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PRACTICAL FIELD INTERPRETATION OF TEMPERATURE SURVEYS

by

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Division of Production
American Petroleum Institute
Dallas, Texas

PRACTICAL FIELD INTERPRETATION OF TEMPERATURE SURVEYS

Billy P. Morris, WACO Inc., Midland, Texas

ABSTRACT

Temperature logs have been used as an evaluation tool since the early 1930's. The simplicity of operation and expression of data once led the industry to believe that formation reaction and data interpretation could be stereotyped.

Attempts at quantitative analysis of the collected data revealed that temperature information collected in the borehole is the end result of one of the most complicated energy transfer systems encountered in downhole survey operations. Efforts to reconcile these myriad variations have resulted in many interpretive techniques making useful field interpretation of temperature data highly controversial and subject to a high degree of error if misapplied.

Some basic characteristics are reflected in each and every temperature curve, and if properly analyzed, can serve as a useful qualitative tool for evaluation of current downhole conditions.

INTRODUCTION

Downhole temperature surveys have long enjoyed immunity from the more exacting and precise evaluation methods that are applied to other types of well bore surveys. They have retained much of their popularity by virtue of the simplicity of the physical operation and unsophisticated presentation of data. One merely lowers a "thermometer on a string" in the well, takes readings at various depths, and records the results as a graph of temperature (fahrenheit or centegrade) vs. depth.

Conditions are usually assumed stable and fairly constant, and the temperatures recorded in the well bore are inferred to be the conditions extending for some distance into the formation.

All modifying or contingent conditions must be applied by the interpreter, and every man becomes an "expert" after seeing one or two temperature logs.

Temperature logs have been used for all types of investigation; i.e., cement top location, production analysis, casing and tubing leaks, frac evaluation, injection zone definition, and even attempts to locate unevaluated oil bearing sands behind the casing.

The "cook-book" style of interpretation used until recent years produced some successful evaluations and many dismal failures, and overextension of temperature log capabilities has caused misapplication of technique.

Promotional efforts to the contrary, temperature tools of excellent quality are available to the entire industry through several suppliers.

The validity of the information derived depends more upon the application and interpretive technique used than the tools themselves.

A basic understanding of these tools and their capabilities is necessary to properly apply the data they collect.

TOOLS

The downhole recording tools fall into three classifications: (Figure 1).

1. Absolute or normal temperature: A single element tool calibrated and aligned to detect the existing temperature downhole and transmit this information to the surface, where it is recorded as actual temperature versus depth.

   This tool measures the temperature of the borehole fluids at a single point and is subject to the total of the vertical as well as lateral

effects of temperature transition zone. Sharp definition of temperature interfaces is improbable unless the differential is extreme, and slight changes often go unnoticed unless recording sensitivity is high. Total transition from one temperature to another is usually averaged over a long vertical interval.

2. Temperature Differential: The differential tool utilizes two elements physically separated by a given distance. Both elements detect the absolute temperature of the fluids at their respective depths. These temperatures are impressed upon a "comparison circuit" and the difference between them is transmitted to the surface and recorded. Hence, if one element detects 76 degrees and the other, five feet above it, registers 75 degrees, a 1 degree progression for the interval is recorded. As long as this progression remains the same as the tool is moved downhole, no further deflection is recorded, but should the rate of change increase to 2 degrees per five feet interval (i.e. top element 78 degrees and bottom 80 degrees) an additional one degree deflection would appear on the recording for the given interval.

   The two element tool can be calibrated and used as a "true differential" indicator by taking stationary readings. The actual difference in temperature would be determined by the deflection. During most logging operations, the progress downhole is usually continuous; therefore, both the rate and the amount of temperature change affect the readings, and the log is used as a relative temperature change indicator. The actual temperature is recorded simultaneously on a separate circuit. The advantage in this usage is a more prominent indication of temperature change over a given interval.

3. A-Priori "Differential": This principle simulates the differential effect by using a single element and an electronic "memory circuit". The single element detects the temperature of the well fluids and sends this information to a memory cell or delay circuit. After a pre-selected time this temperature impulse is fed back into a "comparison circuit" and is impressed with the impulse currently generated by the temperature element. The difference in temperature detected at the two time-intervals is recorded as differential.

   This tool is not a true differential indicator with respect to depth since it depends upon movement for its depth spacing. Theoretically, the spacing is controlled by logging speed, but in actual practice, the time delay for feed back in milliseconds and normal logging speeds are not compatible. No consistent spacing control is possible without electronic "gateing" keyed to the depth meter. Continuous movement again incurs effect from both the rate and amount of temperature change, and confines the use of this curve to an instantaneous slope change indicator. As with the other differential tools, the actual temperature is recorded on a separate circuit. The downhole tool used in the A-priori method is only the normal

or absolute temperature sonde. All the delay circuits are in the surface instrumentation.

The only basic data collected by the temperature sonde is the absolute temperature inside the well bore and the depth at which it is recorded.

The interpretation of temperature data does not depend upon the downhole temperature that exists, but rather, the degree and rate of change under controlled conditions. An examination of the conditions involved will lay the groundwork for more accurate interpretation.

The normal gradient exists because of a temperature equilibrium process from the interior of the earth (warmer) to the surface (cooler). Heat flow is vertical and forms a gradient or constantly decreasing temperature as it approaches the surface. The existence of a hole in the ground does not change the gradient appreciably (Figure 2-A).

Should the temperature be changed by pumping cooler or warmer fluids downhole, a differential is formed between the well bore and the formation temperature at any given depth and a lateral or horizontal "gradient" is formed between the well bore and the formation (Figure 2-B). A process of equilibrium is set up, and heat flows from the warmer source to the cooler point. The coolest point in the system is the terminal point for this equilibrium process and, therefore, is the last point to be affected by the heat flow.

The well bore is either the source or terminal point of these heat exchanges, and any temperature change must be considered the result of the sequence of heat flow rather than the instantaneous condition of the reservoir outside the well bore.

Fluid moving inside the well bore not only affects the zone accepting the fluid, but the formation temperature is changed outside the entire extent of the hole by conduction (Figure 3). This change is constantly expanded to some distance until the formation will conduct only the amount of heat that is being carried away (or added) by the moving fluids. "Steady state" heat flow then exists, and unless the temperature of the fluid moving in the well is changed, there will be no additional change in formation temperature immediately around the well bore with continued fluid movement. When the fluid movement is stopped, the temperatures in and around the well bore attempt to recover to normal gradient for each depth. The rate of recovery inside the well bore (data collection point) depends not only upon the zones that have or have not accepted the fluid, but also upon the ability of each of the formations to transmit heat to or from the well bore. The formations not only transmit heat directly back to the well, (Figure 4-A), but as one formation warms or cools faster than the adjacent one, local equilibrium effects are set up in the formation which slows the rate of recovery in some zones and speeds that of others, causing a distortion

of the lateral temperature transfer characteristics of these formations (Figure 4-B).

The mechanical arrangement of the well also affects the rate of heat transfer at each depth by increasing or decreasing conductive properties (Figure 5).

Temperature tools have no "Radius of investigation" into the formation and can only measure the temperature inside the well bore. Recorded temperatures at any one given time do not detect the many small changes in the formation that affect the final well bore temperatures.

A "single run" temperature log run and interpreted only by the "cooler or hotter" technique can result in completely erroneous information.

One simple rule of thumb can be applied to "on the spot" interpretations which will greatly increase the accuracy of field analysis of temperature logs:

> Static well bore fluids always assume the temperature of the "Dominant Temperature field" immediately adjacent to the well bore.

This obvious over simplification of conditions can be made applicable if the sequence of events that result in a particular "Dominant field" are examined.

When cooler fluids move thru the well and into the formation "boundary cooling" is caused around the hole and above and below the zone taking fluid. Heat flows back to the well bore from some radius away from the well. Heat at gradient temperature for each depth is available for recovery except in the zones accepting fluid (Figure 6). The heat source across the zone of injection is approximately the same as the well bore fluid temperature, therefore, little or no heat is available to warm the well fluids opposite these zones. There is no warming trend after shut in and this area lags behind in its rate of recovery. The Dominant Temperature Field in the non-injection zone is at normal gradient for that depth, but the Dominant field of the injection zone is approximately the fluid temperature under injection conditions. A trend to positive slope develops over the non-injection interval but no slope trend (either positive or negative) is developed through the zone of injection (Figure 7).

These ideal conditions are relatively easy to identify since they consider only the temperature fields and unobstructed path of heat flow.

Changing well bore mechanics change both the radius of dominant field and the heat replacement rate. The temperature curve will reflect the presence of tubing, casing, enlarged hole, squeezed zones or any other

change from continuous borehole configuration by a deflection from its established slope or trend.

The following examples are reproductions of temperature decay curves run at varying times after shut in. The total pattern of progression identifies the zones readily, but any single curve of each series might well be misinterpreted if analyzed with no other information available.

Figure 8 - The effect of tubing in continuous cased hole - Deflection of temperature towards the injection temperature (cooler) at the base of tubing string.

Figure 9 - Tubing, casing and open hole - Temperature deflections at each change of hole configuration.

Figure 10 - Tubing set to total depth. Note changing direction of deflection at base of tubing with time as one dominant temperature field (annular) space is replaced by secondary field.

Figure 11 - The effects of enlarged hole in non-injection zone. Additional volume of hole distorts otherwise normal progression of temperature after shut in and causes cool anomaly on log.

Figure 12 - Enlarged hole between two injection zones. Boundary cooling above and below combines with increased hole volume (non-injection zone) to cause coolest anomaly in non-injection zone.

These examples point up the possible error to be incurred by indiscriminate interpretation of "cold" spots as zone of injection. Study of the family of curves shows, however, that the established proportional rate of recovery developed in the non-injection zones is retarded in the injection zones by the extended dominant field of nearly constant temperature, and rate of change becomes the factor for interpretation.

Selection of intervals of lateral fluid movement must then be made on a basis of zone temperature stability rather than actual temperature at any given time. To detect this "stability", it is necessary to observe a family of curves recording the sequence of temperature progression after some controlled action.

Many field operations do not allow time for this accumulation of data. Interpretation must be made with inferred temperature sequence based on data collected during a shorter time interval, and augmented or modified by the interpretors knowledge of the physical changes that have been caused by some surface initiated action.

Prior information; i.e., established normal gradient for local area, well bore mechanics, surface temperature of injected or produced fluids, compressible or non-compressible fluids, measured injection or production rates, type of fluids (reacting or stable) etc., must be considered

when assuming sequence of temperature change.

Base logs should be run to establish existing temperature conditions downhole for comparison to subsequent temperatures.

When a large differential (20° F or more) exists between moving well fluids and normal downhole temperatures, or prior temperature logs under the same conditions are available, base logs may sometimes be dispensed with, although interpretation is greatly facilitated by their use. Remember, prior injection zones, squeeze cementing, liner applications, etc., may have generated a dominant formation temperature downhole other than normal gradient.

Figure 13 - Well "B" has been prepared for recompletion in a lower zone by squeezing the upper zone and opening a new zone by perforating.

Lower zone is treated with acid to stimulate production. Examination of the after treatment log shows heating anomalies exceeding the normal gradient in both the new zone and the squeezed zone. Assumed condition; the original zone broke down or acid treatment channelled up to the old producing interval. Comparison with the base log shows that the upper heating anomaly is the result of the cement squeeze and existed before treatment. Since there has been no change in the upper heating indication the conclusion is that the squeeze held and the lower zone treated properly.

In the absence of base log or prior information, it is imperative to make at least two or three temperature traverses over the interval after an initiated change to observe the relative sequence and amount of change incurred by the action. Injection wells normally involve only one induced change (injection to shut in) and the temperature progression is from one stabilized condition towards another. Care must be exercised in gathering prior information, however, lest some change in injection rates or pressures change downhole conditions and generate new and confusing temperature fields.

Figure 14 - This established low rate injection well was subjected to step-rate test which ultimately broke out below the logged depth. The well was then placed back on injection at the previous low rate, allowed to stabilize, and logged with decay series temperature survey. The lower zone and bottom of the hole had been cooled below normal injection temperature by the step-rate tests, but the current injection curve shows no injection past bottom of the hole. Study of this sequence shows positive (warming) trend above 2550 feet, stable temperature at current injection temperature over interval 2550-2600 feet and negative progression below 2600 feet. The dominant temperature fields are three phase, cooler on the bottom with very slight injection at normal rates. Warmer above, no injection,

and constant at current injection temperatures through the center (maximum current injection).

This analysis could not have been positive without prior information but a base run under injection and a shut in curve after 4-6 hours would have identified the stable zone as 2550-2600 feet where no gradient, either positive or negative, was generated. The constant temperature then indicates the major injection zone.

TREATMENT AND PUMP IN ANALYSIS

Intermittent injection or pumping operations never generate "steady state" heat transfer conditions. These operations are usually very short term, and the temperature changes induced by them are subsequently shorter lived. Since the conditions are in a constant state of fluxuation, they are often changed again, before they recover completely. Relative anomalies are obliterated by additional action from the surface before another temperature traverse is made over the interval. Interpretation is made by comparison of the temperature curves, and identification of the more nearly stable zones in relation to the sequence of events.

The same dominant temperature field principles still apply but are sometimes more difficult to identify. When scanning the log for zones of injection, consider the temperature anomaly that should be generated by the last action taken and identify the partially stablized zone in relation to the prior traverse.

A base log of existing temperatures before pumping is an absolute necessity to properly locate the affected interval in recompletions and old producers.

Figure 15 - Examine well "Y". Open hole completion, tubing set to point "D" and producing from zone "B". Tubing is pulled and well readied for retreatment to stimulate additional zones.

A light single stage frac is pumped away and a frac analysis temperature log is run:

Run No. 1 - Compared to known normal gradient shows cooling from casing seat to point "D" with some cooler points opposite all three major zones. Apparently the well has accepted treatment in all three zones.

Run No. 2 - Progression of temperature opposite zone "A" indicates no treatment into "A". Zone "B" is accepting treatment in top and bottom of zone and zone "C" apparently well treated. (Note stable temperatures at bottom.)

Base Log - Comparison of base log over zone "C" shows that stable anomaly in the lower section of "C" was residual from the effects

of producing period and only the very top portion of "C" accepted treatment. The dominant temperature fields are identified in sequence: Base Log, run No. 1, run No. 2, and have indicated the need for further treatment or a change of treating procedures.

Figure 16 - A base log and run No. 2 will provide enough interpretive data if the characteristics of the more nearly stable zones are recognized. Interpret for the zones that indicate no slope either positive or negative and recognize that any slope, either negative or positive, indicates a transient temperature exchange.

TREATING FLUIDS

Acids or reacting treating fluids generate heat when they contact the formation. These reactions must be allowed for in the interpretation of treatment evaluation temperature curves.

The sequence of operation should again be considered and the step by step analysis applied. Treating with cooler fluids first cools the formation by contact, but the heat of reaction warms the zones accepting treatment. This produces a two phase temperature reaction.

The temperature of the treating fluids should be adjusted to maintain all the reactions either positive or negative with respect to normal downhole temperature.

For example: Cool acid is pumped downhole and arrives in place 14 degrees cooler than the normal temperature. The formation is cooled 14 degrees by contact but the heat of reaction in the formation generates a 14 degree temperature rise in the zone accepting treatment. The resulting well bore temperature would be the same as the normal temperature and no anomaly would exist. The curve would have no positive interpretive value (Figure 17-A). Should the acid treatment have arrived downhole at -20 degrees to the normal temperature, the zone accepting treatment would also show deflection from the normal temperature indicating that it had been exposed to the treating fluids. Normal progression of the temperature recovery would then indicate a dominant temperature field in the treated zone while the untreated zones recover at a higher rate (Figure 17-B).

Displacement and overflush fluids should be brought to the same surface temperature as the treating fluids to avoid altering the temperature indications caused by treatment.

Interpretation should always be made from the absolute temperature curve rather than from the so-called "differential" curve. The T or differential curve is not a measurement of temperature, but an indication of slope change. Due to boundary cooling and/or heating, the slope of an absolute curve starts to change at some distance above the actual zone

of injections and the practice of identifying the zones from the differential curve alone can lead to complete misinterpretation of the results (Figure 18).

The use of the Delta curve should be confined to identifying the slope changes of the absolute curves as they enter the zones of "stability". Slight increases in the rate of slope change from transient to "stable" temperature conditions may be more closely defined with respect to depth and the actual zone of fluid acceptance identified more specifically.

Fluid movement in the well bore during the time the temperature traverse is being made destroys all evidence of the anomalies being formed in the formation. The well bore temperatures are constantly being displaced by the moving fluids, and no temperature other than that of the fluid stream is detected. Wells on vacuum, counter-flow, or backflow conditions show only the temperature of the fluid and the vertical extent of its travel as long as the fluid continues to move.

The Dominant Temperature field principle can be used to increase the accuracy of "on the spot" field interpretations if the heat flow characteristics in the formation are related to the resulting data collected in the well bore.

RULES FOR APPLICATION

1. Determine well bore arrangement.
2. Review prior data or logs, if possible, to determine variations from normal temperatures.
3. Run base temperature or establish a constant for comparison from prior data before any action is taken to alter downhole temperatures.
4. Consider the sequence of action with respect to the temperature progression.
5. Interpret any slope (negative or positive) as an area of transient temperature and identify "stable" zones by their approach towards vertical gradient. (No slope) These are the zones of near constant temperature over their entire vertical extent.

CONCLUSIONS

Temperature logs are a valid qualitative field interpretation tool when properly executed and interpreted.

"Single Run" temperature logs without modifying data or prior logging history can easily be misinterpreted.

Interpretation technique must utilize rate and sequence of temperature progression rather than "cooler or warmer" principle.

"Dominant Temperature Field" principle applies to all temperature log analysis and must be considered for consistently accurate interpretation.

"Differential" or Delta-T curves should be used only to more closely define slope changes in the absolute curve, and <u>must</u> <u>not</u> be construed as temperature readings.

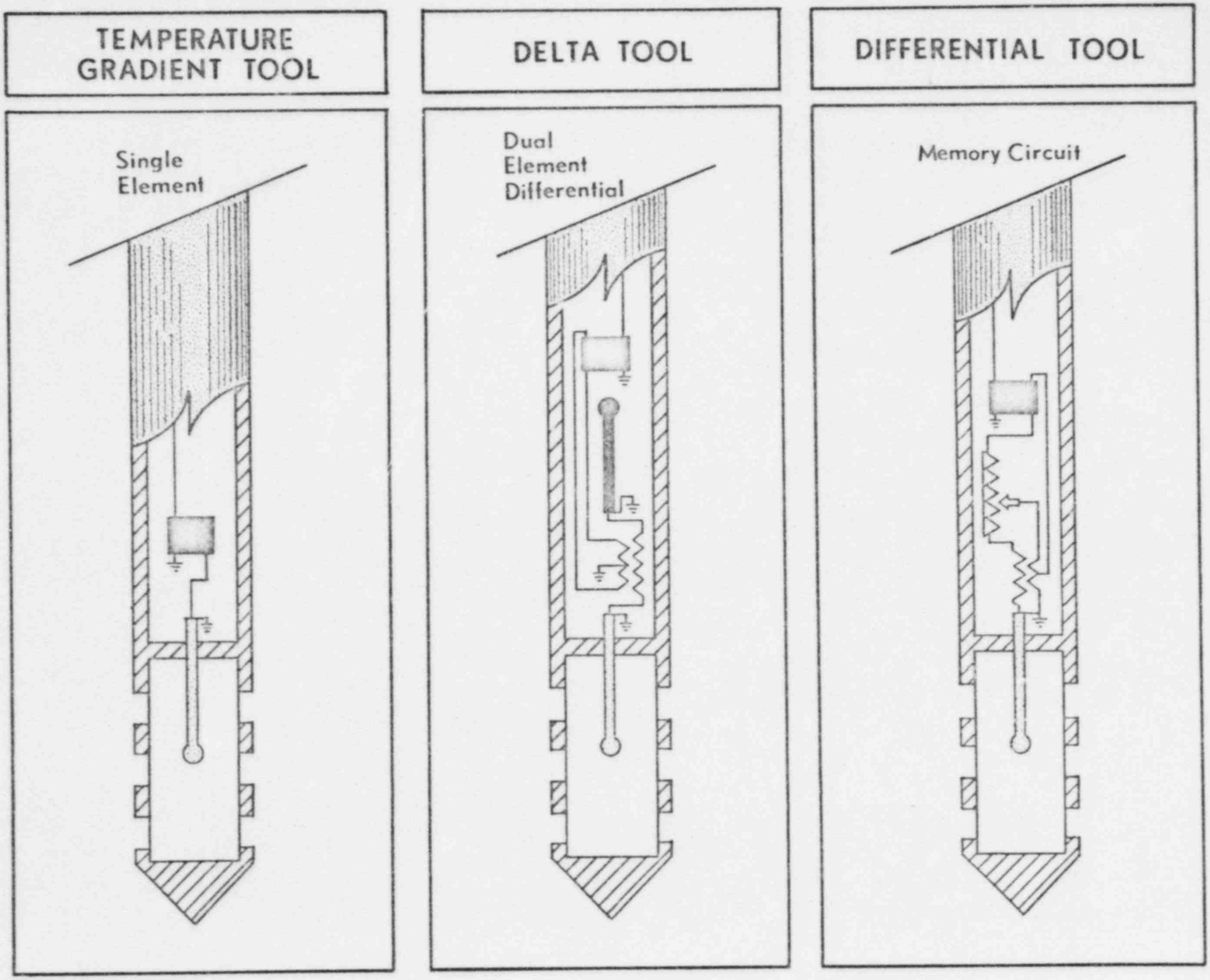

TEMPERATURE GRADIENT TOOL
Single Element
DELTA TOOL
Dual Element Differential
DIFFERENTIAL TOOL
Memory Circuit

FIG. 1

VERTICAL GRADIENT

LATERAL GRADIENT (INJECTION)

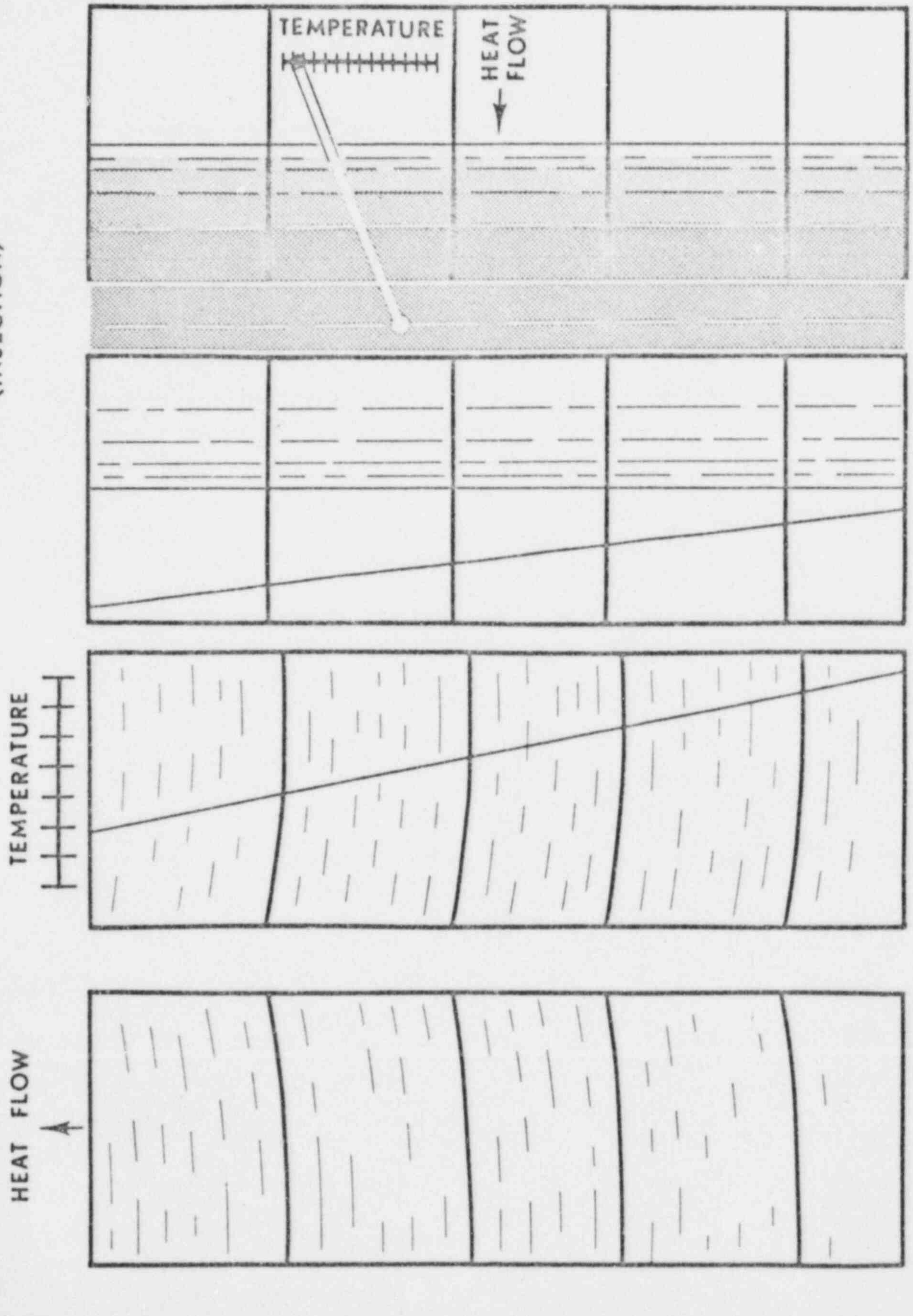


FIG. 2A

FIG 2B

VERTICAL AND LATERAL EFFECTS

STABILIZED INJECTION TEMPERATURES

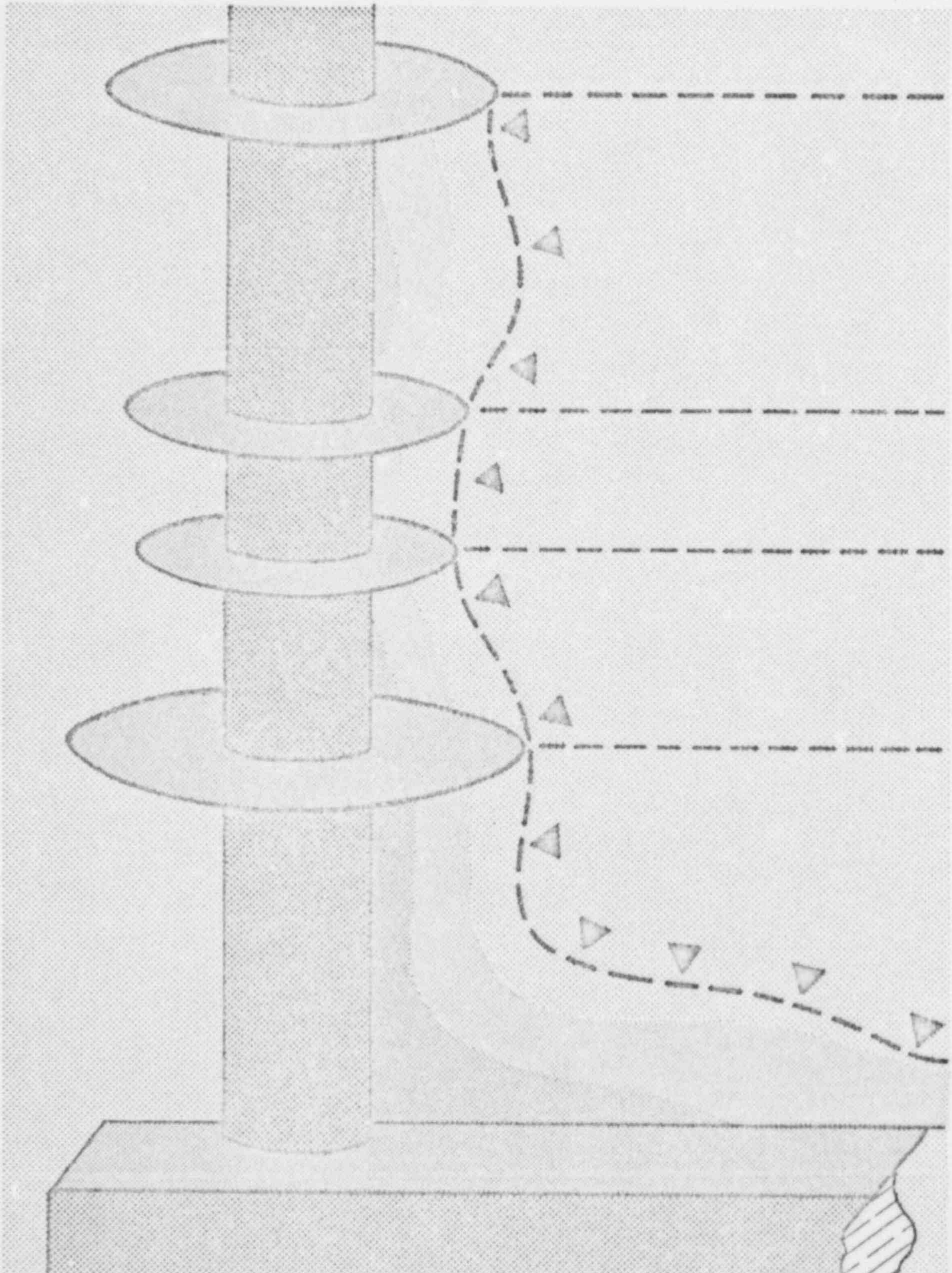


FIG. 3

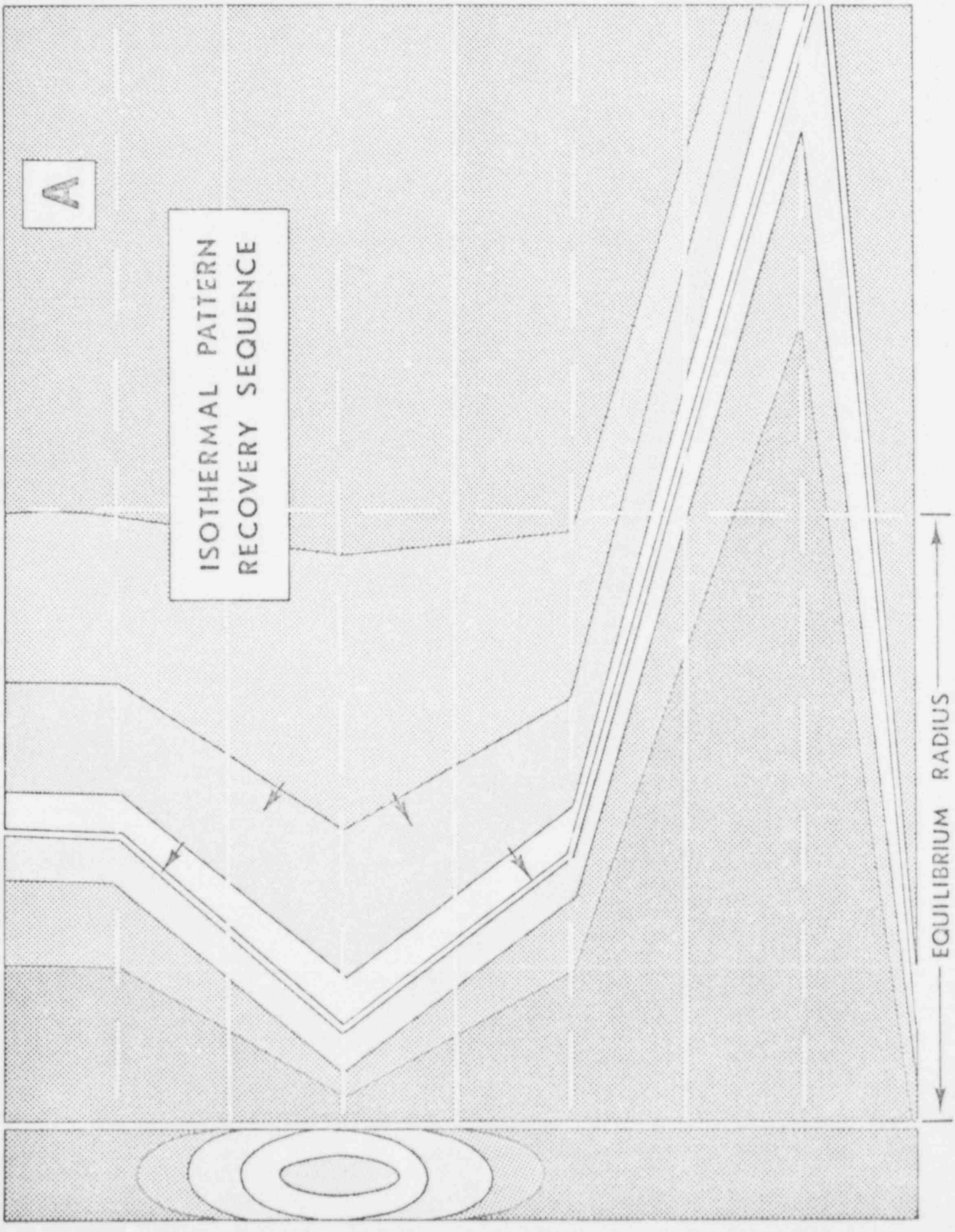

A
ISOTHERMAL PATTERN
RECOVERY SEQUENCE
EQUILIBRIUM RADIUS

FIG. 4-A

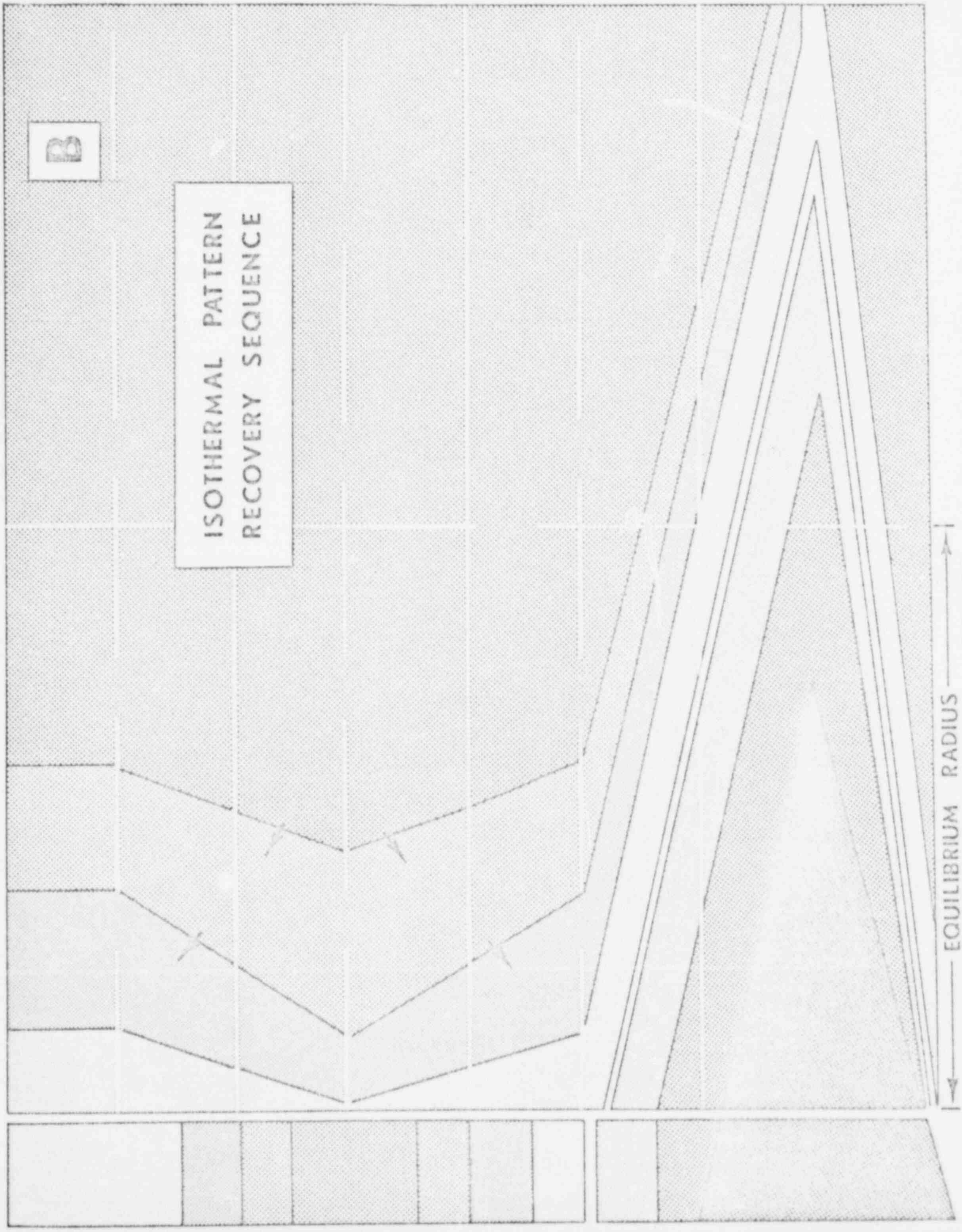

B
ISOTHERMAL PATTERN
RECOVERY SEQUENCE
EQUILIBRIUM RADIUS

FIG. 4-B

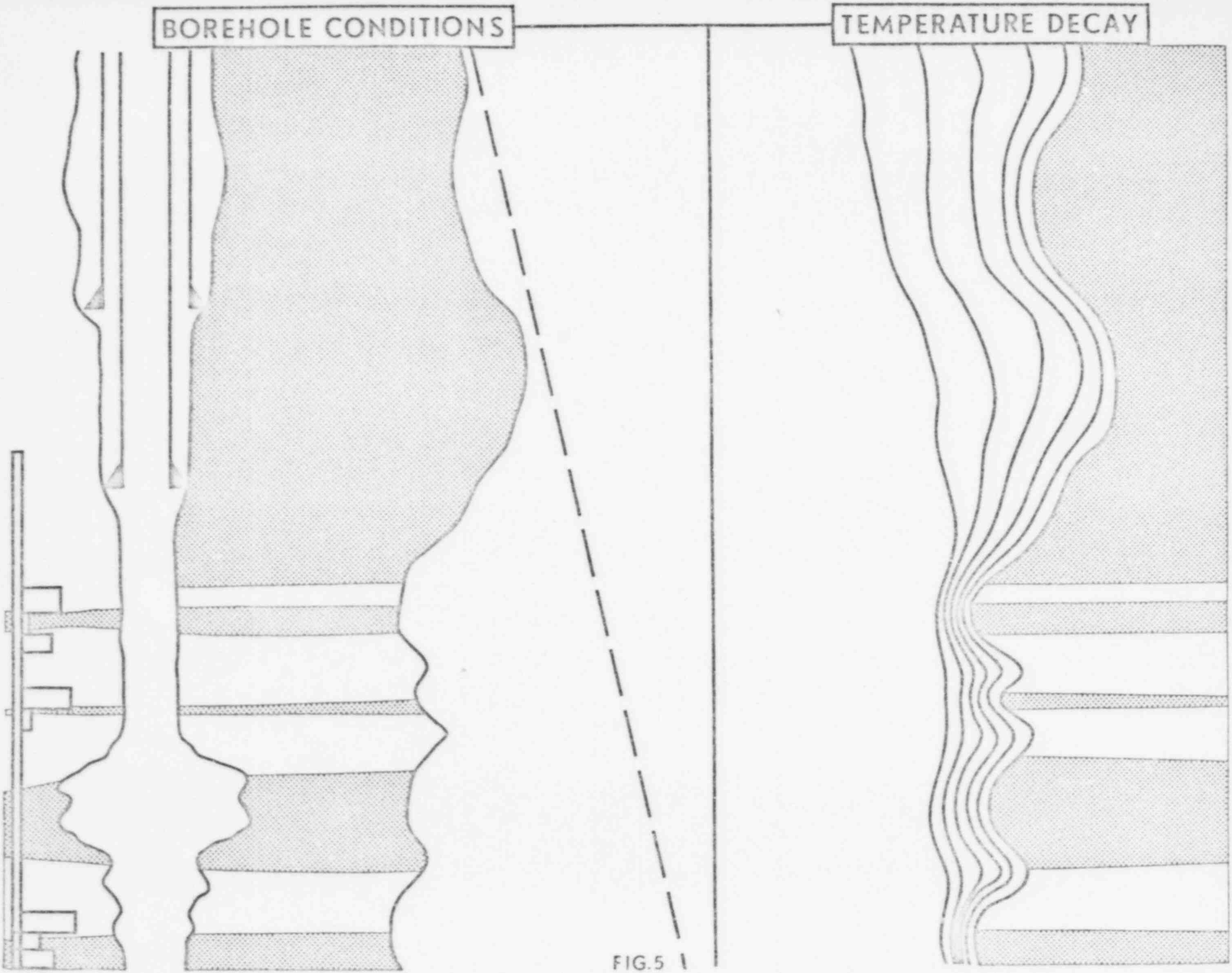


FIG.5

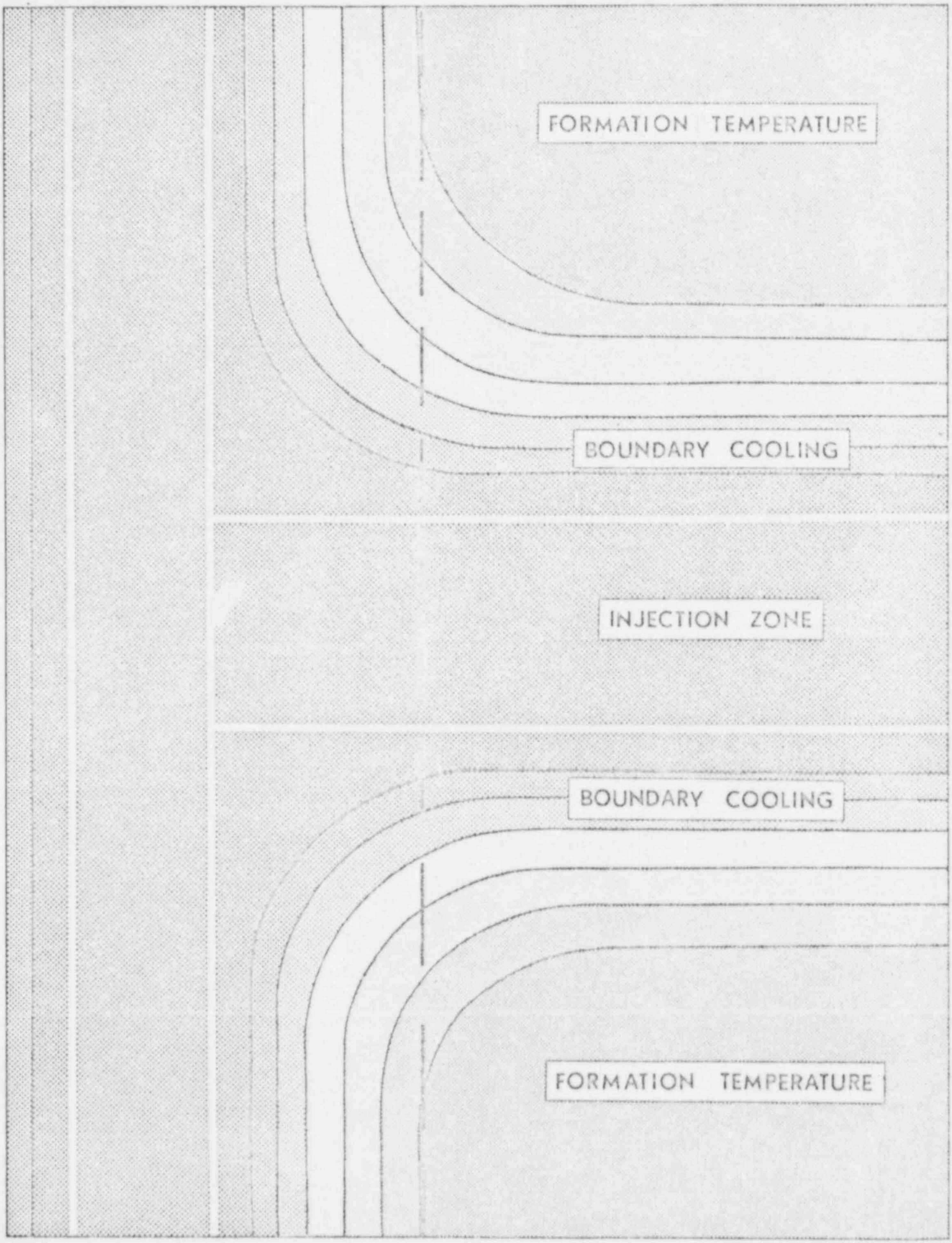

FORMATION TEMPERATURE
BOUNDARY COOLING
INJECTION ZONE
BOUNDARY COOLING
FORMATION TEMPERATURE

FIG. 6

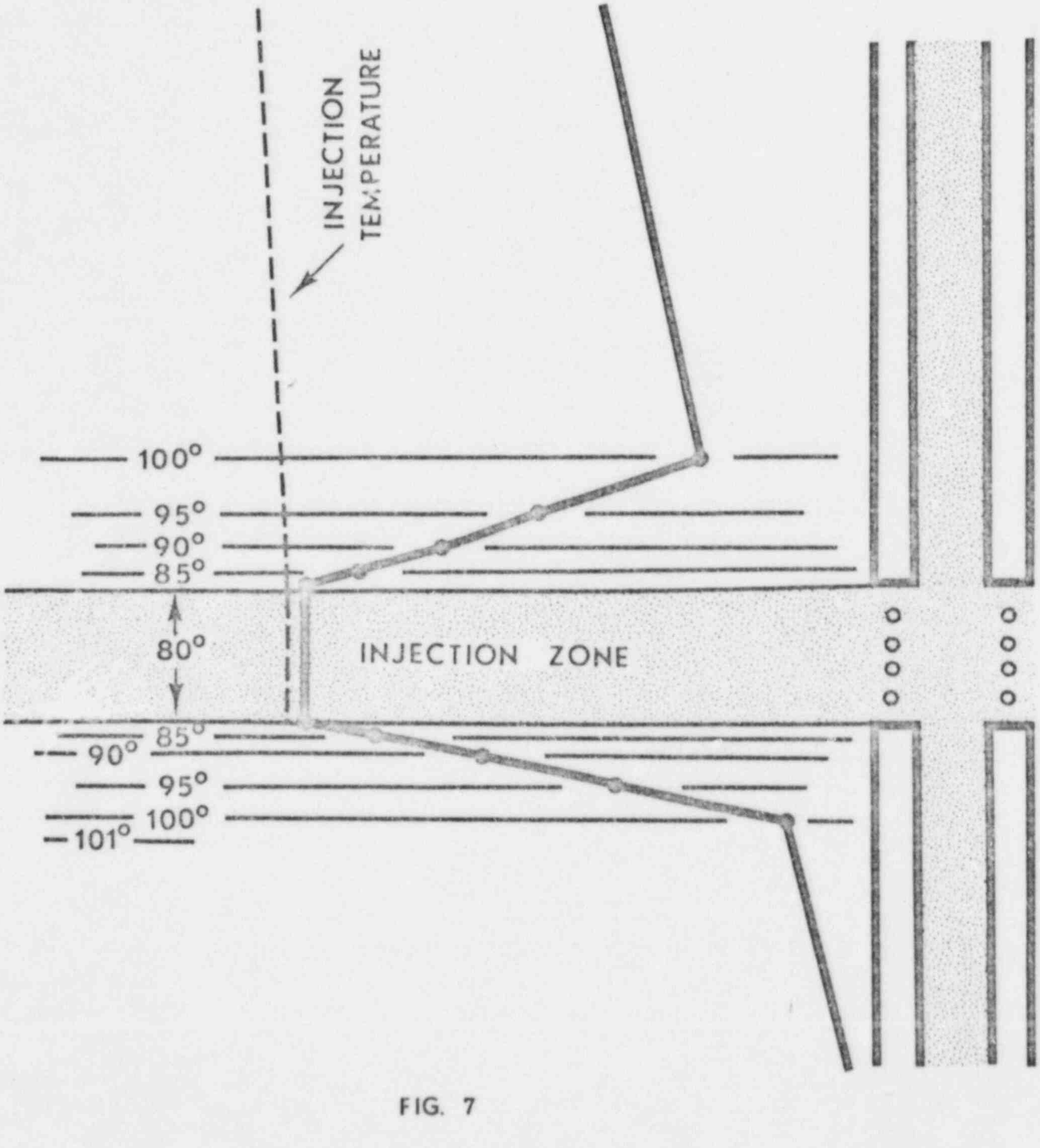
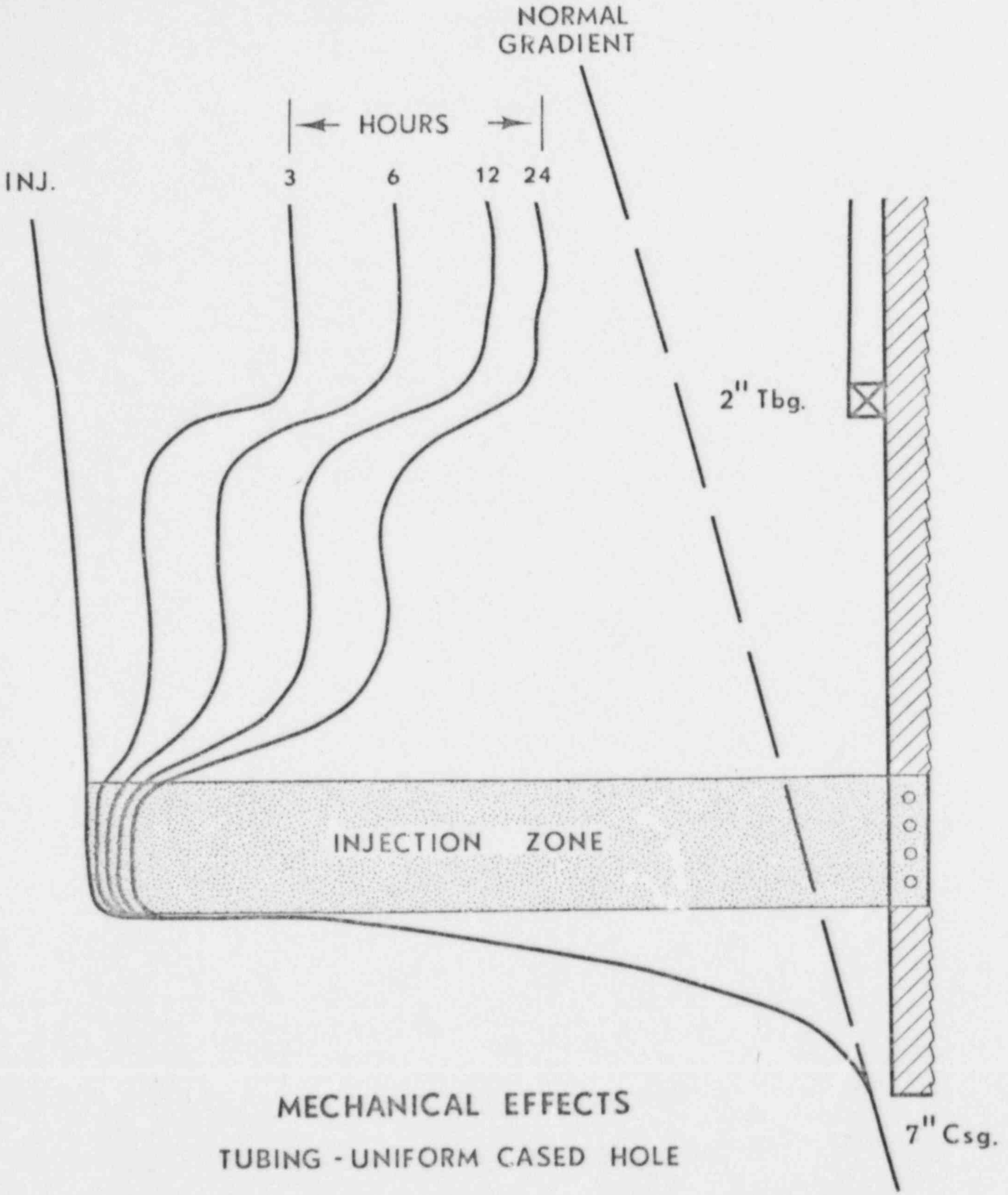

INJECTION
TEMPERATURE
100°
95°
90°
85°
80°
INJECTION ZONE
85°
90°
95°
100°
101°

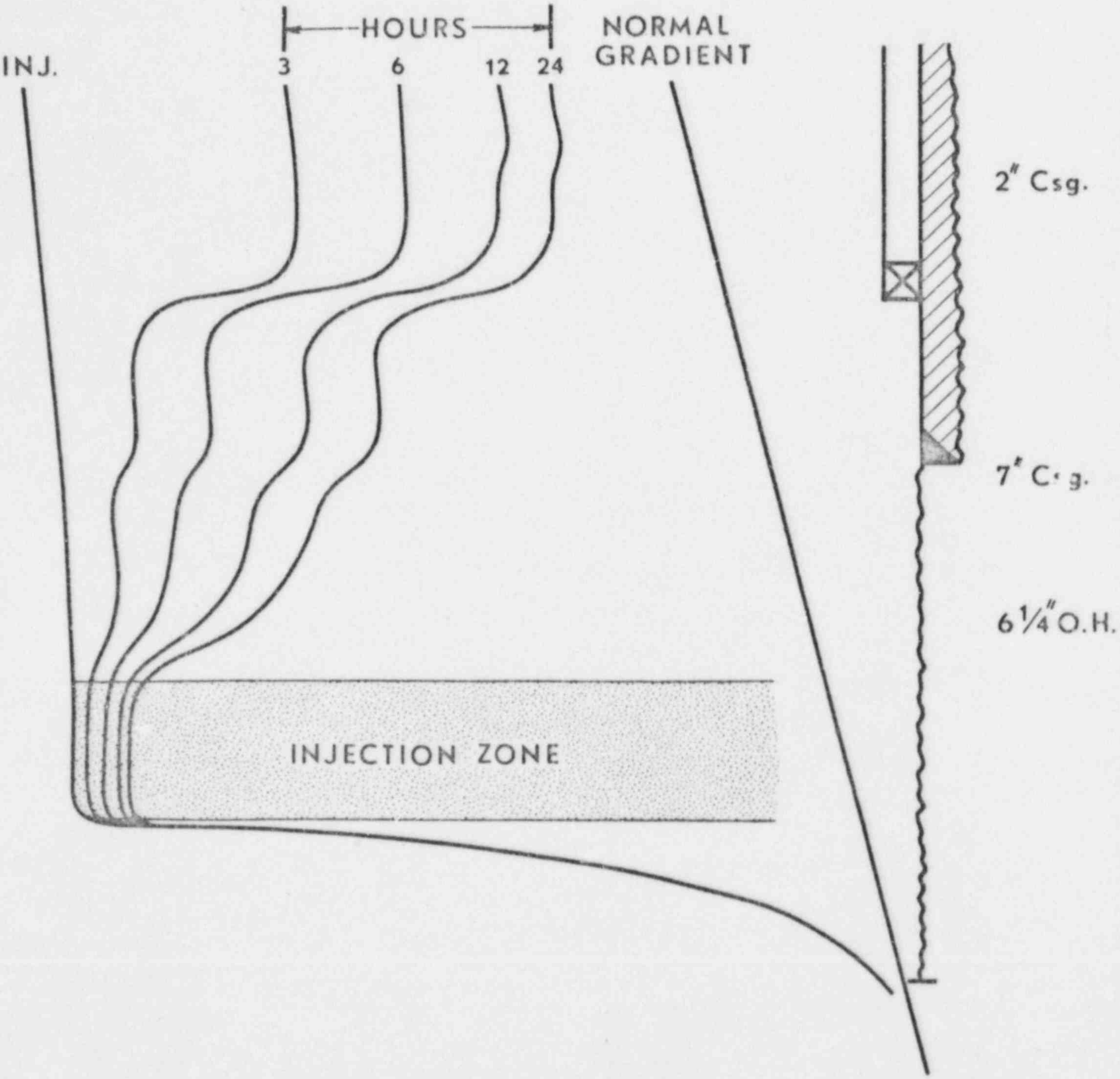
FIG. 7



MECHANICAL EFFECTS

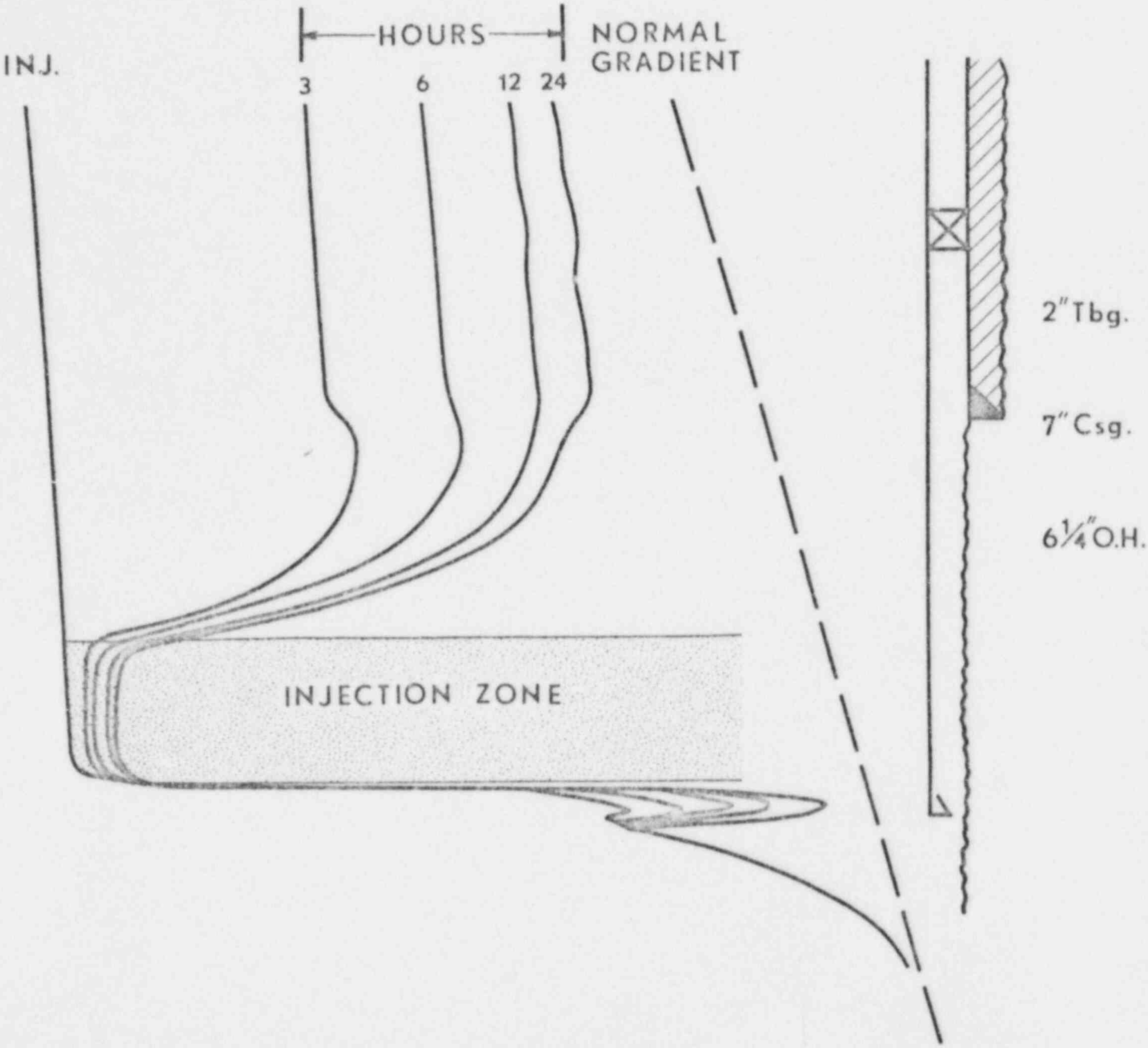
TUBING - UNIFORM CASED HOLE

FIG. 8



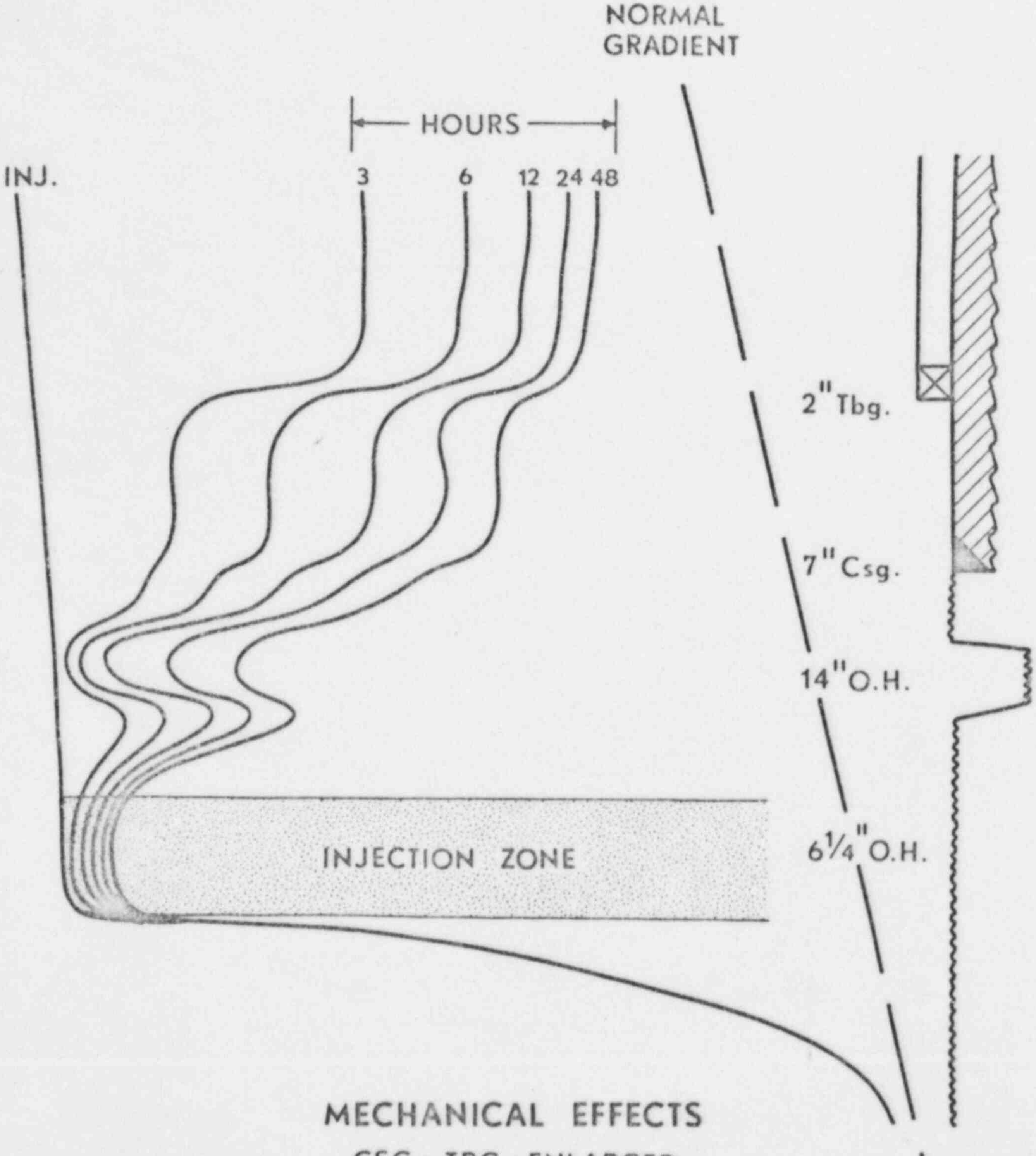
MECHANICAL EFFECTS
TUBING CASING
UNIFORM OPEN HOLE

FIG. 9



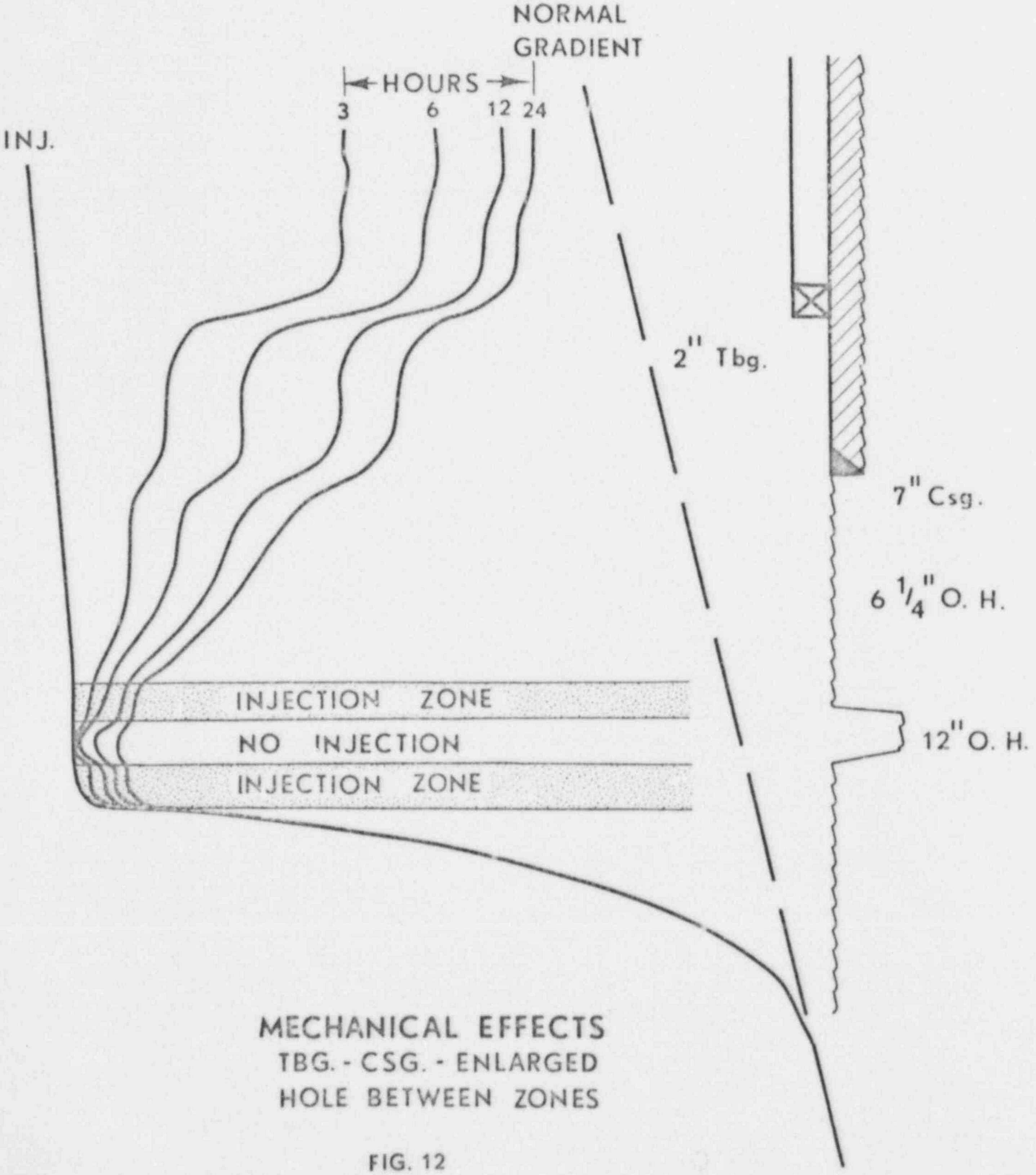
MECHANICAL EFFECTS
CSG – UNIFORM OPEN HOLE
TUBING SET TO BOTTOM

FIG. 10



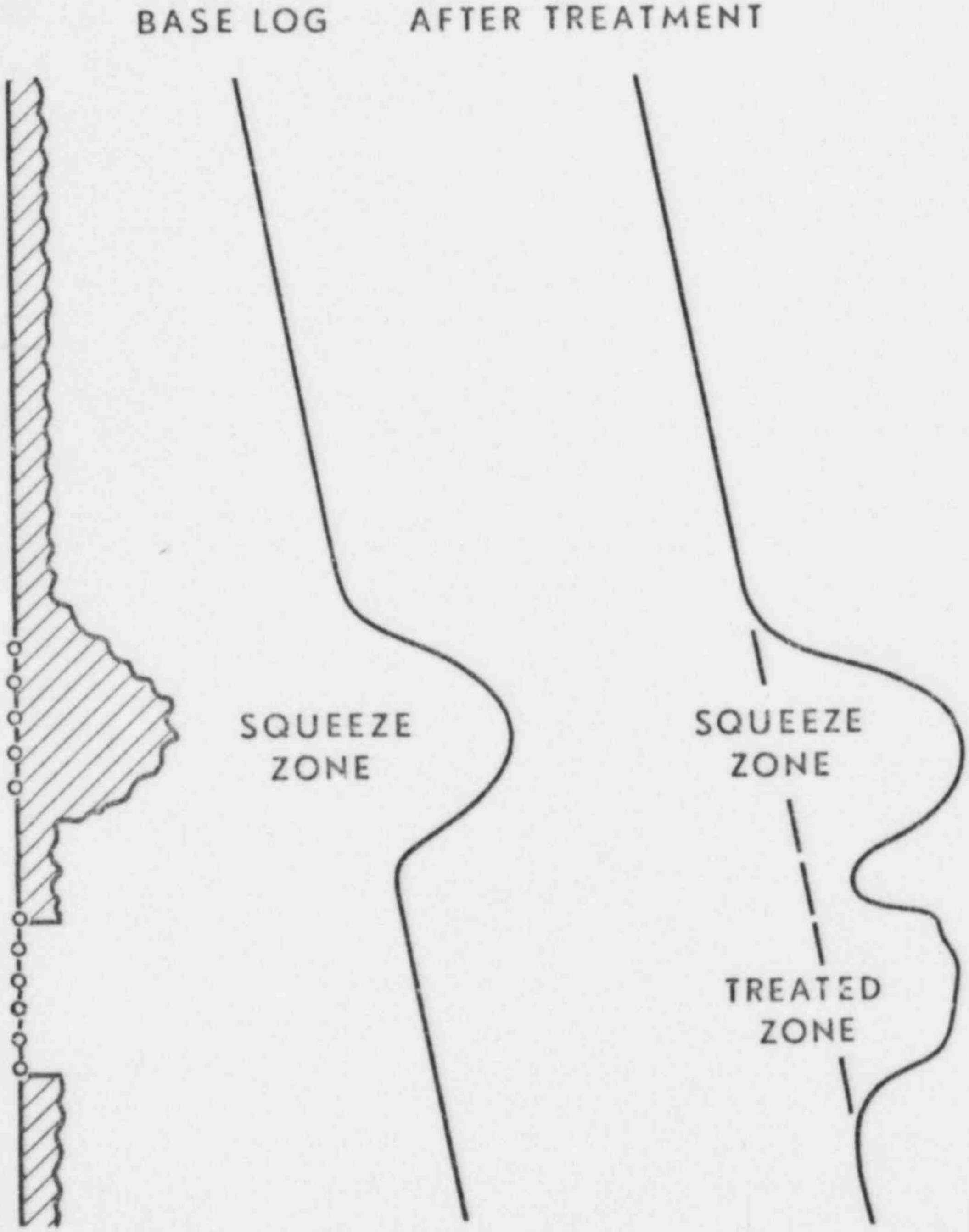
MECHANICAL EFFECTS
CSG - TBG - ENLARGED
OPEN HOLE ABOVE ZONE

FIG. 11



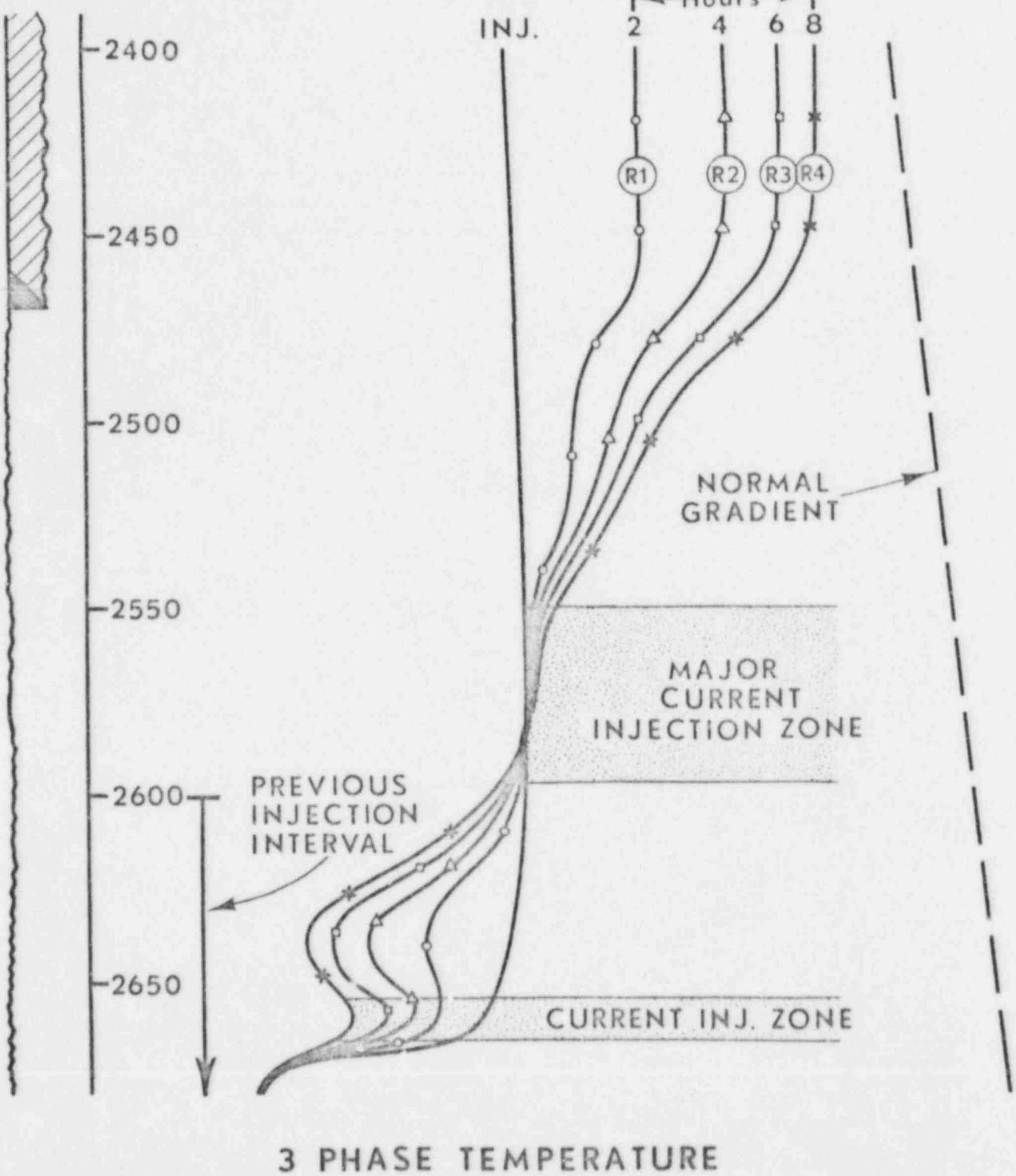
MECHANICAL EFFECTS
TBG. - CSG. - ENLARGED
HOLE BETWEEN ZONES

FIG. 12



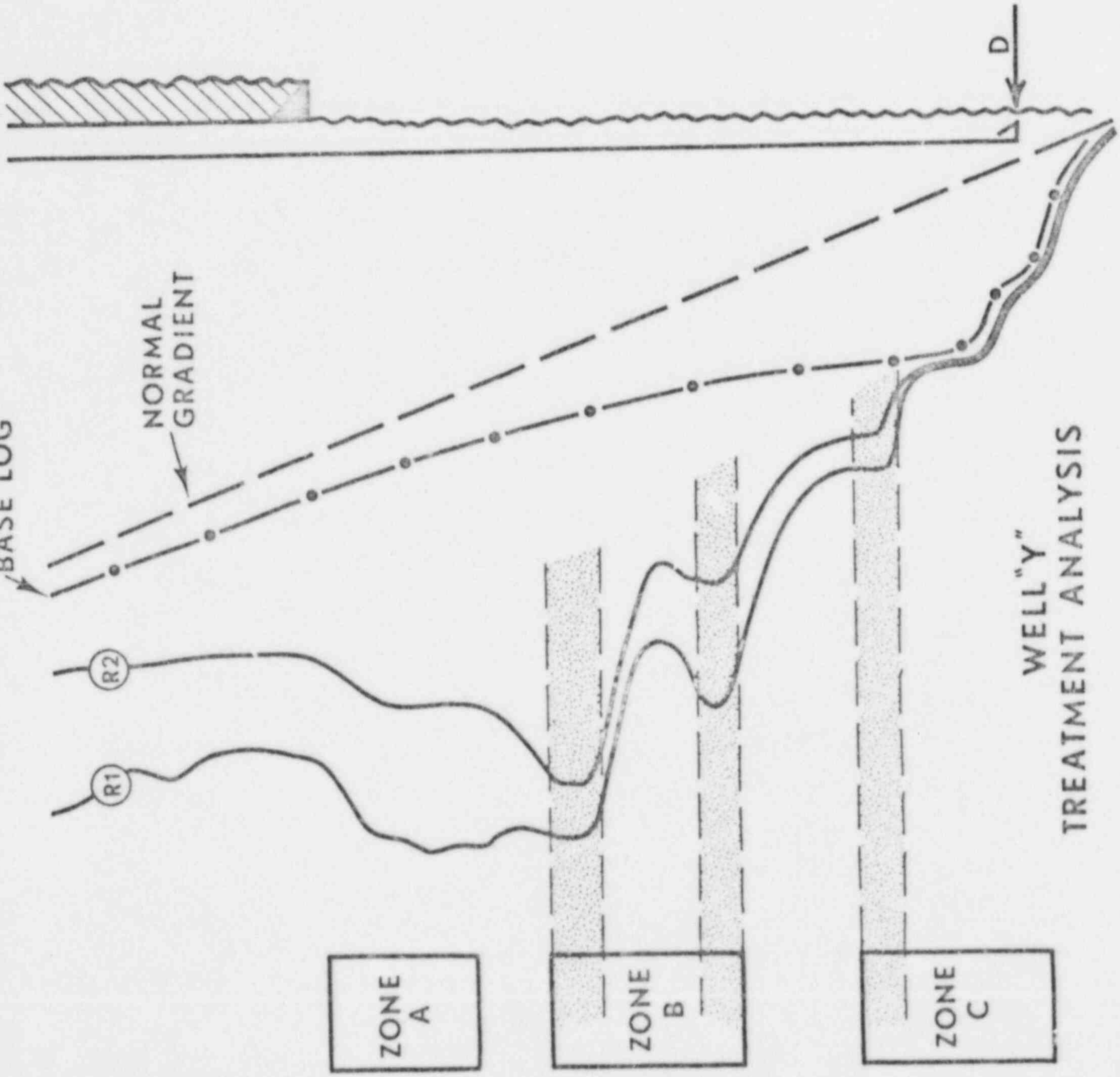
WELL "B"
BASE CURVE COMPARISON

FIG. 13



3 PHASE TEMPERATURE INFLUENCE

FIG. 14



WELL "Y"
TREATMENT ANALYSIS

FIG. 15

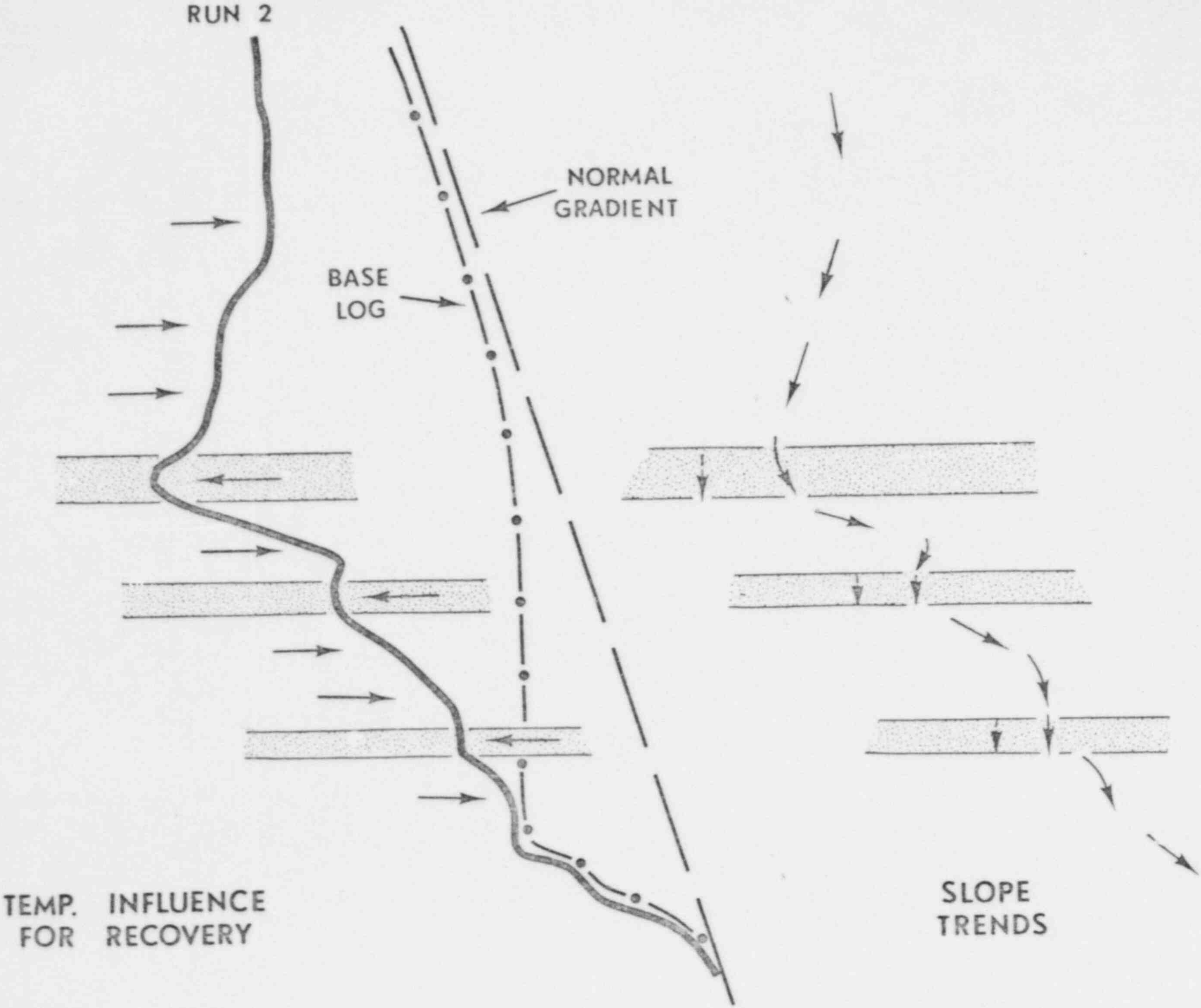

RUN 2
NORMAL
GRADIENT
BASE
LOG
TEMP. INFLUENCE
FOR RECOVERY
SLOPE
TRENDS

FIG. 16

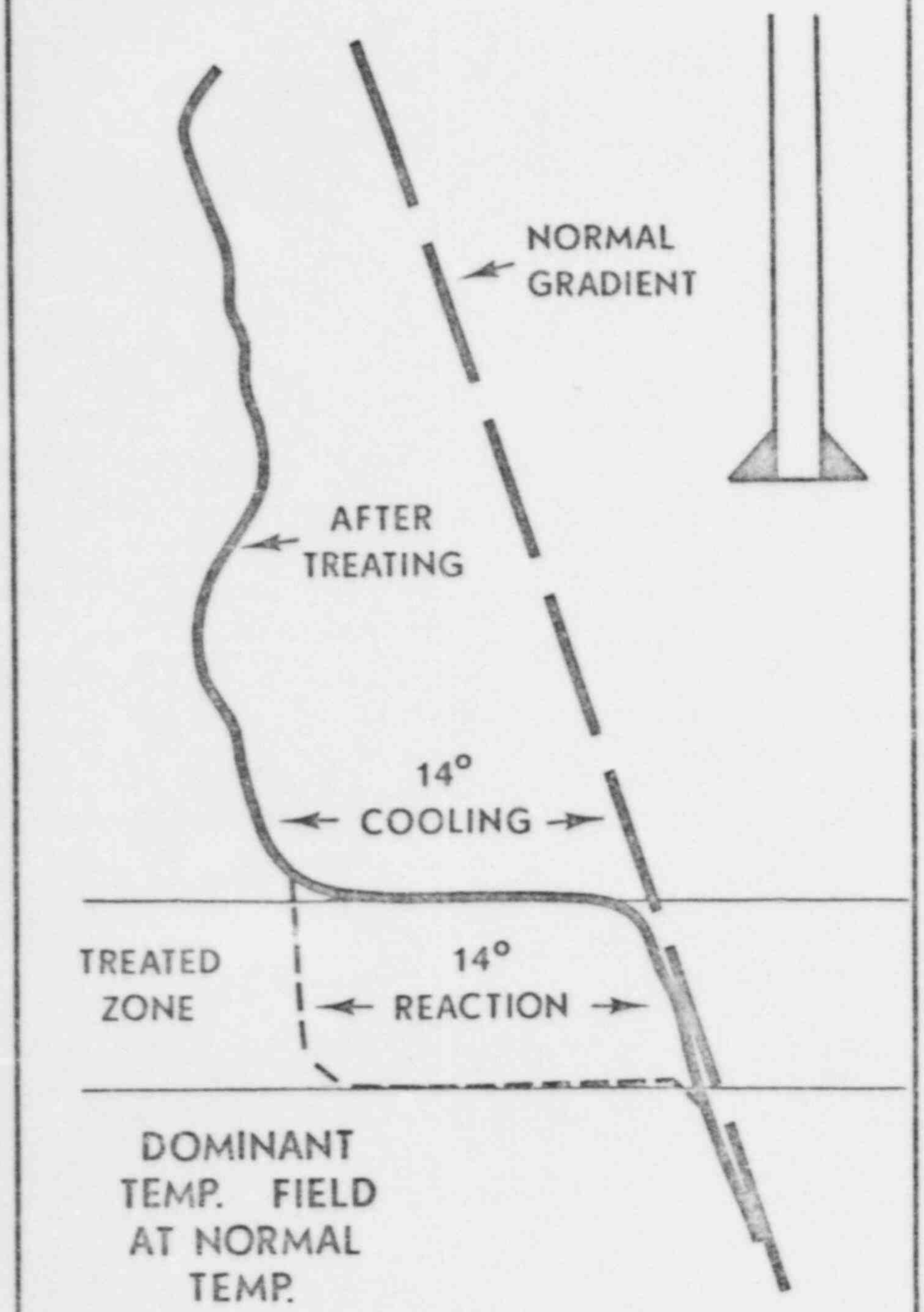


FIG. 17-A

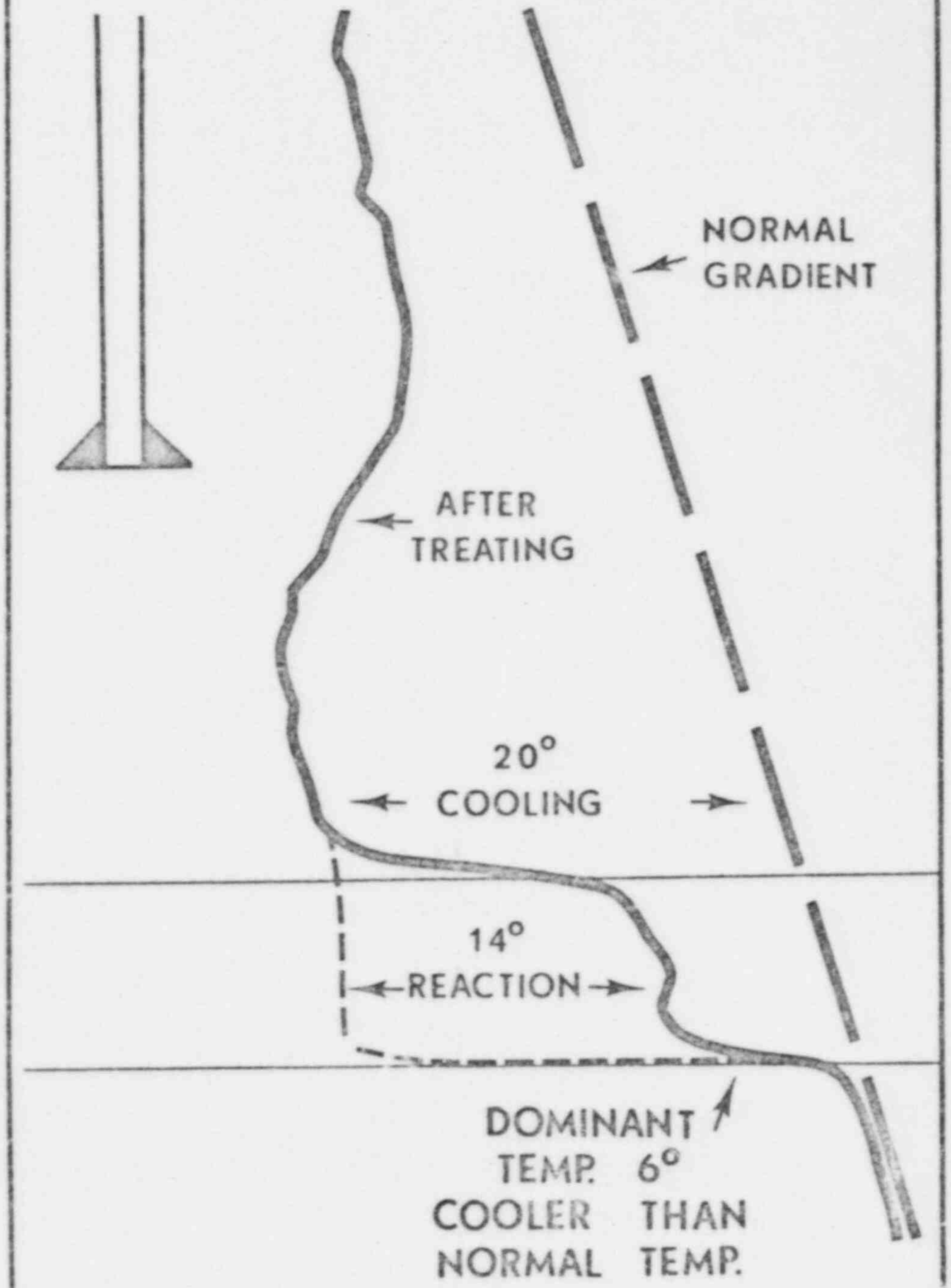
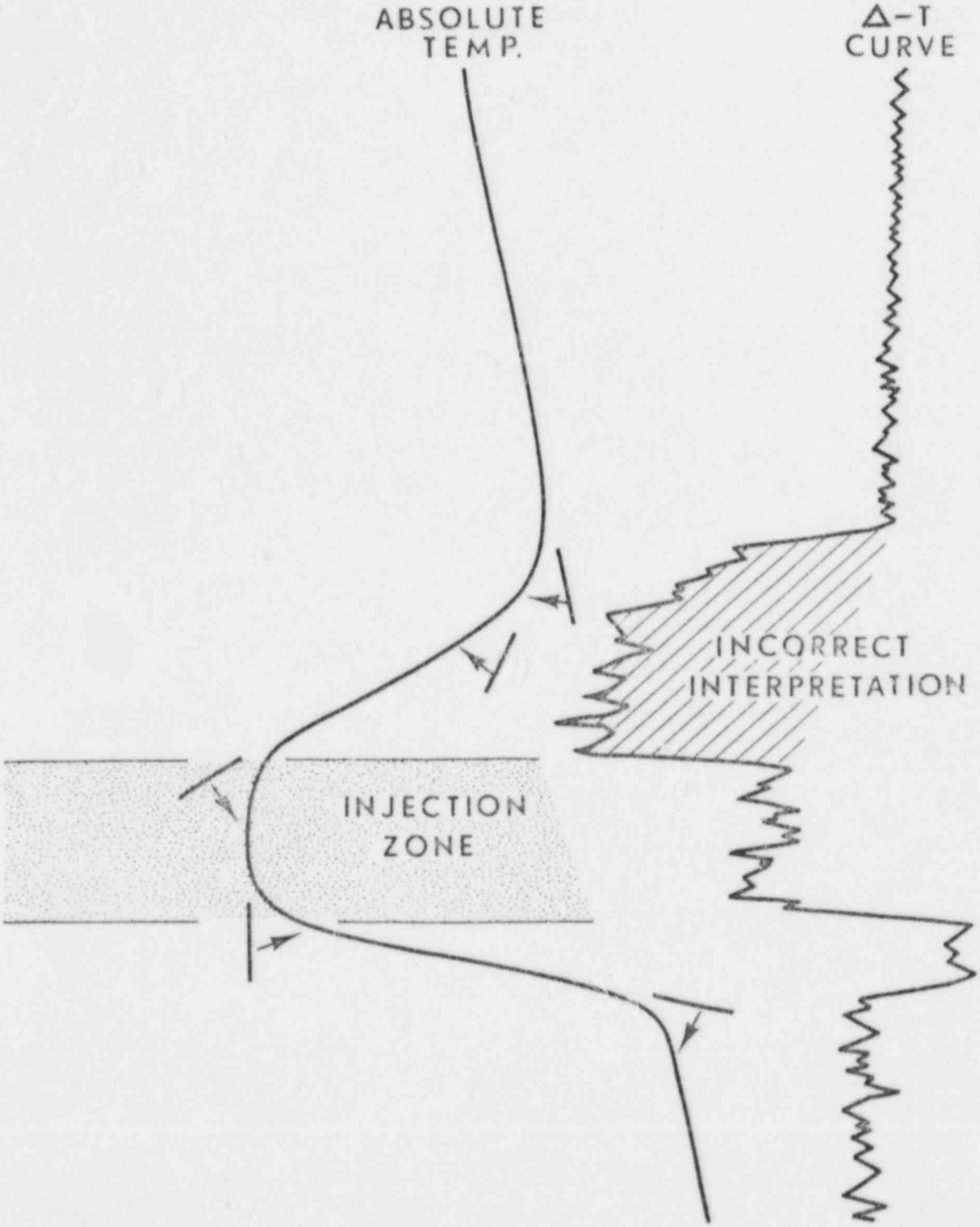


FIG. 17-B



INCORRECT USE OF
"DIFFERENTIAL" CURVE

FIG. 18

OVERSIZE DOCUMENT PAGE PULLED

SEE APERTURE CARDS

NUMBER OF PAGES: 2

ACCESSION NUMBER(S):

8512180168-01

168-01/01

APERTURE CARD/HARD COPY AVAILABLE FROM RECORD SERVICES BRANCH, TIDC
FTS 492-8989

Exhibit D

Regulatory File Cy.

DOCKET NO. 40-8027

Received W/Ltr. Dated MAY 10 1972

SPERRY-SUN

PRECISION PRESSURE GAUGE REPORT

FOR

KERR-McGEE CORPORATION

DOCKETED USAEC MAY 16 1972 REGULATORY MAIL SECTION DOCKET CLERK

SPERRY-SUN

RECEIVED MAY 16 1972 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

TYPE OF TEST: PRESSURE FALL OFF- SURFACE PRESSURE

DEPTH: 2650 FT. TEMPERATURE 87

LEASE: SEQUOYAH WA[illegible] FACILITY WELL NO. 1

FIELD: GORE

COUNTY/PARISH SEQUOYAH STATE OKLAHOMA

DATE OF TEST 6-28 To 7-12-71 JOB NO. SPG-7140

OFFICE: OKLAHOMA CITY, OKLAHOMA Phone: AC/405 685-5648

2661

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE SEQUOYAH WASTE FACILITY WELL NO. 1
FIELD WC LOCATION SEQUOYAH COUNTY OKLA.
COUNTY/PARISH SEQUOYAH
STATE OKLAHOMA
TYPE TEST PRESSURE FALL OFF JOB NO. SPG-7140
DATE OF TEST 6-28-71 TO 6-29-71

REFERENCE ELEV 579. FT. REFERENCE POINT KELLY BUSHING
DATUM -0. FT. REF. SEA LEVEL

NOTE: ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRES. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	183	2900.	-.0	-.000	107.	109,583 + EXT = 64,372
2	183	2900.	-.0	-.000	107.	109,583 + EXT = 66,372

GRADIENT STOPS

DEPTH INTERVAL (FT.)	PRESSURE DIFF. (PSI)	GRADIENT (PSI/FT.)
0. TO 150.	45.40	.3030
150. TO 400.	103.05	.4320
400. TO 800.	187.06	.4680
800. TO 1200.	190.14	.4750
1200. TO 1400.	97.79	.4890
1600. TO 2100.	341.05	.4870
2100. TO 2500.	193.31	.4100
2500. TO 2600.	49.09	.4910

--CONTINUED--

LEASE SEQUOYAN WASTE FACILITY WELL NO, 1

2800, TO 3100, 239,22 ,4700

COMMENTS: THIS IS A 26 HOUR PRESSURE FALL OFF TEST
RAN TANDEM GAUGES IN 2 MIN, MODE
STATIC GRADIENT TAKEN BEFORE INJECTION

LEASE SEQUOYAN WASTE FACILITY   WELL NO, 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
,000	1365,582	17:17	6-29-71	ON BOTTOM
,033	1367,649	17:19	6-29-71	
,066	1368,354	17:21	6-29-71	
,099	1368,729	17:23	6-29-71	
,132	1368,964	17:25	6-29-71	
,165	1369,058	17:27	6-29-71	
,198	1368,964	17:29	6-29-71	
,231	1369,199	17:31	6-29-71	
,264	1369,199	17:33	6-29-71	
,297	1369,199	17:35	6-29-71	
,330	1369,199	17:37	6-29-71	
,363	1369,199	17:39	6-29-71	
,396	1369,481	17:41	6-29-71	
,429	1369,293	17:43	6-29-71	
,462	1369,293	17:45	6-29-71	
,495	1369,434	17:47	6-29-71	
,528	1369,434	17:49	6-29-71	
,561	1369,434	17:51	6-29-71	
,594	1369,434	17:53	6-29-71	
,660	1369,011	17:57	6-29-71	
,693	1369,199	17:59	6-29-71	
,726	1369,528	18:01	6-29-71	
,759	1369,528	18:03	6-29-71	
,792	1369,481	18:05	6-29-71	
,825	1369,528	18:07	6-29-71	
,858	1369,528	18:08	6-29-71	
,891	1369,528	18:10	6-29-71	
,924	1369,528	18:12	6-29-71	
,990	1369,528	18:16	6-29-71	
1,023	1369,528	18:18	6-29-71	
1,056	1369,528	18:20	6-29-71	
,000	1369,528	18:20	6-29-71	START FALL OFF
,033	1363,516	18:22	6-29-71	
,066	1362,905	18:24	6-29-71	
,099	1362,529	18:26	6-29-71	
,132	1362,247	18:28	6-29-71	
,165	1362,012	18:30	6-29-71	
,198	1361,731	18:32	6-29-71	
,231	1361,543	18:34	6-29-71	
,264	1361,355	18:36	6-29-71	
,297	1361,167	18:38	6-29-71	
,330	1361,026	18:40	6-29-71	
,363	1360,932	18:42	6-29-71	
,396	1360,744	18:44	6-29-71	

LEASE SEQUOYAN WASTE FACILITY WELL NO. 1

,429	1360,603	18:46	6-29-71
,462	1360,556	18:48	6-29-71
,495	1360,415	18:50	6-29-71
,528	1360,321	18:52	6-29-71
,561	1360,181	18:54	6-29-71
,594	1360,134	18:56	6-29-71
,627	1360,087	18:58	6-29-71
,660	1360,087	19:00	6-29-71
,693	1359,946	19:02	6-29-71
,726	1359,899	19:04	6-29-71
,759	1359,899	19:06	6-29-71
,792	1359,899	19:08	6-29-71
,825	1359,899	19:10	6-29-71
,858	1359,805	19:12	6-29-71
,891	1359,758	19:14	6-29-71
,924	1359,711	19:16	6-29-71
,957	1359,617	19:18	6-29-71
,990	1359,617	19:20	6-29-71
1.023	1359,617	19:22	6-29-71
1,056	1359,570	19:24	6-29-71
1.089	1359,570	19:26	6-29-71
1.122	1359,523	19:28	6-29-71
1,155	1359,570	19:30	6-29-71
1,188	1359,570	19:32	6-29-71
1,221	1359,570	19:34	6-29-71
1,254	1359,570	19:36	6-29-71
1,287	1359,570	19:38	6-29-71
1,320	1359,570	19:40	6-29-71
1,353	1359,570	19:42	6-29-71
1,386	1359,523	19:44	6-29-71
1,551	1359,523	19:53	6-29-71
1,716	1359,617	20:03	6-29-71
1,881	1359,617	20:13	6-29-71
2.046	1359,617	20:23	6-29-71
2,211	1359,758	20:33	6-29-71
2,376	1359,758	20:43	6-29-71
2,541	1359,852	20:53	6-29-71
2,706	1359,852	21:03	6-29-71
2,871	1359,993	21:13	6-29-71
3.201	1359,993	21:32	6-29-71
3,531	1360,134	21:52	6-29-71
3.861	1360.134	22:12	6-29-71
4,191	1360,228	22:32	6-29-71
4,521	1360,228	22:52	6-29-71
4,851	1360,369	23:11	6-29-71
5,181	1360,369	23:31	6-29-71
5,511	1360,369	23:51	6-29-71
5,841	1360,462	0:11	6-30-71
6,171	1360,509	0:31	6-30-71
6,501	1360,509	0:50	6-30-71
6,831	1360,509	1:10	6-30-71

LEASE SEQUOYAN WASTE FACILITY WELL NO. 1

7,161	1360,509	1:30	6-30-71	
7,491	1360,556	1:50	6-30-71	
7,821	1360,556	2:10	6-30-71	
8,151	1360,556	2:29	6-30-71	
9,801	1360,650	4:08	6-30-71	
11,451	1360,603	5:47	6-30-71	
13,101	1360,556	7:26	6-30-71	
14,751	1360,603	9:05	6-30-71	
16,467	1360,603	10:48	6-30-71	
18,051	1360,509	12:23	6-30-71	
19,767	1360,603	14:06	6-30-71	
21,351	1360,462	15:41	6-30-71	
23,067	1360,321	17:24	6-30-71	
24,651	1360,321	18:59	6-30-71	
25,311	1360,321	19:39	6-30-71	
25,872	1360,321	20:13	6-30-71	END TEST

NO POINTS REPORTED = 111

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE	SEQUOYAH PLANT	WELL NO. 1	
FIELD	WC	LOCATION OKLAHOMA	
COUNTY/PARISH	SEQUOYAH		
STATE	OKLAHOMA		
TYPE TEST	PRESSURE DRAWDOWN	JOB NO.	SPG-7140
DATE OF TEST	JULY 6, 1971		

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	177	2650.	.0	.000	87.	56.296 * EXT - 48.366
2	177	2650.	.0	.000	87.	56.296 * EXT - 48.366

COMMENTS< THIS IS FIVE HOUR TEST WITH INJECTION THE FIRST 15 MINUTES
THEN SHUT-IN FOR REMAINER OF THE 5 HOURS

LEASE SEQUOYAH PLANT　　　　　　　　WELL NO. 1

31006

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
-.262	1273.196	9<~~00~~15	7- 6-71	ON BOTTOM
-.258	1273.727	9<16	7- 6-71	
-.253	1273.944	9<16	7- 6-71	
-.249	1273.775	9<16	7- 6-71	
-.245	1273.896	9<16	7- 6-71	
-.241	1273.896	9<17	7- 6-71	
-.237	1273.872	9<17	7- 6-71	
-.233	1273.823	9<17	7- 6-71	
-.229	1273.751	9<17	7- 6-71	
-.224	1273.992	9<18	7- 6-71	
-.220	1273.823	9<18	7- 6-71	
-.216	1273.944	9<18	7- 6-71	
-.212	1273.944	9<18	7- 6-71	
-.208	1273.896	9<19	7- 6-71	
-.204	1273.872	9<19	7- 6-71	
-.199	1273.992	9<19	7- 6-71	
-.195	1273.920	9<19	7- 6-71	
-.191	1273.968	9<20	7- 6-71	
-.187	1273.896	9<20	7- 6-71	
-.183	1274.040	9<20	7- 6-71	
-.179	1273.896	9<20	7- 6-71	
-.175	1273.920	9<21	7- 6-71	
-.170	1273.944	9<21	7- 6-71	
-.166	1273.920	9<21	7- 6-71	
-.162	1273.823	9<21	7- 6-71	
-.158	1273.896	9<22	7- 6-71	
-.137	1273.896	9<23	7- 6-71	
-.116	1273.872	9<24	7- 6-71	
-.096	1273.872	9<25	7- 6-71	
-.075	1273.920	9<27	7- 6-71	
-.054	1273.920	9<28	7- 6-71	
-.033	1273.847	9<29	7- 6-71	
-.012	1273.847	9<30	7- 6-71	
.000	1273.823	9<30	7- 6-71	END INJECTION
.000	1263.254	9<30	7- 6-71	START FALL OFF
.004	1250.417	9<30	7- 6-71	
.008	1251.841	9<31	7- 6-71	
.013	1266.801	9<31	7- 6-71	
.017	1269.818	9<31	7- 6-71	
.021	1269.118	9<31	7- 6-71	
.025	1268.852	9<31	7- 6-71	
.029	1268.780	9<32	7- 6-71	
.033	1268.732	9<32	7- 6-71	
.037	1268.732	9<32	7- 6-71	

31008

.042	1268.732	9<32	7- 6-71
.046	1268.732	9<33	7- 6-71
.050	1268.708	9<33	7- 6-71
.054	1268.708	9<33	7- 6-71
.058	1268.684	9<33	7- 6-71
.062	1268.684	9<34	7- 6-71
.067	1268.659	9<34	7- 6-71
.071	1268.635	9<34	7- 6-71
.075	1268.611	9<34	7- 6-71
.079	1268.587	9<35	7- 6-71
.083	1268.563	9<35	7- 6-71
.087	1268.539	9<35	7- 6-71
.091	1268.515	9<35	7- 6-71
.096	1268.490	9<36	7- 6-71
.100	1268.490	9<36	7- 6-71
.104	1268.490	9<36	7- 6-71
.108	1268.466	9<36	7- 6-71
.112	1268.466	9<37	7- 6-71
.116	1268.442	9<37	7- 6-71
.121	1268.442	9<37	7- 6-71
.125	1268.418	9<37	7- 6-71
.129	1268.394	9<38	7- 6-71
.133	1268.394	9<38	7- 6-71
.137	1268.346	9<38	7- 6-71
.141	1268.346	9<38	7- 6-71
.146	1268.322	9<39	7- 6-71
.150	1268.322	9<39	7- 6-71
.154	1268.297	9<39	7- 6-71
.158	1268.273	9<39	7- 6-71
.162	1268.249	9<40	7- 6-71
.166	1268.225	9<40	7- 6-71
.187	1268.177	9<41	7- 6-71
.208	1268.104	9<42	7- 6-71
.229	1268.032	9<44	7- 6-71
.249	1267.984	9<45	7- 6-71
.270	1267.911	9<46	7- 6-71
.291	1267.839	9<47	7- 6-71
.312	1267.767	9<49	7- 6-71
.333	1267.718	9<50	7- 6-71
.353	1267.646	9<51	7- 6-71
.374	1267.598	9<52	7- 6-71
.395	1267.525	9<54	7- 6-71
.416	1267.453	9<55	7- 6-71
.457	1267.332	9<57	7- 6-71
.499	1267.260	10<00	7- 6-71
.540	1267.163	10<02	7- 6-71
.582	1267.043	10<05	7- 6-71
.623	1266.922	10<07	7- 6-71
.665	1266.825	10<10	7- 6-71
.707	1266.753	10<12	7- 6-71
.748	1266.681	10<15	7- 6-71

31010

.790	1266.608	10<17	7- 6-71
.831	1266.536	10<20	7- 6-71
.873	1266.464	10<22	7- 6-71
.914	1266.367	10<25	7- 6-71
.956	1266.319	10<27	7- 6-71
.998	1266.222	10<30	7- 6-71
1.205	1265.909	10<42	7- 6-71
1.413	1265.571	10<55	7- 6-71
1.621	1265.329	11<07	7- 6-71
1.829	1265.088	11<20	7- 6-71
2.037	1264.847	11<32	7- 6-71
2.244	1264.654	11<45	7- 6-71
2.452	1264.485	11<57	7- 6-71
2.660	1264.268	12<10	7- 6-71
2.868	1264.051	12<22	7- 6-71
3.076	1263.833	12<35	7- 6-71
3.283	1263.689	12<47	7- 6-71
3.491	1263.496	12<59	7- 6-71
3.699	1263.302	13<12	7- 6-71
3.907	1263.134	13<24	7- 6-71
4.115	1262.965	13<37	7- 6-71
4.322	1262.796	13<49	7- 6-71
4.530	1262.627	14<02	7- 6-71
4.738	1262.458	14<14	7- 6-71 END TEST

NO. POINTS REPORTED = 119

31021

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE SEQUOYAH PLANT WELL NO. 1
FIELD WC LOCATION OKLAHOMA
COUNTY/PARISH SEQUOYAH
STATE OKLAHOMA
TYPE TEST SURFACE RECORDING JOB NO. SPG-7140
DATE OF TEST JULY 6, 1971

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	187	0.	.0	.000	90.	14.343 * EXT - 8.384

COMMENTS< GAUGE USED TO RECORD SURFACE PRESSURE

31022

LEASE SEQUOYAH PLANT WELL NO. 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
.000	128.663	9<12	7- 6-71	SURFACE GUAGE
.004	129.314	9<12	7- 6-71	
.008	129.320	9<12	7- 6-71	
.012	129.449	9<13	7- 6-71	
.016	128.510	9<13	7- 6-71	
.021	127.957	9<13	7- 6-71	
.025	128.583	9<13	7- 6-71	
.029	127.072	9<14	7- 6-71	
.033	128.135	9<14	7- 6-71	
.037	125.739	9<14	7- 6-71	
.041	127.146	9<14	7- 6-71	
.045	126.784	9<15	7- 6-71	
.049	126.888	9<15	7- 6-71	
.054	126.673	9<15	7- 6-71	
.058	126.065	9<15	7- 6-71	
.062	127.429	9<16	7- 6-71	
.066	127.349	9<16	7- 6-71	
.070	126.833	9<16	7- 6-71	
.074	127.717	9<16	7- 6-71	
.078	129.357	9<17	7- 6-71	
.082	128.903	9<17	7- 6-71	
.087	128.804	9<17	7- 6-71	
.091	128.749	9<17	7- 6-71	
.095	130.144	9<18	7- 6-71	
.099	129.001	9<18	7- 6-71	
.103	129.247	9<18	7- 6-71	
.107	129.886	9<18	7- 6-71	
.111	128.473	9<19	7- 6-71	
.115	128.829	9<19	7- 6-71	
.120	129.916	9<19	7- 6-71	
.124	128.792	9<19	7- 6-71	
.128	128.424	9<20	7- 6-71	
.132	130.371	9<20	7- 6-71	
.136	130.107	9<20	7- 6-71	
.140	129.468	9<20	7- 6-71	
.144	129.855	9<21	7- 6-71	
.148	130.039	9<21	7- 6-71	
.153	129.560	9<21	7- 6-71	
.157	129.855	9<21	7- 6-71	
.161	129.204	9<22	7- 6-71	
.165	128.817	9<22	7- 6-71	
.169	129.701	9<22	7- 6-71	
.173	129.640	9<22	7- 6-71	
.177	129.394	9<23	7- 6-71	
.181	130.266	9<23	7- 6-71	

31023

LEASE SEQUOYAH PLANT WELL NO. 1

.186	128.786	9<23	7- 6-71
.190	129.603	9<23	7- 6-71
.194	129.671	9<24	7- 6-71
.198	129.978	9<24	7- 6-71
.202	129.118	9<24	7- 6-71
.206	129.898	9<24	7- 6-71
.210	129.179	9<25	7- 6-71
.214	129.566	9<25	7- 6-71
.219	128.411	9<25	7- 6-71
.223	128.798	9<25	7- 6-71
.227	129.302	9<26	7- 6-71
.231	130.082	9<26	7- 6-71
.235	128.000	9<26	7- 6-71
.239	129.056	9<26	7- 6-71
.243	128.012	9<27	7- 6-71
.247	129.511	9<27	7- 6-71
.252	129.671	9<27	7- 6-71
.256	128.731	9<27	7- 6-71
.260	130.021	9<28	7- 6-71
.264	129.327	9<28	7- 6-71
.268	129.689	9<28	7- 6-71
.272	129.898	9<28	7- 6-71
.276	129.001	9<29	7- 6-71
.280	129.271	9<29	7- 6-71
.285	128.166	9<29	7- 6-71
.289	128.405	9<29	7- 6-71
.293	128.970	9<30	7- 6-71
.297	128.909	9<30	7- 6-71
.301	129.062	9<30	7- 6-71
.305	128.700	9<30	7- 6-71
.309	129.738	9<31	7- 6-71
.313	129.769	9<31	7- 6-71
.318	85.849	9<31	7- 6-71
.322	84.910	9<31	7- 6-71
.326	87.920	9<32	7- 6-71
.330	90.463	9<32	7- 6-71
.334	94.081	9<32	7- 6-71
.338	97.938	9<32	7- 6-71
.342	102.097	9<33	7- 6-71
.346	106.126	9<33	7- 6-71
.351	109.861	9<33	7- 6-71
.355	112.594	9<33	7- 6-71
.359	116.003	9<34	7- 6-71
.363	118.301	9<34	7- 6-71
.367	119.910	9<34	7- 6-71
.371	120.887	9<34	7- 6-71
.375	121.483	9<35	7- 6-71
.379	121.667	9<35	7- 6-71
.384	121.630	9<35	7- 6-71
.388	121.704	9<35	7- 6-71
.392	120.635	9<36	7- 6-71

31024

LEASE SEQUOYAH PLANT WELL NO. 1

.396	119.806	9<36	7- 6-71
.400	119.210	9<36	7- 6-71
.404	119.210	9<36	7- 6-71
.408	119.167	9<36	7- 6-71
.412	119.148	9<37	7- 6-71
.416	119.130	9<37	7- 6-71
.421	119.111	9<37	7- 6-71
.425	119.087	9<37	7- 6-71
.429	119.087	9<38	7- 6-71
.433	119.038	9<38	7- 6-71
.437	119.007	9<38	7- 6-71
.441	119.001	9<38	7- 6-71
.445	118.946	9<39	7- 6-71
.449	118.909	9<39	7- 6-71
.454	118.896	9<39	7- 6-71
.458	118.903	9<39	7- 6-71
.462	118.872	9<40	7- 6-71
.466	118.835	9<40	7- 6-71
.470	118.792	9<40	7- 6-71
.474	118.829	9<40	7- 6-71
.478	118.761	9<41	7- 6-71
.482	118.761	9<41	7- 6-71
.487	118.767	9<41	7- 6-71
.491	118.761	9<41	7- 6-71
.495	118.749	9<42	7- 6-71
.515	118.669	9<43	7- 6-71
.536	118.589	9<44	7- 6-71
.557	118.485	9<45	7- 6-71
.577	118.399	9<47	7- 6-71
.619	118.276	9<49	7- 6-71
.660	118.184	9<52	7- 6-71
.701	118.061	9<54	7- 6-71
.742	117.920	9<57	7- 6-71
.784	117.846	9<59	7- 6-71
.825	117.674	10<01	7- 6-71
1.031	117.232	10<14	7- 6-71
1.237	116.925	10<26	7- 6-71
1.443	116.667	10<39	7- 6-71
1.649	116.433	10<51	7- 6-71
1.856	116.255	11<03	7- 6-71
2.062	116.102	11<16	7- 6-71
2.268	115.862	11<28	7- 6-71
2.474	115.451	11<40	7- 6-71
2.680	115.027	11<53	7- 6-71
2.887	114.695	12<05	7- 6-71
3.093	114.388	12<18	7- 6-71
3.299	114.124	12<30	7- 6-71
3.505	113.841	12<42	7- 6-71
3.711	113.540	12<55	7- 6-71
3.918	113.307	13<07	7- 6-71
4.124	113.061	13<19	7- 6-71

LEASE SEQUOYAH PLANT WELL NO. 1

4.330	112.963	13<32	7- 6-71	
4.536	112.815	13<44	7- 6-71	
4.742	112.864	13<57	7- 6-71	
4.800	112.864	14<00	7- 6-71	END TEST

NO. POINTS REPORTED = 151

30934

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE	SEQUOYAH PLANT	WELL NO. 1	
FIELD	WC	LOCATION OKLAHOMA	
COUNTY/PARISH	SEQUOYAH		
STATE	OKLAHOMA		
TYPE TEST	72-HR. DRAWDOWN	JOB NO.	SPG-7140
DATE OF TEST	JULY 9, 1971		

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	177	2650.	.0	.000	81.	56.296 * EXT - 48.366

GRADIENT STOPS

DEPTH INTERVAL (FT.)	PRESSURE DIFF. (PSI)	GRADIENT (PSI/FT.)
1650. TO 1850.	91.97	.4600
1850. TO 2050.	93.65	.4680
2050. TO 2250.	93.72	.4690
2250. TO 2450.	92.70	.4640
2450. TO 2650.	94.02	.4700

COMMENTS< THIS IS A 72 HR. TEST FOR PRESSURE FALL OFF
GUAGE SET IN 4 MIN. MODE ON JULY 6, 1971 UNTIL JULY 9, 1971

LEASE SEQUOYAH PLANT WELL NO. 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
.000	1259.973	15<05	7- 6-71	START FALL OFF
.067	1261.686	15<09	7- 6-71	
.134	1261.686	15<13	7- 6-71	
.201	1261.662	15<17	7- 6-71	
.269	1261.638	15<21	7- 6-71	
.336	1261.613	15<25	7- 6-71	
.403	1261.565	15<29	7- 6-71	
.470	1261. 65	15<33	7- 6-71	
.537	1261.517	15<37	7- 6-71	
.604	1261.469	15<41	7- 6-71	
.672	1261.444	15<45	7- 6-71	
.739	1261.420	15<49	7- 6-71	
.806	1261.396	15<53	7- 6-71	
.873	1261.396	15<57	7- 6-71	
.940	1261.348	16<01	7- 6-71	
1.007	1261.227	16<05	7- 6-71	
1.075	1261.179	16<09	7- 6-71	
1.142	1261.155	16<14	7- 6-71	
1.209	1261.155	16<18	7- 6-71	
1.276	1261.155	16<22	7- 6-71	
1.343	1261.131	16<26	7- 6-71	
1.410	1261.083	16<30	7- 6-71	
1.478	1261.034	16<34	7- 6-71	
1.545	1261.034	16<38	7- 6-71	
1.612	1260.986	16<42	7- 6-71	
1.881	1260.938	16<58	7- 6-71	
2.149	1260.769	17<14	7- 6-71	
2.418	1260.721	17<30	7- 6-71	
2.687	1260.648	17<46	7- 6-71	
2.955	1260.552	18<02	7- 6-71	
3.224	1260.479	18<18	7- 6-71	
3.493	1260.359	18<35	7- 6-71	
3.761	1260.286	18<51	7- 6-71	
4.030	1260.214	19<07	7- 6-71	
4.299	1260.141	19<23	7- 6-71	
4.567	1260.069	19<39	7- 6-71	
4.836	1259.997	19<55	7- 6-71	
5.104	1259.900	20<11	7- 6-71	
5.373	1259.852	20<27	7- 6-71	
5.642	1259.755	20<44	7- 6-71	
5.910	1259.683	21<00	7- 6-71	
6.179	1259.635	21<16	7- 6-71	
6.448	1259.514	21<32	7- 6-71	
6.716	1259.442	21<48	7- 6-71	
6.985	1259.369	22<04	7- 6-71	

7.254	1259.273	22<20	7- 6-71	
7.522	1259.200	22<36	7- 6-71	
7.791	1259.152	22<52	7- 6-71	
8.060	1259.080	23<09	7- 6-71	
8.328	1259.007	23<25	7- 6-71	
9.403	1258.742	0<29	7- 7-71	
10.478	1258.573	1<34	7- 7-71	
11.552	1258.356	2<38	7- 7-71	
12.627	1258.090	3<43	7- 7-71	
13.701	1257.897	4<47	7- 7-71	
14.776	1257.728	5<52	7- 7-71	
15.851	1257.535	6<56	7- 7-71	
16.925	1257.318	8<01	7- 7-71	
18.000	1257.149	9<05	7- 7-71	
19.075	1256.932	10<09	7- 7-71	
20.149	1256.715	11<14	7- 7-71	
21.224	1256.570	12<18	7- 7-71	
22.298	1256.377	13<23	7- 7-71	
23.373	1256.281	14<27	7- 7-71	
24.448	1256.136	15<32	7- 7-71	
25.522	1256.088	16<36	7- 7-71	
26.597	1255.943	17<41	7- 7-71	
27.672	1255.846	18<45	7- 7-71	
28.746	1255.726	19<50	7- 7-71	
29.821	1255.605	20<54	7- 7-71	
30.895	1255.436	21<59	7- 7-71	
31.970	1255.315	23<03	7- 7-71	
33.045	1255.171	0<08	7- 8-71	
34.119	1255.050	1<12	7- 8-71	
35.194	1254.929	2<17	7- 8-71	
37.343	1254.712	4<26	7- 8-71	
39.492	1254.543	6<35	7- 8-71	
41.642	1254.326	8<44	7- 8-71	
43.791	1254.109	10<52	7- 8-71	
45.940	1253.916	13<01	7- 8-71	
48.089	1253.675	15<10	7- 8-71	
50.239	1253.554	17<19	7- 8-71	
52.388	1253.457	19<28	7- 8-71	
54.537	1253.288	21<37	7- 8-71	
56.686	1253.144	23<46	7- 8-71	
58.836	1252.951	1<55	7- 9-71	
60.985	1252.758	4<04	7- 9-71	
63.134	1252.637	6<13	7- 9-71	
65.284	1252.516	8<22	7- 9-71	
67.433	1252.372	10<31	7- 9-71	
69.582	1252.154	12<40	7- 9-71	
71.731	1251.985	14<49	7- 9-71	
71.798	1251.985	14<53	7- 9-71	
71.866	1251.961	14<57	7- 9-71	
71.933	1251.961	15<01	7- 9-71	
72.000	1251.985	15<05	7- 9-71	END TEST

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE SEQUOYAH PLANT WELL NO. 1
FIELD WC LOCATION OKLAHOMA
COUNTY/PARISH SEQUOYAH
STATE OKLAHOMA
TYPE TEST SURFACE RECORDING JOB NO. SPG-7140
DATE OF TEST JULY 6 TO 9, 1971

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	187	0.	.0	.000	90.	14.343 * EXT - 8.384

COMMENTS< THIS IS RESULTS OF SURFACE PRESSURE WITH SPERRY-SUN GAUGE

LEASE SEQUOYAH PLANT WELL NO. 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
.000	113.608	15<05	7- 6-71	START SURFACE
.067	103.753	15<09	7- 6-71	
.134	96.732	15<13	7- 6-71	
.201	96.689	15<17	7- 6-71	
.268	96.517	15<21	7- 6-71	
.335	96.474	15<25	7- 6-71	
.402	96.425	15<29	7- 6-71	
.469	96.308	15<33	7- 6-71	
.536	96.314	15<37	7- 6-71	
.603	96.246	15<41	7- 6-71	
.670	96.197	15<45	7- 6-71	
.737	94.242	15<49	7- 6-71	
.804	93.646	15<53	7- 6-71	
.872	94.095	15<57	7- 6-71	
.939	95.072	16<01	7- 6-71	
1.006	96.394	16<05	7- 6-71	
1.073	97.722	16<09	7- 6-71	
1.140	98.619	16<13	7- 6-71	
1.207	99.308	16<17	7- 6-71	
1.274	99.394	16<21	7- 6-71	
1.341	99.253	16<25	7- 6-71	
1.408	99.037	16<29	7- 6-71	
1.475	90.105	16<33	7- 6-71	
1.542	95.767	16<38	7- 6-71	
1.609	96.142	16<42	7- 6-71	
1.676	95.976	16<46	7- 6-71	
1.743	95.920	16<50	7- 6-71	
1.810	95.841	16<54	7- 6-71	
1.877	95.779	16<58	7- 6-71	
1.944	95.711	17<02	7- 6-71	
2.011	95.644	17<06	7- 6-71	
2.078	95.545	17<10	7- 6-71	
2.145	95.447	17<14	7- 6-71	
2.212	95.324	17<18	7- 6-71	
2.279	95.213	17<22	7- 6-71	
2.547	94.869	17<38	7- 6-71	
2.816	94.642	17<54	7- 6-71	
3.084	94.488	18<10	7- 6-71	
3.352	94.402	18<26	7- 6-71	
3.620	94.297	18<42	7- 6-71	
3.888	94.033	18<58	7- 6-71	
4.156	93.658	19<14	7- 6-71	
4.425	93.160	19<30	7- 6-71	
4.693	92.822	19<47	7- 6-71	
4.961	92.674	20<03	7- 6-71	

LEASE SEQUOYAH PLANT WELL NO. 1

5.229	92.453	20<19	7- 6-71	
5.497	92.201	20<35	7- 6-71	
5.765	91.795	20<51	7- 6-71	
6.034	91.353	21<07	7- 6-71	
8.179	88.475	23<16	7- 6-71	
10.324	86.428	1<24	7- 7-71	
12.469	84.350	3<33	7- 7-71	
14.615	82.469	5<42	7- 7-71	
16.760	80.871	7<51	7- 7-71	
18.905	80.047	9<59	7- 7-71	
21.050	79.082	12<08	7- 7-71	
23.196	78.086	14<17	7- 7-71	
25.341	77.477	16<25	7- 7-71	
27.486	76.395	18<34	7- 7-71	
29.631	74.729	20<43	7- 7-71	
31.777	72.583	22<52	7- 7-71	
33.922	71.182	1<00	7- 8-71	
36.067	69.841	3<09	7- 8-71	
38.212	68.809	5<18	7- 8-71	
40.358	67.806	7<26	7- 8-71	
42.503	67.474	9<35	7- 8-71	
44.648	67.290	11<44	7- 8-71	
46.793	66.718	13<53	7- 8-71	
48.939	66.454	16<01	7- 8-71	
51.084	65.962	18<10	7- 8-71	
53.229	64.966	20<19	7- 8-71	
55.374	63.583	22<27	7- 8-71	
57.520	62.728	0<36	7- 9-71	
59.665	61.911	2<45	7- 9-71	
61.810	61.068	4<54	7- 9-71	
63.955	60.540	7<02	7- 9-71	
66.101	60.300	9<11	7- 9-71	
68.246	60.515	11<20	7- 9-71	
70.391	60.275	13<28	7- 9-71	
71.464	59.501	14<33	7- 9-71	
71.732	59.365	14<49	7- 9-71	
72.000	59.267	15<05	7- 9-71	END TEST

30970

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE	SEQUOYAH PLANT	WELL NO. 1	
FIELD	WC	LOCATION	OKLAHOMA
COUNTY/PARISH	SEQUOYAH		
STATE	OKLAHOMA		
TYPE TEST	PRESSURE FALL OFF	JOB NO.	SPG-7140
DATE OF TEST	JULY 9, TO 12 1971		

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	177	2650.	.0	.000	81.	56.296 * LXT - 48.366

COMMENTS< THIS IS 72 HR. PRESSURE FALL OFF TEST

30971

LEASE SEQUOYAH PLANT WELL NO. 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
.000	1252.999	15<45	7- 9-71	START FALL OFF
.067	1253.192	15<49	7- 9-71	
.133	1253.313	15<53	7- 9-71	
.200	1253.385	15<57	7- 9-71	
.267	1253.457	16<01	7- 9-71	
.333	1253.457	16<05	7- 9-71	
.400	1253.457	16<09	7- 9-71	
.467	1253.457	16<13	7- 9-71	
.533	1253.457	16<17	7- 9-71	
.600	1253.457	16<21	7- 9-71	
.667	1253.457	16<25	7- 9-71	
.733	1253.506	16<29	7- 9-71	
.800	1253.506	16<33	7- 9-71	
.867	1253.506	16<37	7- 9-71	
.933	1253.506	16<41	7- 9-71	
1.000	1253.506	16<45	7- 9-71	
1.067	1253.506	16<49	7- 9-71	
1.133	1253.506	16<53	7- 9-71	
1.200	1253.506	16<57	7- 9-71	
1.267	1253.530	17<01	7- 9-71	
1.333	1253.530	17<05	7- 9-71	
1.400	1253.530	17<09	7- 9-71	
1.467	1253.506	17<13	7- 9-71	
1.533	1253.530	17<17	7- 9-71	
1.600	1253.554	17<21	7- 9-71	
1.867	1253.578	17<37	7- 9-71	
2.133	1253.578	17<53	7- 9-71	
2.400	1253.578	18<09	7- 9-71	
2.667	1253.578	18<25	7- 9-71	
2.933	1253.602	18<41	7- 9-71	
3.200	1253.578	18<57	7- 9-71	
3.467	1253.602	19<13	7- 9-71	
3.733	1253.602	19<29	7- 9-71	
4.000	1253.602	19<45	7- 9-71	
4.267	1253.602	20<01	7- 9-71	
6.400	1253.530	22<09	7- 9-71	
8.533	1253.457	0<17	7-10-71	
10.667	1253.337	2<25	7-10-71	
12.800	1253.240	4<33	7-10-71	
14.933	1253.192	6<41	7-10-71	
17.067	1253.120	8<49	7-10-71	
19.200	1252.999	10<57	7-10-71	
21.333	1252.854	13<05	7-10-71	
23.467	1252.758	15<13	7-10-71	
25.600	1252.709	17<21	7-10-71	

30973

LEASE SEQUOYAH PLANT WELL NO. 1

27.733	1252.661	19<29	7-10-71	
29.867	1252.685	21<37	7-10-71	
32.000	1252.589	23<45	7-10-71	
34.133	1252.444	1<53	7-11-71	
36.267	1252.372	4<01	7-11-71	
38.400	1252.347	6<09	7-11-71	
40.533	1252.275	8<17	7-11-71	
42.667	1252.203	10<25	7-11-71	
44.800	1252.058	12<33	7-11-71	
46.933	1251.937	14<41	7-11-71	
49.067	1251.841	16<49	7-11-71	
51.200	1251.817	18<57	7-11-71	
53.333	1251.817	21<05	7-11-71	
55.467	1251.744	23<13	7-11-71	
57.600	1251.672	1<21	7-12-71	
59.733	1251.575	3<29	7-12-71	
61.867	1251.503	5<37	7-12-71	
64.000	1251.455	7<45	7-12-71	
66.133	1251.382	9<53	7-12-71	
68.267	1251.286	12<01	7-12-71	
70.400	1251.165	14<09	7-12-71	
71.467	1251.093	15<13	7-12-71	
71.533	1251.093	15<17	7-12-71	
71.600	1251.093	15<21	7-12-71	
71.667	1251.093	15<25	7-12-71	
71.733	1251.093	15<29	7-12-71	
71.800	1251.068	15<33	7-12-71	
71.867	1251.093	15<37	7-12-71	
71.933	1251.093	15<41	7-12-71	
72.000	1251.093	15<45	7-12-71	END TEST

30940

SPERRY-SUN WELL SURVEYING COMPANY
PRECISION SUBSURFACE PRESSURE GAUGE REPORT
--FOR--

KERR-MCGEE CORPORATION

LEASE SEQUOYAH PLANT WELL NO. 1
FIELD WC LOCATION OKLAHOMA
COUNTY/PARISH SEQUOYAH
STATE OKLAHOMA
TYPE TEST PRESSURE DRAWDOWN JOB NO. SPG-7140
DATE OF TEST JULY 9, TO 12, 1971

REFERENCE ELEV 579. FT. REFERENCE POINT
DATUM -0. FT. REF. SEA LEVEL

NOTE< ALL REPORTED PRESSURES ARE ADJUSTED TO THE ABOVE DATUM

RUN NO.	GAUGE NO.	DEPTH (FT.)	DATUM CORR. (PSI)	PRESS. GRAD. (PSI/FT.)	TEST TEMP. (DEG.F)	CALIBRATION (BHP=)
1	187	0.	.0	.000	90.	14.343 * EXT - 8.384

COMMENTS< THIS IS SURFACE GAUGE SET FOR 72 HR. TLST

30941

LEASE SEQUOYAH PLANT WELL NO. 1

DELTA TIME	PRESSURE	TIME	DATE	COMMENT
.000	53.791	14<10	7- 9-71	START ~~FALL-OFF~~ Surface
.065	45.026	14<14	7- 9-71	
.131	47.268	14<18	7- 9-71	
.196	45.542	14<22	7- 9-71	
.261	45.548	14<26	7- 9-71	
.327	44.154	14<30	7- 9-71	
.392	51.519	14<34	7- 9-71	
.457	48.668	14<37	7- 9-71	
.523	48.564	14<41	7- 9-71	
.588	48.742	14<45	7- 9-71	
.653	48.957	14<49	7- 9-71	
.719	48.926	14<53	7- 9-71	
.784	48.748	14<57	7- 9-71	
.849	48.478	15<01	7- 9-71	
.915	45.259	15<05	7- 9-71	
.980	36.776	15<09	7- 9-71	
1.045	45.689	15<13	7- 9-71	
1.111	45.659	15<17	7- 9-71	
1.176	45.708	15<21	7- 9-71	
1.241	51.242	15<24	7- 9-71	
1.307	45.683	15<28	7- 9-71	
1.372	52.680	15<32	7- 9-71	
1.437	57.182	15<36	7- 9-71	
1.503	59.922	15<40	7- 9-71	
1.568	64.314	15<44	7- 9-71	
1.633	62.852	15<48	7- 9-71	
1.699	59.879	15<52	7- 9-71	
1.764	59.817	15<56	7- 9-71	
1.829	59.787	16<00	7- 9-71	
1.895	59.793	16<04	7- 9-71	
1.960	59.799	16<08	7- 9-71	
2.025	59.811	16<12	7- 9-71	
2.091	59.854	16<15	7- 9-71	
2.352	59.916	16<31	7- 9-71	
2.613	60.014	16<47	7- 9-71	
2.875	59.971	17<02	7- 9-71	
3.136	59.762	17<18	7- 9-71	
3.397	59.443	17<34	7- 9-71	
3.659	59.344	17<50	7- 9-71	
3.920	59.357	18<05	7- 9-71	
4.181	59.363	18<21	7- 9-71	
4.443	59.160	18<37	7- 9-71	
4.704	58.810	18<52	7- 9-71	
4.966	58.681	19<08	7- 9-71	
5.227	58.533	19<24	7- 9-71	

30943

LEASE SEQUOYAH PLANT WELL NO. 1

5.488	58.429	19<39	7- 9-71	
5.750	58.325	19<55	7- 9-71	
6.011	58.202	20<11	7- 9-71	
6.272	57.974	20<26	7- 9-71	
6.534	57.772	20<42	7- 9-71	
8.624	57.299	22<47	7- 9-71	
10.715	56.715	0<53	7-10-71	
12.806	56.267	2<58	7-10-71	
14.897	55.229	5<04	7-10-71	
16.987	55.751	7<09	7-10-71	
19.078	56.248	9<15	7-10-71	
21.169	56.218	11<20	7-10-71	
23.260	56.218	13<26	7-10-71	
25.350	56.040	15<31	7-10-71	
27.441	54.897	17<36	7-10-71	
29.532	54.228	19<42	7-10-71	
31.622	53.552	21<47	7-10-71	
33.713	53.067	23<53	7-10-71	
35.804	52.698	1<58	7-11-71	
37.895	52.372	4<04	7-11-71	
39.985	52.256	6<09	7-11-71	
42.076	53.017	8<15	7-11-71	
44.167	53.103	10<20	7-11-71	
46.258	53.232	12<25	7-11-71	
48.348	53.110	14<31	7-11-71	
50.439	53.196	16<36	7-11-71	
52.530	52.508	18<42	7-11-71	
54.621	51.623	20<47	7-11-71	
56.711	51.095	22<53	7-11-71	
58.802	50.530	0<58	7-12-71	
60.893	50.229	3<04	7-12-71	
62.984	49.952	5<09	7-12-71	
65.074	50.628	7<14	7-12-71	
67.165	51.162	9<20	7-12-71	
69.256	51.169	11<25	7-12-71	
71.347	51.414	13<31	7-12-71	
71.412	51.439	13<35	7-12-71	
71.477	51.469	13<39	7-12-71	
71.543	51.469	13<43	7-12-71	
71.608	51.439	13<46	7-12-71	
71.673	51.469	13<50	7-12-71	
71.739	51.463	13<54	7-12-71	
71.804	51.420	13<58	7-12-71	
71.869	51.390	14<02	7-12-71	
71.935	51.328	14<06	7-12-71	
72.000	51.298	14<10	7-12-71	END OF TEST

Exhibit E

PROCESS STUDIES OF ALTERNATE METHODS OF TREATMENT OF SEQUOYAH SX RAFFINATE

The Sequoyah conversion plant must accomplish both the purification and the conversion to uranium hexafluoride of uranium received as an impure concentrate, so-called "yellowcake". In the vast majority of cases, the received uranium compound is an ammonium diurante; but, in some instances, the received "yellowcake" is another compound, e.g. sodium diuranate. In the Sequoyah plant, these concentrates are dissolved in aqueous nitric acid and the resulting nitrate solution processed through a tributyl phosphate solvent extraction system. In this solvent extration operation, all impurities present with the uranium in the received yellowcake are rejected to an aqueous waste or raffinate while the uranium is recovered essentially quantitatively as pure uranyl nitrate solution.

Typically, the processing of one short ton of uranium will result in the production of some 1200-1400 gallons of raffinate. "Major" constituents present in the raffinate from processing of one short ton of uranium comprise the following:

a. Approximately 800 pounds of "nitric acid" (actually present predominantly as nitrate salts, e.g. ammonium nitrate).

b. Approximately 130 pounds of "ammonia" (actually present as ammonium nitrate).

c. Approximately two pounds of natural uranium (representing a 0.1% loss).

In addition, the raffinate will contain all impurities present with uranium in the received yellowcake. These impurities will include all radioactive daughters of U-238 and U-235 which were not removed at the uranium mill plus those daughters which may have grown back in the time intervening between mill processing and Sequoyah processing.

As an alternative to injection of this aqueous solution into a suitable underground site, a substantial study has been made of the possibilities for fixing the radionuclides in a refractory storable solid. In this connection, note the following:

a. Were it possible to entirely recover the "nitric acid" content (ca 800 pounds) of each 1200-1400 gallons of raffinate in usable form ($\geq$40 w/o HNO_3 free of chloride and other halides), this recovered nitric acid could be recycled to Sequoyah operations. At present purchase costs, a maximum cost "savings" of ca $18 per ton of uranium or ca 1.5¢ per gallon of raffinate could be achieved.

b. Were it possible to entirely recover the "ammonia" content (ca 130 pounds) of each 1200-1400 gallons of raffinate in usable form (anhydrous ammonia), the recovered ammonia could be recycled to Sequoyah operations. At present purchase costs, a maximum cost "saving" of ca $2.70 per ton of uranium or ca 0.2¢ per gallon of raffinate could be achieved.

Proceeding from the simpler to more complex approaches for converting the raffinate solution to a storable solid, the following conclusions are obtained:

1. Thermal evaporation of the water from the raffinate solution would produce a salt cake amounting to ca 750 pounds per ton of U in the case of ammonium diuranate yellowcakes and ca 1100 pounds per ton of U in the case of sodium diuranate yellowcakes. With prior neutralization of excess acid present in the raffinate and reasonable investment in de-entrainment facilities, an innocuous evaporator overhead (water) could be achieved. Exclusive of capital investment, the heat cost is estimated at ca \$3.50 per ton of uranium or ca 0.27¢ per gallon of neutralized raffinate.
2. In the case of ammonium diuranate yellowcakes, thermal decomposition of the received yellowcake prior to dissolution would allow U_3O_8 to be fed to the dissolution step. With suitable de-entrainment and scrubbing, the ammonia content could be discarded to the atmosphere as nitrogen. With such a step preceding dissolution, the excess nitric acid added in dissolution would be present in the raffinate as free nitric acid, ostensibly recoverable by distillation. However, quantitative recovery of this nitric acid would require addition of sulfuric acid to "spring" the nitric acid and would result

in a contaminated sulfuric acid solution to be stored. Likewise, such an operation would require exhaustive fractional distillation of the distilled nitric acid to separate it from the halides normally present in yellowcake and the halide fraction would constitute an additional waste. Finally, prior experience would indicate that the decomposition of ammonium diuranate yellowcakes would result in production of refractory uranium compounds (silicates, etc.) which would not dissolve in nitric acid. Thus, uranium losses would be increased and the uranium content of the ultimate waste increased. Finally, when it is considered that such processing would not be feasible with non-decomposable raffinates such as sodium diurantes, the conventional acid distillation approaches for recovering nitric acid from typical Sequoyah raffinates is considered exorbitant in cost.

3. The technique of "springing" nitric acid from ammonium nitrate or sodium nitrate raffinates by addition of excess sulfuric acid is likewise considered exorbitant in cost. With adequate fractionation of the vapor, a halide-free and, therefore, reusable nitric acid fraction would be obtained. However, the nitriate salts would be converted to acid sulfates (NH_4HSO_4 and $NaHSO_4$) and the bulk of solids requiring storage would be actually increased.

4. In final analysis, the conversion of the raffinate solution to a suitably compact and stable solid amenable to economic long-term storage appears possible only via total destruction of the nitrate content. Neutralization of the initial ammonium nitrate solution with an excess of a strong base would allow ammonia to be recovered as an aqueous solution adequately free of radionuclides. Depending on the base used, evaporation of the resultant strongly alkaline solution and high temperature ignition of the solids would allow the nitrate to be decomposed to solid nitrite or to gaseous nitrogen oxides. Given adequate NO_x absorption capability, reusable nitric acid could be recovered in the latter case. If the decomposition yields solid nitrite then contact with ammonia would allow initial nitrate and ammonia to be decomposed to nitrogen per the reaction:

$$NH_4^+ + NO_2^- \rightleftharpoons N_2(g) + 2H_2O(\ell)$$

Various recycle schemes can be envisioned whereby a fraction of the base can be reused and a suitably compact storable solid matrix generated to contain the residual radionuclides.

Substantial development effort is foreseen to achieve safe destruction particularly of the ammonium nitrate and other salts now contained in Sequoyah raffinate and its reduction to a suitable solid

form. Thus, it is considered unlikely that a true waste management approach which would not generate additional potential gaseous or liquid effluents could be implemented in less than five years time. While there is a possibility that at least a portion of the nitrate content of the raffinate can be recovered and reused at Sequoyah, it is extremely unlikely that cost savings so achieved will justify more than a modest fraction of the total capital investment required to reduce the present waste to a compact storable solid. Bench scale work to develop a suitable process is projected for 1972.

Exhibit F

GEOLOGY AND GEOHYDROLOGY STUDY

Structural Geology

The study area is located on the southwest flank of the Ozark Uplift. Regional dip is 2-3° southwest, except in the vicinity of faults. The Carlile School fault, one mile east of the storage well, was mapped on the surface with the aid of aerial photographs and confirmed by core holes. The core hole cross-section (Attachment 1) illustrates the contrast in the stratigraphic section on either side of the fault. There are other faults in the general area as shown on the regional structural map (Attachment 2). The location of these faults was determined from published maps and subsurface data. (Miser, 1954, Geologic Map of Oklahoma. Huffman, 1958, Oklahoma Geological Survey Bulletin #77). According to Huffman in Bulletin #77, the faulting is the result of tensional forces created during the uplift of the Ozark geanticline. This relatively mild tectonic activity ended by Middle De Moinesian time and the region has been structurally stable since then.

Stratigraphy

The youngest rocks exposed locally consist of a sandstone and shale sequence of the Lower Atoka. The outcropping Atoka rocks are approximately 100' thick and they are capped by a 15' thick terrace gravel in the immediate area of the plant site. Attachment 3 is a map of the Sequoyah Plant Site Area showing topography and approximate distribution of surface material. Outcrops are very poor, so it was necessary to rely primarily on core hole data in constructing the surface geological map.

The complete stratigraphic section (Attachment 4) penetrated in the storage well is as follows:

Formation	Thickness	Lithology	Character
Pennsylvanian Atoka	395'	Shale and sandstone	Non-porous, except for the basal Spiro sandstone from 342 to 373'. Contains saltwater.
Morrow	170'	Limestone and shale	Non-porous.
Mississippian	185'	Limestone and shale	Non-porous.

2001

Formation	Thickness	Lithology	Character
Siluro-Devonian Hunton	240'	Dense limestone	Non-porous.
Ordovician			
Sylvan	40'	Shale	Non-porous.
Viola	50'	Dense limestone	Non-porous.
Simpson	250'	Sandstone and interbedded dense limestone	Sandstone is porous in part, contains salt-water.
Cambro-Ordovician Arbuckle	1620'	Dolomite	Dense to very porous. Contains saltwater.
Reagan	145'	Dolomitic sand-stone and sandy dolomite	Impermeable.

Cross-sections A-A' (Attachment 5) and B-B' (Attachment 6) show that there is very good lateral continuity of all subsurface units with the exception of the Atoka series. Electrical log correlations are very good for the pre-Atoka beds covering a broad area of Oklahoma and surrounding states. All of the subsurface units thicken to the south and southwest and reach a maximum thickness in the general area of the Arbuckle Mountains in south central Oklahoma. In a northeasterly direction, approaching the crest of the Ozark Uplift, all stratigraphic units thin by onlap and truncation. For a detailed regional discussion, refer to Huffman, G. G., 1959, "Pre-De Moinesian Isopachous and Paleogelogic Studies in the Central Mid-Continent Region," AAPG Bulletin, Volume 43, pages 2541-2574.

Arbuckle Group - Proposed Injection Horizon

The Arbuckle is a carbonate sequence, dominantly dolomite, with minor shale and chert. It is 1765' thick at the well site, including the basal Reagan sandstone, and reaches a maximum thickness of 7000' in the Arbuckle Mountains. Northeast of the well site, the Arbuckle thins to about 180' at the outcrop of the Cotter dolomite (uppermost Arbuckle) near Spavinaw, Delaware County, Oklahoma (Huffman 1958). The distribution of the Arbuckle group is very wide-spread, being recognized throughout the Mid-Continent region (Huffman 1959).

Rocks of the Arbuckle group vary in character from dense and impermeable to very porous and permeable. In general, the upper part of the Arbuckle is essentially non-porous, the Middle

Arbuckle is characterized by alternating beds of porous and non-porous dolomite and the lower one-third of the section is characterized by thick zones of high order porosity. Measured porosity values of Arbuckle dolomite range from less than 2% to as high as 20%. Permeability ranges from less than 0.1 millidarcy to a high of 768 millidarcies. Porosity-permeability relationships indicate that porosities less than 3% are non-effective. Correlations of the zones of good porosity development are reasonably good throughout the area (see electric log cross-sections, Attachments 5 and 6). Porosity values for the Arbuckle formation were established by a foot-by-foot analysis of the Schlumberger Formation Density Log (Attachment 7) and from the core analysis (Attachment 8). The depths of the five intervals with the highest permeability were derived from the injectivity test data. See Figure 3, Exhibit A. Average porosity values were assigned to each layer and the thickness of the net effective porosity was determined by using a minimum value of 3% as a cut-off. The average porosity ranges from a low of 5.8% for layer #5 to a high of 9.9% for layer #4. The total net effective porosity for the five permeable layers is 116 feet.

It should be noted that both the density log and the Neutron Porosity Log were calibrated for a limestone formation with an assumed constant grain density of 2.71 grams/cc. Since the Arbuckle formation is in fact made up of alternate layers of porous and dense dolomite with a measured average grain density of 2.81, it is necessary to apply a correction to the density curve before computing porosity values. Since the logs were calibrated for limestone, the porosity scale printed on the Neutron Porosity Log cannot be used with accuracy. The error in the apparent porosity resulting from the limestone calibration ranges from two to as high as eight percentage points.

The chemical and physical characteristics of the Arbuckle formation water is given in the water analysis submitted by the Halliburton Company (Attachment 9). Specific gravity is 1.104 at 75°F, pH is 7.0 and resistivity is 0.093 ohms/M^2/M. Total dissolved solids are 142,000 ppm and the chloride content is 88,300 ppm. Reservoir temperature is 126°F as reported by Schlumberger and the reservoir fluid pressure is 1238.45 psi at an elevation of 2071 ft. below sea level. The lithostatic pressure at the base of the Arbuckle (3100') is calculated to be 3490 psi by using a mean density of 2.60 for the overlying rock column. Fracture pressure is estimated by Halliburton Services at 70% of lithostatic or 2440 psi.

The confining bed underlying the Arbuckle consists of impermeable granite. The confining beds above the proposed injection horizon consist of 170' of dense shaley Arbuckle dolomite and 110' of dense Arbuckle limestone. This Arbuckle "caprock" is in turn overlain by a 1300' thick sequence of dense shale, siltstone,

sandstone and limestone. These non-porous beds will effectively prevent the vertical migration of injected fluid.

Groundwater Geohydrology

Information on the geohydrology of the fresh water aquifers at the Sequoyah plant site and vicinity has been taken primarily from:

> Oklahoma Geological Survey Hydrologic Atlas #1 - 1969 "The Water Resources of the Ft. Smith Quadrangle, by M. V. Marcher.

Marcher states that, in general, the Atoka formation is a very poor aquifer. Water quality is poor and yields range from a fraction of a gallon per minute to a few gallons per minute. The best water well in the plant site area is located in the NW NW/4 of Section 27 12N 21E. Depth of the hole is 84', static water level is 29' and yield is 1 gpm. Water quality of this well is better than average for the Atoka formation, with total dissolved solids of approximately 460 ppm. The erratic occurrence of fresh water locally is the result of meteoric water being trapped in fractured shale and constitutes a "perched" water table at an elevation approximately 40' above the water level of the alluvial aquifer of the Arkansas River.

The Arkansas River alluvium is a good aquifer with reported yields as high as 900 gpm. The water is "hard to very hard" (Marcher 1969), but is suitable for irrigation. A typical alluvium water well is located in the SE SE/4 of Section 19 12N 21E. Marcher reports a depth of 44', static water level at 4' and a yield of 400 gpm.

Mineral Resources

The only mineral resource in the immediate area of the well site is a limited amount of terrace gravel. Sandstone has been quarried at two locations approximately one mile north of the well site and sand has been dredged from the flood plain of the Illinois River two miles to the north. Sand has also been dredged from the Arkansas River two miles west of the plant. Nearest gas production is 14 miles west, at the town of Warner. Coal is being mined from a depth of 1400' at Stigler in Haskell County, 18 miles south of the well site. Nearest coal deposits are located about 12 miles southeast of the plant site, but the mines are currently inactive.

Seismicity

As previously stated, Huffman (1958) considers the area under discussion to have been tectonically stable since Middle De Moinesian time. This conclusion is supported by the Coast and

and Geogetic Survey Report 41-1 (revised) "Earthquake History of the United States". The report lists minor to moderate seismic activity in the El Reno area, west of Oklahoma City, the Tulsa area and in the Ouachita Mountains of southeastern Oklahoma and west central Arkansas. The earthquake epicenter nearest the well site is near Poteau, Oklahoma, 40 miles to the south. This earthquake of April 27, 1961, is listed at intensity V on the Modified Mercalli scale (very minor damage to dishes and windows). All of the listed earthquakes appear to be associated with structural features outside of the southwest Ozark tectonic province (Tectonic Map of United States, USGS and AAPG 1961). It is concluded that earthquakes do not constitute a significant hazard at the Sequoyah well site.

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ATTACHMENT 8
Exhibit F

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

October 28, 1969

REPLY TO
8 N. W. 42ND ST.
OKLAHOMA CITY, OKLA.
73118

Received W/Ltr. Dated MAY 10 1972

Kerr-McGee Corporation
705 Kerr-McGee Building
Oklahoma City, Oklahoma 73102

Attn: Mr. Tom C. Danie

Subject: Core Analysis
Sequoyah Factory Waste
Disposal No. 1 Well
Sequoyah County, Oklahoma
CLI File No. CP-1-7049

Gentlemen:

The Arbuckle Formation was diamond cored in the subject well at various intervals from 1451 to 3032 feet. The core was preserved at the well-site and transported to the Oklahoma City Laboratory for analysis by whole core methods. The analysis results are presented in tabular form on the accompanying page of this report.

Grain Density measurements were requested at scattered intervals and appear along with the tabular data.

Thank ,ou for this opportunity to be of service.

Yours very truly,

CORE LABORATORIES, INC.

J. G. Evertson, Jr.
District Manager

JGE:sh
5cc: Addressee

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

CORE ANALYSIS RESULTS

Company KERR-MCGEE CORPORATION Formation ARBUCKLE File CP-1-7049
Well SEQUOYAH FACTORY WASTE DISPOSAL #1 Core Type DIAMOND Date Report 10-28-69
Field Drilling Fluid WATER BASE MUD Analysts BOYLE
County SEQUOYAH State OKLAHOMA Elev. 579' KB Location 997' FEL & 3231' FSL, SECTION 21-12N-21E

Lithological Abbreviations

SAND-SD, SHALE-SH, LIME-LM, DOLOMITE-DO, CHERT-CH, GYPSUM-GYP, ANHYDRITE-ANHY, CONGLOMERATE-CONG, FOSSILIFEROUS-FOSS, SANDY-SDY, SHALY-SHY, LIMY-LMY, FINE-FN, MEDIUM-MED, COARSE-CSE, CRYSTALLINE-XLN, GRAIN-GRN, GRANULAR-GRNL, BROWN-BRN, GRAY-GY, VUGGY-VGY, FRACTURED-FRAC, LAMINATION-LAM, STYLOLITIC-STY, SLIGHTLY-SL/, VERY-V/, WITH-W/

SAMPLE NUMBER	DEPTH FEET	PERMEABILITY MILLIDARCYS PERM. MAX.	PERM. 90°	POROSITY PER CENT	RESIDUAL SATURATION PER CENT PORE OIL	TOTAL WATER	SAMPLE DESCRIPTION AND REMARKS
	WHOLE CORE ANALYSIS						
1	1451.2-52.1	4.0	3.4	9.5	0.0	89.1	Dol, vuggy, vert frac
2	52.1-53.0	0.1	<0.1	7.7	0.0	92.9	Dol, vert frac
3	53.0-54.5	0.1	0.1	9.9	0.0	91.6	Dol, few pp vugs
4	54.5-55.5	0.2	0.1	11.2	0.0	89.6	Dol, sl/vuggy
5	55.5-57.0	0.3	0.1	12.4	0.0	91.5	Dol, pp vugs
6	57.0-58.0	<0.1	<0.1	5.9	0.0	93.3	Dol, sl/shy, few pp vugs
7	58.0-59.0	<0.1	<0.1	11.0	0.0	92.2	Dol, pp vugs
8	59.0-60.0	0.7	0.6	8.5	0.0	87.8	Dol, few pp vugs
9	60.0-61.2	2.3	1.9	10.7	0.0	90.0	Dol, few pp vugs
10	61.2-62.0	1.2	1.1	12.1	0.0	87.7	Dol, few pp vugs, sl/cherty
1	62.0-63.5	1.5	1.3	13.4	0.0	88.5	Dol, few pp vugs
12	63.5-65.3	0.1	0.1	9.4	0.0	88.9	Dol, few pp vugs
13	65.3-66.8	<0.1	<0.1	5.1	0.0	91.4	Dol, sl/shy
14	66.8-68.2	<0.1	<0.1	3.7	0.0	89.3	Dol, sl/shy
15	68.2-69.5	<0.1	<0.1	3.4	0.0	90.6	Dol, sl/shy
16	69.5-70.6	<0.1	<0.1	4.4	0.0	93.4	Dol, sl/shy
17	70.6-71.7	0.1	<0.1	4.9	0.0	91.8	Dol, vuggy
18	71.7-73.3	0.1	<0.1	3.7	0.0	89.2	Dol, vuggy
19	73.3-74.4	0.1	0.1	8.2	0.0	91.5	Dol, few pp vugs
20	74.4-76.0	0.1	<0.1	6.8	0.0	97.2	Dol, shy
21	76.0-77.0	<0.1	<0.1	4.9	0.0	85.9	Dol, few pp vugs
	1477.0-1737.0						Drilled
22	1737.0-38.7	<0.1*		3.3	0.0	76.7	Dol, sl/shy, few pp vugs
	38.7-43.0						Lost core
	1743.0-1912.0						Drilled
23	1912.0-13.0	<0.1	<0.1	2.1	0.0	67.4	Dol, sl/vuggy
23	13.0-14.2	<0.1	<0.1	1.9	0.0	33.3	Dol
25	14.2-15.7	<0.1	<0.1	1.4	0.0	50.0	Dol, sl/cherty
26	15.7-16.7	<0.1	<0.1	1.9	0.0	47.6	Dol
27	16.7-18.3	<0.1	<0.1	2.4	0.0	39.8	Dol, sl/cherty
28	18.3-19.7	<0.1	<0.1	2.4	0.0	34.8	Dol
29	19.7-21.0	<0.1	<0.1	2.3	0.0	33.3	Dol
30	21.0-21.7	<0.1	<0.1	0.9	0.0	64.3	Dol, shy
31	21.7-23.3	<0.1	<0.1	3.1	0.0	46.9	Dol
32	23.3-24.2	<0.1	<0.1	1.4	0.0	41.9	Dol, sl/shy
	1924.2-2294.0						Drilled
33	2294.0-95.6	101	24	9.8	0.0	64.6	Dol, vuggy, sl/cherty
34	95.6-96.6	0.1*		9.0	0.0	69.1	Dol, vuggy, vert frac
35	96.6-98.0	768	1.8	9.6	0.0	[illegible]7.3	Dol, vuggy
36	98.0-99.4	30	0.2	9.2	0.0	69.8	Dol, vuggy, vert frac

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

File CP-1-7049 Page No. 2

Well Sequoyah Factory Waste Disposal No. 1

CORE ANALYSIS RESULTS

SAMPLE NUMBER	DEPTH FEET	PERMEABILITY MILLIDARCYS MAX.	90°	POROSITY PER CENT	RESIDUAL SATURATION PER CENT PORE OIL	TOTAL WATER	SAMPLE DESCRIPTION AND REMARKS
37	2299.4-01.2	2.0	1.9	9.5	0.0	69.0	Dol, vuggy, vert frac
38	2301.2-02.8	0.8	0.4	6.9	0.0	68.5	Dol, vuggy
39	02.8-03.8	0.1*		5.2	0.0	73.6	Dol, vuggy, vert frac
40	03.8-05.2	22	0.2	6.7	0.0	75.1	Dol, vuggy, vert frac
41	05.2-06.5	1.1	0.9	4.3	0.0	76.4	Dol, vuggy
42	06.5-07.9	0.6	0.3	6.6	0.0	76.4	Dol, vuggy
43	07.9-09.4	0.2	0.1	3.4	0.0	86.4	Dol, pp vugs, cherty
44	09.4-11.0	1.0	0.9	5.9	0.0	77.2	Dol, pp vugs, sl/cherty
	2311.0-12.0						Lost core
	2312.0-3021.0						Drilled
45	3021.0-22.4	0.2	0.1	5.3	0.0	76.4	Sd, dol
46	22.4-23.2	0.5	0.2	5.2	0.0	78.6	Sd, dol
47	23.2-24.8	0.2	0.1	2.8	0.0	86.4	Sd, dol, sty
48	24.8-26.6	0.1	0.1	6.1	0.0	67.5	Sd, dol, sty
49	26.6-28.4	0.3	0.1	3.1	0.0	85.4	Sd, dol, sty
50	28.4-29.7	0.2	0.1	3.7	0.0	80.9	Dol, sl/sdy, vuggy
51	29.7-31.5	0.8	0.7	4.4	0.0	72.6	Dol, vuggy, vert frac
	3031.5-32.0						Lost core

	GRAIN DENSITY
1452-53	2.808
1455-56	2.769
1457-58	2.762
1459-60	2.815
1462-63	2.845
1464-65	2.799
1466-67	2.798
1469-70	2.793
1471-72	2.833
1474-75	2.840
1476-77	2.837
2294-95	2.817
2298-99	2.818
2303-04	2.808
2307-08	2.800
2310-11	2.794
3021-22	2.706
3024-25	2.693
3028-29	2.822
3031-31.5	2.827

*DENOTES PLUG PERMEABILITY

THIS IS THE FINAL REPORT.

ATTACHMENT 9
Exhibit F

HALLIBURTON DIVISION LABORATORY

OKLAHOMA CITY, OKLAHOMA

HALLIBURTON COMPANY

FIELD LABORATORIES MAINTAINED AT VARIOUS POINTS ... THE OIL FIELDS

LABORATORY WATER ANALYSIS

Date November 24, 1969

Report No. WA2-11-69

To Kerr-McGee Corp.

Oklahoma City, Oklahoma

Submitted By .... Date Received November 12, 1969

Well No. #1 Sequoyah Facility Depth not given Formation not given

Sequoyah County

Location Oklahoma Section ...... Township ...... Range ......

Specific Gravity	1.104 @ 75 F.	
pH	7.00	
Total Dissolved Solids	142,000	Parts per Million*
Calcium (Ca)	11,380	Parts per Million
Magnesium (Mg)	2,470	Parts per Million
Chlorides (Cl)	88,300	Parts per Million
Sulfates (SO_4)	120	Parts per Million
Carbonates (CO_3)	0	Parts per Million
Bicarbonates (HCO_3)	159	Parts per Million
Total Iron (Fe)	22	Parts per Million
Sodium (Na)	39,760	Parts per Million
Remarks: R_w	0.095 @ 75 F..	Ohms/M

Received W/Ltr. Dated MAY 10 1972

DOCKETED USAEC MAY 16 1972

RECEIVED MAY 16 1972 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

DOCKET NO. 40-8027

*Parts per million, by weight, uncorrected for Specific Gravity.

cc: Mr. D. C. Moriarty

Respectfully submitted,

HALLIBURTON COMPANY

By Wirt Davis

Division Chemist

NOTICE: This report is limited to the described sample tested. Any user of this report agrees that Halliburton shall not be liable for any loss or damage, whether due to act or omission, resulting from such report or its use.

DOCKET NO. 40-8027

PREINJECTION TREATMENT PROGRAM

Raffinate Treatment

Solvent extraction raffinate treatment facilities are provided. The raffinate treatment facilities include a raffinate decanter, raffinate holding tanks and associated pumps and lines.

The primary purpose of the solvent extraction raffinate treatment system is to prepare the raffinate for injection into the waste storage well system. Reasonable effort is made to minimize the radioactivity contained in the raffinate effluent which is released to the unrestricted area via deep well disposal.

The raw raffinate contains a considerable volume of the organic solvent tributyl phosphate (TBP) and may contain more than a desirable amount of uranium. The TBP is removed since it is detrimental to the lining material on the disposal well tubing. The excess uranium is removed for economic reasons and to reasonably control the radioactivity releases.

To remove the TBP, the raffinate is scrubbed with hexane in a decanter. In this operation, an average of about 435 pounds per day of TBP is recovered and re-used. After the TBP is removed, the scrubbed raffinate flows to one of two 5,000 gallon hold tanks where it is held until a laboratory analysis is performed to determine the residual uranium content. If the uranium content is within the economical recovery limits, the raffinate is released to the well surge tank for injection to the disposal well. Provisions exist for recycling raffinate to a pump decanter. In case the raffinate is high in uranium content, the raffinate is recycled to solvent extraction and the excess uranium is removed.

Raffinate wastes generated to date have been neutralized with either $Ca(OH)_2$ or NH_4OH prior to storage in ponds. It is planned that these stored wastes would be mixed with fresh, acidic raffinate and injected into the underground storage also. These neutralized raffinate have undergone some precipitation of chemical and radioactive contaminants and as a result would be somewhat more pure in radioactive contents and chemicals than fresh raffinate with the exception of the Ca and NH_3 added for neutralization.

Exhibit H Regulatory File Cy.

DOCKET NO. 40-8027

WELL LOCATION, DESIGN AND TESTING PROCEDURES

Well Location

The Kerr-McGee Sequoyah Disposal Well is located 3094' from the south line, 1482' from the east line, Section 21 12N 21E, Sequoyah County, Oklahoma. This location is approximately two miles southeast of Gore, Oklahoma. See the Site Plan and Area Map included as Enclosure 1 which shows the relationship of the well to the Facility and general vicinity. Ground elevation is 563' and rotary drive bushing elevation was 579'. All depth measurements cited were made from the top of the drive bushing (Kelley Bushing or K.B.).

Enclosure 2 is a Structure Contour Map of SE Gore Area, Sequoyah County, Oklahoma, which depicts the following:

Received W/Ltr. Dated MAY 8 1972

1) plant site location
2) location of disposal well
3) culture
4) drainage
5) Kerr-McGee property boundary
6) near surface structure of a marker bed in the Atoka formation
7) location of core holes, water wells and the only plugged and abandoned oil and gas test well within two miles of the disposal well
8) the surface trace of the Carlile School fault and the location of the fault monitor well drilled by Kerr-McGee.

Status of Dry Holes in Area

The Leonard #1 Smith, located SW NW SE/4 of Section 23 12N 21E, is two miles east of the Kerr-McGee storage well. The #1 Smith was drilled to a total depth of 2354' in 1955 and was plugged and abandoned as a dry hole. Formations penetrated are:

Pennsylvanian Atoka shale at the surface
Lower Pennsylvanian Wapanucka limestone-----------1115'
Mississippian limestone--------------------------1300'
Siluro-Devonian Hunton limestone-----------------1470'
Upper Ordovician Sylvan shale--------------------1740'
Viola limestone----------------------------------1775'
Middle Ordovician Simpson sandstone and limestone--1830'
Lower Ordovician Arbuckle limestone and dolomite---2080'

The Simpson sandstone was drill steam tested from 1940-50' with a recovery of 10' of mud. A drill steam test from 1951-2002- recovered 66' of saltwater cut mud. 5-1/2" casing was set at 2144' with 80 sacks of cement. The Simpson sandstone was perforated from 1946-56' and after fracture treatment operator swabbed salt-

water and reported "a hole full of saltwater". The well was plugged as follows:

> 1717' of 5-1/2" casing was pulled. The 10-3/4" surface casing, set at 70' with 70 sacks of cement, was left in the hole. The hole was filled with heavy mud and a cement plug was placed in the top of the 10-3/4" casing.

The Carter #1 Highfill, located NE SE NE Section 5 11N 21E, is three miles south of the Kerr-McGee storage well. This dry hole is shown on the Regional Structure Map (Attachment 2 to Exhibit F) along with all other dry holes and producing wells in a 16-township area around the storage well. The Carter well was drilled to a depth of 4706' and plugged and abandoned November 1, 1954. Formations penetrated are:

Atoka at the surface
Wapanucka--------------1910'
Mississippian----------2100'
Hunton-----------------2330'
Sylvan-----------------2560'
Viola------------------2600'
Simpson----------------2650'
Arbuckle (estimated)---2915'
Granite----------------4660'

Casing was set as follows:

10-3/4" at 120' with 50 sacks
5-1/2" at 4040' (amount of cement not reported)
4-1/2" liner from 3838' to 4675' (amount of cement not reported)

The hole was plugged back to 4500' with cement and the Arbuckle was perforated from 4464-70'. Operator reported a show of gas and "a heavy flow of water". The well was plugged and abandoned by pulling 807' of the liner and 3000' of the 5-1/2" casing. The hole was filled with heavy mud and a 10-sack cement plug was placed in the top of the surface casing.

In addition to the two wells nearest the Kerr-McGee plant site, all available Oklahoma Corporation Commission plugging reports were examined for the dry holes within a radius of eight miles of the storage well. The records reflect that all of the dry holes were abandoned by leaving the surface casing in the hole and placing one or more cement plugs in the hole. Copies of the plugging record for the two nearest wells are included as Enclosures 3 and 4.

Drilling and Testing

A geological report by Peter L. Scott, a consulting geologist, is attached as Enclosure 5. The Kerr-McGee Sequoyah Storage

Well was drilled with rotary tools to a total depth of 3122' in granite. The following intervals of the Arbuckle formation were diamond cored:

Core #1	1452 - 77'
Core #2	1737 - 43'
Core #3	1912 - 25'
Core #4	2294 - 2312'
Core #5	3021 - 32'

The following logs were run by Schlumberger:

Induction-electrical survey from 133-3121' (Enclosure 6)
Compensated Formation Density from 498-3128' (See Attachment 7, Exhibit F)
Sidewall Neutron Porosity from 298-3126' (Enclosure 7)

After running logs, the 7" casing was cemented at 1619', 300' below the top of the Arbuckle. The 7" casing was pressure tested at 1000 psi for 30 minutes with no pressure decline. The drilling mud in the well was displaced with fresh water and the Arbuckle formation was swab tested through 2-7/8" tubing set at 3089'. Saltwater was swabbed for eight hours at a rate of 79 barrels of water per hour. The fluid level during swabbing remainted fairly constant at a depth of 250' below ground level. A sample of the formation water was retained for analysis. Twelve hours after swabbing was terminated, the fluid level was at 50' below ground level.

The initial injection test with fresh water had the following results:

Rate	Volume Pumped	Pump Press	Instant Shut Down Pressure
2 BPM	120 Bbls	500#	200#
3 "	180 "	750	200
4 "	240 "	900	150
5 "	220 "	1100	100

The open hole section of the Arbuckle was then treated with 6000 gallons of Halliburton 7-1/2% MCA acid. The well was swabbed to clean up after the acid treatment and the second injection test was run:

Rate	Volume Pumped	PSI TBG Pump Pressure	PSI SI Casing Pressure
2 BPM	120 Bbls	0	50
3 "	180 "	0	50
4 "	240 "	100	75
5 "	300 "	200	100

Compatibility with Subsurface Fluids

Laboratory permeability tests were conducted by Core Laboratories, Inc., Dallas, Texas. The tests demonstrated that the injected waste fluids and formation water are essentially compatible. No serious reduction in permeability was measured after flushing the formation core with synthetic raffinate fluids. In fact, the laboratory indicates that the waste fluids will generally slightly increase the permeability. The results of the laboratory permeability tests are shown in Enclosure 8. (The porosity and permeability values for these cores, principally obtained in the upper portions of the Arbuckle and useful for density log calibration are not representative of the more porous zones which will take injection, but are thought to be reasonably representative of the injection zones from a chemical reactivity standpoint.)

Casing and Cement

Enclosure 9 is a sketch of the waste storage well. The well was cased as follows (all depths measured from rotary drive bushing):

Casing Size	Weight	Grade	Type	Depth	Cement
16" O.D.	55#	H 40	ST&C	135'	200 sacks regular with 2% CaCl and 1/4# Flocele per sack. Cement circulated to surface.
10-3/4" O.D.	32.75#	H 40	ST&C	498'	350 sacks HLC with 2% CaCl. Cement circulated to surface.
7" O.D.	20#	J 55	ST&C	1619'	400 sacks HLC with 10# Gilsonite per sack plus 100 sacks 50-50 Pozmix with 9% CRF-Z and 10% CaCl. Cement circulated to surface.

Subsurface Equipment

The bottom two joints of 7" casing are Carpenter 20 alloy steel with a Howco guide shoe on the bottom and a float collar at the top of the second joint. The bottom joint is equipped with two centralizers and six Genoco Coilflex wall cleaners. Two centralizers were also run on the third, fifth and seventh joints and 15 additional centralizers were spaced at 90' intervals above the seventh joint. The bottom seven joints of 7" casing are Ruff-Coted.

Tubing and Well Head Equipment

The injection string is 3-1/2" O.D., 9.3#, J 55, EUE tubing internally coated with Plasticap 600 PVC. The tubing is set in a Baker Model A tension packer set at a depth of 1611'. The

packer is internally and externally coated with Plasticap 600 PVC. The casing-tubing annulus is filled with 45 barrels of fresh water treated with 10 gallons of Aquaness Cronox 609. The well head equipment consists of a tubing hanger and a 2000# working pressure Cameron flange type 3" plug valve. The tubing head is internally coated with polypropylene. Enclosure 10 is a drawing of the well head assembly and description of equipment items.

Surface Equipment

General Description of System and Location

Chemical waste from all sources is collected in a surge tank located at the west end (inside) of the solvent extraction building. From there, the waste is continuously pumped to the storage well. Liquid level in the surge tank is maintained by means of control valves downstream of the pump which recycles the flow as necessary back to the surge tank. The general location of the equipment is shown on the General Plot Plan, drawing 110-C-152 (Enclosure 11). The system is shown schematically on Figure No. 1.

Details

Holding Tanks and Flow Lines

The surge tank has a nominal capacity of 2500 gallons. It is made of fiberglass-reinforced plastic with a 20 mil coating of epoxy (trade name "C-Vail") over the inside surface.

The following pipe line materials were used:

Location	Spec[1]	Material
Feed lines to surge tank and lines between surge tank and disposal pumps.	CHW	Schedule 40, Type I polyvinyl chloride (PVC) pipe, plain end with socket type solvent cement weld fittings.
Lines from disposal pumps to well.	DWW	Schedule 40 carbon steel pipe coated on the inside with 30 mil of PVC (plasticap 600 as supplied by Plastic Applicators, Houston).
Branch lines from main disposal line (DWW) to settling basins.	DPW	(Same as CHW above)
Injection tubing from well head to injection zone.	(None)	3-1/2" diameter well tubing with 30 mil coating of PVC.

[1]See Figure No. 1.

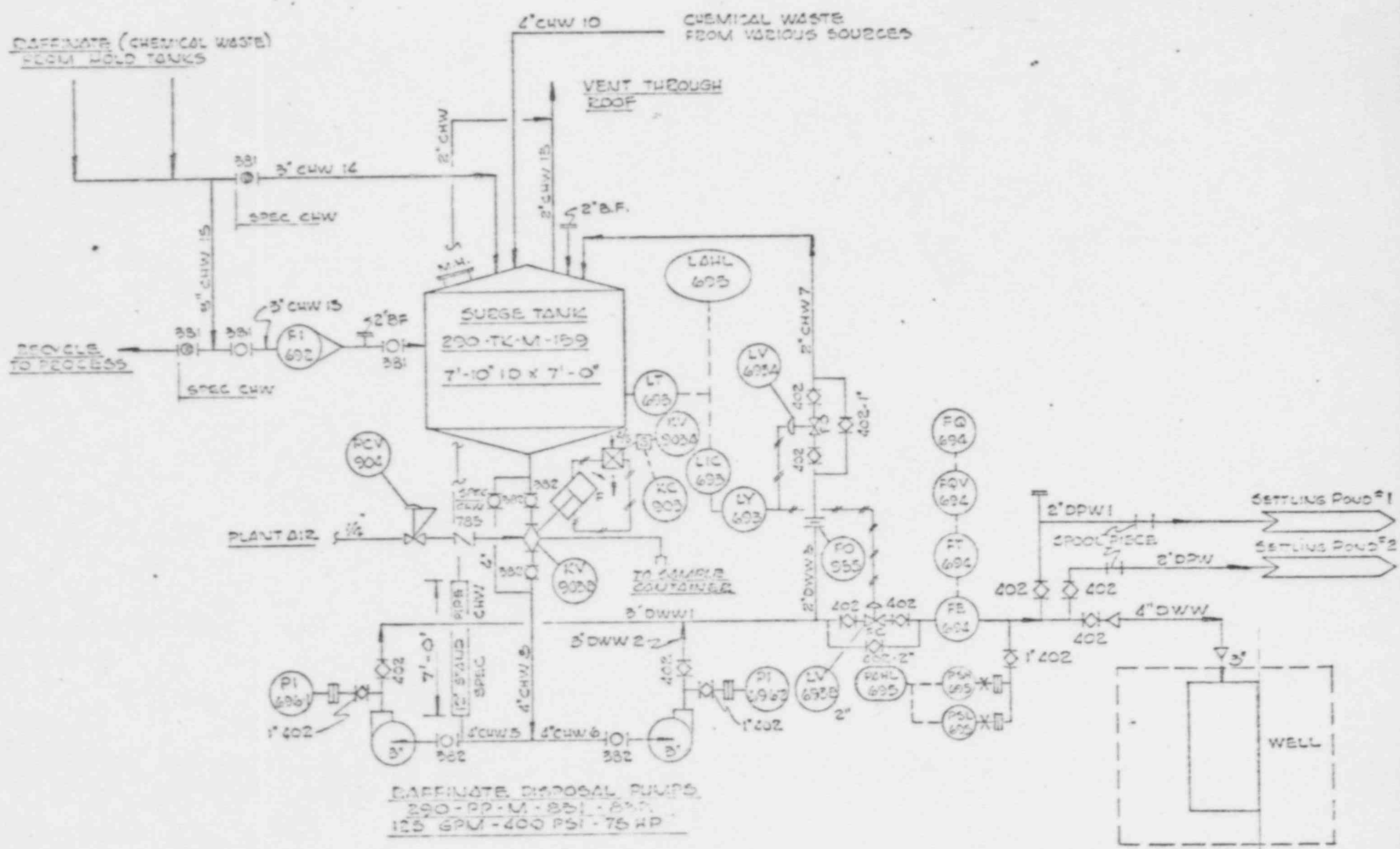

FIGURE NO. 1

SEQUOYAH FACILITY

WASTE DISPOSAL WELL FACILITIES

The valves used in the various lines are described below:

Line Spec	Valve Mark Number[1]	Valve Description
CHW	381	Ball valve, PVC normal impact type, double lip teflon seats, socket ends.
CHW	382	Ball valve, PVC normal impact type, teflon seal, flanged ends.
DWW	402	300# plug valve, polypropylene lined cast steel, bolted bonnet, teflon bearing rings, teflon "V-Type" packing, locked in plastic liner, flanged ends.

[1]This mark number is shown by each valve in Figure No. 1.

Filters

There are no filters in the system.

Pumps

Two centrifugal waste disposal pumps are provided, one of which is an installed spare. Both are Sundyne Pump Model LMV-311 manufactured by Sundstrand-Denver. Each is capable of 125 gpm at 400 psi. The wetted surfaces of the pumps are made of Hastelloy "C". The pumps are driven by 75 hp Louis Allis motors.

Flow and Pressure Monitoring Devices

Flow to the well in gallons is totalized on an instrument located in the control room (FQ 694 on Figure 1). The sensing element (FE 694) in the line is a magnetic type instrument with 0.125" Saran liner and Hastelloy "C" electrode.

Pressure in the waste line is sensed at the discharge of both pumps and downstream of FE 694. At the pump discharge, the instruments are simple Bourdon type pressure indicators with Hastelloy "C" body material and tantalum diaphragm material.

The downstream sensing device consists of two Bourdon type pressure switches - one high pressure and one low pressure - both Hastelloy "C" wetted parts. On either high or low line pressure, an alarm signal will be displayed in the control room.

In addition to the devices shown on Figure 1, prior to the start of a waste injection program, it is planned that we would add the following additional instruments:

1. Flow indicator and recorder utilizing the existing magnetic flow sensing element to supplement the flow information available now from the existing flow totalizer.

2. Well head injection pressure indicator and recorder utilizing a sensitive pressure sensor mounted at the well head with signal transmitted to the control room.

3. Well head injection temperature indicator and recorder utilizing a sensitive temperature sensor mounted at the well head with signal transmitted to the control room.

4. Well head tubing-casing annulus pressure indicator and recorder utilizing a sensitive pressure sensor mounted at the well head with signal transmitted to the control room.

Sampler

An automatic sampler takes a sample of the chemical waste leaving the surge tank every 30 minutes. Approximately one gallon of sample is collected every eight hours for testing in the laboratory. The sampler is made of Hastelloy "C".

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SEE APERTURE CARDS

NUMBER OF PAGES: 2

ACCESSION NUMBER(S):

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ENCLOSURE 3
Exhibit H

DOCKET NO. 40-8027

31733

Received W/Ltr. Dated MAY 1 8 1972

PLUGGING RECORD 181732

OKLAHOMA CORPORATION COMMISSION

NOTICE: All questions on this form must be satisfactorily answered.

Company Operating: O. P. Leonard

Office Address: 300 Huston St. Ft. Worth, Tex.

County: Sequoyah Sec. 23 Twp. 12 N Rge. 21 E

Location in Section: SW NW SW

Farm Name: Bart Smith Well No. 1 Field

Character of Well (whether oil, gas or dry):

Locate Well Correctly

Commenced Plugging Aug 2 1955 Finished Aug 9 1955 Total Depth 2340 FT

Was permission obtained from the Corporation Commission or its agents before plugging was commenced? Yes

Name of Conservation Officer who supervised plugging of this well: Hansal Payne

Name of producing sand: NONE Depth top Bottom

Show depth and thickness of all fresh water, oil and gas formations.

SAND OR ZONE RECORDS				CASING RECORDS		
FORMATION	CONTENT	FROM	TO	SIZE	PUT IN	PULLED OUT
NONE				5½"	2140 FT	1717 FT
				10¾"	110'	Left in

Describe in detail the manner in which the well was plugged, indicating where the mud fluid was placed, and the methods used in introducing it into the hole. If cement or other plugs were used, state the character of same and depth placed.

Filled with Fluid Mud – Bottom to Top – After Settling Refilled & Cement Capped

Does the above conform strictly to the oil and gas regulations? Yes

The Law requires that adjacent lease and land owners be notified; give their names with their addresses below:

J. W. Green, Gore, Oklahoma

Schuyler Hawkins, Gore, Oklahoma

REMARKS: Why plugged Dry Hole. If abandoned oil or gas well, state amount and date of last production: No Production

Correspondence regarding this well should be addressed to: Travis C. Cravens, 300 Houston Street, Fort Worth, Texas

Address

I, the undersigned, being first duly sworn upon oath, state that this well record is true, correct and complete according to the records of this office and to the best of my knowledge and belief.

[signature]

Name and title of representative of company

Subscribed and sworn to before me this the day of 19

Commission expires

[signature]

Notary Public

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DOCKETED USAEC MAY 1 8 1972

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2661

291737

No. 31-6022A

NATIONAL OIL WELL INDEX
OKLAHOMA CITY

OKLA. CORPORATION COMMISSION OIL AND GAS CONSERVATION DEPT.

COUNTY Muskogee SEC 5 TWP. 11N RGE. 21E

COMPANY OPERATING W. H. Carter

OFFICE ADDRESS 200 Houston, Ft. Worth, Texas

FARM NAME Ed Highfill WELL NO 1

DRILLING STARTED 11-28-19 53 DRILLING FINISHED 11-1- 19 54

DATE OF FIRST PRODUCTION none COMPLETED

WELL LOCATED NE ¼ SE ¼ NE ¼ 990 North of South Line and 1980 ft. East of West Line of Quarter Section

Elevation (Relative to sea level) DERRICK FLOOR ______ GROUND ______

CHARACTER OF WELL (Oil, gas or dryhole) Dryhole

Locate well correctly

OIL OR GAS SANDS OR ZONES

Name	From	To	Name	From	To
1 Arbuckle	4464	4470	3		
2			4		

Perforating Record If Any				Shot Record			
Formation	From	To	No. of Shots	Formation	From	To	Size of Shot
Arbuckle	4464	4470	24				

CASING RECORD

Size	Wt.	Thds.	Make	Amount Set Ft.	In.	Ft.	In.	Amount Pulled Size	Length	Packer Record Depth Set	Make
10-3/4				120							
5½	15.5	8		4040				5½	3000		
4½ Liner				837					807		

Liner Record: Amount 837 Kind ______ Top 3838 Bottom 4675

CEMENTING AND MUDDING

Size	Amount Set Ft.	In.	Sacks Cement	Chemical Gal.	Make	Method of Cementing	Amount	Mudding Method	Results (See Note)
10-3/4	120		50	50 sacks of cement at the bottom					
				and 10 at the top.					

Note: What method was used to protect sands if outer strings were pulled? Heavy laden mud

NOTE: Were bottom hole plugs used? yes If so, state kind, depth set and results obtained Cement

TOOLS USED

Rotary Tools were used from 0 feet to 2856 Cable tools were used from 2856 feet to 4706

______ feet, and from ______ feet to ______ feet, and from ______ feet to ______

Type Rig Rotary and cable tools

INITIAL PRODUCTION TEST

Describe initial test; whether by flow through tubing or casing or by pumping ______

Amount of Oil Production ______ bbls. Size of choke, if any ______ Length of test ______ Water Production ______ bbls. Gravity of oil ______ Type of Pump if pump is used, describe ______

Formation	Top	Bottom
Surface	0	160
Blk Bitum sh	160	420
Blk fissile sh	420	540
Blk limey sh	540	600
Black bit shale	600	1600
Blk bit shale & sand	1600	1910
Limestone, dolomitic	1910	2054
Dolomitic and grey sdy lime	2054	2510
Gry shale	2510	2555
Lime	2555	2660
Top Wilcox sand	2660	2973
Top Arbuckle	2973	4675
Granite wash	4675	4706
Total Depth		4706

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ENCLOSURE 4
Exhibit H

2661

RECEIVED MAY 16 1972

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ENCLOSURE 5
Exhibit H

OCTOBER 28, 1969

GEOLOGICAL REPORT

KERR-McGEE CORPORATION

SEQUOYAH FACILITY WASTE DISPOSAL #1

SECTION 21, T 12N, R 21E

SEQUOYAH COUNTY, OKLAHOMA

PETER L. SCOTT
INDEPENDENT GEOLOGIST
OKLAHOMA CITY, OKLAHOMA 73102

Spud: 9-27-69 Logged: 10-27-69

Contractor: Unit Drilling Company

Elevations: K.B. 579
G.L. 563

Total Depth: 3122 Logger
3118 Driller

Cores: #1 - 1452-77 Dolo, fr por, no vis perm
#2 - 1737-43 Rec. 20" Dolo W/Sh Partings
#3 - 1912-25 Rec. 12'2"
#4 - 2294-2312 Rec 16'8" Dolo, M xln W/gd por, vug
#5 - 3021-32, Rec. 10'6" Dolomite, Sandy Dolomite & Dolomitic Sand.

DST: None

Logs: Schlumberger IES 133-3121
FDC 498-3128
SNP 498-3126

Bits Used: 32

FORMATION TOPS

Formation	Log Tops	Sub-Sea
Spiro	342	+ 237
Wapanucka	392	+ 187
Mississippian	537	+ 42
Chatanooga	750	- 171
Hunton	761	- 182
Sylvan	998	- 419
Viola	1034	- 455
Simpson	1090	- 511
Arbuckle	1337	- 758
Granite	3102	-2523

Samples were examined from 40' to total depth and a 2½" = 100' sample log was made through this interval.

No shows of hydrocarbons were noted in the samples although several zones of porosity were drilled in the Simpson and Arbuckle.

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NUMBER OF PAGES: 2

ACCESSION NUMBER(S):

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-11/01
-11/02
-11/03
-12/01
-12/02

8512180168-13
-13/01
-13/02
-13/03

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KERR-McGEE CORPORATION
SEQUOYAH WASTE DISPOSAL WELL

Subject: Results of laboratory tests conducted by Core Laboratories, Inc. to determine the effects of permeability damage using the formation core and formation water as a reference and flushing the formation core with synthetic waste fluids.

Results

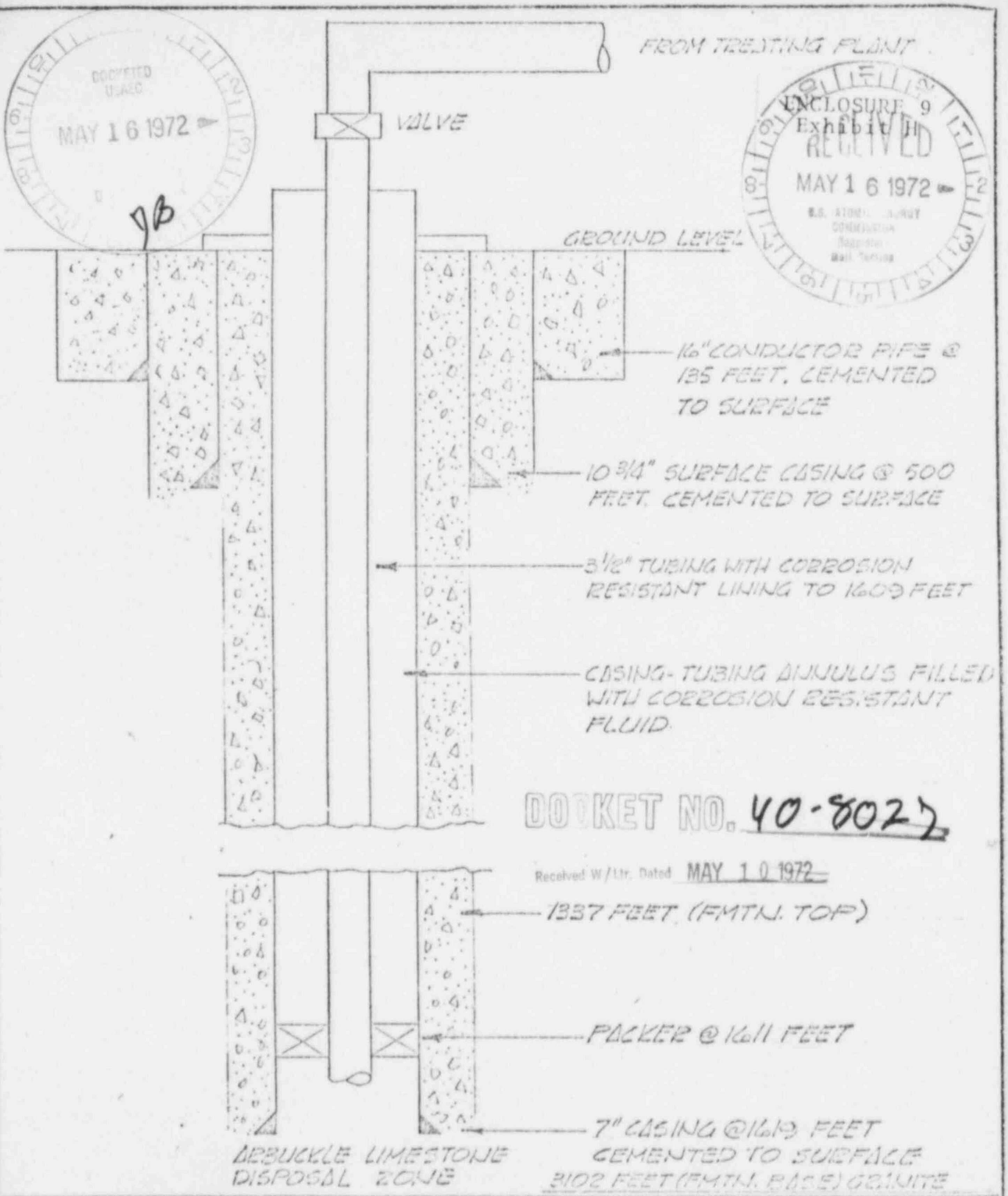
Sample No.	Depth (ft)	Air Perm. md	% Porosity	Fluid Permeability, md.[1] Formation Water (initial)	Neut. Raffinate	Diluted Raffinate	Diluted HF	Formation Water (final)
4	1456	0.18	13.3	0.068	0.07			0.065
5	1456	0.17	13.8	0.26*		0.09		0.09
7	1462	1.7	13.4	0.52			0.54	0.40
16	1471	0.02	6.7	0.0017		0.002		0.0012
18	2301	0.02	7.4	0.0019	0.001			0.0011
24	3023	0.18	6.0	0.022			0.025	0.015

(1) Volume of fluid used in determining permeability was approximately 10 pore vol.
* questionable value.

Composition of Synthetic Raffinate (grams per liter):

V_2O_5	0.05	As	0.2
PO_4	0.4	Fe	0.7
Cl	0.3	NH_4NO_3	60
Mo	0.3	HNO_3	50
SO_4	10	Na_2SiO_3	1

ENCLOSURE 8
Exhibit H



KERR-McGEE CORPORATION

NUCLEAR DIVISION — OKLAHOMA CITY, OKLA.

DRAWN	DATE	TITLE	SCALE
NORTON	8-16-70	SKETCH OF WASTE DISPOSAL WELL - SEQUOYAH NUCLEAR FACILITY	NONE
APPROVED			DRAWING NUMBER
			2C71

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NUMBER OF PAGES: 2

ACCESSION NUMBER(S):

8512180168-14

168-15

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Exhibit I

SURFACE AND SHALLOW SUBSURFACE

MONITORING PROGRAM Received W/Ltr. Dated MAY 10 1972

A monitoring program of surface and shallow subsurface liquids from nearby streams, run off collection ponds, and shallow wells will be carried out to confirm that the deep well reservoir contained fluid and injected wastes are being confined at the lower levels as planned. In the unlikely event that some type of loss of confirnment occurred which was not detected by other means as planned, the monitoring program will provide early warning so that environmental effects will be avoided or minimized through the appropriate action.

The monitoring program of sampling and analyses shown in the attached table, will detect the presence of either waste fluids or insitn formation waters which are very high in calcium, sodium, chlorides, and briarbonates.

To provide base line valves for the four constituents mentioned in the paragraph above, a series of base line samples and analyses should be made for one month prior to the start of waste injection.

Base line valves for the other constituents are already available.

Sample Source	Sample Volume	Sampling Frequency		Sample Analyses Performed									
		Collection	Analysis	α	β	U	F	N	Ra	Ca	Na	Cl	HCO_3
1. Rivers and Creeks													
a) Arkansas River-Upstream	1 gal	Weekly	Monthly	X	X	X	X	X	X (Qtrly)	X	X	X	X
b) Arkansas River-Downstream	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
c) Illinois River-Upstream	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
d) Illinois River-Downstream	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
e) Salt Fork Creek	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
f) Vian Creek	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
g) Dirty Creek	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
h) K-M South Creek (Terrell Branch)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
2. Lakes and Ponds													
a) Tenkiller Lake (7 miles North of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
b) Sourface Pond (1/4 mile South of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
c) Surface Pond (1/2 mile East of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
d) Surface Pond (1/4 mile Southeast of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
e) Surface Pond (1/2 mile Southeast of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X

Sample Source	Sample Volume	Sampling Frequency		Sample Analyses Performed									
		Collection	Analysis	α	β	U	F	N	Ra	Ca	Na	Cl	HCO_3
3. Shallow Wells													
a) K-M Monitor Well (3/4 mile East-Southeast of Facility)	1 gal	Weekly	Monthly	X	X	X	X	X	X (Qtrly)	X	X	X	X
b) Carlisle School Well (1 mile East-Northeast of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
c) Domestic Well (1/4 mile South of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X
d) Residence Well (1/2 mile Northeast of Facility)	1 gal	"	"	X	X	X	X	X	X "	X	X	X	X