UNIVERSITY OF DENVER
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Denver Research Institute
Laboratories for Applied Mechanics / 303•753-2616

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Summary of Data Acquisition by the Denver Research Institute at Geothermal Well "Utah State" 14-2

In cooperation with Thermal Power Company, AMAX Corp., and the United States Geological Survey (USGS), personnel from the Laboratories for Applied Mechanics of the Denver Research Institute logged geothermal well "Utah State" 14-2 in the Roosevelt Hot Springs KGRA during May 1978. The tool used measures pressure and temperature in real time, and was developed by DRI under contract to the Division of Geothermal Energy, Department of Energy. This research was undertaken as part of the DOE/DGE Industry-Coupled Program, administered by the Nevada Operations Office.

During the tests, problems were encountered with the seven-conductor logging cable on the USGS rig. Under high temperature operation (greater than 450°F), the insulation between conductors in the cable experienced catastrophic degradation. The phenomenon was shown to be completely reversible when the cable was cooled to ambient temperatures. This definitely affected performance of the logging, and resulted in the loss of all temperature data.

Pressure data was successfully recovered due to the design of the transducer unit. It employs a Bourdon tube to operate a 1000 ohm potentiometer wound with 330 turns of wire. The transducer range is 0 to 2000 pounds per square inch, absolute, resulting in a resolution of 6.06 psi per turn of the pot. Although it was not possible to measure the specific resistance of the transducer when operating down hole, data was acquired by counting the jumps in signal which are characteristic of the change for an incremental turn of the pot.

The data acquired and reduced using the above technique are presented on the accompanying sheets. The flowrate measurements were made using a modified James method, since there was a problem measuring pressure drop at the orifice used to determine enthalpy. Therefore the flowrates shown are approximate.

Plans are being made to repeat these measurements in an additional test to be made in October 1978. Improved equipment is expected to result in successful acquisition of pressure and temperature data. Further information on the May tests are available from the Denver Research Institute, P. O. Box 10127, Denver, Colorado 80208; Attention: Mr. Jim Butz, Geothermal Programs.

Log No. 2 Flow Rate 357,000 lbs/hr. (?)

TPC/AMAX Well 14-2

Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
49		379	1713	31	573
118	0 (reference)	385	1752	32	579
178	1	391	1793	33	585
237	2	397	1821	34	591
314	3	403	1853	35	597
382	4	409	1898	36	603
409	5	415	1932	37	609
430	6	421	1966	38	615
486	7	427	2001	39	621
608	8	433	2028	40	627
663	9	440	2059	41	633
728	10	446	2090	42	640
779	11	452	2129	43	646
832	12	458	2163	44	652
878	13	464	2188	45	658
939	14	470	2223	46	664
990	15	476	2250	47	670
1036	16	482	2280	48	676
1086	17	488	2313	49	682
1140	18	494	2342	50	688
1178	19	500	2359	51	694
1229	20	506	2386	52	700
1283	21	512			
1329	22	518			
1370	23	524			
1412	24	530			
1459	25	537			
1508	26	543			
1545	27	549			
1594	28	555			
1634	29	561			
1676	30	567			

Comments:

Suspect Flash Horizon at ~ 2450'
Flowrate value seems low for given wellhead pressure and level of flash horizon.

Log No. 3 Flow Rate 447,500 lbs/hr.

TPC/AMAX Well 14-2

Depth (ft)	Transudcer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
50	0 (reference)	355	2032	32	549
134	1	361	2076	33	555
239	2	367	2122	34	561
324	3	373	2167	35	567
380	4	379	2213	36	573
452	5	385	2255	37	579
529	6	391	2283	38	585
597	7	397	2337	39	591
615	8	403	2374	40	597
641	9	410	2415	41	603
702	10	416	2455	42	610
846	11	422	2490	43	616
913	12	428	2525	44	622
978	13	434	2560	45	628
1063	14	440	2606	46	634
1125	15	446	2643	47	640
1180	16	452	2672	48	646
1249	17	458	2711	49	652
1300	18	464	2746	50	658
1353	19	470	2781	51	664
1410	20	476	2820	52	670
1470	21	482	2855	53	676
1515	22	488	2873	54	682
1568	23	494	2901	55	688
1634	24	500	2950	56	694
1686	25	507	2964	57	700
1733	26	513	2990	58	707
1784	27	519			
1834	28	525			
1883	29	531			
1933	30	536			
1982	31	543			

Comments:

Suspect flashing in formation.

Log No. 4 | Flow Rate 255,000 lbs/hr.

TPC/AMAX Well 14-2

Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
12	0 (reference)	435	1575	33	635
70	1	441	1610	34	641
118	2	447	1642	35	647
162	3	453	1686	36	653
216	4	459	1721	37	659
264	5	465	1748	38	665
312	6	471	1786	39	671
360	7	477	1822	40	677
414	8	483	1862	41	683
457	9	490	1897	42	690
515	10	496	1937	43	696
558	11	502	1959	44	702
606	12	508	1994	45	708
664	13	514	2042	46	714
716	14	520	2065	47	720
769	15	526	2095	48	726
820	16	532	2131	49	732
861	17	538	2170	50	738
922	18	544	2205	51	744
974	19	550	2245	52	750
1015	20	556	2274	53	756
1067	21	562	2322	54	762
1118	22	568	2366	55	768
1163	23	574	2398	56	774
1213	24	580	2446	57	780
1258	25	587	2489	58	787
1300	26	593	2540	59	793
1328	27	599	2577	60	799
1374	28	605	2634	61	805
1421	29	611	2688	62	811
1464	30	617	2770	63	817
1505	31	623	2932	64	823
1544	32	629	2994	65	829

Comments:
Log taken before flow completely stabilized. Values in lower part of wellbore are particularly suspect. Log made from 3000' level upward.

Log No. 5 Flow Rate 255,000 lbs/hr.

TPC/AMAX Well 14-2

Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
52	0 (reference)	441	1473	33	641
98	1	447	1502	34	647
142	2	453	1542	35	653
208	3	459	1572	36	659
259	4	465	1596	37	665
297	5	471	1634	38	671
350	6	477	1660	39	677
410	7	483	1693	40	683
444	8	489	1723	41	689
494	9	496	1758	42	696
549	10	502	1775	43	702
583	11	508	1804	44	708
633	12	514	1844	45	714
687	13	520	1858	46	720
738	14	526	1878	47	726
777	15	532	1908	48	732
822	16	538	1933	49	738
866	17	544	1962	50	744
911	18	550	1983	51	750
960	19	556	2008	52	756
1004	20	562	2032	53	762
1043	21	568	2057	54	768
1088	22	574			
1122	23	580			
1162	24	586			
1205	25	593			
1235	26	599			
1265	27	605			
1306	28	611			
1340	29	617			
1376	32	623			
1410	31	629			
1442	32	635			

Comments: Flash Horizon at about 1850'
Indicated single phase pressure gradient is low.

Log No. 6 Flow Rate 368,800 lbs/hr.

TPC/AMAX Well 14-2

Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
32	0 (reference)	391	1624	32	585
70	1	397	1657	33	591
134	2	403	1694	34	597
188	3	409	1736	35	603
222	4	415	1769	36	609
230	5	421	1809	37	615
280	6	427	1844	38	621
400	7	433	1880	39	627
456	8	439	1913	40	633
505	9	446	1946	41	639
554	10	452	1986	42	646
610	11	458	2020	43	652
654	12	464	2048	44	658
718	13	470	2087	45	664
764	14	476	2116	46	670
812	15	482	2149	47	676
867	16	488	2187	48	682
924	17	494	2215	49	688
972	18	500	2237	50	694
1016	19	506	2267	51	700
1078	20	512	2301	52	706
1129	21	518	2320	53	712
1177	22	524	2348	54	718
1221	23	530	2380	55	724
1272	24	536	2408	56	730
1320	25	543	2430	57	736
1378	26	549	2450	58	743
1412	27	555	2478	59	749
1460	28	561	2512	60	755
1500	29	567	2534	61	761
1539	30	573	2552	62	767
1584	31	579	2580	63	773

Comments:

Log No. 6

Flow Rate 368,800 lbs/hr.

TPC/AMAX Well 14-2

Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)	Depth (ft)	Transducer Count (No. of Steps)	Pressure (psia)
2601	64	779			
2624	65	785			
2647	66	791			
2670	67	797			
2690	68	803			
2715	69	809			
2732	70	815			
2754	71	821			
2774	72	827			
2804	73	833			
2814	74	839			
2832	75	846			
2855	76	852			
2878	77	858			
2899	78	864			
2922	79	870			
2936	80	876			
2955	81	882			
2979	82	888			
2996	83	894			

Comments:

Flash Horizon at about 2350'
Indicated single phase pressure gradient is low.

GL04414_2

MONTHLY REPORT FOR MAY, 1978

ACTIVITIES

The flow test of TPC/AMAX well "Utah State" 14-2 was conducted during May 7-13, and all tasks performed for the month were directly related to the test, either in preparation, at the site, or work with the resultant data.

An adapter to permit use of the LASL downhole sampler on the USGS 7-conductor cable was fabricated in the DRI Machine Shop. Jim Butz made a trip to LASL to check the fit of the close tolerances on the adapter, to finalize plans for LASL participation, and confirm the wiring configuration to be used.

The DRI tool was checked on the USGS cable system to ensure proper operation in the field. All DRI equipment that was used in the field test was taken to the USGS logging truck for transport to the well site. The Data Agreement between USGS and the well owners was OK'd by the government and subsequently signed.

Site preparation at Well 14-2 near Milford, Utah was completed. Work included the following tasks: (1) rebuilding of the sump pit to contain a volume equivalent to 48 hours flow; (2) a six inch valve, mating flange, and associated hardware were rented, delivered, and installed on the wellhead; and (3) the flowline, throttle valve and surface pressure measurement system were moved from well 72-16 to the site, assembled, and anchored into position for the flow tests. Part of the costs for this site work will be covered by DRI as outlined in the contract.

The USGS logging truck left Denver on 6 May and arrived at the site on 7 May. The mast service truck provided by Sandia Labs' Geothermal group was already on site. The process of rigging up the wellhead to accomodate the USGS/DRI riser assembly was begun, and it was discovered that the Sandia mast did not have capability to tilt far enough to position the upper sheave directly over the wellhead. After some discussion, we decided to order a mast service truck from OTIS Engineering in Vernal, Utah, to support the tests. The OTIS truck arrived early Monday morning and was immediately put to use in completing the rigging for the test.

The first survey to be run was a USGS temperature log of the shut-in well. There was a definite degradation of the signal with depth, so the tool was removed from the well and the cablehead and cable examined. The elastomer boot used to seal the individual conductors from each other at the cablehead solder connection had failed as indicated by distortion, discoloration, and splitting. The cablehead was repaired, but the signal degradation persisted on subsequent runs. The extreme high temperature of the well was thought to be the cause of the problem.

Improvements in the performance of the cablehead were made through the use of a silicone high temperature grease and revised soldering procedures; however, intermittent high temperature failure of cable head boots occurred throughout the tests.

To run the USGS Borehole Televiewer tool, the well was cooled by the injection of 500 barrels of ambient temperature water. The BHTV has downhole electronics in the probe, so that some type of protection from high temperatures is necessary. The downhole electronics package is also enclosed in a vacuum dewar to minimize heat transfer rates. The televiewer worked quite well in the cooled borehole, and some excellent data was taken. This information will be published by the USGS as part of a study of the geophysics of geothermal boreholes.

The USGS also ran their Gamma-spectral tool at several stations in the borehole, while it was still cooled due to the water injection. All USGS logs were run with the well shut in.

On Friday, 12 May, we began the flow tests. The DRI tool was assembled with three, 40-pound sinker bars to the USGS cable. It was also necessary to add another length of riser pipe to the riser assembly to accomodate the sinkers. A log under shut-in conditions was made to check operation of the transducers in the probe. A grounding problem in the pressure transducer was identified during the checkout run, so that the probe was disassembled and the transducer repaired.

The well was then opened to initiate flow. Once flow had stabilized at an estimated rate of 300,000 lbs/hour (total flow), we began to run a pressure/temperature log from the top down into the well. A point was quickly reached at which the indicated temperature (the resistance of the RTD element) began to fall. Since this is an impossible condition in a flowing well, we suspected a problem with the conductor insulation: degradation with increased length of cable exposed to temperatures above 450°F. In fact, it appeared that the parallel resistance through the insulation was falling so fast that the data was indicating a negative temperature gradient (decreasing temperature with increasing depth) in the flowing well. Thus, early in the flow test we knew that no reliable temperature data could be obtained. An interesting note on the high temperature degradation phenomenon should be made: the effect was completely reversible upon cooling of the cable as the tool was brought back up the well. When the riser was disassembled and the cablehead checked with an ohmmeter at the surface, the insulation between conductors was found to be in the megohm range.

The nature of the pressure transducer used in the DRI probe saved the flow test data from being totally useless. The unit uses a Bourdon Tube to operate a 1000 ohm potentiometer. There are 330 turns in the pot, so that as the wiper moves from one turn to the next, a three ohm jump in resistance is seen. These jumps are clearly visible on the strip chart record, in spite of a general decline in the resistance valve during the period that the wiper remains in contact with a particular turn of the pot. The wiper will remain in contact until sufficient additional pressure to move it to the next turn is encountered. This differential pressure has been measured in the laboratory to range from 4 to 7 psi. As the probe is lowered into the flowing well, the pressure on the Bourdon tube element increases until the above-specified differential is reached, at which time the wiper advances to the next turn.

Figure 1 is a sample section of the data chart, showing the (apparent) negative temperature gradient and a total fo 5 wiper steps of three ohms each (although due to parallel resistance effects, each step shows as about two ohms). The pressure reading can be found by reference to the value with the probe at the wellhead, which, in turn, is determined from a calibration curve, since there is no cable immersed in the flowing fluid. Each step is then considered to be 2000 psi/330 turns = 6.06 pounds per square inch. The pressure reading at any step can now be determined by adding the product of the number of steps and the per-step increase to the wellhead reference pressure.

Using this described technique, a total of five logs were run under flow conditions. Two of those logs were made at the same flowrate, because we did not have a stabilized condition during the first run at the flowrate. The conditions are summarized below:

Log No.	Wellhead (Reference) Pressure, PSIA	Flowrate, lbs/hr
1	(no-flow checkout run)	
2	385	357,000
3	355	447,500
4	435	255,000
5	441	255,000
6	391	368,800

Flowrates were determined using a modified James method. This was necessary due to the lack of an orifice meter to measure the differential

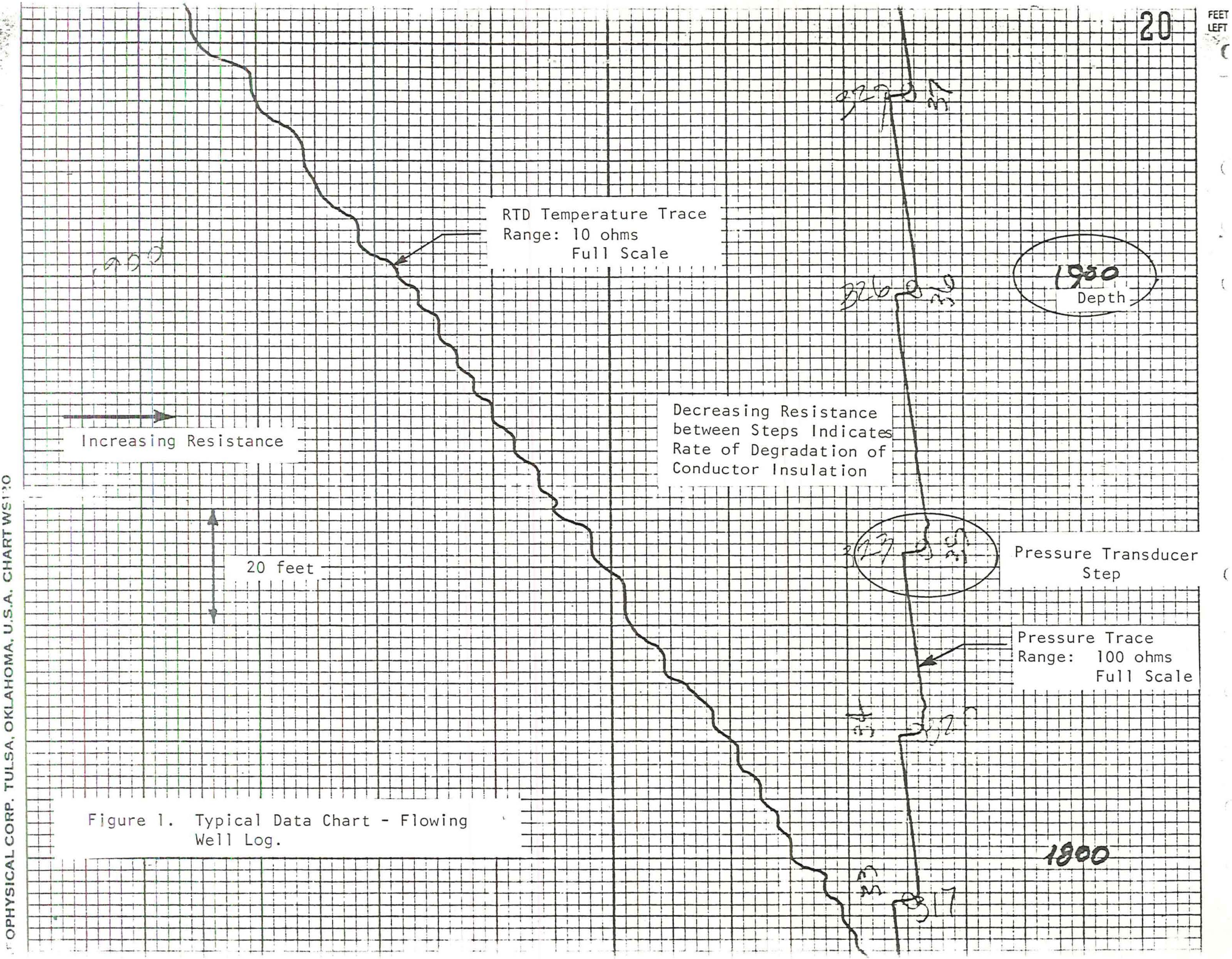

Figure 1. Typical Data Chart - Flowing Well Log.

pressure at the mixing orifice. Therefore the enthalpy value used was that given for the fluid at the flash horizon, less 3 Btu/lb considered lost to the wellbore and wellhead piping; the net enthalpy used was 485 Btu/lb.

The logs were taken at a speed of about 100 feet per minute. Since there was no way to obtain useful temperature data it was not necessary to log more slowly to allow for response time of the RTD.

After completing the flow logs, the well was shut in and we attempted to run the LASL downhole sampler. The tool was installed on the cable and operations checked at the surface. The tool was quickly run down the hole to the depth desired for the first sample, and the power supply was switched on. Due to the insulation degradation effect, the current was almost totally shorted across the conductor leads, and the motor which operated the sampling valves would not run. The sampler was raised 1000 feet up the wellbore and another attempt was made to operate the motor, but the result was the same as the first.

Surface samples had been taken during flow by personnel of the University of Utah Research Institute and from Battelle-Pacific Northwest Labs. This data will be examined to determine its utility in the computer analysis to be done by DRI.

The USGS is conducting an extensive investigation of the failures in the 7-conductor cable insulation and cablehead components. They are planning to issue a Technical Note on the problems and their probable causes.

Data reduction and analysis were begun immediately upon return to Denver from the wellsite. The technique described previously was used to make tables of pressure readings at various depths for each of the five flow logs. Orthogonal polynomials were used to determine the optimal degree of least-squares polynomial to which to curve-fit the data. The results indicated that a least-squares quadratic would be quite adequate. The data was then curve-fitted, with correlation coefficients ranging from 0.985 to over 0.999. The self-consistency of the data was thus confirmed, and our confidence in the utility of the test data was strengthened.

The data has shown a pressure gradient in the single phase flow regime that is depressed from that normally encountered at the downhole conditions. We are investigating possible reasons for this, and will present further details in the next monthly report.

Before leaving the test site, informal discussions were held on the possibility of returning to run additional well tests. The USGS is in the process of purchasing a new 7-conductor cable from Vector Cable Corporation which is performance rated to 550°F.

This cable uses a different conductor insulation material than the present cable. It is very likely that the DRI probe could perform as designed when used with the new cable.

DRI has initiated efforts to secure permission from the well owners to repeat the flow tests after the USGS has obtained its new 7-conductor cable. Our formal request has been submitted to Thermal Power Company, who is considering it at this time. If the request is granted, arrangements will be made with the USGS on available dates. We will then formally request an extension of the present contract and possibly additional funds to cover some of the expense of the testing. The amount of additional funds is not yet known, because all expenses for the May tests have not yet been billed to DRI. We would hope to complete any additional tests before the end of 1978.

FINANCIAL STATUS

For the month of May the following expenditures were made:

Balance Forward	$55,913.58
Direct Salaries and Fringe	2,578.12
Overhead	2,217.18
Travel	707.61
Supplies and Expenses	3,483.16
Remaining Uncommitted Funds	$46,927.51

Note: As of 1 June, all invoices for field test expenses have not been received or paid by DRI.

PROBLEMS AND PROPOSED SOLUTIONS

A problem with the acquisition of temperature data was encountered in the field test, as described in the "Activities" section. We hope to be able to propose to DOE a return to the well to run tests with improved equipment. If this is not possible, analysis of the well potential will be made using the pressure data only. We expect to be able to make a decision when Thermal Power Company acts on our request for further testing.

DRI will also request a redistribution of funds within budget categories. These funds are included in the total budget approved for the present contract. An amount was originally marked for permanent equipment purchases. The needed equipment was either rented or borrowed and we wish to transfer the permanent equipment funds to salaries and supplies budgets to cover the time and costs expended to arrange the rentals. This action will be undertaken through DRI Contracts and Grants during the month of June.

PLANNED ACTIVITIES

DRI will continue to reduce and analyze the test data during June. The work begun on securing permission for additional tests will be continued, along with a budget analysis to determine what additional funds will be needed, if any. The data from the May well tests will be distributed, as required by the present contract.