	1503	-31.8

Table A-4 Measurements serial 2, counter clockwise

Time	Serial	Direction	Reference		MetaPower	
			RPM	Torque [Nm]	RPM	Torque [Nm]
13:16:00	2	CCW	299	4.2	299	-0.4
13:17:00	2	CCW	299	10.7	299	6.5
13:18:00	2	CCW	299	14.7	299	10.5
13:18:30	2	CCW	299	20.3	299	17.4
13:20:00	2	CCW	601	5.1	603	1.3
13:21:00	2	CCW	602	10.6	603	6.9
13:21:30	2	CCW	602	15.9	603	12.1
13:22:00	2	CCW	602	19.6	603	16.8
13:22:30	2	CCW	602	25.3	603	22.2
13:23:00	2	CCW	602	30.2	603	26.9
13:23:30	2	CCW	602	39.0	603	35.1
13:24:00	2	CCW	902	5.7	904	2.1
13:25:00	2	CCW	902	9.5	904	5.6
13:25:30	2	CCW	902	15.8	904	11.9
13:26:00	2	CCW	902	20.7	904	17.9
13:26:30	2	CCW	902	25.0	904	21.8
13:27:00	2	CCW	902	29.9	904	26.5
13:27:30	2	CCW	902	39.2	904	35.4
13:29:00	2	CCW	1199	5.4	1201	1.7
13:29:30	2	CCW	1198	9.6	1200	5.9
13:30:00	2	CCW	1197	14.9	1199	11.0
13:32:00	2	CCW	1197	20.0	1199	17.0
13:32:30	2	CCW	1197	25.7	1199	22.4
13:33:00	2	CCW	1197	30.7	1198	27.3
13:33:30	2	CCW	1196	39.0	1198	34.9
13:35:00	2	CCW	1504	5.3	1506	1.8
13:35:30	2	CCW	1503	10.4	1506	6.9
13:36:00	2	CCW	1503	14.8	1506	11.3
13:36:30	2	CCW	1503	20.7	1506	18.1
13:37:00	2	CCW	1503	25.6	1506	22.9
13:37:30	2	CCW	1503	30.1	1506	27.3

- o0o -