MINUTES

JOIDES Downhole Measurements Panel Meeting
Ocean Research Institute, Tokyo
November 7-8, 1986

87-279
RECEIVED APR - 3 1987

Panel Members Present

M. Salisbury (Chairman)
R. Anderson (ex-officio)
K. Becker (LITHP liaison)
S. Bell
J. Hovem
E. Howell
R. Hyndman (WPAC liaison)
A. Jageler
R. Jarrard (ex-officio)
R. Jung
H. Kinoshita
M. Langseth (PCOM liaison)
S. O'Connell (TAMU liaison)
J. Pozzi
R. Stephen
P. Worthington

Absent

G. Ohloeft
F. Sayles
R. Traeger

Guests

Y. Hamano (ORI)
D. Karig (Cornell)
T. Nagao (ORI)
F. Paillet (USGS)
J. Segawa (ORI)
A. Sutherland (NSF)
K. Tamaki (ORI)
N. Tesigawa (JAPEX)
S. Uyeda (ORI)

1. NSF (Sutherland)

The Soviet Union has announced that it intends to sign an agreement for participation in ODP in January. This will allow us to increase the FY'87 ODP budget by $1M from the current level of $34.26M. EXCOM recommends spending the new money on engineering efforts to improve drilling performance (recovery, penetration rate), on inventory (spare pipe, parts and tools) and on public relations. Specific recommendations of interest to DMP were that LDGO acquire two digital BHTVs, two 12 channel sonic tools and two wireline packers.

COSOD II is scheduled for July 6-8 in Strasbourg. Approximately 150 U.S. and 200 non-U.S. scientists will be invited.

Discussion (Langseth): PCOM's enhancement budget recommendations differ from EXCOM's. In particular, they grouped all proposed expenditures into two categories, Priority I and II, and ranked the expenditures of interest to DMP as follows:

Priority I
2nd: tools engineer
5th: backup analog BHTV

Priority II
4th: digital BHTV
5th: 12 channel sonic
6th: repair and maintenance

2. LDGO (Jarrard)

Since the last meeting, ODP has conducted some of the most intensive logging operations since the start of the program. These included the first use of the ACT and attempts to use the sidewall entry sub and the modified RFT tool. Legs 109 (see July minutes) and 111 were fabulous from the standpoint of DMP but 110 was awful.

Recent Results

Leg 110: Barbados

A total of only 100 m of logs was obtained at 3 sites. The only interesting scientific results from logging were that the logging and laboratory velocities were about equal in the sediments. Good water samples were taken at the decollement but not by the RFT tool which failed its acceptance tests before the leg (the excentralizer arms bent).

The problems on Leg 100 were due to hole instability. This had been anticipated but the measures taken to solve the problem were not successful: the mud program (capillary suction tests, KCl additives to the drilling mud) failed to prevent swelling and the sidewall entry sub failed its acceptance tests (it was to brittle). A new sub is being fabricated and should be ready for Leg 112. When the sub is working satisfactorily, it is planned to put the sub close to the seafloor, the pipe near TD and then log with the tool just below the pipe as the tool and pipe are brought up together.

Leg 111: 504B (Becker, Anderson, Kinoshita)

Drilling on Leg 111 was only marginally successful. In 29 days devoted to drilling, only 100 hrs. were spent rotating for a penetration of 212 m. Recovery was relatively high (20%) in the first 50 m but decreased with depth. Large breakouts in a zone of high resistivity, high velocity and low porosity contributed to drilling difficulties in the bottom of the hole. Drilling was terminated when an experimental (and ineffective) diamond bit broke along with the float valve and support bearing. By the end of the leg, milling and fishing had removed about half of the junk.

Downhole measurements, however, were very successful. After re-entering the hole, 5 days were devoted to experiments before the resumption of drilling. During this interval, the packer, the ACT and French temperature tool were run successfully, the latter measuring gradients of 116°C/km and 61°C/km between 500-800 and 800-1300m subbasement, respectively, and a temperature of 150°C at the bottom of the hole. This implies an enigmatic increase in heat flow from 180 mW/m^2 at intermediate depths to 210 mW/m^2 near the bottom of the hole. Water sampling was only marginally successful. The RFT could only take borehole fluid samples and the Kuster tool only worked once in 10 attempts.

A much more extensive series of measurements which included sonic (MCS), BHTV, magnetometer (GPIT), resistivity (DLL), density (LDT), porosity (ACT) and geochemical (GST, neutron activation) logging as well as packer tests and a detailed VSP experiment were conducted after drilling was terminated. The porosity decreases from 15% in the upper pillows to less than 1% in the dikes while the resistivity increases to over 1000 ohm-m in the dikes. Interestingly, the packer tests show that the permeability in the lower 1 km of Hole 504B is 10^{-17} m^2; since this includes some zones of high apparent porosity, conducting clays must be present. The MCS and VSP mns were both very successful. The latter took two days (the tool was clamped every 10 m over 1.5 km) and detected a major reflector (the layer 2/3 boundary?) 150 to 450 m below TD. BHTV and magnetometer logging were also successful, the BHTV detecting breakouts similar to those seen on Leg 92 and the magnetometer detecting a 7° change in inclination atnthe pillow/dike boundary. The geochemical combination tool worked very well, giving the relative abundances of Al, Ca, Fe, K, Mg, S, Si, U and Th vs depth; this made it possible to identify unit boundaries, alteration zones and relative abundance of phyric vs aphyric basalt.

Only two tools were affected by high temperatures: The Japanese magnetometer (which fried) and the MCS tool which failed at 125°C but came back on as the tool came up the hole into lower temperature water. No attempts were made to cool the hole.

Toward the end of the leg, several days were spent in coring and taking pore water samples in the sediments.

Leg 112: Peru-Chile Trench (Anderson)

Logging on Leg 112 was successful when it was attempted but a stuck core barrel prevent logging at the first site and insufficient time remained after drilling to log the last hole. An excellent set of LDT, ACT and resistivity data which showed an unusual zone of saline pore water was obtained at the second site. The sidewall entry sub was not used.

Tool Development

RFT

The Repeat Formation Tester has not worked as intended yet (the arms bent, preventing the tool from sucking pore water from the borehole wall). Nonetheless, the tool has obtained good water samples from the borehole along with pressure and temperature data.

Wireline Packer

EXCOM has approved the purchase of three wireline packers, two this year and one next. The first test will be on Leg 116.

FY '87 Enhancement Budget

PCOM and EXCOM have both presented enhancement budget recommendations for 1987 which differ from that of LDGO, which is that three BHTVs be acquired, two for the ship and one for backup.

FY '88 Budget

For the FY'88 budget, LDGO suggests the following acquisitions and upgrades:

1) Digital LSS/dual induction tool. By converting the present tools to digital operation they could be run with other tools, making logging operations more efficient.

2) Formation Multiscanner (FMS). The Formation Multiscanner or imaging dipmeter (see July minutes) is considered by industry to be one of the best new tools on the market. It even has the potential of being a high temperature tool. It would have to be scaled down, however, for ODP use since it is 4 1/2" in diameter. This would cost about $300K for a 4-arm tool or $80K for a single arm tool. Processing would be free but Schlumberger would also charge a day rate of $300-500.

3) Neutron activation software. Software is needed to read neutron activation spectra and obtain quantitative elemental analysis on board ship.

4) Terralog software stations. It has been proposed to put Terralog software stations in each member country. Terralog originally charged LDGO $1 for its log analysis package but recently gave a $90K quote to the French for the same software. By setting up the stations in a package deal through LDGO it may be possible to get a better price.

5) Backup BHTV, MCS and wireline packer.

In addition, responsibility for the logging cable and winch is being shifted to LDGO. Lamont is being given 33,000 feet of cable by TAMU but will now have to buy replacement cables and maintain the winch.

After a brief discussion, the Panel recommended (see Appendix 1, Recommendation 1) that LDGO convert two BHTVs to digital operation and acquire a backup analog BHTV in FY'87. The budget suggestions for FY'88 were accepted in principle, with the understanding that dollar figures would be added as they become available (App. 1, Recommendation 2).

Personnel

Three personnel changes have taken place since the last meeting. Rick Jarrard is now the logging Chief Scientist, Tom de Winte is the Operations Manager and Mike Hobart is the

Computer Systems Manager.

Propaganda

Logging schools similar to the one just held in Japan prior to this meeting are scheduled in Europe (U.K., France and Germany) for this January. Each will be two days long, with a day of presentations by LDGO and DMP members and a day of papers by logging scientists from the host country. No school is presently scheduled in the U.S. The panel felt one or more schools should be held in the U.S. and instructed Salisbury to ask USSAC about funding (App. 1, Recommendation 28).

A draft of Volume 2 of the LDGO logging manual (applications with cases from ODP, DSDP) was distributed to Panel members just before the meeting. If it meets with Panel approval, it will be printed and distributed to the ODP community.

3. Upcoming Leg Plans and Recommendations

Leg 113: Weddell Sea - Planning completed (see January and July, 1986 minutes).

Leg 114: S. Atlantic - Planning is completed (see July, 1986 minutes) but a problem has arisen. Drilling is proposed at four sites (SA 2, 3, 5 and 8) to depths of 500-800 m. If all four sites are logged, more time will be required on site (48d) than is available (33d), given the long steaming requirements of the leg. The co-chiefs have asked DMP to recommend deleting logging at two sites (our choice) so that more sites can be drilled or to join them in requesting a 9-day extension of the leg. After a long debate, the Panel rejected both requests and reiterated the 400 m rule (App. 1, Recommendation 10).

Indian Ocean and Western Pacific Legs. (O'Connell and Jarrard with assistance from Kinoshita, Nagao and Tamaki).

At this point, the Panel conducted an extensive (and exhausting) review of the objectives of each leg planned in the Indian Ocean and the Western Pacific and made site-by-site recommendations for downhole measurements. These are presented in detail in Appendices 1 (Recommendations 11-27) and 2.

Physical Properties Minileg. (Karig)

In addition to the legs already being considered by WPAC and PCOM, Karig proposed a minileg in the Nankai Trough to study physical property changes in sediments undergoing subduction and accretion. In particular, he suggests drilling a dedicated physical properties hole near sites NKT-1 and 2. The advantages of the area are excellent seismic coverage, structural simplicity, the absence of clathrates and the possibility of correlation with previous and planned drilling. Specific objectives would be to monitor dewatering and sediment mechanical properties insitu, to correlate physical properties and property gradients with fabric, grain size and porosity variations, to determine the role of faults in water circulation (barriers or aquifers?) and to integrate and calibrate lab and log data. Measurements of particular interest would include porosity, stress magnitude and orientation, pore pressure, temperature and permeability.

To accomplish many of these measurements, special tools will have to be used and in some cases, developed, including push-in tools, self-boring tools, and a new class of "probe hole" tools designed to take insitu measurements in the relatively undisturbed sediments penetrated ahead of the bit by XCB or Navidrill techniques. In addition, oriented cores will be needed for fabric and stress relaxation studies. Since the upper levels of the hole will be unconsolidated and many tool lowerings will be required, a re-entry cone and casing will be needed. The knowledge gained by insitu measurements would make the site a strong candidate for a borehole observatory.

The Panel strongly endorsed Karig's proposal, and recommended that a physical properties minileg be scheduled in the Nankai Trough area to study physical properties in actively deforming sediments and that a re-entry cone be set at NKT-2 to accomplish these ends (App. 1, Recommendation 26).

Magnetotelluric Experiment. (Hamano)

Hamano outlined an active borehole magnetotelluric experiment which can measure the thickness of the conductive layer. The Panel encouraged him to conduct the experiment at one the WPAC oceanic reference sites or in one of the basement holes planned by LITHP and CEPAC in the Eastern Pacific.

Central and Eastern Pacific (CEPAC) Preview. (Salisbury)

A brief preview of the legs being proposed in the Central and Eastern Pacific was given. Highlights include the moat sites around Hawaii, barerock drilling on the East Pacific Rise, and hydrothermal drilling on the Juan de Fuca Ridge. The Panel postponed a discussion of preferences and planning until a subsequent meeting when more details, and time to discuss them, would be available.

4. New Technology

To assist in long term budgetary planning, PCOM has asked DMP to identify areas where major expenditures will be needed starting in 1987 in order to develop or acquire new technology for ODP use. During the course of a prolonged discussion which was returned to several times during the meeting, 7 recommendations were made:

Physical Property Lab Upgrades (TAMU)

At the Physical Properties Workshop held at Cornell in June, a number of major weaknesses were identified in the current program and several recommendations were made for improvement. Among the principle recommendations were:

1) Develop a multifunction core logger (J_{NRM}, I_{NRM}, velocity susceptibility, GRAPE, natural gamma ray) to streamline the physical properties lab.
2) Develop a borehole geotechnical/mechanical properties program.
3) Initiate measurements of R_W, grain density, cation exchange capacity and boundwater state (DTA analysis) in direct support of logging (ie., for calibration).
4) Measure selected properties at elevated pressures.

In general, the Panel endorsed these suggestions (App. 1., Recommendation 3) but postponed a detailed review of the Workshop report until the next meeting.

Wireline Re-entry

The Panel recommended again that wireline re-entry be developed so that tools may be deployed and serviced in the absence of the drillship (App. 1, Recommendation 4). Such a capability would allow more extensive and sophisticated downhole measurement activities since it would permit longer visits and return visits for monitoring on-going experiments and for deploying and servicing observatories.

Discussion: (Pozzi) The French have conducted sea trials of a submarine-assisted wireline re-entry vehicle (described in January, 1986 minutes) and plan to test it in Hole 396B early in 1987.

(Langseth): USSAC is drafting the technical and management specifications for a U.S. wireline re-entry system. The strawman system consists of a tethered ROV with optical sensors and interchangeable modules for tools, plus a winch and cable for power and data transmission. It is hoped to have the system ready for testing in 1 1/2 years. JOI is sponsoring a workshop in La Jolla in late February to outline its scientific justification.

Fishing and Sidetracking Gear (TAMU)

The Panel regards the continued deepening of Hole 504B to be of the utmost importance since it presents our best opportunity to determine the composition of Layer 3, the nature of the 2/3 boundary, the validity of the ophiolite hypothesis and the insitu properties of ocean crust. To do this, and resume drilling in several other holes with junk in them (such as Hole 395A), we need better fishing and hole cleaning gear (mills, shaped charges, magnetic fishing tools) or sidetracking equipment (App. 1, Recommendation 5).

Hardrock Drilling (TAMU)

The rate of penetration in basement experienced by DSDP and ODP is poor (1-3 m/hr) and the recovery rate, except in old crust, is poor to almost unacceptable (as low as a few %). High tech logging can recover a lot of the missing data but new hardrock drilling techniques leading to higher recovery are needed to narrow extrapolation errors (App. 1, Recommendation 6).

Barerock Guidebases (TAMU)

New barerock guidebases (a minimum of three) will be needed for drilling planned in the Lau Basin, the Juan de Fuca Ridge and the East Pacific Rise (App. 1, Recommendation 7). More will be needed if an array of holes is drilled at any one of these sites.

High Temperature Logging

One the of the most difficult technical hurdles which ODP must solve is high temperature logging. Many tools exist which can operate to about 300°C for a few hours using dewars, heat sinks and phase change materials and a few simple tools exist which can operate indefinitely at higher temperatures (see Jan. 1986 minutes). To develop the integrated suite of sophisticated tools needed to log the high temperature wells planned by ODP (Juan de Fuca Ridge, EPR, Gulf of California, 504B) will require a major tool development effort based on existing and evolving Japanese, U.S., German and French technology (App. 1, Recommendation 8).

Discussion (Tesigawa). JAPEX has developed a number of tools which operate to 450°C using the cooling (or delayed heating) techniques noted above and metal O-ring seals (see App. 3 and 4). The system is run from a 2-3 ton truck and is operated by two people. It could be made available for ODP use but since the tools are used operationally by JAPEX in their high temperature fields, a lead time of at least 6 months would have to be given. The Panel expressed great interest in using this equipment on high temperature legs in the Indian Ocean and the Pacific. If the Red Sea leg is retained by PCOM in the drilling schedule, Salisbury will contact Dr. Miyairi for more details.

(Jung). The Germans are developing a large number of high temperature tools for use in the German continental drillhole. These will include a magnetometer with a 1 nT resolution which can operate for 24 hrs. at 300°C and 1500 bars (available in 1-2 yrs.); a 300°C, 1300 bar temperature tool (already operational); a 300°C water sampler; a BHTV designed to operate to 200°C and 7 km (built by WBK); an overcorer designed to operate to 5 km; a wireline straddle packer with a BHTV placed between the elements which is designed to work in 3-6" holes to 200°C and 6 km; and a clamped geophone array consisting of five 3-component geophones designed to operate indefinitely to 250°C and 1500 bars.

(Salisbury) Silicon Systems in Calgary has built a series of dewared prototype tools which can operate to moderately high temperatures. An unusual feature is that the tools are modular and can be operated as an array. The potential exists for running all of the logs in a single lowering, thus saving time and removing the depth ambiguities which arise between different logging runs.

Observatories

The most challenging technical hurdle facing the Ocean Drilling Program is presented by the need to make long term observations from boreholes. Problems include emplacement, power delivery, size constraints, data recording and transmission, servicing and long term reliability in a hostile environment. Given the importance and complexity of the problem, the Panel recommends a major cooperative development program, perhaps between the U.S. and Japan (App. 1, Recommendation 9).

Discussion (Hyndman). A workshop on long term ocean bottom observatories (LOBOs) is being held in April, 1987 in Oregon. The objectives are to outline the science that needs to be done with such instrumentation, the problems likely to be encountered and possible solutions. While the workshop is not limited to borehole observatories, it is important that ODP and DMP collaborate with these efforts (Langseth, Hyndman and Becker will be attending the workshop and Delany should be invited to attend the next DMP meeting). A major target will almost certainly be to instrument a ridge crest segment between transforms from end to end with strainmeters, seismometers, gravimeters, magnetometers, tiltmeters, temperature sensors and flowmeters and to monitor these instruments over time scales ranging from hours to years. Sophisticated undersea technology, including wireline re-entry and ROVs will be needed to deploy and service this equipment. To the extent that these observatories must be placed in boreholes, drillship time will be required to prepare holes and possible to deploy instruments. To succeed on the scale envisioned, any LOBO program must be a national effort. If several countries embark on such an effort (for example, the U.S., France and Japan) the greatest success will be realized if they collaborate and endorse each others efforts.

(Kinoshita). The Japanese currently have two operational long term observatories, one meteorological and one seismic, the latter operating 150 km offshore in 4 km of water. Efforts are now underway to build intermediate (60-180 d) and long term observatories to be deployed in ODP holes off Japan. The intermediate term observatory will include a 3-axis magnetometer, a temperature sensor, a low frequency tilt meter, a low frequency event-triggered strain gauge, an event-triggered hydrophone and a spontaneous potential sensor. The long term observatory will include an event-triggered tiltmeter, a tiltmeter which records 1 data point/d, a 3-axis magnetometer (1/min.), an Oberhauser magnetometer (4/d), a strain gauge (1/d) and a spontaneous potential sensor (1/d). Some of the tools will be new Schlumberger gear.

5. Other Developments

(Jung). An electromagnetic radar sonde is being developed in Germany which operates at 20-40 MHz and can penetrate tens of meters into the formation.

(Pozzi). The French have developed a total field magnetometer which can be used in high NRM (x10 normal) sediments.

6. Other Business

COSOD II.

The 2nd Conference on Scientific Ocean Drilling will be held in Strasbourg 6-8 July, 1987. The purpose of the meeting, which will be attended by about 350 scientists (150 U.S., 200 from partner countries) is to define the objectives of the Ocean Drilling Program for the next decade. Sessions are planned around the following themes:

1) Global environmental change and the evolution and extinction of oceanic biota.
2) Mantle - crust interaction.
3) Fluid circulation and global chemical budgets.
4) Brittle and ductile deformation.

Although no call has been made for DMP to submit a white paper, the Panel strongly recommended that one be submitted anyway (App. 1, Recommendation 29). It should outline the contributions which downhole measurements can make to each of these themes, the current state of technology and what new technology will be required in the future program. (Worthington and Salisbury will draft the final manuscript with submissions from Anderson, Jarrard, Stephen, Becker, Sayles and Bell by Feb. 1). In addition to submitting a white paper, it is important that logging scientists attend each session.

Panel Membership

Since January, four DMP members have rotated off (per instructions from PCOM) but only one new member (Ralph Stephen) has been added. The Panel is thus seriously understaffed, particularly if it is to maintain a liaison network with other panels. The Panel reviewed the list of nominations submitted to PCOM in July, added Roy Wilkens (M.I.T.) and re-submitted the list for PCOM consideration (App. 1, Recommendation 30).

Next Meeting. 13-14 April in Miami (App., Recommendation 31).

RECOMMENDATIONS SUMMARY

JOIDES Downhole Measurements Panel

Ocean Research Institute, Tokyo

November 7-8, 1986

LDGO

1. 1987 Enhancement Budget

a) Convert 2 BHTVs to digital operation.
b) Acquire backup analog BHTV.

2. 1988 Enhancement Budget

a) Convert LSS/dual induction tool to analog operation.
b) Acquire 4-arm slimhole Formation Multiscanner (FMS).
c) Acquire software to read neutron activation (GST) data.
d) Put Terralog processing station in each member country.
e) Assume responsibility for logging cable and winch.
f) Acquire backup multichannel sonic tool (MSC).

ODP

New Technology

In response to a request from PCOM, DMP identified 7 areas in which major expenditures should be initiated in 1987 to develop or acquire new technology for future ODP use.

3. Physical Property Lab Upgrades (TAMU)

Develop multifunction core logger, measure selected physical properties at elevated pressure and acquire capability to measure Rw, Lg, cation exchange capacity and bound water state in support of logging.

4. Wireline Re-entry

Develop wireline re-entry to deploy and service borehole tools in the absence of the drillship.

5. Fishing and Sidetracking Equipment (TAMU)

Acquire equipment (whipstocks, magnetic fishing gear, shaped charges) to clean or sidetrack Hole 504B so that it can be deepened to Layer 3.

6. Hardrock Drilling Technology (TAMU)

Develop new technology to improve penetration and recovery.

7. Bare Rock Guide Bases (TAMU)

Acquire 3 new guidebases by 1989 for Lau, Juan de Fuca and/or EPR drilling.

8. High Temperature Logging

Develop integrated high temperature logging capability for use in Juan de Fuca, Gulf of California and EPR drilling using Japanese, U.S., French and German technology.

9. Long Term Observations

Develop long term observatory packages for use in ODP holes, perhaps as co-operative Japanese-U.S. venture.

PCOM

Leg-by-Leg Recommendations

After reviewing the objectives of each leg and the geological and geophysical data available for each site, the DMP made the following recommendations (times include hole preparation).

10. Leg 114 Subantarctic

The Panel considered a request from the Leg 114 Co-Chiefs to 1) recommend deleting logging at selected sites so that additional sites could be drilled, or 2) to ask PCOM to extend the leg so that all sites could be logged. The Panel rejected both requests, stating that it would only recommend dropping logging a priori under extraordinary circumstances (such as those on Leg 113) and that it considered it more important to start the Indian Ocean program on schedule than to extend 114. The Panel refused to prioritize the Leg 114 sites and reiterated that whatever sites are drilled should be logged, e.g. as follows:

SA2, 3, 5, 6 Seismic stratigraphy and geochemical combination tools	1.1 d/site

11. Leg 115 S.W. Indian Ridge (see July minutes)

If significant basement penetration is made at the prime re-entry site, DMP recommends a supplementary minileg later in the Indian Ocean program to conduct the Oblique Seismic Experiment and equilibrium temperature measurements.	10 d + transit

12. Red Sea

2 Nereus Deep (if drilled 200 m into basement):

Lithoporosity and geochemical combination tools	19 hrs
Dual laterolog resistivity	5
12 Channel sonic	6
BHTV	7
Magnetometer	10
Susceptibility meter	5
T	5
Wireline packer or Kusten sampler	10
Packer	18
Flowmeter	5
	3.75 d

N.B. Sidewall entry sub and RE cone required.
High T logging gear advisable.

1, 11, 17.5°N
5, 6 Mabahiss

Standard logging suite (seismic stratigraphy, lithoporosity and geochemical combination tools)	28 hrs
BHTV	7
Magnetometer	10
Susceptibility meter	5
T	5
Wireline packer or Kuster sampler	8
Flowmeter	5
	2.8 d/site

N.B. Sidewall entry sub required.
High T logging gear advisable.

7 Shaban Deep

Standard logging suite	21 hrs
Magnetometer	10
Susceptibility meter	5
T	5
	1.75 d

N.B. Sidewall entry sub required.
High T logging gear advisable.

3 Bannoch Deep	None
4 Main Trough	None
8 Sudanese Delta	None

13. Neogene

NP6, 7, 8, 9

Standard logging suite	1.5 d/site

NP4, 5

Standard logging suite	34 hrs
VSP	24
	2.4 d/site

NP1, 2,3 — None

N.B. Add dipmeter at sites NP4-9 if available.

14. Makran

1, 4, 6, 7

Seismic stratigraphy and lithoporosity combination tools	.75 d/site

2, 3, 5

Standard logging suite	30
BHTV	8
T	6
Wireline packer	10
Drill-in packer (frac)	5
Flowmeter	6
	2.75 d/site

15. South Kerguelen/Pryd Bay

KP2, 10, 11, 12A

Standard logging suite	1-1.7 d/site

KP5, 6

Standard logging suite	48 hrs
BHTV (bottom 100 m)	11
VSP (if holes 1 km or more deep)	24
	3.5 d/site

N.B. Use dipmeter in lieu of BHTV at sites KP5 and KP6 if available.

16. North Kerguelen

KHP4, 5

Standard logging suite	1.3-1.4 d/site

KHP3

Standard logging suite	46 hrs
BHTV (bottom 200 m)	7
VSP	24
	3.25 d

KHP1

Standard logging suite	31 hrs
BHTV (bottom 200 m)	6
	1.5 d

N.B. Use dipmeter in lieu of BHTV at sites KHP 1 and 3 if available.

17. 90°E/Broken Ridge

90 ER-1

Standard logging suite	35 hrs
BHTV (bottom 100 m)	8
	1.7 d

90 ER-2, BR-1, 2, 3, 4

Standard logging suite	1.0-1.2 d/site

18. Intraplate Deformation

BF-1

Standard logging suite	46 hrs
BHTV (bottom 200 m)	12
	2.4 d

BF-3, 4

Seismic stratigraphy and lithoporosity combination tools	24 hrs
BHTV (bottom 200 m)	10
T	8
Wireline packer or Barnes/Uyeda	12
Packer	24
Flowmeter	7
	3.5 d/site

N.B. Minicone required for packer

BF-2, 5

Seismic stratigraphy and lithoporosity combination tools	24 hrs
T (Barnes/Uyeda)	2
	1.1 d/site

19. Argo/Exmouth

EP1, 1W, 3, 4A

Standard logging suite	1.7-2.1 d/site

AAP-1A

Standard logging suite	57 hrs
BHTV (bottom 200 m)	15
Magnetometer (basement only)	10
Susceptibility (basement only)	9
VSP	24
T (Barnes/Uyeda)	8
	5.2 d

20. Bonin I and II

BON1, 2. 8

Standard logging suite (plus HPC-T at BON1)	1.3-1.7 d/site

BON3, 4A, 4B, 5A, 5B, 7; MAR2, 3

Standard logging suite	38 hrs
Wireline packer	12
(plus HPC-T at BON3)	-
	2.1 d/site

BON6

Standard logging suite	43 hrs
BHTV (bottom 200 m)	11
Magnetometer (basement only)	7
Susceptibility meter (basement only)	6
Wireline packer	10
HPC-T	-
	3.2 d

N.B. RE cone required at one site for long term observatory.

21. Japan Sea

J1b

Standard logging suite	37 hrs
BHTV (bottom 150 m)	9
Magnetometer (basement only)	8
Susceptibility meter (basement only)	7
Oblique seismic experiment	7 d
T (HPC-T or Barnes/Uyeda)	-
Packer (frac)	24 hrs
	10.5 d

N.B. RE cone required; ship time reduced to 3.5 d if OSE done later by wireline RE.

J1d, e

Standard logging suite	39 hrs
BHTV (bottom 100 m)	9
Magnetometer (basement only)	8
Susceptibility meter (basement only)	7
T (HPC-T or Barnes/Uyeda)	-
	2.6 d/site

J2a

Standard logging suite	48 hrs
VSP	24
T	7

Wireline packer	10
Induced polarization	6
	4 d

J3a

Standard logging suite	34 hrs
BHTV (bottom 100 m)	8
Magnetometer	8
T	7
	2.4 d

N.B. RE cone required for long term observatory.

JS-2

Standard logging suite	29 hrs
T (HPC-T or Barnes/Uyeda)	[illegible]
	1.2 d

22. Sunda

S1, T1

Standard logging suite	38 hrs
BHTV (bottom 100 m)	8
	1.7-1.9 d/site

S2, T2

Standard logging suite	34 hrs
BHTV	9
T	6
Wireline packer	10
	2.5 d/site

F1, 2

Standard logging suite	44 hrs
T	7
Wireline packer	10
	2.5 d

S3

Standard logging suite	35 hrs
BHTV (bottom 100 m)	5
	1.7 d

23. Banda/Sulu/S. China Sea

SCS1, BND A2, SULU5

Standard logging suite	46 hrs
BHTV (bottom 100 m)	11
T (HPC-T, Barnes/Uyeda)	[illegible]
	2.4 d

N.B. Also run dipmeter at SULU5 if available.

BND A1, A3

Standard logging suite	44 hrs
T (HPC, Barnes/Uyeda)	-
	1.8 d

SCS2

HPC-T	-

24. Great Barrier Reef

GBR1, 2, 3A, 6

Lithoporosity and geochemical combination tools	37 hrs
Dual laterolog	9
12 Channel sonic	15
	1.7-1.9 d/site

GBR5C

Lithoporosity and geochemical combination tools	37 hrs
Dual laterolog	9
12 Channel sonic	15
VSP	24
	2.9 d

25. Lau Basin

Generic Sites (site details not available at time of meeting)

Standard logging suite	36-48 hrs
Magnetometer	8
Susceptibility meter	7
T (Barnes/Uyeda)	-
Wireline packer	10
	2.5-3 d/site

N.B. To be revised as site details become available.

26. Nankai Trough

NKT-1

Standard logging suite	44 hrs
BHTV (bottom 100 m)	11
T	8
Borehole geotechnical studies	24
	3.6 d

NKT-2

Standard logging suite	52 hrs
BHTV (bottom 100 m)	13
Borehole geotechnical (including frac.)	24
	3.7 d

N.B. In addition, DMP strongly recommends that a RE cone be set at NKT-2 for long term observatory studies and that a physical properties minileg be conducted at the site to conduct push and drill-in instrumented probe studies (per Karig proposal).

27. Vanuatu

IAB-1, 2

Standard logging suite	1.7 d/site

DEZ-2

Standard logging suite	46 hrs
BHTV (bottom 100 m)	10
Wireline packer	10
Packer	24
Pressure meter	10
	4.1 d

DEZ-3, 4

Standard logging suite	44 hrs
BHTV (botom 100 m)	9
Wireline packer	9
Packer	23
	3.5 d/site

BAT-1, 2

Lithoporosity and geochemical combination tools	28 hrs
Dual laterolog	8
12 Channel sonic	10
Magnetometer	10
Susceptibility meter	7
T	7
	2.9 d/site

DMP

28. U.S. Logging School

Request USSAC to fund U.S. logging school.

29. COSOD II

DMP should submit white paper on long range plans to COSOD II.

30. Panel Membership

Four Panel Members have rotated off the Panel since last January (per PCOM directive). The Panel requests that PCOM restore DMP to full strength and submits (again) the following list of nominees for consideration:

Wendell Givens	-	Mobil; nuclear logging
Carl Sondergeld	-	AMOCO; physical properties, rock mechanics
Ralph Wiley	-	AMOCO; nuclear logging, quality control
Adrian Richards	-	FUGRO; geotechnical studies

and one of:

Nafi Toksoz	-	M.I.T.; log analysis
Arthur Cheng	-	M.I.T.; velocity logging
Roger Turpenning	-	M.I.T.; VSP
Roy Wilkens	-	M.I.T.; log analysis

31. Next Meeting

13-14 April in Miami.

SOUTHWEST INDIAN RIDGE

The Southwest Indian Ridge is a very slow spreading ridge (0.86 cm/yr half rate) extensively offset by large relief fracture zones. The area proposed for drilling is southeast of Madagascar where either the Melville Fracture Zone or the Atlantis II Fracture Zone intersects the Southwest Indian Ridge. The major objectives for this leg are 1) to establish the vertical stratigraphy and structure of the preliminary lithofacies in different parts of a transform fault and its fracture zone extensions; 2) to conduct an oblique seismic experiment to determine directly the seismic character of variably serpentinized mantle, particularly its P and S wave velocities and anisotropy; and 3) to examine the thermal structure of young ocean crust along a fracture zone floor and at its intersection with the rift valley axis.

RED SEA

As a very young ocean basin developing in a continental rift, the Red Sea presents an opportunity to investigate four major topics: 1) evolution of the lithosphere through the transition from continental rifting to seafloor spreading;
2) a "natural laboratory" in an active hydrothermal system, fluid-hot rock interactions, and basement alteration; 3) Miocene to Holocene paleoenvironments and paleo-oceanography, and Red Sea sapropels; and 4) unserpentinized and undepleted mantle peridotites.

INTRAPLATE DEFORMATION (Central Indian Ocean Basin and Lower Bengal Fan) - NINETYEAST RIDGE

A remarkable example of intraplate deformation is found in the central Indian Ocean Basin, in the distal part of the Bengal Fan. Oceanic crust and overlying sediments are deformed into long wavelength (about 200 km) undulations and are disrupted by closely-spaced (about 5-10 km) faults showing a reverse sense of motion. Drilling objectives include determination of: 1) age of onset of the deformation and subsequent history of movement of individual fault blocks; 2) the relationship of the fault zones to the upward water flow; and 3) the tectonic history of uplift of the Himalayas and deposition of the Bengal fan.

NEOGENE PACKAGE (Oman Margin/Owen Ridge/Indus Fan)

"Neogene Package" is a reference term for a collection of shallow APC/XCB drilling sites in the Arabian Sea arranged in a transect from the Oman Margin across the Owen Ridge to the Indus Fan. Meteorological records and climatic studies indicate that the annual monsoonal cycle in this region is influenced by seasonal changes of insolation over the Asian continent. A sedimentary record of monsoon strengths as shown in shallow cores should thus reflect changes in the size and elevation of the Asian continent and the seasonal distribution of solar radiation, as well as changes in the sea surface temperature of the Indian Ocean. A complete sequence through Pleistocene and older sediments might show a rhythmic variation related to the evolution of global climates.

MAKRAN FOREARC

The Makran coast of Pakistan is an active margin setting. It offers the advantage over other actively accreting margins in that the fore-arc basin is emergent; approximately two-thirds of the 400-km-wide accretionary prism is exposed onshore. Drilling objectives include investigation of the rate of accretion and uplift, the patterns of sedimentation in the Quaternary offshore and the analogous Neogene processes preserved and exposed in coastal Makran. This will allow an opportunity to assess distribution of deformation across an accretionary prism.

NORTH KERGUELEN

The Kerguelen Plateau is the world's largest mid-ocean plateau. The subsidence history of this linear structure is critical for understanding the movement of water between the Atlantic and Pacific oceans. Recovery of a complete stratigraphic record from the upper Cretaceous to the present will address these problems: 1) the nature and age of the different sedimentary sequences and the age of the oldest clastic deposits; 2) shift of the polar front through time; 3) age of the major discordance which marks the rifting between Kerguelen-Head Plateau and Broken Ridge; 4) pre-rifting and post-rifting subsidence history of the ridge; and 5) nature and age of the basement in the northern and southern part of the ridge.

SOUTH KERGUELAN - EAST ANTARCTICA

Planning for this leg is still in preliminary stages. In addition to the basement objective mentioned in conjunction with North Kerguelen drilling, over 16 sites from Prydz Bay (east of the Amery Ice Shelf) to approximately 50°S have been proposed. A selection of sites will be chosen that is best able to: 1) provide information about the Cretaceous to Recent climatic and glacial history of Antarctica; 2) yield ages for the glacial erosional events, which led to the lowering of the Antarctic Continental Shelf; and 3) demonstrate the breakup history and environment of Antarctica and India and the subsequent margin evolution.

NINETYEAST RIDGE - BROKEN RIDGE

Ninetyeast Ridge is the longest "aseismic" ridge in the world, extending from at least 17°N, beneath the Bengal Fan, to over 30°S at the intersection with Broken Ridge. Most models now suggest that it was formed by a hot spot which now underlies Kerguelen and Heard Islands.

This leg is part of a package of proposals to understand the complex hot spot traces in the eastern Indian Ocean and to establish a continuous N-S paleoceanographic transect. Recovery of a complete sediment section will help establish age relationships, subsidence and uplift history of the Ridge, and paleo-oceanography of this part of the Indian Ocean.

ARGO BASIN - EXMOUTH PLATEAU

The eastern Indian Ocean is a remnant of the Tethys superocean and is sediment starved. Drilling in the Argo Basin will provide information about Mesozoic/Cenozoic paleoceanography and paleobiogeography, date anomaly M-25, and provide a distal record of margin sedimentation and evolution. The area is also dominated by a well established continental crustal feature - the Exmouth Plateau - which has subsided from shallow to bathyal water depths since breakup. Completion of an Exmouth Plateau/N.W. Australian shelf transect will provide unique data on margin sedimentation, subsidence and structural evolution, as well as sea level fluctuations and thermal history for a long time after breakup.

BANDA SEA

Recent geophysical and geological studies of the Banda Sea suggest that its origin may be a combination of entrapment of several small basins and slivering of a contintental borderland into the region. This proposed model of a constructional origin of a marginal sea through strike-slip faulting of continental and oceanic crustal fragments provides a modern analog for rock associations in ancient mountain belts and a system for understanding possible histories of amalgamation of tectonostratigraphic terranes.

The proposed drilling program consists of determining the stratigraphy of the lower sections in the north and south Banda basins to test for similarity or difference in origin, and to compare results with those from the Sulu sea. The Neogene sections will provide information on changes in paleoceanography as the Indian and Pacific ocean circulation systems were isolated, the volcanic history of the eastern Sunda arc, and the timing and history of rifting and emplacement of the ridges.

JAPAN SEA

Japan Sea, one of the western Pacific back-arc basins, is believed to have been formed by multi-axial rifting of the continental arc, much different from the rifting of the oceanic arc. Five major drilling objectives are identified for the Japan Sea: 1) nature and age of the basin basement; 2) style of multiple rifting; 3) obduction of oceanic crust; 4) paleoceanography and marine climatic history in an isolated back-arc basin; and 5) metallogeny in a failed back-arc rift.

EASTERN SUNDA ARC-CONTINENT COLLISION ZONE

The collision between the Australian continent and the eastern Sunda arc has progressed to the stage where continental crust underlies both the forearc in the western part, near Sumba Island, and the forearc beneath Timor Island. The young collision has produced significant uplift of both accretionary wedges and forearc basement, backthrusting of the wedge over the forearc basin and backarc thrusting along the northern slope of the arc. Drilling in this area will allow us to study the timing, sequence and magnitude of backthrusting and backarc thrusting, and the processes responsible for uplift of the forearc.

BONIN INTRA-OCEANIC ARC-TRENCH DEVELOPMENT

The Bonin drilling program is designed to investigate the processes of intra-oceanic arc-trench development in an inherently simple system (continuous subduction since the Eocene without major collisions or arc reversal) in a well surveyed area. The Bonin forearc has experienced little structural disruption since its inception. A broad forearc basin has accumulated volcaniclastic and hemipelagic sediments behind an outer-arc high. The onlap of strata onto this high, together with Eocene shallow-water fossils found on the Bonin islands, indicates that it has been a relative structural high since early in the history of the arc.

ZENISU RIDGE

The Zenisu ridge is an oceanic crustal slab, dipping to the NW, accreting clastic sediments as its base, and accommodating part of the convergence motion between Japan and the Philippine Sea plate. It can be considered as a classical example of intraoceanic accretion and deformation. Drilling in this region will: 1) establish the nature and age of the "trench-fill letre" basin, south of Zenisu; 2) investigate the deformed sediments along the southeastern slope of Zenisu Ridge; 3) establish the nature and age of the crust of the western Zenisu ridge and document the stratigraphy of the overlying sedimentary sequence; and 4) determine the age and the rate of basement tilting of the oceanic crustal slab, along the northern slope of Zenisu Ridge.

LAU BASIN

The Lau Basin is an active back-arc basin between the Lau Ridge (remnant arc) and the Tonga Ridge (arc). Major drilling objectives to be addressed in this region include: 1) the petrologic development of the Lau Basin, particularly the evolution of the basin's basalts from having a significant island-arc geochemical signature to having virtually none at all; 2) the role of silicic magmatism in certain parts of the basin; 3) back-arc geothermal and hydrological processes and their evolution through time; and 4) the nature/development of the Tongan forearc and the history of arc volcanism.

GREAT BARRIER REEF - QUEENSLAND TROUGH

The Great Barrier Reef area is an excellent example of a mixed carbonate/siliciclastic province in a passive margin setting. This area can provide important facies and stratigraphic models for understanding ocean history, the evolution of passive margins, and ancient carbonate depositional systems. The following objectives will be addressed: 1) sea level controls on sedimentation; 2) the effect of plate motions and subsidence cycles on sedimentation, paleoclimate, and paleoceanography; 3) tectonic cycles in relation to sea level cycles; 4) changes in paleoclimate related to plate position and the effect on sedimentation; 5) basin fill history; 6) diagenetic history in a stratigraphic framework; 7) comparison of the history of a continental margin and an isolated plateau (Queensland Plateau); and 8) diagenesis of mixed carbonate/siliciclastic and pure carbonate sequences in an undersaturated ocean regime significantly different to that in the Caribbean and Indian Ocean.

SULU SEA

Paleoceanographic objectives in the Sulu Sea are focused on the anoxic and suboxic sedimentary record known to exist in this silled marginal sea. Insights into the depositional and paleoceanographic evolution of the Sulu Sea basin will have important implications for the interpretation of analogous Mesozoic and early Tertiary basins which evolved in similar carbonate-rich equatorial settings.

The Cagayan Ridge divides the NW-Sulu Basin (Outer Sulu Basin) and the SE-Sulu Basin (Inner Sulu Basin) and is an excellent area to unravel the complex geodynamic evolution of this region. Drilling here combined with that in the SE-Sulu Basin has direct implications for the interpretation of plate tectonic reorganizations which occured since the Eocene in SE Asia. Recent models relating the Banda, Celebes and Sulu basins as fragments of a once-continuous Indian Ocean plate can be tested by drilling at least one site in the Sulu Sea, in conjunction with the sites in the Banda sea.

SOUTH CHINA SEA

The history of opening of the South China Sea remains unresolved. Conventional dating of ocean basins by magnetic anomaly patterns does not easily work in small basins like the South China Sea. Thus drilling is necessary to confirm the age and history of opening, as well as to determine the history of the surrounding zone of tectonic collision, arc initiation and cessation, and uplift. Stratigraphic records in this basin will show variations in the composition, rate of accumulation, and modes of sediment transport during each phase of rift history reflecting eustatic control on terigenous sediment, climatic control of pelagic materials, and volcanic events accompanying collisional events to the east.

NEW HERBRIDES (VANUATU)

During the Miocene and early Pliocene time the New Hebrides island arc apparently underwent a reversal in arc polarity, after which the Australia-India plate began to underthrust the arc from the west at a rate of at least 10 cm/year. Since this polarity reversal, extensional back-arc troughs formed that probably are still in an early stage of rifting. The d'Entrecasteaux zone (DEZ) encompasses two east-trending aseismic ridges that tower over the Australia-India plate, and the rapid convergence between this plate and the arc carried the DEZ eastward to collide with the central arc beginning about 2 Ma. The unusual morphology and structure of the central arc, as well as the distribution and rates of vertical deformation and the historical seismicity pattern, have been strongly influenced by collision of the DEZ with the arc.

The principal objectives of proposed drilling include: 1) the study of arc processes involved in arc-ridge collision; 2) back-arc rifting; 3) subduction-polarity reversal; and 4) the formation of intra-arc basins.

NANKAI TROUGH

The Nankai Trough is especially suited for studying the complex interactions between stress, physical properties and dewatering processes within the accretionary prism, thought to control the development of small-scale structural fabrics and the evolution of large-scale structural elements such as decollement and major imbricated thrusts. This is because a) the structural framework of the toe of accretionary prism is extremely well-resolved, b) the depth and scale of the decollement and major thrusts are well defined, c) the trench floor is shallow and gas concentration is low, d) the sediments are terrigenous clastics whose response to stress and strain are better understood than that of biogenic sediments, and e) a large amount of supporting and site survey data exist.

The strategy of drilling is similar to the Barbados leg (Leg 110): a reference hole at the undisturbed trench-fill and a deep hole to sample a complete sequence of deformed sediments at the toe of the prism are planned.

宮入　誠・山本純治・手塚和彦・大橋辰英・伊藤寿恒

HIGH TEMPERATURE GEOTHERMAL WELL LOGGING SYSTEM; (Part 1) TEMPERATURE, PRESSURE and SPINNER TOOLS

by

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and

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ABSTRACT

A Super High Temperature Geothermal Well Logging System for temperatures as high as 450°C (842°F) has been developed. The tools developed are Temperature, Pressure and Spinner sondes. These tools are so designed that all the down hole probes can be operated up to 450°C. Therefore, the following new technologies have been introduced.

1) A logging cable which consists of magnesium oxide powder insulator.
2) A cable head which is able to pass through a wire line lubricator of small diameter.
3) A sealing mechanism between the cable head and pressure chamber achieved by the use of specially designed metal "O" rings.
4) Super high temperature sensors which are used in nuclear reactor technologies.
5) A heat insulation system for down hole electronics which consists of the combination of special designed dewar flask and heat sink materials.

About a hundred times, field tests were carried out from 1983 to 1984 in the Fushime geothermal wells where the maximum temperatures were 240 to 340°C (464 – 644°F). The results of field tests showed that this well logging system has sufficient reliability in such severe environment of geothermal wells.

As the second phase of the Super High Temperature Logging System, slim hole Sonic Log, Latero Log, Bore hole fluid Sampler and Noise Log (which detect a flash point and production zone) were constructed in 1984, and will be put to field test in 1985.

INTRODUCTION

In the Fushime geothermal field located in southern Kagoshima, Japan, the downwhole temperature usually exceeds 320°C. The conventional geothermal well logging system based on teflon cable cannot be operated under such high temperature conditions.

In 1982, the project was started to develop high temperature well logging tools in accordance with the time schedule shown in Table 1. All the down hole tools were designed to be operated up to 450°C by considering the available technical background and future of geothermal development.

We had five difficulties with super high temperature tools. These were logging cable, cable head, sealing mechanism, sensors, and heat insulation for downwhole electronics. To overcome these difficulties the following technologies were introduced.

1) A logging cable which consisted of magnesium oxide powder insulator.
2) A cable head which could pass through the wire line lubricator of small diameter.
3) A sealing mechanism between the cable head and pressure chamber achieved by the use of specially designed metal "O" rings.
4) Super high temperature sensors which are used in nuclear reactor technologies.
5) A heat insulation system for down hole electronics which consisted of the combination of a specially designed dewar flask and heat sink materials.

By using these technologies, production logging tools (such as temperasture, pressure and spinner tools) were designed and constructed in 1982, and then put to field test in June, 1983. Through the field tests these tools and system were improved and now put into the routine work for the Fushime geothermal wells.

THE ESSENCE OF SUPER HIGH TEMPERATURE LOGGING SYSTEM

The fundamental specifications are shown as follows:

1) Maximum operating temperature: 450°C
2) Maximum operating pressure: 350 kg/cm²
3) Maximum operating time: 4 hrs (for 450°C)
4) Maximum operating depth: 3000 m
5) Outer diameter of sonde: 56 mm
6) Grease injection lubricator: 7/32 inches, max. 275°C
7) Surface control unit: Computer controlled digital recording

Logging Cable

A conventional teflon insulated cable is no longer used when the temperature exceed 320°C. Therefore a specially designed magnesium oxide insulated wire with four conductors was developed and assembled as a logging cable. The schematic diagram, electrical and mechanical characteristics of the cable are shown in Figure 1. We found the following superior and inferior points through the test in laboratory.

Superior points

1) Stable up to 500°C
2) A sealing of cable conductor inlet to cable head housing is achieved easily by welding an outer stainless steel sheath.
3) If a termination of a cable is exposed to the borehole environment. Very little water come up inside the cable because of an extremely pressed powder. Therefore the cable can be restored by cutting off few meters from the termination in case of an accidental leakage of water.

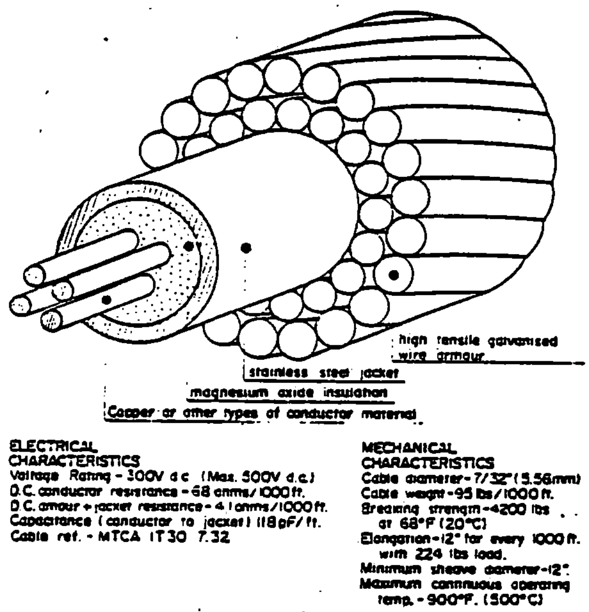


Figure 1. Super high temperature logging cable

Tools	Sonde Diameter (inches)	Minimum Hole Diameter (inches)	PHASE I (1982-1984) Maximum Operating Function: Temperature (°C)	Pressure (kg/cm²)	Operating Period (hours)	PHASE II (1983-1985) Maximum Operating Function: Temperature (°C)	Pressure (kg/cm²)	Operating Period (hours)	Remarks
Temperature survey	2 1/4	3	600	700					Platinam resistance sensor.
Pressure measurment	2 1/4	3	450	350	4(450°C)	540	350	4(450°C)	Strain guage sensor Eddy current densor
Continuous flowmeter	2 1/4	3	595	350	4(450°C)				Eddy current sensor
Noise log	2 1/4	3							
accelerometer						500	500	4(450°C)	
microphone						700	350	4(450°C)	Lithium niobate
Slim-hole Latero log	2 1/4	3				600	750		Ceramic coated sonde
Slim-hole Sonic log	2 1/4	3				500	350	4(450°C)	Feiite transmitter and microhone
4-arm Caliper	2 1/4	3				500	350	4(450°C)	Differential transformer
Borehole fluid sampler	2 1/4	3				450	350	4(450°C)	Single stage
Cable	7/32		500	1000					Magnesium oxide insulator 4-conductor
Wireline lubricator		2 1/2	275	210					

Table 1. Time schedule of Super High Temperature Geothermal Well Logging System

Inferior points

1) The conductor at the termination is very fragile to handle.
2) The termination absorbs moisture very easily because the powder is loose at that point.

Termination treatment is essential to use this wire as a logging cable. Several kinds of techniques for this treatment were tested and a special ceramic cementation material was chosen as a terminator.

CABLE HEAD

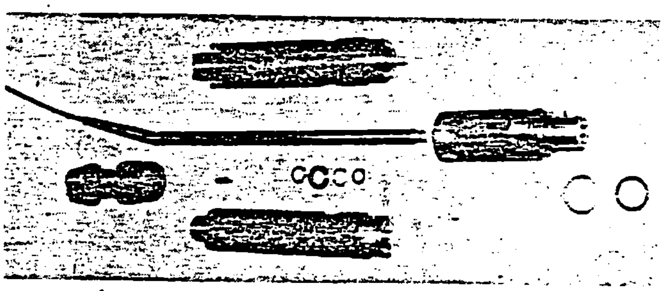
The cable head was designed to be able to pass through the standard grease injection lubricator. The cable head designed is dis-assembled into slim cable head housing of 18 mm dia. as shown in Photo. 1-a and after passing through the lubricator. It is assembled as shown in Photo 1-b.

Sealing

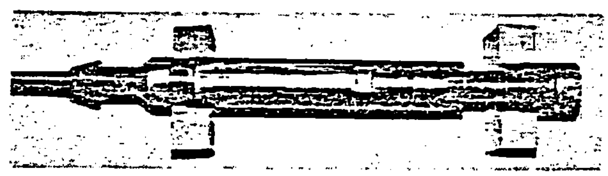
The use of a "O" ring was minimized and most the sealing was performed by welding. Only two sizes of "O" rings were used for our tools. One was for dis-assembled cable head. The other was for the connection between pressure chamber and cable head or sensor probe. A metal "O" ring was tested for these sealing. A specially designed metal "O" ring was chosen for our tools. For reliability, it was necessary to control the size of "O" ring strictly. Figure 2 shows cable head and the connection part between sonde.

HEAT INSULATION

The heat insulation system for the downhole electronics consisted of a combination of dewar bottle and heat sink material. A high quality dewar flask was required in using this system for tempera-



a) Dis-assembled



b) Assembled

Photo 1. Cable head

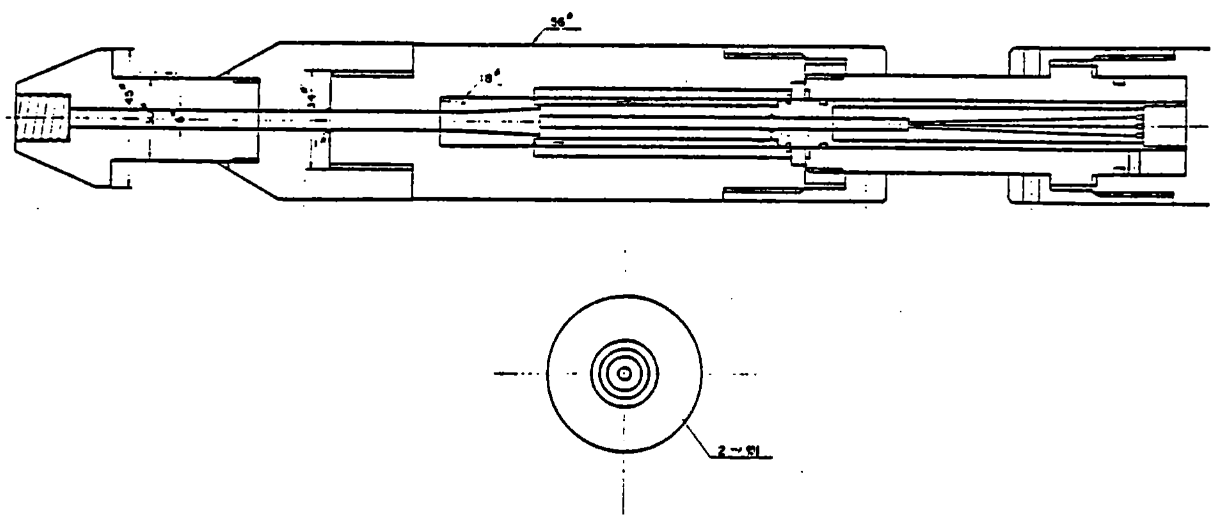


Figure 2. Cable head

tures up to 450°C. Several kinds of dewar bottles of different makers were tested. Figure 3 is a temperature response curve of the dewar which we chose. A stable operation could easily be performed at a time more than 8 hours because all the electronics are designed to be operated for temperatures up to 150°C. The heat flow coming into a dewar was roughly estimated by following equation.

$$Q = K_a*(\theta_0 - \theta)$$

where, Q : heat flow (cal/sec.)
K_a : apparent heat flow coefficient (cal/sec.°C)
θ_0 : ambient temperature (°C)
θ : inside temperature of dewar (°C)

This apparent heat flow coefficient, K_a depends on the size of dewar and ambient temperature. In case of Figure 3, K_a is derived as follows.

$K_a = 5.7 \times 10^{-3}$ (cal/sec.°C)
.... ambient temp. = 270°C

From the test data of 430°C (800°F) delivered with dewar, K_a is calculated as follows:

$K_a = 6.3 \times 10^{-3}$ (cal/sec.°C)
.... ambient temp. = 430°C

If the heat flow depends on conductive heat only, the value of K_a should be constant. The value of K_a increases with ambient temperature because of the contribution of radiation heat flow. In case of an ambient temperature of 450°C, operation time is estimated to be about 4 hours.

For the quality control of the heat insulation system. all the systems were standardized in the same dimensions independently of size of electronics. The value of K_a was checked as quality factor of dewar.

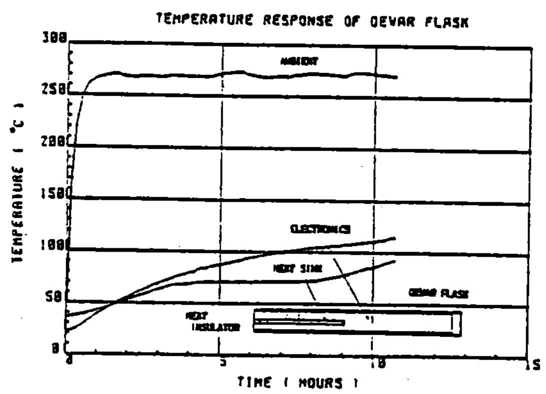


Figure 3. Temperature response of heat insulation system

SENSORS

The following super high temperasture sensors were used.

Temperature

Two sets of specially designed platinum resistance thermo-sensors (600°C): One was for absolute temperature and the other was for differential temperature of one meter. The principle of temperature maeasurement is shown in Figure 4. No downhole electronics was necessary.

The following sensors have been used in nuclear reactor technology.

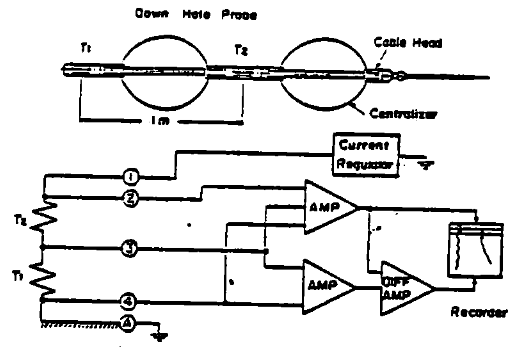


Figure 4. Principle of temperature measurement

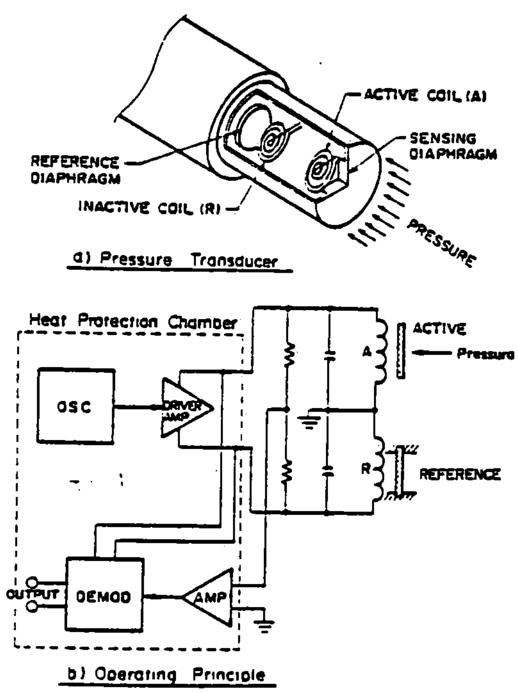


Figure 5. Principle of pressure measurement

Pressure

Eddy current type pressure sensor (540°C)
Figure 5 shows a principle of pressure measurement.

Spinner

Eddy current type displacement sensor (595°C)
The principle is the same as that of pressure sensor but the exciting frequency is lower than pressure sensor. In using this sensor, the spinner tool was designed as shown in Figure 6. The target facing the sensor rotates with the impeller. There are two types of target; plane type and saw tooth type. Saw tooth type target can detect flow direction.

All of these sensors can be exposed to the borehole environment directly and sealing is performed by just welding.

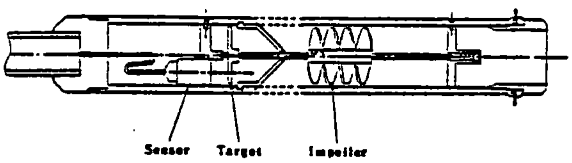


Figure 6. Sensor part of spinner tool

FIELD TESTS AND RESULTS

All the systems were completed and mounted on logging truck as shown in Photo 2.

The whole system was put to field test immediately after completion. Approximately hundred logging operations were performed by using these tools in the Fushime geothermal field. 60% of jobs were performed under temperatures of over 280°C, and 20% of them exceeded 320°C. Through the case study of these operations, we have improved the system.

In the first phase of field tests, we checked the following items:

- Applicability of mineral insulated wire to a logging cable.
- Reliability of metal "O" ring.
- Performance of downhole probes.

The results are shown as follows.

Logging Cable

Through the field tests, we have found that the cable could be operated in the same manner as standard logging cable, although it should be handled with more attention to kinks than standard one.

With regard to the termination of cable, the procedures of termination treatment were improved. For example, sintering of ceramic material for the termination should be done by increasing temperature gradual-

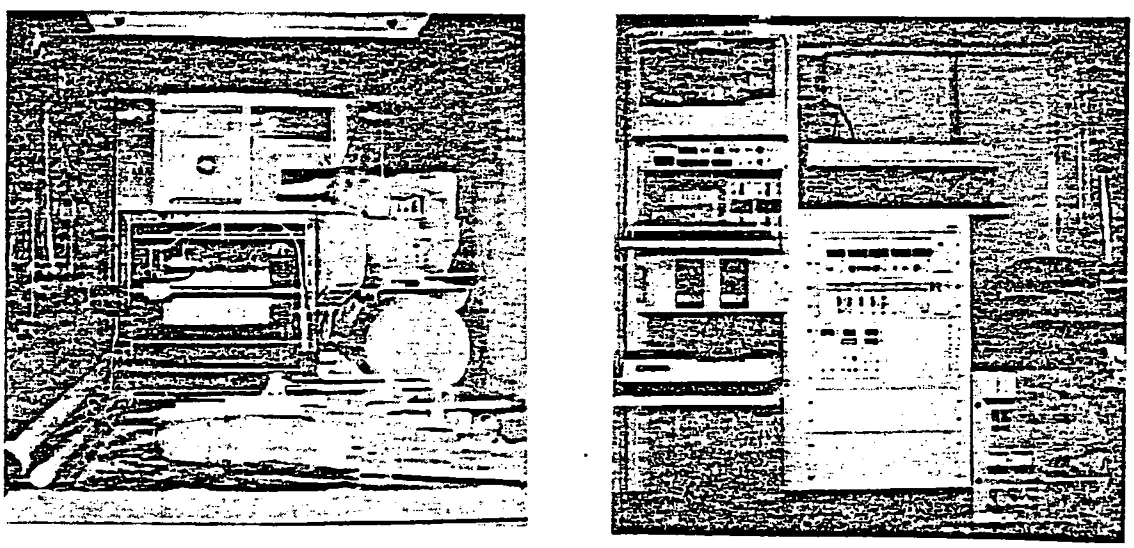


Photo 2. Super high temperature logging system mounted in logging track

ly for 24 hours in order to avoid a nest inside the ceramics. By this kind of improvement, insulation resistance was kept perfect without any maintenance.

The biggest problem was the corrosion of armoring wire in geothermal wells. Most of it was caused by hydrogen embrittlement in high concentration of H_2S. The experience suggested that the first operation of new cable should be carefully done and wells of high concentration of H_2S should be avoided because new cable has low resistance to hydrogen embrittlement. Once the cable surface gets good coating by oxidation inside wells, the cable has good resistance to corrosion. This fact was proved by the following result.

Although the first cable was scraped by corrosion of armoring steel wire at the total travel length of 20 km within one month, the second cable is still in use at the total travel length of 200 km and no degradation of strength was observed.

Sealing

The operation procedures were improved. The careful handling of the surface of the "O" ring mechanism and the strict control of "O" ring size made it's reliability 100%. Several operations were possible without changing the "O" ring in case of temperature build up operation.

Downhole Probes

No problem was found with the temperature and spinner probes. It was found that the eddy current type pressure sensor was very sensitive to the electrical condition because of the high excitation frequency of 1 MHz. It was concluded that further improvement of electronics was necessary for the use of this sensor in such a dynamic environment.

Therefore, second pressure sonde based on a new idea was constructed and successfully operated. The second one used a conventional strain gauge type sensor but all the sensors were dipped in heat sink deep inside the dewar. Pressure was conducted through the spiral tube as shown in Figure 7.

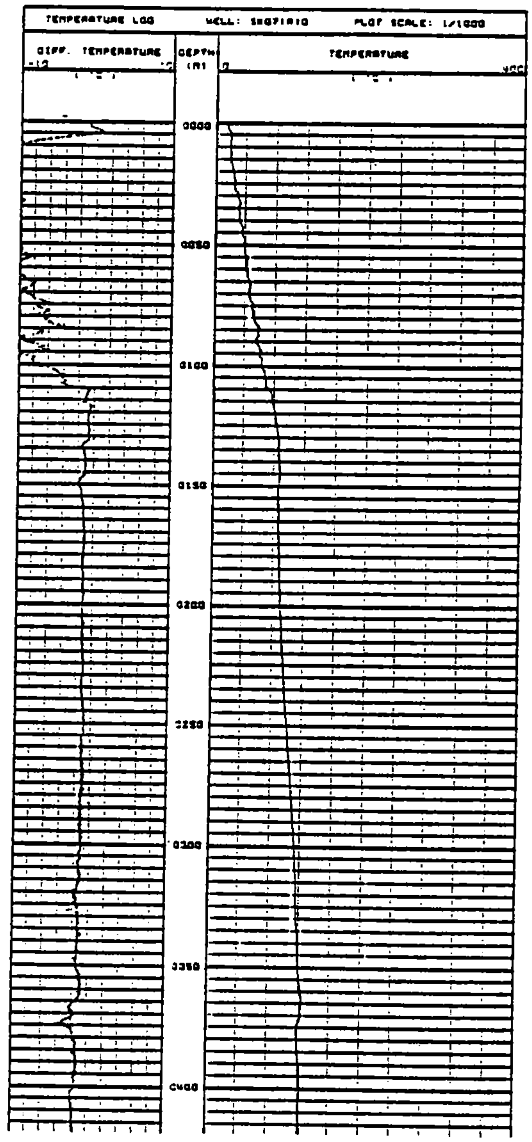


Figure 8. Basic presentation of raw data

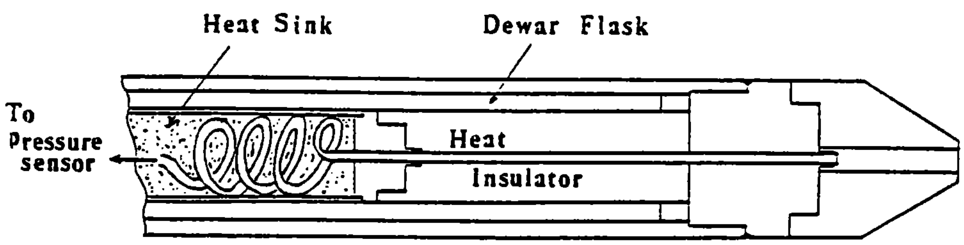


Figure 7. Main part of pressure probe

LOG EXAMPLE

The high temperature well logging tools have been used for geothermal reservoir evaluation in the Fushime geothermal field.

Figure 8 is fundamental presentation of the log which is a standard log format used in oil wells but the data can be displayed in any format suitable for analysis at the well site.

Temperature Build Up

A temperature build up curve is a most fundamental data for evaluating a geothermal reservoir. Figure 9 is an example for the well, Fushime SKG-11D. The temperature build up was measured after water injection of 200 ton. It is very easy to point out the injected zones from this curve but an injected zone is not always a production zone.

Production Profile

Production zones are easily detected by spinner tool. Figure 10 is a production profile of the same well shown in Figure 9. The solid line of left hand track (track 1) is a response of spinner tool. The curve tends to decline with the depth except for the abrupt change of flow velocity at 1237 m in which casing size changes from 8-1/2 to 7 inches. This decline is explained by the volume change of steam with the depth. The broken line in track 1 is an estimated spinner response which is calculated by using following equation.

$$N = No \frac{\rho_0}{\rho} \qquad \text{(rpm)}$$

where, N : estimated spinner response (rpm)
No : spinner response of a datum depth (rpm)
ρ : density of steam (g/cm^3)
ρ_0 : density of steam at a datum depth (g/cm^3)

The density of steam was calculated by using the temperature and pressure curve in track 2 of Figure 10.

Both curves agree with each other very well. The separation above 350 m is due to the tow phase flow of steam and hot water. And the separation below the 1520 m is interpreted that some production zone exist below this depth. The production zones analyzed are marked by arrows in the Figure 10. The big production zones, located in 1530 m and 1800 m, produce 70% of total steam.

Figure 11 is an example of flow analysis in case of open hole (SKG-8D). The solid line of track 2 is a spinner response during production and broken line is a spinner response during shut-in. The difference between the two responses shows the production profile as shown in track 1. The production zones analyzed are marked by arrows. The biggest zone exists in 2110 m and produces about 40% of total flow.

Pressure Build-up and Fall-off

Pressure build-up and fall-off curves measured in injection test are useful for evaluating the ability of injection wells. Figure 12 is an example of downhole

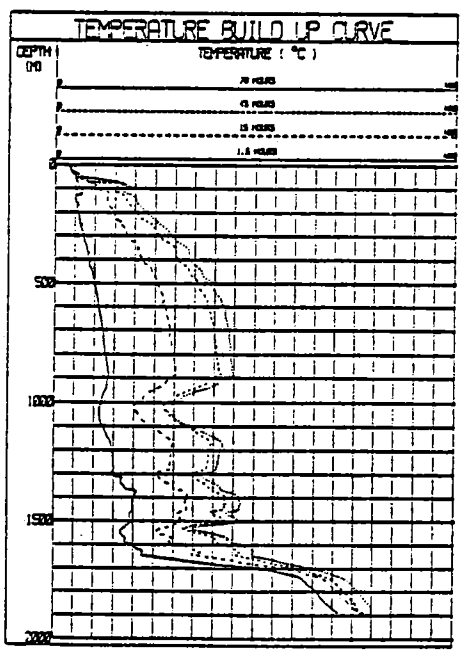


Figure 9. Temperature build up curve in Fushime SKG-11D

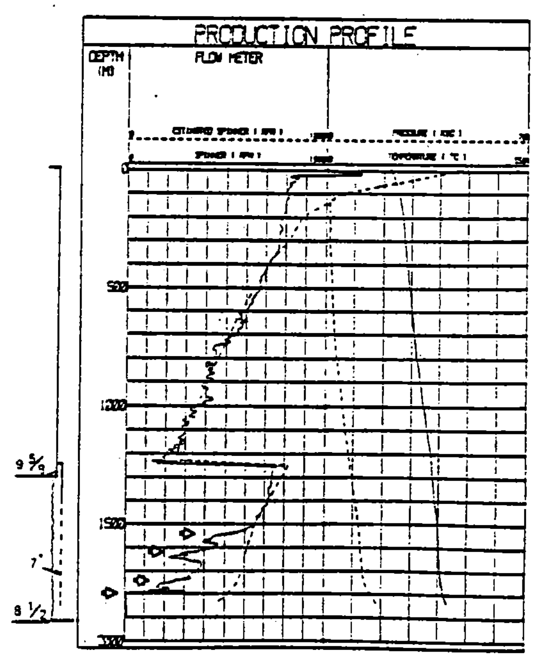


Figure 10. Production profile of SKG-11D

pressure curve measured in the injection test of the well SKG-14D. Pressure sonde was placed to monitor the downhole pressure in 600 m. For each test segment, the step rate change in injection was initiated upon achieving a stable downhole pressure at the previous rate. Injection rates were 90 kl/hr and 150 kl/hr. The data was analyzed to estimate the injectivity index (darcy-m) and skin effect as shown in Figure 13. The dot and circle in Figure 13 are fall-off curves corre-

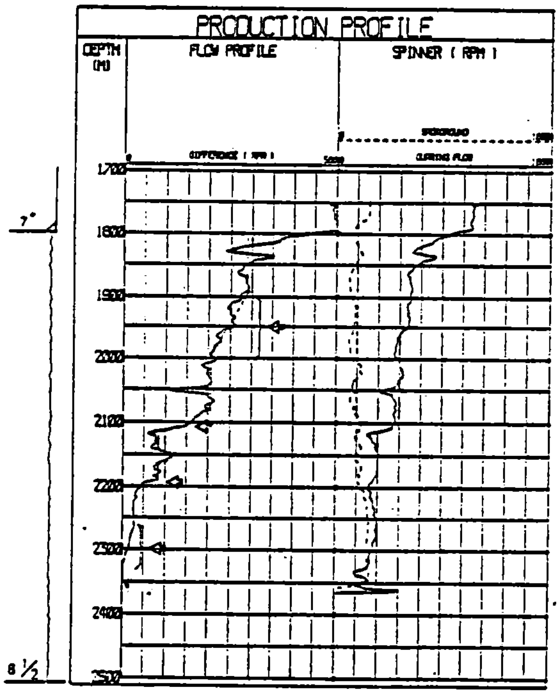


Figure 11. Flow analysis of open hole in Fushime SKG-8D

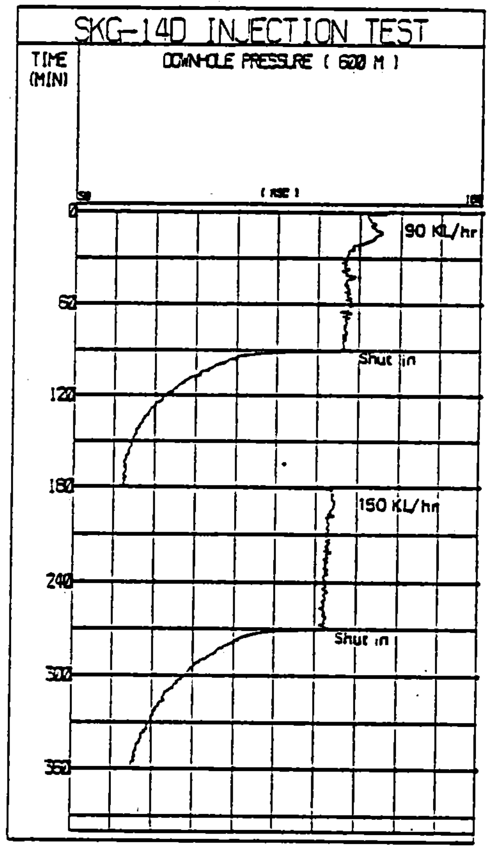


Figure 12. Result of injection test in Fushime SKG-14D

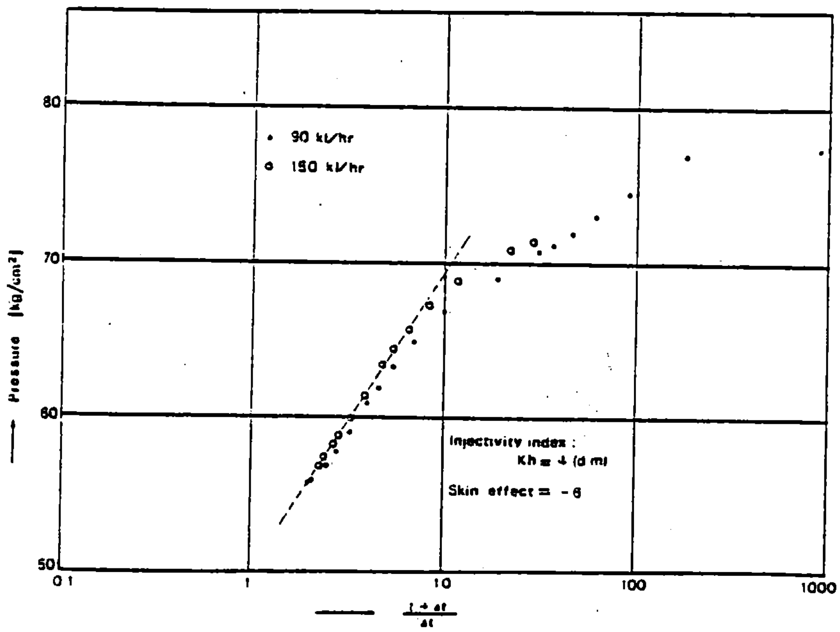


Figure 13. Pressure transient analysis of fall-off curve

sponding to injection of 90 kl/hr and 150 kl/hr respectively. A pressure build-up curve could not be used because of the high injection rate comparing to the small injectivity of the formation.

CONCLUSION

A super high temperature well logging system has been developed. The tools developed are temperature, pressure and spinner tools. Through nearly a hundred field operations in the Fushime geothermal wells where maximum temperatures are 240 to 340°C, it was confirmed that the system has sufficient reliability in such severe environments. The system is also very useful for the development of geothermal reservoirs.

Although the tools developed give us valuable and previously unknown information about reservoirs. With the advances in the development of reservoirs, more information will be needed for the detailed delineation of reservoirs. Therefore, we are developing new super high temperature tools such as slim hole sonic and latero-log, borehole fluid sampler, caliper tool for scale detection and noise log to assist a spinner tool. These tools will be put to field test in FY 1985.

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Appendix 4

HIGH TEMPERATURE GEOTHERMAL WELL LOGGING SYSTEM

Japan Petroleum Exploration Co. (JAPEX)

FUNDAMENTAL SPECIFICATION

- Maximum Operating Temperature : $450^{o}C$
- Maximum Operating Pressure : 350 kg/cm^2
- Maximum Operating Depth : 3000 m

TEMPERATURE TOOL

Temperature Rating	: 450 °C
Fluid Pressure	: 350 kg/cm^2
Length	: 1550 mm
Diameter	: 56 mm
Weight	: 8 kg
No. of conductors	: 4

~ 3 hrs.

301 °C → 6 to 8 hrs.

PRESSURE TOOL

Temperature Rating	: 450 °C
Fluid Pressure	: 350 kg/cm^2
Max. Operating Time	: 4 hours (450 °C)
Length	: 1180 mm
Diameter	: 56 mm
Weight	: 15 kg
No. of conductors	: 4

SPINNER TOOL

Temperature Rating	: 450 °C
Fluid Pressure	: 350 kg/cm^2
Max. Operating Time	: 4 hours (450 °C)
Length	: 2830 mm
Diameter	: 56 mm
Weight	: 32 kg
No. of Conductors	: 3+GND

CALIPER TOOL

Temperature Rating	: 450 °C
Fluid Pressure	: 350 kg/cm^2
Max. Operating Time	: 4 hours (450°C)
Length	: 3015 mm
Diameter-closed	: 56 mm
Max. Hole Size	: 300 mm (11.8 inch)
Weight	: 30 kg
No. of Conductors	: 3+GND

ACOUSTIC DETECTOR

Temperature Rating	: 450 °C
Fluid Pressure	: 350 kg/cm^2
Max. Operating Time	: 4 hours (450°C)
Length	: 3560 mm
Diameter	: 56 mm
Weight	: 42 kg
No. of Conductors	: 4

microphone & accel.
clamp.