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THE YBM DEVELOPMENT OF A HIGH-TEMPERATURE/HIGH-PRESSURE GEOTHERMAL LOGGING SYSTEM

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ABSTRACT

An ingenious geothermal-well logging system based upon simultaneous real-time high-temperature/high-pressure operations has been developed by YBM (Yoshida Boring Machine Manufacturing Co., Ltd.) in cooperation with a Research Group from Kyushu University.

The logging system was tested up to a maximum of 330°C and 340 kgf/cm2 in an autoclave installed to test the sealing system for various joints of the probe in high temperature/high pressure water conditions, under conditions indentical with that of deep high-temperature geothermal wells, with corrections being made in the pressure values caused by temperature changes in the pressure transducers. Data acquisitions are made, and correction systems are operated automatically by the use of a microcomputer.

1. INTRODUCTION

Logging probes for geothermal wells are normally used up to 260°C in real time and simultaneous (temperature and pressure) measuring systems. In Japan, many geothermal wells have been drilled in depths up to 2,000 meters. Some have attained 3,000 meters in depth. The temperatures measured have frequently gone higher than 260°C, and at times have exceeded 300°C at the deepest points in the geothermal wells (MIYAIRI and ITOH, 1985).

Back in 1984, YBM and its cooperative team commenced the planning and began to develop a high-temperature/high-pressure simultaneous logging system which could be applied in a well 3,000 meters deep, filled with a high temperature geothermal fluid. In the early stages of the program, it was most important and crucial to select a pressure transducer operable at 330°C or more, and 7-conductor cable operable under these high-temperature/high-pressure conditions. Much of the time was spent on lengthy tests in an autoclave which created conditions corresponding to that of a deep geothermal well of 3,000 meters in depth.

2. TEST FACILITIES

At the intial stage of development in the logging system, the test facilities, consisting mainly of the autoclave connected with the data acquisition system was positioned in a bore hole, 3.5 meters in depth and 60cm in diameter, for reasons of safety (Fig.l)

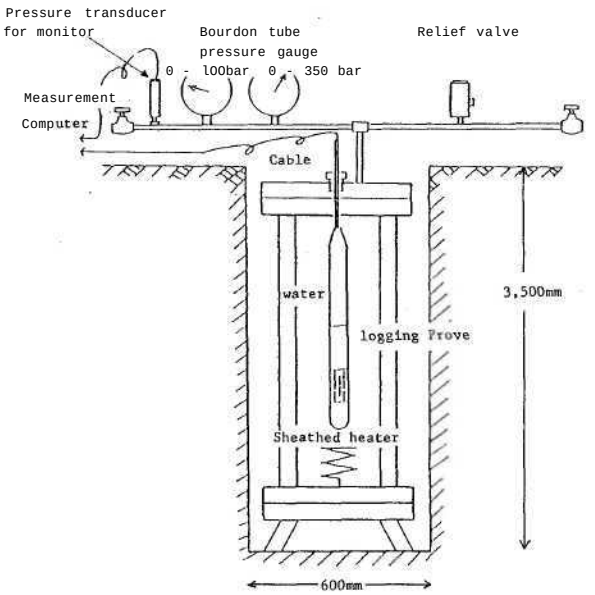

Fig.l. Test Facilities

The main purpose of the test facilities was:

i) to simulate geothermal wells (up to 3,000 meters in depth) in the laboratory,
ii) to calibrate the pressure transducers,
iii) to check leakages of water in the many connecting seals of the sensor probes and cable heads under high-temperature/high-pressure water conditions, and,
iv) to check/inspect the completed logging probes.

The autoclave was designed to obtain high-temperature/high-pressure water conditions of a maximum of 350°C and 350 kgf/cm2 by using a 9 KW sheathed electric heater.

The pressure transducer (strain gauge type) for calibration (monitoring) was constantly being checked severely with Bourdon tube pressure gauges.

3. TEMPERATURE AND PRESSURE GAUGES

It is most important to select optimum sensors for high-temperature/high-pressure water conditions in deep geothermal wells.

i) Thermometers :
A platinum wire-resistance thermometer was chosen to measure the temperatures because of its high accuracy and reliability.

Table 1. Calibration data for a pressure transducer

HEI; (NO)	I int	P (V	Temp	PRIM	PRCIU)	PRESSURf
1 16i	10:19:ii	1.1014	319.557	9.6715	15.657	255.650
1 170	18:20:03	1.1074	321.226	9.8720	15.816	258.175
1 174	10:20:13	1.1055	320.169	9.8753	15.931	259.925
1178	1e:20:IS	1.1065	320.725	9.B7 28	16.063	262.000
1182	18:21:03	1.1083	321.727	9.8882	16. 198 264 . 1 13	
1106	18:22:t:	1.1069	320.947	9.8844	16.339	266.275
1 190	IB:;j 13	1.1064	320.669	9.8789	16.486	268.462
1194	IS:24:Oi	1.1111	323.286	9.8908	16.662	271.175
119B	IS:24:43	1.106 7	321.949.	9.8869	16.833	273.775
1202	18:25:1s	1.1118	323.676	9.8874	17.010	276.475
1206	18:26:03	1.1093	322.284	9.8920	17.140	278.525
1210	18:26:83	1.1123	323.954	9.8943	17.300	280.988
1214	18:21.11	1.1102	322.781	9.9023	17.469	283.500
1218	1B:JO:t>3	1.1092	322.228	9.8991	17.605	285.725
1222	18:28:43	1.1125	32-1.065	9.6972	17.772	268.225
1226	10:29:23	1.1129	324.288	9.9020	17.949	290.938
1230	10:30:03	1.1146	325.236	9.9050	1fi.088	293.036
123*1	10:30:43	1.1124	324.010	9.9030	18.243	295.512
1238	1B:31:23	1.1145	324.180	9.9033	18.360	297.125
1242	18:32:03	1.1126	324.121	9.9141	18.511	299.538
1246	18:32:43	1.1127	324.177	9.9171	18.705	302.563
1250	18:33:23	1.1142	325.013	9.9110	18.0-1.1	304.713
1254	18:34:03	1.11-15	325.180	9.9162	19.007	307.063
1258	1G:34:43	1.1166	326.350	9.9146	19.188	309.725
1262	18:35:23	1.1162	326.127	9.9153	19.323	312.037
1266	1a:36:03	1.1160	326.016	9.9182	19.481	311.260
1270	18:36:43	1.1162	326.127	9.9271	19.(-30	.316.537
1274	1a:37:23	1.1171	326.629	S.9222	19.796	319.212
1278	18:38:03	1.1181	327.187	9.9252	17.3\1	SM'>36
1282	18:38:43	1.1190	327.689	S.9297	1d 07	311.462
1266	18:39:23	1.1187	327.521	9.9306	20.257	326.175
1290	18:40:03	1.1202	328.358	9.9255	20.430	328.862
1294	18:40:43	1.1202	328.358	9.9352	20.505	33 1.150
1298	10:41:23	1.1190	327.609	9.9393	20.7.39	333.562'
1302	18:42:03	1.1202	328.350	S.9353	50.615	330.712
1306	1a:42:43	1.1201	328.-169	S.9380	20.341	326.775
1310	10:43:23	1.1206	328.501	9.9403	19.387	311.525
1314	10:44:03	1.1190	327.609	9.9332	19.537	314.288
131E)	18:44:43	1.1207	328.627	9.9356	19.71.1	3.18.087
1322	18:45:23	1.1197	320.079	S.9383	1 9.91 5 32) . .0E)8	
1326	18:<6:03	1.1253	330.088	9.9446	20.126	323.637
1330	18:46:43	1.1219	329.307	9.9.147	SO. 113	326.500
1334	18:47:23	1.1222	329.474	9.9480	20.452	328.600
1333	18:•8:03	1.1220	329.362	9.9490	20.624	331.350
13-12	18:•8:43	1.1246	330.814	9.9517	M. . I?I 332. 73(1	
1346	10:49:23	1.1258	331.484	9.9453	20.892	335.150
1350	10:50:03	1.1258	331.484	9.9547	21.025	337.250
1354	18:50:43	1.1246	330.814	9.9601	I 1 1 >1	339.675
1358	10:51:23	1.1244	330.702	9.9600	21.35S	342.362

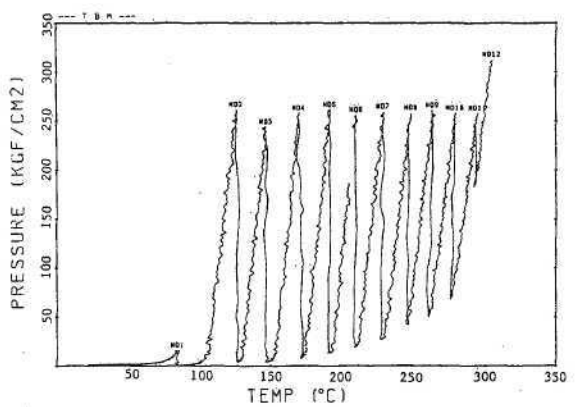

Fig.2. Full analogue calibration records for a pressure transducer.

This type of gauge is commonly used for measuring temperature in bore holes (USHIJIMA et.al., 1975, HOWARD et. al., 1979)

ii)Pressure gauges :

Two different types of pressure gauges were tested in the autoclave to introduce our logging system. They were both sputtered strain gauge pressure transducers. One was operable up to 343°C and 350 kgf/cm2 water conditions/ the other was a newly developed one which has been tested repeatedly to ascertain maximum operable pressure/temperature conditions and other properties.

At present, the former has been used in the logging probes. All gauges introduced were compensated, using temperature ranges from room temperature up to 340°C, in the autoclave.

Table 1 shows a part of the printed-out data. Rec. No. 1342 reveals a temperature exceedung 330°C and a pressure of 335 kg/cm2 respectively. The pressure reaches a maximum of 342 kgf/cm2 at Rec. No. 1358, although the temperature record is reduced by the convection of heated water in the autoclave. Figure 2 shows one of the full analogue records from the start to the end of the calibration. It takes about 10 hours to get up to 330°C.

As mentioned previously, the pressure values revealed by the monitoring gauge (strain gauge pressure transducer) were strictly checked by Bourdon tube pressure gauges read through a transit theodolite (made by NIKON) from an observation room.

4. LOGGING SYSTEM

The system is composed primarily of a logging probe, a seven-conductor cable, a data acquisition unit, a winch-mounted four-wheel-drive truck, a head sheave and a guide pully etc. (Fig. 3).

i) Logging Probe :

The logging probe is divided into two parts, the cable head and the sensor unit. The cable head was designed to prevent the penetration of water from the connecting system between the 7-conductor armoured cabie and the cable head under high-temperature/high-pressure water conditions. After lengthy and repeated tests in the autoclave, it was confirmed that the connecting system was acceptable and in perfect working condition.

The sensor unit installs the platinum wire-resistance thermometer and the sputtered strain gauge pressure transducer at the end of the unit with a protector.

Specifications of the logging probe are listed as follows:

Cable head	1,480 mm
Sensor unit	1,645 mm
Total length	3,125 mm
Diameter	80 mm
Weight	75 kg
Measuring range	
Temperature	0 - 330°C
Pressure	0 - 340 kgf/cm2

ii) Seven-Conductor Cable :

YBM newly developed a 7-conductor PTFE Teflon sheathed cable in co-operation with TEW & C *Co.*, Ltd. and NE Co., Ltd. Many types and makes of PTFE sheathed cables were manufactured for the high-temperature/high-pressure tests in the autoclave.

Satisfactory results were obtained after two and half years of effort in researching and developing the cable. We noticed during these repeated tests, that water

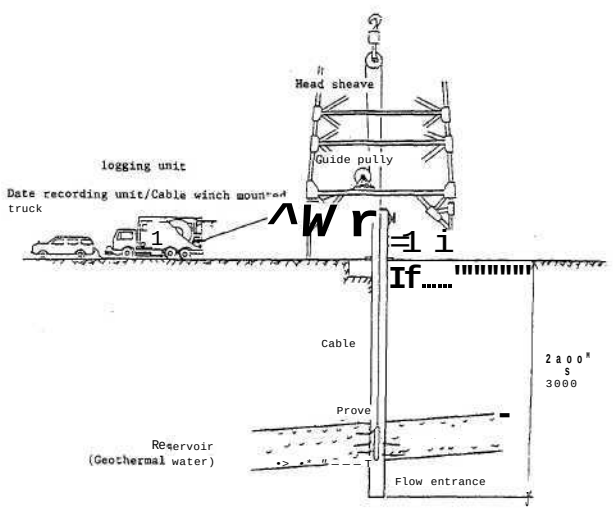

Fig.3. Logging system

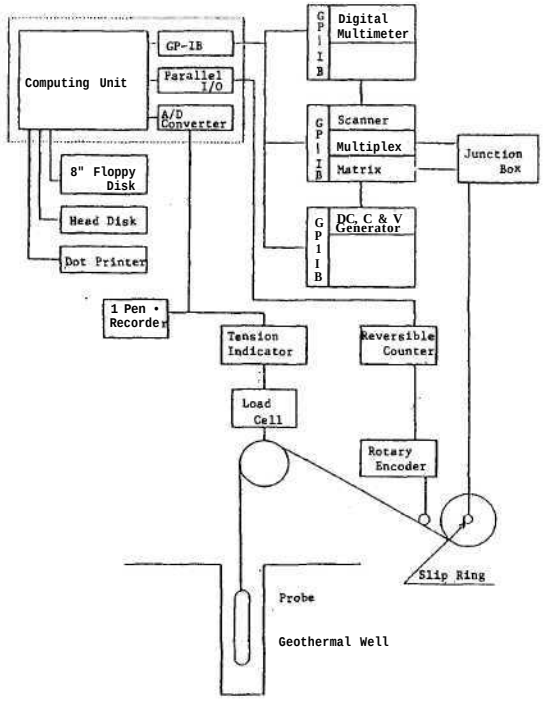

Fig.4. Data aquisition system

Photo.1. Cable winch mounted 4-wheel drive truck.

penetrated into the PTFE Teflon sheathed cable from the surface of the PTFE Teflon sheath itself at temperatures of between 190 and 210°C. This barrier was also finally overcome.

iii) Data Acquisition Unit :
The data acquisition system is schematically shown in Figure 4.

iv) Cable Winch Mounted Truck :
The hydraulic winch, with line speeds from 0 to 30 meters per minute and cable capacities up to 3,000 meters of 10 mm cable, is mounted on the 4-wheel drive truck (Photo.1). Power for hydraulic winch is derived from the truck engine through PTO.

v) Head Sheave and Guide Pully :
The head sheave is composed of a framework of a half-circle, 2 meters in diameter, and sheaves of 10 cm in diameter equipped in a half circumference to reduce the weight of the large diameter sheave as much as possible. The structure and size of the guide pully is the same as the head sheave.
The completed YBM logging system has been tested in geothermal wells in the island of Kyushu. Several problems occuring in real geothermal wells has been already solved and a simultaneous logging data such as shown in Fig 5 has been obtained in real-time.

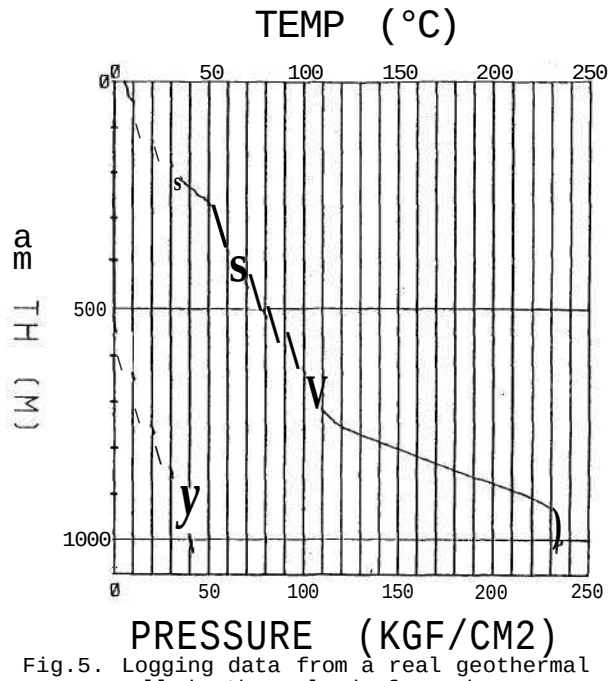

Fig.5. Logging data from a real geothermal well in the Island of Kyushu.

5. SUMMARY

The YBM Geothermal Logging System has been completed in co-operation with Professors T.Ito, K.Ushijima and their staffs (Research Group of Kyushu University). The logging system has been in actual performance on job sites in the Hacchobaru Geothermal Field in which the Hacchobaru Geothermal Electric Power Plant II is new under construction by the Kyushu Electric Power Co., Ltd.

ACKNOWLEDGMENTS

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REFERENCES

HOWARD,R.K., EDWARD,A.D. and WARREN,G.G. (1979) : Temperature and pressure logging tools using no down-hole electronics. Geothermal Resources Council, TRANSACTIONS, Vol.3 Sept. 1979. 353-356.

MIYAIRI, M. and ITOH,T. (1985): Super high temperature geothermal well logging system. SPWLA Twenty-sixth Annual Logging symposium, June 17-20, 1985, 1-16.

USHIJIMA,K. NISHIKAWA,K., ITO,T. MATSUMOTO,K., and NOGUCHI,T. (1975): A thermometer for geothermal thermometry in geothermal wells, journal of Japan Geothermal Energy Association, Vol.12, No.2, 15-21.