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Informal Report

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Hot Dry Rock Geothermal Energy Development Project
Cablehead Assembly
Equipment Development Report

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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UNITED STATES
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Dr. 457

MASTER

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UC-66b
Issued: August 1978

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Equipment Development Report

J. R. Archuleta
B. E. Todd

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HOT DRY ROCK GEOTHERMAL ENERGY DEVELOPMENT PROJECT
CABLEHEAD ASSEMBLY
EQUIPMENT DEVELOPMENT REPORT

by

J. R. Archuleta and B. E. Todd

ABSTRACT

This report discusses the development, design, and service history of a multiconductor cablehead capable of operation at 275°C and 103 MPa (15 000 psi). This high-temperature cablehead has been in service for about 18 months; conclusions drawn from this test period are summarized.

1. INTRODUCTION

A program designed to demonstrate the feasibility of extracting energy from hot dry rock in the earth's crust is being conducted at the Los Alamos Scientific Laboratory (LASL). The system is based on the establishment of a pressurized water circulation loop created by drilling two holes from the surface and connecting them by a large network of cracks produced by hydraulic fracturing.¹ Specialized tools had to be designed to investigate the fracture size and location, because the oil-field logging industry did not have tools available that could survive the long-term tests in the severe geothermal environment.

Instruments (sondes) used in reservoir mapping often remain downhole for as long as 30 h at 200°C and 35 - 41 MPa (5000 - 6000 psi). Communication between the downhole sonde and the surface recording facility is by a high-temperature multiconductor armored cable that terminates at the cablehead. The cable must maintain mechanical and electrical integrity during the test. Therefore, the development of high-temperature wellbore instruments (that is, those capable of functioning at 200 - 275°C) is constrained by the quality of the electrical connection between the subsurface electronics and the surface recording equipment.

2. FUNCTIONS OF THE HIGH-TEMPERATURE CABLEHEAD

The primary function of the high-temperature cablehead is to provide a cable-to-sonde electromechanical coupling device, which protects the electrical

conductors from the downhole high-pressure and high-temperature water environment. Other functions of the cablehead are:

1. To establish a transition area from the downhole fluid, high-pressure environment to the dry, low-pressure environment in the sonde.
2. To provide a protected area for splicing the cable conductor ends to the high-pressure bulkhead.
3. To allow the sonde and cable to be separated if the sonde becomes jammed in the wellbore.
4. To provide a gripping groove (fishing bell) for overshot fishing tools.
5. To protect the cable from right-angle bending as sondes are being raised from the assembly table to the vertical position over the wellhead.

The cablehead designed at LASL (Fig. 1) is intended to complement the multi-conductor armored cable, which is rated for continuous service up to 250°C, and to provide increased reliability needed for the more demanding geothermal conditions. Satisfactory electrical characteristics at maximum pressure and temperature must be maintained by the cable and cablehead assembly. Temperature affects the full length of the cable, but in a predictable manner. Generally, pressure does not appreciably affect cable performance but will affect the cablehead's ability to seal out water in a fluid-filled borehole. The most probable place for water to enter an electrical conductor is at the downhole end of the cable, and frequent exposure of the conductor ends to water decreases the useful life and quality of a multiconductor cable. Providing a moisture-free environment at the downhole end is the most difficult function of a cablehead. Data obtained from long-duration tests will range in quality from highly accurate to qualitative, depending on the moisture condition at the cablehead.

A well-logging service company's typical cablehead is moisture protected by simply encasing the splice area with grease. Cablehead failure occurs when the grease breaks down or moisture collects at the high-pressure feedthrough block. Also, the quick-connect bridle and torpedo arrangement of many cablehead assembly designs on the market is a major source of leakage.

Four distinct cableheads, incorporating the same basic design, have been fabricated at LASL:

1. A 70-mm (2.75-in.) -diam cablehead (81Y210142, the first design) has been in service for 1-1/2 yr (see detail drawing 81Y210142);*

*Detail drawings are enclosed in the back pocket.

2. A second cablehead configuration (81Y210165) was designed for initial evaluation of a new cable containing six-twisted-pair conductors and a coaxial (Figs. 2 and 3) (see also detail drawing 81Y210165);

3. A third-generation 45-mm (1.75-in.) -diam cablehead (81Y210181) was designed to allow entry through a wellhead restriction and directional orientation surveys through drill collars (see detail drawing 81Y210181);

4. A 53-mm (2-1/8-in.) -diam cable head (81Y210200) is a standardized head used with a 11.9-mm (0.468-in.) -diam seven-conductor cable or with a 16.6-mm (0.656-in.) -diam six-twisted-pair conductors and a center coaxial cable (see detail drawing 81Y210200).

3. SEALING CONCEPT

The LASL cablehead design has only one water entry path (Fig. 4) to the conductor splicing cavity, which is sealed with silicone rubber. The silicone rubber is a two-component, room-temperature vulcanizing rubber. The silicone rubber is injected as a viscous fluid through a port in the splice cavity housing (see Fig. 4). Silicone rubber fills the annulus around the cable and most of the voids between the core and the wrapped armor wire (Fig. 2). The auxiliary injection port located in the cable packoff housing must be used if the pumping pressure exceeds 41 MPa (6000 psi). The material sets within 24 h at room temperature to a Shore A durometer hardness of about 60 (Ref. 2). Water migrating to the splicing cavity must enter at the top of the cablehead into the cable packoff cavity, which is the first seal. Water that migrates past this area to the splicing cavity must then flow radially through the cast silicone rubber bushing to the conductor splice, which is nearly centered in this cavity. The splice joining the conductor from the cable and from the high-pressure bulkhead is sealed by Teflon shrink tubing. When heated the shrink tubing bonds to the conductor insulation, thus forming a continuous jacket to the bulkhead (see Fig. 3). The connector at the high-pressure bulkhead is protected further by a Viton boot (Fig. 5). The electrical conductors in the low-pressure side of the bulkhead are terminated at a quick-disconnect connector, which is affixed to the lower end of the cablehead. Thermal expansion of the silicone rubber increases the sealing pressure, thus aiding its function as a water barrier. The 81Y210200 cablehead has an epoxy end-cap installed below the cone basket to prevent the expanding silicone rubber from pushing the core into the cable, thereby breaking the conductors (see Fig. 6).

4. CABLEHEAD CONSTRUCTION

Most of the components, except at the separation joint, are manufactured from 4340 high-strength steel heat-treated to 1.24 - 1.38 GPa (180 000 - 200 000 psi), allowing service to 103 MPa (15 000 psi). The components at the separation joint are made from high-strength stainless steel, thus minimizing corrosion at the shear face, which could affect the break-away force.

The cablehead and sonde automatically separate when the cable tension exceeds 17.8 kN (4000 lb) plus $1.61 \times 10^{-4} \text{ m}^2$ (0.25 in.²) times the ambient fluid pressure. The release load can be accurately determined as a result of the simple shear fuse design. Failure of the two brass fuse pins separates the cable from the tool so that the cable can be retrieved. The splice cavity stays with the cable, providing conductor protection after separation. The large diameter that must be pulled past borehole obstructions, after sonde separation, has been minimized in the 81Y210181 cablehead to 44.5 mm (1-3/4 in.). The cable tension separation load, carried by the armor to the cone basket-type cable termination in the upper portion of the cablehead, will not damage the cable. The quick-disconnect housing stays downhole with the sonde and provides a groove for retrieving overshot fishing tools.

A cable gripping ring installed in the upper portion of the cablehead ensures electrical grounding of the armor (see Fig. 7). The ground is carried to the sonde through a conductor to the connector or through the cablehead body (see Fig. 8).

Torque transmitted through the shear joint develops thrust and shear loads, which must be balanced without overloading the shear pins. Induced thrust loads are balanced at the shear nut as shown in Fig. 9. Torque lugs provide the capability of transmitting 340 N·m (250 ft-lb) of torque through the joint without damaging the shear pins.

Flange-type O-ring design is used whenever possible to provide reliable sealing at critical joints. Metallic O-rings have been used successfully and will provide a satisfactory method of upgrading the cablehead to 275°C.

Multipiece design is used in the splice cavity and cable packoff area for ease in disassembly and reheading.

A free-floating swivel and a quick-change electrical connector at the sonde-to-cablehead interface allows joined parts to be connected without rotation to prevent coiling of the electrical conductors.

5. SERVICE HISTORY

The 81Y210142 cablehead has been in service for about 1-1/2 yr. Conclusions from this test period are summarized below. This head, the first design put in service, used metallic seals in all critical joints. The metallic, self-energized, and silver-plated O-rings manufactured by United Aircraft Products gave satisfactory service in the preliminary tests, but after several reheadings, they developed slow leaks. This was attributed to scratching the seal surface during handling of the tool. After several pressure-temperature cycles, a seal joint will lose its preloads and is apt to leak because of the limited spring-back of a metallic seal. The attachment of sondes to the cablehead is difficult because of the high joint torque required for proper compression of the metallic seal. The metallic seals were replaced with Viton O-rings to allow continued cablehead development and testing at 200°C.

The separation joint was redesigned after a shear pin failed while we were torquing the joint. We added steel pins to provide the capability of transmitting torque through the joint without damaging the shear pins.

The cablehead will average about 150 - 200 accumulative downhole hours before failure. A typical duty cycle imposes 35 - 41 MPa (5000 - 6000 psi) at 200°C for 6 - 30 h. The useful life at 200°C and 35 - 41 MPa, without the temperature-pressure cycling, is about 900 h. Failure occurs when the resistance to ground of any conductor deteriorates to less than 1 MΩ, as checked with a Simpson meter using a 34-V battery.

The 81Y210181 cablehead has been in service for 9 months and has been reheaded once because of cable failure. This cablehead has accumulated about 200 h of downhole service.

The cablehead can be assembled in the field in 6 - 8 h and is ready for service in 24 h (16 h to allow silicone rubber to set). The assembly procedure is divided into four tasks: terminating the armor, splicing the conductors to the high-pressure bulkhead, filling the splicing cavity with silicone rubber, and installing the multipin connector.

REFERENCES

1. LASL HDR Project Staff, "Hot Dry Rock Geothermal Energy Development Project, Annual Report, Fiscal Year 1977," Los Alamos Scientific Laboratory report LA-7109-PR (February 1978).
2. Dow Corning Bulletin 61-080 (March 1972).

Fig. 1.
Cablehead assembly.

Fig. 2.
Cross section of cable showing penetra-
tion of silicone rubber through armor
to core.

Fig. 3.
Splicing cavity.

Fig. 4.
Water entry path to splicing cavity.

Fig. 5.
Moisture protection at high-pressure connector.

Fig. 6.
Cable core movement caused by expanding silicone rubber.

Fig. 7.
Cable grounding insert.

Fig. 8.
Cable armor grounding.

Fig. 9.
Balance of induced thrust loads.

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051-075	5.25	176-200	9.00	301-325	11.75	426-450	14.00	551-575	16.25
076-100	6.00	201-225	9.25	326-350	12.00	451-475	14.50	576-600	16.50
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BILL OF MATERIAL			
PART NUMBER	QUANTITY	UNIT	DESCRIPTION

LASL 2.125 DIA. CABLE HEAD

PN	CONDUCTORS	USE CONNECTOR (MALE)	USE CONNECTOR (FEMALE)
ASSY 100-1 *	7	AMPHENOL M83723-02R1210N	AMPHENOL M83723-13R1210N
ASSY 100-2	14	AMPHENOL M83723-02R1626N	AMPHENOL M83723-13R1626N

TOOL CONFIGURATION
SEE DETAIL A

DETAIL - A

MAT'L = 4340 RC 35/40
OR
HIGH STRENGTH STAINLESS
OR
EQUIVALENT

81Y210200
REV. D-5

TOL.
.X = ±.1
.XX = ±.03
.XXX = ±.005

- GENERAL NOTES:
1. ALL DIMENSIONS IN INCHES.
 2. BREAK ALL SHARP EDGES.
 3. CH. BY ALL TAPPED HOLES TO MAINT. DIAMETER.
 4. CH. BY .001 DIA. ALL DRILLED HOLES.
 5. DIMENSIONS & POSITIONS TO CENTERLINE UNLESS OTHERWISE SPECIFIED.
 6. WELDING SYMBOLS PER AWS A5.1-1968.
 7. SURFACE TEXTURE PER ASA B46.1-1963.

A		ORIGINAL ISSUE	
REVISION	CLASS	DATE	BY
<p>Los Alamos Scientific Laboratory of the University of California</p>		<p>CABLE HEAD 2.125 DIA.</p>	
<p>125 1/32 .005 .0.5</p>		<p>NO REQ</p>	
ORIGINATED	DATE	GROUP	
2/28/77	12/28/77	4	
CHECKED	DATE	GROUP	
2/28/77	12/28/77	4	
PROJ. ENGR	DATE	GROUP	
2/28/77	12/28/77	4	
APPROVED	DATE	GROUP	
2/28/77	12/28/77	4	
RELEASED	DATE	GROUP	
2/28/77	12/28/77	4	
<p>SCALE TOTAL SHEETS DRAWING NO. SHEET NO.</p>		<p>1/1 81Y210200D-5</p>

- GENERAL NOTES.** **UNLESS OTHERWISE NOTED**
1. ALL DIMENSIONS IN INCHES.
 2. BREAK ALL SHARP EDGES.
 3. CHK 2" ALL TAPPED HOLES TO MAJOR DIAMETER.
 4. CHK 2" x .000 DRIF ALL DRILLED HOLES.
 5. DIMENSIONING & POSITIONAL TOLERANCES PER ASM Y14.1-1972.
 6. WELDING SYMBOLS PER AWS Y22.5-1968.
 7. SURFACE TEXTURE PER ASA B46.1-1962

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<p>Los Alamos scientific laboratory of the University of California</p>		CLASSIFICATION OF DRAWING PART <u>U</u> TITLE BLOCK <u>U</u> TITLE <h1>CABLE HEAD</h1>	
TOLERANCES - UNLESS OTHERWISE NOTED FINISH FRACTIONAL DECIMAL ANGULAR <u>125</u> <u>1/32</u> <u>0.005</u> <u>0.5°</u>		NO REQ	
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PART NO.	C'BORE	MAT'L
201	(NO)	17-4 PH COND. H900
* 202	(YES) SEE END VIEW

END VIEW

(203) MAT'L = SST
303

TOL.

.X = $\pm .1$

.XX = $\pm .03$

.XXX = $\pm .005$

- GENERAL NOTE: (UNLESS OTHERWISE NOTED)
1. ALL DIMENSIONS IN INCHES.
 2. BREAK ALL SHARP EDGES.
 3. CHECK ALL SHARP EDGES TO MATCH QUANTITY.
 4. CHECK IF ALL SHARP EDGES TO MATCH QUANTITY.
 5. DIMENSIONS & POSITIVE TOLERANCES FOR AND TO 2-1975.
 6. WELDING SYMBOLS FOR ASAS 192 2-1974.
 7. SURFACE TEXTURE FOR ASAS 1-1962.

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BILL OF MATERIAL			
PART NUMBER	QTY	PER	DESCRIPTION

ASSEMBLY 100

VITON O-RINGS REQ'D

- (1) #2-26
- (1) #2-113
- (1) #2-214
- (3) #2-215
- (3) #2-216
- (1) #2-217
- (6) #2-8

SST SUB

NOTE:

- 1/4-28UNF SETSCREW PRE-ASSEMBLY WITHOUT O-RINGS AND LOCATE- DO NOT BREAK THRU.

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ORIGINATED	ARCHULETA 3-30-77	G-4		1/1		6		81Y210181 D-1
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PROJ. ENGR.								
APPROVED								
RELEASED

PART	QTY PER ASSY	DESCRIPTION
101	12	SETScrew 1/4-20UNF x 1/4 LG.
102	4	O-RING, VITON #2-219
103	7	O-RING, VITON #2-8
104	1	O-RING, VITON #2-113
105	2	O-RING, VITON #2-220
106	2 PR	RETAINING RING #50T-150
107	1	RETAINING RING #N5000-100
108	1	CONM. AMP. H83723-02R120N
109	1	CONM. AMP. H83723-02R1626N
110	AS REQUIRED	GREASE, KYTOX 240 AC
111	AS REQUIRED	SHRINK TUBING
112	7	FEEDTHRU
113	7	INSULATOR
114	14	SOCKET
115	7	BOOT, VITON
116	3	PIPE PLUG 1/4" PT, SOCKET, SST
117	1	CABLE T COND. (U.S. STEEL)
118	1	CABLE 14 COND (VECTOR)
119	1	EPOXY DURALCO 700
120	1	POTTING Dow 955-071RTV
200	1	SUB ASSY (SHEAR PINS)
201	1	HOUSING, QUICK DISCONNECT
202	1	HOUSING, QUICK DISCONNECT
301	1	HOUSING, WIRES
302	1	NUT, QUICK DISCONNECT
303	1	BULKHEAD
304	1	HOUSING, BULKHEAD
401	1	HOUSING, GROUND
402	1	HOUSING, GROUND
403	1	HOUSING, CONE BASKET
404	1	HOUSING, CONE BASKET
405	1	GROUND, RING
406	1	GROUND, RING
407	1	ASSY- JIG
409	1	PROTECTOR, CABLE
410	1	PROTECTOR, CABLE
123	1	20166-205, CONE BASKET
124	1	20166-207, HOLD EPOXY
125	1	20166-202, CONE
126	1	20166-203, CONE
127	1	20166-106, CONE BASKET
128	1	20166-102, CONE
129	1	20166-103, CONE

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NOTE:

- * = 1/4-28UNF SET SCREW
 ** D.A. = DRESSER ATLAS

SECTION A-A

FEEDTHRU HOLE PATTERN

BILL OF MATERIAL			
PART NUMBER	QUANTITY	PER	DESCRIPTION
201	1		CABLE, 20 CONDUCTOR .659 DIA.
202	1		BUSHING, RUBBER
203	1		INNER CONE
204	1		OUTER CONE
301	1		ROPE SOCKET
302	1		O-RING, VITON *2-217
303	1		POTTING SILICONE RUBBER DOW CORNING *95-077 RTV
304	1		1/4 NPT PLUG POTTING PORT
305	1		CRIMP CONNECTOR (20)
401	1		TERMINAL, PRESSURE (20)
402	1		INSULATOR (20)
202	1		SOCKET, CRIMP-ON (20)
	1		BOOT, VITON (20)
	1		TUBING, SHRINK-ON (20)
	1		INERT GAS FILLING PORT
	1		LOCK PLUG (SEE SHT. 4)
	1		VITON O-RING GS-4022/2W-27M
	1		VITON O-RING GS-4031/2W-28Q
	1		METALIC O-RING *U-2312-02-250-50-A UNITED AIRCRAFT PRODUCTS
	1		METALIC O-RING *U-2210-00-750-50-A UNITED AIRCRAFT PRODUCTS
	1		20 PIN CONNECTOR
	1		INSTRUMENT PACKAGE

B	20	ADDED O-RINGS & LOCK PIN	3-8 1977	CH			
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