

TK335F/C
P35
1986

HAWAII DEEP WATER CABLE (HDWC) PROGRAM
SELECTION AND DESIGN OF
LABORATORY TESTING EQUIPMENT

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APRIL, 1986

SELECTION AND DESIGN OF LABORATORY TESTING EQUIPMENT

1. INTRODUCTION

This document incorporates listings of the testing and measuring equipment to be used in the performance of the mechanical and electrical tests described in the January 23, 1986 draft of the Laboratory Test Protocol, inclusive of Appendix A Qualification Tests.

The listings of testing and measuring equipment by test include quantity and source. The source of the equipment is categorized as follows:

- . Equipment presently available in the Pirelli Laboratories A
- . Equipment available for rent from other laboratories, e.g. CESI R
- . Equipment which must be purchased from an outside source P
- . Equipment which must be designed and subsequently purchased from an outside source DP

These lists, while updating the types and numbers of equipment indicated in the Laboratory Test Protocol for each test are not complete in that they do not include (1) miscellaneous pieces of equipment which are generally available and can be identified as necessary for the tests and (2) miscellaneous pieces of equipment the need for which will become apparent during the course of setting up the tests or during the performance of the tests. The lists do not include items of equipment required for testing of joints. They are included in a document on Accessories.

Following the listings of equipment, justification is given for the necessity for design of a number of main items of equipment by Pirelli specialists. In general, the new equipment are adaptations of similar, but smaller, equipment previously employed by Pirelli for cables of somewhat different constructional characteristics tested at lesser mechanical forces.

The document is completed by a list which, for convenience, indicates the units of each item of equipment required to carry out the test program. A drawing number is referenced for each item of equipment required to be designed prior to procurement from an outside source.

The listings of equipment are categorized in accordance with the Laboratory Test Protocol.

2. LISTINGS OF EQUIPMENT

A. Laboratory Individual Tests

A.1 Baseline Electrical Test (LI-1)

	<u>Quantity</u>	<u>Source</u>
a) "Rapid Fitting" 400 kV A.C. Laboratory Terminations	2	A
a') Assembly Kits	2	P
b) Conventional 220kV A.C. Sealing End	2	A
b') Assembly Kits	2	P
c) Special Cable Oil - Liters	1000	P
d) Low & High Pressure Oil Reservoirs (Note 1)	--	P
e) Power Factor Bridge (Note 1)	1	R
f) D.C. Generator (Note 1)	1	R
g) Impulse Generator (Note 1)	1	R
h) Current Heating Transformers (Note 1)	--	R
i) Temperature Monitoring and Recording Equipment	1	R

A.2 High Stress Tensile Test (LI-3)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Head (150 Tons)	2	DP
b) Tensile Test Facility (Note 1)	1	A

Note 1: Refer to Table 1 General Testing Equipment - Laboratory Test Protocol

	<u>Quantity</u>	<u>Source</u>
c) Loading Cell (200 Tons)	1	A
d) Loading Cell Housing (200 Tons)	1	DP
e) Electrical Feeding Apparatus for Loading Cell (200 Tons)	1	DP
f) Cable Fixing Point (200 Tons)	1	DP
g) Free Rotating Head (200 Tons)	1	DP
h) Elongation Gauge	1	A
i) Special Cable Oil - Liters	200	P

A.3 Repeated Flexure Test (LI-4)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Head (150 Tons)	2	DP
b) Tensile Test Facility (Note 1)	1	A
c) Loading Cell (100 Tons)	1	A
d) Loading Cell Housing (100 Tons)	1	A
e) Electrical Feeding Apparatus for Loading Cell (100 Tons)	1	A
f) Cable Fixing Point (100 Tons)	1	A
g) Free Rotating Head (100 Tons)	1	A
h) Elongation Gauge	1	A
i) Winches	2	A
l) 12 m Sheave with Trolley	1	DP
m) Modification to Roof & Storage Facility	—	DP
n) Special Cable Oil - Liters	200	P

Note 1: Refer to Table 1 General Testing Equipment - Laboratory Test Protocol

A.4 Measurement of Static Flexural Rigidity (LI-5)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Heads (10 Tons), (Maintaining Congruence of Cable Components)	6	DP
b) Clamp (Maintain Congruence of Cable Components)		DP
c) Displacement Transducers	2	A
d) Recorder	1	A
e) Equipment for Gradual Application of Vertical Force	1	A

A.5 Measurement of Dynamic Flexural Rigidity and Damping
Coefficient (LI-6)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Heads (10 tons), (see 4a)	2	DP
b) Mechanical Pulling Machine	2	A
c) 2 m Sheave with Trolley	2	A
d) Fixing Point to the 3 m Sheave	2	DP
e) Vibration Inducing Equipment	1	R
f) Accelerometer	3	R

A.6 Cable Oscillation Test Under Simulated Tidal Action (LI-7)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Head (10 tons), (see 4a)	2	DP
b) Mechanical Pulling Machine	2	A
c) 2 m Sheaves with Trolleys	2	A
d) Fixing Point to the 3 m Sheave	2	DP
e) Load Cell (2 Tons)	1	A
f) Vibrating Device Capable of Applying Required Oscillatory Movements to the Cable	1	DP
g) Device for Measuring Oscillations of the Cable	1	A

A.7 Crushing Test (LI-8)

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Heads (150 Tons)	2	DP
b) Tensile Test Facility (Note 1)	1	A
c) Cable Fixing Point (100 Tons)	1	A
d) Free Rotating Head (100 Tons)	1	A
e) Load Cell (20 Tons)	1	P
f) Hydraulically Operated Linear Tensioner Simulating Device	1	DP
g) Recorder	1	A
h) Special Cable Oil - Liters	200	P

A-8 Sleeving Test (LI-9)

	<u>Quantity</u>	<u>Source</u>
a) Cable Pulling Head (5 Tons) (Designed For Pulling The Conductor)	1	DP
b) Cable Pulling Head (5 Tons) (Designed For Pulling The Conductor, Lead Sheath and PE Jacket as a Unit)	1	DP
c) Tensile Test Facility (Note 1)	1	A
d) Free Rotating Head (100 Tons)	1	A
e) Load Cell (20 Tons)	1	P
f) Hydraulically Operated Linear Tensioner Simulating Device	1	DP
g) Recorder	1	A

B. Sequence Tests

The testing and measuring equipment necessary to carry out the sequence tests are in succession the same as those used in the 1) Crushing Test LS-1, 2) Bending Test LS-2 (without electrical tests), 3) Repeated Flexure Test LS-3, 4) Cable Oscillation Test LS-7, 5) External Pressure Test LS-5 and 6) electrical tests in accordance with the Baseline Electrical Test LI-1.

Note 1: Refer to Table 1 General Testing Equipment -
Laboratory Test Protocol

The equipment lists for Tests 1, 3, 4 and 6 are included under A. Laboratory Individual Tests. The equipment lists for Tests 2 and 5 are included under C. Qualification Tests. Since the Bending Test (Test 2) does not include electrical tests only the mechanical equipment, i.e. Items a through m, are applicable.

C. Qualification Tests (Appendix A of Laboratory Test Protocol)

C.1 Bending and Electrical Tests Q-1, 2, & 3

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Heads (150 Tons)	4	DP
b) Tensile Test Facility (Note 2)	1	A
c) Loading Cell (100 tons)	1	A
d) Loading Cell Housing (100 Tons)	1	A
e) Electrical Feeding Apparatus for Loading Cell (100 Tons)	1	A
f) Cable Fixing Point (100 Tons)	1	A
g) Free Rotating Head (100 Tons)	1	A
h) Elongation Gauge	1	A
i) Cable Sealing Heads (Type A)	4	DP
l) 12 m Sheave with Trolley	1	DP
m) Modification to Roof & Storage Facility	--	DP
n) Conventional 525 kV a.c. Sealing End	4	A
n') Assembly Kits	4	P
o) Conventional 220 kV a.c. Sealing End	4	P
o') Assembly Kits	2	P
p) DC Generator (Note 2)	1	R
q) Impulse Generator (Note 2)	1	R
r) Current Heating Transformers (Note 2)	--	R
s) Temperature Monitoring and Recording Equipment	1	R
t) Low and High Pressure Oil Reservoirs (Note 2)	--	B
u) Special Cable Oil - Liters	5000	P

Note 2: Refer to Table Q-1 General Testing Equipment - Laboratory Test Protocol

C.2 Tensile Test Q-4

	<u>Quantity</u>	<u>Source</u>
a) Cable Mechanical End Heads (150 Tons)	2	DP
b) Tensile Test Facility (Note 1)	1	A
c) Load Cell (100 Tons)	1	A
d) Load Cell Housing (100 Tons)	1	A
e) Electrical Feeding Apparatus for Load Cell (100 Tons)	1	A
f) Cable Fixing Point (100 Tons)	1	A
g) Free rotating head (100 Tons)	1	A
h) Elongation Gauge	1	A
i) Special Cable Oil - Liters	200	P

C.3 External Water Pressure Withstand Test Q-5

	<u>Quantity</u>	<u>Source</u>
a) Pressure Tube	1	A
b) Pressurizing Apparatus	1	A
c) Pressure Transducers	2	A
d) Three Channel Recorder	1	A
e) Vacuum Pump	1	A
f) Cable Sealing Head (Type B)	2	DP

C.4 Internal Oil Pressure Withstand Test Q-6

	<u>Quantity</u>	<u>Source</u>
a) Pressurizing Apparatus	1	A
b) Pressure Transducer	1	A
c) Two Channel Recorder	1	A
d) Cable Sealing Head (Type C)	2	DP
e) Antitwist Clamps	2	DP

Note 2: Refer to Table Q-1 General Testing Equipment - Laboratory Test Protocol

General Purpose Equipment

	<u>Quantity</u>	<u>Source</u>
a) Degasifier 600 l/h	1	P
b) Oil Reservoir Type A2/120	24	P
c) Oil Reservoir Type P2/25	18	P
d) Under Vacuum Oil Recovery Pump	2	P
e) Oil Strainer	1	P
f) Oil Pumping Plant	1	P
g) Trolleys (Small)	80	P
h) Ramps	4	P
i) Thermal Insulation For Cable - meters	200	P

3. JUSTIFICATION FOR DESIGN AND OR PURCHASE OF EQUIPMENT

The justification given hereafter follows the order in which the various items appear for the first time in the above lists. No justification is given for self-explanatory items of equipment.

Special Cable Oil and Low and High Pressure Reservoirs

The special cable oil and oil pressure reservoirs must be purchased since the cable for the HDWC Program is impregnated with a special high density oil. The ancillary equipment presently available in SCP Laboratories is impregnated with decylbenzene, i.e. with the synthetic oil normally used by SCP for SCOF cables.

Cable Mechanical End Head (150 Tons)

Before undergoing mechanical tests, a submarine cable must be provided with end heads compatible with its constructional characteristics and adequate for the mechanical forces to which it will be subjected and the electrical tests to which it will be subjected afterwards. A mechanical end head suitable for 150 tons force required by the Laboratory Test Protocol is not available. Its design will be based on Pirelli experience on similar mechanical end heads with a rated tensile capability of 100 tons.

Load Cell Housing (200 Tons) and Electrical Feeding Apparatus for Load Cell Rated for 200 Tons

A load cell for 200 tons is available in Pirelli Laboratories. However its use requires the design and procurement of the above mentioned auxiliary equipment. The relevant design will be based on the experience gathered in past years with similar equipment employed for up to 100 tons.

Cable Fixing Point (200 Tons) and Free Rotating Head (200 Tons)

Justification for design and procurement of these items of equipment is as indicated heretofor for similar equipment.

12 m Sheave With Trolley

In order to achieve generally accepted values of mechanical stresses of the cable components arising from cable bending with a tensile force of 85 tons, it is necessary to design and procure a suitable sheave having a 12 m diameter. The design of this new sheave is similar to that of the sheaves available in the Pirelli Laboratories having diameters up to 6 m. The 12 m diameter is acceptable from the point of view of the cables ship requirements.

Modification to Roof & Storage Facility

The existing roof is approximately 7 m high and can shelter sheaves having diameters up to 6 m. In order to accommodate the new 12 m diameter sheave with trolley, it is necessary to build a suitably higher roof and a supporting structure along the rails to stabilize the sheave trolley. To provide this test facility, an existing building must be demolished and the office presently located in this building must be relocated.

Cable Mechanical End Head (10 Tons)

When the test does not involve high tensile forces, the 150 ton heads are not required. Moreover they should prove too bulky and heavy for the purposes of the static and dynamic flexural rigidity measurements. This is the reason why smaller and lighter heads must be designed and purchased.

Clamp Suitable to Maintain Congruence of Cable Components

To block a cable end, it is necessary to design and purchase a clamp fitting the cable constructional characteristics.

Fixing Point to the 3 m Sheave

The cable must be blocked to the top of the sheaves. Therefore it is necessary to design and purchase fixing points fitting the constructional characteristics of the cable.

Vibrating Device

A vibrating device is required capable of applying the specified oscillatory movements to the cable. Previous experimentation of this phenomenon in the Pirelli Laboratories was performed using a device which is inadequate for the purposes of the HDWC Program. It is therefore necessary to design and purchase a similar but greater capacity vibrating device.

Load Cell (20 Tons)

This high capacity load cell is not available in Pirelli Laboratories.

Hydraulically Operated Linear Tensioner Simulating Device

A linear tensioner suitable for performing the crushing and sleeving tests and to match the characteristics of the tensile test facility is not available in Pirelli Laboratories. It is therefore necessary to design and purchase a linear tensioner simulating device having the required characteristics. This device will facilitate the determination of (1) maximum withstand crushing force for the cable (2) the coefficient of friction between the cable and the device and (3) the congruence of the cable components during deployment retrieval operations. In addition, it will provide experience for the design of the linear tensioner for use on the cables ship.

Cable Pulling Heads (5 Tons)

In the sleeving test, there are tensile forces applied to the cable components with the exclusion of the armor. It is therefore necessary to design and purchase a pulling head suitable to the case of force applied to the conductor only and a pulling head suitable to the case of force applied to the cable components inclusive of the conductor to the polyethylene sheath as a unit. It is intended that the pulling heads not impair the congruence of the cable components involved.

Cable Sealing Ends Types A-B-C

It is necessary to design and purchase cable end caps suitable to cope with the constructional characteristics of the cable and for the Types B-C, with the particular stresses present with the tests.

Antitwist Clamp

This device, necessary to allow application of the tensile load and the elongation of the cable without twisting, must be designed according to the cable constructional characteristics and then purchased. The design will be based on the previous experience.

Degasifier 600 Liter/Hour Under Vacuum Oil Recovery Pumps Oil Strainer Oil Pumping Plant

This equipment, although normally used in the Pirelli Laboratories, must be purchased for the HDWC program because of the special high density cable oil that is required. The Oil Pumping Plant will be utilized for recovery of the oil from the impregnating tank.

Trolleys (Small) And Ramps

This equipment, normally used by Pirelli, is not available in the Pirelli Laboratories in sufficient quantities to satisfy the needs of the test program.

4. SUMMARY LIST OF EQUIPMENT AND MATERIALS REQUIRED FOR PERFORMANCE OF THE TEST PROGRAM

The following list summarizes the number of units of each piece of equipment and amounts of materials required to perform the test program. The list breaks down the total number of units into two categories, required and spare. For those main items of equipment required to be designed prior to procurement, the applicable drawing number(s) is referenced.

ITEM	QUANTITY			DRAWING REFERENCE	
	REQUIRED	SPARE	TOTAL		
220 kV A.C. Sealing End Assembly Kit	6	2	8	RC247S (Note 1)	
525 kV A.C. Sealing End Assembly Kit	4	2	6	RC247R (note 1)	
400 kV A.C. "Rapid Fitting" Sealing End Assembly Kit	2	0	2	2011/10-80007 (Note 1) Items/1 e/2	
Cable Mechanical End Head (150 Tons)	14	2	16	RC 247 B B/M RC 247 B RC 247 B-1 RC 247 B-2 RC 247 B-3 RC 247 B-4 RC 247 B-5-9-10	RC 247 B-6 RC 247 B-7 RC 247 B-8 RC 247 B-11 RC 247 B-12 RC 247 B-13 RC 247 B-14
Cable Mechanical End Head (10 Tons)	8	2	10	RC 247 G	
Cable Pulling Head (5 Tons) (Designed for Pulling the Conductor)	1	1	2	RC 247 F	
Cable Pulling Head (5 Tons) (Designed for Pulling the Conductor, Lead Sheath and PE Jacket)	1	1	2	RC 247 E	

ITEM	QUANTITY			DRAWING REFERENCE	
	REQUIRED	SPARE	TOTAL		
Cable Sealing Head (Type A)	6	2	8	RC 247 N	
Cable Sead Head (Type B)	4	2	6	RC 247 D	
Cable Sealing Head (Type C)	2	2	4	RC 247 C B/M	RC 247 C.3
and				RC 247 C	RC 247 C.4
Antitwist Clamp	2	2	4	RC 247 C.1	RC 247 C.5
				RC 247 C.2	RC 247 C.6
Load Cell Housing (200 Tons)	1	-	1	RC 249 A	RC 249 A.8
				RC 249 A.1	RC 249 A.9
				RC 249 A.2	RC 249 A.10
				RC 249 A.3	RC 249 A.12
				RC 249 A.4	RC 249 A.13
				RC 249 A.5	RC 249 A.14
				RC 249 A.6	(Note 2)
Electrical Feeding Apparatus for Load Cell (200 Tons)	1	-	1	RC 249 E.1	RC 249 E.6
				RC 249 E.2	RC 249 E.7
				RC 249 E.3	RC 249 E.8
				RC 249 E.4	RC 249 E.9
				RC 249 E.5	(Note 2)
Free Rotating Head (200 Tons)	1	-	1	RC 249 B B/M	RC 249 B/9
				RC 249 B	RC 249 B/10
				RC 249 B/1	RC 249 B/11
				RC 249 B/2	RC 249 B/12
				RC 249 B/3	RC 249 B/13
				RC 249 B/4	RC 249 B/14
				RC 249 B/5	RC 249 B/15
				RC 249 B/6	RC 249 B/16
				RC 249 B/7	(Note 2)
				RC 249 B/8	
Cable Fixing Point (200 Tons)	1	-	1	RC 249 C	RC 249 C.7
				RC 249 C.1	RC 249 C.9
				RC 249 C.2	(Note 2)

ITEM	QUANTITY			DRAWING REFERENCE
	REQUIRED	SPARE	TOTAL	
12 Meters Sheave with Trolley	1	-	1	RC 249 D 1 of 12 RC 249 D 2 of 12 RC 249 D 3 of 12 RC 249 D 4 of 12 RC 249 D 5 of 12 RC 249 D 6 of 12 RC 249 D 7 of 12 RC 249 D 8 of 12 RC 249 D 9 of 12 RC 249 D 10 of 12 RC 249 D 11 of 12 RC 249 D 12 of 12*
Modification to Roof and Storage Facility	1	-	1	RC 249 F Plus Report
Clamp (Maintain Congruence of Cable Components)	1	-	1	RC 247 G Items 1-6, 3u - 4u
Fixing Point to 3 meters Sheave	2	-	2	RC 247 M
Machine to Apply Oscillatory Movement to the Cable	1	-	1	RC 247 H B/M RC 247 H (General) RC 247 H (Longitudinal) RC 247 H (Section) RC 247 H (Transverse) RC 247 H-1 RC 247 H-5 RC 247 H-2 RC 247 H-6 RC 247 H-3 RC 247 HS.E RC 247 H-4
Load Cell (20 Tons)	1	-	1	See HBM Data Sheet

* Calculation Report of Sheave Design (12 pages)
 Structural Report of Foundation Beam (36 pages)
 Check of Hydraulic Pulling System (16 pages plus Engineering Data Sheets)

ITEM	QUANTITY			DRAWING REFERENCE
	REQUIRED	SPARE	TOTAL	
Linear Tensioner Simulating Device	1	-	1	RC 247 A B/M RC 247 A RC 247 A bis RC 247 A ter RC 247 A.1 RC 247 A (Details 2-11) RC 247 A (Details 12-27) RC 247 A (Details 28, 29, 30 & 31)
Measures Relating to the Dynamic Flexural Rigidity	-	-	-	See C.R.M. S.p.A. Letter
Degasifier 600 l/h	1	-	1	RC 122
A2/120 oil reservoirs	24	-	24	401.5.023 401.5.025
P2/25 oil reservoirs	18	-	18	
Under Vacuum oil Recovery Pump	2	-	2	2011-10-79022
Oil Strainer	1	-	1	-----
Oil Pumping Plant	1	-	1	RC 247 T
Special Oil	8000 litres	1000 litres	9000 litres	-----
Trolleys (Small)	80	-	80	RC 173.F
Ramps	4	-	4	RC 173 G
Cable Thermal Insulation	200 m	-	200 m	-----

Note 1: Refer to Table 1 General Testing Equipment - Laboratory Test Protocol

Note 2: The complete hydraulic tensile facility has been checked and found suitable for 200 tons. However, the load cell housing electrical feeding apparatus for the load cell, free rotating head and cable fixing point must be replaced with units suitable for the required higher pulling forces.