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June 14, 1985

Mr. Charles A. Harper
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Subject: SALTON SEA SCIENTIFIC DRILLING PROJECT -- Use of continuous slim hole wireline coring systems in deep geothermal wells

Dear Mr. Harper:

I am enclosing my report covering earlier conversations with you and your people while in San Francisco and have directed my efforts to reviewing the use and performance of slim hole wireline tools as applied to the Salton Sea Drilling Project which embodies a very deep hole drilled under very high (400°C temperatures).

Sincerely,

Jack D. Powers

JDPowers:bsp/aps

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USE OF CONTINUOUS SLIM HOLE WIRELINE CORING SYSTEMS ON THE SALTON SEA SCIENTIFIC DRILLING PROGRAM (SSSDP)

The following topics are the subject of discussion in this report.

1. SUMMARY COMPARISON OF CONVENTIONAL VERSUS CONTINUOUS WIRELINE CORING

2. ENGINEERING AND CONCEPTUAL DESIGN BASIS FOR THE EVALUATION

3. WHAT ARE THE DESIGN AND OPERATING FEATURES OF CONTINUOUS WIRELINE CORING?

4. WHAT TECHNICAL OR PRACTICAL LIMITATIONS ARE INVOLVED FOR SAFE COMPLETION OF A HOLE SUCH AS THE SSSDP?

5. WHAT ADAPTATIONS OR BREAKTHROUGHS WOULD BE REQUIRED?

6. WHAT SORT OF DEVELOPMENT PROGRAM WOULD BE REQUIRED, WHAT ARE ITS ESTIMATED COSTS, AND DEVELOPMENT TIMETABLE?

7. A SHORT REVIEW OF U.S. CONTINUOUS WIRELINE CORE DRILLING CONTRACTORS THAT HAVE PARTICIPATED IN CORING IN GEOTHERMAL ENVIRONMENTS

8. A REVIEW OF LONGYEAR'S NEW 10,000 FOOT DRILL RIG

9. COMPARATIVE COST OF DRILLING AND CORING FROM 6,000 TO 10,000 FEET USING THE CONVENTIONAL OIL FIELD ROTARY METHOD AND CONTINUOUS WIRELINE CORING METHOD

10. CONCLUSIONS

1. SUMMARY COMPARISON OF CONVENTIONAL VERSUS CONTINUOUS WIRELINE CORING

A. Core Versus Cost

	Conventional Rotary	Continuous Wireline
Probability of reaching 10,000 ft	Very high (95%+)	Low (50%)
Potential core recovery (30 ft cores/60 ft cores)	800/1,600	4,000
Core diameter	4 in.	2.5/1.7 in.
Estimated time to drill from 6,000 to 10,000 ft	65 days	64 days
Estimated cost*	$576,000	$810,400

*Includes rig, fuel, mud, drilling tools, casing and cement.

B. Additional Requirements for Continuous Wireline Coring

1. Extra mobilization and demobilization
2. 25 to 30 ft high substructure lease required
3. 5 in. casing (6,000 ft) and cement (250 ft minimum)
4. 4 in. casing (7,500 ft) and cement (2,750 ft minimum)
5. 3,750 ft of 101 mm drill rod expended
6. 5,000 ft of 76 mm drill rod expended

C. Dimensional Limitation of Continuous Wireline Cored Well

1. 2.98 in. diameter wellbore is inadequate for Kennecott flow test (5 in. minimum is required).

2. Sandia's temperature, pressure, and flow logging tool (3 in. diameter, 8 ft length) can be lowered only to 7,500 ft

3. Los Alamos' fluid sampler (3.5 in. diameter, approximately 10 ft length) can be lowered only to 7,500 ft before 4 in. casing (3.476 in. ID, 3.351 in. drift) is set and can not be put down the hole at all after the casing is set.

4. Placing the 5 in. and 4 in. casing strings in the well, especially if they must be cemented to the surface, seriously limits any options Kennecott might wish to exercise for latter commercialization of the well or for the science groups to test drilling or logging tools.

D. Technical Features of Continuous Wireline Coring Creating Engineering Concern and Requiring Further Study

Small flow rates (small flow annuli) and no flow during core retrieval could have the following effects:

- Limit cooling effectiveness and encourage metal corrosion and fatigue failure. (Frequent inspection of drill rods will be required to identify and remove damaged or cracked rods. Half of the 101 mm and 76 mm drill rod strings are expected to be scrapped at the completion of the job. The core retrieval cable may have to be replaced during the job.)

- Wellbore temperatures near the surface may get high enough during extended periods of no circulation to create a high potential for flashing, requiring the use of a core unloading chamber at the surface. Core retrieval rates might have to be reduced as well.

- Cuttings removal could be ineffective, resulting in frequent sticking of the drill string

- Relatively small zones where the formation took fluid could result in lost circulation. The typical materials pumped down the drill stem bore to block off the formation and reestablish circulation could clog the annuli in the continuous wireline coring system instead.

2. ENGINEERING AND CONCEPTUAL DESIGN BASIS FOR THE EVALUATION

The base case used in the analysis is that the well would be completed to 6,000 ft by conventional rotary drilling and coring. Bechtel estimates that this point would be reached in early November. Continuous wireline coring would then ensure using the Longyear HD600 system. One of these rigs has been built for export to South Africa. Longyear has indicated that they would build a second of these rigs were they to receive an award for the job and believe they could have it operational in about 2 months. The mast is 80 ft, enabling the rig to handle triple stands (60 ft) of drill rod. Core length would be 20 ft. The substructure is only 8 ft high. The hoist capacity is 85,000 lb, but the limiting load handling capacity is that of the drill string feed control system which is 60,000 lb.

The specifications of the drill rods and core barrels are shown in Table I, reproduced from the most recent Longyear brochure. These are the "standard" sizes used in the industry.

Table I

Specifications

	Metric			English		
	CHD 76	CHD 101	CHD 134	CHD 76	CHD 101	CHD 134
Hole Diameter (Regular)	75.7 mm	101.3 mm	134.0 mm	2.980 in	3.990 in	5.250 in
Core Diameter	43.5 mm	63.5 mm	85.0 mm	1.713 in	2.500 in	3.344 in
Drill Rod						
Rod OD	70.0 mm	94.0 mm	127.0 mm	2.754 in	3.701 in	5 000 in
Rod Joint ID	55.0 mm	78.5 mm	104.8 mm	2.165 in	3.091 in	4.125 in
Rod Midbody ID	60.3 mm	83.0 mm	114.3 mm	2.375 in	3.268 in	4.500 in
Rod Weight/3 m	25.2 kg	40.6 kg	69.7 kg	55.6 lb	89.5 lb	153.9 lb
Rod Joint Pre-Torque	2034 Nm	3390 Nm	4070 Nm	1500 lbf ft	2500 lbf ft	3000 lbf ft
Thread Length	50.8 mm	50.8 mm	73.0 mm	2.0 in	2.0 in	2.875 in
Depth Rating	2750 m	3050 m	3050 m	9000 ft	10,000 ft	10,000 ft
Core Barrel						
Outer Tube OD	73.0 mm	98.4 mm	127.0 mm	2.875 in	3.875 in	5.000 in
Outer Tube ID	57.2 mm	79.4 mm	104.8 mm	2.250 in	3.125 in	4.125 in
Inner Tube OD	50.8 mm	73.0 mm	95.3 mm	2.0 in	2.875 in	3.750 in
Inner Tube ID	45.3 mm	66.9 mm	88.9 mm	1.781 in	2.635 in	3.500 in

CHD rods are available in 1.5 m, 3 m, 4.5 m and 6 m lengths, or 10 ft and 20 ft lengths.
Standard core barrel lengths are 3 m and 6 m. Special length on request.
Note: 1. Specifications are subject to tolerances and are therefore approximate.
2. Depth ratings are based on straight, vertical, clean, fluid-filled holes.

(A special 6-3/4 in. drill rod was fabricated for Norton-Christensen several years ago for use on a hazardous waste injection well in Nevada. The project was cancelled and the 3,000 ft of rods were never used. The small quantity available and high weight of approximately 25 lb/ft makes it unusable for the SSSDP).

The weight of the drill rods, the maximum length of drill string that could be used on the Longyear rig, and the associated costs are shown in Table II.

Table II

Drill Rod Type	Lb/ft for 20 Ft. Rods	Maximum string length at 60,000 lb*	Cost per Foot	Cost for String
CHD 134	13.10	4,800	$27.50	$132,000
CHD 101	8.53	7,400	$20.10	$149,000
CHD 76	5.56	11,300	$14.20	$142,000**

* Bouyancy factor = 0.859 for 9.2 lb/gal mud; Drag = 10%
** To 10,000 ft

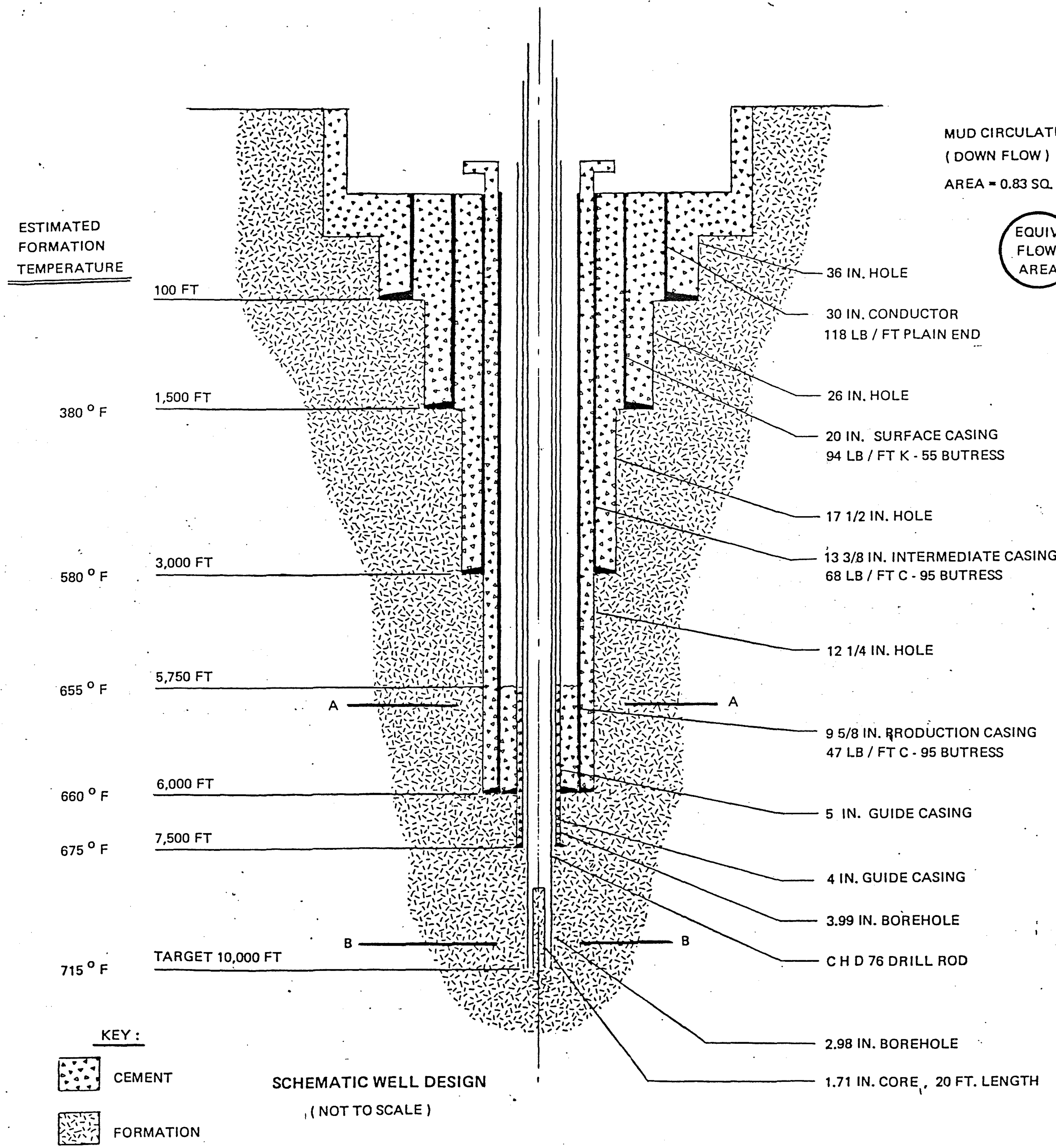
The 60,000 lb weight limit precludes use of the 134 mm (5 in.) drill rods in the SSSDP well. Coring would have to be started at the 6,000 ft casing point to about 7,500 ft with the 101 mm (3.875 in.) drill rods, switching to the 76 mm (2.875 in.) drill rods from there to total depth. If the 101 mm string got permanently stuck before reaching the 7,500 ft limit, the 76 mm string would be inserted through the 101 mm string, the 101 mm drill head reamed out, and coring continued on until the 76 mm string reached total depth or got stuck. Using the Longyear rig, and the 101 mm and 76 mm strings, the driller could only get permanently stuck twice before operations would have to be discontinued or side tracking the hole attempted.

Other coring rigs with weight capacities suitable for using the 134 mm (5 in.) drill rods from 6,000 ft to total depth exist in the United States and could be outfitted for use on the SSSDP if suitable time were available. Tonto Drilling, one of the leading independent wireline coring contractors, expressed interest in this alternative. It would take them about four months to locate, overhaul, and be ready to mobilize such a rig. If Bechtel could award a contract for continuous wireline coring by September, the larger rig would not be ready until January, two months later than required. Being able to start coring with the 134 mm and to run both that and the 101 mm string to total depth would have been a much preferable position to be starting from on this first-of-a-kind application for continuous wireline coring.

The conceptual design for a coring program using the Longyear rig is shown in Figure 1. In summary, a 5 in. casing would be installed from the surface to 6,000 ft to guide and support the 101 mm string. At a minimum, the bottom 250 ft (5,780 ft well depth) would have to be cemented in to provide blow out protection. Ideally, it would be cemented to the surface. With only 250 ft cemented, the 9-5/8 in. BOP stack would be kept in place as a precaution during the continuous wireline coring operation. The 5 in. casing would be set by the rotary drilling contractor just prior to demobilization and move out. At 7,500 ft, a 4 in. casing would be cemented back to 5,750 ft to guide and support the 76 mm string. The 4 in. casing string would be set using the coring rig. If the 10,000 ft target depth were reached, the final well configuration would have 7,500 ft of 4 in. (3.476 in. ID, 3.351 in. drift) cased hole and 2,500 ft of 2.980 in. open hole.

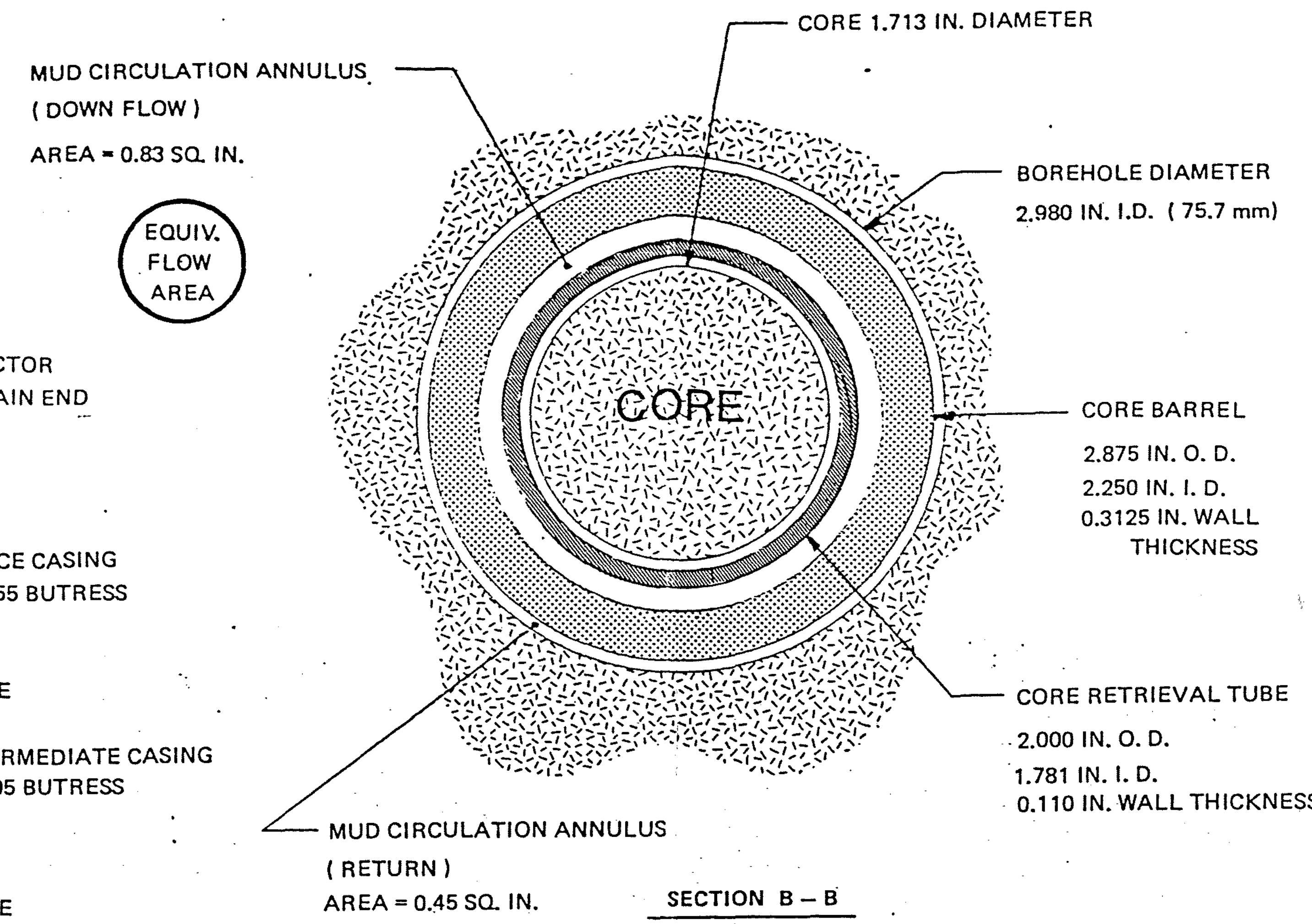
The combination of the 9-5/8 in. BOP stack and the BOP for the coring strings would be about 30 ft tall. The Longyear rig would have to be mounted on a substructure at least 25 ft high. This would require that a suitable substructure be fabricated or leased from a rotary drilling contractor willing to idle his rig during the coring period.

During coring, the annuli between the drill string and the borehole and the core barrel and the core retrieval tube are quite small. As shown in Figure 1, Section A-A' and B-B', the downflow annulus on the 76 mm system



SCHEMATIC WELL DESIGN

(NOT TO SCALE)



SECTION B – B

CROSS SECTION THROUGH CORE BARREL WITH CORE IN PLACE ;

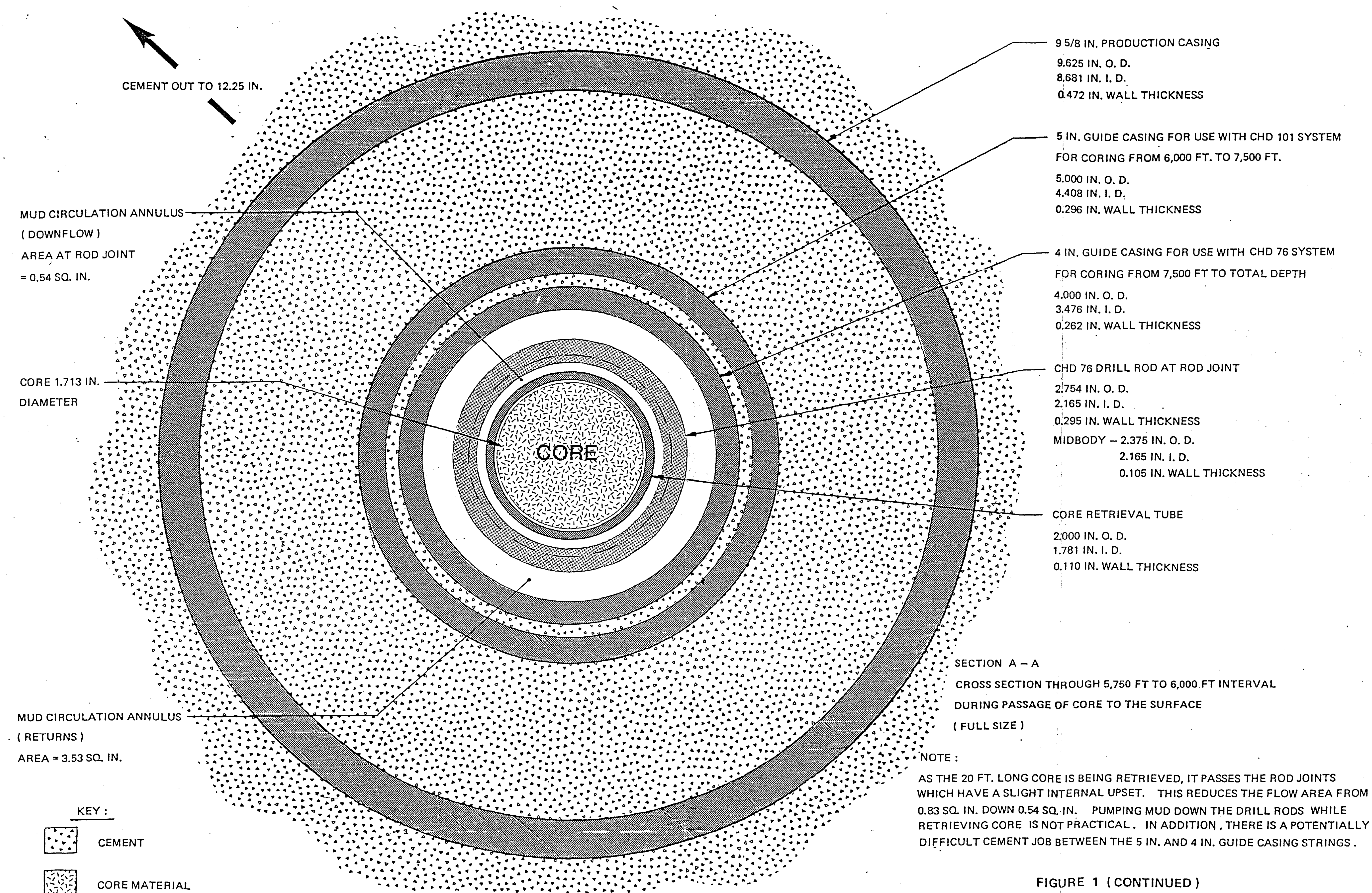
CHD 76 mm DRILL SYSTEM

(FULL SIZE)

NOTE :

THIS CONFIGURATION WOULD OCCUR DURING CORING FROM 7,500 FT. TO FINAL DEPTH. FORMATION TEMPERATURES RANGE FROM 675 ° F TO ABOUT 715 ° F IN THIS INTERVAL. MAXIMUM CIRCULATION RATES FOR COOLING AND CUTTINGS REMOVAL ARE LIMITED TO ABOUT 15 gpm., PASSING THROUGH AN EQUIVALENT TUBULAR FLOW AREA , SHOWN. ABOVE TO THE LEFT. DURING CORE RETRIEVAL, CIRCULATION IS NORMALLY STOPPED.

FIGURE 1
SALTON SEA SCIENTIFIC DRILLING PROGRAM
WELL CONFIGURATION IF CONTINUOUS WIRE LINE CORING IS USED FROM 6,000 FT. TO 10,000 FT. INTERVAL



SECTION A – A

CROSS SECTION THROUGH 5,750 FT TO 6,000 FT INTERVAL DURING PASSAGE OF CORE TO THE SURFACE

(FULL SIZE)

NOTE :

AS THE 20 FT. LONG CORE IS BEING RETRIEVED, IT PASSES THE ROD JOINTS WHICH HAVE A SLIGHT INTERNAL UPSET. THIS REDUCES THE FLOW AREA FROM 0.83 SQ. IN. DOWN 0.54 SQ. IN. PUMPING MUD DOWN THE DRILL RODS WHILE RETRIEVING CORE IS NOT PRACTICAL. IN ADDITION, THERE IS A POTENTIALLY DIFFICULT CEMENT JOB BETWEEN THE 5 IN. AND 4 IN. GUIDE CASING STRINGS.

FIGURE 1 (CONTINUED)

is 0.125 in. (total areas for flow = 0.83 in.^{2}) and the return annulus is 0.05 in. (total area for flow = 0.45 in.^{2}) until entering the final 6,000 ft where it increases to 0.72 in. (total area for flow).

Typical circulation rates used by Longyear while coring are 7 to 10 gpm, with a practical maximum of about 15 gpm. A calculated pump pressure of approximately 600 psi would be required for 15 gpm flow in the well as shown. Theoretically increasing the flow to 25 gpm would require a pump pressure of about 1,500 psi. At 50 gpm, the pressure requirement would increase to about 6,500 psi. The maximum rating on the standard Longyear pump is 35 gpm @ 1,000 psi. During core retrieval, circulation is normally stopped. Round trip time at 9,000 ft., for example, is estimated at 130 minutes, under normal circumstances. During this period, the drill string would be exposed to formation temperatures and any brines which entered the well bore.

The average expected coring rate from 6,000 to 10,000 ft is estimated at about 2.6 ft/hr, based on total time from mobilization to demobilization, and about 3.25 ft/hr when coring. If the core retrieval rate must be reduced to control downhole flashing, the average coring rate would have to be adjusted downward.

3. WHAT ARE THE DESIGN AND OPERATING FEATURES OF CONTINUOUS WIRELINE CORING?

A. Potentially 100 percent of the hole is cored.

B. A relatively large core is taken compared to hole size, generally resulting in a very good percentage of core recovery in most rock formations. For example, with 101 mm system holes size (3.895 in.) core size is 2.500 in. or for 76 mm system holes size (2.980 in.) the core size is 1.713 in.

C. In harder formations, much faster core penetration rates result because of the narrow kerf of the diamond bit.

D. Very accurate feed control and high rotator speeds (500 - 750 rpm) increase core recovery and penetration rates while coring.

E. Core is extracted by pulling the inner barrel laden with core through the string of pipe to the surface with a wireline. This allows for almost immediate review of the recently cored material, and since the rods do not have to be removed each core trip, there is less chance of hole deterioration. Because it is easy to pull and check core in the inner tube, a core blockage or short run can be easily tripped to the surface and checked rather than continuing the run and losing core. Continued grinding of a broken core decreases bit life, core penetration rates, and most important reduces core recovery.

F. Because of the system's small size and weight, it requires much less rig horsepower, both in hoisting and rotating, and has smaller fluid systems requirements. Hence, rigs are generally much smaller in physical size, and in most cases the rigs are run with much smaller crews. However, in the case of the SSSDP, the crew size could be almost as large as on a conventional oil rig.

G. The thin walled drill rods (0.25, 0.129, and 0.19 in.) and small annuli (0.125, 0.145, and 0.113 in.) reflect a design optimization for coring in crystalline rock for minerals explortation. Under these circumstances, the borehole supports the drill string and provides stability. The smooth, nonpermeable borehole wall efficiently conducts the cuttings to the surface with little or no fluids loss to the formation.

4. WHAT TECHNICAL OR PRACTICAL LIMITATIONS ARE INVOLVED FOR SAFE COMPLETION OF A WELL SUCH AS THE SSSDP?

A. One-Way Valves. A wireline drill rod string is open from the coring bit to the circulation swivel; there are no one-way fluid valves in the pipe string as would be used in conventional systems. This eliminates one of the normal safety features. Careful planning and management of well control would be required.

B. Pipe Wear and Corrosion. The continuous wireline coring system relies on high alloy (4130 heat treated tool joint, tensile strength 125,000 psi and 1035 or 4130 mid body, 90,000 psi) for high strength with low weight. Thin wall tubing with thicknesses from 0.188 to 0.219 in., do not lend themselves to exterior wear, stress cracking, and corrosion that will likely occur in the high temperature, saline environment. Drill rod failure may be considerably more frequent then in non-geothermal wells, in spite of best efforts to inspect frequently.

C. Poor Well Cooling. While retrieving core, circulation is normally stopped, allowing the stagnant wellbore fluids to heat up and cuttings to settle out. As the hole gets deeper, you will be spending more time retrieving the inner tube laden with core than will be spent coring a 20 ft run. Continuous fluid circulation while extracting core through the string is highly desirable, but may not be physically possible. At 9,000 ft, circulation could be interrupted 130 minutes or more. Table III is an estimate of time required for making a complete core cycle in a 9,000 ft hole. At temperatures approaching 700°F, the strength of the drill rods decreases about 10 percent. Some additional development and planning must be worked out to accommodate this condition.

Table III

a.	Insert core retrieving overshot	
	0 - 9,000 ft	30 min
b.	Retrieving inner tube with core	
	9,000 - 0 ft	40 min*
c.	Inserting new inner tube and circulating to aid drop time	
	0 - 9,000 ft	40 min
d.	Adding pipe connections and disconnecting extras	20 min
	Total Time =	130 min
	Time spent pumping inner tube	-40 min
	Time when hole is not being circulated	90 min
	Estimated Core Time per 20 ft core run	60 min

The 90 minute period where there is no circulation could present hole problems due to not moving the fine cuttings to surface plus not continuing to cool with circulating fluid.

* Assumes approximately 200 ft/min retrieval rate.

D. Mud Cleanup System. Because of the very small annulus between hole and drill pipe, low fluid volumes are used (about 15 gpm maximum for the 76 mm string). Additional fluid volume at depth only increases fluid pressure and could direct fluid into the formation, rather than up the hole. Reverse circulation may have the same effect. When circulation is stopped during core retrieval, cuttings may settle out of the mud column and accumulate in the bottom of the hole. It becomes very important to get these cutting out of hole and that the mud and fluid systems do not break down at the temperatures and pressures expected. The use of desilters and deslimers plus large return mud tanks would be a must to minimize the chances of differential sticking of the drill pipe.

E. Supplementary Cooling Options. It may be necessary to supercool all fluids entering the hole, plus use larger return tank-system, cooling tower or heat exchanger to aid in cooling before reentry to the hole. These large tanks might also be used to reduce solids in the return fluid.

F. H_2S Embrittlement. There is a possibility of hydrogen (H_2S) embrittlement, which could adversely affect the wireline and drill rod. They are already at a lower factor of safety at total depth of 2 to 1, whereas conventional API pipe has a 3 to 1 factor of safety. H_2S may not be encountered, however, because of the amount of free metal ions in the brine. But since this type of drill pipe has never been used in this environment, at this depth, H_2S should be carefully monitored.

G. Small Retrieval Cable. The continuous wireline coring system relies on a small diameter cable (3/16 in., 0 to 3,000 ft, 1/4 in., 0 to 5,000 ft, 3/8 in., 0 to 10,000 ft) to retrieve core-laden inner barrel from the bottom of the core hole. This means that the wireline cable is subjected to the effect of brine as well as very high temperature. It may not be a major problem, but it is another consideration that must be planned for and constantly watched, in an effort to reduce rope failure that could shut down the core drilling process.

H. Core Barrel Life. Continuous wireline core barrels and associated parts do not seem to present any additional problems that would not exist with the conventional or field core barrels. There are however, more mechanical working parts to be considered, even though these barrels have functioned well in the shallow geothermal holes. Corrosion and abrasion could present the major problems with these systems and would require the operator to replace parts more often or set specific maximum footage or rotating time limits for each complete core barrel.

I. Bit Life. Diamond bits used in continuous wireline coring systems at the temperatures in question appear to be state of the art. All diamond bit manufactures questioned do not view 400°C as a major problem.

J. Logging Tool Diameters. Fluid sampling, wireline logging, temperature measurements and flow information can be gathered through the 134 mm and 101 mm boreholes. The 76 mm (2.98 in.) borehole may restrict the use of larger tools. However, through the drill string logging has not been done at the depths or temperatures in question by a continuous wireline core contractor to date.

K. Blow-out Preventors. Continuous wireline contractors have used blow-out preventors (BOPs) in the past, and their use is not envisioned as a problem. However, the availability of smaller specialty BOP's may be limited.

L. Directional Control. The core-drilling industry over the years has been able to maintain hole straightness through the use of packed-hole core barrels (core barrels that have been fitted with special stabilizers that are very close to hole gauge), by increasing or decreasing rotational speeds, and by carefully watching the weight on the diamond bit. Traditionally, deviation hasn't been a major problem in crystalline rock. There may be a tendency to drift in the sedimintary formation in the Imperial Valley. Typically, hole correction has been done with similar tools as those used in the oil field, such as Nave Drill, Dyna Drill or whip-stock methods. There has never been any directional or corrective drilling done at temperatures or depths that are remotely near the ones that maybe encountered in the SSSDP.

M. Hole Flashing Problems. Initially hole flashing problems were of concern due to high downhole temperatures. After consideration it seems to be more of a problem near the surface than at the bottom of the well. There is still some concern that the very low fluid circulation rate of the wireline system may allow the well to get hot enough near the surface that flashing could be induced during core retrieval and perhaps even during rotary core tripping. This needs more extensive analysis.

ANALYSIS OF FLASHING POTENTIAL IN THE LOWER PORTION OF THE SSSDP WELL

	Estimated Temperature °F	Hydrostatic Head @ 0.4775 psi/ft. (Mud weight 9.2 /gal)	Flash Point of Water	Pressure Drop Required for Flashing
6,000 ft	660	2,865	2,340	525
7,000 ft	670	3,342.5	2,520	823
8,000 ft	680	3,820	2,700	1,120
9,000 ft	690	4,297.5	2,880	1,417
10,000 ft	715	4,775	3,240 (vapor)	-

5. WHAT ADAPTATIONS OR BREAKTHROUGHS WOULD BE REQUIRED?

A. Develop a loading chamber system atop the drill string so that the core laden tubes can be isolated from the heat and pressure of the hole during core removal. The operation method used at present subjects personnel to some potential safety problems if flashing occurs.

B. Conduct a complete test of continuous wireline core retrieving cables under Salton Sea brine conditions. The main concern is the effect of corrosion on cable performance.

C. Subject continuous wireline core drilling pipe and core barrels to some simulated wear and corrosion tests to indicate rotating hour life for safe operation.

D. Develop a system to continue to circulate sufficient volumes of fluid while coring and retrieving core to help keep the hole temperature down and to keep the solids moving to the surface for hole cleaning.

E. Previous drilled rotary holes in the Salton Sea area indicate very high drag forces in both torsional and tension, in some cases as much as 100,000 lb above the string weight. Continuous wireline core pipe could be subjected to proportional testing to simulate these conditions.

F. In the long run, develop larger diameter drill rods and rigs to reach greater depths.

6. WHAT DEVELOPMENT PROGRAM WOULD BE REQUIRED, WHAT ARE ITS ESTIMATED COSTS AND DEVELOPMENT TIMETABLE?

A. Suggested development program:

1. It appears that the interest is very high toward the continuous wire line coring methods. Demands on existing systems that were designed for the mineral industry have expanded to geothermal, gas, oil and scientific programs, many of which demand special disciplines. With this in mind, it is suggested that a committee be established consisting of core drill manufacturers, core drilling contractors, interested rotary manufacturers and contractors, oil and mineral companies, plus those companies and individuals who need, use, or have expertise in these disciplines. This should include government agencies.

2. Suggest the above committee or group start by working on problems that are outlined in No. 3 listed earlier.

3. Perhaps a government grant through a research or engineering group could provide funds to actually set up a field testing program.

B. Estimate costs of development type of program:

Any estimate at this point is speculation, but a $500,000 program should get the existing drilling system up to speed in all areas.

C. Timetable that must be required:

A timetable that would cover those conditions as tests in No. 3 might be accomplished in as short as 9 months to as long as 15 months.

7. A REVIEW OF U.S. CONTINUOUS WIRELINE CORE-DRILLING CONTRACTORS THAT HAVE PERFORMED DRILLING SERVICES IN GEOTHERMAL ENVIRONMENT

The experience of U.S. contractors is summarized below:

Contractor	Geothermal Wells			Deepest Hole Under
	No. Holes	Max Depth	Max Temp	Mineral Conditions
Tonto Drilling Services Size	30	4,000 ft	350°F	6,900 ft - 'H'
Longyear	18	3,000 ft 3,000 ft	390°F 490°F	7,100 ft 101 MM 7,400 ft 'B' Size
Boyle Bros Drilling	2	2,800 ft	-	6,100 ft 'N' Size
Himes Drilling Co. Inc.	2	2,800 ft+	-	- - - - - - - - -

This review reveals that two (2) contractors have done, by far, the majority of the drilling. Tonto Drilling Services has drilled the deepest hole, 4,000 ft, while Longyear has drilled in the hottest environment (reportedly 390°F). Mr. Dick Swayne, Manager of Longyear's Contract Drilling Division, has reported that 490°F was encountered in China Lake Well No. 5. The above table also shows the maximum depths that each contractor has drilled under normal mineral drilling conditions.

A review of the work done to date reveals that these U.S. contractors have not had any drilling experience in super-high temperature geosolution, nor have any reached the 10,000 ft depth requirements that are planned in the SSSDP.

The majority of continuous wireline core drilling contractors have been very successful drilling geothermal holes 3,000 ft to 4,000 ft deep that have a loose circulation condition (no return circulation). Under this condition the core drillers using the continuous wireline method were able to advance the hole in the blind condition plus recover the core. Wireline core systems allow these holes to be continued and bottomed, whereas the conventional rotary equipment made hole advancement extremely difficult and very expensive.

8. A REVIEW OF LONGYEAR'S NEW 10,000 DRILL RIG

Derrick - 80 ft extended
43 ft retracted
60 ft (triple) stands
API Rated at 100,000 lb
Crown sheaves rated at 100,000 lb

Draw Works - Hydrostatically driven with automatic release on drum while coring. Built-in spring loaded brake system for static holding only. Drum 24 in. OD with rope grooving. Load handling through 6 part line using 7/8 in. rope, giving maximum hook load of 85,000 lb.

Line Speed Bare Drum - 6 part line
High 1,356 ft/min - 226 ft/min hook speed
Low 498 ft/min - 83 ft/min hook speed

Top Drive Head and Feed System
60,000 lb hold back load while coring
Head can chuck 3-15/16 in. when drilling over 5,000 ft a Hex Ring Kelly System is used through the top drive head to handle maximum weight condition.

Rated Capacity of the Drill Unit in a Fluid Filled Hole
CHD - 134 mm = 5,000 ft
CHD - 101 mm = 7,500 ft
CHD - 76 mm = 11,500 ft

A quick review of the above specifications reveals that the 60,000 lb maximum hold back feed system is the limiting depth factor of this drill rig. Though the hoist has more capacity, 85,000 lb, it cannot be used in the feed or rotating mode, hence the drill's capacity is limited to 60,000 lb. You can theoretically drill a 10,000 ft hole, but this hole must be done with 76 mm size 2-3/4 in. OD pipe in a 3 in. OD hole. In the case of the Salton Sea hole, you would seriously limit your alternatives because you do not have the option of starting the coring with the larger 134 mm system. From a hole engineering point of view, you should maintain the largest size system until required to reduce due to in-hole conditions. This allows you the safety of continuing the hole with 101 mm, leaving you the option of an additional reduction to 76 mm to assure completion to 10,000 ft total depth. (Detailed drill rod specifications are presented on the following page.)

DRILL ROD SPECIFICATIONS

	76 mm	101 mm	134 mm
Rod OD	2.75" (69.8mm)	3.701" (84.0mm)	57 (137mm)
Midbody OD	2.375" (60.3mm)	3.268" (83.0mm)	4.5" (114.3mm)
Midbody Wall	.187" (4.7mm)	.2165" (5.5mm)	.2500" (6.35mm)
Threads Inch	2.5	2.5	2.5
Coeff. Friction (Lubrication)	.2	.2	.2
Tensile Strength Box Material	125,000 psi	125,000 psi	125,000 psi
Tensile Strength Pin Material	125,000 psi	125,000 psi	125,000 psi
Tensile Strength Midbody Material	90,000 psi	90,000 psi	90,000 psi
Weight of Rod	5.56 lb/ft	8.53 lb/ft	13.1 lb/ft
Area of Box (Min.)	1.137 sq. in.	1.519 sq. in.	
Area of Pin (Min.)	.751 sq. in.	1.244 sq. in.	
Midbody Area	1.509 sq. in.	2.37 sq. in.	
Burst Pressure	9, 545 psi	8,189 psi	9,000 psi
Collapse Pressure	7,479 pis	6,025 psi	4,380 psi
Kerf Area	4.67 sq. in.	7.6 sq. in.	
Yield of Box in Tension	113,713 lbs.	151,963 lbs.	257,000 lbs.
Yield of Pin in Tension	75,114 lbs.	124,379 lbs.	257,000 lbs.
Yield of Midbody in Tension	120,755 lbs.	189,600 lbs.	
Failure of Box in Tension	142,141 lbs.	189,954 lbs.	
Failure of Midbody in Tension	135,849 lbs.	213,300 lbs.	
Yield of Joint in Torsion	8,773 ft/lbs	17,201 ft/lbs	
Failure of Joint in Torsion	10,967 ft/lbs	21,501 ft/lbs	
Pre Torque of Joints	1,550 ft/lbs	2,500 ft/lbs	3,000 ft/lbs
Max. Rated Torque	2,000 ft/lbs	3,400 ft/lbs	5,000 ft/lbs
Thread Length	2"	2"	2.975"
Depth Rating (2-1 Safety Factor)	2,900 metres	3,000 metres	3,000 metres
Weight of 6 metre Rod	110 lbs.	165 lbs.	262 lbs.
Standard Core Size	1.713"	2.5" (HQ)	2.244" (PQ)
Standard Hole Size	2.98"	3.99"	5.250"
Midbody Material	Grade 1035 or 4130	Heat Treated UTS	- All CHD the same
Joint Material	Grade 4130	Heat Treated UTS	- All CHD the same

It is understood this drilling unit was designed for South Africa, which has a requirement of drilling to 10,000 ft, and the maximum hole size in that part of the world is 2.98 in. OD using the 76 mm system. So while the drill meets the depth requirements, it does not allow the additional hole size and depth alternatives that may be needed to meet hole conditions that could be present on the SSSDP.

Per Mr. Dick Swayne of Longyear Co. the following is a typical hole that was recently drilled in New Mexico on an Oil Gas exploration well.

Rotary 0 - 900 ft, 9 7/8 in. bit
900 - 2,500 ft, 7 7/8 in. bit

Casing 0 - 2,800 ft, 6 5/8 in. Casing

Coring 2,500 - 4,000 ft, 134 mm - 5 1/2 to 6 in. bit

Casing 0 - 4,000 ft, 5 in.
4,000 - 7,000 ft + 101 mm - 4-3/8 in. Bit

Rotary Pump - GD - 5-1/2 in. x 8 in.

Core Pump Bean Twine Model 835
Hydrostatically Driven
10 to 70 GPM @ 850 PSI

<u>Ideal Core Rig Capacity</u>. From a continuous wireline coring point of view the drill rig should have the capacity to handle both hoisting, rotating and feeding of the 134 mm string to the maximum depth of 10,000 ft. If in hole conditions didn't demand casing, it would be to the advantage of the program not to case and change hole size. However if the hole condition required casing and size reduction, we have that alternative available, plus an addition size smaller as a last resort.

0 - 10,000 ft	134 mm System	131,000 lb
0 - 10,000 ft	101 mm System	85,300 lb
0 - 10,000 ft	76 mm System	55,600 lb

It would appear the drill rig with a hook load capacity of 225,000 lb would be more desirable plus have feed and rotating capacity of 150,000 lb to handle the 134 mm system to the 10,000 ft depth.

9. THE COMPARATIVE COST OF DRILLING AND CORING FROM 6,000 TO 10,000 FT USING THE CONVENTIONAL OIL FIELD ROTARY METHOD AND CONTINOUS WIRELINE CORING METHOD.

The proposed approach would have the first 6,000 ft drilled conventionally and cased. The rotary unit would drill through the high pressure gas zone and set the 9 5/8 in. casing to 6,000 ft. After completion, this same rig could set the 5 in. casing string for use with the 101 mm system.

The following are some of the cost considerations:

A. There are move-in move-out costs for the rotary drill, as well as the core drill. For the coring part of the hole, Longyear estimates these costs to be approximately $100,000.

B. The rotary drill substructure should be left in place to accommodate all of the BOPs needed. A review of the hole casing plan for the rotary indicates 9-5/8 in. production casing with its normal BOP stack plus wireline coring 5-1/2 in. casing to accommodate CHD-101 mm wireline coring system plus 4 in. casing string to accommodate CHD 76 mm wireline coring system. These casing <u>and</u> drilling strings will require a BOP stack.

   The substructure of oil rotary rig has sufficient clearance, 25 to 30 ft, to accommodate these BOP stacks, but the Longyear coring rig only has about 8 ft clearance. The Longyear drilling rig is of modular design, so it can be easily mounted on the deck of the substructure without its subbase but would require a rental crane to mob and demob. Additional arrangement must be made with the rotary contractor to lease his substructure during the coring operation. The cost of the substructure has not been included in the wireline coring estimate.

C. Coring costs will increase as a result of only drilling the lower part of the hole for the following reasons:

1. Mob and demob would be the same as if started from 0 to 10,000 ft, but you can only write off this cost against 4,000 ft of drilling.

2. Under this scenario the contractor will be required to have two (2) strings of pipe 101 mm 0 to 7,500 ft and 76 mm 0 to 10,000 ft and must write off wear and cost over only 4,000 ft of drilling, though he is required to invest a very large amount for the entire string of pipe.

3. This method requires a very large core drilling rig because of depth and size, and all the related costs of the large rig must be written off against a small amount of footage drilled.

4. If this hole is planned to be used for production, there is a good chance that these small strings of casing or stuck rods could not be removed, or if so it might be done at a substantial cost. The small core drill does not have hoist capacities to remove the 5 in. casing string that was set by the rotary. In order to rework the hole for production, a remob of the rotary drill may be required.

The following pages show a rough cost estimate for continuously wireline coring the SSSDP from 6,000 to 10,000 ft and a comparable Bechtel estimate for conventional rotary drilling and coring. The continuous wireline coring estimate is about 30 percent higher.

Continuous Wireline Coring	$810,365
Conventional Rotary Coring and Drilling	$576,050

BID CALCULATION FORM

DATE: 6/11/85

CUSTOMER: Bechtel

LOCATION: STATE: California

COUNTY: ______ TOWN: ______

FOOTAGE FOR CALCULATION: CORE 6000-10000 ROTARY: ______

1. CORE (SIZE 101mm-76mm)	EST. FTS. / F.P.D.H.	HOURS	2. ROTARY	HOURS	TOTAL
0-500					
500-1000					
6000-6500	4.5	111			
6500-7000	4.5	111			
7000-7500	3.5	143			
7500-8000	3.5	143			
8000-8500	3	167			
8500-9000	3	167			
9000-9500	2.5	200			
9500-10000	2	200			
000-500					
500-000					

TOTAL DRILLING HOURS 1242 % OF DRILL TIME 78%

	HOURS
3. REAMING (EST. FOOTAGE / F.P.D.H.)	
4. CASING	30
5. CEMENTING	30
6. SURVEY, PAID DELAY, LOST CIRCULATION	40
7. MOB. & DEMOB.	60
8. MOVING, SET-UP, TEAR DOWN (MOVE ___ HRS. EA.)	
9. EQUIPMENT BREAKDOWN	60
10. WEATHER DELAY	
11. HOLE PROBLEMS	40
12. OTHER DELAYS	20

SERVICE HOURS 160

DELAY HOURS 120

TOTAL NON-DRILLING HOURS 280

TOTAL HOURS 1522 SHIFTS PER DAY ______

63 ft/day 2.65 ft/hr

HOURS PER DAY ______ JOB DAYS 64 DURATION MOS. ______

LABOR COST 13.	PER HR.	PER DAY	TOTAL
FOREMAN (1)	15.00	168.00	
F. DRILLER (1)	13.50	151.20	
DRILLER (3)	12.00	403.20	
HELPER (6)	8.00	537.60	
DRIVER (1)			
TRAVEL TIME			
SUB-TOTAL		1260	
PAYROLL BURDEN STATE %	32	403	
SUBSISTENCE		205	
FRINGE			
		1868	

TOTAL LABOR COST $ 119565.00

SUPPLIES 14.	PER DAY	TOTAL
BULK FUEL	300.00	19,000
CREDIT CARD GAS	45.00	2,880
CORE BBLS.	3.5 ft	14,000
DRILL TOOLS	2.25	9,000
CASING & cement		101,800
SPECIAL SUPPLIES	2.00	8,000
MISCELLANEOUS		10,000
STATE TAXES 6%		7,478
mud $6.00/ft; FREIGHT & LINE TRUCK		24,000
Well head tools	30.00	1,920
ROTARY BITS F ___ C/F ___	→	4,000
DIA. BITS F ___ C/F 9.00		36,000
SALES TAX % 6%		2,160
TOTAL		240,418

RENTALS 15.	PER DAY	TOTAL
MOB. & DEMOB.		100,000
R.DRILL ( )		
D. DRILL (X)	150.00	11,000
PUMPS (X)	50.00	3,200
W. TRKS (X)	25.00	1,600
MILES 30x1.00	30.00	1,920
PICKUPS (X)	40.00	2,560
MILES 100x25		
RODS 76mm 10000'		145,937
TRAILERS 101mm 7500'	-	
COMPRESSOR	-	
OTHER RENTALS B.O.P.	100.00	6,400
TOTAL		272,617

CONTRACT EXPENSES 13, 14, 15

		TOTAL
CONTRIBUTION TO		632,600
OVERHEAD	15 %	
PROFIT	15 % 30 %	177,765
REQUIRED CONTRACT INCOME		810,365
LESS SERVICE REVENUE		149,500
INCOME REQUIRED FOR DRILLING		660,865

$\frac{810,365}{4,000ft}$ = $202.59/ft

SOURCE OF SERVICE REVENUE

#3. Mud $6.00	___ x ___	24,000
#4. HOURLY RATE	(225.00) 30	6,750
#5. HOURLY RATE	(225.00) 30	6,750
#6. HOURLY RATE	(225.00) 40	9,000
#8. HOURLY RATE	( )	
MOBILIZATION & DEMOB. COLLECTED		100,000
WATER HAUL CHARGES (TRUCK DRIVER, MILES, ETC.)		2,000
Core Boxes 4000'x50/ft; OTHER CHARGES, STATE TAXES, BITS, ETC.		1,000
TOTAL SERVICE REVENUE		149,500

THIS SECTION FOR BID ON FOOTAGE BASIS:

INCOME REQUIRED OF DRILLING ( )

DRILLING CREW HOURS ITEM 1 & 2 ( )

REQUIRED INCOME PER DRILLING CREW HOUR $ ______

2.63ft/hr

THIS SECTION FOR BID ON HOURLY BASIS:

INCOME REQUIRED FROM DRILLING ( )

TOTAL CREW HOURS-NON PAID TIME ( )

PER HOUR $ ______

INCOME REQUIRED FROM SERVICES ( )

TOTAL CREW HOURS ( )

CALCULATED PRICE PER HOUR $ ______

BID PER HOUR $ ______

	CALCULATED PRICES NC	NX	BX	ROTARY	BID PRICES NC	NX	BX	ROTARY
0-500								
500-1000								
1000-1500								
1500-2000								
2000-2500								
2500-3000								
3000-3500								
3500-4000								
4000-4500								
4500-5000								
5000-5500								
5500-6000								

80-170

BECHTEL ESTIMATE FOR ROTARY DRILLING
AND CORING FROM 6,000 TO 10,000

Component	Daily Rate	Approximate Days in Use	Subtotal Daily Cost
Rig rental (includes crew and drill pipe)	$5,600	65	$364,000
Rotating head rental	55	65	3,575
Drill bits	235	20	4,700
Drill tools	765	20	15,300
Mud and chemicals	1,685	65	109,525
Core barrels and bits	1,150	45	51,750
Coring supervisor	525	45	23,625
Trucks, crane, welding and other misc.	55	65	3,575
TOTAL			$576,050
Cost per ft.			$144.01

10. CONCLUSIONS

From an engineering point of view there is no question in my mind that if hole completion is important, the rotary oil rig with all its proven systems and its excess capacities would assure one of successfully completing this hole to 10,000 ft. However, from a scientific point of view one could certainly obtain additional scientific information by continuous wireline coring in areas where presently there is limited information.

One must weigh using the continuous wireline method against the following facts.

A. The 10,000 ft core drilling rig presently being built by Longyear has never attained that depth.

B. No continuous wireline coring contractor in the United States has personnel that have drilled to 10,000 ft nor at temperatures close to those that will be encountered at the Salton Sea Project.

C. Wireline core drilling tools have been subjected to geothermal environments but none have been subjected to such high temperatures or possibly as corrosive and abrasive geothermal solutions as will be encountered in the 10,000 ft Salton Sea hole.

D. Because of the very close tolerances between hole size and casing used, cementing holes could present real problems. Add to this condition 400°C hole temperatures plus brine solutions, and cementing may be impossible. At any rate, as of now, it is an unknown for the wireline core driller.

E. I have a serious concern with the continuous wireline core method in the following areas:

a. Corrosion

b. High drag forces (torsional and tension)

c. Wear

d. Temperature

e. Very low fluid volumes used in drilling present some safety questions

f. Hole deviation because of in-hole conditions that are different (sedimentary formation versus granitic formation) where most of wireline work has been done using the continuous wireline core method

The task of deep wireline core drilling is not impossible. However, there are certainly many unknown conditions in the Salton Sea project, that the wireline core drilling contractors would be eager to start solving. To do so in a timeframe that would assure completing the hole to 10,000 ft may take from 9 to 15 months of development work prior to beginning drilling.

There are two things that tend to assure hole completion:

1. Seasoned personnel that have drilled in these conditions to the proposed depths with support people they are familiar with

2. Proven rigs, tools and support systems

In view of the task at hand, it would appear that the continuous wireline coring system needs the support of a separate research program.

RESUME

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EXPERIENCE

1982 - Present Consulting Engineer. Have maintained a drilling consulting business servicing with mining and oil companies. Have successfully completed projects for Amoco Minerals, Getty Oil and Minerals, World Bank, Dresser Industries, Denison Mines, Bureau of Reclamation, Rio Colorado, Prodrill, Exxon, Noranda Mining, Hanna, Roberts Union Corp., and Irish Base Metals. Have traveled much of the world as consultant to the above and have recently helped RUC, South Africa reach 5,000 meters with wireline core drilling systems.

1982 - present Acquired part ownership in Matrix Drilling Products Co., which manufactures wireline core drilling rod by plasma welding system. Have worked with Matrix to develop special super deep DH5000 wireline rods to set world wireline core depth record. Matrix group has several developments to its credit.

1. Small, lightweight, reverse circulation string and system.
2. Lite Pipe, high strength, light rotary rods for Water Well and Oil industries.
3. Ultra-lite high speed rods for underground drill.

1972-1982 Longyear Co.
925 Delaware St. S.E.
Minneapolis, Minn. 55414
Duties and Responsibilities

1974-1982 Manager of Operation of the contract drilling division. Managed seven (7) operating zones stategically located throughout the United States and serving the mineral and geotechnical industries with gross sales of more than $32,000,000 annually.

1976-1982 Vice President, Longyear Americas INc. Responsible for all exploration drilling outside of North America in the Western Hemisphere; coordinated management and all field requirements.

1968-1972 Boyles Bros. Drilling Co.
P.O. Box 25068
Salt Lake City, Utah 84125
Utah District Manager. As manager was responsible for a 20 drill operation which includes shop and district office.

Before becoming manager, set up complete company maintenance program, wrote maintenance manual and computerized equipment and maintenance.

1964-1968 Joy Manufacturing Co.
Salt Lake City, Utah
Area manager

1960-1964 Nichols Drilling Co.
(Morrison-Knudsen Co.)
Selby Drilling Co.
Boise, Idaho
Chief Engineer -chief estimator.

1954-1960 E.J. Longyear Co.
Salt Lake City, Utah
Western Zone Manager
Set up the first operating zone for Longyear Co.

EDUCATION

1951- Michigan Technological University
B.S. Mech. Engr.
Registered Professional Engineer
1949- University of Minnesota
Business & Accounting B.A.
1945- Duluth Central High School diploma

Also obtained certificates from Baroid Mud School, Halliburton Cement School, plus management seminars at University of Minnesota, University of Utah, and University of Idaho.
Conducted Drilling Management and Information classes at University of Minnesota, Colorado School of Mines.

PROFESSIONAL MEMBERSHIPS

AIME, American Society of Mechanical Engineers, Canadian Diamond Drilling Assoc., Colorado Mining Assoc., National Drilling Contractors Assoc., Northwest Mining Assoc., Southwest Mining Assoc.

REFERENCES

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Mr. Robert H. Ruggari, Pres.
Utah-Wyoming Consolidated Oil Co.
P.O. Box 1045
Moab, Utah 84532

1-801-259-5611

PERSONAL

Date of birth: 11/11/25
Place of birth: Duluth, Minnesota
Marital status: married (Susan)
Ages of children: two sons, 22 and 25.