Memorandum

UNOCAL 76

August 11, 1986

TO: Alex Schriener

FM: Daniel L. Carrier

ALEX SCHRIENER
Schriener
AUG 21 1986

RE: EVALUATION OF SUBSURFACE TRACE-ELEMENT AND WHOLE-ROCK OXYGEN-ISOTOPE DATA FROM THE MEDICINE LAKE HIGHLAND, CA

SUMMARY

The analysis of temperature borehole and deep exploration well trace-element mercury and arsenic and rock-oxygen isotope data successfully establishes that high-temperature hydrothermal activity has and possibly still is occurring at Medicine Lake Highland. Three principal areas of significant hydrothermal activity are the : (1) Mt. Hoffman - Hot Spot area, (2) Telephone Flat area, and (3) Schonchin Spring - Grouse Hill area. Since deep (>3000') drilling has only been attempted near Mt. Hoffman, that area alone shows direct evidence of a well-developed, high-temperature geothermal system. Nevertheless, the geochemical data suggest that high-temperature geothermal activity has probably been widespread. Whether the geochemical anomalies result from current or extinct hydrothermal activity can not be determined from this data set alone. Therefore, geochemical, mineralogical and the proprietary subsurface temperature data must be synthesized to correctly evaluate the potential geothermal resource at Medicine Lake Highland.

RECOMMENDATIONS

The comprehensive understanding of hydrothermal activity and alteration assemblages have been shown to be essential for geothermal resource development and management in the Philippines and Indonesia. Therefore, the following studies are recommended on the thermal borehole and exploration well samples from Medicine Lake Highland:

1. Detailed petrographic and XRD data should be collected and integrated in order to (a) classify and describe alteration mineral assemblages and (b) identify any relationships between the assemblages and general stratigraphy. This study should include GMF 68-8.

2. Hydrothermal quartz and calcite should be sampled for fluid inclusions and oxygen isotopes. These data are useful for approximating the temperature, salinity, and oxygen isotopic composition of the fluids in equilibrium with the alteration mineral assemblages. The wells recommended for sampling are GMF 28-32, GMF 44-33, GMF 45-36, GMF 17A-6, GMF 56-3, GMF 68-8, and ML 36-28.

INTRODUCTION

Medicine Lake Highland (MLH) is a basaltic to rhyolitic volcanic complex located in the southern part of the Cascade geologic province in Siskiyou County, California. Volcanic rocks at MLH are primarily lava flows that range in age from 1.18 m.y. to 1,000 years (Luedke and Smith, 1981; Mertzman, 1982). Surface hydrothermal manifestations consist of argillic alteration and weak fumarolic activity (168°F) at the Hot Spot (Figure 1), and argillic alteration and local silicification in the Schonchin Spring and Crystal Spring areas (Hausback, 1984). Unocal has actively leased competitive and non-competitive federal land at MLH. The majority of the Unocal leases were incorporated in 1982 into the Glass Mountain Federal Unit. Unocal operates the unit and Santa Fe Geothermal and Geysers Geothermal are active participants.

This report integrates whole-rock oxygen-isotope and trace-element mercury and arsenic data from 24 temperature boreholes and one exploration well (GMF 17A-6) drilled at MLH. The purpose of this study is to (a) develop a conceptual geochemical model for the MLH geothermal system, (b) select borehole and well intervals for fluid inclusion sampling, and (c) determine in which boreholes warrant detailed mineralogical studies.

METHODOLOGY

A. OXYGEN ISOTOPES

Whole-rock oxygen-isotopes are effectively used to map the coincidence of high temperatures and high water-to-rock ratios. Oxygen-18 isotopic exchange between rocks and water is systematic and varies from $\delta^{18}O$ enrichment of the rock at low temperatures to depletion at high temperatures. The "crossover" temperature between enrichment and depletion is dependent upon rock mineralogy and the $\delta^{18}O$ of unaltered rocks and the geothermal fluids. Since the $\delta^{18}O$ of the geothermal fluids at MLH have not been measured, the $\delta^{18}O$ of local meteoric water (Gallinatti, 1984) is used to estimate a "crossover" temperature that ranges from 60° to 130° C (or 140° to 265°F; Brian Smith, personal comm.).

B. MERCURY AND ARSENIC

Elemental mercury (Hg°), being volatile and having a relatively high water solubility, is an extremely mobile element in the geothermal environment. When a Hg°-bearing geothermal fluid mixes with cool oxygenated water, or with low-pH oxidizing water, Hg° is oxidized and precipitated as HgS. If a geothermal fluid develops a vapor phase, Hg° is strongly partitioned with the vapors and migrates away from the high-temperature area. The mercury vapor is then either (1) precipitated as HgS when steam condensation and fluid acidification occurs, (2) adsorbed on the surface of clay, organic, and organometallic compounds, or (3) lost to the atmosphere. The end result is generally a halo of mercury enrichment around the geothermal system (Varekamp and Buseck, 1984).

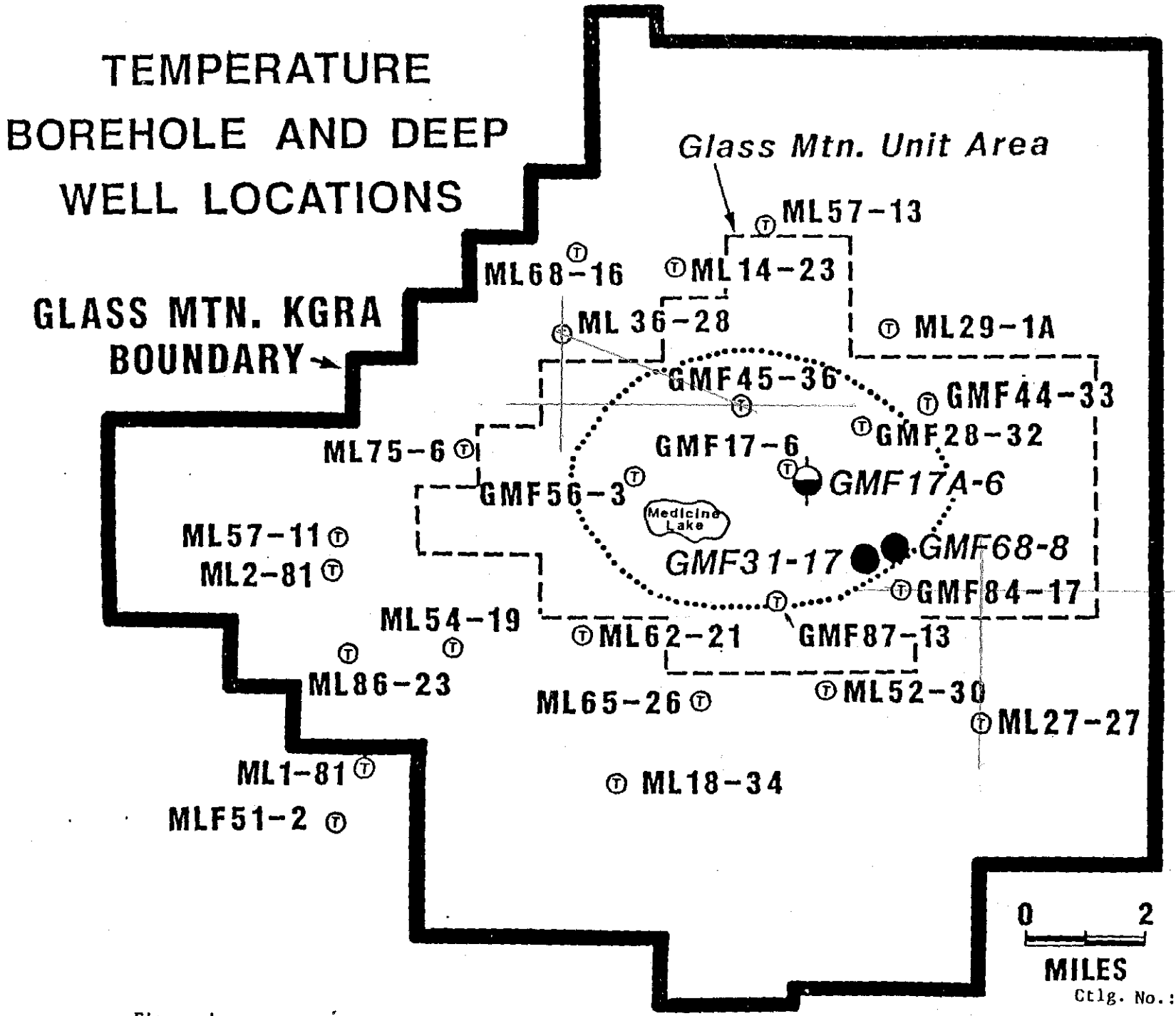

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Figure 1

Memorandum CA-GMT-910

UNOCAL 76

CONFIDENTIAL

DAVID SUSSMAN

MAY 12 1989

CONFIDENTIAL

April 26, 1989

TO: David Sussman

FM: Daniel L. Carrier

RE: GLASS MOUNTAIN BOREHOLE AND WELL DATA

This memo contains summary data from temperature boreholes and exploratory wells drilled in and around the Glass Mountain KGRA, Medicine Lake Highland, California. Principal facts for the boreholes and deep wells are presented in chronological order in Tables 1 and 2, respectively. Included in the tables are information on completion dates, total depths, bottom hole temperatures and gradients, and mineralogy. In addition, production and casing information are included for the wells in the "comments" section of Table 2. By convention, those boreholes and wells drilled inside the Glass Mountain Federal unit are designated as "GMF", and those drilled outside the unit are designated as "ML" or "MLF". These data were all obtained from Unocal files. The information presented here is current through March, 1989, and will be updated as new wells are added.

A location map for the boreholes and wells is shown in Figure 1. Figures 2 to 7 contain composite temperature-depth profiles for all the wells and groups of the boreholes. Individual temperature-depth profiles are presented in Appendix 1. Principal facts for boreholes and wells are shown on a summary map in Plate 1.

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UNOCAL 76

CA-GMT-925
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DAVID SUSSMAN
MAY 12 1989

April 26, 1989 CONFIDENTIAL

TO: David Sussman

FM: Daniel L. Carrier

RE: GLASS MOUNTAIN BOREHOLE AND WELL DATA

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Table 1: Principal facts for temperature boreholes drilled in the Glass Mountain KGRA 1981-1984. See Figure 1 for locations.

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TEMP. BOREHOLES	ELEV. (FEET)	TD (FEET)	BHT(°F) (DEPTH)	BHG (°F/100') INTERVAL (FEET)	TMAX (°F) (DEPTH)*	COMPANY	DATE	COMMENTS
ML 1-81	5640	600/ETD	40.4 (600)	0.2 400-600	44.2 (50)	Unocal	10/81	Unaltered; isothermal to TD.
ML 2-81	6400	233m 764 725/ETD	38.7 (725)	0 675-725	54.0 (125)	Unocal	11/81	Unaltered; isothermal to TD.
GMF 56-3	6800	1788	134.5 (1788)	10.1 1425-1788	134.5	Unocal	09/82	Zeolite-smectite alteration from <205'-1058'; argillic alteration 1058'-TD; isothermal to 500'.
GMF 44-33	6940	2263	377.2 (2232)	-1.64 1800-2200	396.3 (1580)	Santa Fe Phillips	09/82	Zeolite-smectite 300'-1350', argillic 1350'-TD; significant water entry @ 2260', isothermal to 775'.
GMF 87-13	6720	918	309 (918)	28.0 650-918	309	Unocal	10/82	Bottom hole temp. exceeded tool capabilities, and a maximum readin thermometer was used to measure the temperature. Zeolite-smectite 242'-900', argillic 900'-TD; no isothermal section.
GMF 84-17	6960	1636	239.9 (1636)	11.7 1500-1636	239.9	Unocal	10/82	Zeolite-smectite alteration 1419'-TD; isothermal to 175'.
GMF 17-6	6720	4009	478.5 (3980)	11.5 3840-3980	478.5	Santa Fe Phillips	11/82	Zeolite-smectite 1280'-2680', argillic 2680'-TD; isothermal to 125
MLF 51-2	5473	1836	49.6 (1836)	-.4 1575-1780	64.2 (1025)	Unocal	08/83	Zeolite-smectite 900'-1150', isothermal to 675', possible zone of lateral fluid flow 900'-1100'.
ML 52-30	6380	1972	84.0 (1972)	6.8 1750-1972	84.0	Unocal	08/83	Zeolite-smectite 1100-TD; isothermal to 1375'.
ML 36-28	6700	2146	192.7 (2132)	19.3 1658-2121	192.7	Phillips	09/83	Zeolite-smectite 1500'-2084'; argillic 2084'-TD; isothermal to 145
ML 75-6	6600	1998	110.4 (1983)	8.6 1775-1983	110.4	Unocal	09/83	Zeolite-smectite 1050'-TD; isothermal to 1050'.
ML 54-19	6200	2201	98.4 (2191)	13.8 1940-2180	98.4	Unocal	10/83	Zeolite-smectite 1900'-TD; isothermal to 1250'.
ML 65-26	6230	2180	150.1 (2171)	2.7 2025-2171	150.1	Unocal	10/83	Not altered; isothermal to 1175'.
GMF 45-36	6960	4000	369.9 (3967)	2.6 3560-3967	369.9	Santa Fe	10/83	Zeolite-smectite 1000'-1820', argillic 1820'-2500', and 3430'-3720' propylitic 2500'-3430' and 3720'-TD; isothermal to 1150'.
ML 29-1A	6640	3080 (2800)	158.6 (2800)	9.8 2640-2800	158.6	Anadarko	10/83	Zeolite-smectite 2803'-TD; isothermal to 1250'.

*Depth is shown if different from the depth used for BHT.

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Table 1 Cont'd.

TEMP. BOREHOLES	ELEV. (FEET)	TD (FEET)	BHT(°F) (DEPTH)	BHG (°F/100') INTERVAL (FEET)	TMAX (°F) (DEPTH)*	COMPANY	DATE	COMMENTS
GMF 28-32	7240	(OH)3460 (DP)4500	528.2 (4495)	9.0 4182-4495	528.2	Santa Fe Phillips	11/83 10/84	Zeolite-smectite 800'-TD; isothermal to 1500'.
ML 57-11	6100	(OH)1982 (RD)3002	117.8 (3002)	5.5 2500-3000	117.8	Unocal Phillips	11/83 10/84	Zeolite-smectite 2929'-TD; isothermal to 950'.
ML 57-13	6140	3002	136.5 (2968)	10.9 2740-2860	136.5	Phillips	07/84	Zeolite-smectite 1035'-2115', argillic 2115'-TD; isothermal to 1250'
ML 68-16	6330	2939	140.8 (2935)	5.5 2844-2935	140.8	Phillips	07/84	Zeolite-smectite 2227'-TD; isothermal to 1800', possible fluid flow in the 2500'-2900' interval. Located in Section 21 and not Section 16.
ML 62-21	6590	2142	311.4 (2125)	8.8 1921-2124	311.4	Phillips	08/84	Zeolite-smectite 1554'-3503'; isothermal to 2450'.
ML 86-23	6040	3503	163.1 (3502)	6.5 3320-3492	163.1	Phillips	09/84	Zeolite-smectite 2932'-TD; isothermal to 2000'.
ML 18-34	5860	3500	137.4 (3475)	15.6 3351-3475	137.4	Phillips	10/84	Unaltered; isothermal to 2500'.
ML 27-27	5800	3000	88.0 (2995)	5.5 2655-2969	88.0	Phillips	10/84	Zeolite-smectite 1462'-TD; isothermal to 2350'.
ML 14-23	6560	3000	174.9 (3000)	11.4 2600-2949	174.9	Unocal	11/84	Zeolite-smectite 2480'-2680', argillic 2680'-3460', propylitic 3460'-TD; isothermal to 1250'.

*Depth is shown if different from the depth used for BHT.

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Table 2. Principal facts for deep exploratory wells drilled in the Glass Mountain Unit 1984-1988. See Figure 1 for locations.

DEEP EXPLORATORY WELLS

TEMP. BOREHOLES	ELEV. (FEET)	TD (FEET)	BHT(°F) (DEPTH)	BGH (°F/100') INTERVAL (FEET)	TMAX (DEPTH)*	COMPANY	DATE	STATUS	COMMENTS
GMF 17A-6	6740	9620	429.5 (9436)	5.5 8964-9436	499 (4357)	Santa Fe Phillips	08/84	SUSP.	Casing: 20" from 0-577', 13 3/8" from 0-3750', 12 1/4" open hole to TD. History: a parting occurred in the 13 3/8" casing at 3612'-3629'. A 9 5/8" liner was run from 0-3104' (cemented) and a 9 5/8" liner was hung 3554'-4240' (cemented); a bridge plug was placed at 4800' and top of plug is at 4650'. The 3250'-3350' and 3450'-3550' intervals were perforated and tested. No significant production was found. BHT is from a temperature survey run to TD two days after an injection test and prior to placing the cement plug. Maximum temp. is from survey to 4550' taken after the cement plug was in place and the well was shut in for 252 days. Granitic rocks were drilled from 7760'-TD. Propylitic alteration from 3900'-TD.
GMF 68-8	6991	(OH)6571	540 (6525)	3.6 6000-6525	540 (6525)	Unocal	08/85	POTEN. PROD.	Casing: 13 3/8" from 0-1084', 9 5/8" from 912'-3515', 7" perforated liner hung from 3377'-8410'. Liner plugged from 8100'-8410'. Multiple productive zones: 5000 to 5600' and at 6500 ±200'. Produced 300K #/hr THF and 72K #/hr STM at 102 psia and at an estimated 500 BTU/#. Propylitic alteration from 3000' to TD.
		(DP)8417	556 (8100)	0 7900-8100	556 (7900)	Unocal	07/88		
GMF 31-17	7000	8787	541.5 (8400)	5.8 8000-8400	541.5	Unocal	09/88	POTEN. PROD.	Casing: 13 3/8" from 0-1123', 9 5/8" from 911-3074', 7" perforated liner from 2890' to 8777'. Liner plugged to 8400'. Productive interval: 3760' to 3920'; produced 480K #/hr THF and 78K #/hr STM at 102 psia and at an estimated 425 BTU/#. Multiple granitic dikes observed from 8110' to TD. Propylitic alteration from 2700' to TD.

* Depth is shown if different from the depth used for BHT.

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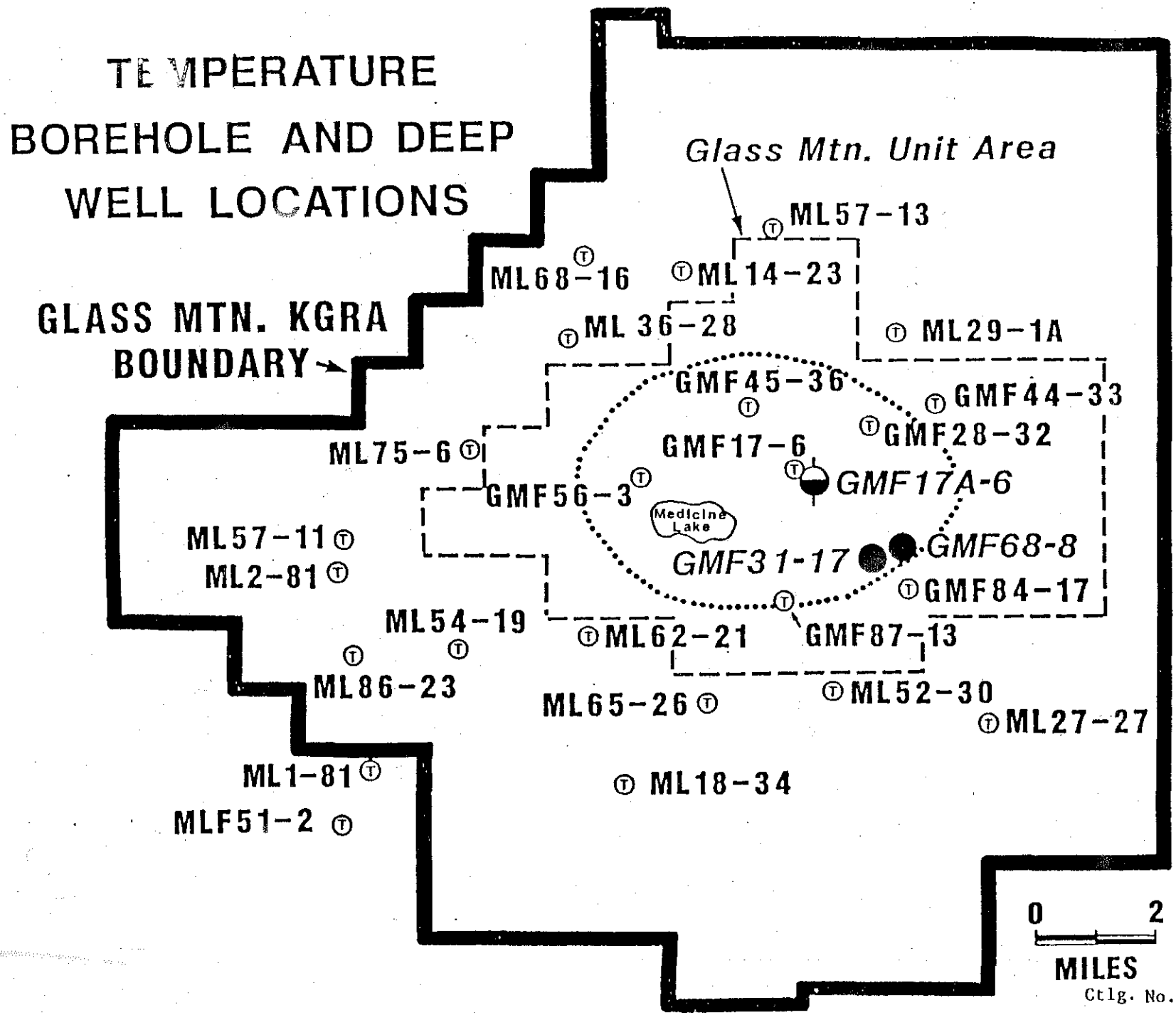

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Figure 1

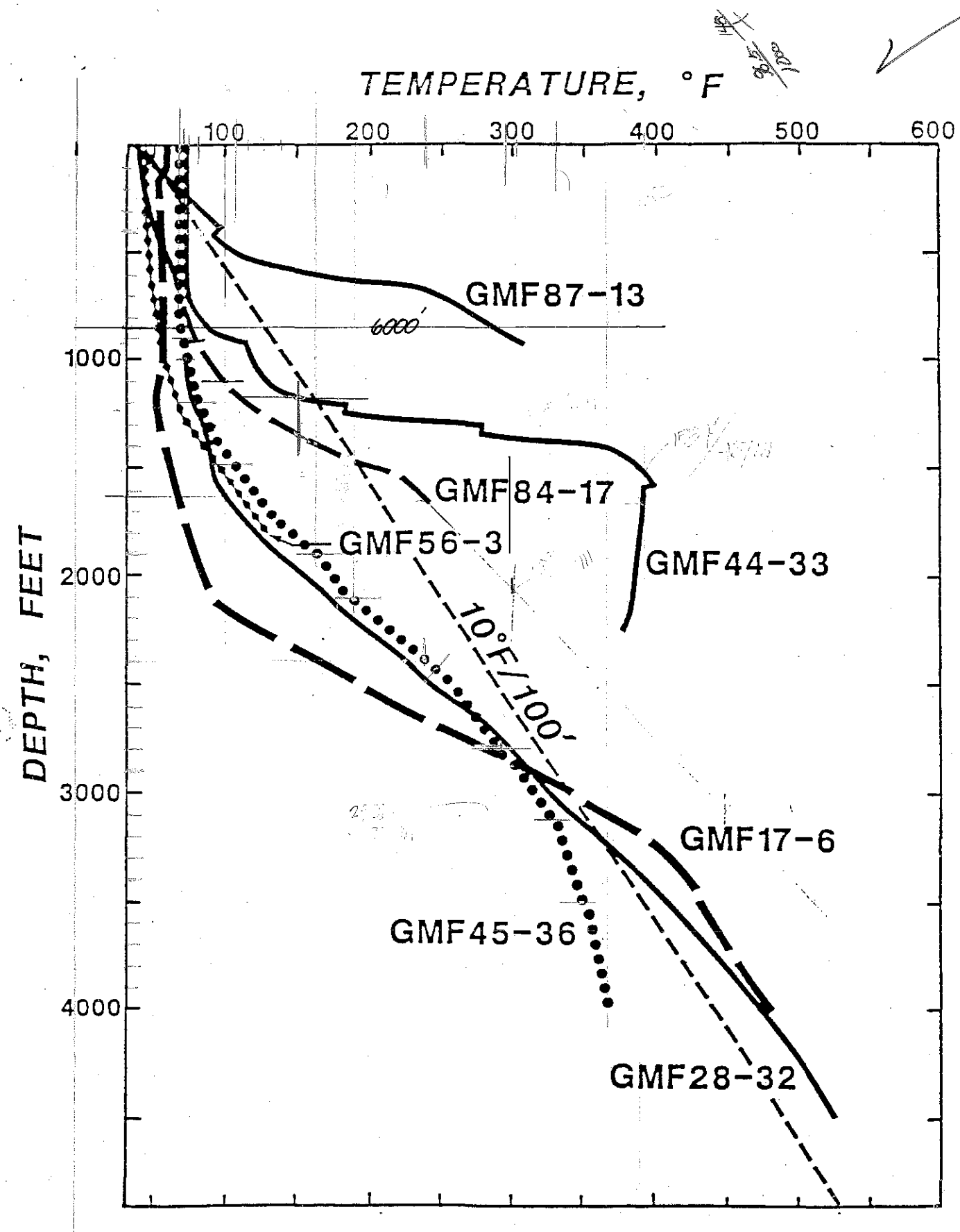

Figure 2: Temperature and depth profiles for boreholes located in the Glass Mountain Unit.

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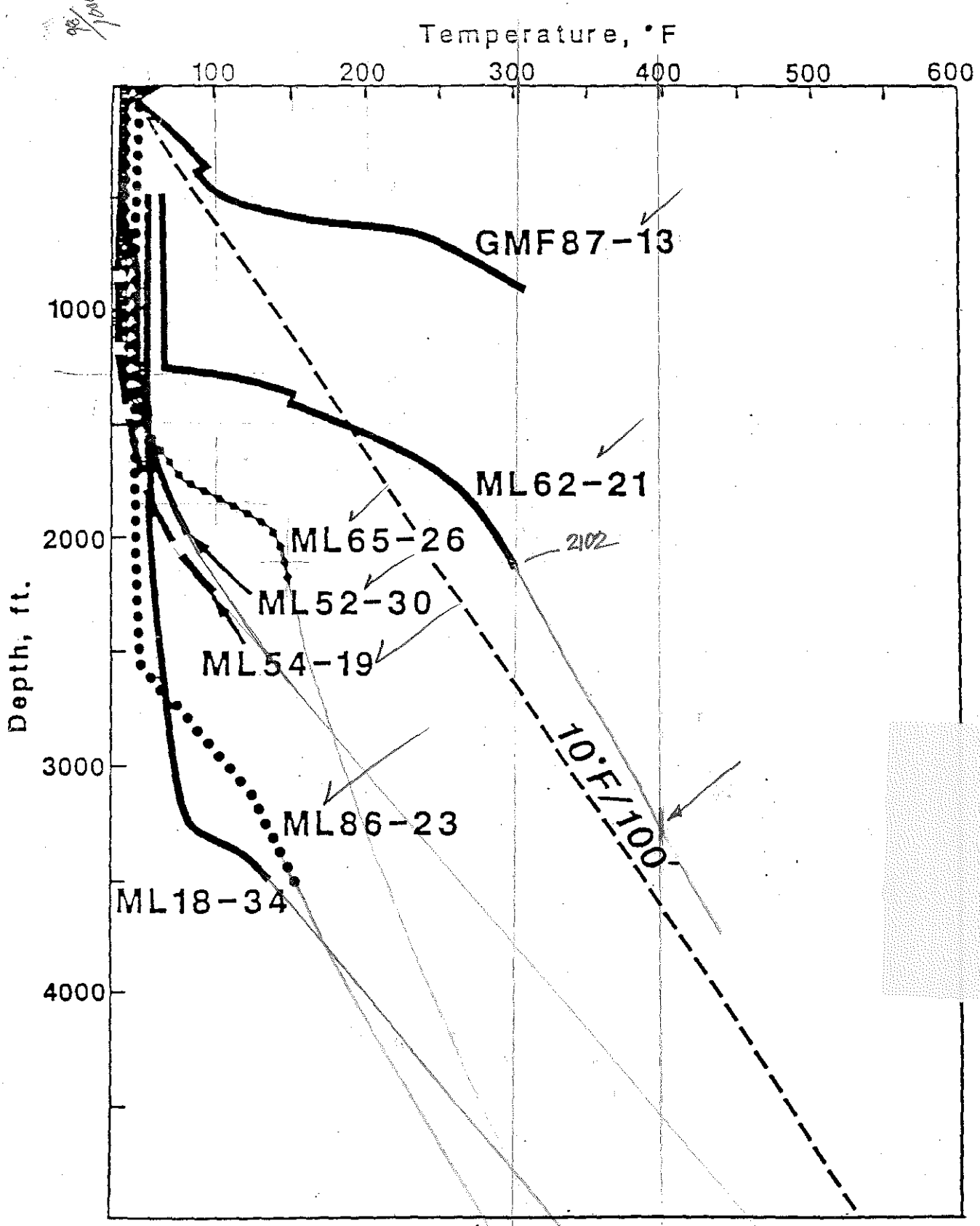

Figure 3: Temperature - depth profiles for boreholes located southwest of the Glass Mountain Unit. GMF87-13 is shown for reference.

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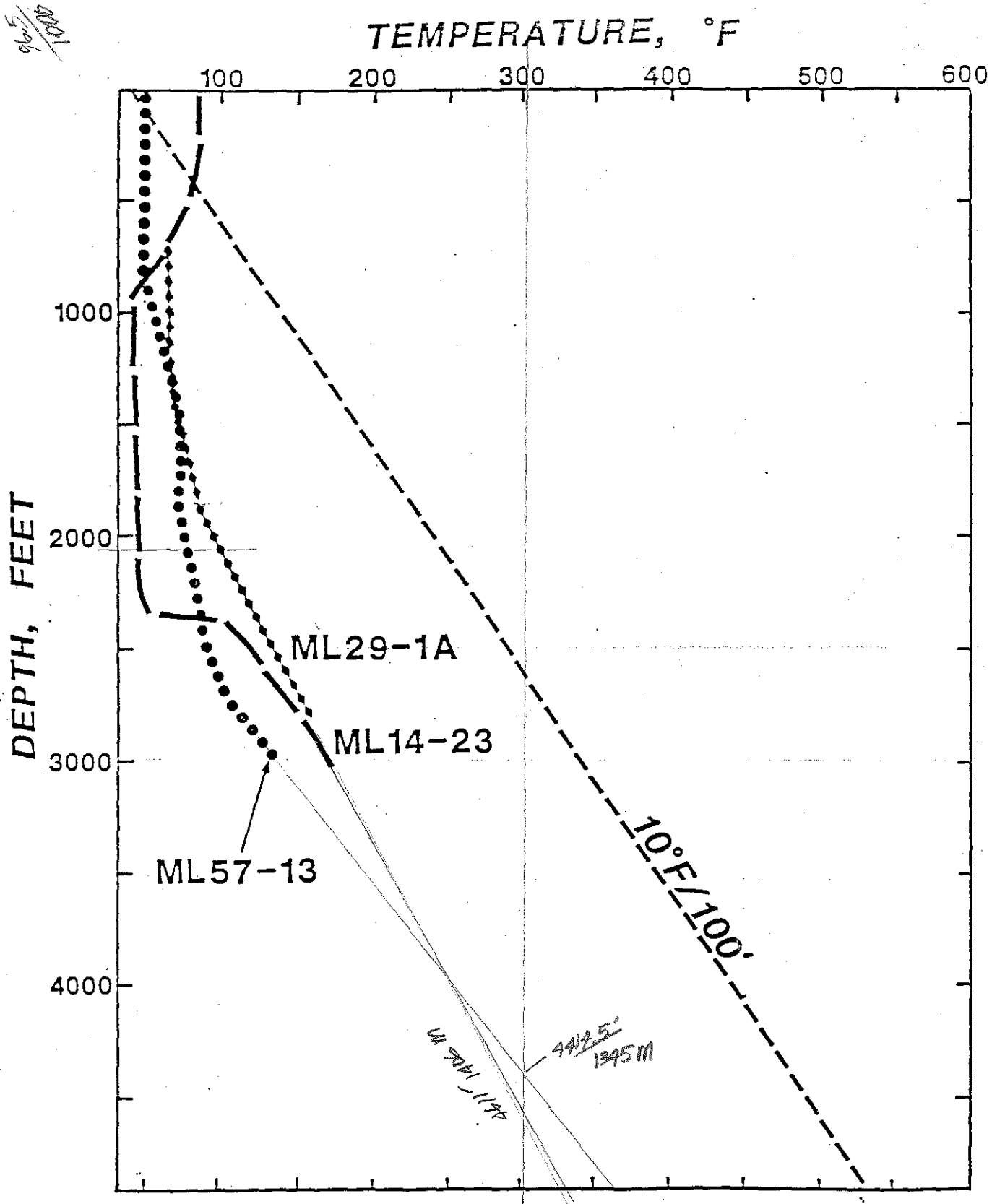

Figure 5: Temperature - depth profiles for boreholes drilled north of Glass Mountain Unit.

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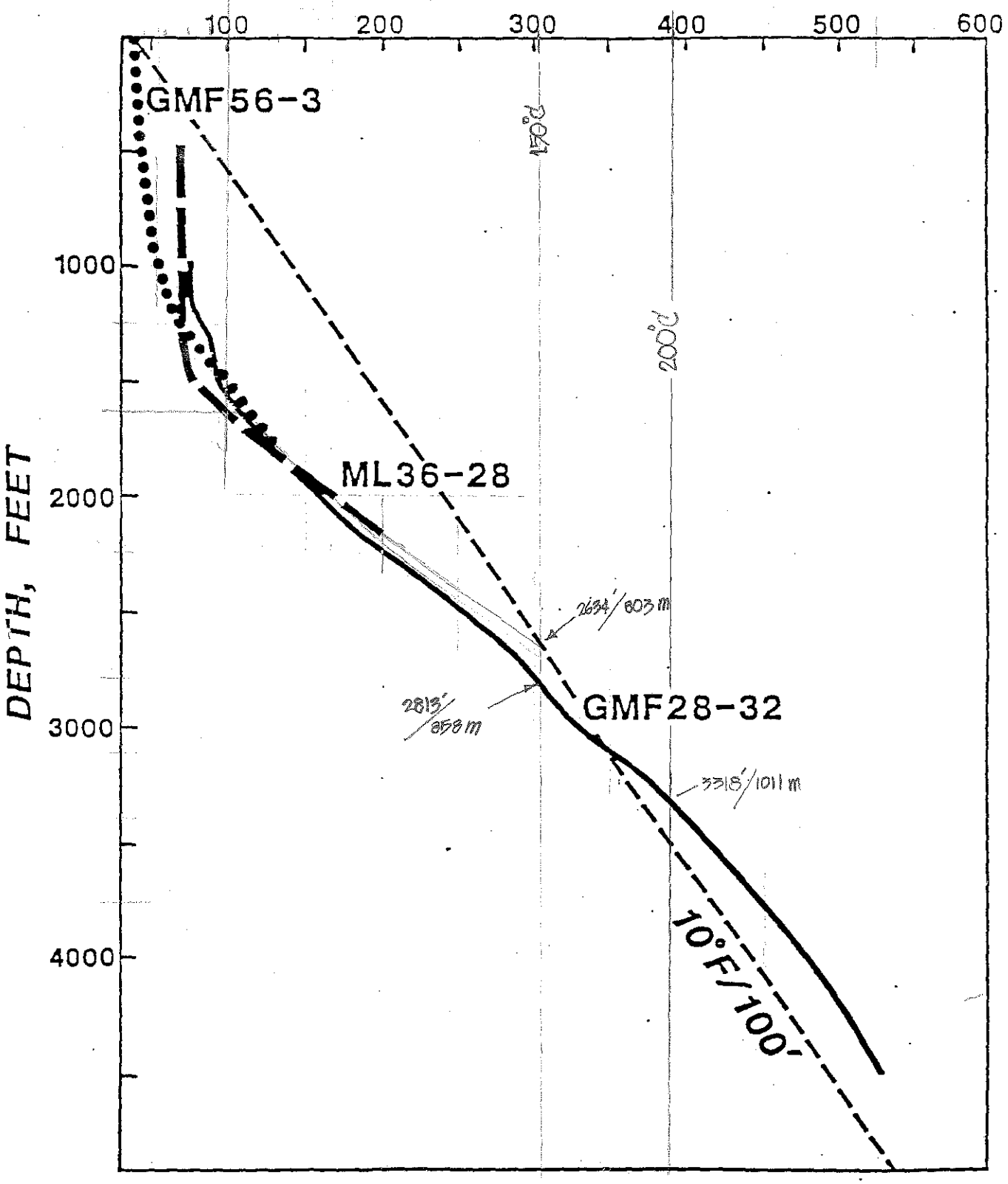

Figure 6: Temperature - profiles for boreholes GMF56-3, GMF28-32 and ML36-28.

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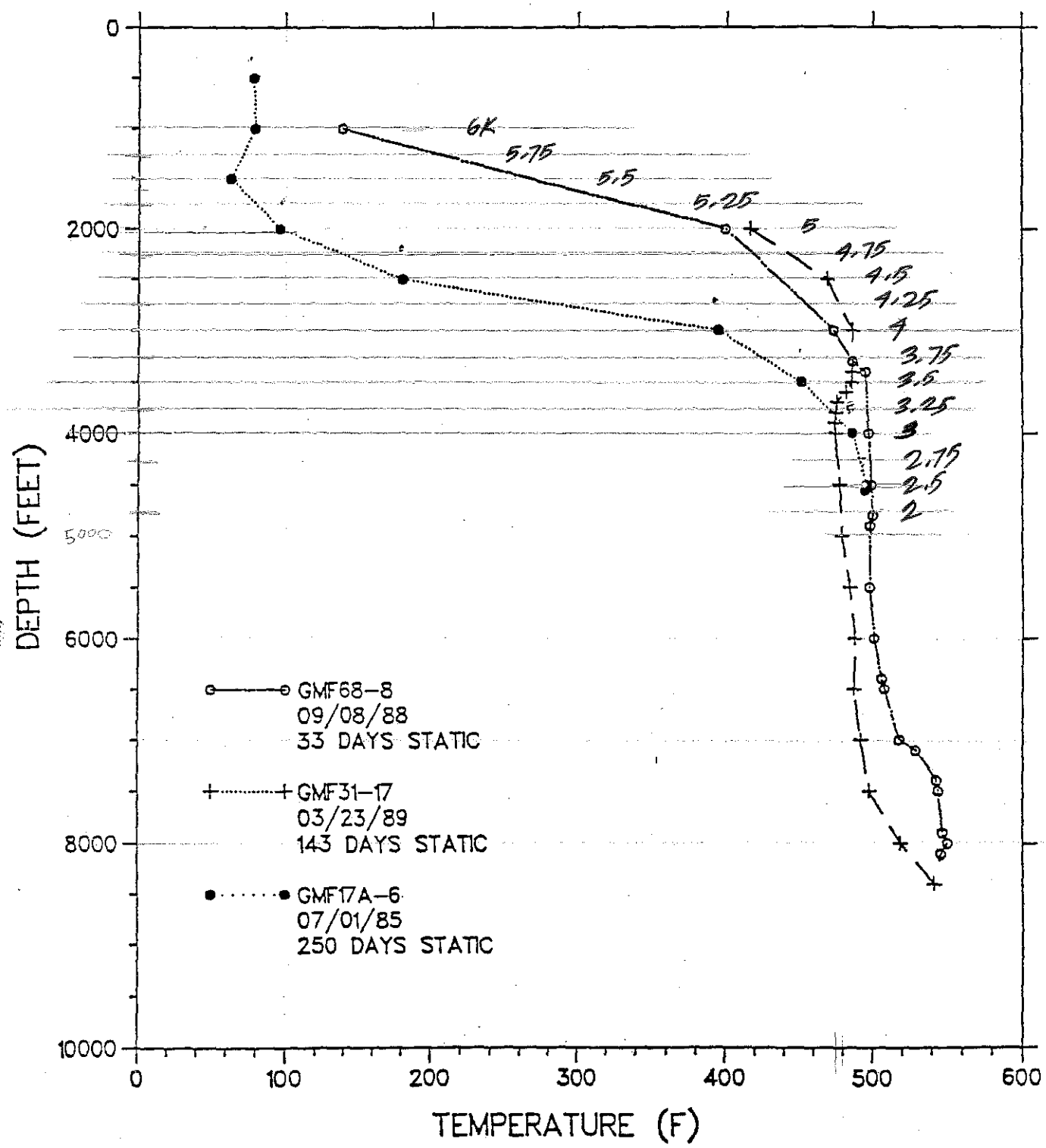

Figure 7: Temperature - depth profiles for three exploratory wells drilled at Glass Mountain. Temperatures for GMF68-8 have not fully returned to undisturbed formation temperatures.

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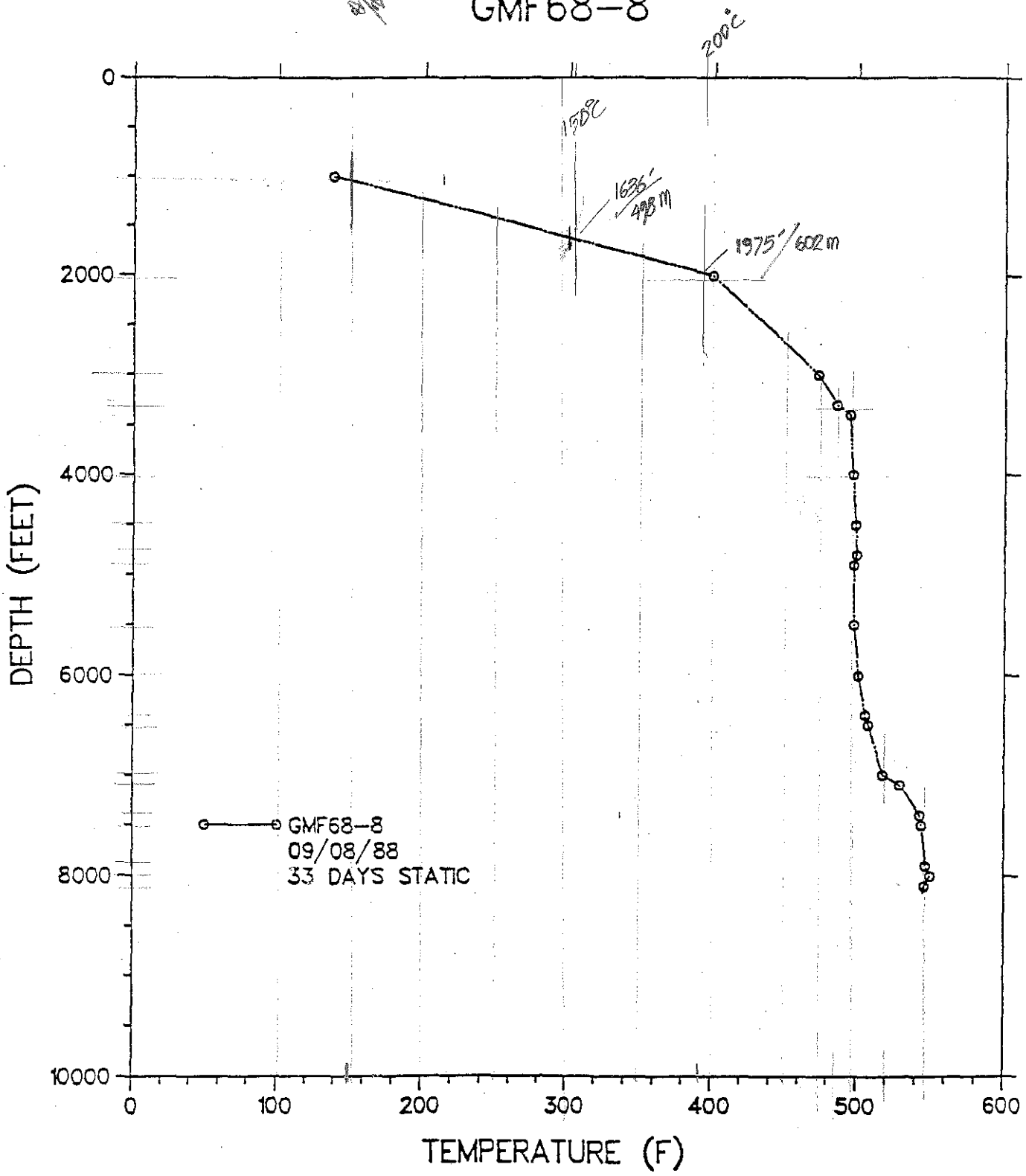
APPENDIX 1

Temperature-depth profiles for

exploratory wells and temperature boreholes

GMF68-8



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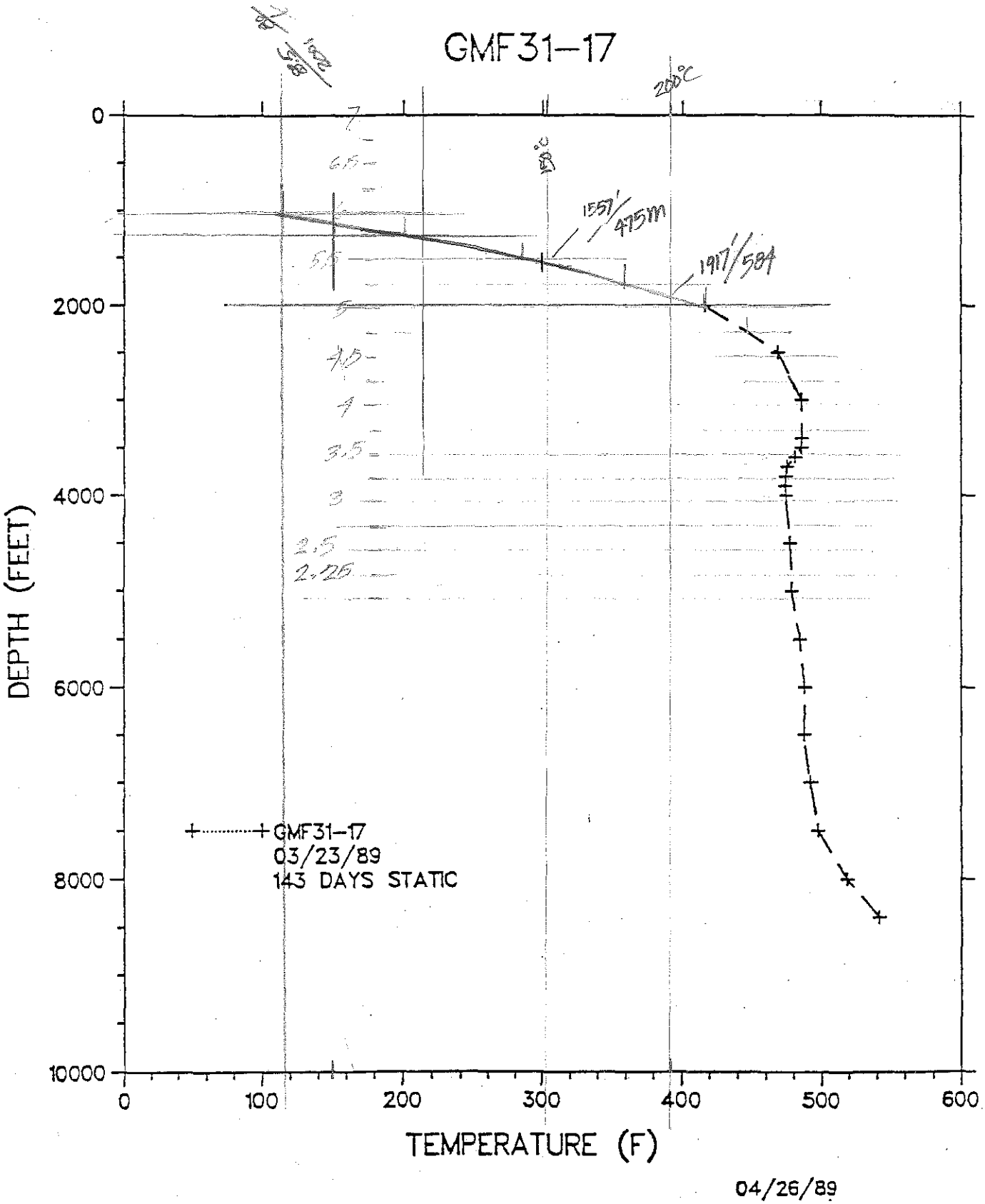

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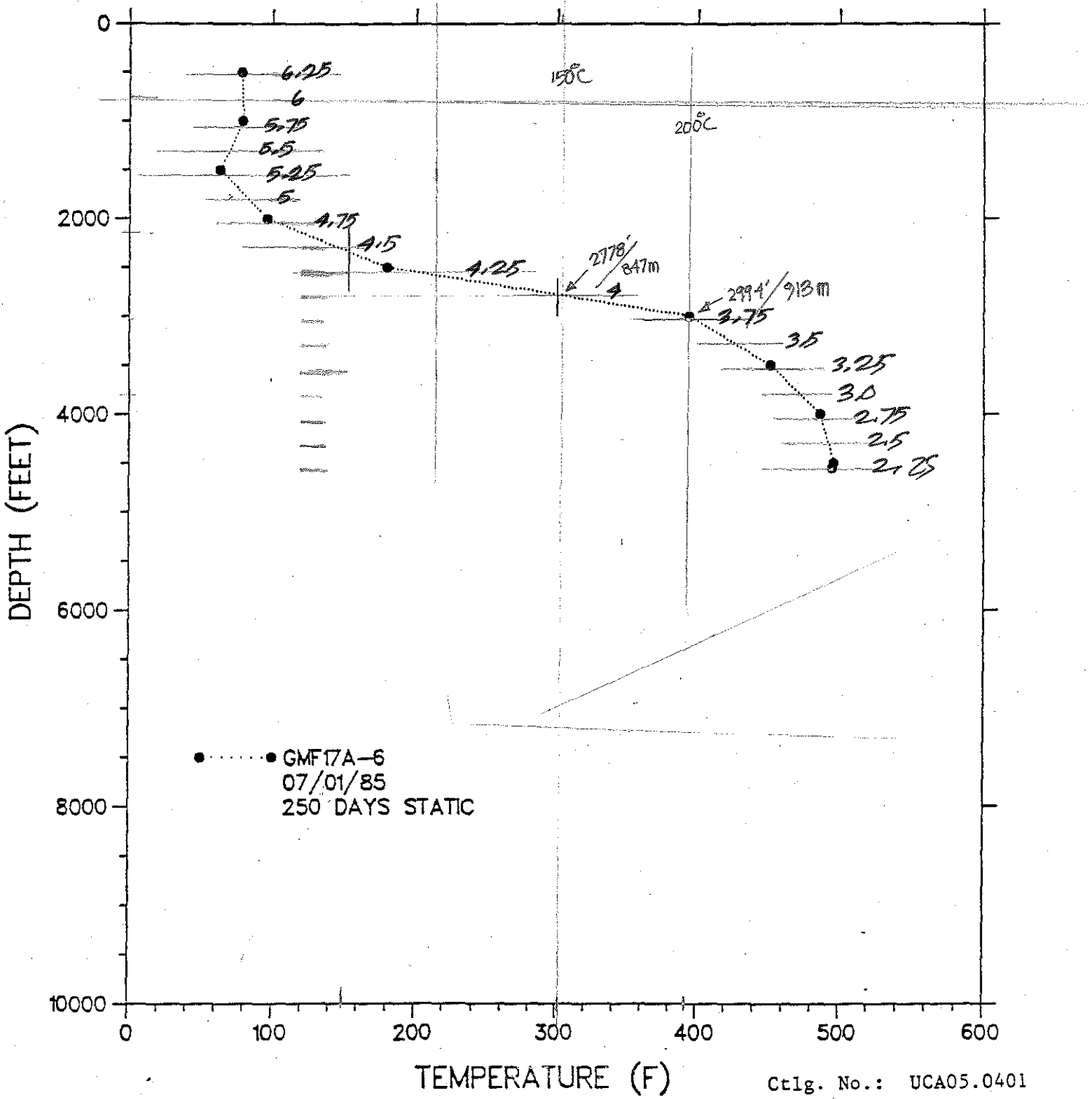
GMF17A-6



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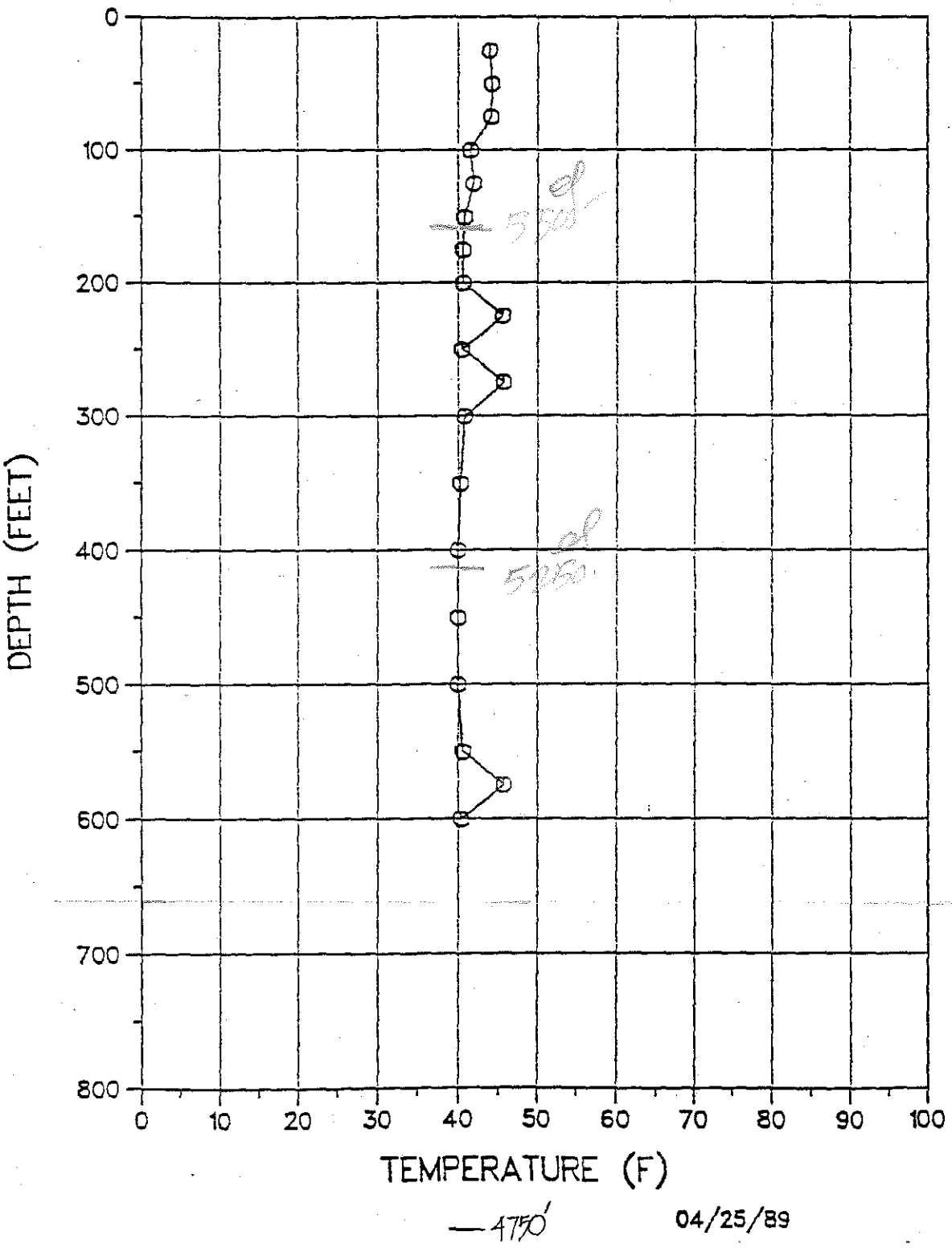
ML-1-81



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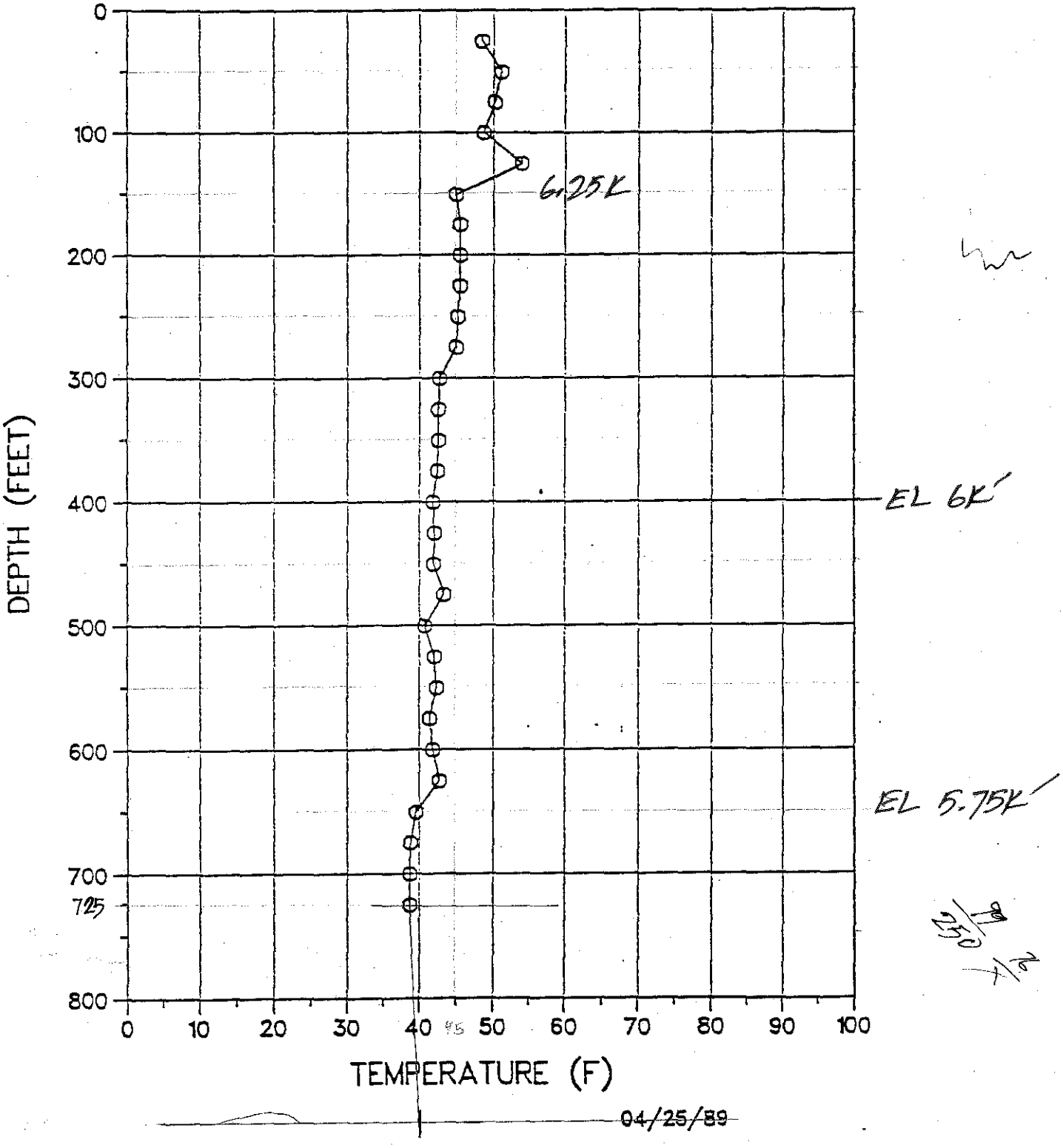
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400
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DEPTH (FEET)
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EL 6K'
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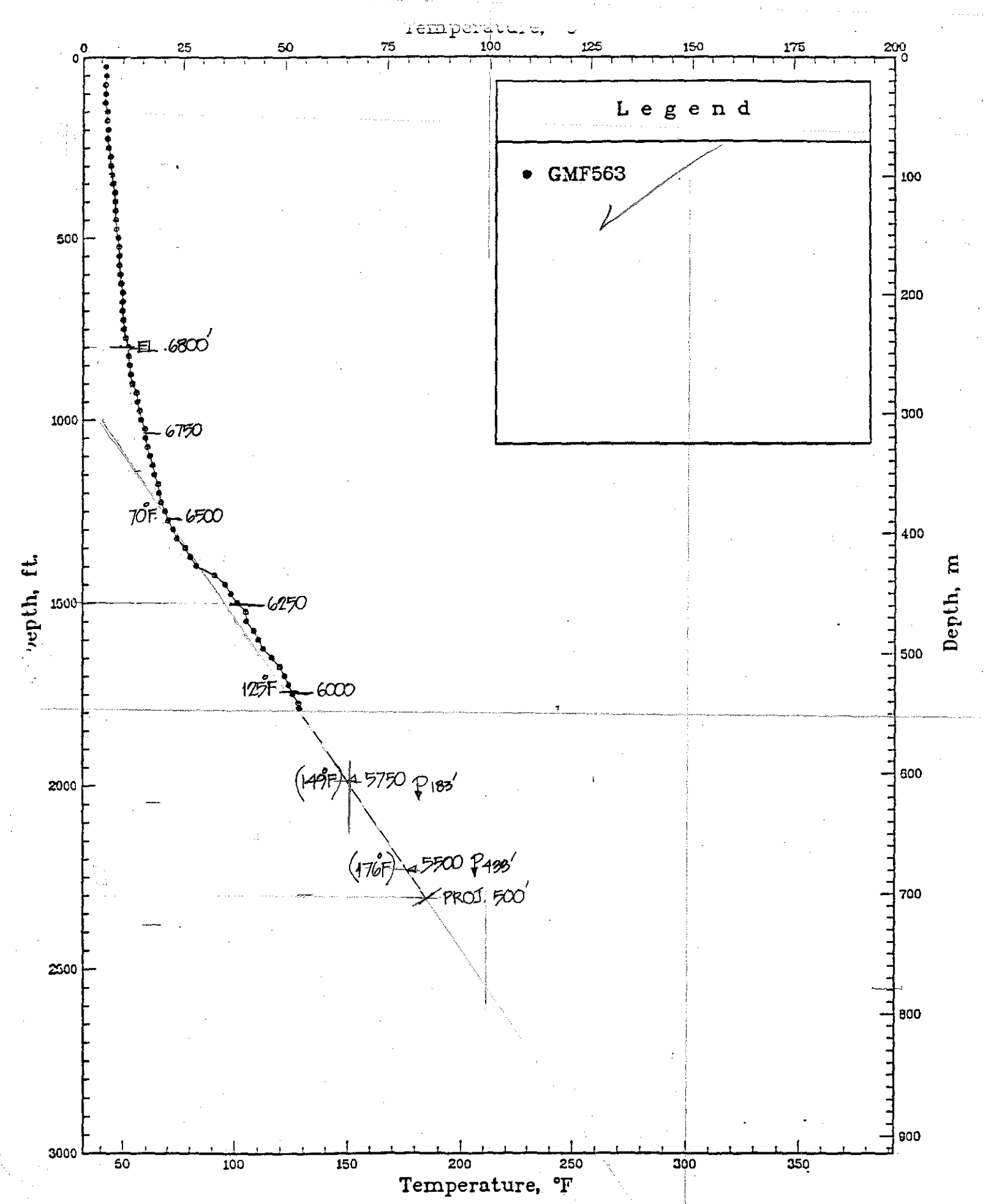
TEMPERATURE (F)
04/25/89



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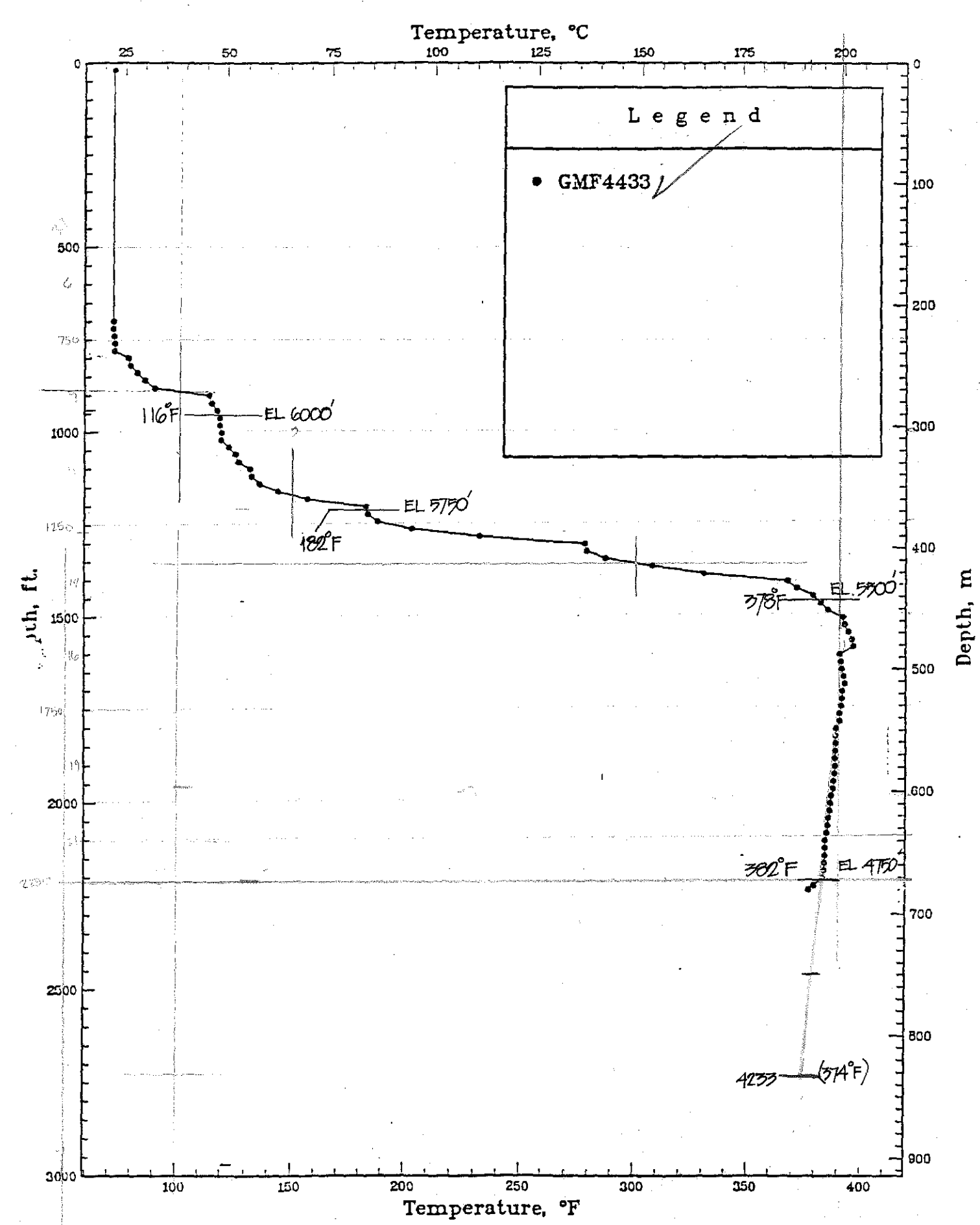

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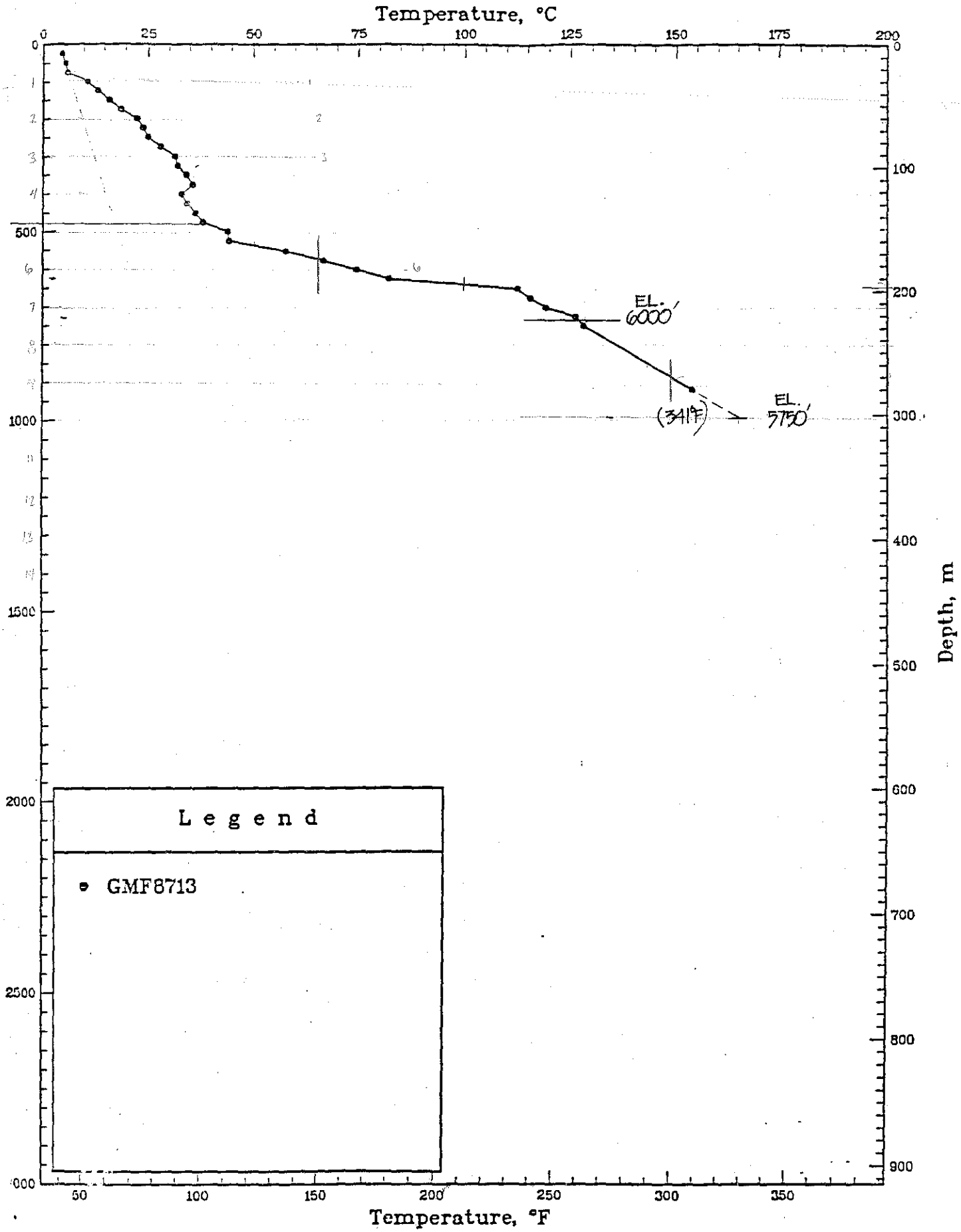

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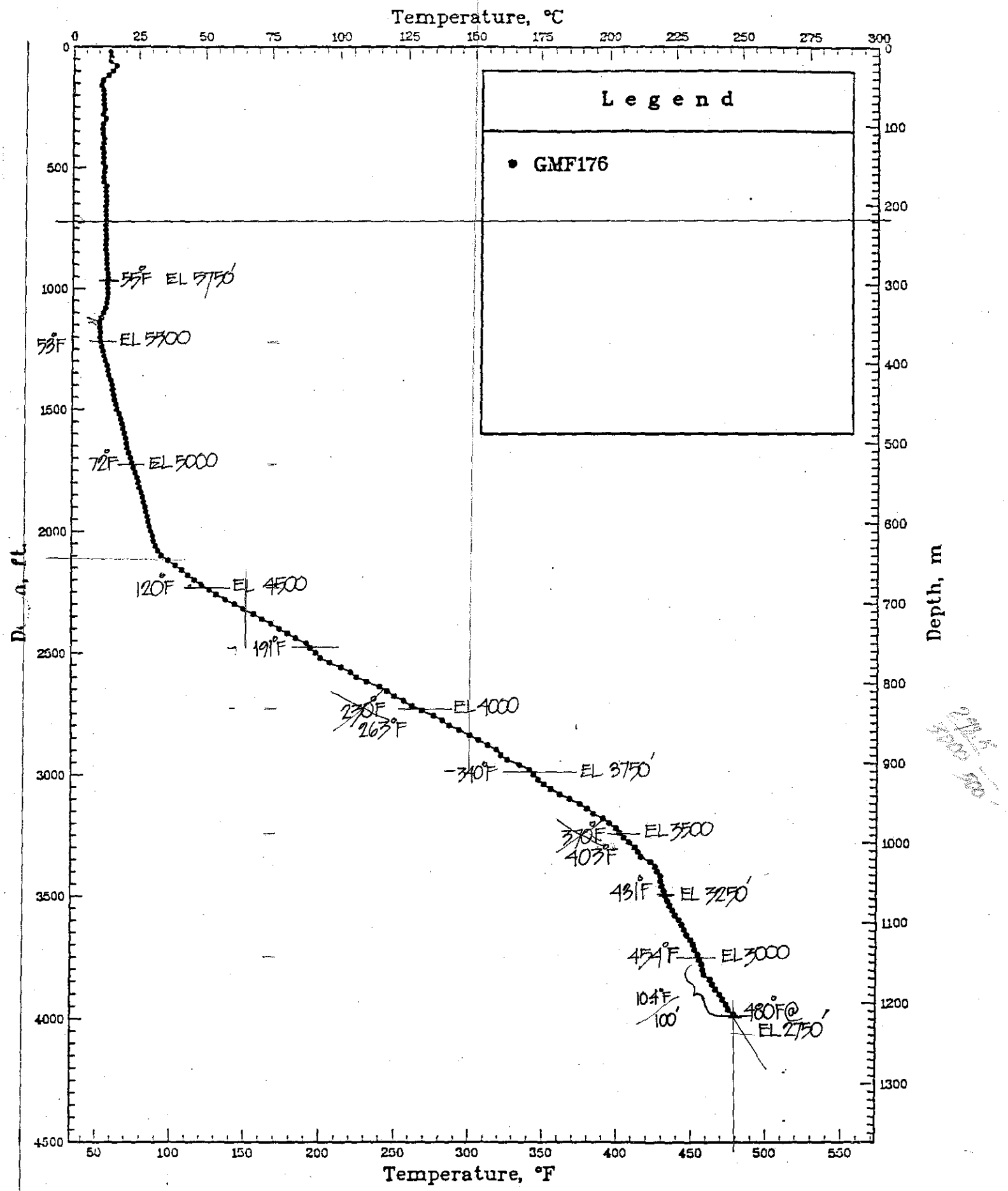
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Legend
GMF176
55°F EL 3750'
53°F EL 5500
72°F EL 5000
120°F EL 4500
191°F
270°F
263°F EL 4000
340°F EL 3750'
370°F EL 3500
403°F
431°F EL 3250'
454°F EL 3000
104°F
100'
480°F@
EL 2750'
Depth, ft.
Depth, m
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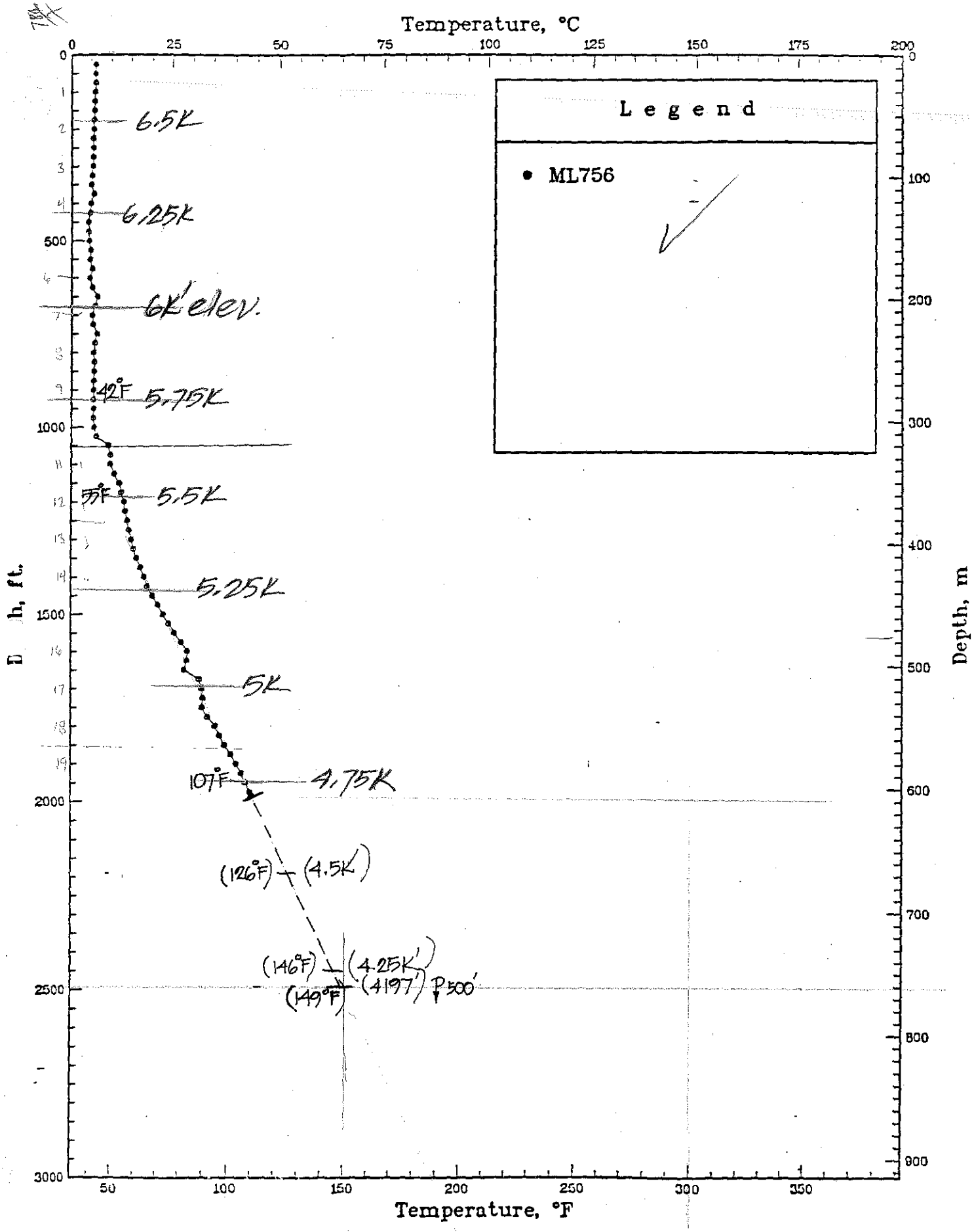
Temperature, °F



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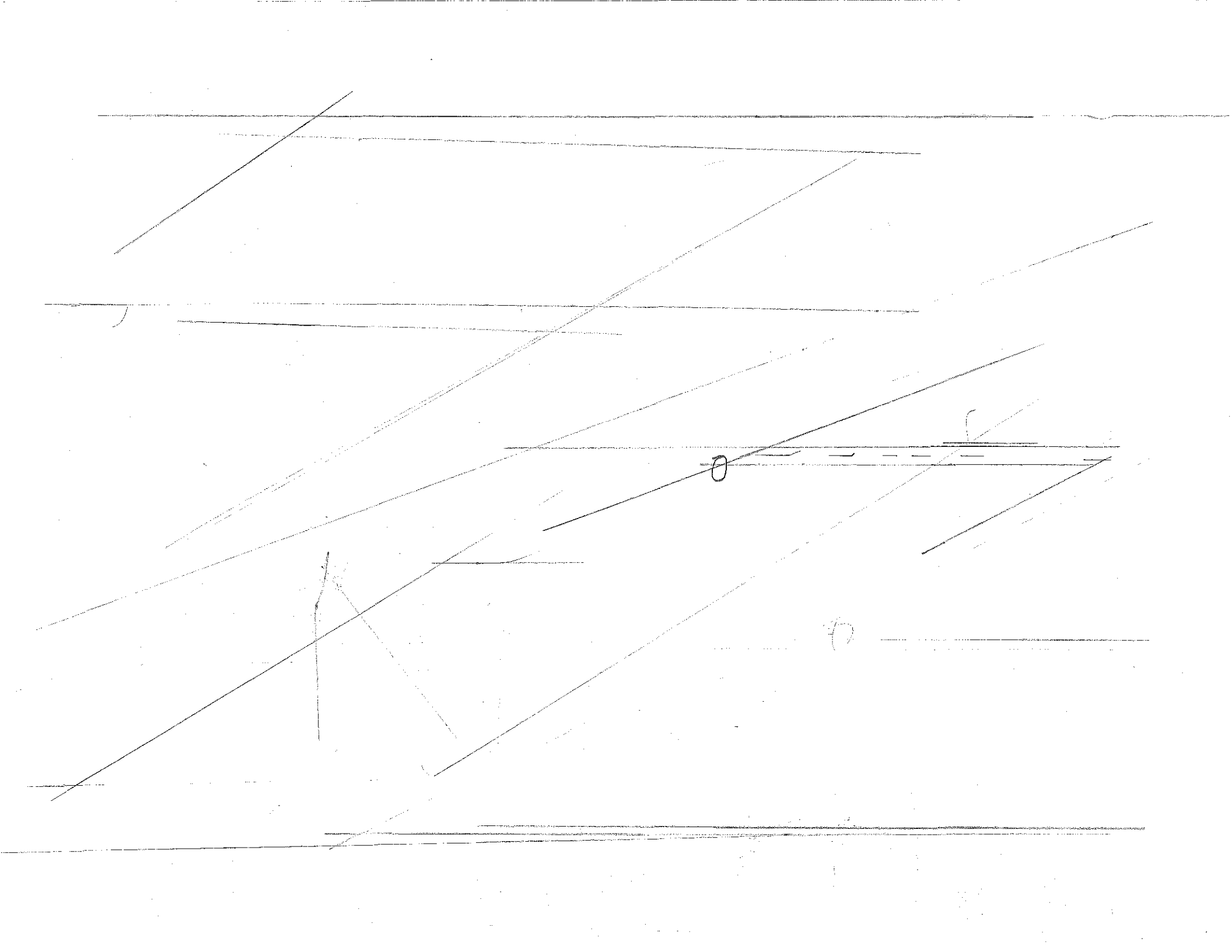

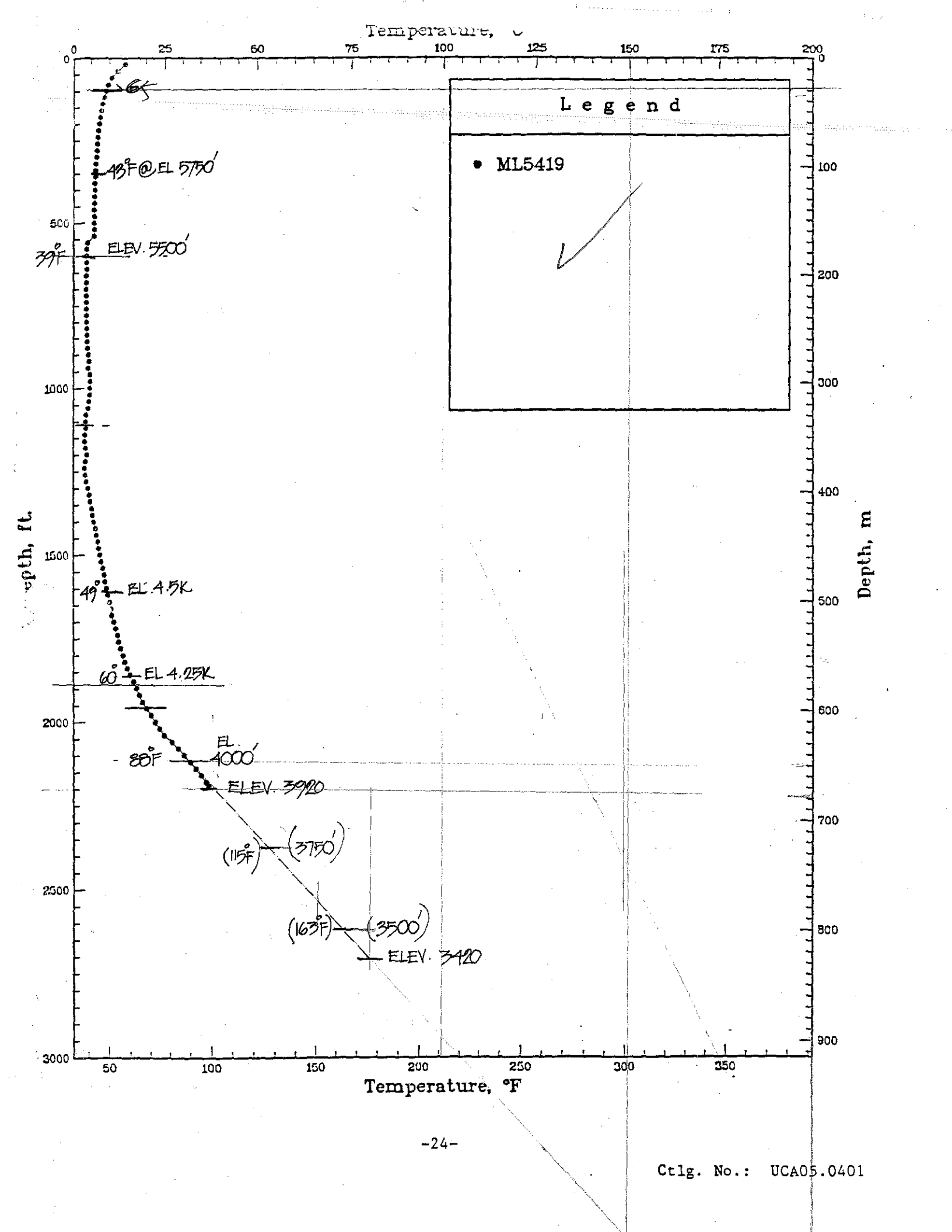

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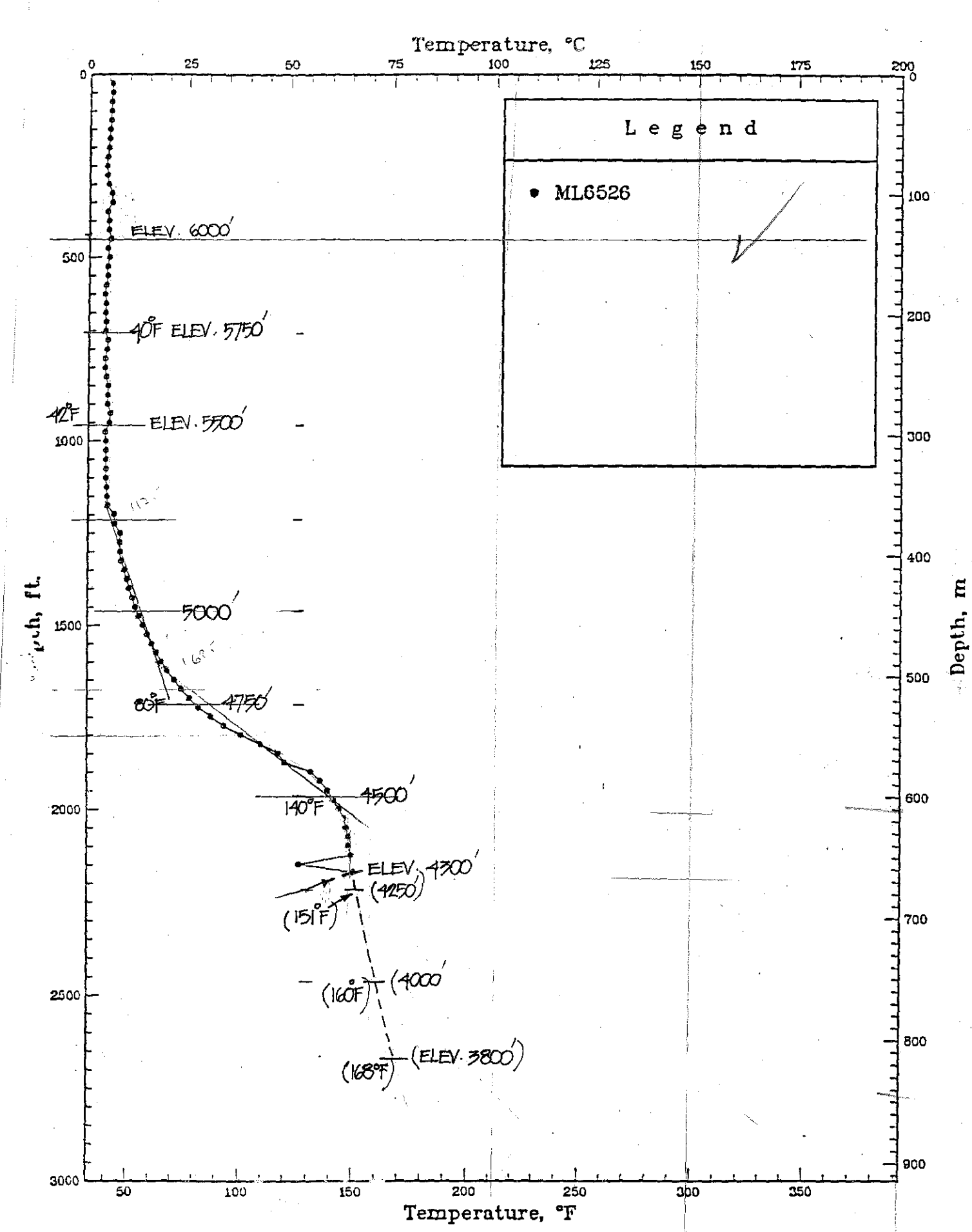

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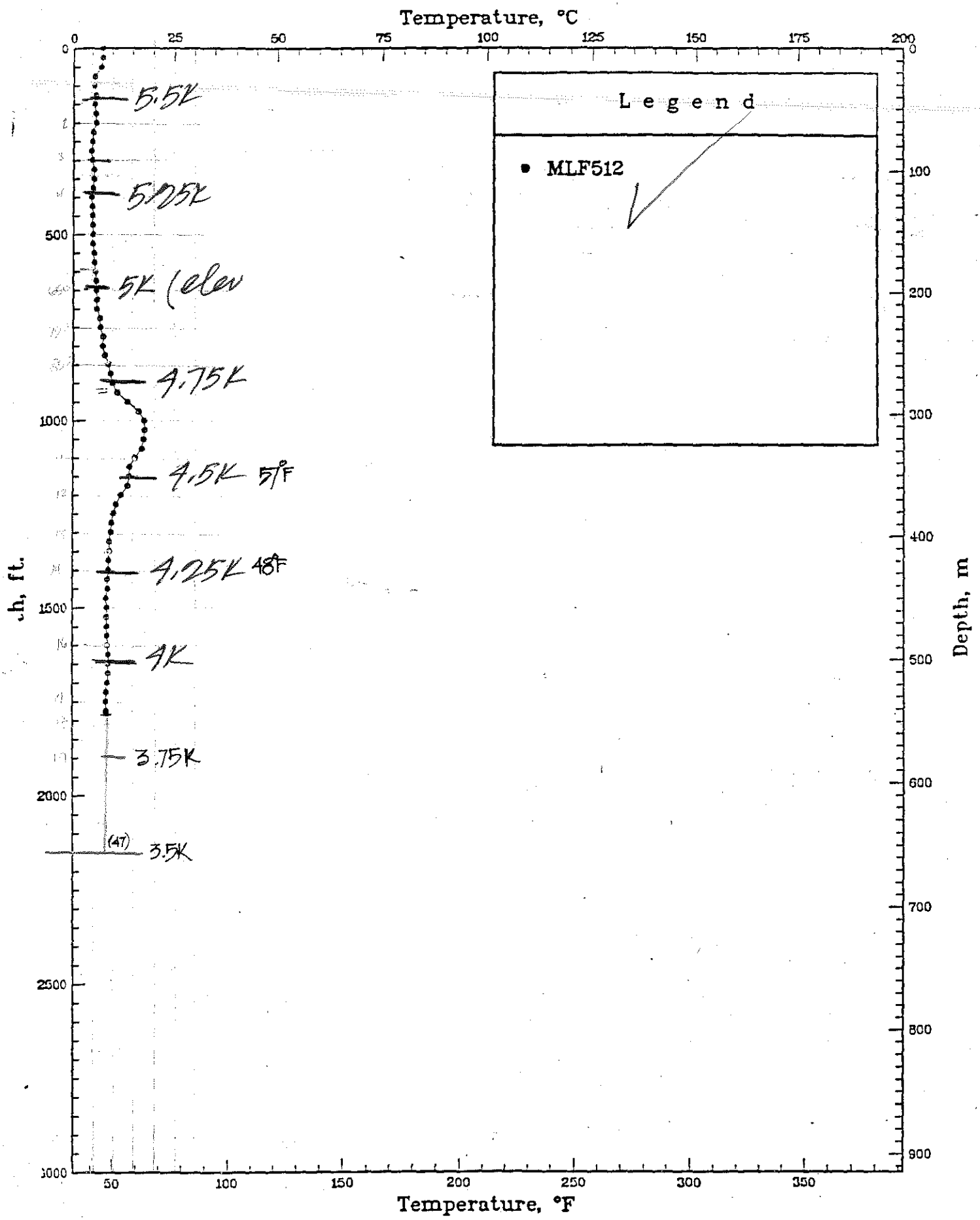

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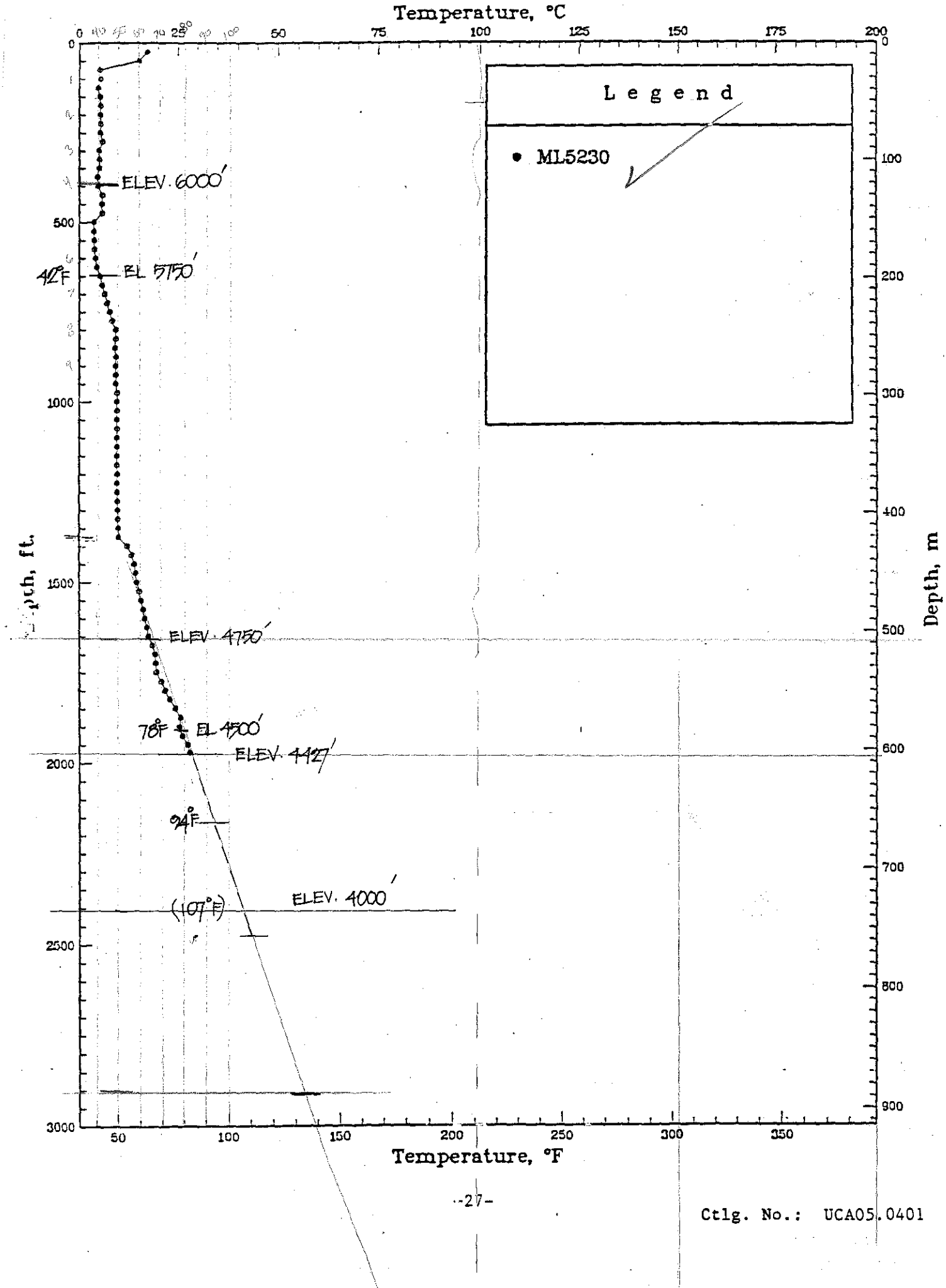

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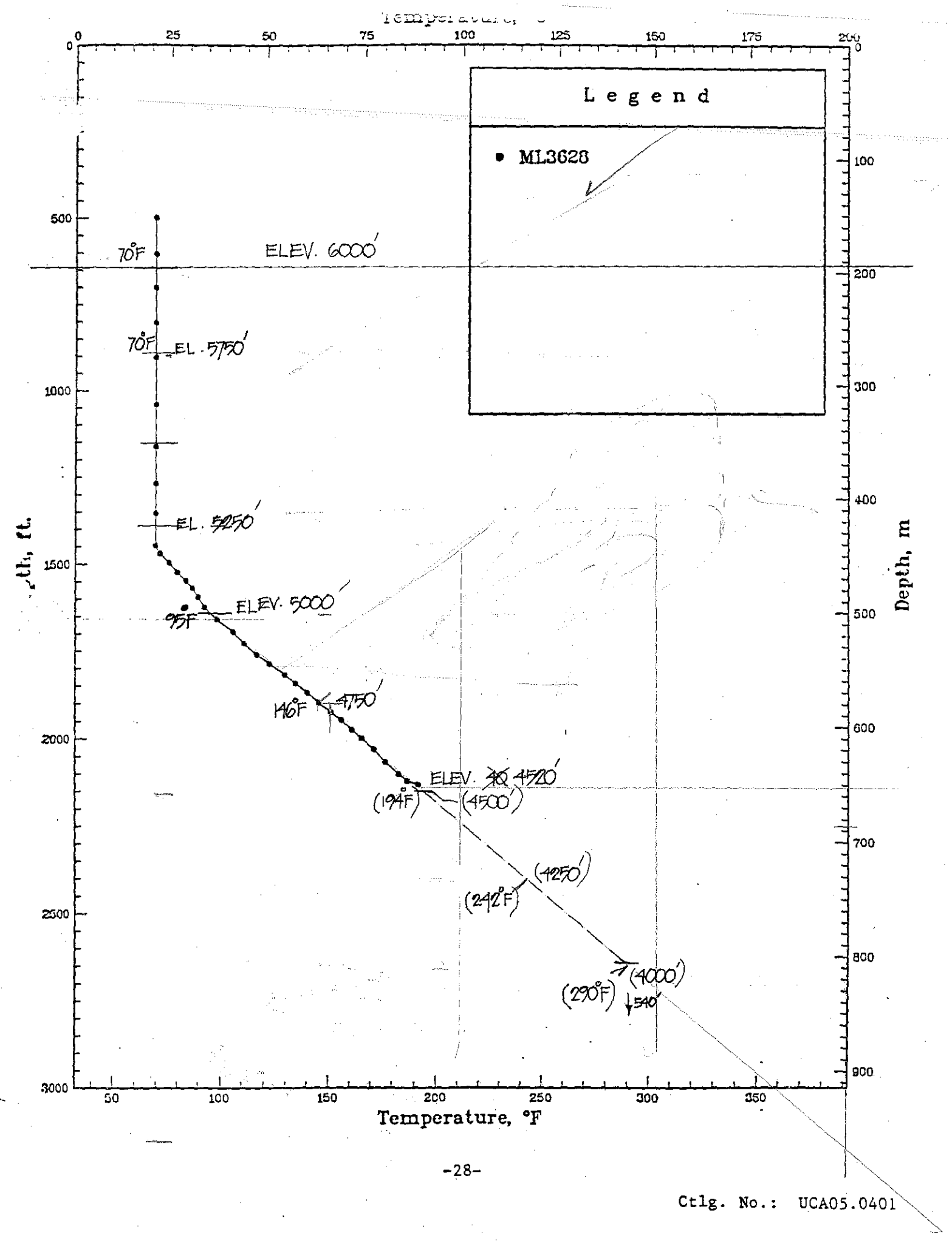

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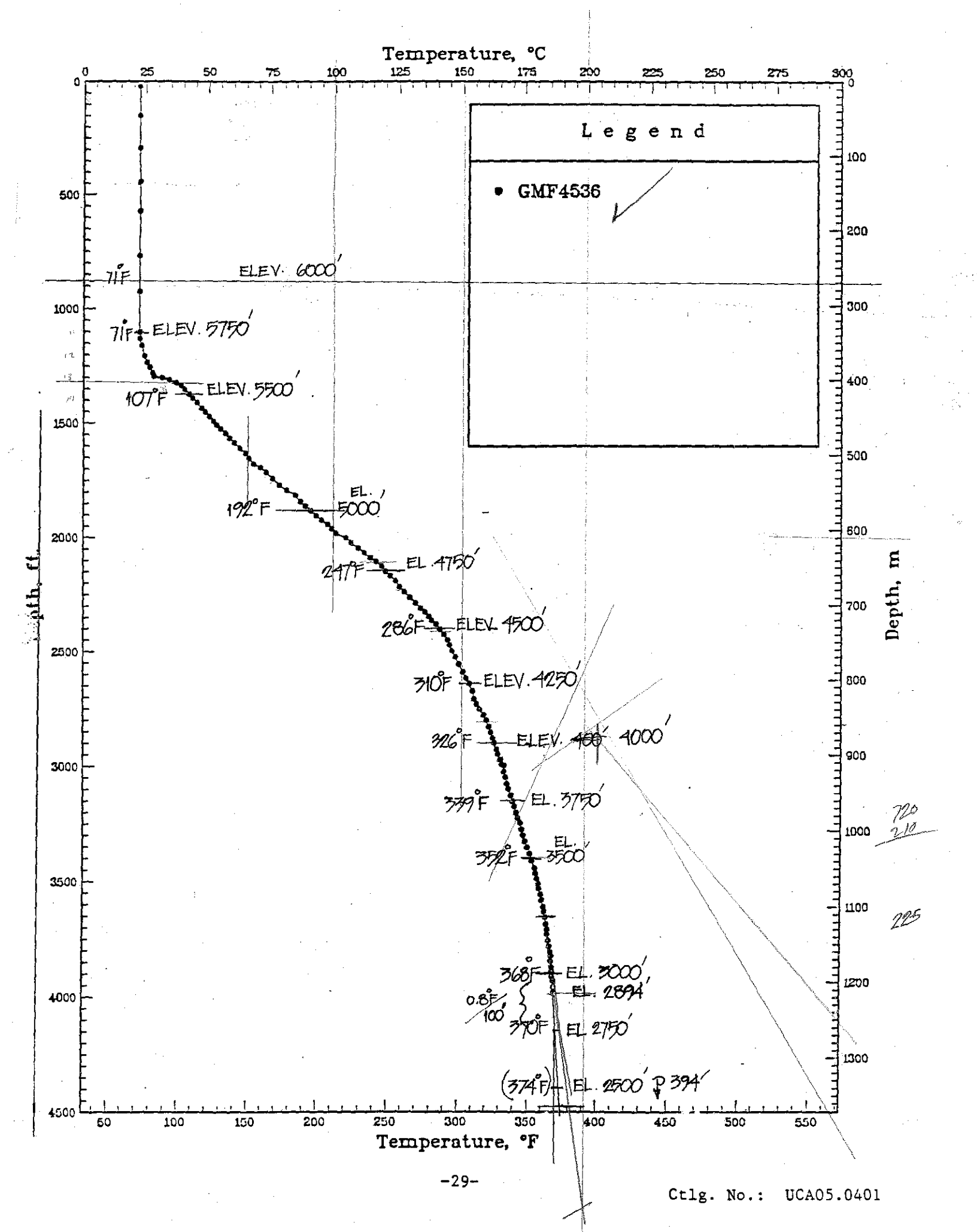

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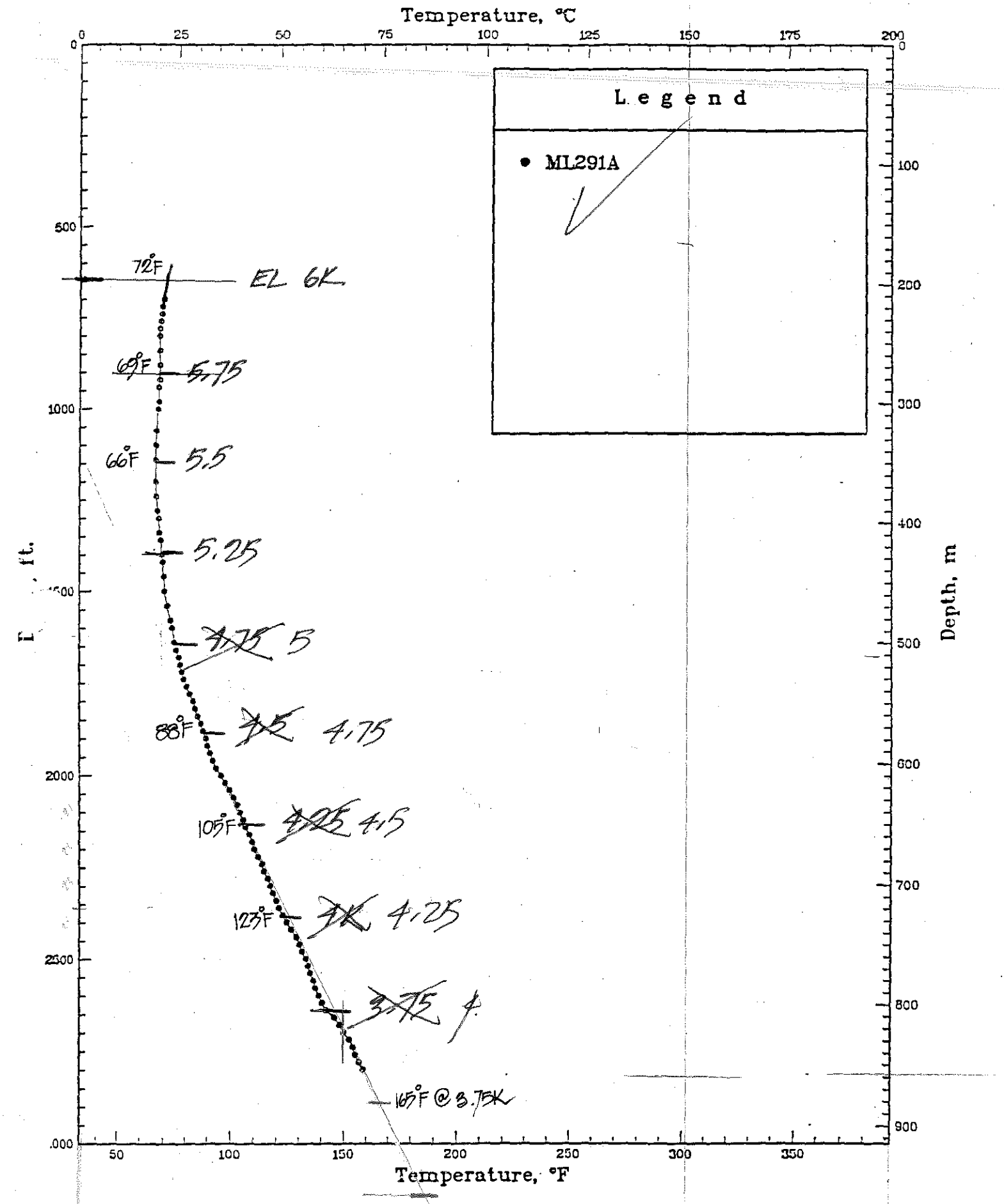

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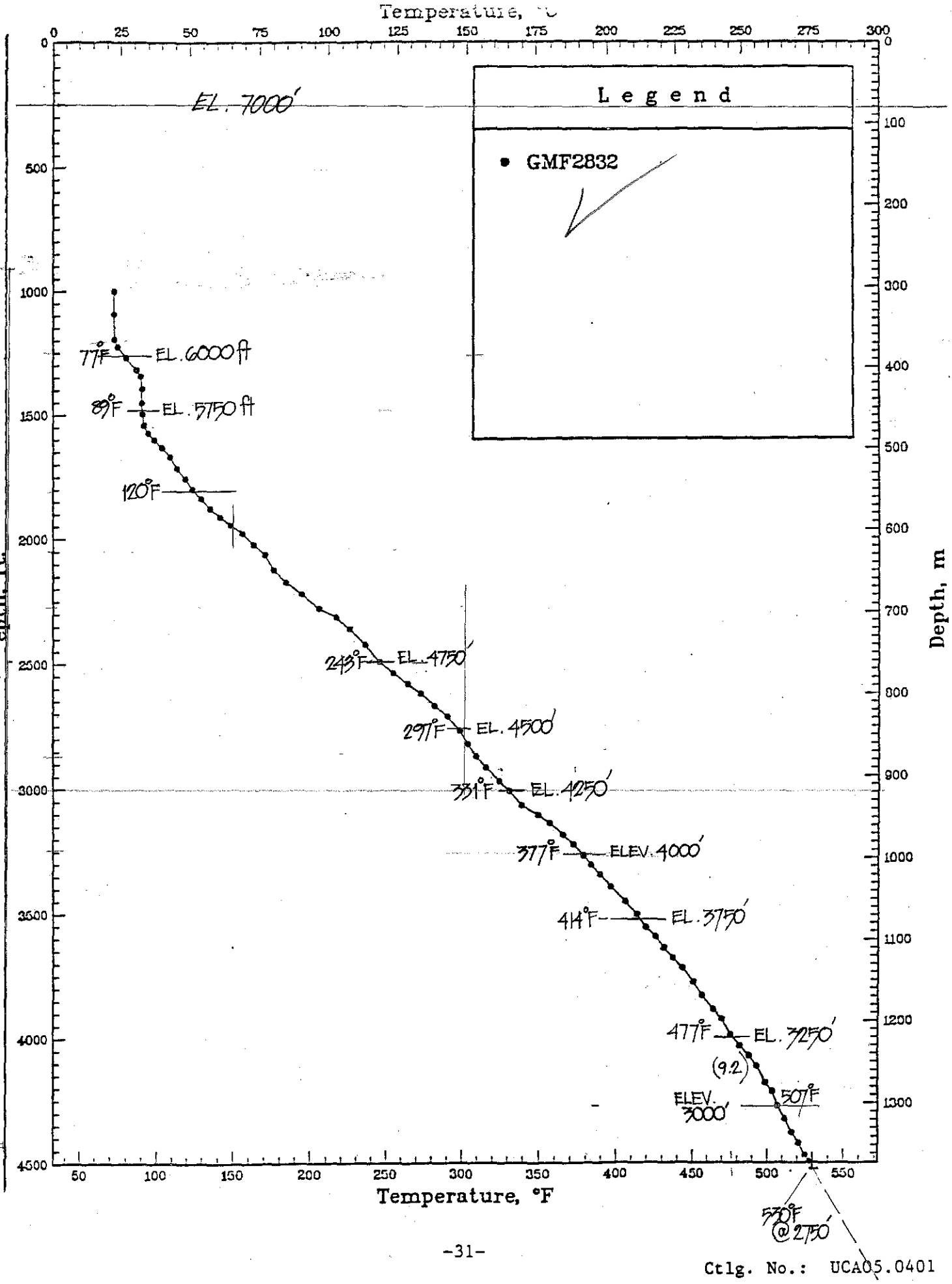

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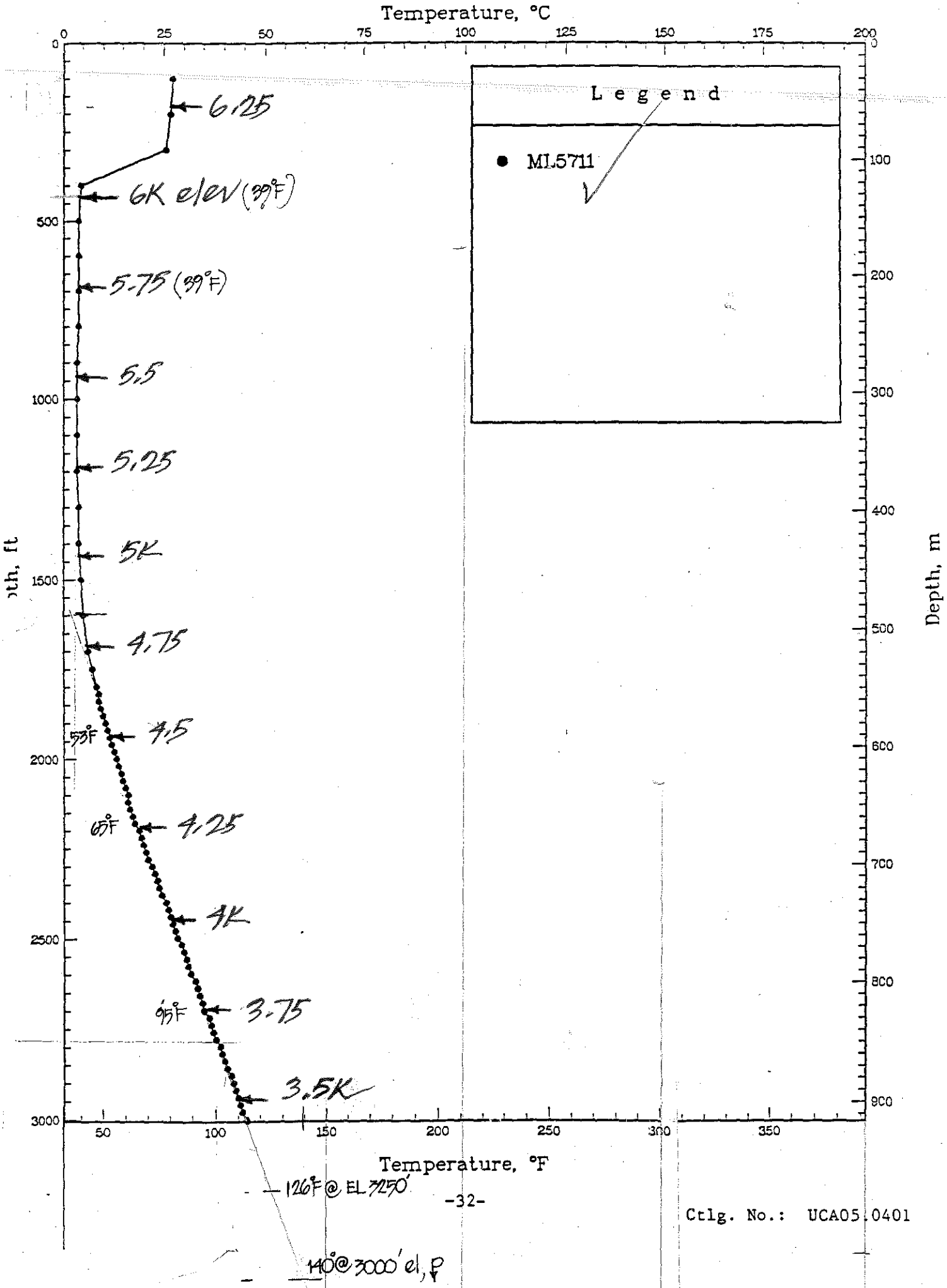

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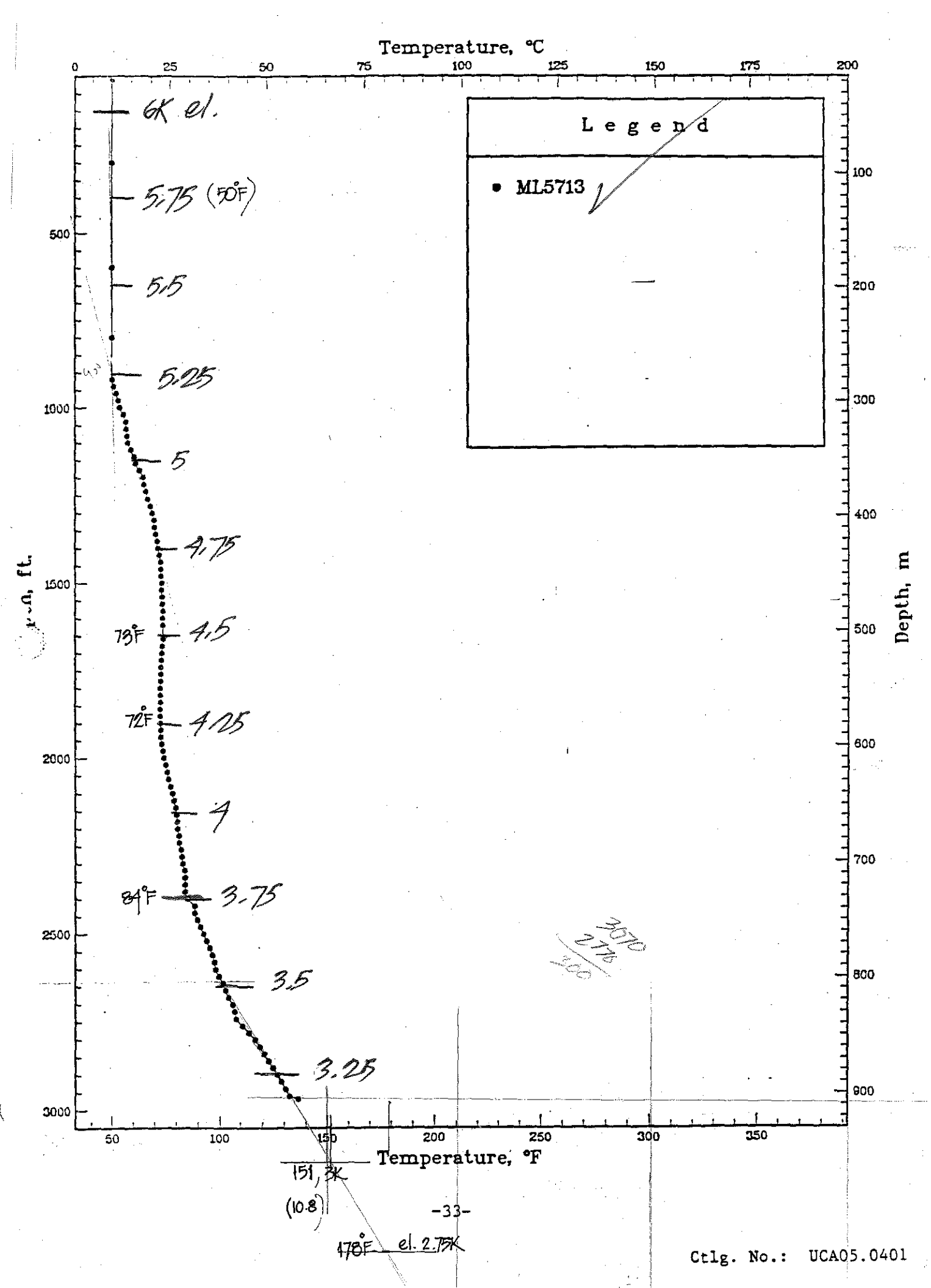

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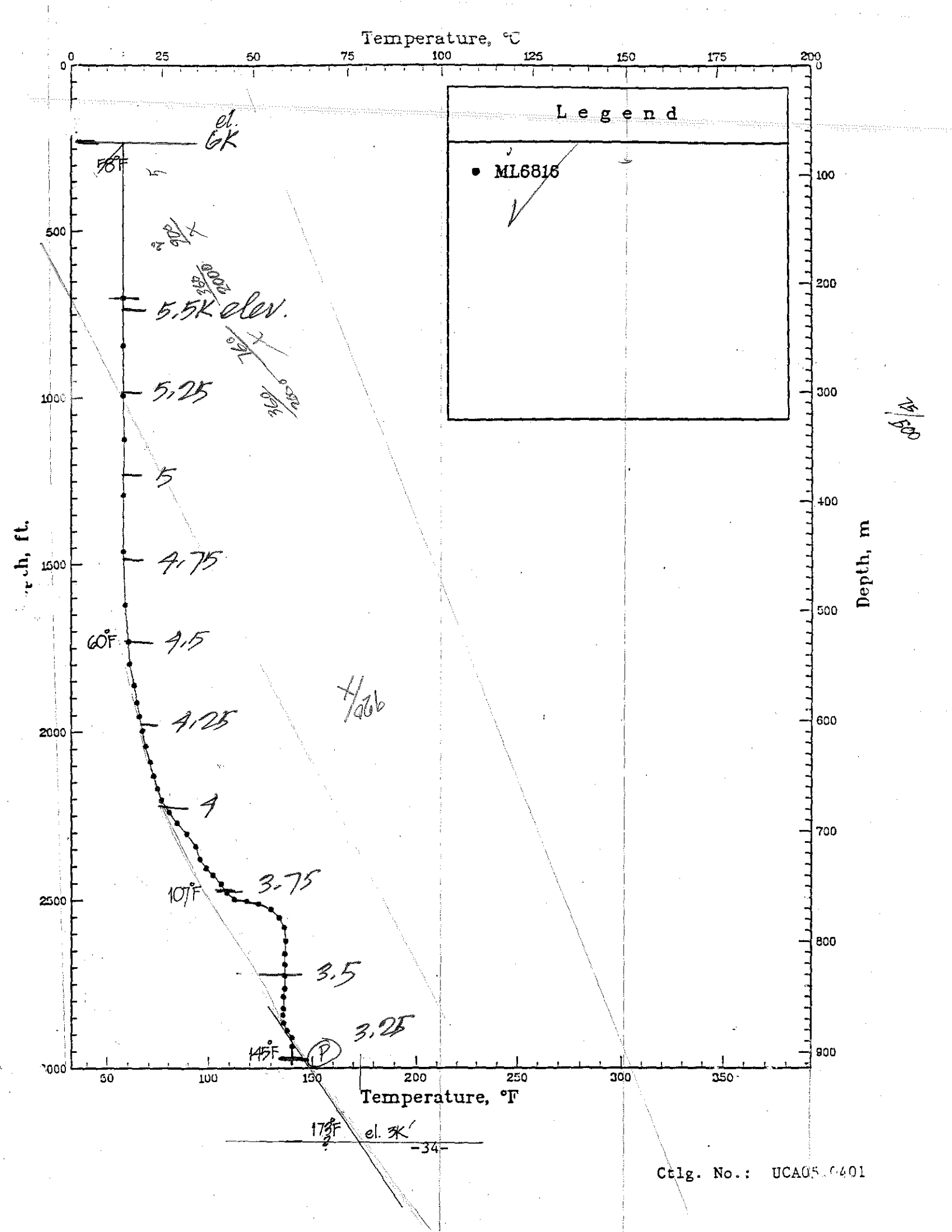
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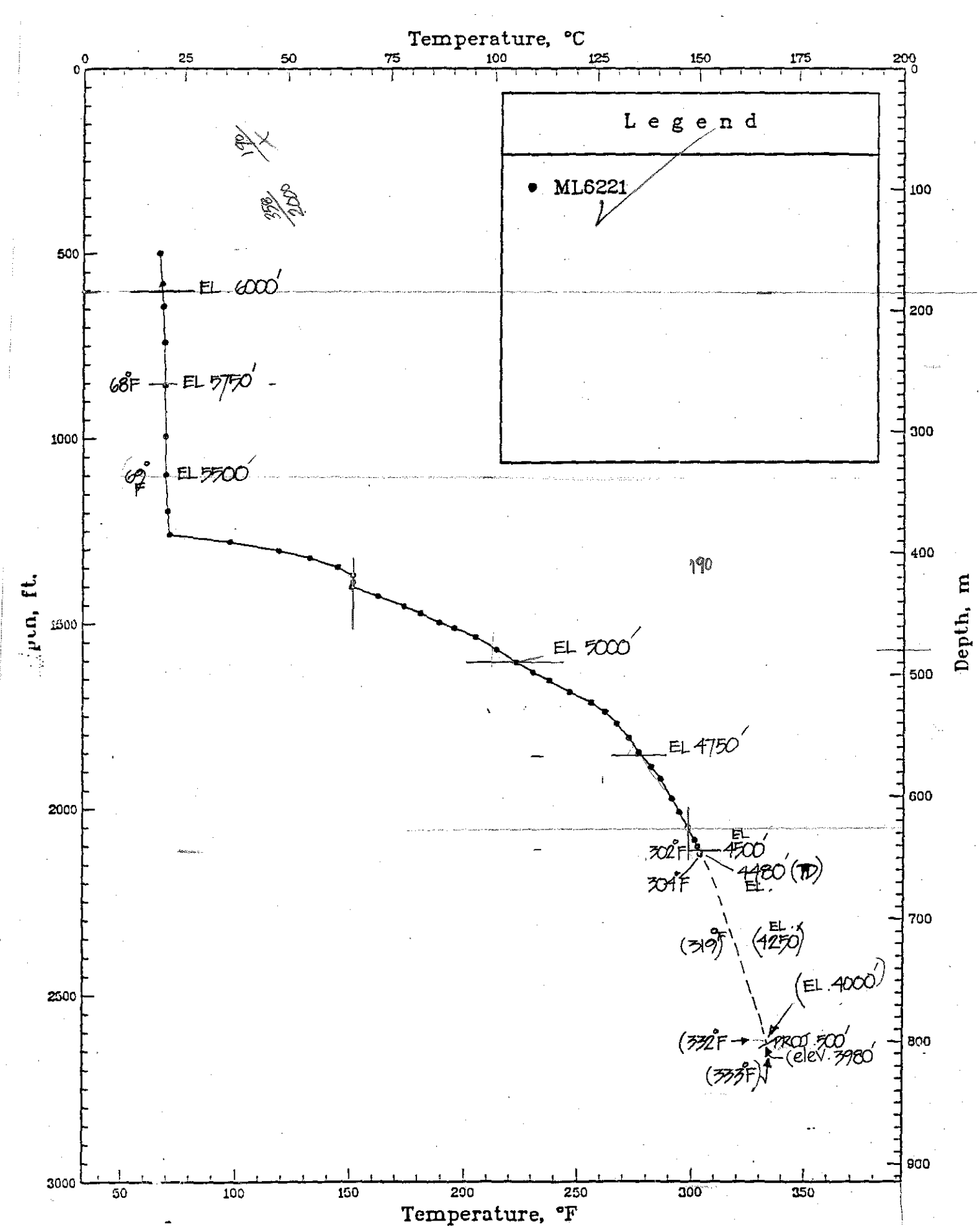
50
75
100
125
150
175
200
Legend
ML6816
el. 6K
58°F
5.5K elev.
5.25
5
4.75
60°F
4.5
4.25
4
101°F
3.75
3.5
3.25
145°F
P
Depth, ft.
Depth, m
500
1000
1500
2000
2500
3000
100
200
300
400
500
600
700
800
900
50
100
150
200
250
300
350
Temperature, °F
175°F el. 3K'
-34-
Ctlg. No.: UCA05 0401



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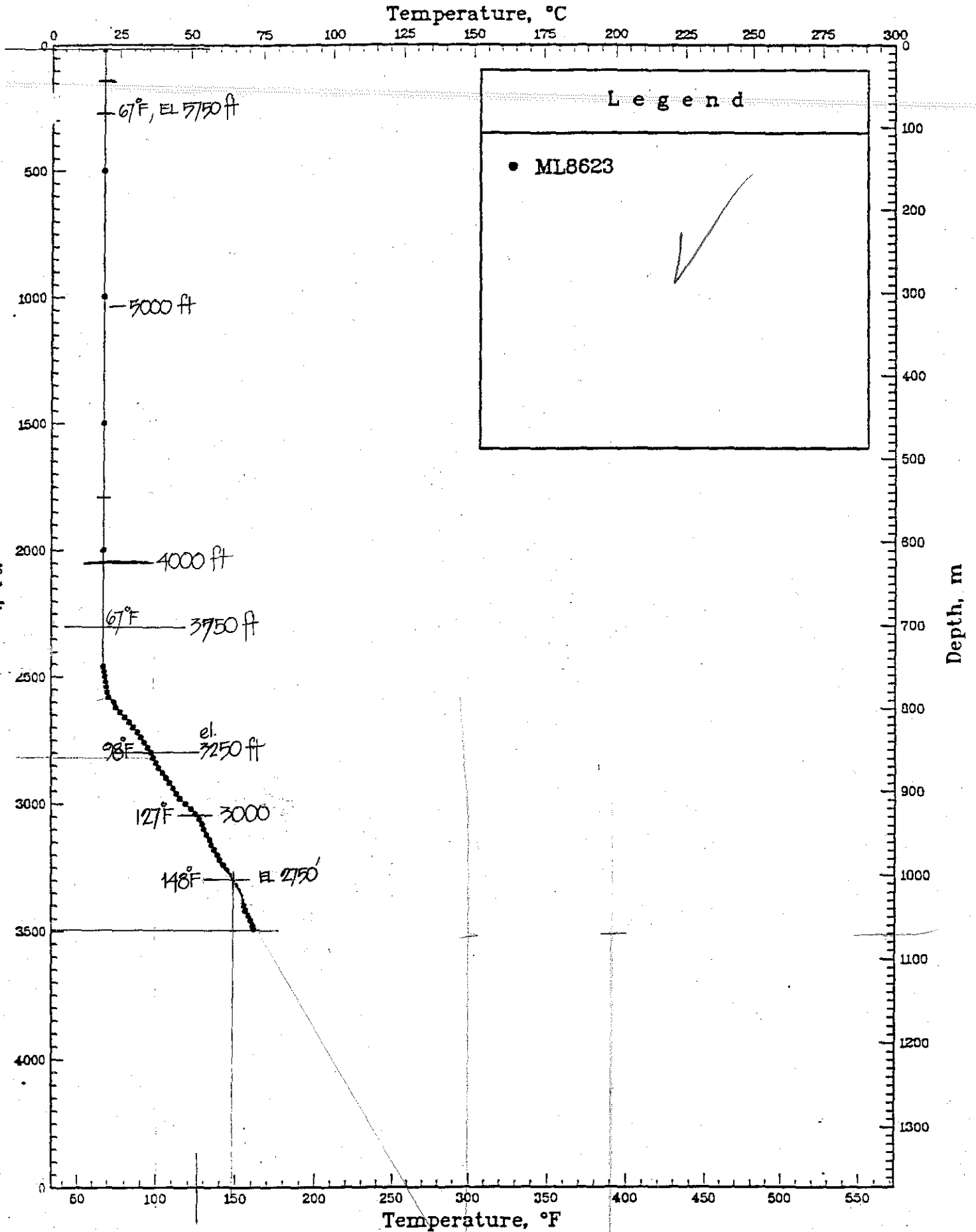

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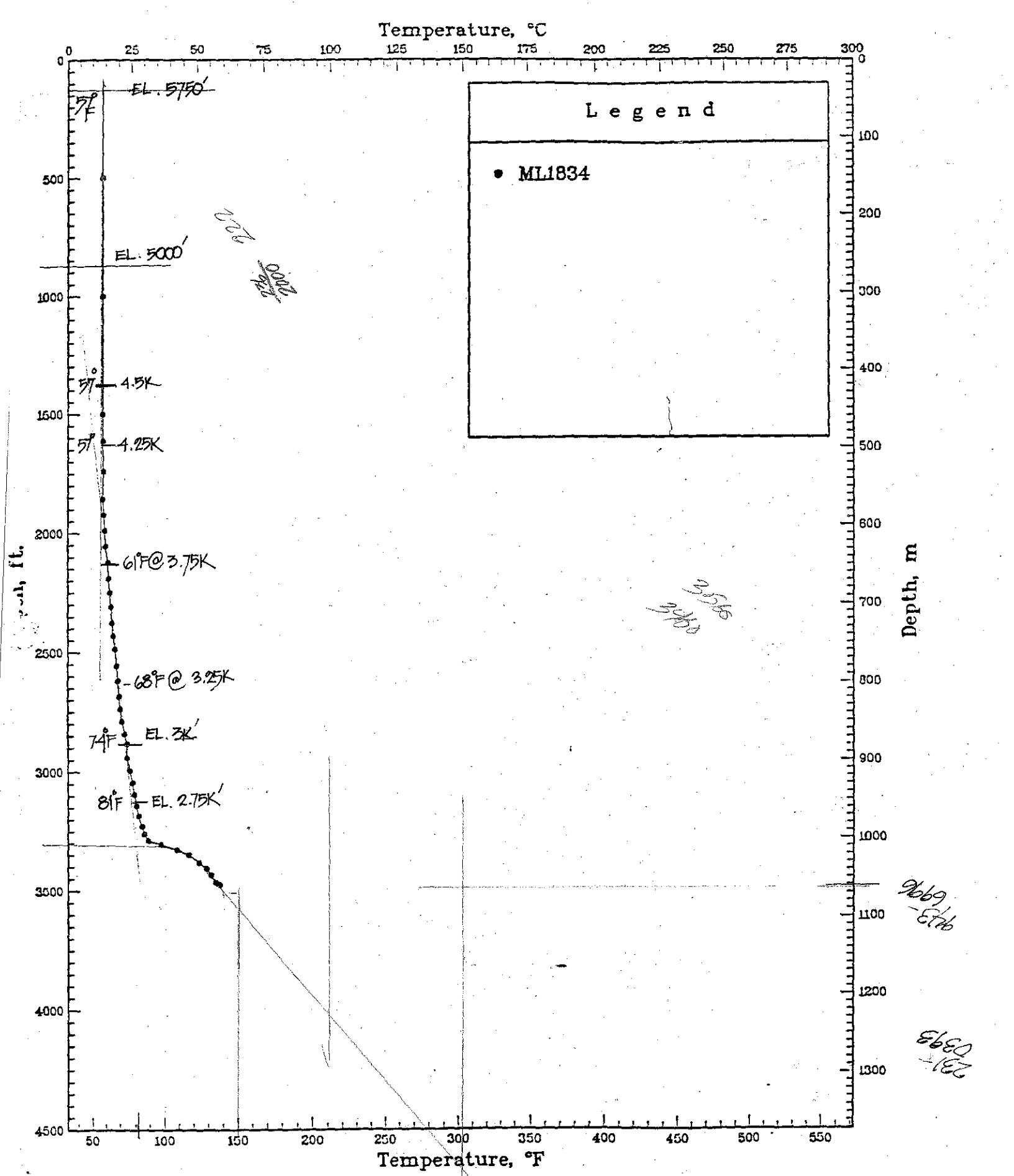

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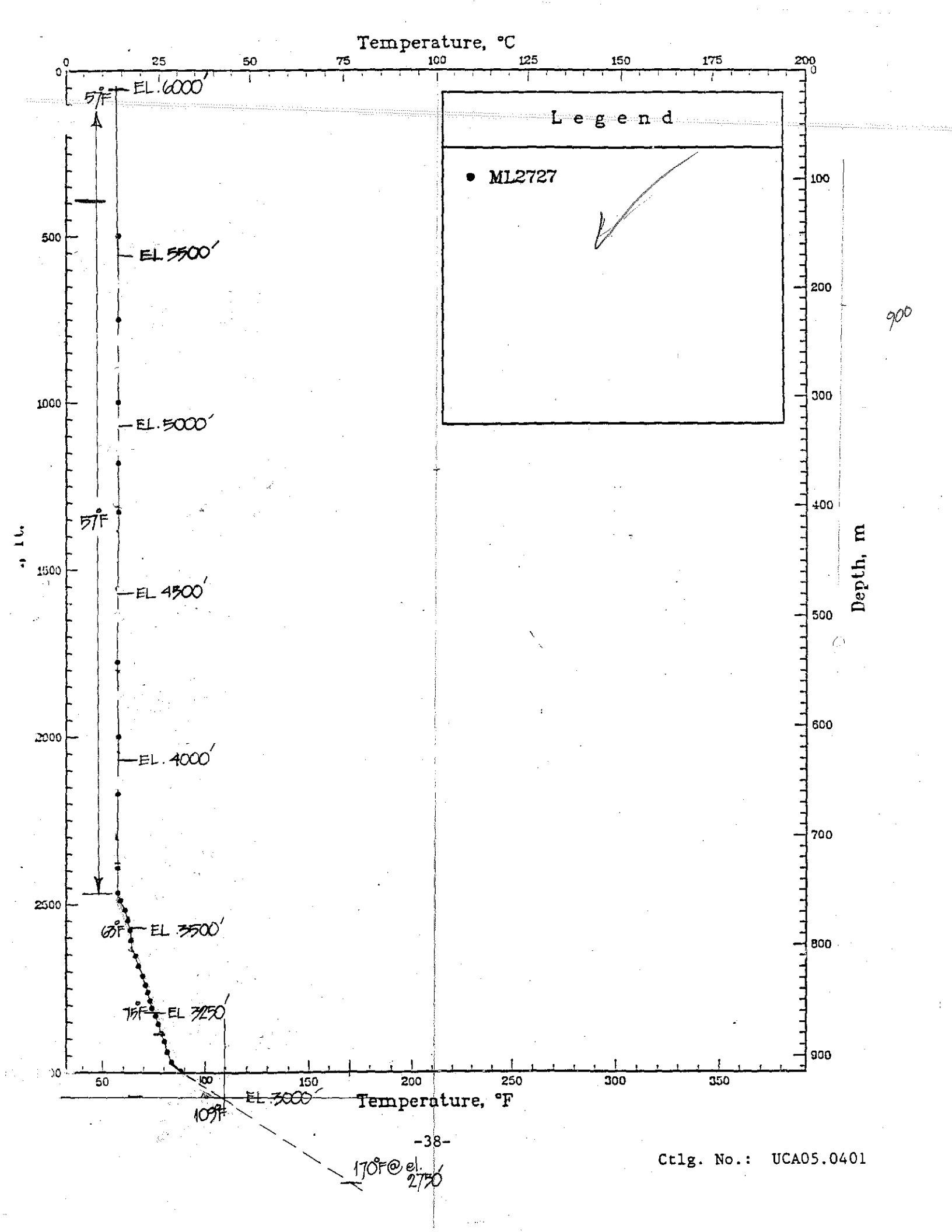

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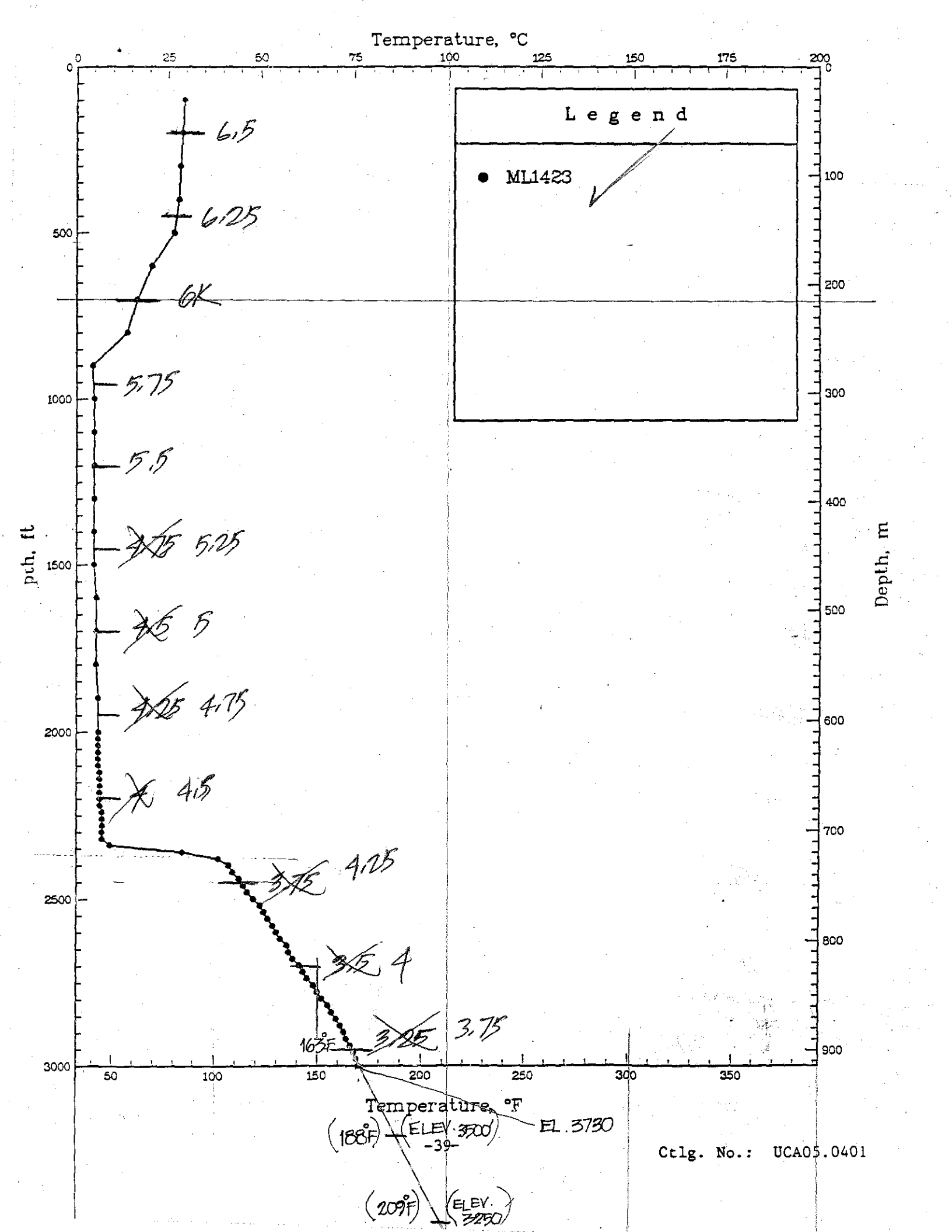

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