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PRESERVATION OF ARCTIC WELLS

FOR

SUBSURFACE TEMPERATURE OBSERVATIONS

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PRESERVATION OF ARCTIC WELLS FOR SUBSURFACE TEMPERATURE OBSERVATIONS

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Summary

Since 1962 a total of 65 wells drilled for northern oil and gas exloration have been preserved for subsurface temperature observations. The majority of these preservations, some 56, have been made since 1970. To date the total cost of preservations has been $120,862 or an average of $1860 per well. In the past several years an increasing number of the wells made available to us have been financed entirely by industry with a consequent reduction of average preservation costs to E.M.R. per well in 1975, for example, to $610. Of the 14 wells preserved in 1975 we paid the partial cost of preservation for only one well. Of the preserved wells, the geothermal group accepted responsibility for placing the surface plugs in 26 at the completion of the scientific programme. To date 9 of the wells have been finally abandonned to D.I.N.A. specifications. Abandonment of the wells completed prior to 1973 requires a cement plug to be placed in the bore of the surface casing; however, since that time an agreement has been in effect between D.I.N.A., E.M.R. and industry which greatly simplifies the abandonment procedure.

17 left.

Continued support for the programme of preservations at a level of $20,000 per year for 5 years is recommended. Industry wells will probably continue to be made available at no cost in the Sverdrup Basin and Mackenzie Delta. Therefore, it is recommended that EPB use its funds to complete the regional coverage by concentrating on preserving wells in the Eastern Arctic, Banks Island, Victoria Island and the northern Yukon.

1. INTRODUCTION

The purpose of the northern geothermal well preservation is three-fold;

1. To provide base thermal data to government regulatory bodies and to the resource industries.
2. To determine the distribution of the thermal field across northern Canada as;
   a) a means of determining the thickness and distribution of permafrost
   b) a means of predicting the gas hydrate potential
   c) an aid to understanding the genesis and nature of the lithosphere
3. To provide an assessment to regulatory bodies of the impact of development through an understanding of the thermal regime.

This report examines the cost and mechanics of the well preservation programme, identifies future costs and recommends a future course of action for the programme. No examination is included of the northern geothermal work carried out in cooperation with mining companies because such boreholes used for geothermal measurements are subject to somewhat different regulations.

2. PRESERVATION PROGRAMME

Since 1962 a total of 65 wells, drilled as part of northern oil and gas exploration programmes, have been preserved for subsurface temperature observations. The first of these wells, Dome Winter Harbour #1, was drilled on Melville Island and preserved by the United States

Geological Survey in 1962. The measuring programme on the installed multisensor cable terminated in 1964, long before the well returned to thermal equilibrium, but was reactivated by Earth Physics in 1968 and continued until final abandonment and clean-up of the site in 1973. Between 1962 and 1968 a total of 5 wells were preserved in the N.W.T. and Yukon including amongst these the first well drilled in the Mackenzie Delta (B.A., Shell, I.O.E. Reindeer D-27). After the stimulation of exploration by the creation of Panarctic Oils in the late sixties and the increased interest in the Delta, the amount of drilling activity increased markedly. Initially industry expressed minor interest in subsurface temperatures thus the number of preserved wells was limited by the EPB funds available. Subsequent to the realization by industry in 1971 that permafrost could present serious problems in exploration and eventually in production, an increasing number of wells have been made available at no cost to the geothermal programme. Between 1971 and 1975 a total of 56 wells were preserved of which only 16 were partially or totally funded by EPB. These were generally in areas remote from the major discovery areas and thus of little present interest to industry while important for EPB's regional coverage. Table 1 shows a breakdown of the number of wells preserved in each year and the total annual cost of the preservations to EMR. To date the total cost of well preservations to EMR has been $120,862 or $8,633 per year, at an average cost of $1,860 per well.

3. PRESERVATION METHODS

The problems associated with temperature measurements in northern boreholes are considerable, including those of either preserving an open borehole or instrumenting it with multisensor cables and yet fulfilling the requirements of regulatory agencies, the cost and difficulty of access to some areas, and the length of time that a northern borehole may take to return to thermal equilibrium with its surroundings.

Usually, boreholes greater than 120 m in length must comply with conservation regulations of the Department of Indian and Northern Affairs, which administers the Canada Oil and Gas Land Regulations in the Northwest Territories and the Yukon Territory. These regulations require surface casing to be placed through the permafrost and left in place as part of the abandonment. Normally, to abandon a borehole, the regulations require the usual cement plugs to isolate porous horizons, a 30-m cement plug bridging the base of the surface casing and the open hole below, a further cement plug with a top a metre below the surface. Casing is usually cut one metre below the surface leaving only a well-sign visible on the surface. The drilling mud is left in the hole and allowed to freeze. Initially, the approach to preserving open holes for temperature measurements was, at the completion of drilling and logging, to have the usual plugs placed, up to and including that at the base of the surface casing, the drilling mud displaced by arctic diesel fuel, and the surface plug left out until completion of the measurements. The surface casing was cut as usual below the surface and a riser installed to provide access to the well for logging. A typical well-preservation is shown in Fig. 1 (Appendix 2). This technique has worked very successfully, but does have several drawbacks: Diesel fuel can be very expensive in the Arctic, particularly at sites serviced only by aircraft. Convective overturn occurs in the bore fluid over high temperature gradient sections of boreholes. Subsequent efforts to eliminate both problems by freezing home-made cables into the drilling mud have been unsuccessful. Methods of gelling the diesel fuel around a multisensor cable or installing smaller diameter tubing in the bore have proven too expensive. In industry, efforts to strap multisensor cables to the outside of the surface casing at the time of its installation have been partially successful. Over much of the mainland of the Northwest Territories and the Yukon Territory the required surface casing is to a depth of 200 m or less. In such cases 5 cm diameter tubing was installed in holes to be preserved to depths in excess of 200 m. The bottom of the tubing and the annulus are both filled with cement, the bore with diesel fuel.

The preferred method of preservation by displacing drilling mud with an antifreeze is the one most commonly used by industry and ourselves. Of the 51 wells preserved in this fashion and in which at least one temperature log could be made with the portable mode equipment, only 3 wells have become blocked at a later stage. At EPB #87 and #98 the riser plate broke from the surface casing and allowed water into the top of the hole and in #177 an ice-plug developed at some depth presumably because of poor flushing procedures during preservation. Many of the wells have suffered partial casing collapse although it has been insufficient to prevent passage of the temperature probe. Three of the wells preserved by industry and made available for our use have proved impossible to log because of shallow blockages of uncertain cause in the casing.

In 1971 home-made 600 m. long multithermistor cables were installed directly in the drilling mud at the completion of wells EPB #92, 93 and 97. All three cables failed within a year presumably due to differential rates of freezing and the resulting pressures generated in the well bore. Similar cables, installed at wells EPB #62, 63 and 73 in a surface casing in which the drilling mud had been displaced by diesel fuel, or an antifreeze, have survived for 10 years.

A similarly poor success has been attached to industry's attempts to attach multisensor cables to the outside of the surface casing. To the authors knowledge only 3 cables, all being logged by E.P.B. (sites #166, 195 and 255), have survived beyond freezeback to depths in excess of 150 m. Admittedly, the primary purpose of the majority of cables was to monitor temperatures during drilling rather than to determine equilibrium temperatures after well completion.

The technique of installing a smaller diameter casing either within a larger diameter casing or within a larger diameter open-hole has been used at 7 locations of which 2 attempts failed. At site EPB #90 the diesel-filled tubing was installed in drilling mud within a conventional surface casing but collapsed within a few months. At EPB #174 a small diameter tubing was installed in an open-hole but became blocked prior to the first log, probably during installation.

A total of 65 wells drilled for northern oil and gas exploration have been preserved for and have had at least one set of subsurface temperature observations made in them. Six additional wells made available proved impossible to log either because of shallow blockages in the well bore or destruction of the surface installation during site clean-up. Of the 65 successful preservations, 6 wells were lost, for a variety of reasons, between the first and subsequent logs.

The most important fact to note is that fairly standard techniques and procedures of well preservation have been developed and have proven to have a high success ratio if the completion is carefully performed. Other seemingly cheaper solutions, both in time and cost, had somewhat lower rates of success and probably do not warrent further trial.

4. PRESERVATION COSTS

Of the wells preserved to date 42 have been at no cost and no acceptance of responsibility for the well to EMR Thus the average cost per well of $1,860 is an artificial one. A more realistic figure is $5,255, the average cost per well based only on wells for which we paid all or partial preservation costs. This figure is reduced to $4,421 if the very expensive preservation of EPB #95 is omitted. It is apparent that these figures in no way represent the total true cost of preservation, and again with the exception of several early wells, namely EPB #62, 63 and #95 rig time costs, conditioning costs and most material costs (with the exception of the diesel fuel and in some cases small diameter tubing) have been borne by the operators. Figures ranging from $15,000 to $25,000 have been given the authors by industry as representing the total true cost over and above normal abandonment costs. This is of course, a very small cost when compared with total drilling costs of $2 million to $4 million for a northern well.

Although industry is progressively making more and more wells available to us, particularly as they approach production design in some areas, we still need to retain at least $10,000 per year for preservations in areas presently being wildcatted. In 1975 only one well was preserved to which the Branch contributed some of the cost. The cost, however, of 5300 gallons of diesel fuel with which to fill the well bore to 600 m was $8,547 reflecting the rapidly rising fuel costs.

By far the most expensive completion to date was that of EPB #95 which cost $19,180 to preserve as a temperature observation well. The very high costs were considered warranted because of the unique location of the site on Rowley Island in the Foxe Basin (It remains today as the only well drilled in the area). The well was strictly a stratigraphic test rather than an oil exploration hole and therefore, was not completely cased through permafrost. A large proportion of the costs incurred were those of purchasing small diameter tubing, flying it to the very remote location and installing it in the drill-hole to a depth 500 m.

Table 2 lists the number of wells preserved each year and the average cost of each preservation that year. The increasing number of industry financed preservations from 1972 onwards is reflected strongly in the average well cost. Average well costs were highest in 1971, the year that EPB was able financially to implement a systematic northern geothermal programme to fill an identified need for thermal information on deep permafrost conditions. In 1975 one company made 12 wells available at no cost to ourselves while budget cuts curtailed EPB's northern programme drastically; thus the average well cost is very low.

Table 3 gives statistical information on well preservations by operator Immediately apparent is the fact that the largest companies have provided the greatest assistance, e.g. 44 of the preservations are of wells drilled by 3 operators and 53 by 5 operators. Preservation of those 44 wells, 68% of the total, cost EMR only 48% of the money spent. By far the most expensive wells were those of the smaller operators in the north; eight such wells or 12% of the total cost 32% of the total funds. Almost 50% of this money was admittedly spent on a single well. If this well is excluded the average well cost to EMR for 7 wells is $2,870 , still high compared with the three major operators.

Table 4 divides the number of wells and preservation costs by region. The two regions where the average preservation cost per well is lowest are, not suprisingly, those of most interest to industry, i.e. Sverdrup Basin and Mackenzie Delta. Over 65% of the wells preserved but only 35% of the funds were spent in these two areas. Well preservations have been most expensive, over $4,000 per well, in the Arctic Platform, Arctic Fold Belt and the Yukon. This situation will no doubt change if and when any hydrocarbon reservoirs are discovered. Not surprisingly perhaps, preservation costs have generally been higher in the Arctic; although a similar number of sites have been preserved in the Arctic and the Northern Mainland 76% of the expeditures have been in the Arctic.

Appendix 1 lists each well preserved by the EPB#, by an abbreviated well name and by year of preservation. The individual costs of preservation and abandonment are given for each well. Where further costs may yet be incurred by EPB for purposes other than logging trips a symbol 'B' is found in the "Abandonment Cost" column.

In the future increasing numbers of wells will probably be made available at no cost to us in both Sverdrup Basin and Mackenzie Delta particularly as development wells are drilled. These are of considerable relevance in studies of local thermal variations. However, EPB funds will continue to be necessary to complete a regional coverage. Areas deficient in thermal data at present are Banks Island, Victoria Island, Axel Heiberg Island, Bathurst Island, Devon Island, Baffin Island and the Yukon. Unless major discoveries are made or serious problems are encountered in these areas, EPB may have to invest some funds to complete the coverage.

5. ABANDONMENT METHODS

All of the wells preserved with diesel fuel to date must at some stage be abandoned in a manner acceptable to the regulatory agencies. Of the 65 wells preserved EMR accepted the responsibility for the final abandonment of 26 at the completion of our science programme. Nine of these wells have presently been abandoned to regulatory specifications. The measuring programme is complete at 4 further wells which will be abandoned when funds are available.

At wells completed prior to 1973, final abandonment requires the placing of a surface plug, usually cement, within the bore of the surface casing. Since that time a simpler form of surface installation requiring a much simpler surface plug has been developed cooperatively with D.I.N.A. The surface installation is completed as shown in Appendix 2 requiring only the placing of a bull-plug at programme completion.

It must be stressed that this final surface plug is not necessary to the safety of the well itself. All such plugs are placed before the drill-rig leaves the well-site. The surface plug ensures merely that an open pipe-stand does not remain at the surface. Its routine placement was adopted in the settled parts of Canada and the southern regulations adopted in the north. For the sake of completeness, however, its placement is warranted.

ABANDONMENT COSTS

Of the 9 wells abandoned to date for which EMR had responsibility 4 have been carried out by EPB, and 5 through the courtesy of industry at no cost to EPB. Of the former, installations of surface plugs at sites #62 and #70 were carried out by EPB personnel and at sites #55 and #94 were completed through contracts at an average cost per well of $2k. EMR is responsible for the final abandonment of a further 17 wells once the science programmes are complete. Of these, 11 will require a cement plug to be placed and 6, plus any subsequent wells will require only a bull-plug. The difference is of course significant as the latter can easily be set by our field parties during a routine logging trip, whereas the former is somewhat more complex and requires a prolonged stay. Of the wells still requiring cement plugs 4 are in the Mackenzie Valley and Delta and can be completed by small contracts to local mechanical contractors at costs of a few thousand dollars each. The other 7 are in the Arctic Islands and some at quite remote locations. With the agreement of D.I.N.A. wells at these locations will be abandoned by ourselves or by small contracts to the petroleum companies when suitable camps are in the area and logistics costs can be minimized. The costs of completing the final 11 "difficult" abandonments should not exceed $40k spread over at least 5 years.

7. RECOMMENDATIONS

a) EPB should continue to financially support a small number of Arctic Well preservations. A level of $10k per year would provide minimal support this effort.

b) EPB has an outstanding responsibility to complete the abandonment of several wells. A level of $10k per year would ensure the responsibility being fulfilled.

c) The group continue in close cooperation with industry to expand the available geothermal information in northern Canada both on a local and a regional basis.

d) Primary areas to obtain geothermal data should be the Eastern Arctic,Banks Islands and the northern Yukon.

YEAR	No. of Wells	TOTAL COST TO EMR $
1960-1967	5	20,455
1968	1	2,000
1969	1	1,630
1970	2	6,776
1971	10 *2 (9)	43,847 (24,667)
1972	9	11,629
1973	14	14,718
1974	9	11,260
1975	14	8,547
TOTAL	65	120,862 *1

Note:

*1 The total includes abandonment costs to EMR (Abandonment total $ 4.115)

*2 A large proportion of expenditures ($ 19.180) were on well #95.

Table 1 TOTAL NUMBER OF WELLS PRESERVED AND COSTS INCURRED BY YEAR.

YEAR	NO. WELLS	AVERAGE WELL COST TO EMR
1962	1	2,443
1963	1	7,020
1965	3	4,478
1968	1	2,000
1969	1	1,630
1970	2	3,388
1971	10	4,385
1972	9	1,292
1973	14	1,051
1974	9	1,251
1975	14	610

Table 2 AVERAGE COST OF EACH PRESERVATION BY YEAR

NAME OF COMPANY	NO. WELLS	TOTAL COST TO EMR $	AVERAGE COST PER WELL TO EMR
PANARCTIC OILS	20	45,101	2,255
GULF CANADA	11	11,060	1,005
IMPERIAL OIL	13	2,000	0,154
SHELL OIL	5	3,300	0,660
ELF OIL	4	14,000	3,500
ARCO CANADA	2	6,129	3,065
[illegible]ME PRETROLEUM	2	0	0
OTHERS	8	39,272	4,909

Table 3 WELLS PRESERVED AND COSTS BROKEN DOWN BY OPERATOR

NO. WELLS	REGION	PRESERVATION COSTS TOTAL	TO EMR PER WELL
		$	
19	SVERDRUP BASIN	37,236	1,960
6	ARCTIC PLATFORM	29,200	4,867
6	ARCTIC FOLD BELT	25,565	4,261
31	ARCTIC TOTAL	92,001	2,968
24	MACKENZIE DELTA	7,662	319
4	MACKENZIE VALLEY	10,496	2,624
5	N.W.T. OTHER	4,073	815
1	YUKON	6,632	6,632
34	MAINLAND TOTAL	28,863	849

Table 4 WELL COST BROKEN INTO REGIONS

APPENDIX I PRESERVATION AND ABANDONMENT COSTS OF NORTHERN WELLS

- Costs to EMR

YEAR	E.P.B. #	WELL NAME	PRESERVATION COST	ABANDONMENT COST	TOTAL COST
				$	
1960-67	55	Resolute Bay L-41	4,605	2,415	7,020
	62	N. Cath YT B-62	6,632	0.	6,632
	63	Reindeer D-27	4,360	B[1]	4,360+ [2]
	73	Winter Harbour #1	0.	0.	0.
	66	Yellowknife-Baker L.	2,443	0.	2,443
1968	70	Providence A-47	2,000	0.	2,000
1969	76	Kugaluk N-02	1,630	0.	1,630+
1970	86	Hoodoo Dome H-37	6,776	B	6,776+
	77	Horton River G-02	0.	0.	0.
1971	87	Wilkins E-60	6,000	0.	6,000+
	90	Amund Central Dome	5,000	B	5,000+
	91	Jameson Bay C-31	5,000	B	5,000+
	92	Garnier 0-21	0,	B	0. +
	93	Cornwallis K-40	0.	B	0. +
	95	Rowley Island M-04	19,180	B	19,180+
	97	Fosheim N-27	0.	0.	0.
	98	Storkerson Bay A-15	3,000	0.	3,000
	89	Beaverhouse Creek H-13	3,300	0.	3,300
	94	Dahadinni M-43A	667	1,700	2,367
1972	99	Devon E-45	0.	0.	0.
	155	Kristoffer Bay B-06	0.	0.	0.
	158	Brock I-20	5,500	B	5,500+
	170	Thor P-38	0.	0.	0.
	171	Dome Bay P-36	0.	0.	0.
	172	Drake B-44	0.	0.	0.
	100	Hume River D-53	3,092	B	3,092+
	151	West Whitefish H-34	3,037	B	3,037+
	165	Kilagmiotak F-48	0.	0.	0.
1973	166	Mokka A-02	0.	0.	0.
	168	Dundas C-80	4,505	B	4,505+
	169	Louise Bay 0-25	6,837	B	6,837+
	175	Gemini E-10	3,376	B	3,376+
	195	Linkens P-46	0.	0.	0.
	200	Hecla I-69	0.	0.	0.
	167	Unipkat I-22	0.	0.	0.
	173	Niglintgak H-30	0.	0.	0.
	174	Highland Lake I-23	0.	0.	0.
	176	Ya Ya P-53	0.	0.	0.
	177	Titalik K-26	0.	0.	0.
	178	Parsons N-10	0.	0.	0.
	179	Reindeer F-36	0.	0.	0.
	192	Kugpik 0-13	0.	0.	0.
	193	Ikhil I-37	0.	0.	0.

YEAR	E.P.B. #	WELL NAME	PRESERVATION COST	ABANDONMENT COST $k	TOTAL COST
1974	196	Bent Horn N-72	0.	0.	0.
	197	Neil 0-15	6,700	B	6,700+
	198	Drake D-68	0.	0.	0.
	199	Drake E-78	0.	0.	0.
	256	Sutherland 0-23	0.	0.	0.
	257	Pedder Pt. D-49	4,560	B	4,560+
	194	Atigi 0-48	0.	0.	0.
	253	Tedgi Lake K-24	0.	0.	0.
	254	Ya Ya A-28	0.	0.	0.
1975	258	Pat Bay A-72	8,547	B	8,547+
	259	Drake D-73	0.	0.	0.
	255	Adgo P-25	0.	0.	0.
	260	Red Fox P-21	0.	0.	0.
	261	Kimik D-29	0.	0.	0.
	262	Atertak E-41	0.	0.	0.
	263	Pikiolik M-26	0.	0.	0.
	264	Pikiolik E-54	0.	0.	0.
	265	Mallik A-06	0.	0.	0.
	266	Ivik J-26	0.	0.	0.
	267	Taglu C-42	0.	0.	0.
	268	Taglu F-43	0.	0.	0.
	269	Taglu D-55	0.	0.	0.
	270	Niglintgak M-19	0.	0.	0.

NOTES:

1 B — EMR still responsible for surface plug at completion of measurement programme.

2 + — Additional expense may be incurred by final abandonment.

APPENDIX 2

OIL AND MINERALS DIVISION

DEPARTMENT OF INDIAN AND NORTHERN AFFAIRS

Suspension of Wells for Temperature Observation and Final Abandonment of Same

I. Suspension by Operators

1. Abandonment procedures as stipulated by the District Oil and Gas Conservation Engineer, must be followed up to and including the placement of a 100 foot cement plug across the shoe of the innermost casing string in the well.

2. Cut off casing 4 feet below ground level.

3. Weld plates to seal off innermost casing and casing annulus as shown in attached diagram (Figure 1)

4. Install a pipe having minimum 2½ inch I.D., with a 2½ inch full opening gate valve as shown in attached diagram. Pipe must be securely welded to plate.

5. Fill casing with diesel oil or other non-freezing fluid.

6. Install identification plate and elbows as shown.

II. Final Abandonment by Seismology Division - EMR

1. Remove valve.

2. Using thread locking compound, install bull-plug with collar welded to it (Bull plug and two Collars to be supplied by EMR) to receive pipe with identification plate attached. (Figure 2)

3. Install identification plate.

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SUSPENSION OF WELLS FOR TEMPERATURE OBSERVATION

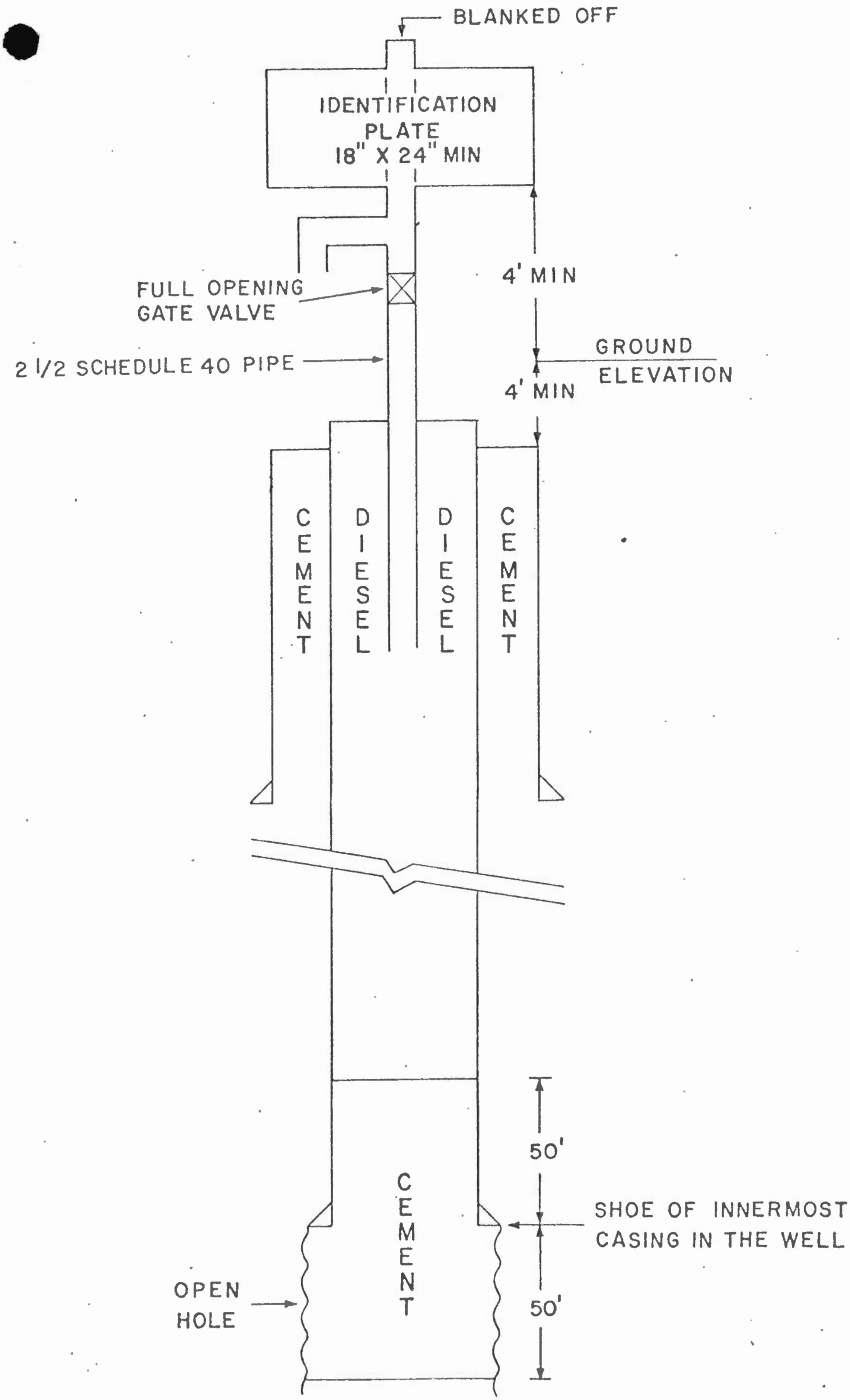

FIGURE 1

FINAL ABANDONMENT OF TEMPERATURE OBSERVATION WELLS BY SEISMOLOGY DIVISION - E.M.R.