



CERTIFICATION PACK

CUSTOMER:	MONTERAY BAY AQUARIUM RES, INST
CUSTOMER PO:	PO82110258
PRODUCT DESCRIPTION:	MAIN ROV LIFT CABLE
FIBRON PART NO:	RM0058
FIBRON PROJECT NO:	18950

00	21/10/21	As Built	SLC	SLC
Rev.	Issue date	Revision description	Prepared	Checked



CERTIFICATION PACK

MAIN INDEX

SECTION	DESCRIPTION
1	UMBILICAL DESIGN
2	CERTIFICATION
3	TESTING



CERTIFICATION PACK

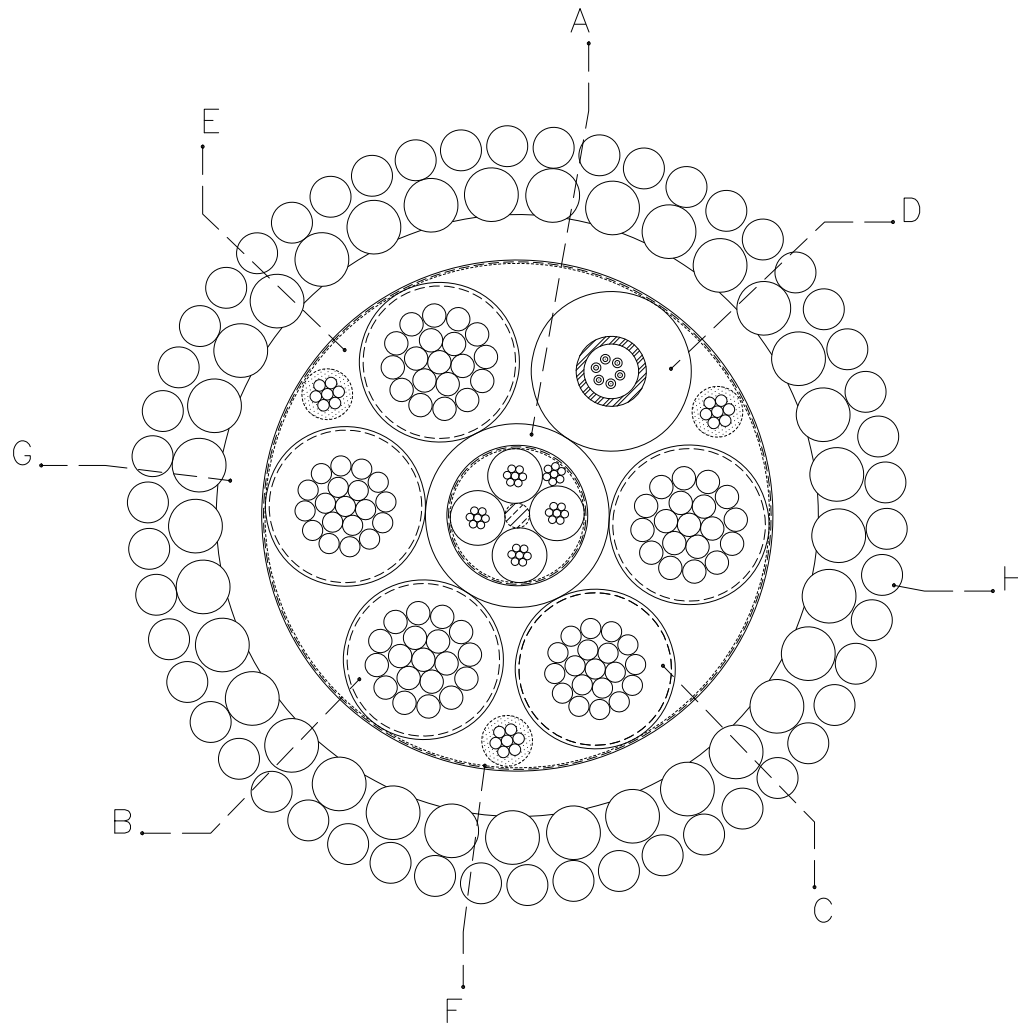
SECTION 1

UMBILICAL DESIGN AND MANUFACTURE SUB-INDEX

SECTION	DESCRIPTION
1.1	CROSS SECTION DRAWING

1.1

Rev:	Date:	Description:	Drawn:	Check:
00	11/03/21	Initial release.	S.McQ.	D.G.H.
01	21/06/21	Minor amendment to description.	S.McQ.	D.G.H.



Nominal Mechanical Characteristics:

Finished diameter:	20.0 mm $\pm$ 0.3 mm.
Weight in air:	1,260 kg/km.
Weight in sea-water (note 1):	940 kg/km.
Minimum recommended bend radius:	400 mm (dynamic).
Minimum breaking load:	180 kN.
Maximum safe working load:	60 kN.

Note 1) Assumed sea-water density: 1,026 kg/m³.

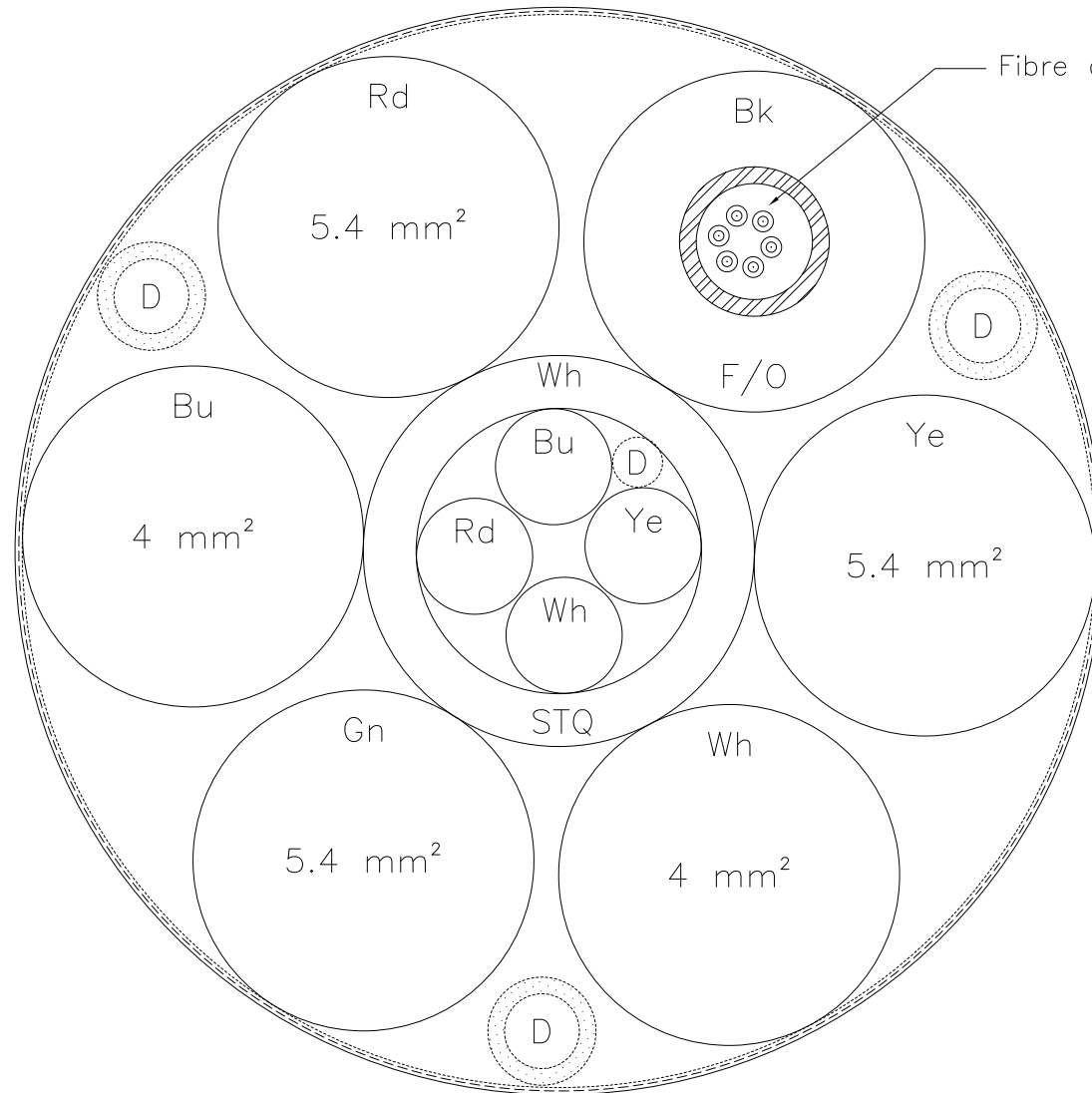
Assembly Detail:

- A) 1 off screened and jacketed 0.22 mm² stranded plain copper twisted signal quad.
Screen comprises copper/polyester laminate tape and tinned copper drain wire.
 - Conductor resistance: 90 Ω /km max. @ 20°C.
 - Voltage rating (U_0/U): 0.3/0.5 kV_{rms} max.
 - Insulation resistance: 1 G Ω .km min @ 0.5 kV_{dc}.
- B) 3 off dual layer insulated 5.4 mm² stranded plain copper power conductors.
 - Conductor resistance: 3.7 Ω /km max. @ 20°C.
 - Voltage rating (U_0/U): 2.4/4.2 kV_{rms} max.
 - Insulation resistance: 1 G Ω .km min @ 4.2 kV_{dc}.
- C) 2 off dual layer insulated 4 mm² stranded plain copper power conductors.
 - Conductor resistance: 4.9 Ω /km max. @ 20°C.
 - Voltage rating (U_0/U): 2.4/4.2 kV_{rms} max.
 - Insulation resistance: 1 G Ω .km min @ 4.2 kV_{dc}.
- D) 1 off jacketed, gel filled stainless steel tube containing 6 x single-mode optical fibres.
 - Attenuation: 0.4 dB/km max. @ 1,550 nm.
 - 0.6 dB/km max. @ 1,310 nm.
- E) Assembly voids filled with silicone rubber compound.
- F) Collective screen comprising copper/polyester laminate tape and 3 x semi-conductive coated 0.5 mm² plain copper drain wires.
- G) Polyethylene sheath, (1.2 mm nominal thickness).
 - Diameter: 15.4 mm $\pm$ 0.3 mm.
- H) Two dressed, contra-helical layers of high tensile galvanised steel wire armour.

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Fibron Unit C, RD Park, Stephenson Close, Hoddesdon, Herts, EN11 0BW +44 (0) 1992 471 444 www.fibron.com		DESCRIPTION: R.O.V. CABLE	
SCALE: NTS	DRAWING No: RM0058	SHEET: 1 of 2	
TEMPLATE: FIBRON UK A4 X-SECT			

Colour Code/Lay-up Configuration:—

Rev:	Date:	Description:	Drawn:	Check:
00	11/03/21	Initial release.	S.McQ.	D.G.H.
01	21/06/21	Minor amendment to description.	S.McQ.	D.G.H.



Fibre colours: Bu, Bn, Gn, Gy, Og, Wh.

Key:—

Bk: Black.
Bu: Blue.
Bn: Brown.
Gn: Green.
Gy: Grey.
Og: Orange.
Rd: Red.
Wh: White.
Ye: Yellow.

D: Drain wire location.

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SCALE: NTS		DRAWING No: RM0058		SHEET: 2 of 2	



CERTIFICATION PACK

SECTION 2

CERTIFICATION

SUB-INDEX

SECTION	DESCRIPTION
2.1	TEST CERTIFICATES
2.2	VOLTAGE ENDURANCE PROCEDURE AND REPORT
2.3	HYPERBARIC PRESSURE TEST PROCEDURE AND REPORT
2.4	TTI TESTING

2.1

ELECTRICAL TEST CERTIFICATE

Product: RM0058 Client: MBARI

P/O No: PO#2110258

Length(s): 5000M

W/O No: 18950

Certificate No: 25508

ROUTINE TESTS

Component	Conductor Resistance (Ω /km max. @ 20°C)	Insulation Resistance (G Ω .km min. @ kV _{dc})		
		Core / Core	Core / Ground*	Screen / Screen
0.5 mm ² STQ (x 1):	90	1 @ 0.5	1 @ 0.5	0.1 @ 0.5
4 mm ² (x 2):	4.9	1 @ 5.5	1 @ 3.2	----
5.4 mm ² (x 3):	3.7	1 @ 5.5	1 @ 3.2	----

* Ground incorporates 0.5 mm² drain wires, F/O tube & armour.

ADDITIONAL TESTS

Component	Test Description	Test Parameter(s)
4 mm ² (x 2):	HV core/core.	5.5 kV _{dc} for 5 min [†] .
	HV core/ground*.	3.2 kV _{dc} for 5 min [†] .
5.4 mm ² (x 3):	HV core/core.	5.5 kV _{dc} for 5 min [†] .
	HV core/ground*.	3.2 kV _{dc} for 5 min [†] .
** HV performed prior to IR above. **		
SM fibre (x 6):	Attenuation @ 1,310 nm.	0.6 dB/km max.
	Attenuation @ 1,550 nm.	0.4 dB/km max.

[†] 5 mm² cores have been high voltage tested at 9.5 kV_{dc} for 5 minutes and insulation resistance tested at 5.0 kV_{dc} for 1 minute during manufacture.

We certify that the product(s) detailed hereon have been inspected and tested / conform in all respects with Fibron specification(s) and, unless otherwise stated, conform in all respects with the requirements of the contract or order.

Signed: [Signature]
For Fibron.



Dated: 23 / 08 / 21

Signed: _____
For third party witness (where relevant).

2.2

DOCUMENTATION FRONT SHEET				
Document Category: Voltage Endurance Procedure.	Fibron Order: 18950	Total Pages: 12	Document Number: WARM0058-18950A	
02	24/09/21	Test results added to report	P.J.K	S.McQ.
01	17/08/21	Amend cable description to umbilical throughout.	S.M ^c Q.	D.G.H.
00	23/07/21	Initial Issue.	S.M ^c Q.	D.G.H.
Rev:	Date:	Reason for issue:	Prepared:	Checked:
Voltage Endurance. Procedure and Report.  R.O.V. Umbilical Umbilical Part Number: RM0058 Purchase Order: PO#2110258 Works Order No: 18950				
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1. Introduction.

1.1 Purpose and Scope.

Fibron Ltd. has been contracted by Monterey Bay Aquarium Research Institute (MBARI) to manufacture two R.O.V. umbilicals – part number RM0058. This document details the test parameters that will be used to carry out the voltage endurance test. This is to verify the compliance of the umbilical regarding the outline test regime set in the technical bid.

Abbreviations:

- FAT - Factory acceptance test.
- P/N - Part number.
- QC - Quality control.
- QP - Quality plan.
- VE - Voltage endurance.

1.2 References.

Following documents to be used as the basis for the information in this procedure:

- /1/ RM0058 - Cross sectional drawing of R.O.V. umbilical.
- /2/ SQ30978, rev:02 - Fibron Technical & Commercial Bid Document.

2. Test Parameters.

Umbilical part number:	RM0058
Umbilical serial no:	82428 (from contract/work-sheets).
Umbilical drawing ref:	RM0058 latest revision.
Sample length:	10 x 5 m samples of 5.4mm ² insulated conductor. 10 x 5 m samples of 4.0mm ² insulated conductor.
Monitoring required:	Electrical monitoring.
3 rd party witness:	MBARI representatives to witness test (optional).

3. General

Voltage endurance testing will be used to determine the initial quality and expected reliability of the insulated ROV conductors.

The voltage breakdown of the insulation of a cable is random for a ramp voltage test and the time to breakdown is random for a constant voltage test. The random nature of the failures follows the well-defined statistical distribution of Weibull. Thus, the results from the testing will be treated using this analysis.

3.1 Umbilical Samples

10 x 5 m samples of 5.4mm² insulated conductor and 10 x 5 m samples of 4.0mm² insulated conductor will be used to perform the voltage breakdown tests.

3.2 Testing

Short term breakdown test shall be assessed. As the voltage to be applied is AC, the Fibron 0 to 50 kV AC transformer with its interlocked safety cage shall be used.

3.3 Short-Term Break Down Tests

Each 5m core length will be stripped both ends so that approximately 1 cm of copper conductor is exposed. The insulated core will be immersed in an earthed stainless steel water bath containing a saline solution. The stripped ends of the core will be held out of the water using a support stand to prevent flash over/break down at the ends. Thus, there will be approximately 5 m of insulated conductor tested.

The voltage will be applied in the form of a step voltage break down. The voltage will be applied between the insulated core and the earthed water bath, one core at a time. The voltage will be raised in 2 kV_{ac} (50 Hz) steps and held for 60 secs at each step, until the conductor insulation breaks down.

The following tables will be completed during the test:

5.4mm² POWER CORES

Core Identification:	Withstand test voltage (kV AC):	Comments
RED 1	24	Failed after 6s of the 24 kV hold period.
RED 2	24	Failed after 24s of 24 kV hold period.
RED 3	18	18 kV hold completed, failed during voltage increase to 20 kV hold period.
RED 4	22	Failed after 30s of 22 kV hold period.
GREEN 1	22	22 kV hold completed, failed during voltage increase to 24 kV hold period.
GREEN 2	22	Failed after 51s of 22 kV hold period
GREEN 3	20	Failed after 12s of 20 kV hold period
YELLOW 1	26	Failed after 21s of 26 kV hold period
YELLOW 2	24	Failed after 3s of 24 kV hold period
YELLOW 3	18	Failed after 6s of 18 kV hold period

TABLE 1

4.0mm² POWER CORES

Core Identification:	Withstand test voltage (kV AC):	Comments
BLUE 1	16	Failed at start of 16 kV hold period.
BLUE 2	16	Failed after 12s of 16 kV hold period.
BLUE 3	22	Failed after 24s of 22 kV hold period.
BLUE 4	18	Failed after 12s of 18 kV hold period.
BLUE 5	16	Failed after 12s of 16 kV hold period.
WHITE 1	12	12 kV hold completed, failed during voltage increase to 14 kV hold period.
WHITE 2	24	24 kV hold completed, failed during voltage increase to 26 kV hold period.
WHITE 3	16	16 kV hold completed, failed during voltage increase to 18 kV hold period.
WHITE 4	20	Failed at start of 16 kV hold period.
WHITE 5	18	Failed after 48s of 18 kV hold period.

TABLE 2**3.4 Treatment of Short-term Break Down Values**

The above results will be reviewed using the Weibull analysis. This is accomplished by first ranking the failures from smallest to largest and noting the rank order. The tables below will be populated after completion of section 3.3:

5.4mm² POWER CORES

Voltage break down: (kV)	Electrical Stress at break down: (kV/mm)	Rank Order:	<i>P_r</i>
18	39.3	1	0.067
18	39.3	2	0.163
20	43.7	3	0.260
22	48.1	4	0.356
22	48.1	5	0.452
22	48.1	6	0.548
24	52.5	7	0.644
24	52.5	8	0.740
24	52.5	9	0.837
26	56.8	10	0.933

TABLE 3

4.0mm² POWER CORES

Voltage break down: (kV)	Electrical Stress at break down: (kV/mm)	Rank Order:	P_f :
12	20.6	1	0.067
16	27.5	2	0.163
16	27.5	3	0.260
16	27.5	4	0.356
16	27.5	5	0.452
18	30.9	6	0.548
18	30.9	7	0.644
20	34.3	8	0.740
22	37.8	9	0.837
24	41.2	10	0.933

TABLE 4

The probability of failure (P_f) is estimated from the rank order. P_f is estimated using the Bernard approximation, using the equation below for a test population ≥ 10 :

$$P_f = (i-0.3)/(N + 0.4)$$

Where i = rank order.

N is the sample size, i.e. 10 in this case, and is recommended by the report CIGRE WG 21-09 Document 88-22. The title of the Bernard report is “*Applications of Weibull Distribution to the Study of Power Cable Insulation*”.

The values in the table will be modelled using a Weibull analysis to allow the probability of a failure occurring at the working voltage to be predicted. The Weibull cumulative distribution function is transformed so that it appears in the familiar form of a straight line. The voltage breakdown data is entered into the model and the output, in graphical format, is shown in Appendix A.

The Weibull β (or shape) parameter comes directly from the slope of the line, the α (or characteristic life) parameter is calculated as follows

$$\alpha = e^{-\left(\frac{b}{\beta}\right)}$$

where b is the intercept with the Y-axis.

4. Analysis of the Weibull Plots

From the graphs the voltage stresses at 63% probability of failure (η) are:

5.4mm² power cores – 60.64 kV/mm

4.0mm² power cores – 33.07 kV/mm

The operating stress of the 5.4mm² core at a core to earth voltage (U_0) of 2.4 kV AC is 5.2 kV/mm.

From the Weibull probability graph for the 5.4mm² power core the probability of failure at this operating stress is negligible.

The operating stress of the 5.4mm² core at a core to earth voltage ($4 \times U_0$) of 9.6 kV AC is 21 kV/mm.

From the Weibull probability graph for the 5.4mm² power core the probability of failure at this operating stress is 0.05%.

The operating stress of the 4.0mm² core at a core to earth voltage (U_0) of 2.4 kV AC is 4.1 kV/mm.

From the Weibull probability graph for the 4.0mm² power core the probability of failure at this operating stress is negligible.

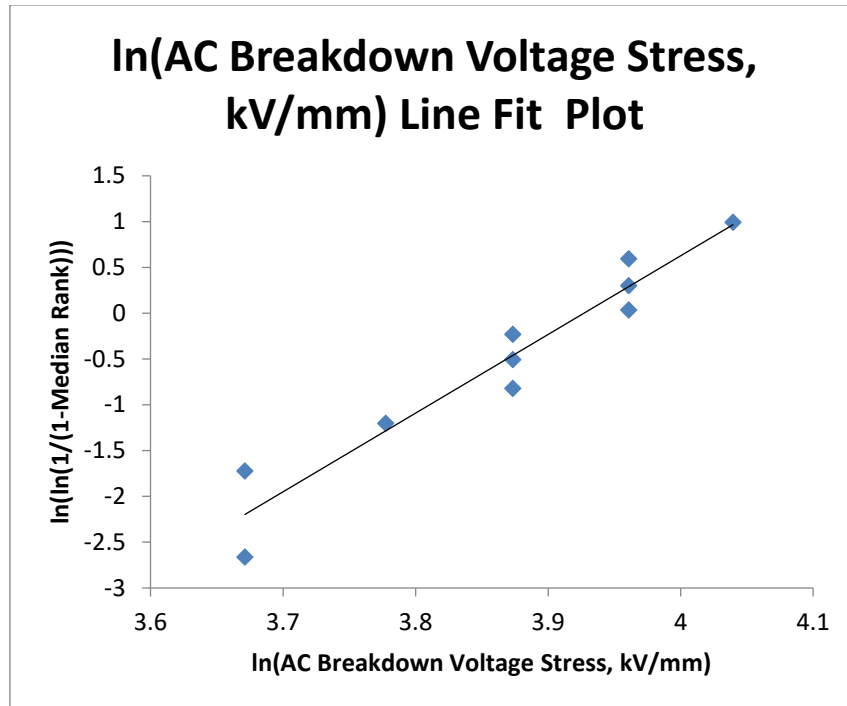
The operating stress of the 4.0mm² core at a core to earth voltage ($4 \times U_0$) of 9.6 kV AC is 16.5 kV/mm. From the Weibull probability graph for the 4.0mm² power core the probability of failure at this operating stress is 2.29%.

5. Weibull Distribution

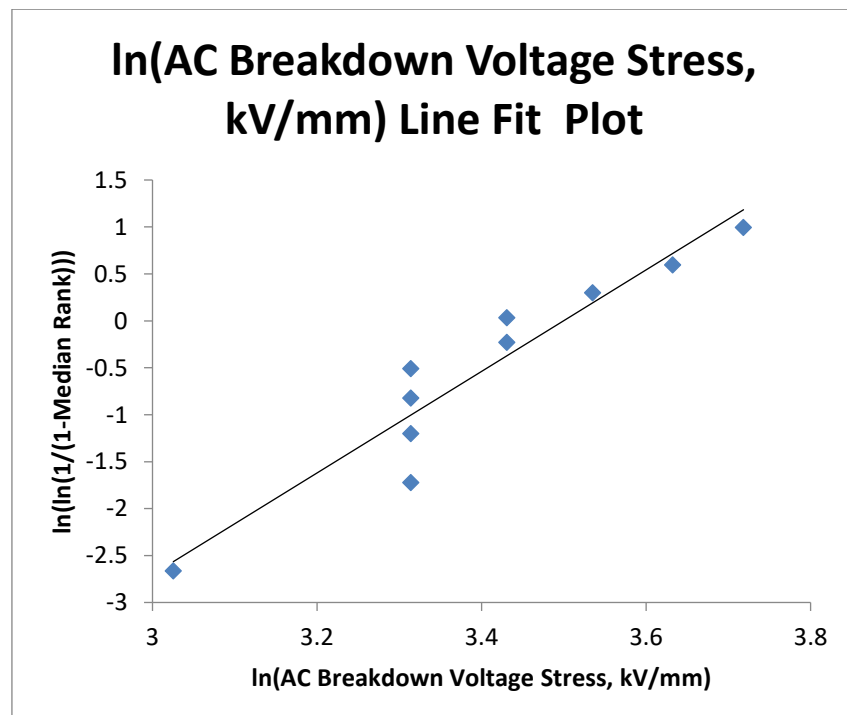
Weibull analysis is an important tool in assessing the suitability of a power core to operate successfully at a set operating voltage. Although in this analysis only short time (step) breakdown voltage testing has been carried out, (note: long term break testing is carried out over years), the short-term breakdown tests show how much safety factor/margin there is. It can be seen from the short-term breakdown test results that the probability of a breakdown at the power core operating stress is extremely low (negligible).

6. Appendix A - Weibull Probability Distribution

5.4mm² Power Cores



4.0mm² Power Cores



Voltage endurance test – certificate/report.

A test certificate/report shall be issued on completion of the tension tests.

WITNESS: SIGN/DATE/STAMP:

Patric Keanney *15th October 2021.*

FIBRON: SIGN/DATE/STAMP:

2.3

DOCUMENTATION FRONT SHEET				
Document Category: Hyperbaric Pressure Test.		Fibron Order: 18950	Total Pages: 12	Document Number: PTRM0058-18950A
02	17/08/21	To correct revision number in header	S.M ^c Q.	D.G.H.
01	17/08/21	Amend cable description throughout.	S.M ^c Q.	D.G.H.
00	22/04/21	Initial Issue.	S.M ^c Q.	D.G.H.
Rev:	Date:	Reason for issue:	Prepared:	Checked:
Hyperbaric Pressure Test. Procedure and Report.  MBARI Monterey Bay Aquarium Research Institute R.O.V. Cable. Cable Part Number: RM0058 Purchase Order: PO#2110258 Works Order No: 18950				
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1. Introduction.

1.1 Purpose and Scope.

Fibron Ltd. has been contracted by Monterey Bay Aquarium Research Institute (MBARI) to manufacture two R.O.V. cables – part number RM0058. This document details the test parameters that will be used to carry out the hyperbaric pressure test. This is to verify the compliance of the cable regarding the outline test regime set in the technical bid.

Abbreviations:

FAT	-	Factory Acceptance Test.
FO	-	Fibre Optic.
P/N	-	Part Number.
QC	-	Quality Control.
QP	-	Quality Plan.
RM	-	ROV Cable.

1.2 References.

Following documents to be used as the basis for the information in this procedure:

/1/	RM0058	-	Cross sectional drawing of R.O.V. cable.
/2/	SQ30978, rev:02	-	Fibron Technical & Commercial Bid Document.

2. Test Parameters.

Cable part number:	RM0058
Cable serial no:	81906 (from contract/work-sheets).
Cable drawing ref:	RM0058 latest revision.
Sample length:	Min. 1 m subjected to hydrostatic pressure + pig-tails. <i>Actual length 2m in pressure vessel + 6.8m pigtails</i>
Hydrostatic pressure:	450 bar (6,525 psi) minimum.
Monitoring required:	Electrical and optical monitoring.
3 rd party witness:	MBARI representatives to witness test (optional).

3. Test Equipment.

Following equipment is required to perform the tests:

- Electrical test equipment; multi-meter, HV tester.
- Power source & light meter or other means of assessing optical continuity.
- Pressure test vessel/chamber.

Fill in test data for relevant test equipment below:

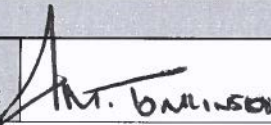
Test Equipment:	Serial No:	Last Calibrated:	Next Calibration Date:	Fibron Test Engineer:
MILLI OHM METER.	001648.	16/3/20.	30/09/21.	
5KV MEGGER.	001421.	4/1/21.	03/01/22.	
FIBRE LIGHT SOURCE.	000014.	20/8/20.	30/09/21.	
FIBRE POWER METER.	001300.	20/2/20.	30/09/21.	
Hydra HMG 3000	000710.	25/1/21.	25/01/22.	
O-Grip BATH THERMOMETER	000766.	28/10/20.	28/10/21.	
PV 8,000.				
25KV MEGGER.	INL4605.	22/1/21.	21/1/22.	

Following pre-requisites to be available:

- Cable drawing (cross sectional drawing).
- All instruments/equipment shall be checked for function prior to testing and shall have valid and current calibration certificates (see above table).

4. Safety.

- Before commencement of any testing all personnel involved shall read this procedure to ensure they understand all the processes involved.
- All test equipment shall be suitably rated and calibrated for the tests to be carried out.
- The test area shall be clearly marked and separated from other working areas and all relevant personnel shall be informed of the forthcoming tests and operations.
- Material safety data sheets shall be available for any hazardous materials to be used. All recommended PPE shall be used when handling these materials.
- Ensure conductors are fully discharged to earth subsequent to high voltage/insulation tests.
-

Signatures:					
Date:	14/9/21.	Fibron signature:	Ayemide Fadahunsi	Witness signature:	

NOTE: The safety procedures were carried out by FET (Forum Energy Technologies (UK) LTD) and not witnessed by Fibron or MBARI.

5. Test preparation.

5.1 Test Sample Preparation.

Whole production length(s) of cable, either as one continuous length or in multiples, will be despatched to the sub-contractor so they can gland out the ends of the cable. The sub-contractor will prepare the ends of the cable so that Fibron personnel can continuously monitor insulation resistance of the conductors and armour.

To prevent damage to the cable, extreme caution shall be used in installing the product in the pressure vessel, with specific attention paid to:

- Cable cleats will be attached to both cable ends inside the chamber, in a position hard up against the chamber penetration flange, to prevent pressure in the chamber initially pushing the cable out.

5.2 Pressure Vessel Setup.

The cable(s) will arrive at the sub-contractor on a reel or in a coil suitable for the total length of cable.

Each end of the cable will be protruding out the pressure vessel with pig-tails prepared for electrical/optical testing. An outline GA of the pressure tank shall be made available on request.



Example Subsea Pressure Tank Set-up (similar configuration to the present arrangement).

5.3 Test Monitoring.

Electrical insulation integrity will be monitored throughout testing: all the conductors will be linked together at one extremity of the vessel pressure gland, and insulation will be measured between all these conductors linked together and the cable screen. A Fibron engineer/technician will be on hand to record the leakage current at intervals throughout pressure exposure, and when/if the value of resistance falls below the required value as stated on the subsequent tables.

6. Test Procedure.

6.1 General Notes.

The RM0058 sample shall arrive at the test facility reeled onto a drum or in a coil suitable for length(s) concerned. The sample may be fully or partially stripped of armour, so that bedding sheath is available for glanding. The sample will then be loaded carefully so the full length is within the pressure tank and suitable pigtails are available for glanding out of the vessel – where relevant, calculations shall be undertaken to ensure the minimum bend radius is not violated during this test. Both ends of the umbilical shall extend out of the pressure vessel and be prepared and glanded to allow electrical/optical monitoring and testing during external pressurisation.

Prior to commencing the test, Fibron will measure the insulation resistance, conductor resistance and optical attenuation.

Fibre optic continuity shall be monitored using a light source and power meter or other suitable device. It is expected that the sample will not be sufficiently long for meaningful assessment of loss increment.

At periods during pressure exposure, measurements will be taken of CR, IR and F/O continuity. The sample will remain under 450 bar of pressure throughout this measurement cycle.

The sub-contractor shall prepare the ends of the sample and install it into their pressure vessel.

The sample shall be exposed to 450 bar (6,525 psi) minimum for a continuous period of 4 hours. The results from the tests shall be logged by a Fibron test engineer.

After completion of test, this procedure will be filled in with the test results and will have status as the official qualification report. Any comments, conclusions or documents generated during the test shall form an attachment to this report.

The test area shall be clearly marked and separated from other working areas and all relevant personnel shall be informed of the forthcoming tests and operations.

Electrical testing is a hazardous operation and the following must be observed:

- Only qualified personnel shall carry out testing.
- All test equipment must be checked prior to use.
- During testing, all non-essential personnel shall vacate the test area.
- All personnel must use appropriate PPE.

Test personnel shall familiarise themselves with health and safety requirements before use.

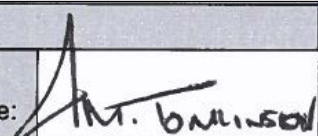
7. Measurements.

7.1 Preliminary measurements.

Fibron will conduct some preliminary measurements to ensure the cable is fully compliant prior to testing. The following will be measured and recorded prior to testing.

- High voltage withstand/insulation resistance.
- Conductor resistance.
- Optical continuity.

DIMENSIONS & TEMPERATURE.				
	Measured (m).	Required (m).	Pass/Fail.	
Sample length:	8.8m total, 2m in pressure vessel	>1m in pressure vessel	PASS	
	Measured (°C).			
Temperature:	19			
CONDUCTOR RESISTANCE.				
Component:	Required max:	Measured (Ω):	Length/Temperature Corrected (Ω/km):	Pass/Fail:
0.22 mm² - Blue:	90 Ω/km @ 20°C.	0.718	81.9	Pass
0.22 mm² - Red:		0.725	82.7	Pass
0.22 mm² - White:		0.725	82.7	Pass
0.22 mm² - Yellow:		0.722	82.4	Pass
5.4 mm² - Green:	3.7 Ω/km @ 20°C.	0.029	3.3	Pass
5.4 mm² - Red:		0.029	3.3	Pass
5.4 mm² - Yellow:		0.030	3.4	Pass
4 mm² - Blue:	4.9 Ω/km @ 20°C.	0.038	4.3	Pass
4 mm² - White:		0.038	4.3	Pass
HIGH VOLTAGE.				
Component:	Required min:	Measured leakage current (µA or nA):	Requirement:	Pass/Fail:
All 5.4 mm² and 4 mm² common:	23 kV _{dc} to screen for 5 minutes.	50 µA	No breakdown.	Pass
INSULATION RESISTANCE* - maintained for one minute to ground (screens, F/O tubes and armour).				
Component:	Required min:	Measured (GΩ):	Pass/Fail:	
0.22 mm² - Blue:	Changed to > 10GΩ @ 0.5 kV _{dc} for these short cable lengths.	17.5	Pass	
0.22 mm² - Red:		16.5	Pass	
0.22 mm² - White:		15.6	Pass	
0.22 mm² - Yellow:		14.8	Pass	
5.4 mm² - Green:	Changed to > 10GΩ @ 0.5 kV _{dc} for these short cable lengths	65.9	Pass	
5.4 mm² - Red:		63.7	Pass	
5.4 mm² - Yellow:		61.0	Pass	
4 mm² - Blue:		58.8	Pass	
4 mm² - White:		56.4	Pass	

OPTICAL MEASUREMENTS.				
Fibre:	Continuity. (Pass/Fail):	1550nm wavelength, all fibres linked in series (daisy-chained). Pass requirement = $(0.4 \times 6) = 0.21\text{dB/km}$ Recorded result 1.78 dB/km		
Blue:	Pass			
Brown:	Pass			
Green:	Pass			
Grey:	Pass			
Orange:	Pass			
White:	Pass			
Signatures:				
Signatures:				
Date:	14/9/21.	Fibron signature:	Ayomide Fadahunsi	Witness signature:
				

* In all cases, measure the IR of each core with respect to all other cores and screens common.

7.2 Measurements to be undertaken during the pressure test.

The following measurements shall be performed during the test whilst under hydrostatic pressure:

- High voltage withstand (leakage current).
- Optical continuity.

5.4 mm² & 4 mm² conductors shall be grouped however is convenient and subjected to 23 kV_{dc} - with respect to the screens and fibre optic tubes (and armour if present) - continuously throughout the pressure test. No breakdown shall occur, and leakage current shall be recorded for reference. Leakage current and optical continuity shall be measured and recorded hourly.

Time:	Breakdown. (Y/N)	Leakage current. (µA or nA)	Optical continuity. (Y/N)	Pass/fail. (Y/N)	Comments.
1 hour:	N	0.06mA	1.79.	Pass	23kV for 5min.
2 hour:	N	0.06mA	1.79.	Pass	23 kV for 5min.
3 hour:	N	0.06mA	1.78.	Pass	23kV for 5min.
4 hour:	N	0.06mA	1.78.	Pass	23 kV for 5min.

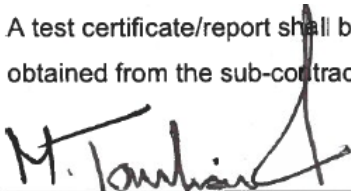
7.3 Measurements/Checks to be undertaken subsequent to the pressure test.

DIMENSIONS & TEMPERATURE.					
	Measured (m).	Required (m).	Pass/Fail.		
Sample length:	8.8m total, 2m in pressure vessel	>1m in pressure vessel	PASS		
	Measured (°C).				
Temperature:	19				
CONDUCTOR RESISTANCE.					
Component:	Required max:	Measured (Ω):	Length/Temperature Corrected (Ω/km):	Pass/Fail:	
0.22 mm ² - Blue:	90 Ω/km @ 20°C.	0.716	81.7	Pass	
0.22 mm ² - Red:		0.723	82.5	Pass	
0.22 mm ² - White:		0.722	82.4	Pass	
0.22 mm ² - Yellow:		0.720	82.1	Pass	
5.4 mm ² - Green:	3.7 Ω/km @ 20°C.	0.03	3.4	Pass	
5.4 mm ² - Red:		0.03	3.4	Pass	
5.4 mm ² - Yellow:		0.03	3.4	Pass	
4 mm ² - Blue:	4.9 Ω/km @ 20°C.	0.039	4.3	Pass	
4 mm ² - White:		0.038	4.3	Pass	
INSULATION RESISTANCE* - maintained for one minute to ground (screens, F/O tubes and armour).					
Component:	Required min:	Measured (GΩ):	Pass/Fail:		
0.22 mm ² - Blue:	Changed to > 10GΩ @ 0.5 kV _{dc} for these short cable lengths.	14.9	Pass		
0.22 mm ² - Red:		14.3	Pass		
0.22 mm ² - White:		13.5	Pass		
0.22 mm ² - Yellow:		12.6	Pass		
5.4 mm ² - Green:	Changed to > 10GΩ @ 0.5 kV _{dc} for these short cable lengths	58.9	Pass		
5.4 mm ² - Red:		56.5	Pass		
5.4 mm ² - Yellow:		54.2	Pass		
4 mm ² - Blue:		52.4	Pass		
4 mm ² - White:		50.8	Pass		
OPTICAL MEASUREMENTS.					
Fibre:	Continuity. (Pass/Fail):				
Blue:	Pass	1550nm wavelength, all fibres linked in series (daisy-chained). Pass requirement = (0.4 x 6) = 0.21dB/km Recorded result 1.78 dB/km			
Brown:	Pass				
Green:	Pass				
Grey:	Pass				
Orange:	Pass				
White:	Pass				
Signatures:					
Signatures:					
Date:	14/9/21.	Fibron signature:	Ayemide Fadahunsi	Witness signature:	

* In all cases, measure the IR of each core with respect to all other cores and screens common.

8. Hyperbaric pressure test – certificate/report.

A test certificate/report shall be issued on completion of the tension tests. A copy of this shall be obtained from the sub-contractor.


M. Tounkian
WITNESS: SIGN/DATE/STAMP:


Ayomide Fadahunsi

FIBRON: SIGN/DATE/STAMP:

2.4



Qualification testing on RM0058 for MBARI

Reference number TTI-IMLR-2021-5739

Date	Rev.	Description	Prepared by	Authorised by
11/10/21	0	For issue to client	IMLR	REH

Distribution:

TTI Testing Ltd (author, file)
Fibron BX

Attention:

IMLR, REH
Ayomide Fadahunsi

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1 Introduction

Fibron BX (**Fibron**) contracted **TTI Testing** to undertake mechanical testing on a ROV main lift cable, their part no. RM0058 for their customer Monterey Bay Aquarium Research Institute (**MBARI**). Four tests were required:

1. Pressure test
2. Tensile test (including both elongation-rotation measurement and breaking load) [1];
3. Tension-Tension test around a sheave (Bent T-T) [2]; and,
4. Cyclic bending over sheave (CBoS) test [3]

This document describes the testing methodology and presents the results of the work which TTI Testing undertook in fulfilment of the Tensile test, Bent T-T test and CBoS test. The pressure test was outside TTI Testing's capabilities and was conducted elsewhere.

2 Cable RM0058

Figure 2.1 presents a cross section of the ROV main lift cable RM0058. Table 2.1 presents the typical mechanical characteristics of the cable.

Fibron supplied a 50 m length of cable which was made into samples for the tensile test, Bent T-T and CBoS tests. The 50m supplied included some spare length in case any repeat testing was required.

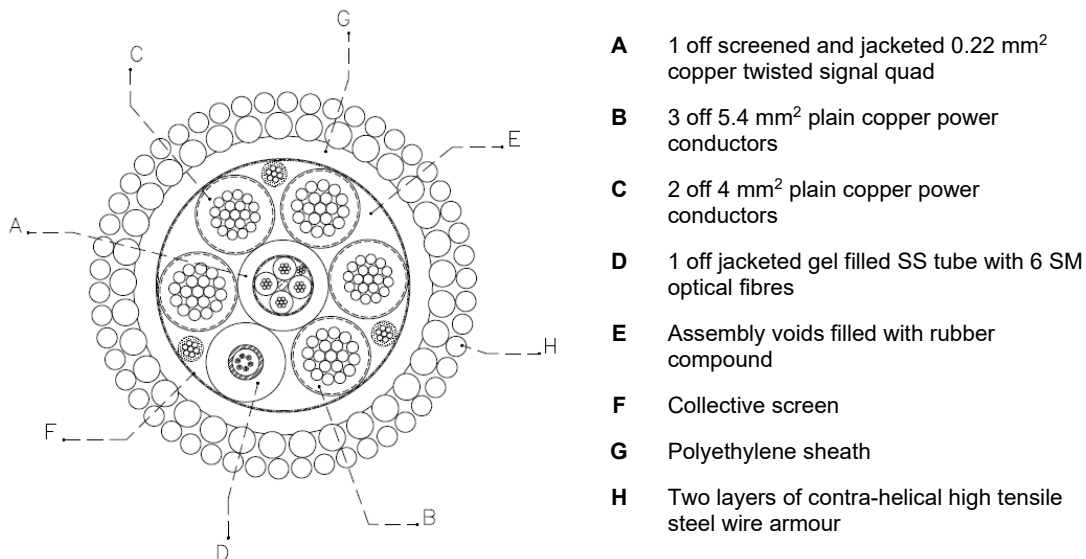


Figure 2.1: Typical cross section of ROV main lift cable RM0058 (from [4]).

Parameter	Value
Outer diameter [mm]	20.0 ±0.3
Weight in air [kg/m]	1.260
Recommended minimum dynamic bend radius [mm]	400
Minimum breaking load [kN]	180
Max. safe working load (SWL) [kN]	60

Table 2.1: ROV main lift cable RM0058 mechanical characteristics.

Samples were made up in TTI Testing's proprietary "top hat" fittings (tensile test and bent T-T) such as shown in Figure 2.2, or open sockets (CBoS) as required. These were completed with Wirelock® resin compound. The samples for the Bent T-T and CBoS included pigtails of suitable length passed out of the back of the termination at each end to permit periodic monitoring during the test.



Figure 2.2: Example showing armoured cable terminated in TTI Testing top-hat end fitting.

3 Test equipment

TTI Testing's 200 kN and 600 kN long bed testing machines were used to undertake the tests described in this document. Figure 3.1 shows a view of the 200 kN machine, which is geometrically similar to the 600 kN machine. In the case of the CBoS test it was necessary to fit column extensions and a rotary drive. Table 3.1 below presents the main parameters of the 200 kN and 600 kN machines.



Figure 3.1: 200 kN testing machine at TTI Testing's laboratory in Wallingford, UK.

Parameter	200 kN	600 kN
Load capacity (kN)	200	600
Actuator stroke (mm)	2,000	2,000
Moveable 'static' crosshead	Y	Y
Rotary motor attachment	Y	Y
Controller	CUBUS	CUBUS
Fatigue rated	Y	Y
Complex and block loading	Y	Y
Bed length (mm)	Up to 10 m	Up to 15 m

Table 3.1: Main parameters of the 200 kN and 600 kN long bed tensile testing machines.

4 Test setup

4.1 Test setup – Tensile test

4.1.1 Elongation-rotation test

A sample nominally 5 m long was made up in TTI Testing's proprietary "top hat" sockets. It is noted that there was no requirement for pigtails to be extended out of the back of the socket to permit monitoring during this test.

Figure 4.1 shows a general arrangement of the 200 kN machine set up to run a zero torque test on a cable.

One end of the sample was mounted on the torque load cell (which is in turn mounted on the end of the rotary motor), whilst the other end was mounted on the main actuator.

The sample was loaded axially by retracting the main actuator (right hand end Fig. 4.1). At the same time, the rotary motor was commanded to follow zero torque thus modelling rotation of a free end.

It was also required to measure the extension of the sample at the working load of 60 kN. In order to achieve this lightweight clamps were mounted on the sample with a gauge length of about 4 m. The gauge length was measured under an initial low pre-tension and again at SWL.

4.1.2 Breaking load measurement

After the zero torque test was complete it was required to load the sample to failure in simple tension. As there was concern that the breaking load could be over the capacity of the 200 kN machine, the sample was transferred to the 600 kN machine.

This test was set up with both ends rotationally fixed.

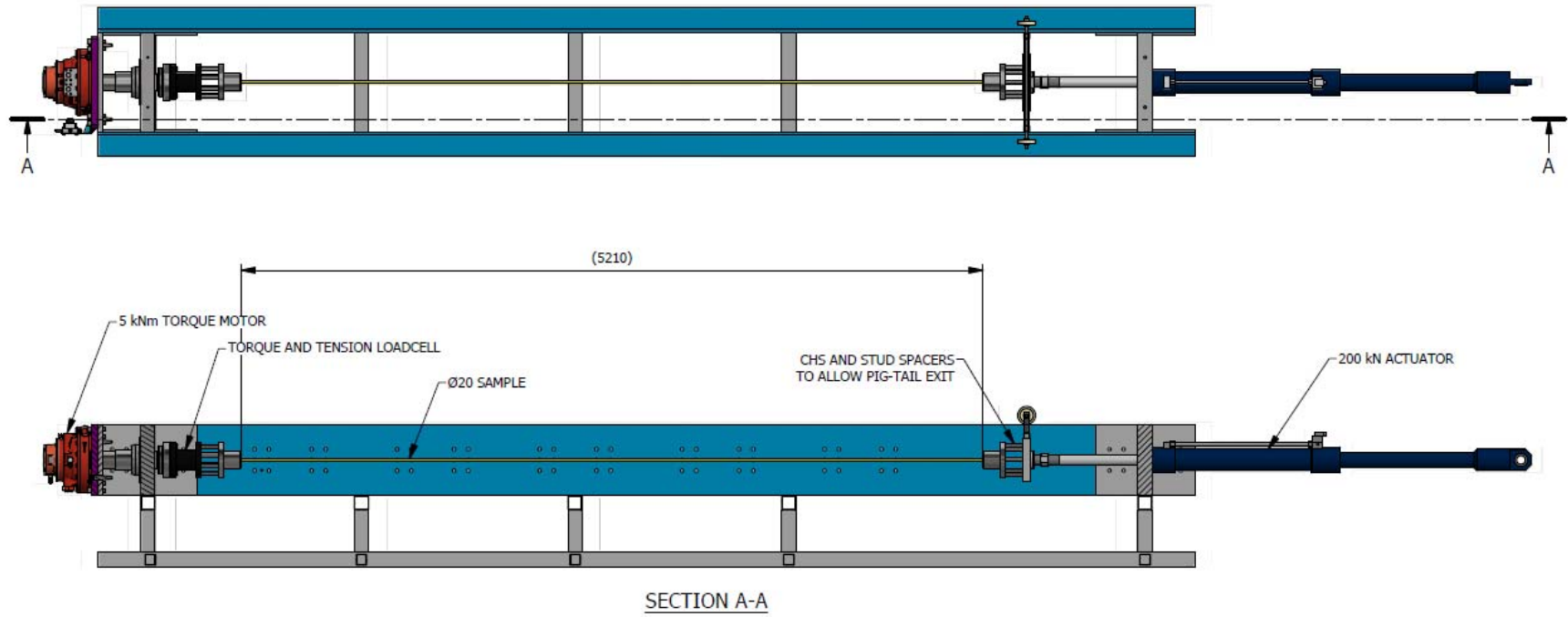


Figure 4.1: 200 kN testing machine set up to run a zero torque test.

4.2 Test setup – Bent T-T test

For reasons of optimising machine usage, the Bent T-T test was conducted in the 600 kN machine (with the intention that the CBoS test could be set up in parallel on the 200 kN machine).

Figure 4.2 shows the general arrangement of the 600 kN machine set up for the Bent T-T test. In this test a sample of umbilical was wrapped through 180° around the nylon test sheave (it was intended to then transfer this sheave to the 200 kN machine for the CBoS test).

A vertical moving crosshead was designed and manufactured which permitted the top hat terminations to be mounted on the end of the actuator, while maintaining the appropriate separation for the 180° wrap (Figure 4.3).

Pigtails were passed out of the back of the terminations to permit periodic electrical and fibre optic testing of the sample before and during the test.



Figure 4.3: Bespoke vertical moving crosshead.

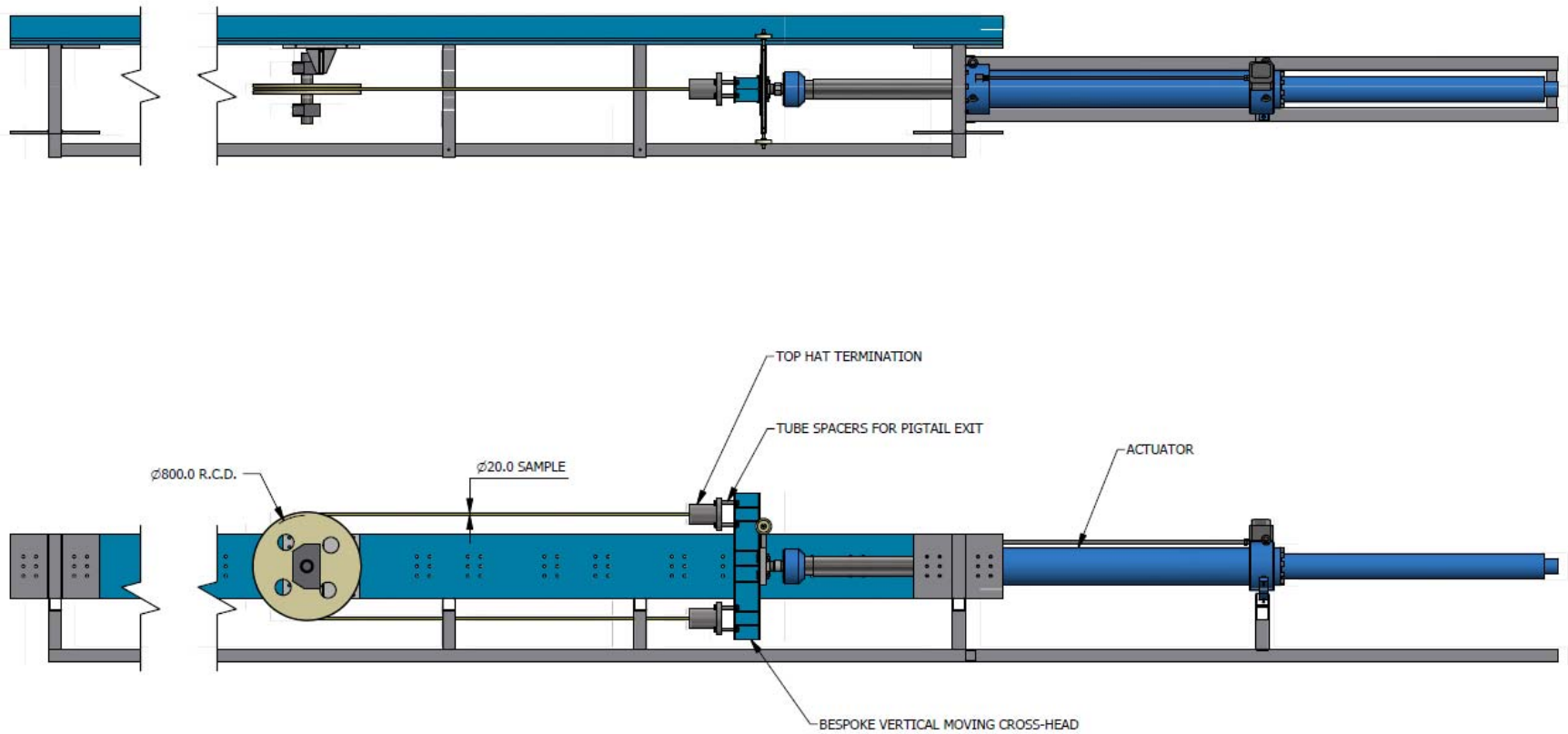


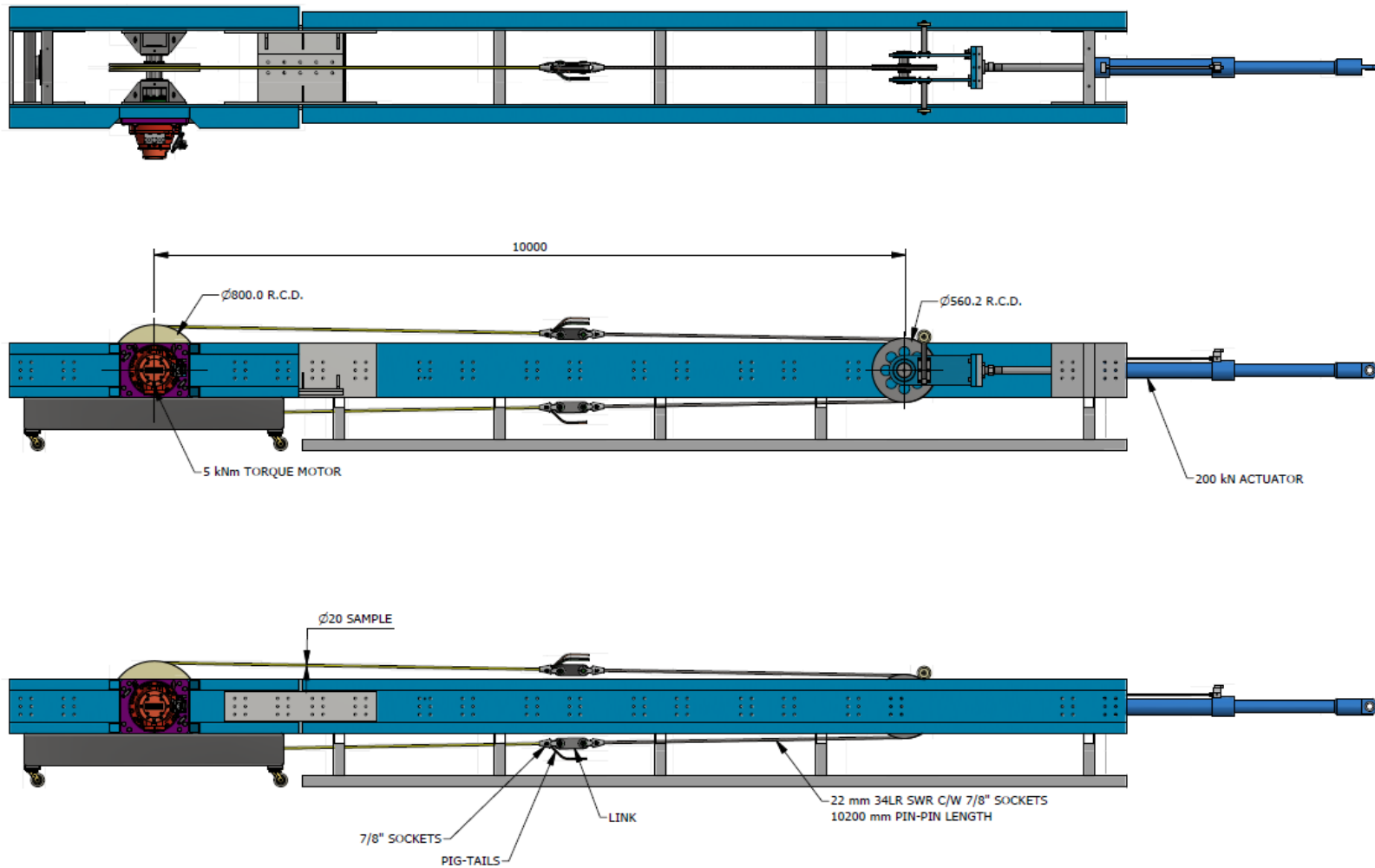
Figure 4.2: 600 kN testing machine set up to run a bent T-T test.

4.3 Test setup – CBoS test

Figure 4.4 presents a general arrangement drawing of the 200 kN machine set up for a CBoS test. A CBoS test is one in which a length of cable is driven back and forth over a sheave under a constant tension. For this set up the sample was formed into a loop by employing a “dummy” rope in series with the test sample. Thus, in this configuration only one test sheave was required (the second was steel and already available). An additional benefit was that a shorter sample length was required, although it is noted that twice as many terminations needed preparing. The dummy rope was torque matched (34LR) to the sample in order to avoid unwanted rotation of the connections.

With reference to Figure 4.4:

- A single nylon sheave of 800 mm RCD was specially manufactured and free issue from Fibron (as per the Bent T-T test). The central bore required for mounting was $\varnothing 190.0$ mm H7.
- The test sheave was mounted on the drive shaft of the rotary motor.
- The dummy sheave (TTI Testing supply) was mounted on bearings on a frame at the end of the main actuator.
- The cable was terminated in suitable open sockets and formed into a continuous loop for testing and connected with joiner plates. The cores were passed out of the assembly to allow monitoring.
- A distance of about 10 m separation between the sheaves was used. This was sufficient to accommodate the connections and the required bending length, still leaving some room for clearance and adjustment of the specimen.
- As well as being free to rotate, the dummy sheave would also move axially (so as to change the linear separation (and load) between the sheaves).
- The wrap angle of the cable around the test sheave was close to, but just over 180° .
- The required load for the $\varnothing 20$ mm sample was 60 kN. A mean cable load was applied by means of the main tensile actuator. The actuator was set to maintain the demand load throughout the test, and would accommodate any cable elongation due to cable stretch or degradation. (Note the actuator load was double the cable load, i.e. 120 kN).
- The bending movement of the rope over the sheaves was provided by the rotary motor. The bending length was 2,514 mm ($0 \pm 180^\circ$).
- It was required initially to undertake 1000 machine bending cycles (see Appendix A), and then repeat in two increments of 1000 cycles up to 3000 cycles total.
- A typical test speed of 80 s period was employed (Care was taken not to overheat the cable.) A thermal camera was used to assess any temperature increase in the cable, and if necessary a slower cyclic speed would be employed.
- Every 1000 cycles tests of IR, CR and fibre optic continuity were made.



SAMPLE LENGTH 12500±100 mm PIN-PIN

Figure 4.4: General assembly drawing of the 200 kN testing machine set up to run the CBoS test.

5 Test procedure

5.1 Test procedure – tensile test

5.1.1 Elongation-rotation test

The following procedure was employed:

1. The test machine load cell(s) was zeroed.
2. The cable sample was installed on the 200 kN test machine (as per Figure 4.1).
3. The machine data logger was started, recording load (200 kN load cell), stroke and torque (torque-tension load cell) and end rotation.
4. The rotary motor was commanded to maintain zero torque.
5. A load of 1 kN was applied slowly to remove the sag. The sample length between sockets was measured. The elongation clamps were checked to ensure they were sufficiently tightened, and the gauge length between them measured using a steel tape.
6. Load was increased using the hydraulic actuator at a loading rate of 0.1 kN/s until the load reached 10 kN.
7. The load was held for about 15 seconds while the end rotation stabilised and to permit measurements to be taken (load, stroke, torque and end rotation).
8. The load in the sample was increased by 10 kN at a loading rate of 0.2 kN/s.
9. At 20 kN the load was again held for about 15 seconds for measurements to be taken and recorded.
10. Loading was increased stepwise (steps of 10 kN at a rate of 0.2 kN/s followed by a 15 s hold) to a total load of 60 kN.
11. The load was held for about 2 minutes whilst the gauge length between the clamps was again measured.
12. The same increments/loading rate were used to un-load the sample, recording measurements at each step.
13. Once back at 1 kN the elongation-rotation test was complete.
14. The end of the sample was returned to 0° and unloaded.

5.1.2 Breaking load measurement

1. After the elongation-rotation test was complete, the elongation clamps were removed, and the sample transferred to the 600 kN machine. (Both ends rotationally retrained.)
2. From 1 kN the sample was loaded at a rate not exceeding 1 kN/s until the sample was unable to support any increase in load.
3. The maximum load sustained and the nature and location of the failure were recorded.
4. The test to breaking load was complete.

5.2 Test procedure Bent T-T test

The following procedure was followed:

1. With the bespoke vertical moving crosshead mounted on the tooling plate, the test machine load cell was zeroed.
2. The cable sample was installed on the 600 kN test machine (as per Figure 4.2).
3. An initial set of electrical and fibre optic readings were taken, as set out in §7 of [3].
4. The assembly was then loaded to 1 kN to straighten the cable, and the machine stroke zeroed. The assembly was then loaded to 5 kN ready for the start of the test. From 5 kN the assembly was loaded to the mean test load over 10 s, before starting a set of five “fade in” cycles (See Figure 5.1). The fade in (and to a lesser extent “fade out”) cycles are designed to avoid overloading the sample while the machine gains adjust to the required test loads.
5. The cable was loaded cyclically 1000 times between 1 – 6.1 tonnes (19.620 kN – 119.682 kN machine load).
6. The sample was unloaded and IR, CR and fibre optic readings taken.
7. The sample was then re-loaded and a further 1000 cycles undertaken, following which IR, CR and fibre optic readings were again taken.
8. The process was repeated until 7,500 cycles were completed.
9. The sample was then removed from the test machine and dissected for condition assessment.

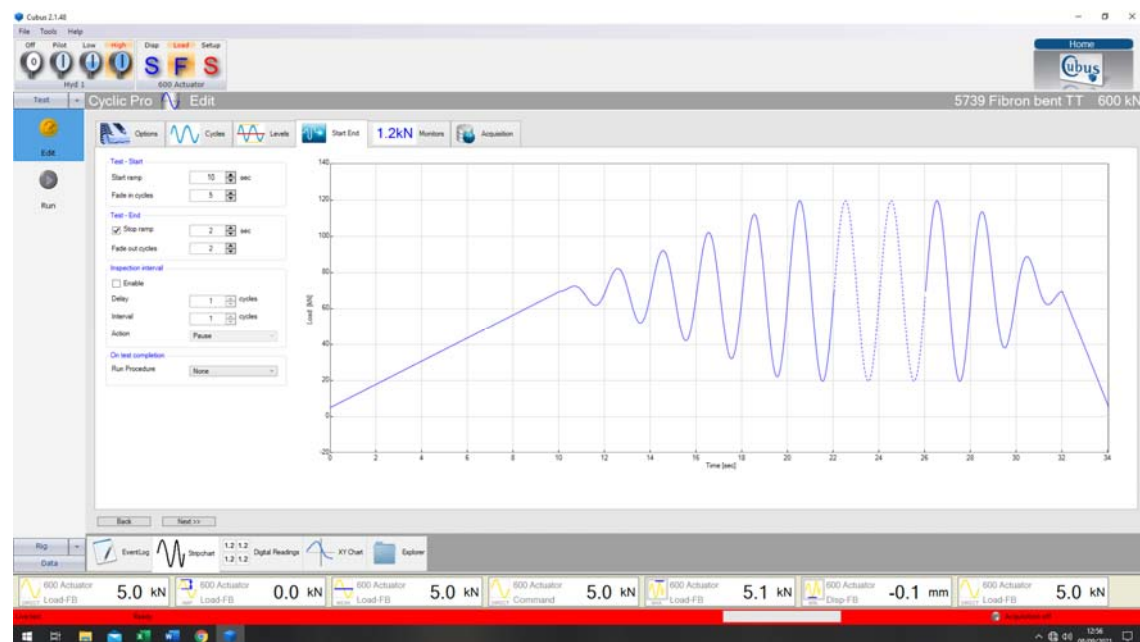


Figure 5.1: CUBUS software showing a schematic diagram of “fade in” and “fade out” cycles.

5.3 Test procedure CBoS test

The following procedure was employed:

1. With the idler sheave assembly bolted to the 200 kN actuator, the test machine load cell was zeroed.
2. The cable sample was installed as per Figure 4.4. The cores were passed out of the back of the terminations to permit periodic monitoring of the electrical and fibre optic continuity throughout the test. An initial set of readings was taken.
3. The cable was loaded to 60 kN by retracting the main actuator (120 kN total load).
4. The rotary motor was commanded to rotate cyclically through $\pm 180^\circ$ (2,514 mm bending length) for 1000 cycles with period 80 s (two fade in cycles were employed to build up to the full rotation amplitude).
5. After 1000 cycles the sample was unloaded and IR, CR and fibre optic readings were taken.
6. The sample was then re-loaded and a further 1000 cycles undertaken, following which IR, CR and fibre optic readings were again taken.
7. The sample was re-loaded and a final 1000 cycles undertaken before again making IR, CR and fibre optic readings.
8. The sample was removed from the test machine and dissected over the full length of the bending length for condition assessment.

6 Witness of testing

The scheduling and duration of the testing meant that it was not feasible for Fibron or their customer to attend TTI Testing to witness the work in person. Instead, arrangements were made for Fibron and MABRI (based in California) to witness the tensile test and parts of the Bent T-T test via webcams connected with TEAMS. Video clips were made of the CBoS test.

7 Schedule

Testing was conducted during September 2021.

8 Definitions

When viewed from the end, e.g. the bottom as shown in Figure 9.1:

- an applied right hand (clockwise) twist leads to a negative increment in torque (more negative); and,
- an applied left hand (anti-clockwise) twist leads to a positive increment in torque.

Note that as the outer layer of armour is left hand, a positive torque would tend to close (shorten the lay-length of) the outer layer of armour.

9 Results

9.1 Tensile qualification

9.1.1 Elongation and rotation

Figure 9.1 shows a view from the end of the 200 kN machine with the rotary motor in the foreground. Figure 9.2 shows a view of the rotational end crosshead from the other side, with the top hat socket mounted on the end of the torque load cell and rotary tooling plate. The (orange) clamp (one of a pair) for measuring the elongation of the sample may also be seen on the cable.

At 1 kN the sample length was measured at 4,996 mm between socket faces. The bolts on the gauge length clamps were tightened, and the gauge length set to 4,000 mm. Ambient temperature for the test was 20.7 °C.

Figure 9.3 presents the load, stroke, torque and end rotation recorded during the test. It may be seen that at low loads the sample was torsionally very “soft” and the initial hold for about 10 minutes was in order to adjust the gains on the controller in order to obtain a better response. At higher loads the machine control was better, but the rotary actuator still hunted around the zero torque command. This behaviour was thought to be due to the friction in the system, both cable and the rotary motor.



Figure 9.1: Tensile sample mounted in the 200 kN machine for the elongation and rotation test.



Figure 9.2: View on rotation crosshead showing torsion load cell and elongation clamp.

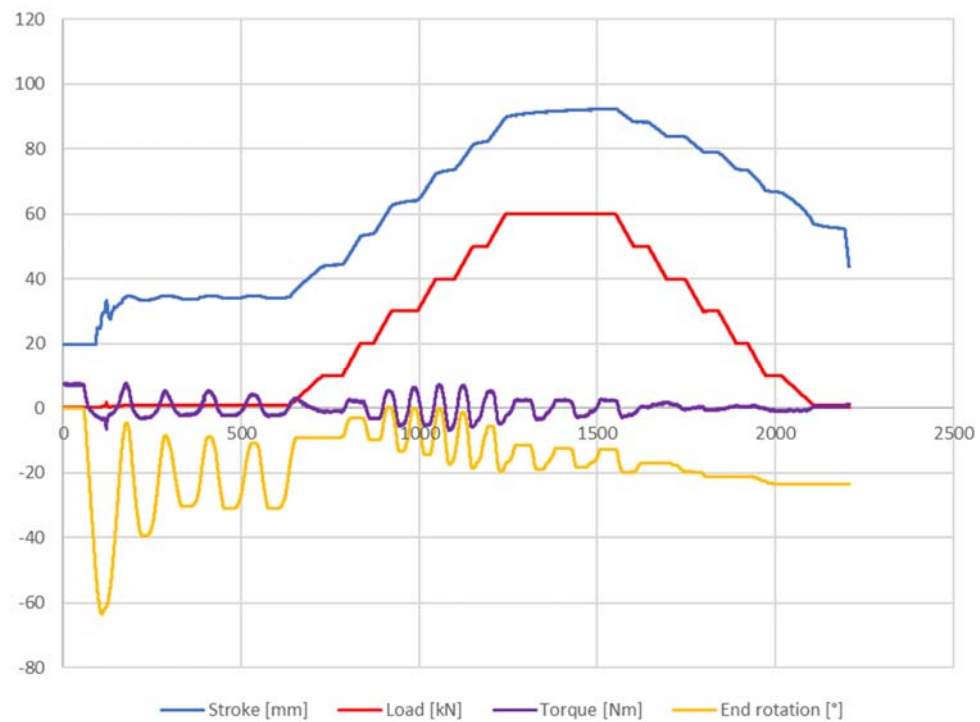


Figure 9.3: Load, stroke, torque and end rotation recorded during the elongation and rotation test.

Owing to the initial control problems mentioned above, the reading of end rotation at zero torque was taken as the sample passed through zero torque. The sample behaviour was much more stable in the second part of the test. Table 9.1 presents the values taken during the loading and unloading sequence.

At 60 kN the load was held whilst the gauge length between clamps was again measured. This was measured as 4039 mm (an increase of 39 mm over 4,000 mm, or just under 1%). Socket draw of 2-3 mm was noted at each end.

On unloading to 1 kN readings were taken and the end of the sample rotated to its original position for the test to breaking load.

Required Load	Actual Load	Stroke	Torque	End Rotation	
[kN]	[kN]	[mm]	[Nm]	[°]	[°/m]
1	1	34.0	-1.5	-30.9	-6.2
10	10	44.1	-0.9	-9.0	-1.8
20	20	53.4	0.0	-5.7	-1.1
30	30	63.4	0.0	-7.6	-1.5
40	40	72.5	0.0	-9.3	-1.9
50	50	81.5	0.0	-12.1	-2.4
60	60	90.0	0.0	-14.5	-2.9
50	50	88.2	0.1	-16.9	-3.4
40	40	83.7	0.0	-18.9	-3.8
30	30	78.9	0.2	-21.2	-4.2
20	20	73.6	0.1	-21.2	-4.2
10	10	67.2	0.5	-23.3	-4.7
1	1	56.7	0.0	-23.3	-4.7

Table 9.1: Load, stroke, torque and end rotation recorded during the elongation and rotation test.

9.1.2 Breaking load

Following the elongation and rotation test, the sample was transferred to the 600 kN machine for the test to breaking load.

The sample was loaded at a rate of 1 kN/s. It failed at a load of 204.3 kN. Failure of the sample was at the actuator end termination, and it is likely that this reduced the breaking strength. An examination of the load-elongation relationship (derived from the stroke of the actuator and based on an initial length of 5019 mm) suggests that the breaking load would be a little higher, possibly 220 kN. However, the measured 204.3 kN is comfortably in excess of the cable MBL of 180 kN.



Figure 9.4: Appearance of the cable failure after testing to breaking load (actuator end termination).

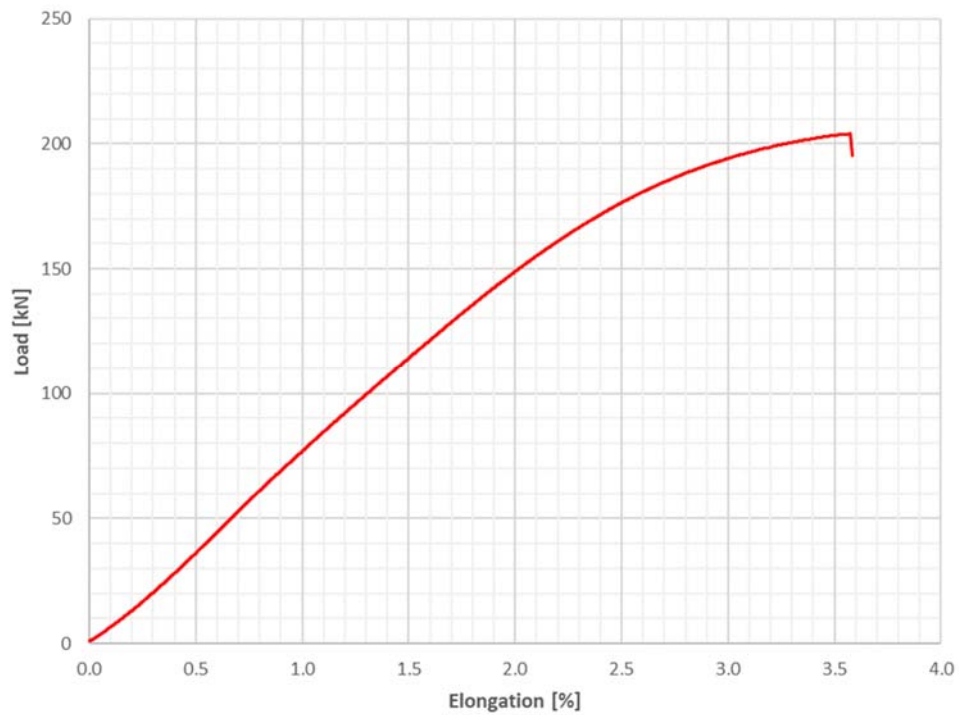


Figure 9.5: Load-elongation relationship recorded during the tensile test to breaking load.

9.2 Bent T-T

9.2.1 Bent T-T fatigue cycling

Figure 9.6 shows the sample set up in the 600 kN machine at the start of the bent T-T test. The sample length was 9.5 m between ends. Preliminary electrical and optical measurements were made on the sample whilst the cable was slack and under no load (see Tables 9.2 and 9.3).

On completion of first block of 1,000 cycles the sample was inspected. Socket draw of approximately 3 – 4 mm was noted at each termination. Grease had squeezed between the wires on the outer layer of armour along the sample length (Figure 9.7).

It was noted that the temperature of the cable had increased during the load cycling. After the first 1,000 cycles the surface temperature was measured with a thermal imaging camera at $\approx 36^{\circ}\text{C}$, about 6°C above ambient. The Fibron test procedure [2, §8] states that this might be the cause of spurious readings. The first set of electrical conductor readings were within the required maximum test values, so for this reason and coupled with the fact that it was impractical to leave the cable to cool to ambient, testing continued.

The external cable temperature seemed to have stabilised by 4,000 cycles at $\approx 43^{\circ}\text{C}$ (Figure 9.8). After 7,000 cycles the sample was left to cool overnight (over 12 hours) before the electrical / optical readings were taken. Reference to Table 9.3 shows that the electrical resistance for the 4 mm^2 core daisy chain did exceed the +5% test maximum at 4,000 and 6,000 cycles, but after cooling was back to an acceptable level for 7,000 and 7,500 cycles.

The optical loss was also noted to have exceeded +5% on the initial value after 3,000 cycles, but again once the cable cooled overnight returned to acceptable levels (Table 9.3).



Figure 9.6: Cable set up in 600 kN machine for the start of the Bent T-T test.



Figure 9.7: Socket draw of approximately 3 – 4 mm noted after 1,000 cycles. Grease has squeezed out from inside the cable (to be expected).



Figure 9.8: Example thermal image taken during checking of the cable external temperature.

On completion of the load cycling the 7,500 cycle measurements the cable was marked at the sheave tangent points with white paint (Figures 9.9 and 9.10) before removal from the machine for post-test inspection / dissection. The surface of the cleaned section of cable was noted to be in very good condition, no distortion to the armour was noted (Figure 9.10).



Figure 9.9: Cable on test sheave on completion of 7,500 cycles. Note the tangent point area has been cleaned to aid marking on the sample.



Figure 9.10: Detailed view on cleaned tangent point area on the sample on completion of 7,500 cycles (before removal for inspection) – the condition is very good.

Table 9.2 presents the results of the preliminary measurements made on the cable sample, whilst Table 9.3 presents the cycle testing measurements and Table 9.4 the post-cycling measurements.

CONDUCTOR RESISTANCE (cable sample 9.5 m long end – end)				
Component	Required Max.	Measured [Ω]	Temperature [$^{\circ}\text{C}$]	Length/Temperature corrected [Ω/km]
0.22 mm ² - Blue	90 Ω/km @ 20 $^{\circ}\text{C}$	0.874	28.5	89.0
0.22 mm ² - Red		0.830	28.5	84.5
0.22 mm ² - White		0.823	28.5	83.8
0.22 mm ² - Yellow		0.817	28.5	83.2
5.4 mm ² - Green	3.7 Ω/km @ 20 $^{\circ}\text{C}$	0.034	28.5	3.5
5.4 mm ² - Red		0.035	28.5	3.6
5.4 mm ² - Yellow		0.035	28.5	3.6
4.0 mm ² - Blue	4.9 Ω/km @ 20 $^{\circ}\text{C}$	0.044	28.5	4.5
4.0 mm ² - White		0.044	28.5	4.5
INSULATION RESISTANCE - maintained for 1 minute to ground (screens, FO tubes and armour)				
Component	Required Min.	Measured [$\text{G}\Omega$]		
0.22 mm ² - Blue	50 $\text{G}\Omega$ @ 0.5 kV_{dc}	>537		
0.22 mm ² - Red		>537		
0.22 mm ² - White		>537		
0.22 mm ² - Yellow		>537		
5.4 mm ² - Green	50 $\text{G}\Omega$ @ 2.4 kV_{dc}	564	Note measurements made @ 2.5 kV_{dc}	
5.4 mm ² - Red		651		
5.4 mm ² - Yellow		428		
4.0 mm ² - Blue		447		
4.0 mm ² - White		335		
FIBRE OPTIC MEASUREMENTS				
Fibre	Attenuation [dBm]			
Blue	3.27	Measured collectively (daisy chained) with $\lambda = 1,550 \text{ nm}$		
Brown				
Green				
Grey				
Orange				
White				

Table 9.2: Preliminary measurements for the Bent T-T test sample.

	Electrical resistance			Ambient Temperature	Corrected electrical resistance (for 20°C)			Insulation Resistance – at voltages given previously			Optical loss	Cable Surface Temperature
	[Ω]			[°C]	[at 20°C, Ω/km]			[GΩ]			[dBm]	[°C]
Daisy chain core size [mm ²]	0.22	5.4	4.0		0.22	5.4	4.0	0.22	5.4	4.0		
No. of cores in daisy chain	4	3	2									
Cycles, 0	3.301	0.105	0.090	28.7	83.996	3.562	4.580	206	279	549	3.27	28.7
Test maximum (+5%)					88.196	3.741	4.809	> 50			3.34	
1000	3.298	0.106	0.091	29.4	83.698	3.587	4.619	288	358	750	3.29	36
2000	3.324	0.107	0.092	29.4	84.357	3.621	4.670	303	342	753	3.23	39
3000	3.346	0.108	0.092	29.5	84.884	3.653	4.668	269	330	748	3.47	39
4000	3.335	0.108	0.099	30.0	84.444	3.646	5.013	302	325	676	3.45	43
5000	3.333	0.108	0.094	30.0	84.394	3.646	4.760	191	318	666	3.59	43
6000	3.331	0.109	0.104	29.8	84.407	3.683	5.271	301	320	639	3.55	43
7000	3.275	0.106	0.093	26.8	83.941	3.622	4.767	366	354	735	3.13	31
7500	3.300	0.108	0.092	26.9	84.549	3.689	4.714	340	347	739	3.04	35

Table 9.3: Cycle testing measurements for the Bent T-T test sample (with cores daisy chained by size).

CONDUCTOR RESISTANCE				
Component	Required Max.	Measured [Ω]	Temperature [$^{\circ}\text{C}$]	Length/Temperature corrected [Ω/km]
0.22 mm ² - Blue	90 Ω/km @ 20 $^{\circ}\text{C}$	0.823	26.5	84.5
0.22 mm ² - Red		0.821	26.5	84.3
0.22 mm ² - White		0.817	26.5	83.9
0.22 mm ² - Yellow		0.897	26.5	92.1
5.4 mm ² - Green	3.7 Ω/km @ 20 $^{\circ}\text{C}$	0.034	26.5	3.5
5.4 mm ² - Red		0.035	26.5	3.6
5.4 mm ² - Yellow		0.034	26.5	3.5
4.0 mm ² - Blue	4.9 Ω/km @ 20 $^{\circ}\text{C}$	0.044	26.5	4.5
4.0 mm ² - White		0.044	26.5	4.5
INSULATION RESISTANCE - maintained for 1 minute to ground (screens, FO tubes and armour)				
Component	Required Min.	Measured [$\text{G}\Omega$]		
0.22 mm ² - Blue	50 $\text{G}\Omega$ @ 0.5 kV _{dc}	>537		
0.22 mm ² - Red		>537		
0.22 mm ² - White		>537		
0.22 mm ² - Yellow		>537		
5.4 mm ² - Green	50 $\text{G}\Omega$ @ 2.4 kV _{dc}	782	Note measurements made @ 2.5 kV _{dc}	
5.4 mm ² - Red		463		
5.4 mm ² - Yellow		530		
4.0 mm ² - Blue		688		
4.0 mm ² - White		446		
FIBRE OPTIC MEASUREMENTS				
Fibre	Attenuation [dBm]			
Blue	3.04	Measured collectively (daisy chained) with $\lambda = 1,550 \text{ nm}$		
Brown				
Green				
Grey				
Orange				
White				

Table 9.4: Post cycling measurements for the Bent T-T test sample.

9.2.2 Post-test inspection

Following the cycle testing on the bent T-T sample, and the marking shown in Figure 9.10 above, the sample was wrapped in plastic in order to remove it from the machine. Once the sample had been removed from the machine, the sockets were removed in order to facilitate inspection of the sample. Inspection covered the portion of cable which had been bent over the sheave and a 300 mm of straight section either side, focusing on the tangent point locations (which were the transition between the two). Figure 9.11 shows the sample laid out on the floor, with the tangent point locations marked by the red and blue tape. Figures 9.12 to 9.20 describe the results of the inspection.



Figure 9.11: Bent T-T test sample laid out for dissection.



Figure 9.12: Section of sample which has been bent over the sheave – the heavier lubricant deposit on the section which had faced away from the groove.

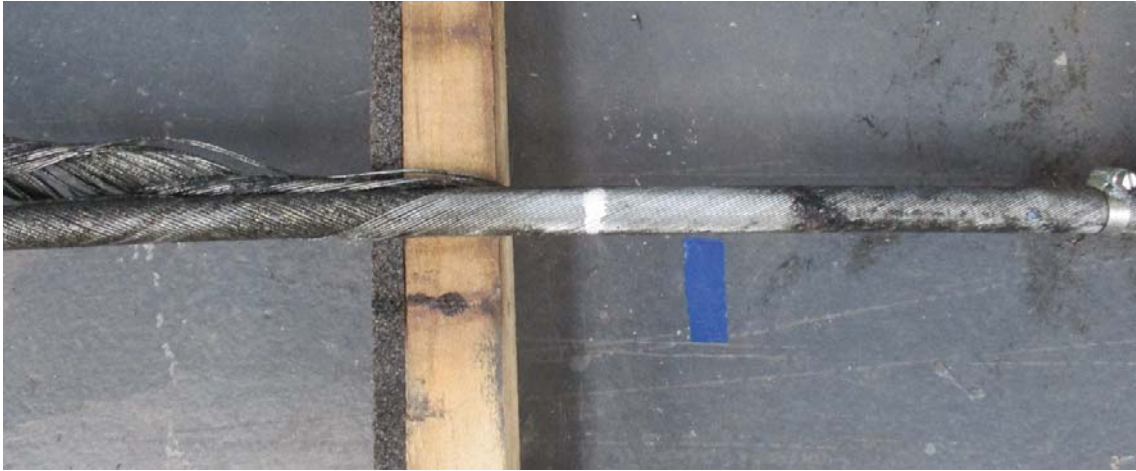


Figure 9.13: Outer layer of armour removed from sample in the bent section. The tangent point is marked by the white paint.



Figure 9.14: Second layer of armour in the region of the "blue" tangent point (note the white paint on the outer layer wires). The second layer lubricant is in good condition and evenly distributed.

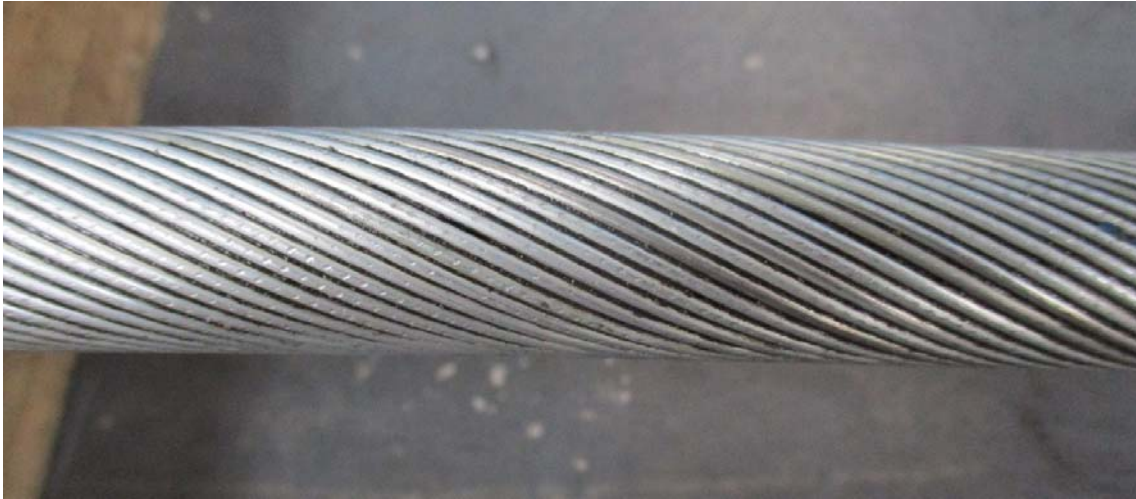


Figure 9.15: Second layer of armour in the region of the “blue” tangent point (after cleaning). The left hand side of the sample towards the bottom in the photograph was facing towards the sheave groove, and light interlayer wire contact points may be seen on the sample. On the right hand side there is a slight distortion in the armour layer as the cable transitions from bent to straight.



Figure 9.16: Polyethylene sheath in the region of the “red” tangent point (after cleaning). The left hand side of the sample was straight, right hand, bent (during the test).



Figure 9.17: Copper/polyester laminate tape wrapping in the region of the “red” tangent point (after cleaning). The left hand side of the sample was straight, right hand, bent (during the test).



Figure 9.18: Larger power conductors and fibre optic tube, drain wires and silicone rubber compound.



Figure 9.19: Distortion noted on the coating of the drain wires in the region of the red tangent point.

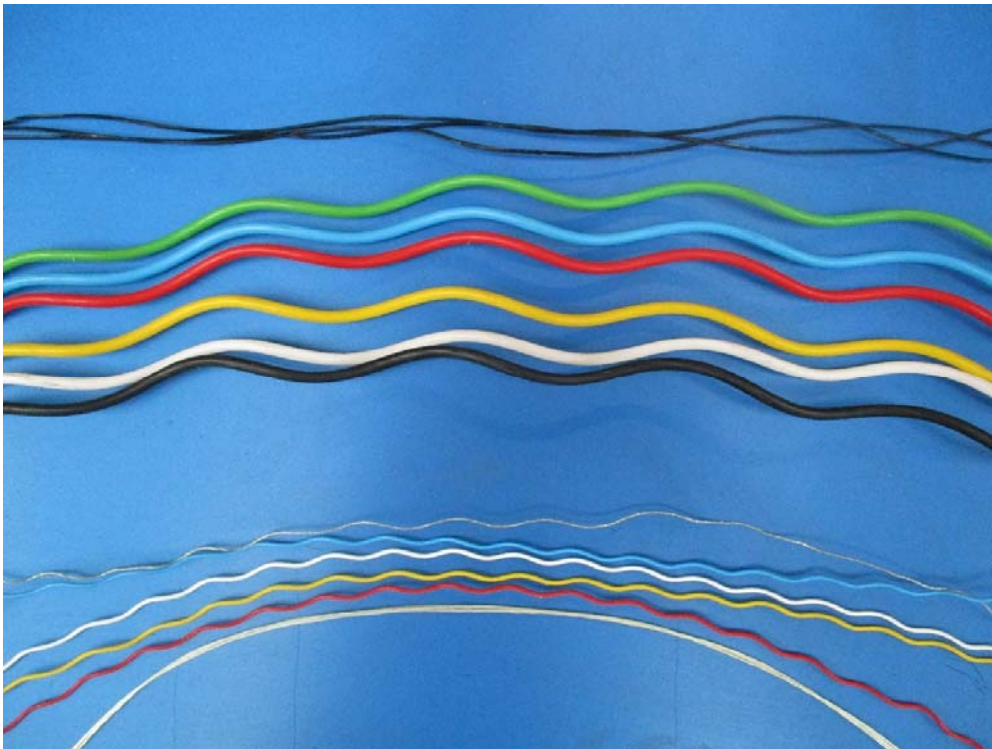


Figure 9.20: Coated drain wires (top) power conductors, fibre optic tube (black) and twisted signal quad (bottom) after dismantling and cleaning (red tangent point).

9.3 CBoS

9.3.1 CBoS fatigue cycling

Figure 9.21 shows the 200 kN test machine with extensions set up to run the CBoS test. The test sample was measured as 12.1 m between socket faces and with overall length of 20.7 m. With the sample and backing rope in the test machine, a load of 20 kN (10 kN cable load) was applied to remove the sag caused primarily by the weight of the sockets mid length. The distance between sheave centres was measured as 10,340 mm. At this separation the wrap angle of the test cable over the sheave was calculated to be a little over 181° , it was therefore acceptable to use a machine test load of 120 kN for the test.



Figure 9.21: 200 kN machine set up to run the CBoS test.

Figure 9.22 shows a view on the sample looking towards the test sheave at the end of the machine. Note that there is little if any twist at the sample interface, also the long pigtail which was employed in order to accommodate the bending length movement. Just after the test was started, the pigtail caught on the pins of the lower socket coupling. This dragged the pigtail and broke two of the optical fibres by bending them against the end of their tube. It was decided that rather than immediately stop the test to repair the damage, that the daisy chain would be re-formed at the time of the next reading (after 1,000 cycles). As the pigtail was very long there was ample length to strip back another 500 mm to repair the damage. However, all the joints had to be remade, meaning that the initial fibre optic reading was no longer valid. The pigtail was suspended from the swivel hook on the mobile crane in order to prevent a reoccurrence of this issue (Figure 9.23).



Figure 9.22: View on CBoS test looking towards the test sheave (dummy rope top left), a long pigtail was employed to allow for the movement during the bend cycling.



Figure 9.23: View on CBoS test looking towards the test sheave with the long (top) pigtail looped through the hook of the gantry crane in order to prevent it catching on the sample.

Once the initial problem with the pigtail had been resolved, the CBoS test ran smoothly and completed the 3,000 machine cycles. As the cycling rate was fairly low (80 s period), the heat build-up in the sample was modest (peak temperature $\approx 31^{\circ}\text{C}$), and highest in the double bending zone (Figure 9.24).

Figure 9.25 shows the data recorded during the test. The actuator stroke was zeroed with the machine load at 20 kN at the start of the test (distance between sheaves of 10,340 mm). The stroke data presented in Figure 9.24 is with the sample under 120 kN machine load. Note also that as the sample is wrapped around the test sheave, that the overall elongation is double the values presented in the graph. It may be seen that after a fairly rapid elongation over the first 50 or so cycles, the sample settled and there was a total change in length of about 12 mm (elongation of about 0.1%) over the whole test.

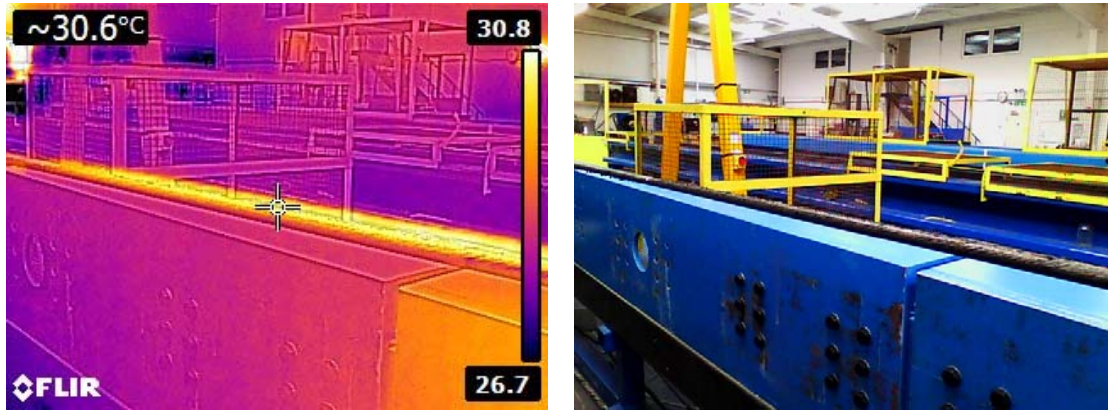


Figure 9.24: Example thermal camera image checking the cable sample temperature in the bending zone (during second block of 1,000 cycles).

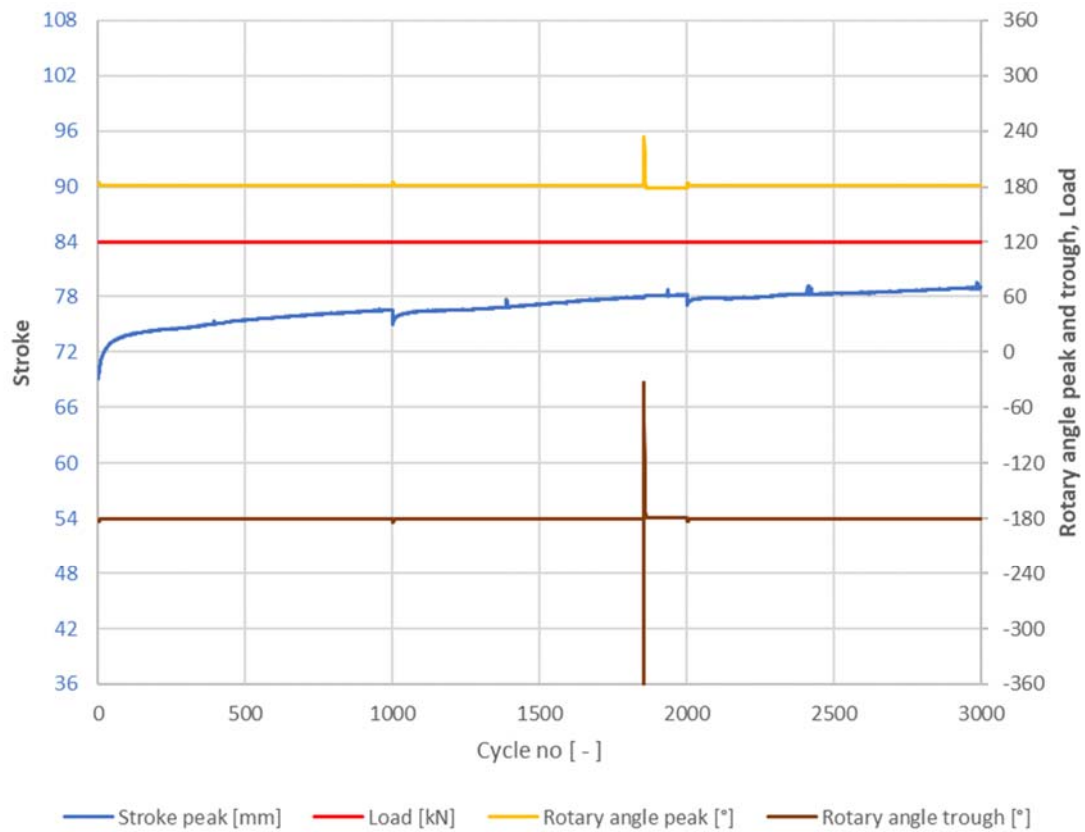


Figure 9.25: Machine data recorded during the CBoS test. Note that the “spikes” on the traces, particularly the rotary angle peak and trough are noise and not true readings. The slight discontinuities at 1000 and 2000 cycles indicate the recovery in length on the sample when it was unloaded for the electrical/optical tests.

Table 9.5 presents the results of the preliminary measurements made on the cable sample, whilst Table 9.6 presents the cycle testing measurements and Table 9.7 the post-cycling measurements.

CONDUCTOR RESISTANCE (cable sample 20.7 m long end – end)				
Component	Required Max.	Measured [Ω]	Temperature [$^{\circ}\text{C}$]	Length/Temperature corrected [Ω/km]
0.22 mm ² - Blue	90 Ω/km @ 20 $^{\circ}\text{C}$	1.686	20.5	81.3
0.22 mm ² - Red		1.701	20.5	82.0
0.22 mm ² - White		1.689	20.5	81.4
0.22 mm ² - Yellow		1.683	20.5	81.1
5.4 mm ² - Green	3.7 Ω/km @ 20 $^{\circ}\text{C}$	0.071	20.5	3.4
5.4 mm ² - Red		0.072	20.5	3.5
5.4 mm ² - Yellow		0.072	20.5	3.5
4.0 mm ² - Blue	4.9 Ω/km @ 20 $^{\circ}\text{C}$	0.092	20.5	4.4
4.0 mm ² - White		0.092	20.5	4.4
INSULATION RESISTANCE - maintained for 1 minute to ground (screens, FO tubes and armour)				
Component	Required Min.	Measured [$\text{G}\Omega$]		
0.22 mm ² - Blue	50 $\text{G}\Omega$ @ 0.5 kV_{dc}	>537		
0.22 mm ² - Red		>537		
0.22 mm ² - White		>537		
0.22 mm ² - Yellow		>537		
5.4 mm ² - Green	50 $\text{G}\Omega$ @ 2.4 kV_{dc}	353	Note measurements made @ 2.5 kV_{dc}	
5.4 mm ² - Red		362		
5.4 mm ² - Yellow		388		
4.0 mm ² - Blue		547		
4.0 mm ² - White		564		
FIBRE OPTIC MEASUREMENTS				
Fibre	Attenuation [dBm]			
Blue	4.76	Measured collectively (daisy chained) with $\lambda = 1,550 \text{ nm}$		
Brown				
Green				
Grey				
Orange				
White				

Table 9.5: Preliminary measurements for the CBoS test sample.

	Electrical resistance			Ambient Temperature	Corrected electrical resistance (for 20°C)			Insulation Resistance – at voltages given previously			Optical loss	Cable Surface Temperature
	[Ω]			[°C]	[at 20°C, Ω/km]			[GΩ]			[dBm]	[°C]
Daisy chain core size [mm ²]	0.22	5.4	4.0		0.22	5.4	4.0	0.22	5.4	4.0		
No. of cores in daisy chain	4	3	2									
Cycles, 0	6.77	0.217	0.186	20.8	81.507	3.483	4.479	>537	222	415	4.76	20.8
Test maximum (+5%)					85.582	3.658	4.703	> 50				
1000	6.900	0.222	0.194	23.5	82.203	3.526	4.622	320	172	366	5.24	
2000	6.900	0.222	0.199	23.9	82.075	3.521	4.734	248	190	441	5.56	31
3000	6.880	0.222	0.190	22.9	82.155	3.535	4.538	200	177	418	5.24	30

Table 9.6: Cycle testing measurements for the CBoS test sample (with cores daisy chained by size).

CONDUCTOR RESISTANCE				
Component	Required Max.	Measured [Ω]	Temperature [$^{\circ}\text{C}$]	Length/Temperature corrected [Ω/km]
0.22 mm ² - Blue	90 Ω/km @ 20 $^{\circ}\text{C}$	1.709	22.7	81.7
0.22 mm ² - Red		1.724	22.7	82.4
0.22 mm ² - White		1.711	22.7	81.8
0.22 mm ² - Yellow		1.709	22.7	81.7
5.4 mm ² - Green	3.7 Ω/km @ 20 $^{\circ}\text{C}$	0.072	22.7	3.4
5.4 mm ² - Red		0.073	22.7	3.5
5.4 mm ² - Yellow		0.073	22.7	3.5
4.0 mm ² - Blue	4.9 Ω/km @ 20 $^{\circ}\text{C}$	0.093	22.7	4.4
4.0 mm ² - White		0.094	22.7	4.5
INSULATION RESISTANCE - maintained for 1 minute to ground (screens, FO tubes and armour)				
Component	Required Min.	Measured [$\text{G}\Omega$]		
0.22 mm ² - Blue	50 $\text{G}\Omega$ @ 0.5 kV_{dc}	>537		
0.22 mm ² - Red		>537		
0.22 mm ² - White		>537		
0.22 mm ² - Yellow		>537		
5.4 mm ² - Green	50 $\text{G}\Omega$ @ 2.4 kV_{dc}	518	Note measurements made @ 2.5 kV_{dc}	
5.4 mm ² - Red		395		
5.4 mm ² - Yellow		399		
4.0 mm ² - Blue		805		
4.0 mm ² - White		809		
FIBRE OPTIC MEASUREMENTS				
Fibre	Attenuation [dBm]			
Blue	5.26	Measured collectively (daisy chained) with $\lambda = 1,550 \text{ nm}$		
Brown				
Green				
Grey				
Orange				
White				

Table 9.7: Post cycling measurements for the CBoS test sample.

9.3.2 Post-test inspection

On completion of the bending cycles, the positions of the bending zones were marked on the sample before removal from the test machine.

The sample was inspected in a similar manner to the bent T-T sample. As is discussed in Appendix A, owing to the nature of the CBoS test, distinct zones may be identified on the sample:

- Always straight - these are sections towards the end of each sample (one on each side of the sheave) which never enter the sheave. The load in these sections of cable will be fairly constant throughout the test, and they will not be subject to fluctuating bending stresses.
- Single bending zones (SBZ) these are sections of cable (one on each side of the sheave) which run into the sheave during the bending cycle, but owing to the amplitude of the bending motion do not run off the “other” side of the sheave; and,
- A double bending zone (DBZ), between the two SBZs, a section of cable which runs into the sheave and off at the other tangent point before the direction of travel is reversed, thereby experiencing two straight-bent-straight bends for each machine cycle.

Experience has shown that the section of sample most likely to experience damage will be at the interface between the SBZ and DBZ, where bending stress fluctuations are greatest as the direction of travel reverses.

A section of cable including all bending zones and with 500 mm of always straight sample at each end was taken. The whole of this sample was inspected, but attention focused on the SBZ-DBZ interface (Figure 9.26). For reasons of practicality, the sample was inspected in two halves.



Figure 9.26: CBoS sample laid out for inspection. The red tape marks the top always straight-SBZ interface. The top SBZ is between red and white tape, and DBZ between white and yellow. The second SBZ is yellow to blue (not shown).

The always straight – SBZ interfaces were clearly identifiable on the sample by inspection of the surface of the sample. Figure 9.27 shows the top always straight section, and it may be seen that the excess grease which has been squeezed from the construction by the application of the tensile (test) load has accumulated on the bottom side of the cable. In contrast, the section which has run into the sheave has been squeezed away from the groove, and tended to accumulate on the top or outer surface (Figure 9.28). Wrapping the cable in plastic to facilitate removal of the sample had the effect of “smudging” these features.



Figure 9.27: CBoS sample in test machine during marking of the bending zones. At the top is a section of always straight cable, and the collection of grease along the bottom side may clearly be seen (the blue – yellow SBZ can be seen at the bottom).



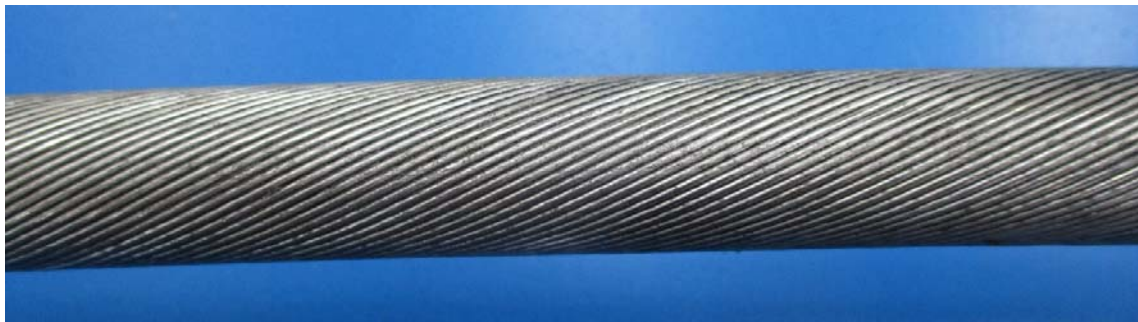
Figure 9.28: CBoS sample in test machine showing the distribution of grease around the cable on a section which has operated over the sheave.

Figures 9.29 to 9.36 show the typical appearance of the different zones of the cable before and after cleaning during the post test dissection. Generally speaking the sample was found to be in very good condition, and no wire breaks were found. As might be expected, the always straight (AS) portions were in the best condition, followed by the SBZ and finally DBZ sections.

Figure 9.29 shows the outer layer of armour after cleaning. The three zones appear very similar, the AS section possibly a little “brighter” but it is fairly subjective. The lay of the armour remains uniform in all areas, and no riding wires or gapping was noted.



Always straight outer layer after cleaning



SBZ outer layer after cleaning



DBZ outer layer after cleaning

Figure 9.29: CBoS sample zones outer layer of armour after cleaning.

Figure 9.30 shows the second layer of armour before cleaning. The lubricant coating was uniform in all regions. The condition of the lubricant in the AS section was very good, of good nature and at a good level. The lubricant in the bending zones was not at such a high level, although still acceptable, and showed signs of being “worked”.



AS second layer before cleaning



SBZ second layer before cleaning



DBZ second layer before cleaning

Figure 9.30: CBoS sample zones second layer of armour before cleaning.

Figure 9.31 shows the second layer of armour after cleaning. The interlayer wire contact points are very evident in the bending zones, and may just be seen on the surface of the wires in the AS sample. The SBZ and DBZ armour is still reasonably even, but there is a suggestion of some gapping between the wires. This seems worse on the DBZ, as might be expected.



AS second layer after cleaning



SBZ second layer after cleaning



DBZ second layer after cleaning

Figure 9.31: CBoS sample zones second layer of armour after cleaning.

The condition of the polyethylene sheath is shown in Figure 9.32. In all sections the second layer of armour had formed a series of ridges on the surface of the sheath, which were most pronounced in the DBZ. The jacket remained intact along the length of the sample examined and no holes or splits were noted.



AS



SBZ



DBZ

Figure 9.32: CBoS sample zones polyethylene sheath before cleaning.

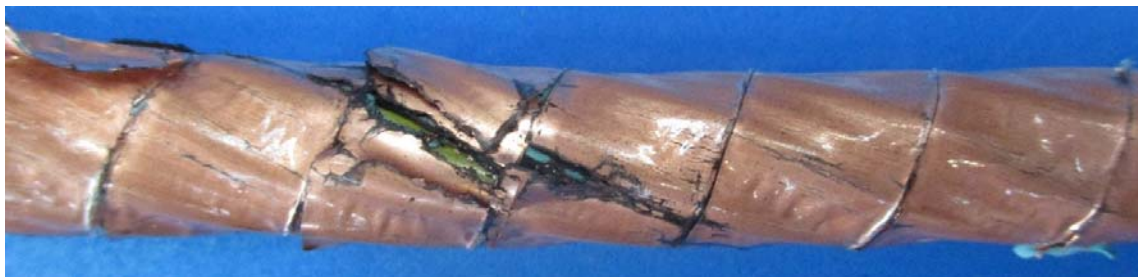
Figure 9.33 shows the condition of the copper/polyester tape. In the AS section the tape has been squashed onto the power cores below, but remains undamaged and bright in colour. In contrast, in the bending zone sections the tape is discoloured and breaking up. The DBZ is clearly more degraded than the SBZ.



AS



SBZ



DBZ



Copper tape at SBZ – DBZ interface (white tape)

Figure 9.33: CBoS sample zones copper/polyester tape (no cleaning).

Figure 9.34 shows the sample with the laminate tape removed to reveal the larger power cores, (black) jacketed fibre optic tube, jacketed drain wires and silicone compound. In the AS section this has the appearance of being as new. The SBZ is “grubby” a discolouration which is associated with rubbing against the laminate tape. The DBZ is more discoloured, but even so all sections remained in an acceptable condition.



AS conductors and FO tube



SBZ (grubby)

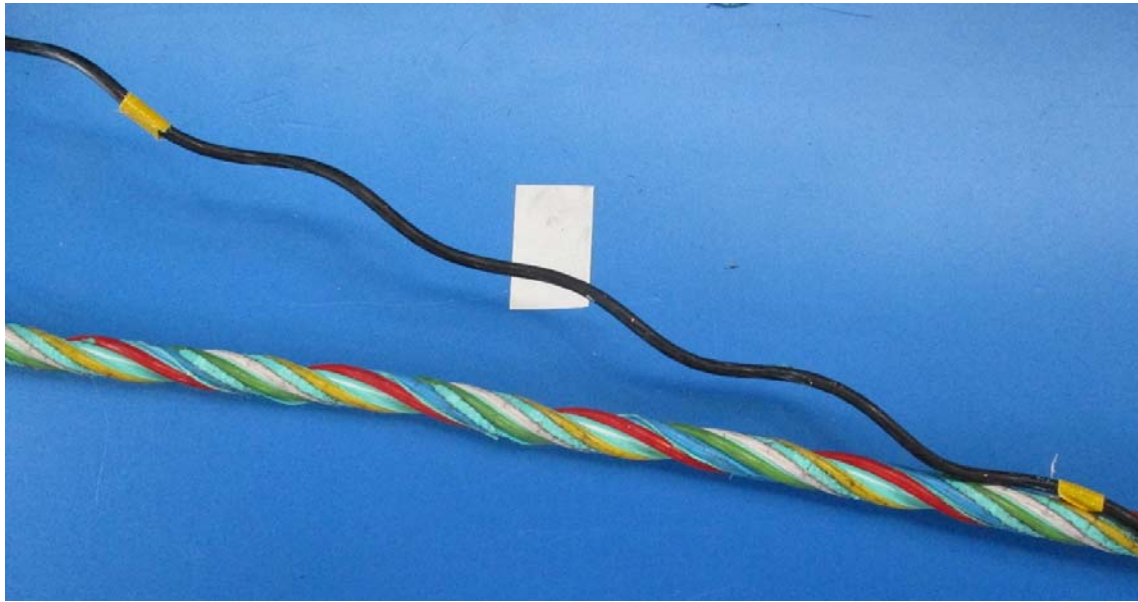


DBZ more grubby / worked

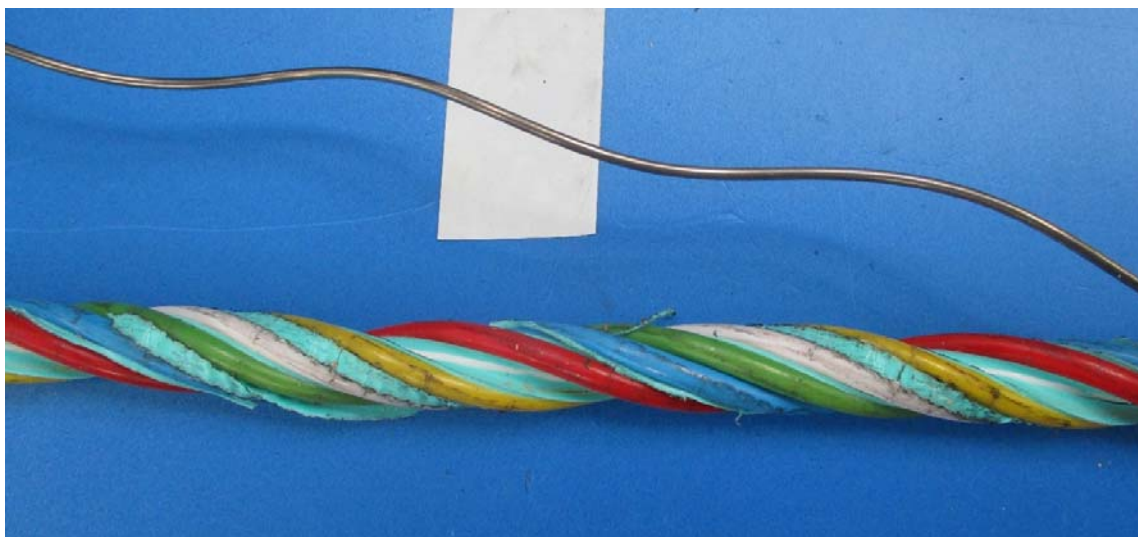
Figure 9.34: CBoS sample zones large power conductors and FO tube (black) (no cleaning).

An inspection was made of the fibre optic tube in the SBZ-DBZ transition (indicated by the white tape in Figure 9.35). The black plastic jacket appeared in very good condition, and was removed over the portion indicated by the yellow tape in Figure 9.35. The stainless steel tube was in very good condition. No kinks or bends were noted.

Finally a section of signal quad from the SBZ-DBZ interface was examined. Its condition was very good and no signs of degradation were noted.



Fibre optic tube with jacket



Stainless steel tube

Figure 9.35: CBoS sample fibre optic tube in the region of the SBZ-DBZ interface (white tape).



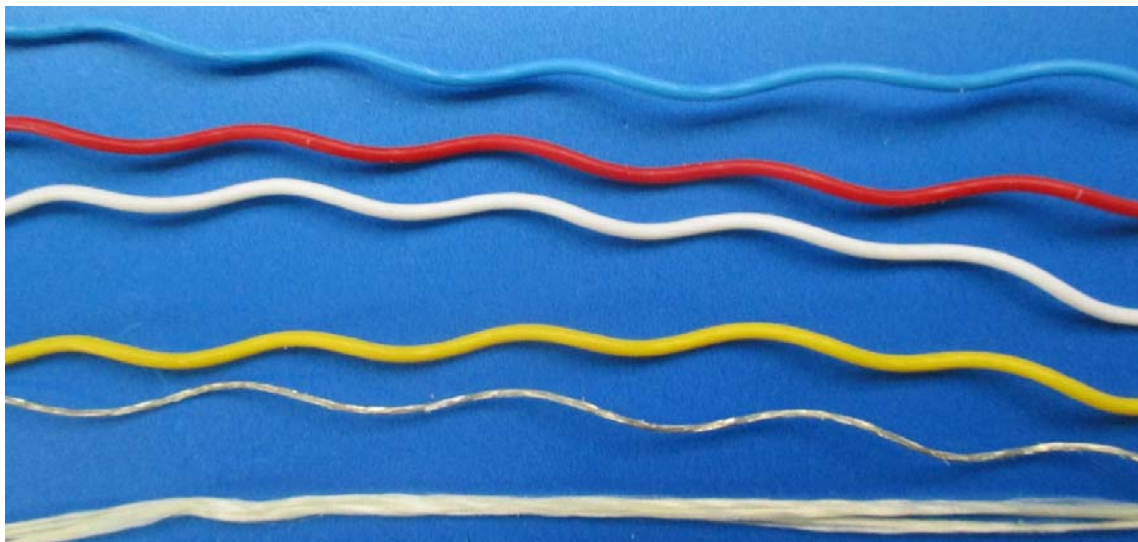
Jacket on signal quad



Laminate tape on signal quad



Signal quad with laminate tape removed



Signal quad wires, drain and central carrier

Figure 9.36: CBoS sample jacketed signal quad in the region of the SBZ-DBZ interface (white tape).

10 Conclusions

This report has detailed the methodology and presented the results of a series of tests undertaken on Fibron ROV umbilical part no RM0058. The following conclusions may be drawn.

10.1 Conclusions relating to the tensile test

A rotation-elongation test was made to assess the cable load-rotation and load-elongation relationship at loads up to 60 kN (33% MBL). The sample was rotationally soft at lower loads (which is quite normal as lower torques are produced to react any rotation). At increased loads the behaviour was stiffer and a rotation of just under 3°/m was measured at 60 kN. The axial elongation of the sample was measured at just under 1% under the same load.

In the test to breaking load it was thought that the result was affected by failure at the actuator end termination. Even so, a breaking load of 204.3 kN was measured, comfortably in excess of the cable MBL of 180 kN.

10.2 Conclusions relating to the Bent T-T test

The Bent T-T test sample completed the 7,500 fatigue cycles (cable load 1 to 6.1 tonnes) over a MBR of 400 mm remaining in very good condition.

The electrical (and possibly fibre optic) measurements were affected by the heat build up in the sample during fatigue cycling, but returned to acceptable levels once the sample cooled.

The post-test dissection of the sample showed it to be in very good condition.

10.3 Conclusions relating to the CBoS test

In the CBoS test the cable completed 3,000 machine cycles (6,000 cable bending cycles in the DBZ) at a tensile load of 60 kN.

The electrical and fibre optic elements all performed well during the testing.

A post-test dissection of the sample showed it to be in very good condition.

Overall it is concluded that the sample performed very well in the set of tests reported here.

11 References

- [1] Fibron, *Tensile qualification test (inc. elongation, rotation and break) for Umbilical part no. RM0058*, Fibron Document no. PRM0058-18950A rev. 01, 17th August 2021.
- [2] Fibron, *Tension-Tension under Bend Test for Cable part no. RM0058*, Fibron Document no. TTRM0058-18950A rev. 02, 17th August 2021.
- [3] Fibron, *Cyclic Bend Over Sheave (CBoS) (Reverse Bend Test) for Cable part no. RM0058*, Fibron Document no. CBOSRM0058-18950A rev. 02, 17th August 2021.
- [4] Fibron, *ROV Main lift cable, drawing no. SQ30978-A, Rev 00* 1st March 2019.

Appendix A - Bending cycle definitions

A cable (or hose) bending cycle is defined as going:

- from the condition straight, bent and back to straight again (straight-bent-straight); or conversely,
- from the bent condition, to straight and back to bent again (bent-straight-bent).

Figure A.1 shows the cable as it passes over the test sheave each cycle. Figure A.1a shows it at an extreme end of stroke. The length A-C is the bending length, 2,514 mm, and is fully off the sheave. During the bending cycle the rope approaches and runs onto the sheave. The section B-C runs onto the sheave, and if A-C is longer than the arc X-Y (1,257 mm), as point A continues to approach the sheave and section B-C runs off at the opposite tangent point until A reaches the end of the stroke (point X on the sheave - Figure A.1b). Thus in half of a machine cycle, the section B-C goes from straight to bent to straight again (straight-bent-straight) which is one rope bending cycle. Sections A-B go from straight to bent, and C-D from bent to straight; half a bending cycle.

In the next half of the machine cycle the rope returns to its original position (Figure A.1a) and section B-C completes another full rope bending cycle and sections A-B and C-D another half bending cycle each.

Hence in *one machine bending cycle*:

- sections A-B and C-D complete one rope bending cycle; and,
- section B-C completes two rope bending cycles.

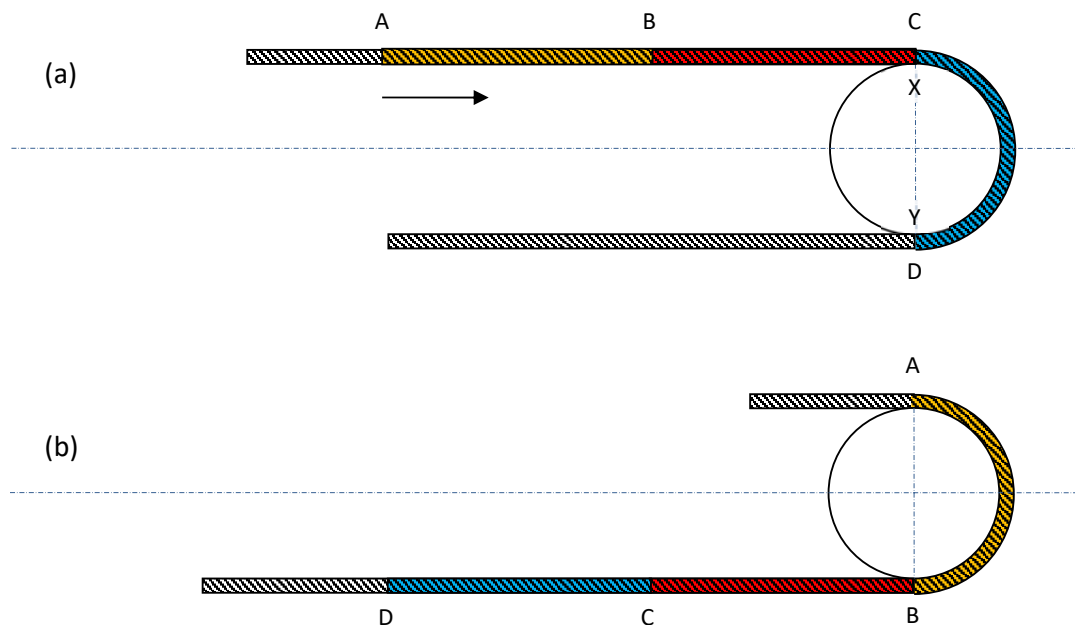


Figure A.1: Schematic diagram defining cable and machine bending cycles.

Appendix B – Calibration Certificates

This Appendix contains calibration certificates for the following equipment:

200 kN test machine

Torsion load cell serial no. 931750

600 kN test machine

KI 2600GE serial no. 30904

KI 2824 serial no. 31146

Thermometer (RS) serial no. 202112006

Fluke 1555 serial no. 345025

Cropico 4001 serial no. 28F-0857 (Fibron equipment)

CERTIFICATE OF CALIBRATION

ISSUED BY:

SERCAL MATERIALS TESTING MACHINES SERVICES LTD
UKAS ACCREDITED CALIBRATION LABORATORY

CERTIFICATE NUMBER: 57085

DATE OF ISSUE: 09 June 2021



0375

SERCAL MTMS LTD.

Page 1 of 3 Pages

Sercal Materials Testing Machines Services Ltd.
Southern Avenue, Leominster,
Herefordshire, HR6 0QH.
Tel: +44 (0) 1527 514015 Fax: +44 (0) 1527 514016
E-mail: enquiries@sercalcalibrations.co.uk

Approved Signatories

J. Swann
Dr N. Wrigley

Issued To:	ZwickRoell Ltd (for and on behalf of TTI Testing Ltd)		
Address:	Unit 2, Hithercroft Road, Wallingford, Oxfordshire, OX10 9DG		
Machine Description:	200kN Horizontal Actuator	Serial Number:	3407913
Manufacturer / Type:	Fox VPS	Force Capacity:	200kN
Display System:	Single Range Computer Display	Software:	Cubus Version 2.1.48
Force Transducer:	250kN Interface Load Cell	Serial Number:	299118A
Associated Equipment:	Lenovo Computer System	Serial Number:	000423
Associated Equipment:	Cats3 Servo Controller	Serial Number:	227536

Date of Calibration: 04 June 2021 **Ambient Temperature:** 25.2°C

Sercal Quote Reference: Q210431R **Location:** Test Laboratory

Previous certificate number: N/a

Method:

The testing machine identified above has been calibrated in accordance with the requirements of **BS EN ISO 7500-1:2018** over the ranges given below for increasing forces only. The calibration was performed using force proving devices and / or masses which meet the requirements of BS EN ISO 7500-1 and equipment which is calibrated in accordance with BS EN ISO 376:2011

The machine complied with the requirements of the standard for the following ranges and classifications with regard to the relative error, repeatability, resolution and zero return to which table 2 of the standard refers:

Range	Mode	Status	Classification of range(s) to minimum force
200kN	Tension	As found	200kN Class 1 down to 2kN
200kN	Compression	As found	200kN Class 0.5 down to 4kN Class 1 down to 2kN

Detailed tabulated results are shown on the following pages.

Calibrated by: Russell Sheriff

Certified by:

N.S. Wrigley

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CERTIFICATE OF CALIBRATION

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CERTIFICATE NUMBER: 57085

DATE OF ISSUE: 09 June 2021

Page 2 of 3 Pages

The following traceable force proving equipment was used for the calibration:

Description	Capacity	Class	Serial Number	Certificate Number	Date Calibrated
Nobel DC Ratio meter	-	-	19-5005	2019110134-1	28 July 2020
Load Cell	100kN	0.5	020033S	2002033	19 February 2020
Load Cell	600kN	0.5	600/4U	2019110192-1	23 July 2020

With reference to clause 6 of BS EN ISO 7500-1 the proving equipment used has been calibrated to BS EN ISO 376 and the class of the proving device(s) was equal to or exceeded the class to which the machine has been verified.

The expiry date of the certificates of calibration for the elastic proving devices used is 26 months and for masses 5 years from the dates given above.

Where masses are used, the value for gravity (g) used to calculate the forces exerted by the masses was 9.815m/s^2

When using elastic proving devices the constant indicated force method was used to effect the verification. When masses are used the constant true force method was used to effect the verification. Three verification runs were made on each range

The Interval between verifications, clause 9 of the standards refers.

The time between verifications depends upon the type of testing machine, the standard of maintenance and the amount of use. Unless otherwise specified it is recommended that the verification be carried out at intervals not exceeding 12 months.

The machine shall in any case be verified if it is moved to a new location necessitating dismantling or if it is subject to major repair or adjustment.

The Sercal Calibration Laboratory is accredited by UKAS to BS EN ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories) to perform the calibration which is reported on this certificate.

Prior to verification the machine was inspected for good working order and was found to satisfy the guidelines given in section 5 of BS EN ISO 7500-1

The calculation of the accuracy and repeatability errors and the classification of the testing machines performance was made in accordance with the method specified in BS EN ISO 7500-1:2018

In the result tables which follow a negative relative error indicates that the machine indicator lags the true applied force. Where there are adjacent results at the same force increment, these are at the overlap point from the two proving devices used.

The decision rule of the classification does not take into account the uncertainty as described in section 7 of BS EN ISO 7500-1.

The following settings were made in accordance with the manufacturers instructions.

Range	Polarity / Mode	Trans / Type	Voltage / Cal Type	Gain / Sensitivity	Trim - / Trim +	Offset
200kN	Normal / Bipolar	Symetric / DC	10.00V / 2 Point	294 / 3.401mv/V	1.002 / 1.005	0.00kN

Cal File: Small Horizontal Load Act - FB1 04-06-2021.q

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.

CERTIFICATE OF CALIBRATION

ISSUED BY: SERCAL MATERIALS TESTING MACHINES SERVICES LIMITED
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CERTIFICATE NUMBER: 57085
DATE OF ISSUE: 09 June 2021

Page 3 of 3 Pages

Results:

Range 1 200kN Tension			Range 2 200kN Compression		
These results are:	As found - no adjustments were made		These results are:	As found - no adjustments were made	
Nominal Force	Relative Error	Expanded Uncertainty	Nominal Force	Relative Error	Expanded Uncertainty
kN	%	%	kN	%	%
2.00	-0.03	0.40	2.00	0.41	0.40
4.00	-0.12	0.31	4.00	0.27	0.30
8.00	-0.11	0.28	8.00	0.26	0.28
14.00	-0.11	0.27	14.00	0.30	0.27
20.00	-0.13	0.27	20.00	0.24	0.27
20.00	-0.19	0.37	40.00	0.23	0.27
40.00	-0.24	0.36	40.00	0.14	0.27
80.00	-0.15	0.36	80.00	0.18	0.27
120.00	-0.07	0.36	120.00	0.22	0.27
160.00	-0.01	0.36	160.00	0.25	0.27
200.00	0.03	0.36	200.00	0.27	0.27

End of Certificate

In the result table(s) above a negative relative error indicates that the machine indicator lags the true applied force.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.

CERTIFICATE OF CALIBRATION

ISSUED BY:

SERCAL MATERIALS TESTING MACHINES SERVICES LIMITED

UKAS ACCREDITED CALIBRATION LABORATORY

CERTIFICATE NUMBER: 56809

DATE OF ISSUE: 09 June 2021



0375

SERCAL MTMS LTD.

Sercal Materials Testing Machines Services Ltd.
Southern Avenue, Leominster,
Herefordshire, HR6 0QH.
Tel: +44 (0) 1527 514015 Fax: +44 (0) 1527 514016
E-mail: enquiries@sercalcalibrations.co.uk

Page 1 of 2 Pages

Approved Signatories

J. Swann
Dr N. Wrigley

Issued To: Zwick Roell Ltd (For & On behalf of TTI Testing Ltd)

Address: Unit 2, Hithercroft Road, Wallingford, OX10 9DG

Host Machine Description: Universal Actuator **Serial Number:** 3407913 TTI0000009

Manufacturer / Type: Fox VPS / TTI Testing Frame **Force Capacity:** 250kN

Transducer Type: Integral Digital Encoder **Serial Number:** 3407913

Display Type: Single Range Computer Display **Software:** Cubus Version 2.1.48.2 423

Transducer Conditioning: Cats 3 Servo Controller **Serial Number:** Unknown

Associated Equipment: Lenovo Computer System **Serial Number:** 423

Date of Calibration: 06 June 2021 **Ambient Temperature:** 24.2°C

Sercal Quotation No: Q210431R **Location:** Test Area

Previous Certificate No. 56027 **Dated:** 30 November 2020

Method:

The displacement indication system of the machine identified above has been verified in accordance with Sercal procedure 06-10 using the proving device(s) listed on page 2 and which are traceable to National Standards.

The proving device was mounted between the actuator ram / crosshead and a fixed point on the machine. The actuator ram / moving crosshead was moved to an initial starting position where the displacement indicator and the reference device indicators were set to zero. The actuator was then displaced, in the direction and by the quantities indicated in the tables and the machine and proving device readings recorded. Both indicators were re-zeroed after each run.

The system range of the transducer, the calibrated range of the transducer, the starting position of the test, the two measurements taken at each increment and the uncertainty of measurement are shown in the result table(s) on the following pages.

The results only relate to the item calibrated, described above.

System Range	Status	Direction	Calibrated Ranges			Start Position
1000 mm	As found	Negative	1000 mm	down to	100 mm	0 mm
1000 mm	As found	Positive	1000 mm	down to	100 mm	0 mm

The following settings were made in accordance with the manufacturers instructions.

Range	Polarity / Mode	Trans / Type	Excitation	Gain	n (-ve) / Trim (+)	Offset
1000 mm	Inverted / Unipolar	Asymmetric / DC	20V	1	1.000 / 1.012	25.14mm

1000 mm Range: Cal File: 2000mm Small Horizontal Displacement 04.06.20

Calibrated by: Lee Smith

Certified by:

N.S. Wrigley

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CERTIFICATE NUMBER: 56809
DATE OF ISSUE: 09 June 2021

Page 2 of 2 Pages

The following proving device was used:

Description of Device	Serial Number	Certificate No.	Calibrated	Range
Digimatic Scale	1524	3353020001	30/07/2020	1524mm

Range 1 1000 mm

Direction: Negative displacement

Description: 2000mm Range

Results: Uncertainty of measurement $\pm 0.164\text{mm}$

As found - no adjustments were made

Machine Reading displacement mm	Device Reading displacement mm	% error	Absolute error mm	Device Reading displacement mm	% error	Absolute error mm
100.00	99.93	0.07	0.07	100.01	-0.01	-0.01
200.00	199.70	0.15	0.30	199.74	0.13	0.26
300.00	299.45	0.18	0.55	299.48	0.17	0.52
400.00	399.12	0.22	0.88	399.15	0.21	0.85
500.00	498.77	0.25	1.23	498.80	0.24	1.20
600.00	598.24	0.29	1.76	598.25	0.29	1.75
700.00	697.78	0.32	2.22	697.79	0.32	2.21
800.00	797.20	0.35	2.80	797.22	0.35	2.78
900.00	896.70	0.37	3.30	896.75	0.36	3.25
1000.00	995.97	0.40	4.03	996.05	0.40	3.95

Range 2 1000 mm

Direction: Positive displacement

Results: Uncertainty of measurement $\pm 0.275\text{mm}$

As found - no adjustments were made

Machine Reading displacement mm	Device Reading displacement mm	% error	Absolute error mm	Device Reading displacement mm	% error	Absolute error mm
100.00	99.96	0.04	0.04	100.05	-0.05	-0.05
200.00	199.39	0.31	0.61	199.85	0.08	0.15
300.00	299.35	0.22	0.65	299.56	0.15	0.44
400.00	399.02	0.25	0.98	399.31	0.17	0.69
500.00	498.79	0.24	1.21	499.12	0.18	0.88
600.00	598.44	0.26	1.56	598.88	0.19	1.12
700.00	698.38	0.23	1.62	698.73	0.18	1.27
800.00	798.25	0.22	1.75	798.59	0.18	1.41
900.00	897.85	0.24	2.15	898.21	0.20	1.79
1000.00	997.77	0.22	2.23	998.01	0.20	1.99

End of Certificate

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.

CERTIFICATE OF CALIBRATION

SERCAL

MATERIALS TESTING MACHINES SERVICES LTD

Southern Avenue, Leominster, Herefordshire, HR6 0QH

Telephone: +44 (0)1527 514015 Email: info@sercalcalibrations.co.uk

DATE OF ISSUE

01 December 2020

CERTIFICATE NUMBER

11042

PAGE **1** OF **2** PAGES

Issue to: **Zwick Roell (For and on behalf of TTI Testing)**

Address: **Unit 2 , Hithercroft Road, Wallingford, Oxfordshire, OX10 9DG**

Machine Description: **22597Nm Interface Torsion Load Cell**

Type Reference:

Serial Number: **931750T**

Date of Calibration: **27 November 2020**

Quote Reference: **Q200517N**

Machine Location: **Test Laboratory**

Temperature: **14.65 °C**

Associated Equipment:

Description	Type	Serial Number
Cats3 Servo	Controller	Unknown
Computer	System	TTI 000423

Report:

The transducer input channel on the machine electronics has been verified by simulation using a signal source and calibrated voltage meter and shown in the table on page 2 of this certificate.

Measurements:

The temperature of the device during calibration did not vary by more than +/- 2 degrees C. The uncertainty of the temperature measurement was +/- 0.5 degrees C.

The Measurements taken are summarised in the following tables of recorded results in respect to the relevant error of accuracy, uncertainty and resolution. No correction for temperature has been applied to these results.

Calibration Procedure:

An electrical signal was applied to the input of the required transducer input to simulate the behaviour of the normally attached transducer. A series of measurements were taken at evenly spaced points to cover the transducers measurement range. The reading were repeated a further two times.

Calibration Equipment Used:

Description:	Serial Number	Certificate Number	Date Verified:
Thurlby Digital Multimeter	61891	U1909280	07 October 2019

Calibrated By: **Lee Smith**

Certified By:


N.S. Wrigley

The uncertainties are for a confidence probability of not less than 95%

CERTIFICATE OF CALIBRATION

SERCAL

MATERIALS TESTING MACHINES SERVICES LTD

Southern Avenue, Leominster, Herefordshire, HR6 0QH

Telephone: +44 (0)1527 514015 Email: info@sercalcalibrations.co.uk

DATE OF ISSUE

01 December 2020

CERTIFICATE NUMBER

11042

PAGE **2** OF **2** PAGES

Issue to: **Zwick Roell (For and on behalf of TTI Testing)**

Machine Settings:

Normal , Bipolar, Symetric , DC

10V Excitation, Sensitivity 2.158mv/V, Trim + 0.999, Trim - 0.999, Fine Zero 20.49 Nm

200kN Fox VPS Test Bed

Results:

% of Full Scale Value	Signal Applied	Expected Engineering Output	Machine Display Average Reading	Error	Repeatability	Uncertainty Of Measurement
%	mV	Nm	Nm	%	%	Nm
100	21.580	22597	22621	-0.11	0.00	13.4
90	19.422	20337	20354	-0.08	0.00	13.4
80	17.264	18078	18093	-0.09	0.00	13.4
70	15.106	15818	15818	0.00	0.01	13.4
60	12.948	13558	13560	-0.01	0.01	13.4
50	10.790	11299	11303	-0.04	0.01	13.4
40	8.632	9039	9038	0.01	0.00	13.4
30	6.474	6779	6778	0.02	0.00	13.4
20	4.316	4519	4518	0.03	0.00	13.4
10	2.158	2260	2260	-0.03	0.04	13.4
0	0.000	0	0	-	-	-
-10	-2.158	-2260	-2260	0.00	0.04	-13.4
-20	-4.316	-4519	-4518	0.03	0.04	-13.4
-30	-6.474	-6779	-6777	0.03	0.00	-13.4
-40	-8.632	-9039	-9037	0.02	0.01	-13.4
-50	-10.790	-11299	-11294	0.04	0.01	-13.4
-60	-12.948	-13558	-13560	-0.01	0.00	-13.4
-70	-15.106	-15818	-15818	0.00	0.01	-13.4
-80	-17.264	-18078	-18078	0.00	0.00	-13.4
-90	-19.422	-20337	-20347	-0.05	0.00	-13.4
-100	-21.580	-22597	-22612	-0.07	0.00	-13.4

The uncertainties are for a confidence probability of not less than 95%

CERTIFICATE OF CALIBRATION

ISSUED BY:

SERCAL MATERIALS TESTING MACHINES SERVICES LTD
UKAS ACCREDITED CALIBRATION LABORATORY

CERTIFICATE NUMBER: 57082

DATE OF ISSUE: 09 June 2021



0375

SERCAL MTMS LTD.

Page 1 of 3 Pages

Sercal Materials Testing Machines Services Ltd.
Southern Avenue, Leominster,
Herefordshire, HR6 0QH.
Tel: +44 (0) 1527 514015 Fax: +44 (0) 1527 514016
E-mail: enquiries@sercalcalibrations.co.uk

Approved Signatories

J. Swann
Dr N. Wrigley

Issued To:	ZwickRoell Ltd (For and on behalf of TTI Testing Ltd)		
Address:	Unit 2 Hithercroft Road, Wallingford, Oxfordshire, OX10 9DG		
Machine Description:	Universal Testing Machine	Serial Number:	S4709B000009101
Manufacturer / Type:	Fox VPS	Force Capacity:	650kN
Display System:	Single Range Computer Display	Software:	Cubus Version 2.1.48
Force Transducer:	900kN Interface Load Cell	Serial Number:	352882A
Associated Equipment:	Dell Optiplex 3060 Computer System	Serial Number:	7BNGLR2
Associated Equipment:	Cats3 Servo Servo Controller	Serial Number:	206024

Date of Calibration:	04 June 2021	Ambient Temperature:	23.3°C
Sercal Quote Reference:	Q210431R	Location:	Test Laboratory
Previous certificate number:	55353	Issued:	15 July 2020

Method:

The testing machine identified above has been calibrated in accordance with the requirements of **BS EN ISO 7500-1:2018** over the ranges given below for increasing forces only. The calibration was performed using force proving devices and / or masses which meet the requirements of BS EN ISO 7500-1 and equipment which is calibrated in accordance with BS EN ISO 376:2011

The machine complied with the requirements of the standard for the following ranges and classifications with regard to the relative error, repeatability, resolution and zero return to which table 2 of the standard refers:

Range	Mode	Status	Classification of range(s) to minimum force
650kN	Tension	As found	650kN Class 1 down to 10kN
650kN	Compression	As found	650kN Class 1 down to 10kN

Detailed tabulated results are shown on the following pages.

Calibrated by: Russell Sheriff

Certified by:

N.S. Wrigley

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CERTIFICATE OF CALIBRATION

ISSUED BY: SERCAL MATERIALS TESTING MACHINES SERVICES LTD
UKAS ACCREDITED CALIBRATION LABORATORY 0375
CERTIFICATE NUMBER: 57082
DATE OF ISSUE: 09 June 2021

Page 2 of 3 Pages

The following traceable force proving equipment was used for the calibration:

Description	Capacity	Class	Serial Number	Certificate Number	Date Calibrated
Nobel DC Ratio meter	-	-	19-5005	2019110134-1	28 July 2020
Load Cell	500kN	0.5	600/7U	2019110188-1	15 January 2020
Load Cell	1200kN	0.5	11075	2020110091-1	03 February 2021

With reference to clause 6 of BS EN ISO 7500-1 the proving equipment used has been calibrated to BS EN ISO 376 and the class of the proving device(s) was equal to or exceeded the class to which the machine has been verified.

The expiry date of the certificates of calibration for the elastic proving devices used is 26 months and for masses 5 years from the dates given above.

Where masses are used, the value for gravity (g) used to calculate the forces exerted by the masses was 9.815m/s^2

When using elastic proving devices the constant indicated force method was used to effect the verification. When masses are used the constant true force method was used to effect the verification. Three verification runs were made on each range

The Interval between verifications, clause 9 of the standards refers.

The time between verifications depends upon the type of testing machine, the standard of maintenance and the amount of use. Unless otherwise specified it is recommended that the verification be carried out at intervals not exceeding 12 months. The machine shall in any case be verified if it is moved to a new location necessitating dismantling or if it is subject to major repair or adjustment.

The Sercal Calibration Laboratory is accredited by UKAS to BS EN ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories) to perform the calibration which is reported on this certificate.

Prior to verification the machine was inspected for good working order and was found to satisfy the guidelines given in section 5 of BS EN ISO 7500-1

The calculation of the accuracy and repeatability errors and the classification of the testing machines performance was made in accordance with the method specified in BS EN ISO 7500-1:2018

In the result tables which follow a negative relative error indicates that the machine indicator lags the true applied force. Where there are adjacent results at the same force increment, these are at the overlap point from the two proving devices used.

The decision rule of the classification does not take into account the uncertainty as described in section 7 of BS EN ISO 7500-1.
The following settings were made in accordance with the manufacturers instructions.

Range	Polarity / Mode	Trans / Type	Voltage / Cal Type	Gain / Sensitivity	-ve Trim / +ve Trim	Offset
650kN	Inverted / Bipolar	Symetric / DC	10.00V / 2 Point Cal	306 / 3.268mv/V	1.014 / 1.005	-1.94kN

Cal File: 600 Actuator Load 04-06-2021 - FB1.qtxcfg

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements. The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.

CERTIFICATE OF CALIBRATION

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CERTIFICATE NUMBER: 57082
DATE OF ISSUE: 09 June 2021

Page 3 of 3 Pages

Results:

Range 1 650kN Tension			Range 2 650kN Compression		
These results are:	As found - no adjustments were made		These results are:	As found - no adjustments were made	
Nominal Force	Relative Error	Expanded Uncertainty	Nominal Force	Relative Error	Expanded Uncertainty
kN	%	%	kN	%	%
10.00	-0.02	0.38	10.00	0.08	0.32
13.00	-0.04	0.37	13.00	0.09	0.31
26.00	0.21	0.37	26.00	0.06	0.27
45.00	0.47	0.36	45.00	-0.05	0.27
65.00	0.66	0.36	65.00	-0.18	0.27
130.00	-0.18	0.36	130.00	-0.31	0.27
130.00	0.07	0.35	260.00	-0.38	0.28
260.00	0.13	0.34	260.00	-0.25	0.34
390.00	0.27	0.34	390.00	-0.21	0.34
520.00	0.42	0.23	520.00	-0.24	0.34
650.00	0.52	0.23	650.00	-0.18	0.34

End of Certificate

In the result table(s) above a negative relative error indicates that the machine indicator lags the true applied force.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.

CERTIFICATE OF CALIBRATION

ISSUED BY:

SERCAL MATERIALS TESTING MACHINES SERVICES LIMITED

UKAS ACCREDITED CALIBRATION LABORATORY

CERTIFICATE NUMBER: 57083

DATE OF ISSUE: 09 June 2021



0375

SERCAL MTMS LTD.

Sercal Materials Testing Machines Services Ltd.
Southern Avenue, Leominster,
Herefordshire, HR6 0QH.
Tel: +44 (0) 1527 514015 Fax: +44 (0) 1527 514016
E-mail: enquiries@sercalcalibrations.co.uk

Page 1 of 2 Pages

Approved Signatories

J. Swann
Dr N. Wrigley

Issued To: ZwickRoell Ltd (For and on behalf of TTI Testing Ltd)

Address: Unit 2 Hithercroft Road, Wallingford, Oxfordshire, OX10 9DG

Host Machine Description: Tensile Testing Machine **Serial Number:** S4709B000009101

Manufacturer / Type: Fox VPS / TTI Testing Frame **Force Capacity:** 650kN

Transducer Type: Integral Digital Encoder **Serial Number:** S4709B000009101

Display Type: Single Range Computer Display **Software:** Cubus Version 2.1.48.2 7BNGLR2

Transducer Conditioning: Cats 3 Servo Controller **Serial Number:** Unknown

Associated Equipment: Dell Computer System **Serial Number:** 7BNGLR2

Date of Calibration: 04 June 2021 **Ambient Temperature:** 23.95°C

Sercal Quotation No: Q210431R **Location:** Test Area

Previous Certificate No. 55354 **Dated:** 15 July 2020

Method:

The displacement indication system of the machine identified above has been verified in accordance with Sercal procedure 06-10 using the proving device(s) listed on page 2 and which are traceable to National Standards.

The proving device was mounted between the actuator ram / crosshead and a fixed point on the machine. The actuator ram / moving crosshead was moved to an initial starting position where the displacement indicator and the reference device indicators were set to zero. The actuator was then displaced, in the direction and by the quantities indicated in the tables and the machine and proving device readings recorded. Both indicators were re-zeroed after each run.

The system range of the transducer, the calibrated range of the transducer, the starting position of the test, the two measurements taken at each increment and the uncertainty of measurement are shown in the result table(s) on the following pages.

The results only relate to the item calibrated, described above.

System Range	Status	Direction	Calibrated Ranges	Start Position
2000 mm	As found	Positive	1000 mm down to 100 mm	0 mm
2000 mm	As found	Negative	993 mm down to 100 mm	0 mm

The following settings were made in accordance with the manufacturers instructions.

Range	Polarity / Mode	Trans / Type	Excitation / Cal Type	Gain / Sensitivity	Trim	Offset
2000 mm	Normal / Unipolar	Asymmetric / DC	20V / Standard Cal	1.000 / 500.0 mV/V	1	0.00mm

2000 mm Range: Cal File: 600 Actuator Displacement 04-06-2021 - FB1.qtxd

Calibrated by: Lee Smith

Certified by:

N.S. Wrigley

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to the units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This certificate may not be reproduced other than in full, except with prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

ISSUED BY: SERCAL MATERIALS TESTING MACHINES SERVICES LIMITED
UKAS ACCREDITED CALIBRATION LABORATORY 0375
CERTIFICATE NUMBER: 57083
DATE OF ISSUE: 09 June 2021

Page 2 of 2 Pages

The following proving device was used:

Description of Device	Serial Number	Certificate No.	Calibrated	Range
Digimatic Scale	1524	3353020001	30/07/2020	1524mm

Range 1 2000 mm

Direction: Positive displacement

Description: 3000mm Range

Results: Uncertainty of measurement $\pm 2.306\text{mm}$
As found - no adjustments were made

Machine Reading displacement mm	Device Reading displacement mm	% error	Absolute error mm	Device Reading displacement mm	% error	Absolute error mm
100.00	99.93	0.07	0.07	100.26	-0.26	-0.26
200.00	199.97	0.02	0.03	200.28	-0.14	-0.28
300.00	299.59	0.14	0.41	300.20	-0.07	-0.20
400.00	399.77	0.06	0.23	399.99	0.00	0.01
500.00	499.70	0.06	0.30	499.86	0.03	0.14
600.00	599.70	0.05	0.30	599.92	0.01	0.08
700.00	699.54	0.07	0.46	699.76	0.03	0.24
800.00	799.36	0.08	0.64	799.60	0.05	0.40
900.00	899.39	0.07	0.61	899.40	0.07	0.60
1000.00	1000.94	-0.09	-0.94	999.58	0.04	0.42

Range 2 2000 mm

Direction: Negative displacement

Description: 2000mm

Results: Uncertainty of measurement $\pm 0.201\text{mm}$
As found - no adjustments were made

Machine Reading displacement mm	Device Reading displacement mm	% error	Absolute error mm	Device Reading displacement mm	% error	Absolute error mm
100.00	100.38	-0.38	-0.38	100.49	-0.49	-0.49
200.00	200.36	-0.18	-0.36	199.89	0.06	0.11
300.00	300.05	-0.02	-0.05	300.29	-0.10	-0.29
400.00	400.07	-0.02	-0.07	400.23	-0.06	-0.23
500.00	500.10	-0.02	-0.10	500.24	-0.05	-0.24
600.00	600.06	-0.01	-0.06	600.35	-0.06	-0.35
700.00	700.50	-0.07	-0.50	700.37	-0.05	-0.37
800.00	800.23	-0.03	-0.23	800.85	-0.11	-0.85
900.00	900.44	-0.05	-0.44	900.17	-0.02	-0.17
993.00	991.83	0.12	1.17	992.00	0.10	1.00

End of Certificate

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The uncertainty stated above refer to values obtained during calibration and make no allowances for factors such as long term drift, temperature and alignment effects, the influences of these factors should be taken into account by the user.



Optical Test and Calibration Ltd.

Customer: TTI Testing Ltd

Certificate No: 128526/AA

19-23 Campus Road,
Listerhills Science Park,
Bradford BD7 1HR
Tel +44(0)1274 393857
Fax +44(0)1274 393336
e-mail calibration@otc.co.uk

128526AA

Certificate of Calibration

Equipment Information

Make: KINGFISHER

Model:

KI2600-GE

Description:

OPTICAL POWER METER

Serial No:

30904

Reference:

502

Calibration Category

A01 In specification: no adjustment performed.

Comments

Calibration Information

This instrument was calibrated against laboratory standards which are either traceable to SI units (as realised by National or International Standards) or have been derived by approved ratio techniques. Any specification or uncertainty quoted refers to the measured values only unless otherwise shown, with no account being taken of the ability of the instrument to maintain its calibration.

The calibration was performed in such a manner as to comply with the requirements of BS EN ISO 10012:2003 in accordance with our BS EN ISO 9001:2015 Registration. (Certificate Number FS 11427)

Temperature and Relative Humidity conditions are shown on the results sheet unless not relevant to the measurements performed.

Calibration results are held on file for a minimum period of 3 years and can be made available if required.

Calibrated by: D Saynor

Date of calibration: 10/08/2020

Approved: J Harris QC028

Date: 11/08/2020

Re-calibration date: 09/08/2023 *

* Calibration recall period set to 36 months as requested.

CERTIFICATE OF CALIBRATION

Certificate Number
128526/AA

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Make: KINGFISHER
Model: KI2600-GE

Serial Number: 30904

Ref: 502

ABSOLUTE ACCURACY MEASUREMENTS:

Measurements were performed as shown in the table below:

Laser Diode Wavelength (nm)	Fibre Type (um)	Connector Type: (Customer Supplied)	Nominal Power Level (dBm)	Unit Under Test Wavelength set (nm)	Unit Under Test Specification
1310	9/125	FC/PC	-10	1310	± 0.5 dB
1550	9/125	FC/PC	-10	1550	± 0.5 dB
850	50/125	FC/PC	-10	850	± 0.5 dB

The equipment was allowed to stabilise for at least 30 minutes before measurements were made. The meter was allowed to auto-range at all power levels. The optical power was determined by measuring the emission from a length of optical fibre, coupled to the laser diode source, by reference to sensors traceable to national standards in accordance with OTC calibration procedure(s) OPT39. The ambient temperature and relative humidity (rh) during the calibration was 23 ± 2 °C and 38 %rh ± 10 %rh.

ABSOLUTE ACCURACY RESULTS:

The sensor window was visually inspected and cleaned of any loose contamination using a light air duster prior to calibration. The sensor window condition on receipt was found to be satisfactory.

As received from customer:

Wavelength	Applied Mean Reference	Mean Unit Under Test	UUT Meter Error ¹	Expanded Uncertainty	UUT Meter Error ¹	Expanded Uncertainty	V _{eff}	Coverage Factor	Comment	p _c
nm	Power dBm	Indication dBm	%	± %	dB	± dB		k		
a 1310	-10.000	-9.90	2.33	4.00	0.10	0.18	>10000	2.00	PASS	
b										
c										
d										
e										
f										

As despatched after cleaning:

Wavelength	Applied Mean Reference	Mean Unit Under Test	UUT Meter Error ¹	Expanded Uncertainty	UUT Meter Error ¹	Expanded Uncertainty	V _{eff}	Coverage Factor	Comment	p _c
nm	Power dBm	Indication dBm	%	± %	dB	± dB		k		
a 1310	-10.001	-9.85	3.54	4.00	0.15	0.18	>10000	2.00	PASS	
b 1550	-10.002	-10.12	-2.68	4.00	-0.12	0.18	>10000	2.00	PASS	
c 850	-10.001	-9.94	1.41	4.00	0.06	0.18	>10000	2.00	PASS	
d										
e										
f										

Notes:

1. A negative meter error denotes that the meter is indicating a lower power than the actual power. A positive meter error denotes that the meter is indicating a higher power than the actual power.
2. It is important to note that some power meters exhibit a non-linearity of response at power levels close to the range changes.
3. Measurement wavelengths quoted are "in air" values. Wavelength uncertainty ±1 nm
4. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor *k*. The value of *k* in each case is stated in the results table which for a *t*-distribution and V_{eff} (the effective degrees of freedom), provides a coverage probability of approximately 95 %.

These results are valid when the unit under test is used under similar conditions to those that applied during the calibration. No allowance has been made for subsequent ageing and the polarisation sensitivity and wavelength effects of the unit under test have not been considered in this calibration.

Results indicated as 'PASS*' are within the stated specification but have a probability of conformance below 50%.

'p_c' indicates probability of conformance to the specification used.

CERTIFICATE OF CALIBRATION

Certificate Number
128526/AA

Page 2 OF 3 Pages

LINEARITY MEASUREMENTS:

Measurements were performed as shown in the table below:

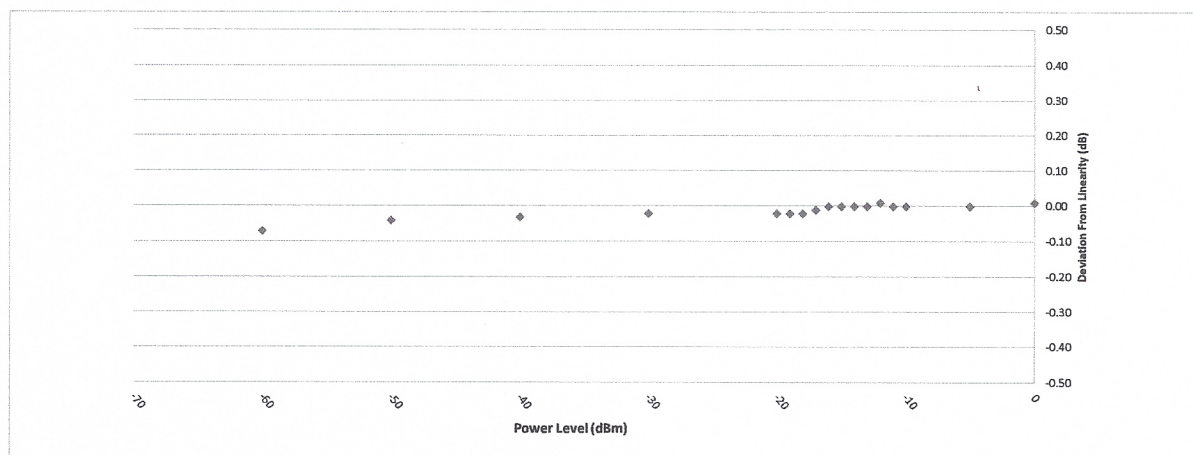
Laser Diode Wavelength (nm)	Fibre Type (um)	Connector Type: (Customer Supplied)	Measurement Range	Unit Under Test Wavelength set (nm)	Unit Under Test Specification (Typical)
1310	9/125	FC/PC	0 dBm to -60 dBm	1310	±0.04 dB over 5 dBm to -60 dBm

The optical power of -10 dBm was determined by measuring the emission from a length of optical fibre, coupled to the laser diode source, by reference to standards directly traceable to national standards. Measurements were then made over the specified range relative to the -10 dBm point.

LINEARITY RESULTS:

The table shows the deviation from a linear response of the meter with reference to the -10 dBm point. A negative dB deviation indicates the meter is indicating a higher relative power level when referenced to the -10 dBm point.

Nominal Power Level	Applied Mean Reference Power	Mean Unit Under Test Indication	Deviation From Linearity	% Deviation	Expanded Uncertainty	Expanded Uncertainty	V _{eff}	Coverage Factor	Comment	p _c
dBm	dBm	dBm	dB	%	± dB	± %		k		
0	0.000	0.00	0.01	0.2	0.10	2.20	>10000	2.00	PASS**	46.60%
-5	-4.997	-4.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-10	-9.999	-9.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-11	-10.998	-10.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-12	-11.999	-12.00	0.01	0.2	0.10	2.20	>10000	2.00	PASS**	46.60%
-13	-12.999	-12.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-14	-13.995	-13.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-15	-14.995	-14.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-16	-16.000	-15.99	0.00	0.0	0.10	2.20	>10000	2.00	PASS**	46.60%
-17	-16.998	-16.98	-0.01	-0.2	0.10	2.20	>10000	2.00	PASS**	46.60%
-18	-17.995	-17.97	-0.02	-0.5	0.10	2.20	>10000	2.00	PASS**	46.60%
-19	-18.994	-18.97	-0.02	-0.5	0.10	2.20	>10000	2.00	PASS**	46.60%
-20	-19.997	-19.97	-0.02	-0.5	0.10	2.20	>10000	2.00	PASS**	46.60%
-30	-29.995	-29.97	-0.02	-0.5	0.10	2.20	>10000	2.00	PASS**	46.60%
-40	-39.997	-39.96	-0.03	-0.7	0.10	2.20	>10000	2.00	PASS**	46.60%
-50	-50.000	-49.95	-0.04	-0.9	0.10	2.20	>10000	2.00	PASS**	46.60%
-60	-60.006	-59.93	-0.07	-1.6	0.10	2.20	>10000	2.00	PASS**	46.60%



Equipment Used: CAL916,701,939,910,983,859,655,604,604C,449,449A,449B

CAL CAT: A01 In specification: no adjustment performed.

Calibrated By: D Savnor

Date: 10th August 2020

Results indicated as 'PASS**' are within the stated specification but have a probability of conformance below 50%.

'p_c' indicates probability of conformance to the specification used.

CERTIFICATE OF CALIBRATION

Certificate Number
128526/AA

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Functional Tests:

During the calibration this unit was powered by Alkaline Batteries

Battery Tests:

Condition:

Battery Type	2 x AA Alkaline	
Battery Voltage on Receipt	1.35 + 1.35	Volts
New Battery Fitted	YES	
New Battery Voltage	1.61 + 1.61	Volts
Charge Function	N/A	

Power Meter Functional Tests:

Condition:

Zero Function	N/A
dB Rel Function	SATIS
Calibration Factors	N/A
Maths Function	N/A
Internal Calibration Date Changed	N/A



Optical Test and Calibration Ltd.

Customer: TTI Testing Ltd

Certificate No: 128526/AB

19-23 Campus Road,
Listerhills Science Park,
Bradford BD7 1HR
Tel +44(0)1274 393857
Fax +44(0)1274 393336
e-mail calibration@otc.co.uk

128526AB

Certificate of Calibration

Equipment Information

Make: KINGFISHER

Model:

KI2824

Description:

STABILISED LIGHT SOURCE

Serial No:

31146

Reference:

501

Calibration Category

T01 Specification stated as 'Typical'. Some of the results are outside of the typical specified criteria.

Comments

Measured output power for 1310 nm is outside of the typical specified criteria.

Calibration Information

This instrument was calibrated against laboratory standards which are either traceable to SI units (as realised by National or International Standards) or have been derived by approved ratio techniques. Any specification or uncertainty quoted refers to the measured values only unless otherwise shown, with no account being taken of the ability of the instrument to maintain its calibration.

The calibration was performed in such a manner as to comply with the requirements of BS EN ISO 10012:2003 in accordance with our BS EN ISO 9001:2015 Registration. (Certificate Number FS 11427)

Temperature and Relative Humidity conditions are shown on the results sheet unless not relevant to the measurements performed.

Calibration results are held on file for a minimum period of 3 years and can be made available if required.

Calibrated by: A Hussain

Date of calibration: 11/08/2020

Approved: J Harris QC028

Date: 11/08/2020

Re-calibration date: 10/08/2023 *

* Calibration recall period set to 36 months as requested.

CERTIFICATE OF CALIBRATION

Certificate
Number 128526/AB

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Make: KINGFISHER

Model: KI2824

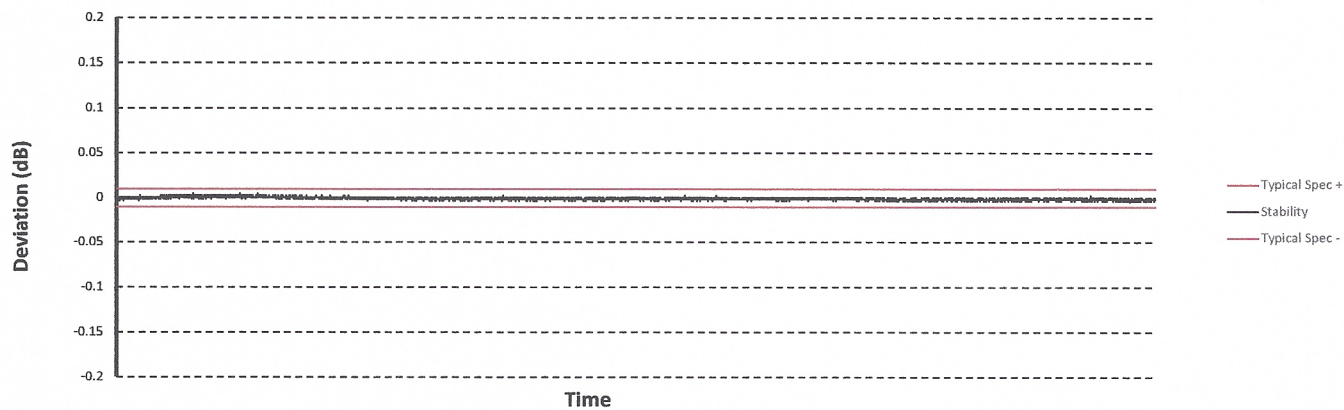
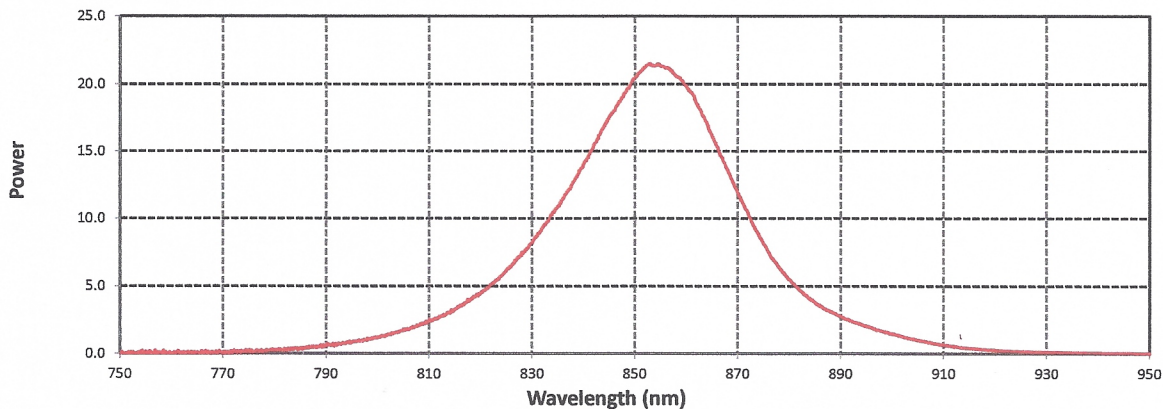
Serial Number: 31146

Ref: 501

The equipment was allowed to stabilise for at least 30 minutes before measurements were made. All measurements were made by connecting the unit under test to OTC's reference fibre: 0F068 62.5/125 FC/PC
The unit under test output facet was visually inspected and cleaned of any debris in accordance with OTC's cleaning procedure CAL129, prior to making any measurements.
The condition of the output facet on receipt was found to be: Satisfactory

Calibration Undertaken:	Specified Minimum	Measured Values:	Specified Maximum	Pass/ Fail	Expanded Uncertainty	V_{eff}	k
Peak Wavelength:		852.9 nm		Not Spec'd	±/- 1.0 nm	500	2.00
Centre Wavelength:		852.0 nm		Not Spec'd			
Spectral Width (RMS):		21.17 nm		Not Spec'd			
Spectral Width (FWHM+):		49.86 nm		Not Spec'd			
Measured Output Power		-19.47 dBm		Typically -20 dBm	±/- 0.3 dBm	500	2.00
Stability: Max Deviation Min Deviation Average		0.005 dB -0.005 dB -0.001 dB		Typically ±0.01 dB	±/- 0.01 dBm	500	2.00

* Based on RMS spectral width multiplied by 2.3548



Notes:

1. Measurement wavelengths quoted are "in air" values.

2. The data logging power meter was set for a sampling rate of five hundred milliseconds. A total of 7200 samples were taken, equating to a total stability time period of approximately one hour.

3. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k . The value of k in each case is stated in the results table which for a t -distribution and V_{eff} (the effective degrees of freedom), provides a coverage probability of approximately 95 %.

These results are valid when the unit under test is used under similar conditions to those that applied during the calibration. No allowance has been made for subsequent ageing and the polarisation sensitivity and wavelength effects of the unit under test have not been considered in this calibration.

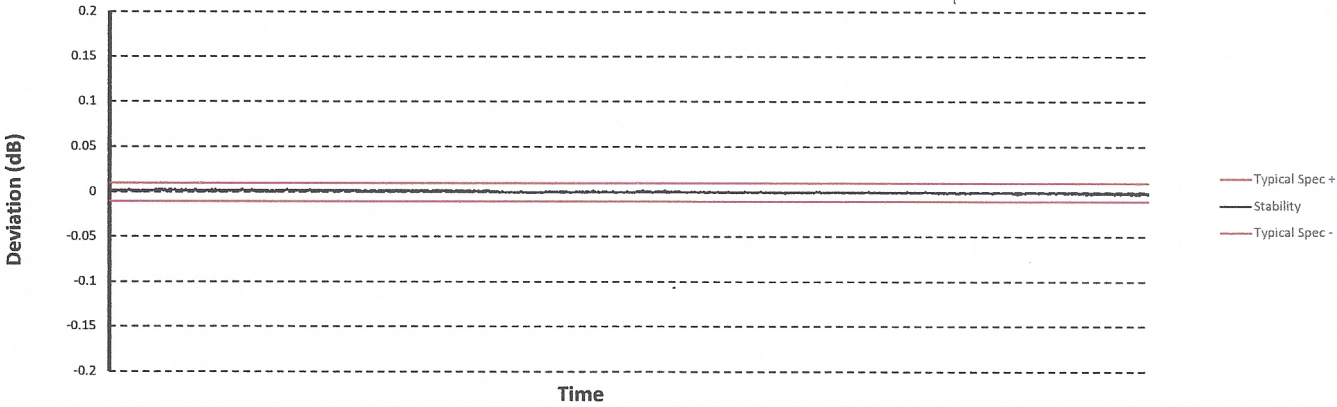
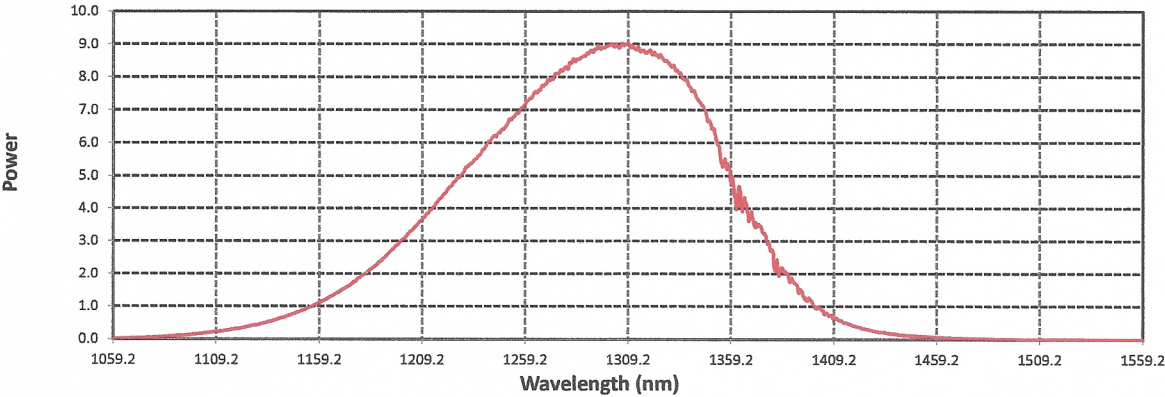
CERTIFICATE OF CALIBRATION

Certificate Number	128526/AB			
PAGE	2	OF	5	PAGES

The equipment was allowed to stabilise for at least 30 minutes before measurements were made. All measurements were made by connecting the unit under test to OTC's reference fibre: 0F068 62.5/125 FC/PC
The unit under test output facet was visually inspected and cleaned of any debris in accordance with OTC's cleaning procedure CAL129, prior to making any measurements.
The condition of the output facet on receipt was found to be: Satisfactory

Calibration Undertaken:	Specified Minimum	Measured Values:	Specified Maximum	Pass/Fail	Expanded Uncertainty	V_{eff}	k
Peak Wavelength:		1309.2 nm		Not Spec'd *	+/- 1.0 nm	500	2.00
Centre Wavelength:		1286.5 nm		Not Spec'd			
Spectral Width (RMS):		59.16 nm		Not Spec'd			
Spectral Width (FWHM+):		139.31 nm		Not Spec'd			
Measured Output Power		-19.49 dBm		Typically -20 dBm	+/- 0.3 dBm	500	2.00
Stability: Max Deviation Min Deviation Average		0.003 dB -0.003 dB -0.001 dB		Typically ± 0.01 dB	+/- 0.01 dBm	500	2.00

* Based on RMS spectral width multiplied by 2.3548



- Notes:
- Measurement wavelengths quoted are "in air" values.
 - The data logging power meter was set for a sampling rate of five hundred milliseconds. A total of 7200 samples were taken, equating to a total stability time period of approximately one hour.
 - The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k . The value of k in each case is stated in the results table which for a t -distribution and V_{eff} (the effective degrees of freedom), provides a coverage probability of approximately 95 %.

These results are valid when the unit under test is used under similar conditions to those that applied during the calibration. No allowance has been made for subsequent ageing and the polarisation sensitivity and wavelength effects of the unit under test have not been considered in this calibration.

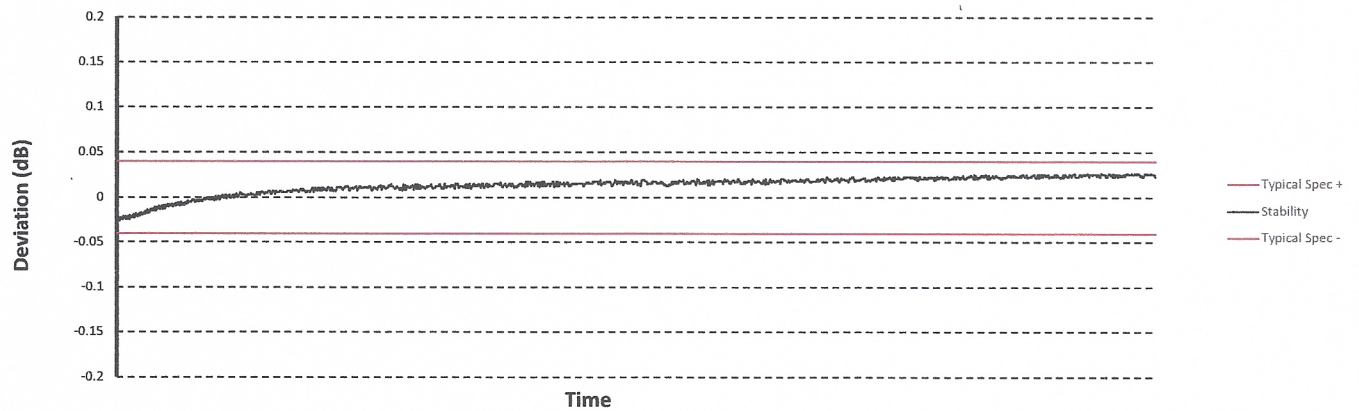
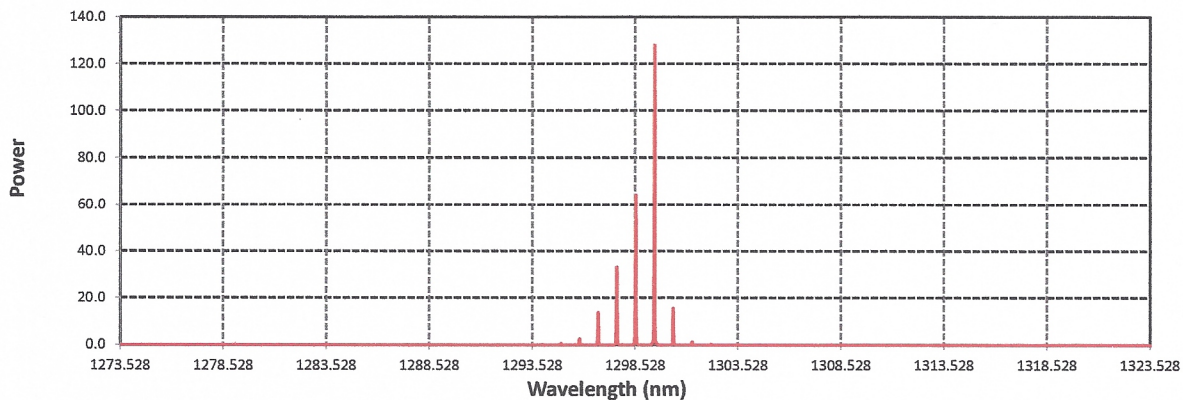
CERTIFICATE OF CALIBRATION

Certificate Number	128526/AB			
PAGE	3	OF	5	PAGES

The equipment was allowed to stabilise for at least 30 minutes before measurements were made. All measurements were made by connecting the unit under test to OTC's reference fibre: OF015 9/125 FC/PC
The unit under test output facet was visually inspected and cleaned of any debris in accordance with OTC's cleaning procedure CAL129, prior to making any measurements.
The condition of the output facet on receipt was found to be: Satisfactory

Calibration Undertaken:	Specified Minimum	Measured Values:	Specified Maximum	Pass/ Fail	Expanded Uncertainty	V_{eff}	k
Peak Wavelength:		1299.5 nm		Not Spec'd *	+/- 1.0 nm	500	2.00
Centre Wavelength:	1290 nm	1298.9 nm	1330 nm	PASS			
Spectral Width (RMS):		0.92 nm		Not Spec'd			
Spectral Width (FWHM+):		2.17 nm		Typ. 3 nm			
Measured Output Power		-0.70 dBm		Typically 0 dBm	+/- 0.3 dBm	500	2.00
Stability: Max Deviation Min Deviation Average		0.027 dB -0.027 dB 0.024 dB		Typically ± 0.04 dB	+/- 0.01 dBm	500	2.00

* Based on RMS spectral width multiplied by 2.3548



Notes:

1. Measurement wavelengths quoted are "in air" values.
2. The data logging power meter was set for a sampling rate of five hundred milliseconds. A total of 7200 samples were taken, equating to a total stability time period of approximately one hour.
3. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k . The value of k in each case is stated in the results table which for a t -distribution and V_{eff} (the effective degrees of freedom), provides a coverage probability of approximately 95 %.

These results are valid when the unit under test is used under similar conditions to those that applied during the calibration. No allowance has been made for subsequent ageing and the polarisation sensitivity and wavelength effects of the unit under test have not been considered in this calibration.

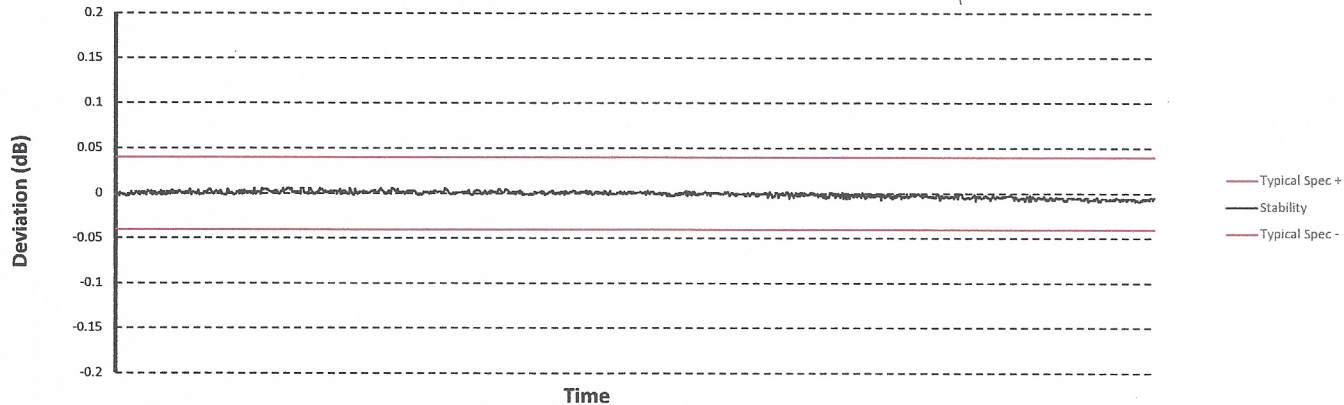
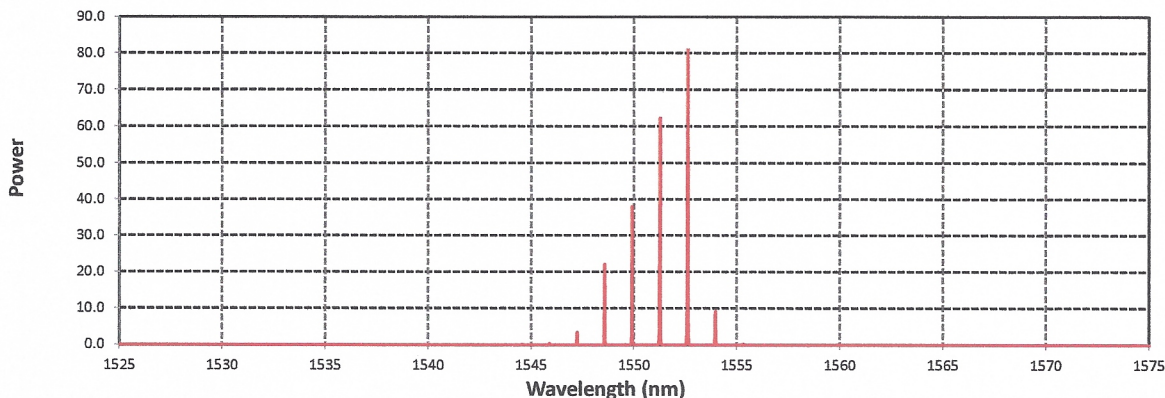
CERTIFICATE OF CALIBRATION

Certificate Number	128526/AB
PAGE	4 OF 5 PAGES

The equipment was allowed to stabilise for at least 30 minutes before measurements were made. All measurements were made by connecting the unit under test to OTC's reference fibre: OF015 9/125 FC/PC
The unit under test output facet was visually inspected and cleaned of any debris in accordance with OTC's cleaning procedure CAL129, prior to making any measurements.
The condition of the output facet on receipt was found to be: Satisfactory

Calibration Undertaken:	Specified Minimum	Measured Values:	Specified Maximum	Pass/Fail	Expanded Uncertainty	V_{eff}	k
Peak Wavelength:		1552.6 nm		Not Spec'd *	±/- 1.0 nm	500	2.00
Centre Wavelength:	1530 nm	1551.4 nm	1570 nm	PASS			
Spectral Width (RMS):		1.47 nm		Not Spec'd			
Spectral Width (FWHM+):		3.46 nm		Typ. 3 nm			
Measured Output Power		0.00 dBm		Typically 0 dBm	±/- 0.3 dBm	500	2.00
Stability: Max Deviation Min Deviation Average		0.008 dB -0.008 dB -0.002 dB		Typically ±0.04 dB	±/- 0.01 dBm	500	2.00

* Based on RMS spectral width multiplied by 2.3548



Notes:

1. Measurement wavelengths quoted are "in air" values.
2. The data logging power meter was set for a sampling rate of five hundred milliseconds. A total of 7200 samples were taken, equating to a total stability time period of approximately one hour.
3. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k . The value of k in each case is stated in the results table which for a t -distribution and V_{eff} (the effective degrees of freedom), provides a coverage probability of approximately 95 %.

These results are valid when the unit under test is used under similar conditions to those that applied during the calibration. No allowance has been made for subsequent ageing and the polarisation sensitivity and wavelength effects of the unit under test have not been considered in this calibration.

CERTIFICATE OF CALIBRATION

Certificate Number	128526/AB
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Functional Tests:

During the calibration this unit was powered by Alkaline Batteries

Battery Tests:

Condition:

Battery Type	2 x AA Alkaline
Battery Voltage on Receipt	1.15 + 1.15 Volts
New Battery Fitted	YES
New Battery Voltage	1.61 + 1.61 Volts
Charge Function	N/A

Light Source Functional Tests:

Condition:

Internal Modulation 270 Hz	SATIS
Internal Modulation 1 kHz	SATIS
Internal Modulation 2 kHz	SATIS

Cal Temp: 21 °C, +/- 2 °C

Humidity: 36 %rh, +/- 10 %rh

Procedure:

OPT06

Equipment Used: CAL644,1019,868,868C,1027,1027G,1017

CAL CAT: T01 Specification stated as "Typical". Some of the results are outside of the typical specified criteria.

Calibrated By: A Hussain

Date: 11th August 2020

Comments: **All wavelengths measured into Air*

Certificate Statements of conformity

RS Components is standardising how it reports conformity across all disciplines in line with requirements within **ISO/IEC: 17025:2017**.

Where the laboratory reports a statement of conformity to a specification, guidance has been drawn on reporting structure and decision rules from the Ilac document series **ILAC G8:03**. Acceptance limits applied are derived from the manufactures specification or applicable standard (e.g. DIN, EEC, BS etc.) unless otherwise instructed by you the customer.

The statements found on this certificate produced by RS Components Laboratory are as follows:

1). Reported values with No Annotation:

The instrument *complies* with the stated specification, even with allowance having been made for the uncertainty of measurement, which carries no implication regarding the long-term stability of the instrument.

2). Reported values annotated with "##":

The measured result is *inside the specification limit* but by a margin less than the measurement uncertainty, it is therefore not possible to state compliance based on the stated level of confidence.

3). Reported values annotated with "###":

The measured result is *outside the specification limit* but by a margin less than the measurement uncertainty, it is therefore not possible to state compliance based on the stated level of confidence.

4). Reported values annotated with "####":

The measured result does *not comply* with the stated specification, even with allowance having been made for the measurement uncertainty.

ILAC G8:03 Key:

####

No Annotation
(blank)

#

##

###

Upper limit of
specification

+ Uncertainty of measurement

Measured Value

- Uncertainty of measurement

Lower limit of
specification

CERTIFICATE OF CALIBRATION

Issued by: RS Components Ltd

Date Issued: 11 May 2021

Certificate No.

1683007



RS Calibration

Calibration and Repair Service

DPN 175, Lammas Rd,
Weldon Industrial Est
Corby, Northants, NN17 9RS

Tel: 01536 405545

Fax: 01536 401590

Page 1 of 3 Pages

Mark Connelly

Client	TTI TESTING WALLINGFORD OXFORDSHIRE OX10 9DG
Instrument	RS PRO 41 Temperature Indicator
Serial No.	S/N:201212006
Client Reference	N/A
Procedure ID.	123_1940_525B Rev. P1
Date of Calibration	11 May 2021

Equipment Used to Carry Out Calibration

Fluke 525B Temperature Calibrator
Type K Thermocouple Wire

Equipment ID.

Cal 1130
Cal 1297

The measurements reported in this certificate were carried out using equipment whose values are traceable to national standards.

All procedures employed and results reported are in compliance with the requirements of the International Standard ISO/IEC 17025

The management controls of the RS Calibration Laboratory are registered under the British Standard BS EN ISO 9001 : 2015 No. RS 00362.

Uncertainties

The reported expanded uncertainties are based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%.

This calibration is of a new instrument.

The following calibration results relate only to the items defined above.

This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

Certificate No.
1683007



Calibration and Repair Service

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Environment

The ambient temperature and relative humidity throughout the calibration were $(20 \pm 2) ^\circ\text{C}$ and $(40 \pm 20) \% \text{RH}$ respectively.

Method

Prior to the calibration the instrument was held within the laboratory for a period of not less than 30 minutes.

Known equivalent thermocouple voltages were applied to the instrument using a calibrator using a thermocouple extension connector. The values were calculated for the equivalent temperatures as found in the BS EN 60584-1:2013 tables.

The cold junction compensation (CJC) was automatically achieved internally.

<u>INPUT 1</u> Function	Equivalent Applied Value	Instrument Indicated	Measurement Uncertainties
<u>TYPE K</u>			
	- 40.00 $^\circ\text{C}$	- 39.5 $^\circ\text{C}$	$\pm 0.41 ^\circ\text{C}$
	- 20.00 $^\circ\text{C}$	- 20.0 $^\circ\text{C}$	$\pm 0.41 ^\circ\text{C}$
	0.00 $^\circ\text{C}$	0.0 $^\circ\text{C}$	$\pm 0.41 ^\circ\text{C}$
	20.00 $^\circ\text{C}$	19.4 $^\circ\text{C}$	$\pm 0.41 ^\circ\text{C}$
	50.00 $^\circ\text{C}$	49.2 $^\circ\text{C}$	$\pm 0.41 ^\circ\text{C}$
	100.00 $^\circ\text{C}$	99.6 $^\circ\text{C}$	$\pm 0.42 ^\circ\text{C}$
	190.00 $^\circ\text{C}$	188.1 $^\circ\text{C}$ #	$\pm 0.41 ^\circ\text{C}$
	300.00 $^\circ\text{C}$	299 $^\circ\text{C}$	$\pm 1.32 ^\circ\text{C}$
	500.00 $^\circ\text{C}$	499 $^\circ\text{C}$	$\pm 1.34 ^\circ\text{C}$
	700.00 $^\circ\text{C}$	699 $^\circ\text{C}$	$\pm 1.34 ^\circ\text{C}$
	900.00 $^\circ\text{C}$	898 $^\circ\text{C}$	$\pm 1.34 ^\circ\text{C}$
	1 100.00 $^\circ\text{C}$	1 098 $^\circ\text{C}$	$\pm 1.34 ^\circ\text{C}$
	1 200.00 $^\circ\text{C}$	1 196 $^\circ\text{C}$	$\pm 1.34 ^\circ\text{C}$
	932.00 $^\circ\text{F}$	931 $^\circ\text{F}$	$\pm 1.52 ^\circ\text{F}$

CALIBRATED BY :- MSC

CERTIFICATE OF CALIBRATION



Calibration and Repair Service

Certificate No.
1683007

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Compliance to Specification

The specification published by the manufacturer and found in the instrument's handbook has been used to determine performance at the measured points.

Reported values not annotated.

The instrument complies with the stated specification, due allowance having been made for the uncertainty of measurement which carries no implication regarding the long term stability of the instrument.

Reported values annotated with a #

The measured result is inside the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state compliance based on the stated level of confidence.

END OF CERTIFICATE



Optical Test and Calibration Ltd.

Customer: TTI Testing Ltd

Certificate No: 132991/AA

19-23 Campus Road,
Listerhills Science Park,
Bradford BD7 1HR
Tel +44(0)1274 393857
Fax +44(0)1274 393336
e-mail calibration@otc.co.uk

132991AA

Certificate of Calibration

Equipment Information

Make: FLUKE

Model:

1555

Description:

INSULATION TESTER

Serial No:

3456025

Reference:

000459

Calibration Category

A01 In specification: no adjustment performed.

Comments

Calibration Information

This instrument was calibrated against laboratory standards which are either traceable to SI units (as realised by National or International Standards) or have been derived by approved ratio techniques. Any specification or uncertainty quoted refers to the measured values only unless otherwise shown, with no account being taken of the ability of the instrument to maintain its calibration.

The calibration was performed in such a manner as to comply with the requirements of BS EN ISO 10012:2003 in accordance with our BS EN ISO 9001:2015 Registration. (Certificate Number FS 11427)

Temperature and Relative Humidity conditions are shown on the results sheet unless not relevant to the measurements performed.

Calibration results are held on file for a minimum period of 3 years and can be made available if required.

Calibrated by: TER CALIBRATION

Date of calibration: 20/05/2021

Approved: K G Dove QC006

Date: 25/05/2021

Re-calibration date: 19/05/2022

CERTIFICATE OF CALIBRATION

Date Of Issue 21 May 2021
Issue Number 1
Certificate Number TERISO_717449
Issue By TER Calibration



Page 1 of 3

**TER CALIBRATION LTD**

Unit 1, Armstrong Point, Wigan, WN2 4AU
Tel:-01942 882275 Fax:-01942 897958
E:-me@ter.co.uk Web:-www.ter.co.uk

Approved Signatory
Les Finnen

Submitted By	Optical Test & Calibration Limit Listerhills Science Park 21-23 Campus Road Bradford BD7 1HR
Engineer	DEANG
Procedure Number	010010404
Order Number	X32902
Date Received	17 May 2021
Calibration Date	20 May 2021
Request Recalibration	19 May 2022
Equipment	FLUKE 1555 Insulation Tester
Serial Number	3456025
Owners Identification	
TERID	328285
JobNumber	717449
Temperature	19°C ±1°C
Conditions Prior to Calibration	
Within the Manufacturer's Specification	

This is to certify that the equipment detailed hereon has been calibrated and now conforms to the Manufacturer's published specification and where applicable BS EN 61010, unless otherwise stated above.
All measurements made are traceable to national standards and conform to the requirement of ISO-17025.
The Q.A. arrangements for the above are in strict conformity to BS EN ISO 9001:2015

CERTIFICATE OF CALIBRATION

Date Of Issue 21 May 2021
Issue Number 1
Certificate Number TERISO_717449
Issue By TER Calibration

Page 2 of 3

Test 1 Insulation Resistance

Range	Applied Resistance	Unit Under Test	Specification	Uncertainty of Measurement
250 V	1.000 Mohm	1.01 Mohm	±5%	±0.02Mohm
250 V	1.005 9 Gohm	1.02 Gohm	±5%	±0.03Gohm
250 V	10.465 Gohm	10.5 Gohm	±20%	±0.6Gohm
500 V	200.0 kohm	201 kohm	±5%	±2kohm
500 V	1.000 Mohm	1.01 Mohm	±5%	±0.02Mohm
500 V	10.00 Mohm	10.1 Mohm	±5%	±0.2Mohm
500 V	100.0 Mohm	101 Mohm	±5%	±2Mohm
500 V	1.005 9 Gohm	1.01 Gohm	±5%	±0.03Gohm
500 V	103.99 Gohm	103 Gohm	±20%	±6Gohm
1 000 V	1.000 Mohm	1.00 Mohm	±5%	±2kohm
1 000 V	1.005 9 Gohm	1.00 Gohm	±5%	±0.03Gohm
1 000 V	103.99 Gohm	103 Gohm	±20%	±6Gohm
2 500 V	2.518 5 Mohm	2.51 Mohm	±5%	±0.02Mohm
2 500 V	100.0 Mohm	98.9 Mohm	±5%	±0.6Mohm
2 500 V	1.005 9 Gohm	1.00 Gohm	±5%	±0.03Gohm
2 500 V	103.99 Gohm	103 Gohm	±20%	±6Gohm
5 000 V	100.0 Mohm	98.9 Mohm	±5%	±0.6Mohm
5 000 V	1.005 9 Gohm	999 Mohm	±5%	±0.03Gohm
10 000 V	100.0 Mohm	98.5 Mohm	±5%	±0.6Mohm
10 000 V	1.005 9 Gohm	988 Mohm	±20%	±0.03Gohm

CERTIFICATE OF CALIBRATION

Date Of Issue 21 May 2021
Issue Number 1
Certificate Number TERISO_717449
Issue By TER Calibration

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Test 2 Insulation Voltage

Test Voltage	Measured Voltage	Specification	Uncertainty of Measurement
250 V @ 0.25 Mohm	261.3 V	250 V (-0% to +10%)	±1%
250 V @ 300 Mohm	270.1 V	-	±1.5%
500 V @ 0.5 Mohm	521.4 V	500 V (-0% to +10%)	±1%
500 V @ 300 Mohm	530.5 V	-	±1.5%
1 kV @ 1 Mohm	1.044 kV	1 000 V (-0% to +10%)	±1%
1 kV @ 300 Mohm	1.050 kV	-	±1.5%
2.5 kV @ 2.5 Mohm	2.597 kV	2 500 V (-0% to +10%)	±1.5%
2.5 kV @ 300 Mohm	2.618 kV	-	±1.5%
5 kV @ 5 Mohm	5.199 kV	5 000 V (-0% to +10%)	±1.5%
5 kV @ 300 Mohm	5.226 kV	-	±1.5%
10 kV @ 300 Mohm	10.431 kV	-	±1.5%

Test 3 Voltage (Live Circuit Warning)

Range	Applied Voltage	Unit Under Test	Specification	Uncertainty of Measurement
30 V to 1 100 V	40.00 V D.C.	40 V	±(15% + 2V)	±1V
30 V to 1 100 V	100.0 V D.C.	99 V	±(15% + 2V)	±1V
30 V to 1 100 V	500.0 V D.C.	497 V	±(15% + 2V)	±2V
30 V to 1 100 V	40.00 V at 50 Hz	36 V	±(15% + 2V)	±1V
30 V to 1 100 V	100.0 V at 50 Hz	89 V	±(15% + 2V)	±1V
30 V to 1 100 V	500.0 V at 50 Hz	446 V	±(15% + 2V)	±2V

CERTIFICATE OF CALIBRATION

Issued By Sunbelt Rentals (454)

Date of Issue 02 June 2021

Certificate Number

INLB108277

Page 1 of 3 Pages



2 Ellerbeck Way
Stokesley Business Park
Stokesley, TS9 5JZ
Tel: 01642 718900
calibration@inlec.com

Approved Signatory

☐ L. Wojcik

☐ R. Cowie

☒ A. Robson

☐ M. Kutyla

☐ A. Tremain

Customer : Fibron BX Ltd
Unit 2, R D Park, Stephenson Close,, Hoddesdon
Hertfordshire

Date Received : 05 May 2021

Instrument :	System ID :	C01F-0857	Job Number :	110173
	Description :	Milli-Ohm Meter	Ref. Number :	28F-0857
	Manufacturer :	Cropico	Site :	
	Model Number :	4001	Location :	
	Serial Number :	28F-0857	Last Calibration Certificate :	INLB102142
	Procedure Version :	1/RL	Last Calibration Date :	16/12/2019

Environmental Conditions

Temperature : 22°C +/- 2°C
Relative Humidity : 50% +/- 20%

Mains Voltage : 230V +/- 10V
Mains Frequency : 50Hz +/- 1Hz

Comments

All Tests Passed calibration after minor adjustment .

Traceability Information

Instrument description	Serial number	Certificate number	Cal. Date	Cal. Period
Cropico MTS 1A	09H-0477	SEA052565/2R	19/04/2021	52
Cropico MTS 2	09H-1222	SEA052573/2R	19/04/2021	52

Calibrated By : A. Robson

Date of Calibration : 02 June 2021

This certificate provides traceability of measurement to recognised National Standards, and to the units of measurement realised at the National Physical Laboratory or other recognised National Standards laboratories.

Copyright of this certificate is owned by the issuing laboratory and may not be reproduced except with the prior written approval of the issuing laboratory. This certificate complies with the requirements of BS EN ISO 10012:2003.

CERTIFICATE OF CALIBRATION

AS FOUND RESULTS

Certificate Number
INLB108277

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Test Title	Tolerance	Applied Value	Reading	Pass/Fail
Resistance Tests				
4kΩ Range	2.8Ω	4.000kΩ	4.000kΩ	Pass
400Ω Range	280mΩ	400.0Ω	400.0Ω	Pass
40Ω Range	28mΩ	40.00Ω	40.00Ω	Pass
4Ω Range	3.2mΩ	4.000Ω	4.001Ω	Pass
400mΩ Range	400uΩ	400.0mΩ	400.1mΩ	Pass
40mΩ Range	60uΩ	40.00mΩ	40.07mΩ	Fail
	42uΩ	4.00mΩ	4.05mΩ	Fail

CERTIFICATE OF CALIBRATION

AFTER ADJUSTMENT RESULTS

Certificate Number
INLB108277

Page 3 of 3 Pages

Test Title	Tolerance	Applied Value	Reading	Pass/Fail
Resistance Tests				
4kΩ Range	2.8Ω	4.000kΩ	4.000kΩ	Pass
400Ω Range	280mΩ	400.0Ω	400.0Ω	Pass
40Ω Range	28mΩ	40.00Ω	40.00Ω	Pass
4Ω Range	3.2mΩ	4.000Ω	4.000Ω	Pass
400mΩ Range	400uΩ	400.0mΩ	399.8mΩ	Pass
40mΩ Range	60uΩ	40.00mΩ	39.98mΩ	Pass
	42uΩ	4.00mΩ	3.98mΩ	Pass