Draft
Technical Report

Geothermal Well Ascension #1

prepared for

Eastern Space and Missile Center
Patrick Air Force Base, Florida

and

U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho

by

University of Utah Research Institute

and

EG&G Idaho, Inc.

July 31, 1987

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GEOTHERMAL WELL ASCENSION #1

TECHNICAL REPORT

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DRAFT REPORT
July 31, 1987

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1.0 EXECUTIVE SUMMARY

This report details the technical aspects and studies of results from geothermal test well Ascension #1 located on Ascension Island in the South Atlantic Ocean. The objective of this well is to intersect and allow testing of a geothermal resource which could be used as a source of renewable energy for the USAF Ascension Auxiliary Airfield.

The drilling section documents the drilling methods used and presents a chronology of drilling events. This section also discusses drilling problems encountered and recommended means for mitigating those problems in the future.

The geology section analyzes the structural setting of the project area. The locations of high-temperature geothermal systems are controlled by faults and fractures, and a knowledge of fault patterns is therefore important in analyzing the results from this hole and in planning additional exploration on Ascension Island. Also included in this section is a discussion of the rock types encountered in drilling the well. Attention has been paid to the zonation of alteration minerals found in Ascension #1. The mineral zonation encountered is indicative of geothermal systems with temperatures over 400^{o}F.

The section on fluid chemistry is principally devoted to liquid and gas samples collected during testing at 8706 feet. However, it also contains an analysis of reservoir fluids sampled from below 9800 feet. The conclusions of this section are that geothermal fluids from the well are derived from seawater and that their chemistry is modified by both low-temperature and high -temperature interaction with the rocks that make up the Ascension Island pedestal. This chemistry has also been modified by boiling processes within the well bore.

The section on geophysical well logs discusses the results from logging runs made in Ascension #1. These include deviation surveys which show that the well has drifted to the north and west of the collar location. Temperature surveys not only document the maximum temperature of 479^{o}F, they also indicate the geothermal flow regimes intersected by the well. An analysis of dipmeter data shows that fractures intersected in the well trend generally to the southwest parallel the faults of the southwestern rift system. However, analysis of breakouts show that the present stress regime is one where the least horizontal stress is oriented east-west.

A well test program was conducted at a depth of 8706 feet. The test procedures and results of this operation are described. The flow encountered at this point in the well was not substantial enough to support production.

The results of the previous section are combined to form a conceptual model of the geothermal resource. The key point of this model are that seawater recharges the system through faults and fractures that are associated with the southwestern rift. These waters are heated and ascend along the same fault. At the present depth of Ascension #1, the interaction of these heated waters with the country rocks have produced alteration assemblages that have sealed the faults preventing the quantity of flow necessary for geothermal power production. However,temperatures are continuing to increase at the bottom of the well indicating that it is possible to intersect additional entries with continued drilling.

It is recommended that Ascension #1 be deepened to continue to search for the quantity of fluid production necessary to support power generation. In addition, it is recommended that another leg of the well be drilled starting below the casing at a depth of about 5000 feet. This leg will be drilled to the north in order to intersect the same structures about 2000 feet along strike in hopes of finding an area that has not been sealed through the precipitation of hydrothermal minerals. It is also recommended that attempts be made to fracture the well using the injection of fluids. This will be attempted in order to stimulate and improve production. It is also recommended that a net be set up to monitor seismicity in the prospect area. Low levels of seismic activity are often associated with high-temperature geothermal fields, and it is anticipated that these seismic events will define structures that can be explored through drilling.

2.0 INTRODUCTION

Ascension Island is located in the South Atlantic Ocean approximately 100 km to the west of the active spreading center of the Mid-Atlantic Ridge. The island is volcanic in origin, and recent authors have characterized it as the most active volcano in the South Atlantic.

The drilling of Ascension #1 is the culmination of a geothermal exploration program which has been conducted for the U.S. Air Force by the University of Utah Research Institute since 1982. Initial efforts on the project involved the detailed geologic mapping of Ascension Island (Nielson and Sibbett, 1982). This study concluded that, although there were neither hot springs nor fumaroles on the island, the potential for discovery of a high-temperature geothermal system was high. This conclusion was based on the young age of the volcanic activity and the presence of rhyolite dome complexes which imply a viable heat source for geothermal systems at depth.

Geologic mapping was followed by geophysical exploration involving electrical resistivity, aeromagnetic, and temperature gradient surveys. Electrical resistivity geophysical methods are used to measure the earth's ability to conduct electricity. Higher concentrations of salts in geothermal fluids as well as their higher temperatures cause lower electrical resistivity. Results of the electrical resistivity surveys are presented in Ross et al. (1984a) and Ross et al. (1984c). The second report describes supplemental surveys which were completed following temperature gradient drilling. Both sets of surveys identified areas of lower electrical resistivity to the south of the present location of the Traveler's Hill RAF base. Due to the small size of Ascension and the surrounding conductive seawater, it was not possible to model results deeper than 2500 feet.

During 1983, a detailed aeromagnetic survey was conducted over Ascension. This method was used to define buried fault and dike trends and is based on variations in magnetic signature of rocks encountered. An irregular area was defined in the vicinity of Ascension #1 which contained low magnetization and demonstrated considerable structural complexity. This area corresponded with zones of low electrical resistivity, and it was concluded that this was the most likely area for a geothermal system in the depth range of 3000 to 9000 feet.

Results from the geologic, electrical resistivity, and aeromagnetic surveys were used to site temperature gradient holes. These holes were drilled with a Longyear 44 core rig operated by Tonto Drilling Services of Salt Lake City. The results of this drilling and subsequent temperature gradient measurements are described in Sibbett et al. (1984). The locations of the temperature gradient holes are shown in Figure 2-1. Figure 2-2 shows the thermal profiles from these holes and clearly demonstrates the higher temperature gradients in the vicinity of GH-1, 2, 6 and LDTGH. GH-6 is located in the eastern portion of the island at a much greater distance from the U.S. base which relegated it to a second priority exploration site.

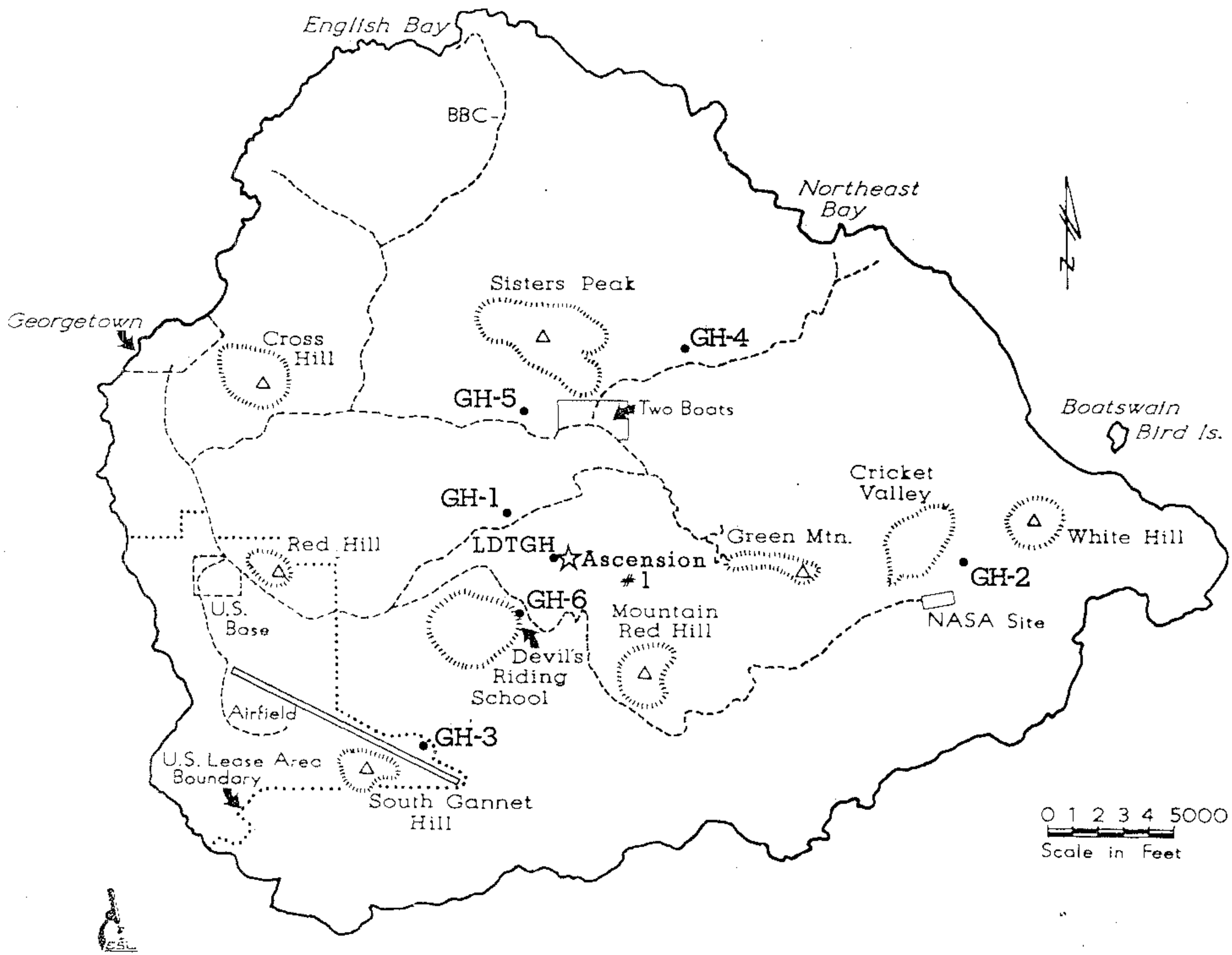

Figure 2.1

AI-003

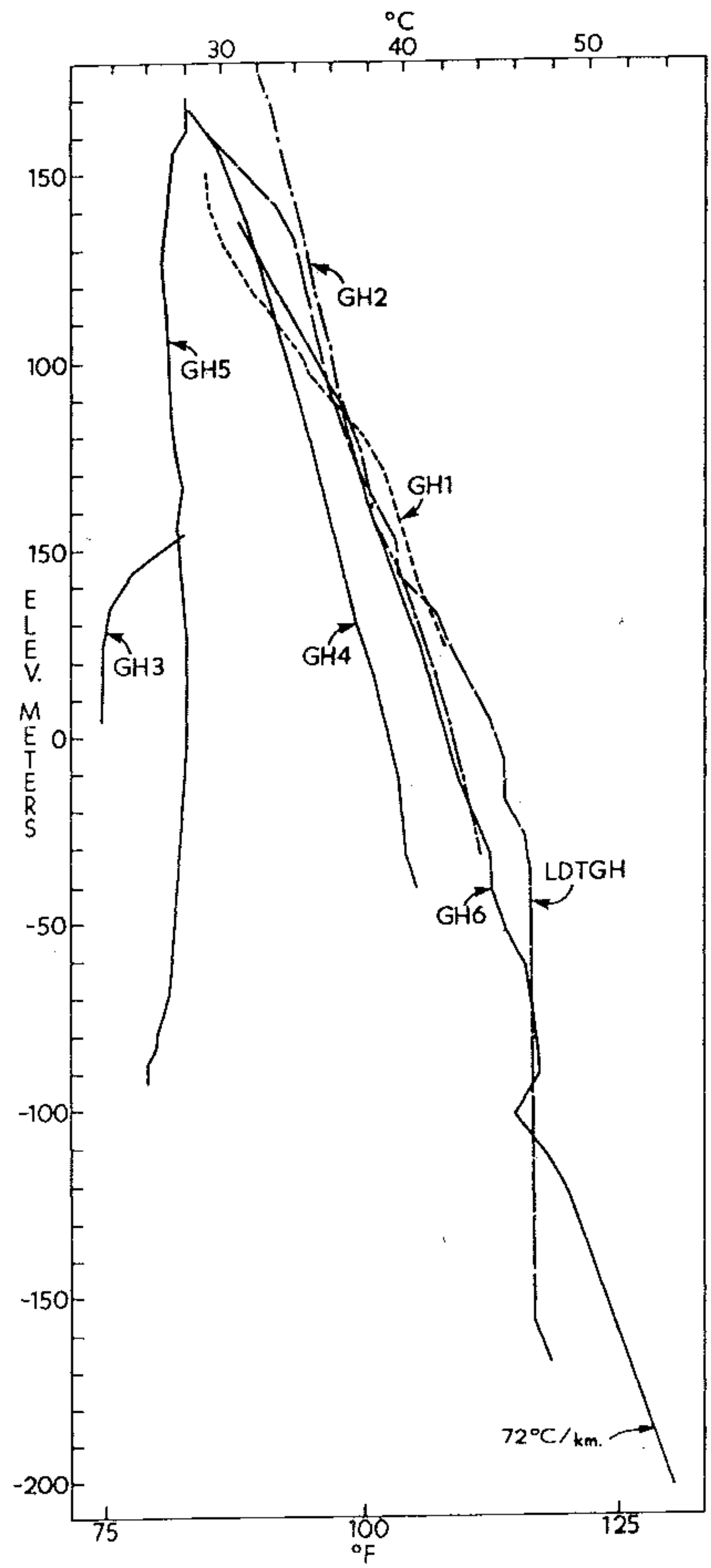

Figure 2.2
Temp Gradients

The area around GH-1,2, and LDTGH corresponded with low electrical resistivity anomalies, the structural complexity identified by the aeromagnetic surveys, and favorable geologic indicators, and was chosen for Ascension #1.

3.0 Drilling

****** ASCENSION ISLAND GEOTHERMAL PROJECT ******

EXPLORATION WELL ASCENSION 1

* *

DRILLING OPERATIONS

Pertinent Data

June 1987

SECTION 1

The original well plan was developed in March 1986 from information gathered from six temperature gradient wells and extensive geological reconnaissance and interpretation of all data by the University of Utah Research Institute. As in all exploration wells where no deep temperature gradient holes were drilled to furnish more exact temperature data, the depth of the deep test hole is usually a projection of temperature gradient to a desired temperature, from which a generator can be run. In this drilling plan a conservative estimate of 5000' was arrived at with the plan to include the equipment and drill pipe to get to 8000'. It was projected to have temperatures that would necessitate the use of a down hole geothermal pump which would be set at around 1400'-1500'. The objective of the hole was to determine if geothermal fluid was present of suffient volume and temperature to produce electricity with a wellhead generator.

This is the Draft Report of the equipment used, problems encountered, and results and interpretation of data gathered from the drilling of Exploration Well ASCENSION # 1.

DRILLING RIG AND ASSOCIATED EQUIPMENT:

(1) Contractor - Parker Drilling Company - Tulsa, Oklahoma. (918) 585-8221. Mr Lee Cooley - Western Hemisphere Operations Manager.

(2) Drilling Rig # 185 PARCO TBA 2000 Series. The TBA series of rigs were designed and built by Parker at their manufacturing facility at Odessa, Texas. Rig 185 was built in 1981 and is rated for 15,000'. The rig and all associated equipment can be broken down into 4,000 lbs. loads if necessary or in this case 15 tons to meet the 15 ton dock crane capacity on Ascension Island.

Drawworks: TBA 2000 Drawworks complete with Parmac 342A Hydromatic Brake.

Rig Drive: The four engine rig drive consists of four KTA1150 Cummins diesel engines,four Allison Transmissions with torque converters.

Catworks: The catworks rotary drive unit is chain driven from number one engine extension shaft through two extra heavy duty spiral bevel gear boxes and torque tube. Catworks has Foster Type 24 AH breakout cathead and Foster 27 AH spinning cathead with air controls.

Mast and Substructure: PARCO Cantilever Mast, 136' x 21'- 4" base plus a 21' high floor (18' clear under rotary beams). Mast has been rated at a static hook load capacity of 750,000 lbs. with ten lines strung to the traveling block. Casing capacity of 722,000 lbs. simultaneously with 552,000 lbs. setback capacity.

Mud Pumps: Three OPI 350D triplex pumps with forged steel fluid ends, mounted on master skids. The forged steel fluid end has 6" bore by 8" stroke and utilizes standard type liners and consumables.

One OPI 350D independent triplex pump with forged steel fluid end, mounted on a steel skid and driven by a KTA1150 Cummins diesel engine. The steel fluid end has 6" bore by 8" stroke and utilizes standard type liners and consumables.

Rotary Table: Ideco 27½" Model LR-275 rotary table with square split master bushings for kelly drive. Varco kelly drive bushing with pin drive.

Traveling Equipment: Combination block hook, Ideco UTB 360 block has five 42" sheaves grooved for 1¼" drilling line complete with 360 ton Ideco hook.

Kelly Spinner: Foster kelly spinner type 77.

Swivel: Grey swivel type B-44, 500 tons with quick change gooseneck assembly.

Mud Pits and mixing equipment: Nine 120 bbl steel mud pits, 8'x12'x7', with sloped bottoms for easy cleaning, complete with stairs, walks, two mud hoppers, standard bottom guns and jets, with seven pits manifolded into an active mud system and two storage pits. Three mud-mixing supercharging pump units, each consisting of a 5"x6" centrifugal pump, direct driven by D-3304T Caterpillar diesel engine. Four Brandt Model 74Q10 lightnin mixers, installed in the active pits. One Demco desander unit. Two 12" cone desander, with D3304T Caterpillar engine and 5"x6" centrifugal pump. One Bariod mud cleaner with 5"x6" centrifugal pump. Eight 4" cones. Powered by D3304T Caterpillar engine. Two Bariod double deck shale shakers.

Blow Out Preventer Equipment: One 13-5/8" 5,000 psi Shaffer light weight spherical. Three 13-5/8" 5,000 psi Shaffer single ram type with CIW Hubs. 16" and 13-5/8" 2,000 psi Grant Rotating Heads. One 13-5/8" 5,000 psi Banjo Box with CIW Hubs and all necessary adapter spools and x-over flanges.

Blow Out Preventer Controls: Koomey accumulator Model T26160-3G, 3,000 psi WP, 160 gals., powered by T315-20-3 Koomey triplex plunger pump driven by 20-H.P. 1,800 RPM, 220/440 volt, 60 cycle , 3-phase, explosion proof electric motor, with air package. One Koomey auxiliary remote control panel, Model GARC-5, 5 station. One set BOP control line suitcases and steel chicksan hose to wellhead.

Fuel and Water storage: Six 145 bbls. cylindrical water tanks skidded for horizonal usage. Two 145 bbls. cylindrical fuel tanks skidded for horizonal usage.

Electric Generators: Four D-3306T Caterpillar electric sets, 135 KW prime power , 115 KW continuous, with mechanical safety shutdowns and integral control panels.

Air Compressor: Air compressior wash down pump unit, consisting of 2-5120 Quincy air compressors eacjh driven by 20-H.P. electric motor, one mounted on 200 gallon horizonal air receiver tank. One 2"x3" mission centrifugal pump driven by 20-H.P. electric motor all mounted on one steel skid.

Wire Line: 5,000' x 1¼" , 6 x 19.

Kellys and Drill Pipe: Two 5¼" x 40' hex kelly with scabbard. One 3½" x 40' kelly with saver subs for both size kellys. All drillpipe premimum grade.
7,000' 5" - 19.50# Grade E With 6-3/8" OD 4½" IF tool joints with 18° taper on the shoulders and internal plastic coating, no hard banding.
8,000' 3½" 13.30# Grade E with 4-3/4" OD 3½" IF bottleneck tool joints.
5,000' 3½" 15.50# Grade S-135 with 5" OD 3½" IF bottleneck tool joints.
Drill Collars and Subs: 30 8"OD x 2-13/16" ID, Box and pin with slip recess, 6-5/8" API Regular connections, and spiral grooving.
Two bit subs bored for a float and one x-over sub to 7-5/8" API Reg.
30 6½" OD x 2-13/16" ID x 31' box and pin with slip recess and 4½" IF connections and spiral grooving.
24 4-3/4" OD x 2" ID x 31' box and pin with 3½" IF connections and spiral grooving. Bit subs and x-over subs to fit drill collars.
Elevators, Slips, and Tongs, for Drill pipe, Drill Collars and casing.:
Elevators for 16", 11-3/4", 7-5/8"and 4½" casing. 5" and 3½" drillpipe.
Tongs with jaws for sizes 3½" through 20".
Slips to fit all drill pipe, drill collar and casing sizes.
Measuring line: Mathey wireline measuring unit, 15,000' of .092 Nickel coated wireline, 25 H.P. motor.
Fishing Tools: Complete lot of overshots , jars and bumper subs magnets etc. for the various sizes of drill pipe and drill collars used.
Welding Equipment and Welder: One certified welder and Lincoln diesel powered Model K-1146 300 AMP, ARC welder with all associated welding and cutting apparatuses.
Lighting and Rig Houses: Set of vapor proof rig lights and sufficient lighting for all work areas complete with control panels.
2 - steel dog houses for storage and mud sample house.
1 - 8' x 20' skid mounted toolpushers house with bath and office for contractor's toolpusher.
Drilling Instruments: Martin Decker mud gauge, MD-type D weight indicator,Rotary torque indicator, Tong torque gauge, Drilling recorder, 6-pin Totco.
Forklift and vehicles: One Caterpillar 922 Forklift one car and one pickup truck.
Inventory Warehouses:
A inventory of consumables, spare and replacement parts valued in excess of $500,000, estimated to sustain a year's normal operation.

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AIR COMPRESSORS AND ASSOCIATED EQUIPMENT:

(1) Contractor - Nova Mud Corporation - West Jordan, Utah. (801) 266-6682. Mr Larry Newman - President.

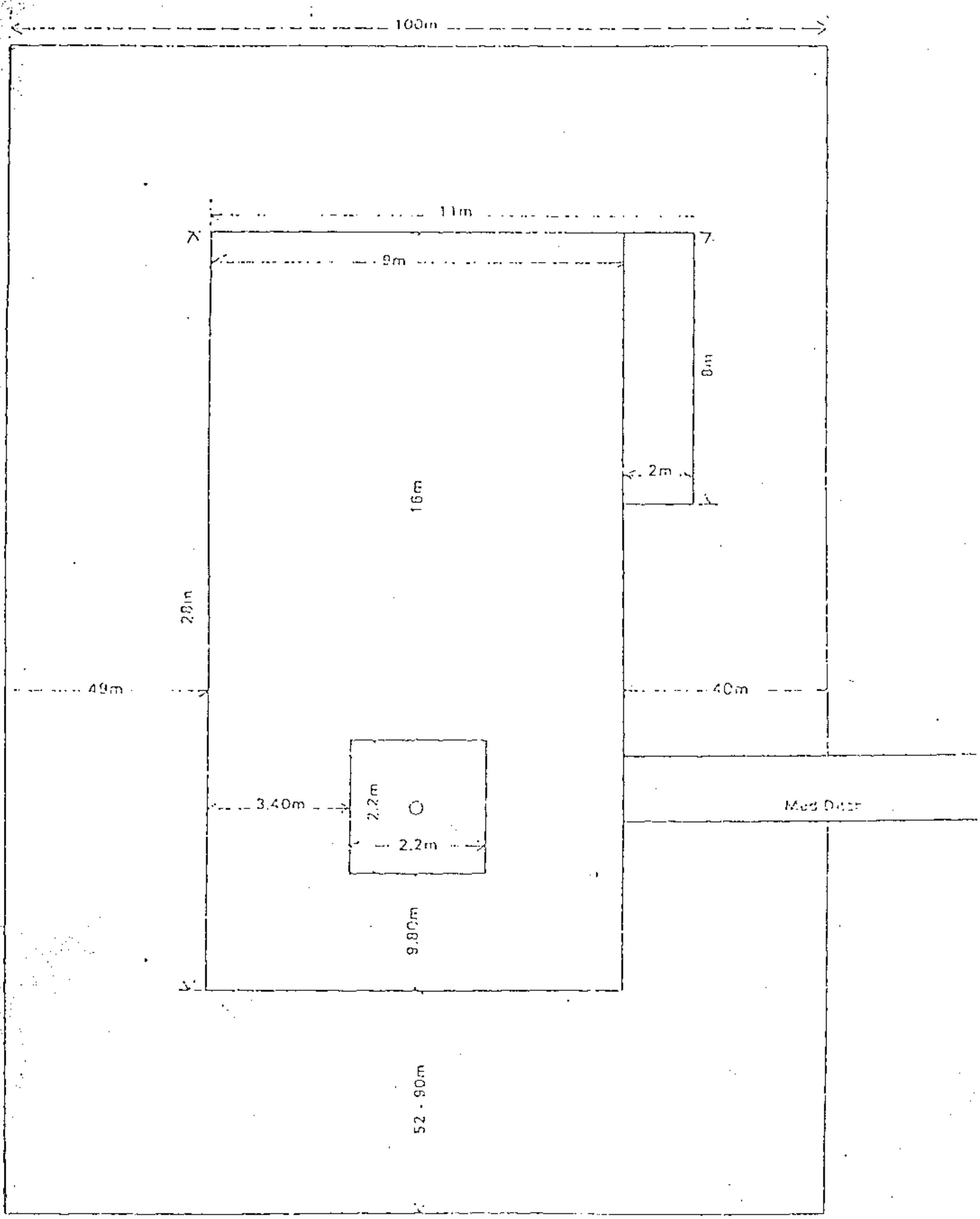
(2) Air compressors: . 3 - 850 CFM each, 200 psi Quincy Primary Compressors.

(3) Booster: . 1 - Joy 2 stage 1250 psi 2400 CFM.

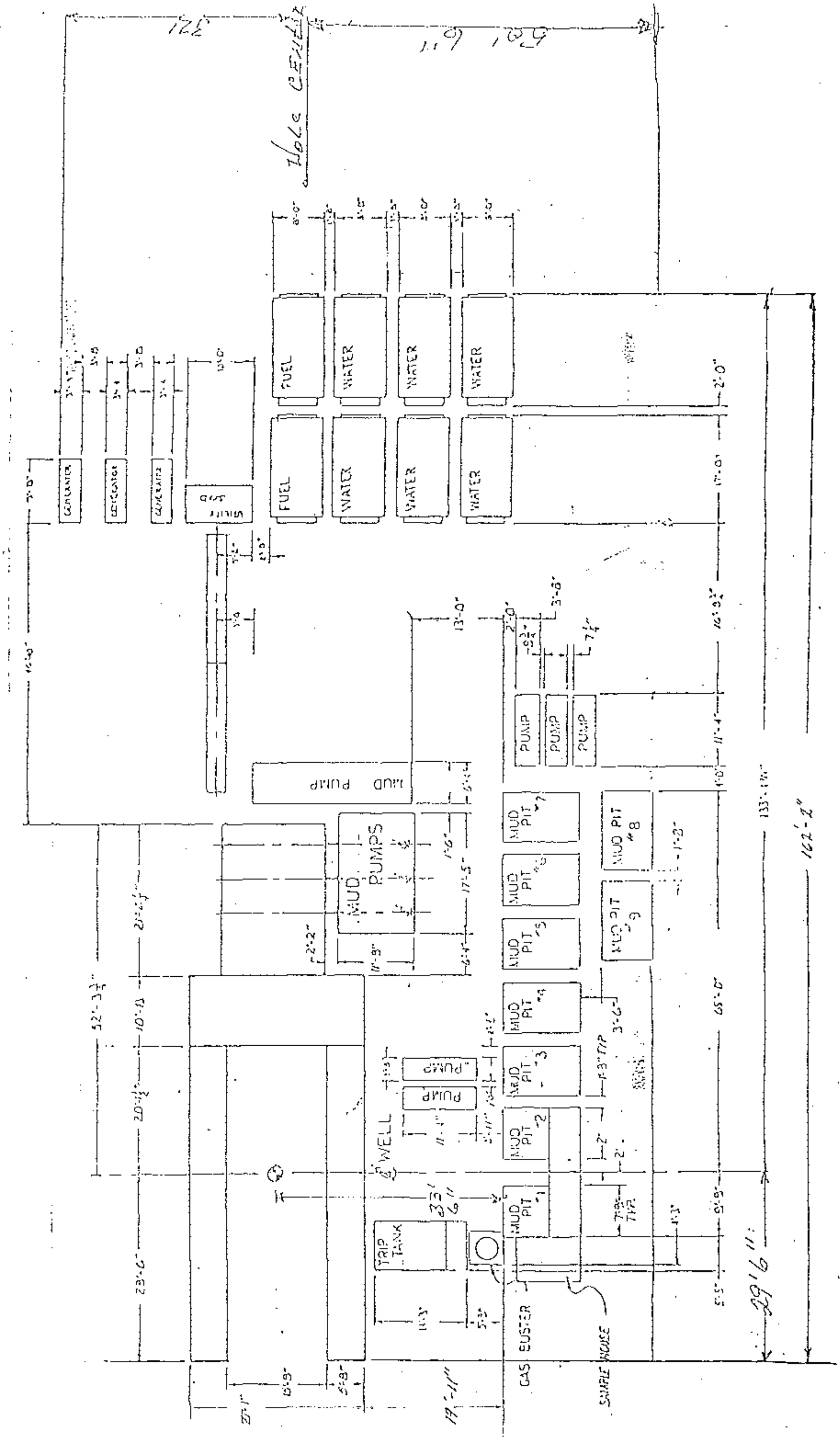
(4) Mist and Chemical Pumps. . 1 - PS 25 Gardner-Denver Mist pump - With Texteam Chemical pump.

All manifolding and piping from compressors to rig, standpipe, lube and oils, Jet subs, blooey line and pressure gauges and recorder. 2 operators and 1 Mud/Corrosion Control Engineer.

LOCATION SIZE ----- RIG NO. 185



(Figure 1)



RIG 185 Equipment Layout

(Figure 1-A)

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MUD LOGGERS AND ASSOCIATED EQUIPMENT:

(1) Contractor: - Energylog - Sacramento, California. (916) 452-7541. Mr Ben Cahill - President.

(2) Energylog has converted a sea-van into a logging unit. (figures 2 & 3). This was done to help facilitate mobilization of the unit to Ascension Island. This unit is staffed 24 hours a day by two graduate geologists, when in operation, and provide a continuous log of the operations while drilling. Standard Mud Logging services include ditch and blendor catalytic hydrocarbon detectors, depth-penetration rate recorder, dual pump stroke counters, pit level monitor with alarm, spot check of mud resistivity and chloride measurements, flowline detection of H_2S, CO_2 and CH_4 , Continuous mud temperature (in and out) measurements while mud drilling, and while air drilling a measurement of air pressure (in) as well as the other services noted above, Drill cuttings collection and analysis, daily and final mud log reports. Drill cuttings are sacked and labeled and provide the University with accurate uncontaminated samples for farther in-depth studies. The Mud Loggers are also our first and most important line of defense and safety against the presence of toxic gases with their constant monitoring of these gases and alarm system. Energylog is also providing the project with 10 Scott Air Packs in the event of a toxic gas emergency. The mudloggers also provide accurate data to the drillers on depth. pressure and temperature of steam or hot water entries or complete or partial loss circulation zones. These zones are pinpointed by having a permanent record that can be studied. They also monitor methane and other colorless, odorless highly inflammable gases to cut down the risk of fire.

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(1) Contractor - Halliburton Services,International Operations-Latin Region - Houston, Texas. (713) 561-1444. Mr Tom McGraw - Operations Manager.

HOWCO CEMENTER AND ASSOCIATED EQUIPMENT:

Pump Unit: Twin HT-400 with RCM (Recirculating Mixer) powered by twin GM-8V-71 Engines, skid mounted.

Storage; 4 - 500 cu. ft. Vertical Storage Bins.

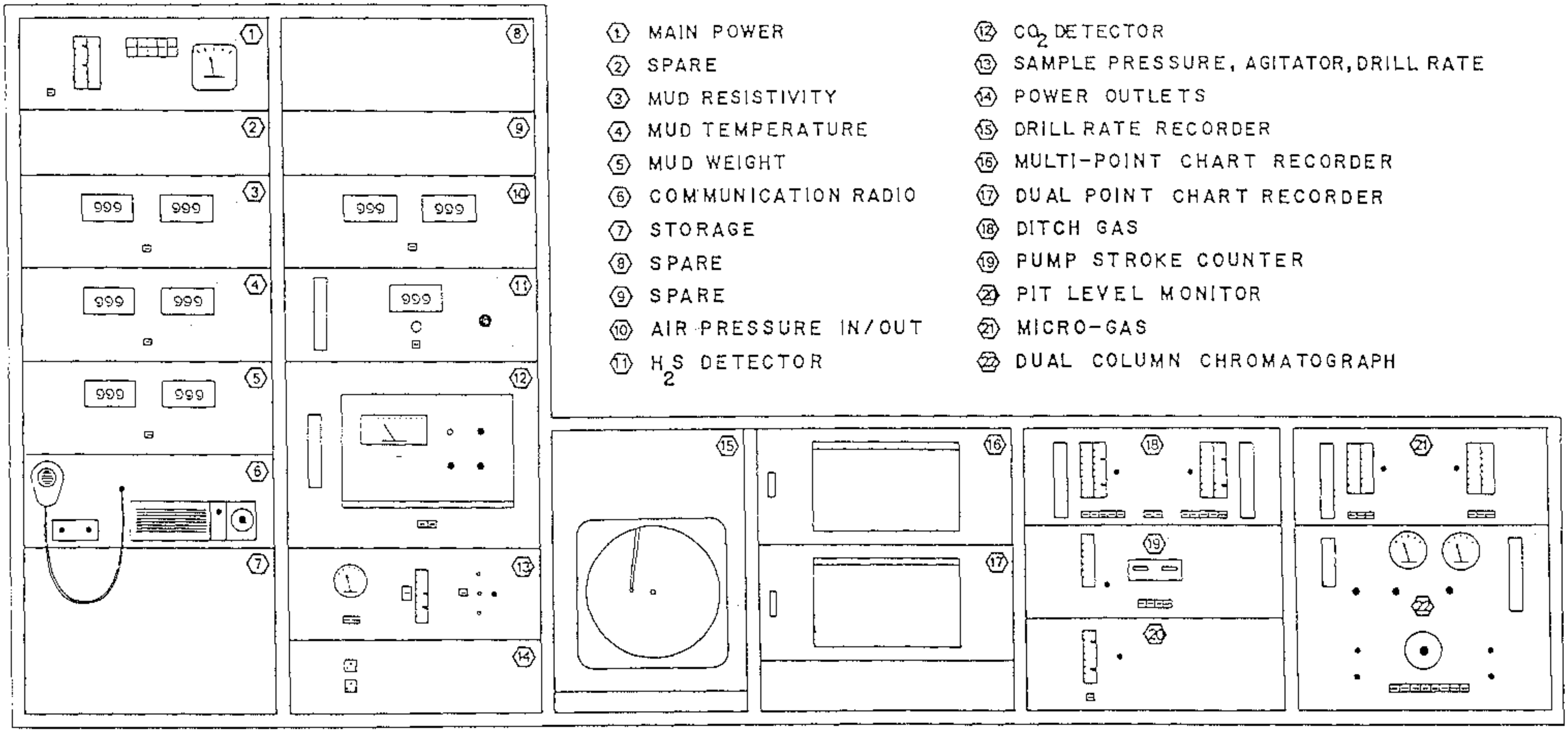
Mixing Tank: 1 - 28 cu. ft. 4'x6' Pressure Tank 40 PSC WP with Hopper & Cutting Table.

Surge Tank: 1 - 80 cu. ft. Vertical Steady Flow Pneumatic Surge Tank.

Compressor: 1 - 300 SCFM Diesel, 40 PSC Compressor with Aftercooler.

Personnel; One Multiservice Operator on rig at all times.

TYPICAL INSTRUMENT LAYOUT



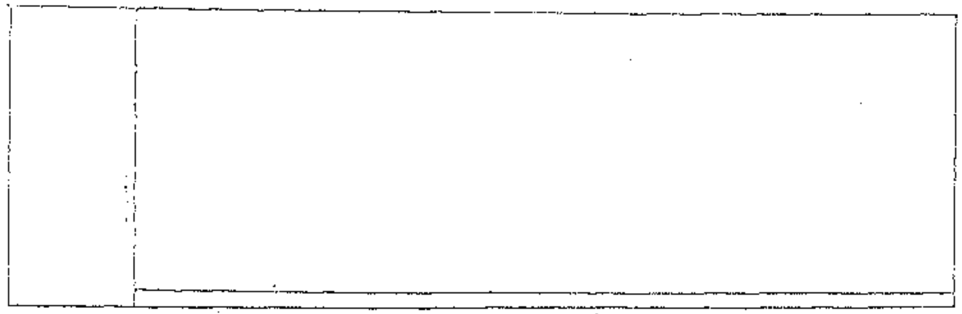
(Figure – 2)

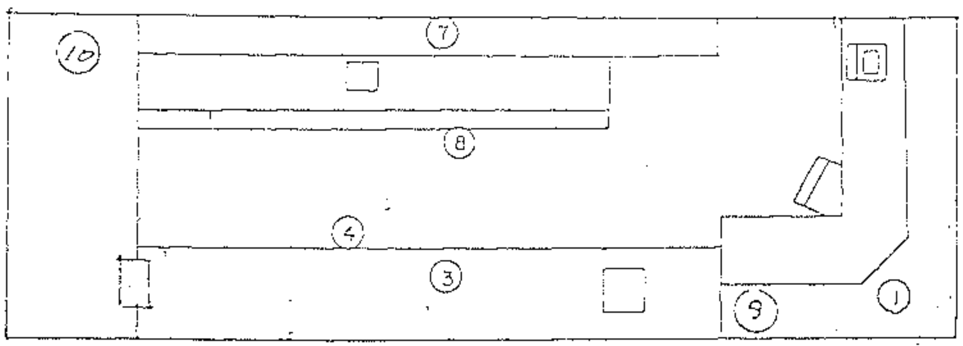
ENERGYLOG

INSTRUMENT LAYOUT

2 OF 2

00-0053





(1) INSTRUMENT RACKS AND LOGGER WORKSPACE

(3) SAMPLE ANALYSIS WORKSPACE WITH STAINLESS STEEL COUNTER

(4) REFRIGERATOR UNDER COUNTER

(5) COAT CLOSET AND STORAGE

(6) OPERATOR WORKSPACE

(7) OVERHEAD STORAGE

(8) LIGHT TABLE AND COUCH AREA

(9) ROTOLITE COPIER

(10) LINE STORAGE AREA

ENERGYLOG

SCALE:	APPROVED BY:	DRAWN BY LSA
DATE: 2/81		REVISED

LOGGING UNIT LAYOUT

DRAWING NUMBER
CO-0080

(Figure - 3)

SECTION 3

Description of Drilling Operations by Hole Size & Depth:

All Depths are Rotary Table Elevation.

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CONDUCTOR HOLE:

Hole Size - 20"
Depth - 0' - 173'

Casing Size - 16" New - 65# - H 40 - ST&C
Set At - 0' - 165' - 4 Joints (166.99').

Cement Job - Sting into float shoe @ 165' using 5" drill pipe with a stab-in adapter. Circulate and condition hole and mud for cement job. Pump 15 bbls. saltwater ahead of cement, mixed 252 sacks class "H" cement , displaced with 3 bbls. saltwater. Good circulation throughout job and good cement returns. WOC 18 hrs. Cement did not fall back in casing-hole annulus. Samples showed good compressive strength at 12 hrs. and excellent compressive strength at 18 hrs.

Bit History
Bits Used - - - - 1
Size - - - - 20"
Feet per hr.- - - - 13.3'
Total rotating hrs. - - 13

Problems encountered this section of hole:
Plugged Bit (rust from the inside of the drill collars).
Rig Repairs Pump Selectors. 1 hr.RR
Rig Repairs Cellar Jet. (washed out). 4 hrs.RR.
Rig Repairs One Shale Shaker Motor burned up. 7 hrs. RR
Rig Repairs Both Shale Shaker Motors burned up. (wired wrong). 2 hrs.RR.
Total Hours Rig Repair this section = 14

Comment: All problems in this section were of a minor nature. They consisted mainly of mechanical problems associated with the shakeout of the equipment from being stacked and moved. The Rat and Mouse holes were drilled with air. The first 46' of 20" hole was drilled with air as a convenience to accommodate the making up of the BHA. The remainder of the hole from 46' to 173' was drilled using mud as the circulating medium. No lost circulation or other problems were encountered. Torque was average and hole deviation was a maximum of 1°. Temperature is low.

SECTION 3 (cont.)

Description of Drilling Operations by Hole Size & Depth:

****

SURFACE HOLE:

Hole Size - 14-3/4"
Depth - 173' - 1760'

Casing Size - 11-3/4" New - 47# - K 55 - Buttress
Set At - 0' - 1706' - 41 Joints (1705.27').

Cement Job - Sting into float collar @ 1622' using 5" drill pipe with a stab-in adapter. Circulate and condition hole and mud for cement job. Pumped 20 bbls. saltwater ahead of cement followed by 300 sacks of class "H" cement with 50% sperelite + 40% SSA-1 + .5% Halad 344 + .2% HR-4 + 4% gel - Displaced with 28 bbls of saltwater. Good circulation throughout job and good cement returns. HOWCO Guide Shoe @ 1706' and HOWCO super seal Float Collar @ 1622'. Float held after job. WOC 12 hours. Cement fell in annulus 200'. Ran 1¼" tubing into annulus to 185'. HOWCO mixed 96 sacks of class "H" cement and pumped into annulus. Good cement returns to surface. WOC 12 hours. Cement did not fall in annulus. Samples showed good compressive strength after 12 hours and excellent compressive strength after 24 hours.

Bit History
Bits used - - - - 4
Size - - - - 14-3/4"
Feet per hour average - 13.7'
Total rotating hrs.- - 116.5

Comment: 1 mill tooth bit was used to drill out approximately 1500' of cement from the cement plug jobs. This bit drilled no formation.

Problems encountered this section of hole:
Plugged Bit @ 303' (rust - dc's).
Plugged Bit @ 333' (rust - dc's).
Plugged Bit @ 1152'(rust - dc's & dp).
Plugged Bit @ 1246'(rust & fill - dp & fill, no float because of rust).

High Torque drilling from Approximately 300' to 920' with worst torque occuring while drilling volcanic breccia and trachyte formation between 670' and 920'.

Loss Circulation @ 179' -	280 bbls. -	2 LCM Pills
Loss Circulation @ 231' -	20 bbls. -	1 Gunk Pill
Loss Circulation @ 303' -	40 bbls. -	1 LCM Pill
Loss Circulation @ 330' -	80 bbls. -	1 LCM Pill
Loss Circulation @ 680' - 735'	200 bbls. -	Carrying LCM in Mud
Loss Circulation @ 1152'- 1165'	100 bbls. -	Carrying LCM in Mud

Description of Drilling Operation by Hole Size and Depth:

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SURFACE HOLE: (cont.)

Loss Circulation @ 1214'-	80 bbls. -	Carrying LCM in Mud
Loss Circulation @ 1246'-	100 bbls. -	Carrying LCM in Mud
Loss Circulation @ 1491'-	50 bbls. -	1 Gunk Pill
Loss Circulation @ 1522'-	50 bbls. -	1 Gunk Pill
Loss Circulation @ 1645'-	30 bbls. -	1 Gunk Pill
Loss Circulation @ 1757'-	50 bbls. -	1 LCM Pill
Loss Circulation @ 1760'-	750 bbls. -	1 LCM Pill

Rig Repairs - Rotary Chain. 1½ hrs. RR.
Rig Repairs - Broken Right Angle Drive Housing and Gears. 92 hrs. RR.
Rig Repairs - Replace Drive Pins in Kelly Bushing. 2½ hrs. RR.
Rig Repairs - Repair Rotary Chain. ½ hr. RR.
Rig Repairs - Repair Rotary Chain. ½ hr. RR.
Total Hours Rig Repair this section = 97.

Rig Shut Down Awaiting Resupply of cement and mud materials. 91 hrs.

Cement Plugs set @ Loss Circulation Zones.	150 Sacks @	158'.
" " " " "	150 Sacks @	158'.
" " " " "	70 Sacks @	180'.
" " " " "	120 Sacks @	180'.
" " " " "	200 Sacks @	647'.
" " " " "	100 Sacks @	1073'.
" " " " "	75 Sacks @	1104'.
" " " " "	100 Sacks @	1203'.
" " " " "	100 Sacks @	1482'.
" " " " "	90 Sacks @	1650'.
" " " " "	115 Sacks @	1748'.

Total Cement used in the 11 Cement Plugs = 1270 Sacks.

Stuck Pipe due to Differential Sticking - @ 1238'.
Stuck Pipe due to differential and fill - @ 1398'.

Comment: This section of hole caused the most drilling problems due to the Circulation problems caused by the 13 loss circulation zones encountered between 179' - 1760'. The amount of LCM, Polymer and Cement available for the project turned out to be of critical importance due to the amount and severity of the problem. As in any exploration well all data was considered and it was noted that the latent possibility of shortages exsisted with our consumables and as such additional orders were placed as possible within the framework of the budget. Unfortunately these supplies proved to be inadequate and no amount of adroitness was able to avoid the delay, (91 hrs.),caused by the required shut down of operations awaiting additional supplies. The now obvious answer to this problem, a larger supply of consumables. (larger budget). (cont. page 26)

Description of Drilling Operations by Hole Size and Depth:

Comment: (cont.). The bits and stabilization used in this section of hole proved to be very good. The bits averaged 531.3' each and had an average penetration rate of 13.7'per hour which is very good for this size hole. ShockSubs should be used through these large sections of hole or a downhole motor used to mitigate or eliminate the very high torque loads generated on the surface equipment and drilling assembly. The stabilization kept the hole straight and no fishing jobs have occured due to failures in the connections of the BHA. Because low angle was present no problems have developed from "keyseats" or excessive drag in the hole. During the first part of the hole a problem developed in the form of plugging of the drill collars , usually at the bit or float, from rust inside the drill collars and drill pipe received from Brazil. Pounding on them removed quite a bit of the looser rust but we finally had to resort to blowing through each joint with high volumes of air, from the air compressiors, while pounding on them to solve the problem The lost time caused by "Rig Repairs", (97 hrs. total), was primarily from the one event with the "Right Angle Drive", (92 hrs.) in which we were required to wait on a new one to be sent from the United States. A spare unit is now kept on hand.

****

INTERMEDIATE HOLE:

Hole Size	–	10-5/8"
Depth	–	1760' – 4605'

Casing Size	–	7-5/8" New – 26.40# – K 55 – Buttress
	–	7-5/8" New – 26.40# – N 80 – Buttress
	–	7-5/8" New – 26.40# – S 95 – Buttress
Liner Hanger	–	Midway single slip with short receptacle
Float Equipment	–	HOWCO Superseal FC & Superseal FS
Casing Hung At	–	Top of Liner @ 1406' & Bottom of Liner @ 4543'

Cement Job – Hung Liner and circulated and conditioned hole for cement job. HOWCO cemented as follows: Pumped 10 bbls saltwater ahead cement, mixed a lead slurry of 192 sacks class "H" cement + 40% SSA-1 + 55 sacks perlite + .5% Halad 344 + .2% HR-12 + followed by Tail-in slurry of 560 sacks of Class "H" cement + 40% SSA-1 + .5% Halad 344 + 2% Gel + sacks perlite + 3% Sperelite + 2% HR-12. Started displacement and cement flash set with 42 bbls. of displacement remaining (911') in casing. Full circulation prior to cement flash setting. Pressure tested top of liner hanger and found it leaking. Howco established an injection rate of 1½ bbls. per minute at 2000 psi. Set 105 sack balanced plug of class "H" cement and "Braden Head squeezed cement into lap. (cont. on page 27)

SECTION 3 (cont.)

Description of Drilling Operations by Hole Size and Depth:

Cement Job (cont.) WOC. Tested lap and was able to pump into lap @ 3/4 bbl.per minute at 500 psi. Set 50 sack balanced plug of class "H" cement and "Braden Head squeezed cement into lap. Had pressure drop to 150 psi. Stage squeezed until cement was displaced to lap with no pressure increase. Mixed 60 sacks (last of cement) class "H" cement and set a balanced plug. "Braden Head" squeezed cement by stages into lap. Had a gradual increase to 450 psi at end of displacement. WOC. Tested top of lap with 500 psi OK.

Bit History
Bits used - - - - - - 3
Size - - - - - - 10-5/8"
Feet per hour average - Air Bit - - - 16.6
Feet per hour average - Journal - - - 28.1
Total rotating hrs.- - - - - - - - 124.5

Comment; 1 mill tooth bit was used as a clean out bit and drilled no formation. The air bit made 900' in 54¼ hrs and graded 8-8-½". The journal bearing bit made 1974' in 70¼ hrs and graded 1-7-I. This was an extreamely good run for a bit of this size. Stiff Foam was used as the circulating medimum with very good results.

Problems encountered this section of hole:
Plugged Bit @ 2664' (rust - dp).

Sloughing hole between 2000' - 2070'. Blowing out 1" size pieces of formation, (light green colored clay altered ash and lapilli).

Tight hole @ 2060'. Appears to be some type of swelling clay from the sloughing zone. Not too difficult to work through. Does not drag coming up.
Tight hole @ 2500' after two months shut down. Minor reaming took care of it.

Due to delays in shipping cement and supplies to project it became necessary to suspend drilling operations and demobilize the personnel for a two months period.

Partial Loss circulation to hole during suspended operations. 50 bbls per day were needed to fill hole.
After start-up of operations 1 - 200 bbl. 25% LCM and 1 - 100 bbl. 25% LCM pills were circulated around and Loss continued at 35 bbls per hr.

Rig Repairs - Replace fillup line valve. ¼ hr. RR.
Rig Repairs - Work on transmisson shiffter lines. ½ hr. RR.
Total Hours Rig Repair this section = 3/4 hr. RR.

Comment: This section of hole had very few drilling problems or mechanical problems with the equipment. The sloughing problem was not a major problem as far as the drilling was concerned but may have played a part in the bridging or flash setting of the cement during the casing cement job. Drilling continued ahead past the 4000' casing depth to 4605'while waiting on resupply of cement. Insufficient supplies arrived and rig was shut down on long term stack rate.

Section 3 (cont.)

Description of Drilling Operations by Hole Size and Depth:

PRODUCTION HOLE:
Hole Size - 6-3/4"
Depth - 4605' - 10,172'

Casing Size - No casing set or planned at the present time.

Circulation Medimum - Stiff Foam & Air Foam.

Bit History

Bits Used	- 10
Size	- 6-3/4"
Feet per hour average	- 29.6'
Total rotating hrs. this section	- 188.3

Comments: Bit #9 Mill tooth bit was used only to drill out cement, FC & FS and made 61' of new hole. Bit #14 was only run 10.5 hrs. we ran out of drillpipe @ 8706'. Bit #15 drilled hard cement from squeeze job and 10 hrs. of new hole and was out of gauge ½". This small size bit will not be able to be run over 10 - 11 hrs. in the bottom 2000' of hole because of the temperature.

Totals for well.

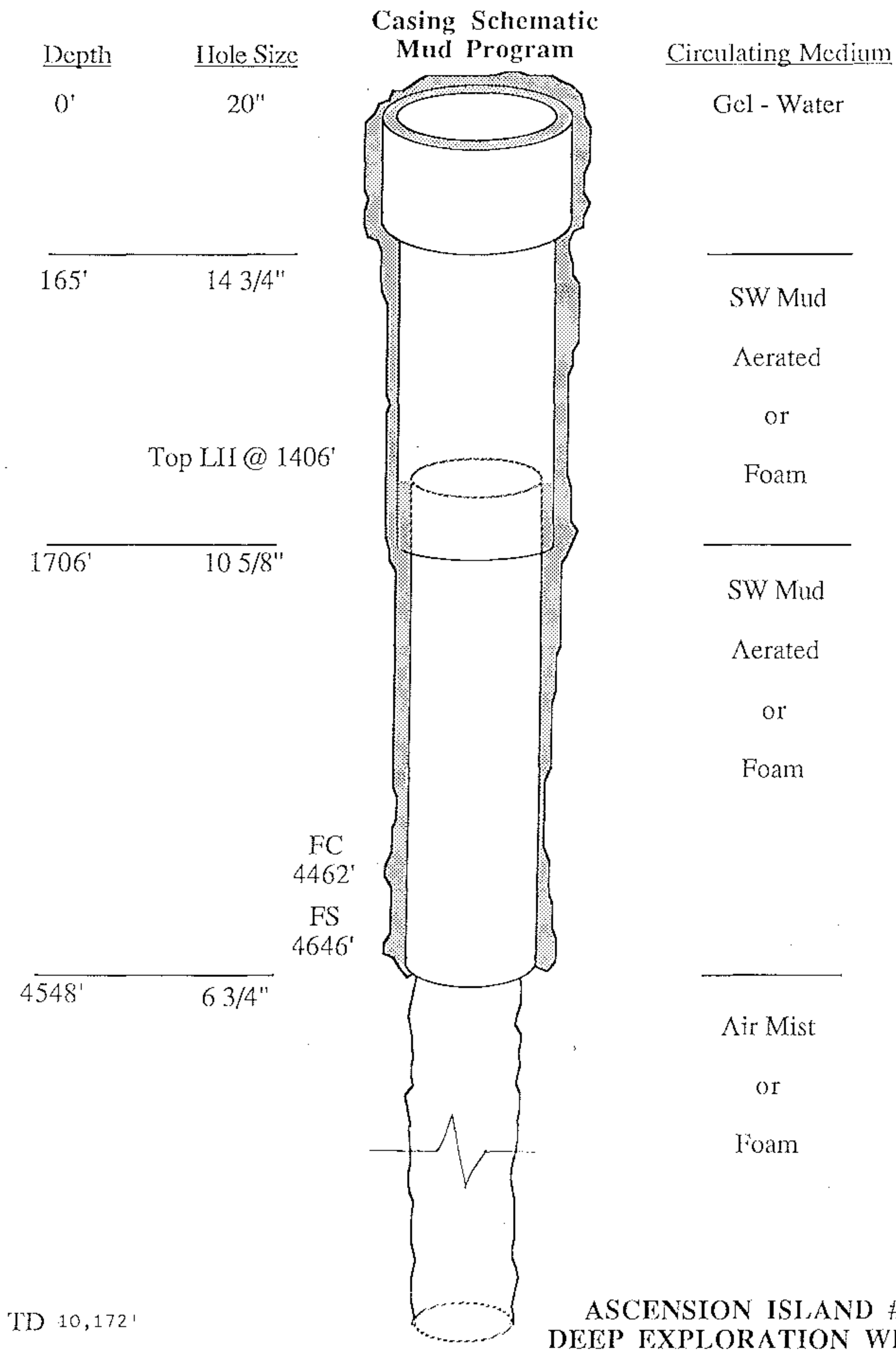
Total Number of bits for well	- 18
Total Rotating hrs. for well	- 429
Total Drilling Days for well	- 17.88
Total Operational Days	- 73

Problems encountered this section of hole:
Plugged Bit @ 4923' (Seals on bottom float failed and let in fill).

Rig Repairs - Tong Safety Lines, Replace. 1½ hrs. RR.
Rig Repairs - #1 Engine. ½ hr. RR
Rig Repairs - Breakout Air Valve, Replace. ½ hr. RR.
Rig Repairs - 4" Standpipe Union washed out, Replace. 3½ hrs. RR.
Rig Repairs - Water Pump, Repairs. 9 hrs. RR.
Rig Repairs - Monkey Board, Rusted out Guard Rails, Replace. 2 hrs. RR
Rig Repairs - Air Valve, Replace. ½ hr. RR.
Rig Repairs - Mudline on mud pit, Repair. 2 hrs. RR.
Rig Repairs - Air Hose & Low Drum air release valve, Repair. 1½ hrs.RR.
Total Rig Repairs this section = 18 hours.

Stuck Survey Instrument Sinker Bars because of broken landing plate. Lost bottom of sinker bars landing nose. Backed off fine thread.

Comments: This section of hole drilled very good considering the high hole angle. High Temperature became a problem for Bit Bearing life in the bottom 2000' of hole. The 5" tool joints on the 15.50# 3½" drill pipe restricted air circulation and hole cleaning the deeper we got. Estimate 11,000' to be approaching limit that this size hole would work, probably less with more water entry. The stabilization used in the bottom section of the hole worked very good but did not wear well because of the higher hole angle.



ASCENSION ISLAND #1
DEEP EXPLORATION WELL

(Figure 4)

****

* ASCENSION ISLAND WELL NO. 1 *

****

*** BIT RECORD ***

RUN NO.	SIZE	COMPANY	TYPE	SERIAL NO.	DEPTH OUT	FEET	HOURS	CUM. HRS.
1	20"	HTC	R2	MC692	173	173	13	13
2	14-3/4	HTC	R1	MC740	303	137	9	22
3	14-3/4	HTC	X44	BE911	1152	849	53½	75½
4	14-3/4	HTC	X44	BE912	1760	608	54	129½
5	14-3/4	HTC	R1	MC693	1731	Drill out cement		
6	10-5/8	HTC	HH33	KP741	2631	900	54¼	183.6
7	10-5/8	HTC	J22	LC172	4605	1974	70¼	253.9
8	10-5/8	HTC	J1	LK085	4605	Clean out bit		
9	6-3/4	HTC	R4	CJ882	4666	61	1	254.9
10	6-3/4	HTC	J55	AX352	5460	794	24½	279.4
11	6-3/4	HTC	J55	AX312	6287	827	33¼	304.3
12	6-3/4	HTC	J55	AX482	7301	1014	39½	343.8
13	6-3/4	HTC	J55	AX344	8360	1059	34½	374.5
14	6-3/4	HTC	J55	AX341	8706	346	10½	385
15	6-3/4	HTC	J22	HN837	8996	290	10	395
16	6-3/4	HTC	J55	AW452	9375	379	11	406
17	6-3/4	HTC	J44	CT877	9885	511	13	419
18	6-3/4	HTC	J44	DA435	10172	287	10	429

TOTAL ROTATING HOURS -- * 429 *

4.0 GEOLOGY

4.1 Structural Setting

Geologic mapping and the aeromagnetic survey conducted as part of this project emphasized the definition of fault systems which could be the conduits for geothermal fluids. These data have been interpreted in terms of a three part rift system which is shown in Figure 4-1. Well Ascension #1 is located within the southwestern rift. Prior to the completion of Ascension #1, the northern boundary of this rift was assumed to be buried under more recent volcanic rocks. The southern portion of the rift was identified during the geologic mapping as a series of faults and basaltic dikes intruding faults to the south of the drill site.

When locating Ascension #1, it was assumed that the high thermal gradients encountered in gradient holes GH-1, 6 and LDTGH were a result of discharge of geothermal fluids from faults which make up part of the rift system. The well was located near the gradient hole with the highest temperatures (LDTGH) since no specific fault could be identified which would serve as a drilling target.

Figure 4-2 is an aeromagnetic map of the vicinity of Ascension #1 from Ross et al (1984). This data defines the boundary between an area containing rocks with a high magnetic signature to the north from an area of low magnetic signature to the south. Ross et al have modeled this boundary, and this result is also shown in Figure 4-2. It is believed that this

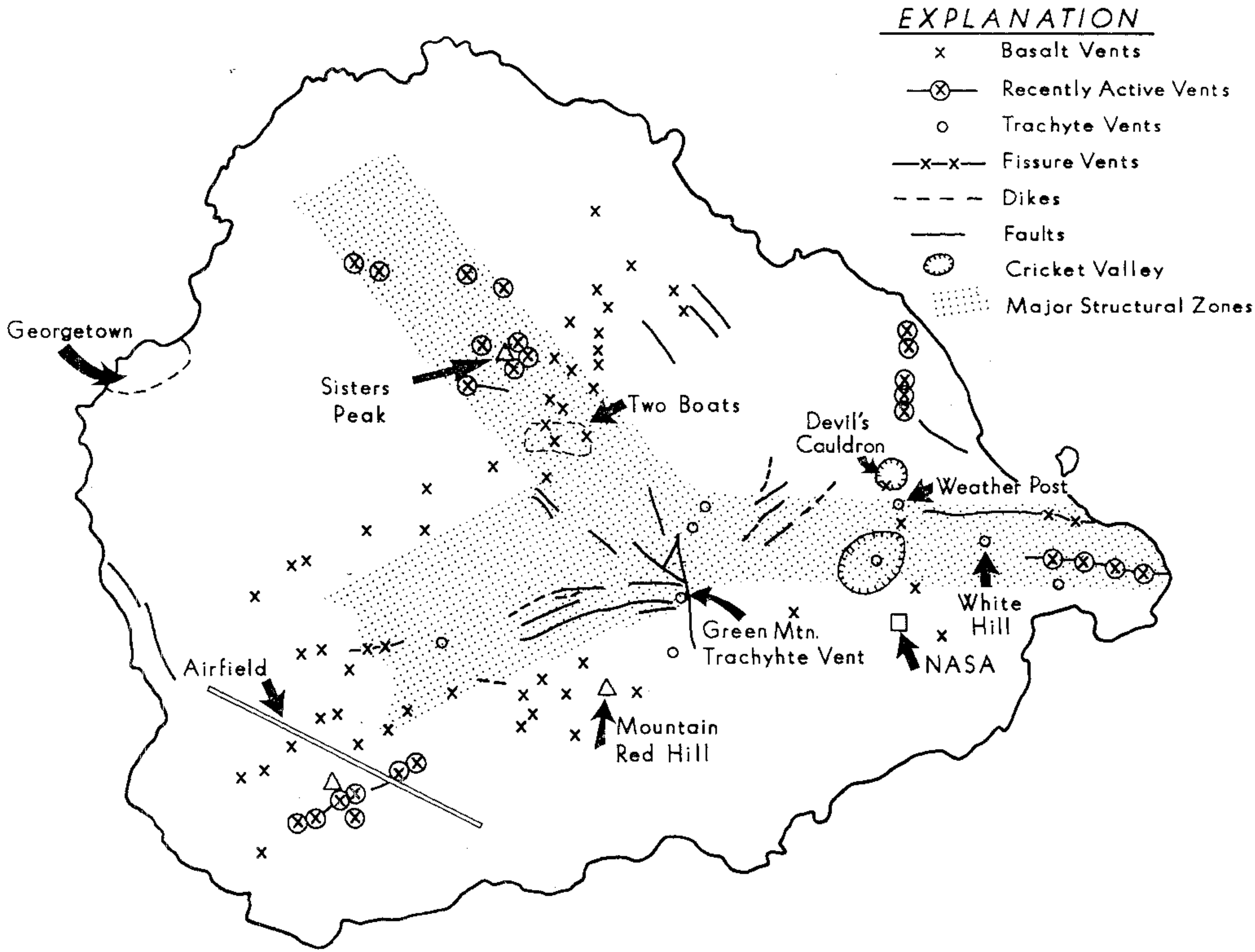
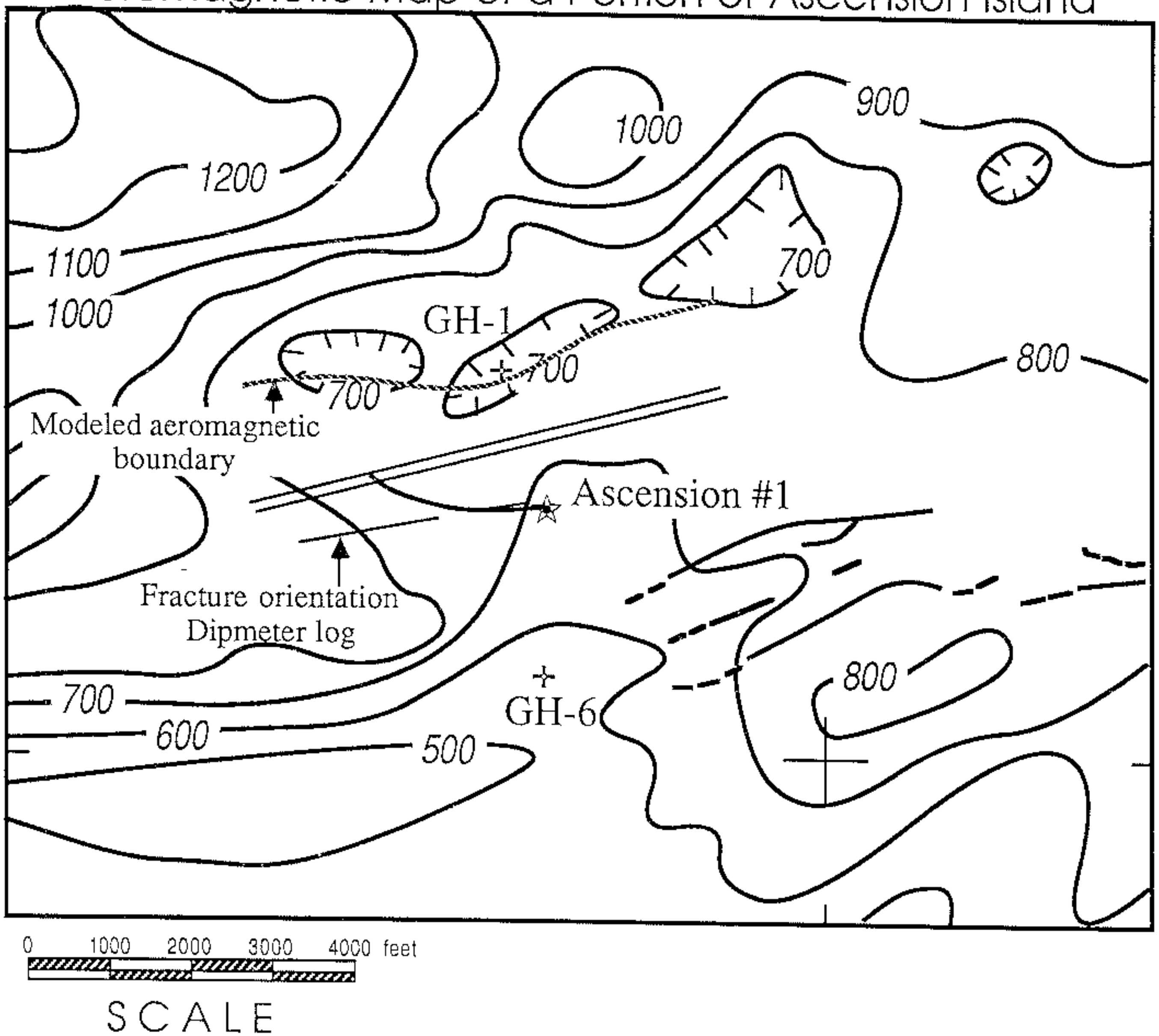

EXPLANATION
Basalt Vents
Recently Active Vents
Trachyte Vents
Fissure Vents
Dikes
Faults
Cricket Valley
Major Structural Zones
Georgetown
Sisters Peak
Two Boats
Devil's Cauldron
Weather Post
White Hill
NASA
Green Mtn. Trachyhte Vent
Airfield
Mountain Red Hill

Figure 4.1

Structural Compilation - Ascension Geothermal Project
Aeromagnetic Map of a Portion of Ascension Island



signature represents the near surface expression of the northern boundary fault of the southwestern rift system. As will be detailed in the final section of this report, this is the fault zone that is hosting the geothermal system at depth, and that will be the target of future exploration.

4.2 Lithology of Ascension #1

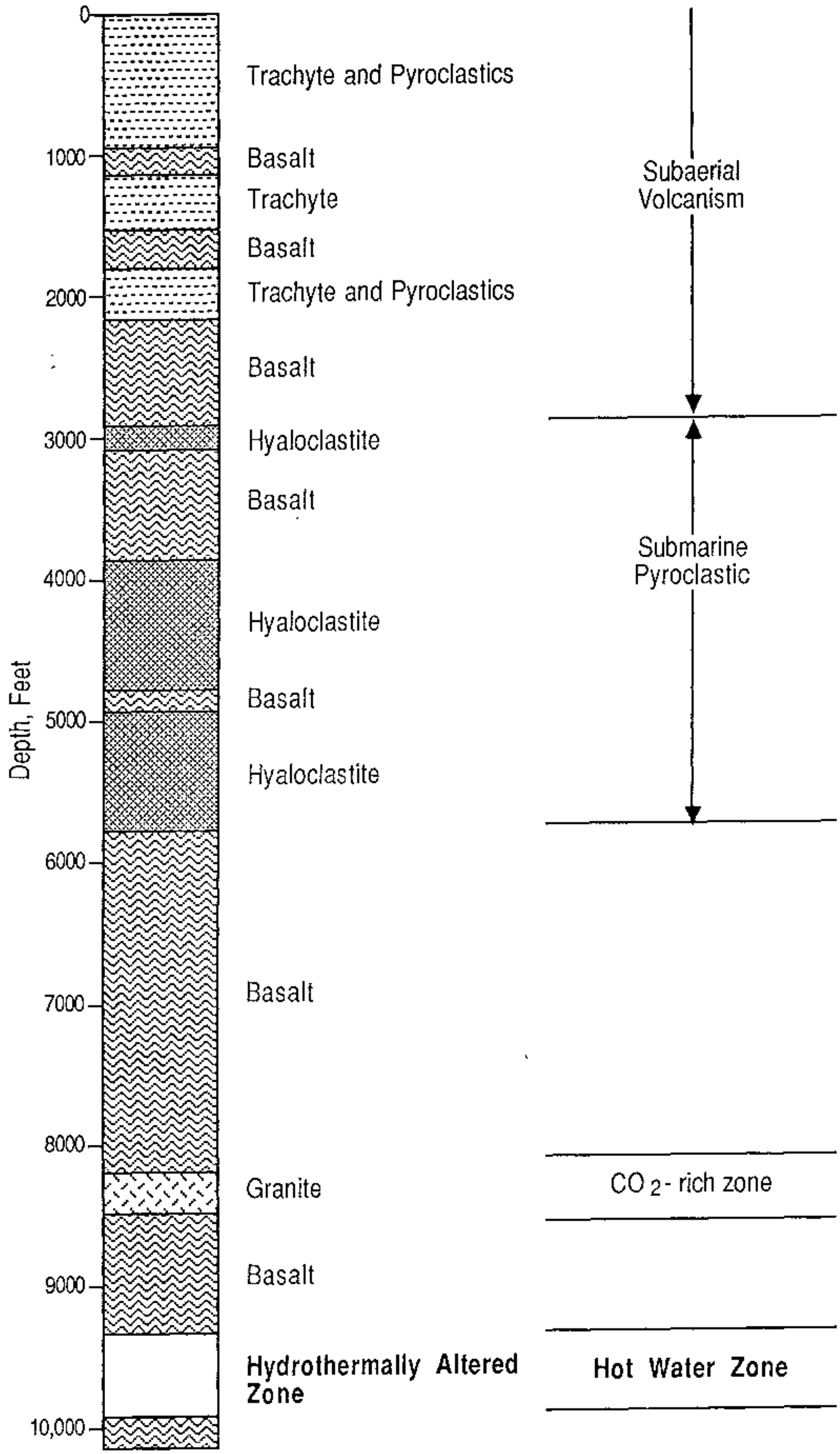
The rock units encountered in Ascension #1 are summarized in Figure 4-3. The well passed through a sequence of volcanic rocks which were formed in a subaerial environment to a depth of 2910 feet. All of the primary felsic volcanic rocks found in the well occur above this point demonstrating that the bulk of the felsic volcanism is recent in the history of the formation of the island.

Below 2910 feet the rocks were either deposited in a submarine environment or intruded into their present positions as dikes. The submarine volcanic rocks are largely basalt flows and hyaloclastites. Hyaloclastites are the submarine equivalents of basaltic ash. They are generally believed to be indicative of eruption within 1500 feet of the surface of the ocean. As will be discussed in a subsequent section, these rocks have been largely altered due to their contacts with seawater and position within a strong thermal gradient.

Below about 5800 feet the sequence is largely basalt flows. From the cuttings samples collected, it is difficult to impossible to distinguish between dikes and flows. Therefore, on the generalized stratigraphic column, the lithologic description

Figure 4.3

Generalized Stratigraphic Column - Ascension #1



basalt is given rather than attempting to distinguish the origin of different units.

At 8200 feet, the well intersects a dike of fine-grained granite. At the top of this unit and in the overlying fractured basalts, CO_2-rich fluid entries are present. The entries are associated with fracturing as evidenced by cuttings samples, drilling breaks, and geophysical well logs. The lower portion of the granite and underlying basalt section contain relatively few fractures.

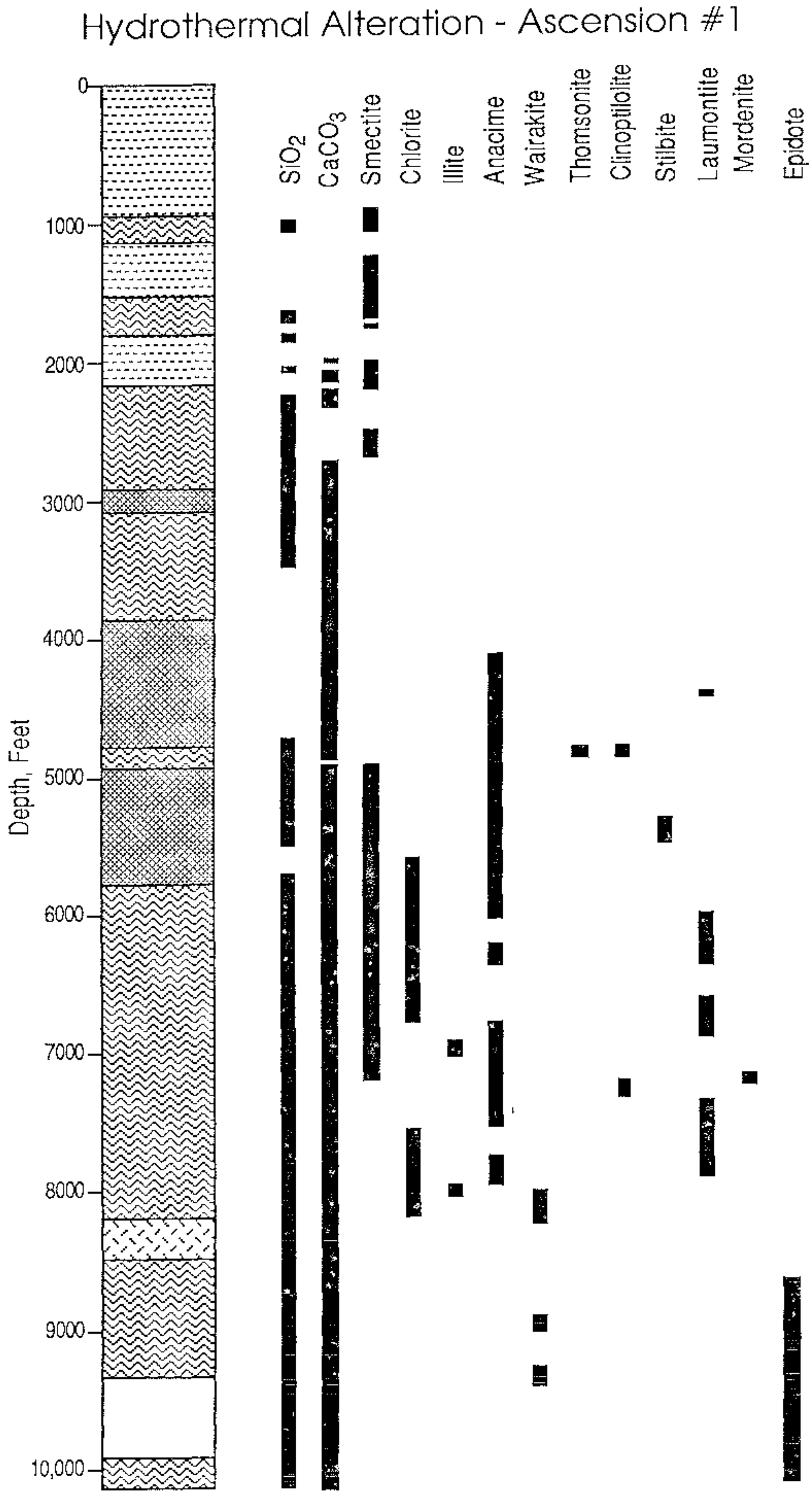
At 9350 feet the well intersected a zone of intense hydrothermal alteration which extends to 9680'. From 9680 to 9770 feet there is a sequence of unaltered basalt. A similar hydrothermally altered section is present from 9770 to 9820 feet. From here to the bottom of the well, the rock is identified as a metabasalt with continued fine quartz + epidote veining.

4.3 Alteration Mineralogy

Minerals developed through the interaction of hydrothermal fluids and rocks provide information on both the thermal regime and the amounts of fluids present within the rocks. Samples collected at approximately 100 foot intervals were analyzed by X-ray diffractometry to determine the constituent mineral phases present. These methods were supplemented with studies of petrographic thin sections.

The distribution of mineral phases present in Ascension #1 are summarized in Figure 4-4. The sequence of alteration

Figure 4.4


Hydrothermal Alteration - Ascension #1
Depth, Feet
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
SiO2
CaCO3
Smectite
Chlorite
Illite
Anacime
Wairakite
Thomsonite
Clinoptilolite
Stilbite
Laumontite
Mordenite
Epidote

minerals found in this well are similar to that encountered in other high-temperature geothermal systems.

From the surface to about 4100 feet, alteration is dominated by smectite and calcite. The smectite is formed through the alteration of volcanic glass. The calcite is formed by precipitation from groundwater. Both occurrences are common at low temperatures, and there is little geothermal significance to their presence.

At 4100′ the zeolite analcime forms, and the rocks enter the zeolite facies of metamorphism. At increased temperature, laumontite also forms. In addition to these principal zeolite species, thomsonite, clinotilolite, stilbite, and mordenite were also detected in the X-ray diffraction patterns, but these minerals have a rather limited distribution. Chlorite and another smectite zone are also present with the zeolite assemblage. At about 8000 feet, both laumontite and analcime disappear.

Wairakite is a high-temperature calcium zeolite which appears at about 8000′. This mineral is characteristic of high-temperature hydrothermal systems, and forms in systems at approximately 400^{o}F (Bird et al., 1984). This is the temperature at which the mineral is formed in Ascension #1.

Epidote is first encountered at 8700′. This mineral has been reported from virtually every geothermal system where temperatures exceed 400^{o}F (Bird et al., 1984). Epidote becomes a dominant phase in the rock at a depth of 9340 feet. Thin sections show that the epidote forms radiating crystal aggregates and is intimately intergrown with quartz. The zones containing abundant epidote show indications of extensive fracturing, and these fractures are apparently cemented by epidote.

Grains of quartz and epidote were selected from a depth of 9510 to 9520 feet and polished to allow the measurement of fluid inclusions. Primary inclusions in quartz gave homogenization temperatures averaging 431°F and those in epidote averaged 428.5°F. The measured temperature at this depth was 455°F which is a minimum temperature considering the short amount of time the hole was allowed to equilibrate following cooling with sea water. Therefore, the zone of intense hydrothermal alteration has heated since the abundant epidote and quartz were deposited. The salinity of the inclusions was also determined through freezing measurements. Those in the quartz were determined to average 3.21 equivalent weight percent NaCl, and those from the epidote, 3.53 weight percent NaCl. As will be seen in Section 5, these measurements compare favorably with a fluid composition of 3.92 weight percent total dissolved solids measured from a sample taken at 9885 feet.

These zones of intense hydrothermal alteration are interpreted as being a partially sealed zone associated with a hydrothermal reservoir which occupies the same structure. Hydrothermal minerals most often deposit in areas where the thermal gradients are steepest, since the solubility of quartz in particular is strongly temperature dependent. The fact that present temperatures are higher than when the bulk of the alteration took place is interpreted as indicating that the hydrothermal system is still active in the proximity of Ascension #1.

5.0 Geochemical Interpretaton of Fluid from Well Ascension #1

5.1 INTRODUCTION

This section documents the collection and interpretation of fluid and gas samples from well Ascension #1, on Ascension Island. At the time of collection of most of these samples Ascension #1 was drilled to about 8706 feet through volcanics and bottoming in a silicic intrusion. Flow in the well is two-phase, with a large gas component.

5.2 SAMPLE COLLECTION AND ANALYSIS

Samples were initially collected at a 1/2" sample port about 30 feet upstream of the end of a James tube. Chemical analysis of these samples indicated that the salinity of the samples was changing from minute to minute because of the randomly heterogeneous two-phase flow. The liquid samples were subsequently taken from the end of the James tube, where the salinity changes were less frequent. The frequency of the salinity changes were checked with an on-site conductivity meter. The fluid samples were filtered through 0.45 m membranes and preserved with nitric acid. Analysis of the fluid cations was made by inductively coupled argon plasma spectrometry using the techniques and instrumentation described by Christensen and others (1980). Analysis of the anions was made using standard wet chemical techniques.

Chemical analyses of the liquid and gas samples are listed on Tables 5-1 and 5-2, respectively. Liquid samples were analyzed at UURI for 36 major, minor, and trace cations by ICP and for the anions Cl, F, SO_4, Br, and carbonate. Gas samples were analyzed at a commercial laboratory for H_2O, CO_2, H_2S, NH_3, Ar, N_2, CH_4, and H_2. Isotopic analyses are listed in Table 5-3. Sulfur isotopes were analyzed at a commercial laboratory, H, O, and C isotopes at Southern Methodist University, He isotopes at the Savannah River Nuclear Reactor facility, and sulfate O isotopes at the University of Waterloo.

The gas phase was sampled using an U.S.G.S. mini-cyclone separator connected to a sample port about 40 feet upstream of the end of the James tube. The temperature at the sampling port averaged 85^{o}C and the pressure varied from 3 to 10 psig during sampling. Under these conditions the two-phase mixture was not hot enough to support a true steam phase. Instead, the flow apparently consisted of a mixed brine + condensate aerosol, a gas + water vapor phase, and a brine flowing along the bottom of the James tube. Thus, the cyclone effect was used to separate the aerosol liquid from the gas phase, although normal usage of the separator is to separate steam from boiling liquid. The conductivity of the condensed liquid from the separator steam line was measured to assure that the gas samples did not contain brine. A low conductivity indicated that the aerosol, which ranged in TDS from 100 to 350,000 ppm, was not contaminating the samples. The gas samples were taken in evacuated flasks

TABLE 5-1. Chemical Analyses of Liquid Samples

	WS87-7	WS87-20	WS87-22
Na*	18900	2370	7260
K	1200	180	497
Ca	10430	1270	3680
Mg	24.5	6.00	17.7
Fe	163	7.60	27.1
SiO2	241	265	344
B	47.6	7.68	20.4
Li	4.70	0.74	2.15
Sr	201	26.2	73.1
Ba	5.42	0.77	2.15
HCO3**	60	268	102
Cl	47100	5770	17700
F	1.04	1.90	1.00
SO4	411	56.0	134
Br			
TDS	78752	10100	26800
pH (20°C)	5.5	7.1	6.2

* Concentrations in ppm by weight.

** Total alkalinity including all titratable species, expressed as HCO3.

TABLE 5-2. Analyses of Gas Samples

Gas*	WS87-4	WS87-13	WS87-15	WS87-17	QA**
H20	3.76E+05	3.57E+05	3.03E+05	2.56E+05	
CO2	6.24E+05	6.43E+05	6.97E+05	7.44E+05	1.0
H2S	<1.43E+01	<1.37E+01	<1.37E+01	<1.63E+01	NA
NH3	<6.79E-01	<6.86E-01	<6.84E-01	<8.17E-01	NA
Ar	4.49E+01	6.28E+00	5.97E+00	3.81E+00	4.5
N2	6.11E+00	3.19E+02	4.80E+02	3.02E+02	6.9, 1.0
CH4	1.11E+01	1.20E+01	1.15E+01	1.51E+01	7.1
H2	2.81E+00	3.00E+00	3.39E+00	4.35E+00	3.1

* Gas concentrations in ppm by weight.

** Percent relative standard deviations calculated as ppm by weight. Ar, N2, CH4, and H2 RSD's are determined on actual samples and not standards. Argon precision is affected by air correction procedure.

TABLE 5-3. Oxygen and Hydrogen Isotope Analyses

Sample	c^{18}O (SMOW)	cD (SMOW)	c^{34}S (CDT)	c^{13}C (PDB)
WS87-1	+0.05	+6.8		
replicate	+0.07	+7.0		
WS87-3	+2.31	+18.9		
replicate		+19.4		
WS87-4				-2.33
replicate				-2.70
WS87-5	+1.62	+12.8		
WS87-6	-1.85	+22.4		
WS87-10	-8.11	-10.3		
replicate	-8.12	-10.9		
WS87-11	-1.99	+21.5	+9.9	
duplicate	-2.01	+22.2		
WS87-12	-0.96	-0.6		
WS87-13				-2.06
WS87-15				-3.62
WS87-17				-3.44
replicate				-3.61
WS87-21	-4.28	+16.1		
WS87-23	-4.36	+9.5		
WS87-24	-10.90	-23.5		
duplicate	-10.91	-24.1		
WS87-25	-14.68	-40.8		
replicate		-40.8		
WS87-27	+0.91	+2.0		
replicate	+0.93	+1.7		

partially filled with degassed NaOH. The flasks were filled to a pressure of 1 atmosphere, absolute. A brief description of the sample conditions is given for each sample in appendix 11.3.

5.3 DISCUSSION

Reconstruction of reservoir chemistry from fluid and gas analyses requires knowledge of the conditions under which the samples were generated. For most geothermal wells, these conditions are simply the temperature and pressure of separation at the separator, and the enthalpy of the total discharge. From this information the steam fraction, produced artificially in the separator, can be defined. However, in the Ascension #1 well the flow is already two-phase and the steam fraction cannot be defined by the separator parameters. In addition, visual observations of the water content of the effluent as well as temperature and pressure records indicate that the well is not flowing in a steady-state condition. Thus, it is not possible to completely or accurately combine the gas and fluid analyses to calculate the reservoir fluid, or to directly obtain any representative sample of the reservoir fluid. However, several conclusions can be made from the individual analyses concerning the origin and temperature of the reservoir fluid. Furthermore, the gas content of the reservoir fluid can be indirectly estimated from wellbore pressure and temperature measurements.

5.3.1 WELLBORE ENVIRONMENT

Pressure and temperature surveys were run concurrently with chemical sampling. Fluid densities were calculated from the pressure gradients recorded in these surveys. The calculated densities were between those of steam and liquid water. Mahon et al. (1980) found similar densities in some New Zealand and Indonesian gas-rich geothermal wells. They attribute these densities to the formation of a CO_2 froth produced by degassing or boiling of gas-rich thermal fluid. Mahon et al. also give densities for CO_2 froths for various temperatures and bulk concentrations of CO_2. Although the pressures at which the densities are produced is not mentioned in the study, it is assumed here that they were produced at just above the bubble point. These densities, along with the calculated densities for three pressure-temperature (PT) surveys of Ascension #1, are shown in Figure 5-1. The three PT surveys were taken under very different conditions. Survey #1 was taken after the well had been open to the atmosphere through a 4 inch James Tube for about 2 months. During this two month period the wellhead pressure had dropped to 3 psig and the effluent had become very dry. As the PT tool was brought out of the wellbore during this survey, large quantities of water were released for at least two hours. As the water released the wellhead temperature and pressure increased from 85^{o}C and 3 psig to 110^{o}C and 30 psig, respectively. Surveys #2 and #3 were taken one day and two days, respectively, after the well unloaded. During survey #3 the wellhead pressure was throttled back to 80 psig.

Densities of the fluids in the Ascension #1 wellbore during surveys #1, 2, and 3 were calculated from the pressure data. Superposition of these density curves on the CO_2 calibration curves of Mahon et al. (1980), shown in Figure 5-1, demonstrate that in each survey the fluid densities decreased from the bottom to the top of the well. This decrease in density corresponds to a decrease in CO_2 weight percent with depth in the well. In addition, the densities changed between surveys. Densities during PT surveys 1 and 2, both run at similar wellhead temperatures and pressures, decreased dramatically. This observation, coupled with the visual observation that during the two months prior to survey #1 the effluent dried out, indicates that the liquid geothermal phase was collecting in the wellbore, and that this collection became more efficient as the liquid phase accumulated in the well, i.e., as the percentage of CO_2 decreased in the wellbore fluid. When the froth column was disturbed by the Kuster tool and the column of stratified densities was disturbed, some of the fluid in the froth boiled as it traveled up the wellbore. This is indicated by the 40°C decrease in the wellbore temperature from survey #1 to Survey #2.

Survey #3, run at a wellhead pressure of 80 psig, demonstrated the effect of increasing pressure on the density of the fluid in Ascension #1. As shown in Figure 5-1, the density greatly increased with the increased pressures, but the fluid did not reach the density of 0.9 to 1.0 g/cc that would indicate a

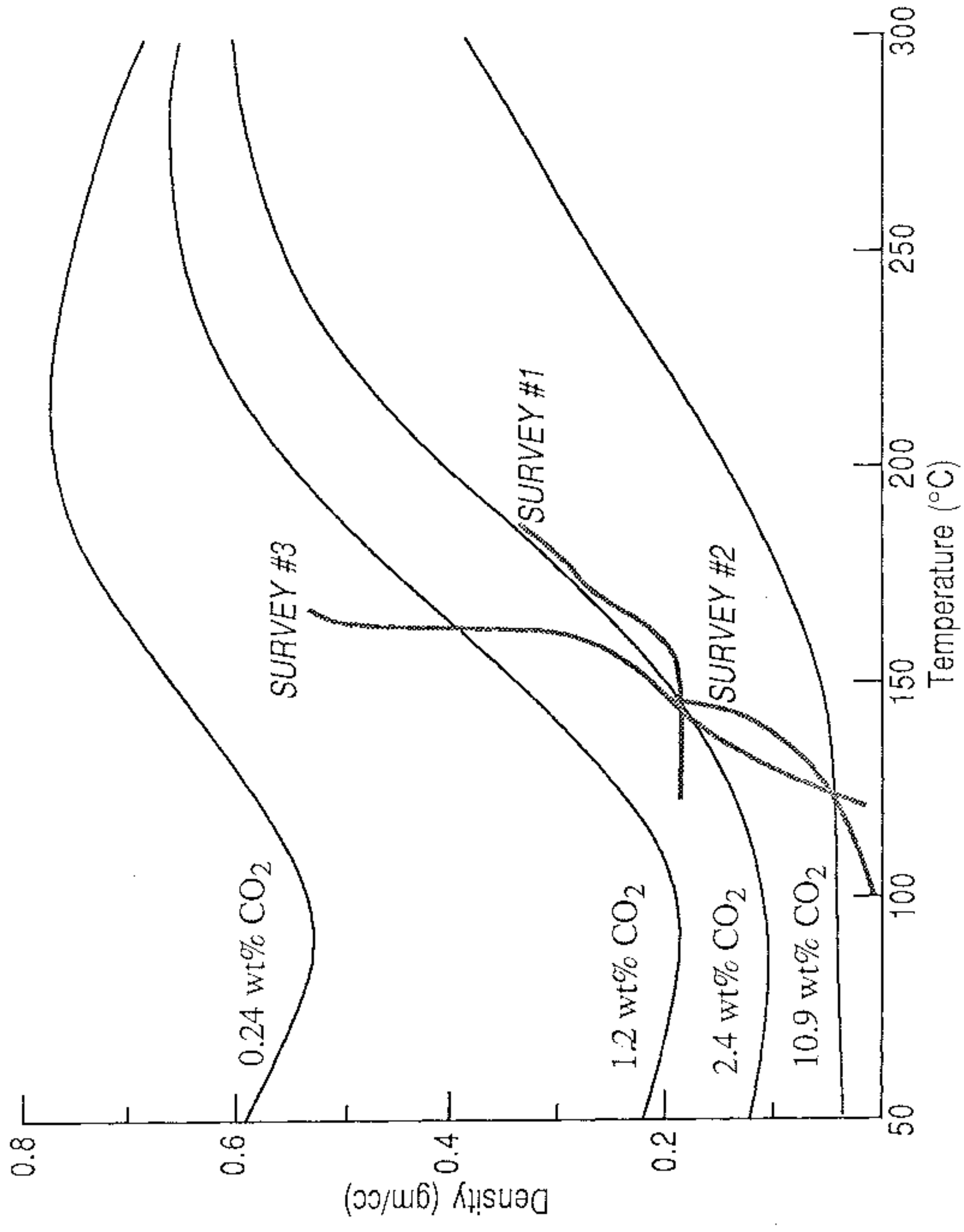


Figure 5.1.
Temperature - density plots from three wireline surveys of well Ascension #1. The density data were derived from a best fit of the downhole pressure data. Also shown are pressure - density curves for several different H_2O - CO_2 compositions (Mahon et al. 1980)

transition to a liquid phase. This implies that the fluid was not at the froth/liquid phase boundary. Thus, the standard curves of Mahon cannot be compared directly to the Ascension #1 density curves because Ascension #1 is underpressured with respect to the type curves. However, the type curves can be used to obtain a maximum CO_2 content. This sort of comparison indicates that the fluid at the bottom of the hole contains a maximum of between .24 and 1.2 wt% CO_2. By matching the bottomhole pressure of 35 bars and temperature of 167°C during survey #3, and subtracting the pressure of water, a P_{CO_2} of 28 bars and a CO_2 wt% of 1.0 is obtained.

These calculations and observations indicate that fluid at the top of the wellbore is enriched in CO_2 relative to reservoir fluid, and that this CO_2 is directly responsible for the high wellhead pressures encountered during attempts to shut in the well. At the CO_2 concentrations found at the top of the well the pressure needed to force the CO_2 into solution would be in excess of 1000 bars. During attempts to shut in the well pressures as high as 800 bars have been reached. We suspect that, if the reservoir fluid were two-phase for a significant formation volume, the gas should have compressed or gone into solution in the formation as the pressure rose. This would lower the rate of pressure increase. Thus, the reservoir fluid may be single phase.

5.3.2 FLUID COMPOSITION

Salinities of the fluid samples vary by as much as three orders of magnitude. In geothermal wells this variation can be produced by either boiling or mixing of two or more distinct fluids. In general, mixing will occur between cool meteoric water, or seawater, and hot geothermal water. This mixing will also produce a temperature reversal in the wellbore temperature profile. Since this has not been detected in the Ascension #1 well logs, a boiling process is the most probable cause of the salinity variation.

A boiling relationship between samples is reflected by a linear relationship with a zero intercept when the conservative elements boron and chloride are plotted. Figure 5-2 shows this linear relationship for most of the Ascension #1 fluid samples; the samples that plot off this line indicate mixing of the geothermal water with seawater, used as drilling fluid, in the first few samples taken from this well. Mixing of fluids is reflected on a conservative element plot as a line with two non-zero end-members. Figure 5-2b shows that although the boron/chloride ratio in the Ascension #1 fluids does not resemble seawater, the bromide/chloride ratio is virtually identical to that of seawater. This is reasonable since geothermal waters are known to rapidly pick up boron, but not bromide.

The reactive elements Ca and SiO_2 are shown in Figures 2c and 2d. Although Ca typically precipitates as calcite when most geothermal fluids are boiled, a perfectly linear relationship is

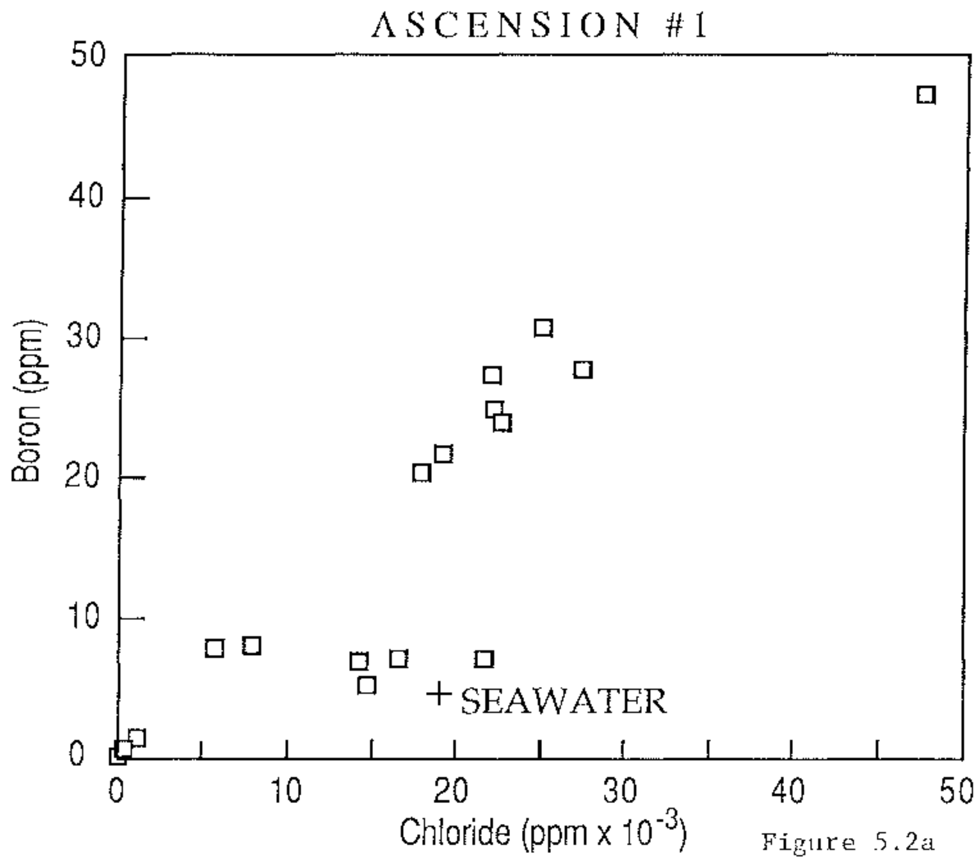


Figure 5.2a

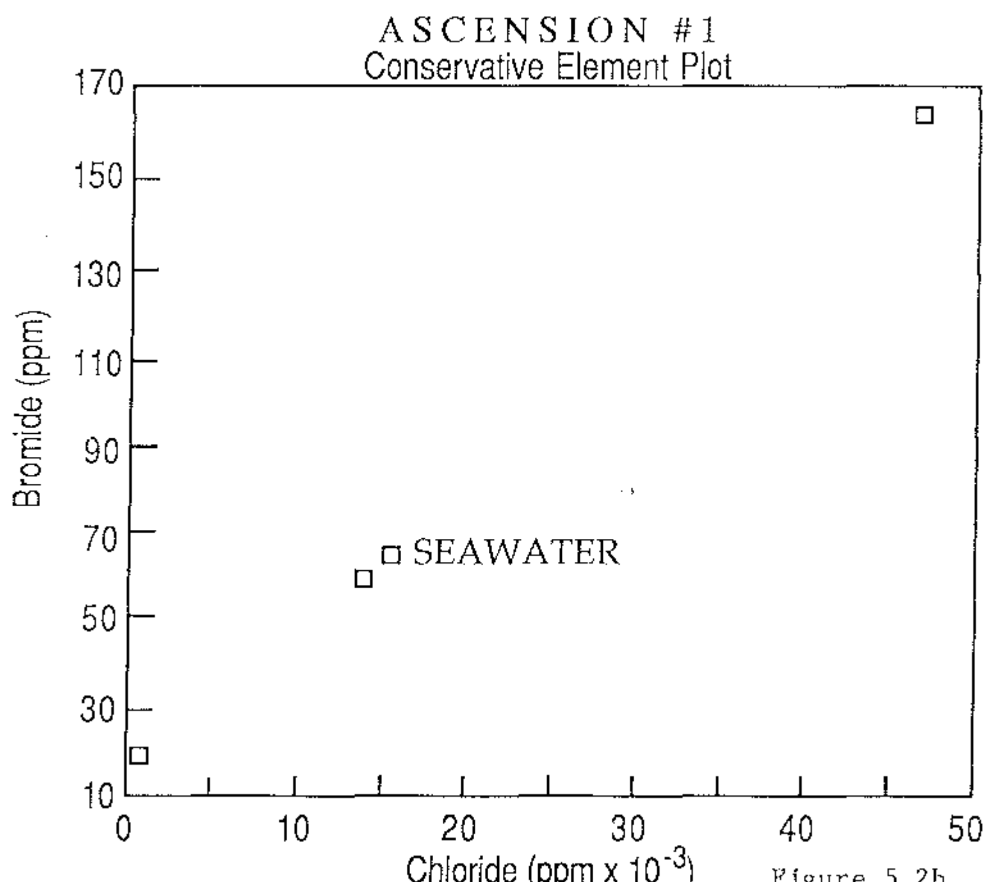


Figure 5.2b

Figure 5.2

Concentration plots for Cl vs B (a), Br (b), Ca (c), and SiO_2 (d). The data are from all analyses of Ascension #1 fluid up to March 1987.

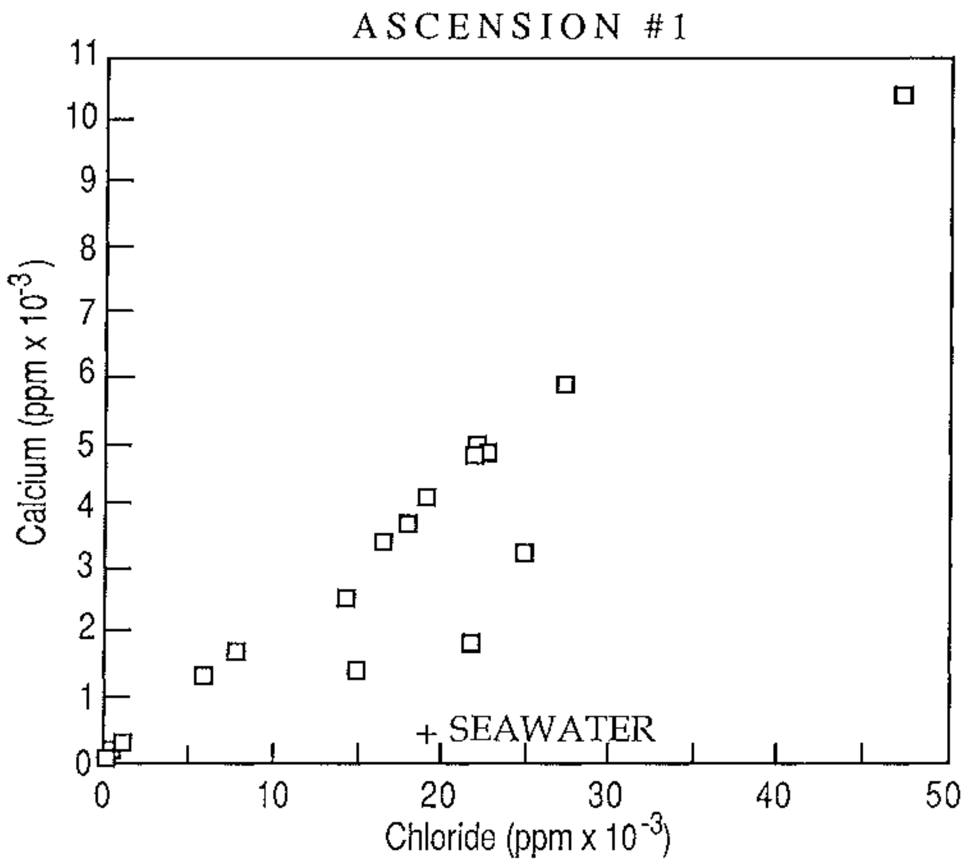

ASCENSION #1
Calcium (ppm x 10-3)
Chloride (ppm x 10-3)
+ SEAWATER
0
1
2
3
4
5
6
7
8
9
10
11
0
10
20
30
40
50

Figure 5.2c

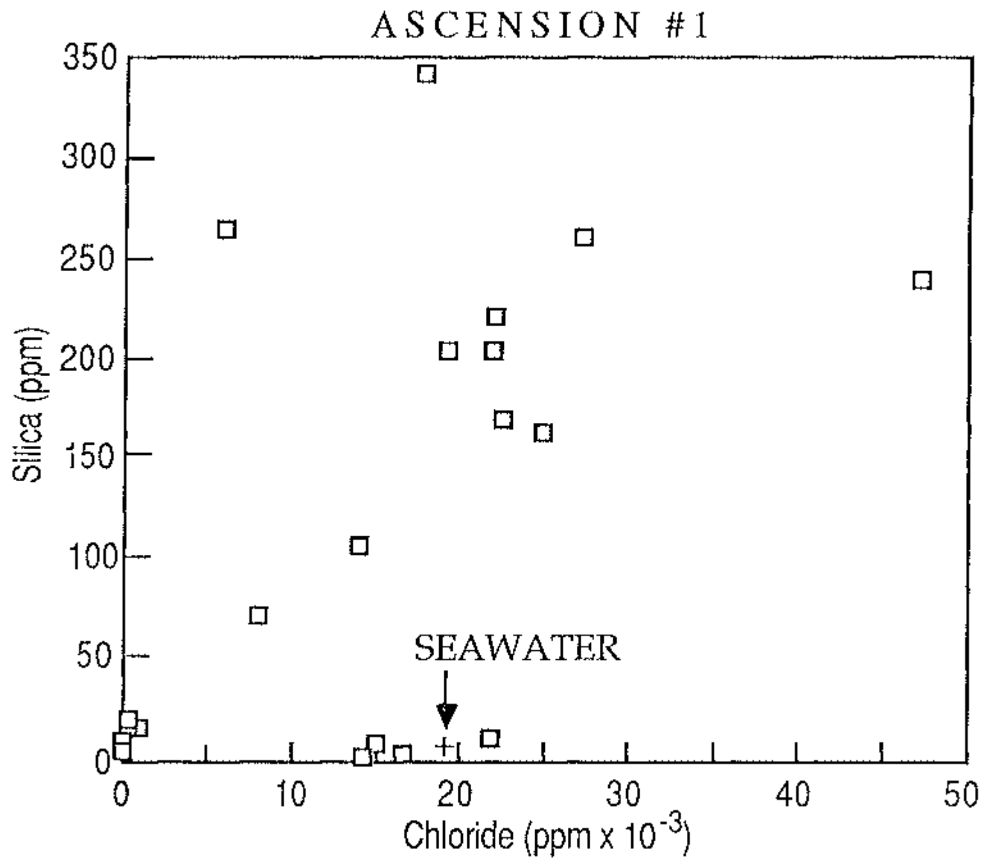

ASCENSION #1
350
300
250
200
150
100
50
0
Silica (ppm)
SEAWATER
0
10
20
30
40
50
Chloride (ppm x 10^-3)

Figure 5.2d

shown in Figure 5-2c. This relationship could only occur if the fluid boiled at the bottom of the well and immediately precipitated calcite. The CO_2-depleted fluid would then be suspended in a CO_2 froth, where lower temperatures and low CO_2 content would prevent further precipitation, even during boiling. In contrast to Ca the SiO_2 concentrations appear to reflect precipitation due to concentration from boiling and temperature decreases.

5.3.3 CHEMICAL GEOTHERMOMETERS

The use of the cation geothermometers for seawater geothermal systems is problematic. These systems were not included in the calibration of either the Na-K (Fournier, 1979) or the Na-K-Ca(-Mg) (Fournier and Truesdell, 1973; Fournier and Potter, 1979) geothermometer. Only a few such seawater systems have been explored; these are in Japan (Matsubaya et al., 1973), Turkey (Brinkmann and Kuhn, 1973), and Iceland Arnorsson, 1978). Table 5-4 lists the chlorinity, reservoir temperature estimate, and calculated Na-K-Ca(-Mg) geothermometer temperature for each system. This Table demonstrates that the Na-K-Ca(-Mg) geothermometer is completely inappropriate for geothermal seawater at low reservoir temperatures and is inaccurate at higher temperatures. It is clear from Table 5-4, however, that the major cations shift with temperature in the direction predicted by the Na-K-Ca(-Mg) geothermometer, and that this geothermometer may predict temperatures within 30°C of the reservoir temperature.

TABLE 5-4. Geothermometer Temperatures of Seawater Geothermal Systems.

Area	Chlorinity (ppm)	Estimated Reservoir Temperature (°C)	Na-K-Ca(-Mg) Calculated Temperature (°C)
Ibusuki, Japan[1]	10,895	150-200	182
Shimogamo, Japan[1]	10,990	150	175
Reykjanes, Iceland[2]	19,727	269-283	242
Svartsengi, Iceland[2]	12,070	242	242
Kaplica, Turkey[3]	16,485	42	17

1) Matsubaya et al.(1973)
2) Arnorsson (1978)
3) Brinkmann and Kuhn (1973)

Na-K-Ca(-Mg) and quartz geothermometer temperatures have been calculated for every fluid sample taken from Ascension #1 since it was drilled. The results, along with the Na content of each sample, are shown in Figure 5-3. It can be seen that the predicted temperatures are fairly constant at 170°-200°C for both of the geothermometers. Since the measured temperature is 186°C at the depth of fluid production, the Na-K-Ca(-Mg) geothermometer range may imply temperatures as high as 230°C. For the quartz geothermometer, however, the range of calculated temperatures reflects the well temperature and is the result of precipitation induced by boiling and cooling. These processes keep the SiO_2 content relatively constant and slightly supersaturated with respect to quartz. The poor correlation of Na concentration with SiO_2 concentration, shown in Figure 5-3, is a reflection of this precipitation.

5.3.4 ISOTOPIC COMPOSITION OF WATER

Hydrogen and oxygen isotopic ratios were determined on brine, gas, rainwater, seawater, and groundwater samples. The results of these analyses are shown in Figure 5-4. Also shown for reference in Figure 5-4 are the global meteoric water line (GMWL; Craig, 1963) and standard mean ocean water (SMOW). The rainwater and groundwater samples taken on Ascension island plot near the GMWL. The seawater sample plots within the accepted deviation (Sheppard, 1986) for seawater. Samples of the geothermal vapor and brine from Ascension #1 plot in a line to

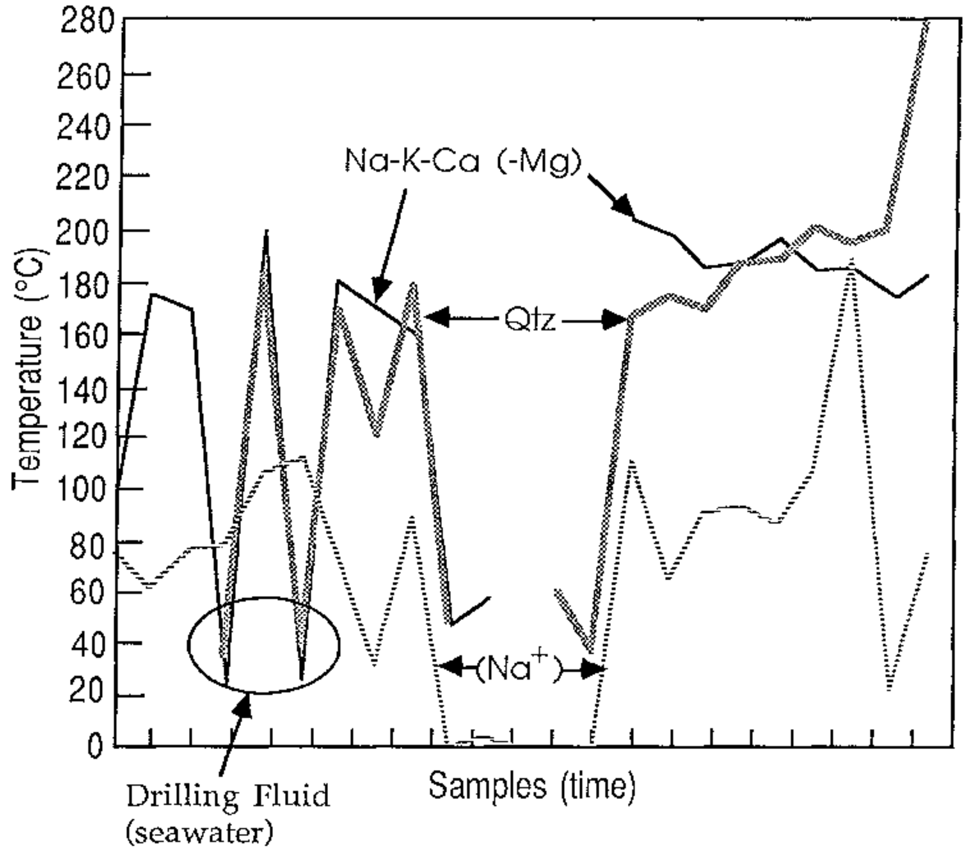


Figure 5.3

Variation of predicted reservoir temperatures (Quartz and Na-K-Ca-(Mg) geothermometers) through time. Na concentrations for each sample are shown to demonstrate the lack of a consistant dilution effect on the predicted temperatures. The x-axis tic marks represent individual samples arranged in order of the date taken so that the x-axis is in units of time (with uneven intervals).

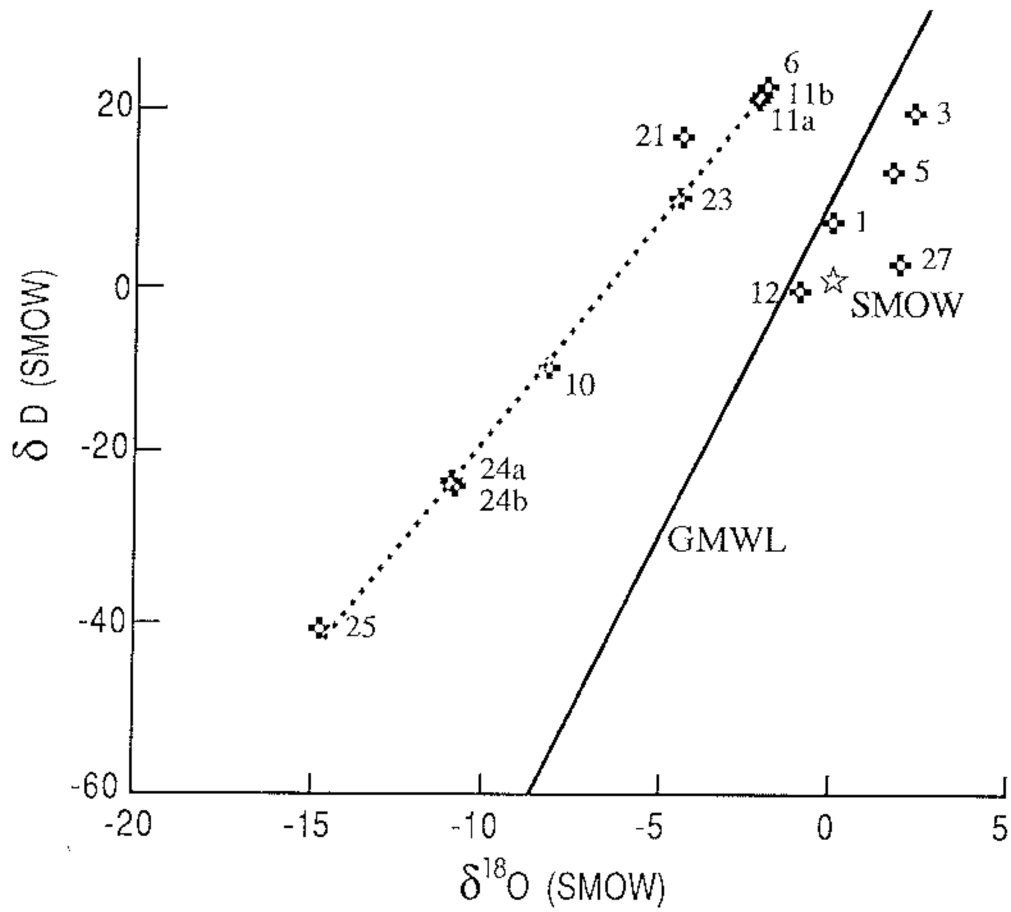


Figure 5.4

Isotopic composition of liquid and vapor water taken from Ascension #1. The numbers refer to the sample numbers. Refer to Appendix III for the state parameters and other conditions of sampling. The global meteoric water line (GMWL) and the composition of standard mean ocean water (SMOW) are shown for comparison.

the left of the GMWL. In all known geothermal systems, the recharge water is derived from meteoric water or seawater, and is frequently shifted (right) toward a heavier isotopic composition by high-temperature interaction with rock. This is opposite the shift shown by the Ascension geothermal waters. Furthermore, the range of isotopic compositions shown by the Ascension samples is larger than that found in most geothermal wells.

The linearity and range of the Ascension #1 isotopic compositions can be explained by two processes, boiling and mixing. Liquid-vapor equilibrium at 100^{o} to 120^{o}C can duplicate the observed slope of the geothermal fluids (fractionation factors from Truesdell et al., 1977). However, the range of compositions cannot be produced by single-stage boiling of any of the brine compositions. However, refluxing, or multiple condensation and boiling of the vapor from a brine, can produce the observed range. The match of the data is shown in Figure 5-5. The parameters used to match the data were a three-stage boiling process. In this model 10% of the initial brine is first boiled and the vapor condensed, then 50% of that condensate is boiled and condensed, and 50% of the final condensate is boiled. This match of the data is not unique, any number of reflux parameters can be used to fit the data. The temperature, however, is unique and indicates that the vapor being sampled from the well is produced, or last-reacted, at the top of the well where temperatures are low. These results indicate that the

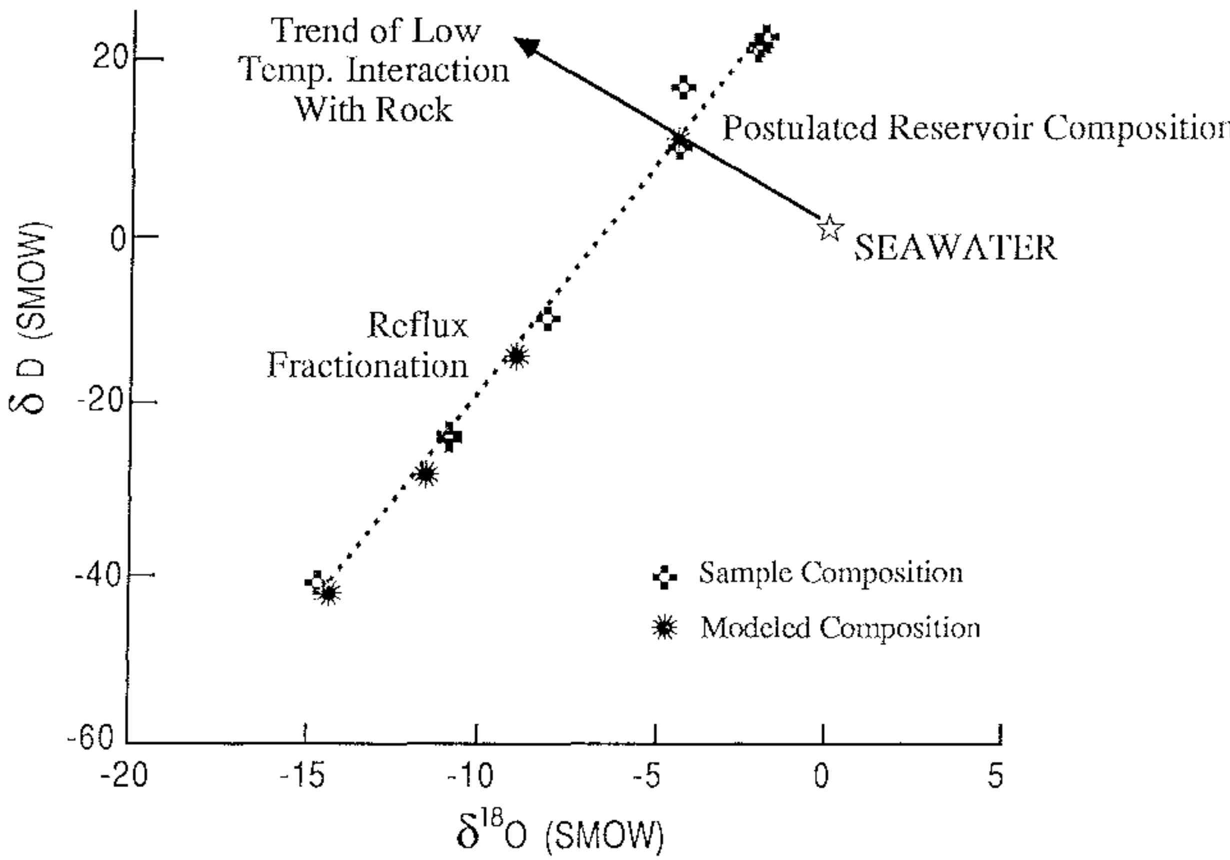


Figure 5.5

Postulated processes that led to the isotopic compositions of liquid and vapor water samples taken from Ascension #1. The postulated reservoir composition is also shown.

vapor samples are produced by reflux of the vapor and are not indicative of the reservoir composition.

The brine compositions, although depleted by boiling, do bracket the initial composition of the geothermal fluid. As an approximation a range of initial isotopic compositions can be bracketed by the three brine samples, WS87-6, -21, and -23. Two of these samples, -6 and -23, were last equilibrated at the top of the well, as indicated by the linearity and slope of their compositions. They may have been the liquid components of the foam at the top of the well. Sample WS87-21 last equilibrated at the top of the foam column, but is off the 120°C line and thus may have equilibrated at a higher temperature, i.e., at the top of a foam column that did not completely fill the well. This is rational since the well was unloaded the day before and was refilling at the time the sample was taken. WS87-6 and -23 span a chloride concentration range of 17,650 to 47,100 ppm. The lower chloride sample, WSS87-23, is similar to seawater in its chloride concentration. Seawater-geothermal fluids in Iceland have chloride concentrations close to that of seawater. Thus an oxygen isotopic composition of -4.36 per mil and a deuterium isotopic composition of +9.5 may be the composition of the reservoir fluid.

5.3.5 GAS COMPOSITION

The compositions of the four gas samples taken from the steam line of the cyclone separator are listed in Table 5-2.

These analyses indicate that the major component of the gas is CO_2, with subordinate H_2O and minor quantities of N_2, Ar, H_2, and CH_4. Concentrations of H_2S and NH_3 were below detection. As discussed above, these gas compositions cannot be combined with the liquid compositions to obtain a reservoir composition because the steam fraction is not known, and because it is suspected that the wellbore was acting as a reflux column and concentrating the gases at the top of the well. Similarly, calculated gas geothermometer temperatures are not valid under these conditions. However, since the gases were quantitatively exsolved from the fluid by boiling, their ratios can be compared with other geothermal systems.

Table 5-5 lists a comparison of the average Ascension #1 gas composition with several other systems. It is obvious that the Ascension gases, with the exception of CO_2, are depleted by several orders of magnitude with respect to other geothermal systems. However, the ratios of the some of the gases, such as the HC to N2 ratio, are within the lower range of expected values. This indicates that the excessive CO_2 contents of the Ascension fluids have diluted the other gases.

5.3.6 OTHER ISOTOPES

Some of the Ascension #1 fluid and gas samples were analyzed for sulfate, carbon, and helium isotopic composition. At the time of this report only the carbon analyses have been reported to us.

Table 5-5. Gas Compositions of Several Geothermal Systems

SYSTEM*	CO2	H2S	HC	H2	N2	NH3
Ngawhu	93.9	0.7	3.9	0.5	1	
Kawerau	94	2.6	2.1	0.3	1	2.1
Wairakei	90	4.1	2.1	0.5	2.4	0.9
Waiotapu	88	10.3	0.2	1	0.5	0.4
Broadland	94.4	1.6	2.2	0.2	1.5	1.5
Larderello	94.1	1.6	1.2	2.3		0.8
Geysers	74	0.4	5	1		5
Geysers	87	7	6	1.5		5
Ascension I.	99.9	<0.003	0.005	0.01	0.04	<0.0003

* New Zealand data from Ellis and Mahon (1977; units of % by volum Larderello data from ENEL (1970), and Geysers data from Kruger and (1973) and Konenig (1970).

The isotopic compositions of carbon dioxide from four of the gas samples are listed in Table 5-3. These values, ranging from -2.1 to -3.6, lie in the field of marine carbonate mixed with mantle CO_2 (Taylor, 1986). The mantle fraction of CO_2 in the Ascension samples ranges from about 20 to 50% by this analysis.

5.3.7 ORIGIN OF RECHARGE FLUID

The geothermal fluid from Ascension #1 is similar in ion ratios to geothermal seawater from the Reykjanes system (Arnorsson, 1978) in Iceland. Differences between the two systems in Na, K, Ca, Mg, SO_4, and HCO_3 concentrations are consistent with the higher P_{CO_2} and the lower temperature of Ascension #1 fluid. At Reykjanes the fluid has been shown to originate as seawater and has an ^{18}O near zero (Cole, 1980). Ascension Island geothermal fluid, however, has a distinctly different isotopic signature. Reykjanes and all other seawater-geothermal systems show a positive shift or no shift with respect to seawater or mixed seawater-meteoric water (Truesdell and Hulston, 1980; Matsubaya et al., 1973). This difference can be explained by the different geologic settings of the two systems. Reykjanes is part of a large and dynamic spreading ridge system. Thus, seawater would flow from the sea through rift fractures directly into the geothermal system, spending little time reacting with rock at low temperatures. Ascension island, on the other hand, is a deep, geothermal system on a volcanic hot spot surrounded by ocean floor. Seawater may percolate slowly through the seabed in such a setting, reacting with rock at low temperatures for long periods of time. The expected isotopic shifts, caused by deposition of smectites, were calculated by Ohmoto (1986) and are shown on Figure 5-5. This trend intersects that of the Ascension geothermal waters very near the composition of WS87-23. The composition of this sample nearly matches the salinity and bromide concentration expected for a geothermally-altered seawater. The exact composition probably does not reflect the reservoir fluid, however, because the sample was, in all likelihood, created by a combination of condensate and boiled brine. However, the isotopic composition of the probable reservoir fluid does match that of seawater modified by low-temperature interaction with volcanic sediments or rock.

The fluid also appears to be modified by high-temperature processes. The Reykjanes brine (Arnorsson, 1978) and ocean ridge hot springs (Von Damm et al., 1985) have extremely low sulfate and magnesium concentrations, and their calcium and potassium concentrations are greatly increased relative to seawater. In addition, trace elements such as strontium and boron are increased to concentrations above that of seawater. These modifications of seawater also occur in the Ascension #1 fluids (Table 5-1).

5.3.8 CONCLUSIONS

The following conclusions can be made from chemical and isotopic analyses of fluid and gas from the Ascension #1 well:

1) Most of the chemical and isotopic variation in the geothermal samples is the result of wellbore processes. These processes are boiling, exsolution of gases, froth formation, multiple condensation/vaporization, entrainment of mixed brine/condensate in the gas flow at the wellhead, and spillover of the froth brine at the wellhead. Thus, the true composition of the reservoir fluid must be inferred rather than directly measured.

2) The loss of CO_2 at the boiling interface at the base of the well is likely to result in the deposition of calcite, reducing the feed-zone permeabilities.

2) The CO_2 content of the feed zone fluid is approximately 1% by weight. At 200°C the minimum pressure to prevent boiling of this solution would be about 47 bars. However, concentration of CO_2 at the top of the well since the well started flowing increases the pressure at which the gas will go into solution. For the outflow compositions that we have analyzed this pressure is on the order of 1000 bars. It may be that the difficulty encountered in shutting in the well is due to a combination of a high CO_2 concentration at the top of the well and an incompressable boundary at the base of the well, i.e., a sealed (calcite) interface or simply a single phase fluid. This should be modeled.

3) The recharge fluid for the geothermal system is seawater, chemically and isotopically modified by low- and high-temperature water-rock interaction. This implies that the recharge fluid is entering the geothermal system by percolation through the seafloor.

4) Application of chemical geothermometers to the Ascension #1 fluids is inappropriate. Cation geothermometers do not accurately predict the reservoir temperature of geothermally-modified seawater. Silica is precipitating in the wellbore, preventing usage of the quartz geothermometer.

5.3.9 FLUID SAMPLES TAKEN AFTER DEEPENING (MAY, 1987)

Ascension #1 was deepened to 9885 feet during May, 1987. Prior to deepening, the producing zones at about 8000 feet were partially cemented. After redrilling, the well began to fill with liquid-phase brine. This fluid was air-lifted to the surface and a sample was taken (WS87-28; Table 5-6).

The fact that a liquid phase rather than a gas-liquid froth was produced implies that either the deeper fluid is gas-poor compared to the fluid produced at about 8000 feet (shallower fluid), or that the shallower fluid was a combination of a gas-dominant fluid and a liquid brine. Both of these choices indicate that the geothermal system is zoned with respect to fluid composition.

The composition of the deeper brine from 9885 feet (Table 5-6) is similar to but distinct from the shallower fluid. The

TABLE 5-6. Chemical Analyses of Liquid Samples Taken After Deepening (May, 1987).

	WS87-28	WS87-29
Na*	10898	142
K	1089	11
Ca	2497	47
Mg	131.3	11.71
Fe	0.23	0.03
SiO2	179	ND
B	47.14	1.59
Li	7.45	0.06
Sr	24.27	0.63
Ba	4.07	ND
HCO3**	238	38
Cl	22800	315
F	0.53	0.16
SO4	145	45
TDS	39250	606
pH (20°C)	6.5	6.5

* Concentrations in ppm by weight.

** Total alkalinity including all titratable species, expressed as HCO3.

deeper brine is higher in TDS, relatively enriched in K, Mg, B, and Li, and relatively depleted in SO_4 and Ca. All of these differences, except for the magnesium enrichment, indicate a higher temperature reservoir than the shallower brine compositions. The depletion in Ca may be due to a lower CO_2 content or to precipitation of calcite in the wellbore. The lack of boiling in the deepened wellbore would indicate that lower CO_2 is more likely, and further indicates that a single, gas-rich fluid was produced at the shallower brine entry.

The sampled fluid from 9885 feet may still not be pristine. The composition of sample WS87-29 (Table 5-6), taken after the air-lift when the wellbore was not filled with liquid but was producing steam and gas, bears a strong resemblance to meteoric water. This may indicate that there is a small contribution of meteoric water in the sample from 9885 feet. The composition of sample WS87-29, however, could have also been produced by a combination of condensate, mineral equilibria, seawater, and geothermal fluid. Thus the hypothesis of meteoric water contribution must be taken as tentative.

6.0 GEOPHYSICAL WELL LOGS

6.1 Introduction

A suite of geophysical well logs were run in Ascension #1 in order to determine the location of the borehole, temperatures within the well, precise location of lithologic contacts, and the distribution and orientation of fractures. Individual logs run are discussed below. Table 6-1 presents a log of the important drilling events along with a summary of the logs run. In a number of instances, tools failed to operate, largely as a result of the high temperatures encountered in the well. However, the required data was eventually recorded through persistent efforts.

6.1 Deviation Survey

The deviation of the well bore was documented using an Eastman deviation tool run within a heat shield. The survey points were collected approximately every 300 feet below the casing to the bottom of the well. Results of these surveys are shown in Table 6-2. The results have also been plotted in map plan in Figure 6-1 and in an east-west cross section in Figure 6-2. It can be seen in Figure 6-1 that the well trends to the east of the collar for approximately 1100 feet before turning to the northwest. The remainder of the well trends to the northwest.

TABLE 6-1. Log of survey events for Ascension #1 deepening.

DATE	TIME	
5/19	1700	RIH to casing shoe, pump water to fill hole.
	1800	Returns established, well takes 5-10 bbls/min when full
5/20	2100	Initiate reaming circulating salt water
5/22	0800	Complete reaming to 8600′
5/23	1900	Place cement 7900′-8600′ and squeeze
5/24	2400	Complete deviation surveys at 4626, 5000, 5373, 5745, 6116
5/25	0630	Complete deviation surveys at 6488, 6863, 7236, 7611, and 7987′
	1430	Start drilling out cement with seawater. Top of cement @ 8224
5/26	0800	Finish drilling cement and 4 hours circulation with salt water
	0900	Complete deviation survey at 8654
	1000	Complete deviation survey at 8301
	1100	Complete deviation survey at 7893
	1400	Begin unloading hole for change to foam drilling
5/27	0730	Drilling with air to 8996′
	2300	Out of hole for bit change
5/28	0200	Running in hole, water level at 6658′
	0900	Reaming and drilling ahead
5/29	0500	Drill to 9375′
	0900	Complete deviation survey at 9300′
	1000	Complete deviation survey at 9000′
	1500	Bit changed, run back in hole
5/30	0900	Drill to 9696′
	1100	Complete deviation survey to 9656′
	1800	Drill to 9885′
	1900	Hole blown, begin pulling out of hole
5/31	0330	Run Schlumberger temperature survey #1
	0820	High-Tempurature dipmeter tool on bottom -tool failure.
	1200	Dipmeter tool failed again
	1519	Completed schlumberger souic log 7288-6284′
	2216	Completed Schlumberger gamma-ray Log 0′-8262′
6/1	0300	Attempt to flow well by air lift at casing shoe.
	1300	Collected water sample WS87-28 on bottoms up
	1400	Drilling ahead
6/2	1230	T.D. at 10172′

Table 6-1 (Continued)

	0430	Complete deviation survey at 10,147 feet and collected water sample WS87-29 from flow at Blooie line
	0600	Hole filled with saltwater
	1200	Schlumberger dipmeter tool malfuntion
	1632	Schlumberger dipmeter data 4544-5790'
6/3	0034	Start Kuster P-T survey thru drill pipe-no float
	0516	Complete Kuster P-T survey
	1330	Finish pulling out of hole
	1900	Two attempts with Schlumberger dipmeter tool failed
6/4	0630	Complete rig down
	0817	Successfuly collected dipmeter data 8088-7605'
	1030	Continuous temperature log 7500-10172' Water level at 3264'

TABLE 6-2. Results of deviation surveys from Ascension #1

Measured Depth	OBS Angle	OBS Direction	True Vertical Depth	Rectangular Coordinates North	South	West
263	1°00′	S81 W	263			5
805	1°25′	S81 W	805		2	16
2589	1°50′	S81 W	2588		9	59
4005	2°50′	S81 W	4003		17	107
4626	4°00′	S81 W	4623		21	136
5000	6°50′	S77 W	4996		29	169
5373	10°50′	S81 W	5365		37	224
5745	14°25′	S79 W	5728		53	302
6116	18°00′	S88 W	6085		56	405
6488	21°50′	S87 W	6435		63	531
6863	28°00′	S89 W	6775		66	688
7236	34°00′	S85 W	7095		62	879
7611	36°50′	N87 W	7401		51	1095
7987	21°50′	N71 W	7730	8		1268
8301	21°50′	N68 W	8022	52		1374
8654	24°75′	N69 W	8347	101		1504
9000	30°50′	N67 W	8654	164		1651
9300	34°50′	N66 W	8907	229		1799
9656	38°00′	N60 W	9194	335		1981
10,147	34°00′	N59 W	9591	483		2228

Figure 6.1

Ascension #1 Deviation Survey, Map Plan

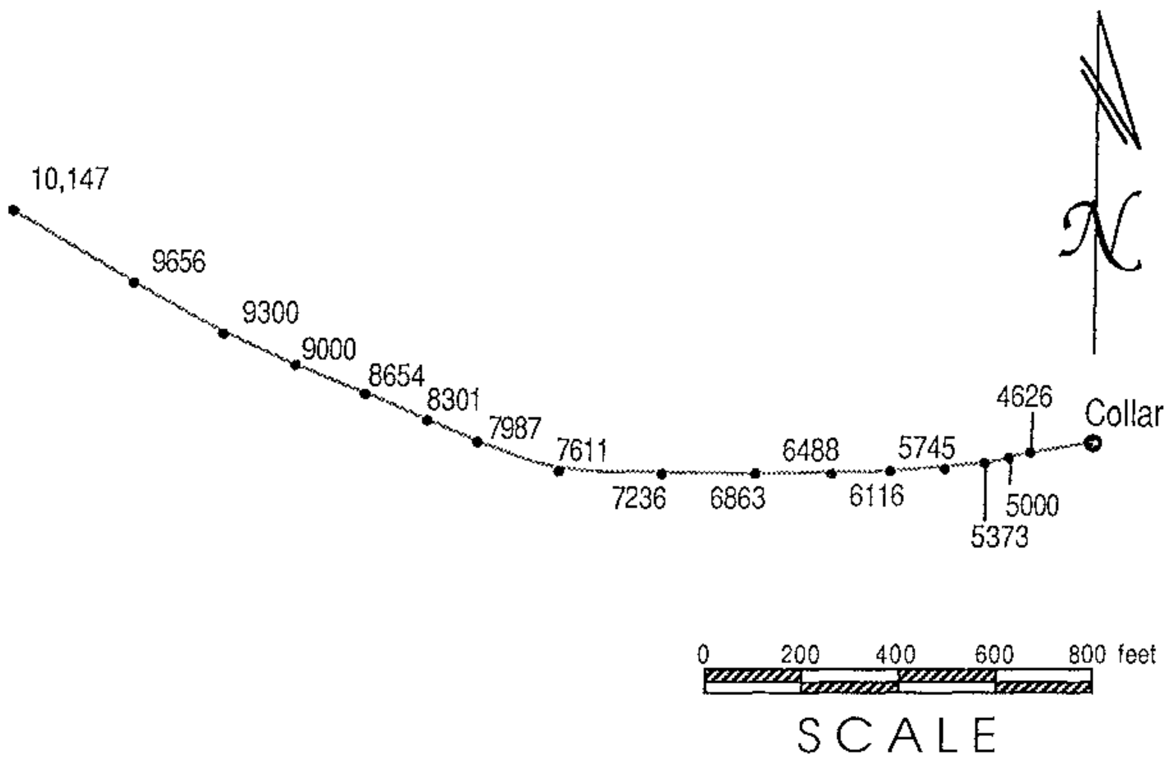
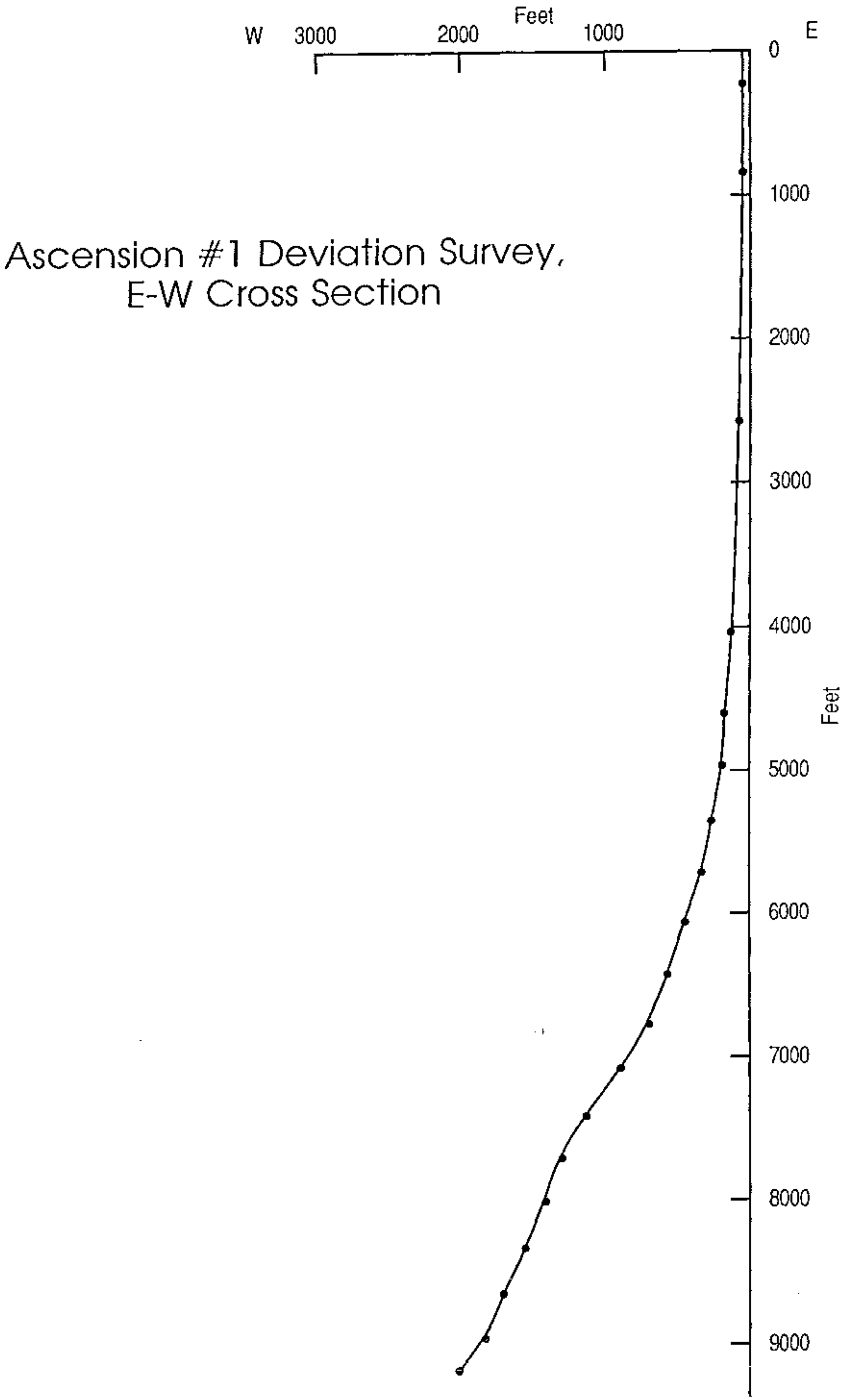


Figure 6.2



Feet
W
3000
2000
1000
E
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Feet
Ascension #1 Deviation Survey,
E-W Cross Section

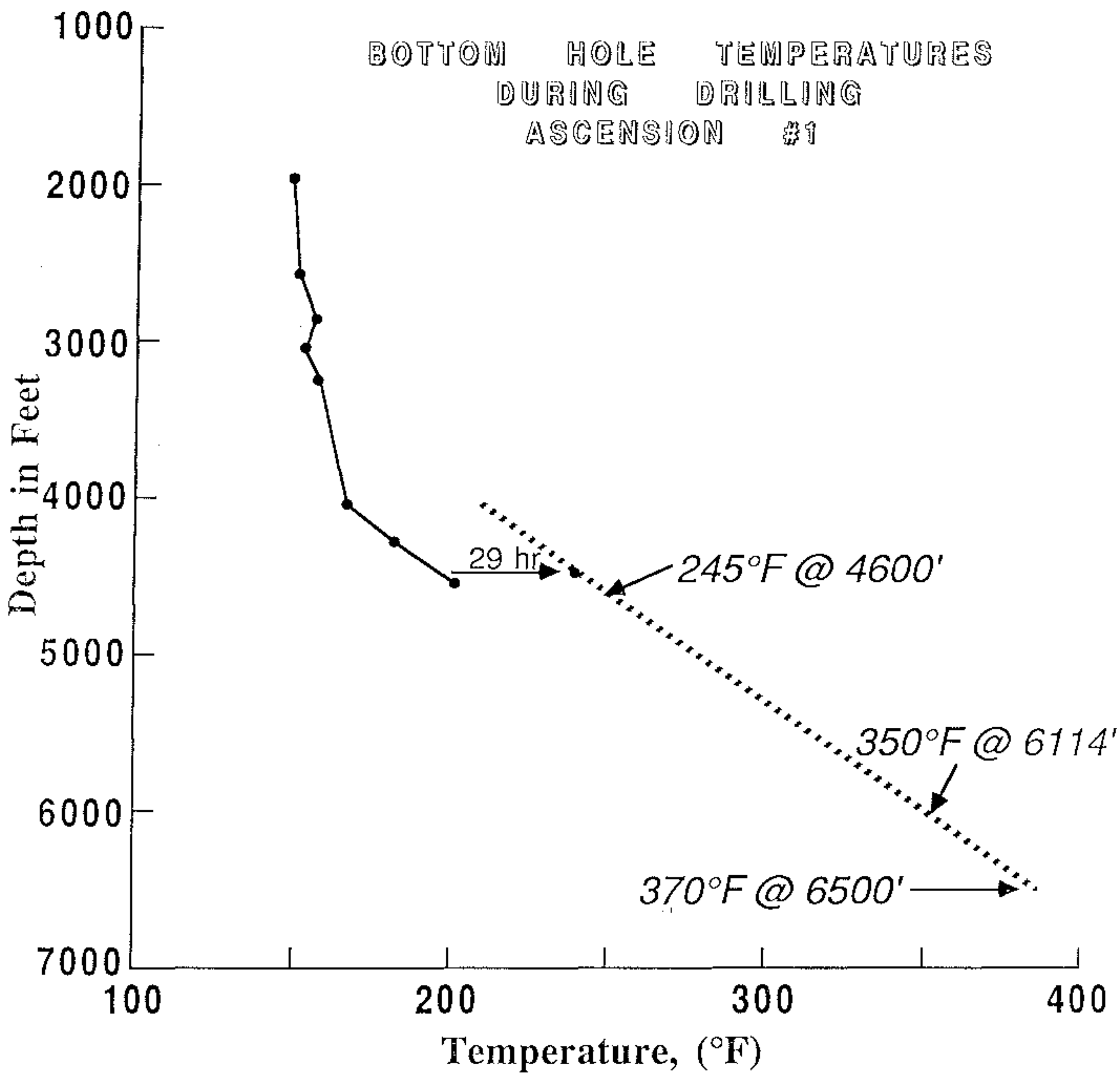
6.2 Temperature Surveys

Temperature surveys run with a variety of methods have been important in understanding the geothermal environment and providing information necessary to make decisions concerning the continuation of the drilling activities. Temperatures were measured using maximum reading thermometers (MRT), Kuster tools, and Schlumberger high temperature probes which provided a continuous temperature profile as a function of depth.

During the initial phase of the drilling operation, temperatures were recorded using MRTs during deviation survey runs. The results of these measurements are shown in Figure 6-1. Measurements at about 4500 feet after allowing the well to warm up for both 24 hours and 2 months (Fig. 6-1) show the effects of wellbore heating. A temperature obtained by Kuster tool at about 6400 feet is also shown in Figure 6-1. This survey was done at a decision point on continuation of the well. It indicated that a steep temperature gradient was continuing, and the well was deepened to a TD of 8706′.

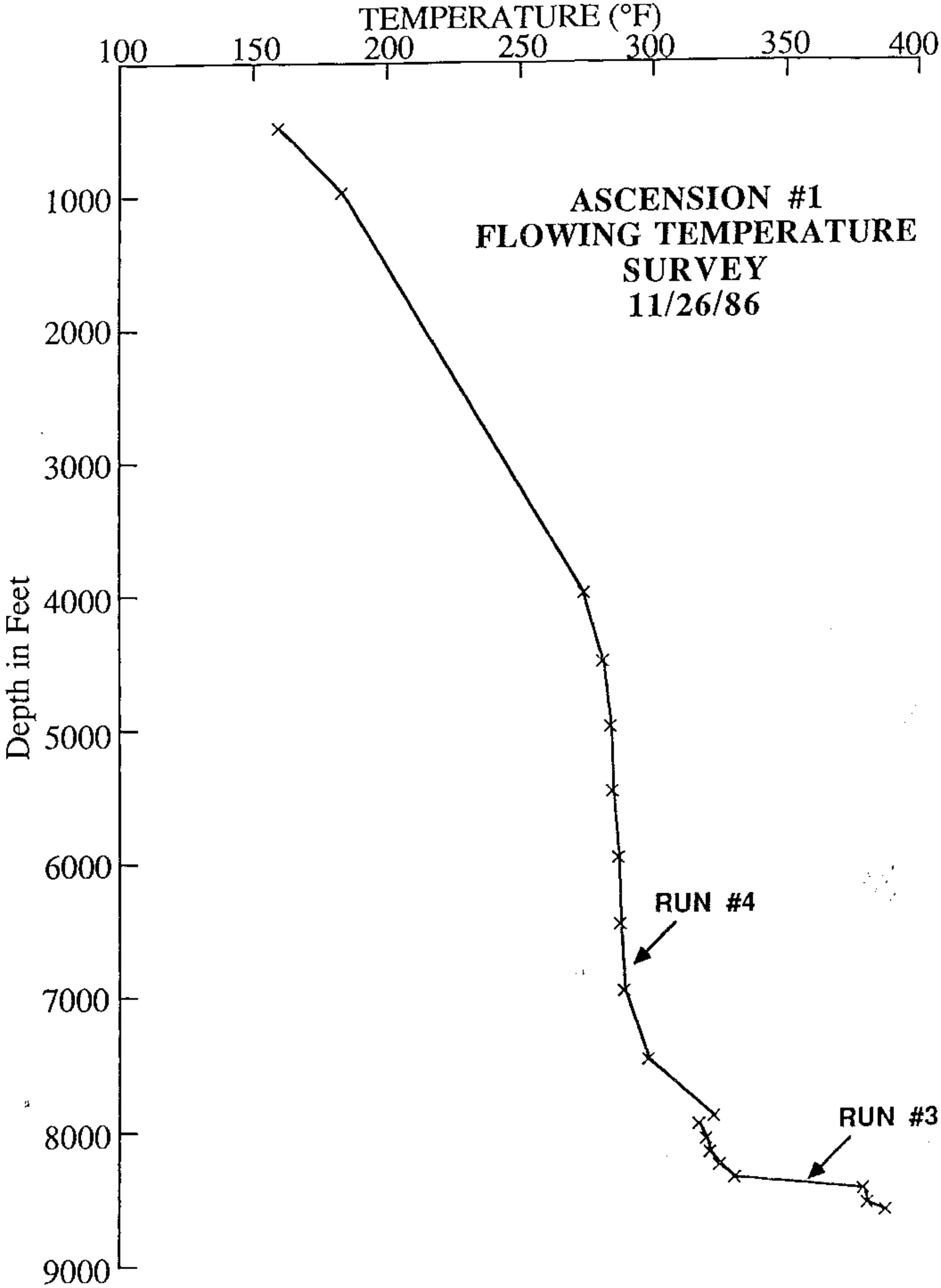
Figure 6-2 is a temperature profile recorded by a Kuster tool following T.D. at 8706′. This survey was initiated at 1002 hours on 25 November, 1986, following the completion of drilling at 2000 hours on 24 November 1986. Run #3 was made within drill pipe in the lower portion of the well. Following this, the drill pipe was raised to 8000 to lessen the possibility of it becoming stuck in the hole. Run #4 was completed to 8000′, also within the drill pipe. During both surveys, the well was flowing water

Figure 6-1



BOTTOM HOLE TEMPERATURES
DURING DRILLING
ASCENSION #1
Depth in Feet
1000
2000
3000
4000
5000
6000
7000
29 hr
245°F @ 4600'
350°F @ 6114'
370°F @ 6500'
100
200
300
400
Temperature, (°F)

Figure 6-2


TEMPERATURE (°F)
100
150
200
250
300
350
400
Depth in Feet
1000
2000
3000
4000
5000
6000
7000
8000
9000
ASCENSION #1
FLOWING TEMPERATURE
SURVEY
11/26/86
RUN #4
RUN #3

and vapor through the blooie line. The CO_2 and water entries encountered between 8142' and 8450' have a profound cooling effect on the well caused by expansion of the gases entering the wellbore. Subsequent sampling and testing of the zones is discussed in the testing and geochemistry sections.

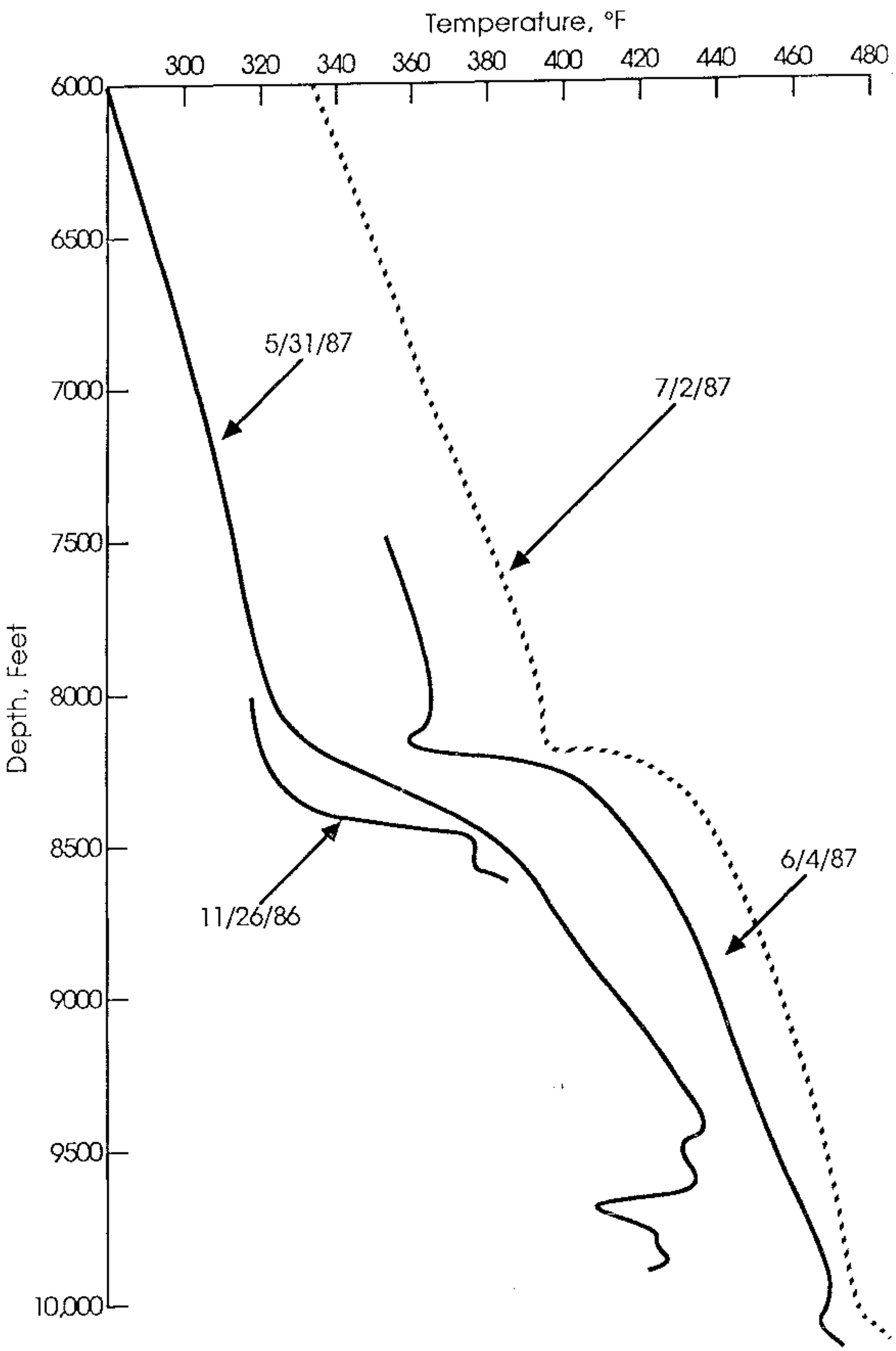
Following a furlough period to allow re-supply, Ascension #1 was re-entered and drilled to 9900. As reported in the section on hydrothermal alteration abundant epidote was encountered at 9440' and continued to 9900. Drilling was terminated at 1900 hours on 30 May and a continuous Schlumberger temperature log was initiated at 0326 hours on 31 May. Data was collected at 3000'/hr. The results of the survey are shown in Plate I. It can be seen that efforts to eliminate the CO_2-rich influx at 8120-8142 feet were only partially successful and that the well was being cooled dramatically at this point. However, the CO_2-rich zones below this point were probably eliminated by the cement job. Below 8141' the temperature increases due largely to the strong cooling effect above. This strong gradient breaks at 8500' and is apparently conductive to 9440'. Below 9440 feet the temperature profile reverses, and this reversal continues to the bottom of the well at 9900'. When considered in light of the alteration mineralogy, this reversal is interpreted as being produced by the cooling of the well during drilling operation. The zones which have been cooled the most are those where the permeability is highest. On the basis of these results and the continued presence of epidote-rich alteration assemblages, the well was continued to T.D. of 10,172 feet.

Following T.D. at 10,172 feet, sea water at a temperature of about 75°F was circulated through the well to cool it. This was done in an attempt to acquire dipmeter data as deep in the well as possible. 700 barrels of water were pumped through the bit at TD before returns were achieved. Since the well volume was about 500 barrels, the well took about 200 barrels of water, most of it in the zone beneath 9440 feet. A total of 1000 barrels were circulated in the well before circulation was stopped at 0600 hours on 6/2/87.

On 6/3/87 a Kuster P-T survey was run at depths of 9550', 9830' and 10,100 feet. This data was collected within the drill pipe, but the lower float had been removed to allow water to enter the pipe. The results of this survey are shown on Table 6-1. One of the objectives was to document a temperature buildup at each of the surveyed depths; however, little change was documented. This phenomenon may have resulted from either affective cooling of the hole and/or warming of the drill pipe within which measurements were made.

On 6/4/87 a second continuous temperature log was collected by Schlumberger between 7500 feet and 10,140 feet. This log is shown on Plate 1 and plotted with the previous temperature log on Figure 6-3. It is clear from these logs that the CO_2-rich zones at about 8150 feet still have a profound cooling effect on the well. It is also clear that the zone beneath 9440 feet has heated confirming the conclusion that cooling in the previous survey represented drilling effects on a permeable zone.

Figure 6-3



Temperature, °F
300
320
340
360
380
400
420
440
460
480
6000
6500
7000
7500
8000
8500
9000
9500
10,000
Depth, Feet
5/31/87
7/2/87
11/26/86
6/4/87

TABLE 6-1 TEMPERATURE MEASUREMENTS

from Ascension #1

DEPTH	DATE	TIME	F°	METHOD
9900'	5/31/87	0820	454	MRT
9000'	5/31/87	1340	436	MRT
8265	5/31/87	2345	382	MRT
9550	6/2/87	0138	414.5	KUSTER
		0238	415.7	KUSTER
9830	6/2/87	0244	431.1	KUSTER
		0346	431.4	KUSTER
		0515	432	KUSTER
10,100	6/2/87	0350	434	KUSTER
		0451	434	KUSTER
8000	6/3/87	1500	350	MRT
8000	6/4/87	0800	359	MRT

During the second Schlumberger temperature survey the water table in the well was located at 3264 feet. It was detected by a decrease in the tension on the cable and an increase in the temperature to 212° F.

6.3 Pressure

6.4 Dipmeter

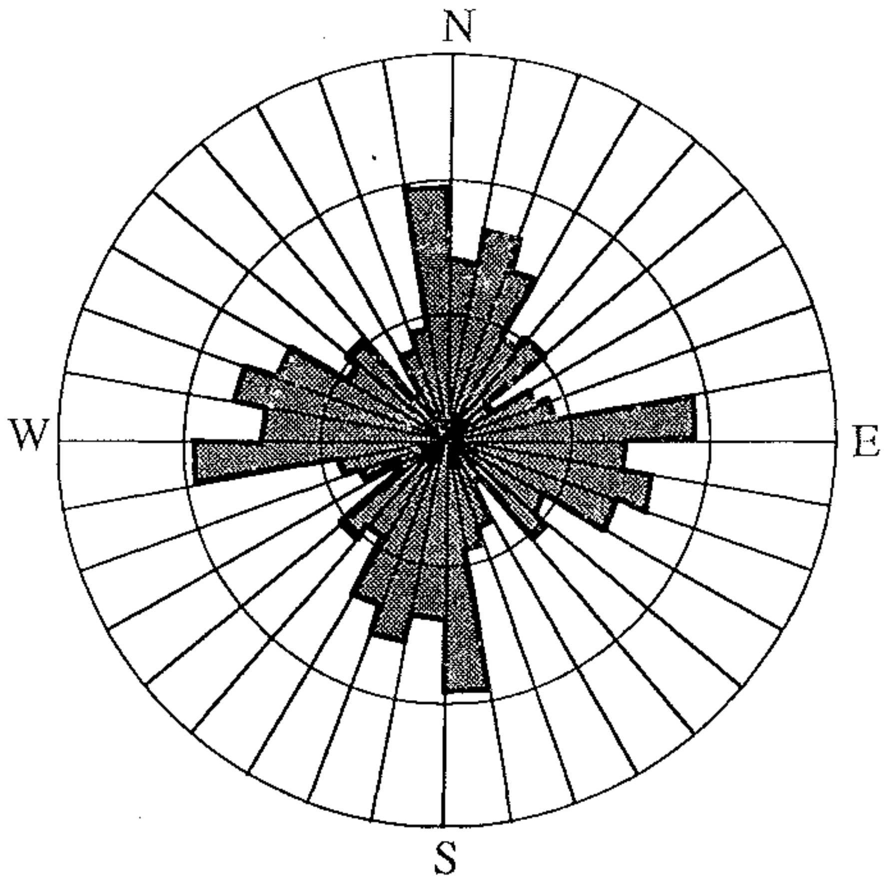
One of the principal logging objectives in the lower portion of the well was to run a Schlumberger Dipmeter survey. This survey can be used to determine the orientation of fractures through changes in electrical resistivity. A special high temperature modification of Schlumberger's tool, rated at 500° F, was mobilized for this logging. However, mechanical problems were experienced probably due to cracking of a protective dewar during shipping. Problems were also experienced in getting the caliper arms of the tool to open. As a result, data was collected only within selected intervals of the well, and it was not possible to log within the deepest portions of the well due to temperature limitations.

Although several different presentation modes are available for data from the dipmeter log, a plot of the distribution of conductivity anomalies is the only one which will be discussed at this time. Figure 6-4 shows both the pad orientation and the distribution of conductivity anomalies for the interval of 8008 to 7606 feet. It can be seen in the distribution of pads plot that the tool did not rotate in the well to give a uniform

Figure 6-4a

Ascension Geothermal Project

DCA Plot
Distribution of Pads Ubication



Company: UURI

Well: Ascension #1

Start: 8008

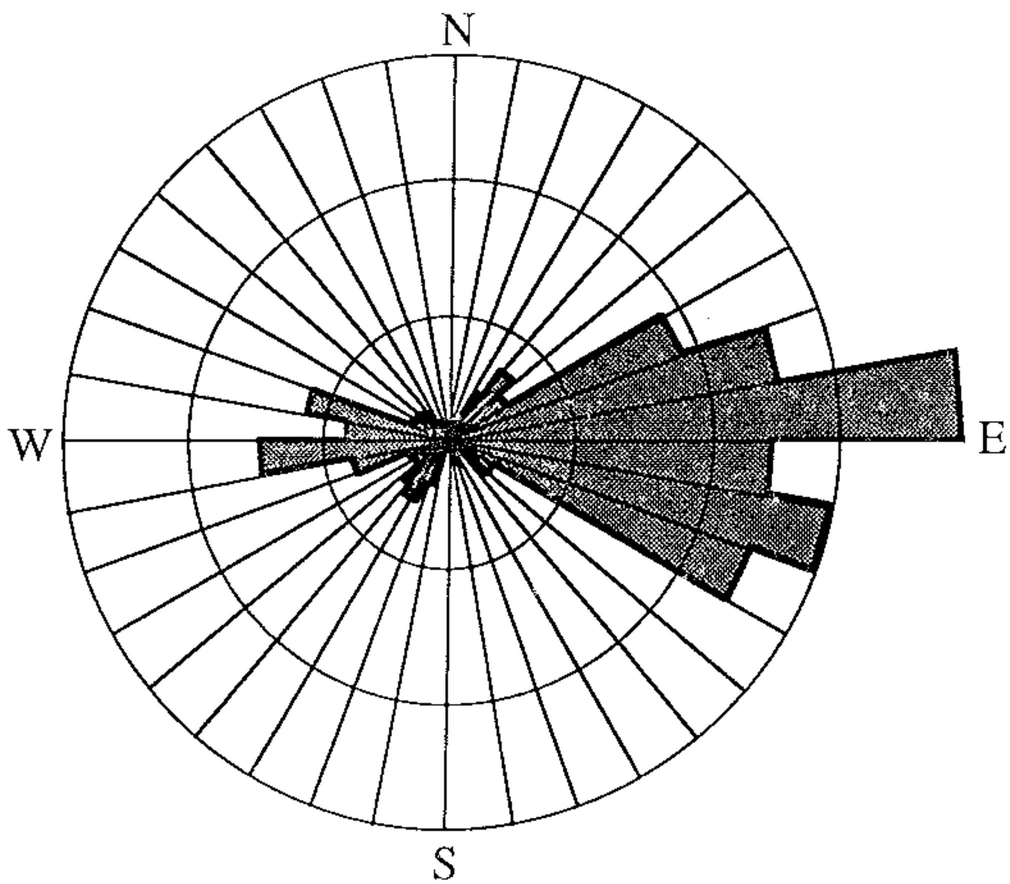
Stop: 7606

Scale: 0-30.0

Figure 6.4b

Ascension Geothermal Project

DCA PLOT
Distribution of Conductivity Anomalies



Company: UURI

Well: Ascension #1

Start: 8008

Stop: 7606

Scale: 0-6.0

sampling of the borehole. this will result in a biasing of the data in those directions measured by the probe. The distribution of conductivities plot shows a preferred orientation in a N80E to N90E direction. The emphasis on the easterly trend results from an equipment error which emphasized the signal from one pad over its opposing pad.

The zone in which this data was collected hosted the CO_2-rich entries described previously. It is the conclusion from the dipmeter data that the fractures hosting these entries are oriented in an east-northeast direction.

The tool run was a high-resolution dipmeter tool (HDT) with four caliper arms at 90 degrees to each other. A resistivity pad is located on each arm and numbered so that pads 1 and 3 are opposite as are pads 2 and 4. Thus the two sets of borehole dipmeter measurements are between calipers (pads) 1-3 and calipers (pads) 2-4. It is presumed that the high-angle (of deviation) model of the HDT was run.

Run 1 logged the interval from 5790′ to 4544′, run 2 from 8008′ to 7605′, where the tool failed.

Data quality

Within the intervals just listed the tool appears to have operated well with the exception of the azimuth curve ("Deviation") which did not function at all. It was therefore necessary to use the deviation surveys done during drilling for calculations. It is estimated that these have a variance of +20 degrees which is comparable to the errors on the HDT azimuth readings themselves.

At the bottom of the interval the tool rotated at the start of logging where the borehole was at its minimum diameter. This argues that the lack of tool rotation uphole is not due to its being stuck.

The quality of computed dips and breakouts is significantly better in run 1 than in run 2. This is probably due to geologic differences between the two intervals.

Processing

The raw resistivity curves were processed using both the GEODIP and CLUSTER programs. CLUSTER results are presented in the tabular listing and on the Continuous Dipmeter (Computed Results) log. CLUSTER uses pairings of the four resistivity curves taken two at a time, to get a series of solutions for the true dip plane. Calculations are made in adjacent overlapping levels so that a number of solutions are generated. When some of them 'cluster' near a specific value it is selected as representative of the group. This tends to identify stable geologic zones to the detriment of identifying faults, discontinuities, etc.

GEODIP uses pattern recognition techniques simultaneously on all four curves. The program looks for the best correlations and relaxes its standards until one is found. The density of output depends on the density of geologic information available. In contrast the CLUSTER program determines one value in each step interval regardless of the real data density. Thus GEODIP is particularly useful in finely divided units. The CLUSTER correlation and step interval of 4′ and 2′ respectively is appropriate for a first-pass structural analysis. However, because of the nature of volcanic flows it may be advisable to rerun the data with an 8′ or larger correlation interval to identify thicker units. Additionally some areas of well defined planar features could be enhanced by using a smaller correlation interval of possibly 1′ or less. The GEODIP processing however may have already identified these smaller-scale features.

The search angle of 35 degrees is measured up from the top of the correlation interval and down from the bottom of it. Since the interval is 4′ this effectively increases the search angle. Using a 6 3/4" borehole produces an effective net search angle from the midpoint of the interval of 83 degrees. Only in exceptionally well defined units are higher dips occasionally found.

Interpretation

Dip analysis. Overall, compared to diplogs in many sedimentary environments, the Ascension results are poor. Data are sporadic, of apparent random orientation, and of low quality. Interpretations based on dip analysis must therefore be qualified. The notable exception is the interval from about 5200′to 5750′. Much of the data here is of 'A' quality although more of it is needed to make a definitive interpretation. Within short intervals however data is sufficient to show structural complexities such as unconformities, faults and drag folds.

Mechanical analysis. Borehole breakouts are the preferential elongation of the borehole due to spalling caused by tectonic stresses. During dipmeter logging the tool will normally rotate about once every 50-100′ in a clockwise direction due to the construction of the cable holding the tool. Where breakouts occur one of the caliper arms will lock into the groove preventing further rotation. In addition, that caliper set will show an enlarged diameter due to the spalling. The criteria to differentiate a breakout from normal hole irregularities is that one set of calipers remains at or near gauge while the other set detects a diameter increase of at least 0.5" (1.27 cm). The elongation has been found to be in the direction of least horizontal stress (Sh). In a highly deviated hole such as at Ascension it is possible to misidentify 'keyseats' (grooves on the low side of the borehole caused by the drag of the drill string) as breakouts. In these cases on the caliper arms will be parallel to the well deviation direction. These intervals can be seen in the "Hole Drift" column on the GEODIP log and eliminated from consideration. This may also eliminate some sections of real breakouts but they can often be recognized because of their continuity with obviously real breakouts.

Results. Because of the volcanic and igneous rocks penetrated no significance can be given to individual computed dips. Rather, clusters or patterns of dips are needed. This is consistent with the conclusions reached by Bengston (1981) for dips even in finely laminated material. The interpretation of a dip sequence by itself is ambiguous if there is no continuity with shallower or deeper dips. Such a sequence could be either structural or stratigraphic.

Most of the dip sequences are believed to be of structural origin for two reasons. First, many of the sequences do have adjacent dips that are consistent with drag above or below faults. Second, dip magnitude variations are commonly at or greater than the angle of repose of sediments. Quite numerous well defined foresets and channels would be necessary to account for all the dip sequences.

If we presume that most of the dip sequences are due to drag on faults we can infer fault orientations and displacement directions. This, however, is inherently dangerous in that drag folds can be oriented any direction relative to the fault. By using all of the supposed drag fold orientations, patterns emerge which probably show the general fault trends.

An azimuth frequency plot of all recognized faults is shown in Figure 6-6 and Table 6-3. It is assumed that all faults are normal and they are plotted such that the direction of fault dip is to the right of the plotted azimuth. Thus a fault shown trending northeast would have a dip to the southeast and would not be shown on the other half of the diagram, i.e. to the southwest. Four groups of faults are recognized. Group 1 is NE-SW trending with predominant SE dip. There is 50+ degrees of azimuthal spread in this group, which, given the nature of the derivation of the data is not unusual. Group 2 is NW-SE trending

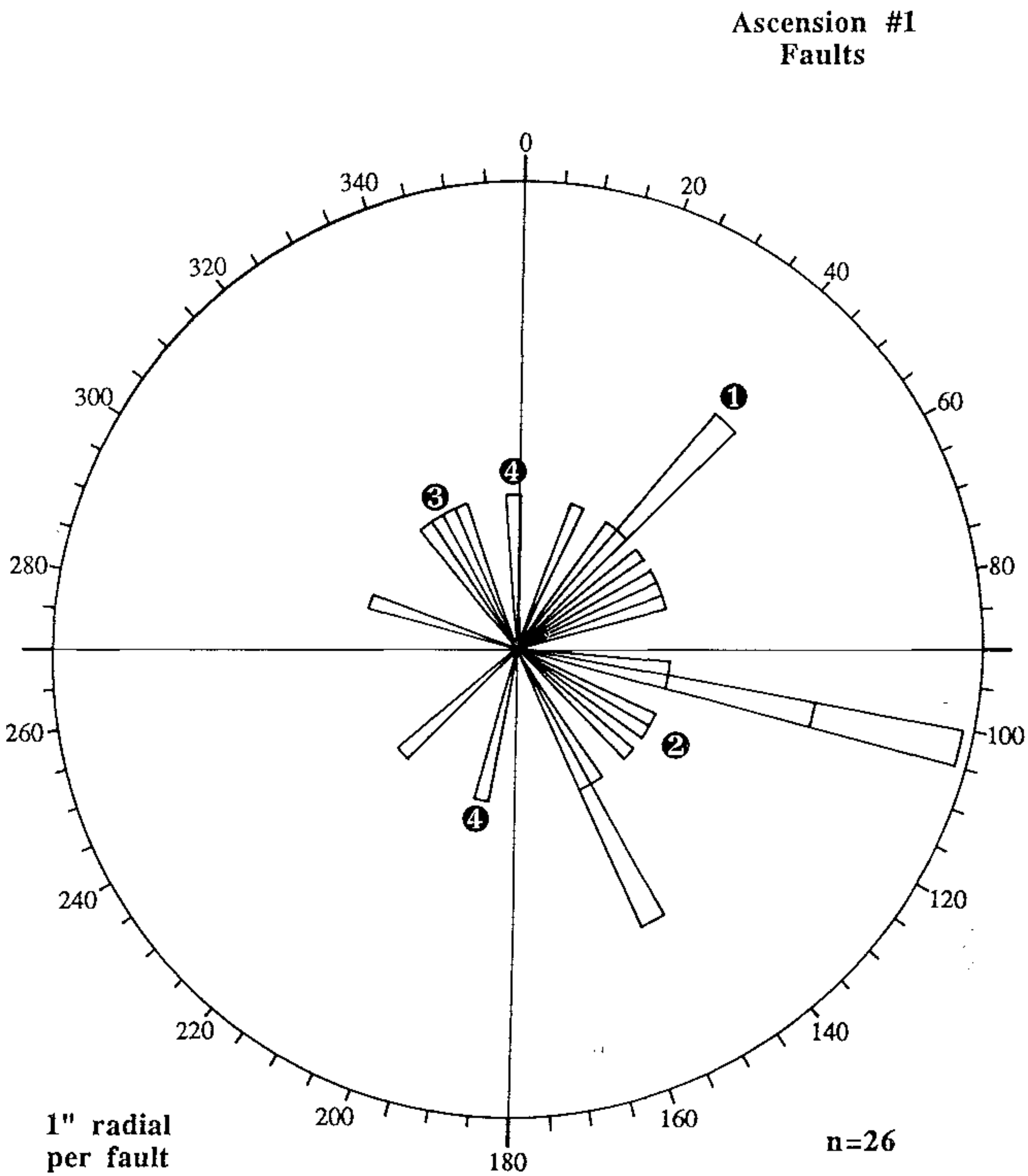


Fig. 6-6 Az.-freq plot of fault strikes derived from apparent drag on dipmeter plots. All faults are presumed to be normal with 'down' direction to the right of the plotted azimuth. Scatter is due in part to wide variation in azimuth of rocks involved in drag.

TABLE 6-3 ASCENSION #1

	DRAG FOLDS AZIMUTH	MAX DIP	DOWN TO	FAULT AZIMUTH	GROUP
4717	235	38	SW	145-325	2
4742	155	34	SE	65-245	1
4747	245	33	SW	155-335	2
5134	135	37	NW	45-225	1
5188	15	35	NE	105-285	2
5256	190	18	S (SE)?	100-280	2
5261	190	33	S	100-280	2
5298	55	32	NE	145-325	3
5304	185	20	S	95-275	2
5308	130	22	SE	40-220	1
5321	160	16	SE	70-250	1
5357	50	38	NE	140-320	3
5384	140	49	SE?	50-230	1
5429	190	32	SW	100-280	2
5458	220	30	SW	130-310	2
5502	25	22	NE	115-295	3
5570	240	16	SW	150-330	2
5731	210	16	SW	120-300	2
7695	130	34	SE	40-220	1
7704	65	50	NE	155-335	3
7714	100	57	W	10-190	4
7770	125	38	SE	35-215	1
7781	110	42	SE	20-200	1
7788	85	56	E	175-355	4
7910	60	45	NE	150-330	3
7968	150	60	SE	60-240	1

and the largest group. It has a similar azimuthal spread and dip is to the SW. Group 3 has a more narrowly defined NW-SE trend and is considered a separate group because dip and thus displacement is to the NE. The last group is composed of a scatter of roughly N-S features.

Group 1 is consistent with rift-bounding faults in the northwest part of the major rift valley being drilled. In the lower part of the logged interval, dips show an overall decrease suggesting the well is climbing structurally, which would be expected as it nears the rift margin. The well deviation also swings more northwesterly to be more nearly perpendicular to this trend.

Group 2 is believed to represent cross faults in the rift valley which may be concentric to the island center and a result of dome inflation. Individual fault segments could be contained within the rift valley but overall such a fault set could be expected to extend around the island. A rhyolite dike at 5699-5712', oriented 118-298 degrees, may have been injected along a fault during the inflation.

Group 3 is another set of cross faults but the opposite sense of dip suggests they may be due to a dome deflation. Their extent should be similar to Group 2.

Group 4 is more the leftovers than a distinct group. However, they are somewhat consistent with stress directions determined from borehole breakouts discussed below.

Borehole breakouts. Table 6-4 lists all the breakouts identified in Ascension 1. Additional breakouts may have been overlooked because of their parallelism to a keyseat. It should be noted that 21 of the 46 breakouts listed have maximum borehole elongations less than 0.5". Although this has been commonly used as a cutoff value there are no calculations that demand this. In fact Gough and Bell (1982) point out that large holes will spall more than small ones, and that in small holes the dipmeter pad diameter is large enough to bridge over many breakouts and thus underestimate their depths. Therefore, any borehole elongation greater than 1/3" in the well was tabulated.

The 46 separate breakouts cover 535′ of the total 1649′ logged or about 32% of the interval. An azimuth-frequency plot (Figure 6-7) shows an extremely strong SH direction of about 175-355 degrees. The SH directions are those of fractures that would develop from this stress system. This is opposed to the normal procedure of plotting the elongation azimuthes. The actual borehole elongation directions are 90 degrees to the SH directions.

The main SH trend is almost exactly parallel to the active Mid-Atlantic Ridge spreading center to the east. It is presumed that the breakouts represent the present day in-situ stress resulting from movement of the South American plate from that segment of the ridge. A handful of breakouts have other orientations and these produce SH directions parallel to the Group 1 and 2 fault directions.

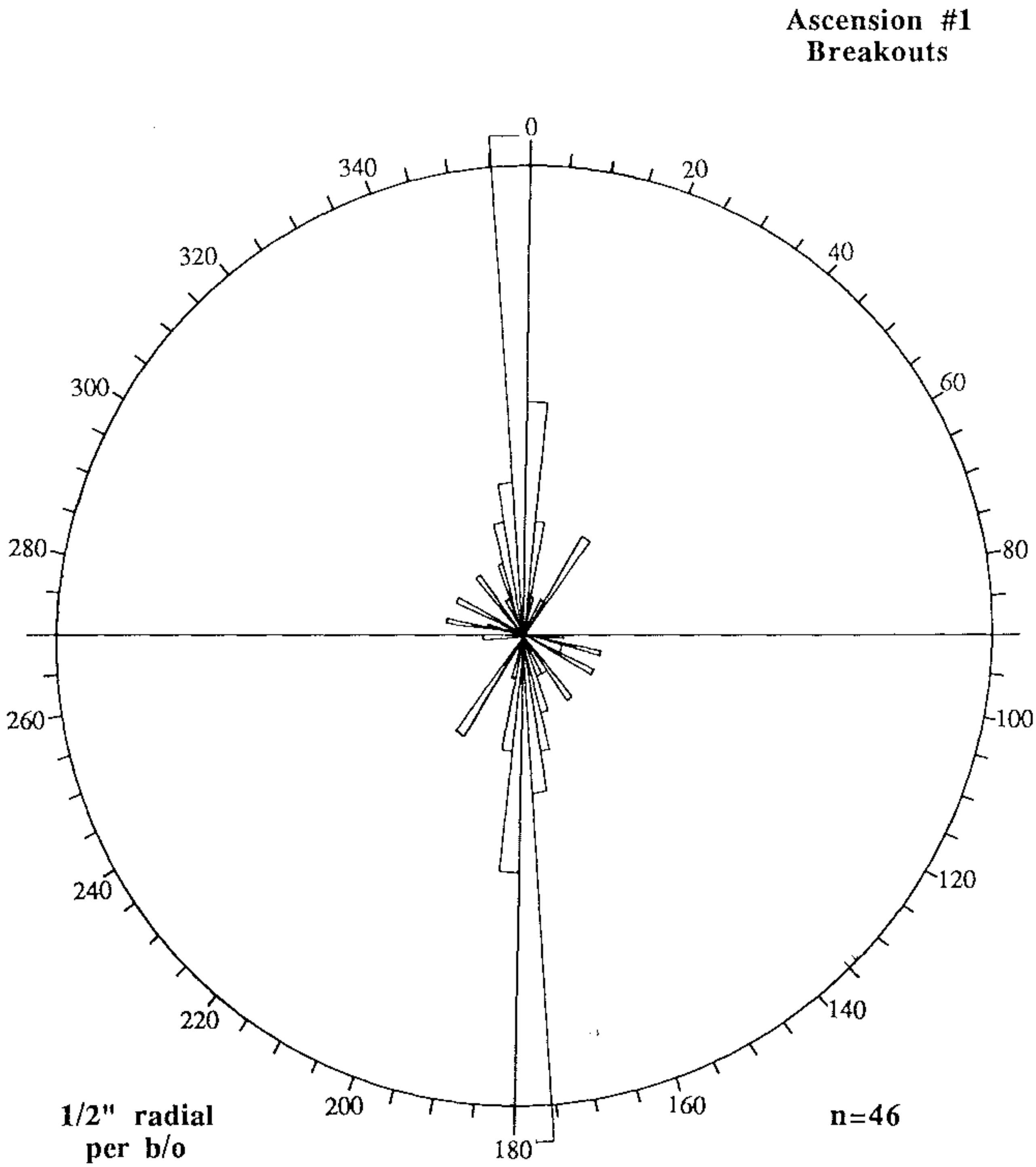


Fig. 6-7 Az.-freq plot of S_H direction (T_1-T_2 plane inferred from 47 breakouts.

TABLE 6-4

ASCENSION #1
BOREHOLE BREAKOUT

DEPTH	LENGTH (FT)	MAX HOLE ELONG.(IN)	DEVIATION (DEGREE)	RELATIVE BEARING	ELONGATION DIR. (S_h)	MAX HOR. COMP. (S_H)
4637-45	8	.7	265	180	85-265	175-355
4646-49	3	.65	265	180	85-265	175-355
4649-72	23	1.25	265	180	85-265	175-355
4684-86	2	.5	268	~200	108-288	28-208
4856-60	4	.4	261	20	281-101	11-191
4864-69	5	.6	265	360	265-85	175-355
4945-53	8	.45	273	350	263-83	173-353
4955-57	2	.35	274	340	254-74	164-344
4962-70	8	.45	275	350	265-85	175-355
4990-96	6	.45	274	360	274-94	184-4
5031-34	3	.7	275	350	265-85	175-355
5053-55	2	.5	275	350	265-85	175-355
5059-62	3	.7	276	350	266-86	176-356
5146-50	4	.35	275	350	265-85	175-355
5153-73	20	.65	275	350	265-85	175-355
5178-84	6	.4	274	350	264-84	174-354
5185-96	11	.4	276	350	266-86	176-356
5232-53	21	.55	275	355	270-90	0-180
5255-98	43	.75	275	360	275-95	5-185
5300-03	3	.35	275	340	255-75	165-345
5303-06	3	.35	275	340	255-75	165-345
5310-83	73	1.0	275	350	265-85	175-355
5387-90	3	.5	275	340	255-75	165-345
5393-5410	17	1.0	274	355	269-89	179-359
5442-45	3	.4	275	330	245-65	155-335
5446-54	8	.45	276	295	121-301	31-211
5455-68	13	.6	276	295	121-301	31-211
5472-98	26	.45	277	295	122-302	32-212
5620-22	2	.75	280	230	60-240	150-330
5622-28	6	2.2	280	220	50-230	140-320
5628-37	9	1.05	280	240	70-250	160-340
5666-92	26	.5	277	225	52-232	142-322
5699-5712	13	3.9	278	200	28-208	118-298
5712-5730	18	4.4	278	185	13-193	103-283
5730-60	30	1.1	279	165	84-264	174-354
5760-76	16	.85	279	175	94-274	4-184
5778-81	3	.8	280	195	25-205	115-295
7641-45	4	.35	280	170	90-270	0-180
7674-86	12	.5	281	175	96-276	6-186
7723-36	9	.35	276	170	176-356	86-266
7737-46	9	.45	280	180	10-190	100-280
7770-81	11	.45	281	160	81-261	171-351
7824-31	7	.45	284	170	94-274	4-184
7852-58	6	.5	285	165	90-270	0-180
7895-7903	8	.6	285	170	95-275	5-185
7910-18	8	.35	286	180	16-196	106-286

535′ of breakout   46 breakouts   11.6′/breakout
1649′ logged   32% of hole has breakouts

Ascension #1
Breakouts

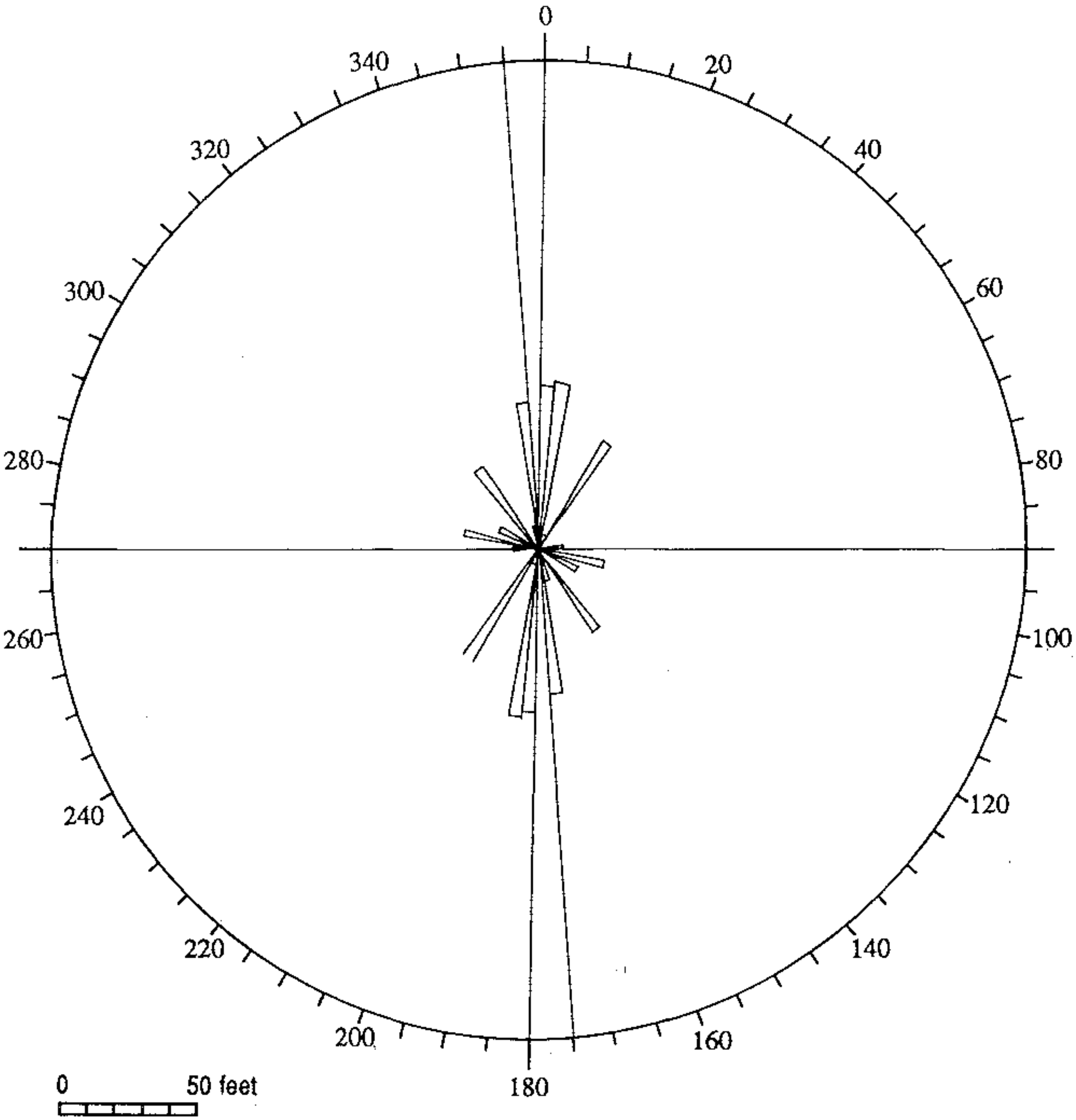


Fig. 6-8   Az(S_H) vs. cum breakout length.

Gamma-ray kicks. Increases of gamma radiation are thought to represent fractures or fault zones but there is not a strong correlation between locations of gamma-ray kicks and the dipmeter-derived faults. This may be due to the incomplete structural coverage from the dipmeter. There is some correlation between borehole breakouts and the gamma-ray kicks. At least some breakouts correspond to gamma kicks between 5300′-5800′. The borehole elongations are among the largest in the well, all greater than 1" except for a 2 foot interval. The gamma increases in these zones may be due to the larger amount of rock spalling into the hole releasing higher amounts of radioactive material.

Conclusions

The structure of the logged interval is more complex than originally believed. Fault patterns derived from fold orientations correspond to surface faulting previously mapped. The cross faults had not been seen in the vicinity of the well but are present towards the center of the island. The faulting is probably a result of the local stress field related to the construction of the Ascension volcanic edifice.

There is no significant N-S faulting either on the surface orin the subsurface so the breakouts represent a stress field too young or too weak to have created fractures and faults. The overwhelming preponderance of the N-S SH direction argues that the local Ascension Island stresses are minor to nonexistent and the island is quiescent.

Recommendation

The dipmeter tool provides useful information that cannot be gathered any other way. As an indicator of fractures it is extremely valuable for geothermal exploration and should be considered as a standard log to be run in all future wells.

6.5 Sonic Log

A sonic log was run between depths of 7288 and 6284 feet. The log run was initiated at 9906 feet; however, the tool failed to function until 7288 feet. The principal problem encountered was a great deal of noise which masked the data at depth. When the tool was recovered, rubber covers on the ends of centralizers had decrepitated due to the heat.

6.6 Gamma ray Log

The gamma ray log detects the natural gamma-ray emitting radiation in a rock. It can normally be correlated with uranium, potassium, and thorium contents of the rock. It is therefore used principally as a stratigraphic tool which documents the changes in rock type.

A continuous gamma-ray log was collected from 8262 feet to the surface. The log's depth was determined by a desire to limit the exposure of the tool to temperatures of less than 400°F. The maximum temperature recorded in the run was 382° F. The log is plotted in Plate I.

In the upper portions of Ascension #1, the gamma-ray log does differentiate between rhyolitic and basaltic units. In the lower portion of the hole, the gamma-ray log was very successful in locating fracture zones. These zones show up as strong increases over background values.

1. SUMMARY

This report documents the test of Ascension #1 that was performed during December 1986 and January 1987. Included is a description of the test, the data collected and the conclusions reached.

The test was originally planned as a single-phase pumped well test. The well, however, produced a mixture of CO_2 and water and was self-flowing. Pressure and temperature measurements were made at the wellhead and at points along the flowline. An orifice originally planned for a single-phase flow measurement was used to estimate two-phase mass flow. Water to gas ratios were estimated using a sample line with a condenser.

A total of sixteen downhole temperature and pressure surveys were conducted, thirteen just prior to and during the test, and three approximately a month after the test. The maximum downhole temperature recorded during the test was 457 °F at 8600 feet. The formation equilibrium temperature projected from a Horner Analysis at 8640 feet is 419°F. The pojected temperature gradient ranges between 23.7°F/100 feet and 1.0°F/100 feet. The temperature gradient in the bottom 350 feet of the well appears to be at the higher end of this range, but there is considerable doubt that it is as high as 23.7°F/100 feet.

Lithologic data[1] and analyses of test data indicate that the well has encountered a CO_2-rich zone at a depth of about 8050 feet, with the permeable zone extending to a depth of about 8400 feet. The well has no significant water inflow zones and there appear to be no inflows below a depth of 8400 feet. The proportion of water and CO_2 being produced by the well are difficult to determine due to the complex downhole conditions. Over a period of time, the well appears to develop a semi-stable two-phase gas froth condition rather than an all-liquid column.

Initial chemical analyses indicate that the produced water is similar to seawater chemistry, although enriched in calcium. The complex downhole condition precludes a determination of fluid chemistry under reservoir conditions.

Data to date are not conclusive in supporting the existence of a hydrothermal resource, however, further exploration appears warranted. The continuous flow of CO_2 indicates that its source is not an isolated pocket. The existence of CO_2 in a reservoir of some size positioned just above an apparent increase in temperature gradient are positive indications that there is a hydrothermal resource in the area penetrated by this well. The postulated resource may either be deeper in this bore or in close proximity.

4. TEST EQUIPMENT

The conditions encountered while drilling and testing Ascension #1 were radically different than those that were assumed in the Test Plan[4] and that were used to generate the specifications for the surface flow test equipment design. The equipment was designed to test a single-phase, pumped liquid resource. However, the well produced a two-phase fluid consisting of CO_2 and subcooled water with brief periods of two-phase water and CO_2. The well was self flowing and the pump was not required.

4.1. Mechanical System

The flow line constructed for the test was modified to allow it to accommodate the drilling rig left over the hole and to attach to a ten-inch flange on the BOPE stack. Figure 4-1 is a piping and instrumentation diagram of the system and Figure 4-2 is a plan schematic of the test equipment. A four-inch vent line was installed on the wellhead in the position that the flow line was originally intended to occupy. This line provided the ability to isolate the flow line without shutting in the well. The vent line was attached to one of the three-inch wellhead wing valves and was constructed from the four-inch pipe that was intended for the pressure relief system on the original flow system and from some three-inch water pipe that was on site.

The flow piping was attached to a twelve-inch tee above the master valve and was lengthened by adding 38 feet of 10-inch casing that was available on site. The casing was run at the elevation of the tee and connected to the downcomer that was included with the original flow system. The original flow system was hydrostatically tested to 650 psig prior to shipping. There were no provision on the island to perform a hydrostatic on the modified system. The orifice plate installed in the eight-inch diameter line had a diameter of 5.871 inches, and remained in the system for the entire test. A four-inch

James Tube was attached to the end of the flow unit for the entire test.

A two-phase sample rake was fashioned from 1/4-inch stainless steel tube and RTD installation hardware. The two-phase sample rake was placed horizonially in the sample port to allow for extraction of fluid samples that better represented the true character of the mixed properties of the fluid. A schematic of the two-phase rake is included in Figure 4-1. The rake is described in section 8.2 of this report.

The flow equipment as modified enabled testing of the well and all the equipment functioned as intended.

4.2. Instrumentation

The flow test instrumentation that was installed was also quite different than originally envisioned and specified in the Test Plan[4]. A schematic of the instrumentation used during the test is shown as Figure 4-3. Table 4-1 is a list of all the instrumentation that was used on the test. The primary data were obtained electronically with a digital data acquisition system using electronic measurement devices. A complete manual system was also installed as a backup to the digital system. Recording pressure and differential pressure devices (Barton meters) were supplied for the wellhead and orifice, respectively, but proved to be of little value. The wellhead Barton meter had a 0 to 600 psig bellows to be consistent with a pumped single-phase test, while the actual pressures at the wellhead for the majority of the test were in the vicinity of 10 psig. The instrumentation piping on the orifice differential pressure taps made measurement of the pressure drop across the orifice difficult. In a two-phase environment "isolation pots" should be used to assure a common and consistent head of water on the instrument. As a result the Barton meter was removed in favor of a "U" tube manometer in an attempt to simplify the differential pressure measurement. Obtaining good measurements at the low pressures encountered in a two-phase system proved to be difficult.

A schematic of the digital data acquisition system used for the test is included as Figure 4-4. Three types of sensors were used. Pressure was measured with Paroscientific crystal transducers and Honeywell strain gauge pressure transducers. Temperature was measured using Resistance Temperature measuring Devices (RTDs).

All of the instruments were calibrated on site prior to installation and the data acquisition computer program utilized the coefficients that resulted from the pressure transducer calibration. No calibration coefficients were required for the RTDs. The location of each instrument and the coefficients used are included in Table 4-2, and a discussion of the instrument accuracy can be found in section 6.3 of this report.

4.3. Data Acquisition

Data were taken both electronically and manually during the test. Copies of the manual data sheets are included as Appendix C. The actual data reduction was performed using the electronic data, with the exception of the orifice pressure drop. The manual data were taken to provide a backup and to provide a redundant and diverse measurement to assure data quality.

A schematic of the digital data acquisition system is included as Figure 4-4. There were two types of electronic instruments used to collect data and each required different conditioning equipment. The strain gauge type pressure transducers and the RTDs produced analog signals that were converted to digital values in an Omega analog-to-digital converter. The Omega is a 64,000 byte digital computer that contains twelve 4 to 20 milliampere loops. The WPT Omega Board has been modified to provide a power supply and loop for four strain gauge pressure transducers. The digital signals were routed to a 640 byte specially equipped IBM-compatible micro-computer.

The Paroscientific transducers produce an frequency modulated (FM) signal. The Paro signal and be "counted" either in a Paroscientific computer or on countercards in the micro-computer. The counter cards were kept as backup and the Paroscientific computer was used to condition the signal and to digitize it for recording on Ascension Island.

The micro-computer used during the test was equipped with two floppy disc drives, and a special program was written to write the data on both the line printer and a floppy disk drive. The computer program was written specifically for this test and is included as Appendix D.

TABLE 4-1

ASCENSION #1 INSTRUMENTATION
FOR
THE DECEMBER 1986 FLOW TEST

P&ID NAME	DESCRIPTION	TYPE	RANGE AND ACCURACY
PA	PRESSURE, AMBIENT	PARO	0-900 PSIA ±0.05%
TA	TEMPERATURE, AMBIENT	RTD	0-500°F, ± 1%
P1A	PRESSURE, WELLHEAD	GAUGE	0-100, 1-300 OR 0-800 PSIG, ±1 OR 2%
P1	PRESSURE, WELLHEAD	BART.	0-600 PSIG, ± 1%
PWH	PRESSURE, WELLHEAD	PARO.	0-900 PSIA, ±0.05%
TWH	TEMP., WELLHEAD	RTD	0-500°F, ± 1%
T1	TEMP., WELLHEAD	DIAL.	100-700°F, ± 1%
P2	PRESSURE, FLOW LINE	GAUGE	0-100 & 0-600 PSIG, ± 2%
P2	PRESSURE, FLOW LINE	HWELL	0-600 PSIG, ± 1%
T2	TEMP. FLOW LINE	DIAL.	100-700°F, ± 1%
T2	TEMP. FLOW LINE	RTD	100-700°F, ± 1%
PO	PRESSURE, ORIFICE	PARO	0-600 PSIA ± .05%
DP	DIFFERENTIAL PRESS	HWELL	0-90 PSIG ± 1%
DP	DIFFERENTIAL PRESS	MANO.	VAR. AS FUNCTION OF FLUID
PJ	PRESSURE, JAMES TUBE	PARO	0-400 PSIA, ±0.05 %
PJ	PRESSURE, JAMES TUBE	GAUGE	0-100 PSIA, ± 2%

LEGEND:

PARO = PAROSCIENTIFIC CRYSTAL PRESSURE TRANSDUCER
RTD = RESISTANCE TEMPERATURE MEASUREMENT DEVICE
GAUGE = BOURDON TUBE PRESSURE GAUGE
BART. = BARTON METER WITH CIRCULAR CHART
DIAL = DIAL TEMPERATURE INDICATOR
HWELL = HONEYWELL STRAIN GAUGE PRESSURE TRANSDUCER
MANO = "U" TUBE MANOMETER - USED WATER AND 1.75 SPECIFIC GRAVITY FLUIDS AT DIFFERENT TIMES

TABLE 4-2

ELECTRONIC INSTRUMENT LOCATION
and
COEFFICIENTS

LOCATION	SERIAL NUMBER	ACQUISITION COEFFICIENTS
PA	PARO 26196	Zero offset=0.307, C=4612.84, D=0.0136887, τ_o=25.60759
PWH	PARO 11874	Zero Offset=0.057, C=5028.66, D=-0.00505, τ_o=24.43285
PO	PARO 26195	Zero Offset=0.067, C=4525.07, D=0.0264811, τ_o=25.88765
PJ	PARO 11242	Zero Offset=0.127, C=1981.14, D=0.00424, τ_o=24.78983
DP	Honeywell 7934	DP=(SIGNAL-19.7)*0.9
P2	Honeywell 7933	P2=(SIGNAL-20.8)*7.04+PA

LEGEND:

PA=Ambient Pressure, psia
PWH=Wellhead Pressure, psia
PO=Orifice Upstream Pressure, psia
PJ=Pressure James Tube, psia
DP=Orifice Differential Pressure, psid
P2=Pressure in the Flow line, psia

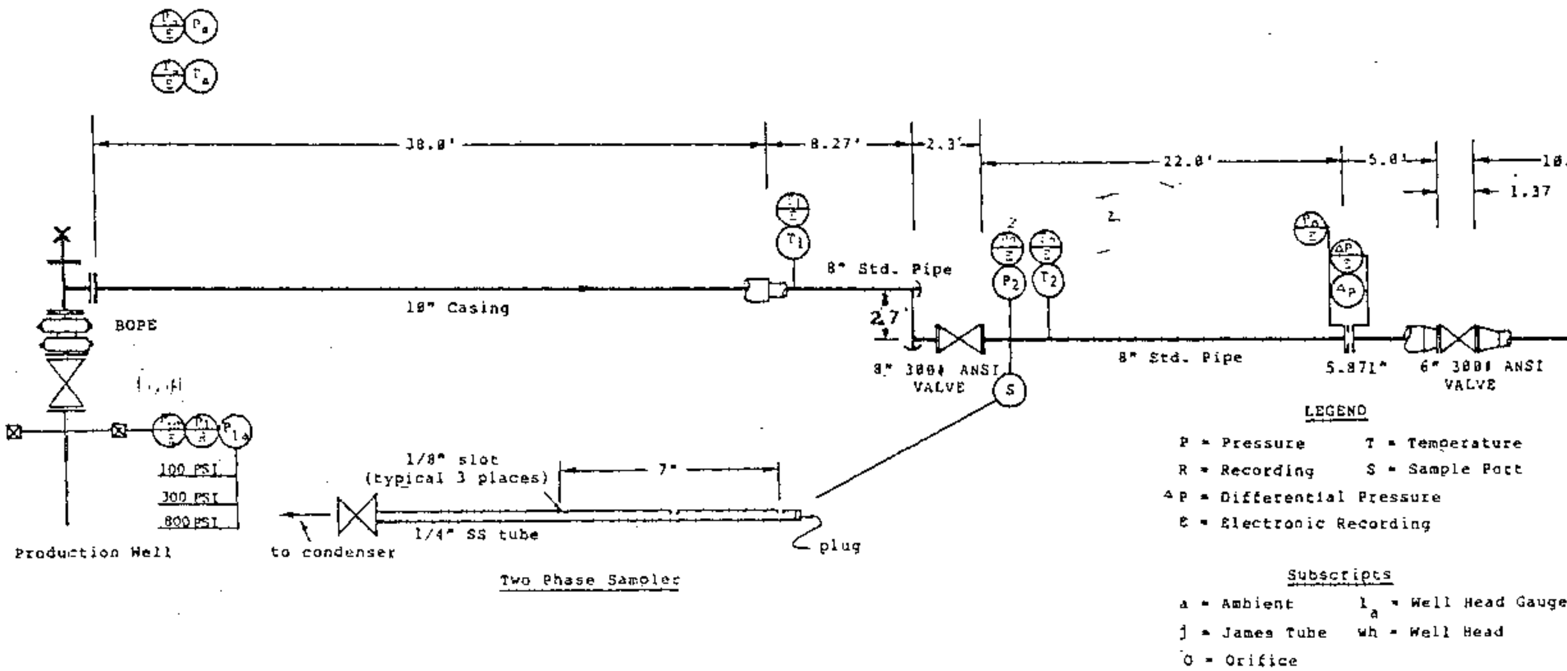
The coefficients C, D and τ_o are defined by the equation:

$$P=C\{[1-(\tau/\tau_o)^2]-D[1-(\tau/\tau_o)^2]^2\}$$

used to convert the Paroscietific signal (τ) to pressure. These coefficients are supplied by Paroscientific.

The RTD signals are found by measuring the resistance change in a 4 to 20 milliamp loop:

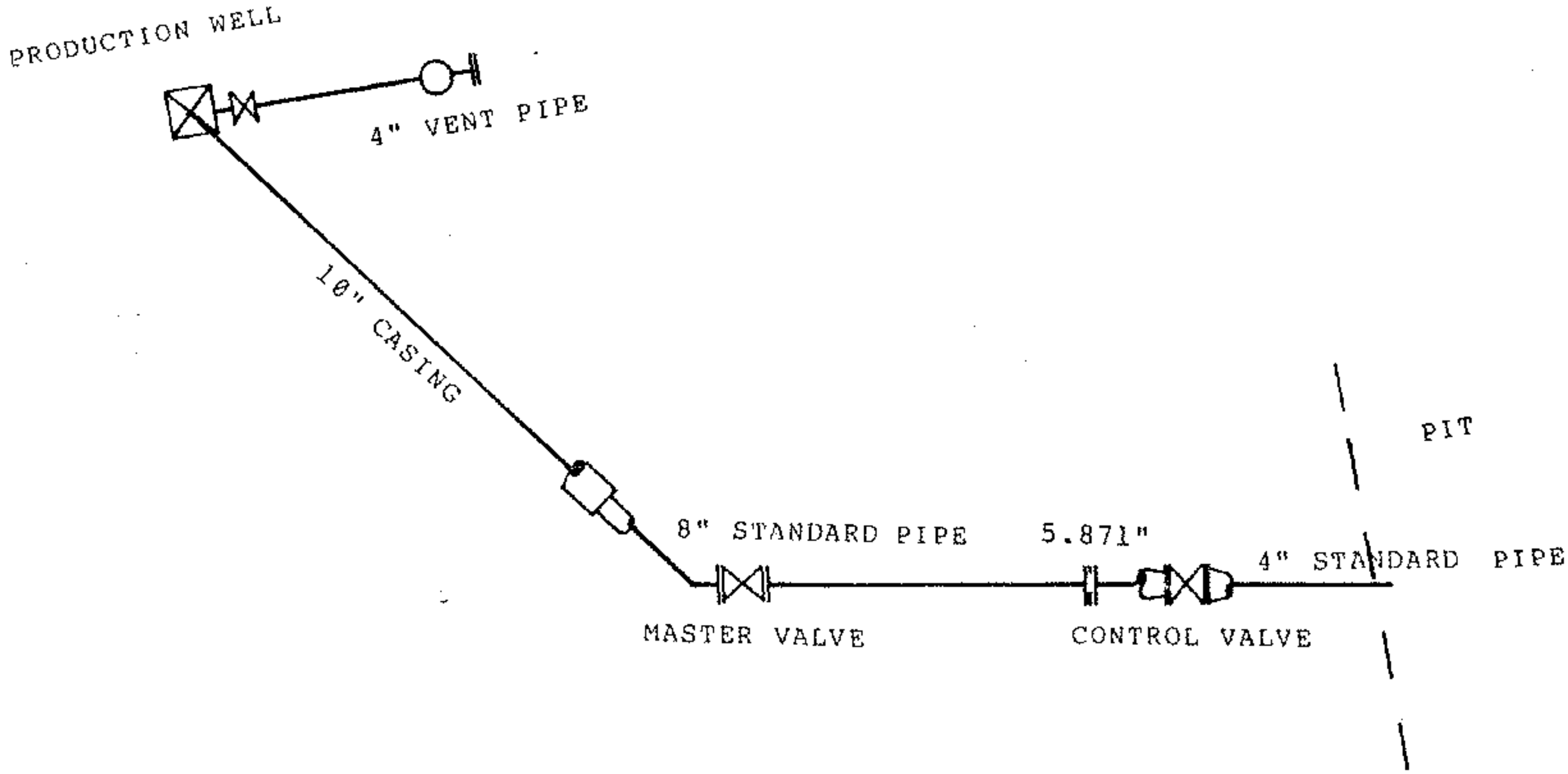
T(°F)=SIGNAL*1.8+32.0



TEST EQUIPTMENT P&ID

FIGURE 4-1

FIGURE 4-2



TEST EQUIPTMENT

PLANFORM SCHEMATIC

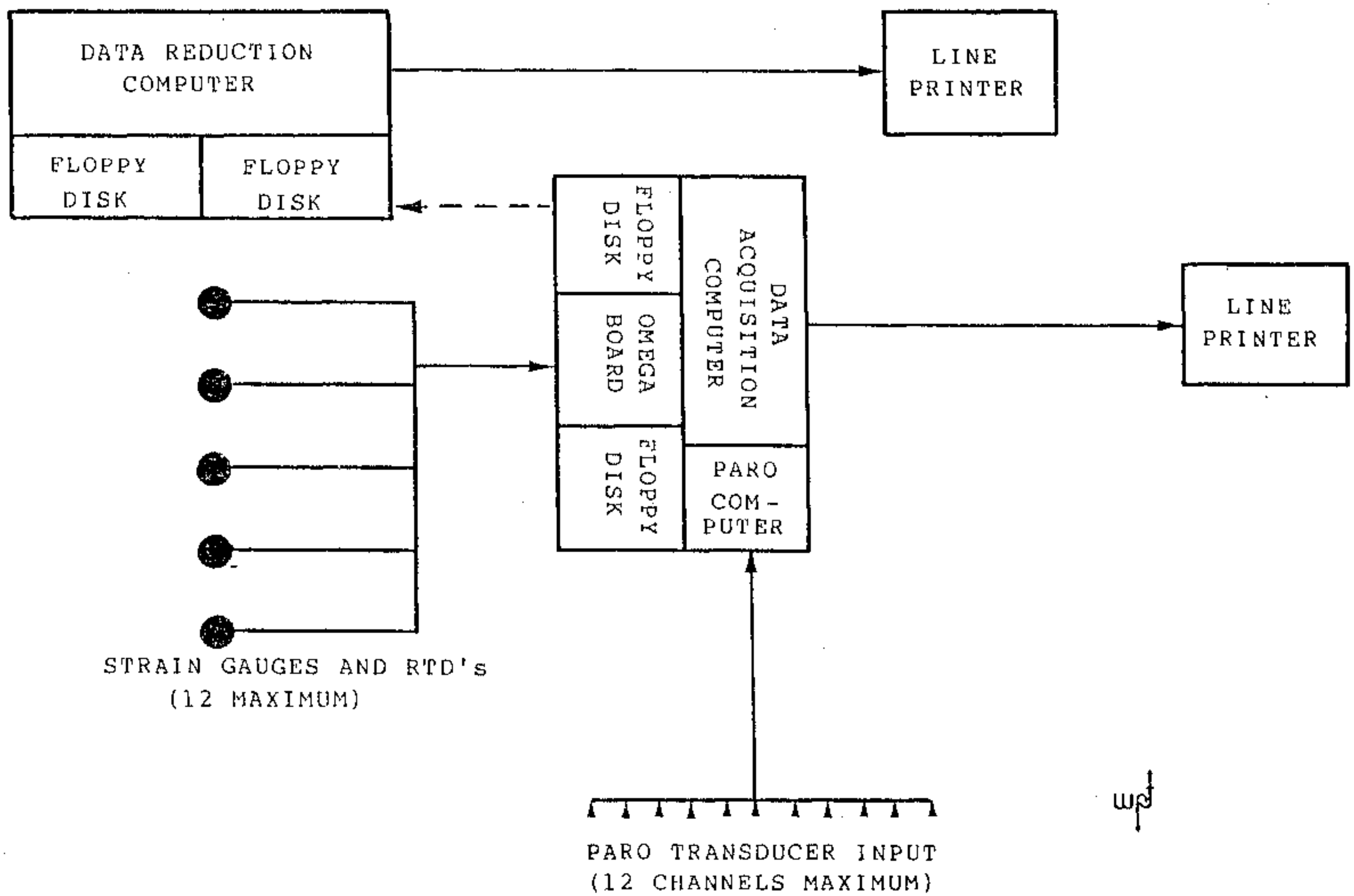


FIGURE 4-3

DATA ACQUISITION SYSTEM

5. OPERATIONS

The well was flowing when it was turned over to the test crew by the drillers and as a result the test start time was rather arbitrarily defined. Downhole slickline surveys for pressure and temperature were conducted during the drilling. After drilling manual data collection was initiated at 1300 hours on November 30, 1986, and computer data acquisition was started on December 1, 1986 at 0600 hours. The data acquisition and reduction software used midnight, December 1, 1986 as zero test time, and all data listings and plots that use test time are consistent with that zero time.

The first eight downhole surveys were run prior to December 1, 1986. The first four were temperature surveys run in the drill pipe. The drill pipe was removed from the hole and the first openhole pressure and temperature survey was run on November 26, 1986. The well was flowing for all but the first survey. A description of the downhole surveys is included in Section 7 of this report.

A plot of wellhead pressure and temperature for the duration of the test is included as Figure 5-1. The well was allowed to flow through the test line with the valves open for the majority of the test. Three step rate tests and a pressure build-up test were run. The first step rate test (Figure 5-2) was started at about 16 hours, test time and had steps of approximately 60 and 130 psia wellhead pressure. Each step was held for approximately 3 hours. The second and third step tests, shown in Figures 5-3 and 5-4, were started at 109 and 131 hours test time and consisted of steps similar to the first. The final build-up test was started at test time 208 hours, when the wellhead pressure was stepped to approximately 300 psia and held at that pressue until 224 hours test time. At that point, on December 10, 1986, the master valve was closed in an attempt to shut in the well. The shut-in was aborted at a wellhead pressure of approximately 750 psia (Figure 5-5) when it became apparent that the wellhead pressure was going to exceed the range of the available wellhead pressure gauges (800 psig). There was concern that the well head and casing should not be exposed to excessive pressures. When it became appearent that the pressure gauge range was going to be exceeded which precluded monitoring the well head pressure, the shut-in was aborted.

A detailed Chronology of Events is included as Appendix B. The following is a summary of key events by the day they occurred.

11/20 Stopped drilling at 6288 ft. Blew out hole for 1 hour. Ran Temperature survey in drill pipe set at 6244 feet.

11/22 Drilling ahead - at 7060 feet the Mud Engineer estimates making 22 bbl/hr of water.

11/24 CO_2 "kick" at 8050 feet from 3000 ppm to 13,000 ppm. At 8120 feet had a 440 psi increase and 16 °F temperature increase (initial increases). Pressure and temperature kicks were also encountered at:

8135 feet, 560 psi, 5 °F
8142 feet, 650 psi, 8 °F
8250 feet, 350 psi, 8 °F
8292 feet, 400 psi
8370 feet, 555 psi, 10°F
8545 feet, 350 psi, 8 °F

Well producing on its own. Ran temperature survey through drill pipe to 8300 feet.
Stopped drilling at 8706 feet.

11/25 Well still producing on its own. Ran temperature survey through drill pipe from 8000 to 8640 feet.

11/26 Ran temperature survey through drill pipe of upper section of the hole (to 7930 feet).

11/26 Ran flowing temperature/pressure survey to 8600 feet.

11/27 Shut-in well to change from 3-inch plastic blooie line to 4-inch steel line. Wellhead pressure increased to 400 psig; opened valve. For about an hour well slugging and flow was "wetter". Wellhead pressure had declined to 20 psig in approximately 90 minutes.

11/28 Flow switched from bleed line to flow line. Ran pressure test to 100 psig. Ran openhole temperature and pressure survey to 4500 feet. Calibrated pressure tool, checked to ± 2 psi in the 0 - 500 psig range.

11/29 Attempted to run a pressure and temperature survey from 4000 feet to bottom hole (TD). Could not get below hole size reduction at 4600 feet. Continued to rig up flow test unit and surface instrumentation.

11/30 Attempted to run downhole survey with a centralizer. Could not get below 4600 feet. Started taking surface data manually from gauges.

12/1 Computer data acquisition system on line. Zero test time is midnight 12/1/86. Ran step rate test with wellhead pressure steps of 60 and 130 psia.

12/2 Continued step test. Plume is very dry at high pressure and sounds like a jet. Opened throttle valve and well produced noticeably more water. Toxic gas detector alarmed briefly. Production back to "normal" in approximately 15 minutes.

12/3 Flowing, valves wide open.

12/4 Ran flowing pressure/temperature survey to bottomhole.

12/5 Ran step test starting at about noon. At 130 psia step, plume looked very dry. Toxic gas monitor alarmed briefly. Opened control valve; well produced lots of water vapor.

12/6 Ran step tests with pressure and temperature tools sitting at 8120 feet to evaluate possible entry at this depth.

12/7 Flowing open

12/8 Flowing open

12/9 Noon: started downhole for last pressure and temperature survey. Will remain on bottom for shut-in. At 1603 hours started shutting throttle valve. Wellhead pressure up to 270 psig at 1641 hours; cracked throttle valve. Continued to close valve until wellhead pressure increased to approximately 300 psig.

12/10 Pressure continuing to decline slightly. At 0525 hours, the wellhead pressure at 300 psig. At 0714 hours wellhead pressure at 321 psig. Downhole tools coming out of the hole.

Shut-in wellhead master valve at 0944 hours. At 1135 hours wellhead pressure rising at at rate of about 3 psi/minute. Wellhead pressure is 650 psia.

At 1222 hours, opened wing valve. Started to vent water at about 1300 hours, blowing about 60 feet into the air. Wellhead pressure beginning to rise from 110 psig to 230 psig. At 1310 hours, opened master valve to vent well through the flow line. At 1540 hours, shut master valve with wellhead pressure at 10 psig and allowed well to vent through the wing valve/vent line.

12/11-1/29/87

Well remained on vent with the wellhead pressure slowly declining from 15.5 psig to 4.5 psig (note that the configuration of the vent line influences the wellhead pressure). Some episodes of "geysering" were observed.

1/30 Returned to conduct additional surveys and sampling. Wellhead pressure 2 psig but increased to 6-9 psig every 10 minutes or so and well "geysers".

1/31 Ran temperature/pressure survey; could not get below 8005 feet. Immediately following survey the well started blowing water 30-35 feet in the air. Geysering continued for about two hours. Switched flow from vent line to flow line.

2/1 Ran temperature/pressure survey to 8140 feet.

2/2 Throttled well to a wellhead pressure of nominally 90 psig for 8 hours for additional sampling and temperature/pressure surveys.

2/3 Shut master valve and left well on vent. Wellhead pressure 1.1 psig.

ASCENSION #1 — FLOW TEST (DEC. 1986)

WELL HEAD PRESSURE & TEMPERATURE

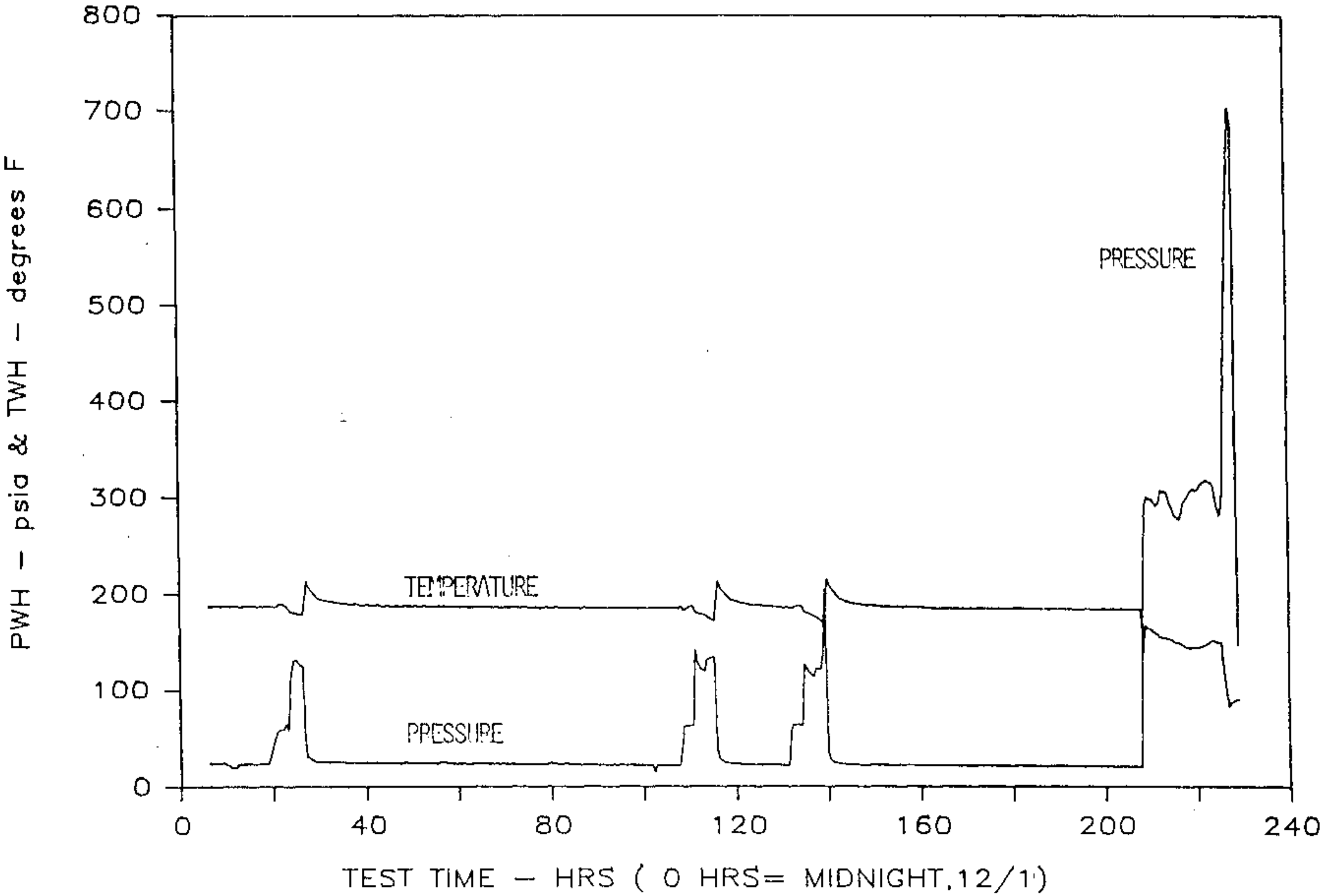


FIGURE 5-1

ASCENSION #1 — FLOW TEST (DEC. 1986)

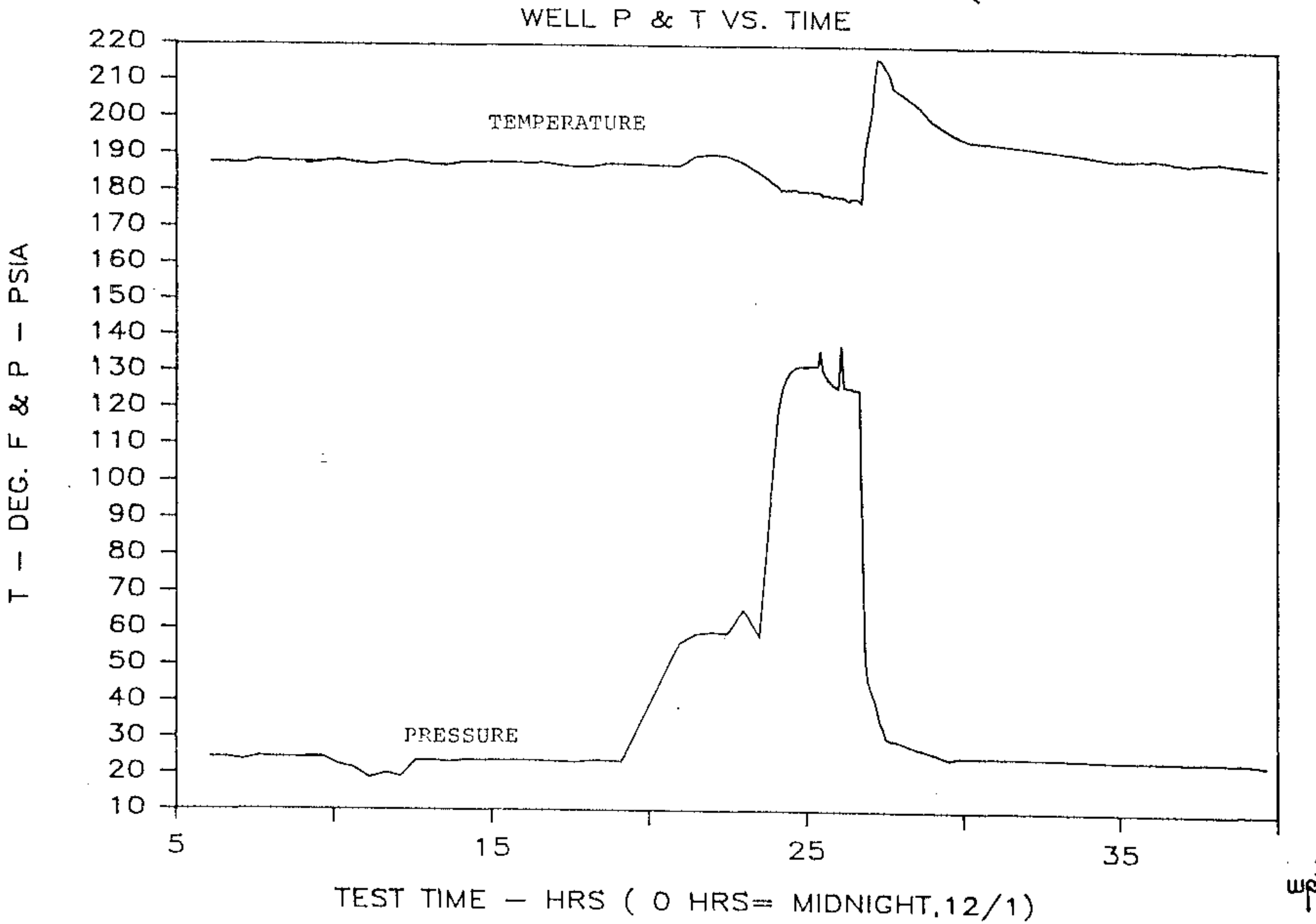


FIGURE 5-2

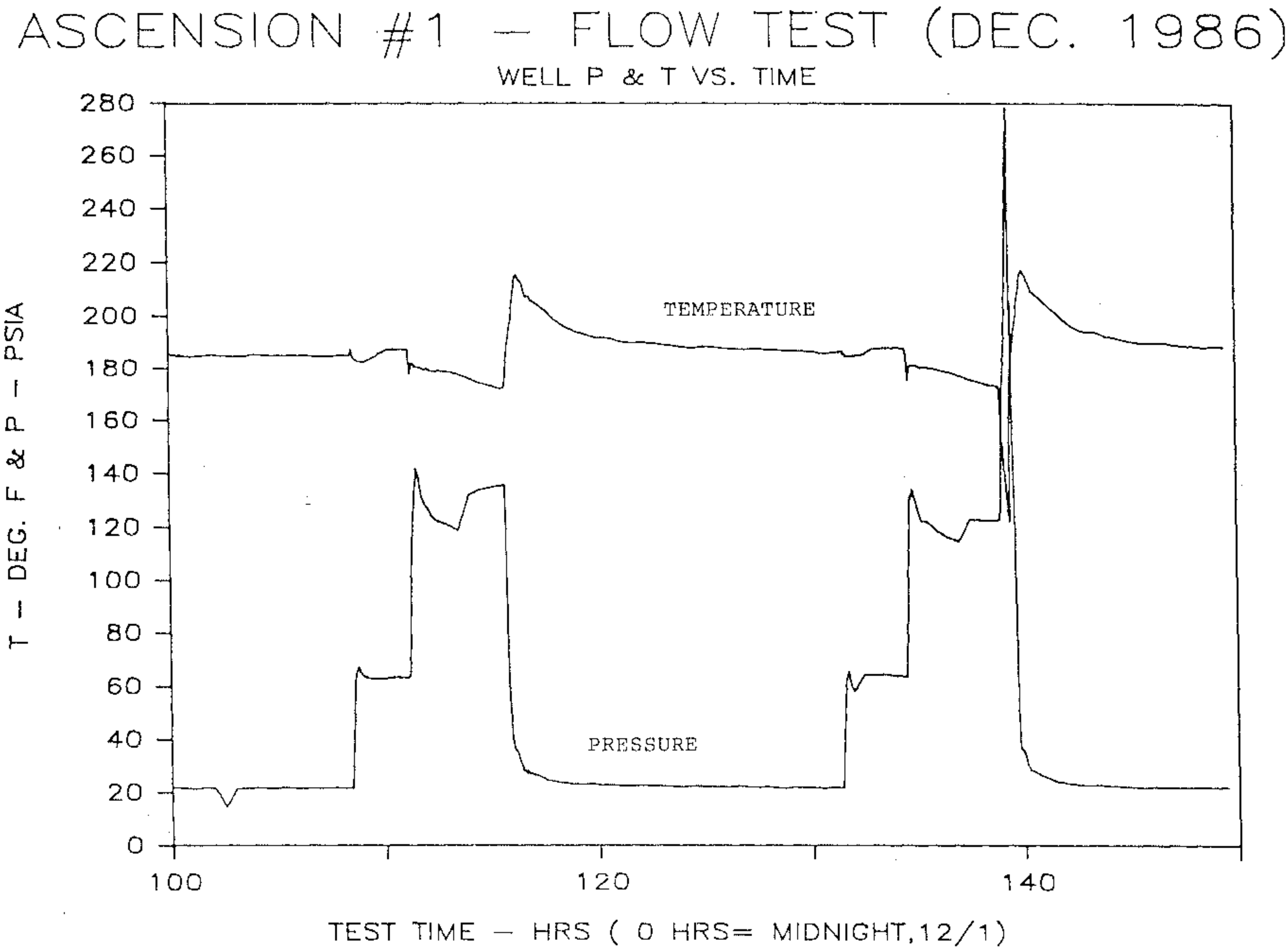

ASCENSION #1 — FLOW TEST (DEC. 1986)
WELL P & T VS. TIME
TEMPERATURE
PRESSURE
T — DEG. F & P — PSIA
TEST TIME — HRS (0 HRS= MIDNIGHT,12/1)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
100
120
140

FIGURE 5-3

ASCENSION #1 — FLOW TEST (DEC. 1986)

WELL P & T VS. TIME

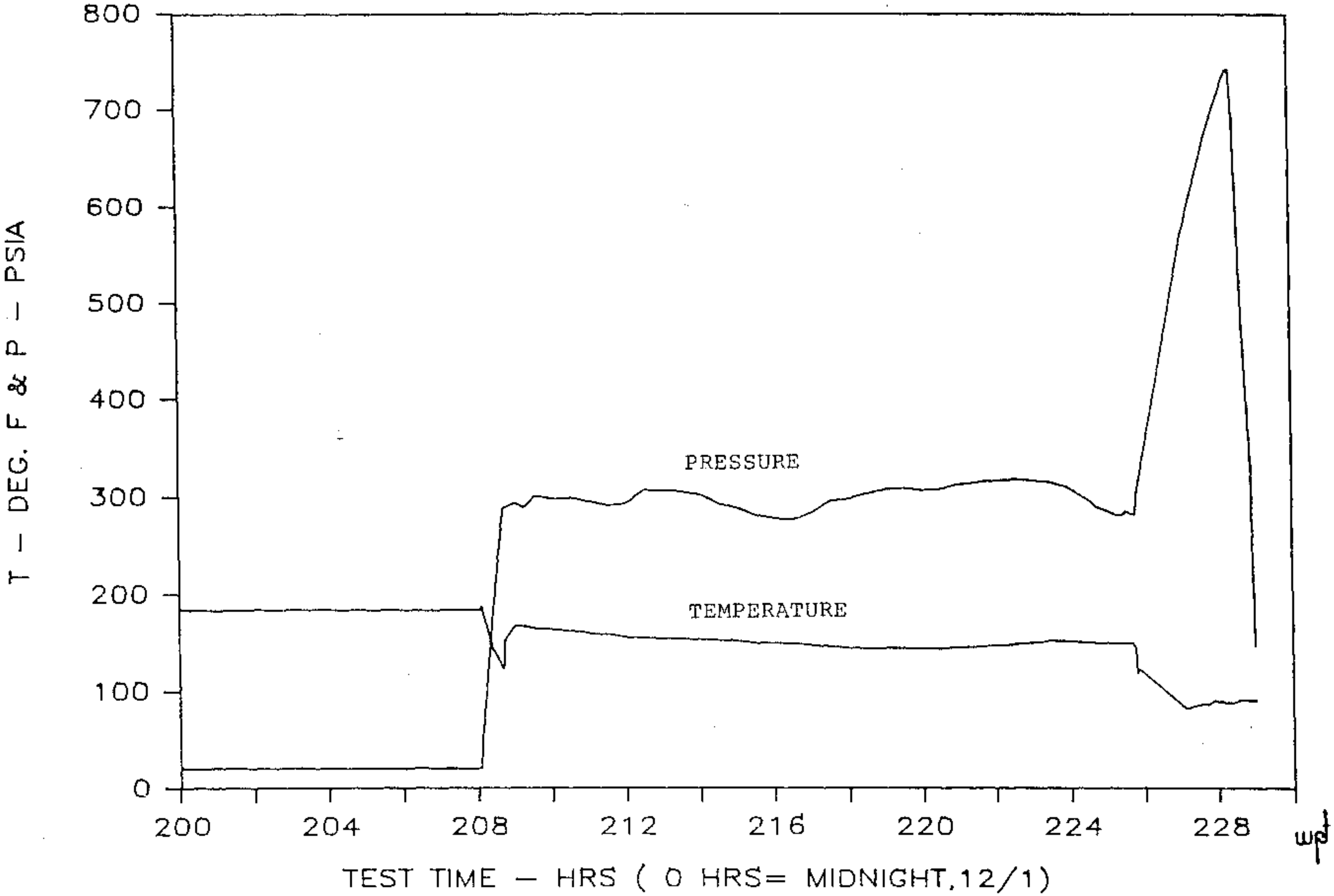


FIGURE 5-4

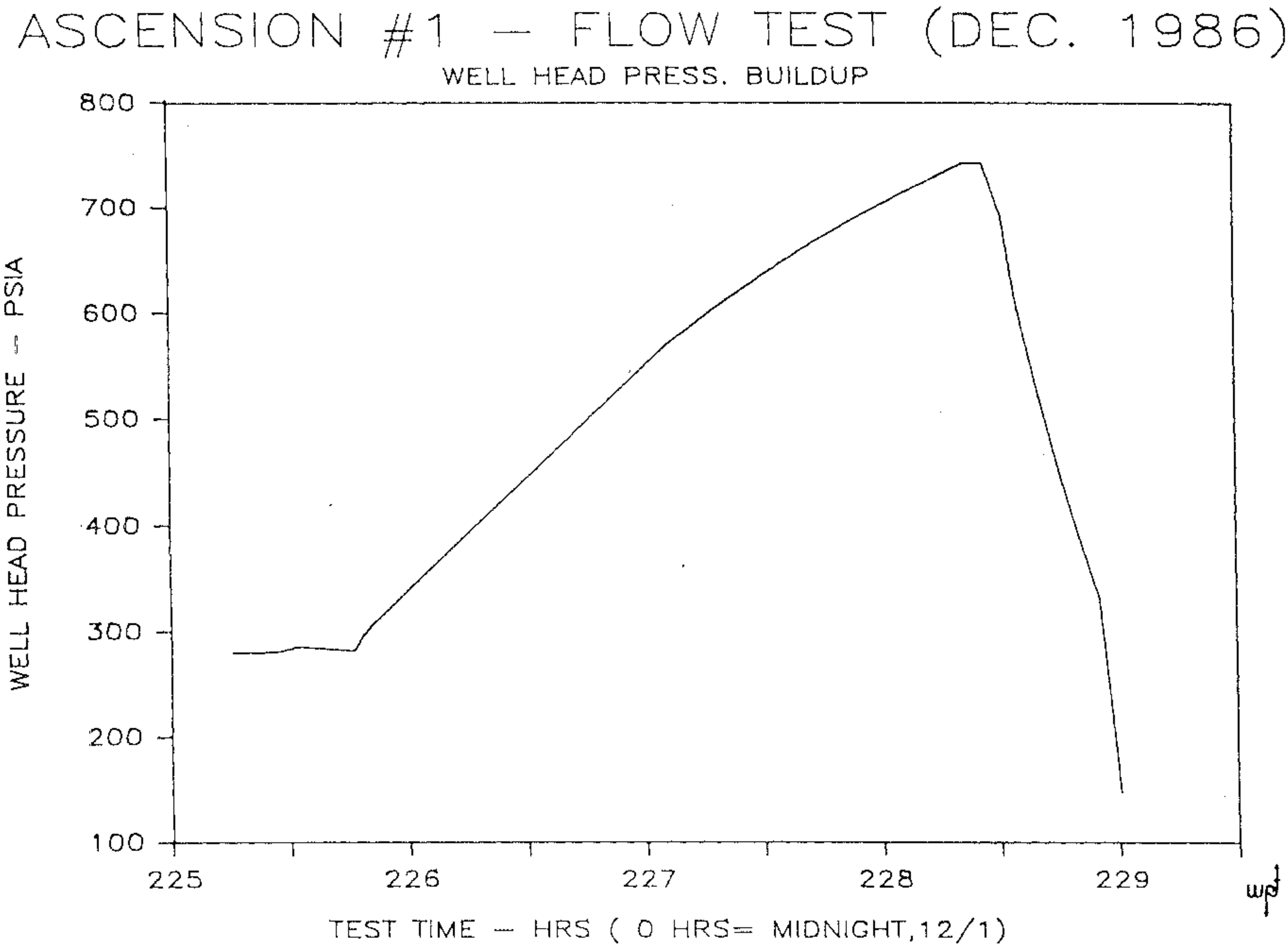

ASCENSION #1 — FLOW TEST (DEC. 1986)
WELL HEAD PRESS. BUILDUP
WELL HEAD PRESSURE — PSIA
800
700
600
500
400
300
200
100
225
226
227
228
229
TEST TIME — HRS (0 HRS= MIDNIGHT,12/1)

FIGURE 5-5

6. DATA REDUCTION

6.1 Instrumentation

The primary surface data was acquired by a digital data acquisition system. A micro-computer read the transducer outputs, converted the signals to engineering units, and recorded the measurements on paper printout and diskettes. The signals were corrected by the results of pretest instrument calibrations. The parameters measured are presented in Table 6-1.

Each of these measurements were backed up by a secondary instrument, except for the James Tube pressure. The instruments were manually recorded nominally every half hour. The secondary devices were included solely to back up the electronically acquired data, and to provide a redundant data source for quality assurance during the test. In general these data are less accurate than the electronic measurements and were not used for data analysis. In the course of events only the manometer poduced data that were needed to validate the eletronic data by supporting the measurement of pressure drop across the orifice plate. The manual data sheets are included as Appendix C.

6.2 Pressure Instrumentation Calibration

Calibration checks were performed on each of the surface pressure devices before and after the test. These checks were performed using a deadweight tester. The Paroscientific devices showed a slight offset (-0.06 to 0.2 psia) and linear trend (1.002 to 1.004). The offsets were adjusted in the data acquisition program, but the slope of the response was not corrected because the trend is not statistically different from 1.0.

The Honeywell gauge sn7933 (P2) indicated a 20.9 mV reading at 0 psig. A value of 20.8 was used in the data acquisition program for the offset for a psia reading. The calibration showed a perfectly linear trend. A comparison to the Paro sn26195 (P orifice) showed less than 1% linear variation in their responses. These instruments are believed to yield accurate readings to better than 1%.

The orifice delta pressure gauge (Honeywell sn7934) is a 0 to 90 psid instrument. The calibration of this instrument was performed over the full scale of the device. The calibration revealed a 19.7 mV offset and a 1.141 linear trend. During the test the gauge was inspected and a 0.5-inch dent was found on the low-pressure face of the diaphragm. The instrument was inspected prior to shipment and and the dent was not noted at that time. The post-test calibration gave the same results as the pre-shipment and pre-test checks. This instrument was working at less than 1% of full scale during most of the test and these full-scale calibrations did not give sufficient indication of the response at this low range. To check the low end sensitivity this device was sent to Honeywell for an additional calibration. The calibration confirmed an accuracy of 0.5% of full scale and indicated a 1.0% accuracy at 1.5 psid.

The manometer was installed during the test to provide a backup and cross-check on the delta P gauge. Unfortunately the manometer was beset with problems associated with the condensation of well fluid in its lines. Until a method was devised to prefill the manometer source lines with water, measurements were accurate only moments after refilling the manometer U-tube with fluid. Hence the manometer did not provide reliable data from which to cross-check the orifice delta pressure readings.

6.3 Data Reduction and Qualification

The data presented in Appendix F have been qualified through the use of pre- and post-test instrument calibrations and the backup instrumentation. The data record has been split into a total test record of half-hour increments and separate records of the transient portions of the test. Some of the raw data have been removed because they were redundant or, in a few cases, obviously erroneous.

Only the pressure drop across the orifice plate required correction. To dorrect a mathematical error the recorded pressure drop across the orifice has been multiplied by 1.141/0.90=1.268. The zero of the delta P exhibited shifts during the test; howeve there was no appreciable change in the zero between the pre- and post-test calibration. It is believed that the shifts were due to a liquid presence in the instrument tubing. The zero was adjusted in the acquisition program on 12/5 at 1530 hours. An offset of +0.17 psig was added to the measurement at this time and remained throughout the remainder of the test. The calibrations of the other pressure instruments showed deviations of less that 1%, which is the limit of resolution of the calibration process. This is not sufficient justification to adjust the data. The temperature measurements agreed with the backup measurements and were consistent between themselves to within 1%.

Flow rate was also calculated assuming that the exit of the flow system was sonic (choked). The calculations use the James tube pressure measurement, but not the James Correlation due to the presence of large amounts of CO_2. The results are plotted in Figure 6-1 along with the flow calculated using the orifice measurements. It appears from the comparison of the flows that the James Tube was sonic only for the times when the wellhead pressure was over 100 psia and the quality approached 1.0. The flows calculated with this method should be disregarded at all other times.

TABLE 6-1

Electronic Instrument List

Parameter	Instrument	Range
Ambient Pressure	Paro #26196	0-900 psia
Ambient Temp.	RTD	
Wellhead pressure	Paro #11874	0-900 psia
Wellhead Temp	RTD	
Pipe pressure (P2)	Honeywell #7933	0-600 psig
Pipe Temp. (T2)	RTD	
Orifice Upstream P.	Paro #26195	0-900 psia
Delta P of Orifice	Honeywell #7934	0-90 psid
James Tube pressure	Paro #11242	0-400 psia

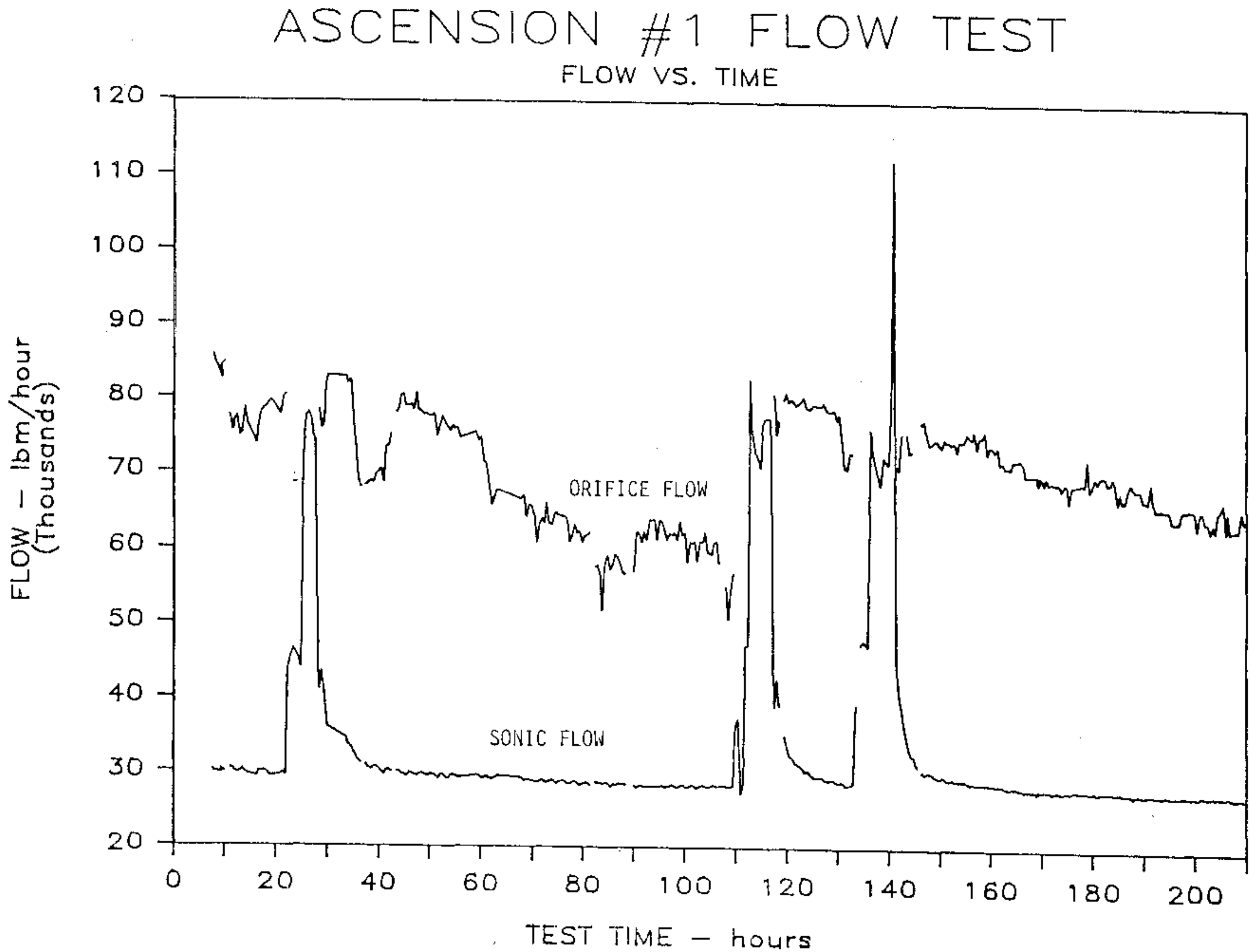

ASCENSION #1 FLOW TEST
FLOW VS. TIME
FLOW – lbm/hour
(Thousands)
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
120
140
160
180
200
TEST TIME – hours
ORIFICE FLOW
SONIC FLOW

FIGURE 6-1

7. WELLBORE LOGS

During the period from November 19 through December 9, 1986, 13 downhole surveys were performed in Ascension #1. As a result of the well performance and to support a better understanding of downhole conditions and possible well rework, more emphasis was placed on the downhole surveys and more data were taken than was originally described in the Test Plan[4]. A list of the surveys is shown in Table 7-1. All surveys were performed using Kuster slickline tools. No electric logs of the well were performed.

The first four surveys were temperature profiles taken inside the drill pipe as the drilling was being completed.

During the subsequent "openhole" surveys a great deal of difficulty was experienced descending below 4160 feet. At this point the hole diameter changes from 10-3/4 inches to 6-3/4 inches, and it is assumed that the tools were stopping on the resulting ledge. Runs 7 and 8 were abandoned since attempts to descend below 4160 feet were unsuccessful. Subsequent attempts to reach bottom hole were successful as a result of allowing the tool to bounce off the ledge and continue downhole. This technique, however, resulted in the element stylus slipping and loss of the time reference in a number of cases (Table 7-1).

The downhole surveys produced a considerable amount of believable and interesting data and to a large part provided the data used to arrive at the conclusions presented in this report.

7.1. Accuracy of Data

The presence of vapor in the wellbore resulted in much lower downhole pressures than were originally expected and as a result the 0-3825 psig Kuster pressure elements were ranged far too high for all but Run #13. One of the Kuster pressure elements was calibrated at low pressures on site using a deadweight tester and found to be within ± 3.0 psi at 100 psig.

7.2. Downhole Data

The original data sheets and the logging technician's logs are reproduced in Appendix G. The data for each run include the log that was kept on the surface while the run was being performed and the data sheet that was prepared on site when the charts were read.

Runs #1, 2 and 3 were made in the drill pipe as the well was being drilled and completed. A temperature of 308°F was measured in Run #1 after the tool was allowed to sit for 84 minutes at 6240 feet (Figure 7-1). That is the highest temperature recorded at that depth. Either this is an anomalous point or flow from lower and cooler zones subsequently cooled the wellbore in subsequent runs.

Temperature vs. time at 6240 feet is plotted in Figure 7-2. This plot indicates that the temperature is building rapidly. The length of the survey (along with the low temperature conductivity of the gaseous phase in the wellbore) was insufficient for the normal exponential temperature buildup period to be accurately calculated. A Horner buildup analysis using these data indicates a projected formation temperature of 444°F. The length of the buildup was limited by concern that the drill bit and string could become stuck in the open-hole section if circulation and rotation were not resumed.

Run #2 was made in the drill pipe to 8300 feet. The data are shown in Figure 7-3. A plot of temperature vs time at 8300 feet is shown in Figure 7-4. Projected temperatures at this depth did not yield reasonable results.

A temperature buildup survey was made at 8640 feet during Run #3. The Horner buildup analysis indicated an equlibrium formation temperature of 418°F. Runs #3 and 4 can be concatenated to provide a temperature profile at the completion of drilling (Figures 7-5 and 7-6). The well was still warming at this point and the common point, 8000 feet, is off-set, but a good indication of the temperature profile results.

Run #5 (Figure 7-7) was the first openhole survey. The pressures must be considered carefully, since the range of the pressure element is 3825 psig and the pressure element may be affected by rapid changes of temperature. The pressure element used in these logs was checked on a deadweight tester on site and was found to be giving readings that were within ± 3 psig at 100 psig. That would indicate that the profiles shown are acceptably accurate. The clock failed during Run #5 at 4000 feet, but the maximum temperature recorded, 348°F, was assumed to have occurred at bottom hole. Since this temperature is significantly lower than the other logs it is assumed to be anomalous.

Runs #6,7 and 8 are not plotted since the tool was stopped at 4160 feet by the ledge in the wellbore, and no openhole data were obtained.

Run #9, Figure 7-8, was run during a step rate test where the wellhead pressure was stepped from 27 psia to 60 and 130 psia. At each of these pressures the well was surveyed from 7500 feet to bottomhole. The results show a cooling trend in the bottom section, which may indicate a reduced water flow in this area.

Run #11 is also a run that was made during a step rate test. The results are plotted in Figures 7-10 and 7-11 and are similar to the previous step rate test.

Run #12 (Figures 7-12 and 7-13) was run during the third step rate test. This time the tool was left at 8120 feet and allowed to equilibrate for 3 hours at 65 psia wellhead pressure and for 3-1/2 hours at 115 psia.

Run #13 (plotted in Figure 7-14), the final survey in the first series, was made to document the steady state temperature and pressure profiles that existed when the well was flowing with a wellhead pressure of approximately 15 psia. There is a high temperature gradient at bottom hole and the pressure appears to be following the boiling curve for a highly CO_2-saturated water. At approximately 8000 feet the temperature exhibits a sharp temperature change, believed to be caused by the entry of large amount of relatively cool CO_2 into the wellbore.

Run #14 was made January 31, 1987 (Figure 7-15). The well had been on vent with the wellhead pressure declining from 15 to 5 psig for approximately 45 days. The temperature at 8000 feet measured 368°F. An obstruction was encountered in the hole at 8005 feet, and logging could not be accomplished below this depth. The pressure gradient, as shown in Figure 7-15, indicates a gas-water mixture in the wellbore from the surface to 8000 feet.

Immediately following Run #14 the well blew down. During this event, which lasted approximately two hours, the wellhead pressure increased to a maximum of 45 psig and the wellhead temperature reached 248°F.

Run #15 was conducted after the wellhead pressure had stabilized at 2.5 psig and the well was venting through the eight-inch flow line. The pressure and temperature profiles are shown in Figure 7-16.

Run #16, shown in Figure 7-17, was made with the wellhead pressure choked back to 81 psig. The temperature and pressuredata obtain during this run indicate that the well was in a transient state.

The pressure gradients from Run #14 were used to estimate the amount of CO_2 and liquid in the wellbore. There was approximately 3.45 weight percent CO_2 in the bottom portion of the wellbore. The large amount of wellbore storage and fluid interaction in the wellbore, however, preclude arriving at any conclusion as to the quality of the fluid flowing into the wellbore or the fluid flowing out of the well. The well appears to be in an unstable state in which the velocity of the incoming gas is insufficient to carry out the water entering the well. The slip velocity (difference between gas and water velocities) becomes large and siginificant amounts of water are held up in the wellbore. Perturbations such as the movement of the logging tool appear to be sufficient for the well to discharge large amounts of the stored water. The calculations using the pressure gradient from Run #14 indicate at that time that CO_2 is flowing at a much higher velocity than the water and appears to be bubbling up through the water in the wellbore. The distribution has the appearance of churn or dispersed flow. The result is a CO_2-water froth that changes quality along the wellbore to account for the pressure change in fluid weight. This system is not stable since it affects the drawdown of the reservoir. As the pressure changes in the reservoir, the fluid conditions in the wellbore will change to reach a pressure balance. In other words, the well can be expected to "geyser".

7.3 Analysis of downhole data

The downhole data are difficult to analyze because of the low flow rates and complex downhole flows of both CO_2 and liquid. The two primary reasons for running the numerous downhole surveys were to (1) determine the flow characteristics of the reservoir and (2) determine the formation temperatures. As a result of the complex downhole conditions it is extremely difficult to accurately interpret the logs to conclusively predict either formation temperature or location of the production zones.

The pressure buildup behavior and flow behavior both suggest a low permeability reservoir that produces a gas (CO_2) with varying amounts of brine. The pressure and temperature data along with the mud logger's data indicate that the flows are between approximately 7,050 feet and 8,430 feet. There does not appear to be any flow into the wellbore from 8,430 feet to 8,707 feet (the total measured depth of the well).

7.3.1 Pressure Buildup Tests

Two buildup tests, Runs #12 and #13, were made after the multiple rate flow test. While the downhole pressure tool was in the hole for Run #12, the well was pinched back at 14:35 hrs according to the supervisors log (14:32 according to the clock on the WH pressure transducer). The buildup data ended at 18:00 hrs for a 3-1/2 hr shut-in. The wellhead pressure (WHP) and the downhole pressure (DHP) data are plotted in Figure 7-19. WHP was maintained in the range of 110 to 130 psia during the shut-in. DHP nearly leveled off at 370 psig after 20 minutes before it began to build up again. After 100 minutes the pressure began to rise more rapidly to the end of the test while the WHP remained essentially constant.

The valve was closed at 16:03 hrs for Run #13 according to the supervisor's log (16:06 according to the WH clock). At 16:42 hrs the valve was opened and manipulated thereafter to maintain WHP.

After shut-in, both WHP and DHP increased in parallel (Figure 7-19) and then leveled off at about 40 minutes after shut-in, then the WHP was maintained at around 300 psig. At approximately 80 minutes the DHP began to rise again, reaching a peak of 1028 psig at 850 minutes. Ater this point it began to drop until the time that the test ended, and the tool was removed from the hole. This decreasing pressure effect appears to have been caused by manipulation of the throttle valve. The test lasted 16-1/2 hours.

The behavior of the DHP in both Runs #12 and #13 indicated that immediately after the well was pinched back, or shut-in, the pressure tool was in gas containing a mist of liquid water. After a period of time, fluid entering the wellbore rose to the depth of the gage and then continued to rise above the level of the gage. Most of the liquid probably came from a zone with a low liquid permeability. Because of the problem of fluid rising above the level of the pressure tool and because of wellbore storage effects, the pressure buildup data were difficult to analyze. Additional analysis was suspended since the homogeneous properties of the CO_2 reservoir where not of interest.

7.3.2 Temperature Data

The temperature data were difficult to analyze because of the flows into the wellbore as a result of the combination of gas and liquid entering the wellbore, and the wellbore pressure being below the saturation pressure of the liquid. The maximum recorded bottomhole temperature was 457 °F at 8,640 feet on survey No. 11. This corresponds to a saturation pressure for pure water of 468 psig. The "flash" point for water containing dissolved CO_2 would be higher than 468 psig; thus, anytime the wellbore pressure was below 468 psig flashing would be occurring at the bottom of the well. During run #11, liquid flashed into the wellbore leading to unsteady near wellbore temperatures. Even when the wellbore pressure exceeded the saturation pressure, as occurred during the pressure buildup on survey Run No. 13, the wellbore temperature was continuing to recover and did not reach the previously measured 457 °F. This appeared to be due to the temperature perturbation caused by liquid entering the wellbore from around 8,040 feet, flowing downward and boiling in the wellbore. During this shut-in the wellbore temperature was also considerably disturbed by convective flows within the wellbore.

Further complications in analyzing the downhole temperature data may be attributed to stratified flows of gases and liquids in the deviated wellbore. The wellbore had deviated over 14 degrees from the vertical at 5700 feet. No directional surveys were taken below this depth. The deviation from vertical in the lower section of the hole is unknown.

Initially it appeared during the drilling from 6,240 feet to 8,707 feet that the temperature gradient was increasing significantly with increasing depth. A detailed analysis of the temperature gradient using separate data sources, however, does not provide consistent results. A temperature survey was taken at 6,240 feet. Drilling was stopped at 6,243 feet for this survey. The maximum recorded temperature was 307.8°F. A Horner analysis of this data is shown in Figure 7-20. The temperature projects to be between 440°F. This projection is considered to be high since drilling was being done with air/foam. A Horner projection was done on the temperature data at 8,640 feet from survey data on Run #3. The projected temperature is 419° (Figure 7-21). This seems to be reasonable since the temperature at 8600 feet was measured to be 457°F in Run # 11. A Horner projection was done on the temperature data at 8,600 feet taken during survey #13 (Figure 7-22). This projected a temperature of 399°F. This is considered to be a low projection. There were four days of flow between survey No. 11 (12/5/86) and survey #13 (12/9/86), and considerable cooling of the wellbore had taken place due to the flow.

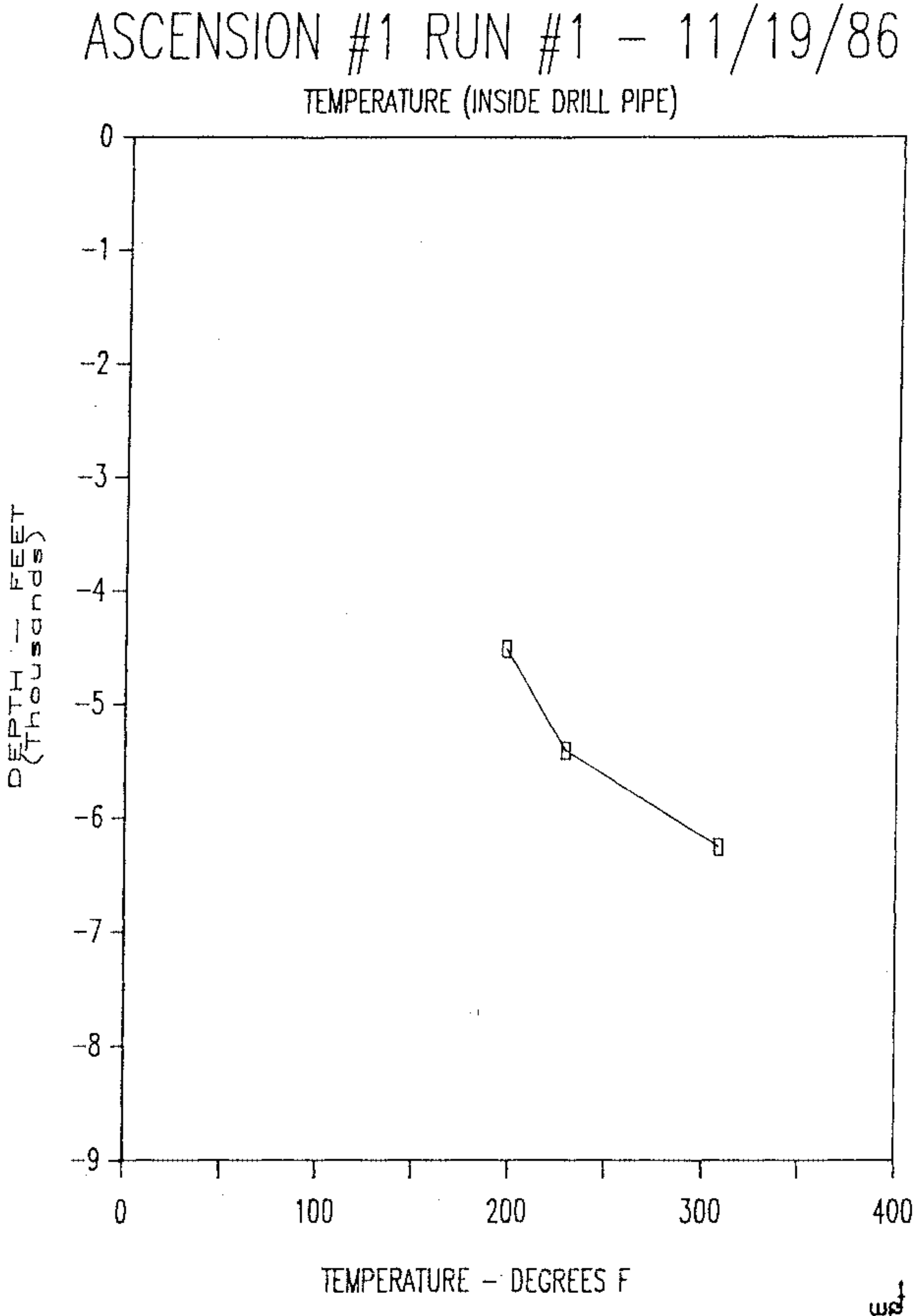
In conclusion, the wellbore temperature around 8,640 feet may be above 457°F. However, the temperature gradient of the formations is still in question. The gradient appears to lie between 23.7°F/100 feet and 1.0°F/100 feet. The maximum measured temperatures during Run #11, which are 457°F at 8,600 feet and 374°F at 8,250 feet, indicate the high gradient. The projected temperature of 434°F at 6,240 feet and the measured temperature of 457°F at 8,600 feet indicate the lower gradient. Neither seems correct. The unstable wellbore fluids suggests that the measurements during Run #11 do not accurately reflect the formation temperatures, and the projected temperature at 6,240 feet are doubtful because of the drilling fluid medium.

The 1.0°F/100 feet gradient represents an average between 6240 feet and 8640 feet, and therefore is conservative when related to the bottom of the well. The actual gradient between 8250 feet and 8600 feet is probably not as high as 23.7°F/100 feet since the temperature at 8250 feet is cooled by the CO_2.

Table 7-1
Ascension #1
DOWNHOLE SLICKLINE SURVEYS

RUN	DATE	DEPTH-FT	DESCRIPTION
1	11/19/86	6,240	Temperature survey inside the drill pipe. Stops at 4500 and 5400 feet
2	1/20/86	8,300	Temperature survey inside the drill pipe
3	11/21/86	8,640	Temperature survey inside the drill pipe. Stops at 8000, 8100, 8200, 8300, 8400, 8500 AND 8600 feet - flowing
4	11/24/86	7,930	Temperature survey inside the drill pipe. Stops at 500, 1000, 4000, 4500, 5000, 5500, 6000, 6500, 7000, and 7500 feet - flowing
5	11/26/86	8,600	Temperature and pressure survey - Stops at 500, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 7500, 7750, 8000, 8230, 8300, 8600 and 3000 feet. Lost temperature chart.
6	11/28/86	4,500	Temperature and pressure survey - Stops at 1000, 2000, 3000, 4000, 4500 and 3000 feet.
7	11/29/86	4,610	Temperature and pressure - unable to pass 4610-4620 feet.
8	11/30/86	4,610	Temperature and pressure - added centralizer in as attempt to get past ledge at 4610 feet - didn't help.
9	12/1/86	8,600	Temperature and pressure - stops at 4000, 7500, 7750, 8000, 8250, 8600 (P WH=29 psig); 7500, 7750, 8000, 8250, 8600 (P WH=45 psig); 7500, 8000, 8250 and 8600 feet (P WH=115 psig). pres. recorder stopped after 4000 feet.
10	12/4/86	8,600	Temperature and pressure - stops at 500, 1000, 4000, 7000, 7500, 7750, 8000, 8250, 8500 and 8600 feet. Lost time reference on pressure chart after 4500 feet.
11	12/5/86	8,600	Temperature and pressure - Stops at 4000, 7500, 7750, 8000, 8250, 8600 (P WH=22 psig); 7500, 7750, 8000, 8250, 8600 (P WH=49 psig); 7500, 7750, 8000, 8250 AND 8600 feet (P WH= 100 psig). Temperature chart lost time reference.
12	12/6/86	8,120	Pressure and temperature. Stops at 4000 and 4148 feet. At 8120 stepped P WH 7, 50 AND 100 Psig
13	12/9/86	8,600	Pressure and temperature. Stops at 500, 1000, 4000, 4670, 7500, 7750, 8000 and 8250 feet. Attempted to shut in well for recovery. Abandoned shut-in at P WH=281 PSIG.
14	1/31/87	8,005	Pressure and temperature survey with P WH=2.4 psig. Pressure element 0-3975 psig range. Stops at 1000, 2000, 3000, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 7900 AND 8000
15	2/1/87	8,100	Pressure and temperature survey. Pressure element 0-800 psig range. Well on vent. Stops at 1000, 2000, 3000, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 7600, 7700, 7800, 7900, 8000 and 8100.
16	2/2/87	8,100	Pressure and temperature survey P WH=81 psig. Pressure element 0-800 psig range. Same stops as 15.

FIGURE 7-1


ASCENSION #1 RUN #1 – 11/19/86
TEMPERATURE (INSIDE DRILL PIPE)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
DEPTH — FEET (Thousands)
0
100
200
300
400
TEMPERATURE – DEGREES F

ASCENSION #1 — SURVEY #1

TEMPERATURE AT 6240 '

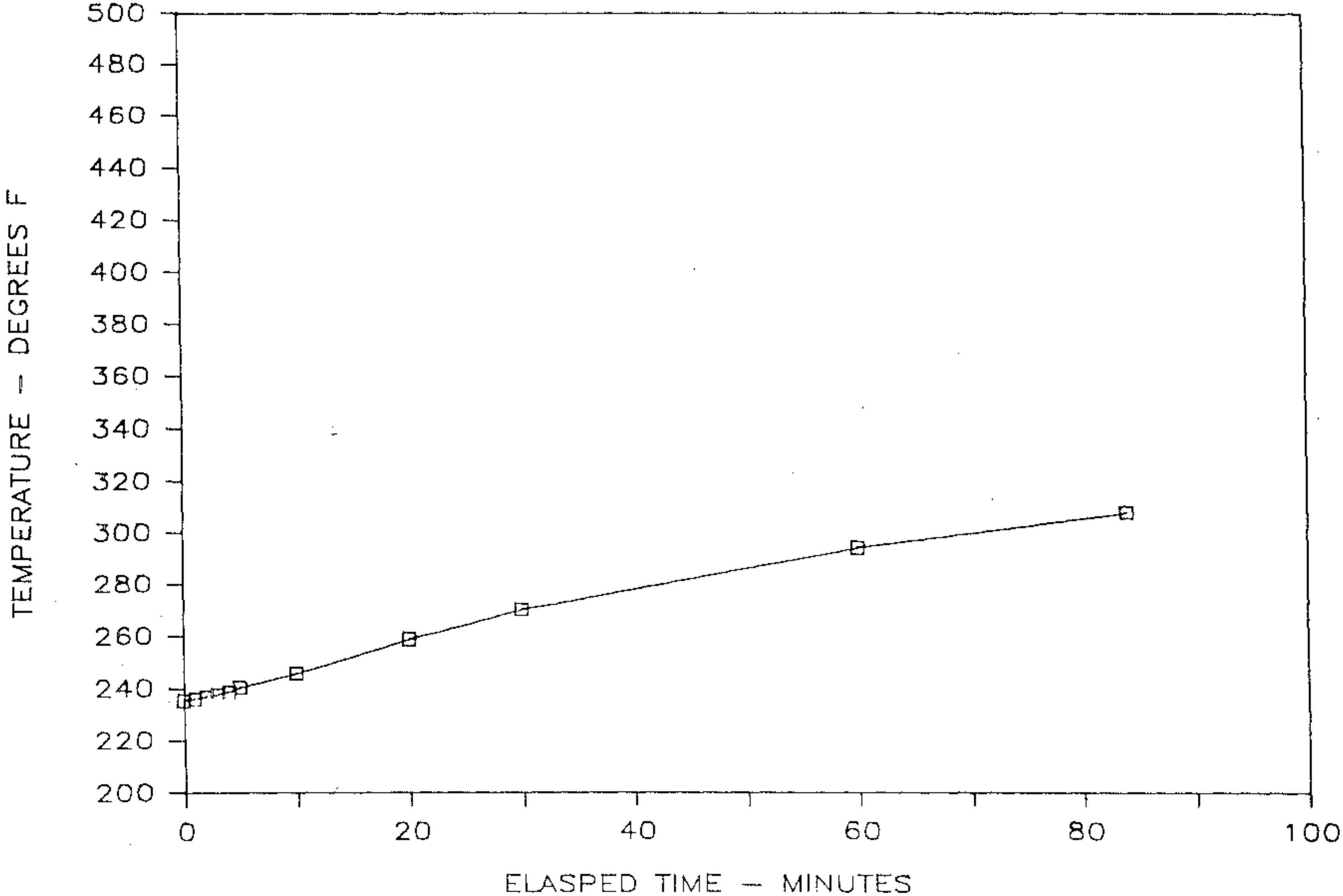
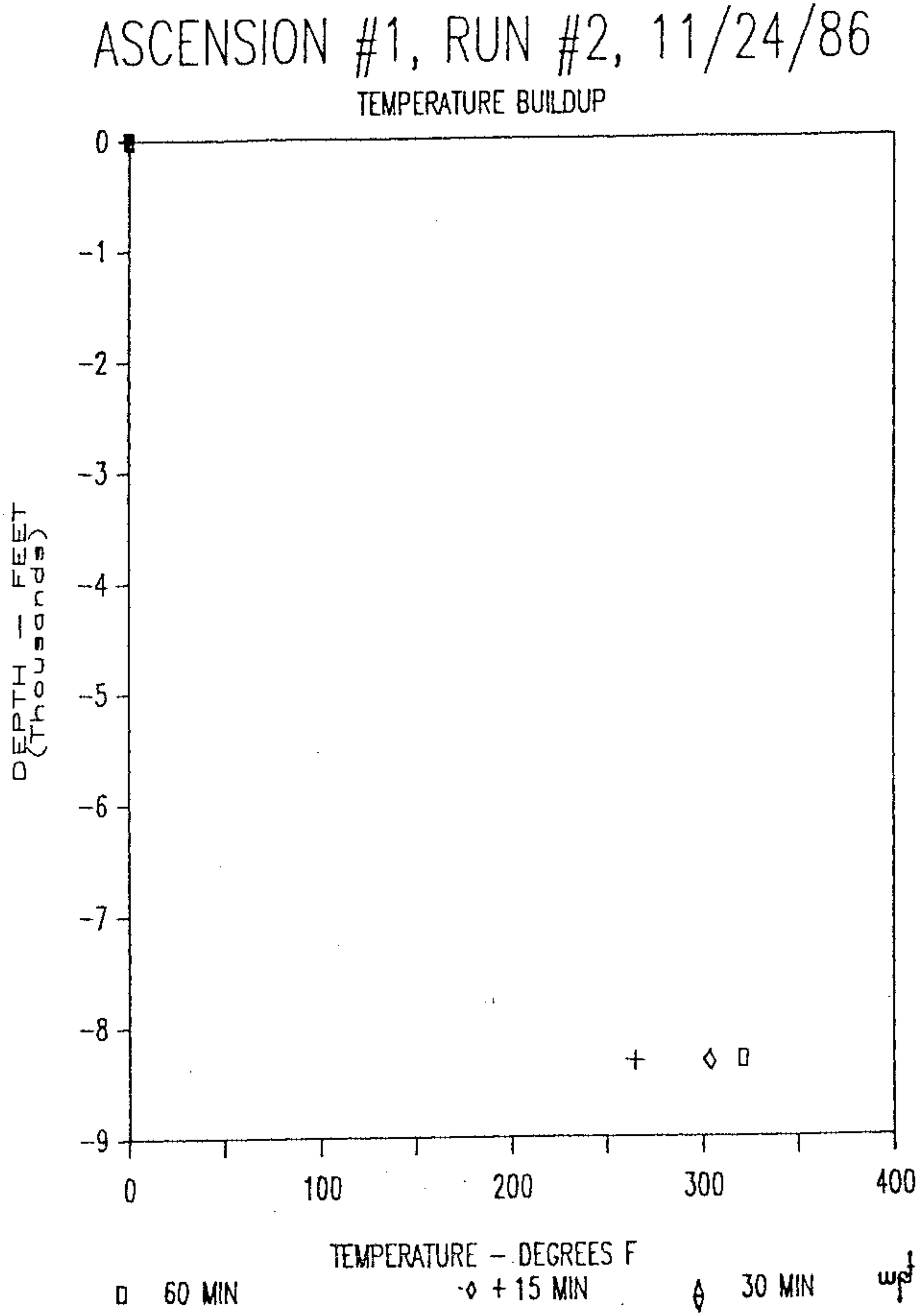


FIGURE 7-2

FIGURE 7-3



ASCENSION #1, RUN #2, 11/24/86
TEMPERATURE BUILDUP
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
TEMPERATURE — DEGREES F
60 MIN
+ 15 MIN
30 MIN

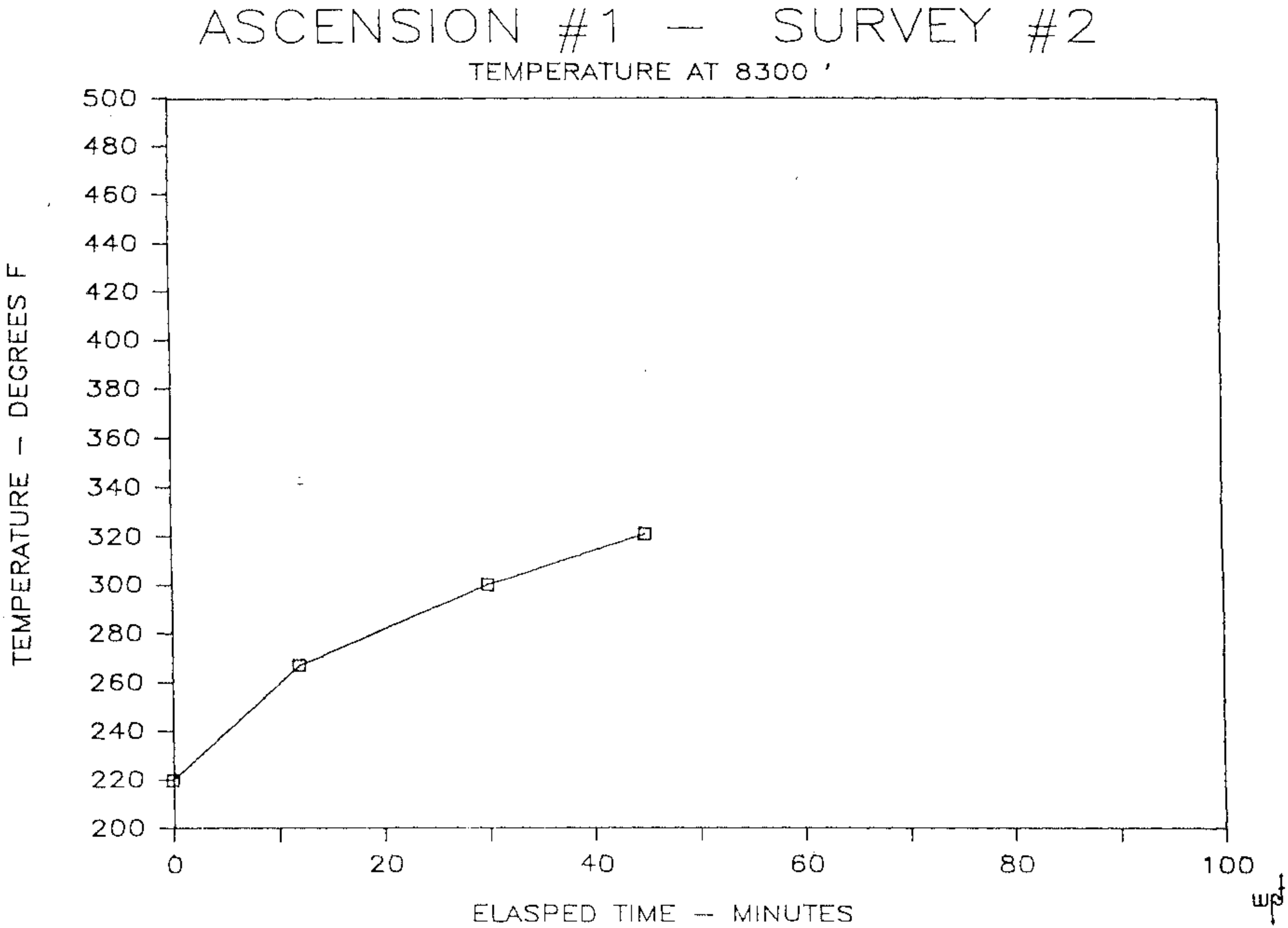

ASCENSION #1 — SURVEY #2
TEMPERATURE AT 8300 '
TEMPERATURE — DEGREES F
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
0
20
40
60
80
100
ELASPED TIME — MINUTES

FIGURE 7-4

FIGURE 7-5

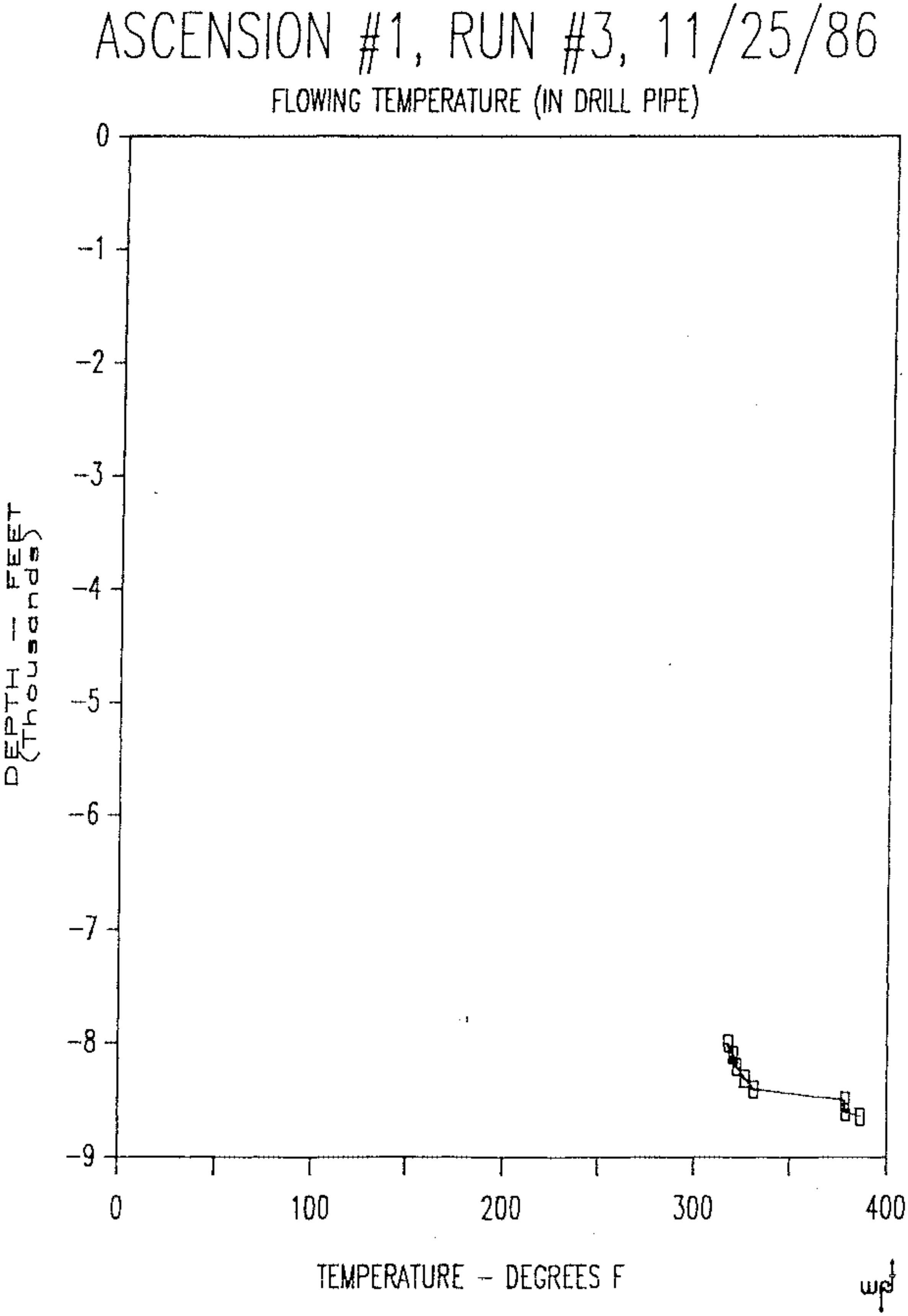

ASCENSION #1, RUN #3, 11/25/86
FLOWING TEMPERATURE (IN DRILL PIPE)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
DEPTH — FEET
(Thousands)
0
100
200
300
400
TEMPERATURE — DEGREES F

FIGURE 7-6

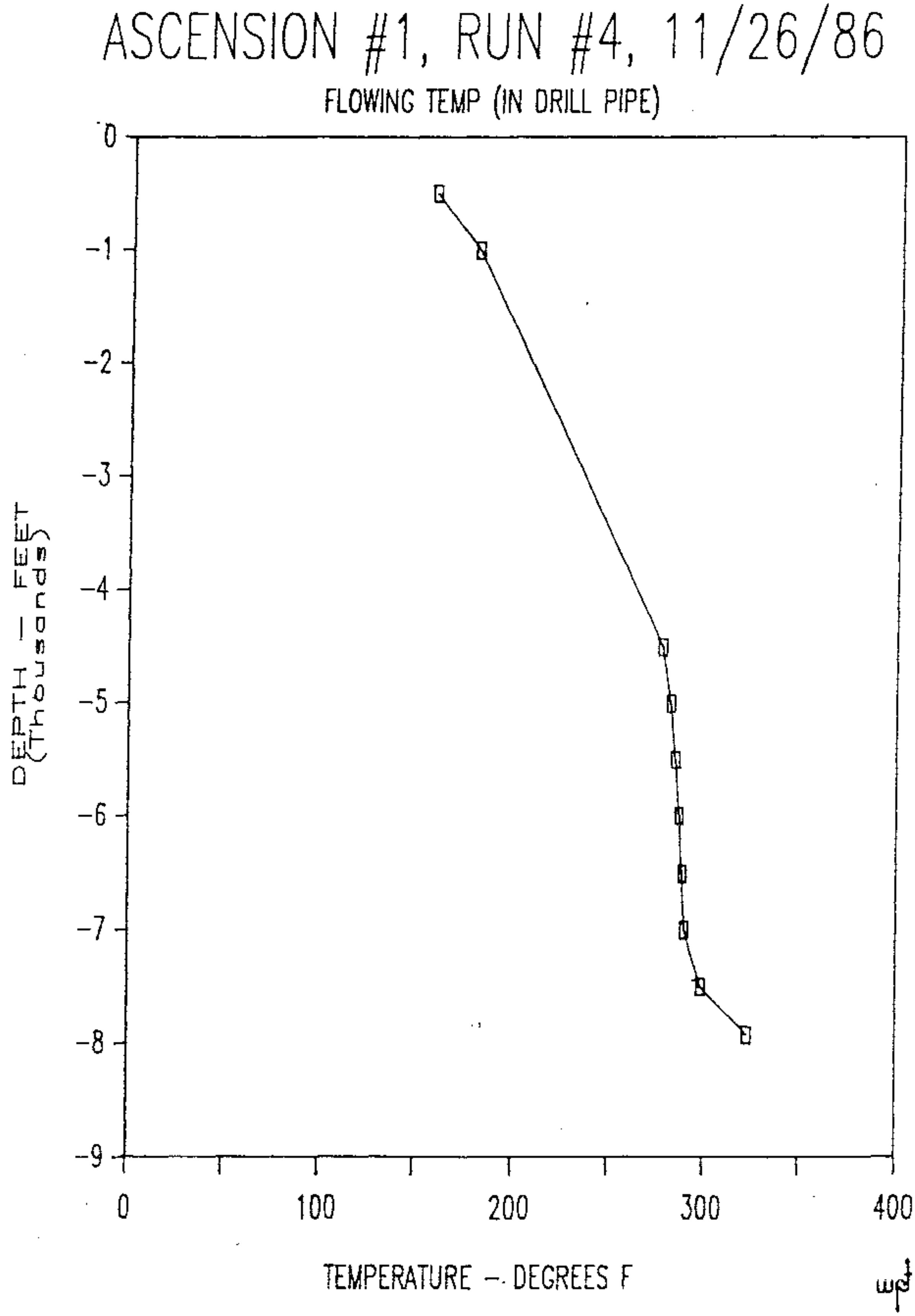

ASCENSION #1, RUN #4, 11/26/86
FLOWING TEMP (IN DRILL PIPE)
DEPTH — FEET
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
TEMPERATURE — DEGREES F

FIGURE 7-7

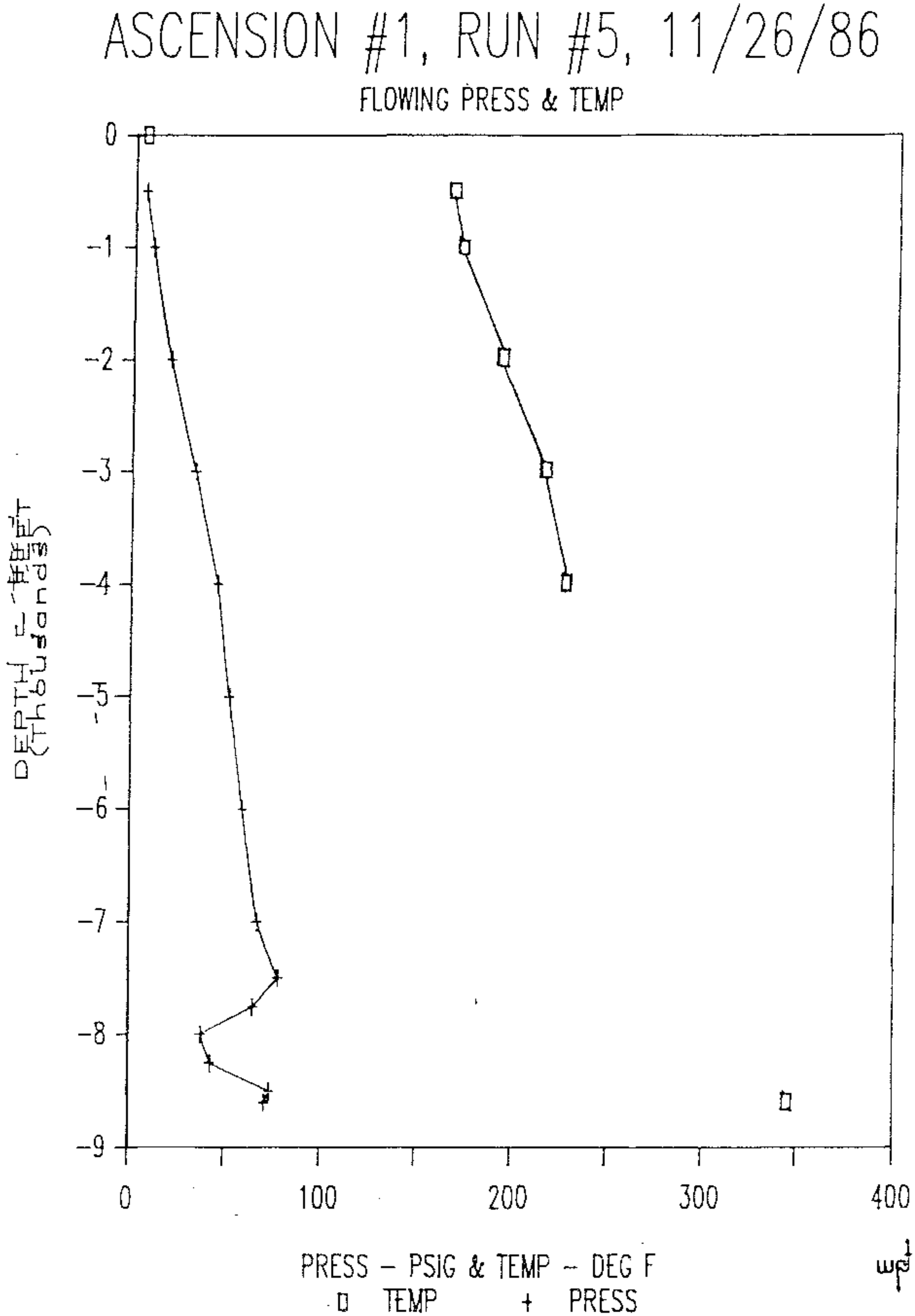

ASCENSION #1, RUN #5, 11/26/86
FLOWING PRESS & TEMP
DEPTH - FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
PRESS - PSIG & TEMP - DEG F
□ TEMP + PRESS

FIGURE 7-8

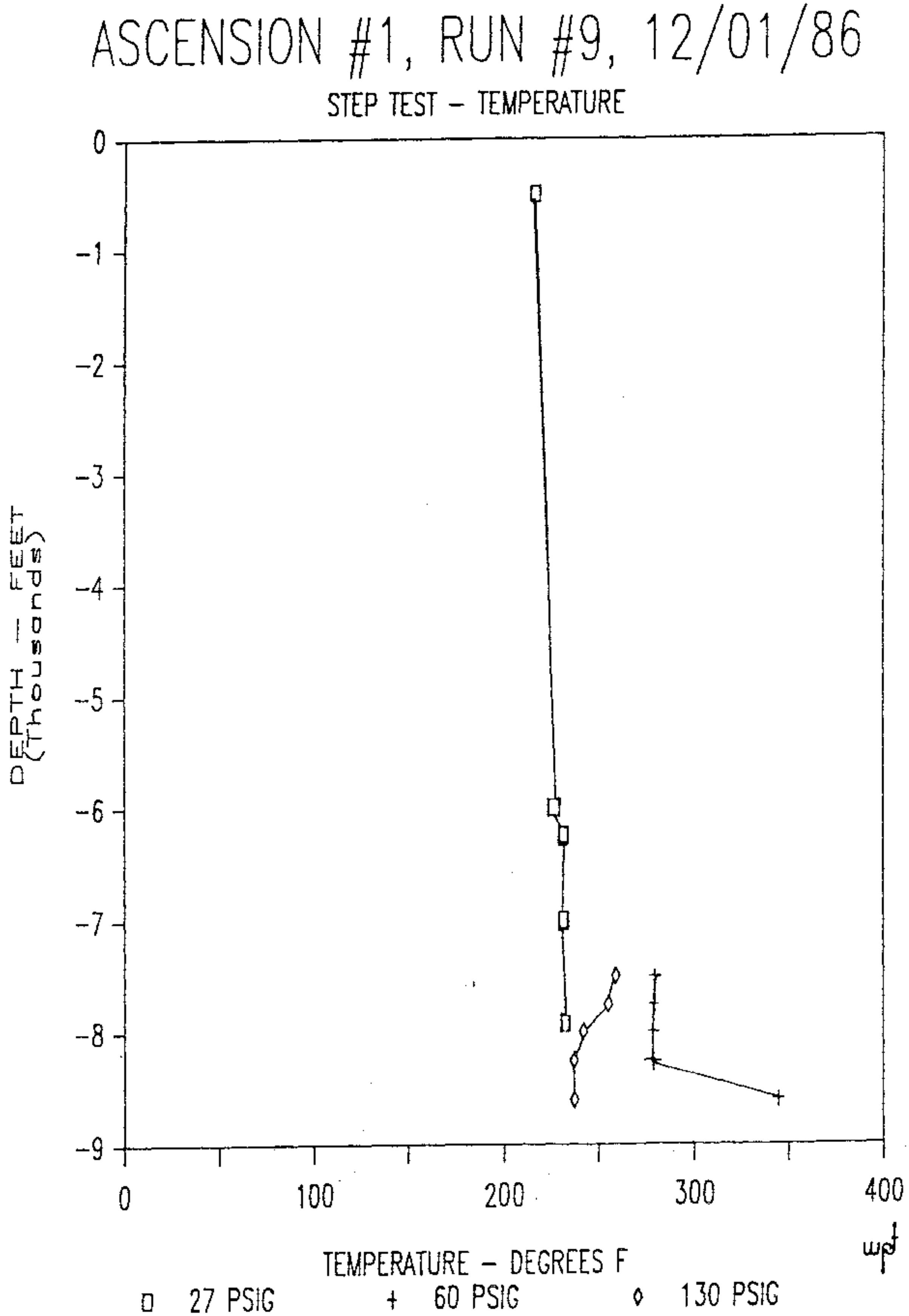
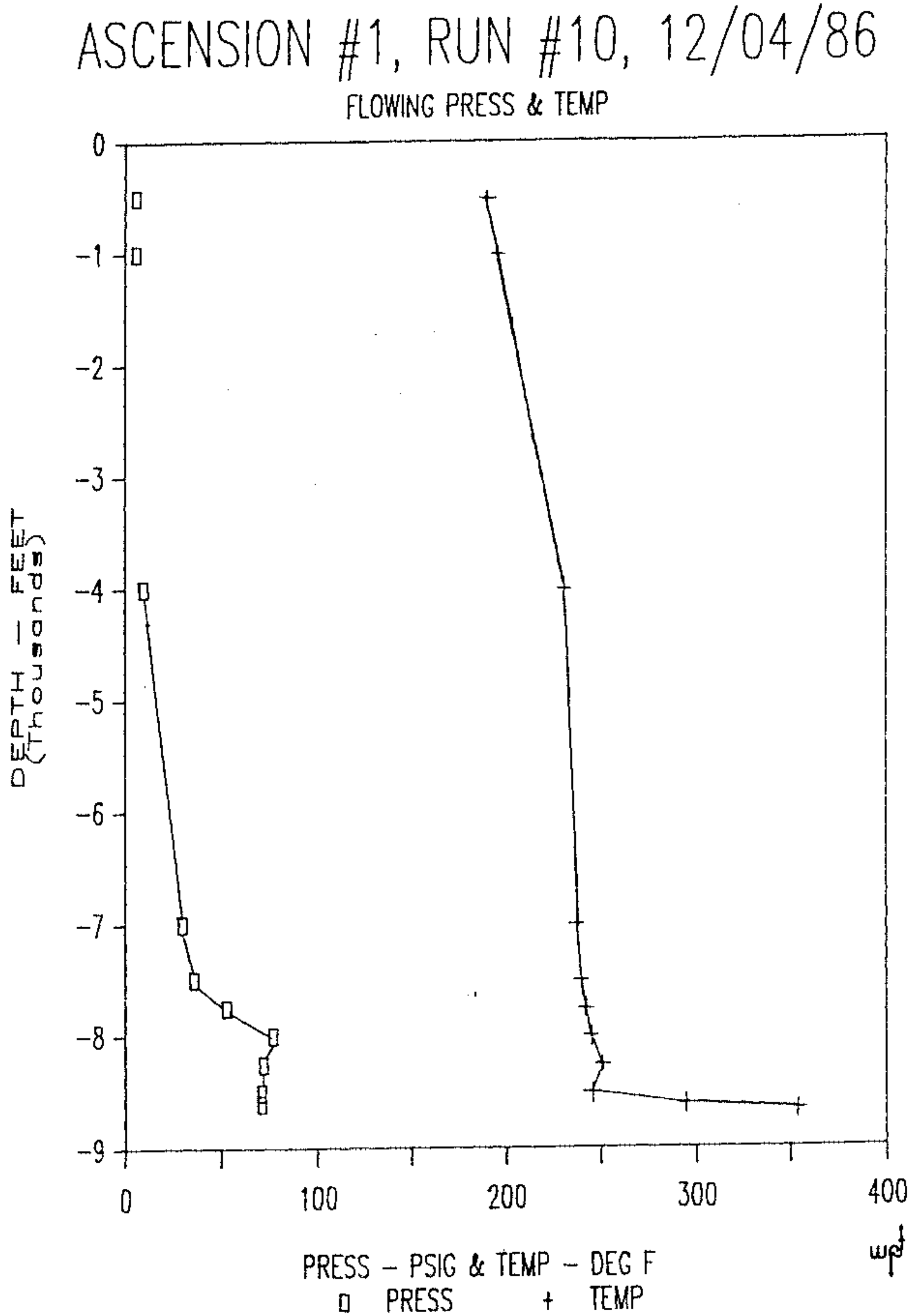

ASCENSION #1, RUN #9, 12/01/86
STEP TEST - TEMPERATURE
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
TEMPERATURE - DEGREES F
wpf
□ 27 PSIG
+ 60 PSIG
◊ 130 PSIG

FIGURE 7-9



ASCENSION #1, RUN #10, 12/04/86
FLOWING PRESS & TEMP
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
PRESS — PSIG & TEMP — DEG F
□ PRESS + TEMP

FIGURE 7-10

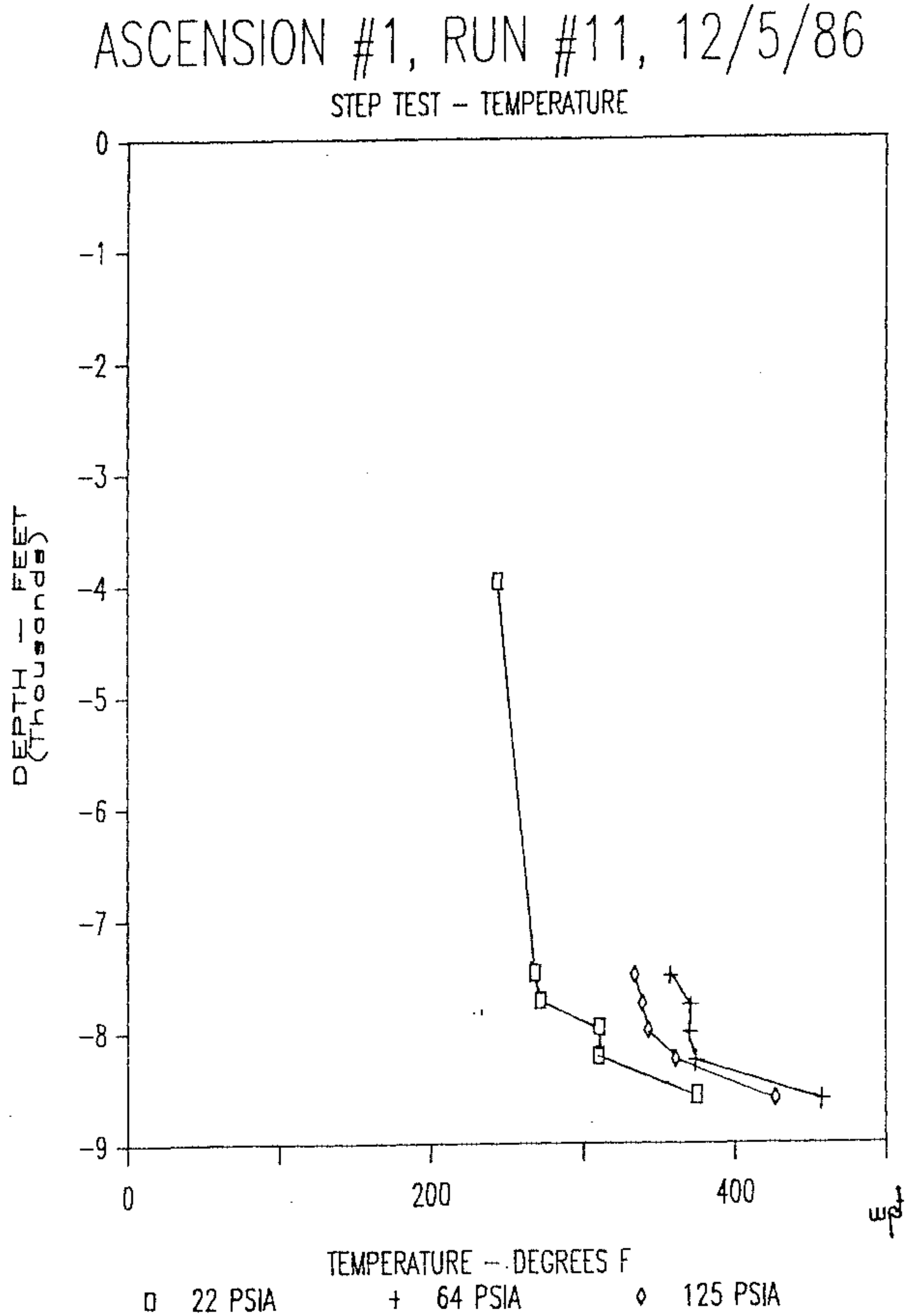

ASCENSION #1, RUN #11, 12/5/86
STEP TEST – TEMPERATURE
DEPTH – FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
200
400
TEMPERATURE – DEGREES F
22 PSIA
64 PSIA
125 PSIA

FIGURE 7-11

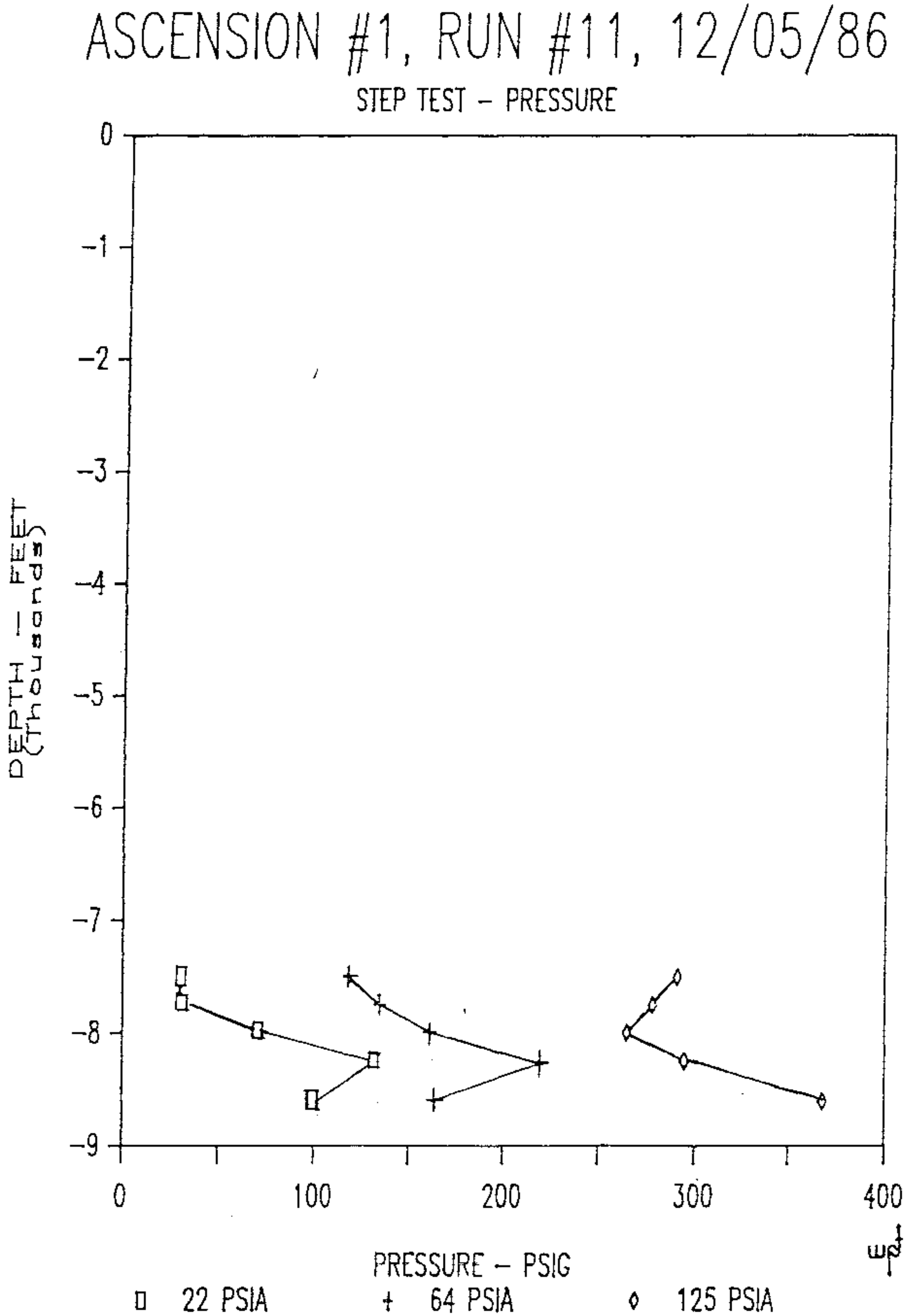

ASCENSION #1, RUN #11, 12/05/86
STEP TEST - PRESSURE
DEPTH - FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
PRESSURE - PSIG
22 PSIA
64 PSIA
125 PSIA

FIGURE 7-12

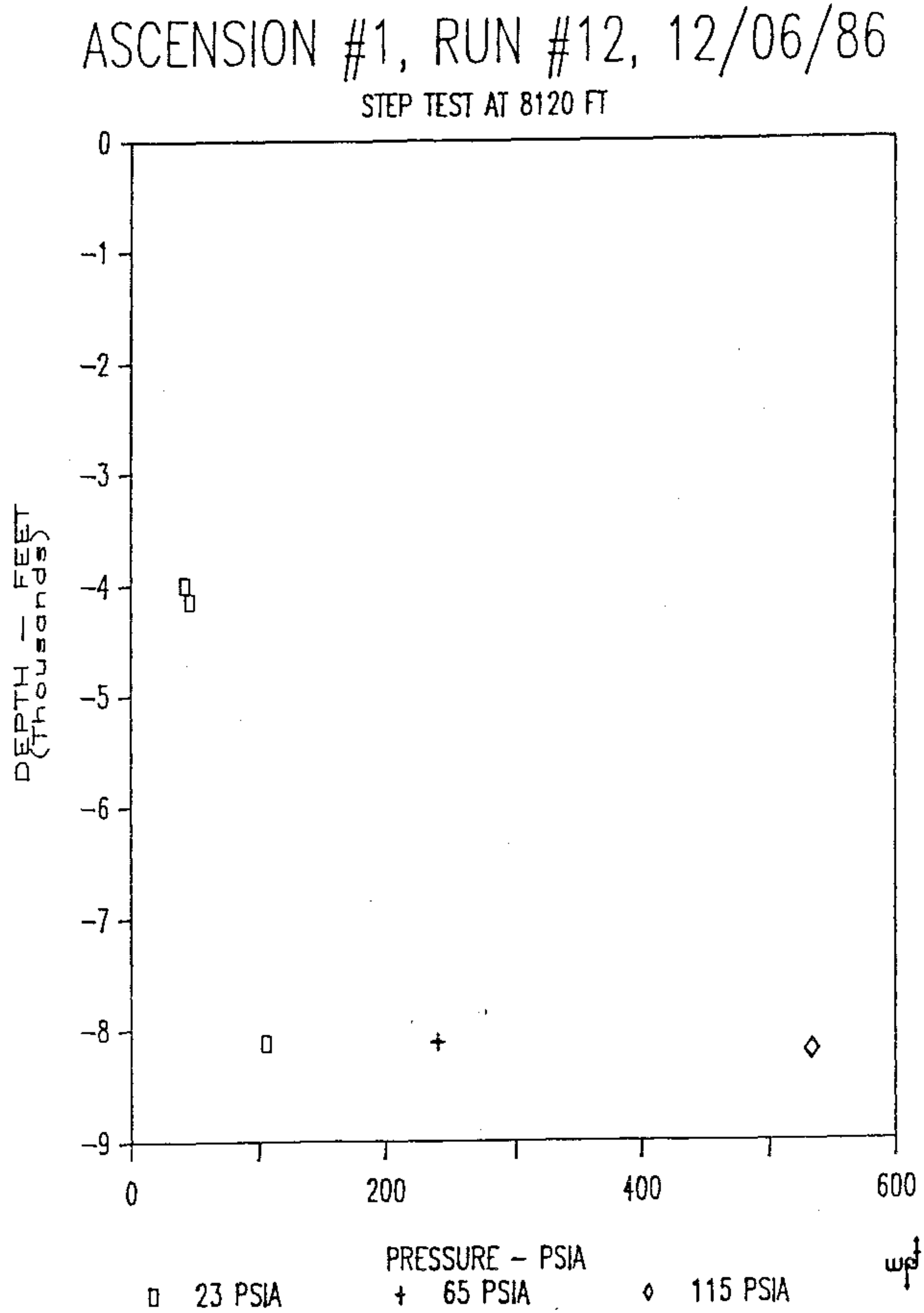

ASCENSION #1, RUN #12, 12/06/86
STEP TEST AT 8120 FT
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
DEPTH — FEET (Thousands)
0
200
400
600
PRESSURE – PSIA
23 PSIA
65 PSIA
115 PSIA

FIGURE 7-13

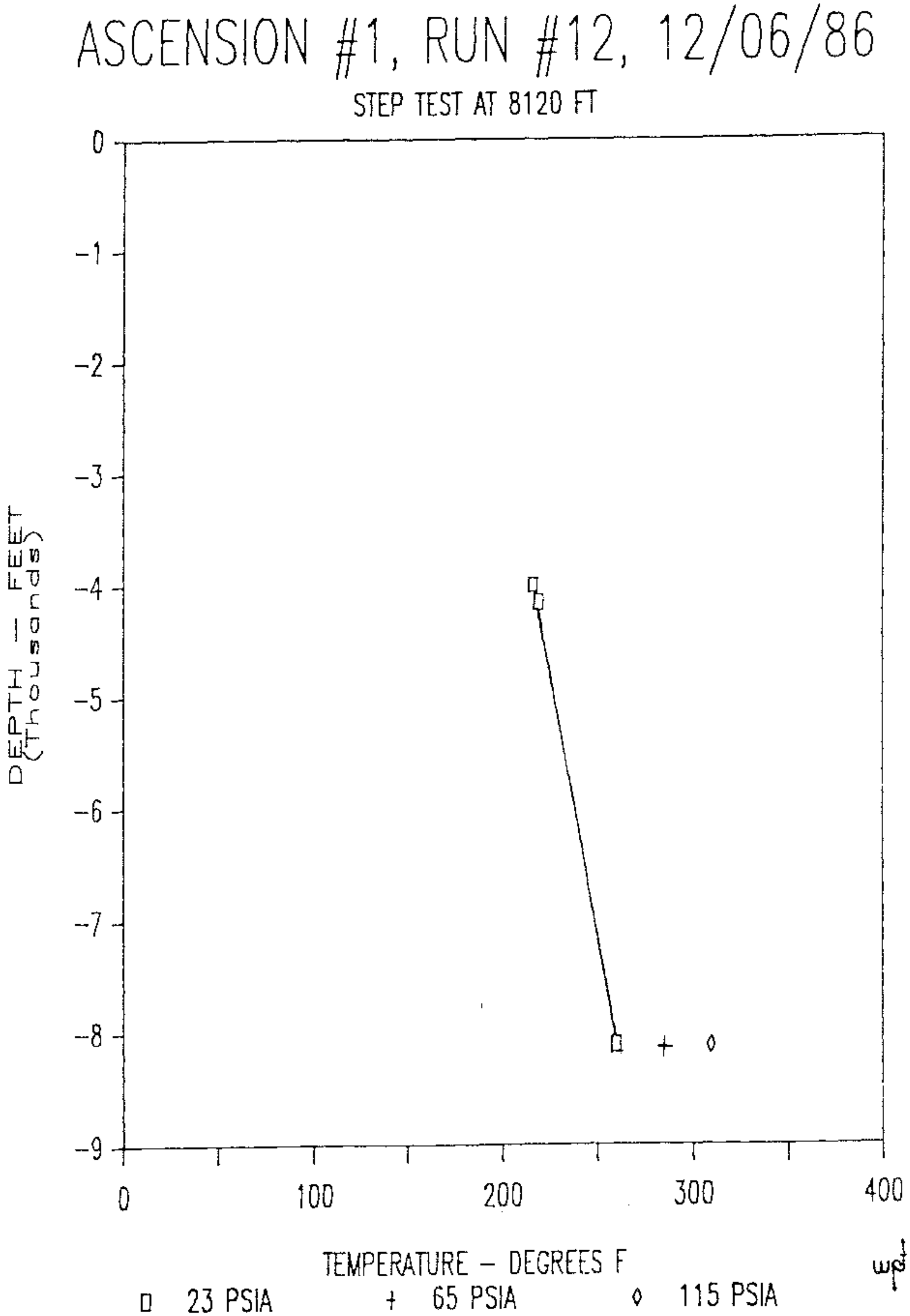

ASCENSION #1, RUN #12, 12/06/86
STEP TEST AT 8120 FT
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
TEMPERATURE — DEGREES F
23 PSIA
65 PSIA
115 PSIA

FIGURE 7-14

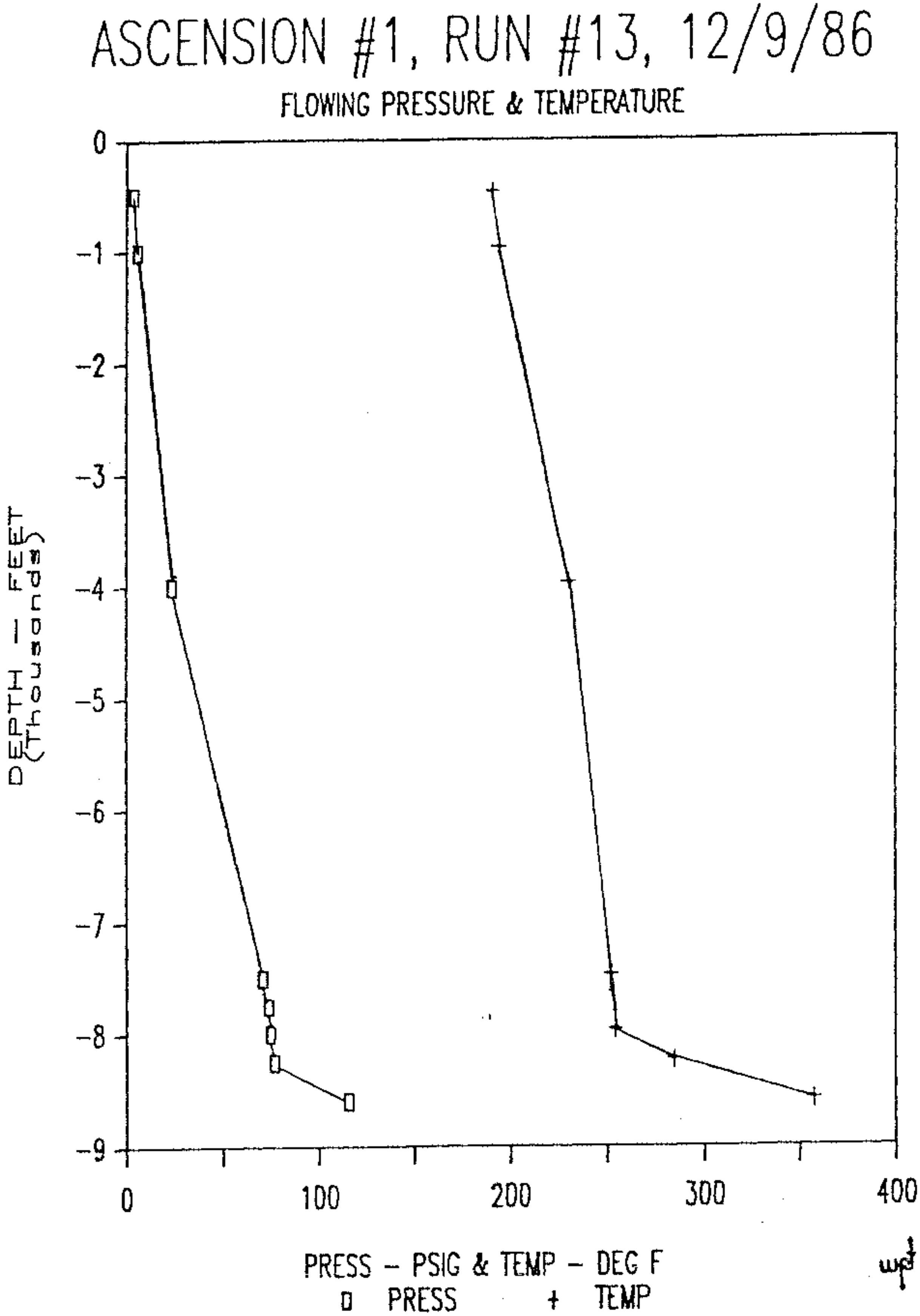

ASCENSION #1, RUN #13, 12/9/86
FLOWING PRESSURE & TEMPERATURE
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
PRESS – PSIG & TEMP – DEG F
□ PRESS
+ TEMP
wpt

FIGURE 7-15

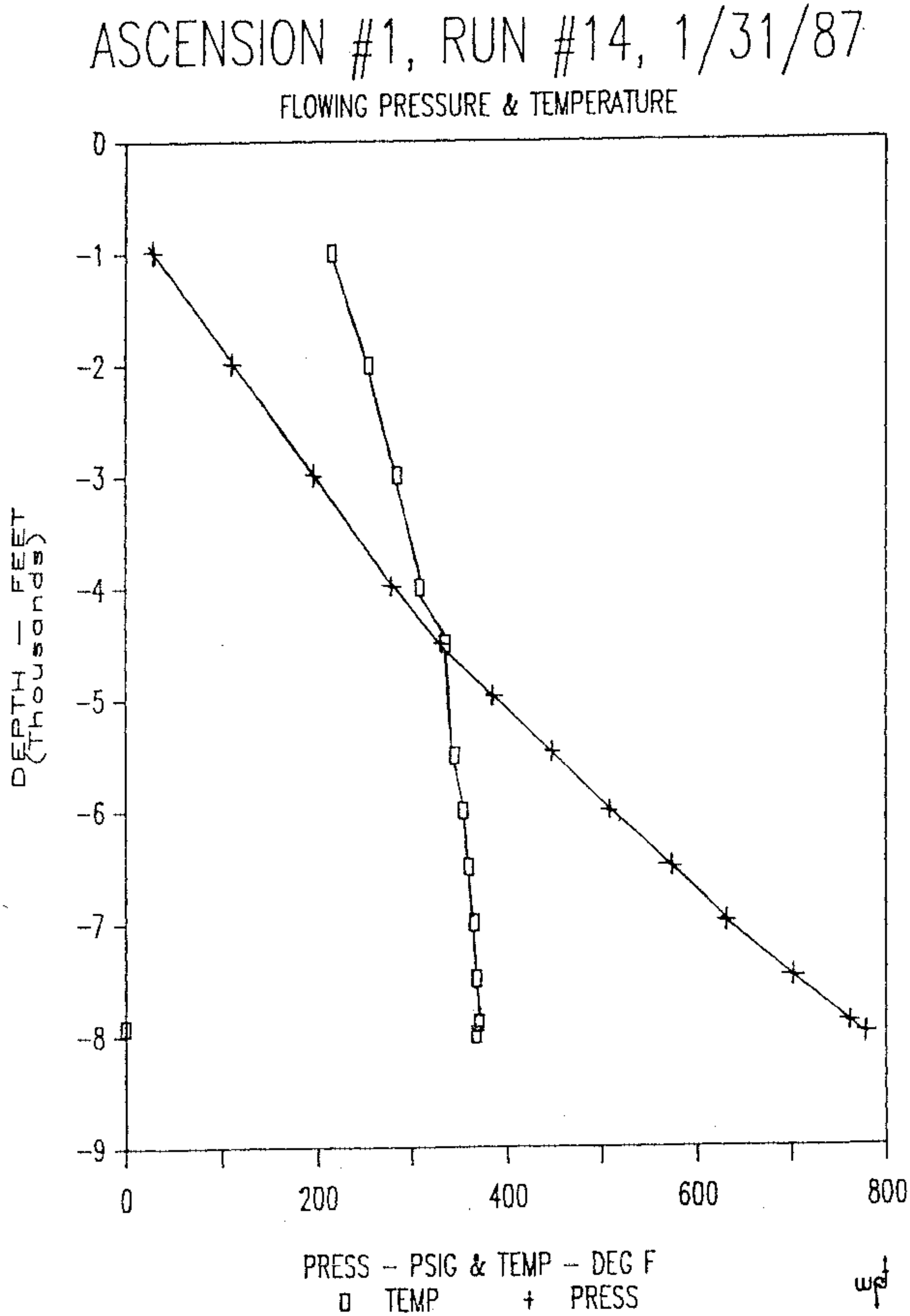
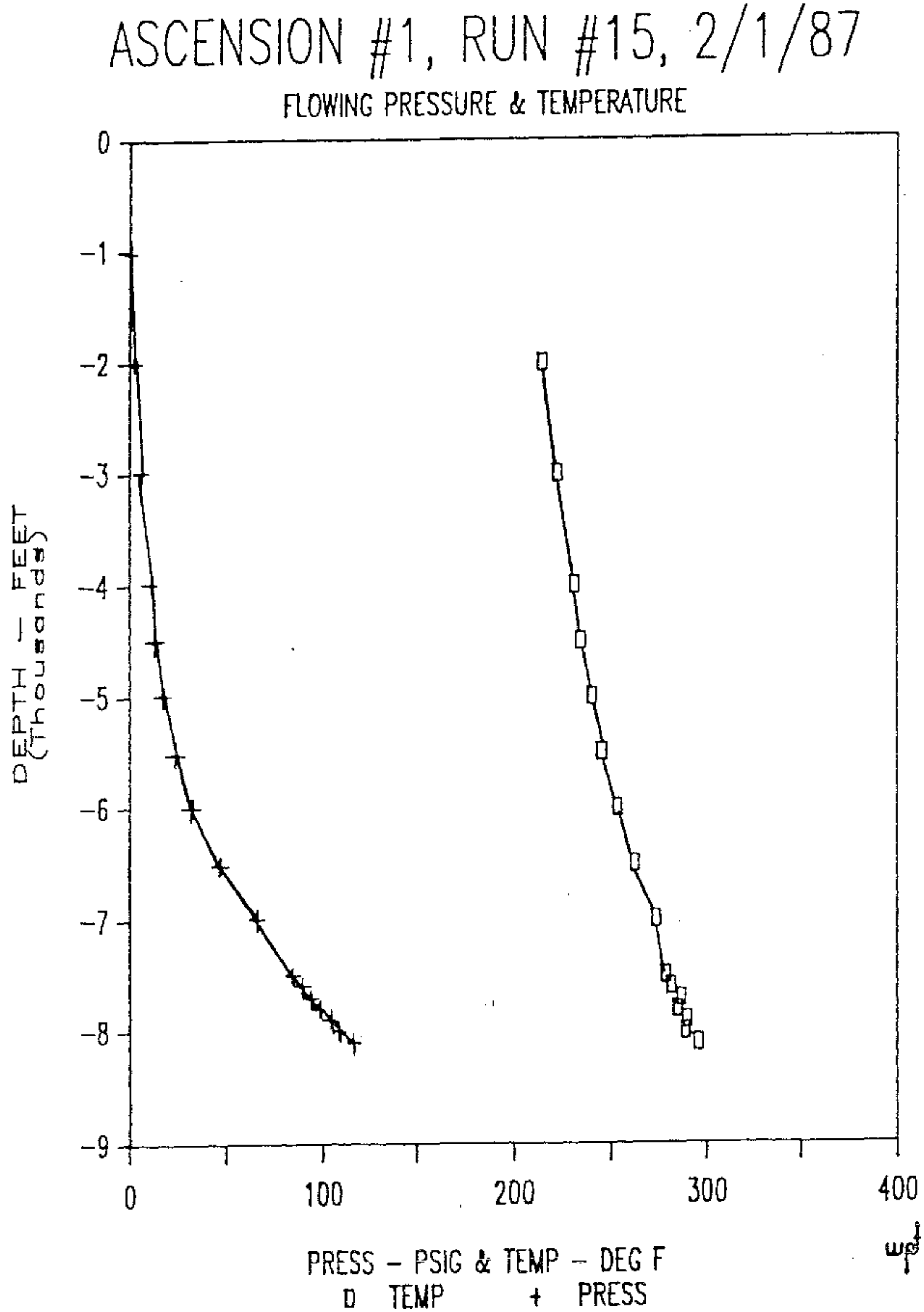
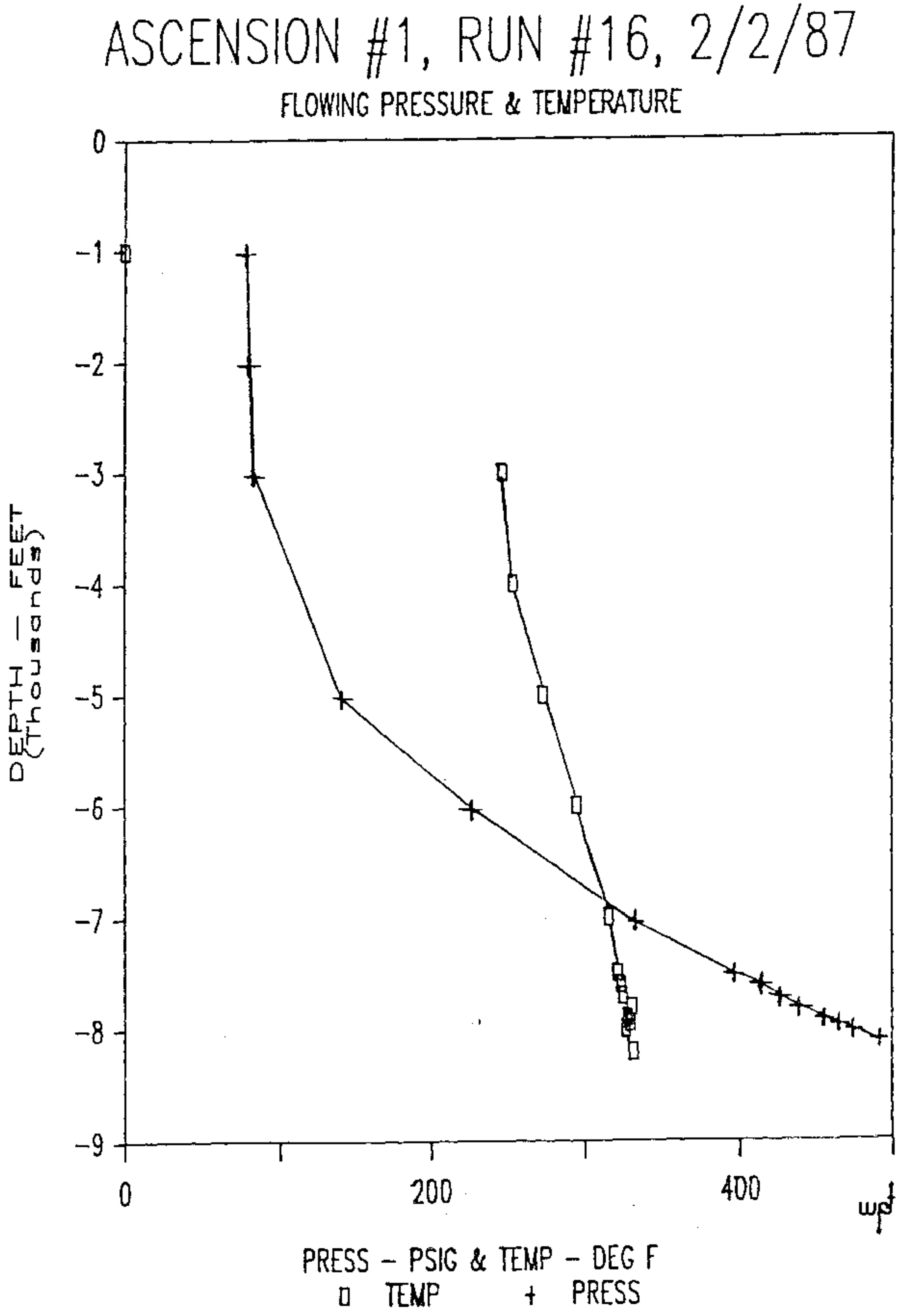

ASCENSION #1, RUN #14, 1/31/87
FLOWING PRESSURE & TEMPERATURE
DEPTH — FEET (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
200
400
600
800
PRESS — PSIG & TEMP — DEG F
□ TEMP + PRESS

FIGURE 7-16



ASCENSION #1, RUN #15, 2/1/87
FLOWING PRESSURE & TEMPERATURE
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
DEPTH — FEET
(Thousands)
0
100
200
300
400
PRESS — PSIG & TEMP — DEG F
□ TEMP + PRESS

FIGURE 7-17


ASCENSION #1, RUN #16, 2/2/87
FLOWING PRESSURE & TEMPERATURE
DEPTH — FEET
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
200
400
PRESS – PSIG & TEMP – DEG F
TEMP
PRESS

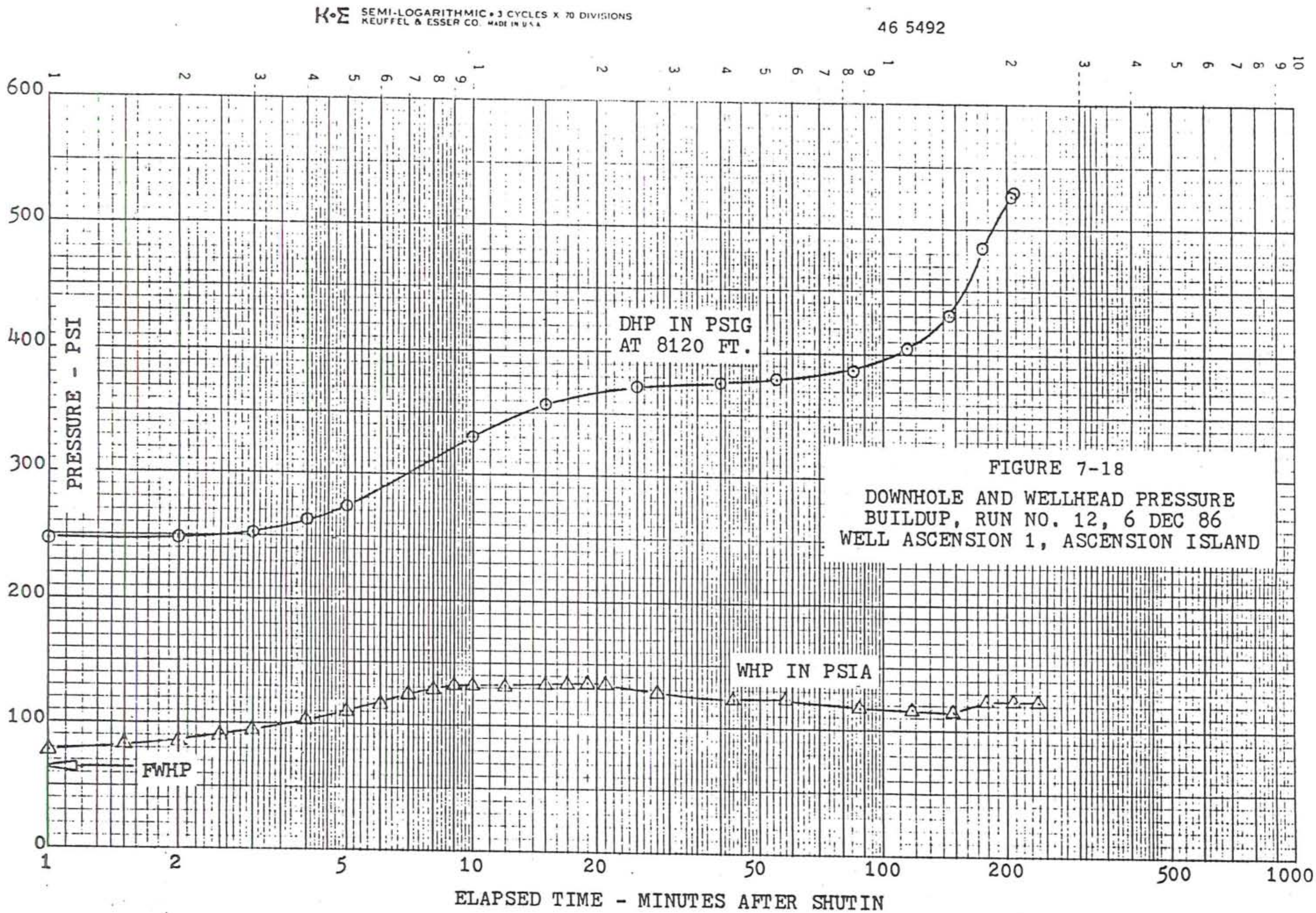


FIGURE 7-18

DOWNHOLE AND WELLHEAD PRESSURE BUILDUP, RUN NO. 12, 6 DEC 86
WELL ASCENSION 1, ASCENSION ISLAND

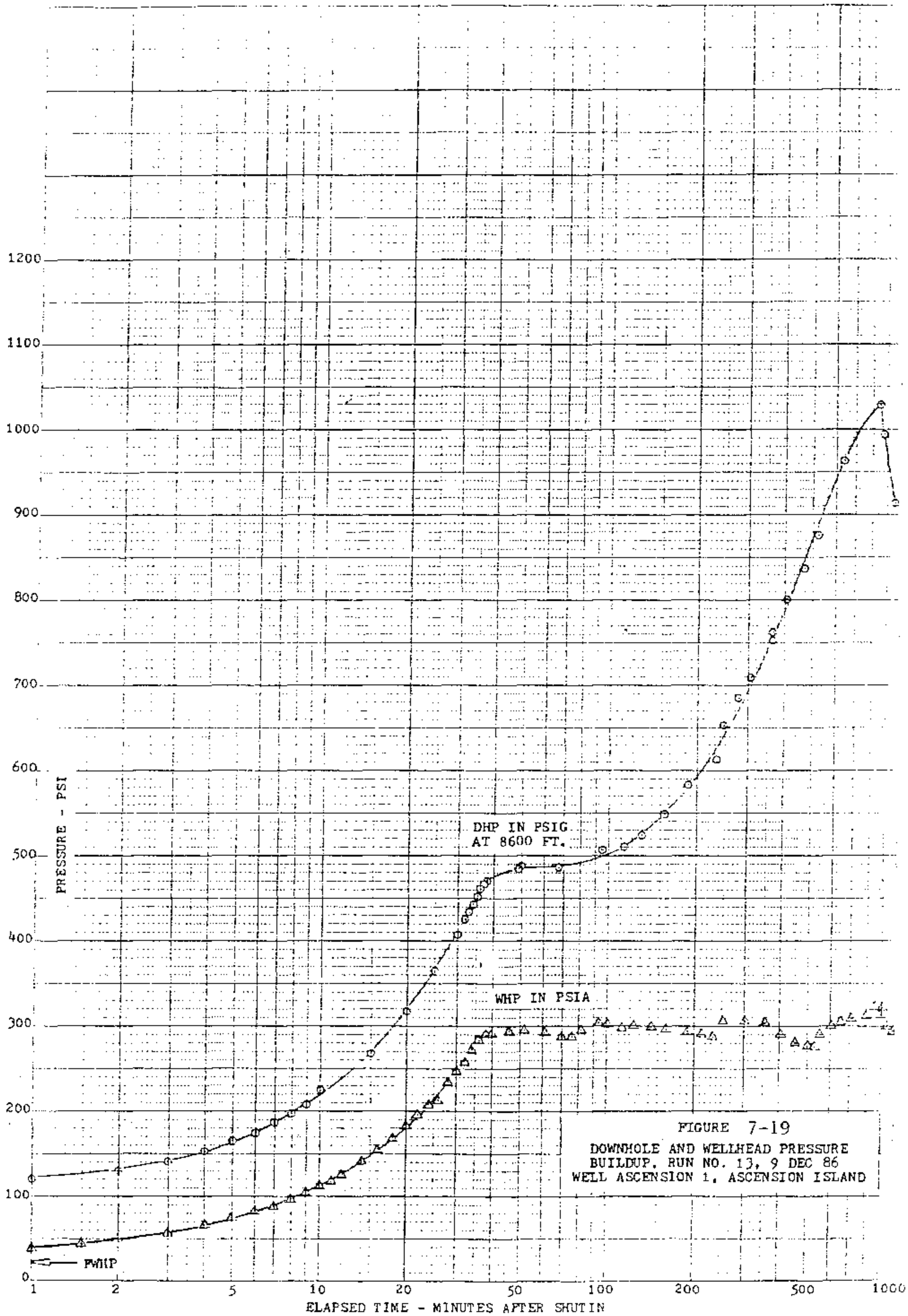


FIGURE 7-19
DOWNHOLE AND WELLHEAD PRESSURE
BUILDUP, RUN NO. 13, 9 DEC 86
WELL ASCENSION 1, ASCENSION ISLAND

ASCENSION ISLAND NO.1

HORNER TEMPERATURE RUN NO.1

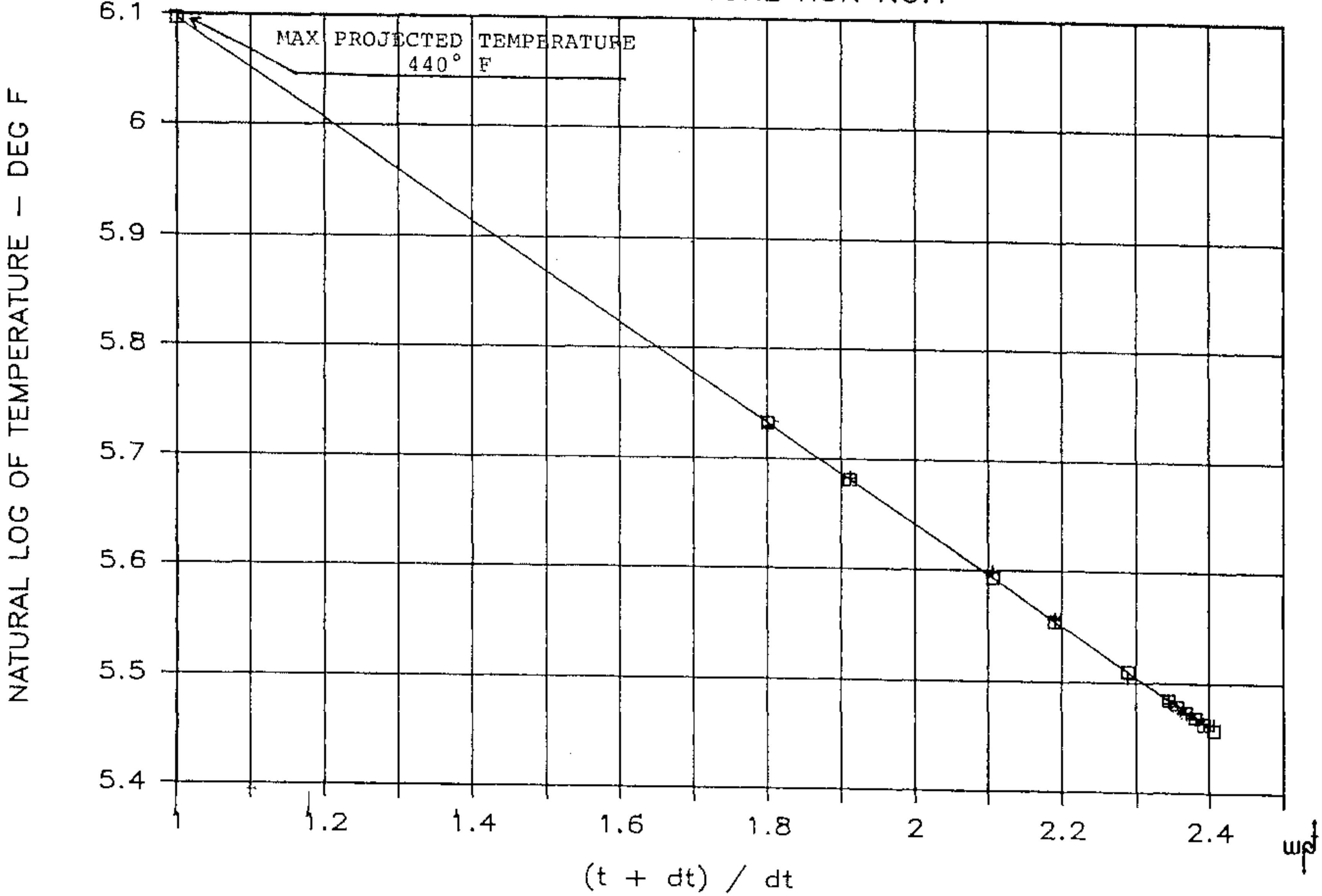


FIGURE 7-20

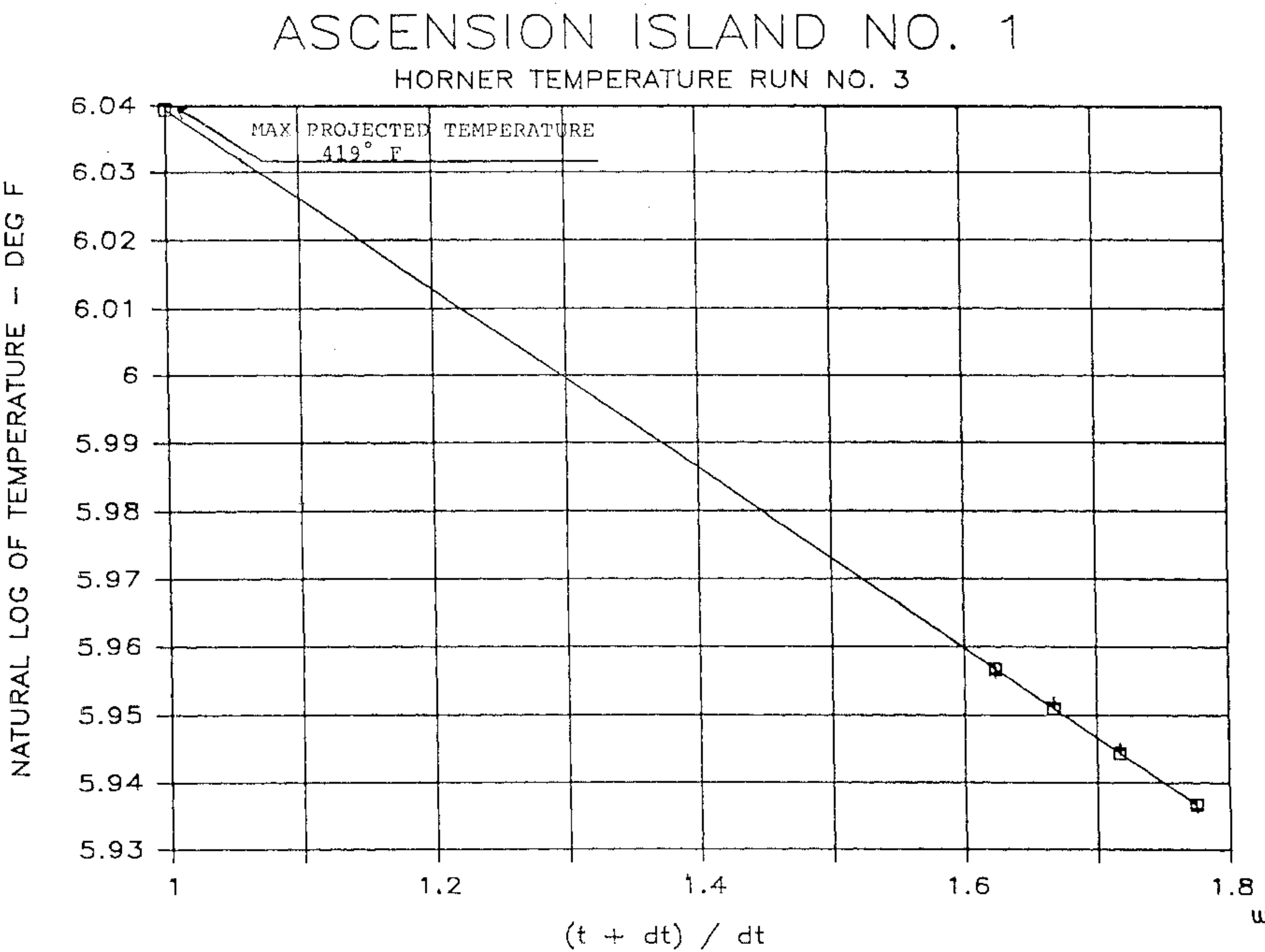

ASCENSION ISLAND NO. 1
HORNER TEMPERATURE RUN NO. 3
MAX PROJECTED TEMPERATURE
419° F
NATURAL LOG OF TEMPERATURE - DEG F
6.04
6.03
6.02
6.01
6
5.99
5.98
5.97
5.96
5.95
5.94
5.93
1
1.2
1.4
1.6
1.8
(t + dt) / dt

FIGURE 7-21

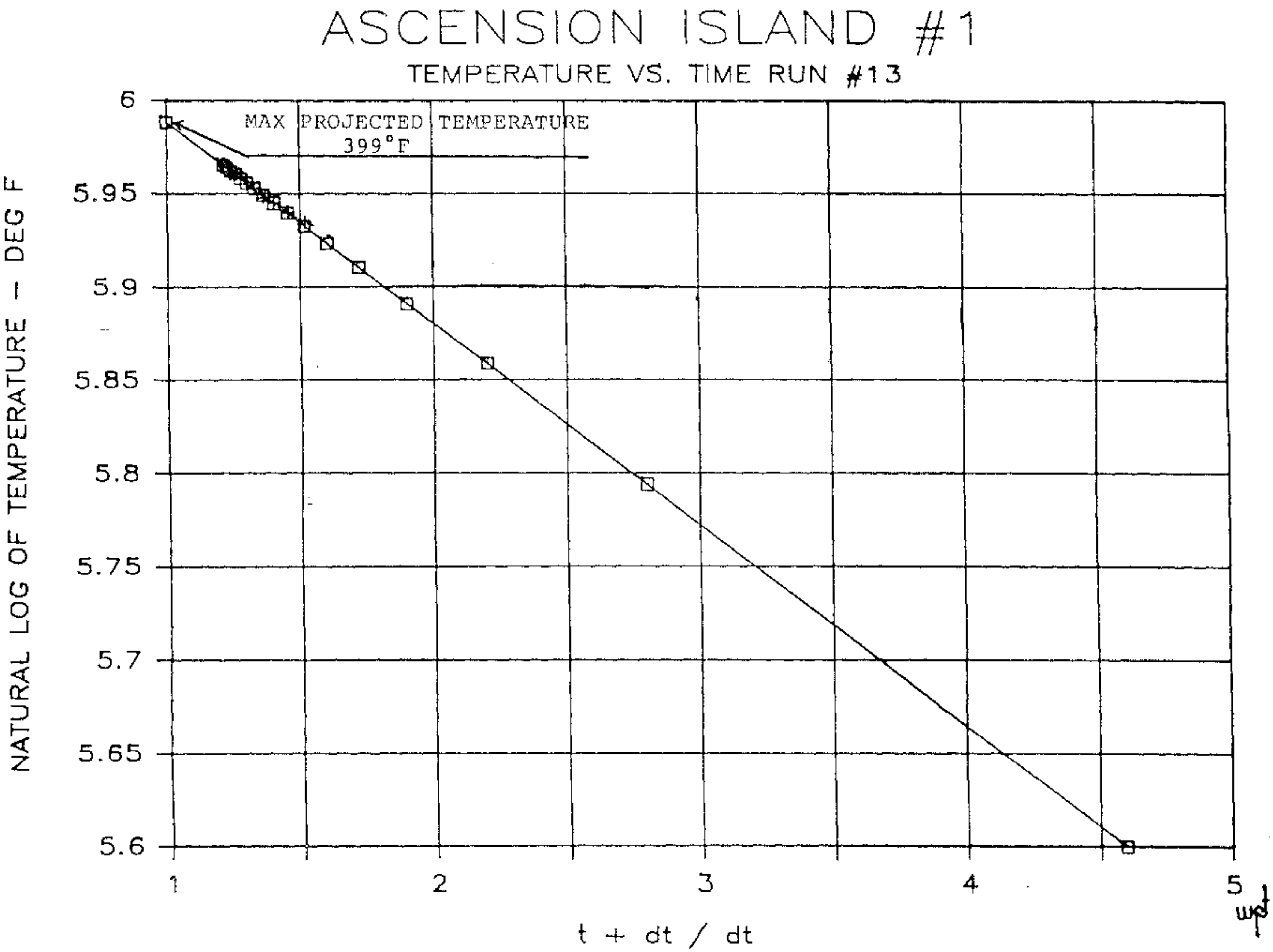

ASCENSION ISLAND #1
TEMPERATURE VS. TIME RUN #13
MAX PROJECTED TEMPERATURE
399°F
NATURAL LOG OF TEMPERATURE - DEG F
6
5.95
5.9
5.85
5.8
5.75
5.7
5.65
5.6
1
2
3
4
5
t + dt / dt

FIGURE 7-22

8. CHEMICAL SAMPLING AND ANALYSIS

The purpose of this section is to explain and document sample collection, the method used to compare fluid vs gas production, the date and time of sample collection, and to present the initial results

8.1. Sample Rake Construction

The sample rake was constructed of 1/4-inch SS tubing approximately 22 inches long. The inboard end of this tubing was plugged. Three slots were milled into the inboard end, one approximately 1/2 inch from the plugged end, one approximately 4 inches from the plugged end, and one approximately 7 inches from the plugged end. These slots were approximately 3/16-inch wide and penetrated approximately 1/3 of the inner diameter of the tubing. On the outboard end of the tubing was a valve, a 0-30 PSIG gauge and a cooling coil suspended in a five-gallon bucket of cool water. A 24-inch piece of Tygon tubing was attached to the end of this coil for gas sampling. The SS tubing was inserted through a 1/4-inch hole in a 1/2-inch NPT double male-ended fitting and a ferrel crimped onto it as a stop. This unit was inserted through a ball valve and into the flow stream (see Figure 4-1).

8.2. Gas Sample Collection

Gas samples were collected in evacuated glass bombs using standard gas sampling techniques. The glass bombs contained a sodium hydroxide solution to absorb CO_2 and cadmium sulfate, which precipitates cadmium sulfide in the presence of H_2S.

8.3 Liquid to Gas Flow Measurement

Samples were taken perildically to measure the ratio of noncondensable gas to water in the well effluent. These samples were collected from the sample rake. To determine the relative flow rates the time to fill a known volume was recorded. A 550-ml sample was used. The water samples filled the bottle to a depth of 1-inch approximately 85-ml). This volume was selected due to the length of time it took to collect that amount of water. The gas samples were acquired by inverting a water-filled bottle in the bath and timing the gas displacement.

These measurements were susceptible to two sources of error. The measurement uncertainty of the gas sample was large due to the short time needed to fill the bottle and difficulties in inserting the sample line into the bottle. An uncertainty of 20% seems reasonable for these measurements. The second source of error is the assumption of uniform water content over the vertical cross-section of the piping. It is possible that a protion of the water is not entrained but flows along the bottom of the pipe. This effect is ameliorated somewhat by the location of the sample port (downstream of two 90° turns), but is still a possible source of error.

8.4 Results of Chemical Analysis

A series of liquid and gas samples were collected from the flow line during the flow test and again in late January, 1987. Preliminary analyses of the samples collected during the flow test have been completed and are included as Appendix H.

The first gas sample collected apparently had some air contamination, as evidenced by the analysis of the gas in the head space. The analysis was corrected for the air contamination by applying a proportional correction to the remainder of the atmospheric gases. The corrected analysis showed:

CO_2 - 98.6% by volume
N_2 - 1.24%
Ar - trace
Hydrogen sulfide, ammonia, methane, hydrogen were not detected (detection limits 2 X 10^{-4} vol %)

The high CO_2 concentration and the relatively slow CO_2/NaOH reaction kinetics complicated gas sample collection and no reliable determination of the weight percent of gas and liquid could be made.

Table 8-2 presents analyses of the first three liquid samples collected during the flow test compared to sea water. A trilinear plot of the 11/28/86 sample (Figure 8-1) indicates that the fluid being produced is similar to sea water, enriched in calcium. This enrichment is probably due to rock-water interactions. Isotope data indicate that the fluids are not magmatic in origin.

Significant variability was observed in the chemical analyses of the liquid samples collected during the test. This is indicative of the complex two-phase, two-component flow dynamics which exist in the wellbore. As a result, there is no reliable basis for determining the chemical composition of the fluids as they exist in the reservoir.

TABLE 8-1

CHEMICAL SAMPLE COLLECTION SUMMARY

DATE	TIME	SYNOPSIS OF SAMPLE COLLECTION
11/28		Liquid sample collected
12/2		Liquid sample collected
12/3	0940	2 Phase sampling device installed
	1000	Two fluid samples collected
	1700	Fluid vs gas flow measured
12/4	0320	Fluid vs gas flow measured
	0945	Fluid vs gas flow measured
	2043	Gas sample collected
12/5	0500	Fluid vs gas flow measured
	0852	Fluid vs gas flow measured
	1330	Fluid vs gas flow measured
	1445	Gas sample collected
	1615	Gas sample collected
12/6	0003	Fluid vs gas flow measured
12/7	1000	Fluid vs gas flow measured
	1400	Fluid vs gas flow measured
	1400	Condensate sample taken
	1800	Fluid vs gas flow measured
	2300	Condensate sample taken
	2345	Fluid vs gas flow measured
12/8	0614	Fluid vs gas flow measured
12/9	0200	Fluid vs gas flow measured
	0920	fluid vs gas flow measured

TABLE 8-2

WATER TO GAS RATIO MEASUREMENTS

SAMPLE NUMBER	DATE	TIME	WELLHEAD PRES. psia	WATER TIME	GAS TIME	MH_2O / MCO_2
1	12/3	1700	24.7	8'0"	4"	0.69
2	12/4	0320	22.5	3'59"	3.55"	1.23
3	12/4	0940	22.4	3'59"	2.39"	0.83
4	12/5	0500	21.5	2'59"	4.74"	2.23
5	12/5	0900	22.2	2'42"	4.54"	2.32
6	12/5	1330	62.7	10'25"	0.84"	0.11
7	12/6	0000	22.5	3'2"	4.25"	1.94
8	12/7	1000	22.0	2'57"	4.64"	2.17
9	12/7	1400	21.8	3'6"	4.90"	2.18
10	12/7	1800	21.5	2'48"	5.17"	2.55
11	12/7	2100	21.1	2'29"	5.40"	3.00
12	12/7	0614	21.3	2'46"	5.10"	2.54
13	12/9	0200	21.2	2'40"	5.70"	2.95
14	12/9	0920	21.0	2'39"	5.29"	2.76

TABLE 8-2

ASCENSION #1 FLUID CHEMISTRY

	11/28/86 (ppm)	12/2/86* (ppm)	12/4/86 (ppm)	Sea water (mg/L)
Na	7780	3280	8830	10500
Mg	16.2	5.85	8.77	1350
Ca	4120	1660	4790	400
K	563	249	701	380
Sr	79.9	34.1	92.8	8.0
B	21.6	7.88	27.5	4.6
Li	3.09	1.87	5.39	0.17
Rb	--	--	--	0.12
Ba	2.20	0.78	2.43	0.03
Fe	127	24.0	75.4	0.01
Zn	0.33	nd	nd	0.01
Al	nd	nd	nd	0.01
Cu	nd	nd	nd	0.003
Mn	3.31	1.52	1.85	0.002
Ni	0.34	nd	nd	0.002
La	0.79	0.33	0.81	$3x10^{-6}$
SiO_2	205	70.8	205	3.0**
Cl^-	18900	7700	21600	19000
$SO_4^=$	132	53.0	143	2660
HCO_3^-	240	217	327	142
Br^-	--	--	--	65
F^-	0.50	0.70	0.65	1.3

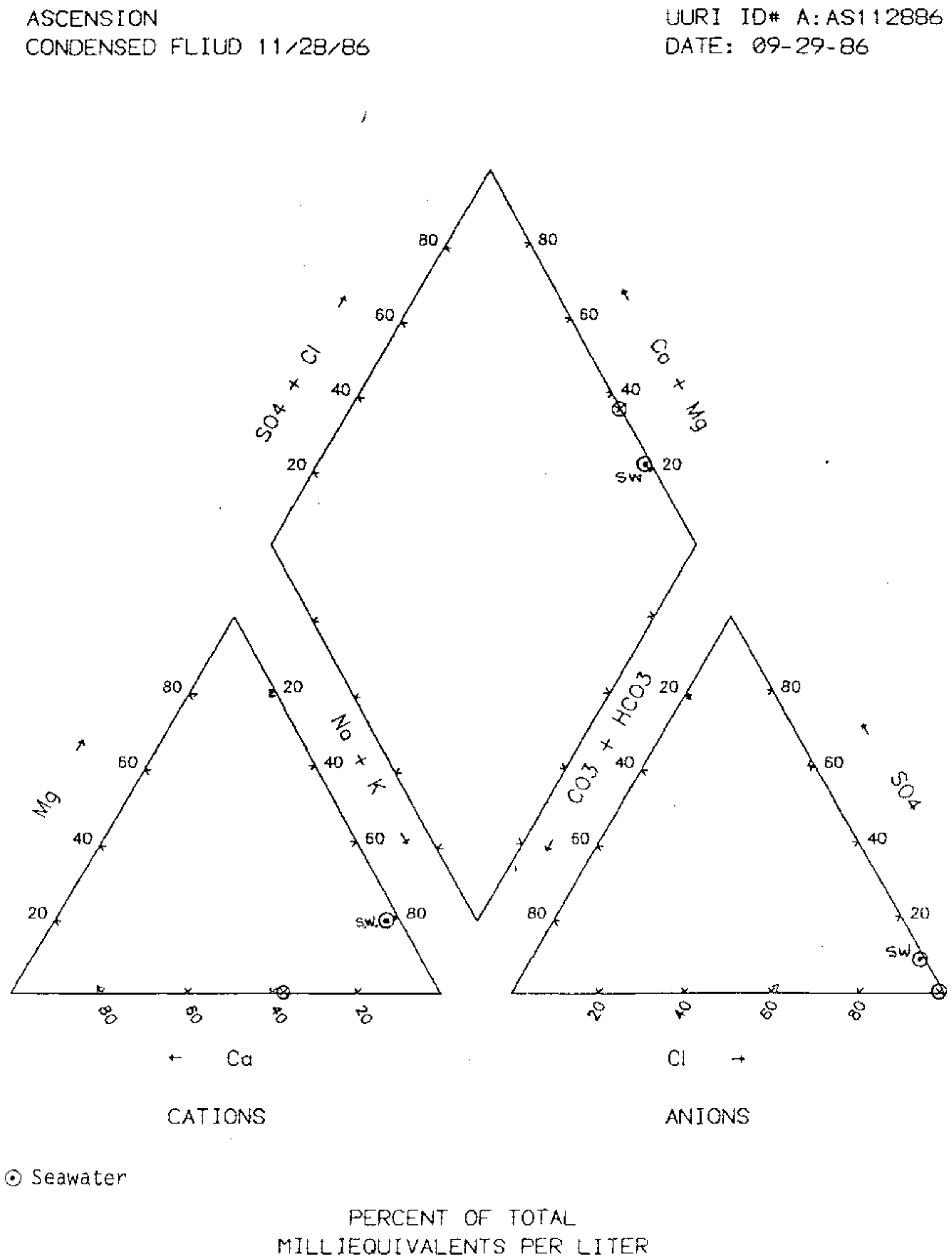
* Sample collected immediately following first step test.

** as Si.

FIGURE 8-1

ASCENSION #1

TRILINEAR PLOT



9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Conclusions

The mud log (Appendix B) and the temperature logs indicate that the well appears to have entered a carbon dioxide zone at approximately 8050 feet which corresponds to the top of a carbonate-rich zone. This permeable zone appears to exist between 8050 and 8400 feet. The well has no significant water inflows, and there appears to be no significant flow into the well below 8400 feet.

The maximum temperature measured in logging run #11 (457°F) in the wellbore is high enough for electric generation at the depths encountered. This temperature is supported by temperature projections from other runs, however a suitable hydrothermal resource has not been encountered, and until water is located in a suitably permeable reservoir the project is still in an exploratory phase.

The temperature gradient from 6240 to 8640 feet is estimated to be 1.0°F/100 feet, and 23.7°F/100 feet from 8250 to 8600 feet. The first gradient is based on a Horner projection of 434°F at 6240 feet from logging run #1 and the maximum measured temperature of 457°F at 8600 feet from logging run #11. The higher gradient is based on a measured temperature of 374°F at 8250 feet and the maximum measured temperature of 457°F at 8600 feet, both from logging run #11. Significant deviation of the wellbore from the vertical would result in a higher than predicted gradient.

There is no evidence of a producing hydrothermal resource at the present depth (8706 feet). The bottomhole temperatures are approaching those required for the well to sustain water flow if a hydrothermal resource were encountered. The slow decrease in wellhead pressure indicates that the carbon dioxide

(CO_2) reservoir above the granite intrusion has a significant volume and low permeability. The continual inflow of gas into the wellbore precludes a column of pure liquid standing in the wellbore. The shut-in wellhead pressure has the potential of reaching 3000 psig, but with some water inflow may stabilize at 2000 psig.

The magnitude of the CO_2 inflow and the high temperature at the bottom of the hole are positive indications of a potential hydrothermal resource. However, it is not clear if the postulated resource is located below or along side of the present well bore. A high temperature gradient would be indicative of a resource below the present well bottom, while a moderate gradient would indicate that the borehole is paralleling the fractures that contain the resource.

Chemical analyses of the recovered fluids indicate that the fluid from a potential hydrothermal zone may be entering the wellbore. The wellbore flow behavior is too complex for detailed chemical analysis to yield definitive results.

9.2. Recommendations for Additional Data

The location of the bottom of the well should be determined by running a directional survey. A downhole water sample should be taken if possible to provide an indication of the nature of the potential resource.

It does not appear to be necessary to collect additional flow data since the present inflow zones do not represent sufficient heat influx for exploitation. A shut-in pressure and temperature survey may provide additional indications of the location and nature of the present producing zones (the present mechanical completion equipment is inadequate to allow shut-in at high pressure conditions).

A suite of electric logs would provide a great deal of information on the formations penetrated by the wellbore and the potential for a hydrothermal resource. A gamma ray/cement bond log, porosity, caliper and sonic log would be advisable. In addition, after running the directional survey, it would be advisable to run a dipmeter to determine the dip of the granite contact and give an indication of the potential direction to drill toward a hydrothermal resource.

9.3. Recommendations for Continuation of the Project

Data to date are not conclusive in supporting the existence of a hydrothermal resource, however, further exploration appears warranted. The continuous flow of CO_2 indicates that its source is not an isolated pocket. The existence of CO_2 in a reservoir of some size positioned just above an apparent increase in temperature gradient are positive indications that there is a hydrothermal resource in the area penetrated by this well. The postulated resource may either be deeper in this bore or in close proximity. If the granite encountered in the bottom of the hole is the host rock for the fractures that contain the resource, the resource should be close to the bore (within 1000 feet).

There are two possible actions for this well:

Isolate the CO_2 zone and deepen to approximately 9500 feet or until a significant production zone is reached.

If the directional survey indicates that the bottom hole is not in the target area, sidetrack the well and complete in the fractured area.

10. References

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3. Sibbett, B.S., D.L.Nielson, M.C.Adams, 1984, "TECHNICAL REPORT GEOTHERMAL GRADIENT DRILLING & MEASUREMENT ASCENSION ISLAND, SOUTH ATLANTIC OCEAN", University of Utah Research Institute.

4. Test Plan for the Flow Test of the Ascension Island Geothermal Exploratory Well", Well Production Testing, Inc., May 19, 1986, I86-05-01

The appendices in this copy have been deleted for brevity.

8.0 CONCEPTUAL MODEL

This section is designed to bring together the information which has been discussed in the previous sections of this report into a conceptual model of the hydrothermal resource. This model will guide further exploration and will be updated as new information is acquired.

Some of the important conclusions from the previous sections of this report are summarized below.

1. Ascension #1 has intersected a high-temperature hydrothermal reservoir which has been partially sealed by the precipitation of hydrothermal minerals.
2. Present temperatures of the reservoir are at least 479° F.
3. The hydrothermal alteration mineralogy is similar to that found in other high-temperature reservoirs through out the world.
4. The geothermal fluids are derived from seawater, and their chemistry is modified by interaction with rocks at both high and low temperature.
5. Data from fluid inclusions shows that the fluids which produced the hydrothermal alteration were similar in chemistry to present reservoir fluids. These data also demonstrate that the reservoir zones have increased in temperature since the precipitation of quartz + epidote.
6. The reservoir is hosted by faults that form the northern boundary of a rift system or structural graben.

Figure 8-1 is a simplified diagram showing the important aspects of the Ascension geothermal system. This figure shows

Ascension #1 penetrating subaerial volcanic rocks, submarine volcanic rocks, and then a series of fault zones which bound the rift to the north and serve as the host for the high temperature geothermal reservoir.

9.0 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that Ascension #1 has intersected a high-temperature geothermal system located within the southwestern rift system. However, present permeability within the well is too low to support the volume of production required for electrical power generation. The following action is recommended.

1. Deepen Ascension #1 to attempt to improve production of geothermal fluids.
2. If necessary, inject fluids to attempt to open additional fractures and improve production.
3. If the above efforts are not successful, drill another leg into the same fault system. This leg will intersect this system approximately 2000 feet to the northeast of the present bottom hole location.
4. Attempt to fracture the reservoir at this location if necessary.
5. Establish a seismic survey that will define the location of active fracturing and better production in the project area.

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Appendix 11.1 Daily Drilling Summary

ASCENSION ISLAND GEOTHERMAL PROJECT
WELL ASCENSION # 1

June 9,1987

This report is a synopsis of the daily events leading up to the drilling of Ascension Geothermal Well # 1 and the actual drilling operations starting with the arrival of the ship "Paul Bunyan" on July 10, 1986 at 17:00 hours.

July 10, 1986
Ship arrived at 17:00 hours but did not begain unloading operations due to lateness of hour.

July 11
Unable to begin unloading operations due to rough seas. Ascension Island has no port facilities other than a short cement pier that extends into very shallow water offshore. This requires ships to anchor off-shore in deeper water and use their own onboard cranes to unload on to self-propelled tenders which transport it to the pier to be unloaded. Rough seas will stop unloading operations because of the safety hazards created by the swells.

July 12
Rough seas continue to prevent unloading operations.

July 13
Rough seas continue to prevent unloading operations.

July 14
Rough seas continue to prevent unloading operations.

July 15
Seas abated and unloading operations start with first load of Parker drilling equipment unloaded onto the pier at 10:00 hours.

July 16
Continue to unload drilling equipment and materials and transport to the drilling site where rig-up operations are underway.

July 17
Continue with unloading, transportating and rig-up operations.

July 18
Continue to unload, transport and rig-up. Received key substructure parts and started rig-up of the substructure and derrick.

July 19
Continue to unload, transport and start final set of equipment.

July 20
Rough seas again stopped unloading operations. Rig-up operations continue at the drilling site.

July 21
Rough seas continue to halt unloading operations. Rig-up operations continue at the drilling site with the available equipment.

July 22
Rough seas continue to halt unloading operations. Rig-up continuing at the drill site with available equipment. Derrick pins were recovered from the ship using a small rubber boat which was able to make a beach landing in a sheltered cove.

July 23
Rough seas continue to halt unloading operations. Rig-up operations continue using derrick pins obtained with rubber boat. Assemble derrick.

July 24
Rough seas until 12:00 hours when unloading operations were resumed. Continue to rig-up at drill site.

July 25
Seas calm but unloading halted because British were unloading DOD ship and no tenders were available. Continue to rig-up at drill site.

July 26
Rough seas again halted unloading operations from ships. Continue to rig-up at drill site.

July 27
Seas calmed by 12:00 hours and unloading again resumed. Raised derrick at drill site.

July 28
Continue unloading ships. Rig-up at drill site. Ship "Paul Bunyan" unloaded.

July 29
Continue unloading Dutch ship. Ship unloading finished at 12:00 hours. Continue rig-up with fork lift only as a crane was not available for rig-up operations.

July 30
Continue to rig-up as possible with fork lift. Crane arrived at 14:15 Hours. Rig-up until 16:00 hours. Parker fork lift down for repair. Crane left drill site at 16:00 hours for other work. Rig-up continuing as possible with small Pan Am fork lift.

July 31
Continue rig-up operations with crane and small fork lift.

Aug. 1
Continue rig-up operations with crane and small fork lift. Continue to receive equipment and supplies for project.

Aug. 2
Continue final rig-up operations. Received 2 primary air compressiors and rig-up same. Drilled "Rat & Mouse holes" with air.

Aug. 3
Continue final rig-up operations. (SPUD WELL 16:00 hours August 3, 1986). Drill 20" hole from 0' to 46' with 20" Bit #1 using air as the circulation medium. Build mud volume (700 bbls.) spud mud. Rigging-up HOWCO units on drill site and bring cement supplies to location. Pick-up and stand back 6 joints of 5" drill pipe in the derrick for cement job. POH to unplug bit (rust). Work on pump selectors and cellar jet.

Aug. 4
Continue to repair cellar jet and shale shaker. Fill hole with mud and drill 20" hole from 46' to 65' and burned out both shale shaker motors. Replaced 1 shale shaker motor and continue to drill 20" hole from 65' to 173'. Circulate and condition mud and hole to run 16" casing. Start wiper trip.

Aug. 5
Continue wiper trip. Circulate and condition hole for 16" casing. Cut and blend 360 sacks cement and blow into bulk tanks. Rig-up cellar jet to dump cement into waste pit. Wash and clean 16" casing threads and weld 16" float shoe on to joint. Rig-up HOWCO cement unit for cement job. POH and lay down 20" bit and stabilizer. Rig-up to run 16" casing. Run 4 joints (166.99') 16"-65#-H-40-STC casing with HOWCO super seal stab-in Float Shoe on bottom. Set Shoe at 165'. Sting into float shoe using 5" drill pipe with stab-in adapter. Circulate and condition hole and mud for cement job. Cement casing as follows: Pump 15 bbls. saltwater ahead of cement, mixed 252 sacks class "H" cement, displace with 3 bbls. saltwater. Good circulation and cement returns. POH with 5" drillpipe. Wait on Cement.

Aug.6
Continue to wait on cement (18 hours). Cut off 16" casing. Weld on 16" API 2000# WP Casing flange. Nipple up "Air Innovators" rotating head. Connect flow line. Install drain plug. Test rotating head with 500 psi. Test OK. Pick-up 14-3/4" BHA (bottom hole assembly). Caliper and measure all tools and drill collars. RIH with bit # 2 and tag top of float collar at 165'. Install hold downs and cables and turnbuckles on conductor. (Note) Cement did not fall back in casing-hole annulus. Samples showed good compressive strength at 12 hours and excellent compressive strength at 18 hours.

Aug.7
Drill out Float Shoe, cement and drill 14-3/4" from 173'-182'and lost complete returns. Mix LCM (lost circulation materials) and pump in hole. No returns Mix LCM pill No. 2 and pump in hole after 1 hour without success. POH with drill collars and RIH with open ended drill pipe to 180'. Mix and spot a 70 sack type "H" balanced cement plug on bottom. WOC (wait on cement) 12 hours and attempt to fill hole with LCM pill # 3 without success. Mix polymer "Gunk" pill and bring 240 sacks of cement to the location.

Aug. 8
Pump polymer "Gunk" pill into hole with no returns. Cut and blow cement into bulk tanks. RIH with open ended drill pipe to 180' and HOWCO mixed and set a 120 sack type "H" balanced cement plug. POH with drill pipe and WOC for 6 hours. Pick-up BHA. Install rotating head. Filled hole and regained circulation with 100 bbls. of mud. Drill 14-3/4" hole with bit # 2 from 173'-250'.

Aug. 9
Continue drilling 14-3/4" hole from 250'-303'. Survey at 263' = 1 degree. POH with bit # 2 and RIH with bit # 3. Could not circulate because of rust packed-off in drill collars. POH and unplug drill collar. RIH and drill 14-3/4" hole from 303'-333' and plugged pipe while making a connection. POH and unplug pipe (rust and LCM on top of float). RIH and lost circulation . Mix LCM and mud volume and regained circulation. Continue drilling 14-3/4"hole from 333'-480'. Survey at 440' = 1 degree. Continue drilling 480'-535'.
(NOTE): Plugging in drill collars is occuring from the extreme amount of rust in the drill collars and heavy weight drill pipe that we received from Brazil. Pounding and washing through them is failing to remove enough of the rust. The float has been removed to facilitate chasing of the drill pipe and currently a line has been rigged up to blow large amounts of air from the compressiors through each joint while hammering on the joint to help remove the rust and scale.

Aug. 10
Continue drilling 14-3/4" hole with bit # 3 from 535'-662'. Survey at 662' = 1¼ degrees. Drill 662'-716'. Broke rotary chain and repaired same. Drilling thru trachyte flows to volcanic breccia and pyroclastics which are causing extremely high torque loads while drilling. Continue drilling from 716'-722' and sheared housing unit on right angle drive because of high torqe loading of drill string. POH using air wench to break drill pipe and drill collars. Rig shut down awaiting repair parts. Down time occured at 17:00 hours 8/10/86

Aug. 11
Rig shut down awaiting parts to repair right angle drive and housing. Parts are being expedited from the USA.

Aug. 12
Rig shut down for repairs. Stacked drill pipe on racks. Moved 11-3/4" casing to racks. Prepare to cut cement materials while waiting on parts.

Aug. 13
Cut and blend cement for 11-3/4" casing cement job and blow into bulk tanks. Remove protectors from 11-3/4" casing. Machine out threads from float equipment. Load out 16" float shoe for return to HOWCO. Rig still shut down for repairs awaiting parts from USA.

Aug.14
Received parts for right angle drive. Repair and install right angle drive. Rig operational at 13:00 hours 8/15/86. RIH with bit # 3rr and ream 30' to bottom. Drill 722'-825. Took survey at 710'=1¼ degrees.

Aug. 15
Drill 14-3/4" hole from 825'-967'. Survey at 927'= 1 degree. Drill 967'-1152' and plugged bit with rust and cuttings. POH and change bits. RIH with bit # 4.

Aug. 16
Drill 14-3/4" hole with bit # 4 from 1152'-1214' and plugged bit while making a connection. POH and unplug bit. Clean shaker pits. Build mud volume and viscosity. RIH with bit # 4 and drill 1214'-1246' and plugged bit with cuttings. POH and remove float and jets. RIH with bit #4rr and ream 30' to bottom. Circulate around high viscosity mud sweep. Drill 1246'-1306'. Survey at 1266'=3/4 degrees. Continue drilling 1306'-1346'.

Aug. 17
Continue drilling 14-3/4" hole with bit # 4rr from 1346'-1429'. Repair rotary chain and continue drilling from 1429'-1491'. Circulate and survey at 1448'=3/4 degrees. continue drilling from 1491'-1604'.

Aug. 18
Continue drilling 1604'-1760' and lost complete returns. Mix LCM pill and pump same without success. POH and stand back drill collars. RIH with opened-ended drill pipe to 1748'. HOWCO started mixing 100' plug.

Aug. 19
HOWCO continue mix 115 sack cement plug and set balanced plug at 1748'. POH and WOC. Attempt to fill hole with 600 bbls mud. Fluid level stands at 60' below RTE (rotary table elevation). Spot polymer "Gunk" loss circulation pill at 1650'. Attempt to fill hole without success. Cut and blow into bulk tanks 90 sacks "H" cement. Spot 90 sack balanced cement plug at 1650'. POH and WOC.

Aug. 20
Continue WOC. Pumped 150 bbls mud with no returns. Mix 150 bbl LCM pill and RIH with open-ended drill pipe and pump in pill with no returns. Mix 150 bbls of gel,polymer and LCM pill and pump through open-ended drill pipe with air assistance and regained circulation of clear salt water. Remove air assistance and circulation is lost. Pull up to 1073' and HOWCO set 100 sacks of class"H" and perlite cement plug. POH and WOC 8 hours. Pump in 80 bbls fluid and regained 40% returns. RIH with open-ended drill pipe and tagged top of cement plug at 1490'. Pull up to 1203' and HOWCO set 100 sack "H" cement and perlite plug. POH and WOC.

Aug. 21
Continue to WOC 6 hours. Pumped 250 bbls. salt water and regained 60% returns. RIH and tagged top of cement plug at 1003'. POH to 647' and HOWCO mixed and set 200 sacks of class "H" cement and perlite balanced plug. POH and WOC. Attempt to fill hole with 70% returns. RIH with open-ended drill pipe and tagged top of cement plug at 568'. Cut and mix 150 sacks of class "H" cement and perlite and blow into bulk tanks. POH to 158' and set blanced plug. POH and WOC.

Aug. 22
Continue WOC 6 hours. Pump 60 bbls salt water and regained 80% returns. Run Temperature Survey. RIH and tagged top of cement at 291'. POH to 158' and HOWCO cut and mixed 150 sacks of class "H" cement with 50% sperelite and 30% SSA-1. Had circulation during displacement of cement. Fluid dropping at 20 minutes. WOC. Filled hole in 6 hours. Fluid dropping slowly in hole. WOC. RIH and tagged top of cement at 260'. POH with open-ended drill pipe and pick up bit and drill collars and RIH. Drilling cement 260'-293'.

Aug. 23
Continue drill out cement plugs to 1238'. Pipe stuck on a connection. Work stuck pipe. Circulate and condition hole and polymer water. Switch over to stiff foam and work pipe free (was differentialy stuck). Circulate hole with stiff foam. Continue drill and clean out cement plugs to 1298'.

Aug. 24
Continue to drill and clean out cement plugs to 1398'. Experiencing 15'-25' fill. Circulate hole. Pipe stuck while rotating and circulating. Work stuck pipe free. POH and wait on resupply of mud and cement supplies. Rig shut down time 11:30 hours 8/24/86.

Aug. 25
Rig shut down awaiting supplies. (mud, cement, rotating head, reamers and shock subs). Total of 800 bbls of salt water pumped in hole with no returns. Clean all mud pits and fill with salt water. Prepare to resume operations.

Aug. 26
Rig shut down awaiting resupply.

Aug. 27
Rig shut down awaiting resupply.

Aug. 28
Continue waiting on supplies. Supplies arrived at drill site 08:30 hours 8/28/86. RIH with open-ended drill pipe to 1104' and pump 200 bbls. of salt water. Cut and mix 75 sacks of class "H" cement and set balanced plug. POH and WOC 6 hours. Mixed heavy polymer LCM pill and build polymer mud volume. Pumped 100 bbl heavy LCM pill followed by 260 bbls salt water and regained circulation. Experiencing 15 bbls loss of fluid per hour. Pumped high viscosity polymer mud and regained 100% returns. Circulate and condition hole and build mud volume prior to drilling out cement. POH and pick up bit # 5 and RIH. Drill cement from 1325'-1427'. NOTE: Received on plane 8/29/86. 3 pallets of class "H" cement, 75 sacks - 1 pallet of Multi-seal LCM and 1 pallet of cedar fiber LCM material - 1 drum of Duraguard - 2 pallets of polymer.

Aug. 29
Continue drilling cement from 1427'-1731' Circulate and condition hole for casing. POH and rig up to run 11-3/4" casing. Run 41 joints 11-3/4" - 47# - K 55 - Buttress casing (1705.27'). Circulate and condition hole for cement. RIH inside casing with 5" drill pipe and sting into Float Collar. HOWCO cemented as follows: Pumped 20 bbls. salt water ahead of cement followed by 300 sacks of class "H" cement with 50% sperelite + 40% SSA-1 + .5% Halad 344 + .2% HR 4 + 4% gel - Displaced with 28 bbls of salt water. Good circulation throughout job and good cement returns. HOWCO Guide shoe @ 1706' and HOWCO super seal Float collar @ 1622'.

Aug. 30
POH from inside casing with 5" drill pipe and WOC. Cement fell in annulus to 200'. Run 1¼" pipe to 185' in annulus. HOWCO cut and mixed 96 sacks class "H" cement and pumped into the annulus thru the 1¼" pipe. Good cement returns to surface. WOC.

Sept. 1
Cut off 16" conductor casing. Cut off 11-3/4" casing and weld on 13-5/8" x 11-3/4" - 2000# WP Casing Head. Test weld - OK. Nipple -up BOPE (Blow out preventer equipment). Install Blooie line. Test Pipe Rams with 1000 psi OK Test Blind Rams with 1000 psi OK. Lay down 15 joints of 5" drill pipe. RIH to 1000' and pick-up rotating head rubber and unload fluid from hole. Rig-up bleed-off line and adjust turnbuckles. RIH and tag cement 1' above Float Collar. Drill Float Collar, cement and Guide Shoe at 1706'. Drill cement from 1731' to 1740' using stiff foam as the circulation medium.

Sept. 2
Continue drilling cement from 1740' to 1760'. Drill new formation from 1760'-2004'. Survey at 1969'= 1¼ degrees. Drill 10-5/8" hole with bit # 6 from 2004'-2260' with. survey taken at 2184'= 1-3/4 degrees.

Sept. 3
Continue drilling with bit #6 2260'-2444'. Survey at 2402'= 1½ degrees. Continue drilling 2444'-2537'.

Sept. 4
Continue drill 10-5/8" hole from 2537'-2589'. Survey at 2589'= 1½ degrees. POH to change bit and reamer. RIH with bit # 7 to 1000' and blow hole. RIH to 2060' and hit bridge. Blow hole. POH 5 stands and repack swivel. RIH and wash thru tight spot 2030'-2072'. RIH 5 stands and wash 30' then ream 2515'-2570'. Replace fill-up line. Ream to bottom, no fill. Drill ahead with bit # 7 from 2589'-2664' and plugged bit. Attempt to unplug bit without success. POH and unplug bit (rust).

Sept. 5
RIH with bit # 7rr to 1200'. Cut drilling line 170'. Install rotating head rubber and blow hole. RIH to 1900'and blow hole. Finish RIH, ream 60' to bottom. Drill 10-5/8" hole from 2664'-2864'. Survey at 2864'= 1½ degrees. Continue drill 2864'-3114' with survey at 3030'= 1-3/4 degrees.

Sept 6
Continue drill 10-5/8" hole with bit # 7 from 3114'-3658' with surveys at 3266'= 1½ degrees & 3520'= 1-3/4 degrees.

Sept. 7
Continue drilling with bit # 7 from 3658'-4349' with surveys at 3772'= 1-3/4 degrees, 4005'= 2½ degrees and 4257'= 3 degrees.

Sept. 8
Continue drilling 10-5/8" hole with bit # 7rr from 4349'-4513'. Survey at 4507'= 3 degrees. Drill 4513'-4605'. Survey at 4595'= 3-3/4 degrees. Displace stiff foam with 200 bbls.of 25% LCM salt water and regained circulation. Change blooie line to flow line. Losing 35 bbls. hour while circulating. Pump 100 bbl 25% LCM pill and build viscosity. Circulate and condition hole and mud.

Sept. 9
Continue circulate and condition hole. POH (short trip) to 1700' and RIH. Wash 41' to bottom with 3' fill. Circulate and condition hole. POH and lay down 10-5/8" reamers and bit # 7rr. Wait on drilling supplies (cement) to be expedited from USA to provide sufficient cement for casing. Ready 10-5/8" reamers and stabilizers for return shipment.

Sept. 10
Continue to wait on resupply of polymer and cement. RIH and found bridge at 2106'. Wash and ream 100' and continue to RIH to 4570' and hit bridge. Run temperature survey after bottom of hole was static for 29 hours. Temperature survey = 7 minutes on bottom = 238 degrees F. Wash and ream 130' to bottom. Pump LCM pill and circulate and condition hole at 4605'. Received Schlumberger equipment.

Sept. 11
Continue to wait on supplies to arrive. Circulate and condition hole. at 4605'. Hole taking 4 bbls of fluid per hour.

Sept. 12
Plane came in and insufficient supplies arrived to permit operations to resume. Decision was made to shut down operations until all needed supplies could be brought to the island. POH and shut down rig on a long term stack rate. A Parker mechanic and 2 other men were left to keep hole full and watch -rig. Rig Shut down on long term stack rate at 24:00 hours 9/12/86.

*

Nov. 13
Start up rig at 24:00 hours 11/12/86. Pick-up bit # 8 rr and RIH to 1100' amd break circulation. Continue to RIH. Ream thru tight spot at 2500' (minor) to 3290' Displace fluid in hole with fresh polymer salt water. Finish RIH to 4500'. Lay down 3 joints. Ran temperature survey on uncirculated hole. Temperature survey = 270 degrees F. Ream to bottom at 4605'. Circulate and condition hole. POH (measure out). RIH and ream 40' to bottom (wiper trip). Circulate and condition hole while cuting and blending cement and blowing into bulk tanks. POH to run 7-5/8" casing.

Nov. 14
Continue to POH. Make-up and stand back liner hanger in derrick. Rig-up and run 76 joints of 7-5/8"-casing as follows: 60 joints of 26.40# K55 Buttress (2491.79') + 16 joints of 26.40# S95 & N80-Buttress (632.45') + HOWCO Superseal Float Shoe on bottom and HOWCO Superseal Float Collar 2 joints above the float shoe (82.86') + Midway single slip liner hanger with short receptacle (7.25') on top of casing. Hit fill 100' off bottom. Pick-up kelly and circulate down 1 joint of pipe. Parker swivel blew its packing and casing was starting to stick. Set liner hanger @4543' with top @ 1406' and circulate and condition hole. HOWCO cemented as follows: 10 bbls of salt water ahead of 192 sacks of type "H" cement + 40% SSA-1 + 55 sacks perlite + .5% halad 344 + .2% HR-12 followed by 560 sacks type "H" cement + 40% SSA-1 + .5% Halad 344 + 2% gel + 31 sacks perlite + 3.5% sperelite. Start displacement and cement flash set with 42 bbls of displacment to go.(911') in casing. POH with liner setting assembly and WOC RIH with 10-5/8" bit to top of liner, no cement on top of liner.

Nov. 15
Closed pipe rams and HOWCO established an injection rate of 1½ bbls per minute @ 2000 psi. POH and RIH with open-ended drill pipe and set a 105 sack balanced plug of class "H" cement. Pull-up drill pipe above cement and "Braden Head" squeezed cement into the lap. POH and WOC. Lay-down excess drill pipe in derrick while WOC. RIH with rr bit. Shut pipe rams and tested lap. Was able to pump into lap @ 3/4 bbls/minute @ 500 psi. POH with bit and RIH with open-ended drill pipe. HOWCO cut and set 50 sack balanced plug of class "H" cement. Pull-up drill pipe above cement and "Braden Head" squeezed cement into lap. Had pressure drop to 150 psi. Stage squeezing until cement displaced, with no pressure increase. Cut and mix 60 sack balanced plug of class "H" cement (last of cement). HOWCO set balanced plug. Pull above cement and "Braden Head" squeeze cement into lap. Stage squeezing and had gradual pressure increase to 450 psi at end of cement. POH and WOC.

Nov. 16
Continue WOC. RIH with bit #8rr to top of liner hanger at 1406'. No cement on top of liner. Circulate and condition mud. Test lap with 500 psi OK. POH and lay-down heavyweight drill pipe, drill collars kelly subs and tools used in large diameter hole. Pick-up 3½" kelly and subs and tools. Pick-up bit # 9 and 18 new 4-3/4" drill collars and new 3½' drill pipe. Drill out seal assembly in liner hanger and continue picking-up new 3½" drill pipe.

Nov. 17
Continue pick-up new 3½" drill pipe. Hit top of cement @ 3438'. Drill cement from 3438'-4465' top of float collar. Change flow line to blooie line. Blow hole and change over to air mist. Drill float collar, cement and float shoe @ 4546'.

Nov. 18
Ream and wash to bottom of 10-5/8" hole at 4605'. Drill 6-3/4" hole with bit #9 from 4605'-4666' (rat hole for BHA). POH and pick-up 6-3/4" BHA (Bottom Hole Assembly). RIH with bit # 10 and ream 30' to bottom. Drill 6-3/4" hole from 4666'-4923'. Survey at 4881'= 5¼ degrees. 3 stand short trip for drift and temperature survey. Bit plugged. POH and unplug bit. Float had failed due to bottom hole temperature and let cuttings plug bit. Repair float . RIH with bit # 10rr.

Nov. 19
Finish RIH and unload hole. Wash and ream 42' to bottom,(10' fill). Drill 4923'-5235', circulate and survey @ 5442'= 11-3/4 degrees. POH 3 stands to recover string float. Survey @ 5193'(bad order). RIH and drill 5235'-5460' and blow hole for trip. POH to change bit. RIH with bit #11.

Nov.20
Finish RIH with bit #11. Survey at 5442'= 11¼ degrees. Ream and wash 74' to bottom,(18' fill). Drill 5460'-5791', circulate and short trip for float. Survey @ 5749'= 14¼ degrees. Ream and wash 15' to bottom. Drill 5791'-5946'.

Nov. 21
Continue drill 5946'-6287' circulate and short trip for string float. RIH with "Custer" wireline temperature tool to 4500' and wait 15 Minutes,RIH to 5400' and wait 20 minutes, to 6240' and wait $1\frac{1}{4}$ hours and POH with "Custer" tool. POH with bit #11. Slip and cut drilling line. Change bit reamer and 2 stabilizers. RIH with bit #12. "Custer" temperature readings was 307 Degrees F @ 6240'.

Nov. 22
Unload hole (750 psi), 15-20 bbls. water in hole. Ream and wash 75' to bottom. Drill 6-3/4" hole with bit #12 from 6287'-6626', change rotating head rubber. Continue drilling 6626'-6895'.

Nov. 23
Continue drill 6895'-7301'. Catch water samples. POH change bit and lay-down reamer and stabilizers. RIH with bit #13 to 6800' and unload hole.

Nov. 24
Finish unloading hole. RIH to 7300' and unload hole for water sample. Ream and wash 70' to bottom,(65' fill). Drill 7301'-8030'.

Nov. 25
Continue drill 8030'-8120'. circulate out 440 psi pressure increase, continue drilling to 8340' with pressure increases at 8135'= 560 psi, 8142'= 650 psi, 8250'= 350 psi and 8292'= 400 psi. Pressure increases were encountered and gradually diminished over a period of 30 minutes. blow hole and make 13 stand short trip for string float. Rig-up lubricator and run "Custer" tool to 8318'. Take 1 hour temperature reading and POH with "Custer" tool. Lay-down lubricator. Continue drilling 8340'-8360'. POH to change bit and rotating head rubber. RIH with bit #14.

Nov. 26,1986
Continue RIH with bit #14. Unload hole and ream 42' to bottom,(40' fill). Drill 8360'-8706'. Pressure increases @ 8370'= 555 psi and 8545'= 350 psi. Blow hole and inject corrosion inhibitor. Short trip for float. Hang bit at 8664'. Rig-up and run "Custer" temperature survey. POH with first run of temperature survey. Pull drill pipe to 8000' and run temperaturee survey #2. Maximum temperature on survey #1 = 387 Degrees F. POH with drill pipe and drill collars and stand in derrick. Shut down rig and prepare to demobilize personnel.

*

May 14, 1987
Start of remobilization with arrival on drill site of 2 personnel from UURI, 3 - Nova air jammers, 3 - Parker (Toolpusher, mechanic and floorhand). Activate rig. Haul fresh water and fuel to rig. Received 15.50# drill pipe and 4-3/4" Monel to drill site. Cargo ship likes 1 day from being unloaded. Inventory supplies.

May 15
Continue receive materials from ship. Could not unload materials in AM because Parker forklift was down for repairs. Received box of supplys for Parker, Reamers and Stabilizers from Drilco, HOWCO supplies of 1 pallet of HR-12 & SSA-1 + 3 vans containing 210 sacks of class "H" cement (630 sacks total). Parker Mechanic fixed forklift in PM. Continue inventory supplies.

May 16

Continue preparing rig for drilling. Parker Mechanic checking and preparing equipment. Discovered that 4-3/4" monel was not bored for a float and had 3½"IF boxes on both ends. No subs on location to allow use of Monel with these connections. Called Parker (Lee Cooley) and ordered cross over subs.

May 17

Filled water tanks without problem (no leaks). Filled mud pits. 3 pits leaking badly. Finish installing #5 motor. Over pumped salt water tank at water pump. Schlumberger equipment arrived on C-5 flight.

May 18

Remainder of crews arrived. 2 Parker crewman short. Instructed Nova and Air crew to order recorder for air compressiors. Air package now consists of 3 primarys and 1 booster. Varified from Parker (L. Cooley) that cross over subs and "O" rings for survey heat shield receiver barrel were ordered. Also instructed him to send more 3½" rotating head rubbers.

NOTE: 0200-0800 = Standby time W/3 men. Start up Rig on full rate minus 2 men = 0800-2400. Rig-up pumps 1-2-3-4 W/ liners, pistons, valves. Rig down EG&G flow test lines and meter run and install blank on banjo box Hook up lines to HOWCO pump unit and check out bulk equipment. Install Grant rotating head and spool and flange up same.

COMMENT: Found significant corrosion and rust on drill pipe and drill collars left in derrick during shut down period. Serious damage to mud pits (already in bad condition) and ladders and corrosion and staining and rusted hinges on doors to Energylog's mud logging unit.

HOWCO unit had substantial corrosion and rust damage to the pump unit and rust and staining on the bulk equipment. Pumping Unit had holes eaten through measuring tanks and controls to operate unit were badly rusted. The conditions that brought on this corrosion appear to be threefold. (1) Atmospheric conditions on Ascension Island are very corrosive due to the salt breezes. (2) The drill pipe and tubulars, mud pits and HOWCO pumping unit were used in a salt water environment and although chemicals were used to ameliorate conditions no fresh water is available to flush the equipment. (3) Well Test crew erected a vent line in a vertical posture in very close proximity to the equipment and during the shut down period the spray of corrosive waters and gases which were blown some 100' into the air, landed on or were blown onto the equipment by the prevailing breezes.

May 19

Finish nipple up Grant rotating head. Rig up fill up line, rotating head lubricator. Fill pits with salt water. Repair air line to Koomey BOPE unit. Repair lights to rig floor. Center BOPE stack and install turnbuckles and tie-down lines on blooie line. Slip Drilling line 20'. RIH w/6-3/4" rr bit (measure in hole). Replace rusted tong safty line. Repair #1 motor. Continue RIH Breaking, redoping and tighting each connection. Stop at shoe of 7-5/8" casing @ 4548' and fill hole with salt water. Hole circulated after 520 barrels pumped. Refill mud pits with salt water and change blooie line to flow line for circulation through mud pits. Hole taking approximately 5-10 barrels per minute of fluid. Repair rig floor lights. Continue RIH.

May 20
Continue RIH breaking and redoping each connection. Found top of fill @ 8425' (281'fill in hole). Break circulation. Wash and ream to 8600'. Circulate. POH 42 stands of drill pipe. Rig Repairs on breakout air valve. Lay down 132 joints of drill pipe. POH W/ drill collars. RIH W/ Stiff BHA to 5053'.

May 21
Reaming 5053'-8244'. Reaming minor to 7101' & medimum to medimum hard below 7101'.

May 22
Continue reaming 8244'- 8600'. Circulate and service rig. Washed out standpipe union. Pull off bottom 210'. Rig repairs to replace 4" union. RIH and wash to 8604'. Circulate and repair mud line to mud mixing equipment. Cut and blend cement for squeeze job. POH and remove stabilizers and reamers. RIH w/open ended drill pipe.

May 23
Rig Repairs on water pump. Out of water at rig. Rig Repairs on monkey board. Continue RIH w/open ended drill pipe. Rig Repairs on air valve. Finish RIH and fill hole with salt water. Pick up 18 joints of drill pipe to replace drill collars. Rig up HOWCO to cement. Circulate. HOWCO set 150 sacks cement plug and POH 20 stands and squeeze CO_2 zones. Cement in place @ 5:30pm. POH and Wait on cement. 3 Schlumberger and 2 Parker personnel arrive.

May 24
Continue wait on cement. RIH w/bit #15 and monel drill collar to 4600'. Survey. Stuck survey tool (landing plate broke, turned sideways and stuck sinker bars). Pulled out of head. POH to retrieve survey tools. Lay down monel drill collar and retrieve survey tool. Rework float and landing plate. RIH to 4626' and fill hole with salt water. Take directional surveys @ 4626', 5000', 5373', 5745', 6116'.

May 25
Continue taking directional surveys @ 6488', 6863', 7236', 7611', 7987', lost the bottom of survey tool at fine thread at bottom section of sinker bars. POH and recover bottom of sinker bar and RIH to casing shoe. Break circulation and F/RIH to top of cement @ 8224'. Lay down 2 joints of drill pipe and ream and wash to bottom. Drill hard cement 8224'-8567'.

May 26
Continue clean out to bottom @ 8706'. (Appears some cement migrated to bottom of hole due to the hardness to clean out fill.) Circulate and pump high viscosity pill to sweep hole. Take directional survey @ 8654'. Lay down 12 joints of 15.50# drill pipe. Take directional survey @ 8301'. POH to 7893' and take directional survey. F/POH to shoe of casing. Rig down flow line and rig up blooie line in preparation to changing to air. Unload hole and stage in hole unloading in 500' increments.

May 27
F/RIH to 8623'. Ream 8623'-8706'. Drill 6-3/4" hole from 8706'-8996'. Circulate for trip. POH and change bit. RIH W/Bit # 16 and new stabilizer. Changed rotating head rubber. Stage into hole. Had 36 ppm of H_2S on first air stage. (Estimate fluid level @ 4000' after 5 hrs-250 bbls or 50 bbls per hour).
Remainder of Schlumberger equipment arrived. HOWCO rigs down equipment in prepration of leaving on 28th .

May 28
Continue stage into hole W/bit #16. Work and ream through tight hole 8675'-8996'(out of gauge). Drill 6-3/4" hole 8996'-9177'.

May 29
Continue Drill 9177'-9375'. Circulate. Short trip to recover string float. Run directional survey @ 9300'. POH to 9000' and run directional survey. F/POH change bit, reamer and stabilizers. RIH to shoe. Slip and cut drilling line. F/staging into hole. Fluid level @ 4100'.

May 30
Ream 9335'-9375'. Drill 6-3/4" hole W/ Bit #17 9375'-9696' and circulate in prepration for short trip for string float. Short trip for float. Run directional survey @ 9656'. Blow hole and unload water. Continue drilling 9696'-9822' and circulate bottoms up. Continue drill 9822'-9885' and circulate for trip. POH and rig up Schlumberger. (Run #1 = Temperature survey).
(Had fracturing and intense formation alteration observed 9430'-9885').

May 31
Schlumberger continued Run #1 Temperature survey from surface to TD @ 9885'. Log shows permeable zone 9430'-9885' with cooling by CO_2 zone @ 8142'. Run #2 Dipmeter misrun due to high temperature. MRT @ TD = 454 degrees F at 0820 hours. Run #3 Sonic Log 9000'-0' (No useful data due to noise).MRT @ 9000' @ 1340 hours = 436 F. Run #4 Gamma Ray Misrun. Work on Gamma Ray tool. Run #5 Gamma Ray 0'-8260' (Good Data). MRT @ 2345 hours = 382 F.

June 1
Schlumberger F/Run #5 and rig down Schlumberger. RIH W/Bit #18 to shoe @ 4545'. Unable to lift fluid. POH to 4022' and blow hole. Fluid level appromimately 3000'. Stage into hole (attempted blow wait technique to flow hole). Abandoned technique due to time pressures and continued stage into hole. Ream hole 9833'-9885'. Drill 6-3/4" hole W/Bit #18 9885'-10,158'.

June 2
Continue drill W/bit #18 from 10,158'to a Total Depth of 10,172' at 0030 hours June 2, 1987. Blow hole and check for flow. Short trip for string float. Run directional survey @ 10,147'. Fill hole with salt water @ 0430-0600 hours to cool hole in preparation to run Schlumberger Dipmeter. Pumped approximately 1000 barrels of salt water. POH and rig up Schlumberger. Run #1 Dipmeter (misrun-caliper arms failed to open). Run #2 Dipmeter (misrun-obstruction @ 5850'?). Rig down Schlumberger. RIH with rrBit W/no float.

June 3

Continue RIH to 10,147'. Rig up and run Kuster pressure temperature survey inside of drill pipe. Stops @ 9550' - 9830' - 10,100'. POH w/Kuster tools and rig down. POH laying down drill pipe. POH and stand remainder of drill pipe in derrick. Rig up schlumberger. Run #1 Dipmeter (misrun could not pass 6160' lost rubber bullnose off of tool. MRT @ 6160' = 331 F at 1700 hours). Rig down Schlumberger and RIH w/drill pipe and drill collars (wipe through 6160' with no discernible bridge). Laying down tubulars.

June 4

Rig down lay down equipment. Rig up Schlumberger. Run #1 Dipmeter 7600'-8000'. Run #2 Temperature survey 7500'-10,172'. Top of fluid = 3210' @ 212 F. Rig down Schlumberger and preparing to shut down operations. OPERATIONS SHUT DOWN AT 2400 HOURS June 4, 1987.

Appendix 11.3. Sample Log

WS87-1 1/31/87	Deuterium and O-18 sample from dewpond at top of Green Mountain. Conductivity at 22°C (estimated) was 180 mhos. pH = 7.0 to 7.2.
WS87-2 1/31/87 1550 hrs	Sample from sample port of test line of Ascension #1. Sample was condensed through " stainless tube in ice water. Pressure in line was 30 psi, temperature in line was 115.5°C. pH = 6.1 at 47°C.
WS87-3 2/1/87 1200 hrs	Rainwater from site, collected from tarp at test line.
WS87-4 2/1/87 1200 hrs	Sample from steamline of minicyclone seperator. Input temperature was 185°F. Water content of total discharge was very low, the well had been flushed out when it unloaded the day before.
WS87-5 2/1/87 1330 hrs	Rain sample from tarp at test line.
WS87-6 2/1/87 1347 hrs	Isotope sample from fluid dripping out of end of test pipe.
WS87-7 2/1/87 1403	Multielement sample from above fluid. pH = 5.3 to 5.5 at 64°C.
WS87-8 2/1/87 1443 hrs	Evacuated flask used to collect gases from steam line to 1 psig. Inflow temperature was 185°F.
WS87-9 2/1/87 1443 hrs	Evacuated flask used to collect gases from steam line to 1 psig. Inflow temperature was 185°F.
WS87-10 2/1/87 1500 hrs	Isotope sample from drops of condensate in steam line of seperator.
WS87-11 2/1/87 1515 hrs	Sulfate isotope sample from high TDS fluid dripping from the end of the test line.

TABLE 1. (continued)

WS87-12 Isotope and chloride sample from bottom of Breakneck
2/2/87 Valley catchment pond. Pond was enclosed in
1030 hrs cement and partially covered with sheet metal. Sparse vetetation in pond. pH = 7.5 and conductivity = 190 mhos.

SLUG FLOW TEST--Well was shut back to 100 psi for 5 hours. During this time the discharge is dry gas. The liquid is presumably built up in the well bore. The purpose of the test is to observe chemical changes in the fluids discharged after well is opened back up and to correlate changes with processes in well. Times are relative to opening the valve after shutin.

GAS SAMPLES

WS87-13 Gas Sample in evacuated cylinder with NaOH.
2/2/87 Sample taken from steam line of seperator.
8:50-17:34 min Temperature of inflow from test line was $180^{\circ}F$.

WS87-14 Gas Sample in evacuated cylinder, intended for
2/2/87 Noble gases. Sample taken from steam
26:00 min line of seperator.

WS87-15 Gas Sample in evacuated cylinder with NaOH.
2/2/87 Sample taken from steam line of seperator.
35:50-27:34 min

WS87-16 Gas Sample in evacuated cylinder, intended for
2/2/87 Noble gases. Sample taken from steam
39:45 min line of seperator.

WS87-17 Gas Sample in evacuated cylinder with NaOH.
2/2/87 Sample taken from steam line of seperator.
42:0-49:30 min

HIGH TDS SAMPLES FROM END OF PIPE

WS87-20 Multielement sample taken from dripping fluid at
2/2/87 end of test line. Taken soon after valve opened. pH = 5.5 at $?^{\circ}C$. Temperature was probably about $60^{\circ}C$.

WS87-21 Isotope sample of above.
2/2/87

WS87-22 Multielement sample taken from dripping fluid at
2/2/87 end of test line. Taken 20 min after last sample. pH 6.0 at $?^{\circ}C$. Temperature was

probably about 60^{o}C. Isotope sample was taken from untreated split, but it should not make any difference because the TDS is so high.

WS87-23 2/2/87	Isotope sample of above.
WS87-24 2/2/87	Isotope sample of liquid fraction of slug through seperator. There is probably condensate mixed in with the liquid.
WS87-25 2/3/87 0900 hrs	Steam fraction of dry effluent in evacuated flask containing NaOH.
WS87-27 1100 hrs	Seawater from 1 m deep in English Bay.

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MEMORANDUM

TO: S. M. Prestwich

FROM: D. L. Nielson

RE: QA meeting on Ascension Geothermal Project

DATE: October 27, 1987

I have established QA reviews for the Ascension project. These reviews utilize recognized experts external to UURI to look at selected aspects of the project that are of immediate importance.

I have been concerned about the negative reservoir engineering assessments given the present well on Ascension. These assessments have contrasted with the exploration data (alteration mineralogy, fluid chemistry, fluid inclusions, and fracture geometry) that I feel are all very positive. I also feel that it is imperative that we do everything possible in this well to make it flow.

While reviewing data from the Baca geothermal project, I was struck by similarities between Ascension #1 and the best producing wells at Baca. These similarities include CO_2 content, stacked reservoirs, and well-bore processes that define the pressure-temperature environment in the well. I contacted Dr. Sabodh Garg of S^3, with whom I'd worked on DOE's Baca review, and he agreed to serve on UURI's QA team for the project. Sabodh is presently serving as a reservoir engineering consultant to the Japanese on a number of their volcanic-hosted geothermal systems.

The topics discussed with Sabodh are outlined in 1 and 2 below along with his approach to the analysis. In both cases I have continued the analysis suggested by Sabodh.

1. Water Level.

The failure of the fluid level in Ascension #1 to come to sea level has led some to the conclusion that the reservoir lacks permeability and is not being recharged by fluid from the ocean. Sabodh rejects this conclusion on the following grounds. The water level in the well reflects the well-bore processes, in addition to reservoir pressures. The evidence is clear from the presently available pressure and temperature logs as well as from the mud logs that high-temperature geothermal fluid is entering the well at depths below 9440'. In addition, we know that there is a permeable fracture zone between 8120' and 8545' because this zone was the subject of testing following drilling of the well to 8706'. The predrilling pressure of this zone is not known because the pressure measurements run during the November-December, 1986 flow tests were collected under flowing conditions. Injection pressures during drilling reached 1000 psi. Following two months of flow, logging run #14 recorded 780 psig at 8000'. The well was filled with a water-CO_2 froth that showed a gradient of 0.18 psi/ft and was static so we can conclude that the fracture had a pressure of about 800 psig. Deepening of the well encountered no additional entries until 9440'. Pressures measured at the end of July, 1987, one month after deepening, show that the well bore in this lower zone had pressures between about 2640 and 2800 psi.

Due to the pressure differential between these two zones, geothermal fluid entering the well from the lower zone will exit the well bore at the low pressure zone between 8120' and 8545'. The water level in the well is therefore a result of this internal discharge and has little to do with the permeability of the reservoir zone. (As further support of this, Sabodh states that he has worked with a well in Japan that is right on the beach. Pressure measurements indicate that the fluid level in the well comes no higher than 200' below sea level.)

The temperature logs from Ascension #1 reflect this internal flow with hot fluids exiting below 8142. The cooler column of water above this depth is partly a result of some leakage of cold water into the well, but it principally results from the loss of heat to the formation by conduction.

If the lower reservoir zone does suffer from poor permeability, then the thief zone will continue to be a problem. However, if the influence of the thief can be eliminated, the well may produce without additional drilling. Casing and cementing are options for eliminating the zone artificially; however, the zone may also fill up by itself and cease to be a problem.

The natural filling of the zone would result in a rise of the water in the well to a level more indicative of the reservoir pressures. It will also allow the upper part of the hole to heat up and give us the opportunity to induce flow. The following data gives evidence that this filling is taking place, i.e. that the water level is rising and that the temperature anomaly at 8142' is being eliminated.

Date	Water Depth	Temp @ 8142
5/31/87	3610'(?)	328°F
6/4/87	3264'	359°F
7/1/87	2750'	396°F

Note that the last measurement was made only a month following the completion of drilling. The thief fracture discharged through the open well bore between 25 November, 1986 and 19 May

1987. It is unlikely that a fracture that discharged for 6 months would be able to fill in only one month.

Conclusion: The data show that the water level in the well is due to the interaction between a deep production zone and a thief zone, and that the thief fracture is filling. It is imperative that another pressure-temperature survey be run as soon as possible in order to plan future activities in the well.

2. Stacked Reservoirs

As close as can be measured, there is geothermal fluid present at sea level at the site of Ascension #1. This fluid was sampled during the gradient well drilling. Its temperature is anomalous at 115^{o}F, and its chemistry is that of seawater modified by interaction with the volcanic rocks. This upper reservoir is present to a depth of around 4000'. From this point to the upper level of the thief fractures at 8120', the well intersects a relatively impermeable section characterized by few and very small fluid entries. Below these fractures, the well intersects a section with little or no permeability between 8545' and the geothermal reservoir at 9440'. Thus there is approximately 5400' of impermeable or under-pressured rock between the lower portion of the upper reservoir and the top of the lower reservoir. Note that the present depth of the well is near that of the sea floor around Ascension and that the island pedestal has a minimum diameter of 31 miles. It is safe to assume that the upper reservoir is being recharged near the shore since its level is closely controlled by sea level. However, the lower reservoir could be recharged from any point on the pedestal. In addition the depth of circulation of the fluids must be below that of the present well. Darcy's Law tells us that the hydraulic head is a function of both the hydraulic conductivity of the medium and the distance over which the head operates. Note that a hydraulic gradient is necessary to ensure recharge of the system.

Conclusion: The geothermal reservoirs at Ascension are stacked with the lower reservoir separated from the upper by approximately one mile of impermeable rock. The recharge paths of these systems are greatly different, A case for poor permeability cannot be made based only on the level of fluid in the well.

3. Making the well flow.

Given the above analyses, it is possible that the present well will flow without additional drilling. You will recall that it was the opinion of Otis Day that the well deserved additional stimulation efforts beyond the 18 hours we were able to give it. Sabodh also suggests attempting to make the well flow by shutting it in to depress the water level and allowing the well bore to heat up. He indicated that one of the Japanese wells required 30 attempts before it finally flowed.

If the problem is the thief and not the reservoir, drilling a new leg will not necessarily improve the situation since we expect to intersect the same structural zones in the kick off. It will be necessary to effectively cement this zone prior to drilling into the reservoir.

Conclusion: Setting aside a week to 10 days to make the well flow seems like a prudent next step. This would require about half the personnel that drilling would. The cost could approach $100,000. The decision to take this step should be based on the results of the pressure-temperature survey recommended above.

4. Condition of the Well During Discharge

Otis Day and I are concerned that Ascension #1 will not sustain production without suffering damage because of the large open hole interval. In past tests, rock fragments as big as 1" in diameter were produced. Much of the open interval is in the zeolite facies with smectite and zeolite being the principal constituents of the rock. In other words, the rock is soft and can be easily eroded. It would be unfortunate to induce flow only to have the well fall apart during the test or soon after a generator is placed on line.

Conclusion: We must be certain that placing a 4.5" liner in this hole would preclude a successful reservoir test. It is unlikely that long-term production is possible through the present open hole.

cc: S. Stiger
P. M. Wright
M. L. Allison
S. Garg

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MEMORANDUM

TO: S. Stiger

FROM: D. L. Nielson

RE: Results of Ascension Island Surveys

DATE: November 24, 1987

On November 9 I mobilized to Ascension with Lee Walden, Earth Engineering, Bill Wilhelm, Parker Drilling, and Lee Allison of UURI. The purpose of this trip was to run additional pressure and temperature surveys in the Ascension #1 well and to monitor pressure buildup during shut-in. The following describe results of the surveys. This memo is an update of the draft I gave you on 17 November, 1987.

Temperature Survey

Figure 1 shows temperatures in the well plotted against measured depth, and Figure 2 shows the same data plotted as true vertical depth. Figure 3 presents a comparison between the values collected last week and temperatures at the beginning of July, approximately one month after drilling was stopped. It can be seen that there has been only a relatively small increase in the temperature of the well, and that this increase has come above 8300 feet.

Pressure Survey

Figures 1 and 2 also show the pressure data recorded in Ascension #1. Note that the pressure measured at 8100 feet is thought to be in error. There are two surveys presented here with a detailed survey above 3000 feet run to determine the depth of the water table. Least squares regression of these values places the top of the water table at 2190 feet below the surface. This represents a rise of 560 feet since the survey at the first of July. Figure 4 shows a comparison between the most recent survey and that completed in July.

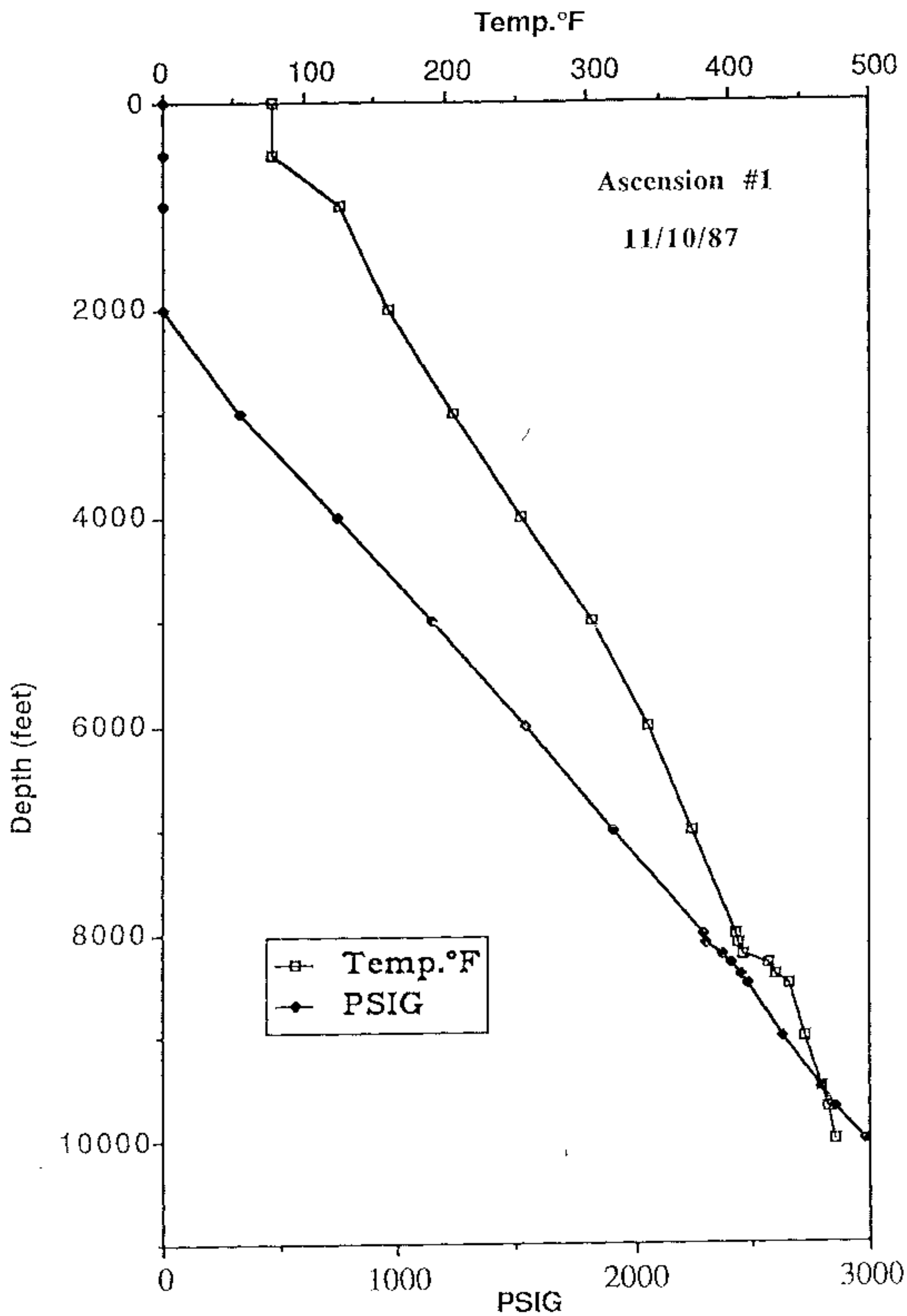

Figure 1 - Temperature and pressure as a function of measured depth in Ascension #1

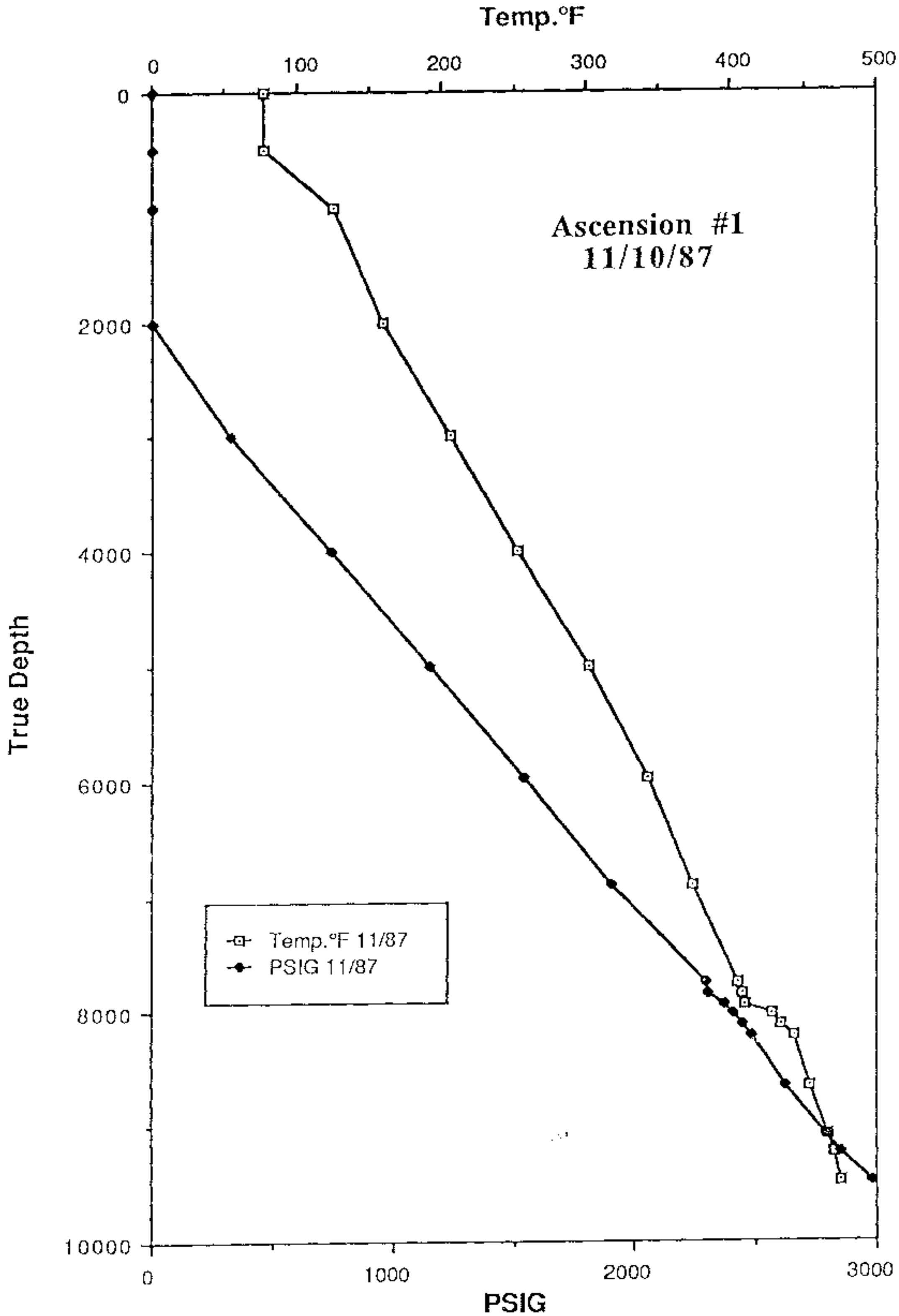

Figure 2 - Temperature and pressure as a function of true depth in Ascension #1

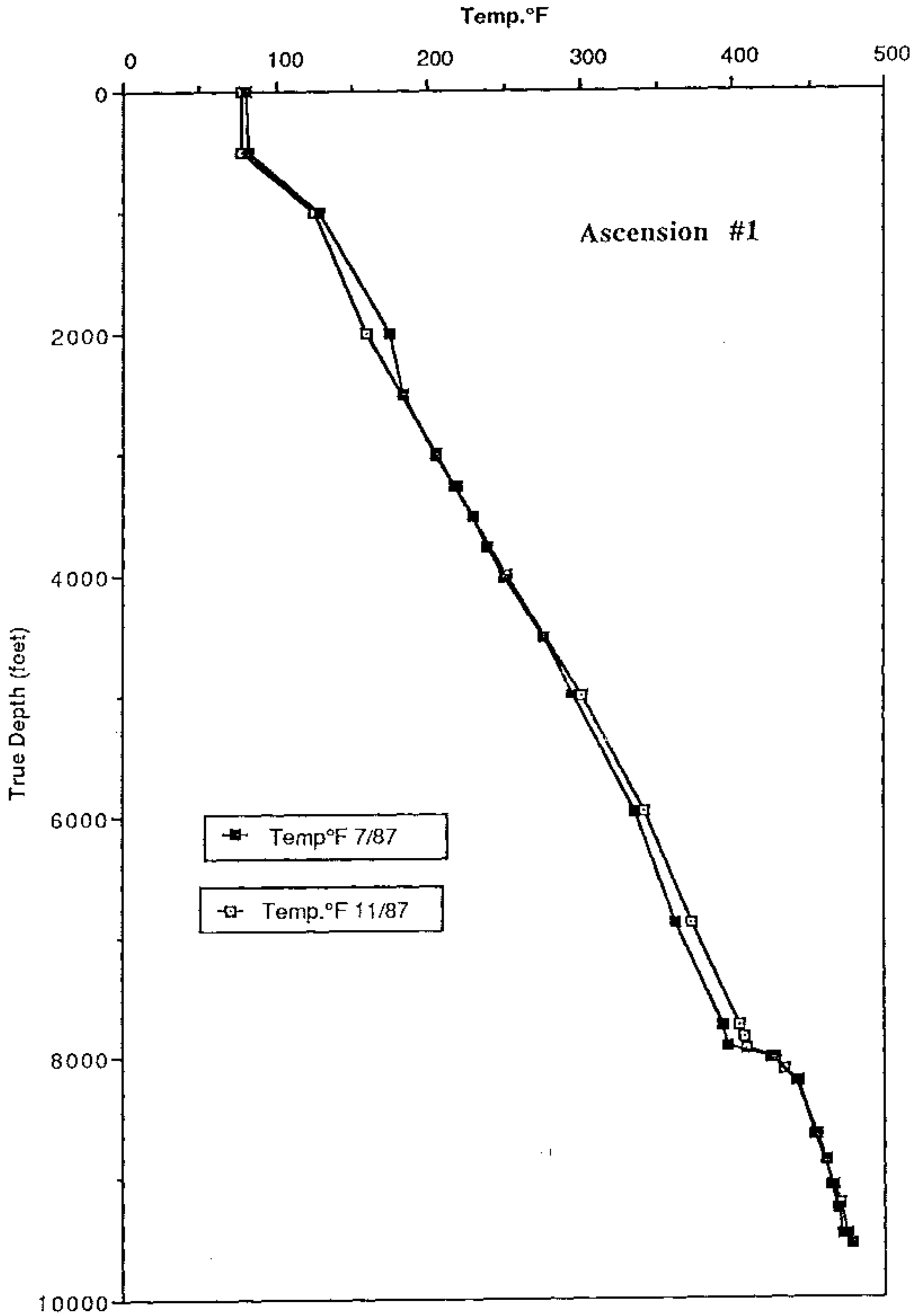

Figure 3 -Comparison of temperature surveys as a function of true depth in Ascension #1

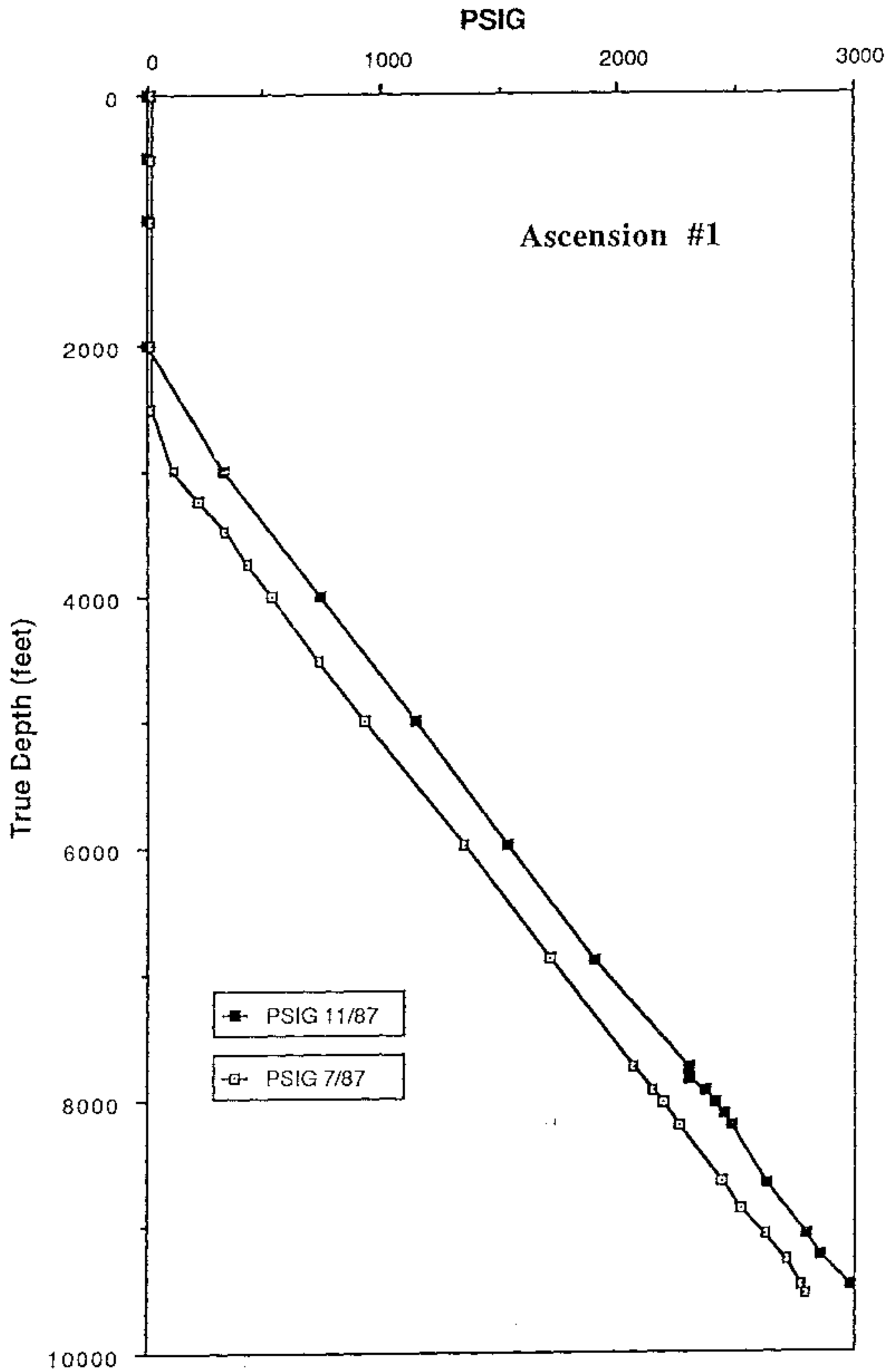

Figure 4 - Comparison of pressure surveys as a function of true depth in Ascension #1

Well Head Pressure

Figure 5 shows the build up of well head pressure following shut in at 1056 hours on 11/12/87. It can be seen that the pressure buildup is gradual; not like the buildup experienced during testing when the well was TD'd at 8706 feet. Following shut-in, temperature and pressure were monitored at 8200 feet for four hours and 10 minutes. During that period of time the well head pressure increased from 0 to 11.2 psig. The temperature at 8200 feet remained at 409 F, and the pressure increased from 2371 to 2389 psig. At the time of this memo, the well continues to be shut in and is being carefully monitored by Lee Allison. The well will be opened if the rate of pressure build up increases or if the pressure reaches 650 psig. Figure 5 shows that the rate of increase is slowing. Hopefully we will be able to maintain the well in a shut-in condition until operations begin in January.

Interpretation

The principal purpose of these surveys were to collect data to evaluate two possible models for the interpretation of down-hole pressure and temperature data. This will determine the operation plan once we mobilize. The model outlined in my memo to Sue Prestwich dated 10/27/87 proposed that the fracture zone intersected between 8120 and 8545 feet is presently a thief zone for fluids produced below 9440 feet. The other model proposed was that the temperature anomaly at 8200 feet represented effects of reservoir cooling by flashing and that measured down-hole pressures were indicative of reservoir pressures. If this model were true, one would expect the temperature anomaly at 8200 feet to disappear and the water level in the well to remain the same. However, the data show that the temperature anomaly is decreasing and that the water level is slowly rising. I interpret this to show that the fracture system between 8120 and 8545 feet is serving as a thief zone that is slowly being filled. As the differential pressure between this zone and the reservoir approaches the hydrostatic gradient a. the water level rises in the well, and b. the temperature of the thief zone and just above the thief increases. However, the continued presence of the temperature anomaly indicates that the thief is still active. It is probable that this zone will have to be cemented prior to drilling deeper.

cc: P. M. Wright
M. L. Allison
S. M. Prestwich

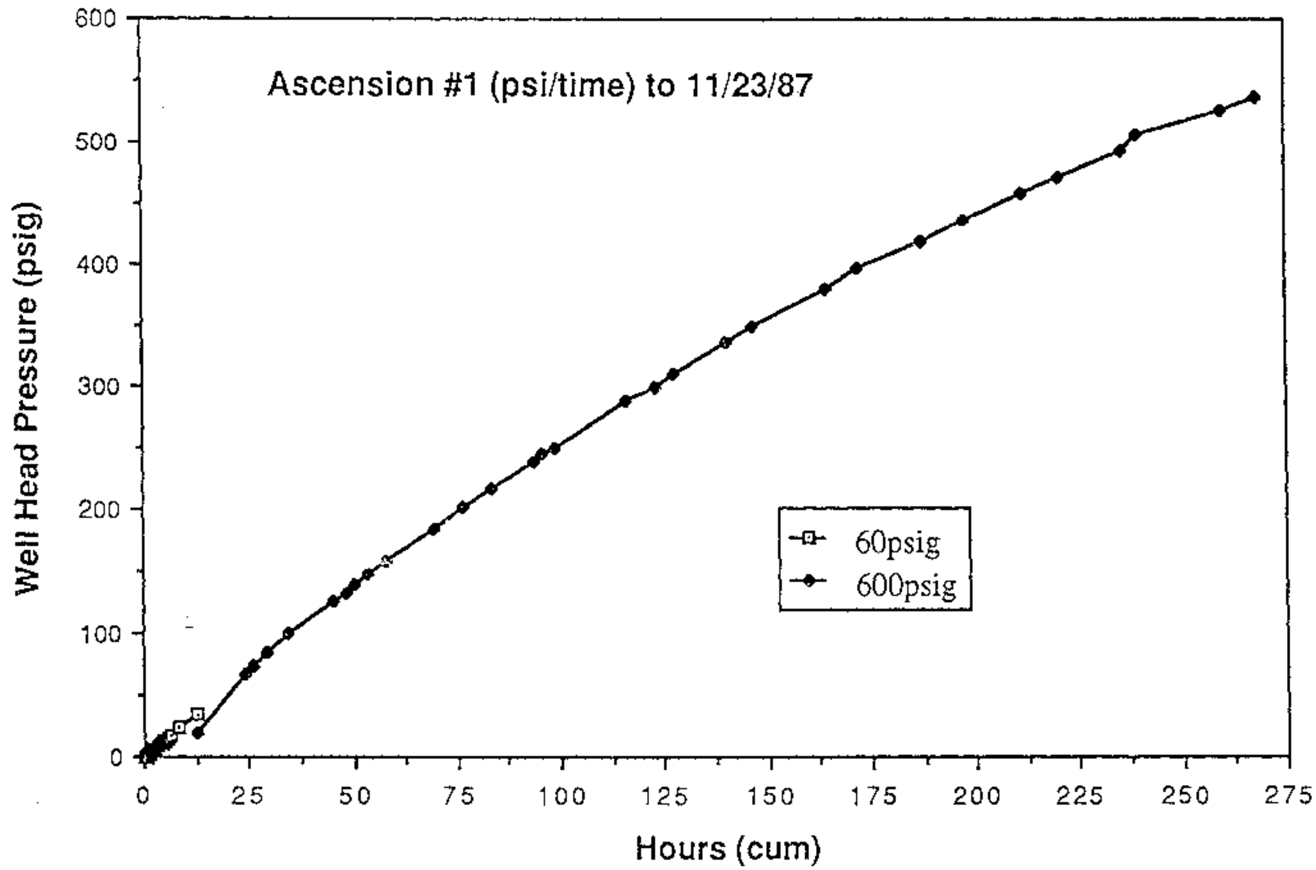

Figure 5. Well head pressure vs. time during shut-in of Ascension #1