



**GEOLOGICAL SURVEY OF CANADA
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Ice Formation in Saline Soils

Volume 2 and 3

by
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University of Waterloo
Waterloo, Ontario

March 1989



Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada

Canada

Inside title page

ICE FORMATION IN SALINE SOILS

VOLUME 2

Report Submitted

to

SUPPLY AND SERVICES CANADA

HULL, QUEBEC

(DSS File No. 63SS.23233-7-1080)

APPENDIX 4

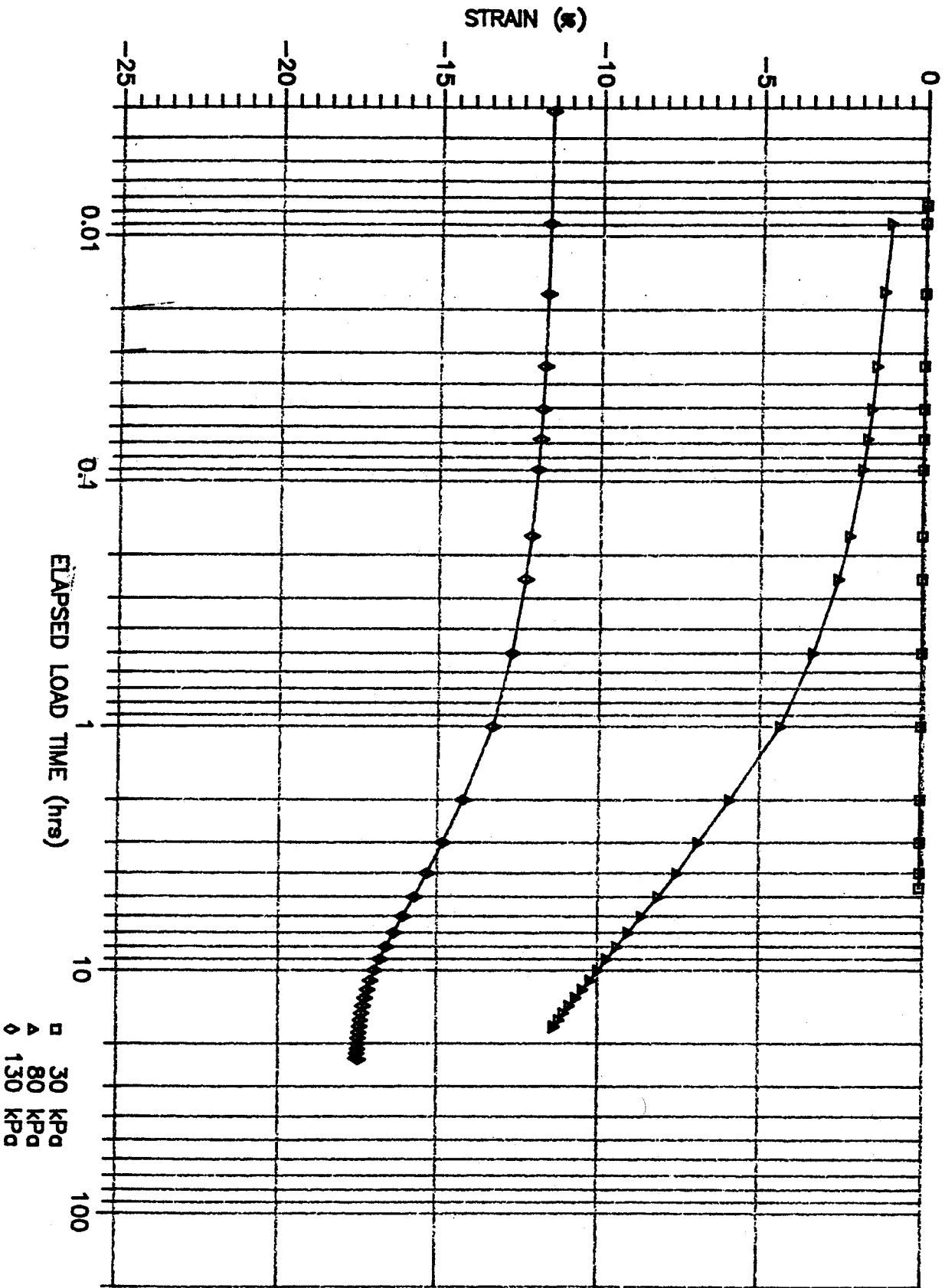
Test Results of Series 1. (No Applied Surcharge)

Prepared by

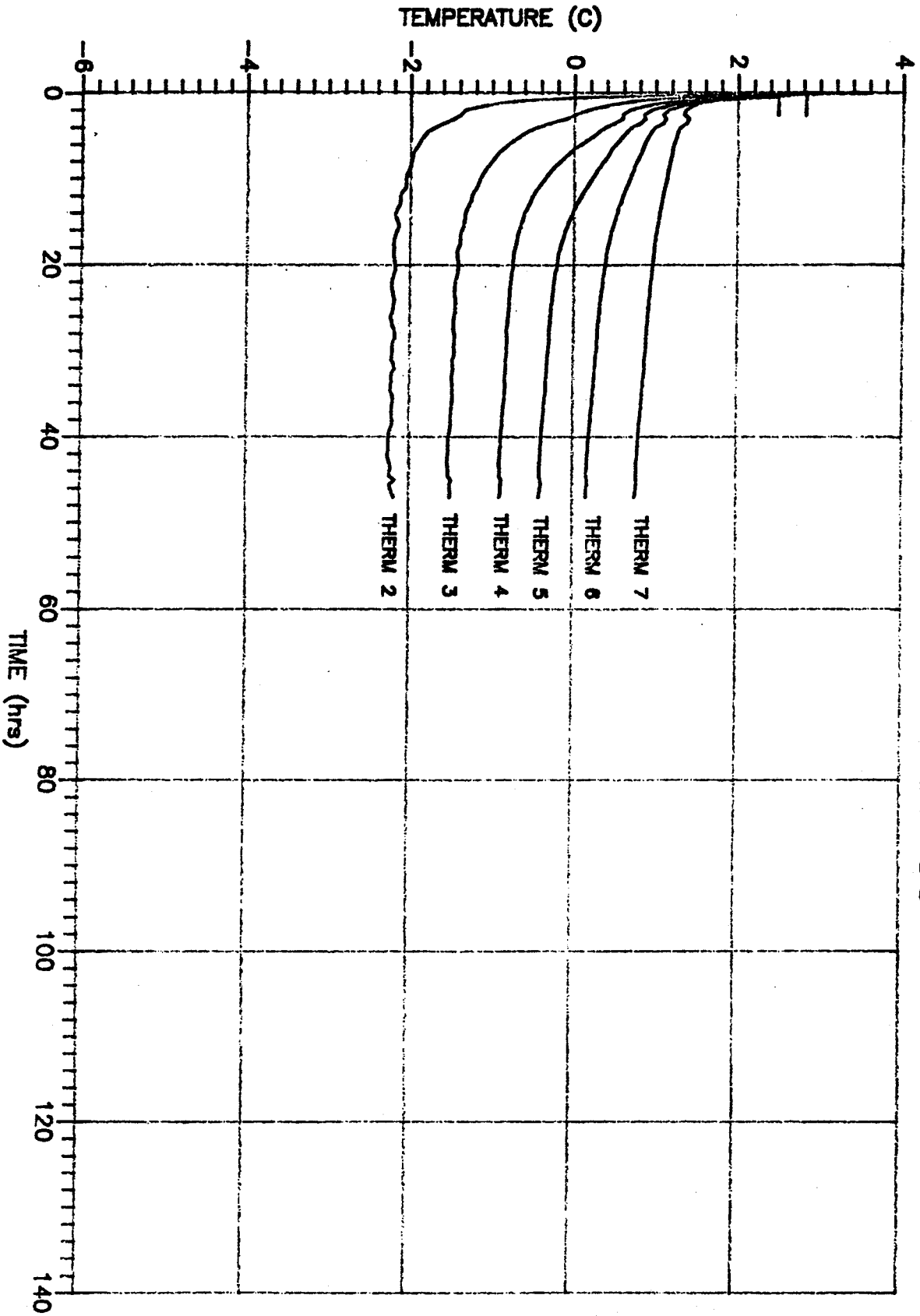
**J.- M. Konrad, Ph.D., P.Eng.
Dept. of Earth Sciences
University of Waterloo
Waterloo, Ontario, N2L-3G1**

March, 1989

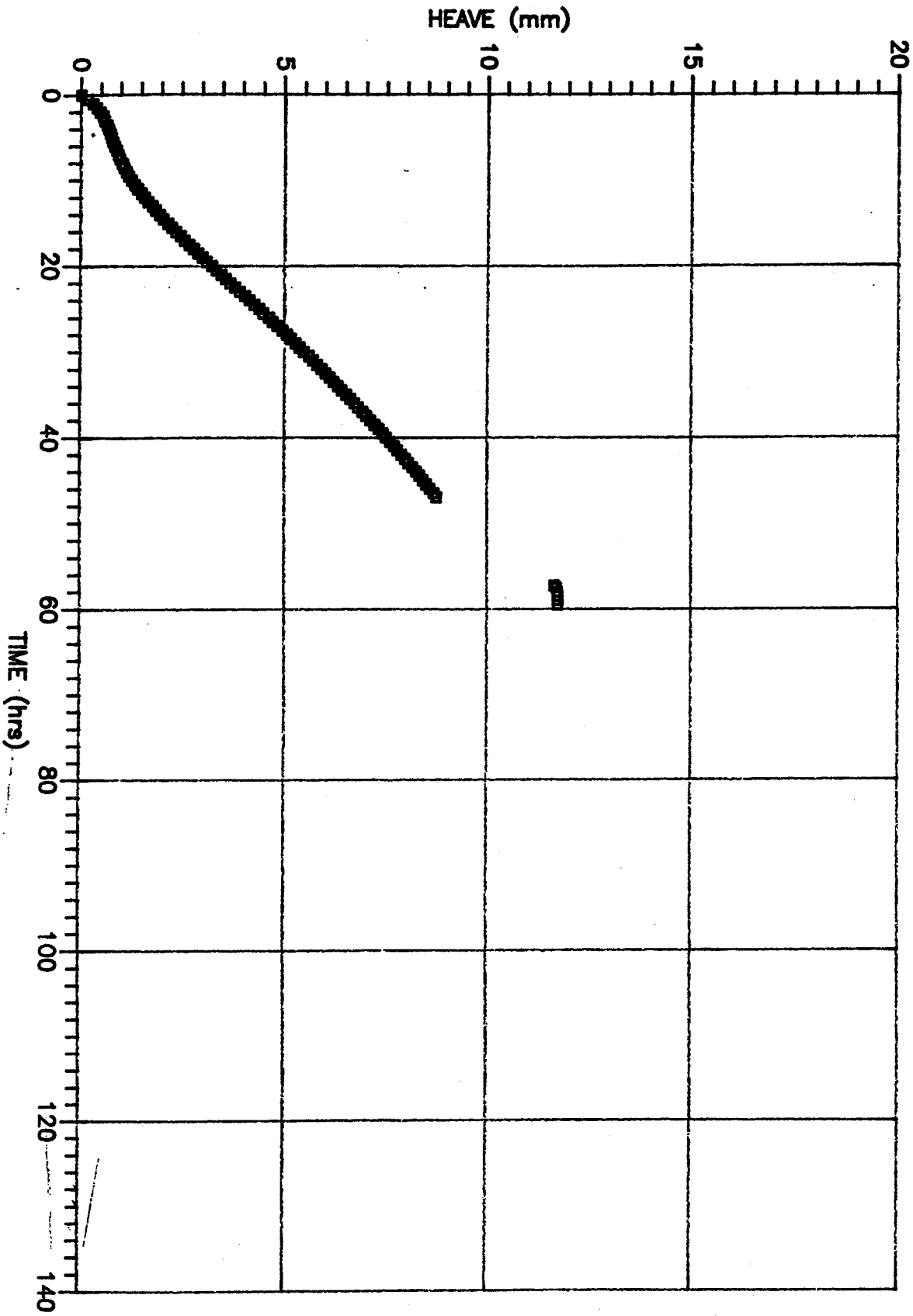
CONSOLIDATION TEST S3



FREEZING TEST S3

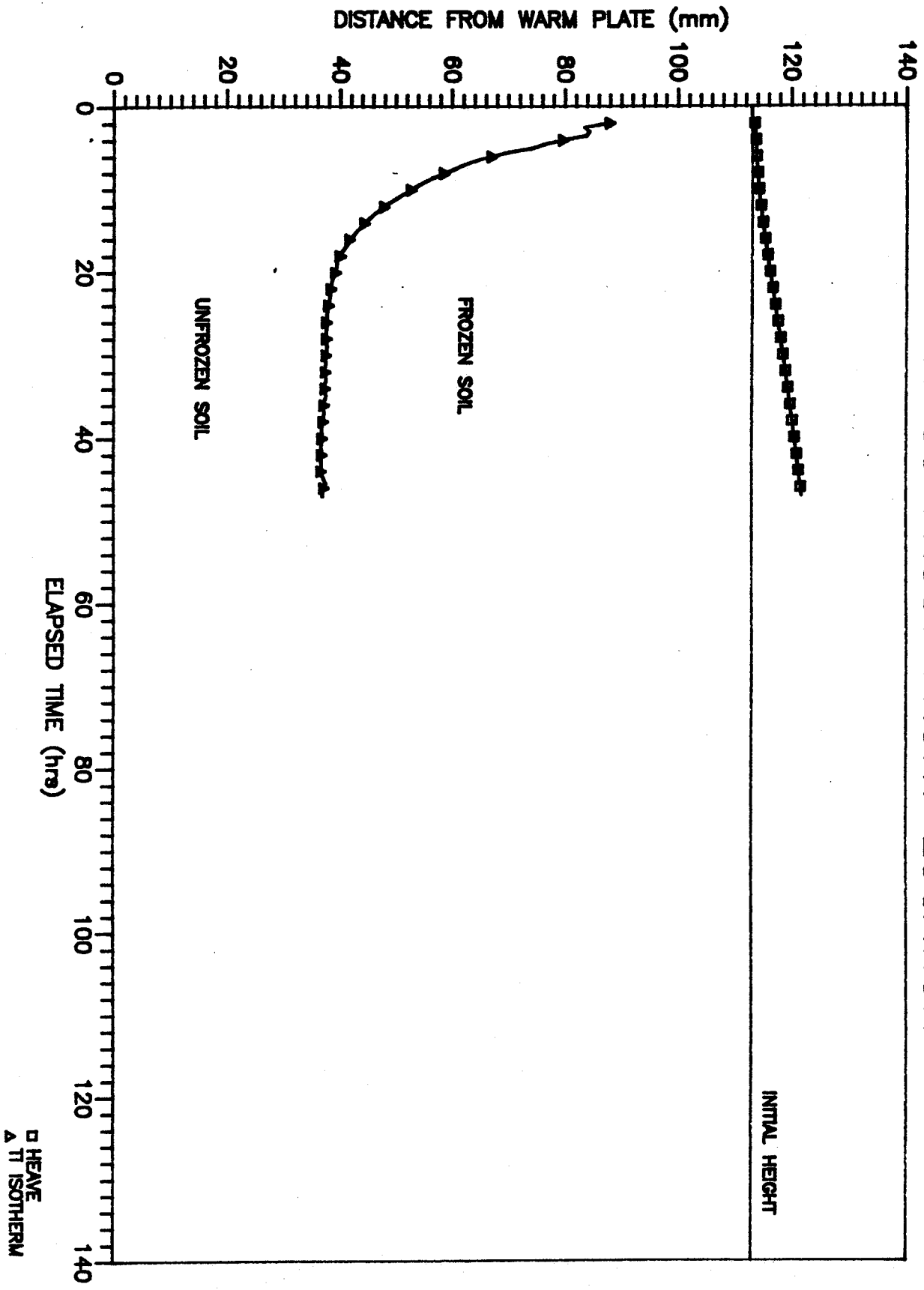


FREEZING TEST S3

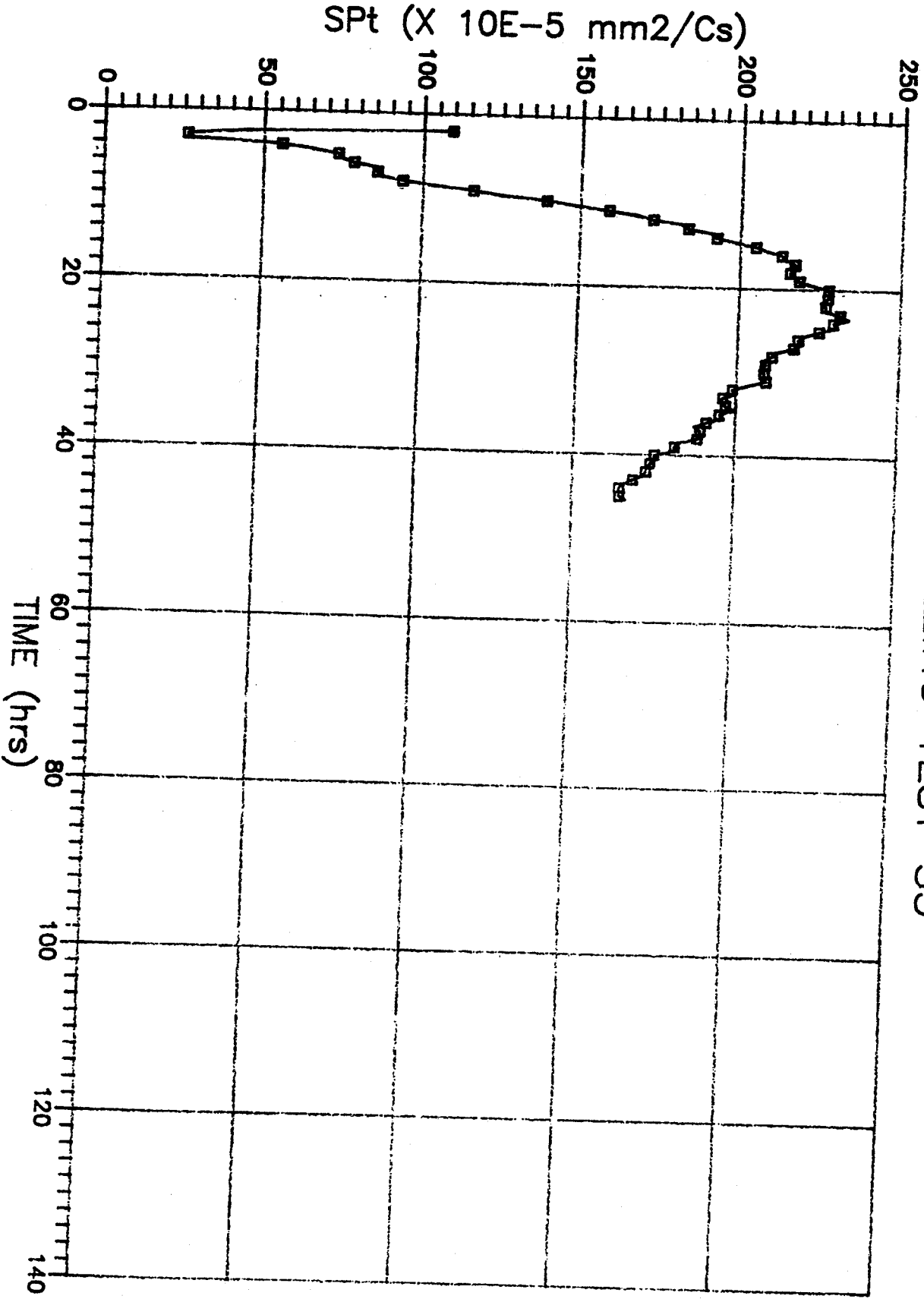


TOTAL HEAVE

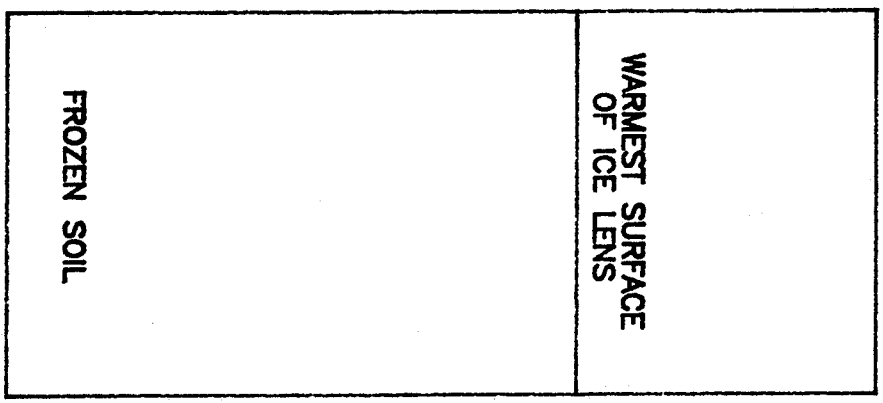
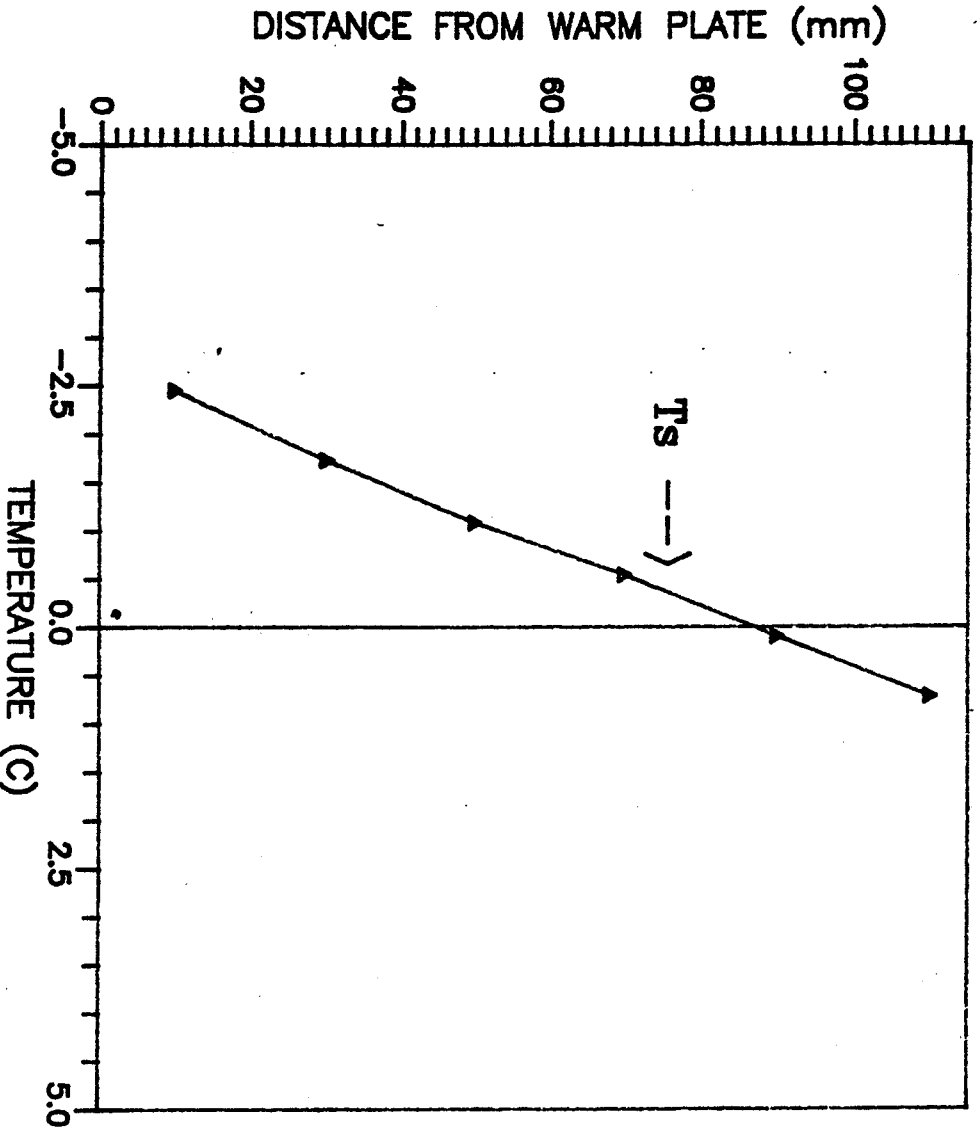
TEST S3 FROST FRONT LOCATION



FREEZING TEST S3

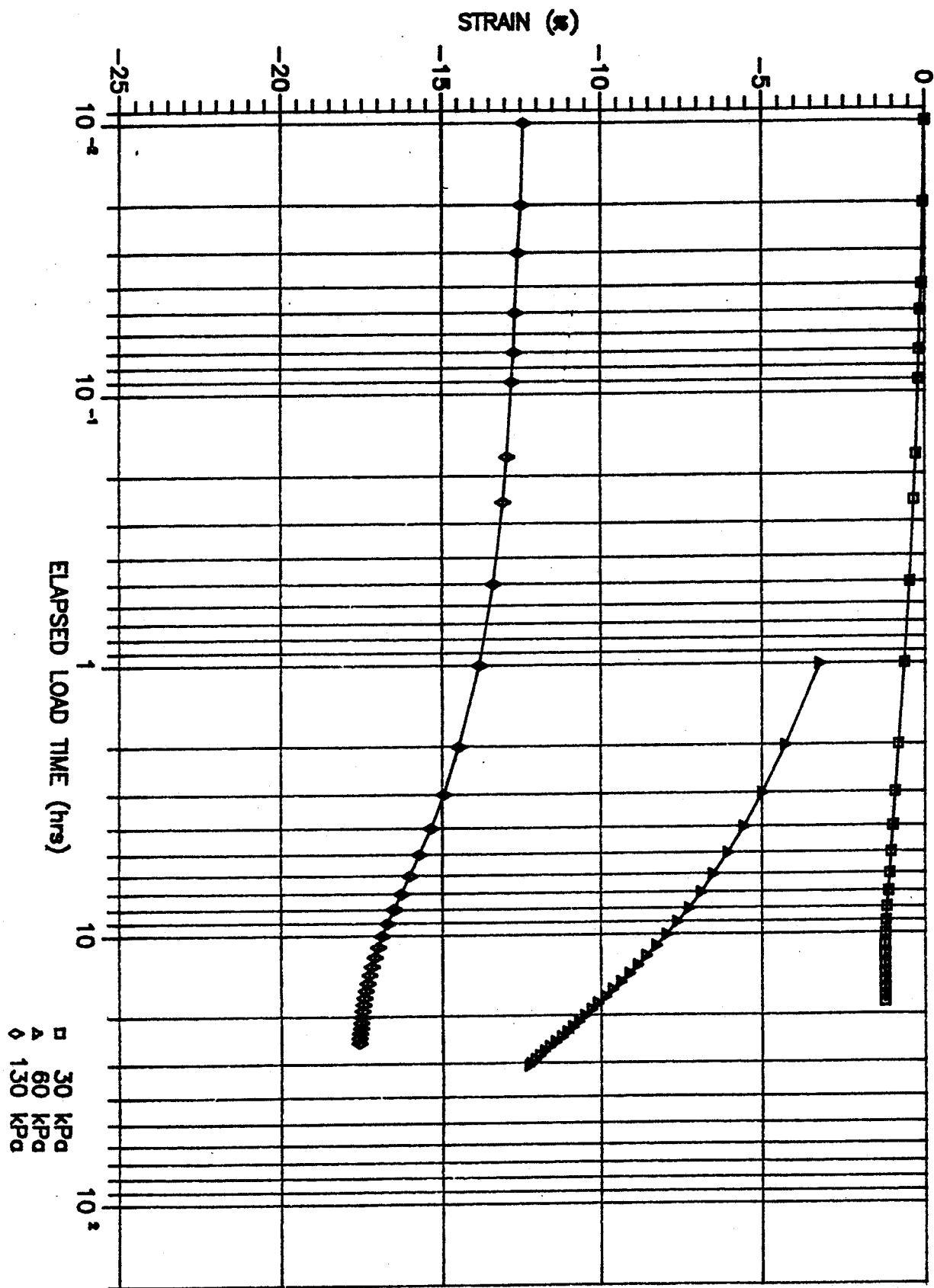


OBSERVED POSITION OF ICE LENS

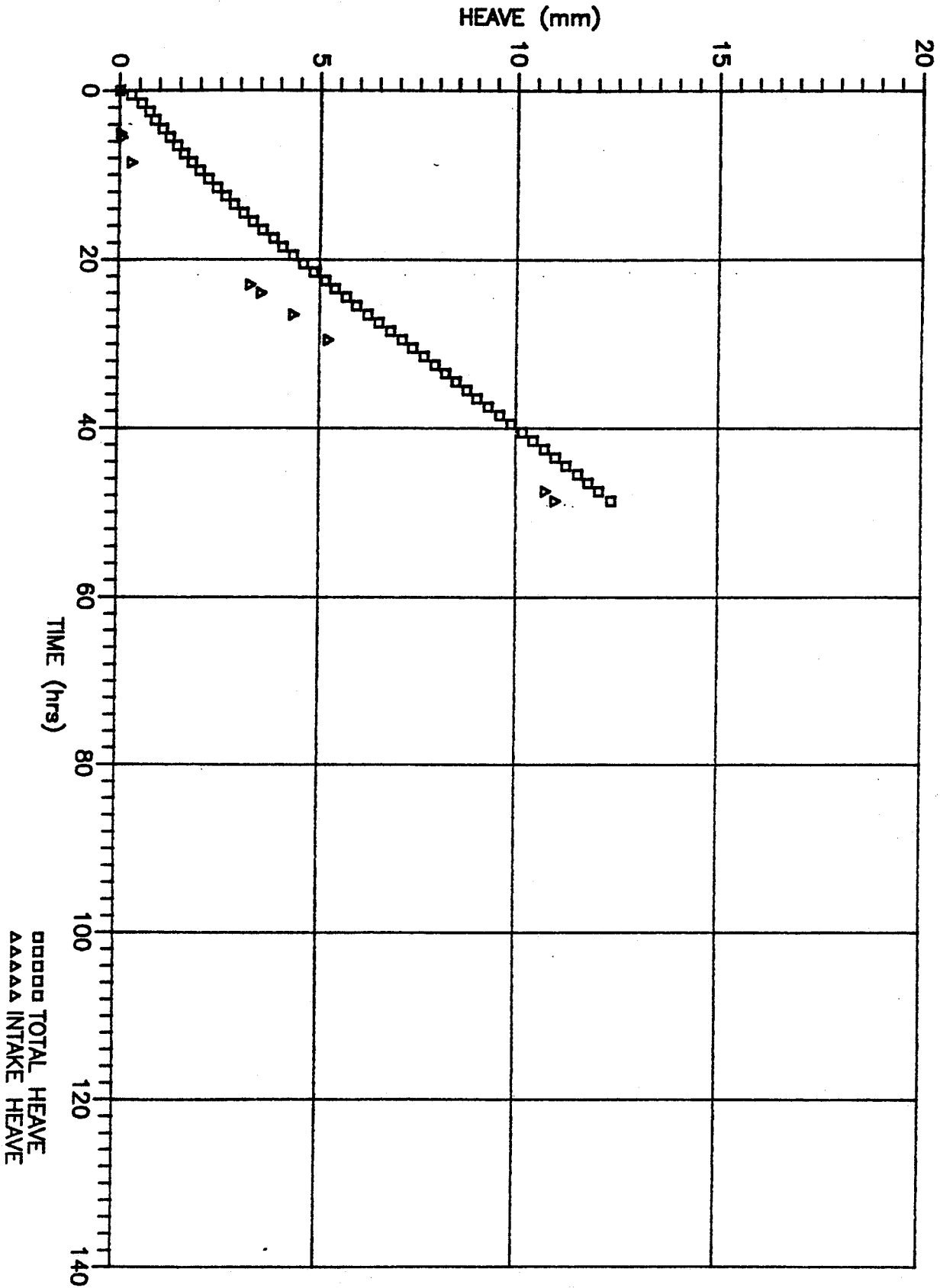


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S3

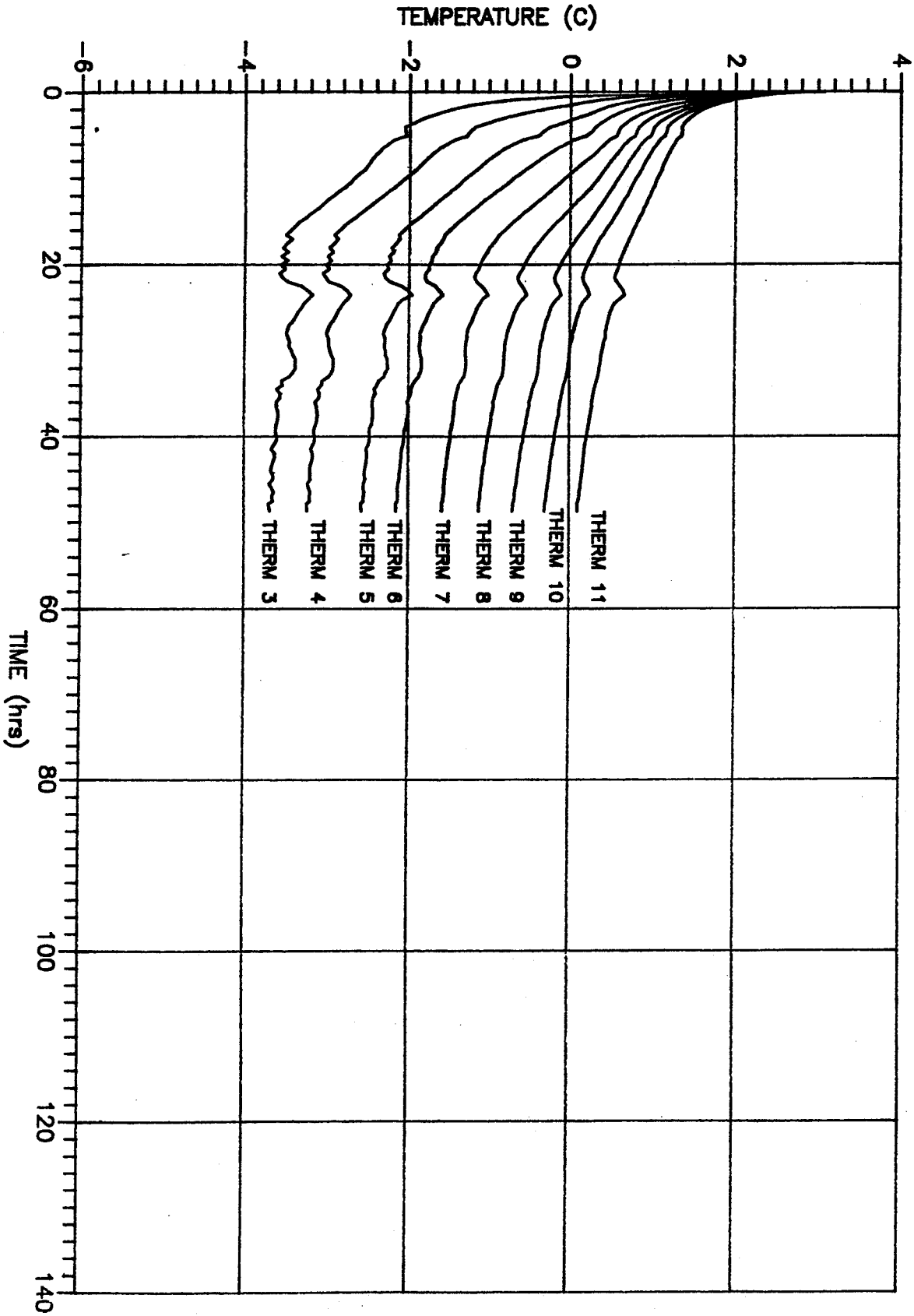
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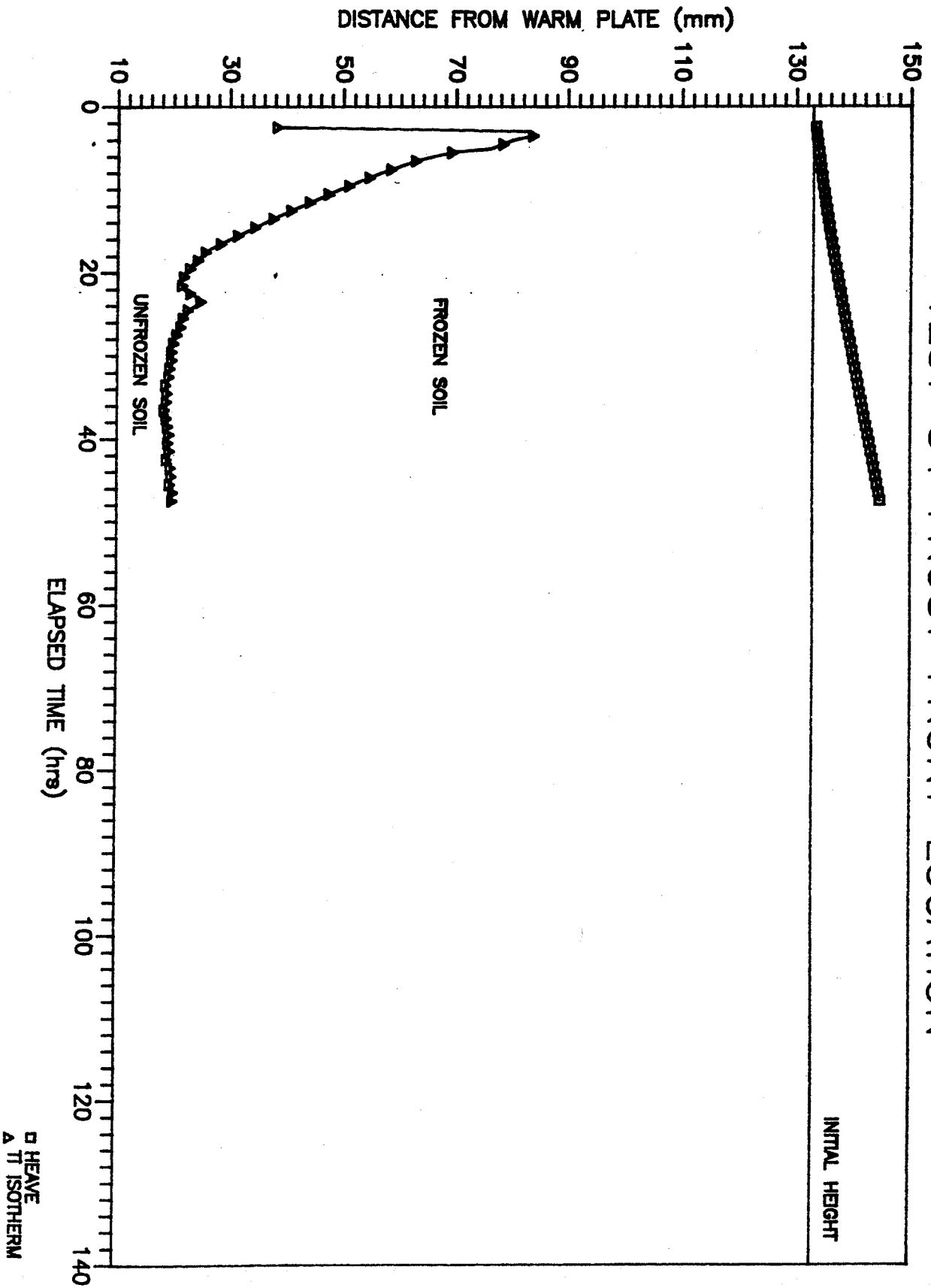
FREEZING TEST S4



FREEZING TEST S4

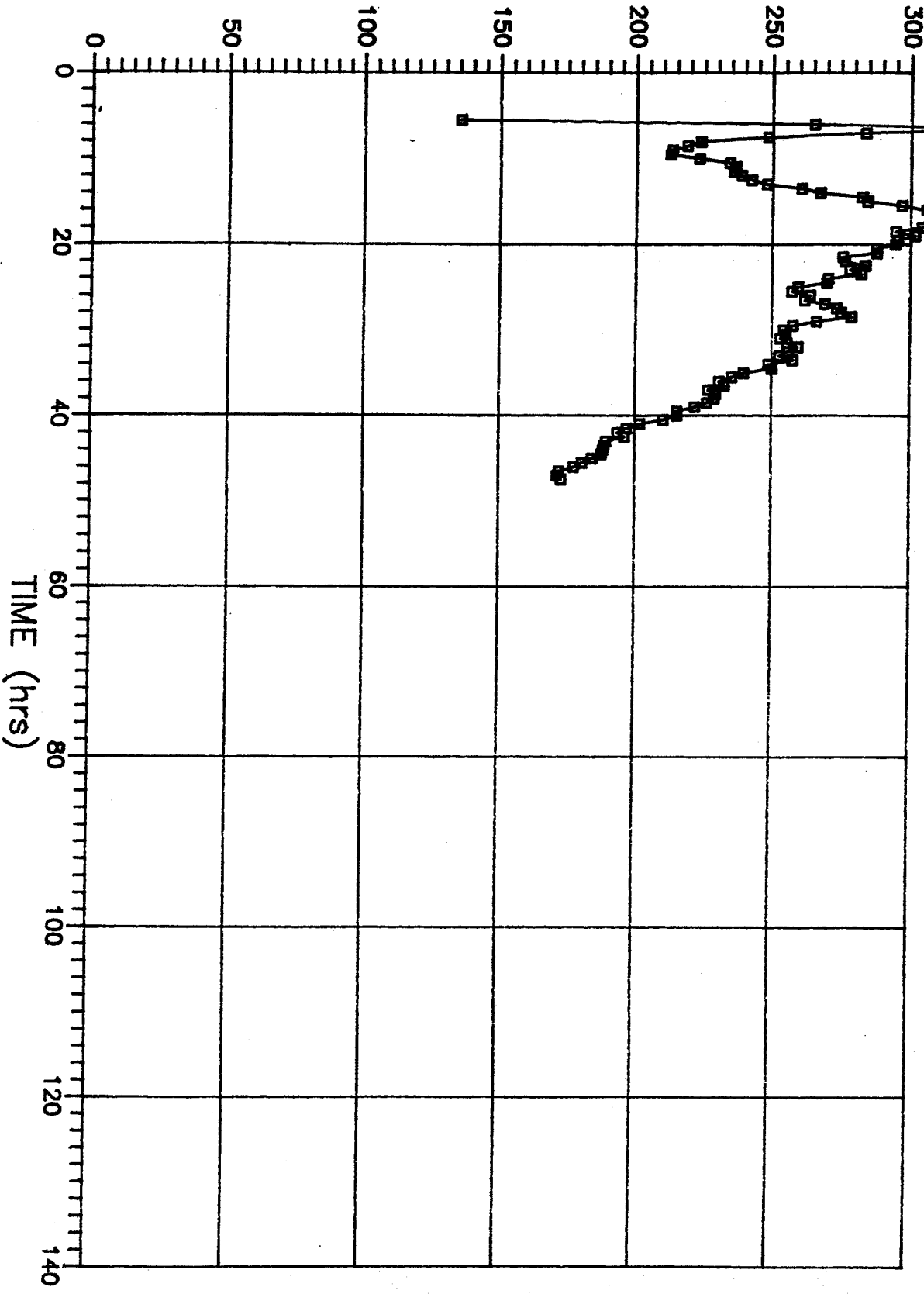


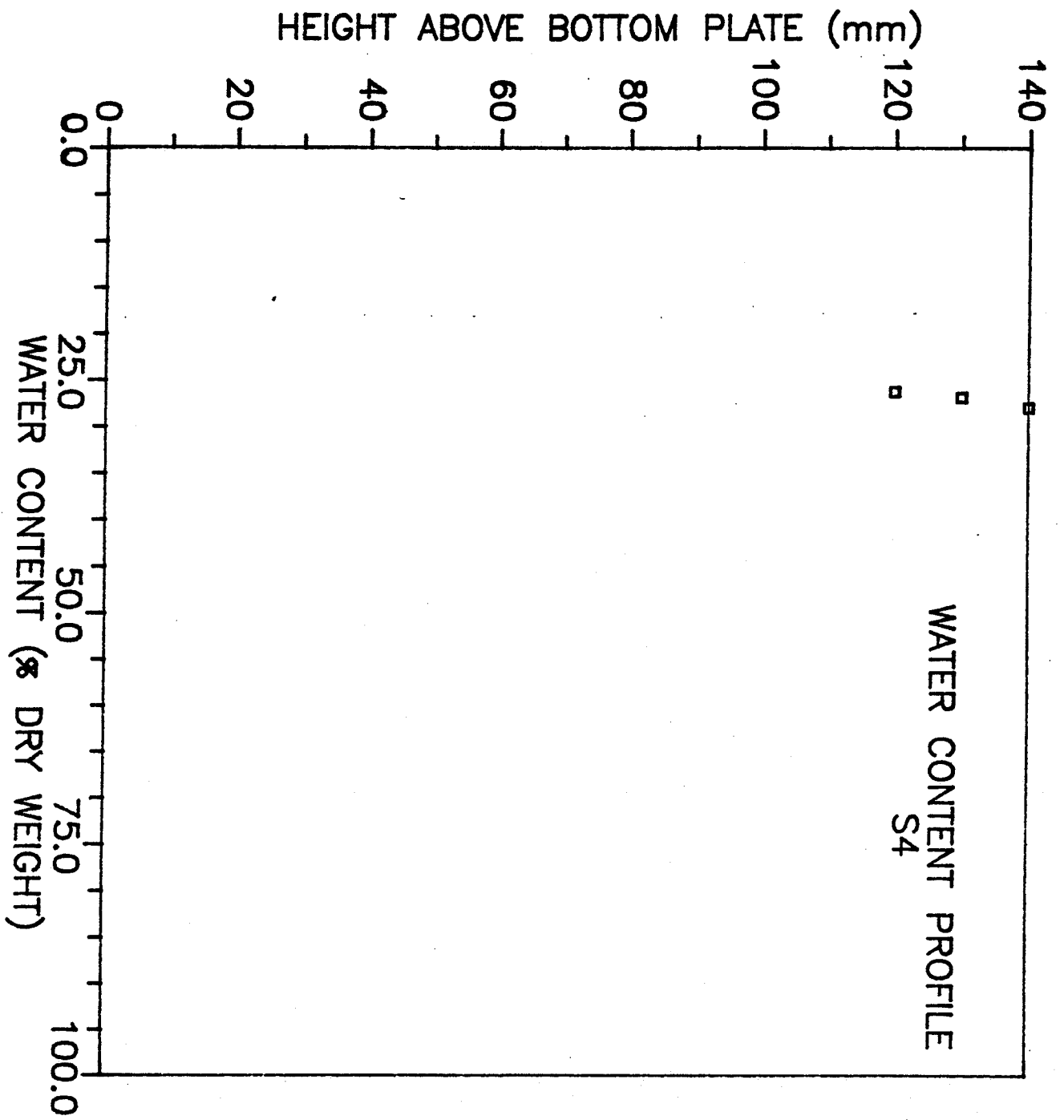
TEST S4 FROST FRONT LOCATION



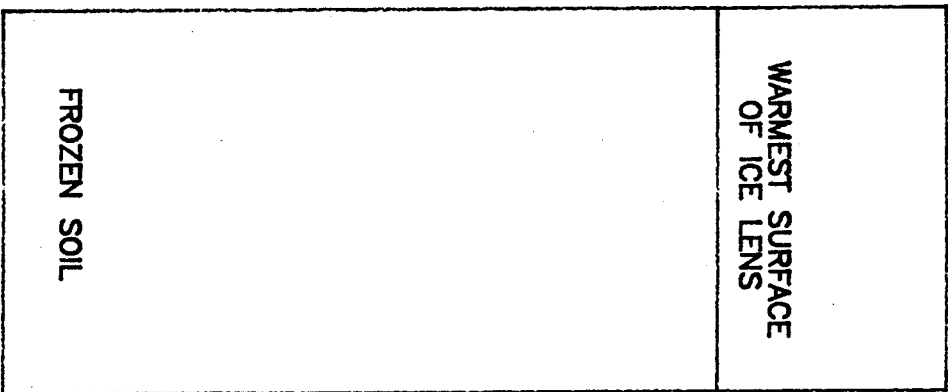
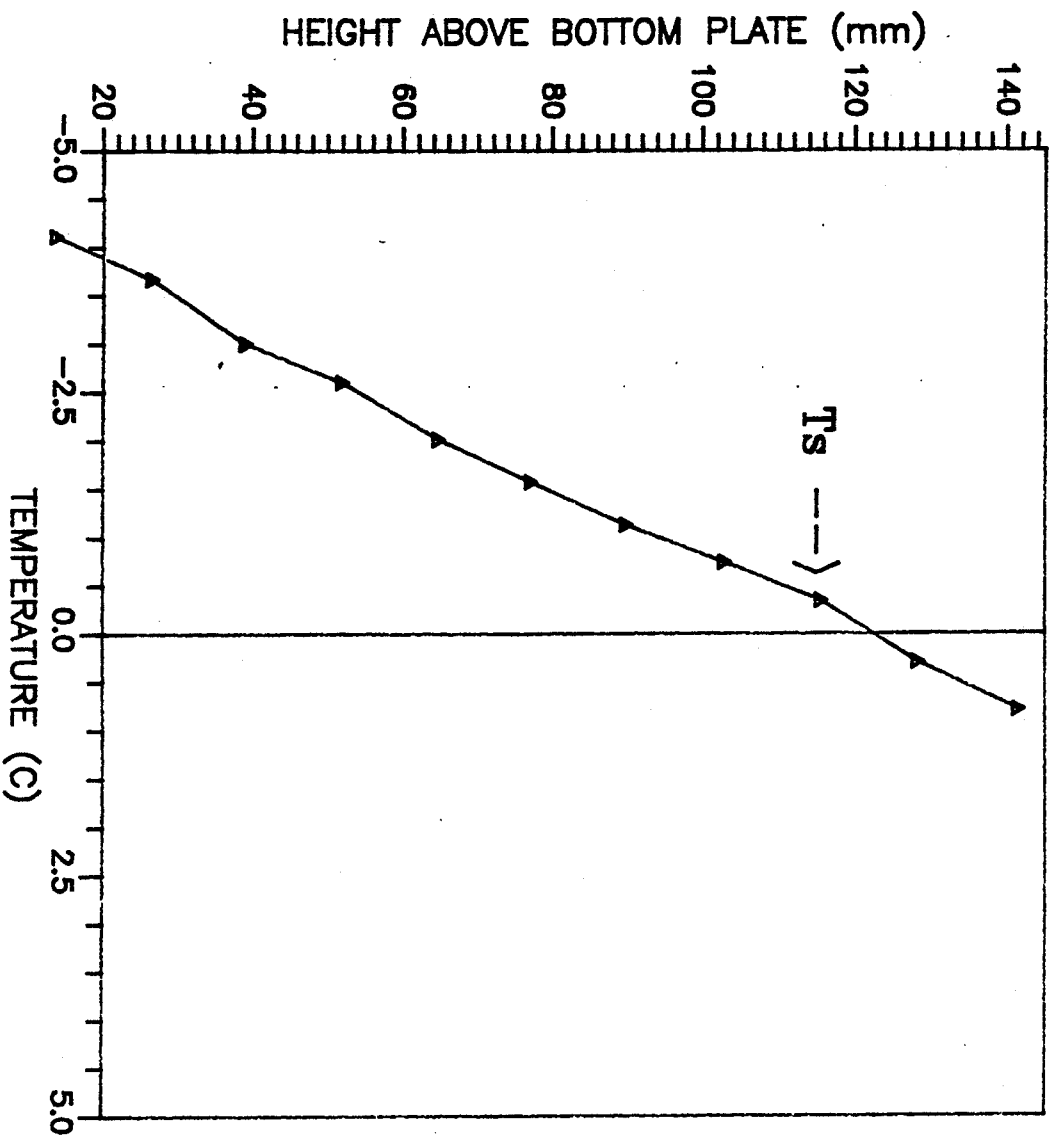
SPT (X 10E-5 mm2/Cs)

FREEZING TEST S4



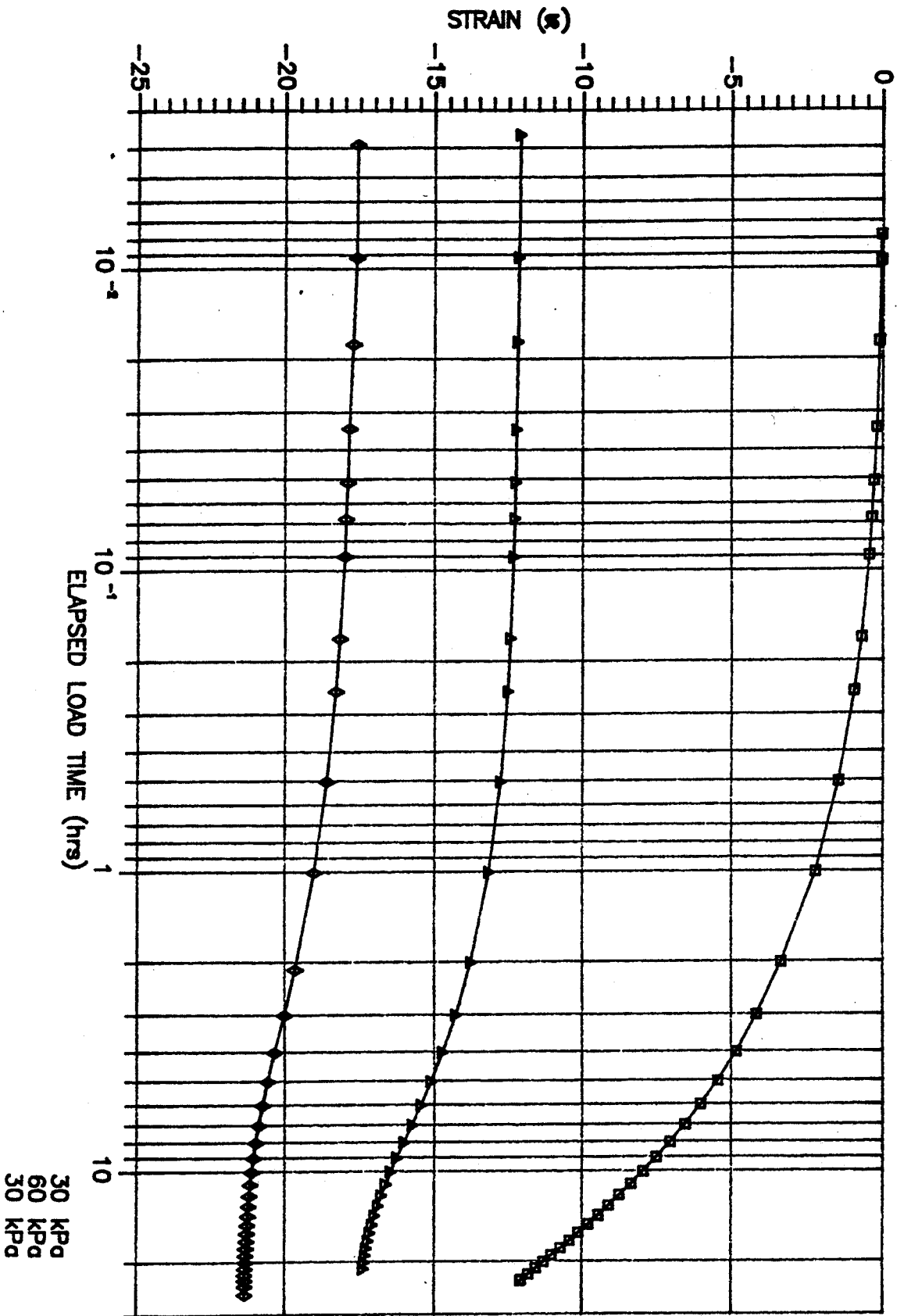


OBSERVED POSITION OF ICE LENS

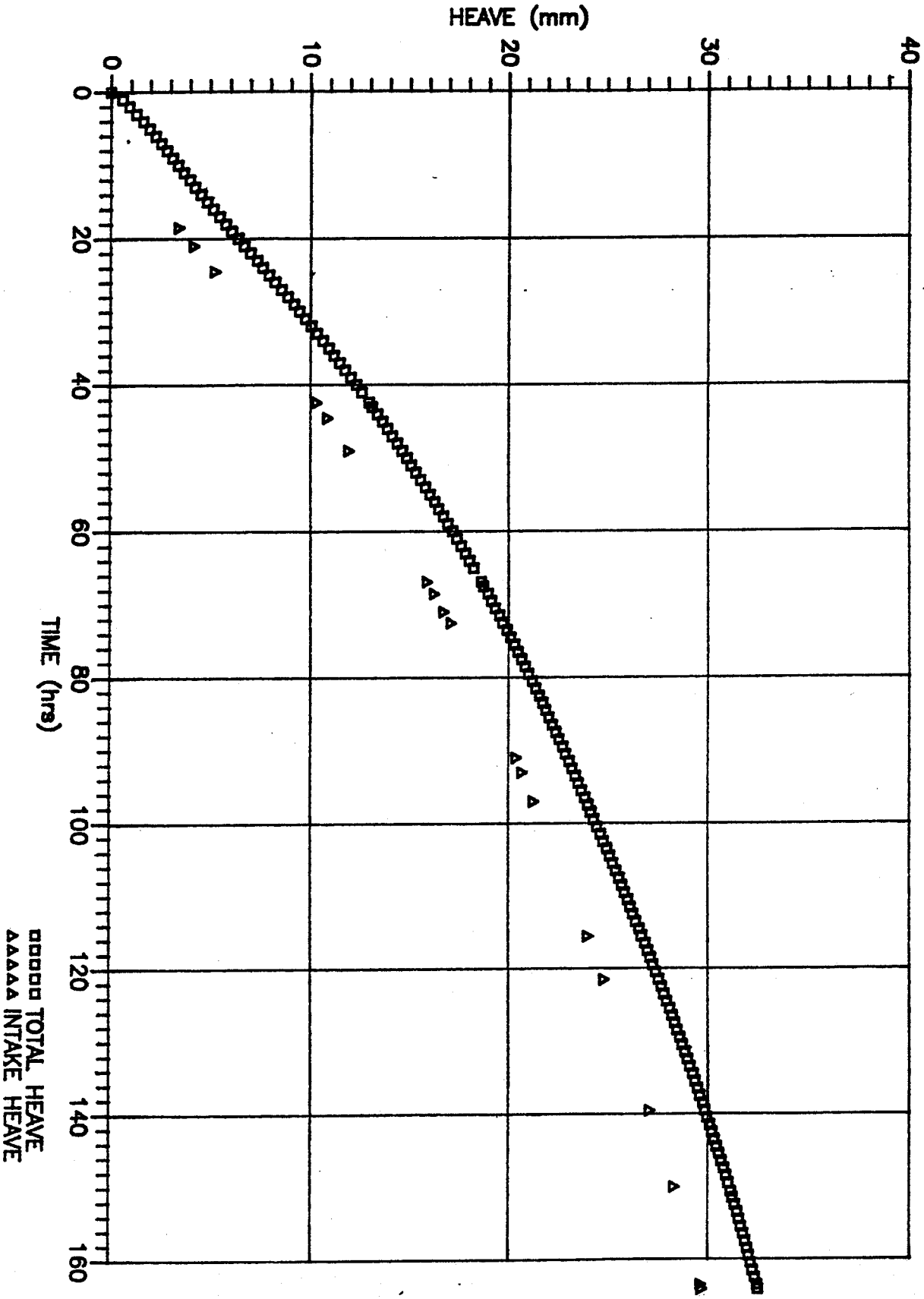


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S4

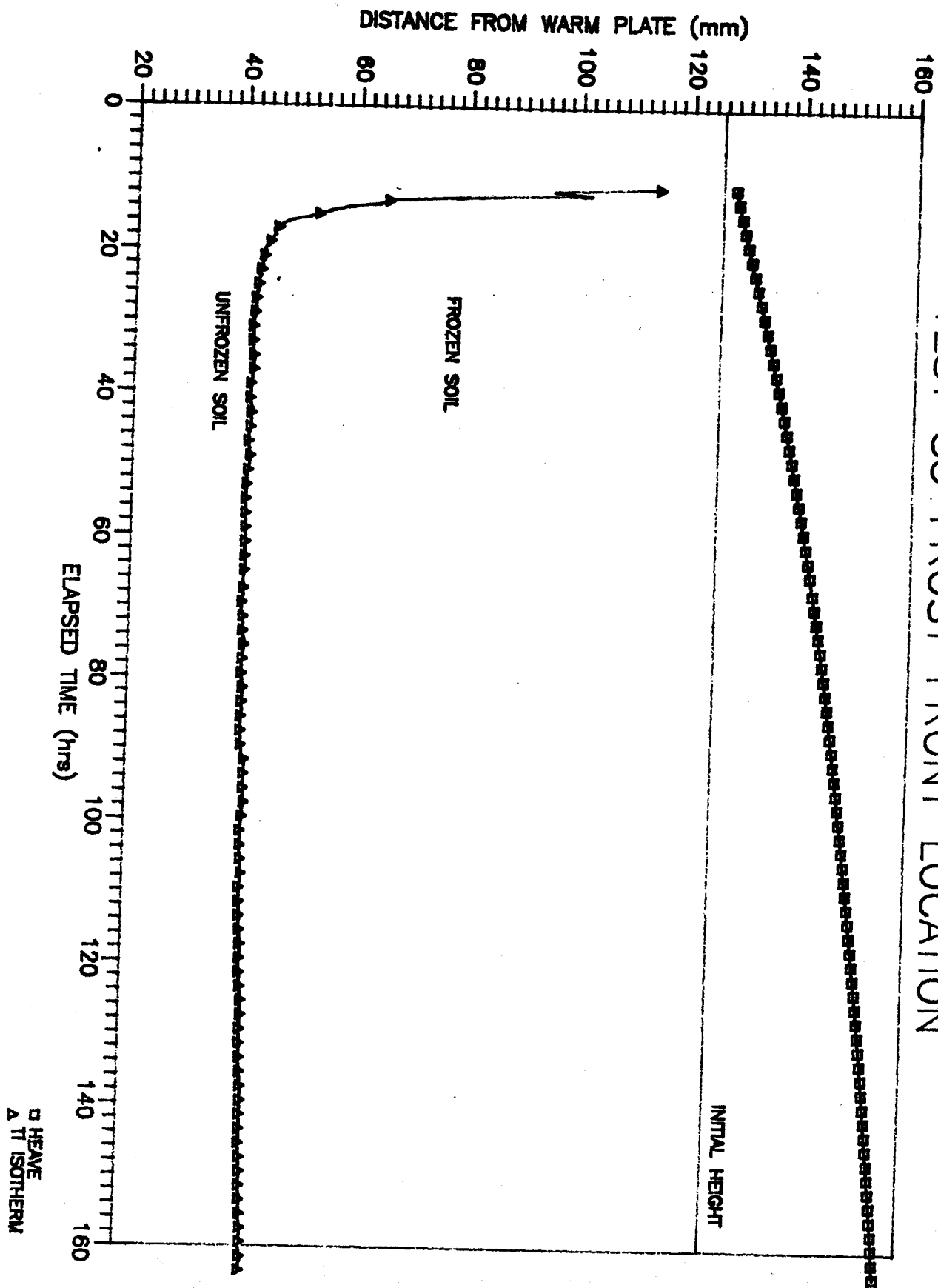
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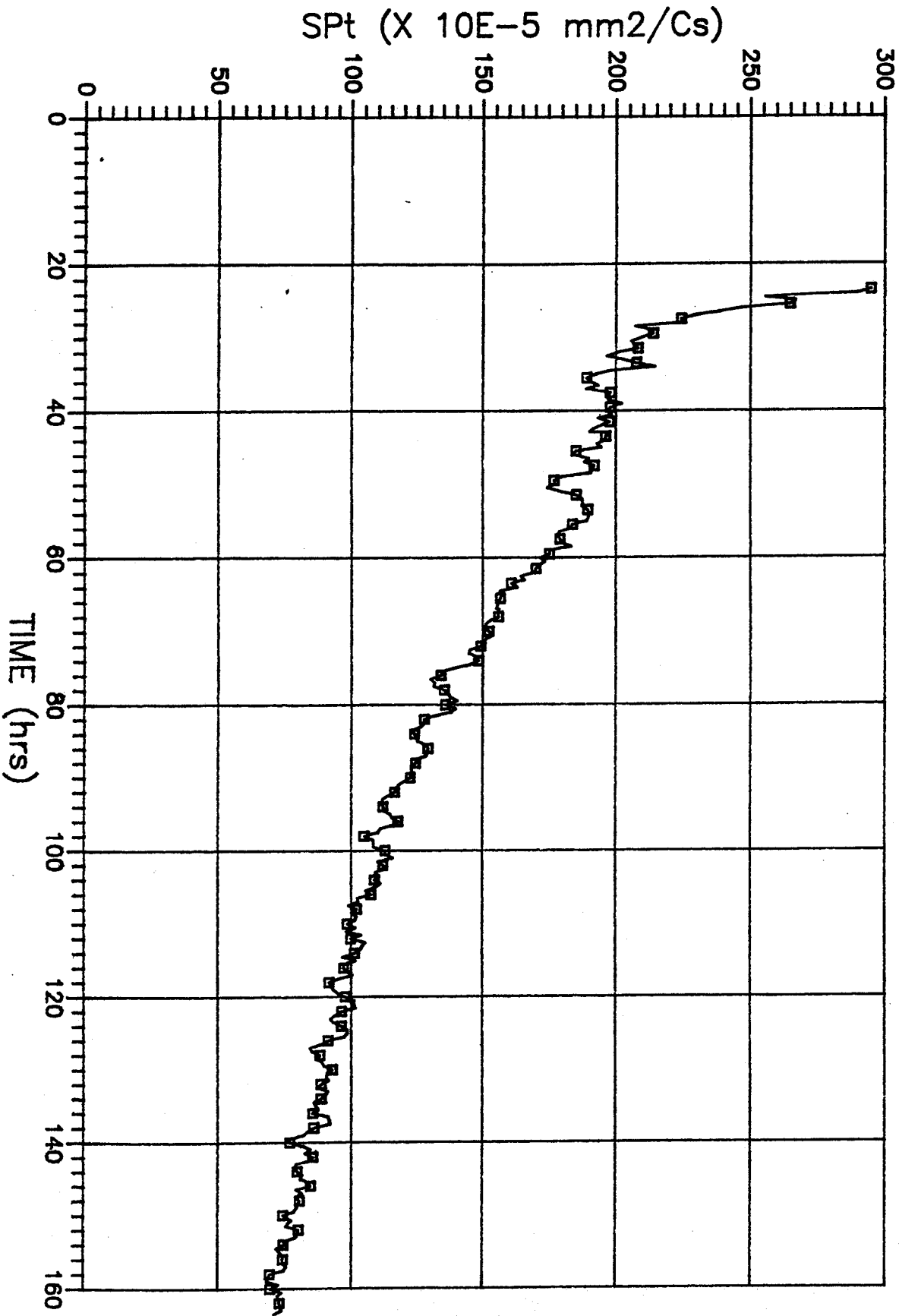
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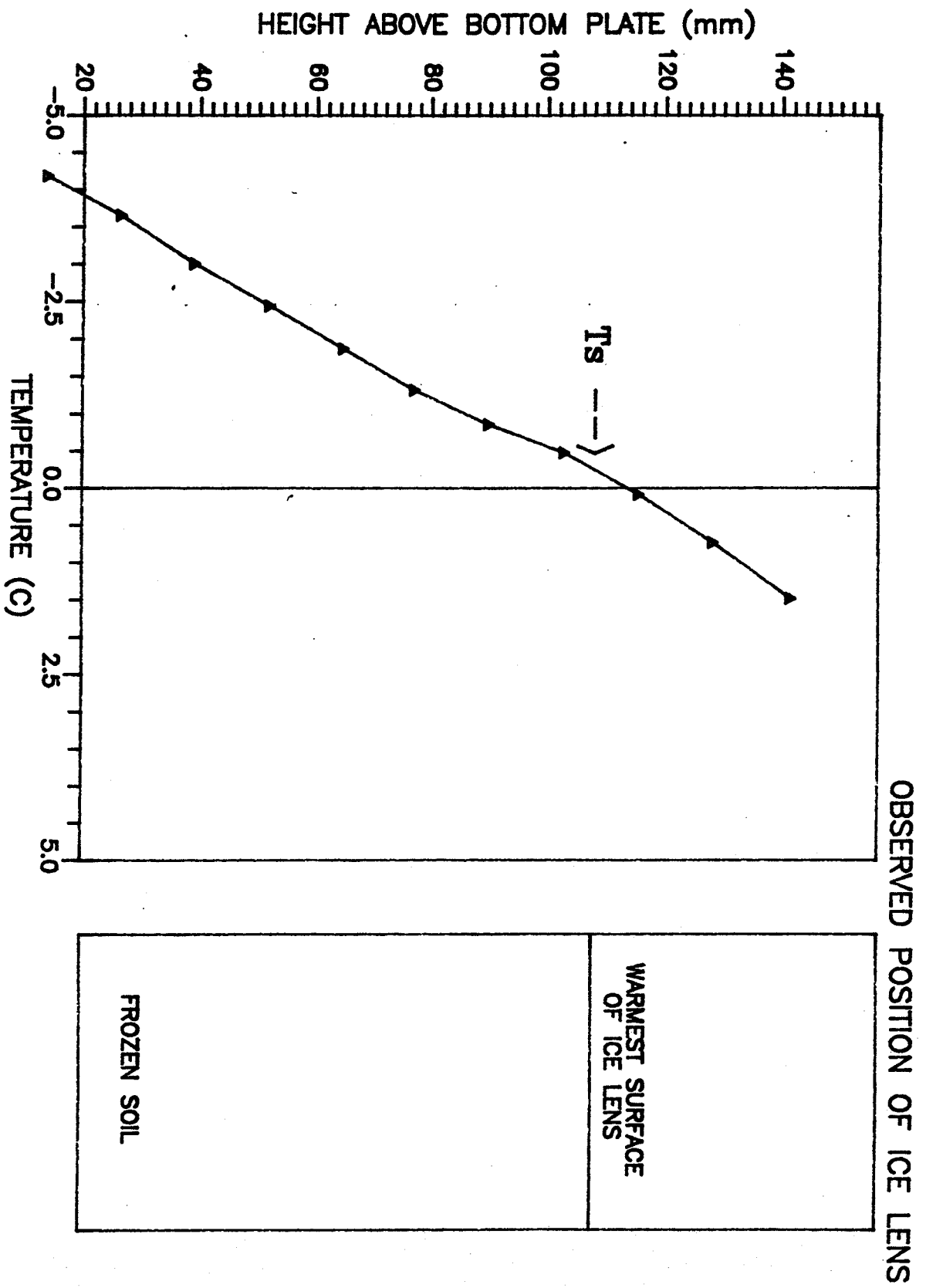


TEST S5 FROST FRONT LOCATION



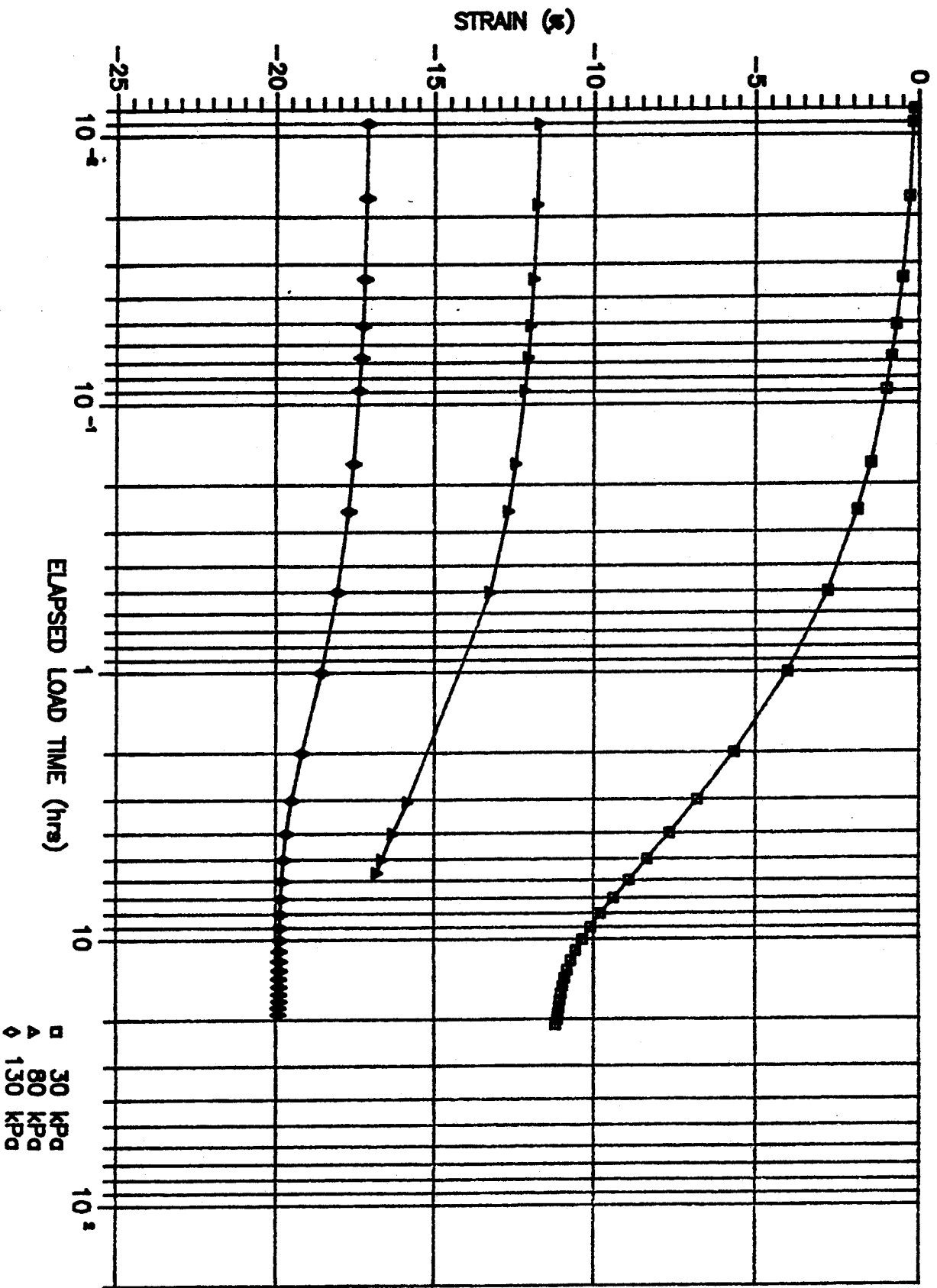
FREEZING TEST S5



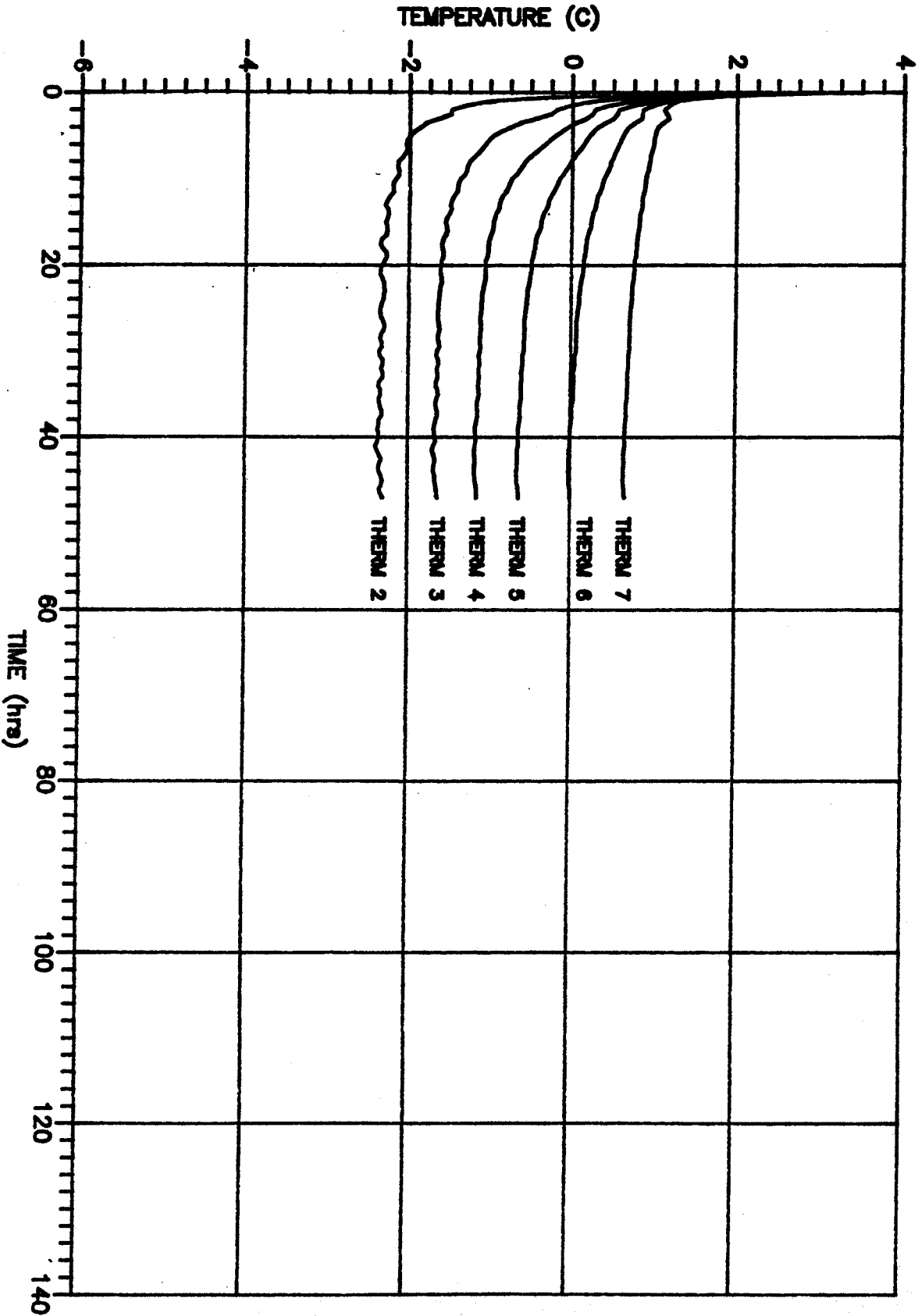


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S5

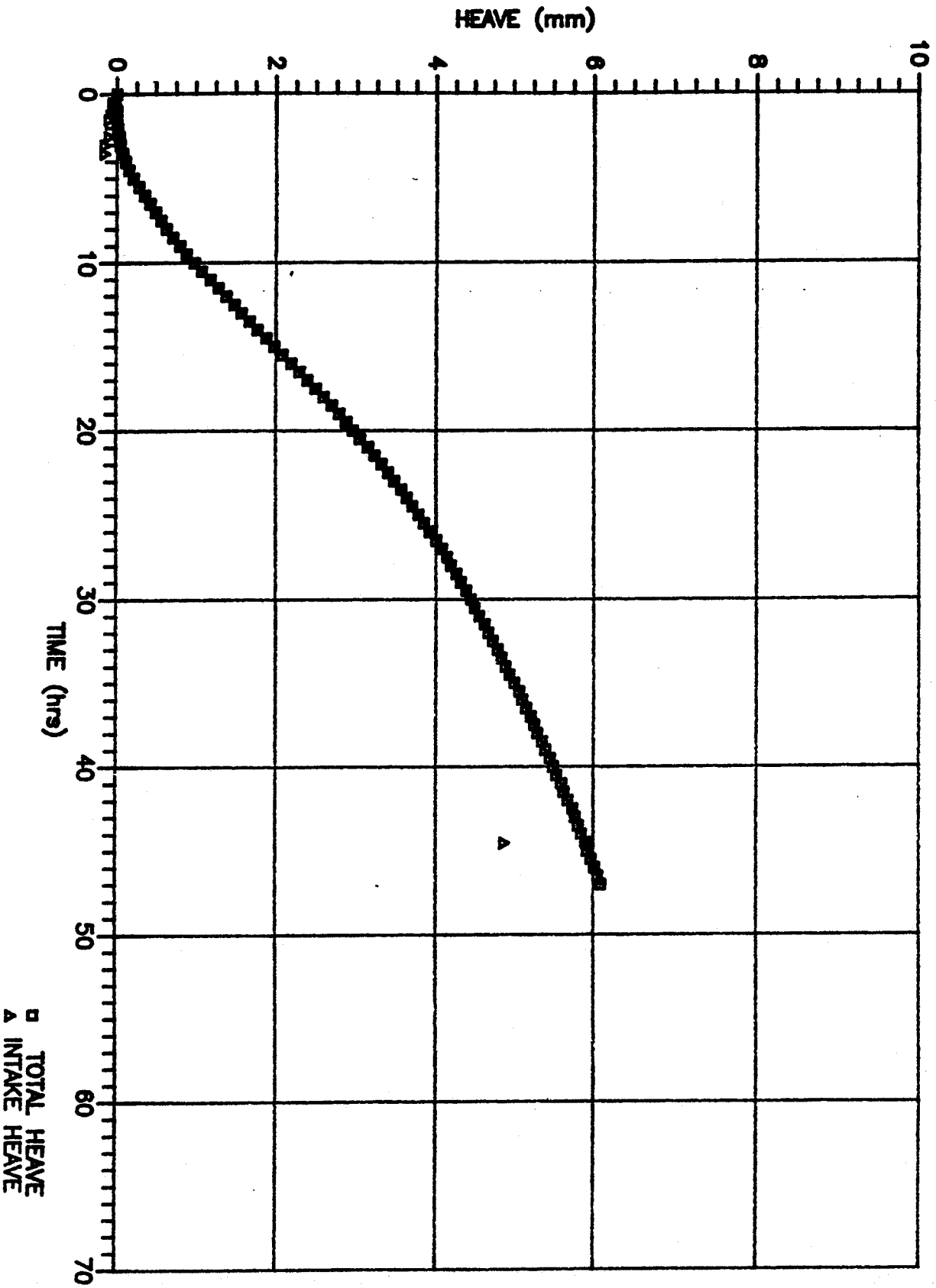
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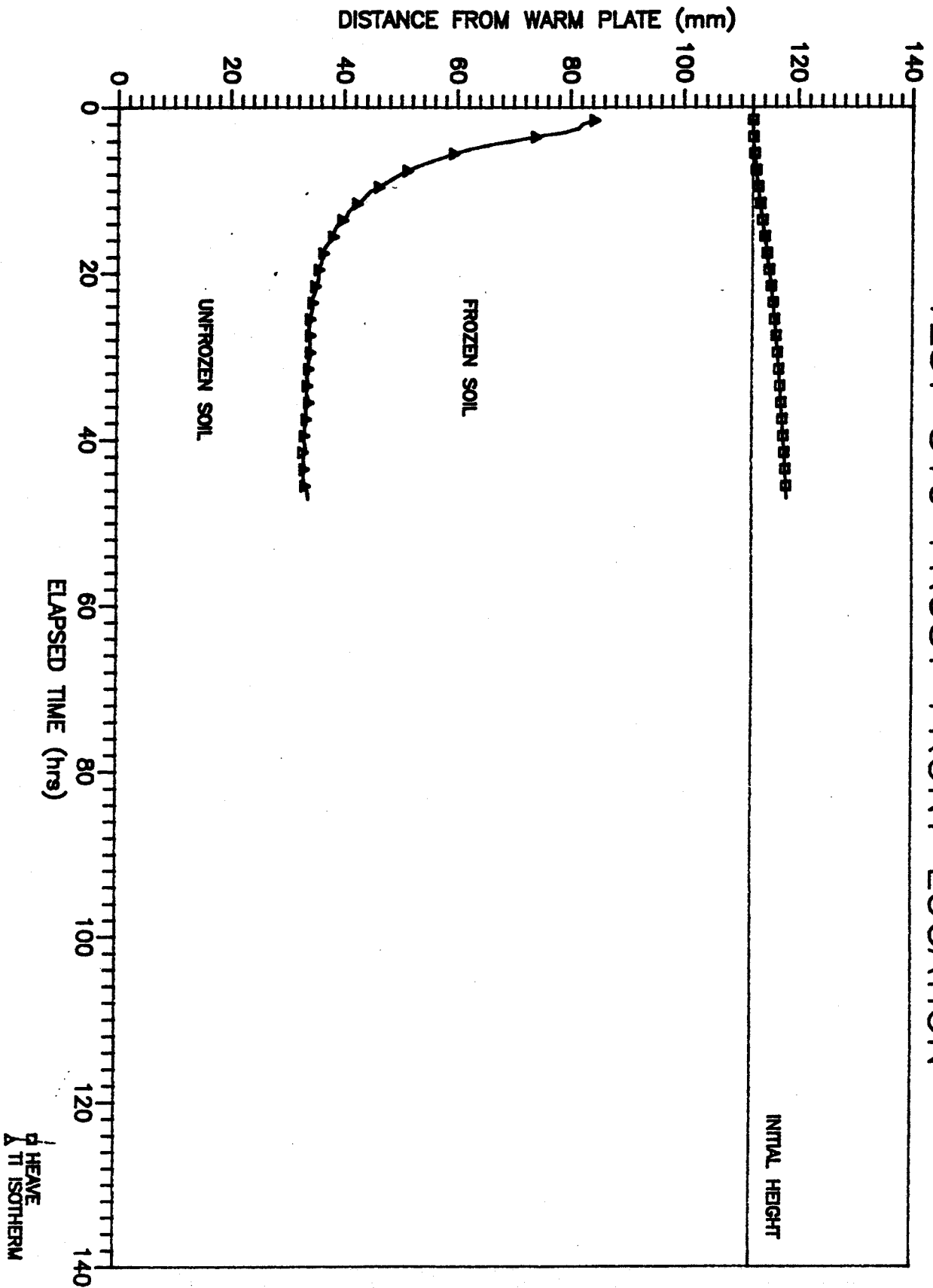
FREEZING TEST S10



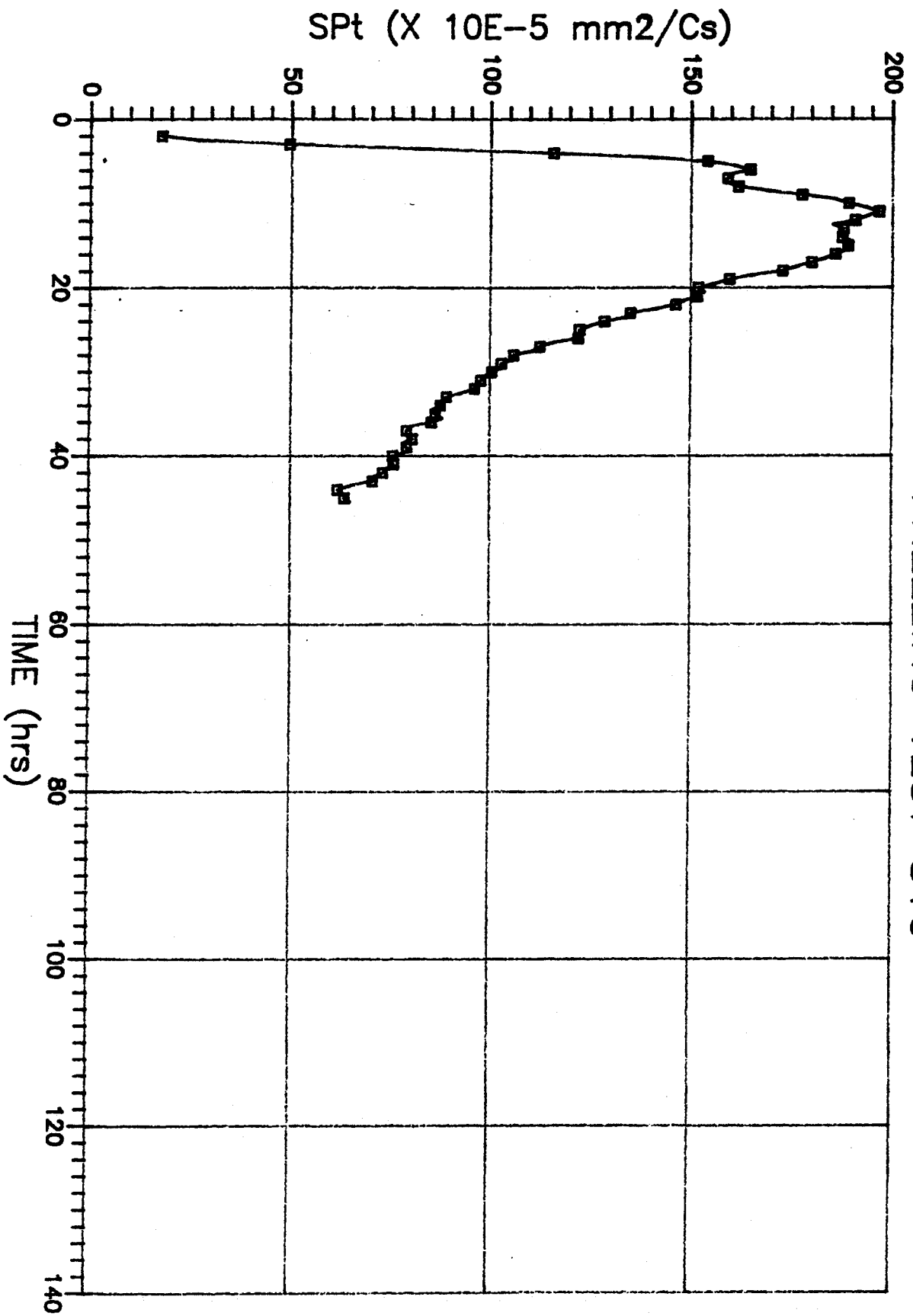
FREEZING TEST S10

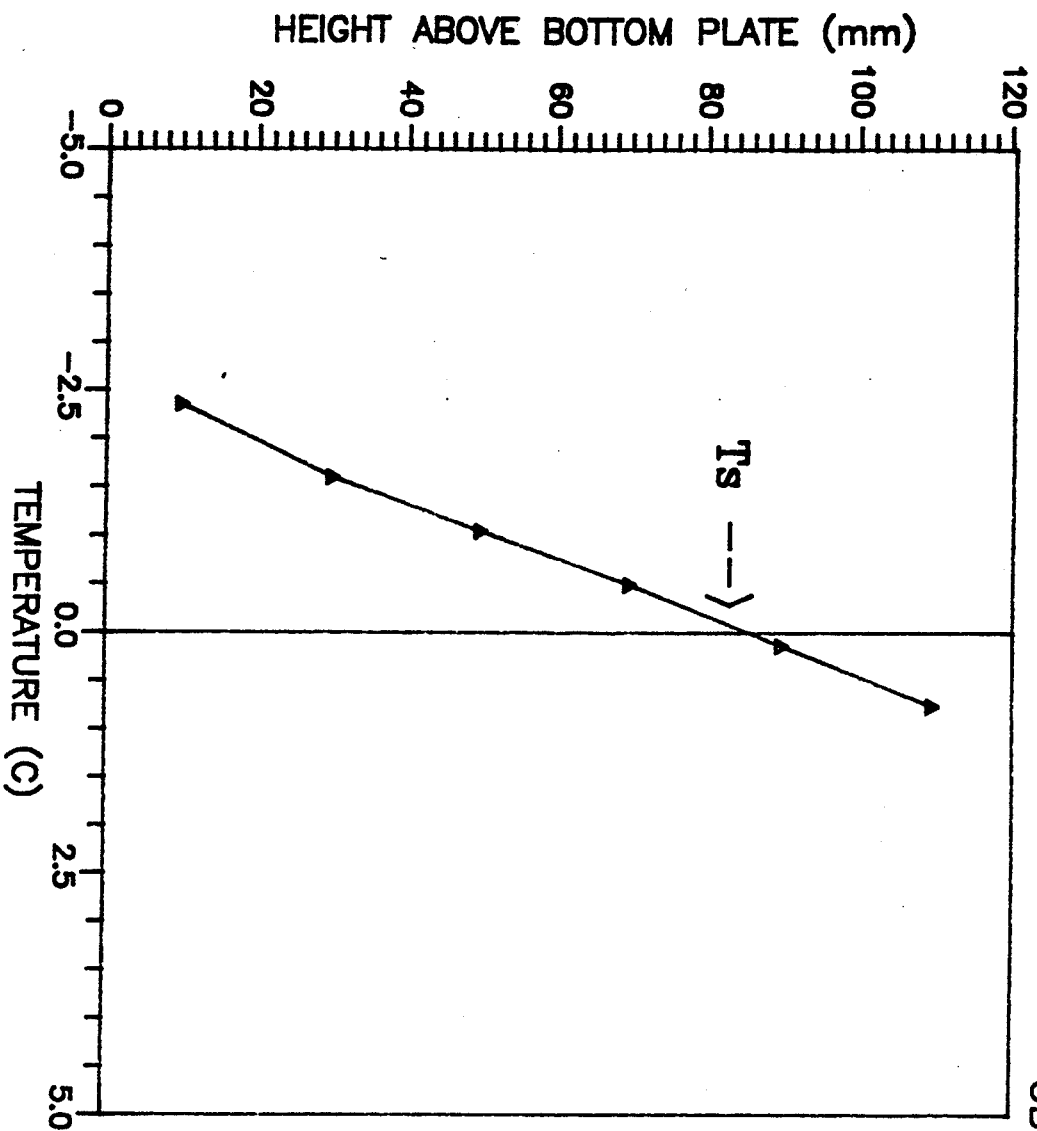


TEST S10 FROST FRONT LOCATION

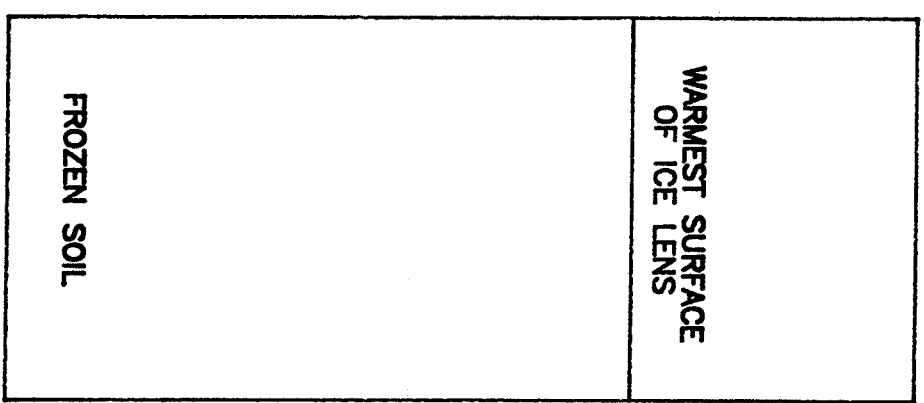


FREEZING TEST S10



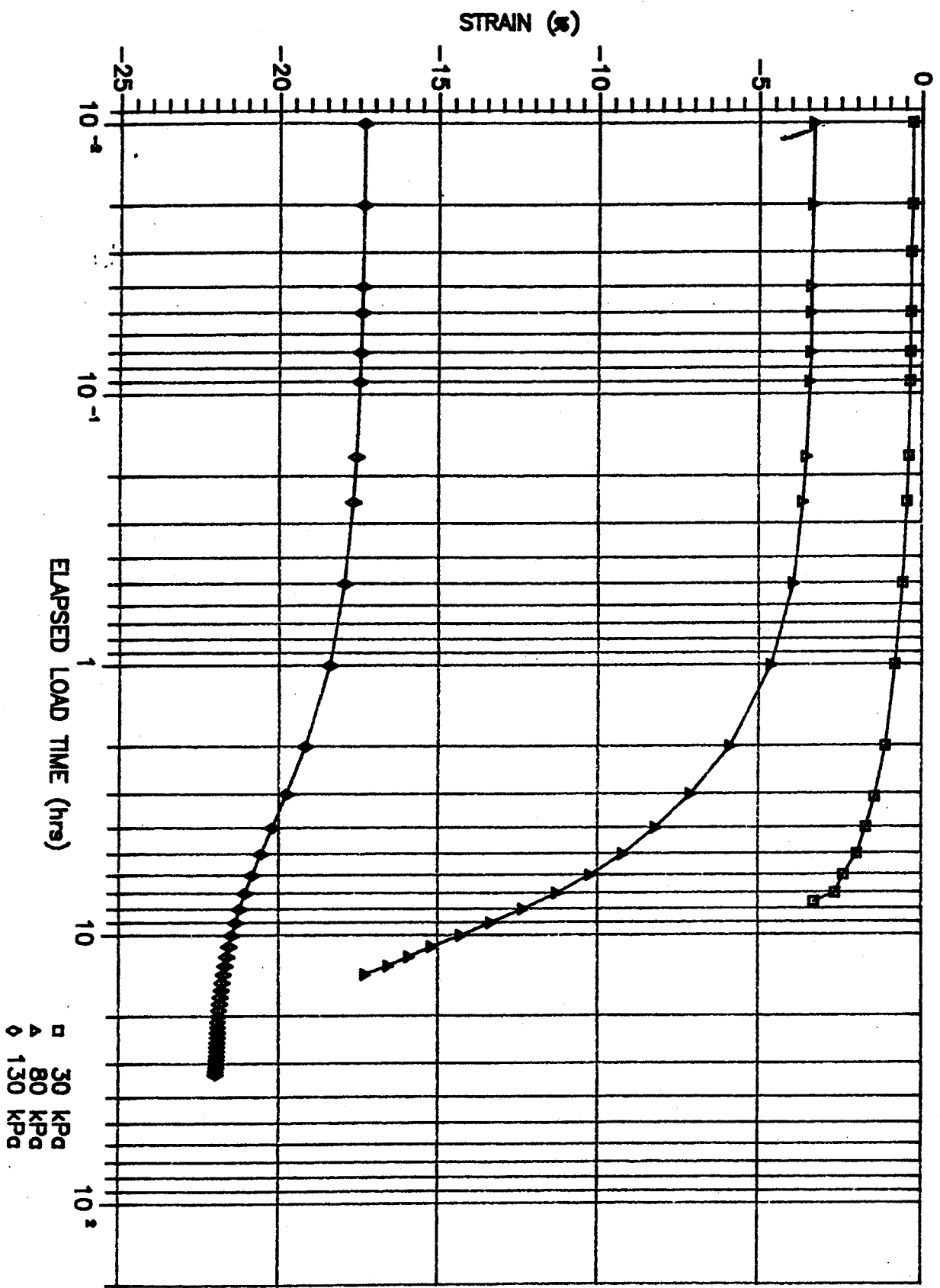


OBSERVED POSITION OF ICE LENS

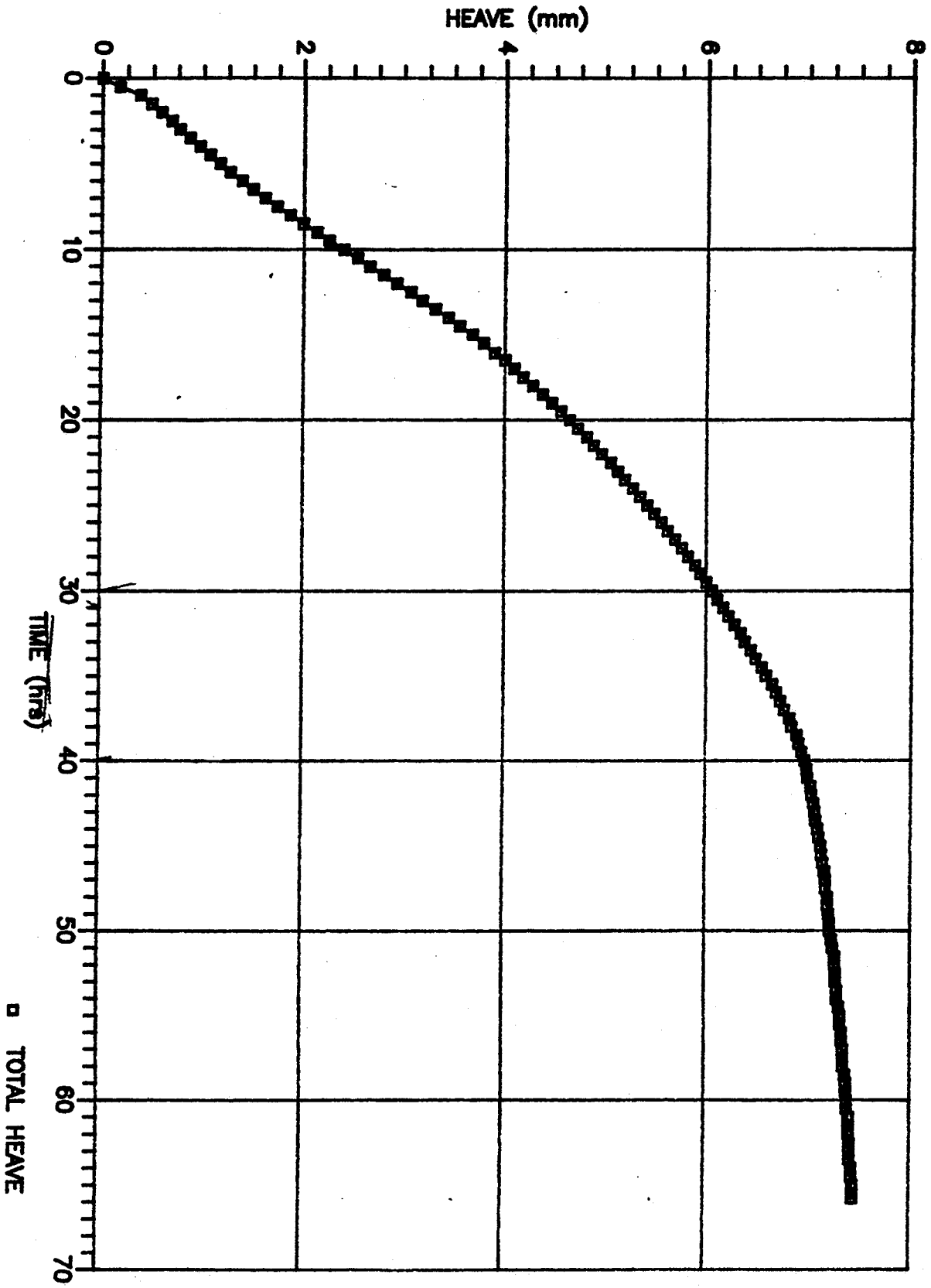


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S10

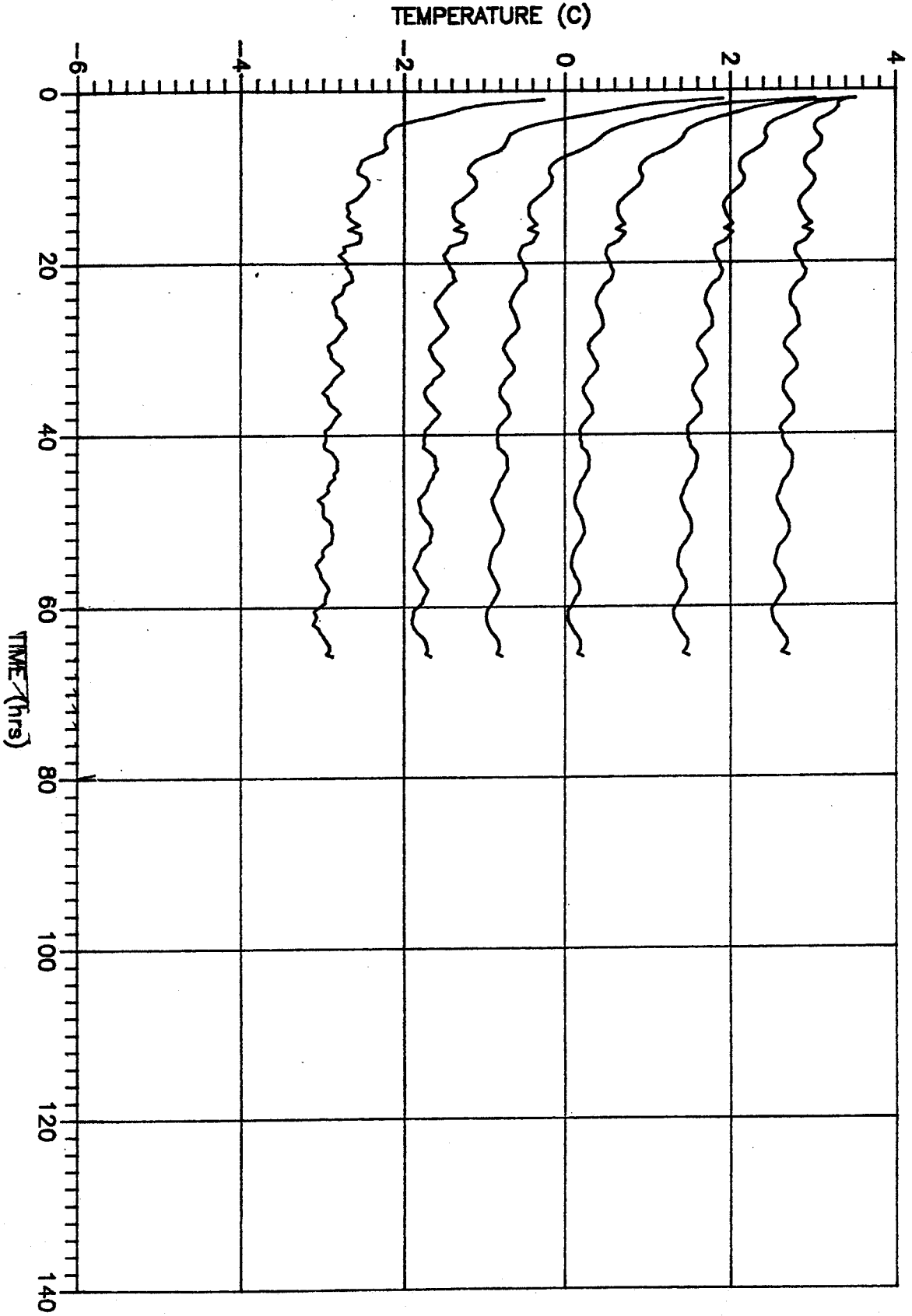
CONSOLIDATION TEST S11



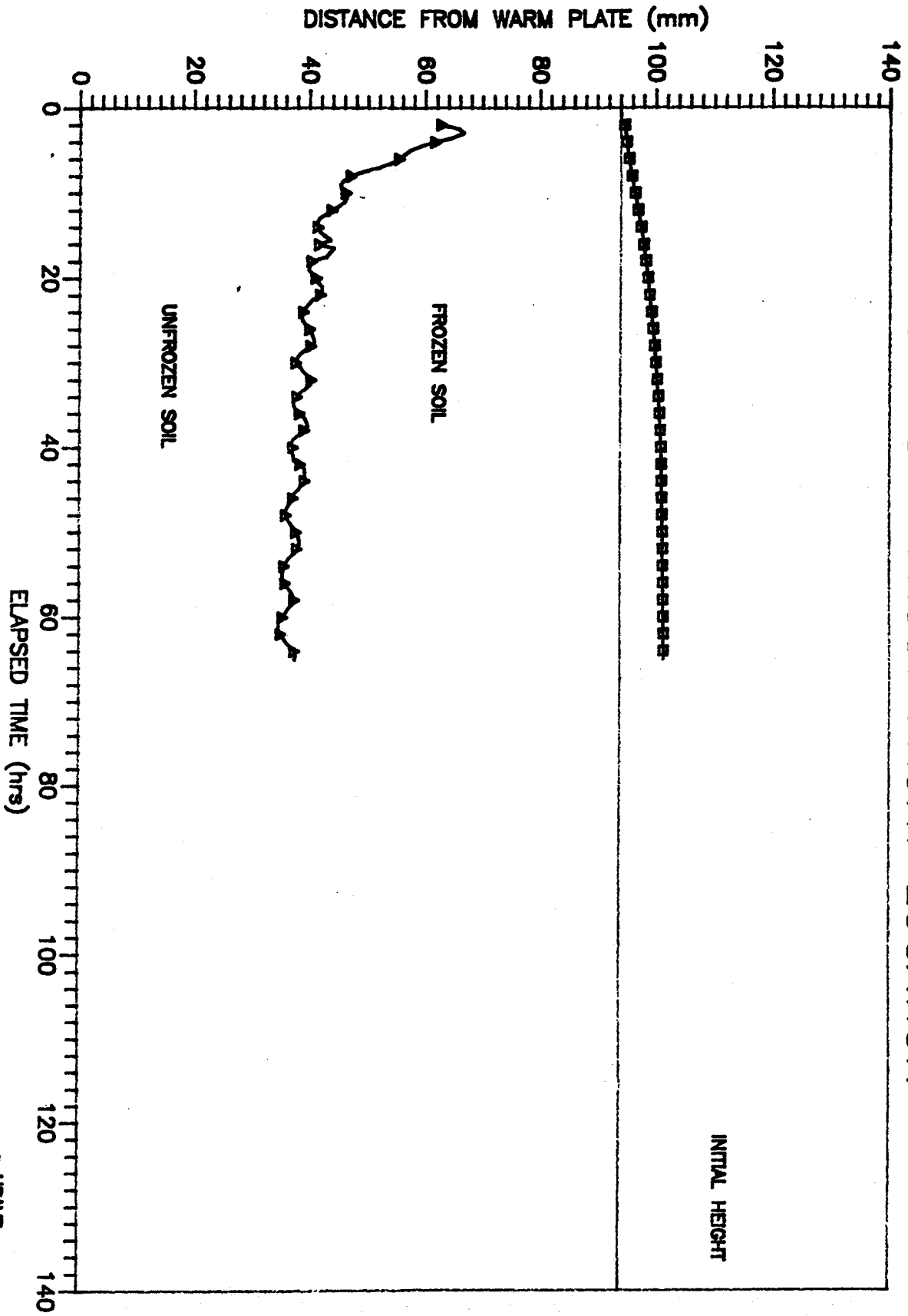
FREEZING TEST S11



FREEZING TEST S11

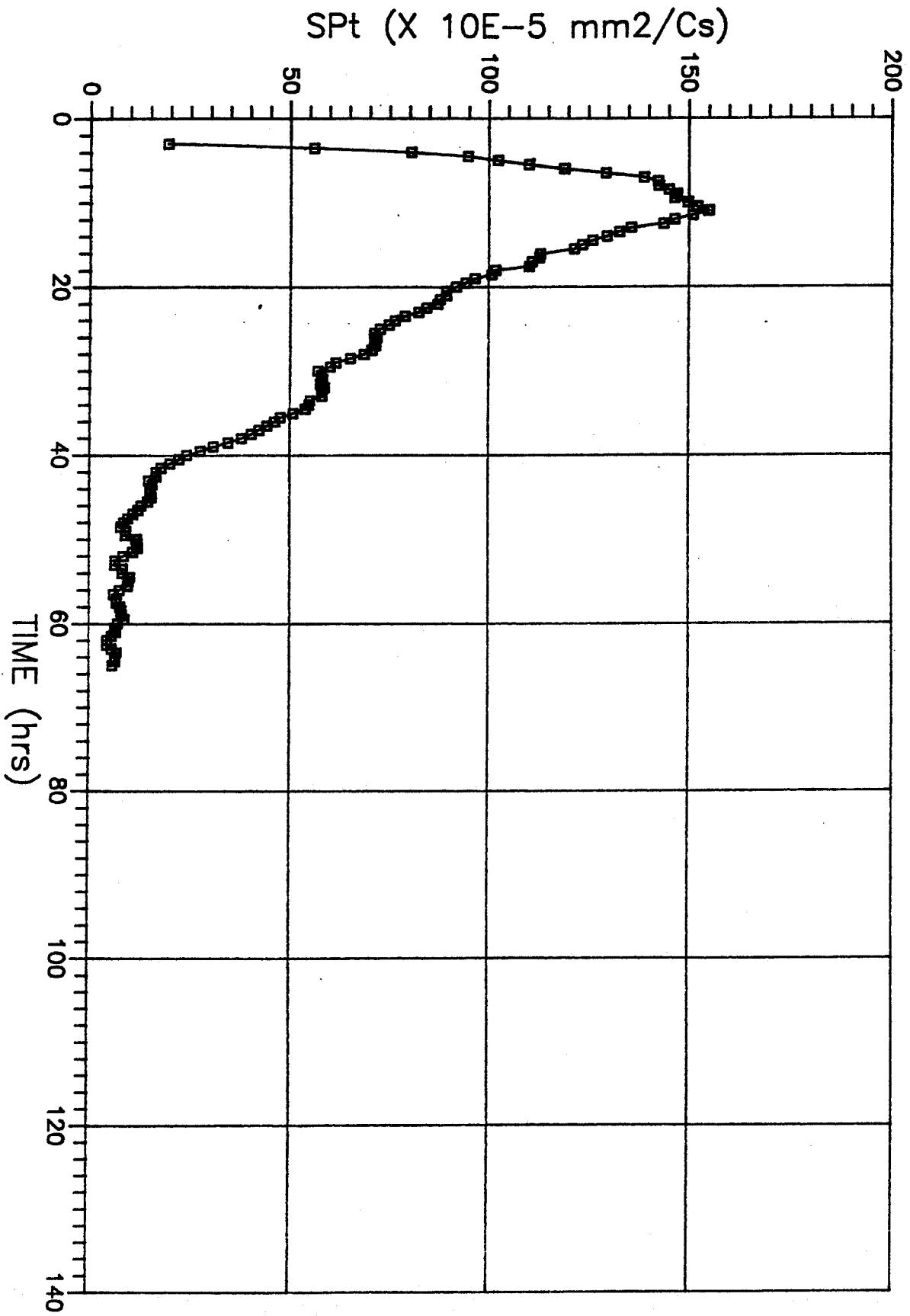


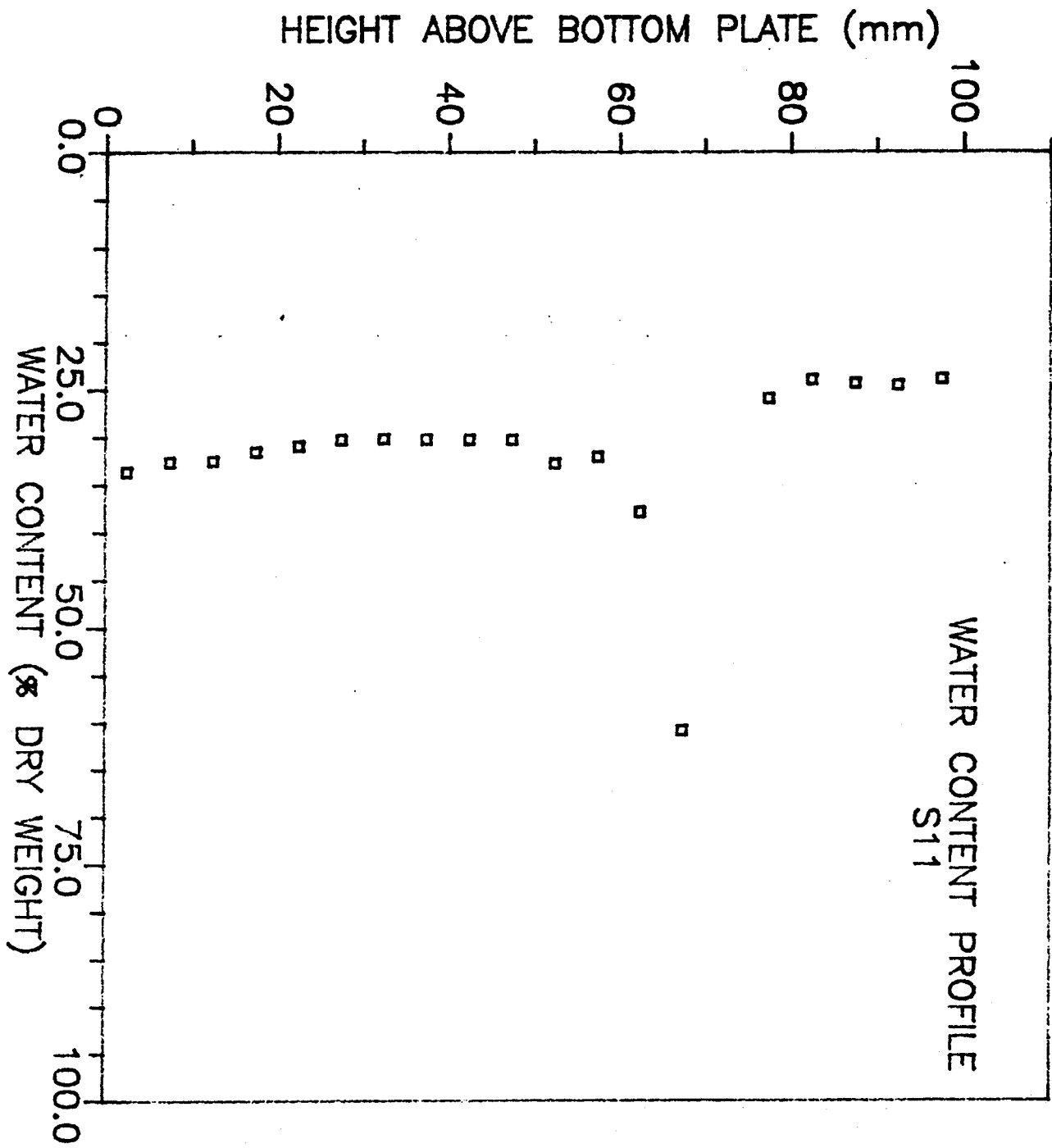
TEST S11 FROST FRONT LOCATION

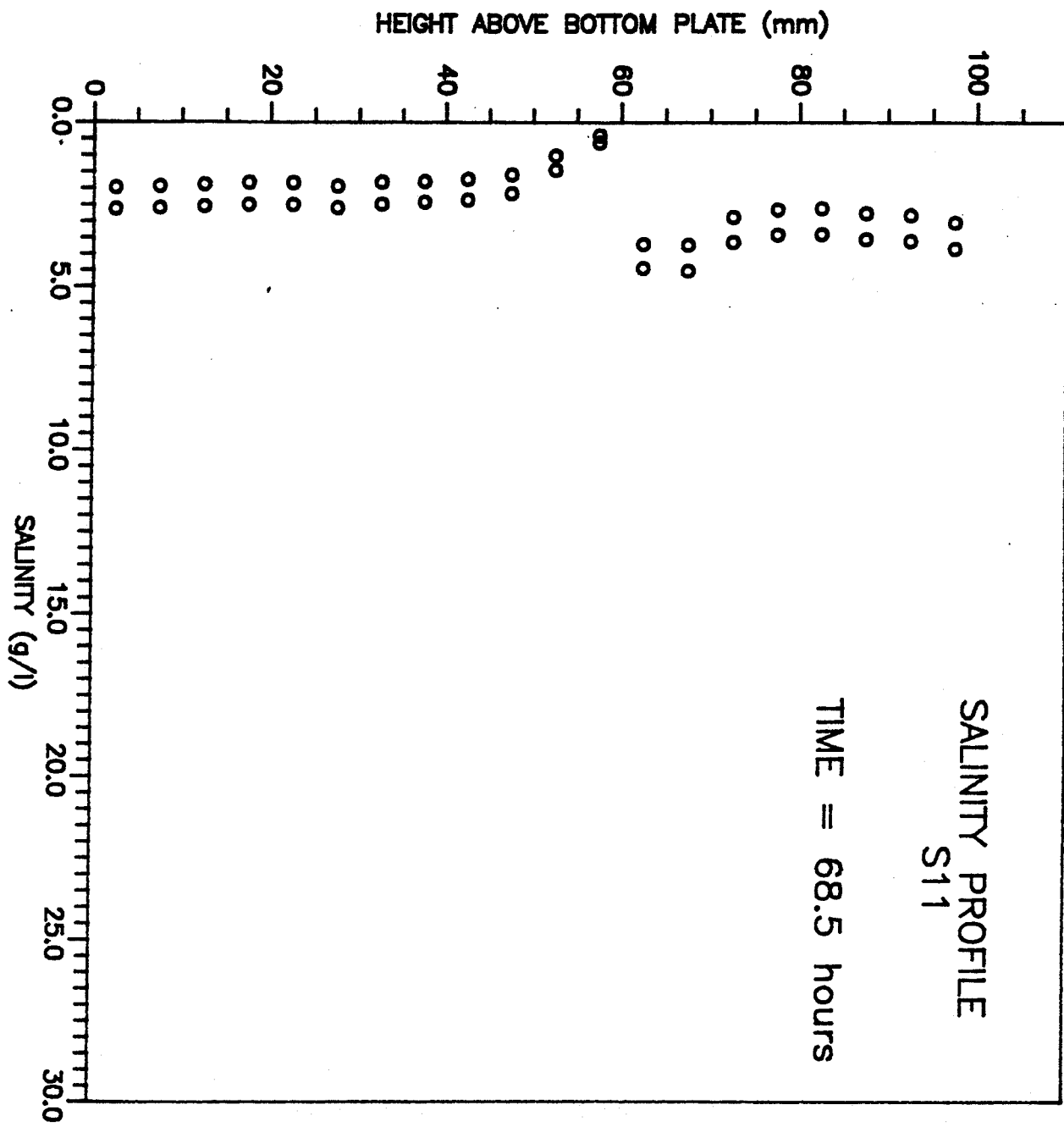


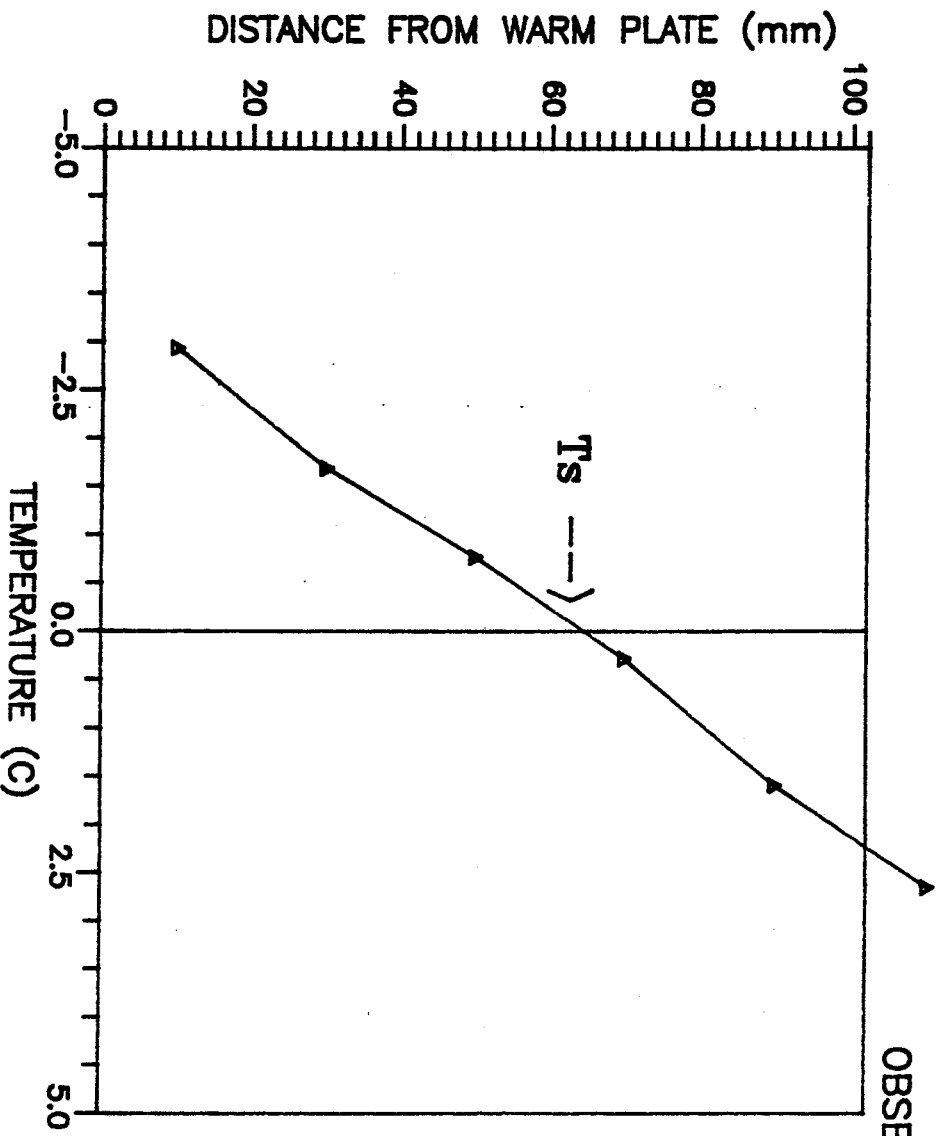
□ HEAVE
△ THERM
| ISOTHERM

FREEZING TEST S11

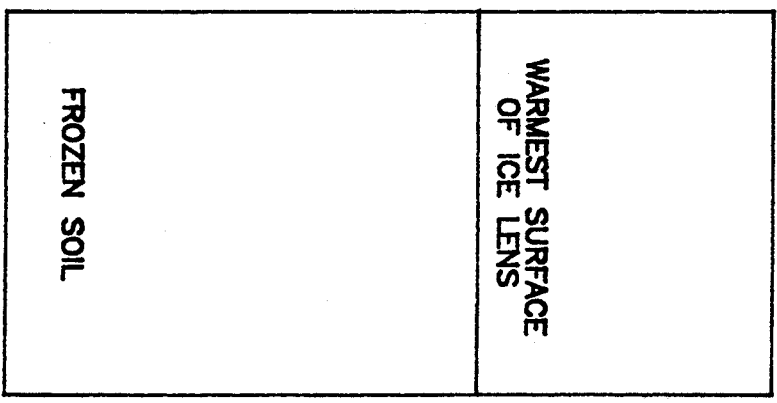






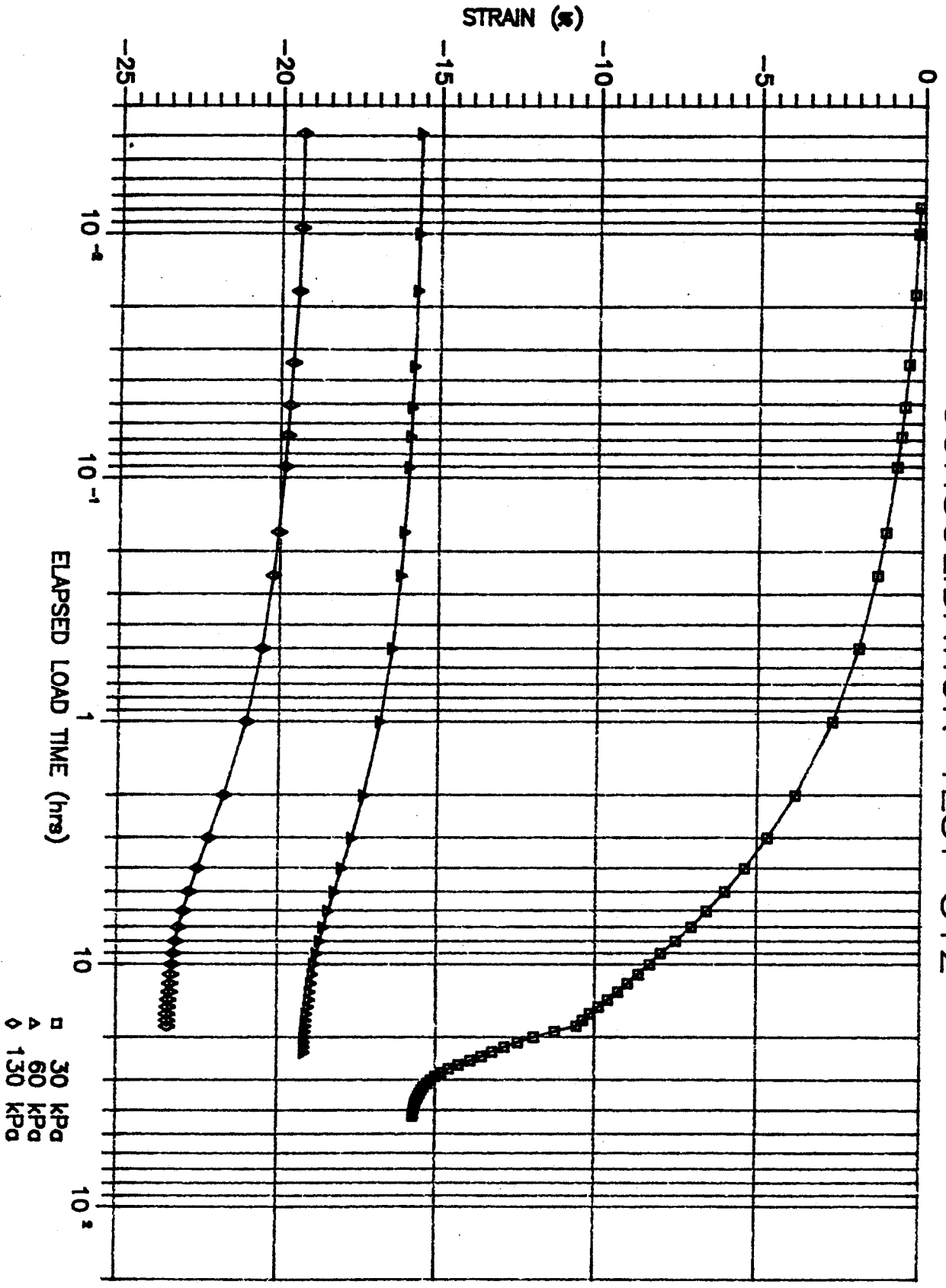


OBSERVED POSITION OF ICE LENS

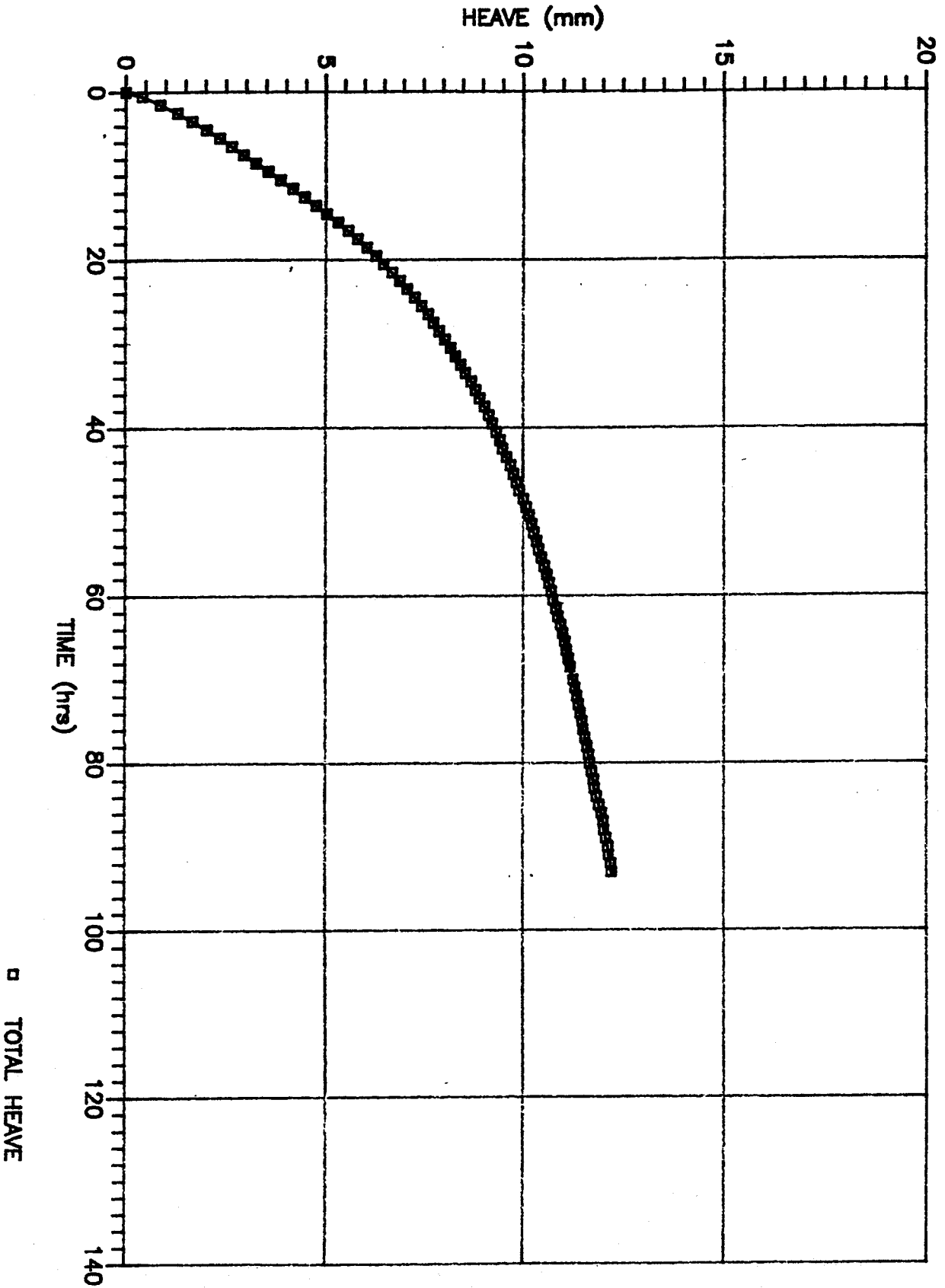


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S11

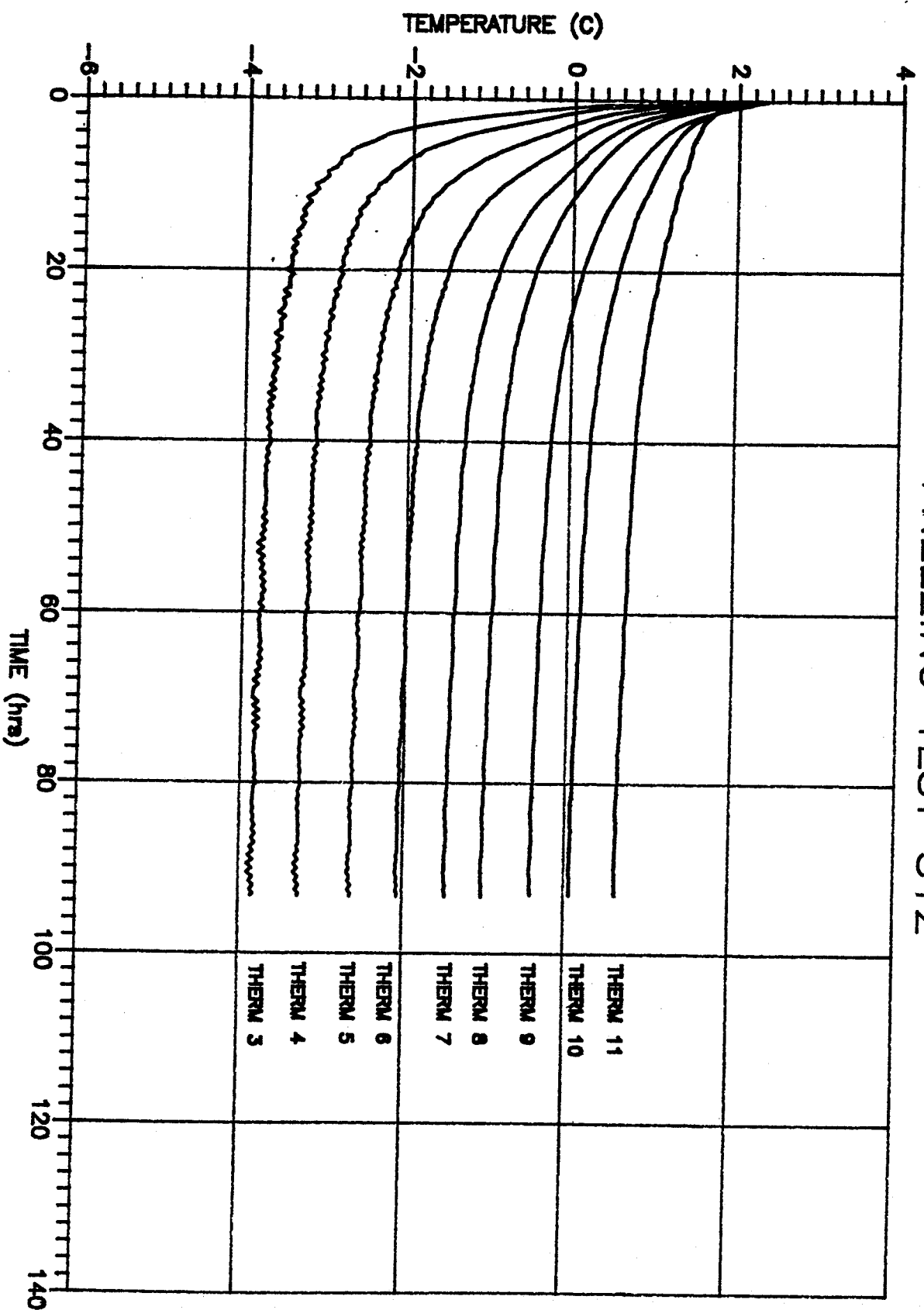
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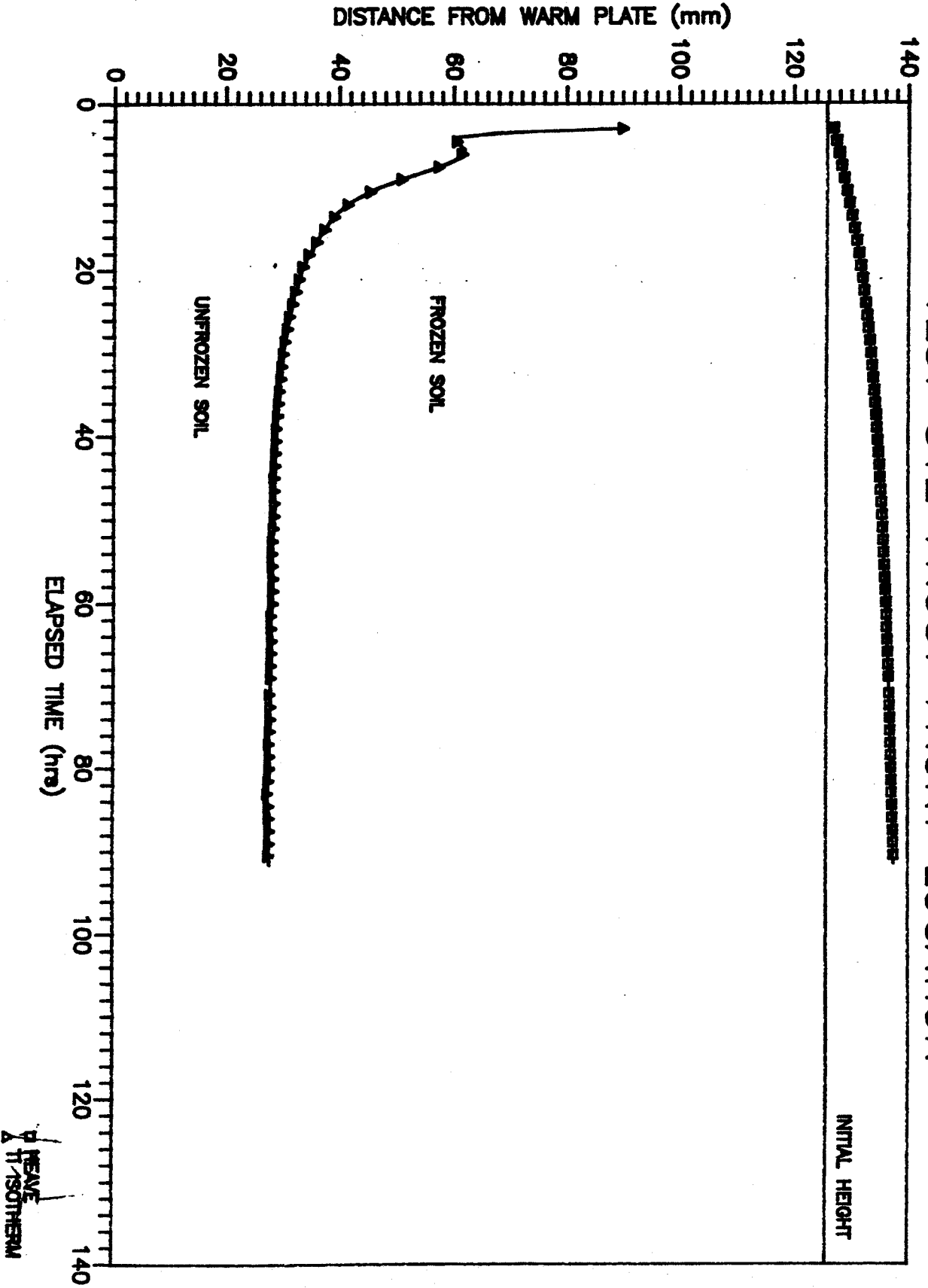
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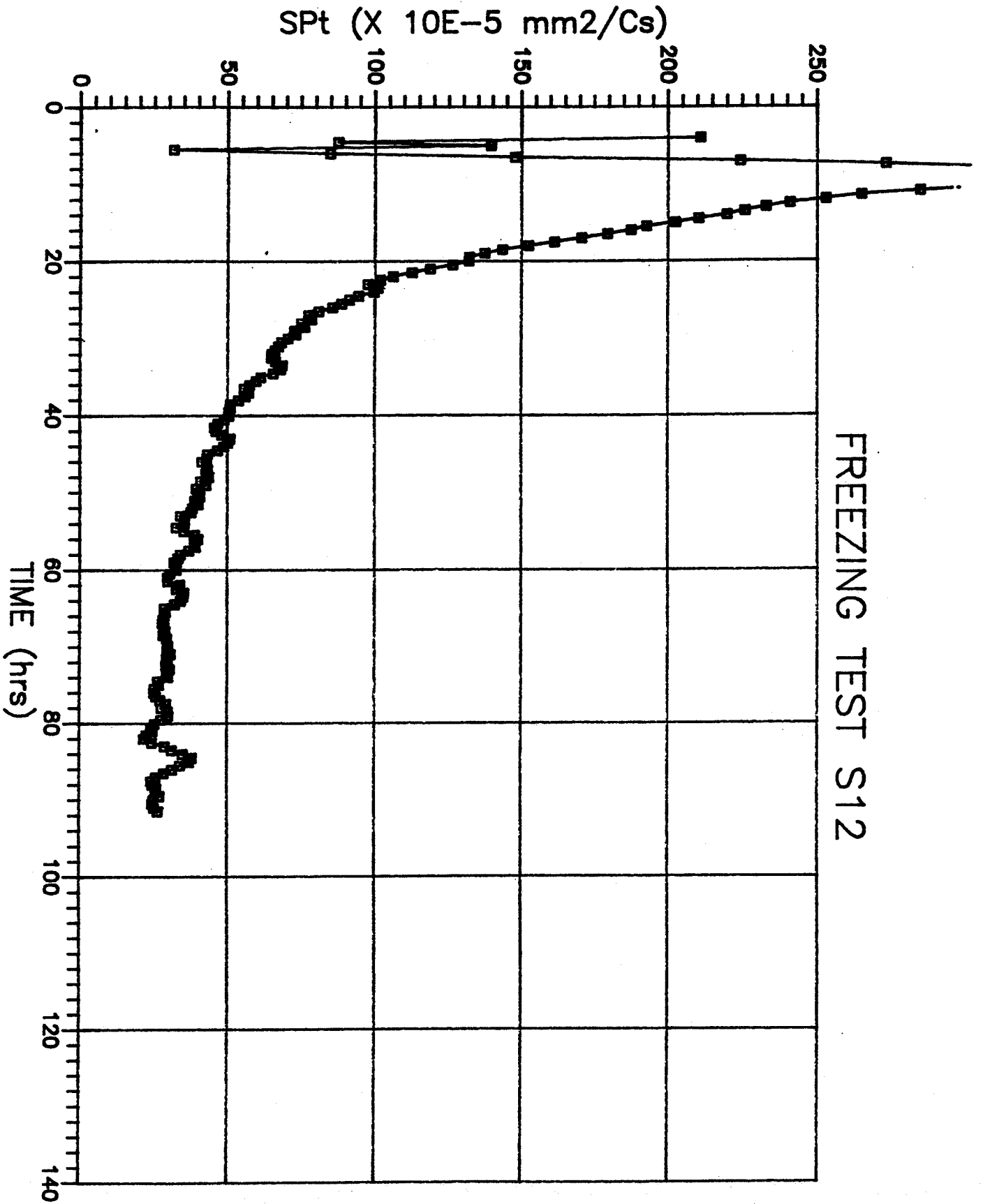
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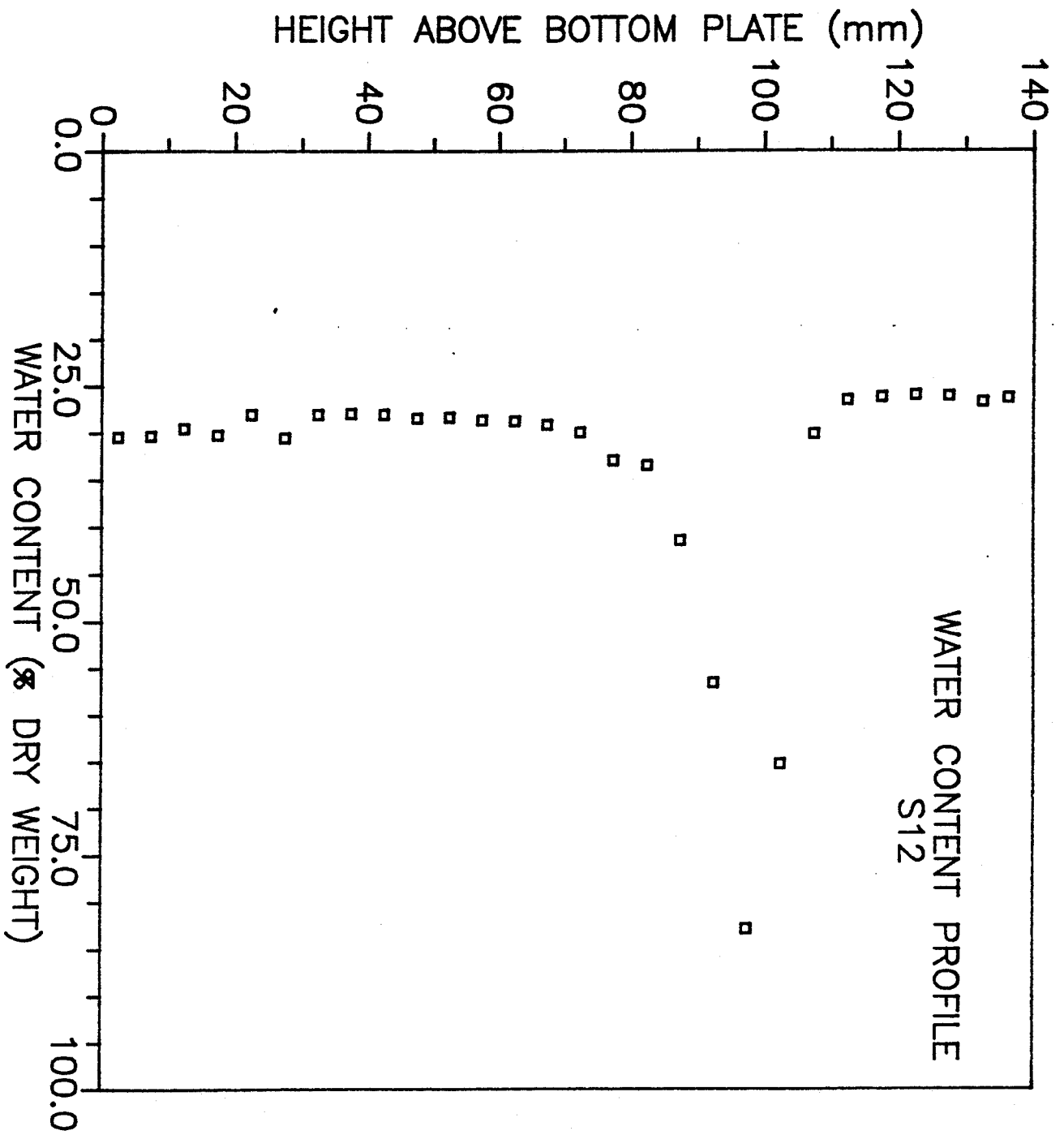


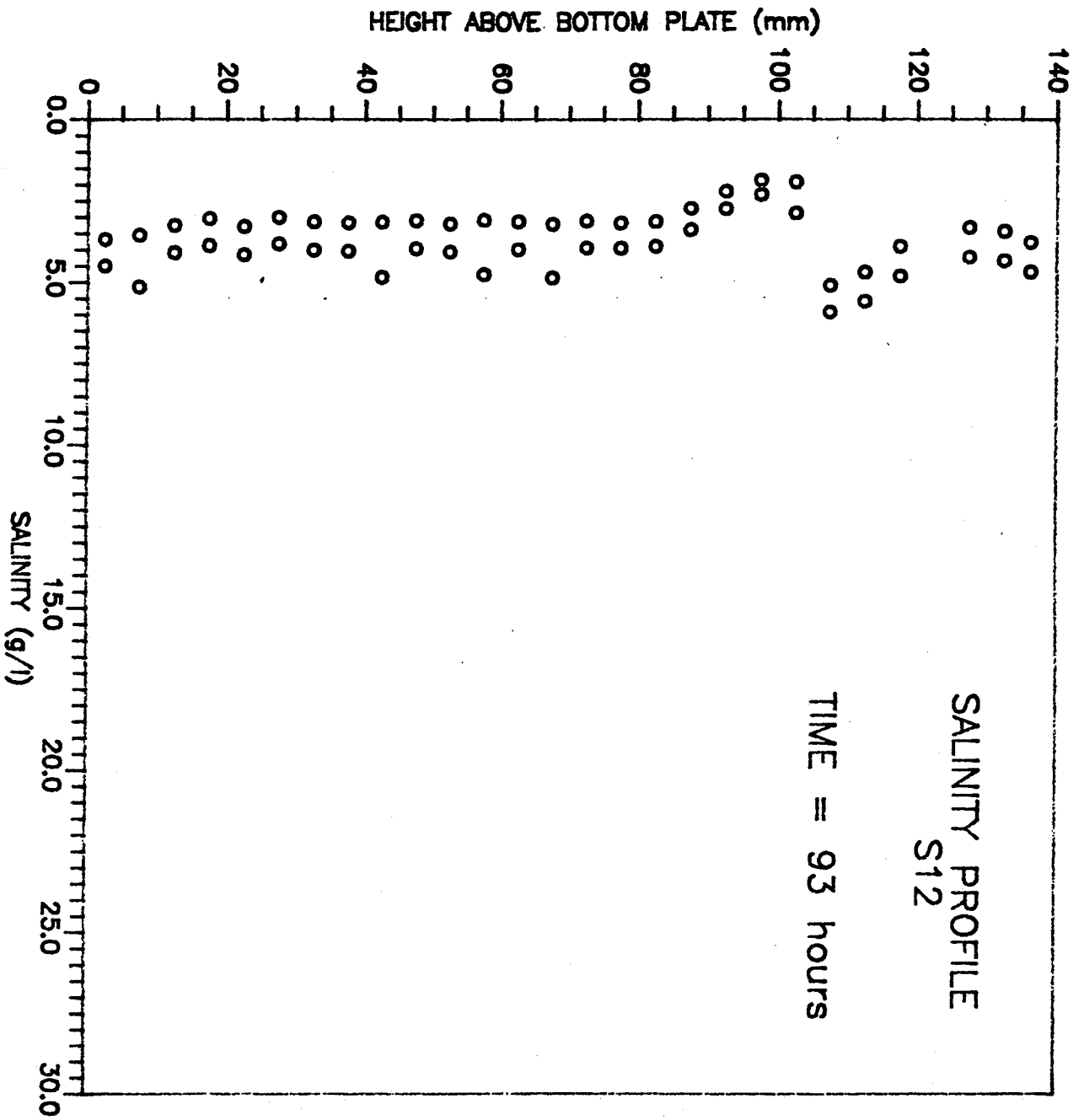
TEST S12 FROST FRONT LOCATION



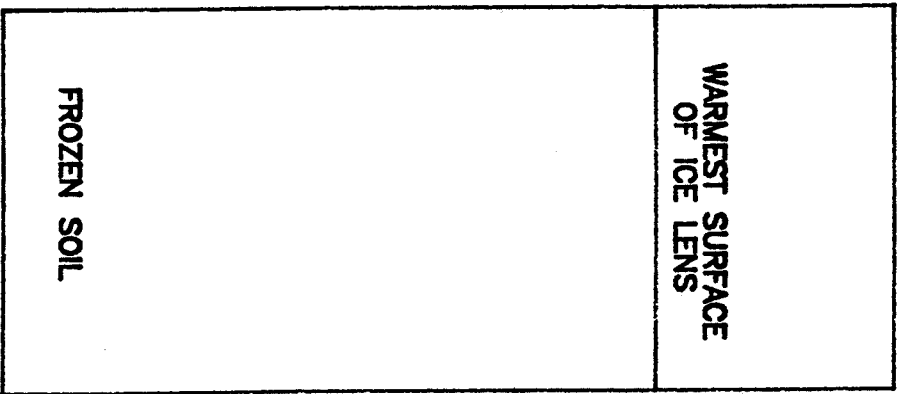
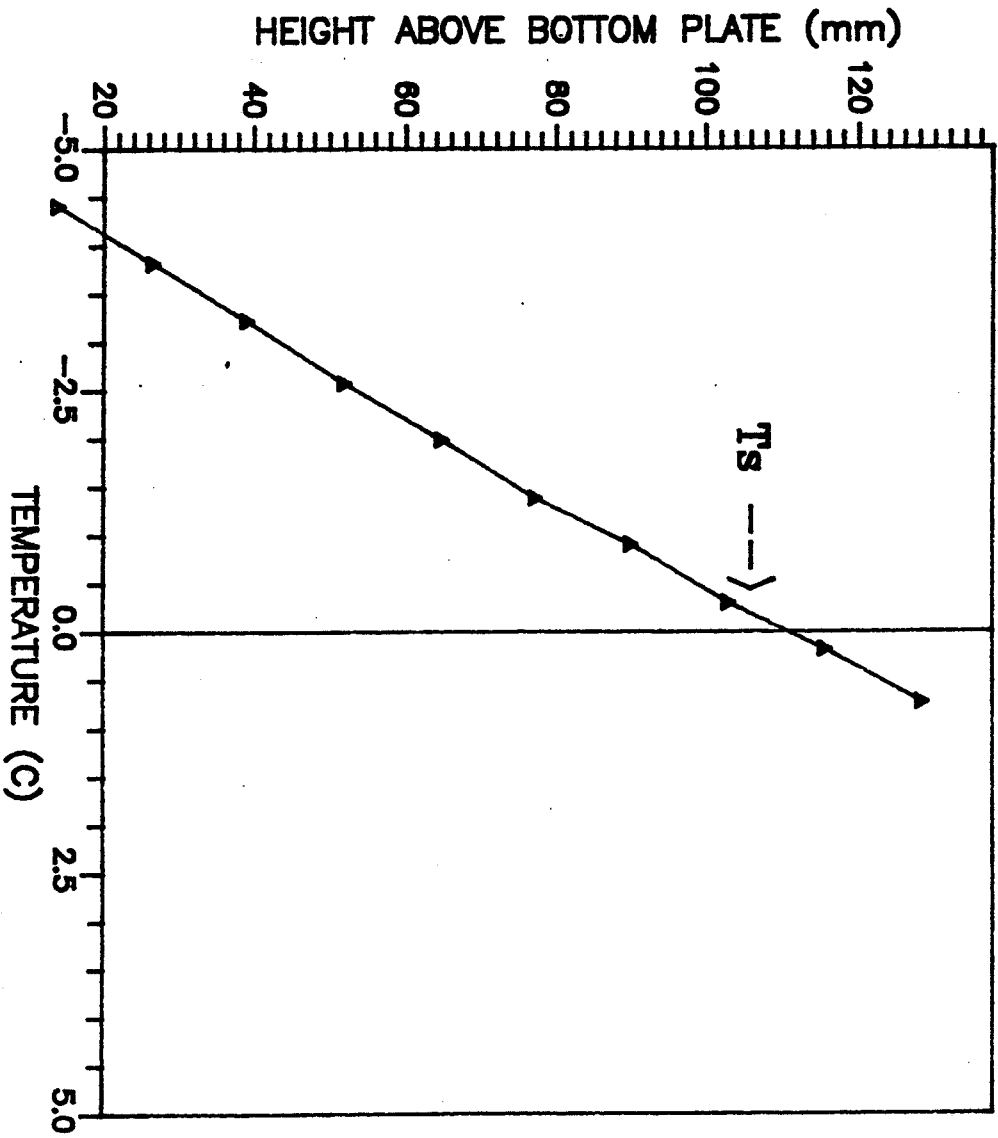
FREEZING TEST S12





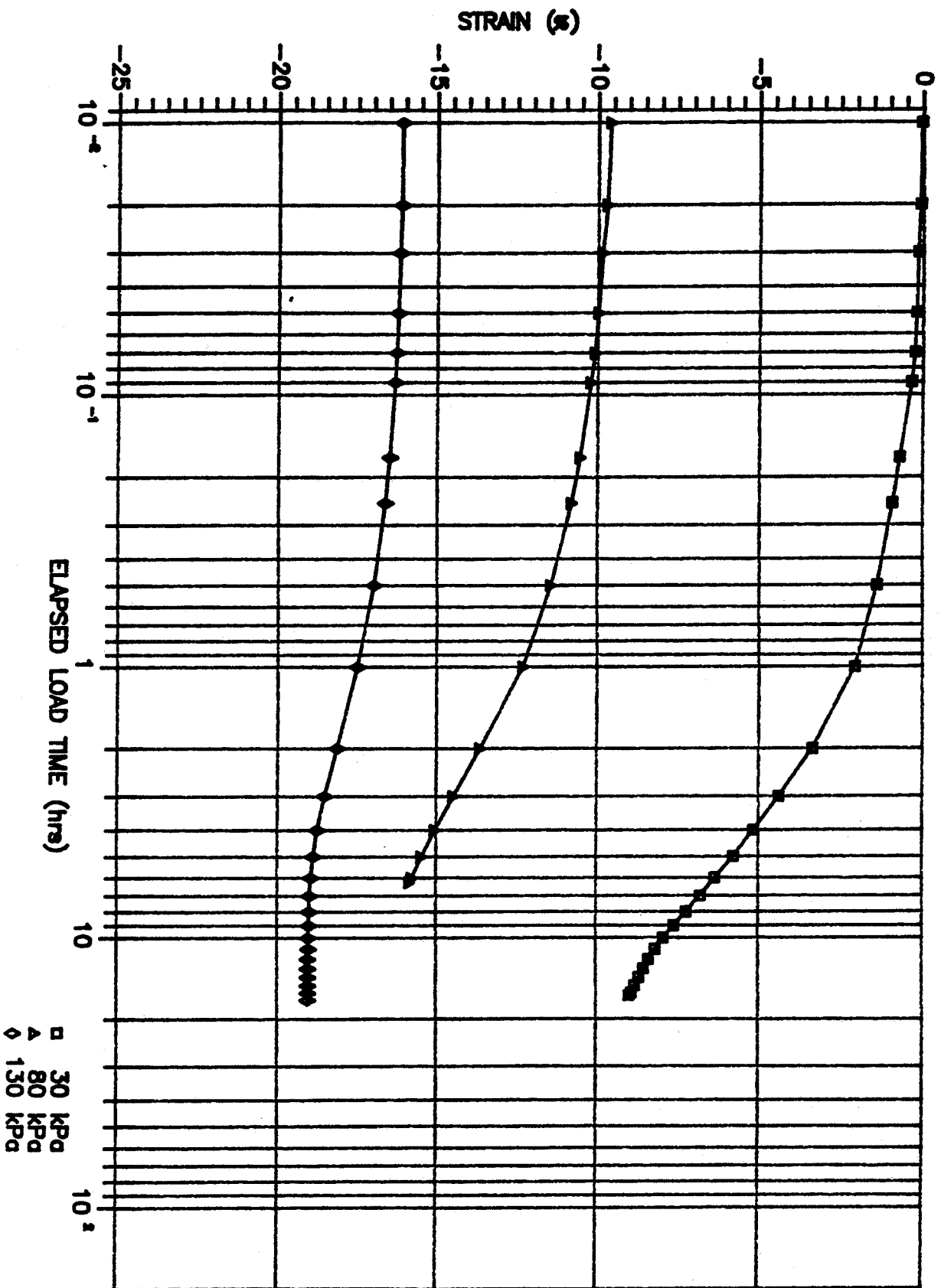


OBSERVED POSITION OF ICE LENS

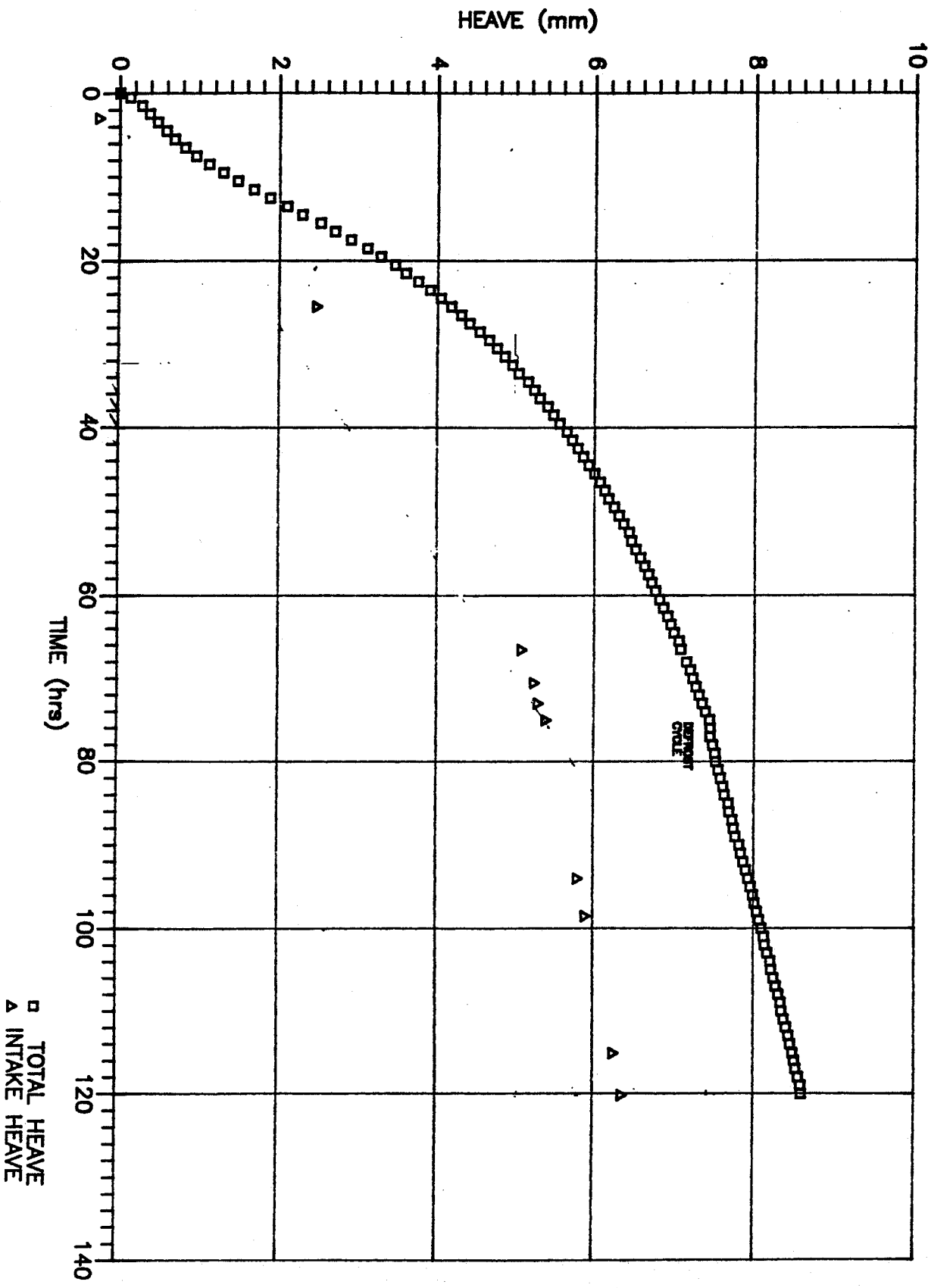


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S12

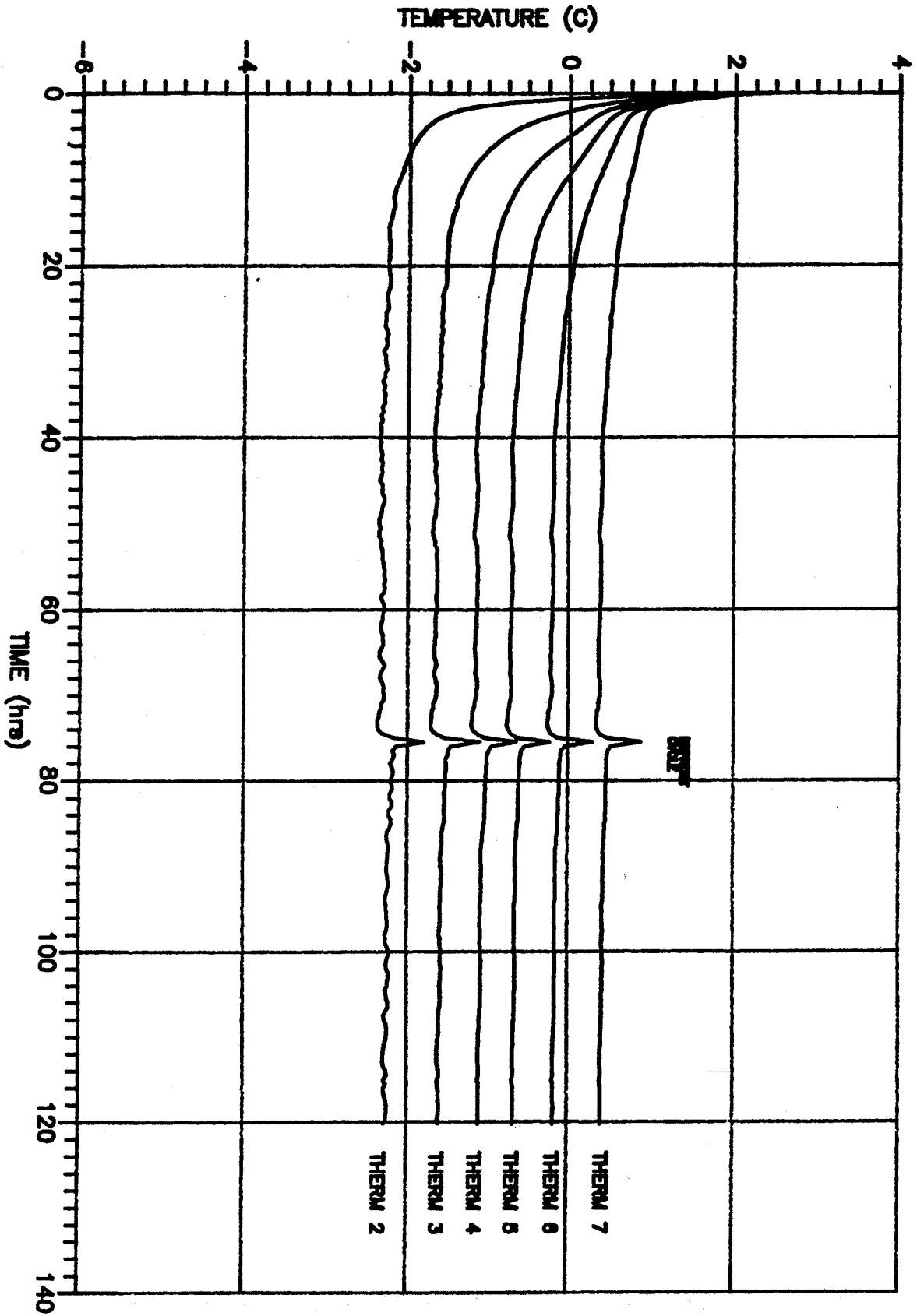
CONSOLIDATION TEST S20



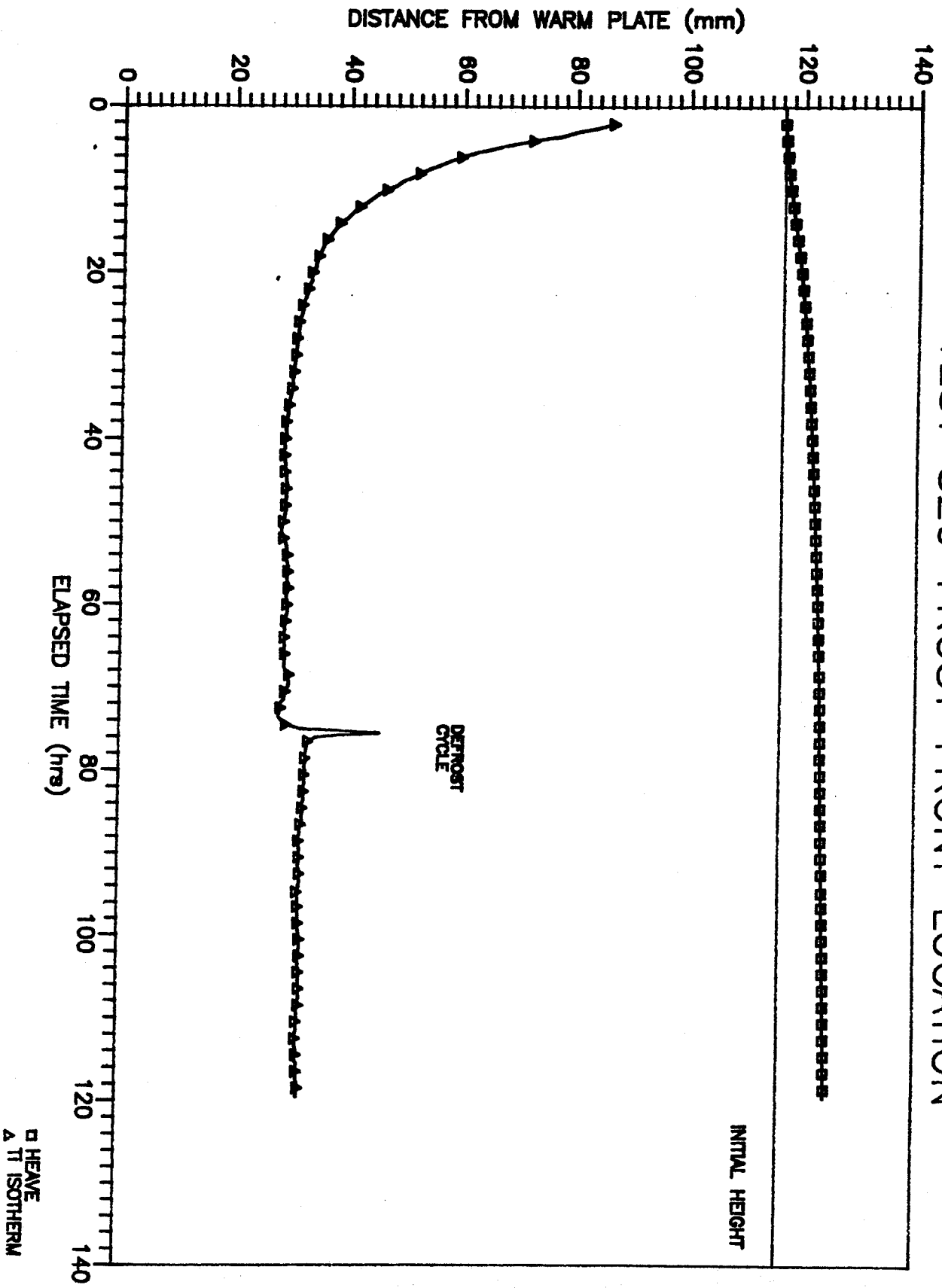
FREEZING TEST S20



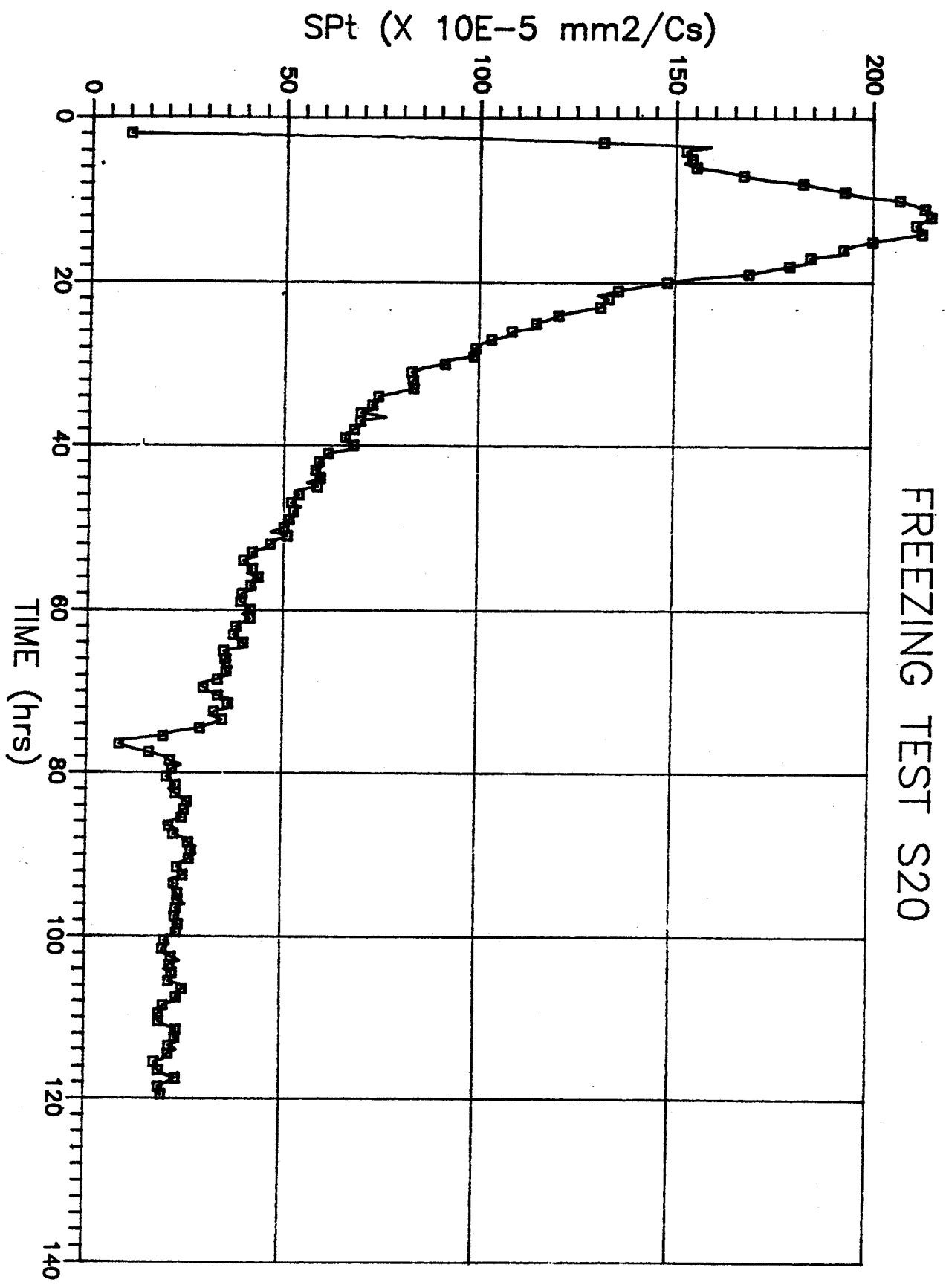
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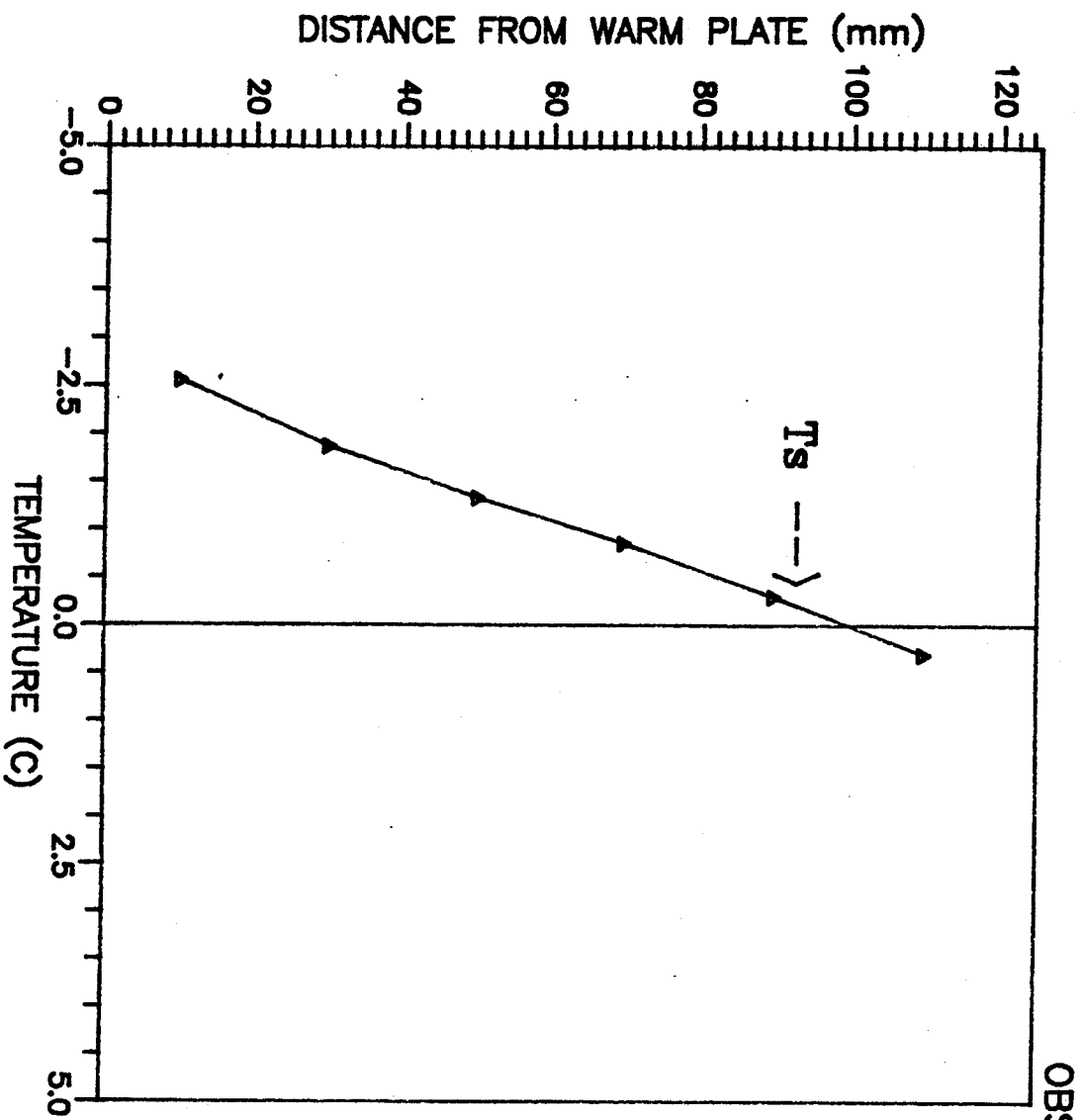


TEST S20 FROST FRONT LOCATION

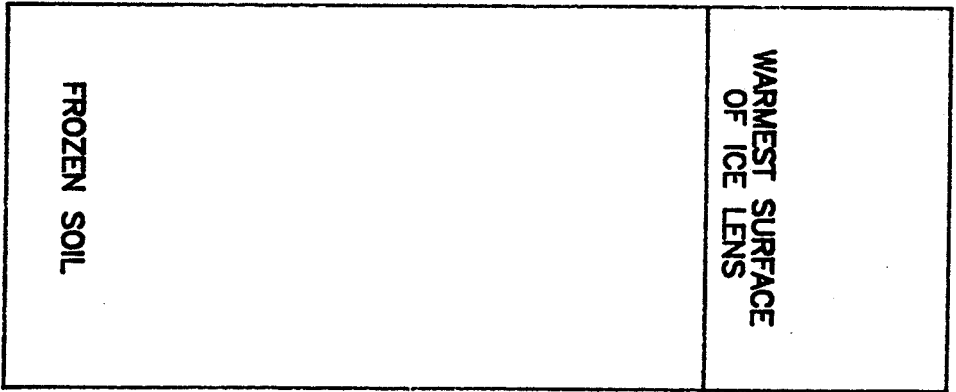


FREEZING TEST S20



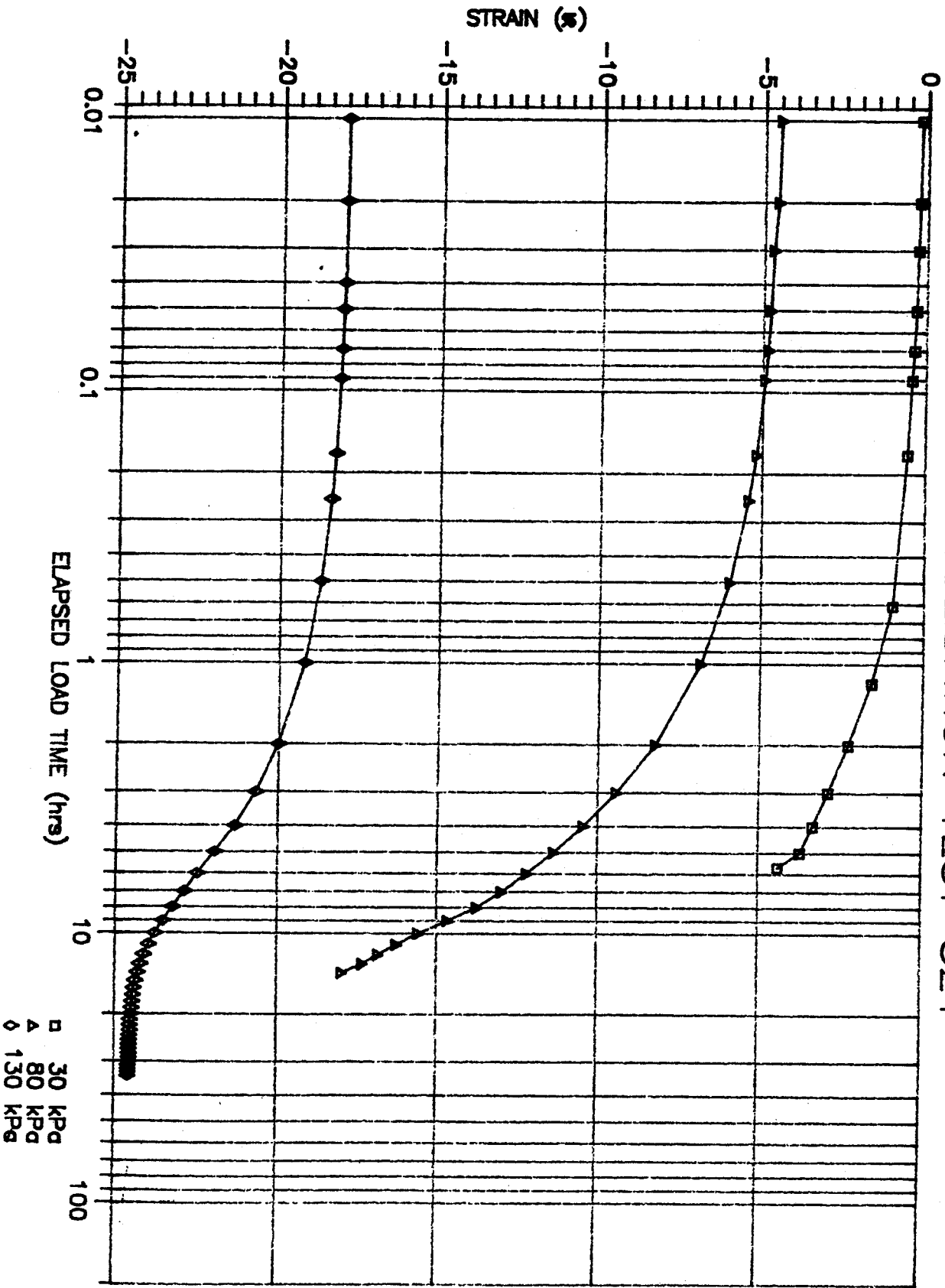


OBSERVED POSITION OF ICE LENS

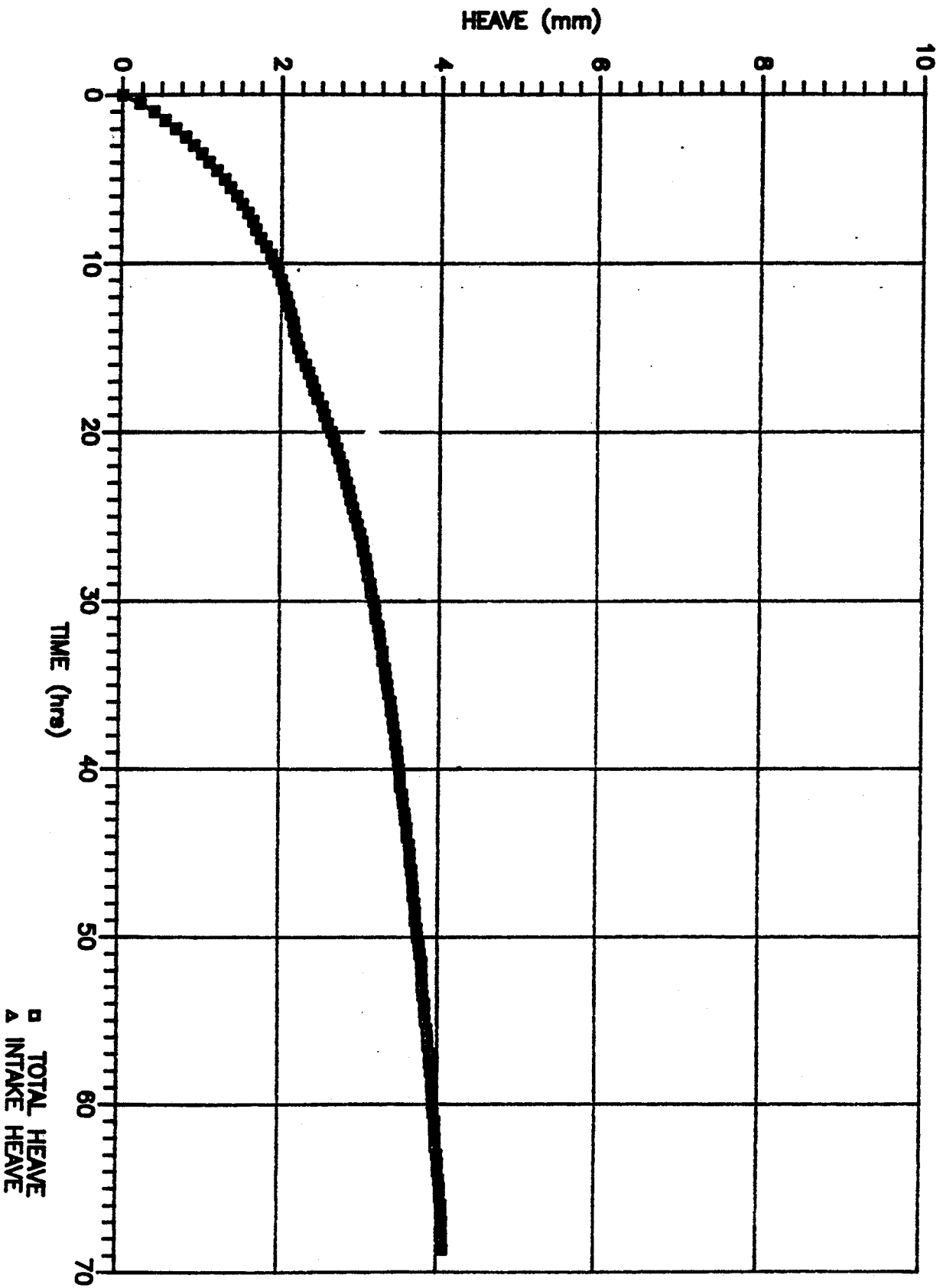


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S20

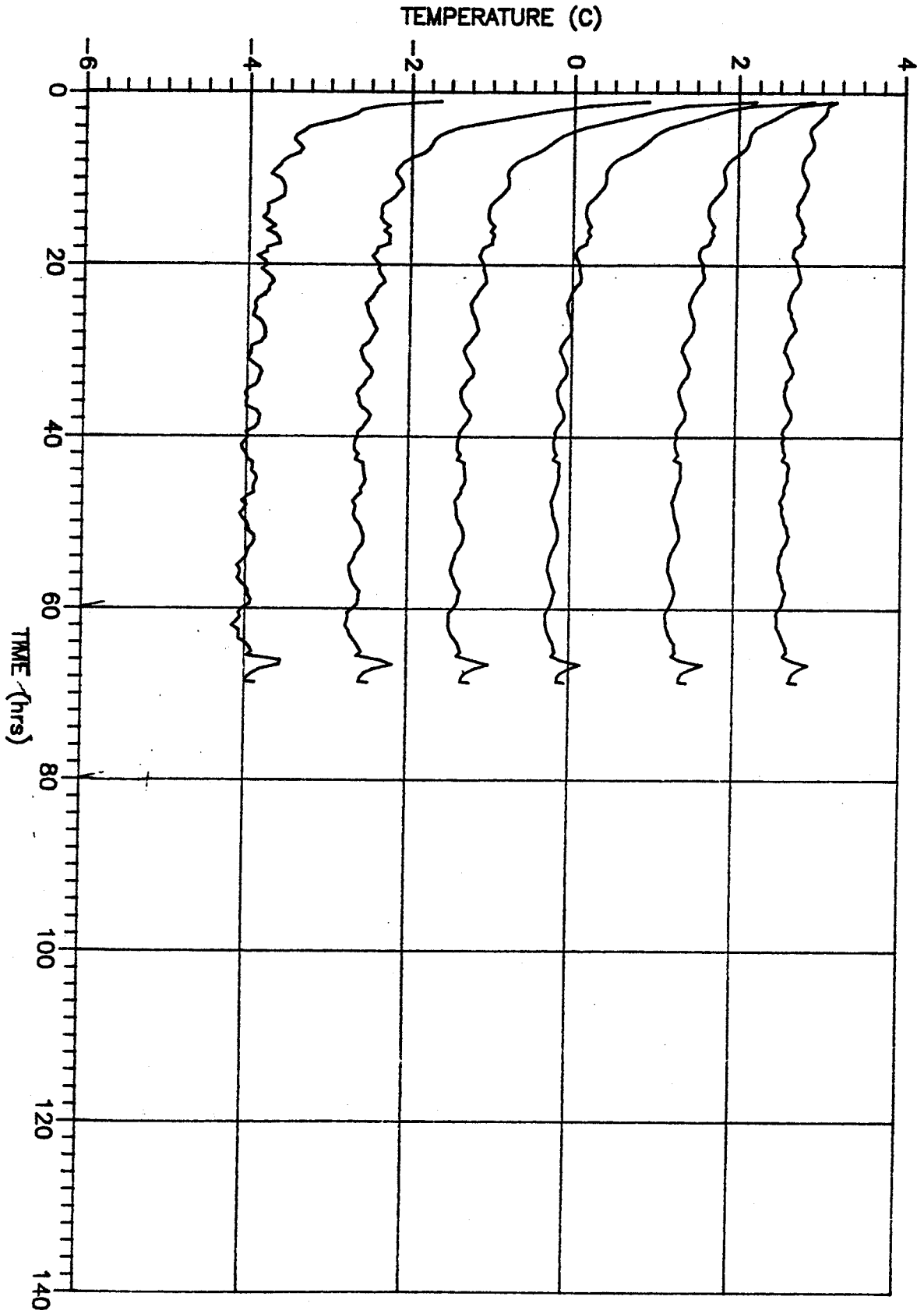
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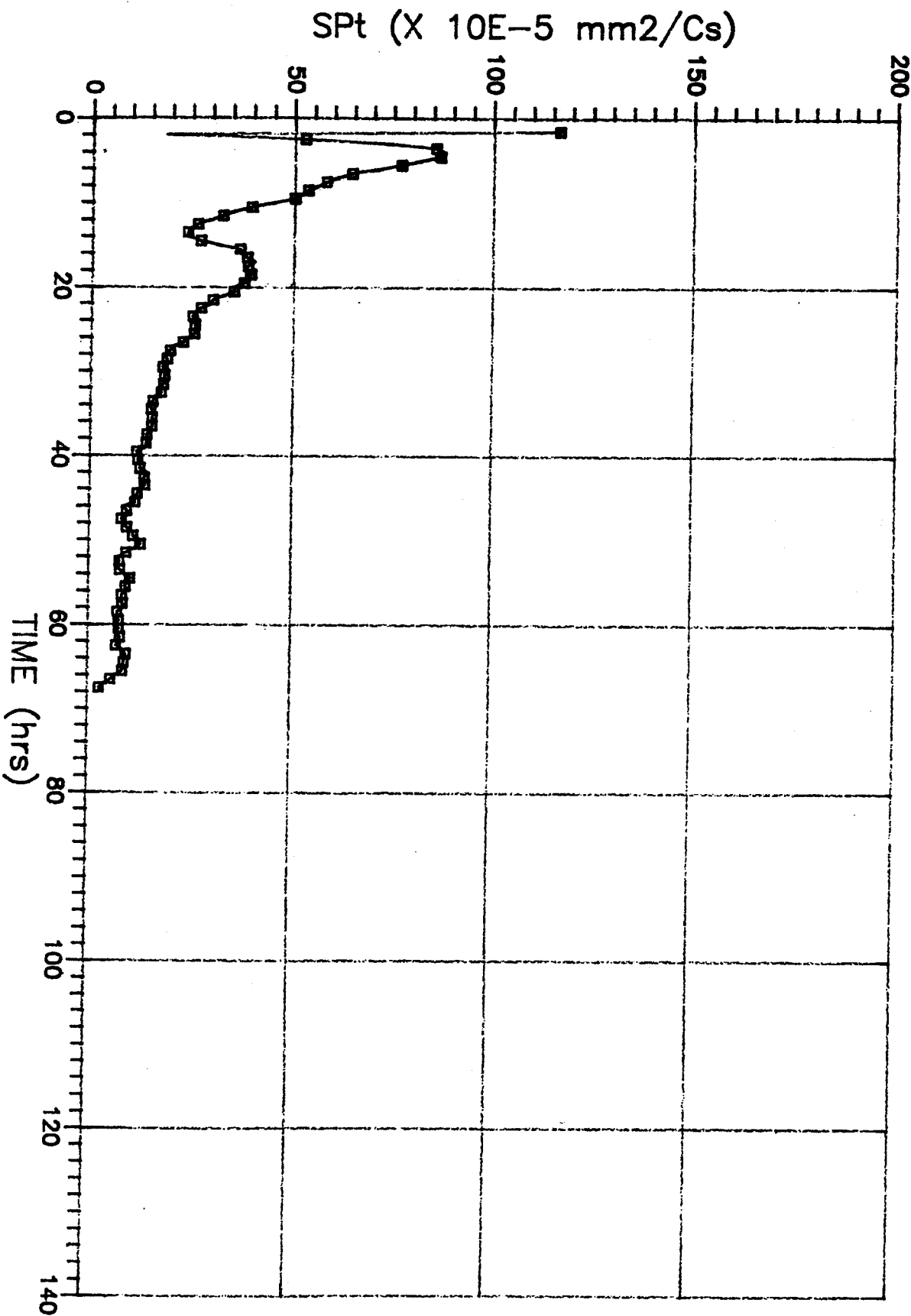
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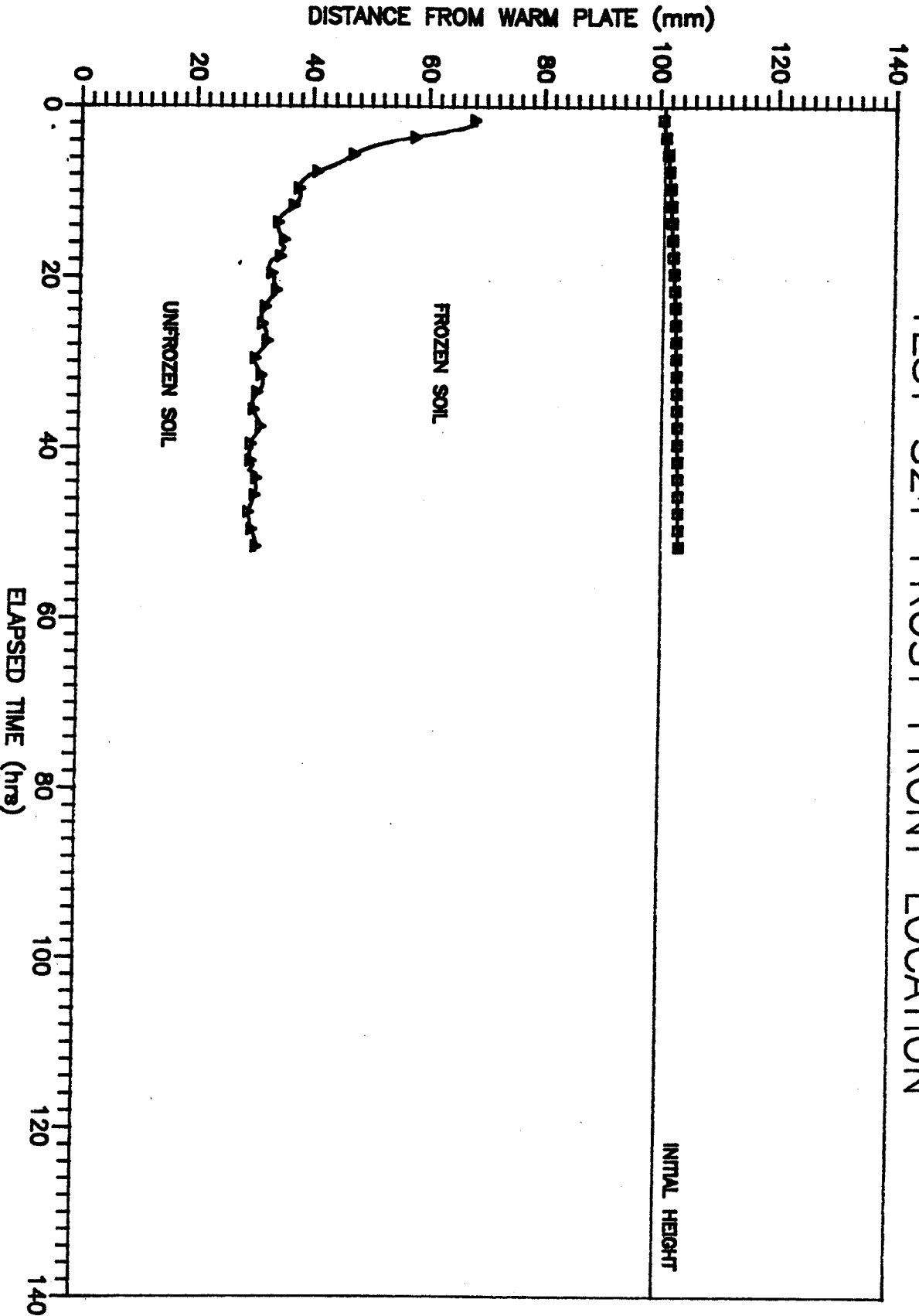
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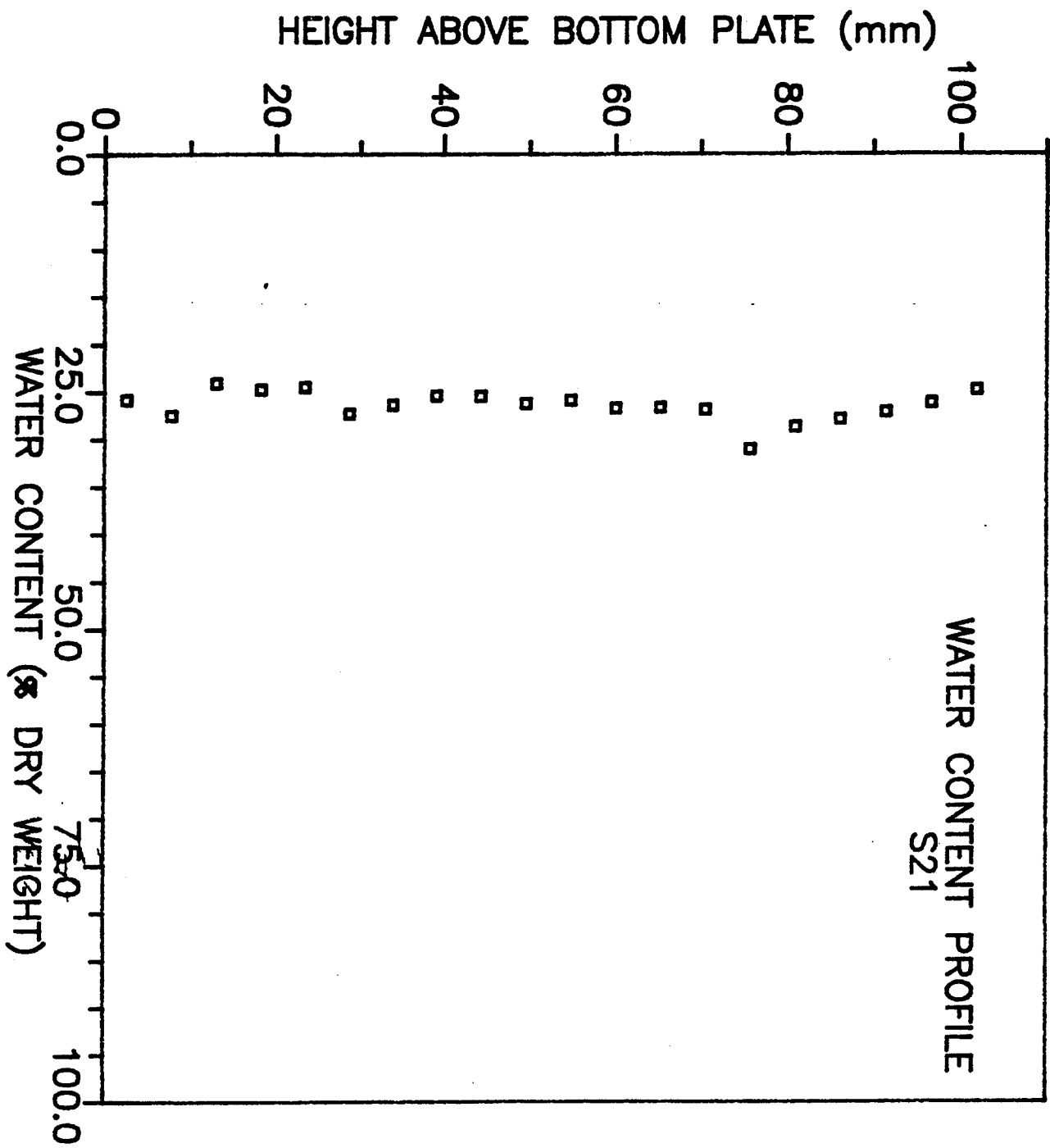


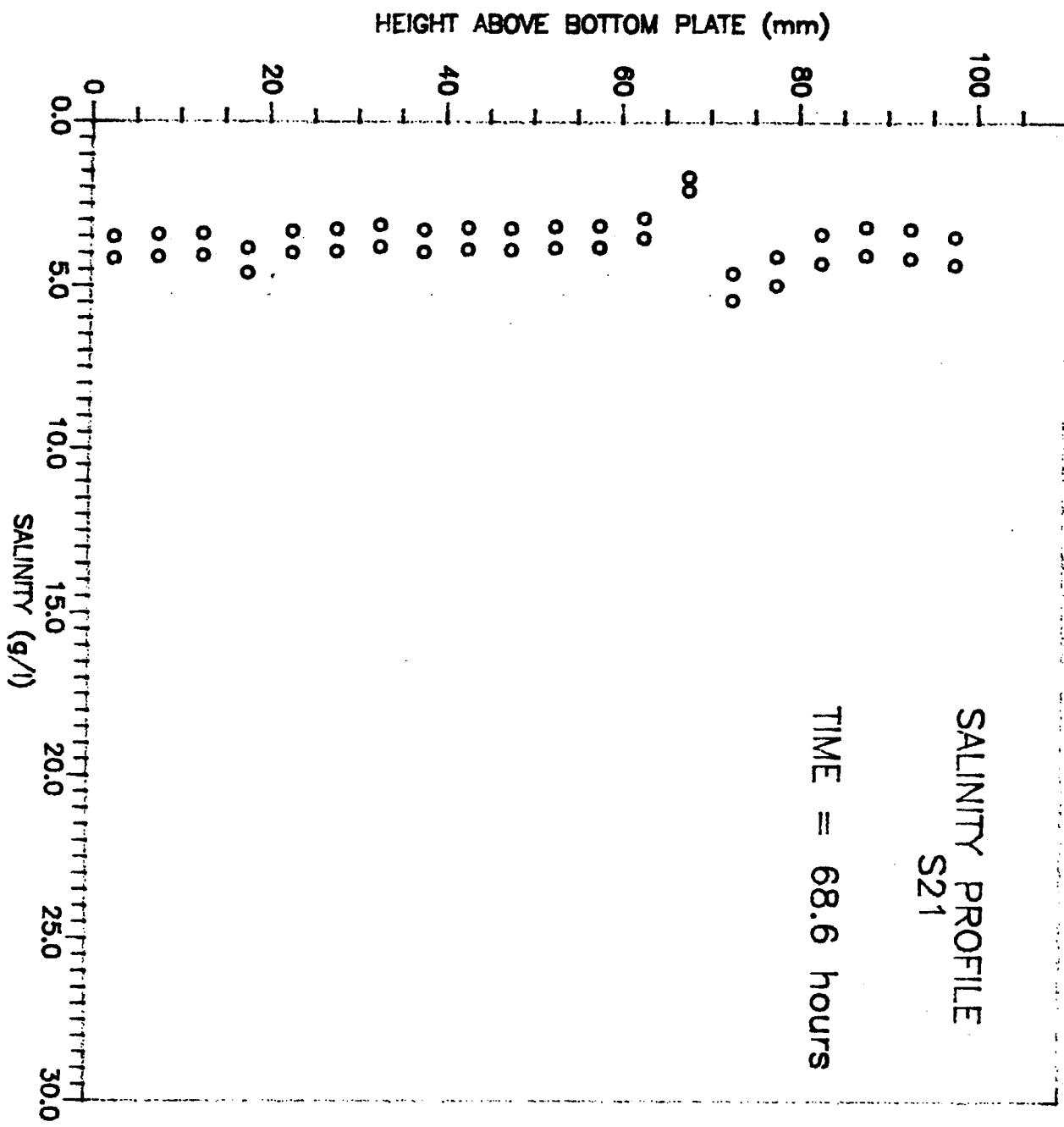
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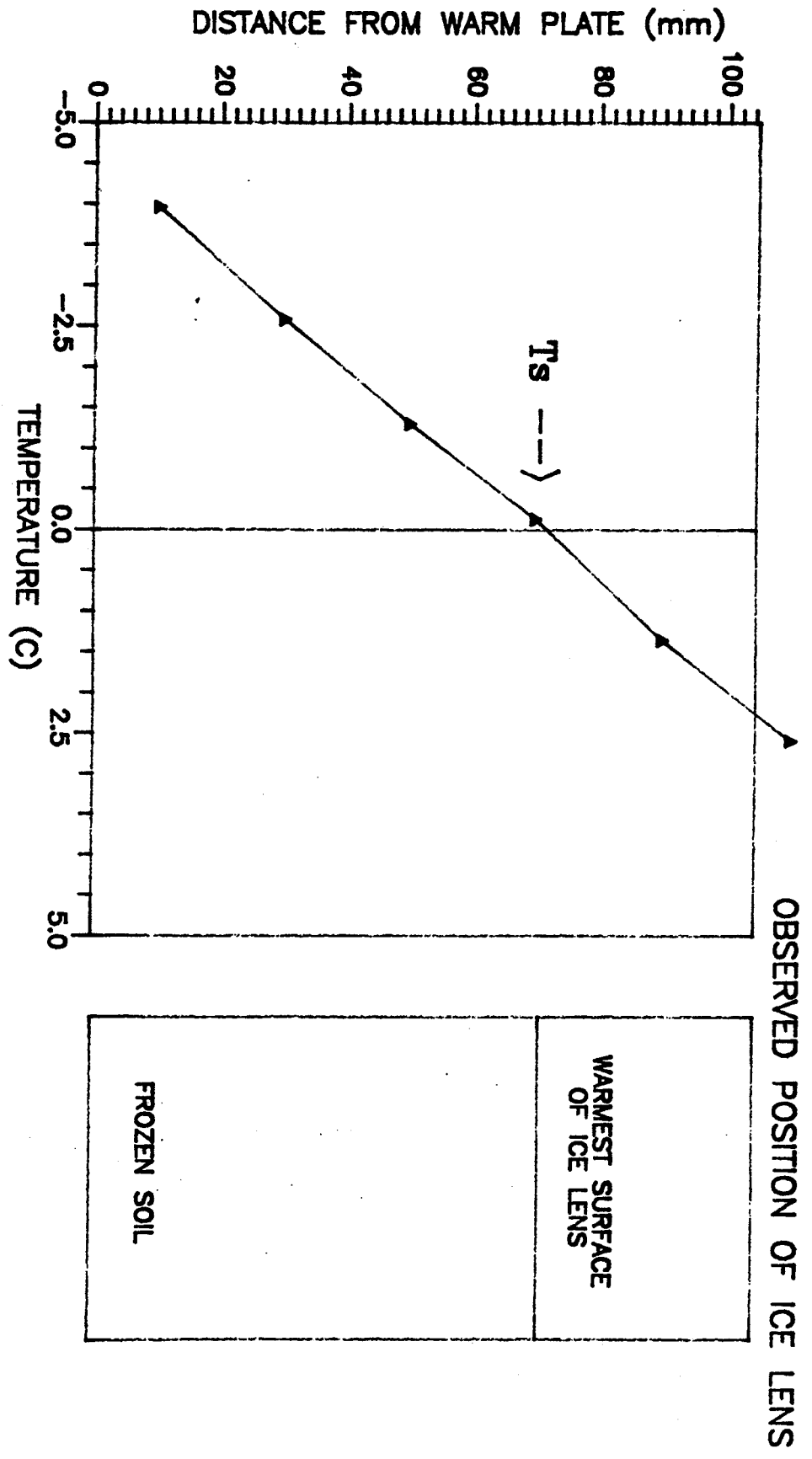
TEST S21 FROST FRONT LOCATION

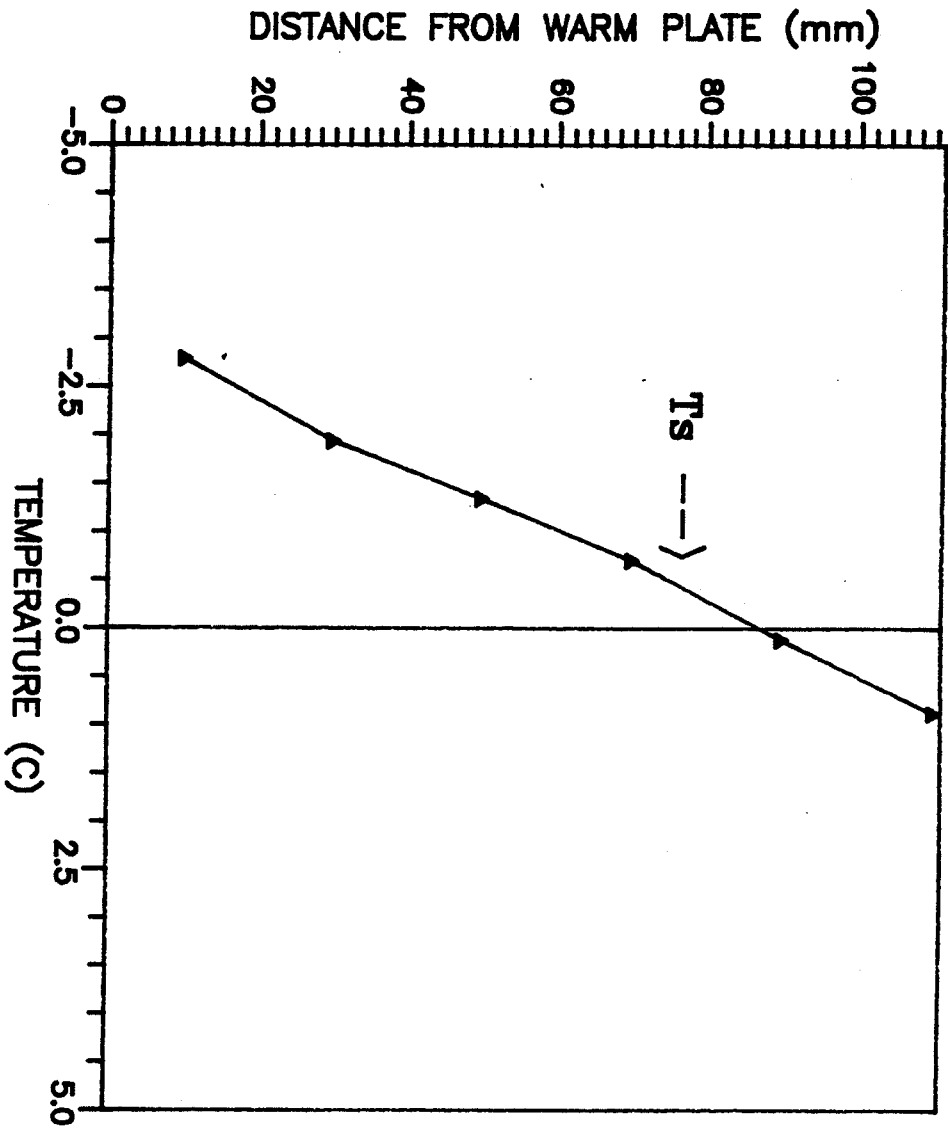




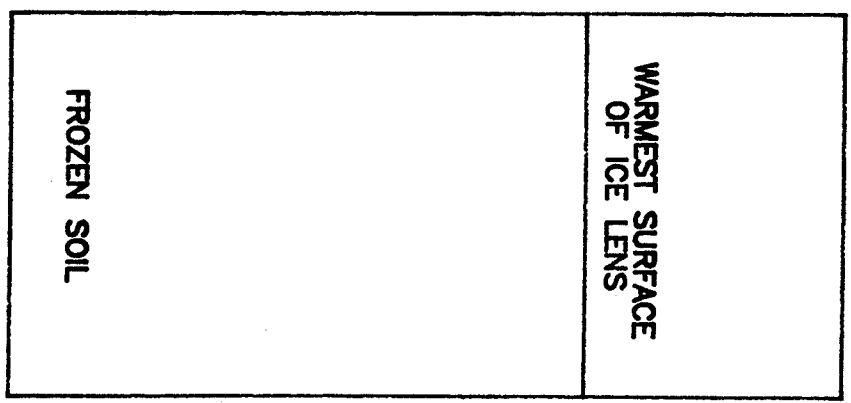


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S21



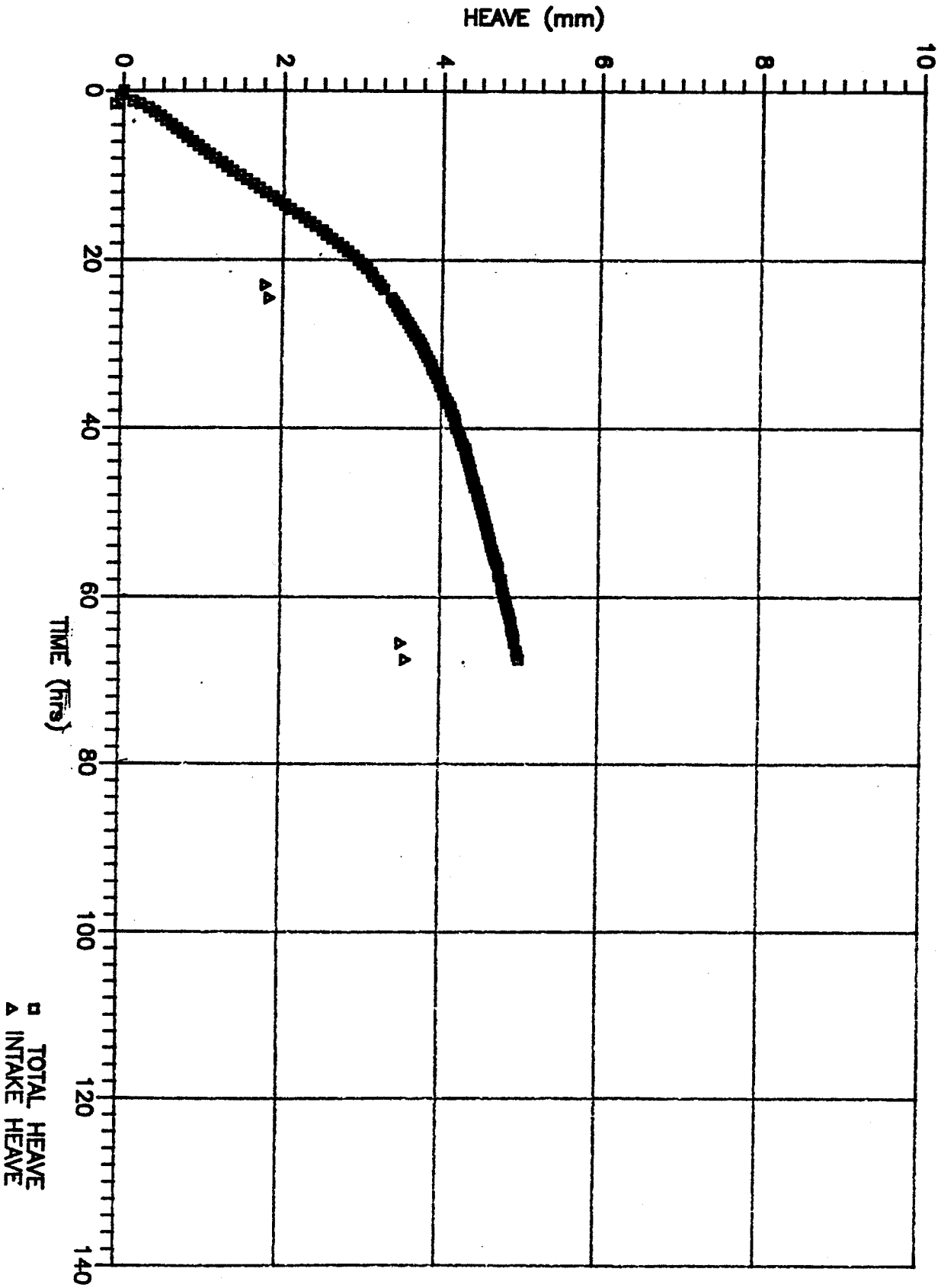


OBSERVED POSITION OF ICE LENS

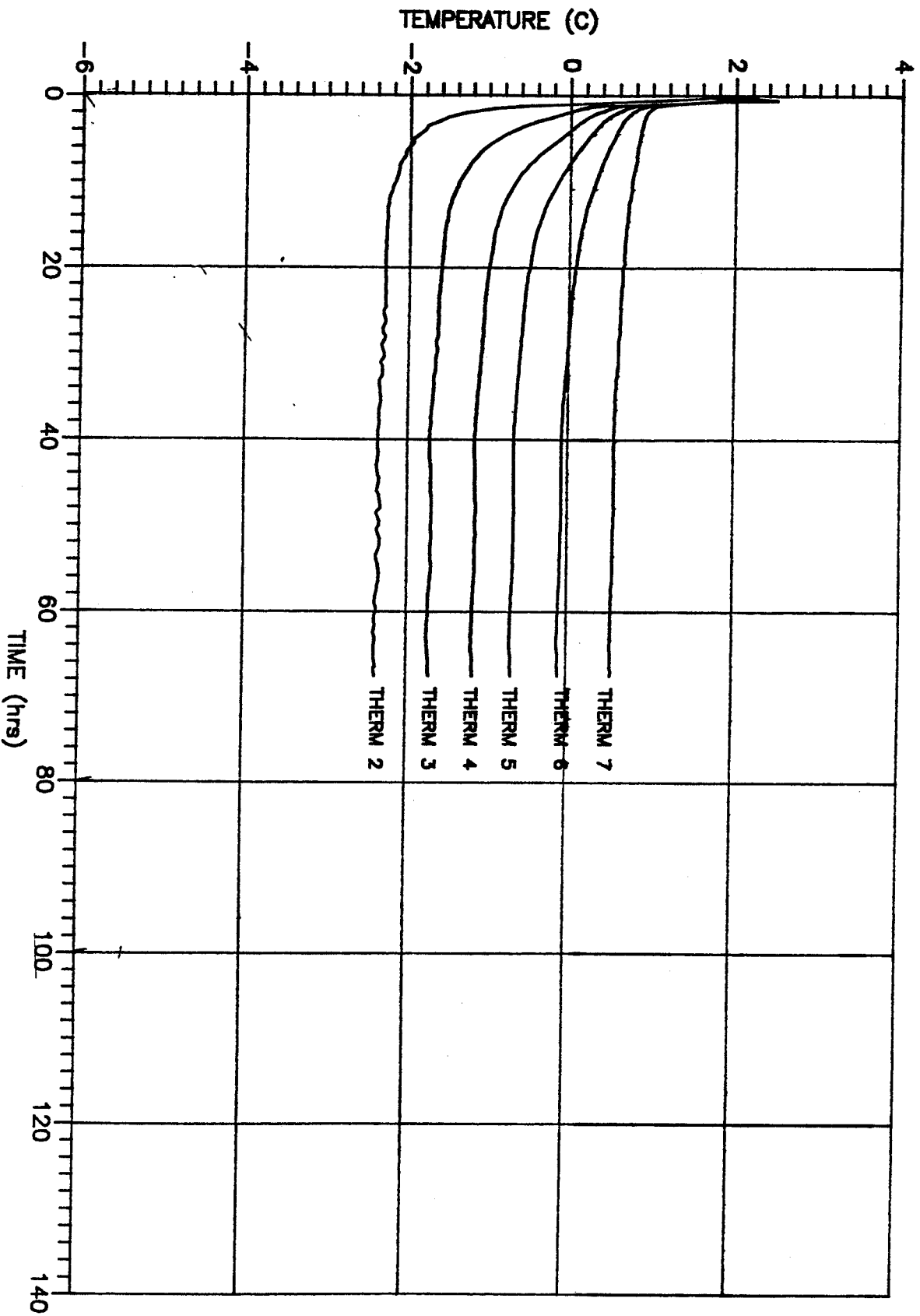


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S31

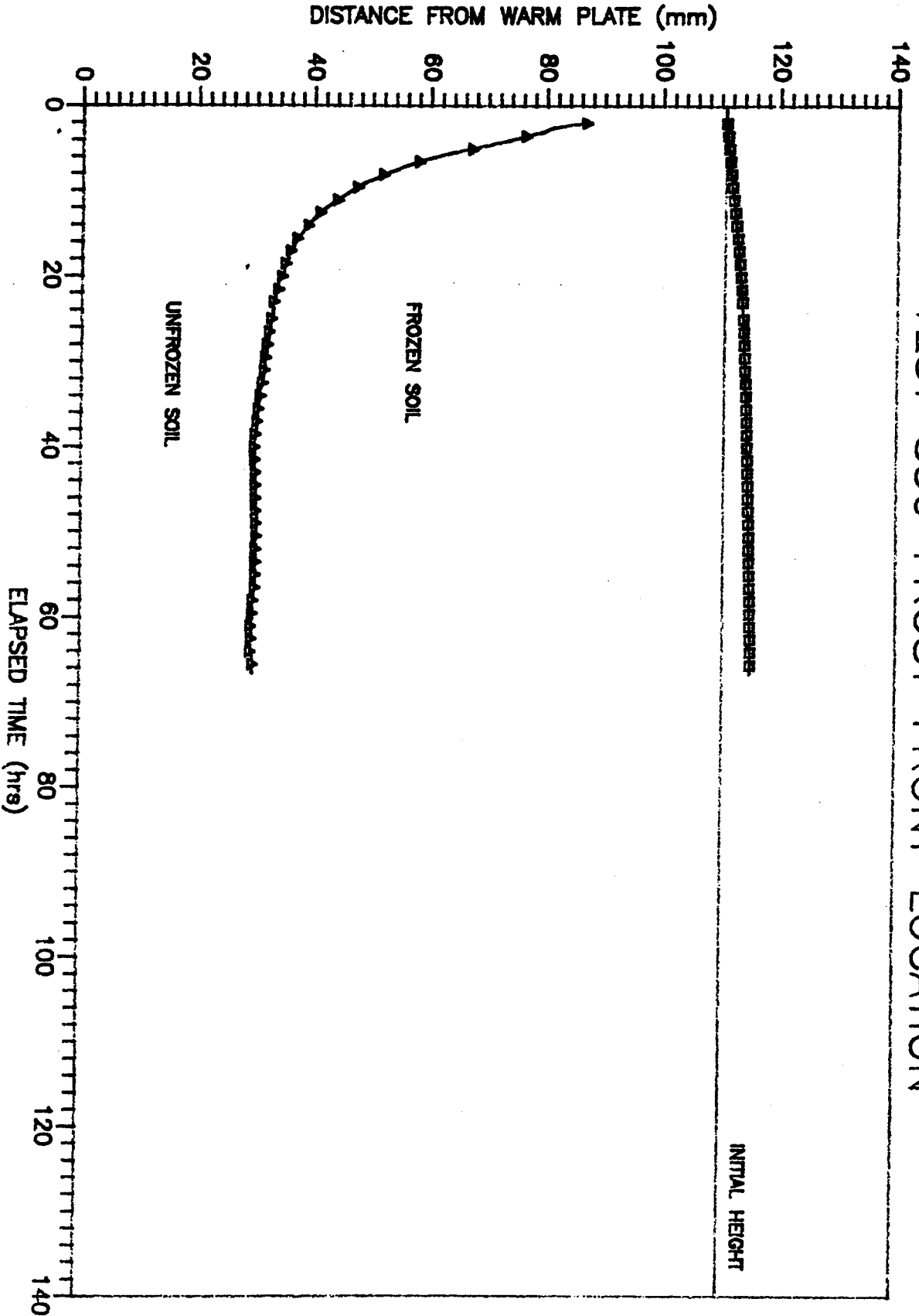
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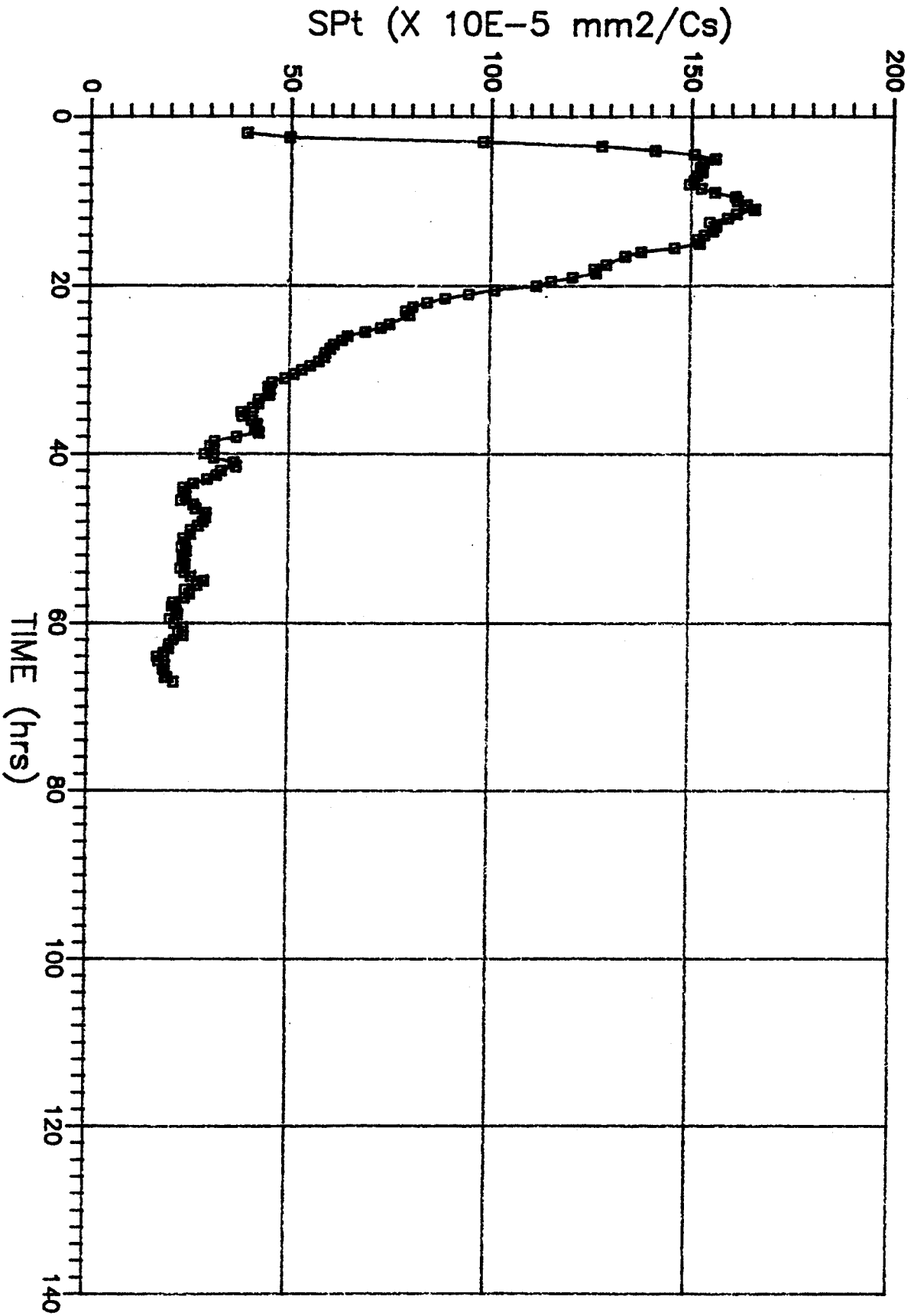
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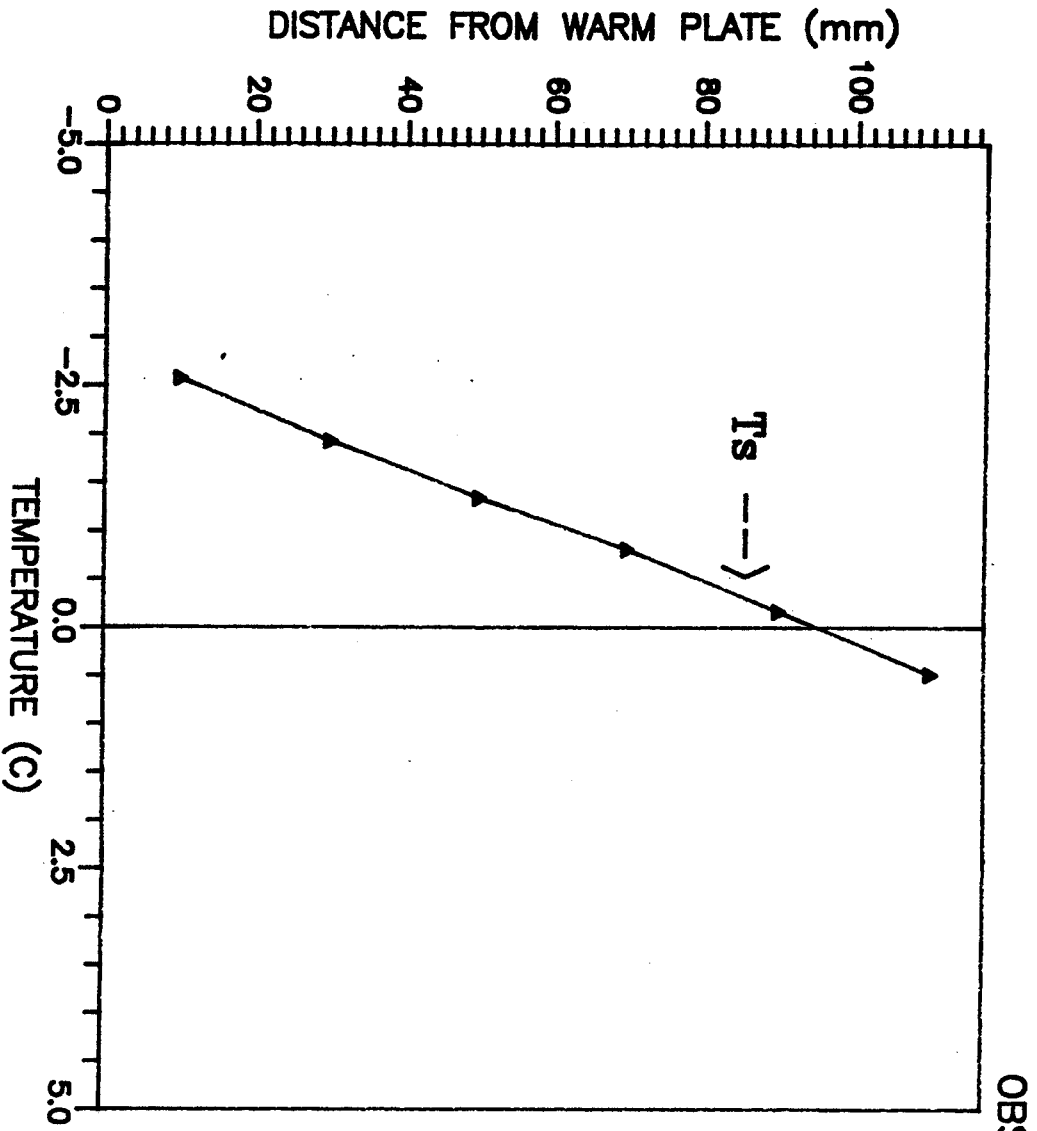


TEST S30 FROST FRONT LOCATION

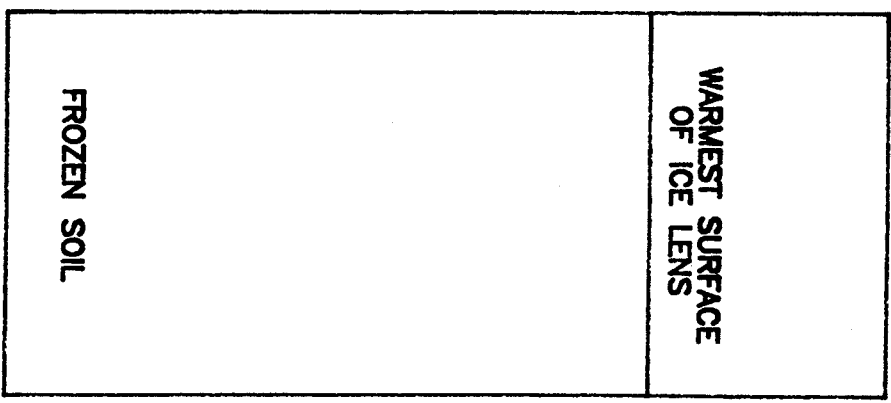


FREEZING TEST S30



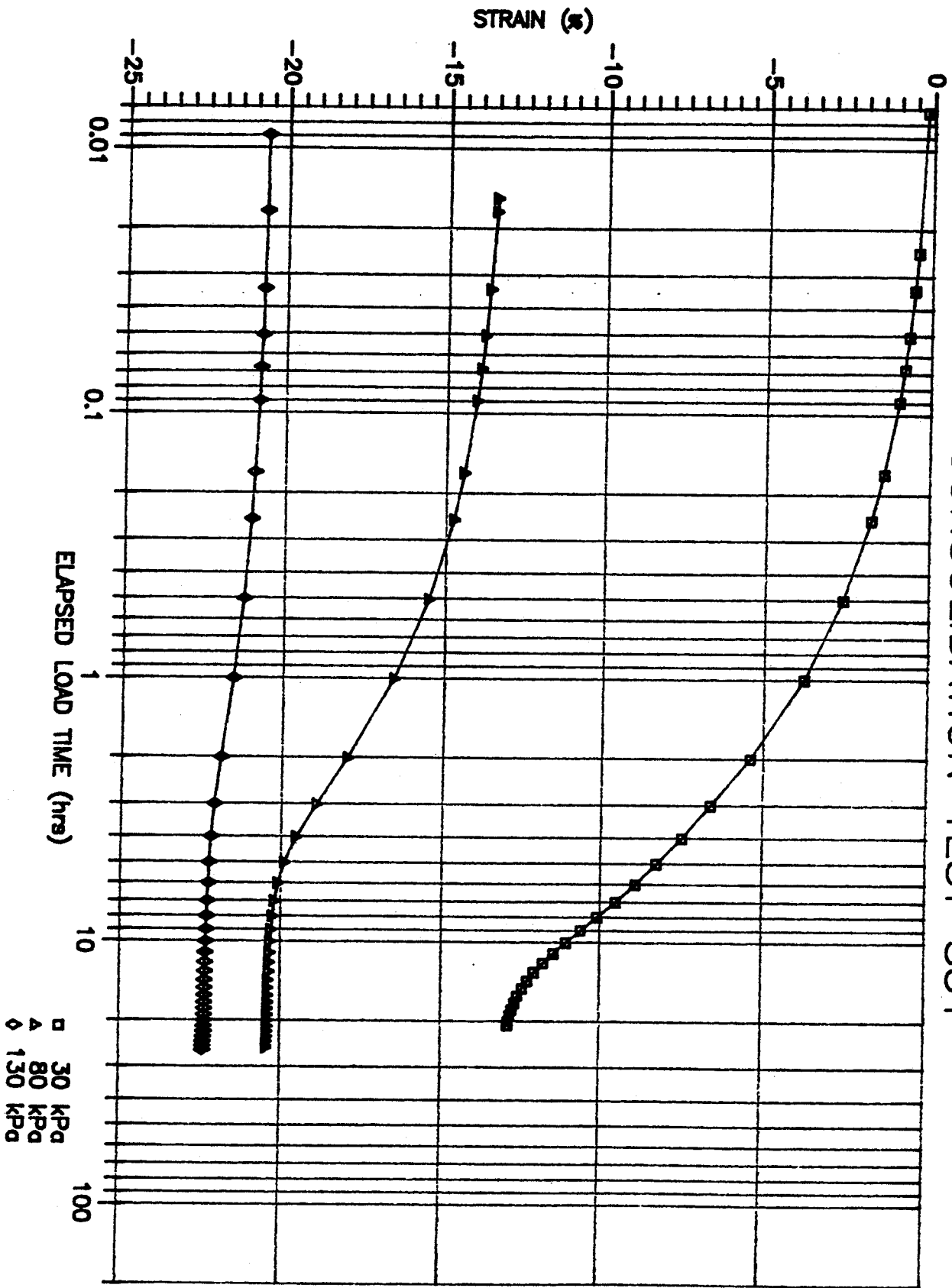


OBSERVED POSITION OF ICE LENS

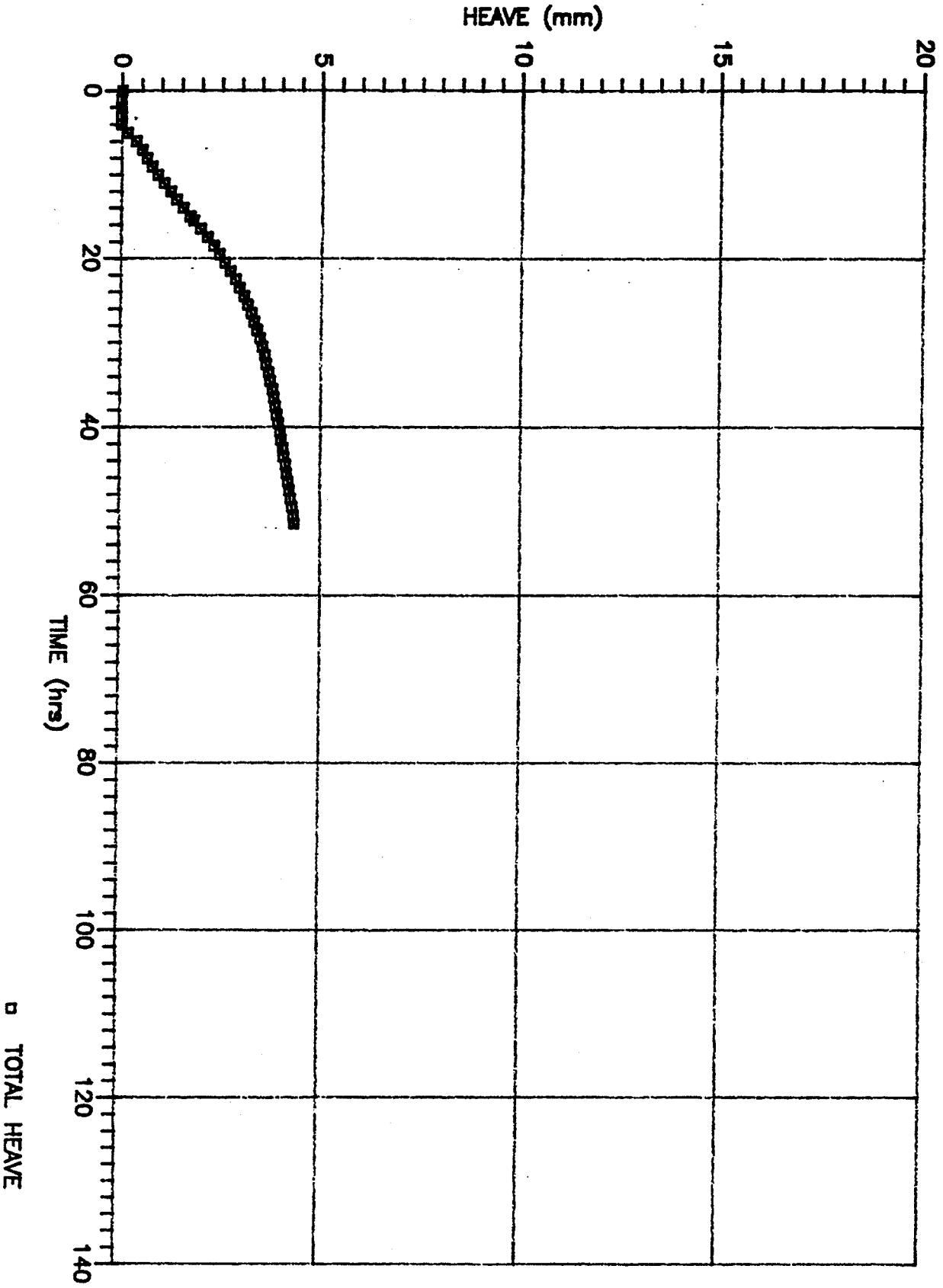


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S30

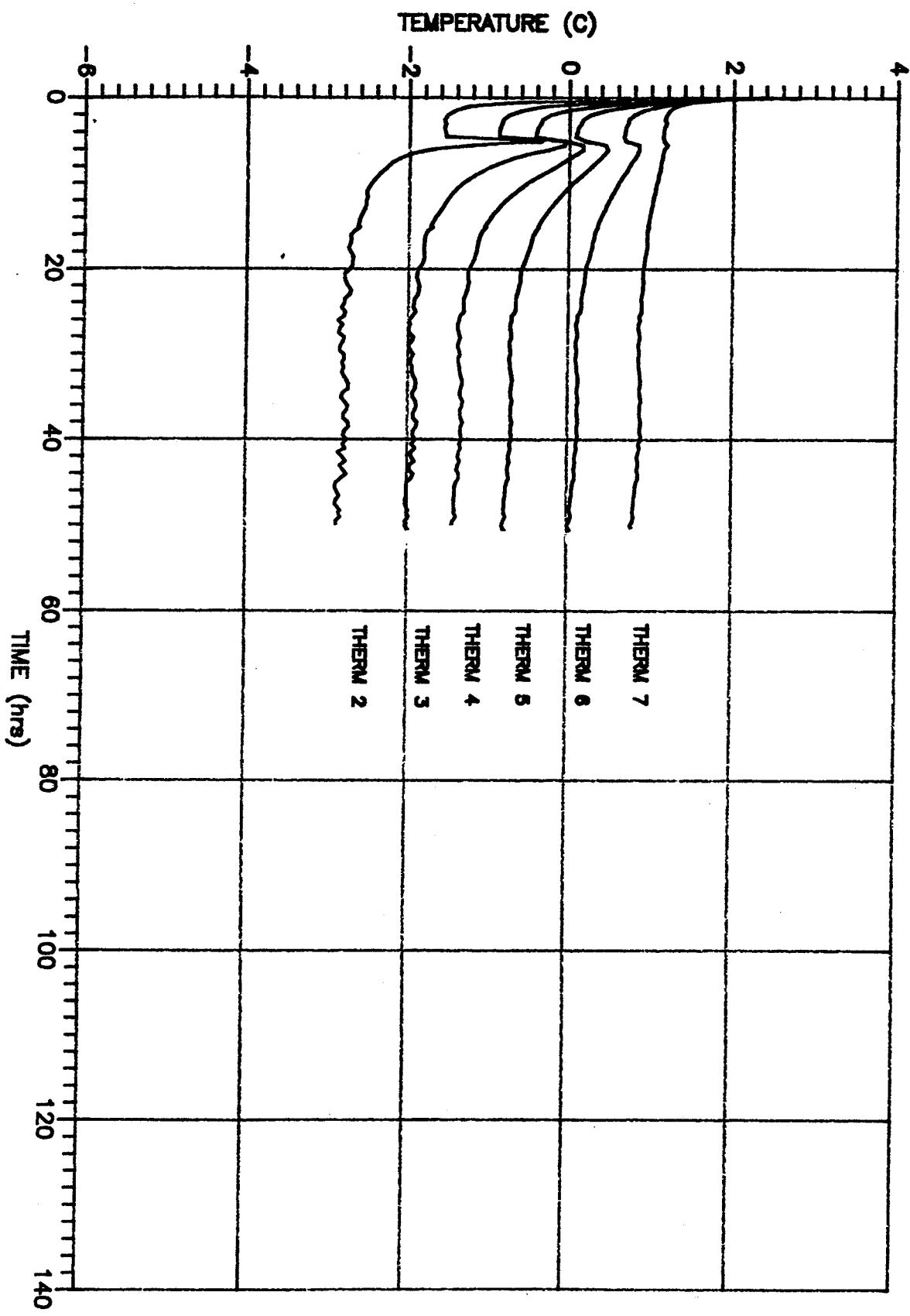
CONSOLIDATION TEST S31



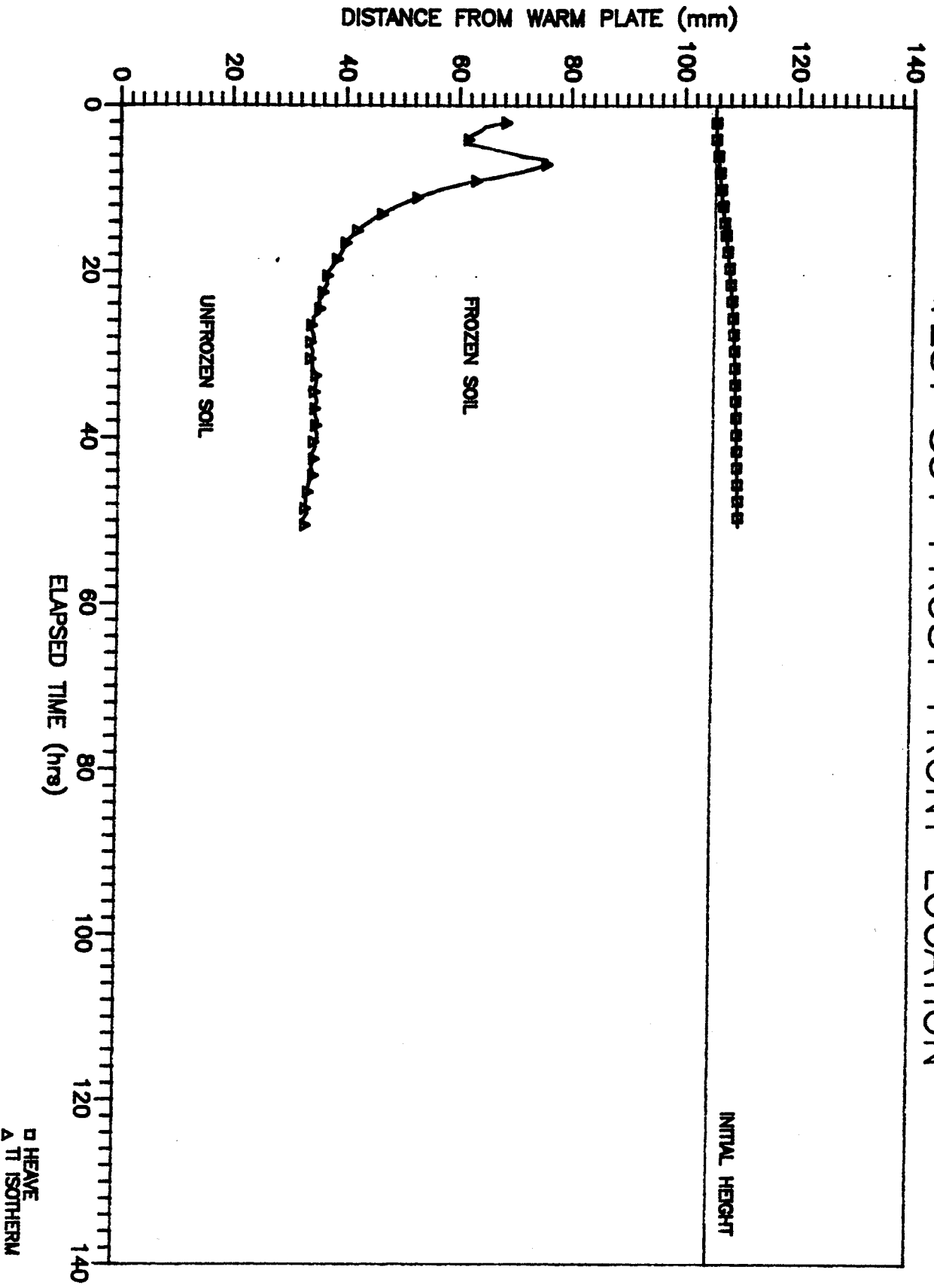
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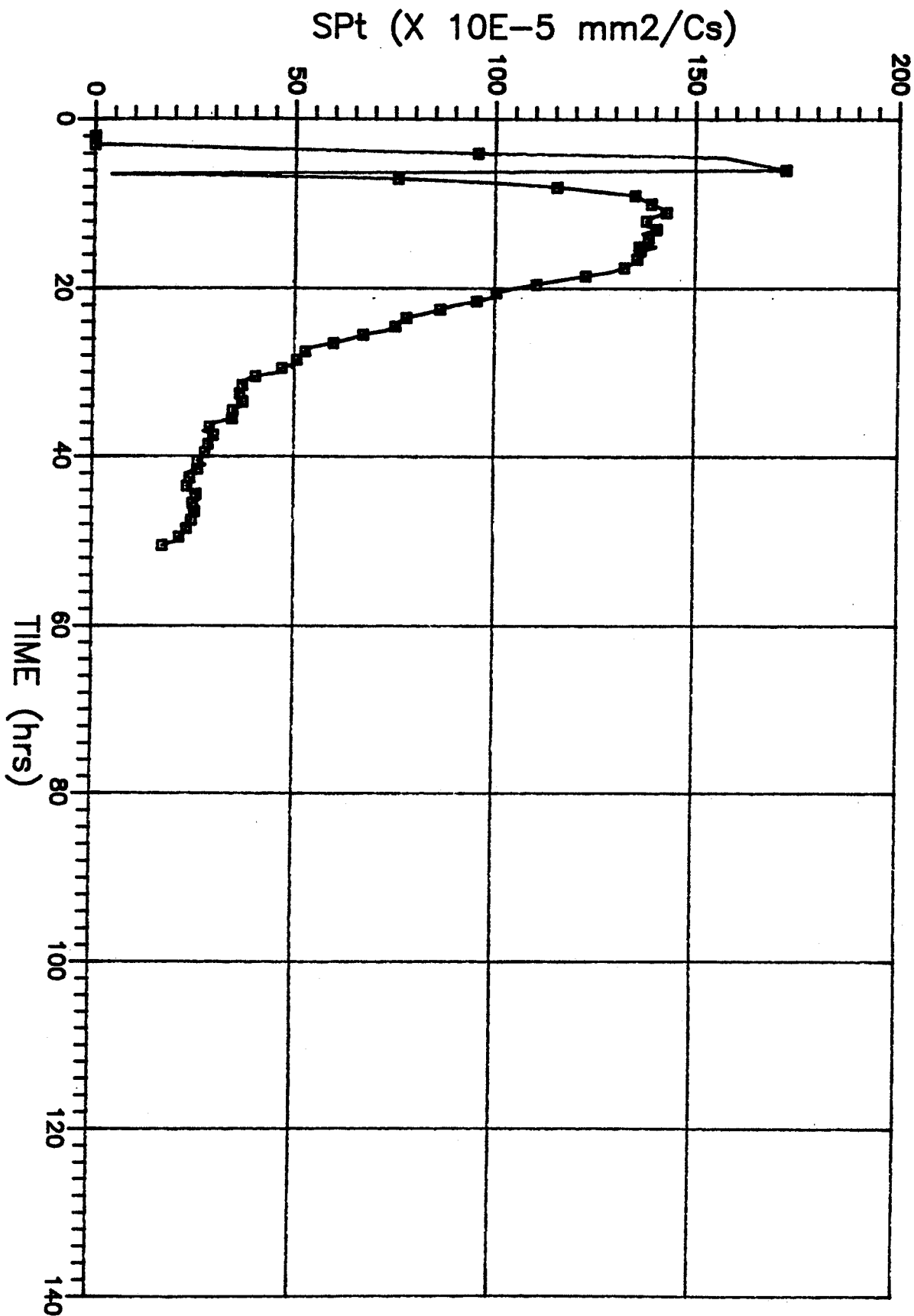
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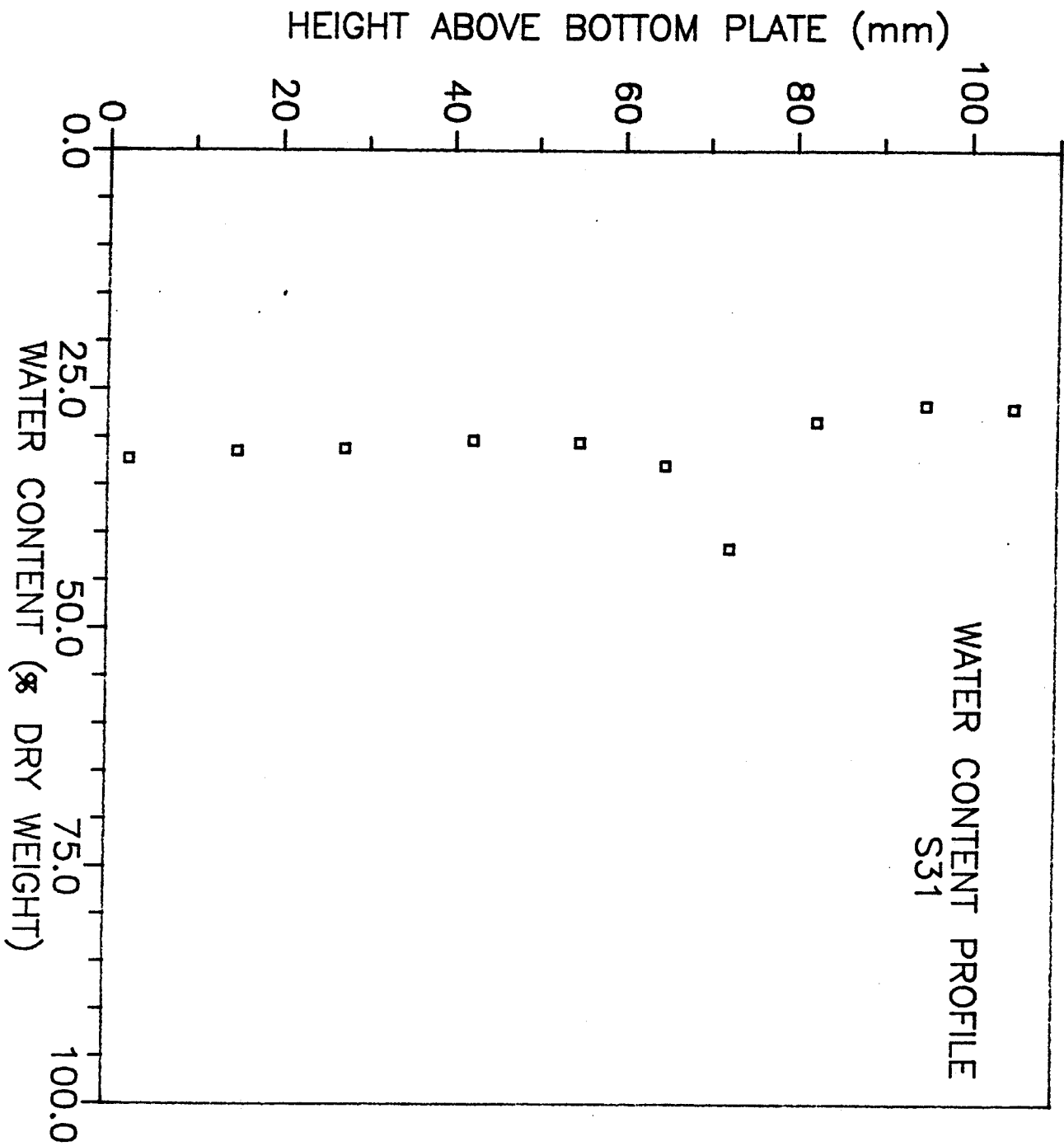


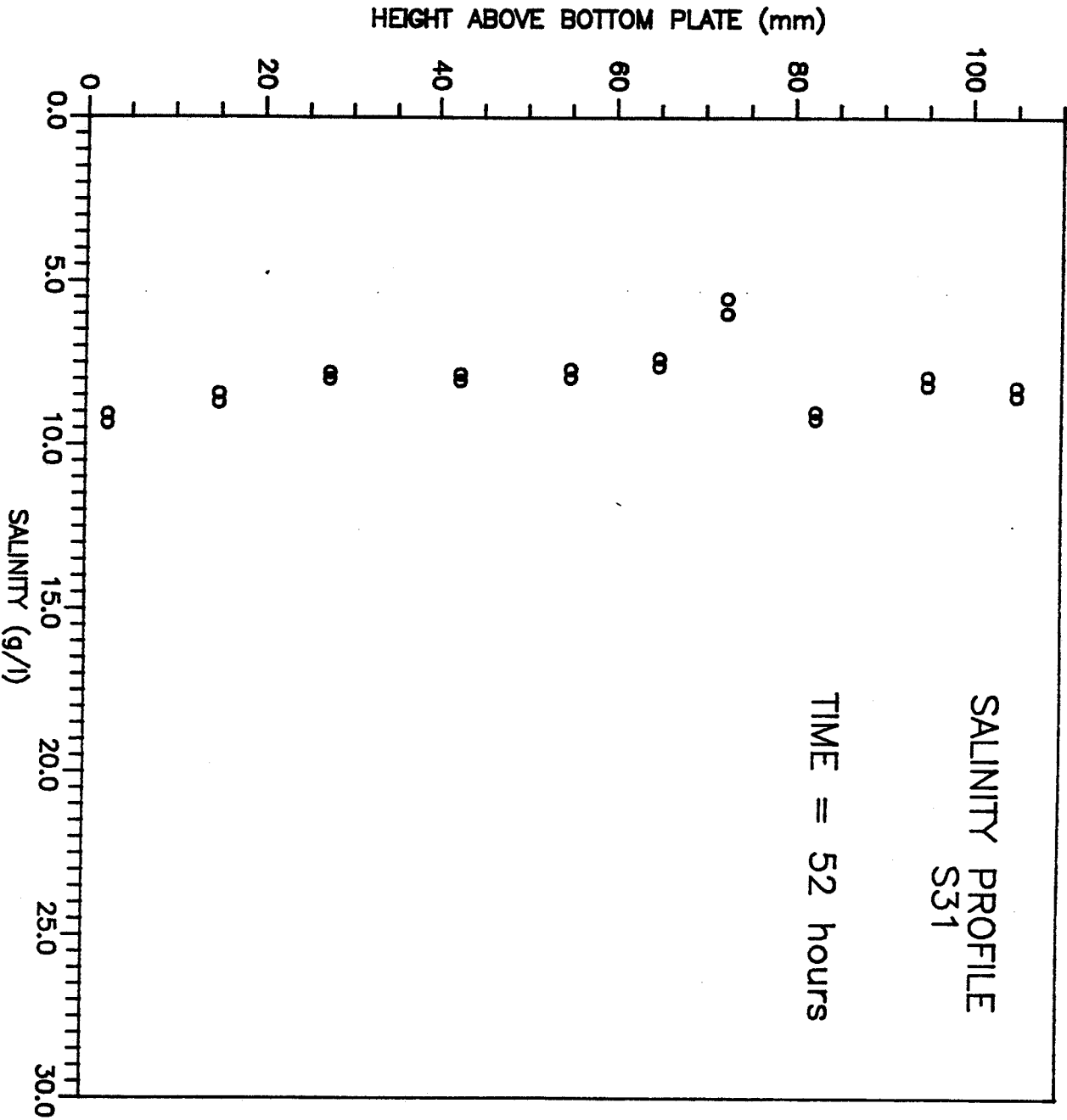
TEST S31 FROST FRONT LOCATION



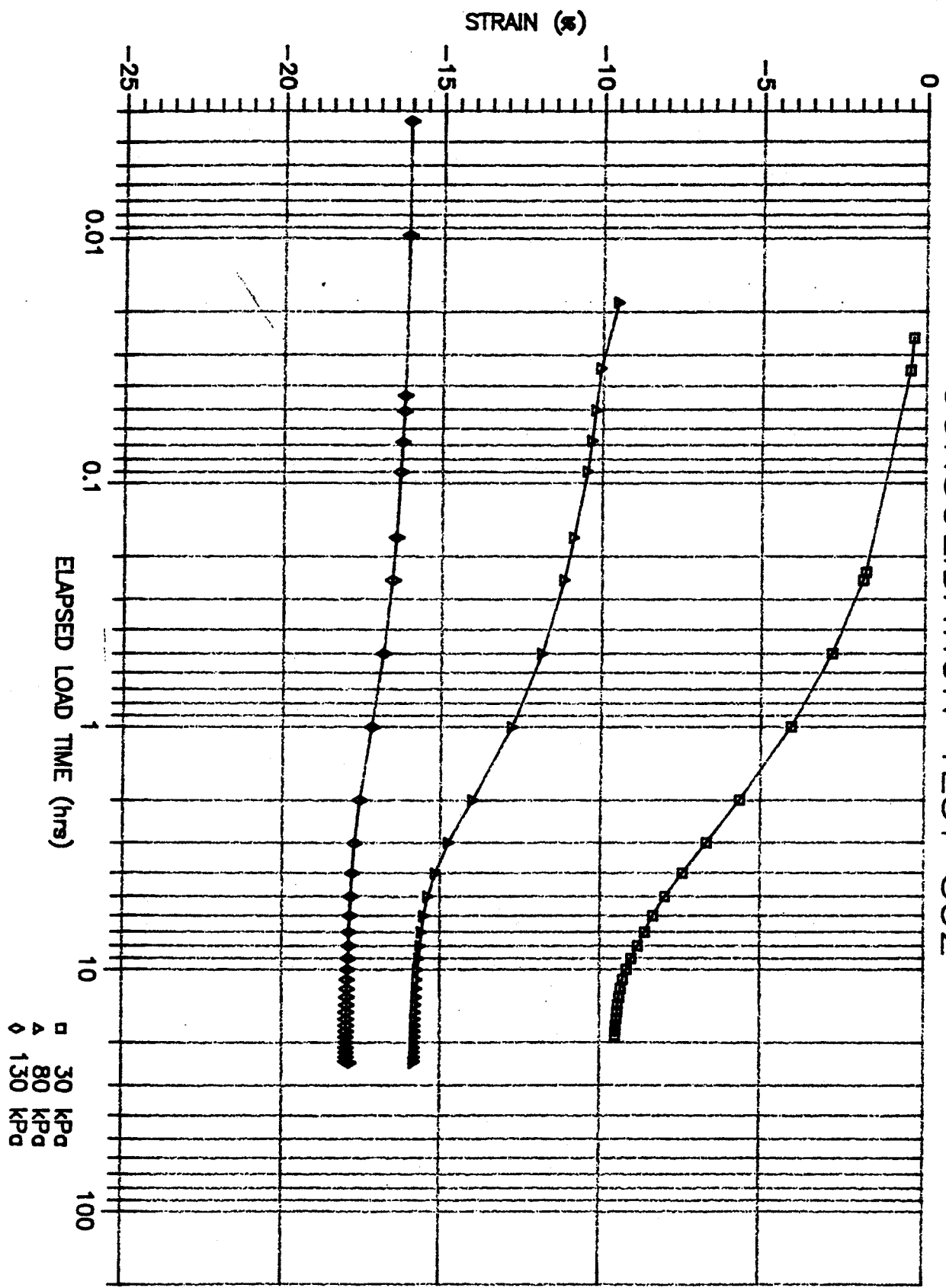
FREEZING TEST S31





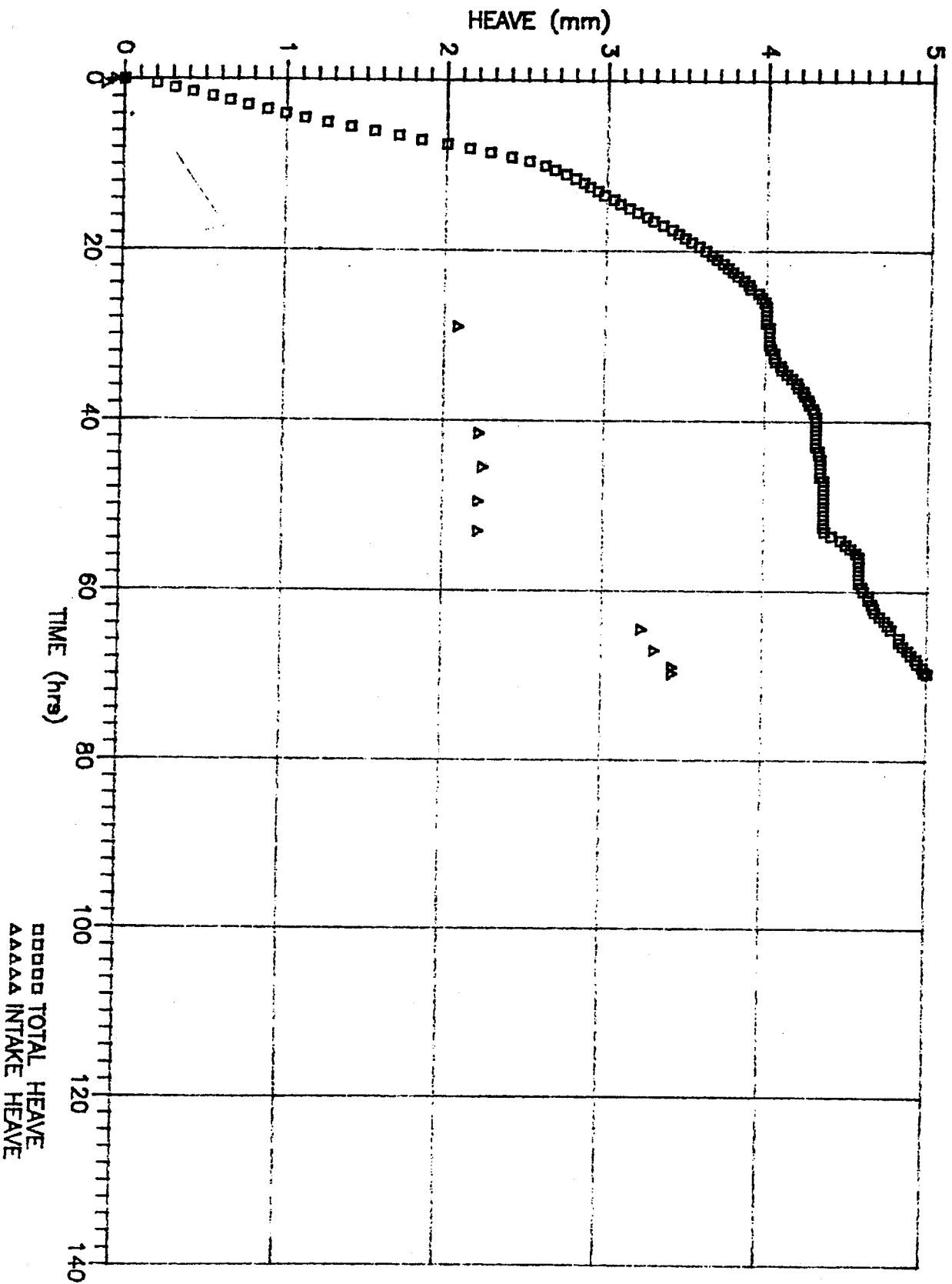


CONSOLIDATION TEST S32

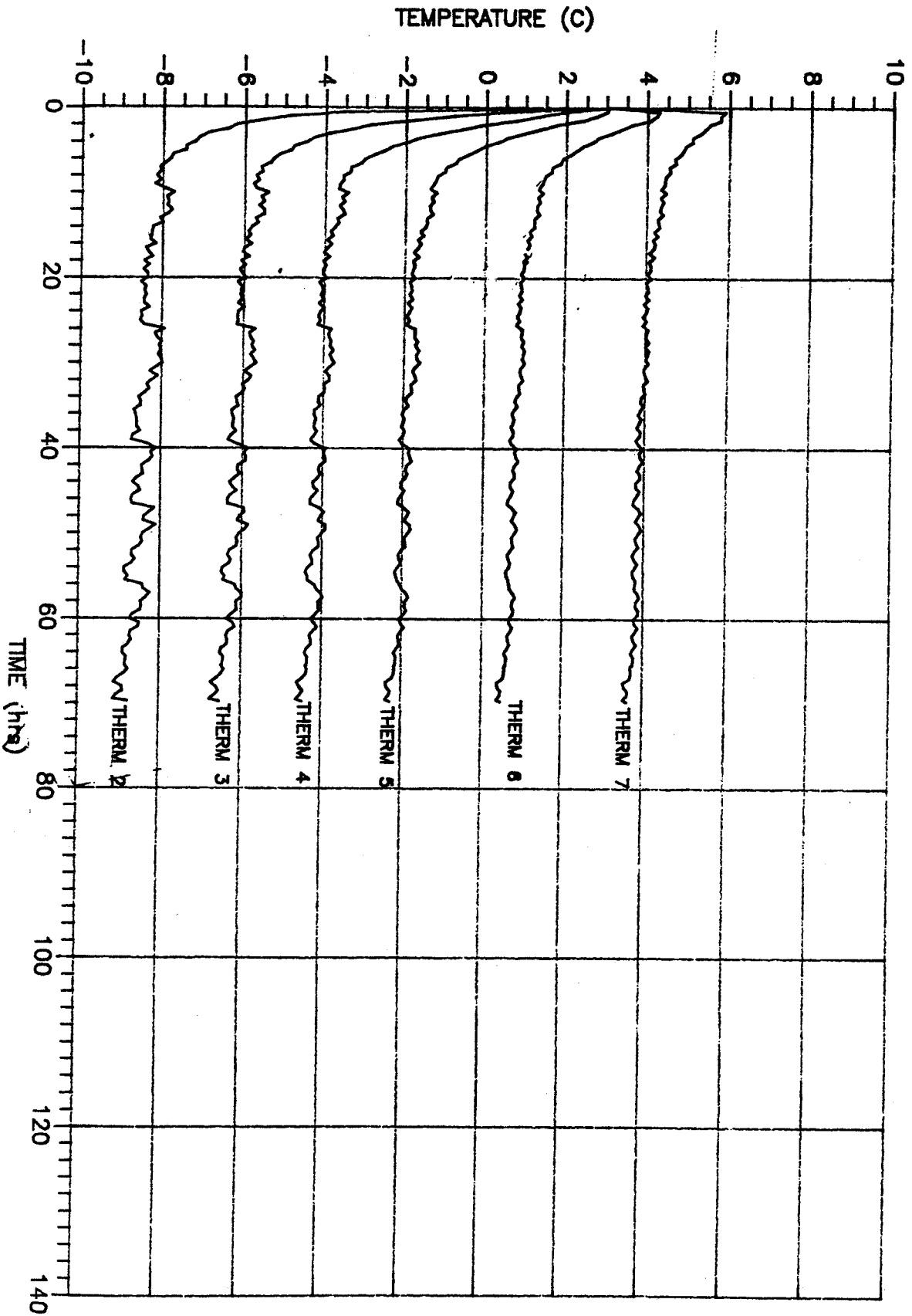


□ 30 kPa
△ 80 kPa
◇ 130 kPa

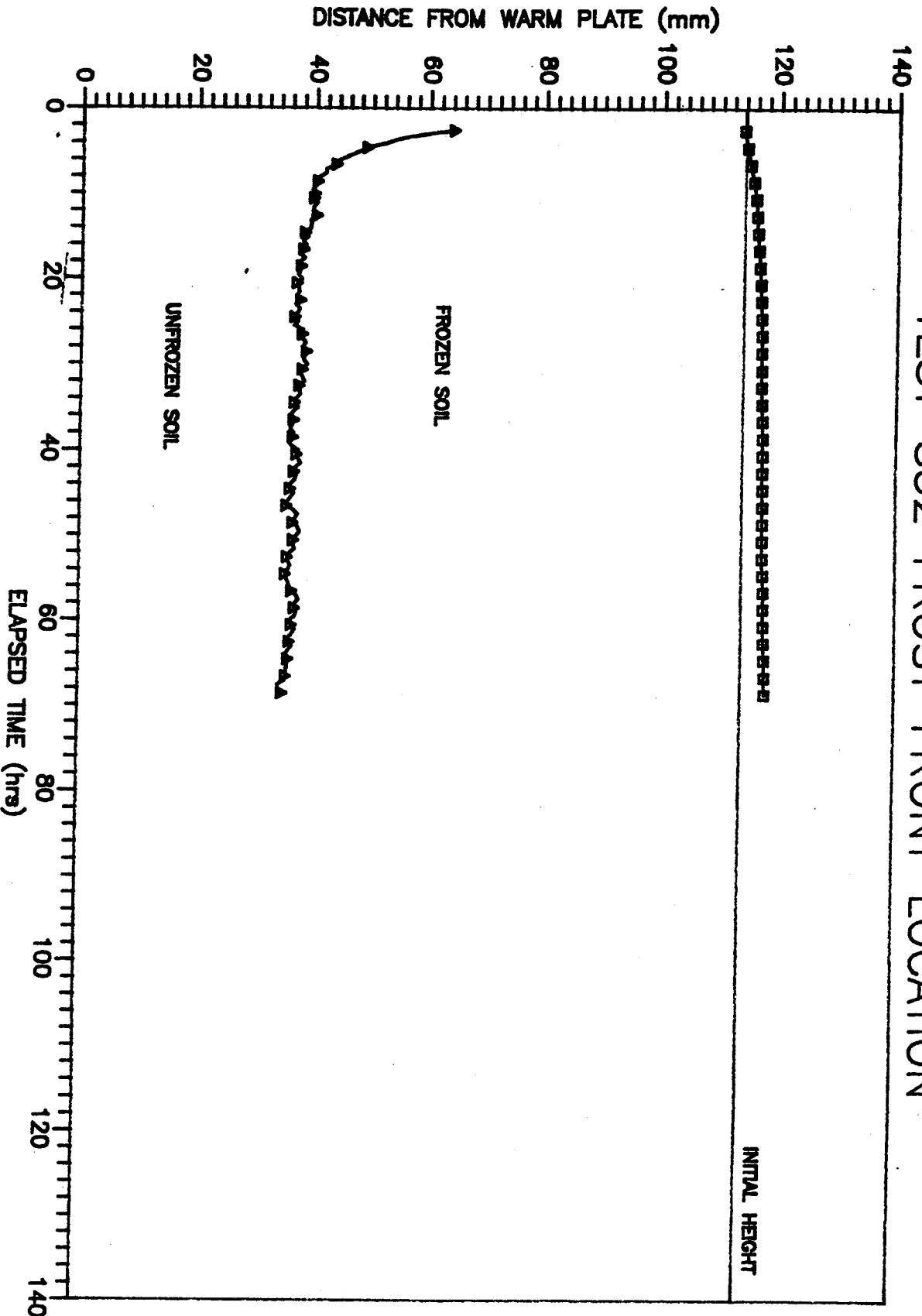
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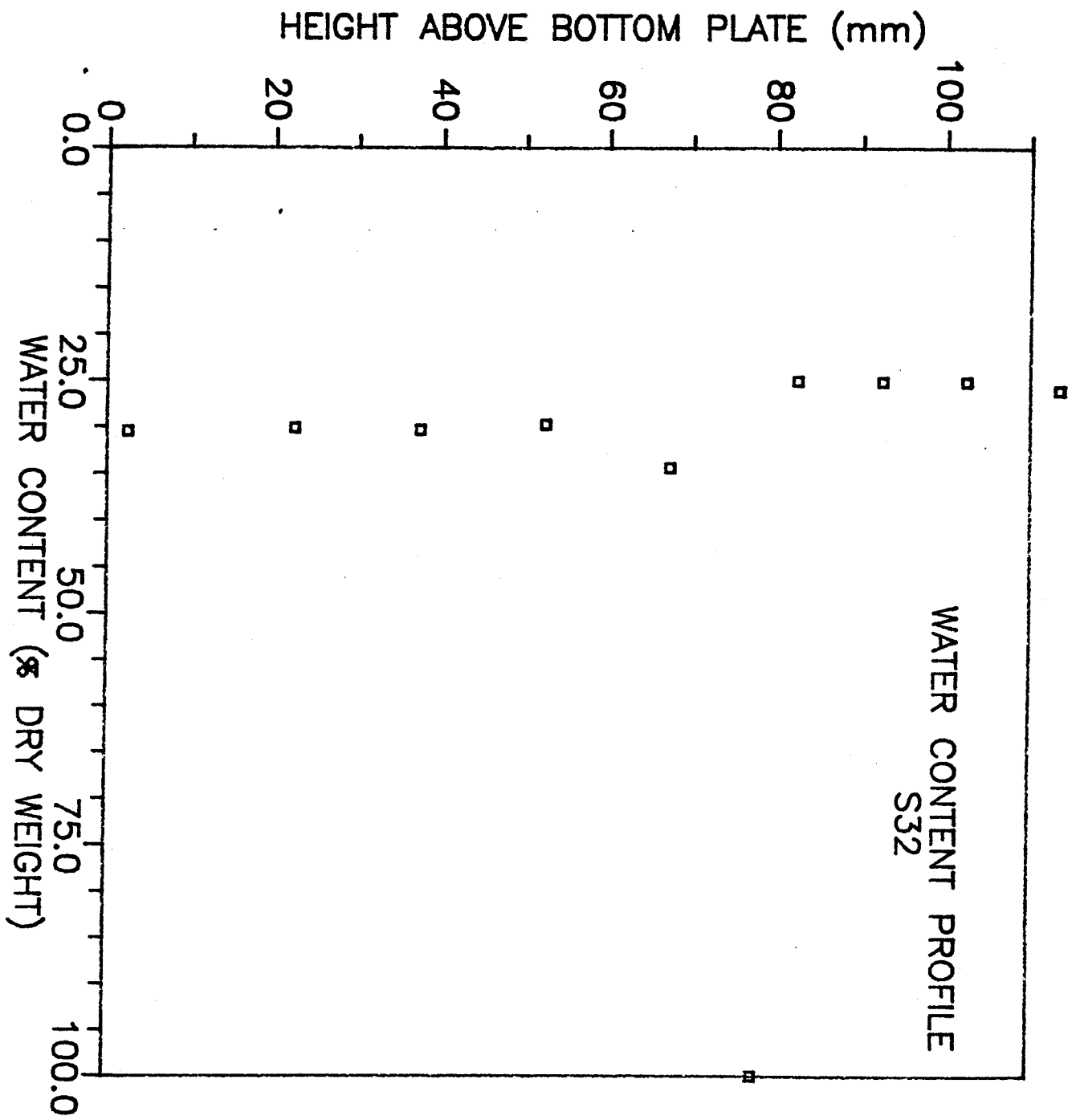
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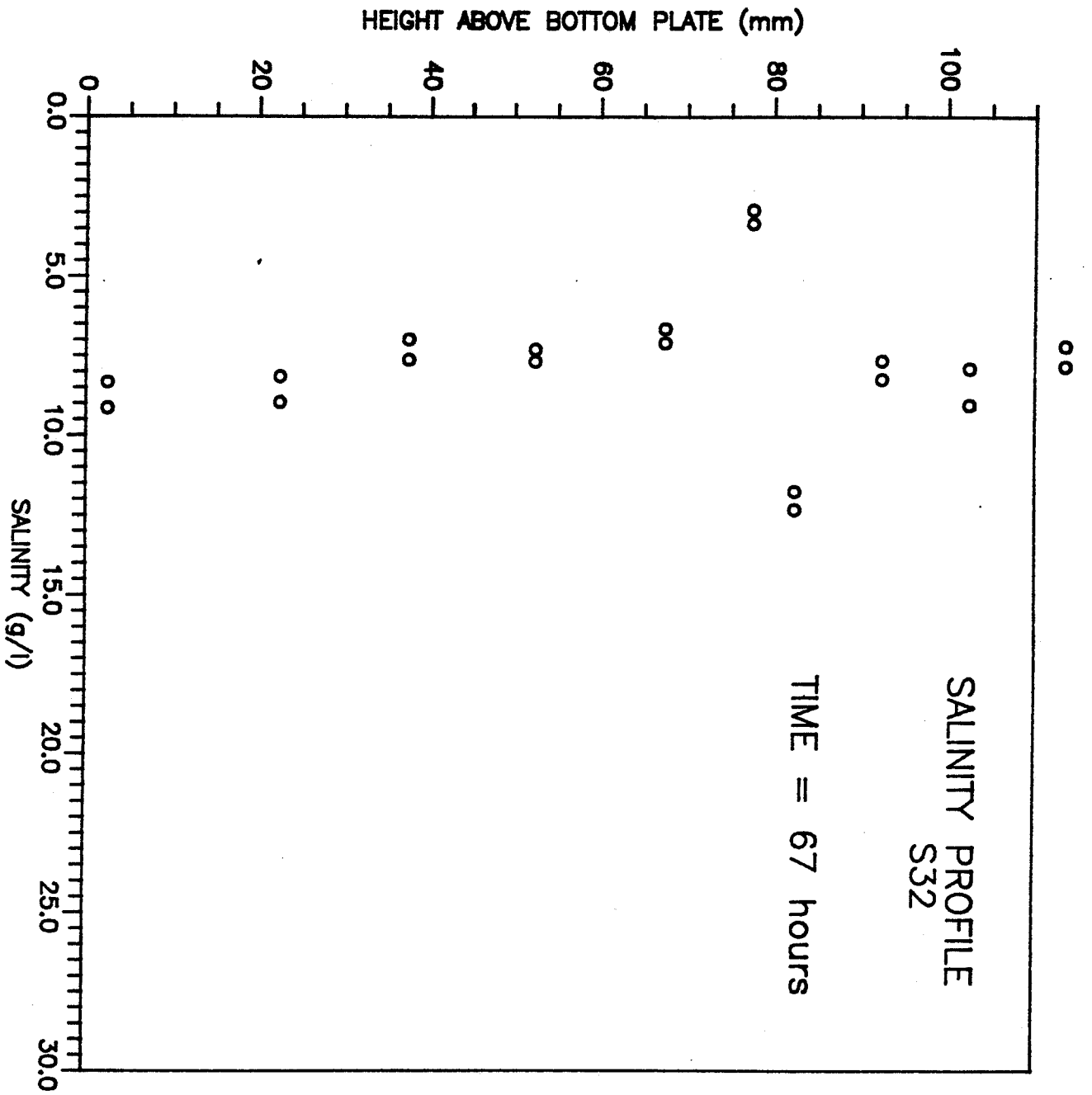


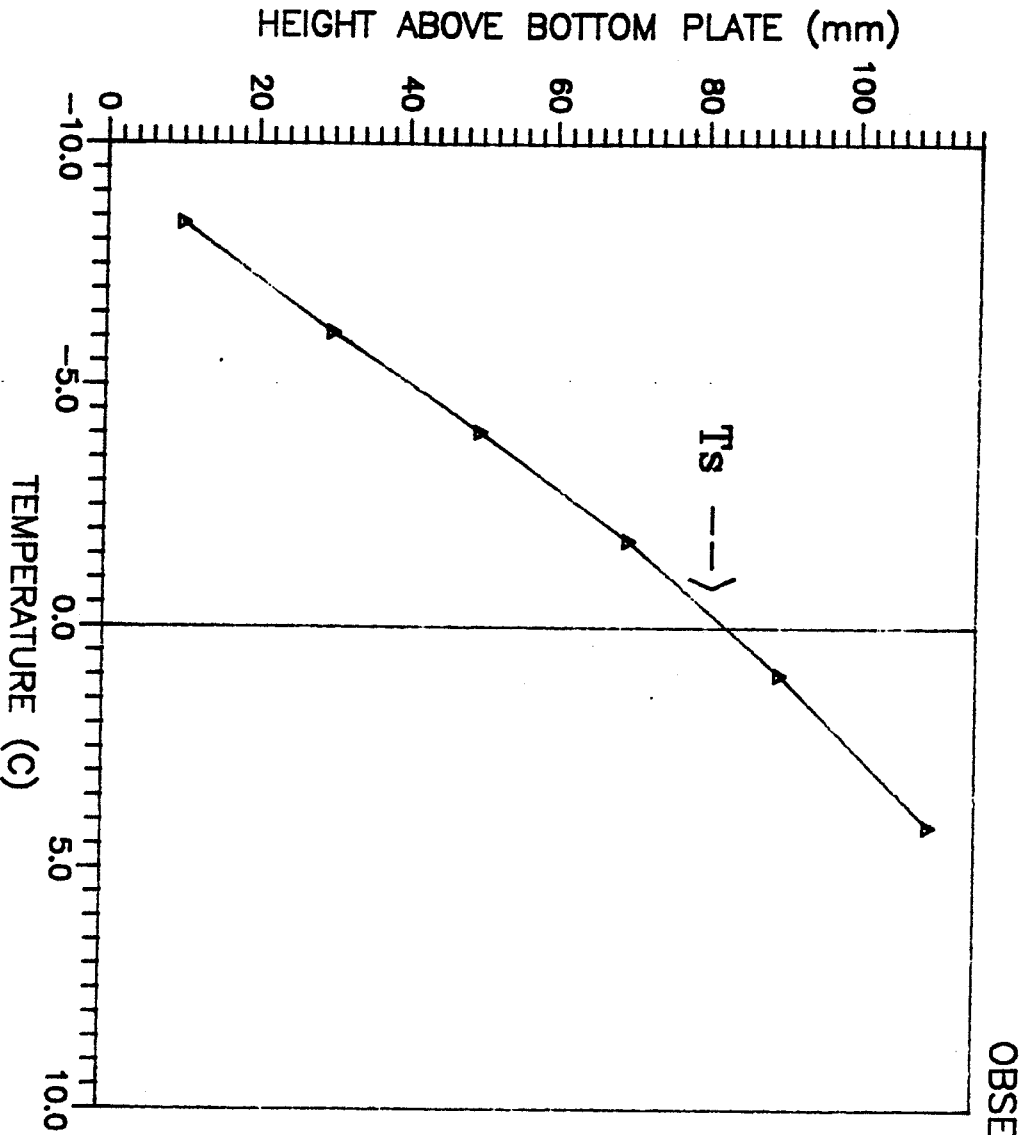
TEST S32 FROST FRONT LOCATION



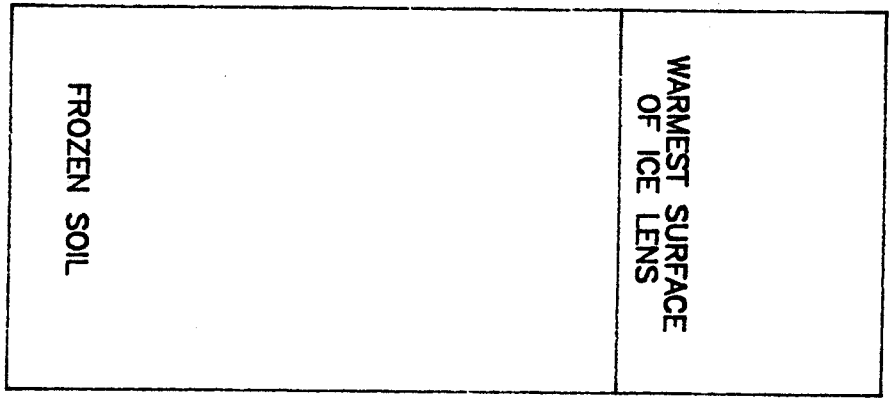
□ HEAVE
△ TI ISOTHERM





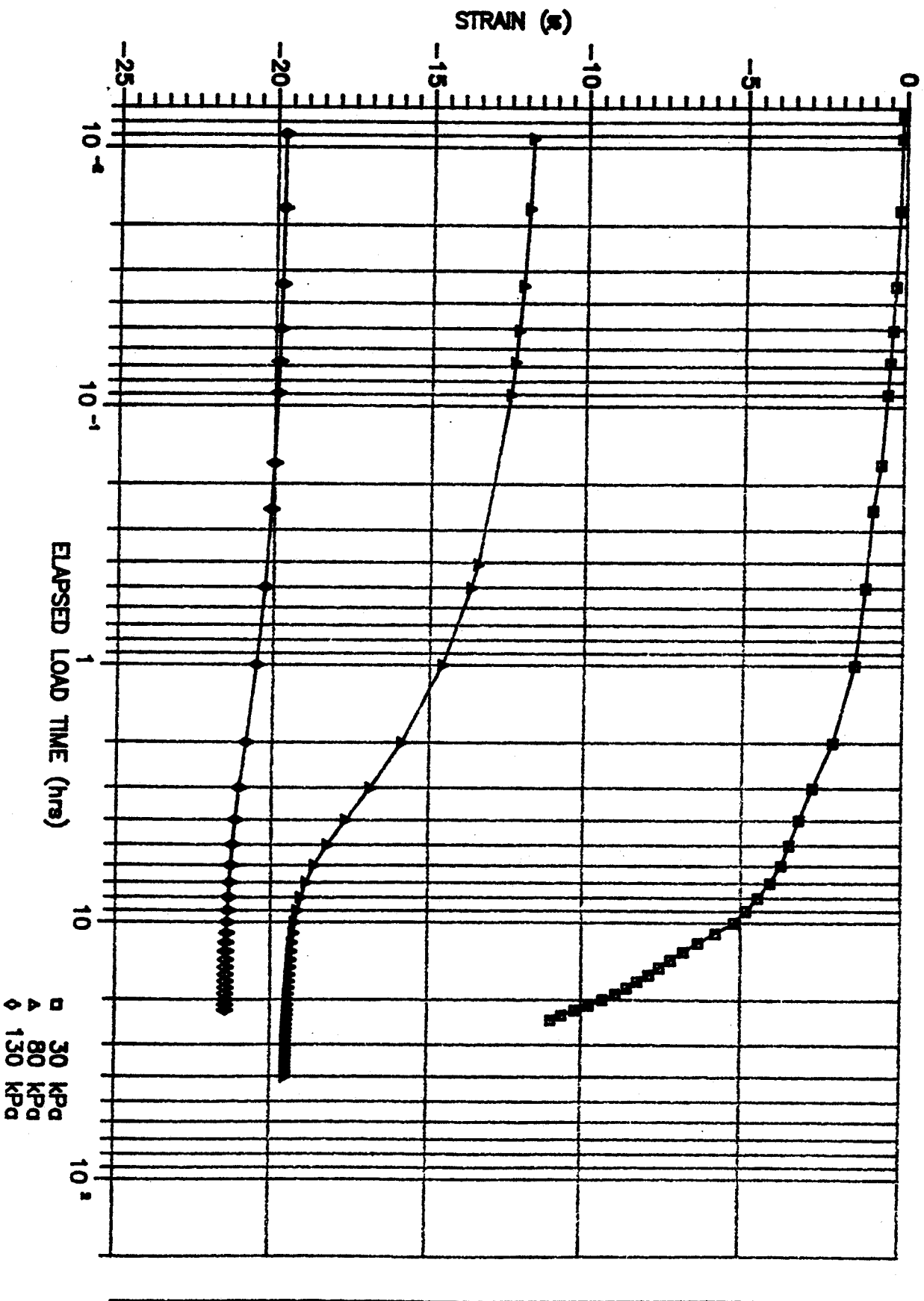


OBSERVED POSITION OF ICE LENS

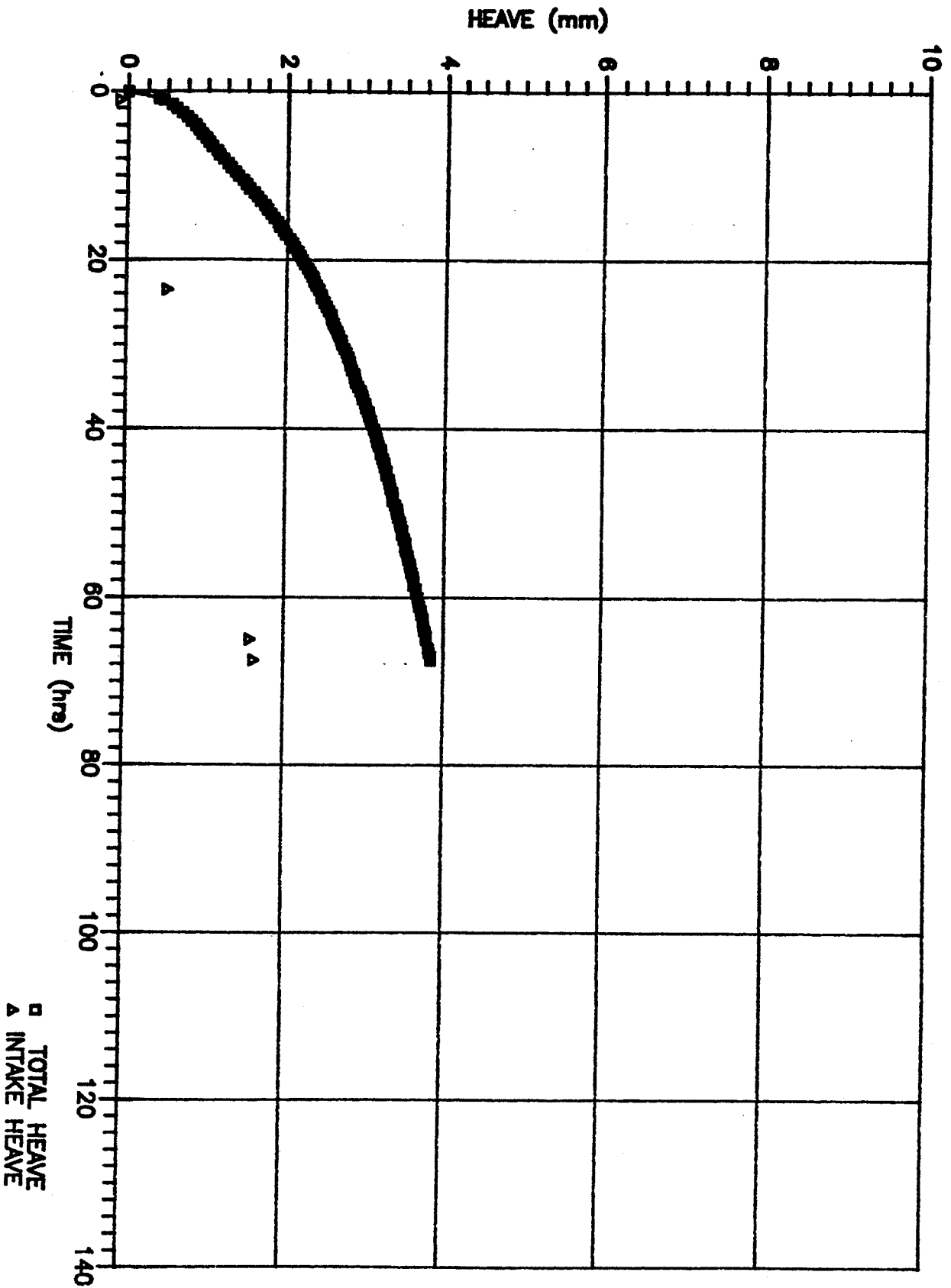


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S32

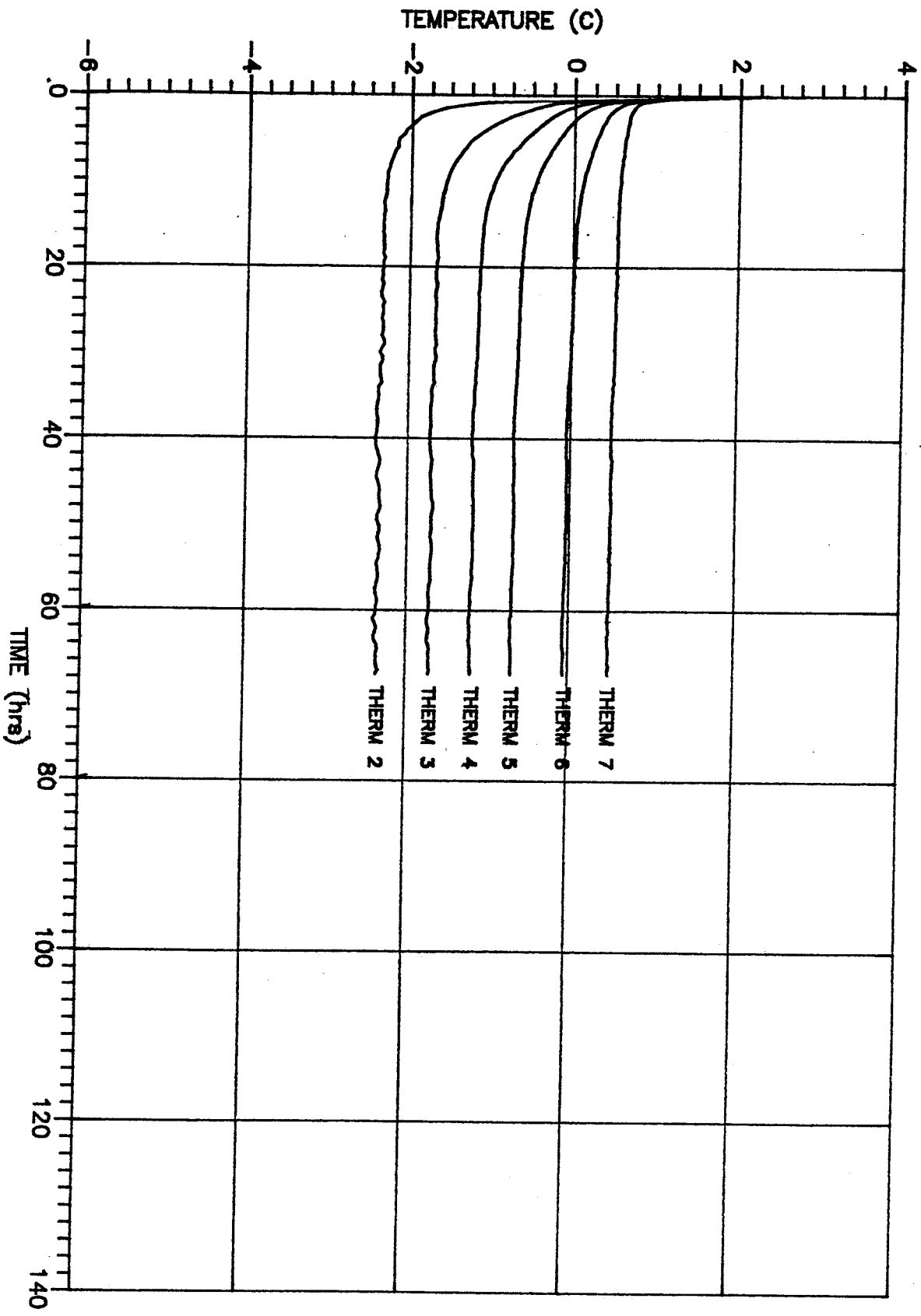
CONSOLIDATION TEST S40



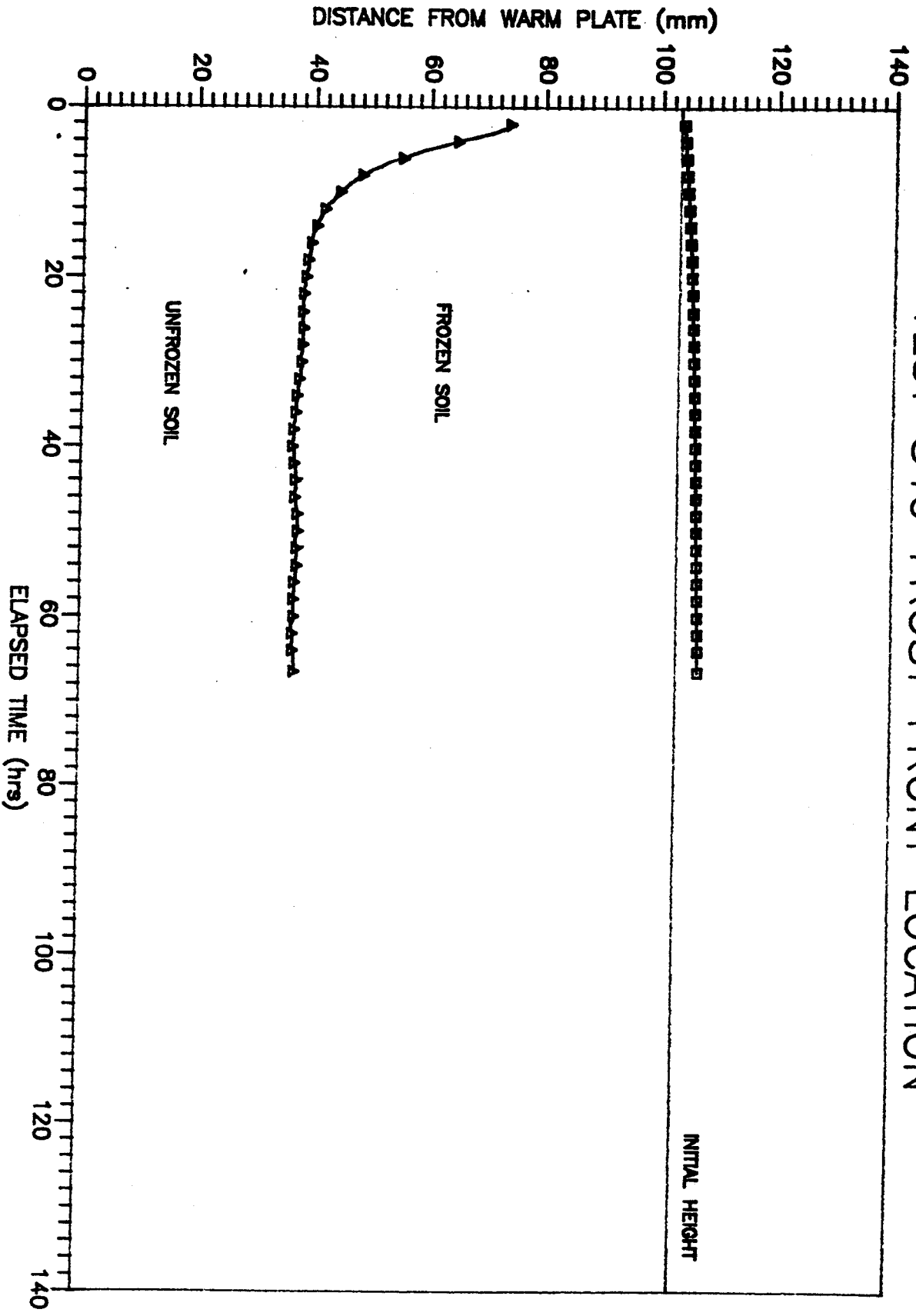
FREEZING TEST S40



FREEZING TEST S40

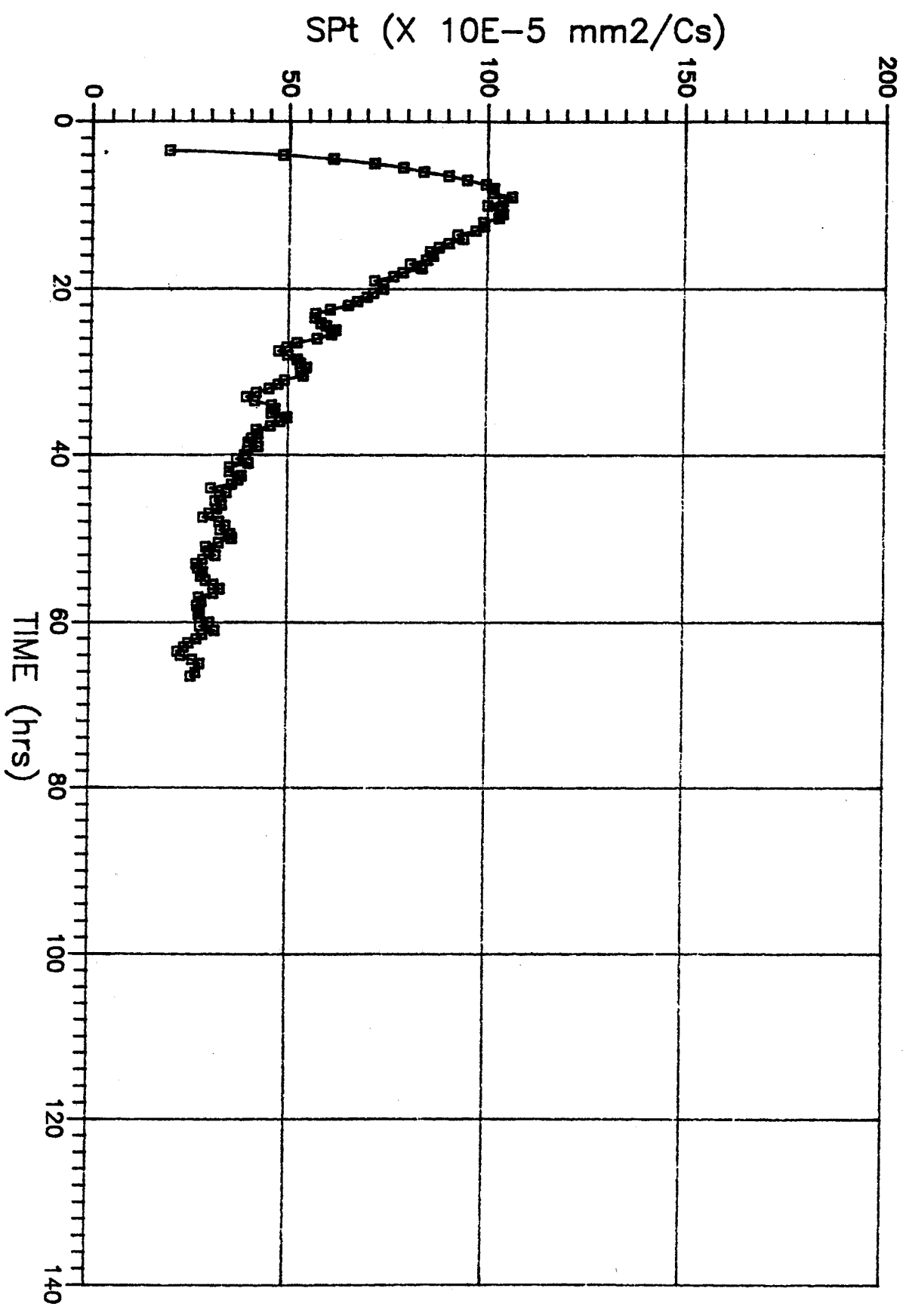


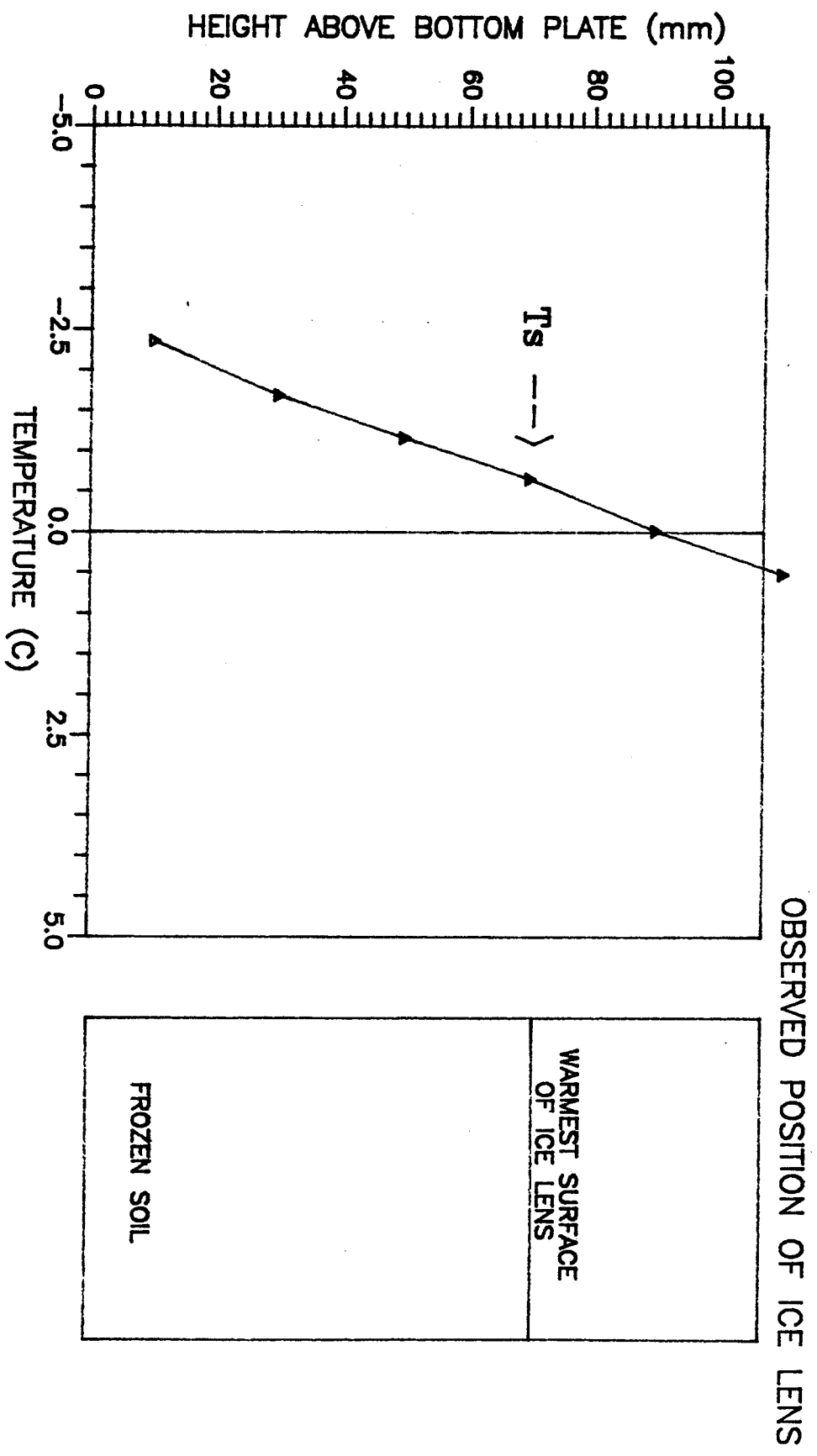
TEST S40 FROST FRONT LOCATION



□ HEAVE
△ T_f ISOTHERM

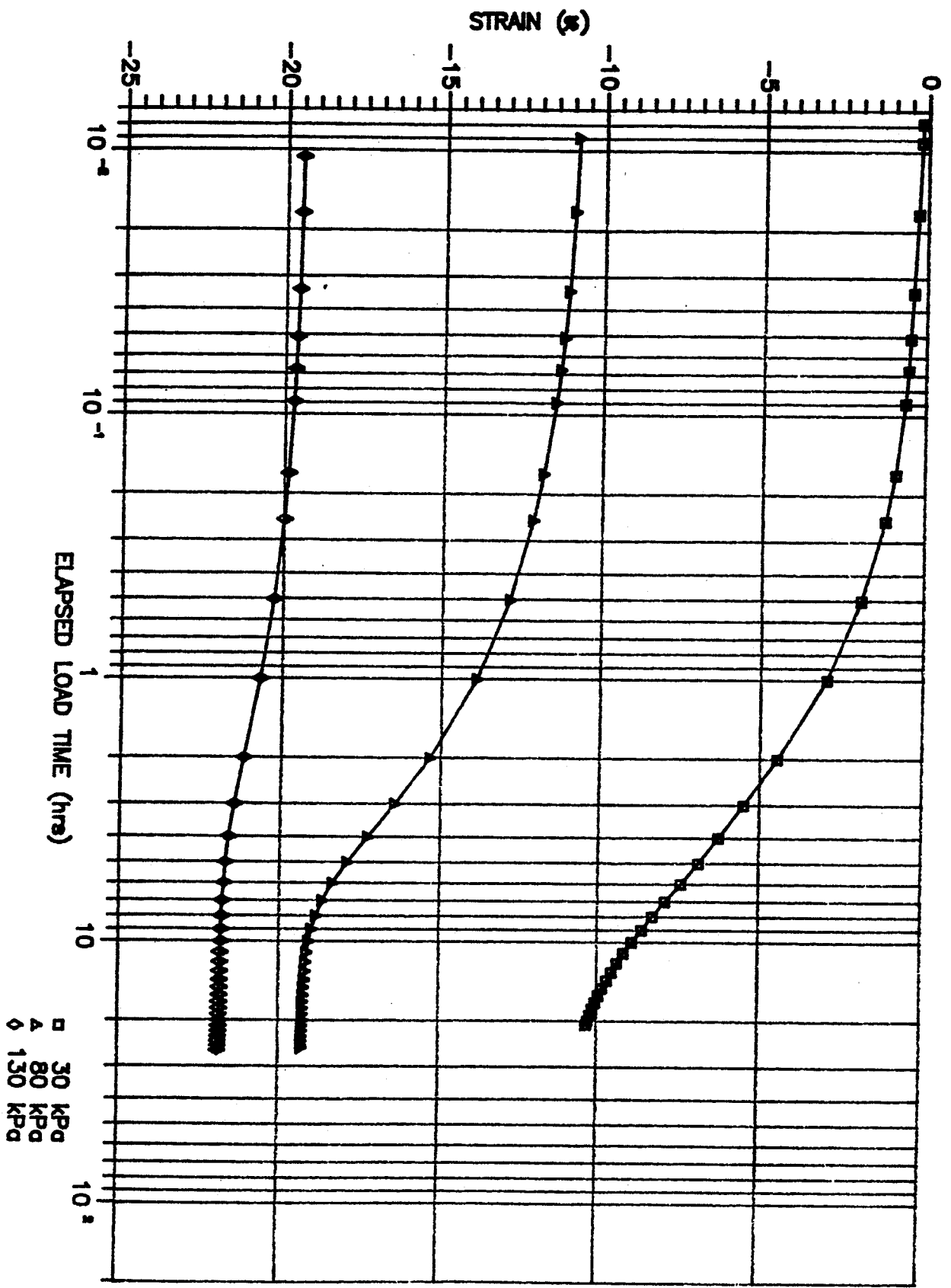
FREEZING TEST S40



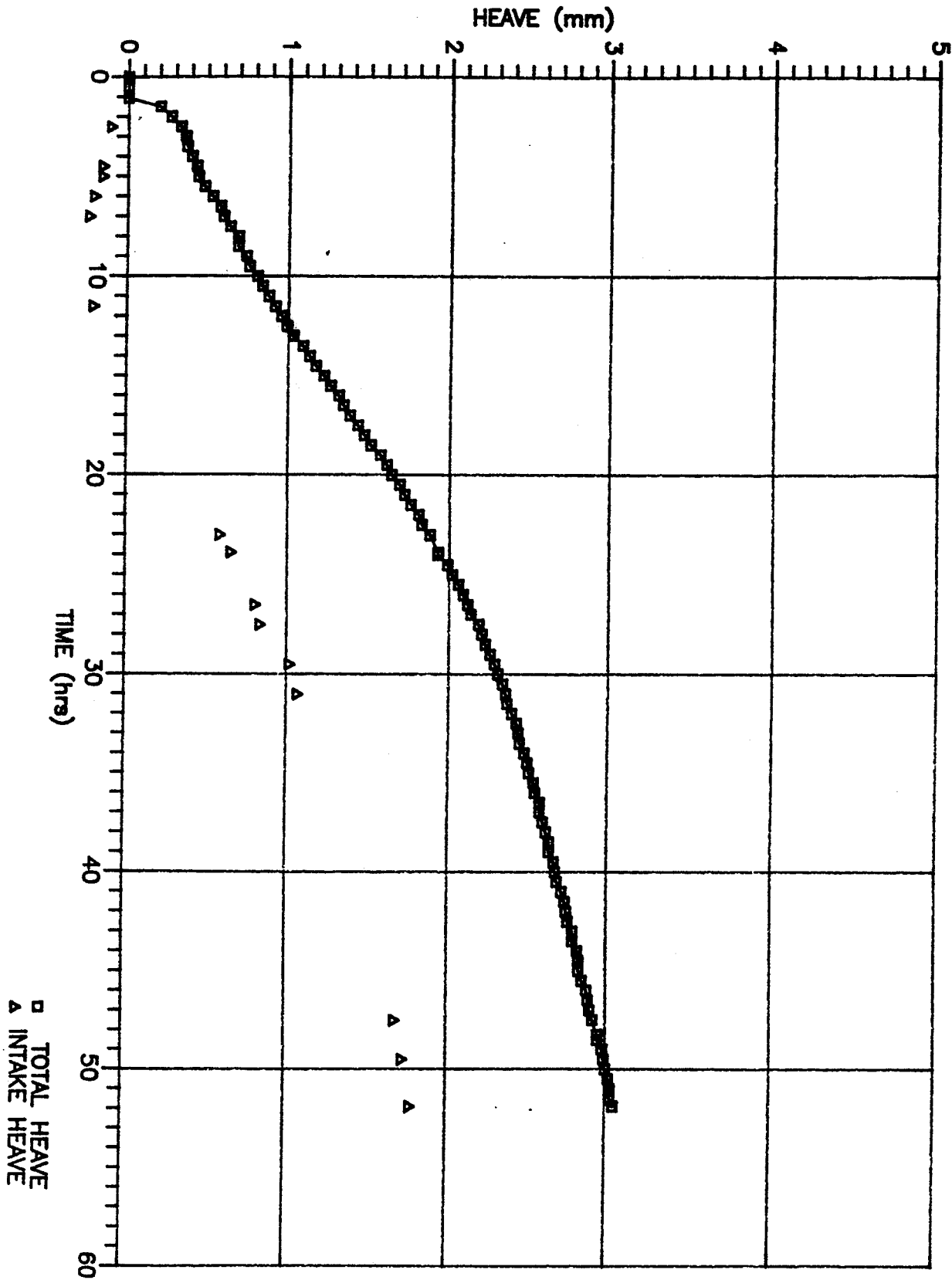


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S40

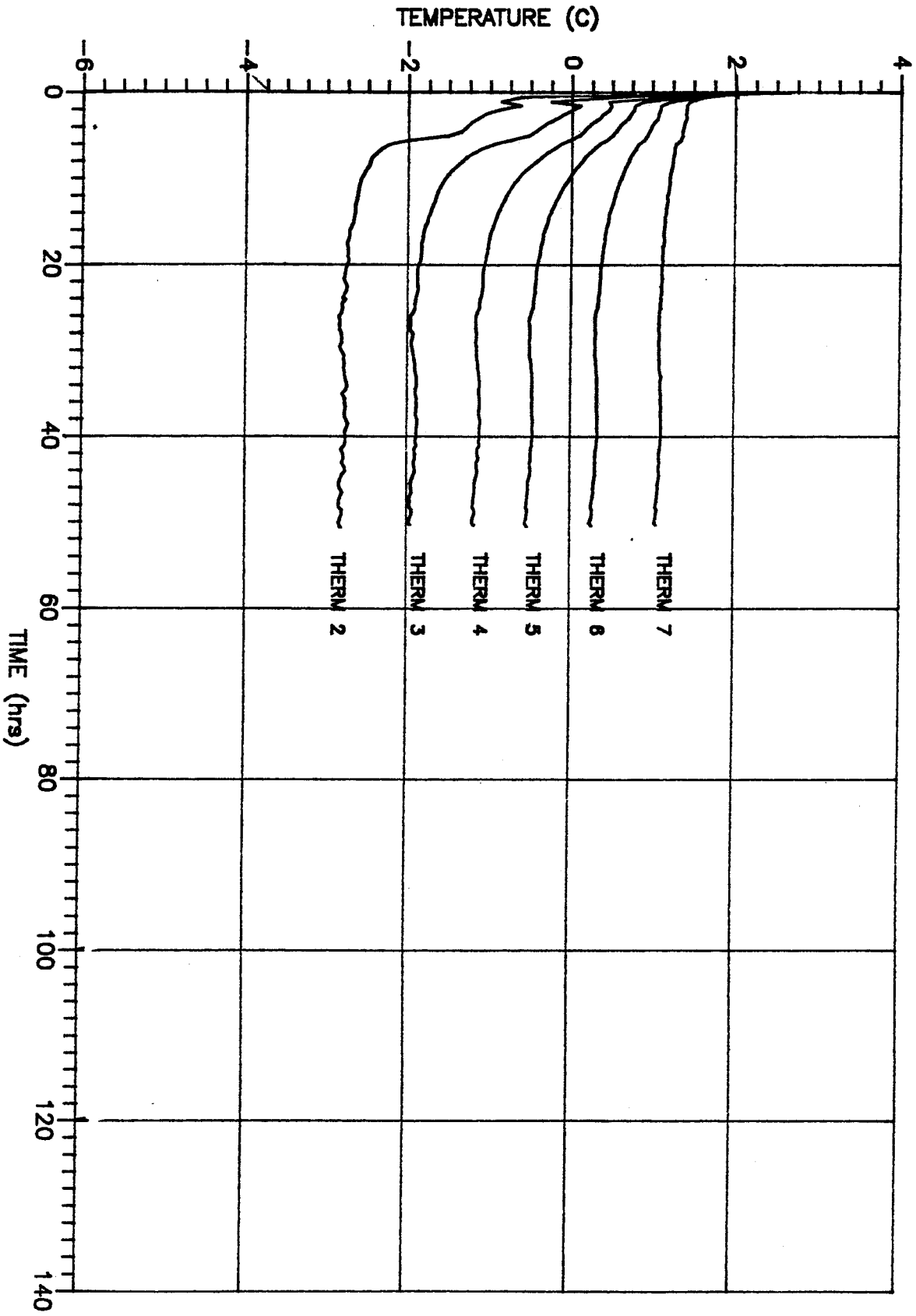
CONSOLIDATION TEST S41



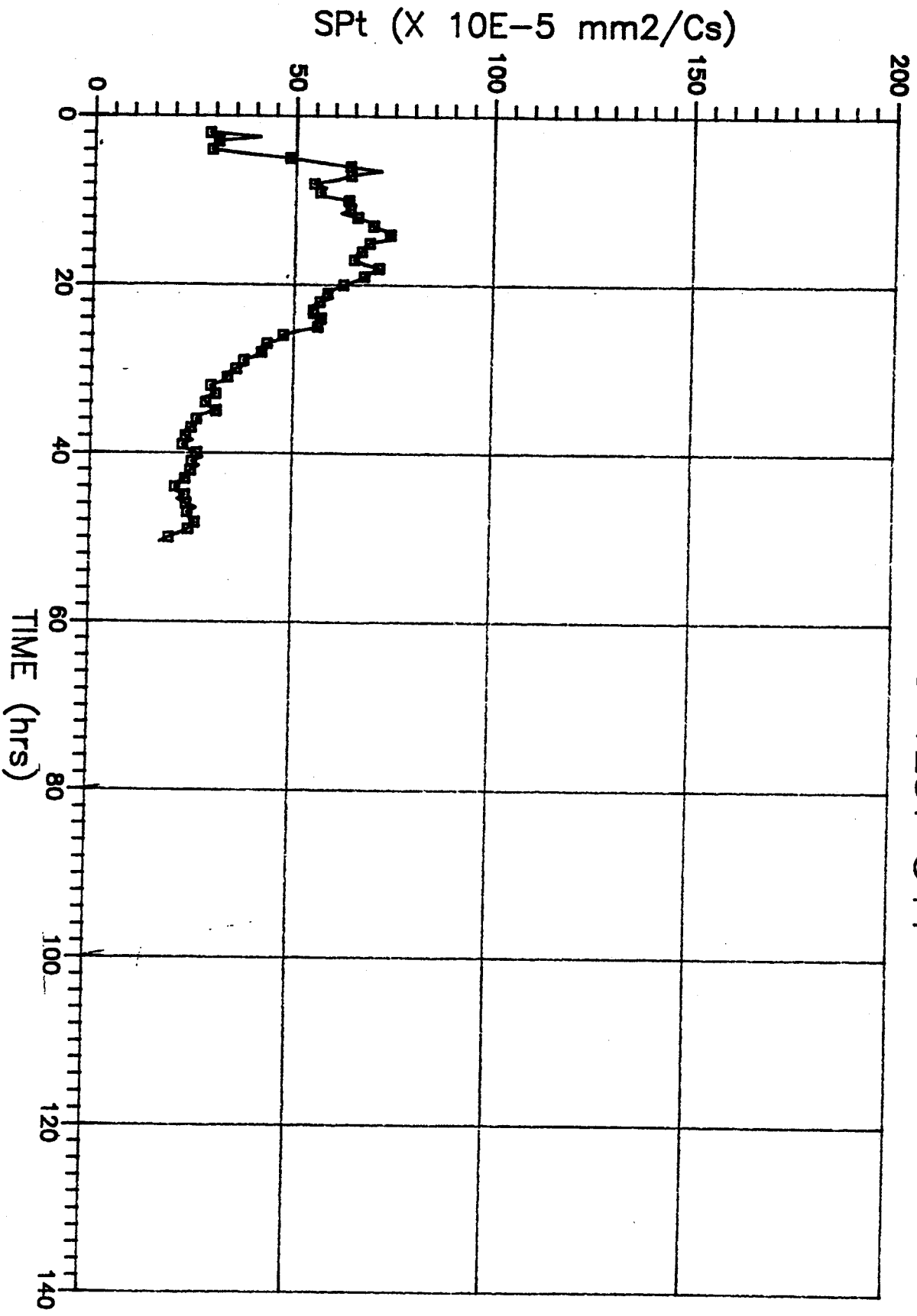
FREEZING TEST S41



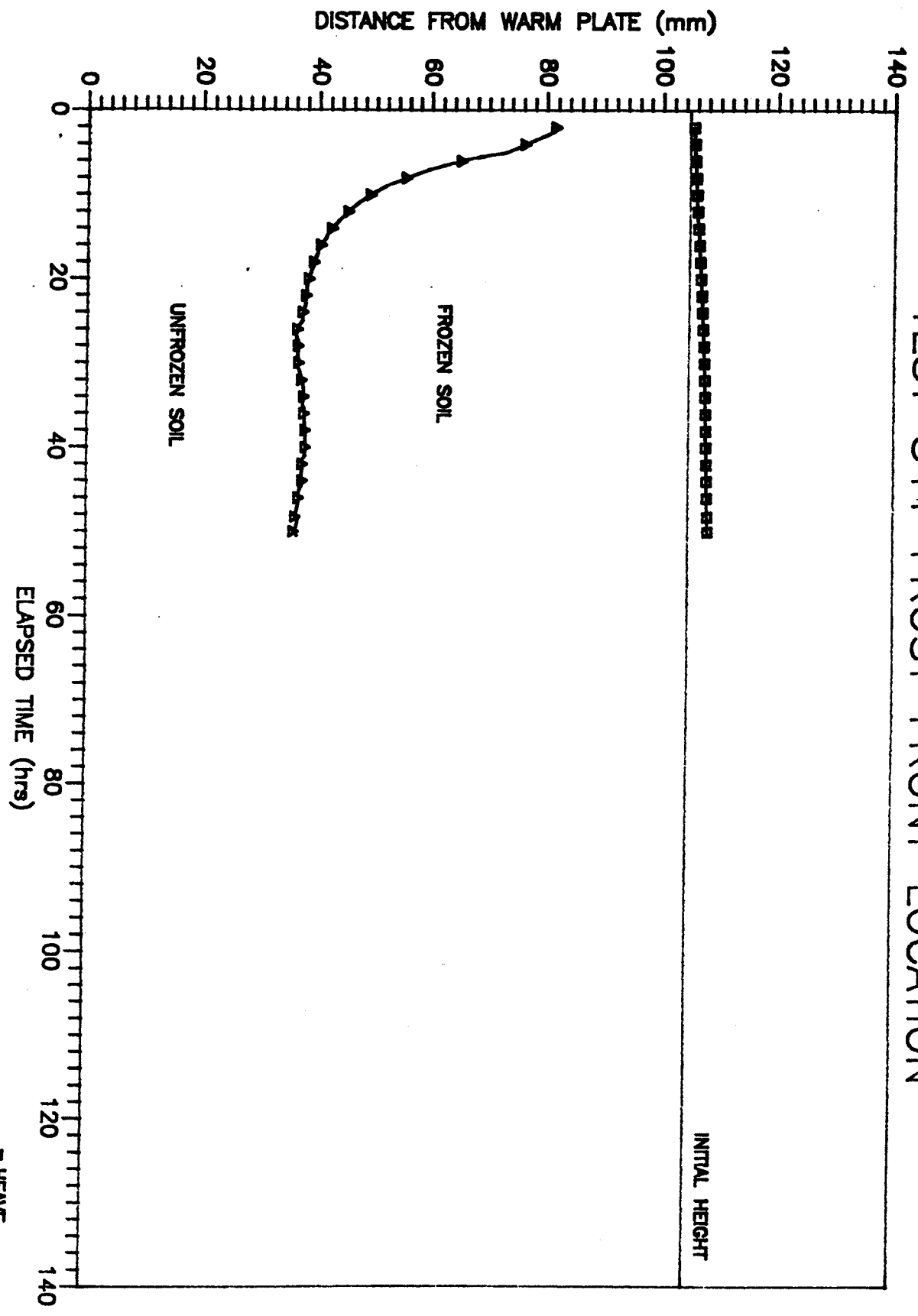
FREEZING TEST S41



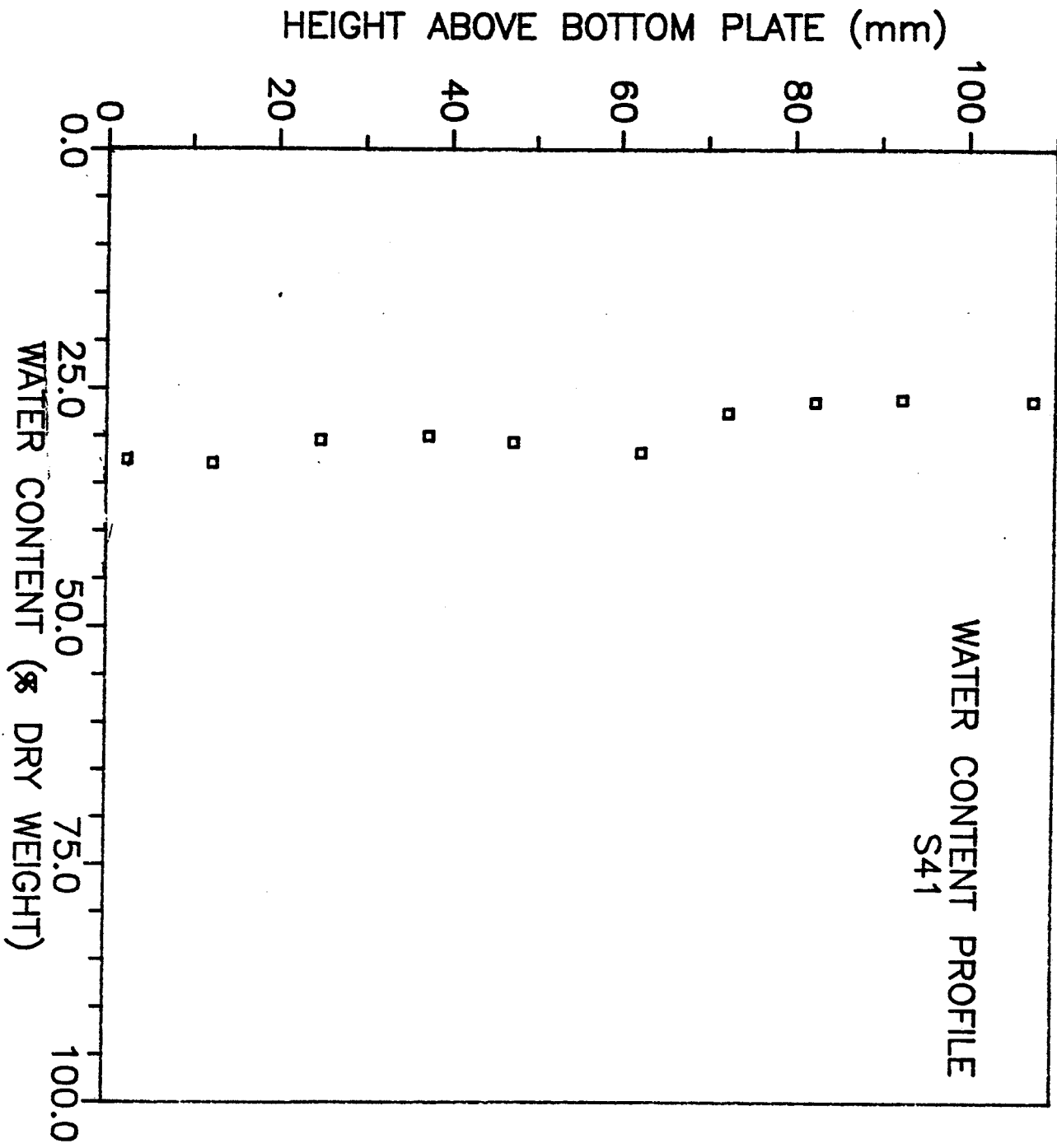
FREEZING TEST S41



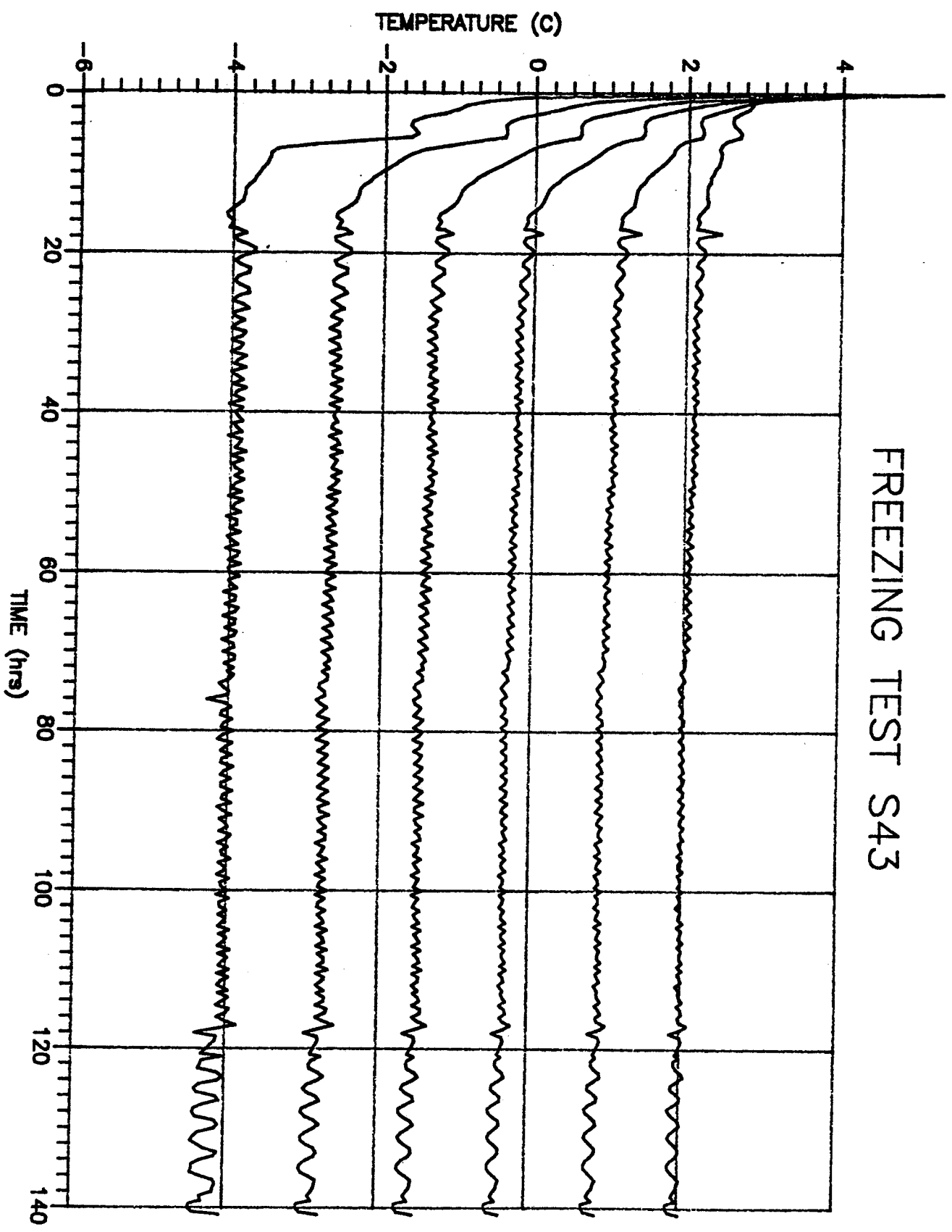
TEST S41 FROST FRONT LOCATION



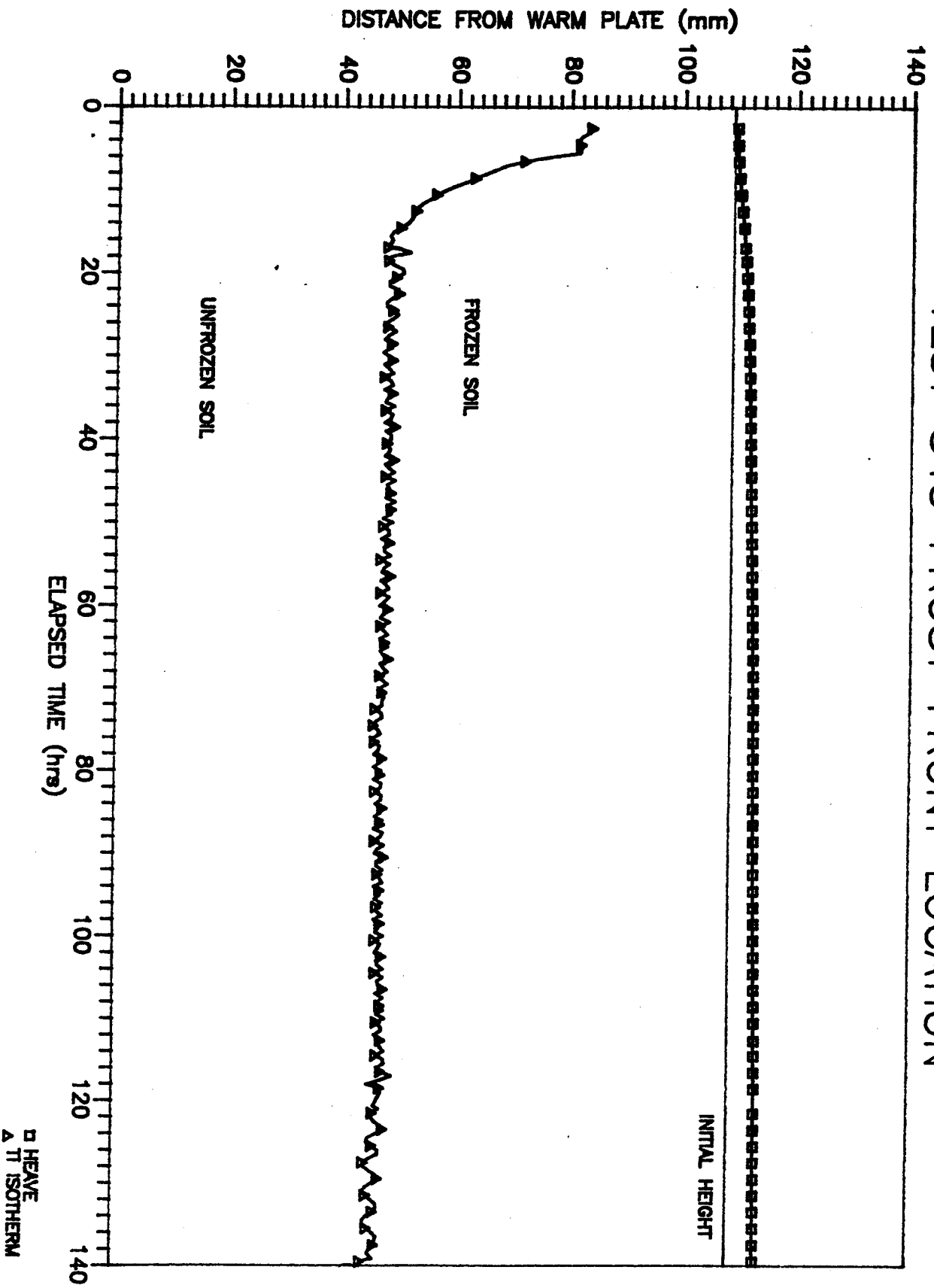
□ HEAVE
△ T T ISOTHERM



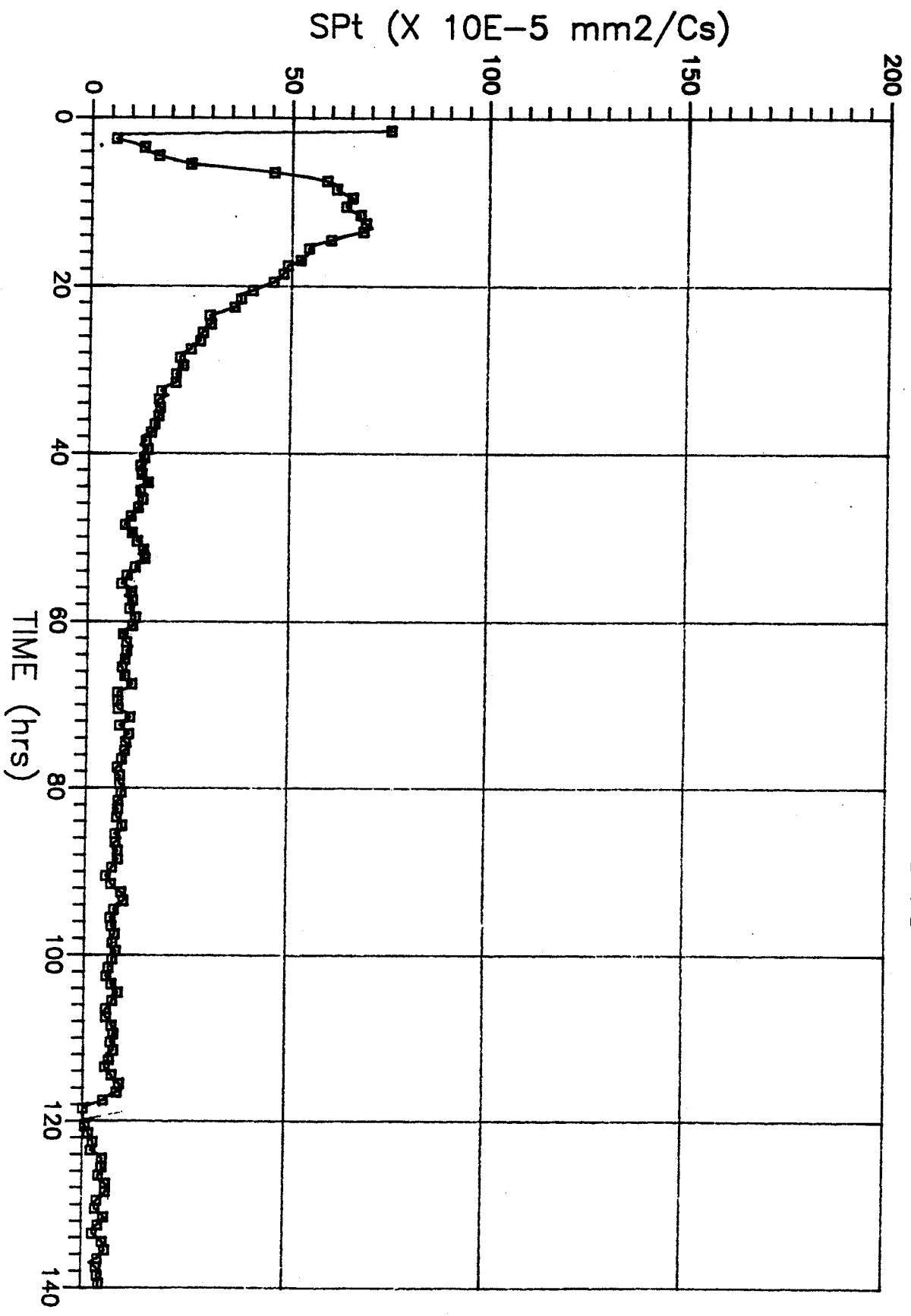
FREEZING TEST S43

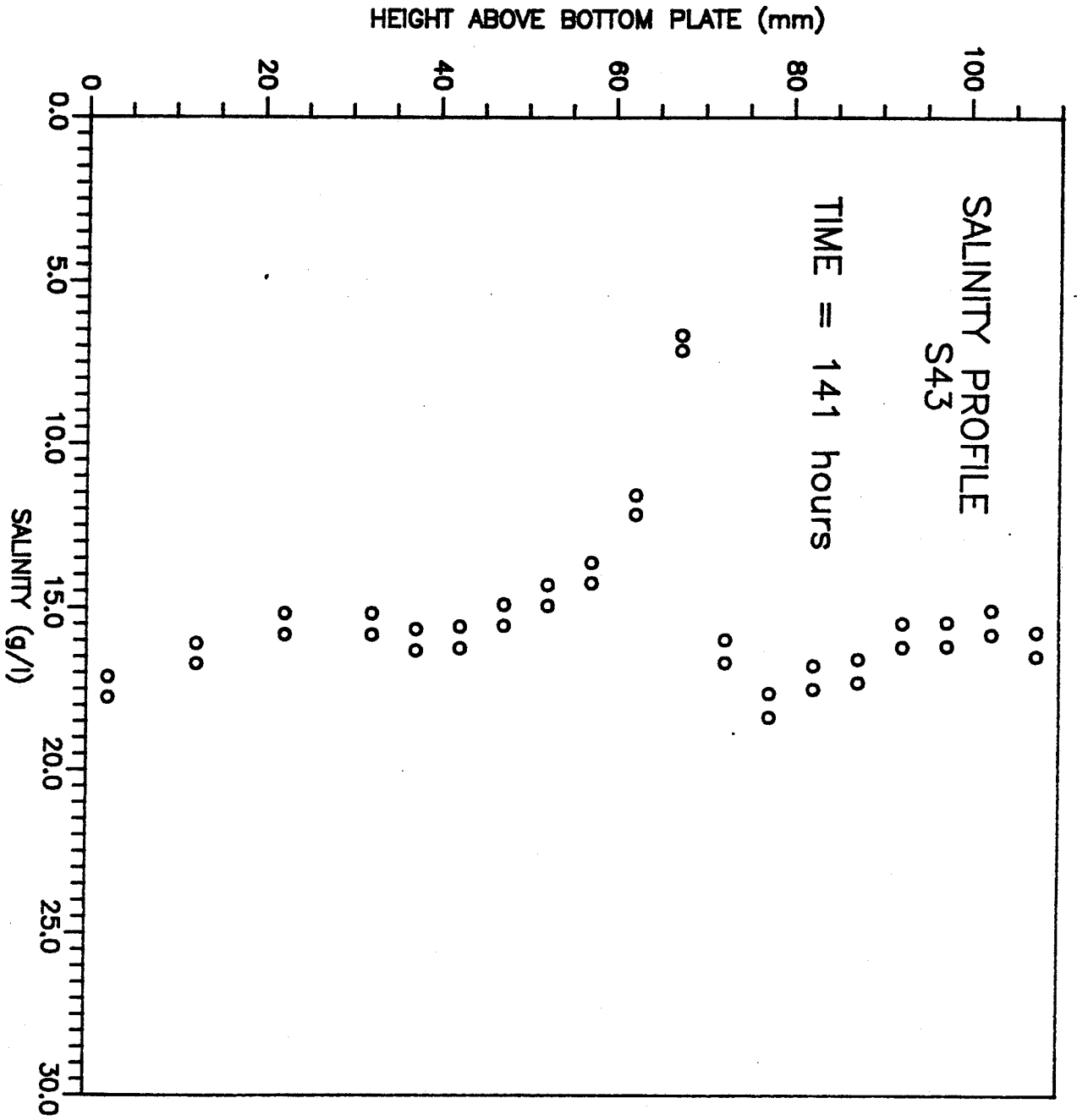


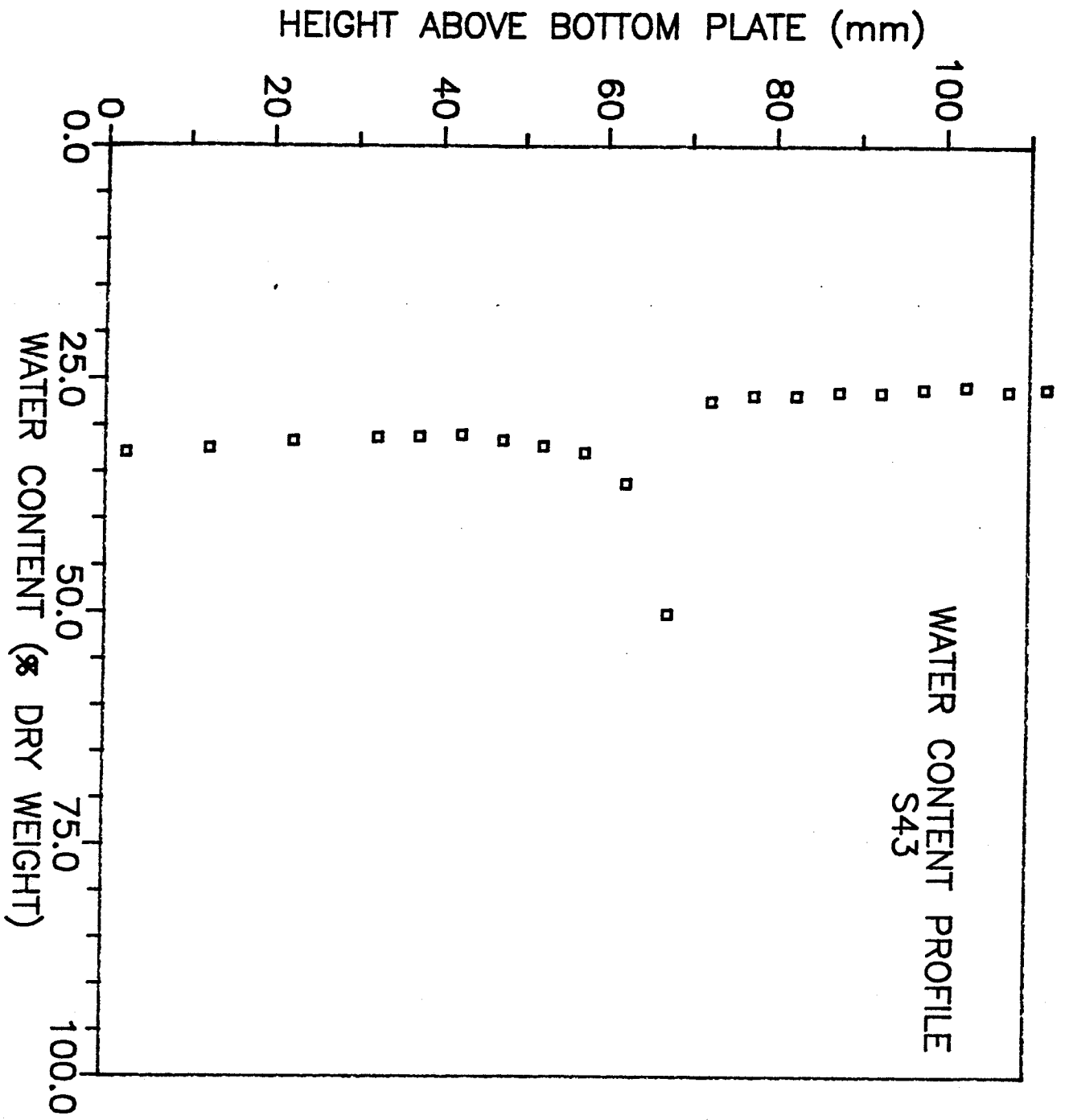
TEST S43 FROST FRONT LOCATION

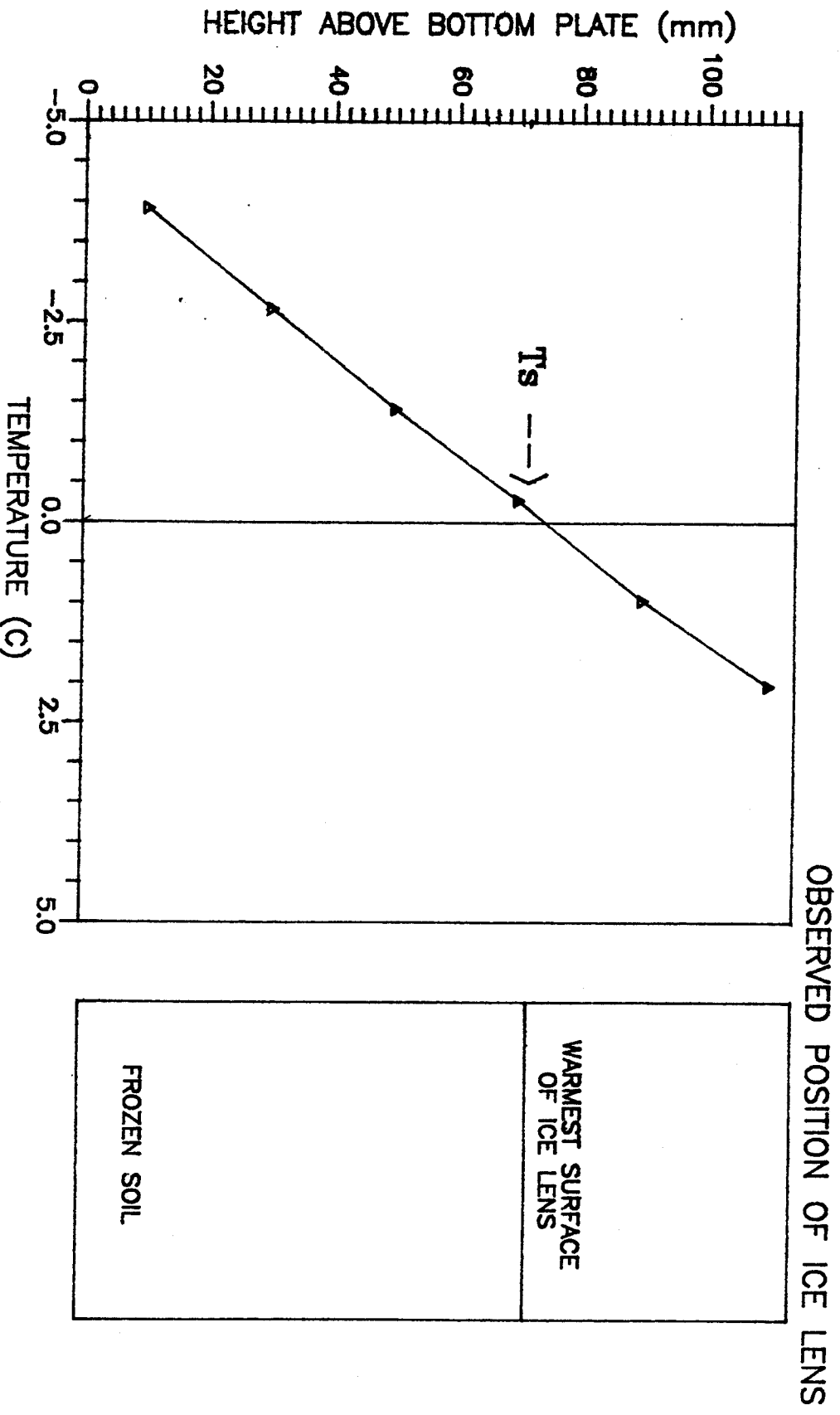


FREEZING TEST S43



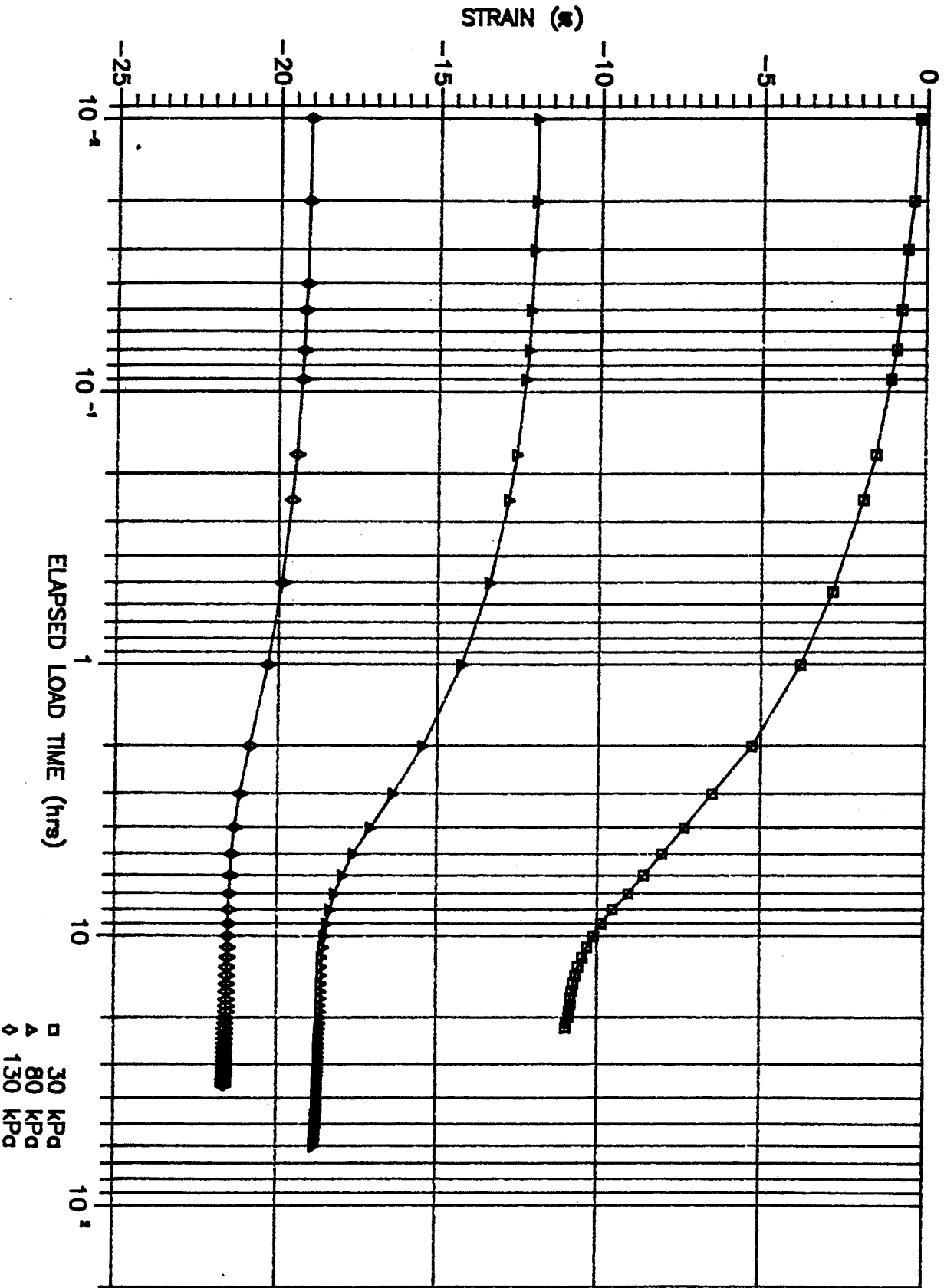




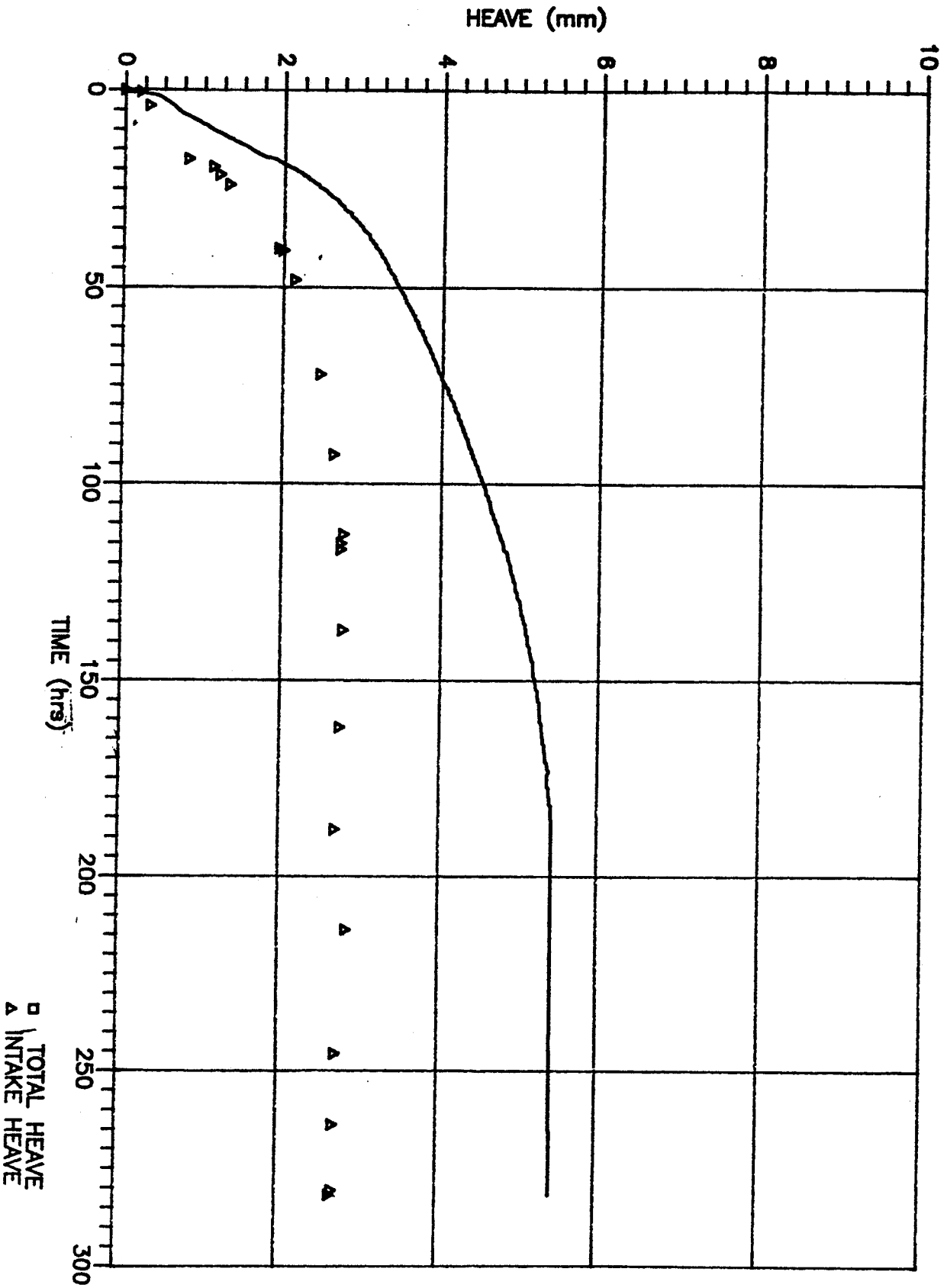


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS -- S43

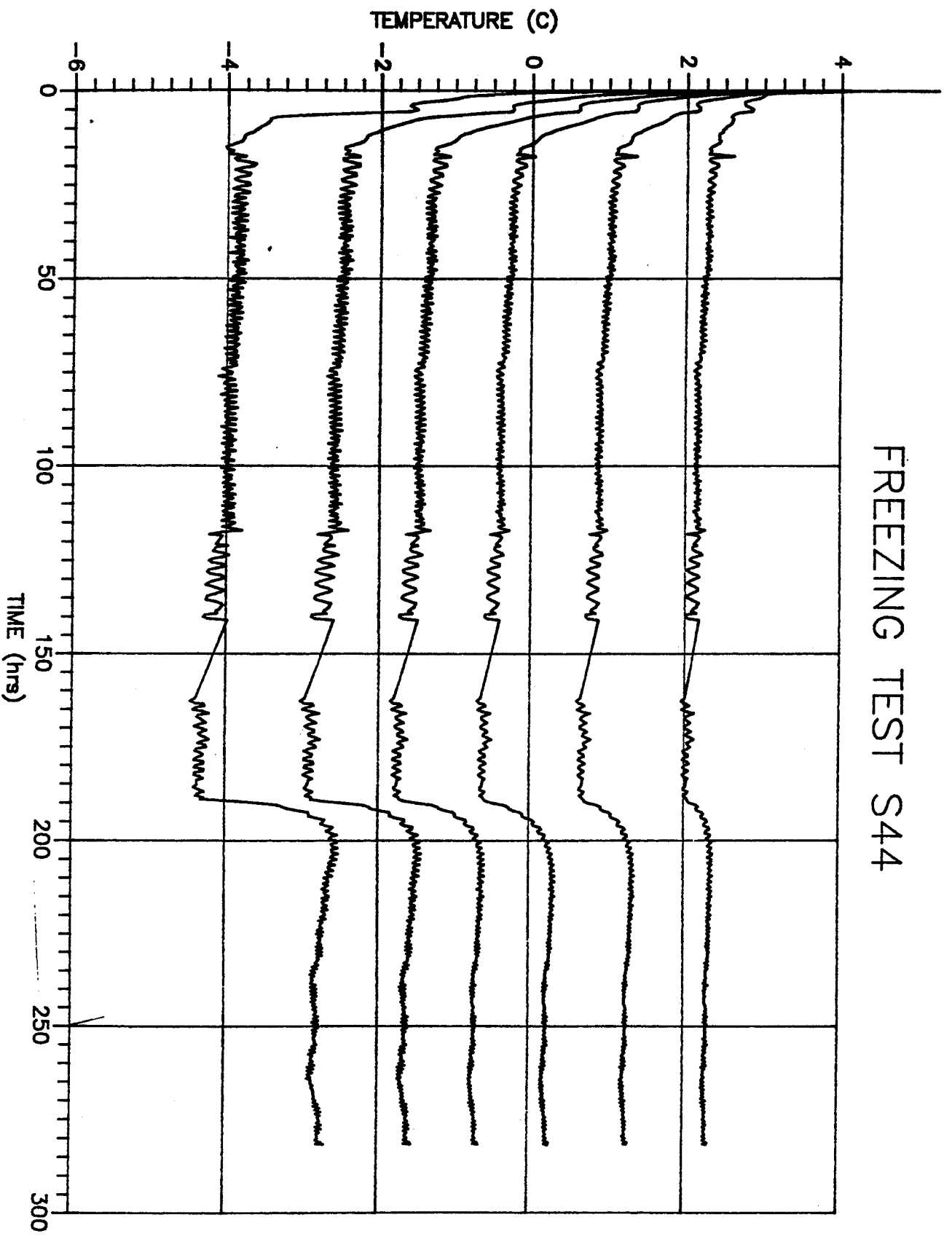
CONSOLIDATION TEST S44



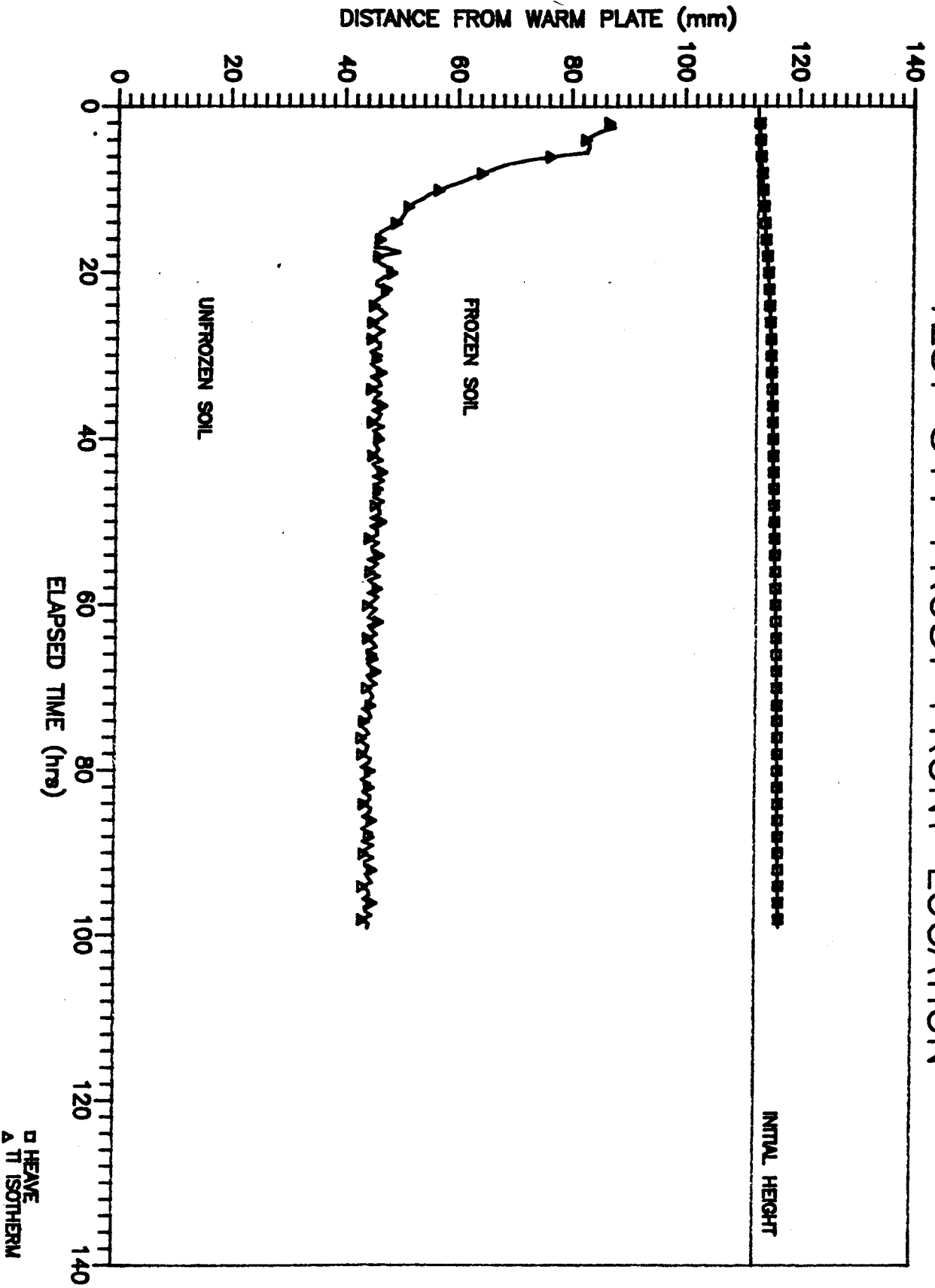
FREEZING TEST S44



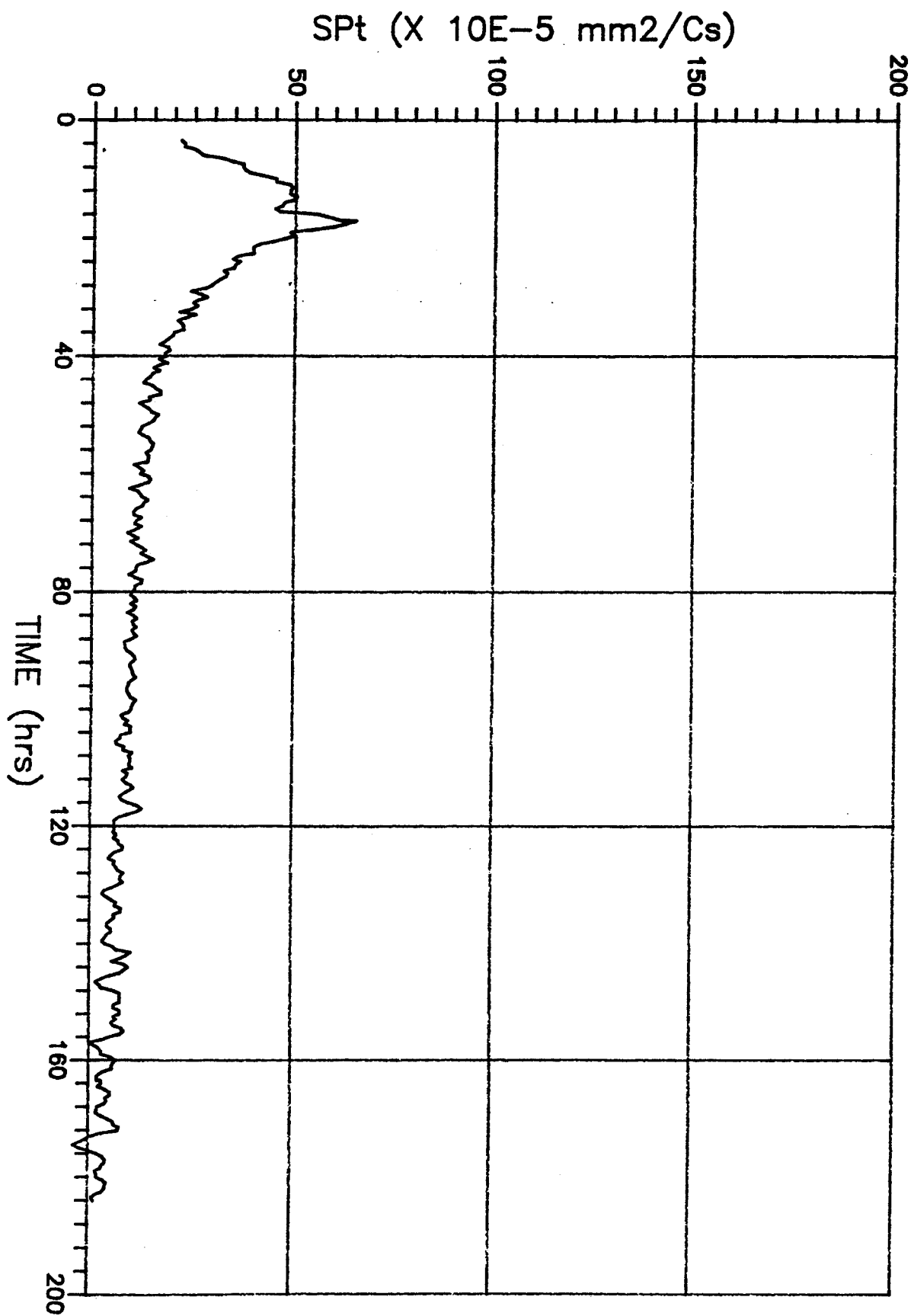
FREEZING TEST S44

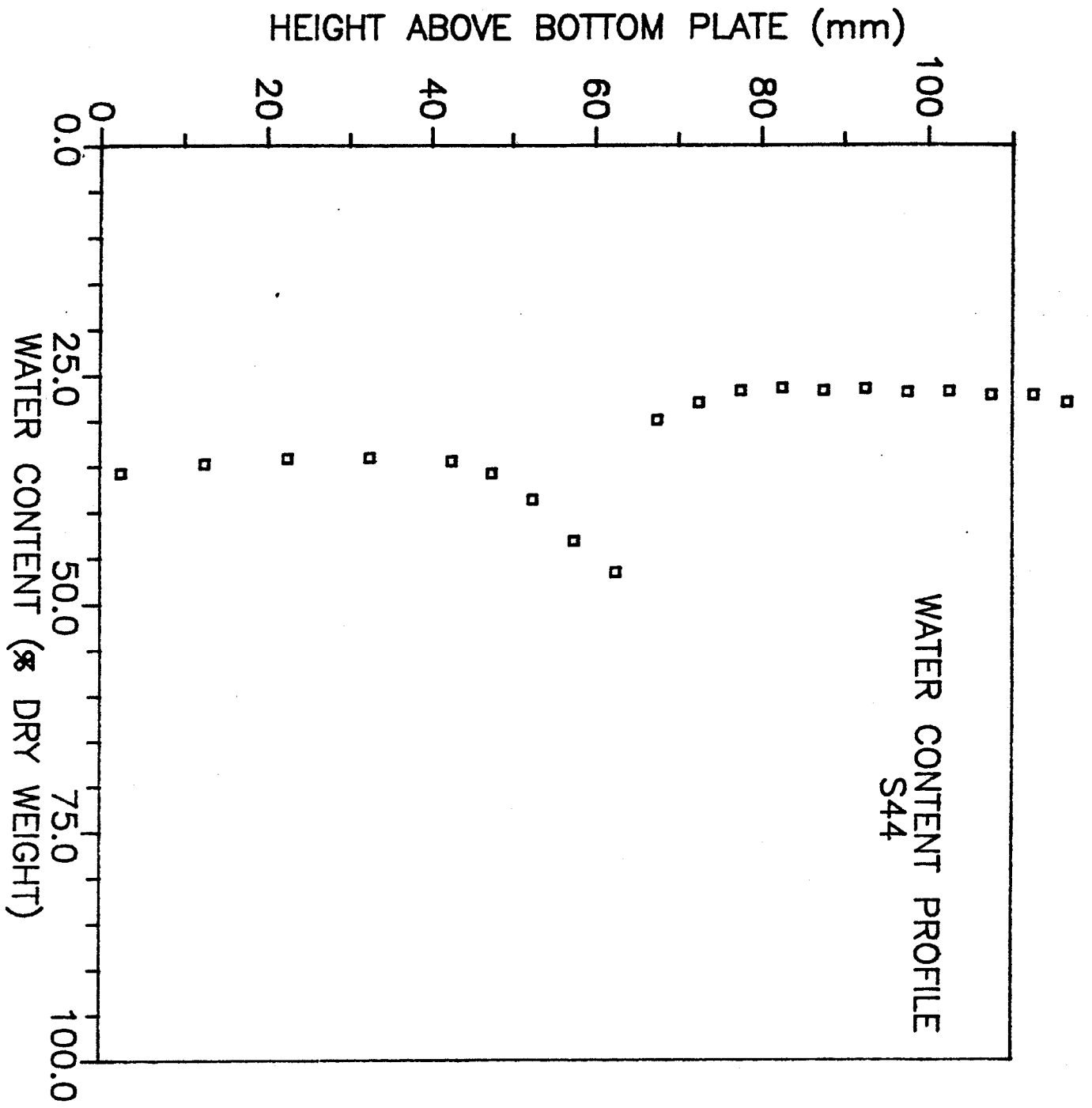


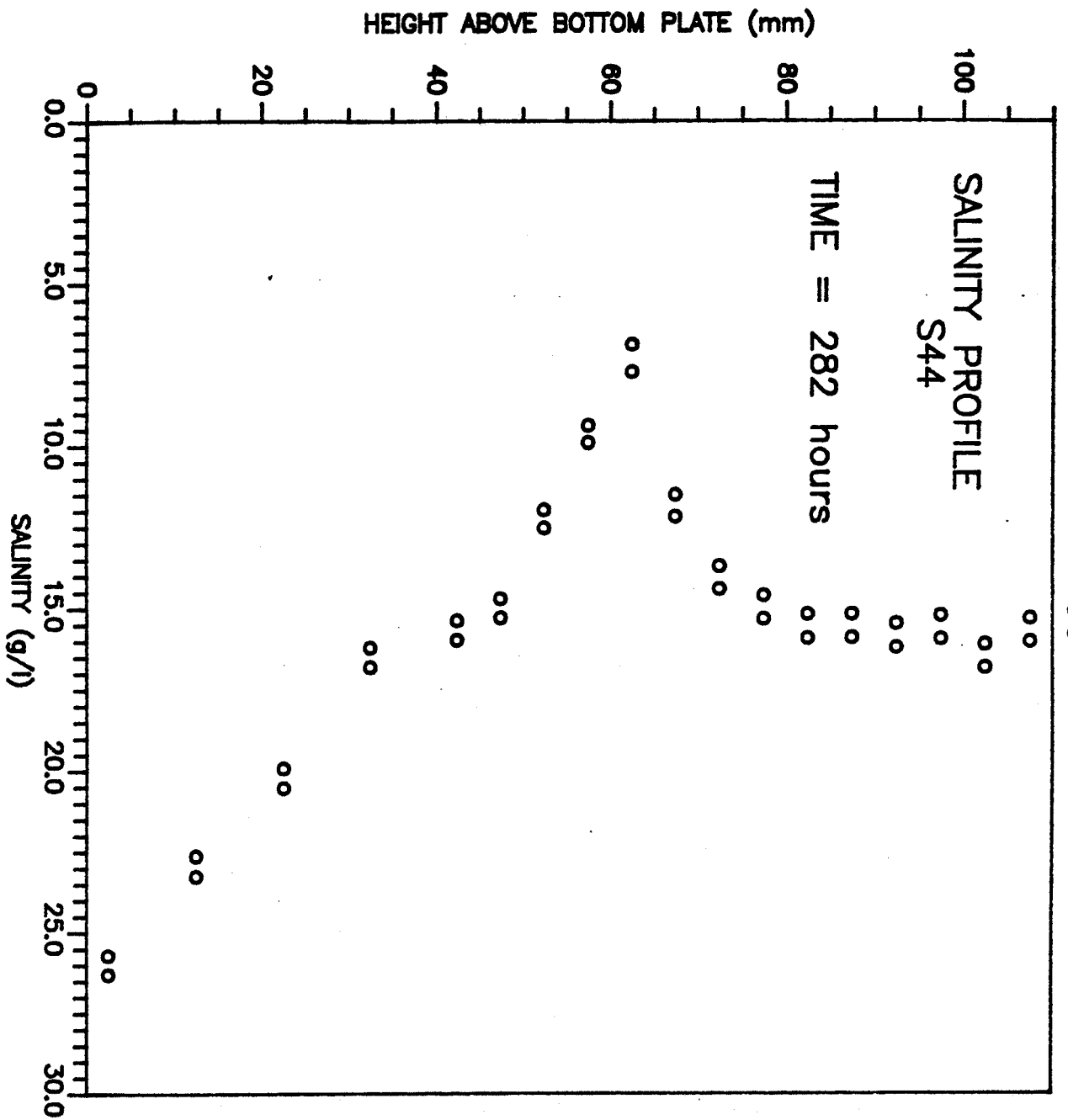
TEST S44 FROST FRONT LOCATION

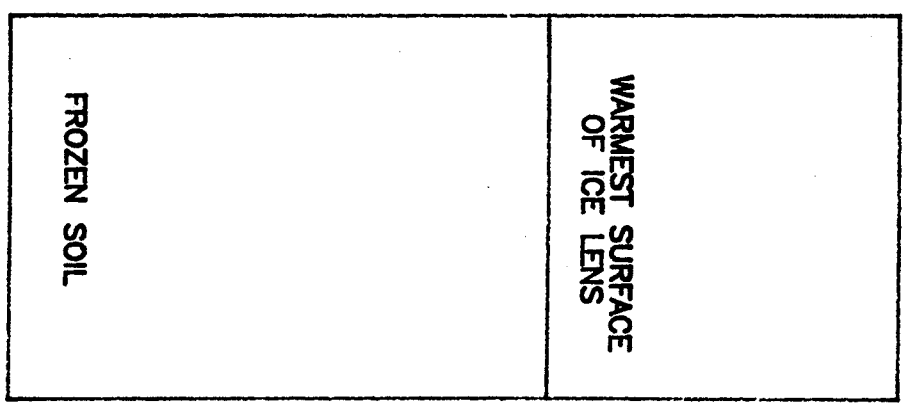
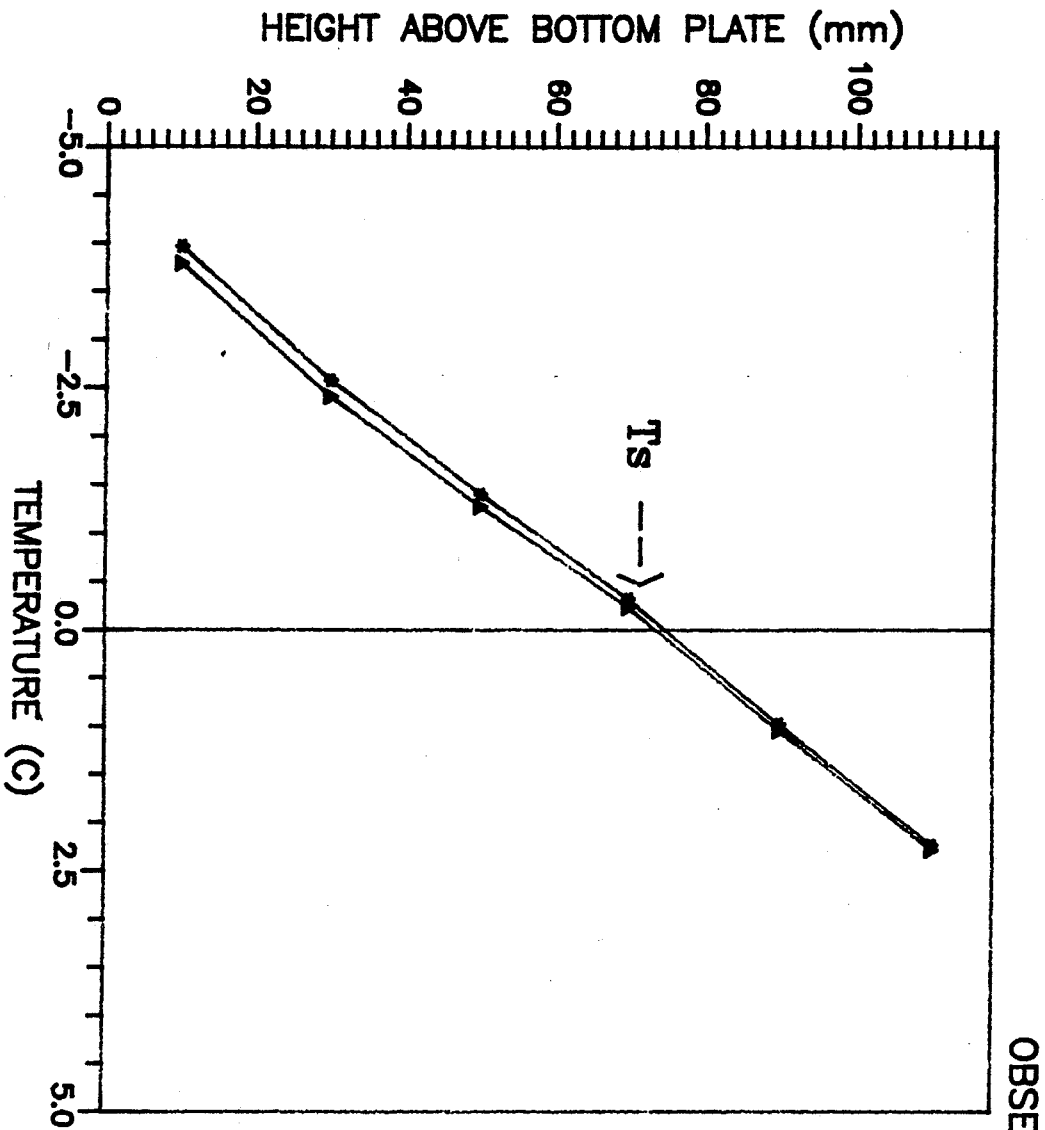


FREEZING TEST S44



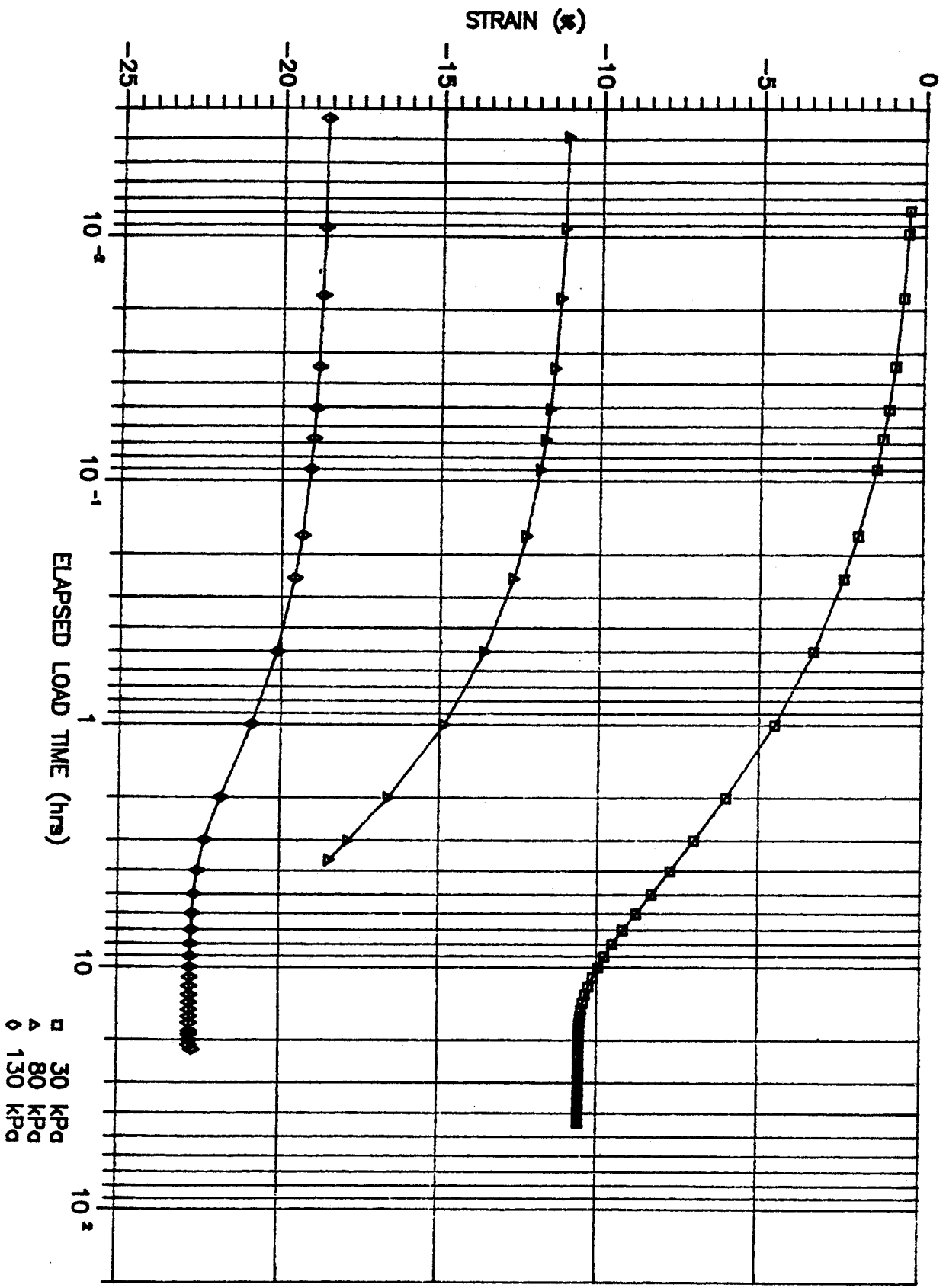




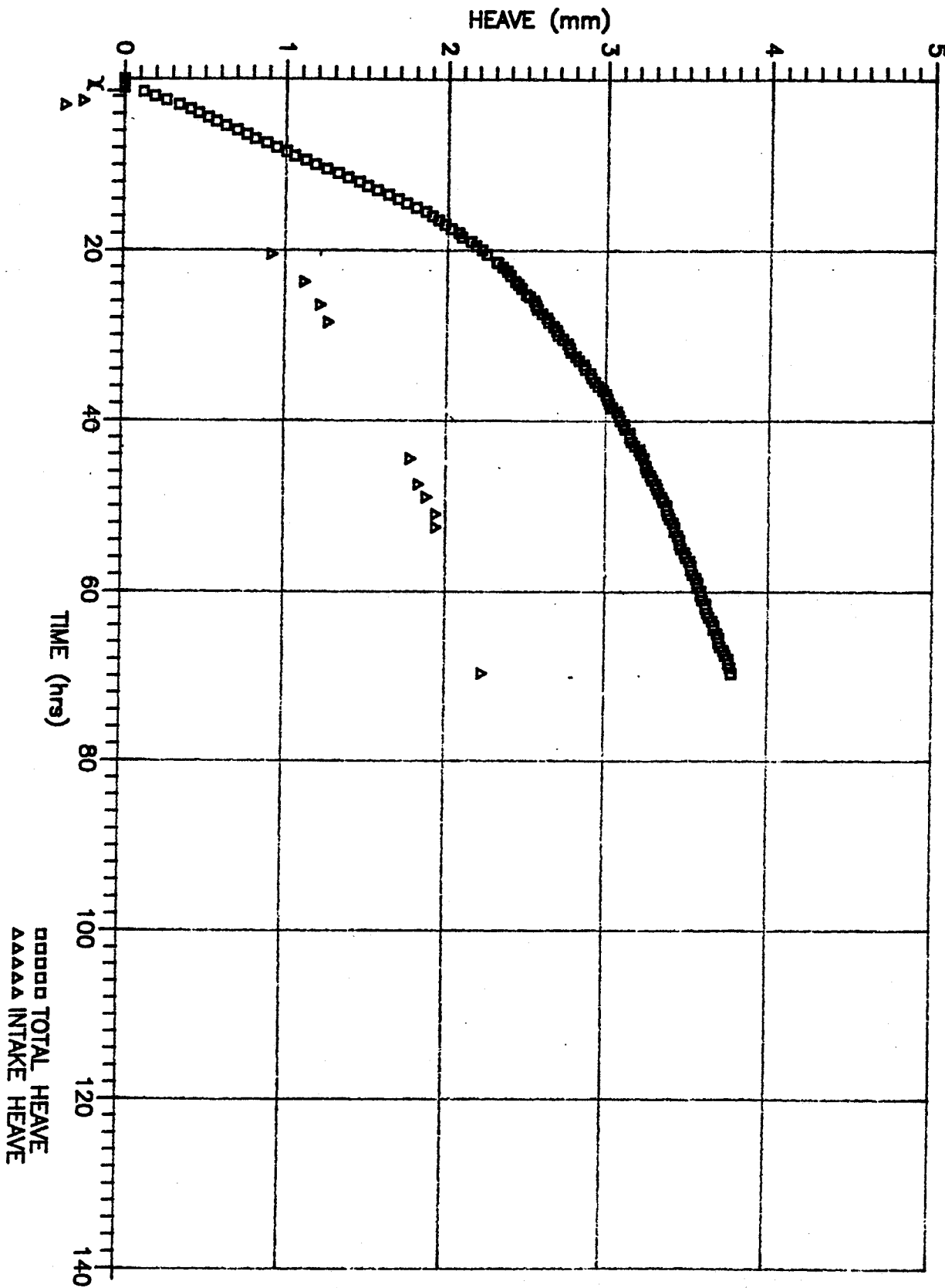


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S44

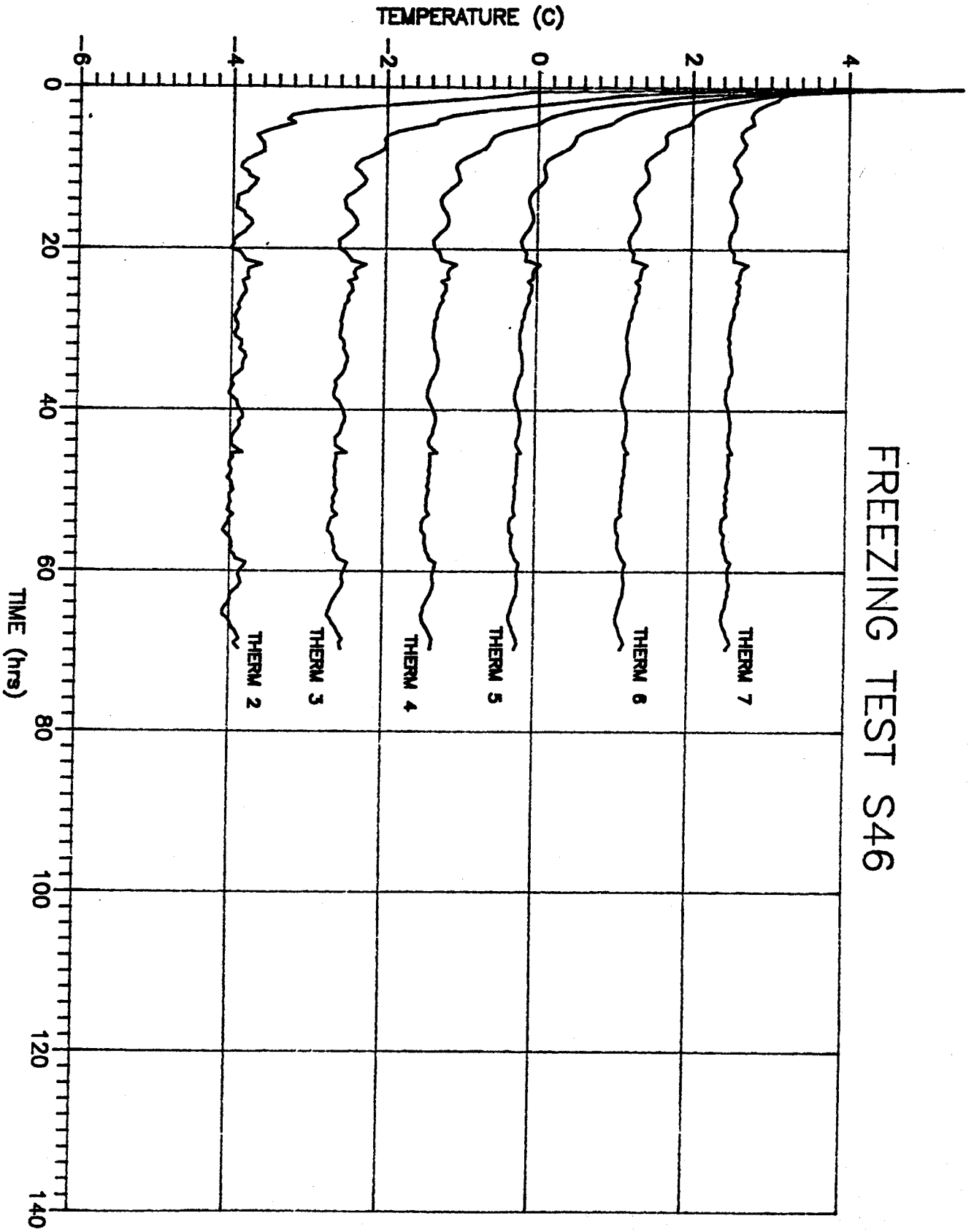
CONSOLIDATION TEST S46



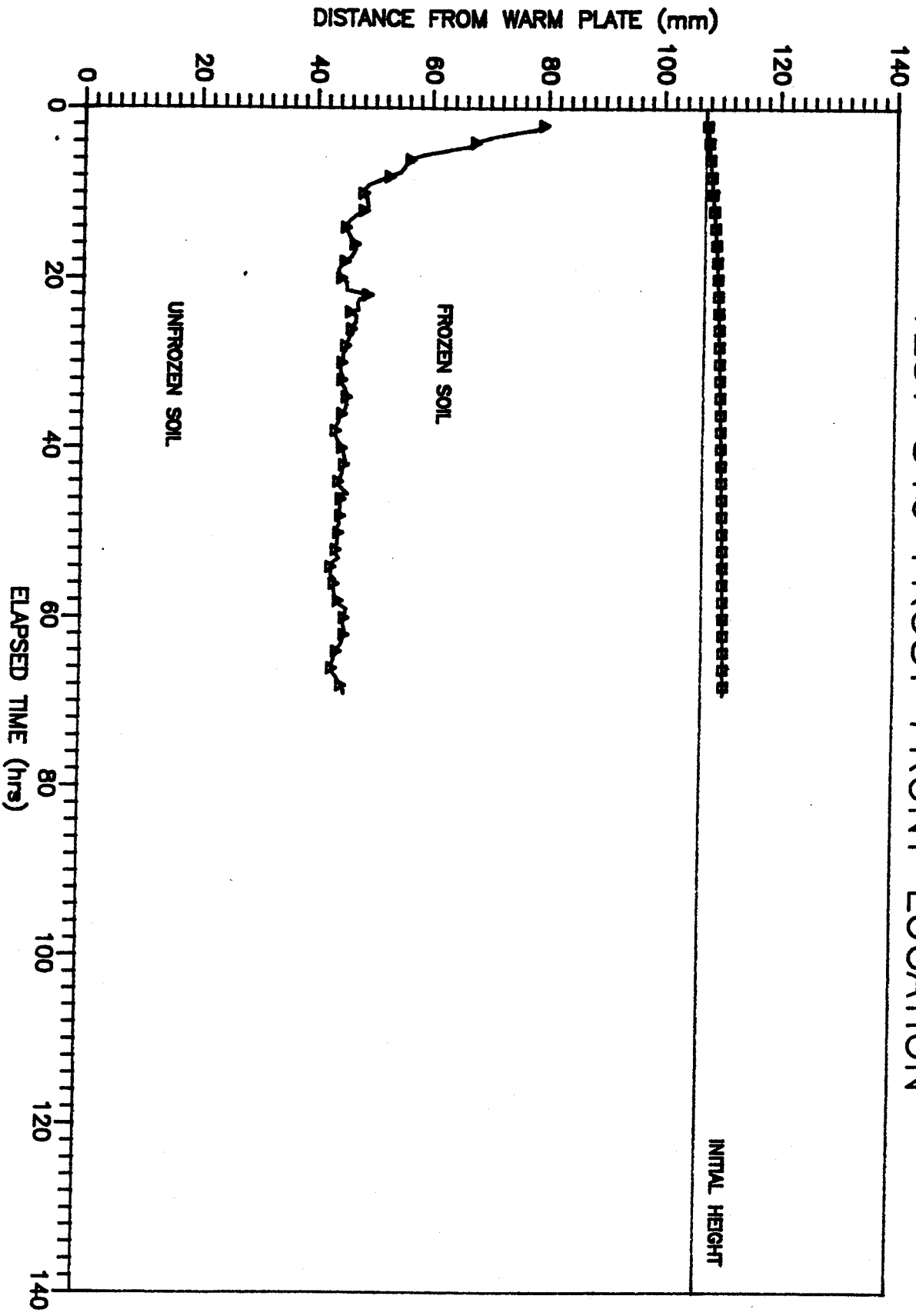
FREEZING TEST S46



FREEZING TEST S46

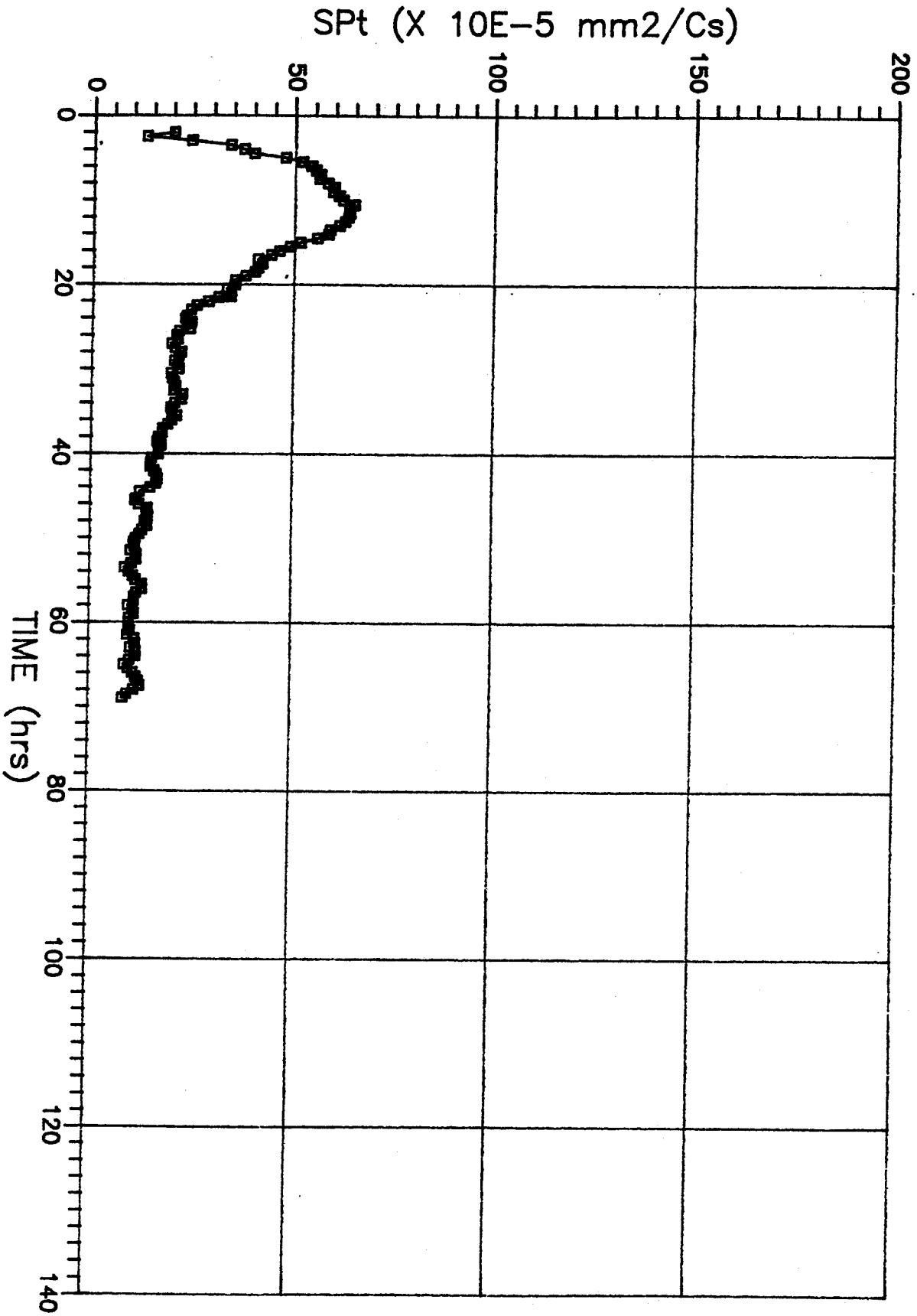


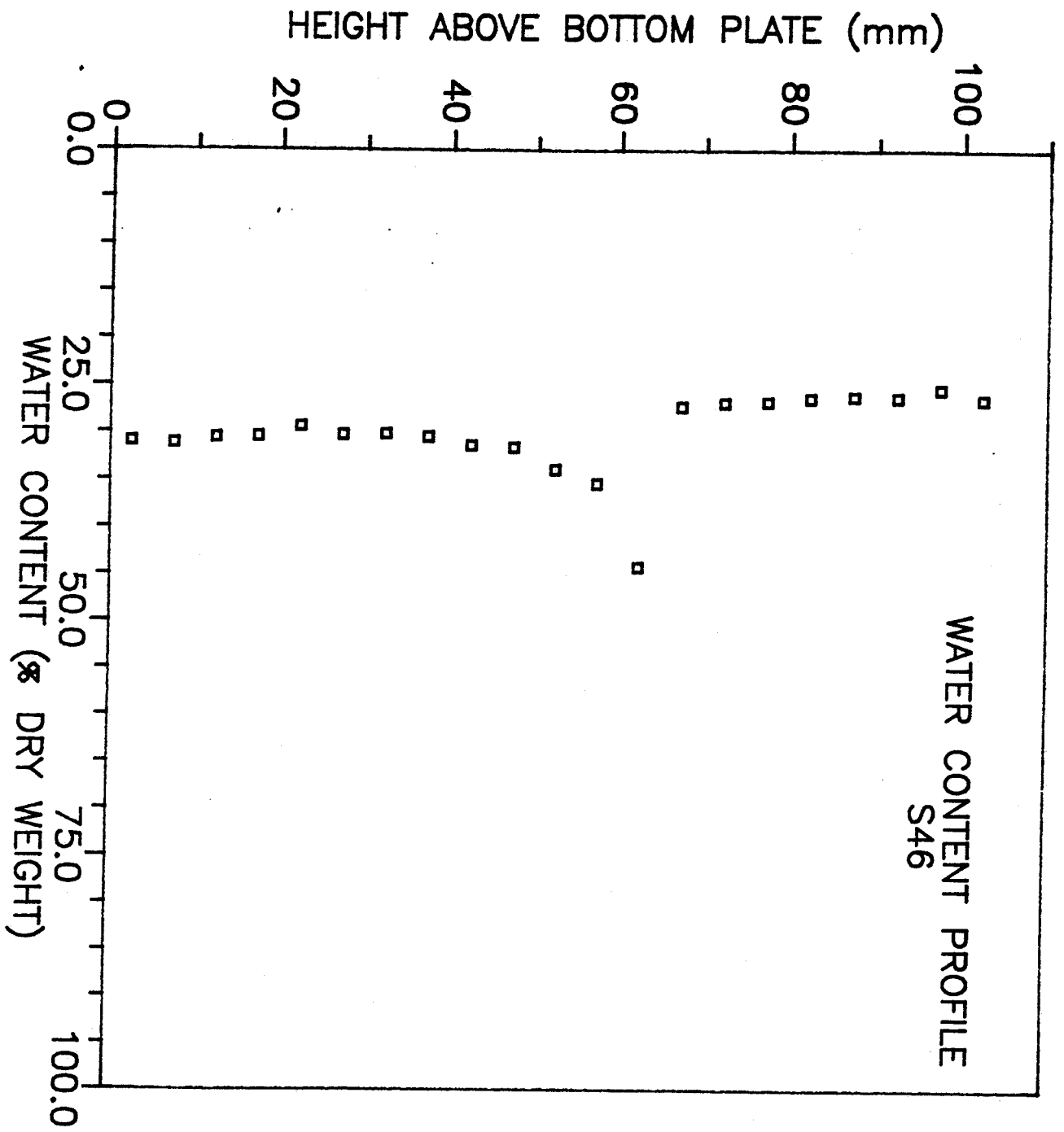
TEST S46 FROST FRONT LOCATION

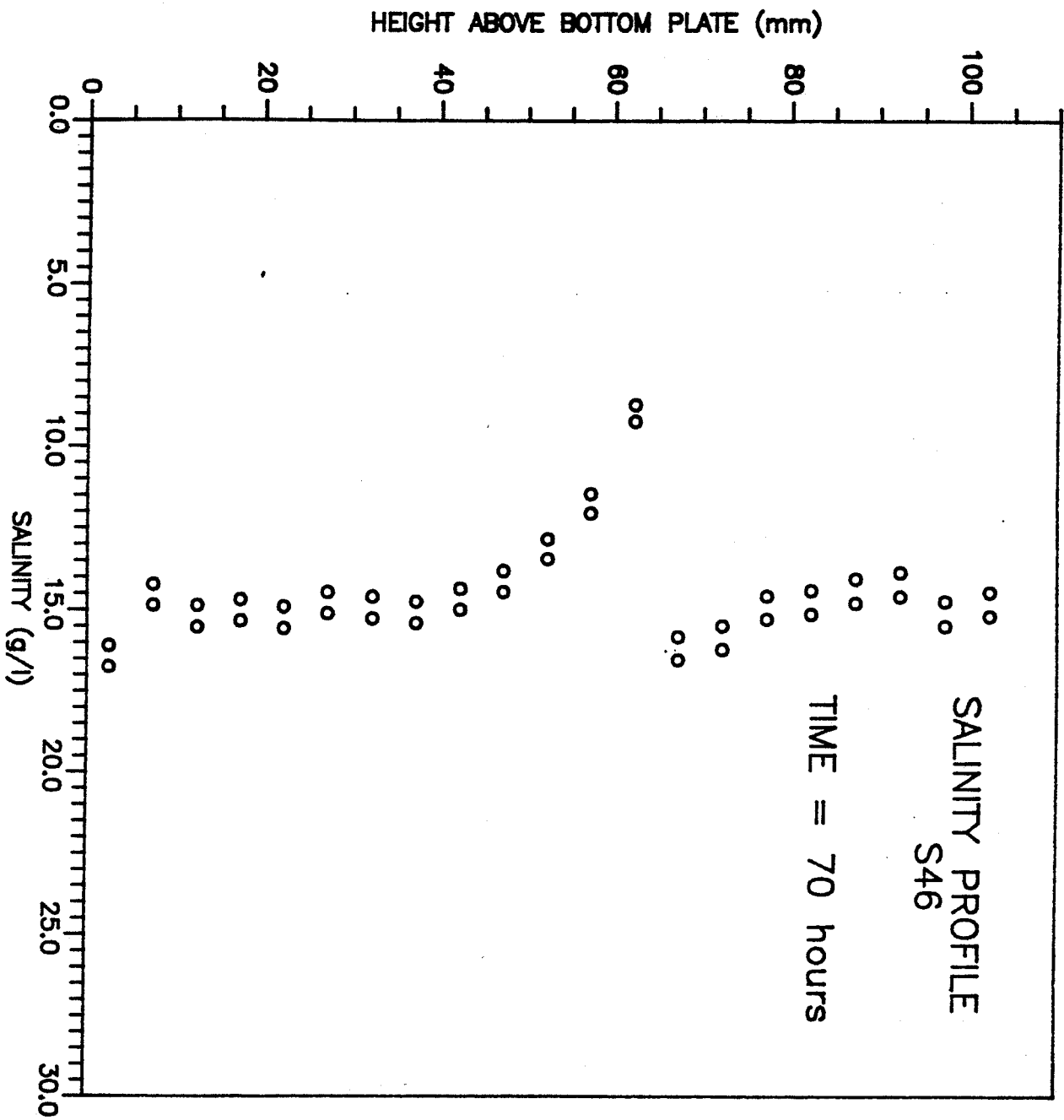


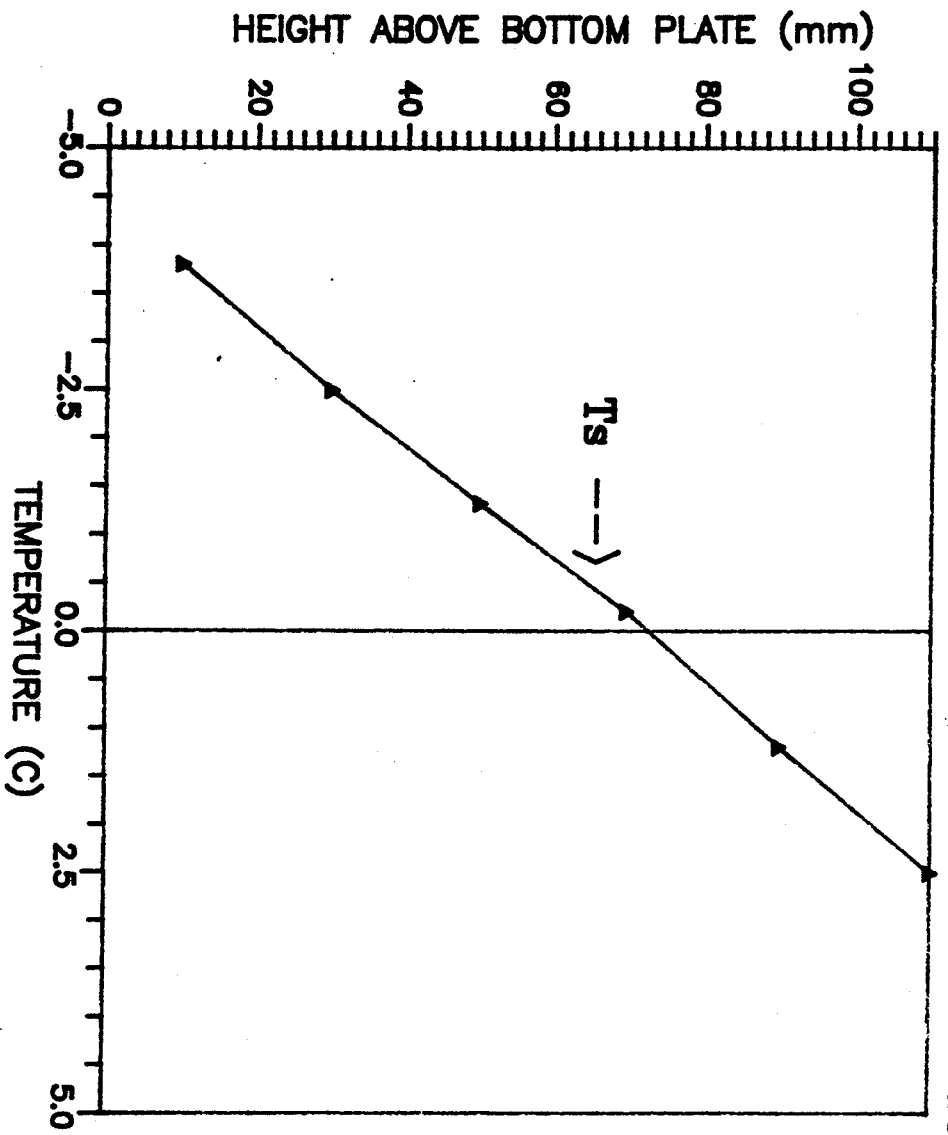
□ HEAVE
△ TT ISOTHERM

FREEZING TEST S46

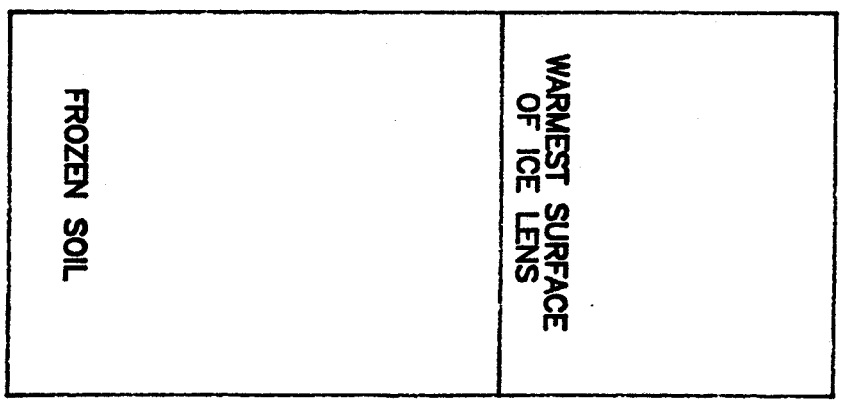






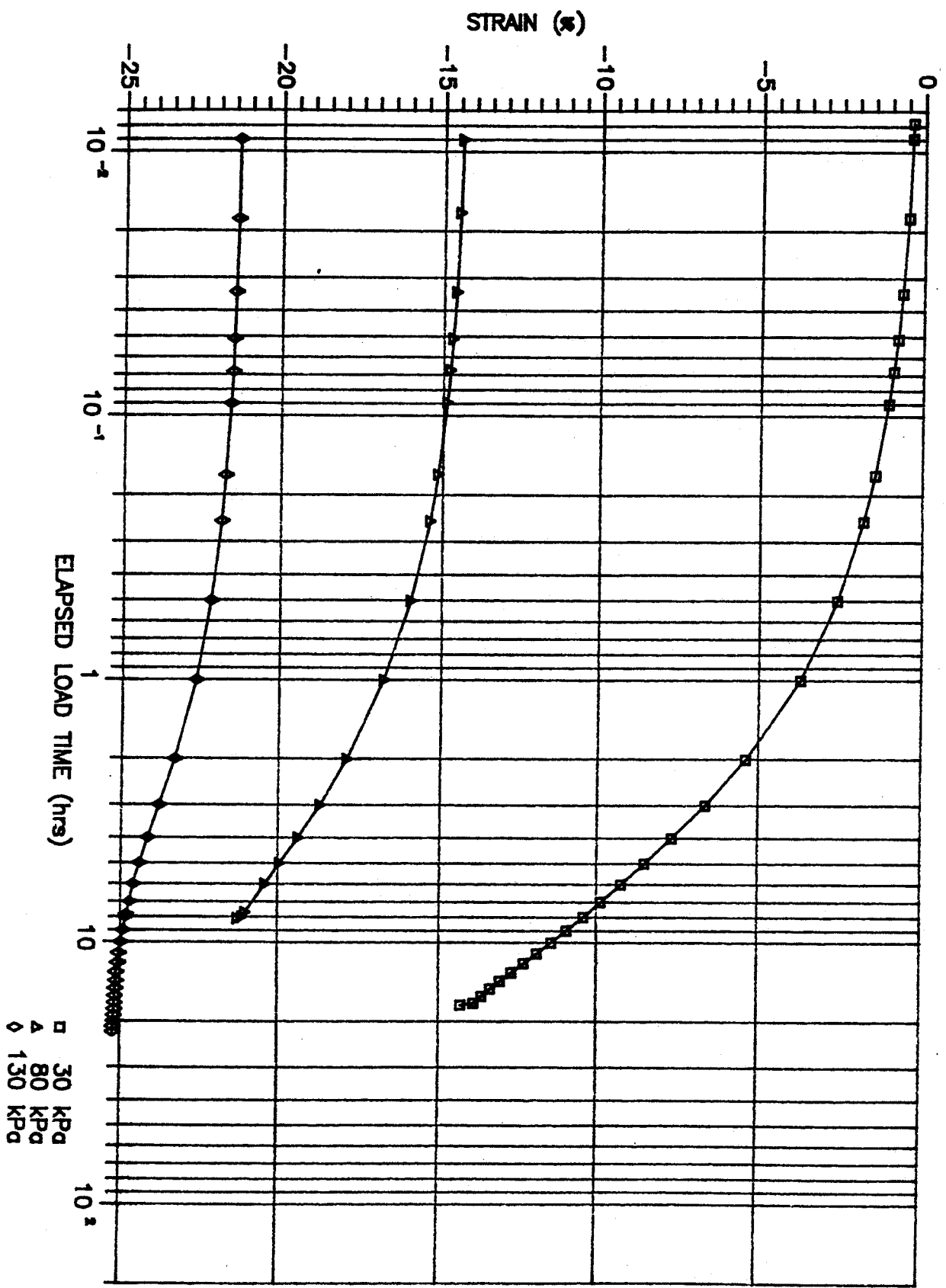


OBSERVED POSITION OF ICE LENS



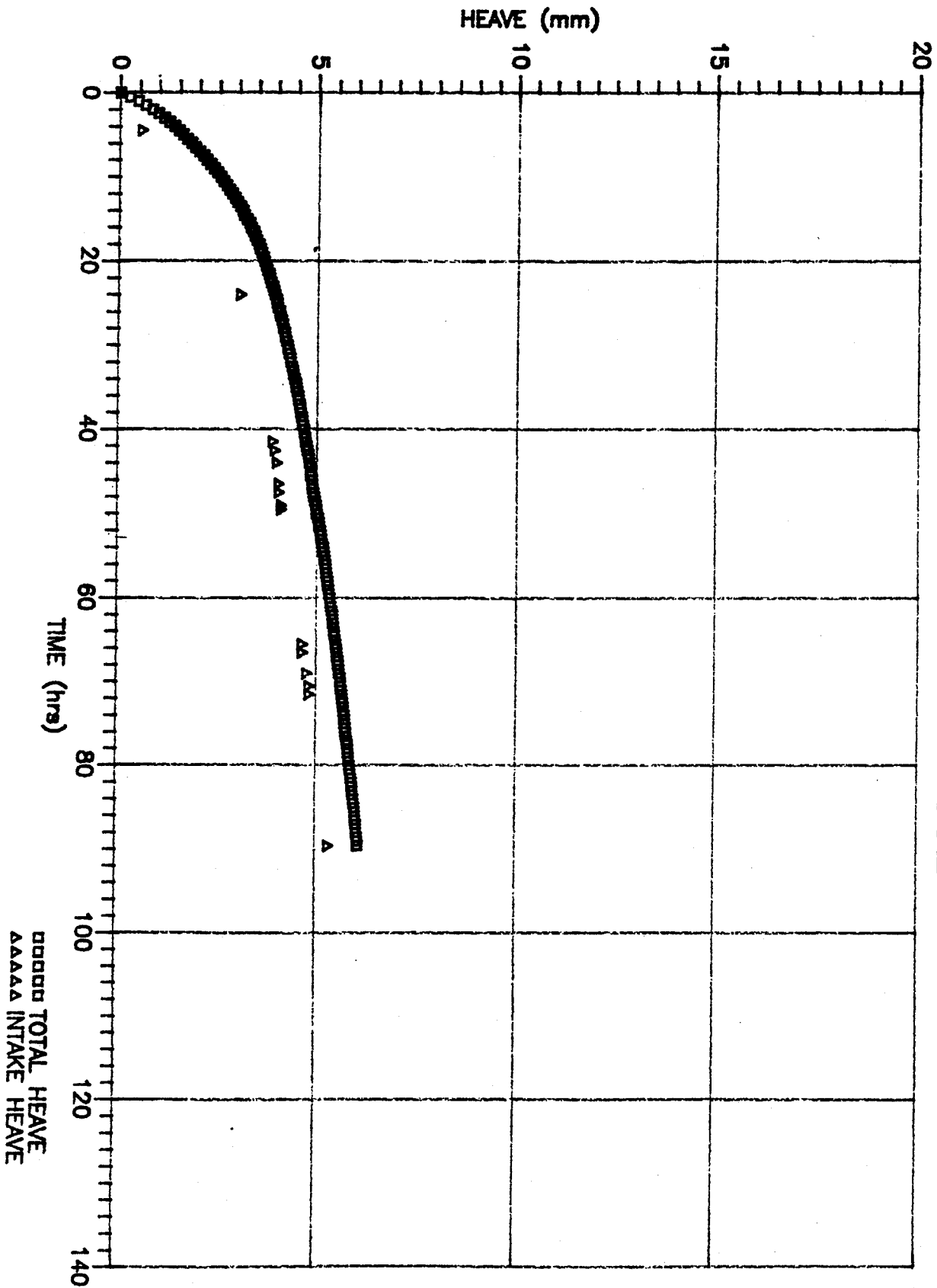
TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S46

CONSOLIDATION TEST S52

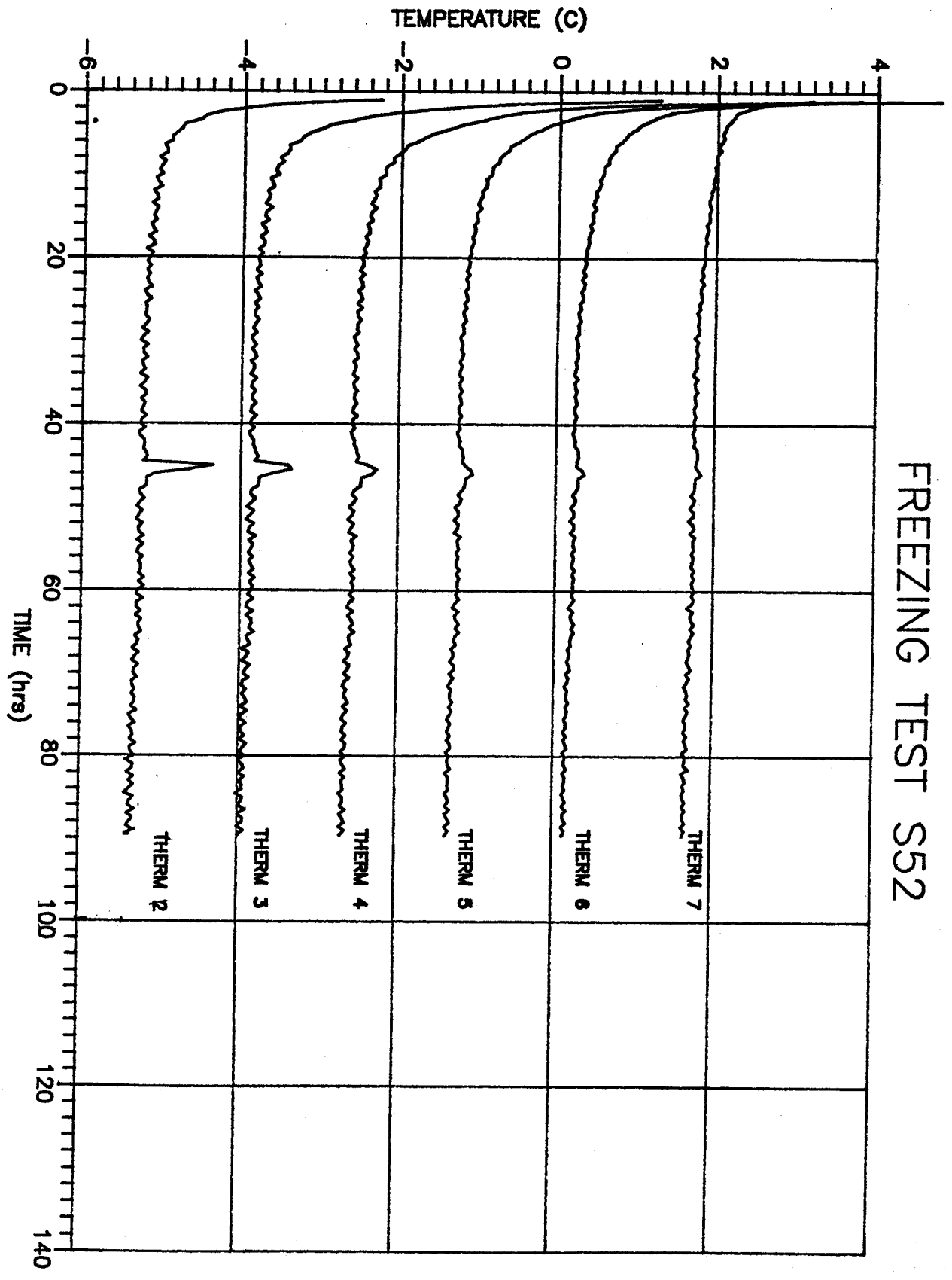


□ 30 kPa
 △ 80 kPa
 ◇ 130 kPa

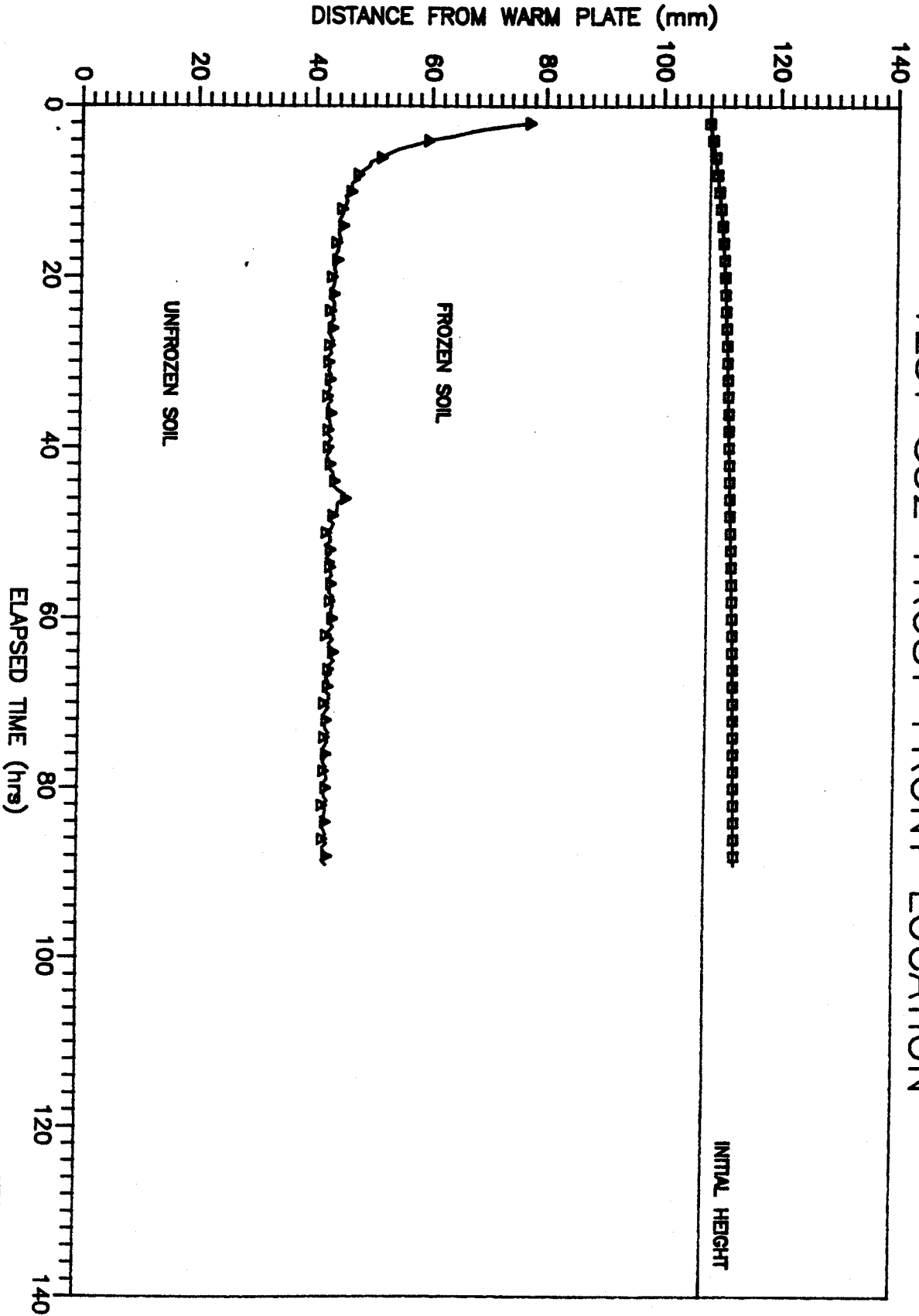
FREEZING TEST S52



FREEZING TEST S52

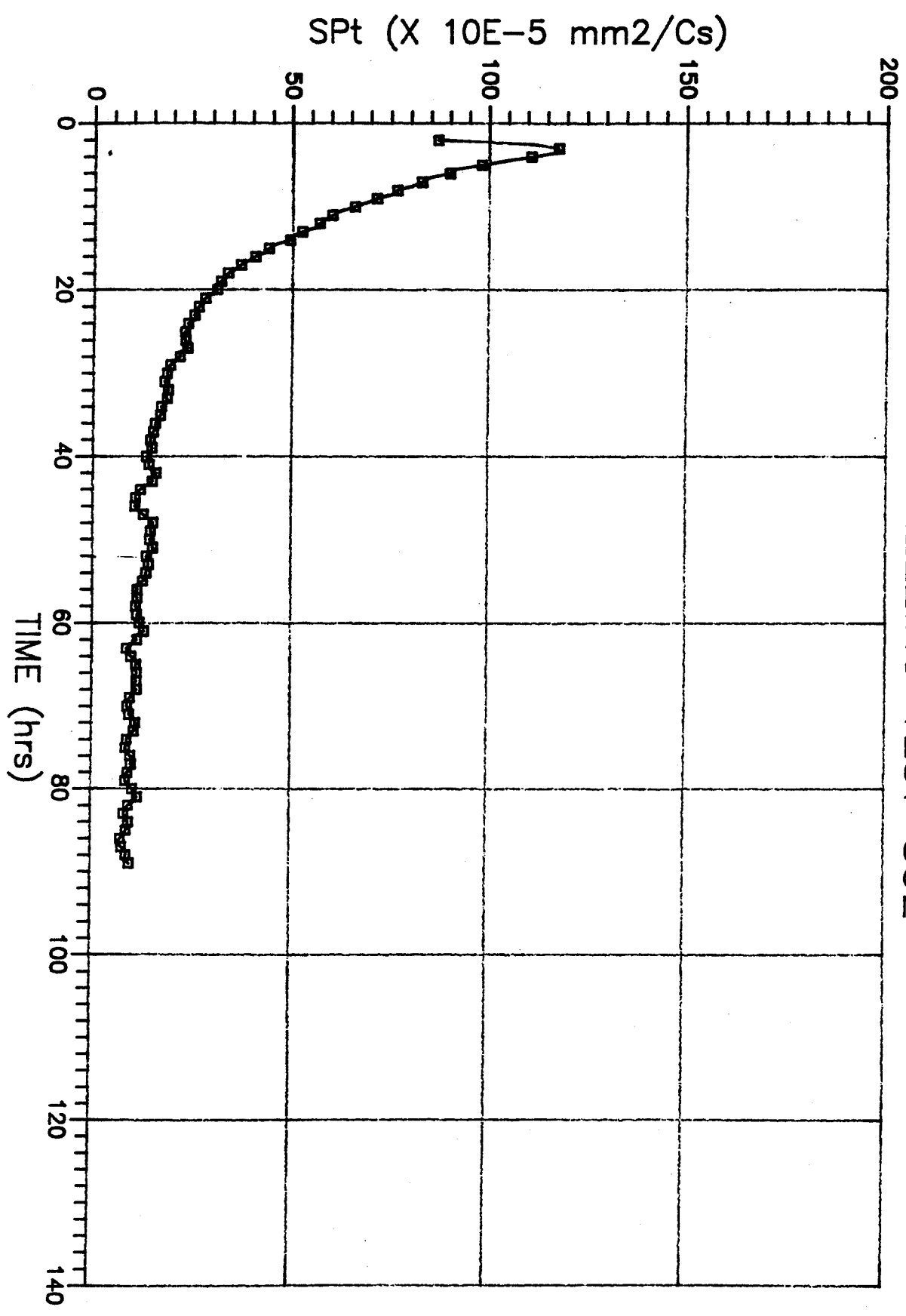


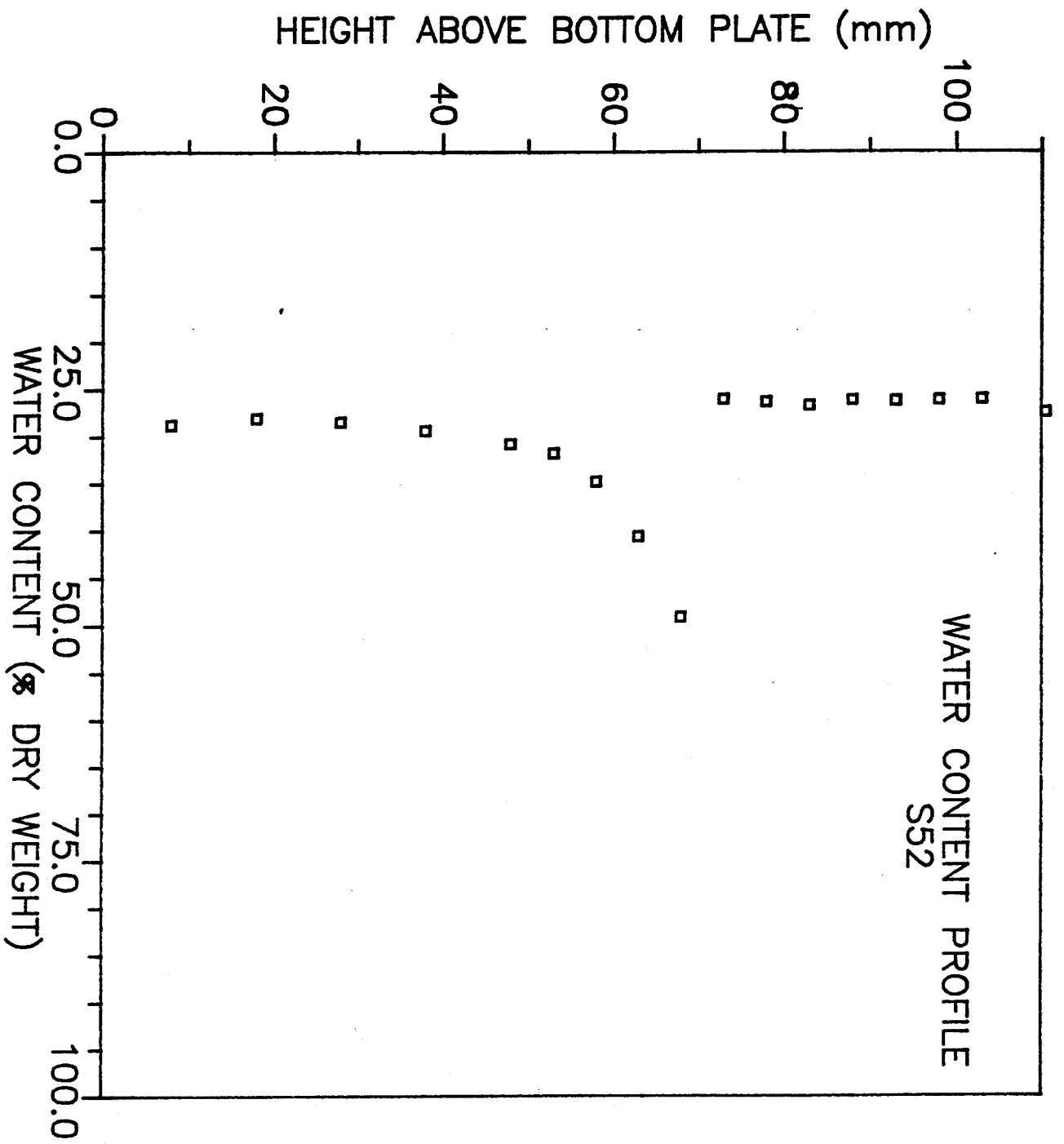
TEST S52 FROST FRONT LOCATION

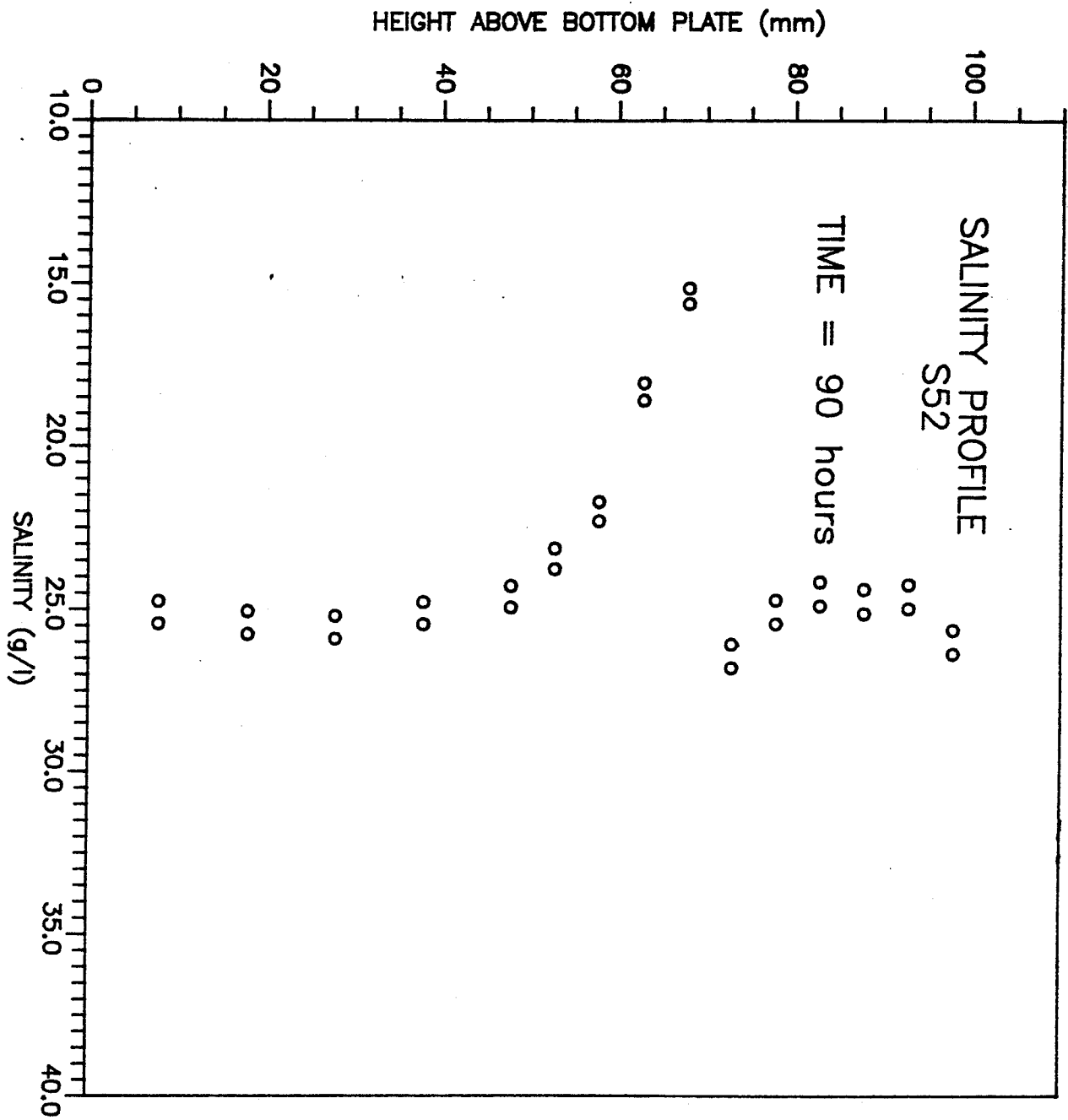


□ HEAVE
△ ISOTHERM

FREEZING TEST S52







ICE FORMATION IN SALINE SOILS

VOLUME 3

Report Submitted

to

SUPPLY AND SERVICES CANADA

HULL, QUEBEC

(DSS File No. 63SS.23233-7-1080)

APPENDIX 5

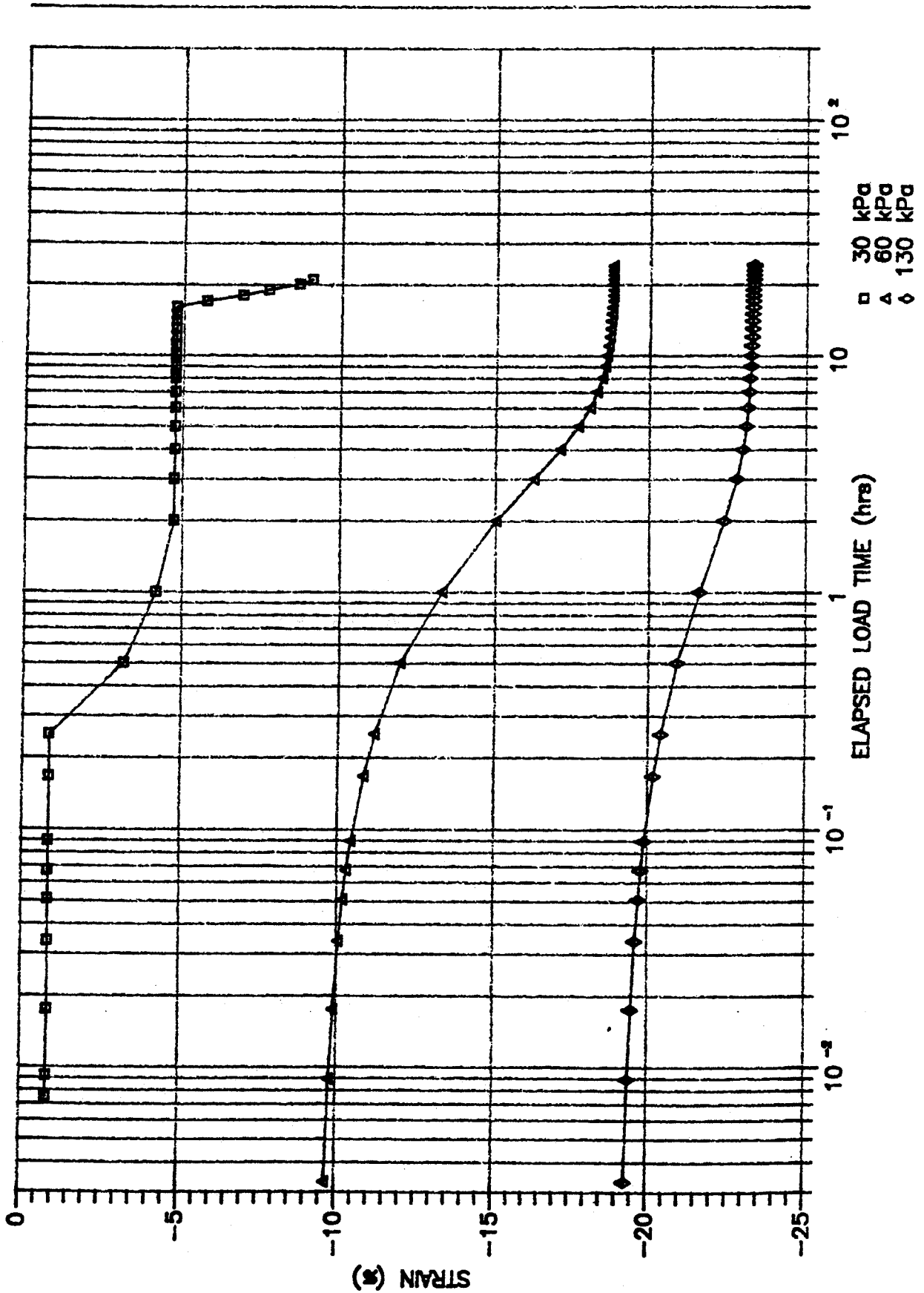
Test Results of Series 2. (Applied Surcharge)

Prepared by

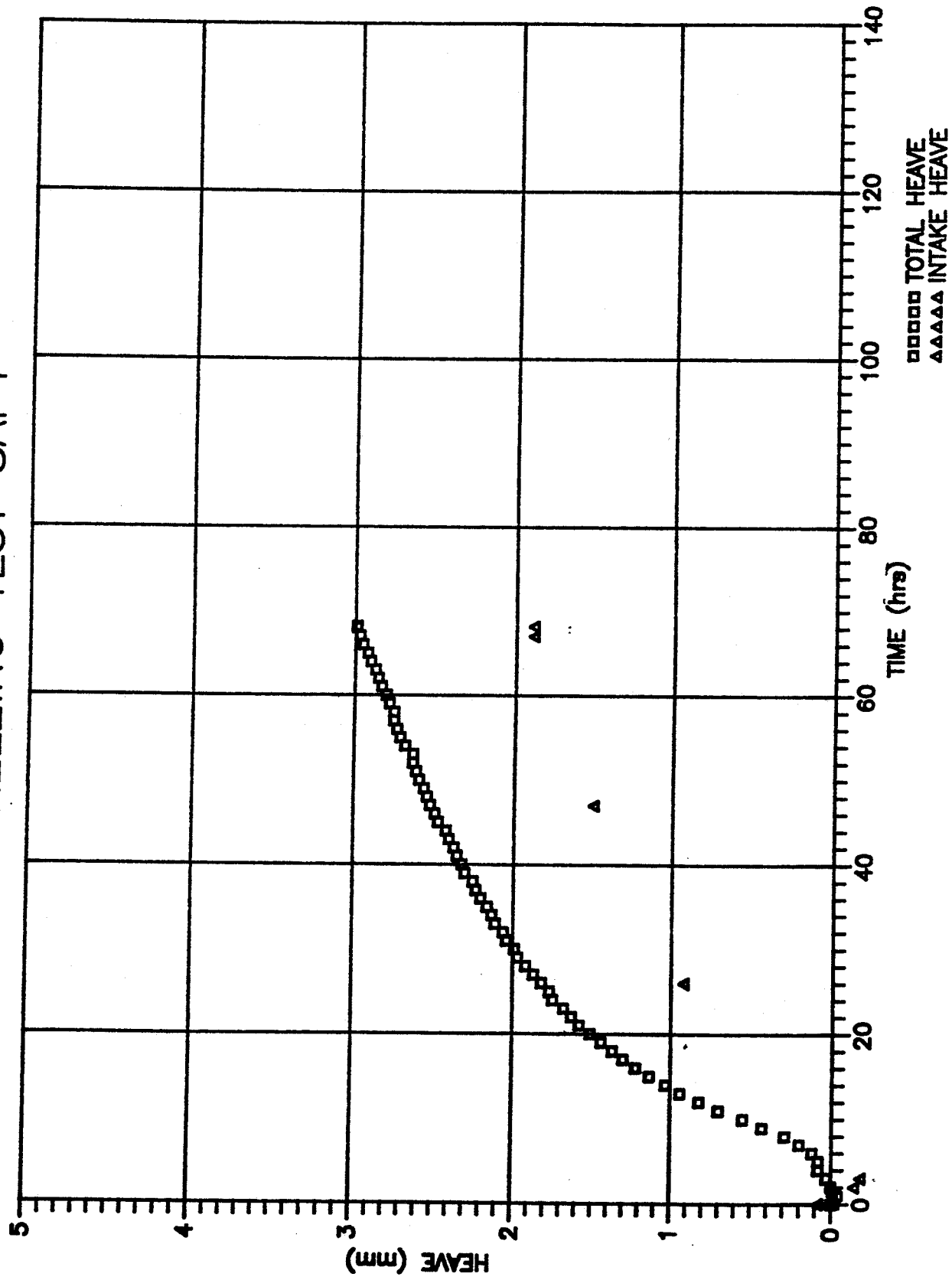
J.- M. Konrad, Ph.D., P.Eng.
Dept. of Earth Sciences
University of Waterloo
Waterloo, Ontario, N2L-3G1

March, 1989

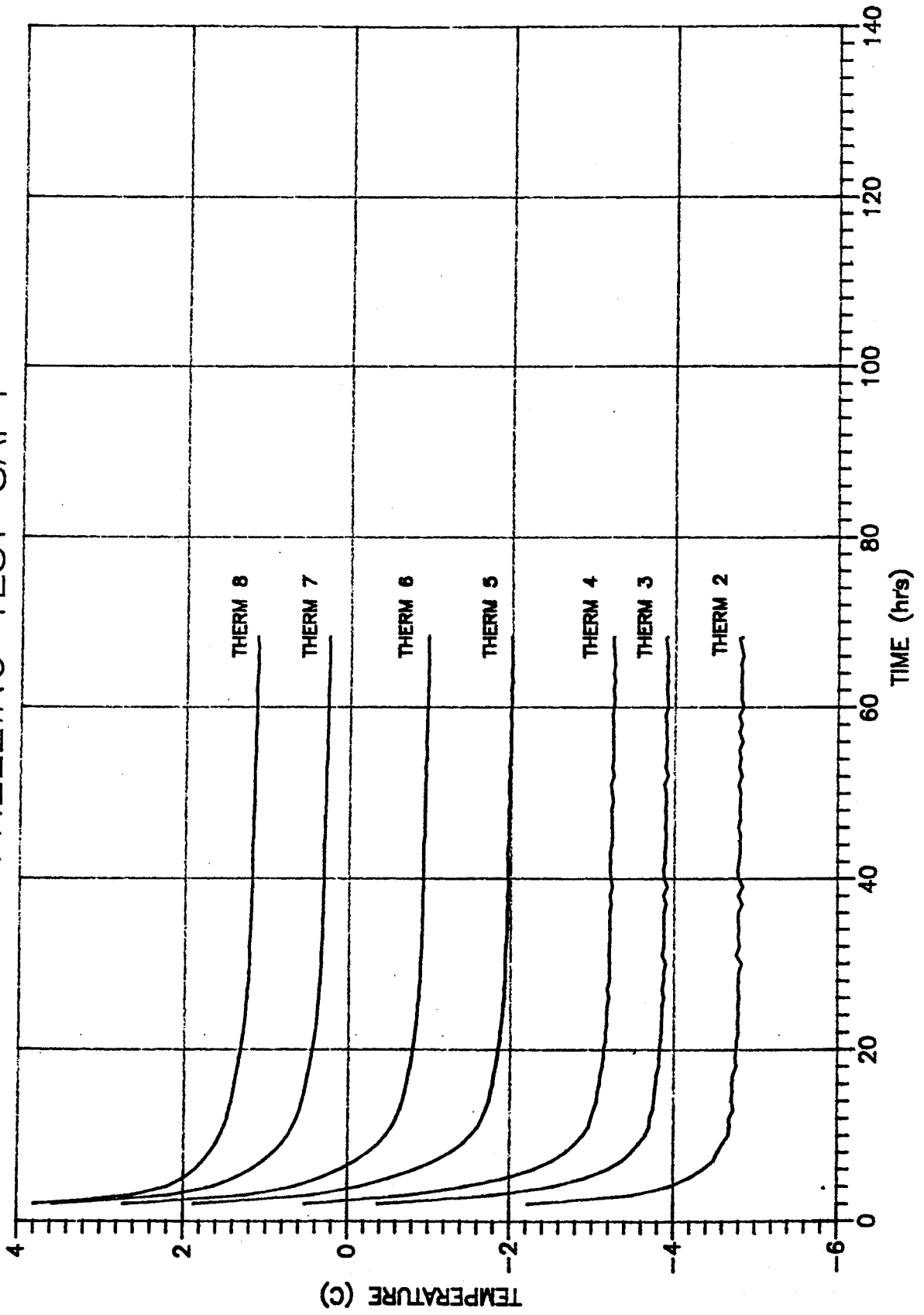
CONSOLIDATION TEST SAP1



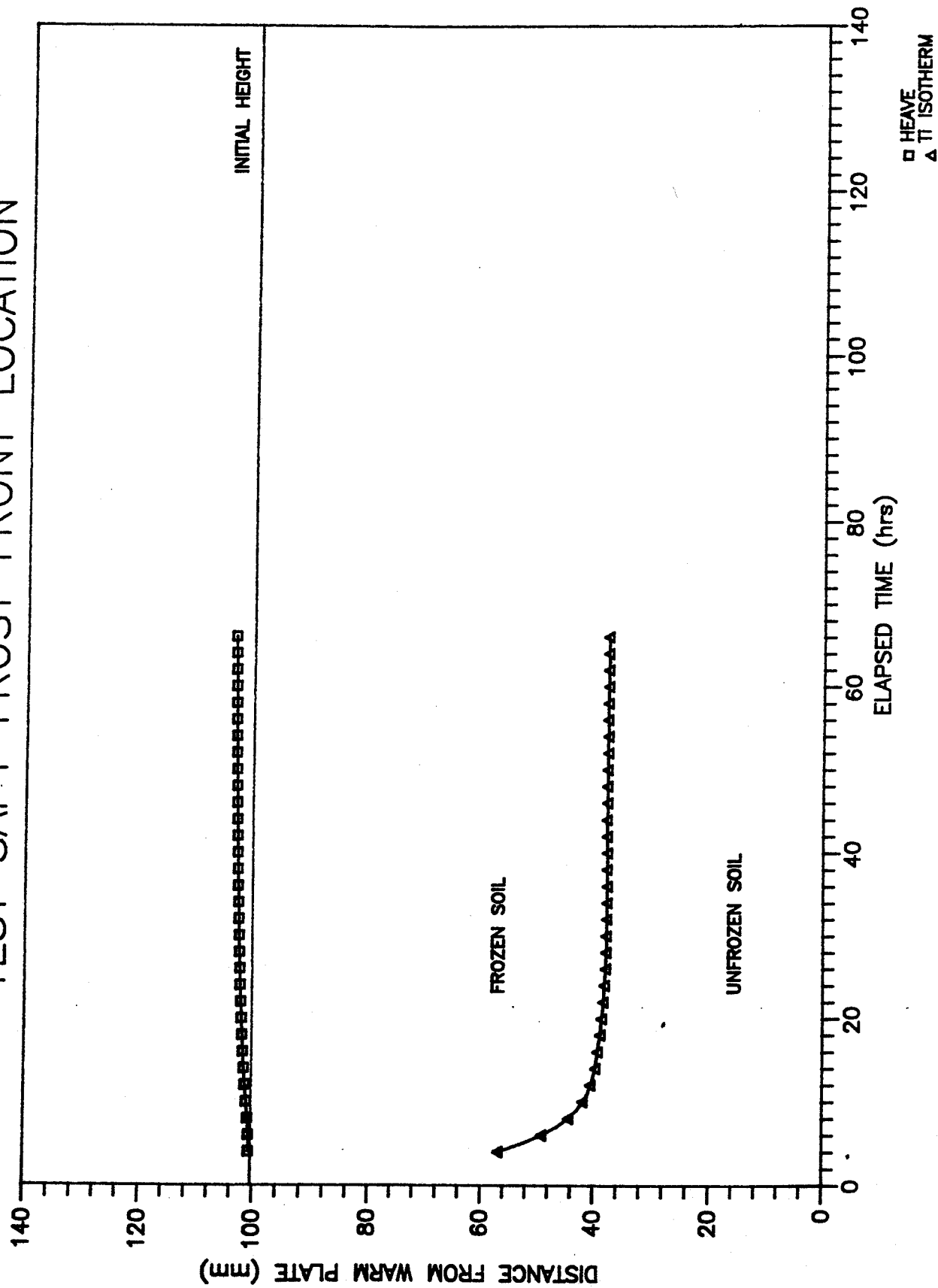
FREEZING TEST SAP1



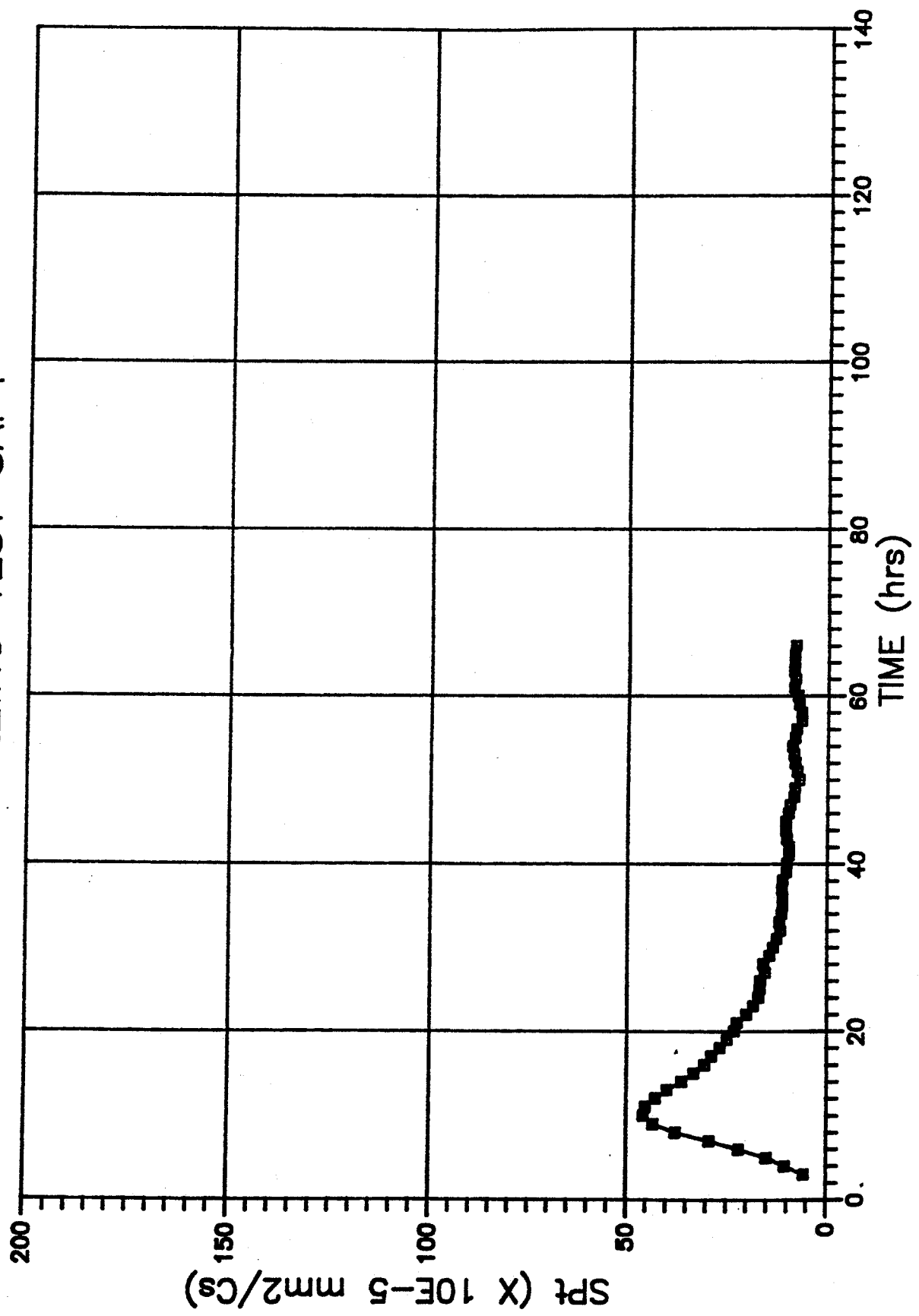
FREEZING TEST SAP1



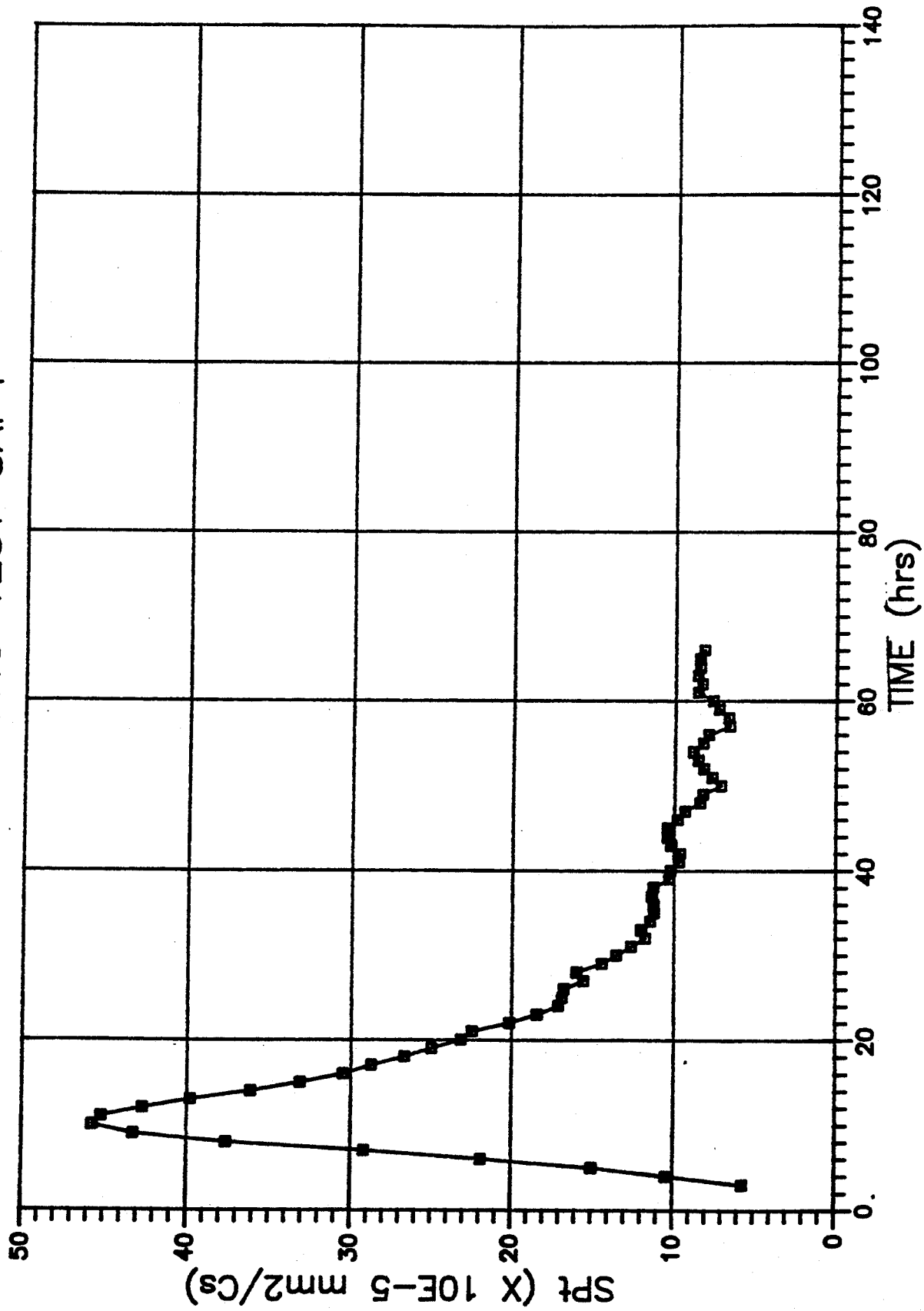
TEST SAP1 FROST FRONT LOCATION



FREEZING TEST SAP1

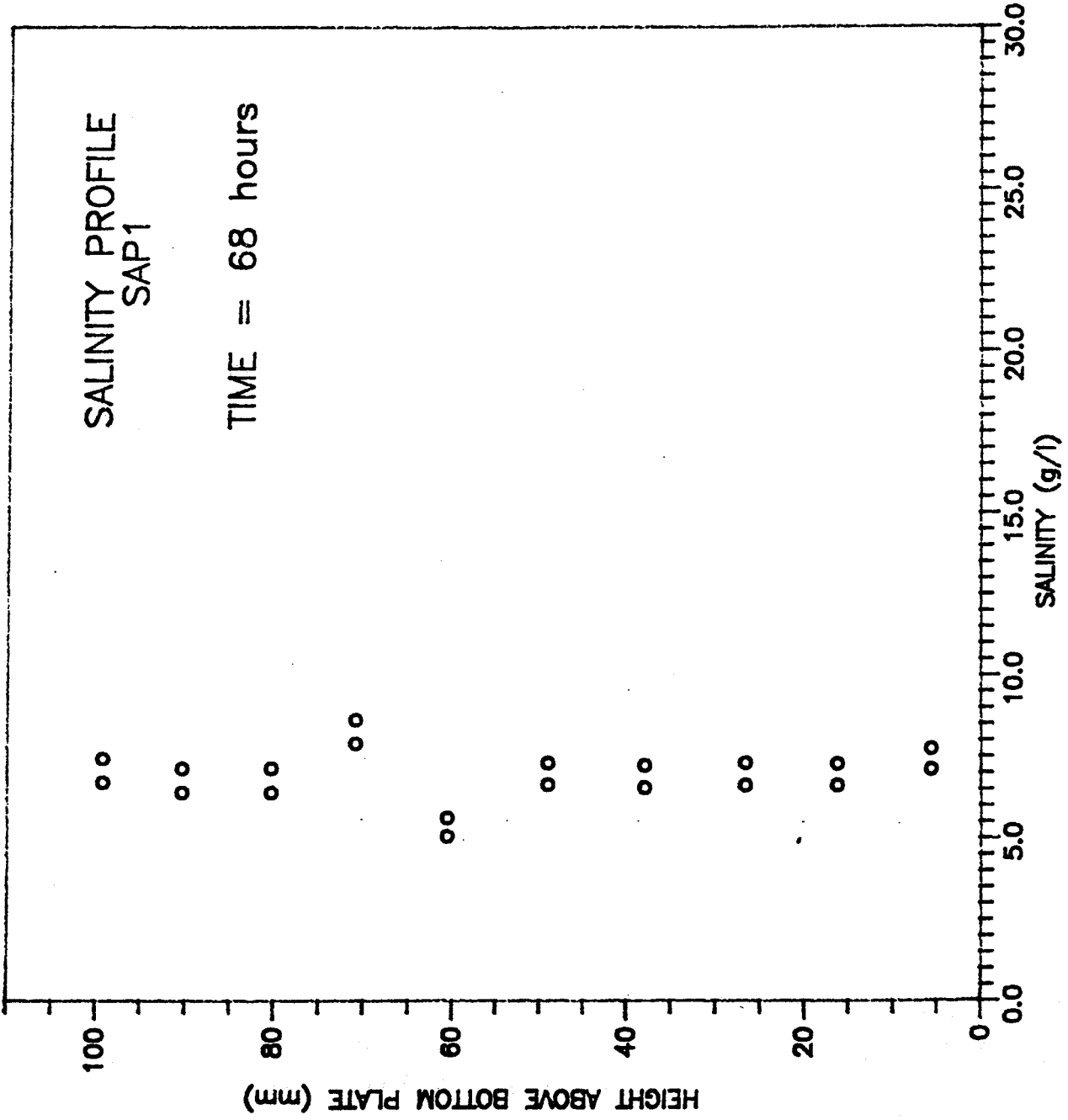


FREEZING TEST SAP1

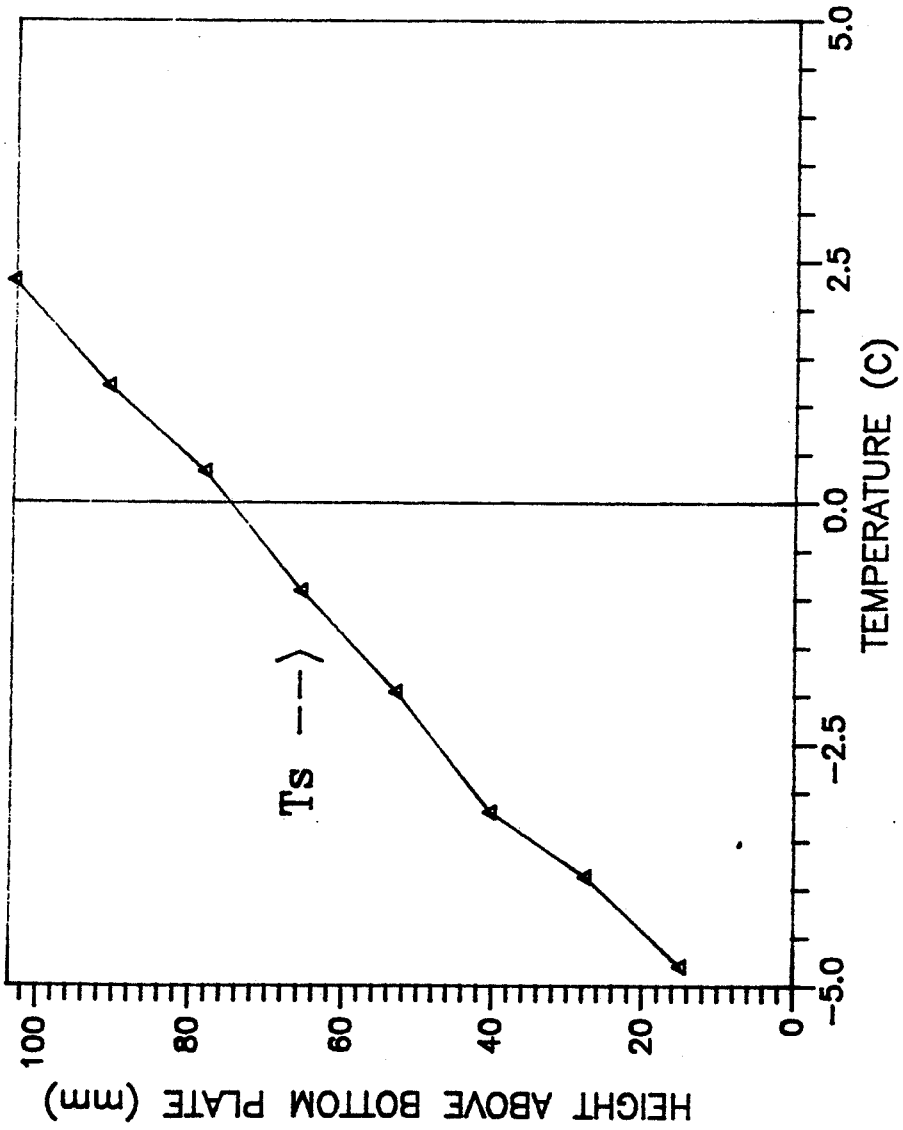
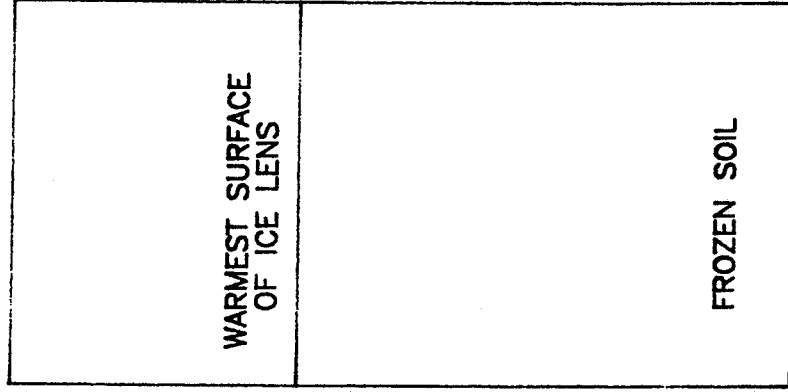


SALINITY PROFILE
SAP1

TIME = 68 hours

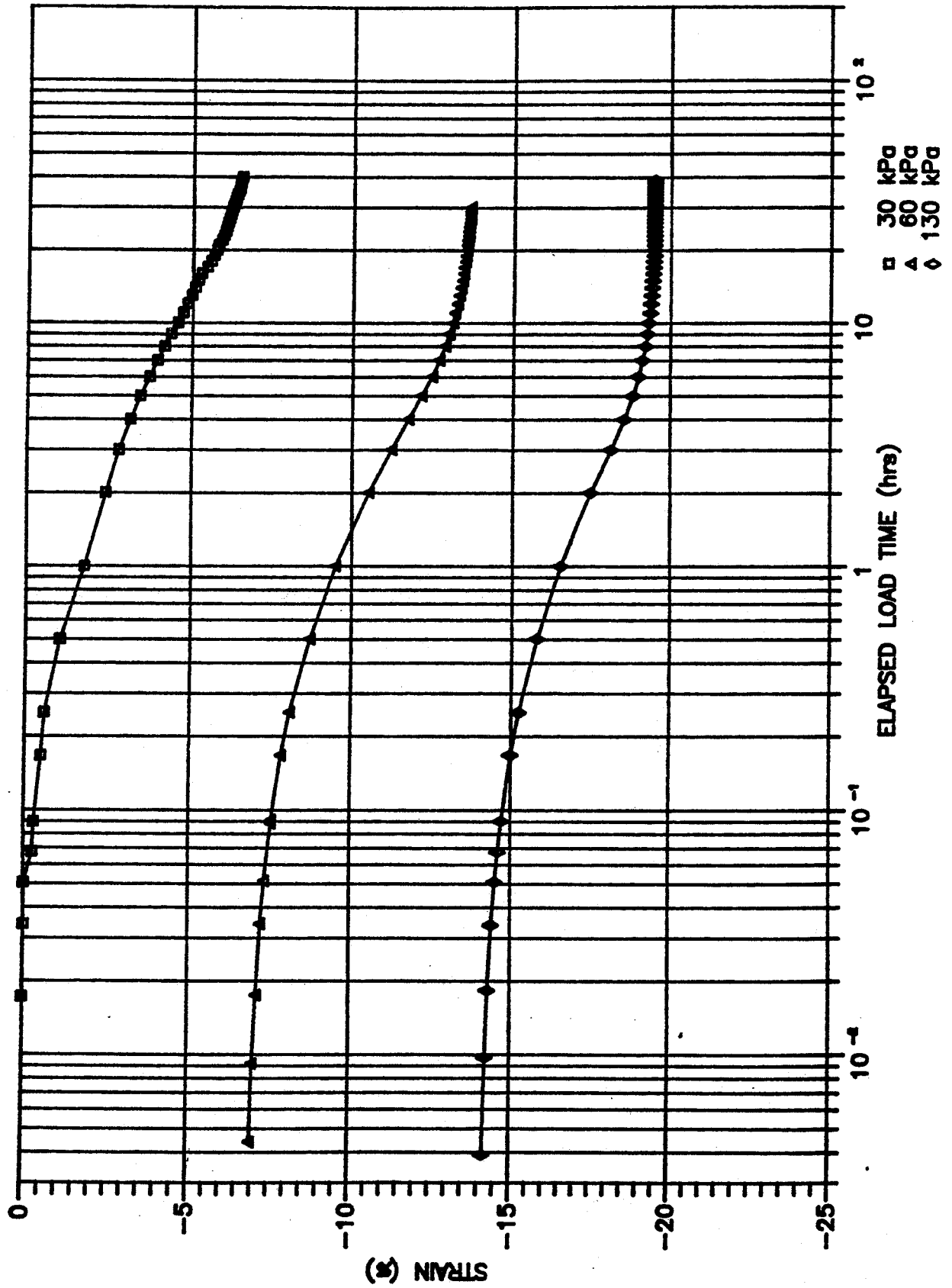


OBSERVED POSITION OF ICE LENS

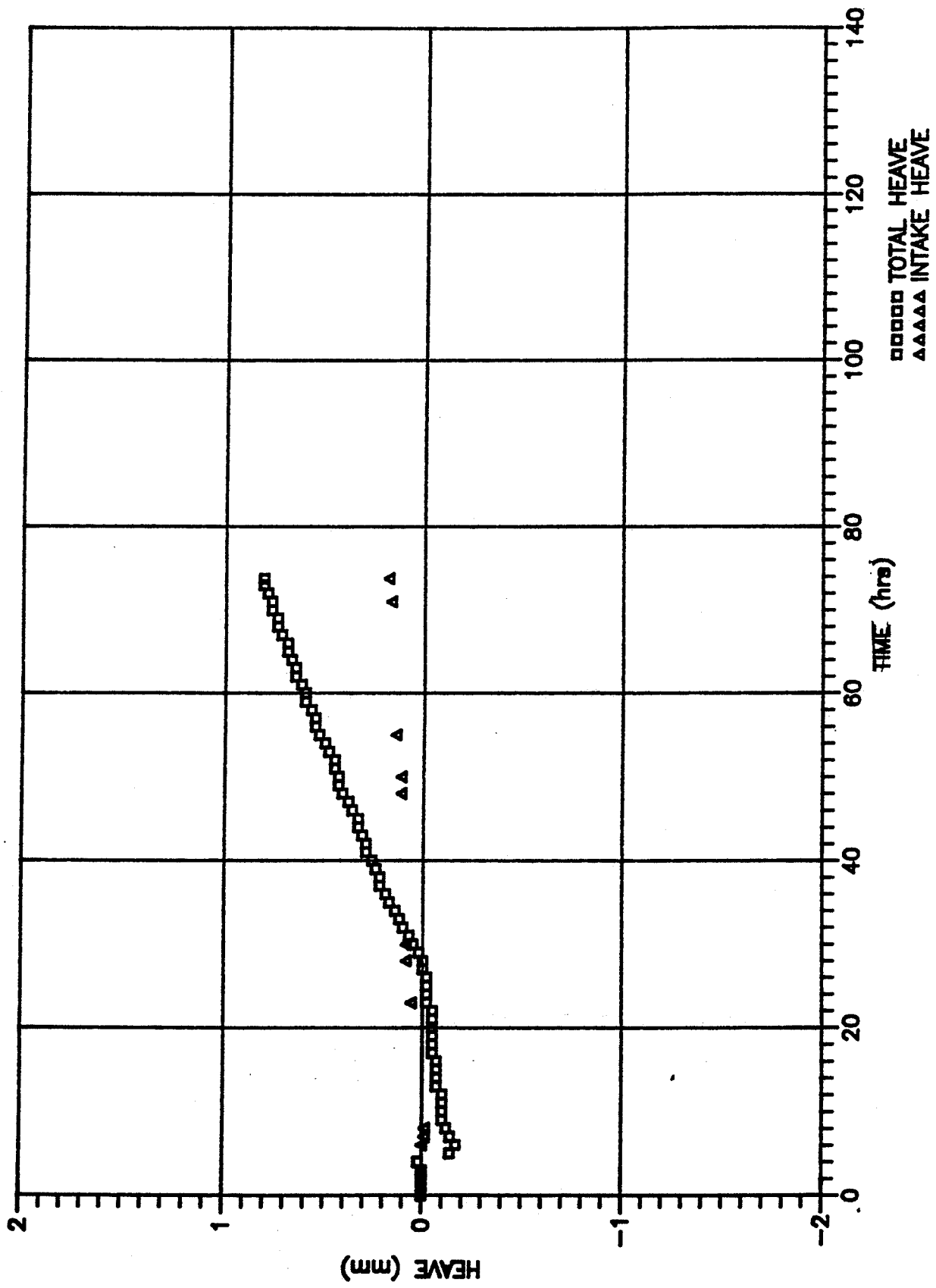


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP1

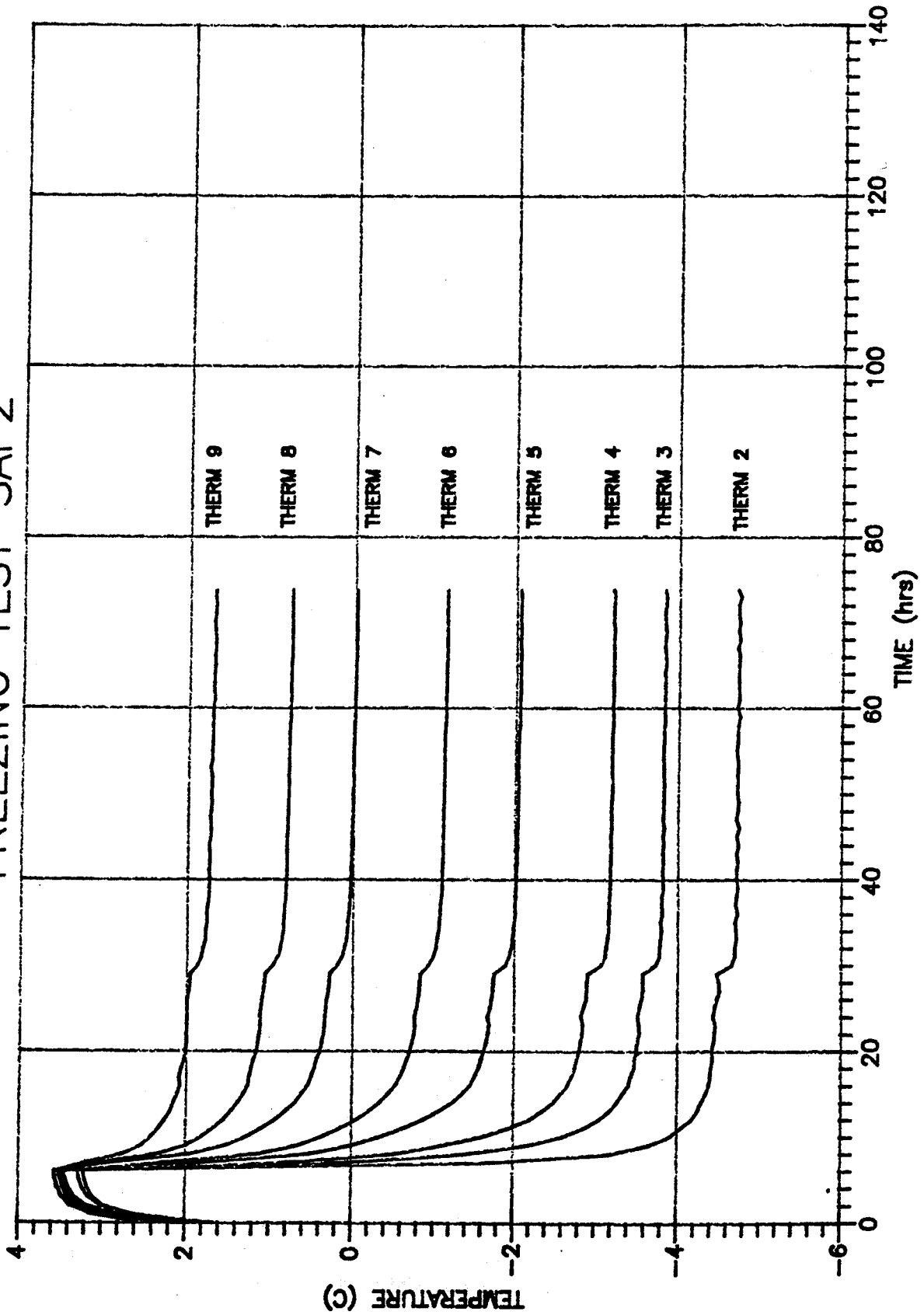
CONSOLIDATION TEST SAP2



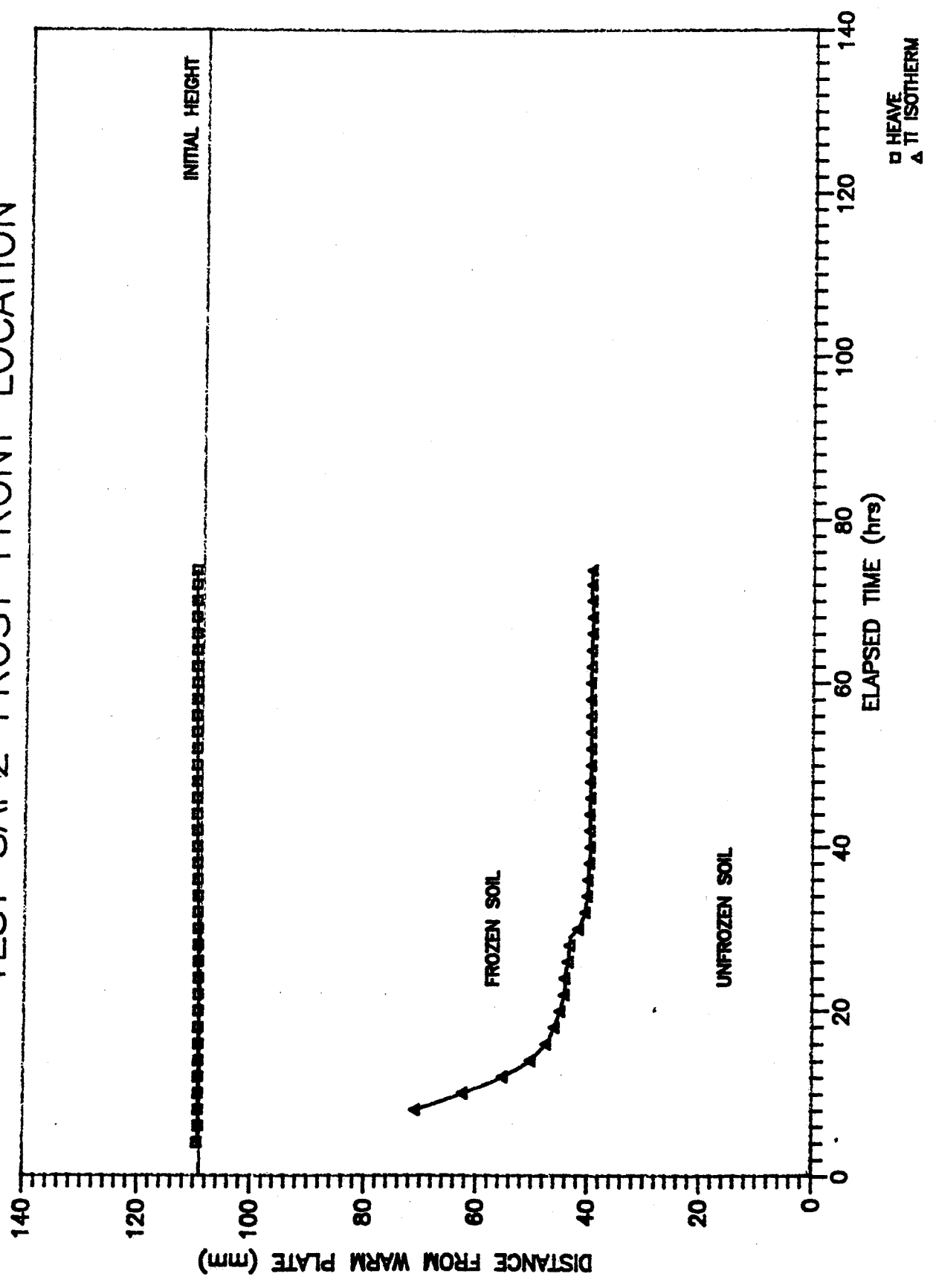
FREEZING TEST SAP2



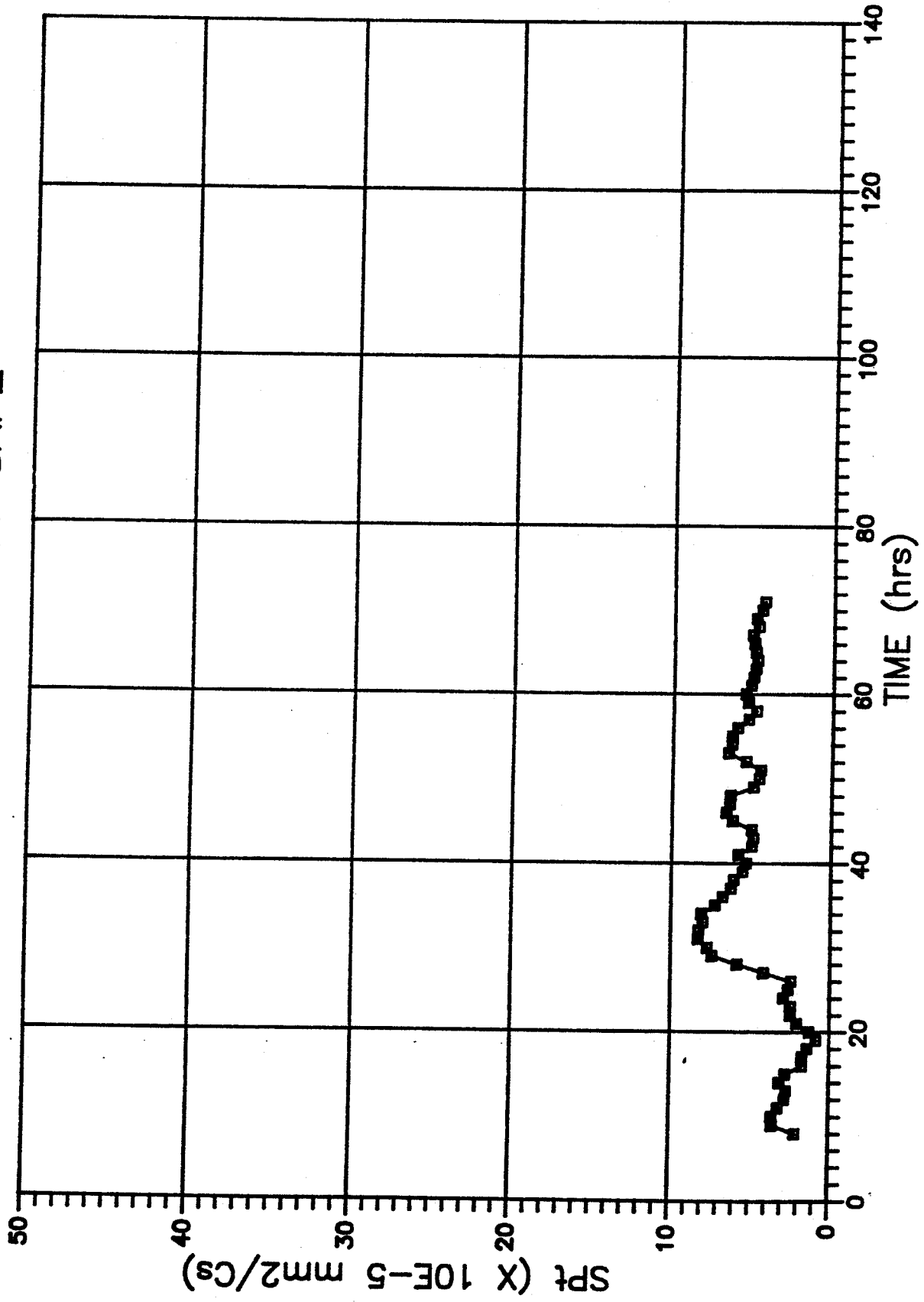
FREEZING TEST SAP2



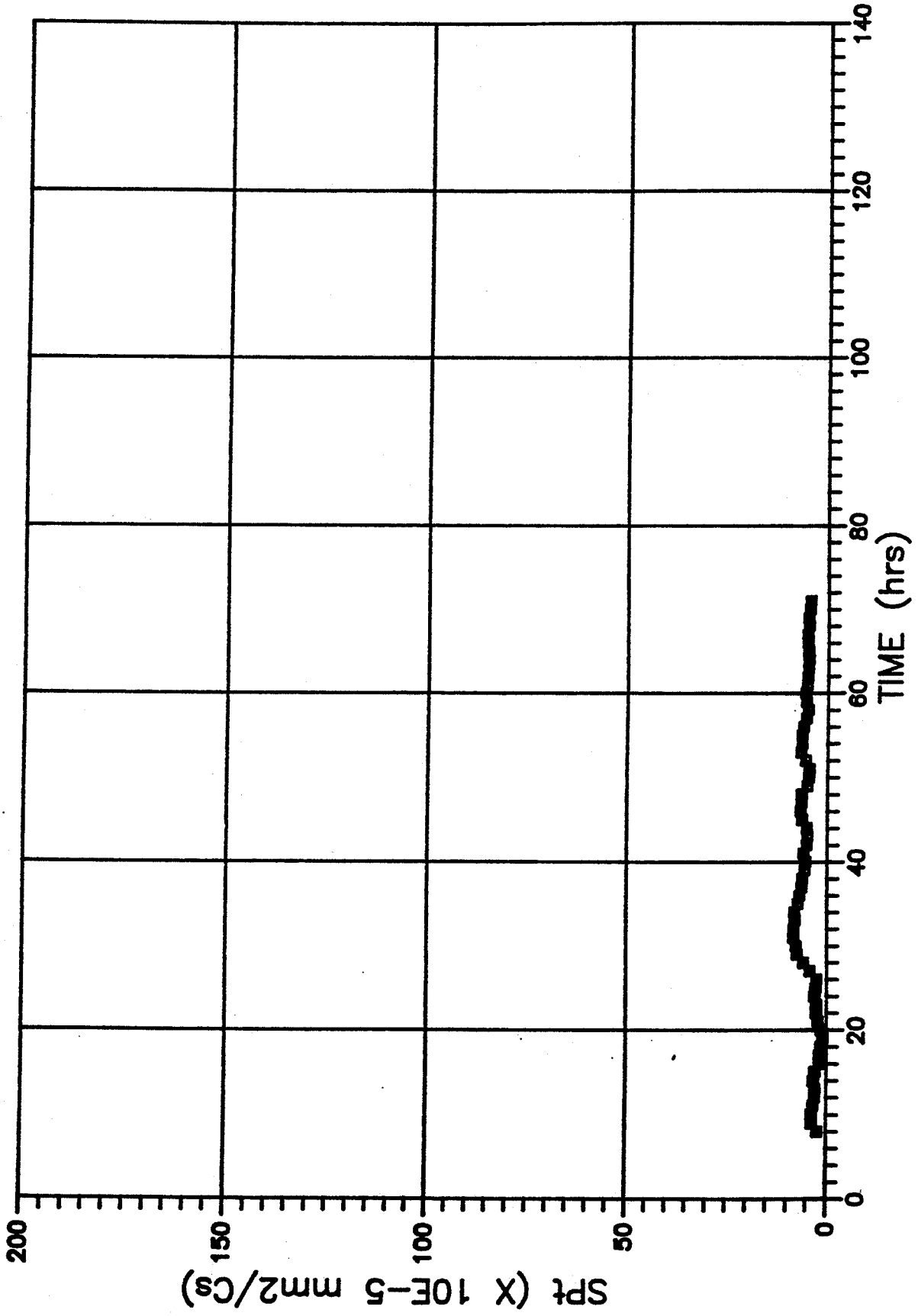
TEST SAP2 FROST FRONT LOCATION



FREEZING TEST SAP2

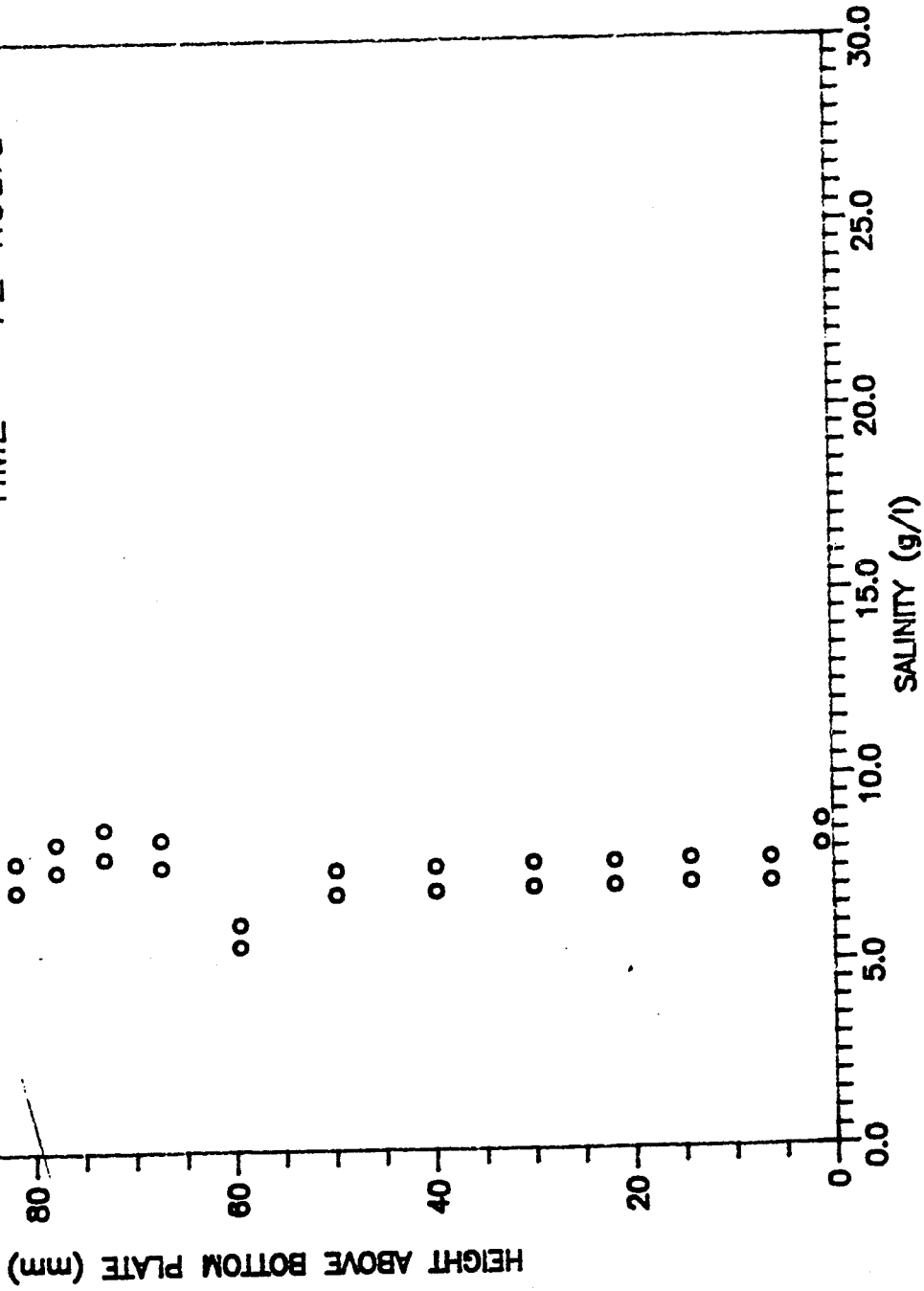


FREEZING TEST SAP2

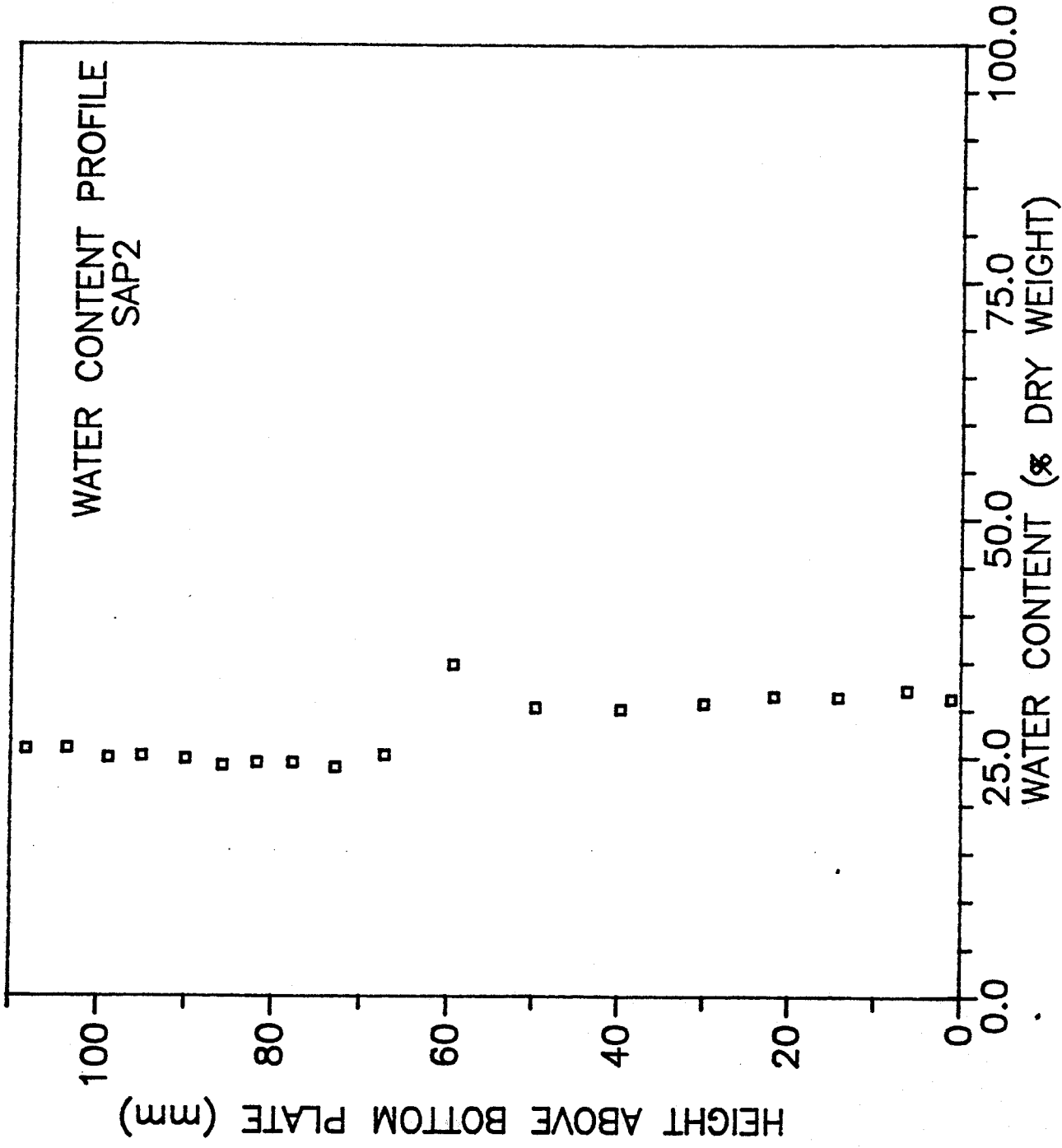


SALINITY PROFILE
SAP 2

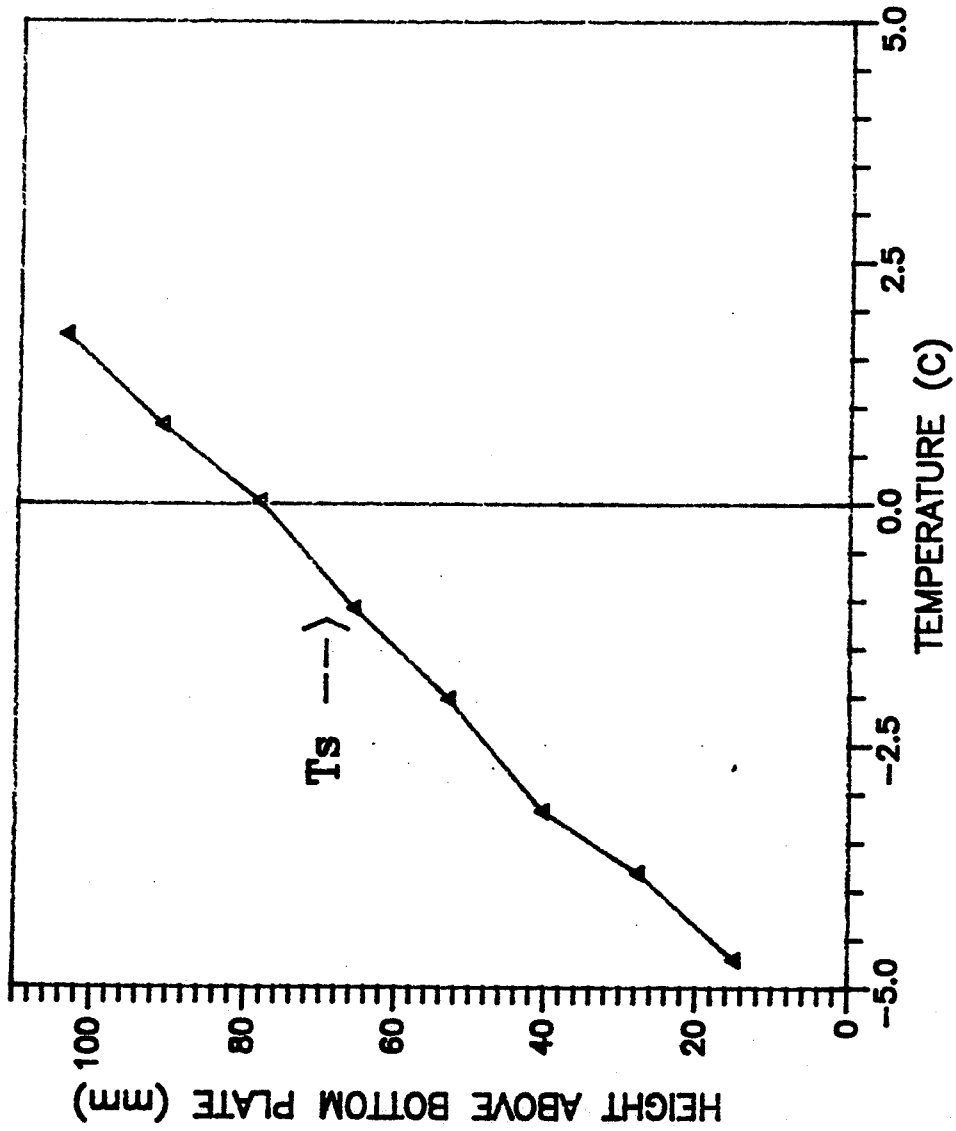
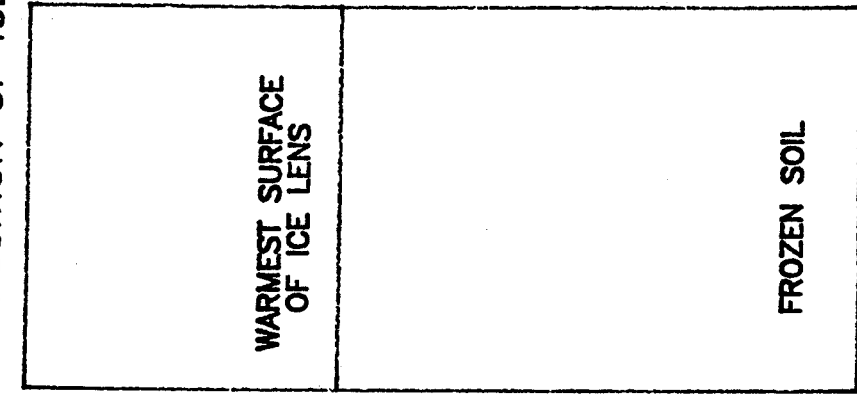
TIME = 72 hours



WATER CONTENT PROFILE
SAP2

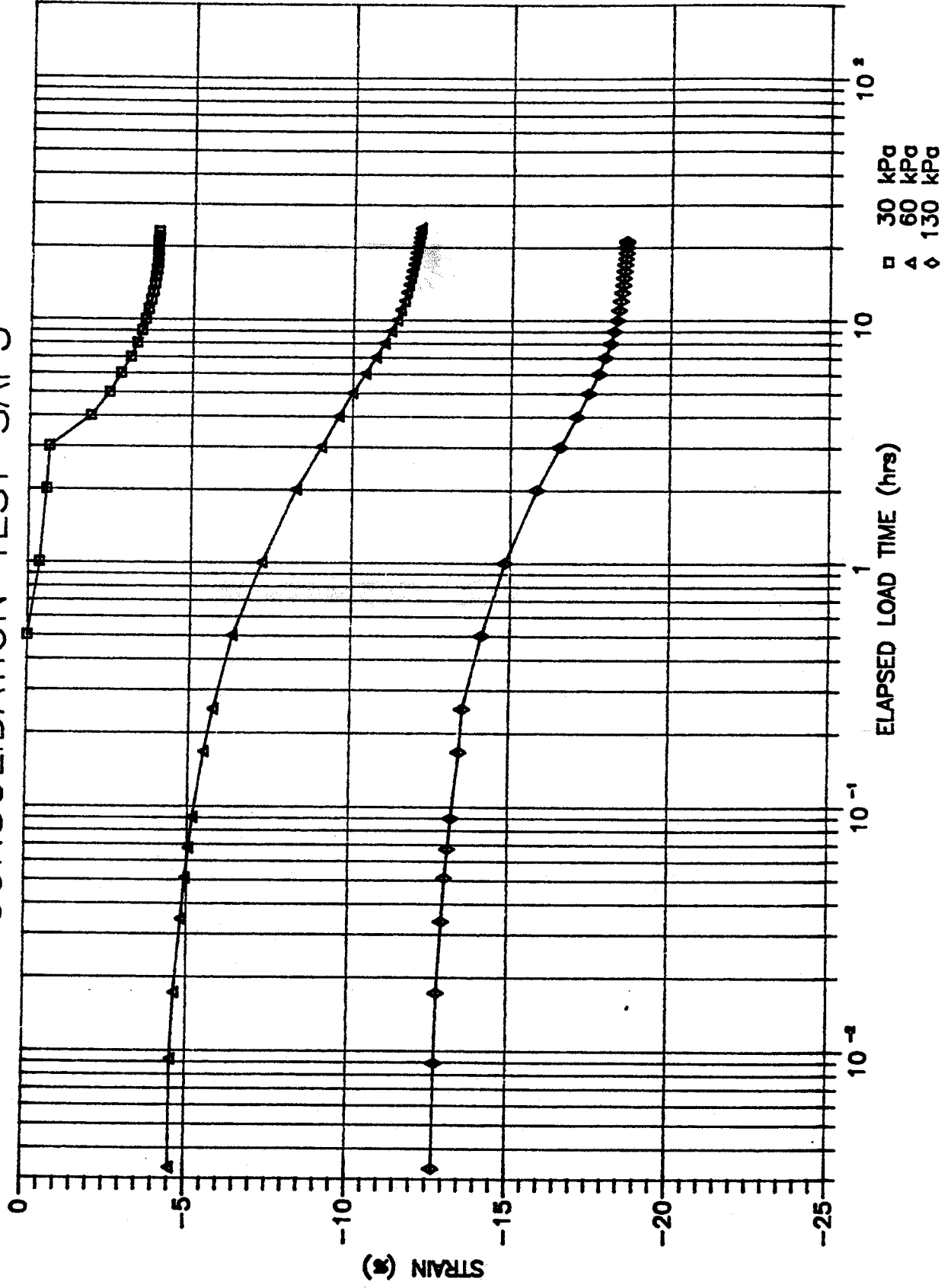


OBSERVED POSITION OF ICE LENS

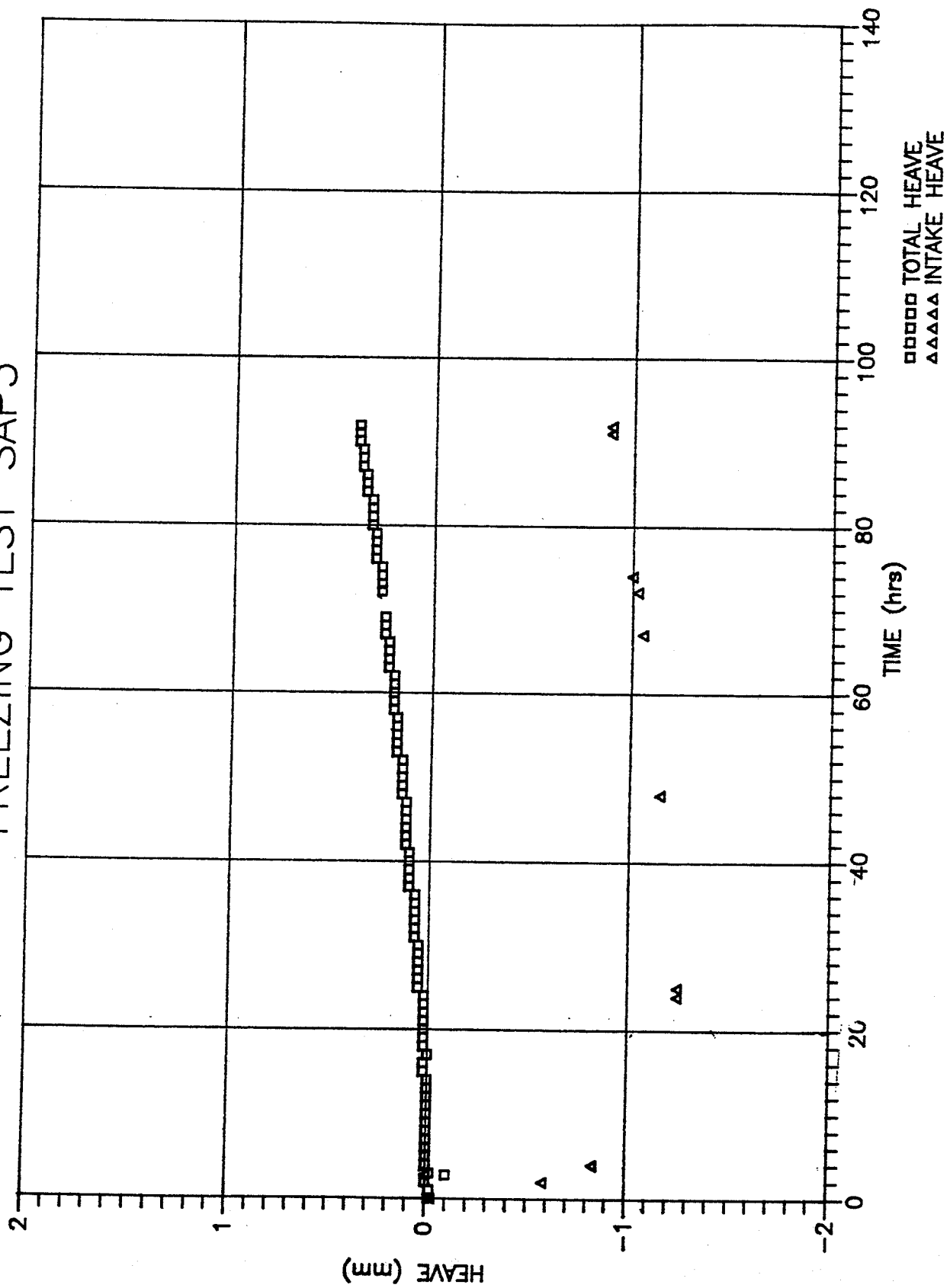


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP2

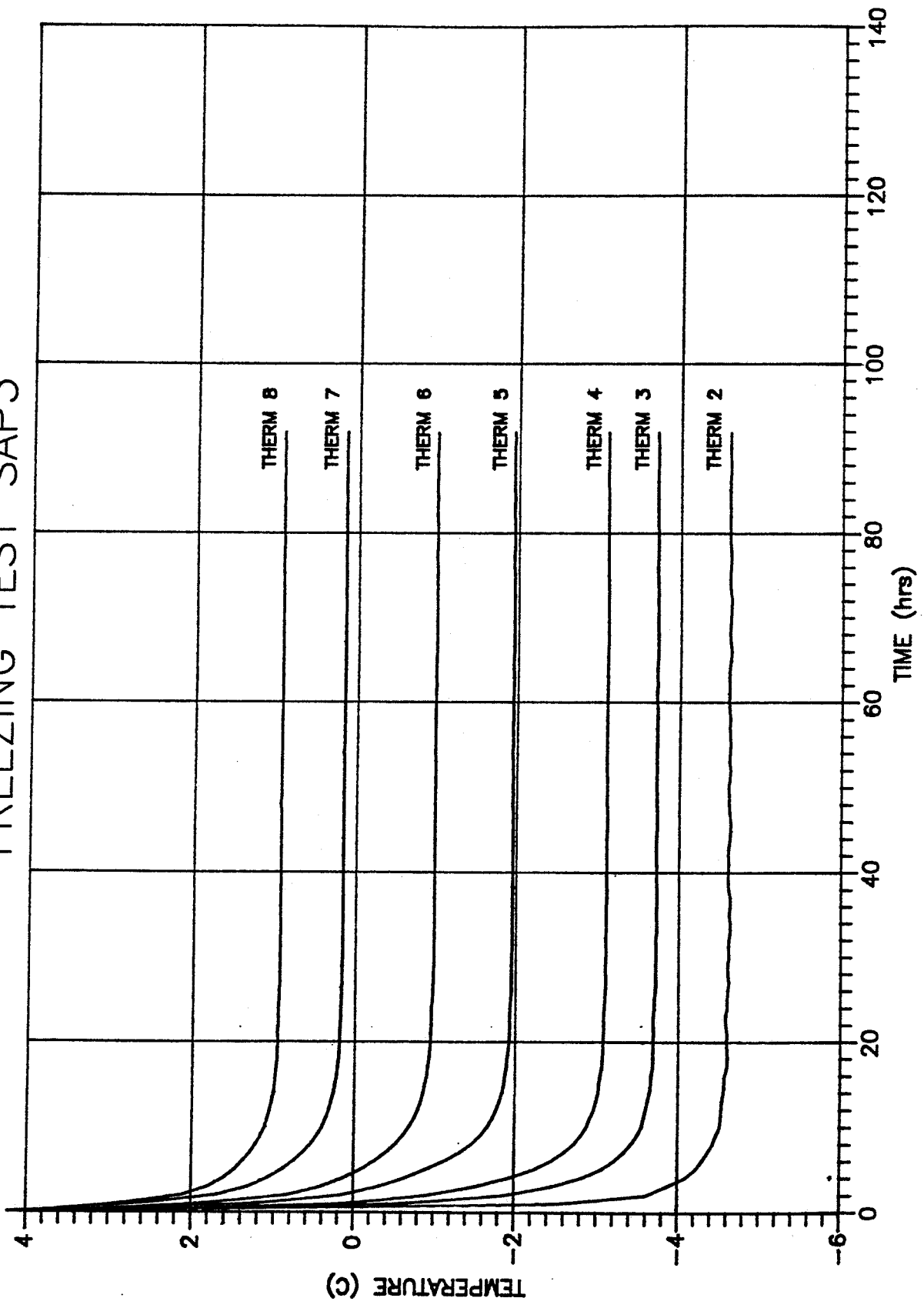
CONSOLIDATION TEST SAP3



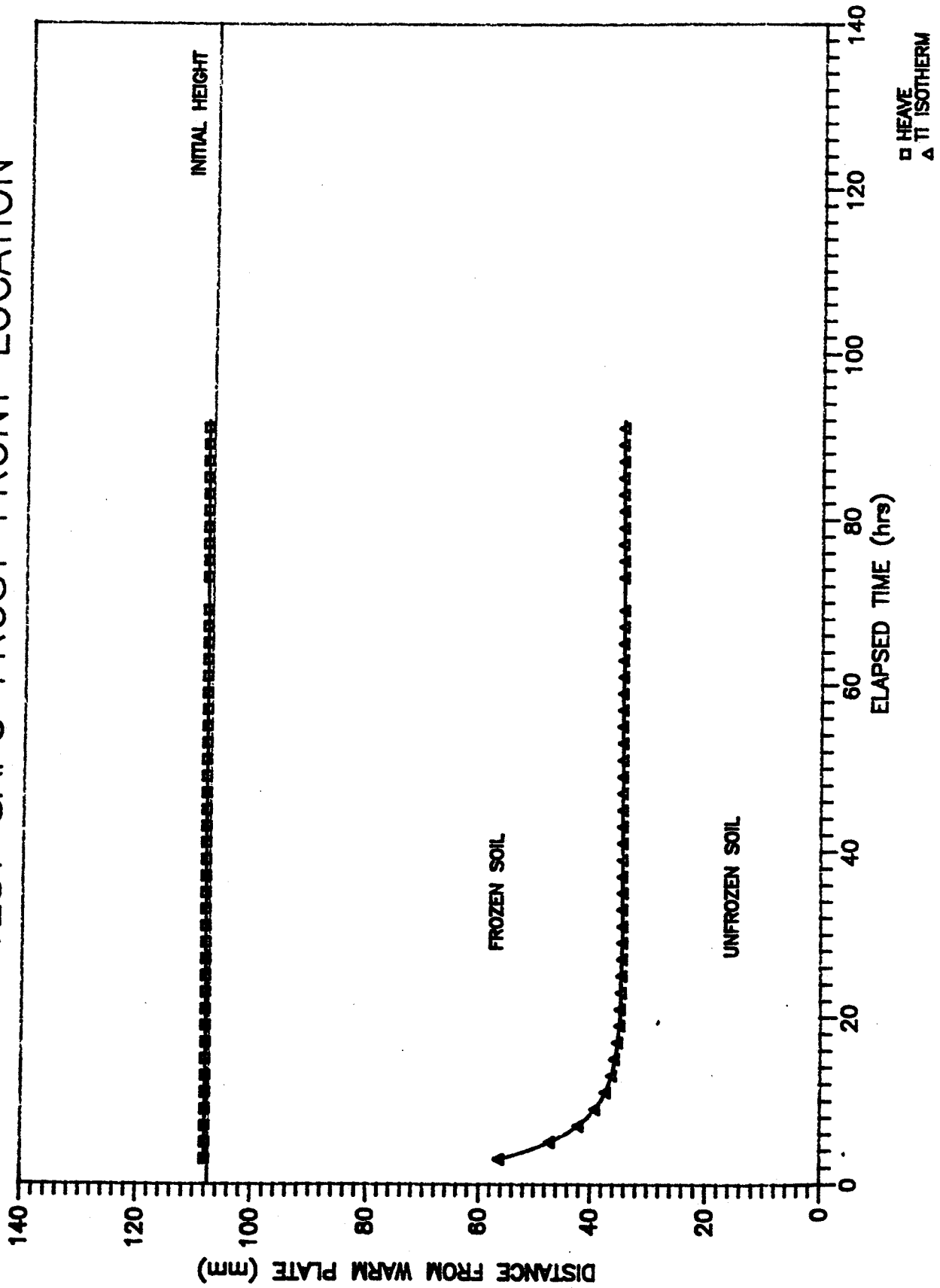
FREEZING TEST SAP3



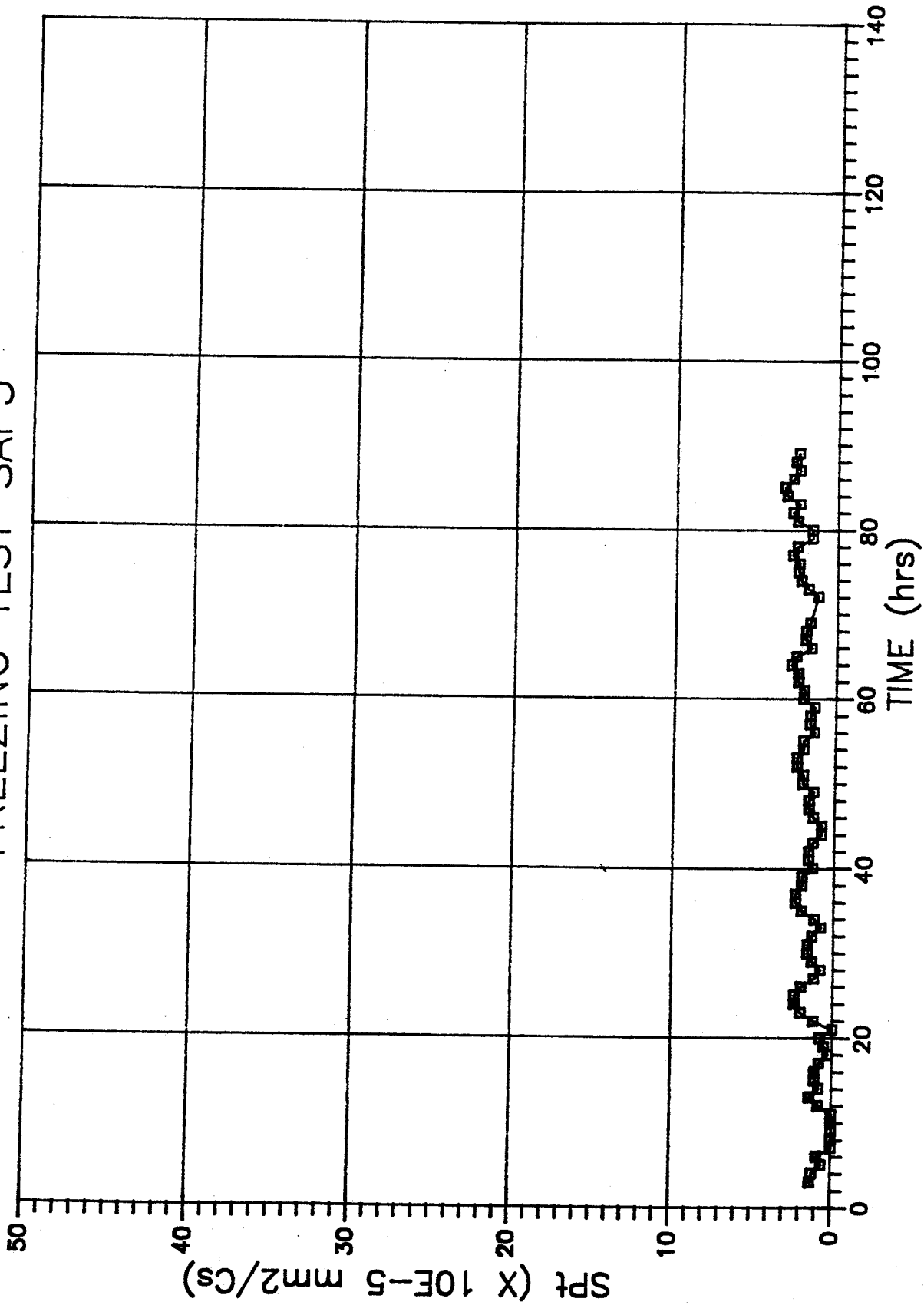
FREEZING TEST SAP3



TEST SAP3 FROST FRONT LOCATION



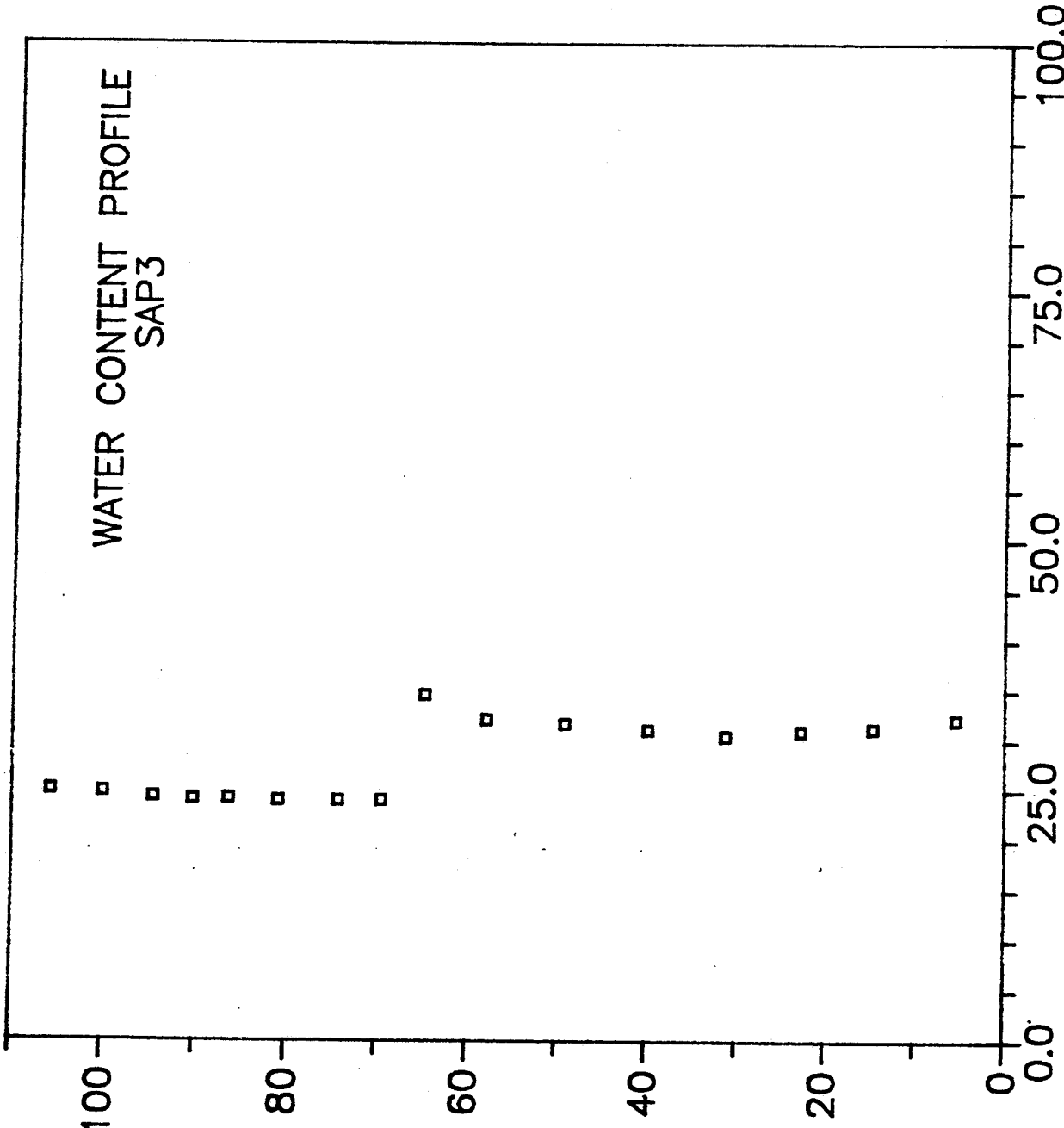
FREEZING TEST SAP3



WATER CONTENT PROFILE
SAP3

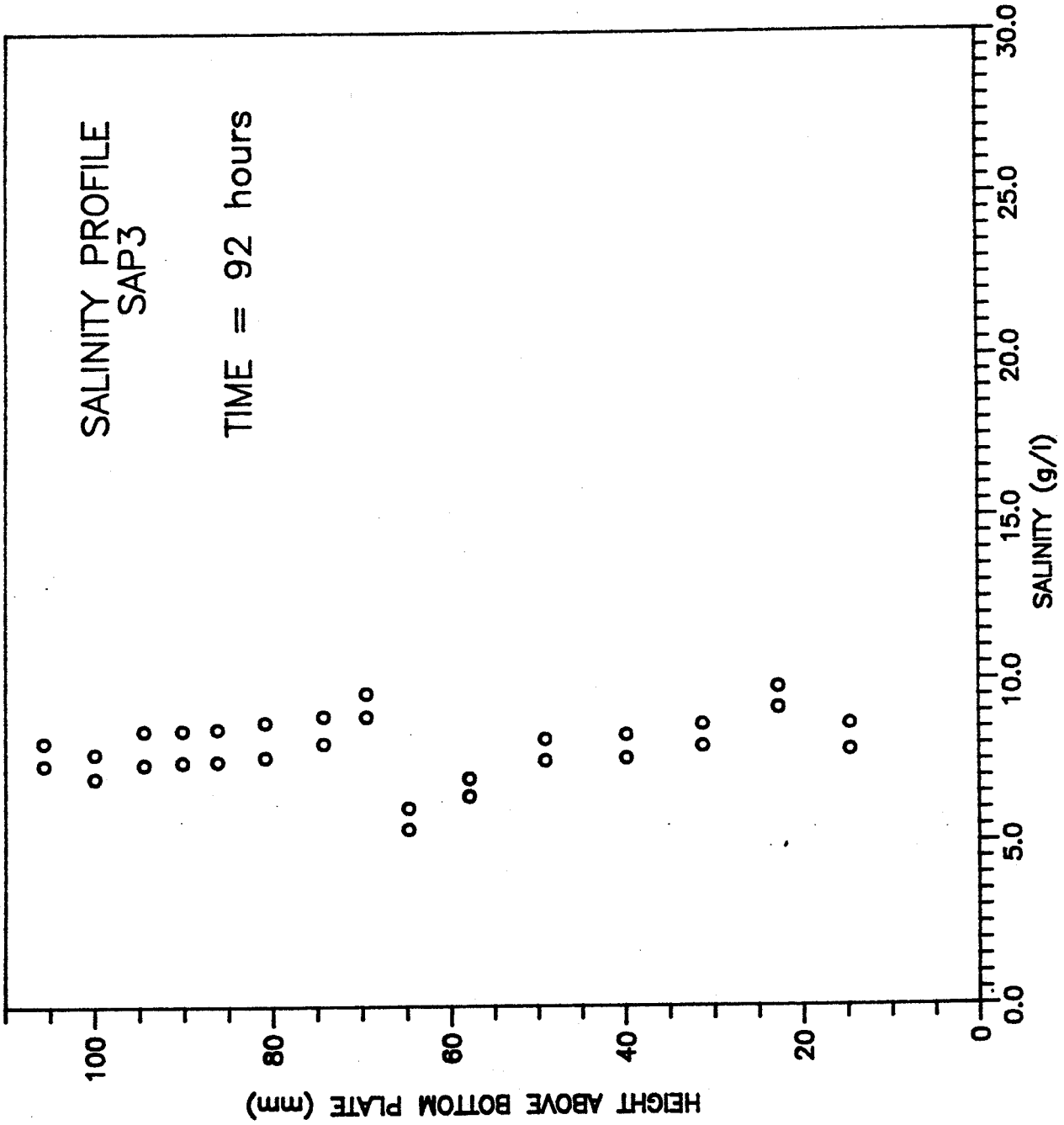
HEIGHT ABOVE BOTTOM PLATE (mm)

WATER CONTENT (% DRY WEIGHT)

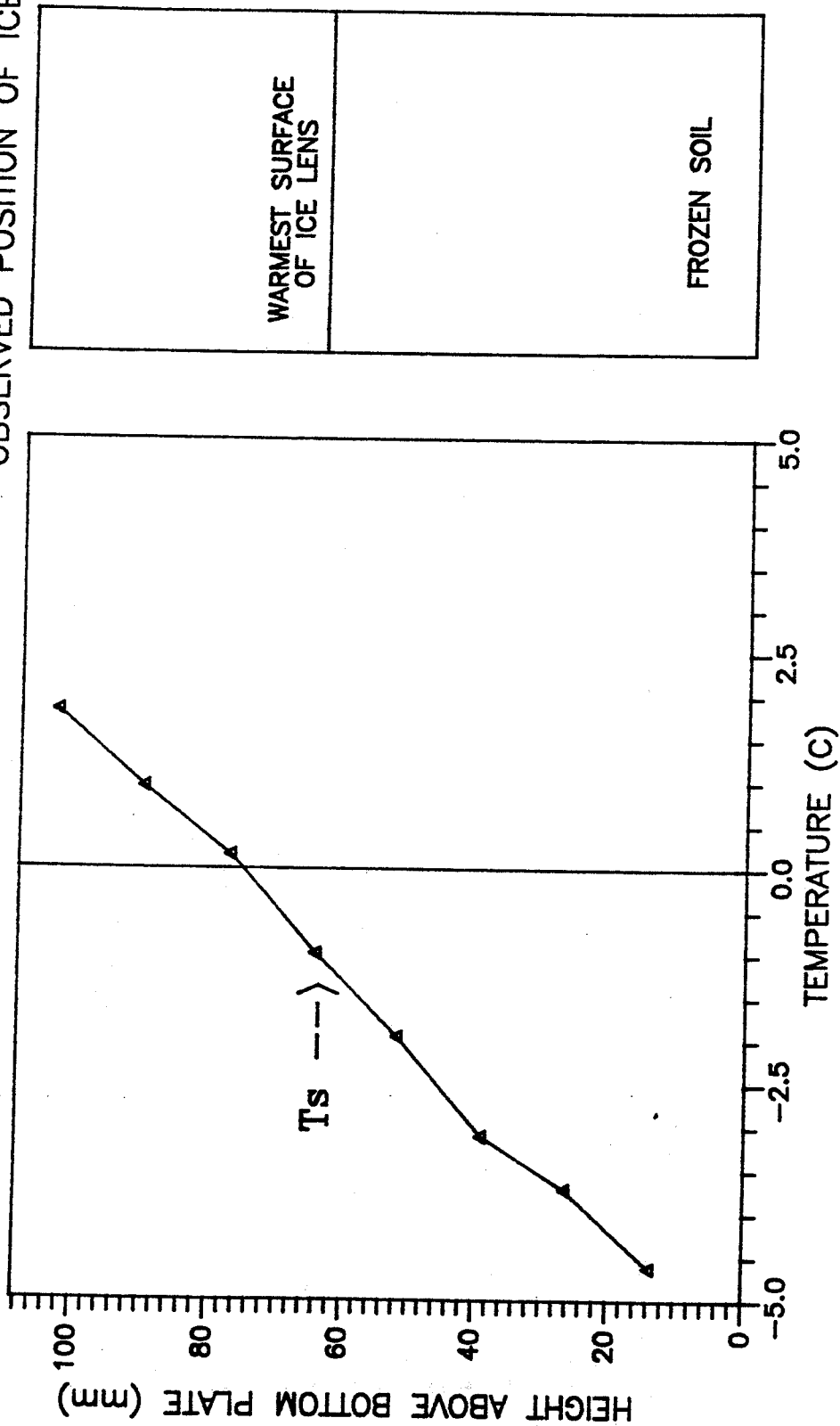


SALINITY PROFILE
SAP3

TIME = 92 hours

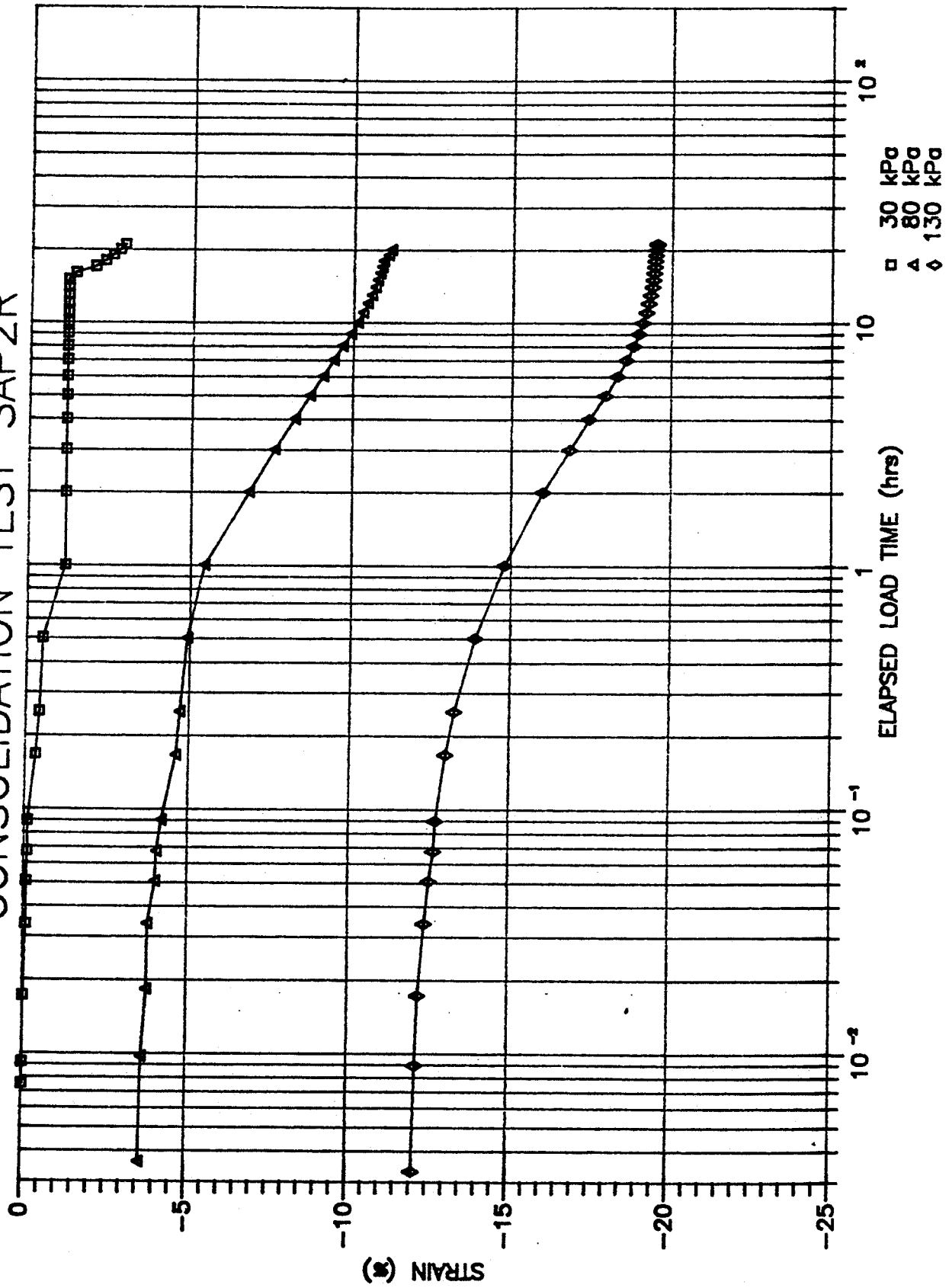


OBSERVED POSITION OF ICE LENS

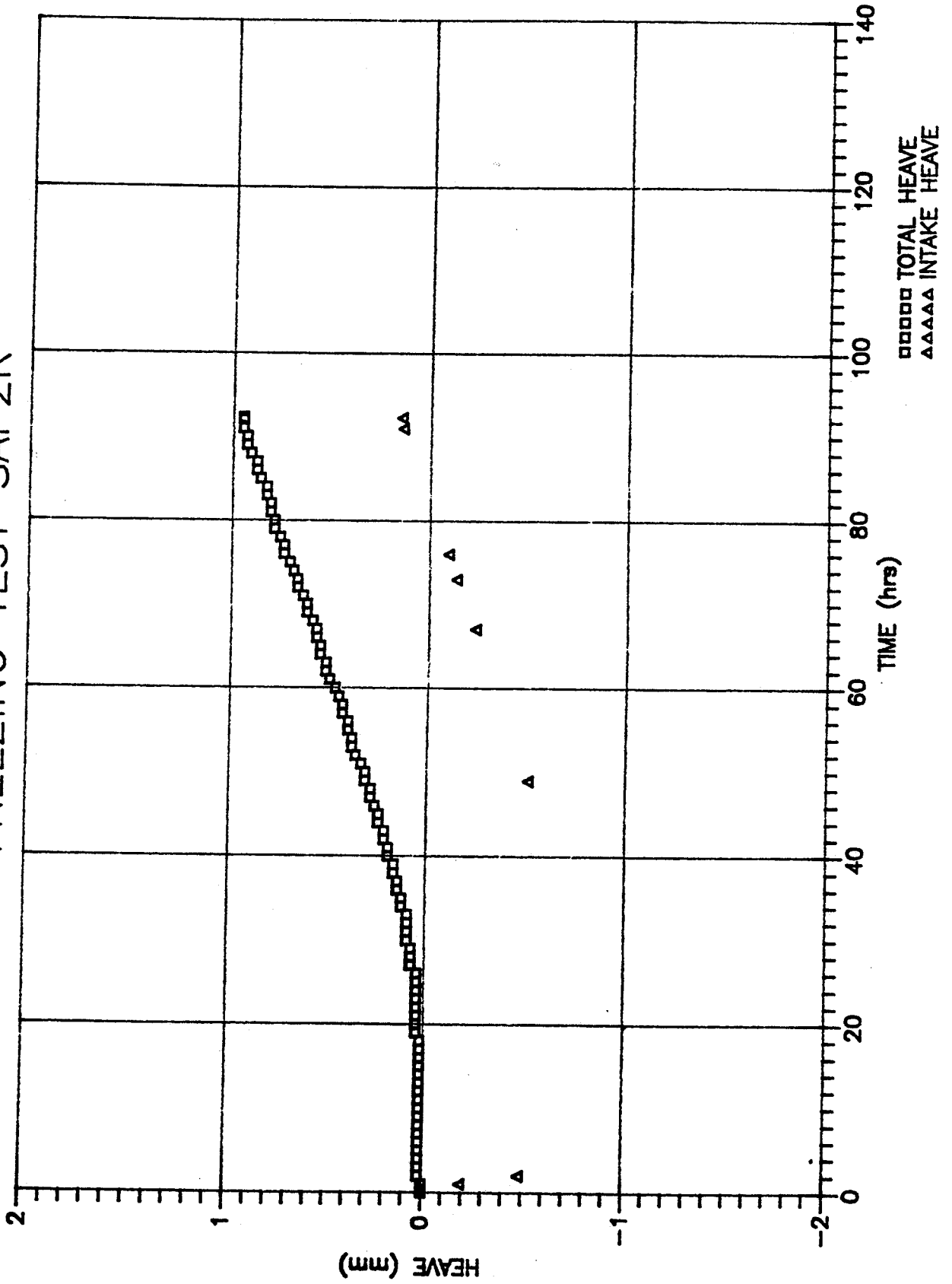


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP3

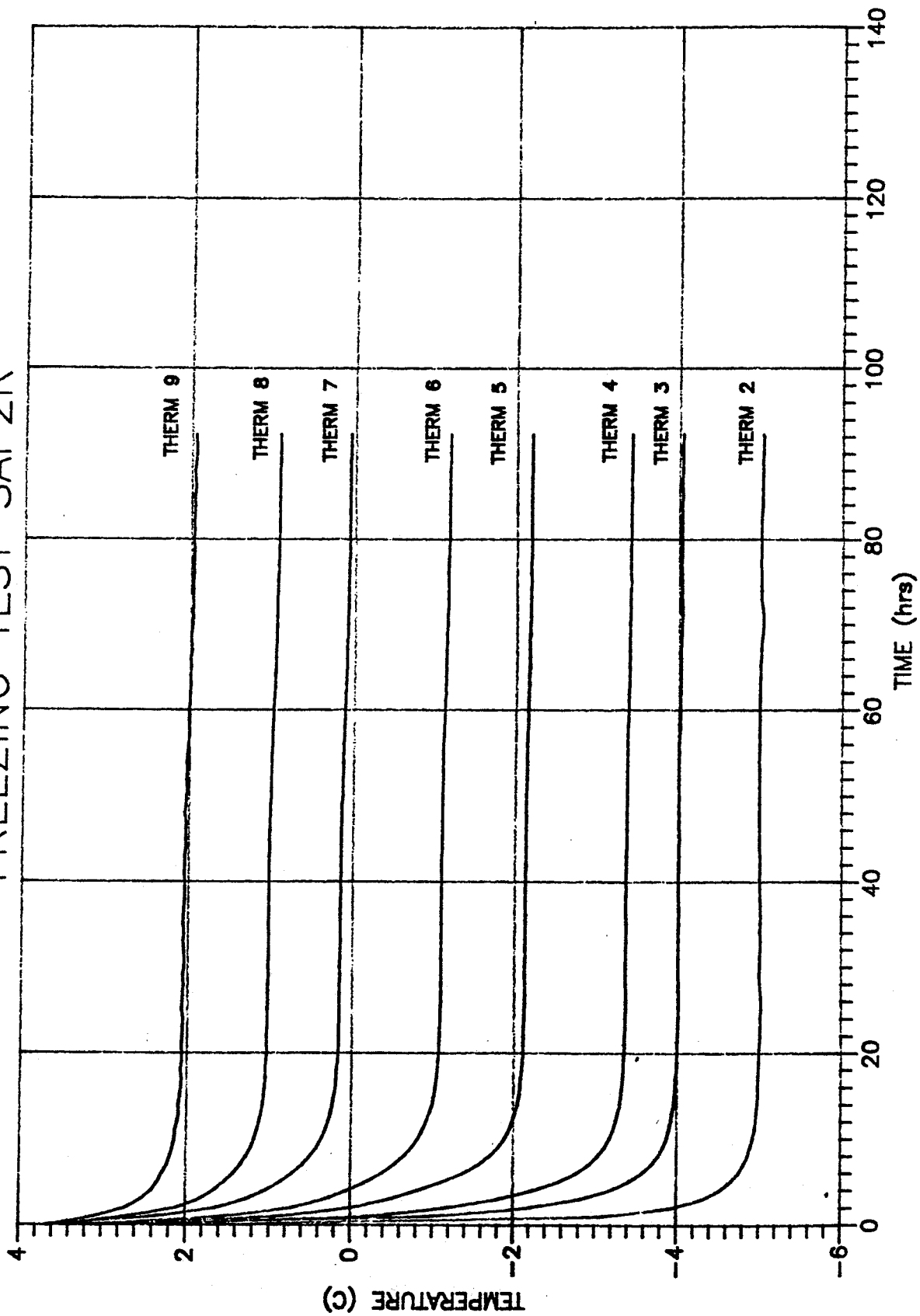
CONSOLIDATION TEST SAP2R



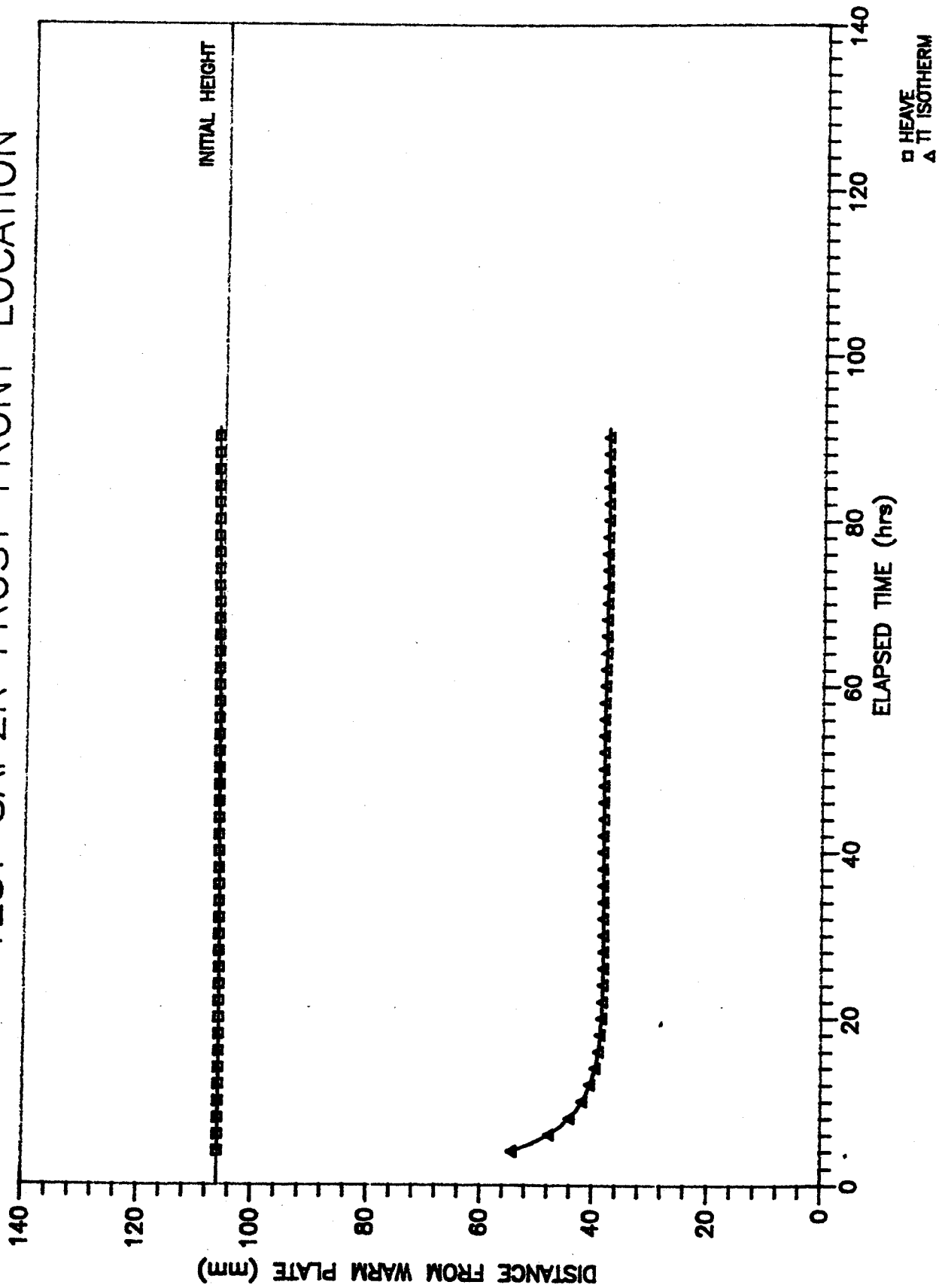
FREEZING TEST SAP2R



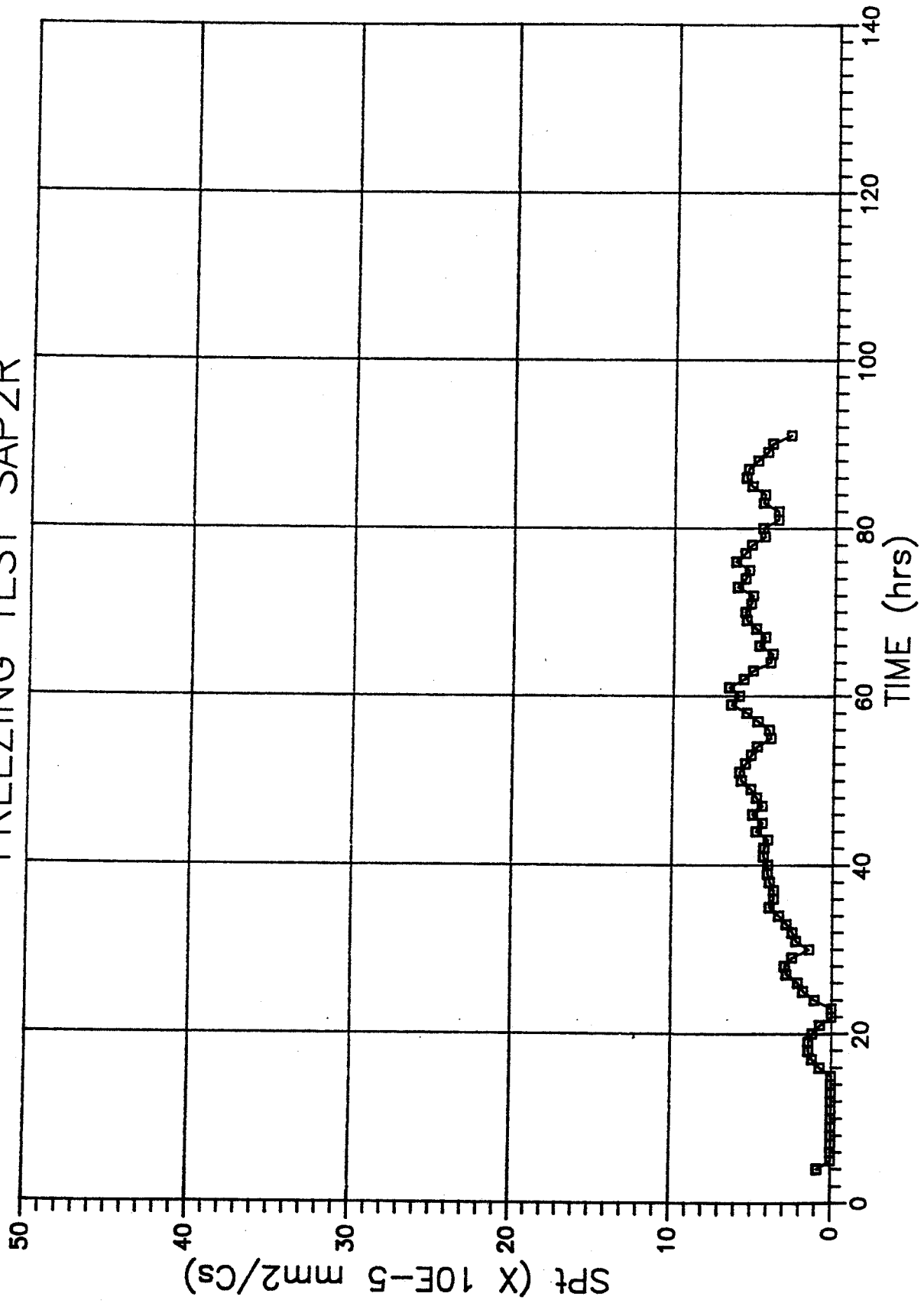
FREEZING TEST SAP2R



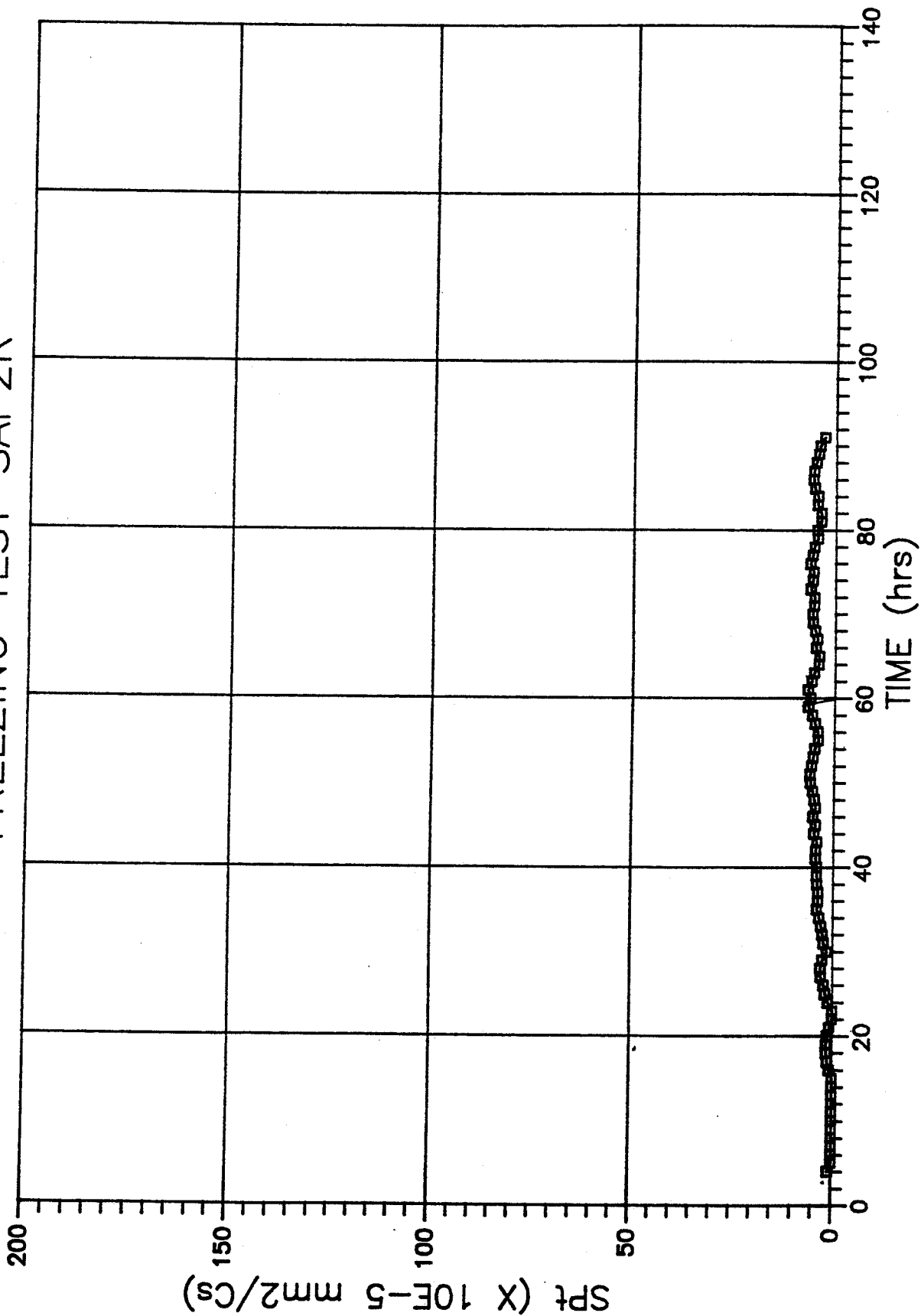
TEST SAP2R FROST FRONT LOCATION



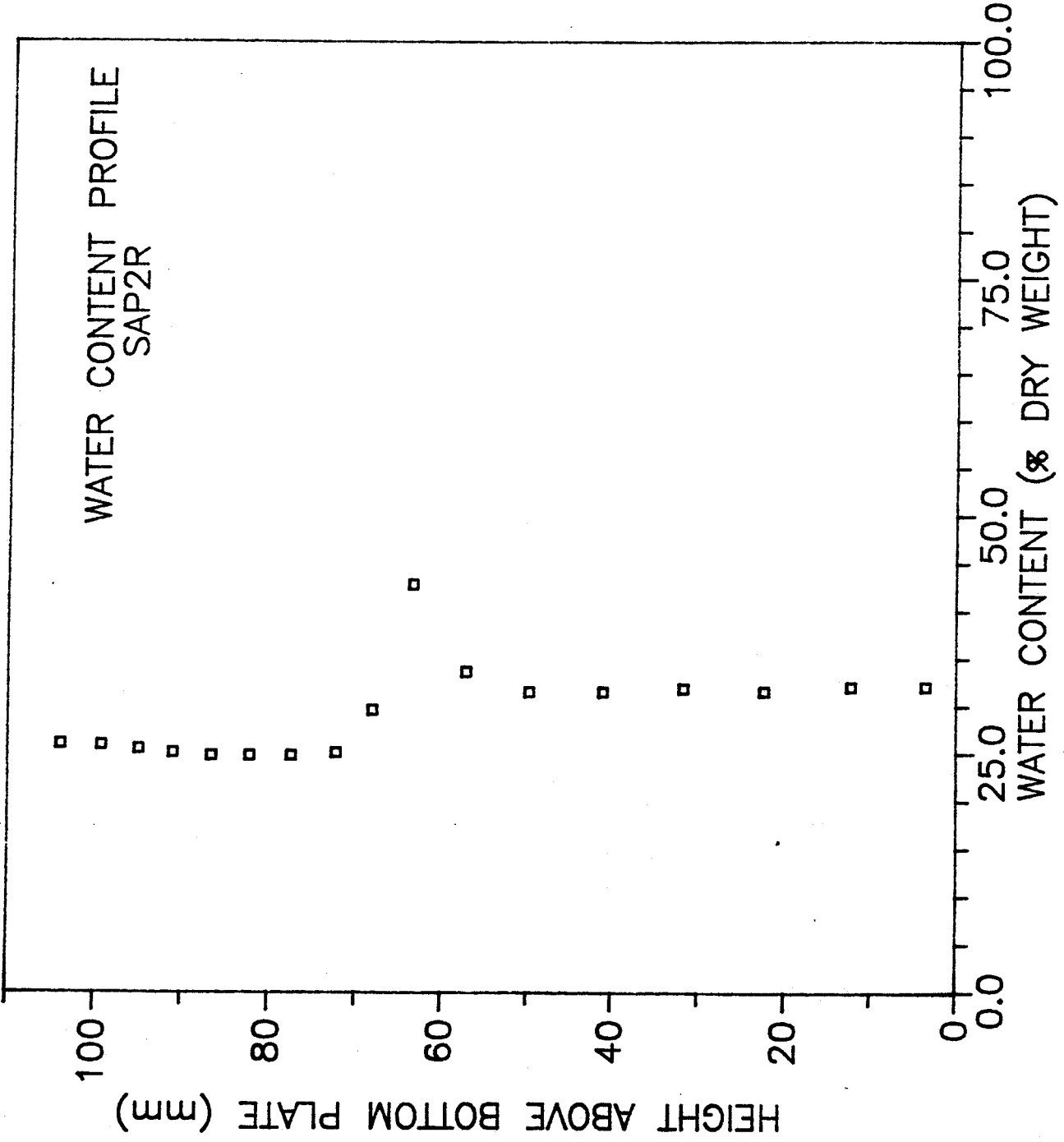
FREEZING TEST SAP2R



FREEZING TEST SAP2R

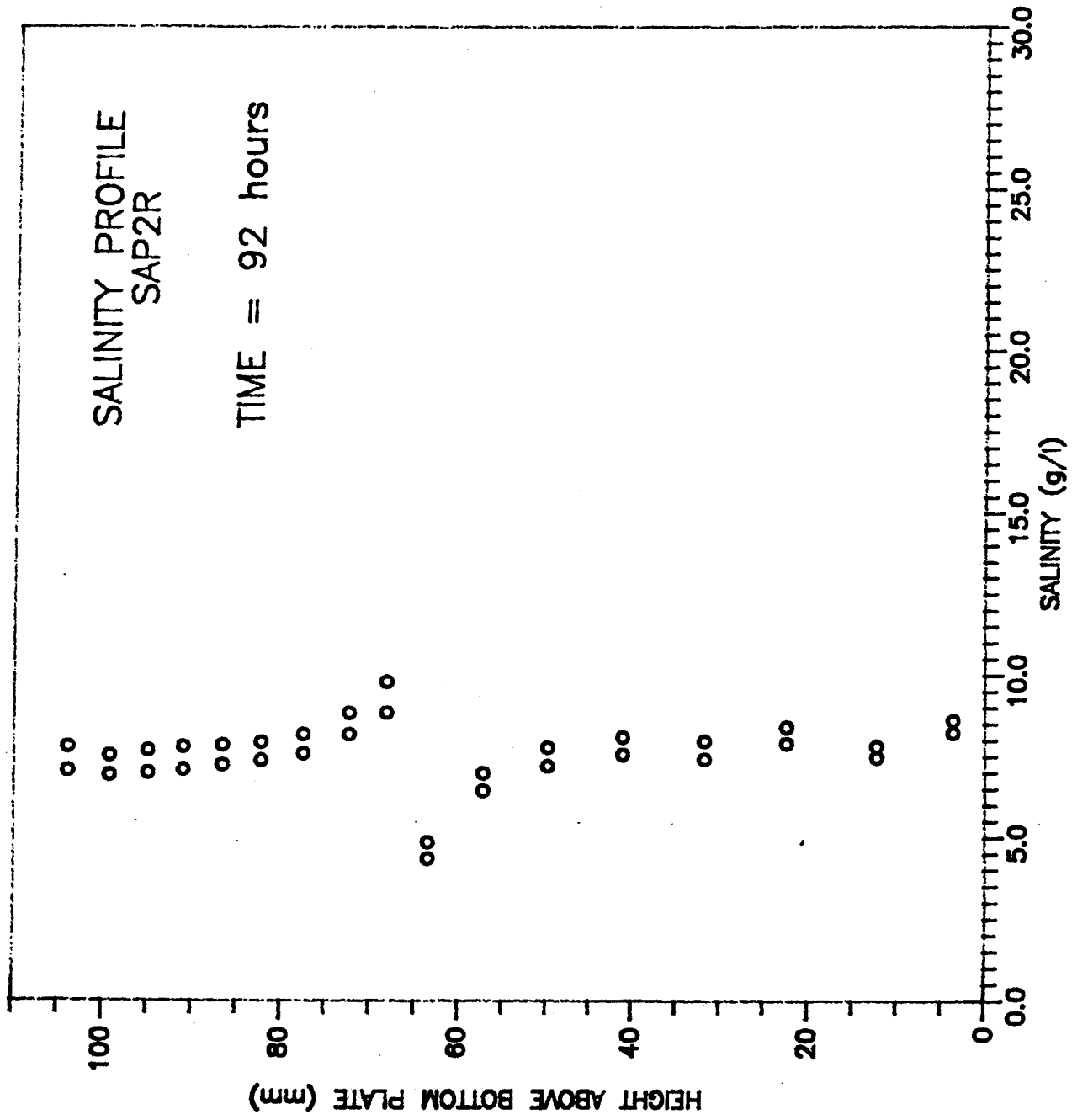


WATER CONTENT PROFILE
SAP2R

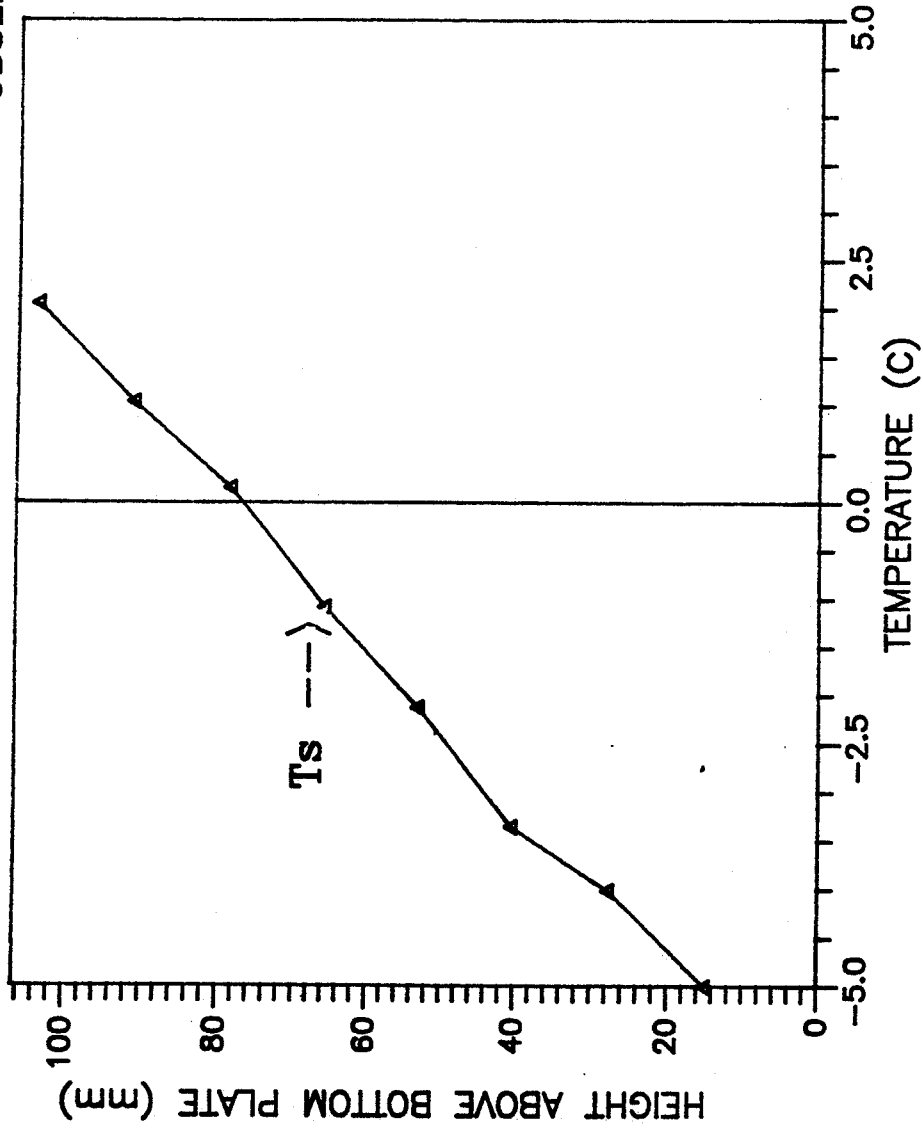
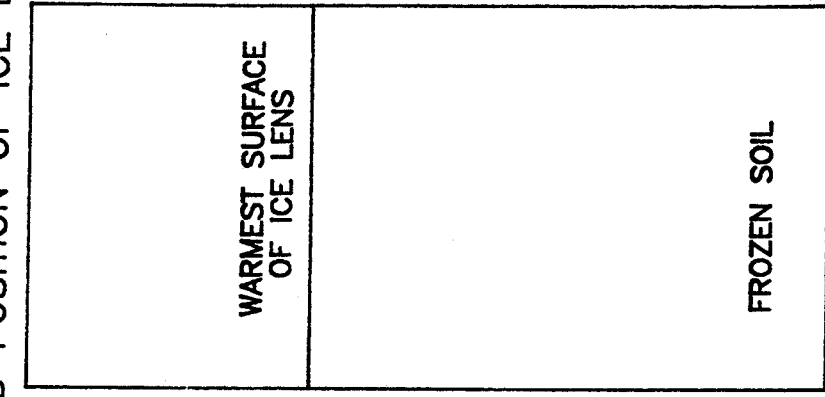


SALINITY PROFILE
SAP2R

TIME = 92 hours

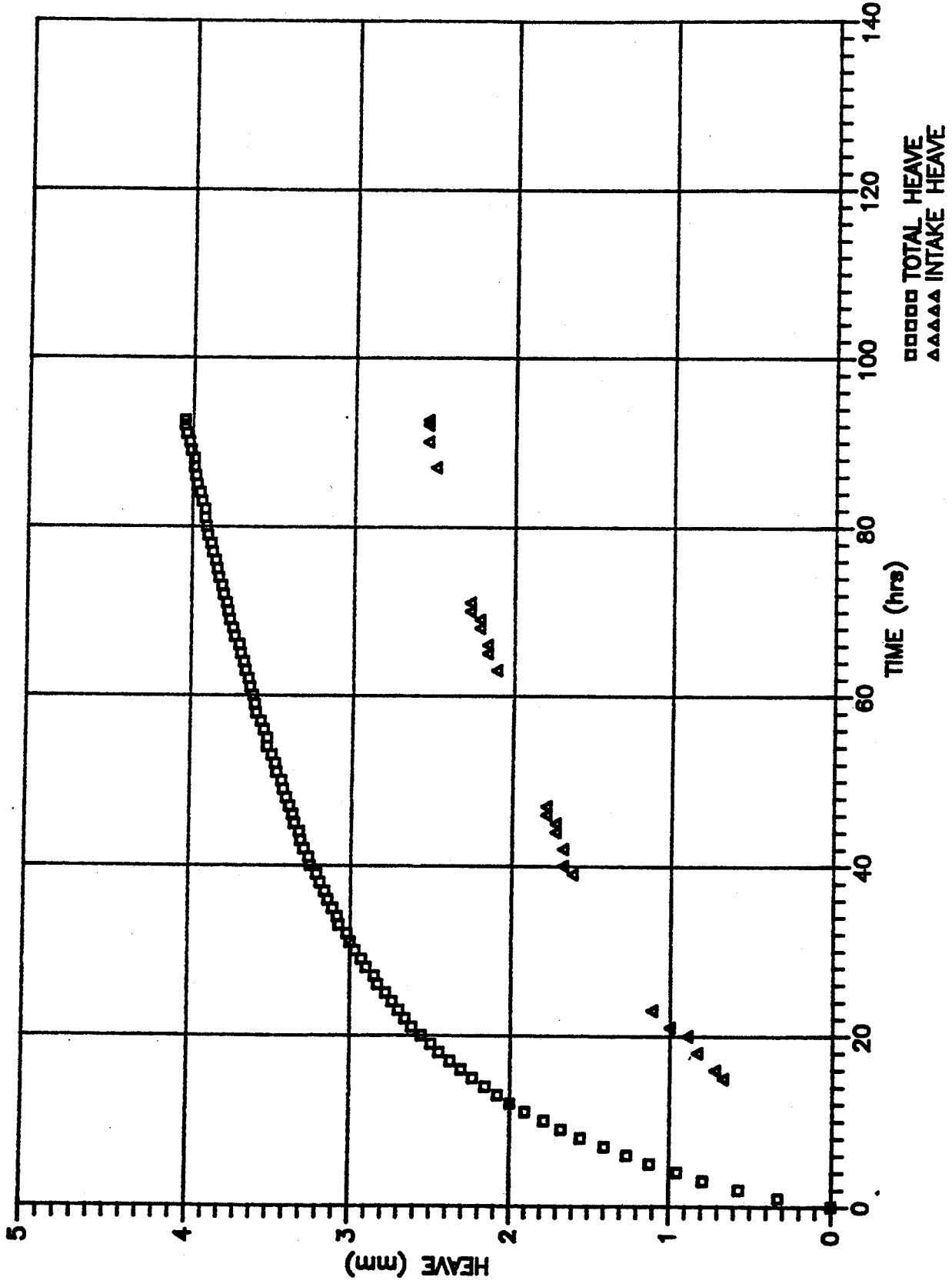


OBSERVED POSITION OF ICE LENS

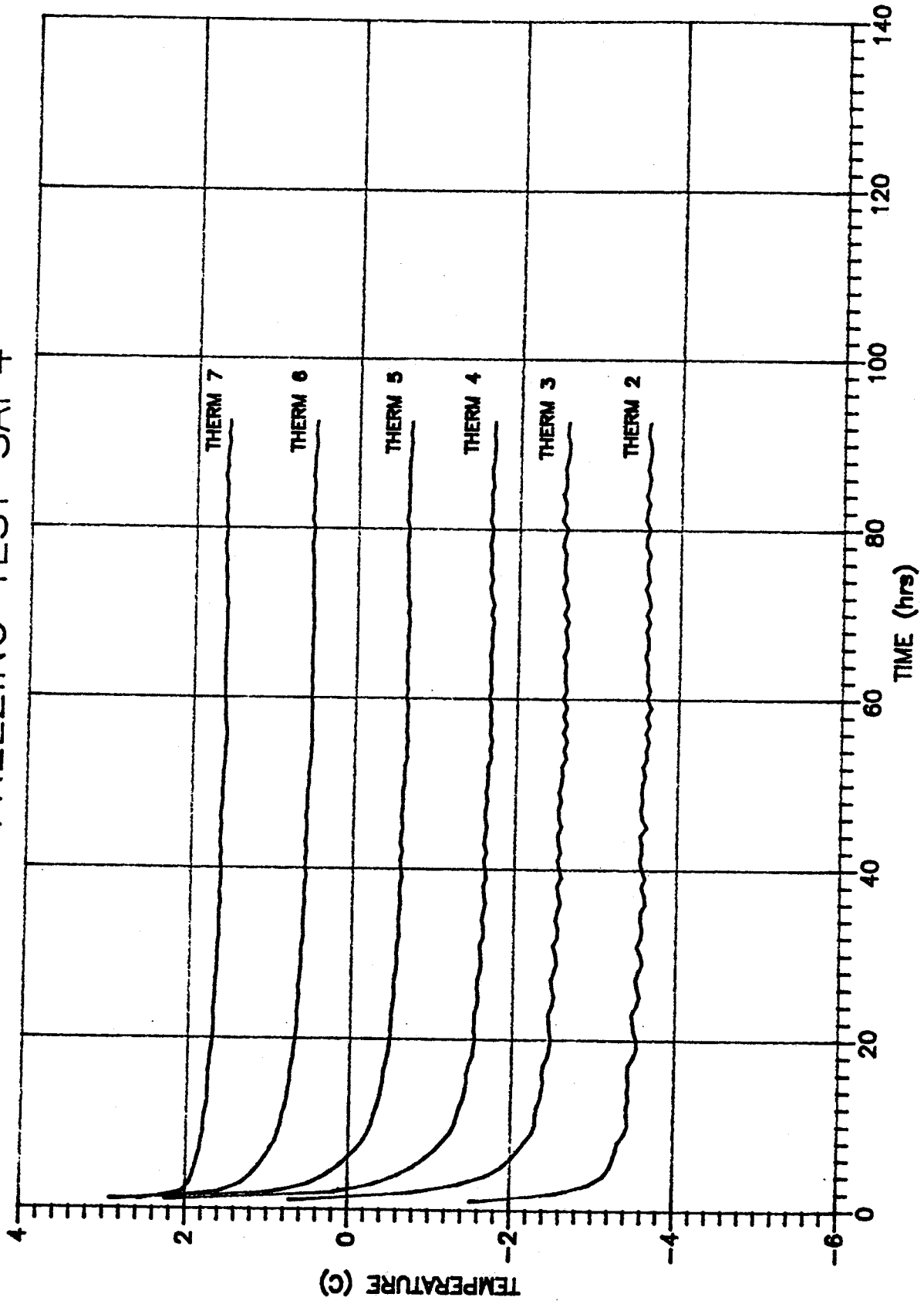


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP2R

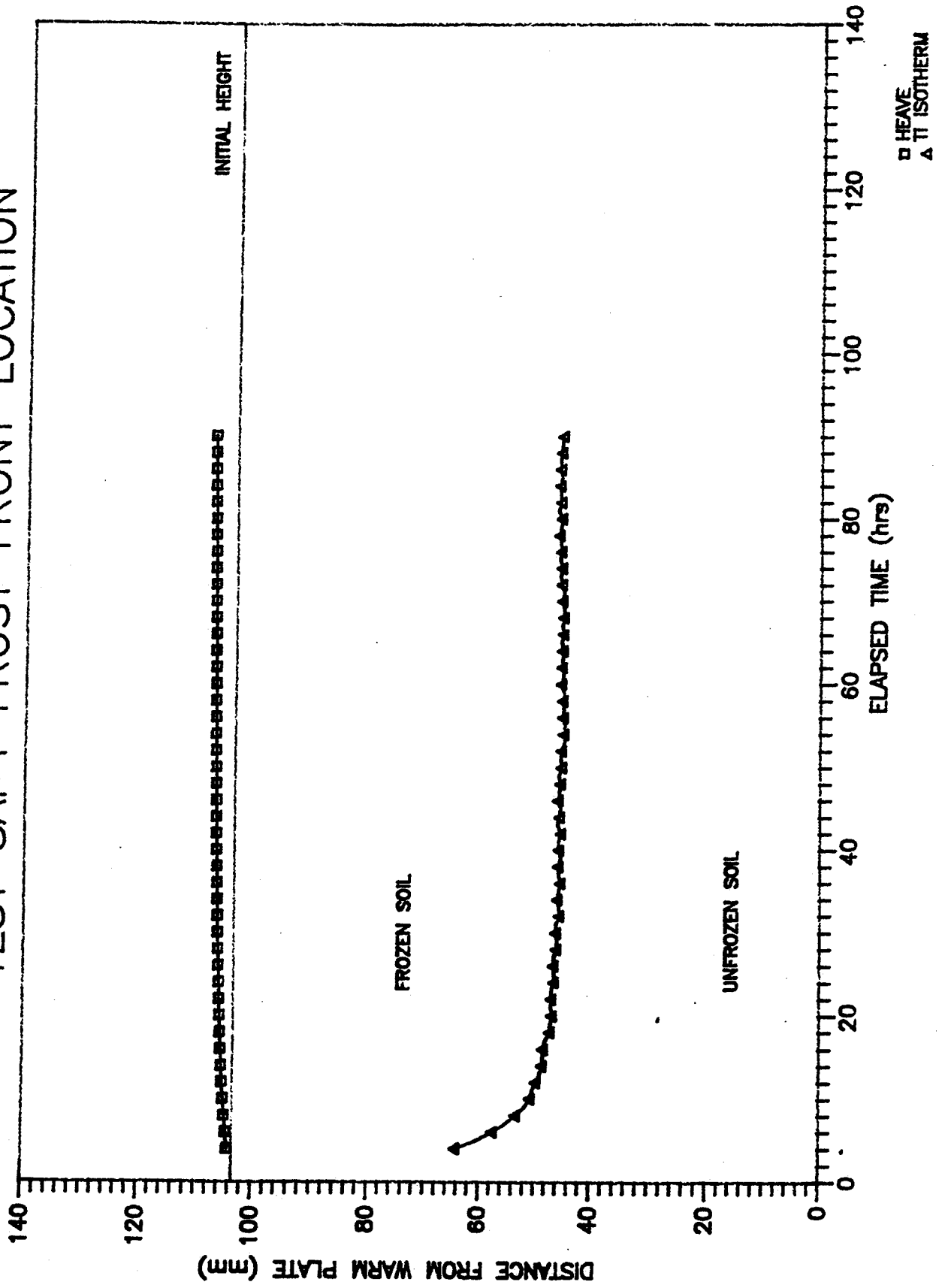
FREEZING TEST SAP4



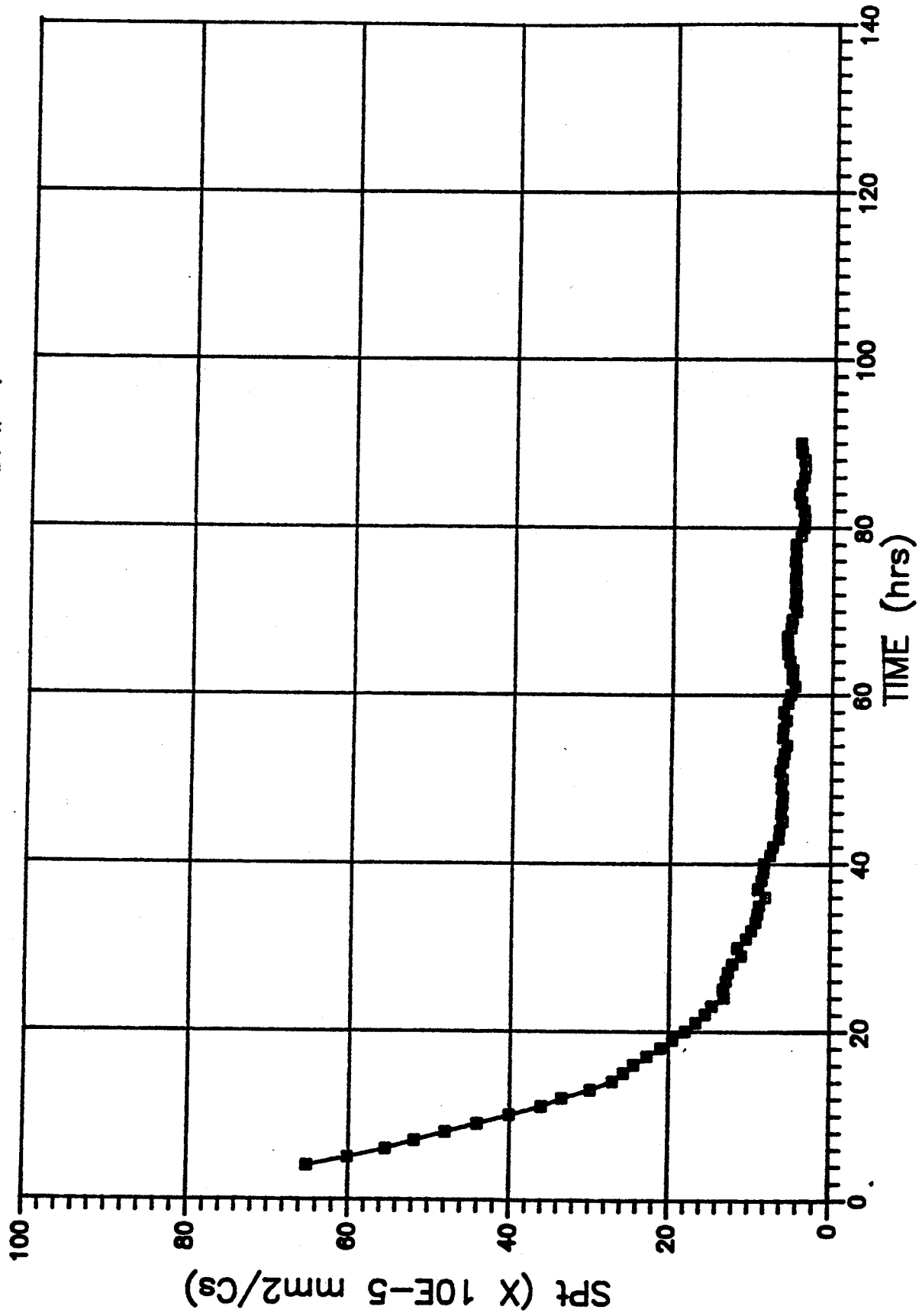
FREEZING TEST SAP4



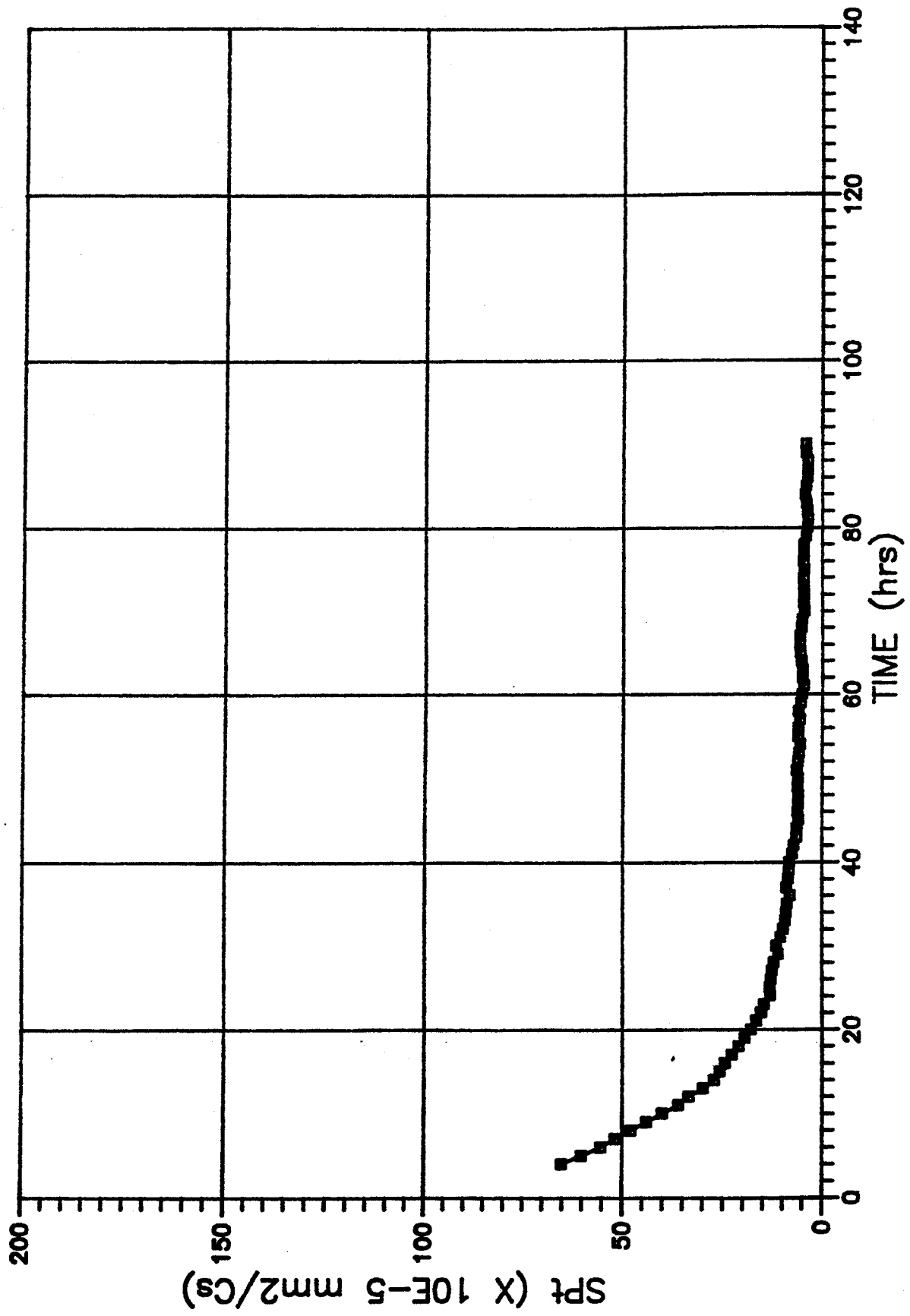
TEST SAP4 FROST FRONT LOCATION



FREEZING TEST SAP4

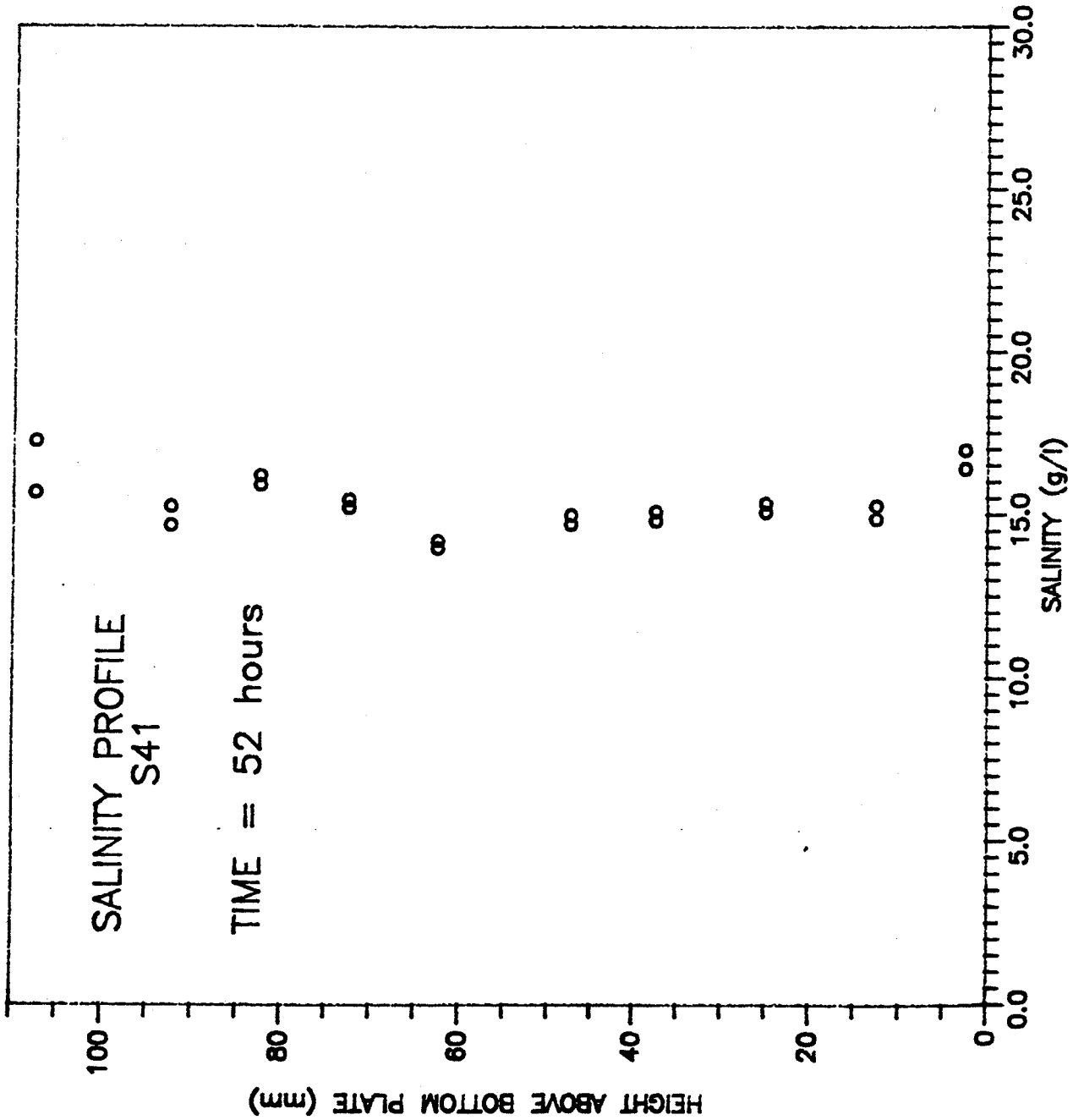


FREEZING TEST SAP4

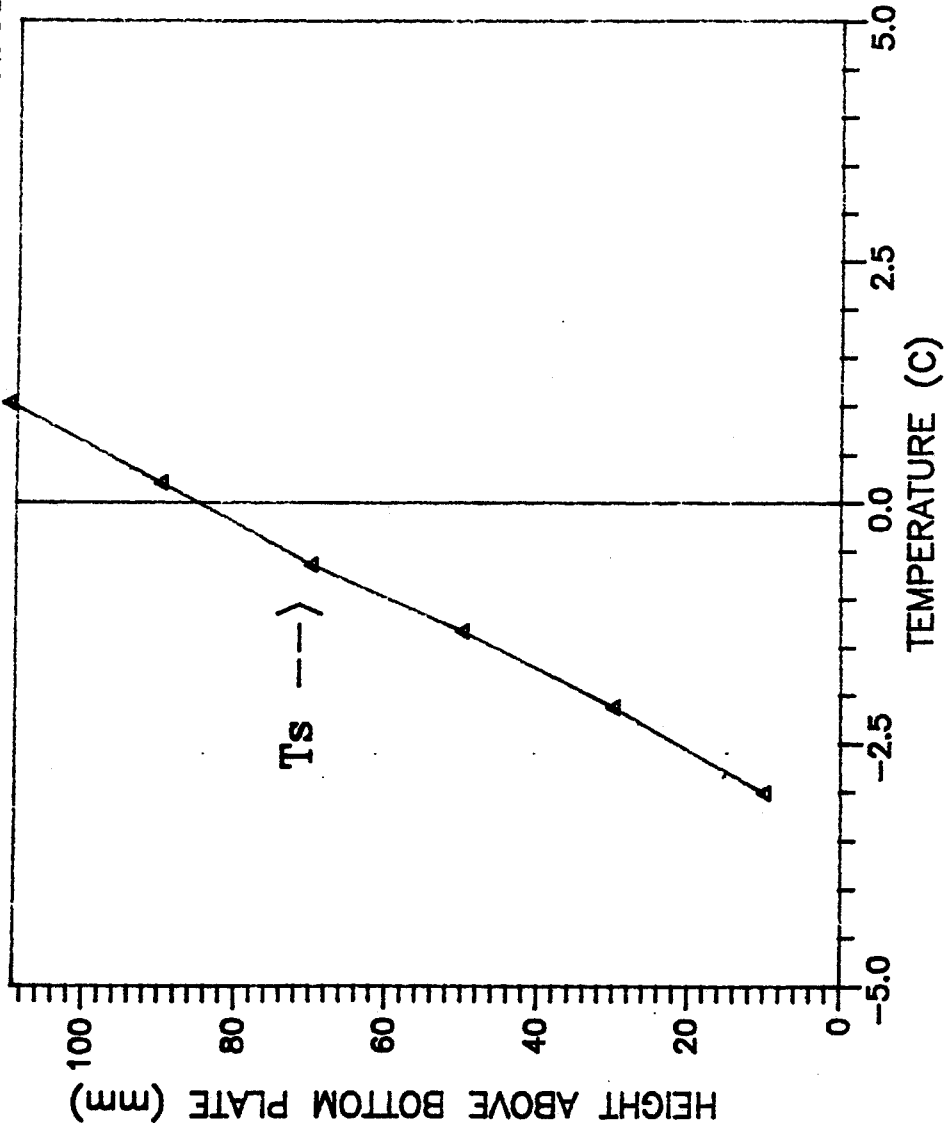
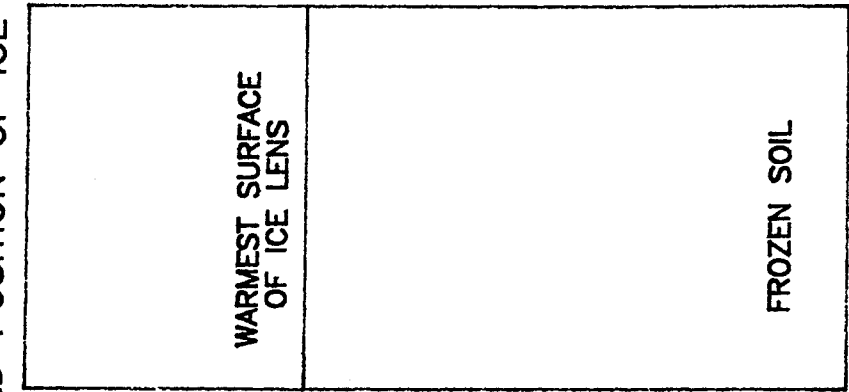


SALINITY PROFILE
S41

TIME = 52 hours

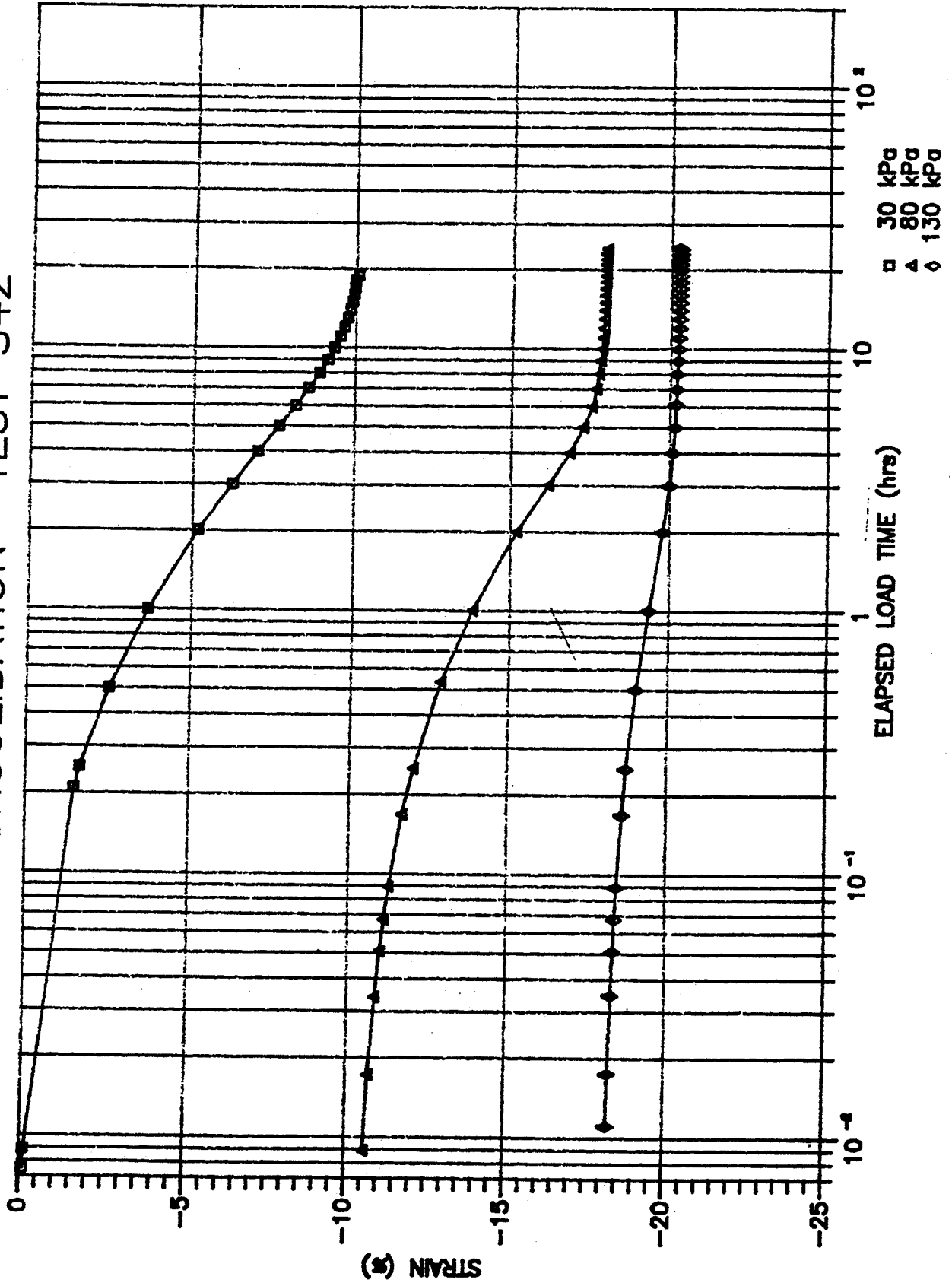


OBSERVED POSITION OF ICE LENS

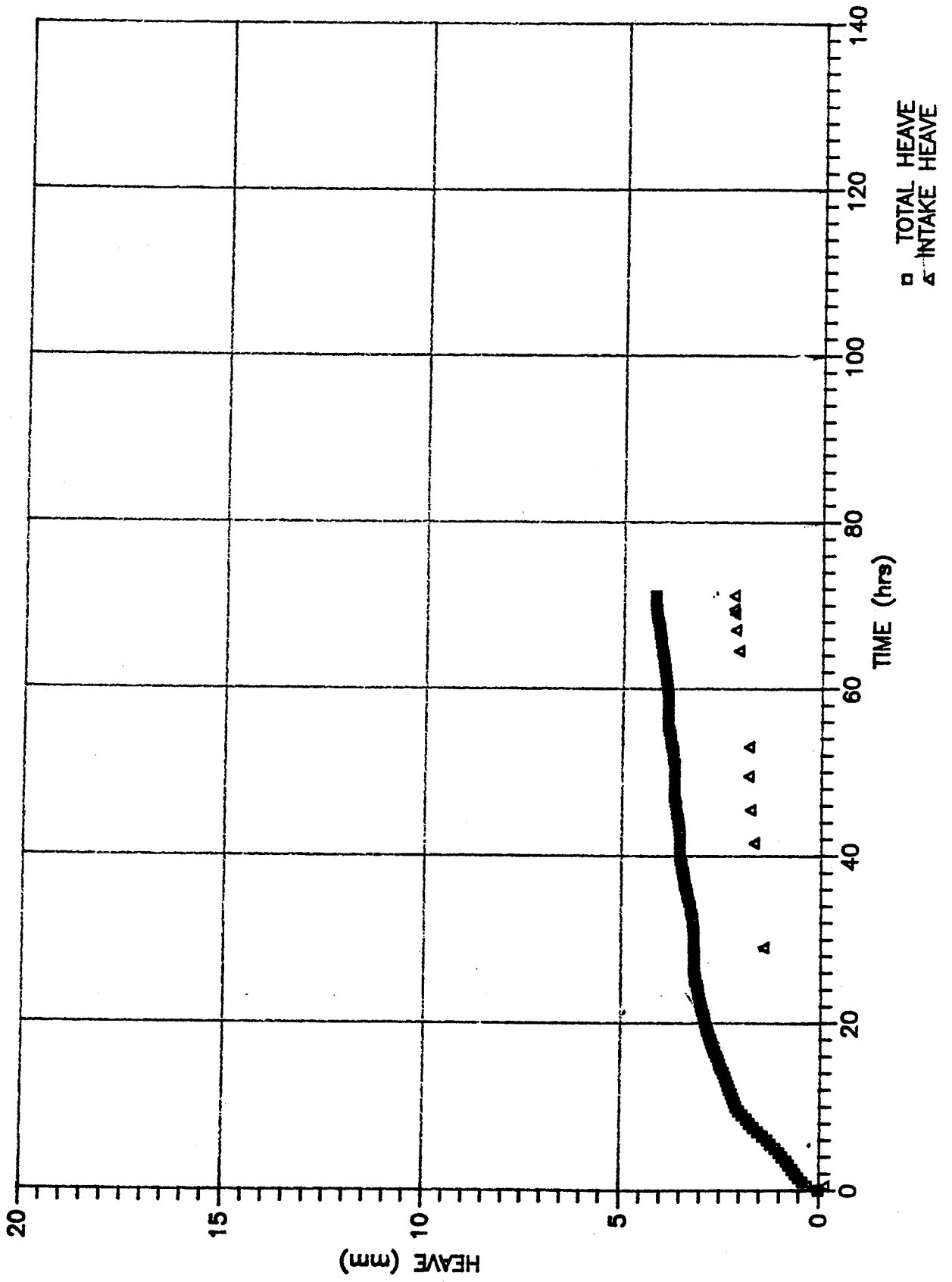


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S41

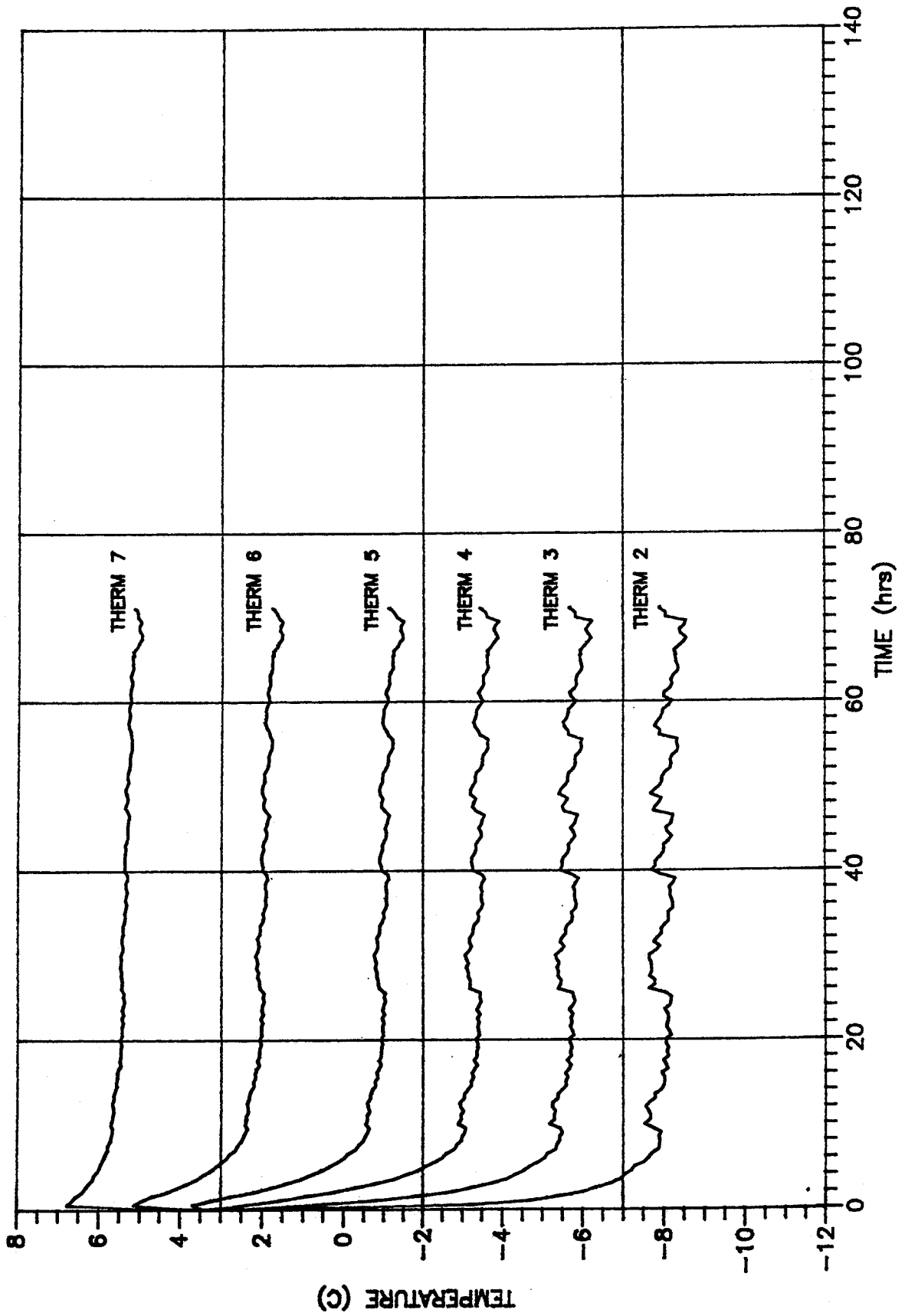
CONSOLIDATION TEST S42



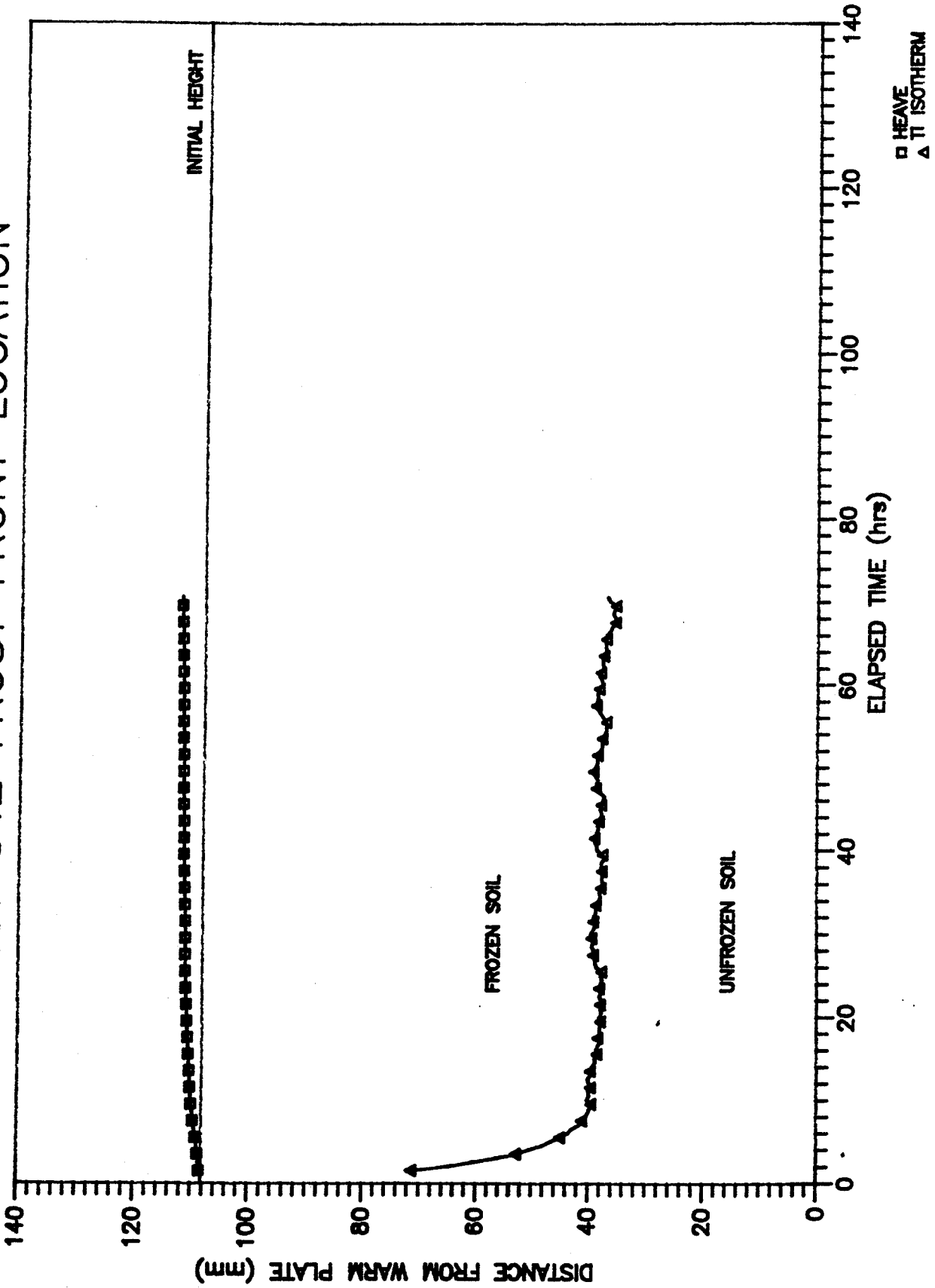
FREEZING TEST S42



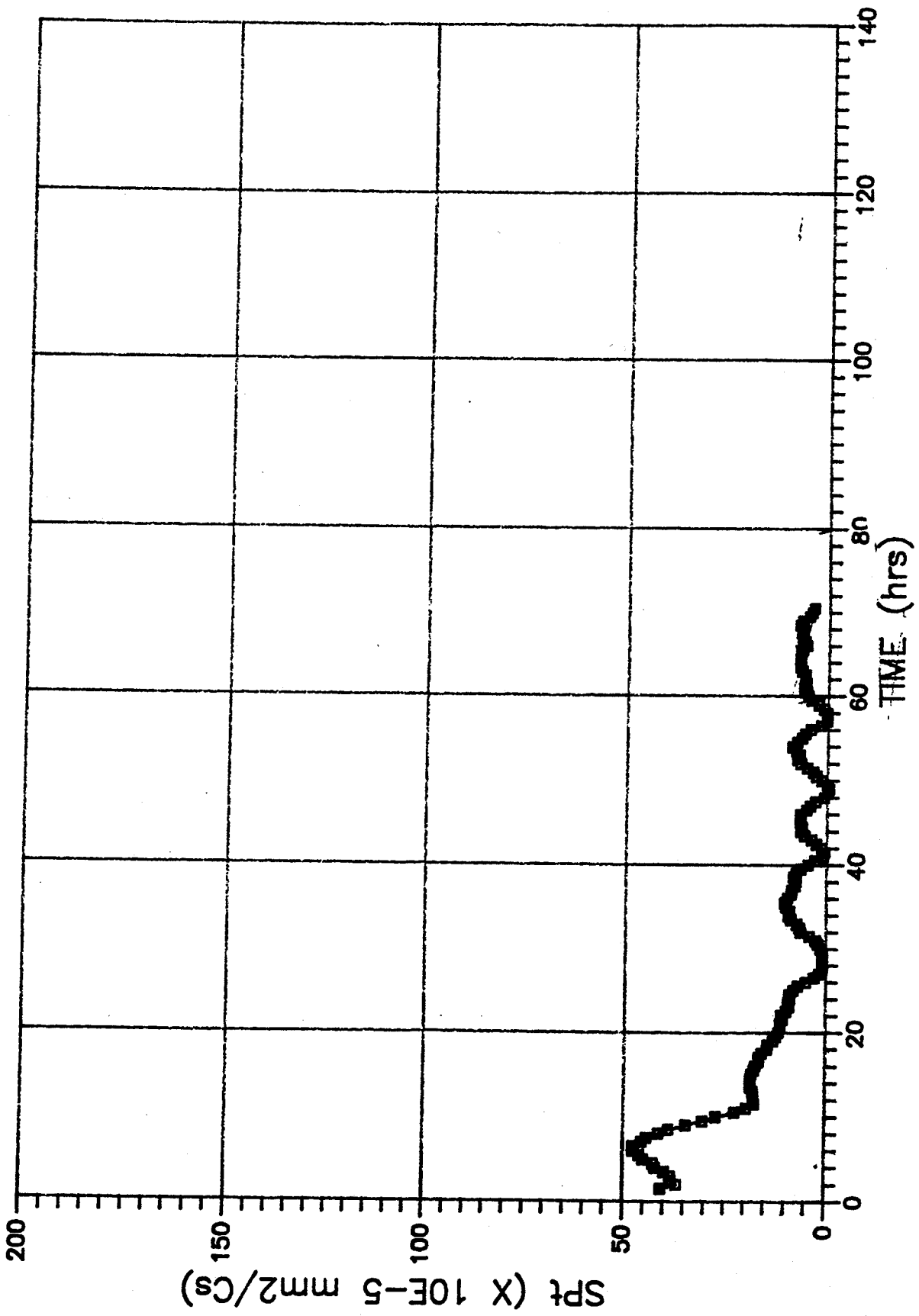
FREEZING TEST S42



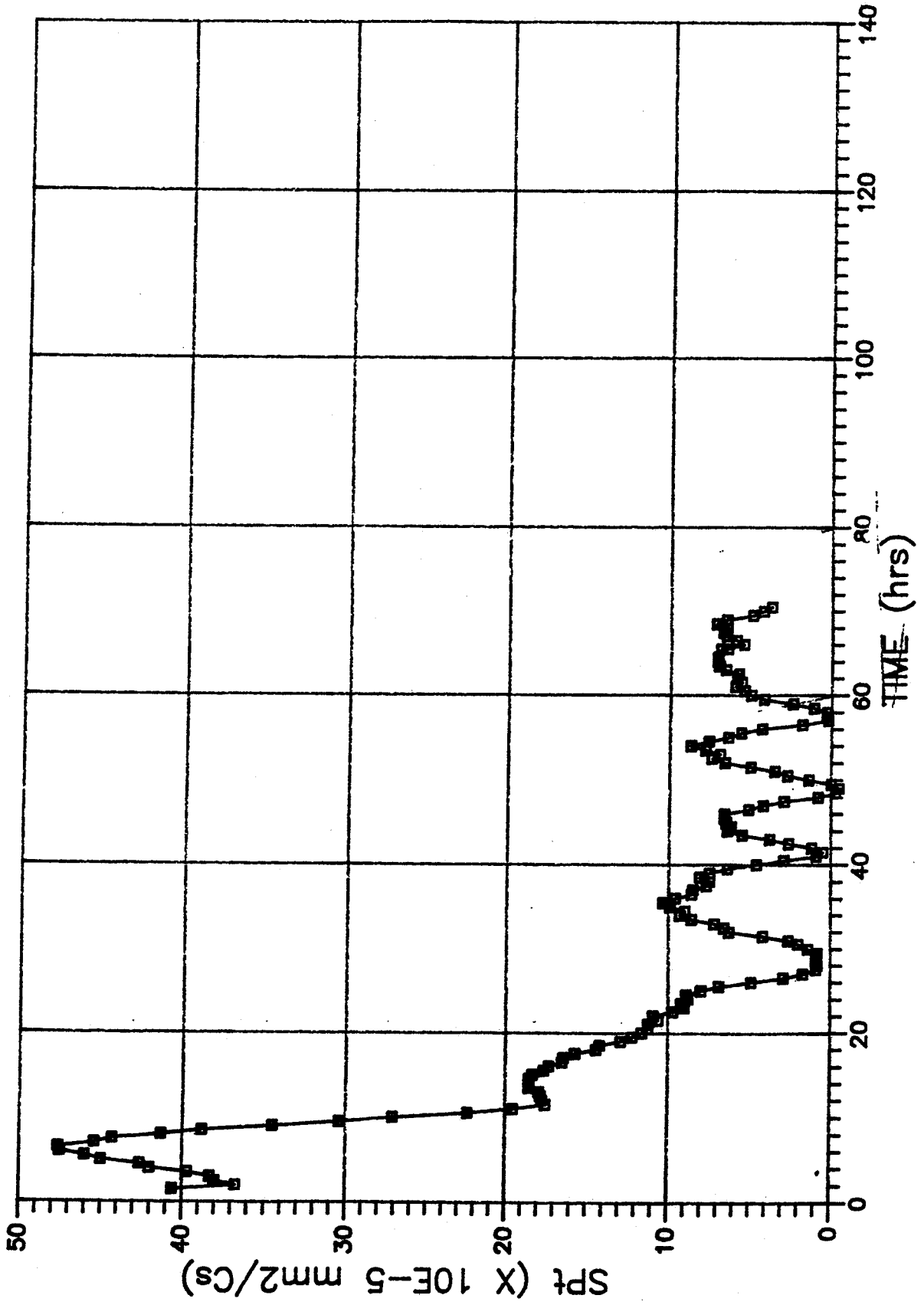
TEST S42 FROST FRONT LOCATION



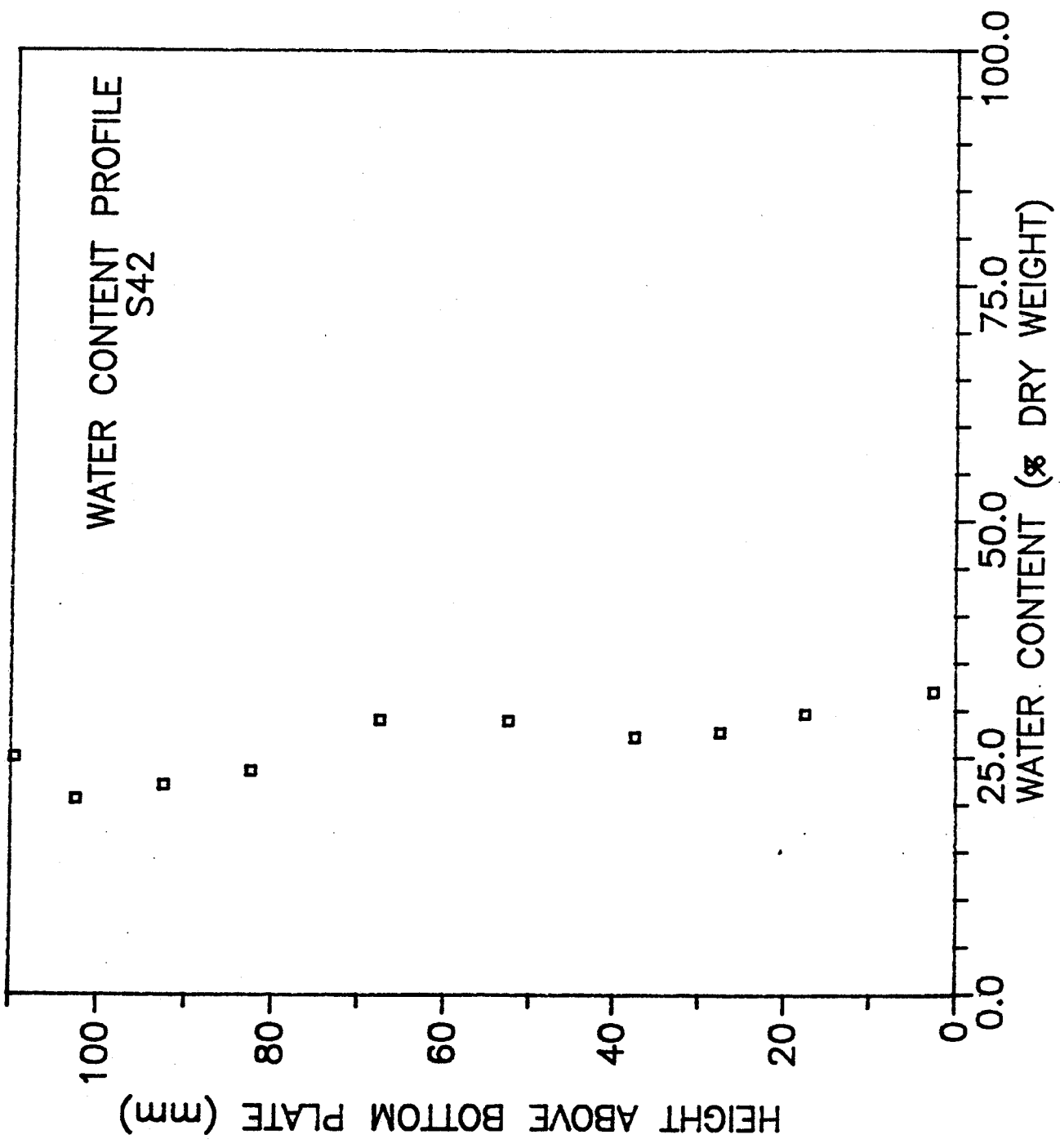
FREEZING TEST S42

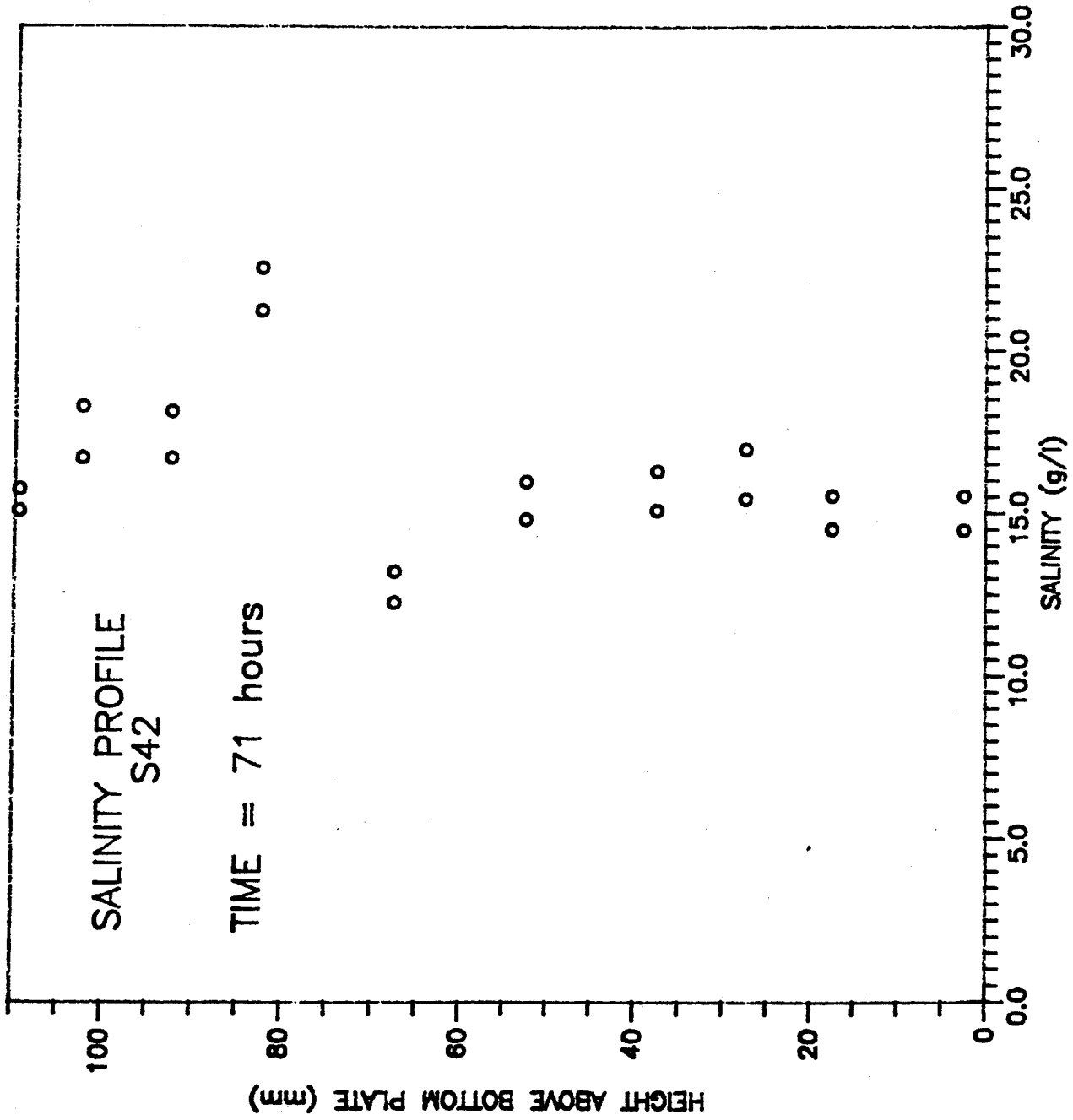


FREEZING TEST S42

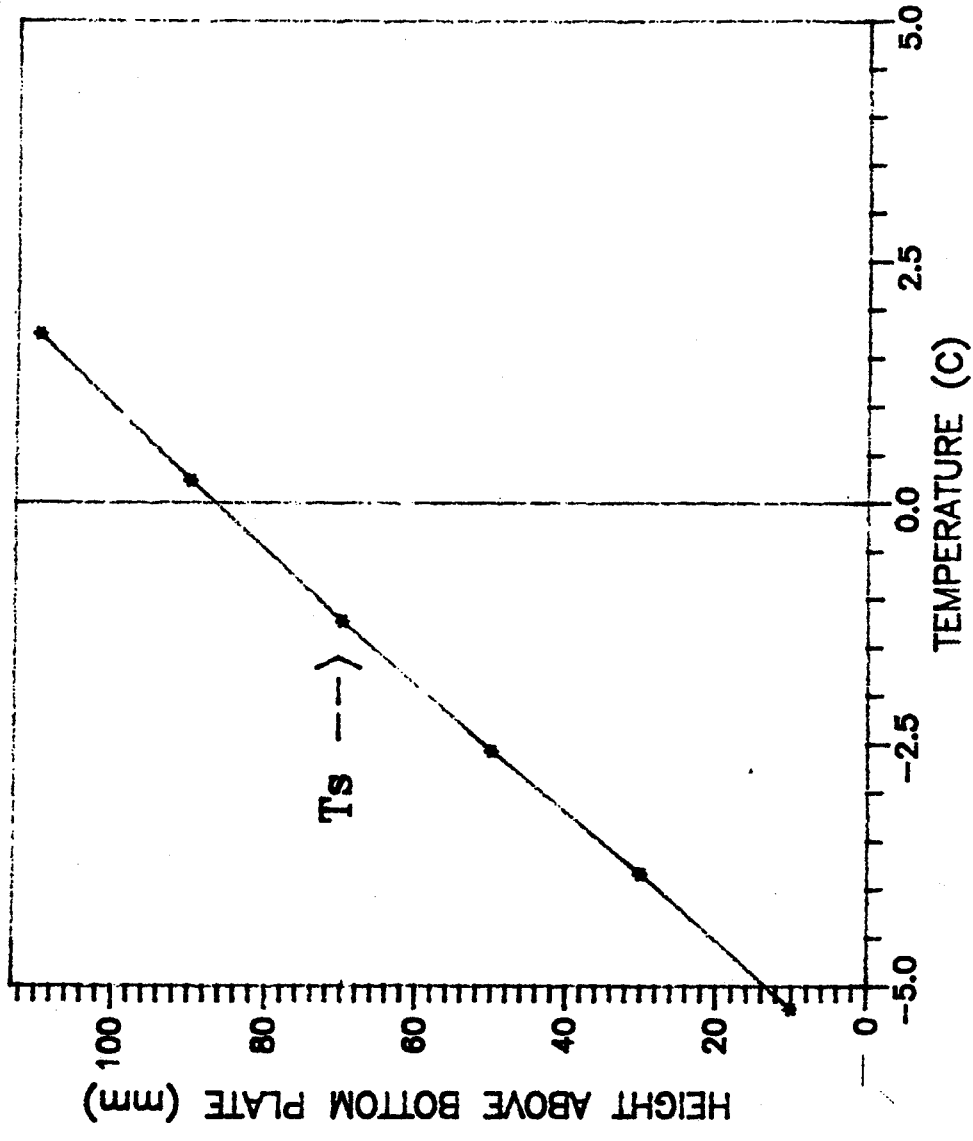
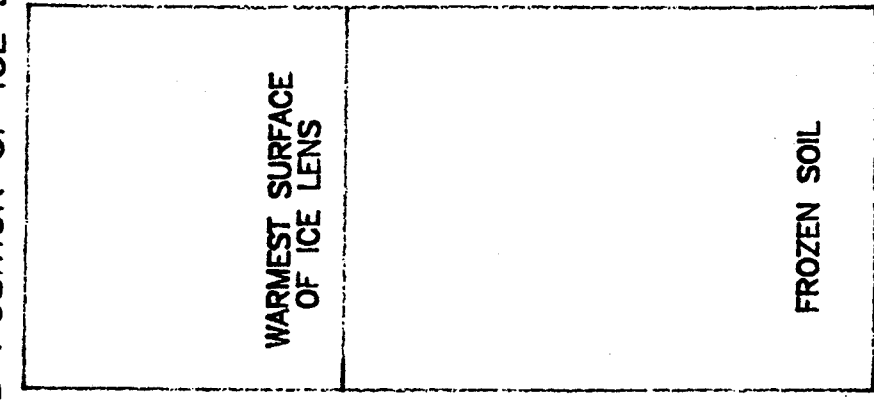


WATER CONTENT PROFILE
S42



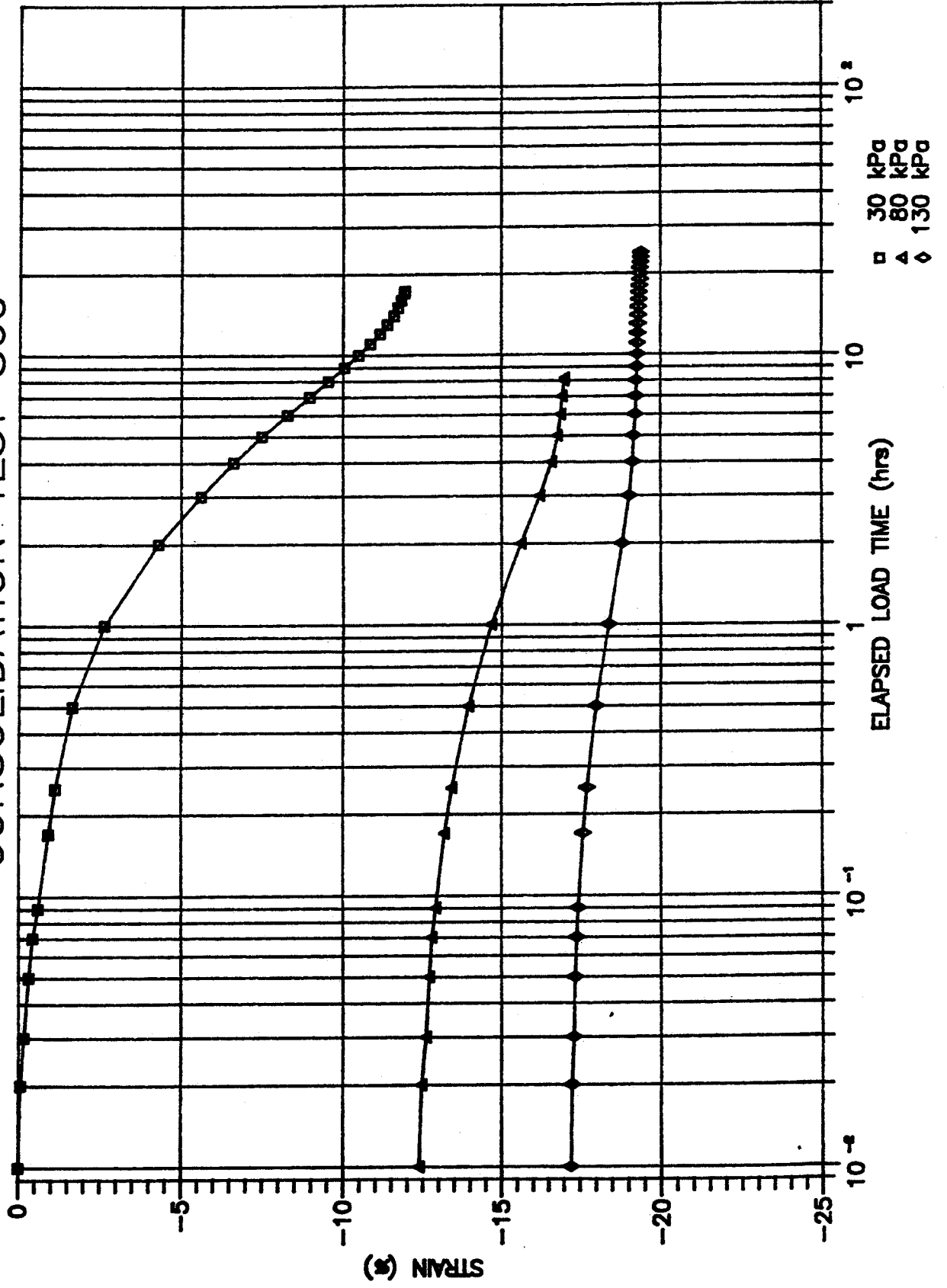


OBSERVED POSITION OF ICE LENS

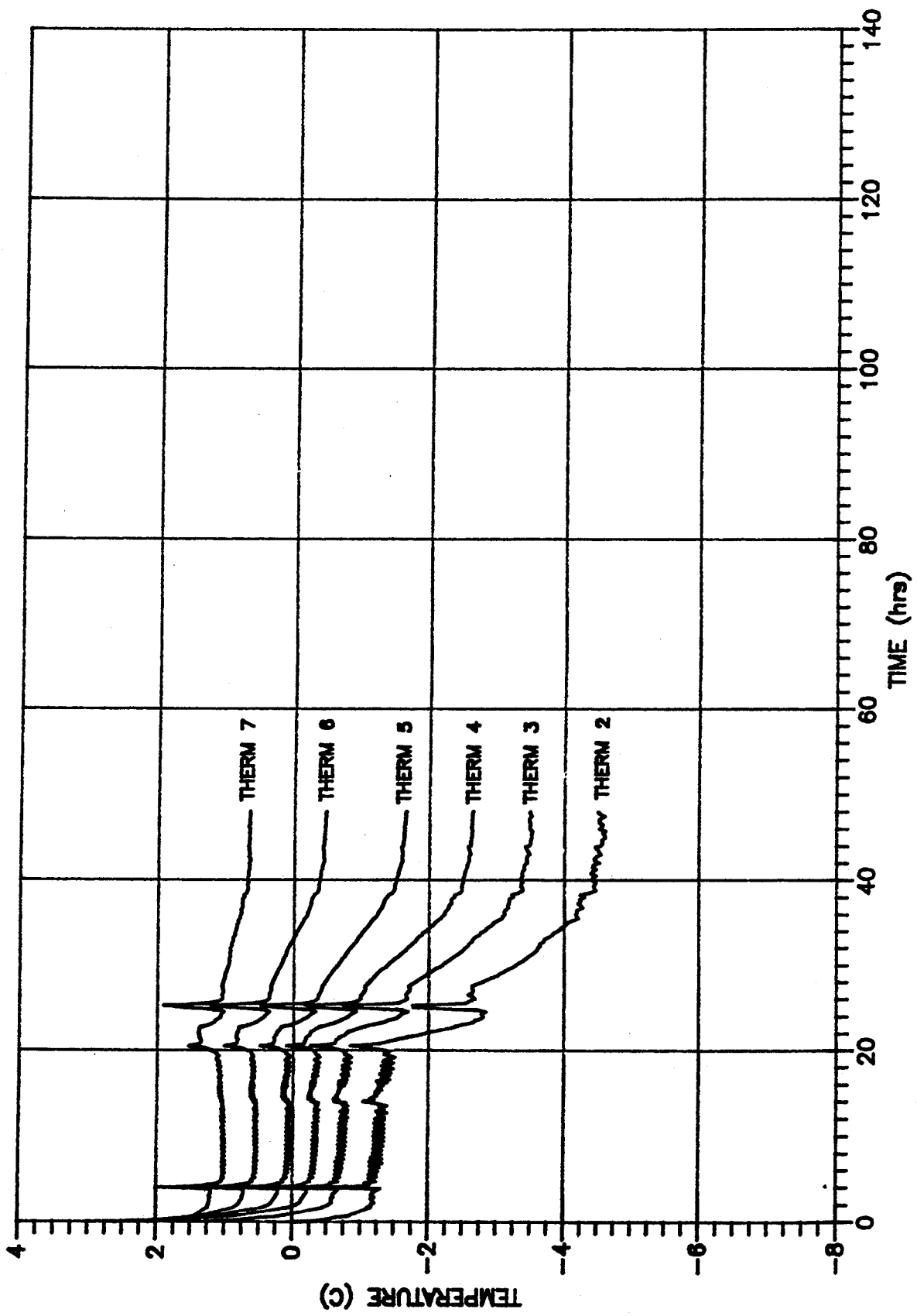


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S52

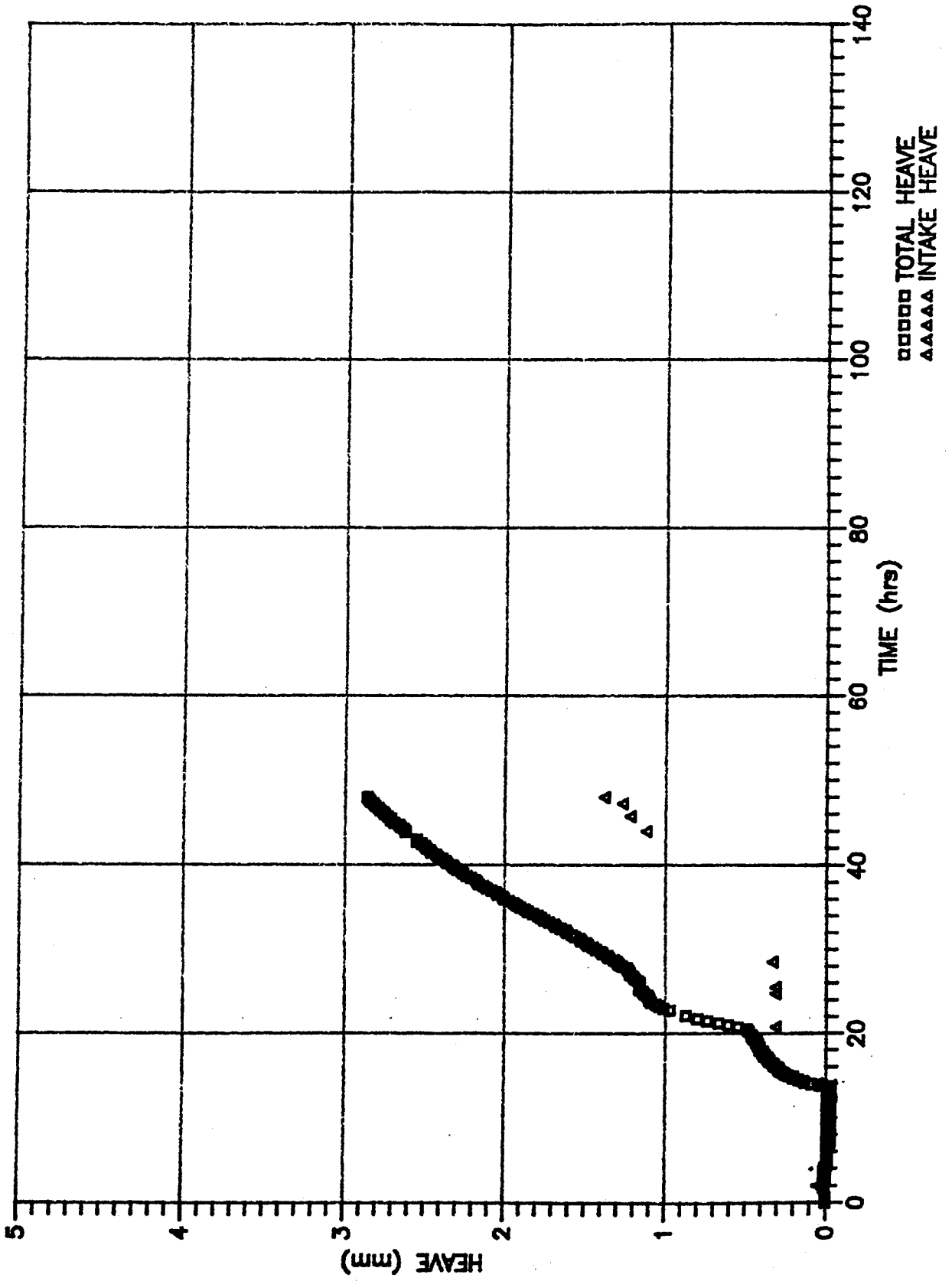
CONSOLIDATION TEST S60



FREEZING TEST S60



FREEZING TEST S60

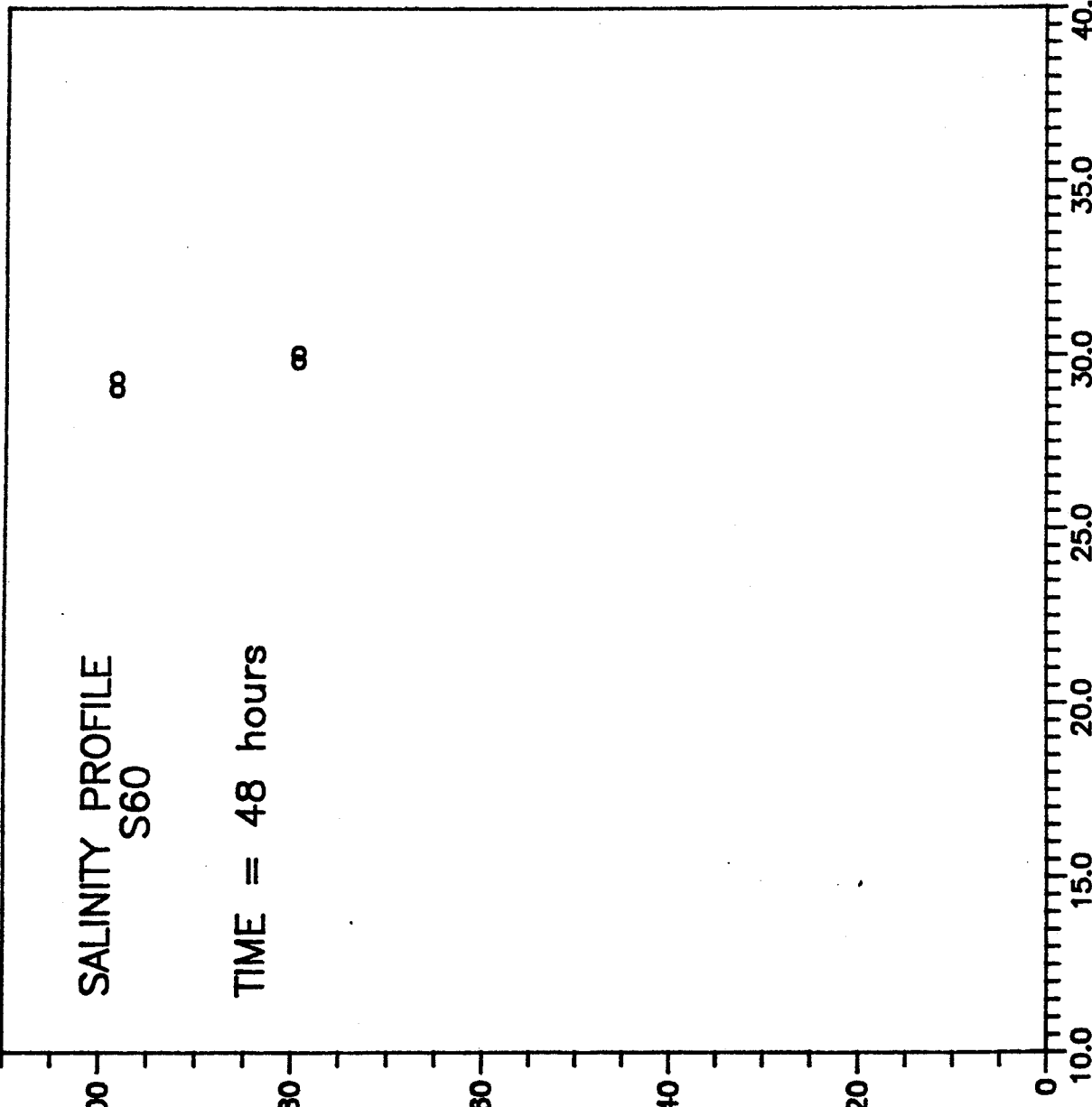


SALINITY PROFILE
S60

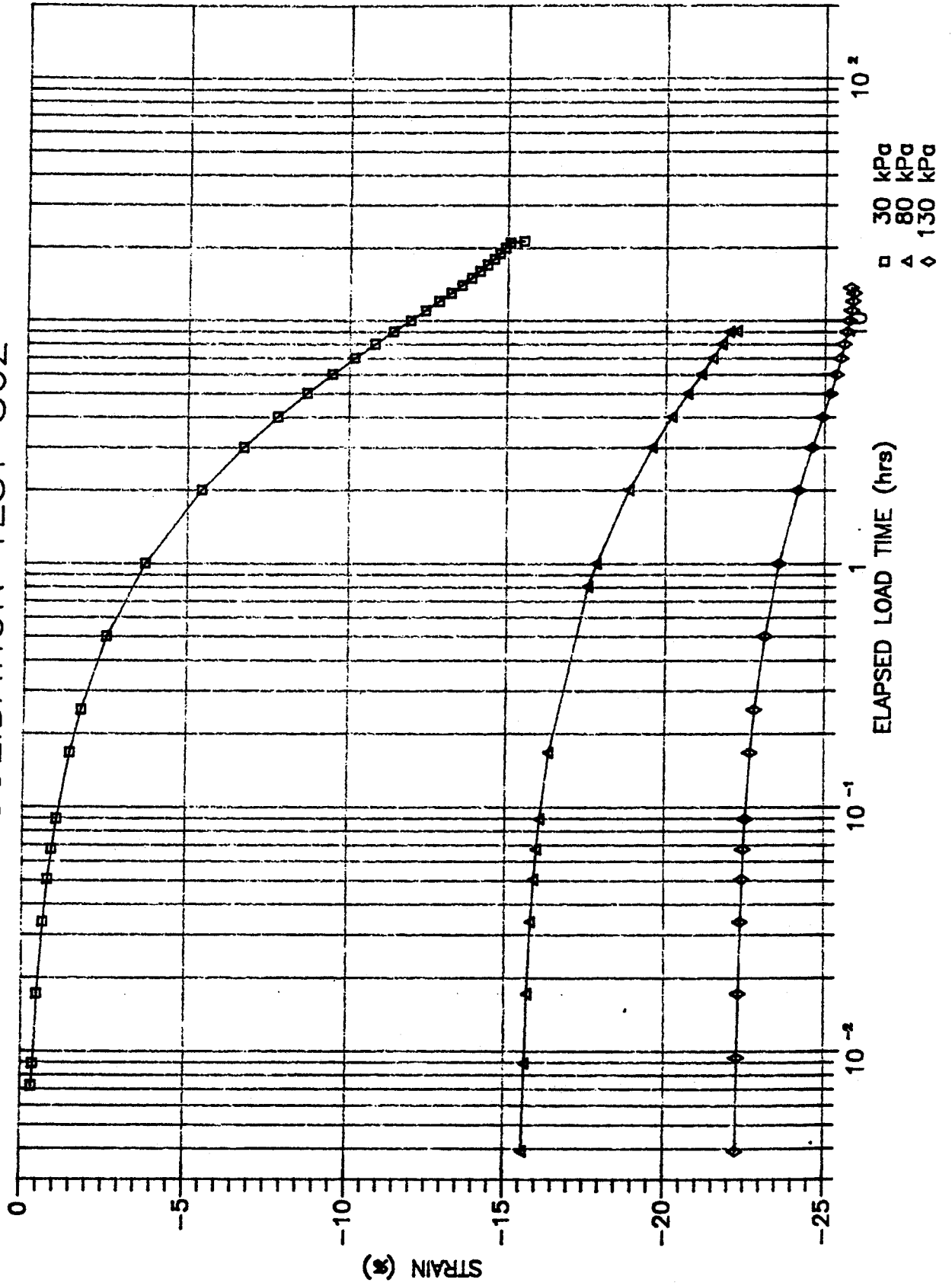
TIME = 48 hours

HEIGHT ABOVE BOTTOM PLATE (mm)

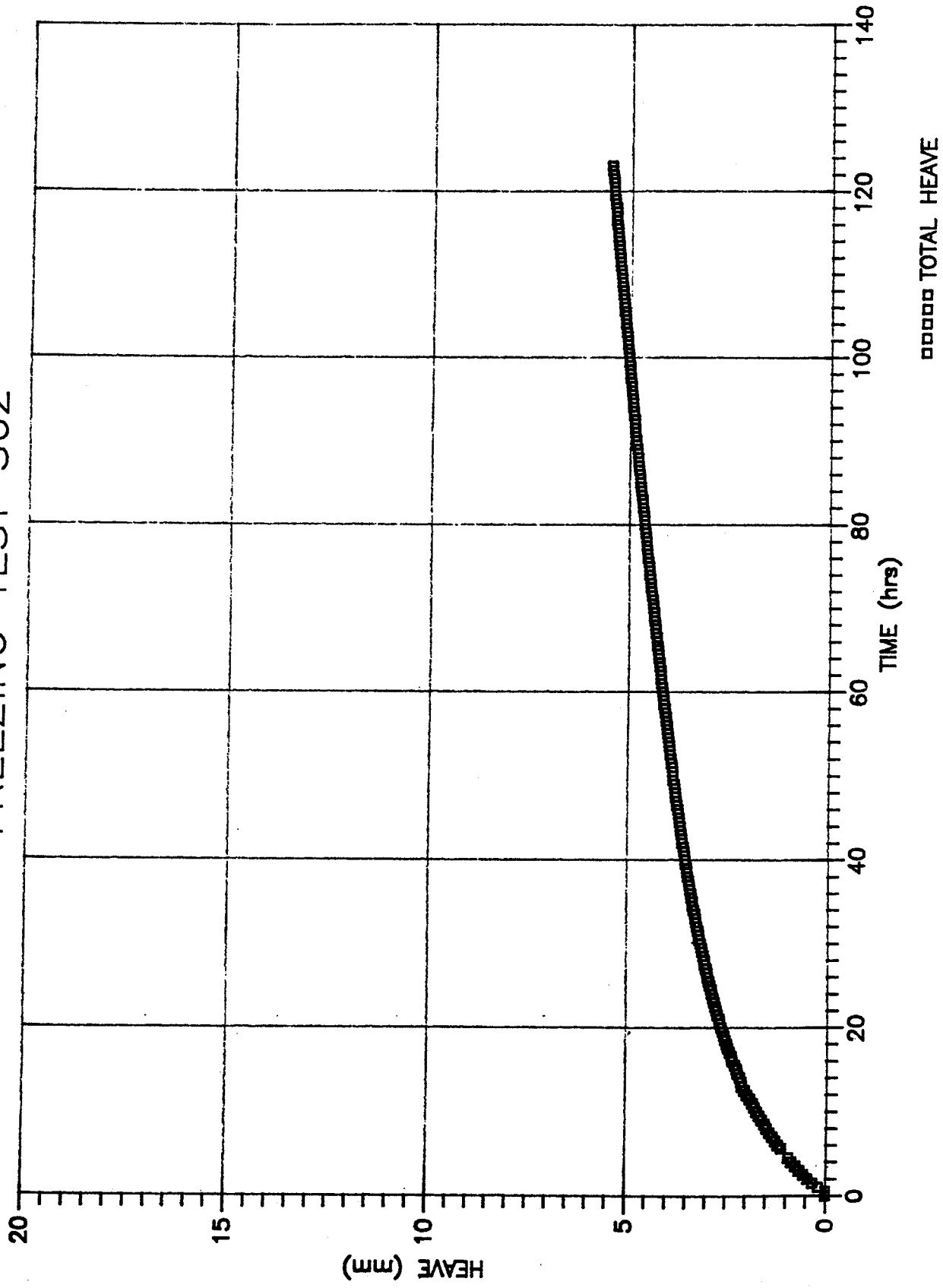
SALINITY (g/l)



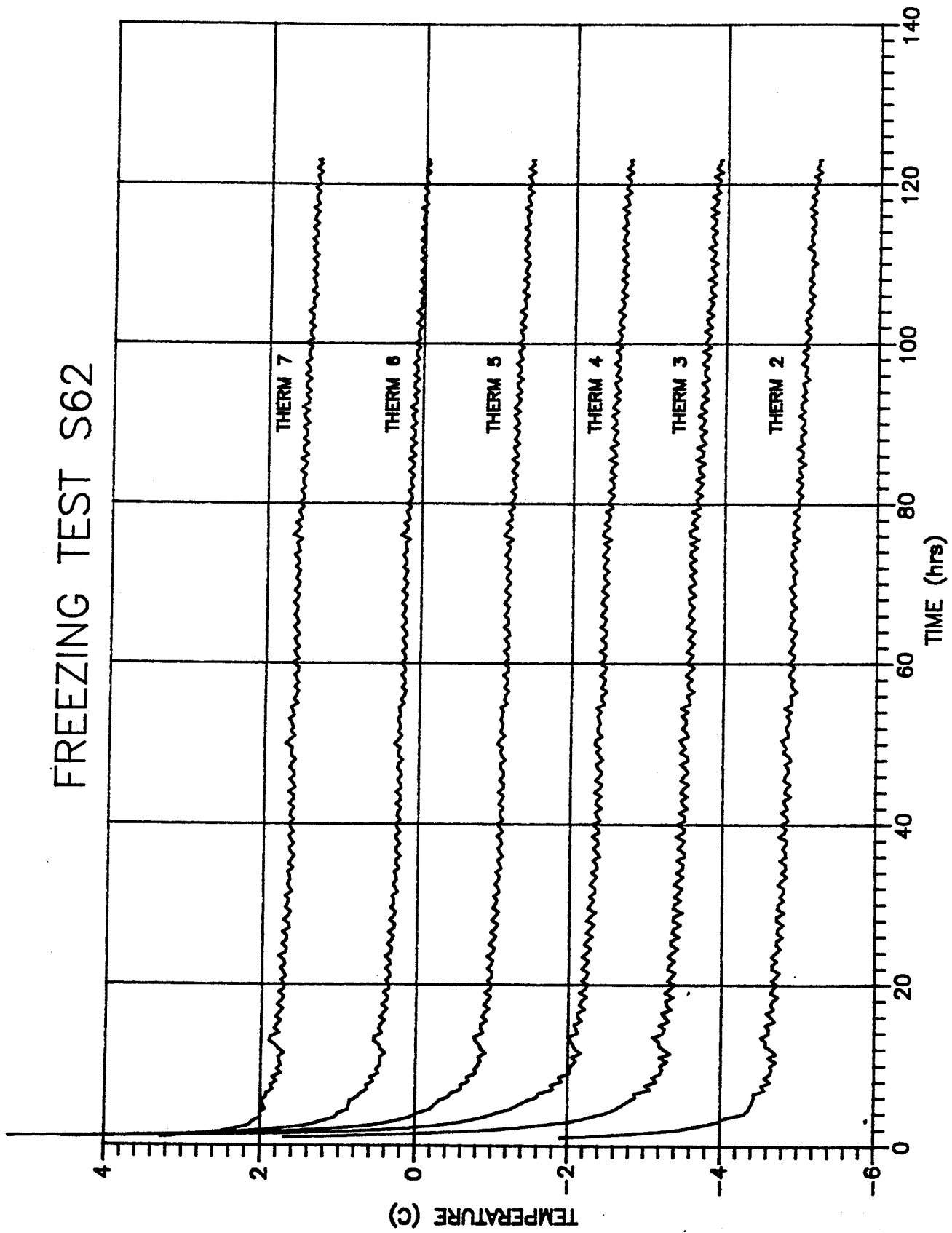
CONSOLIDATION TEST S62



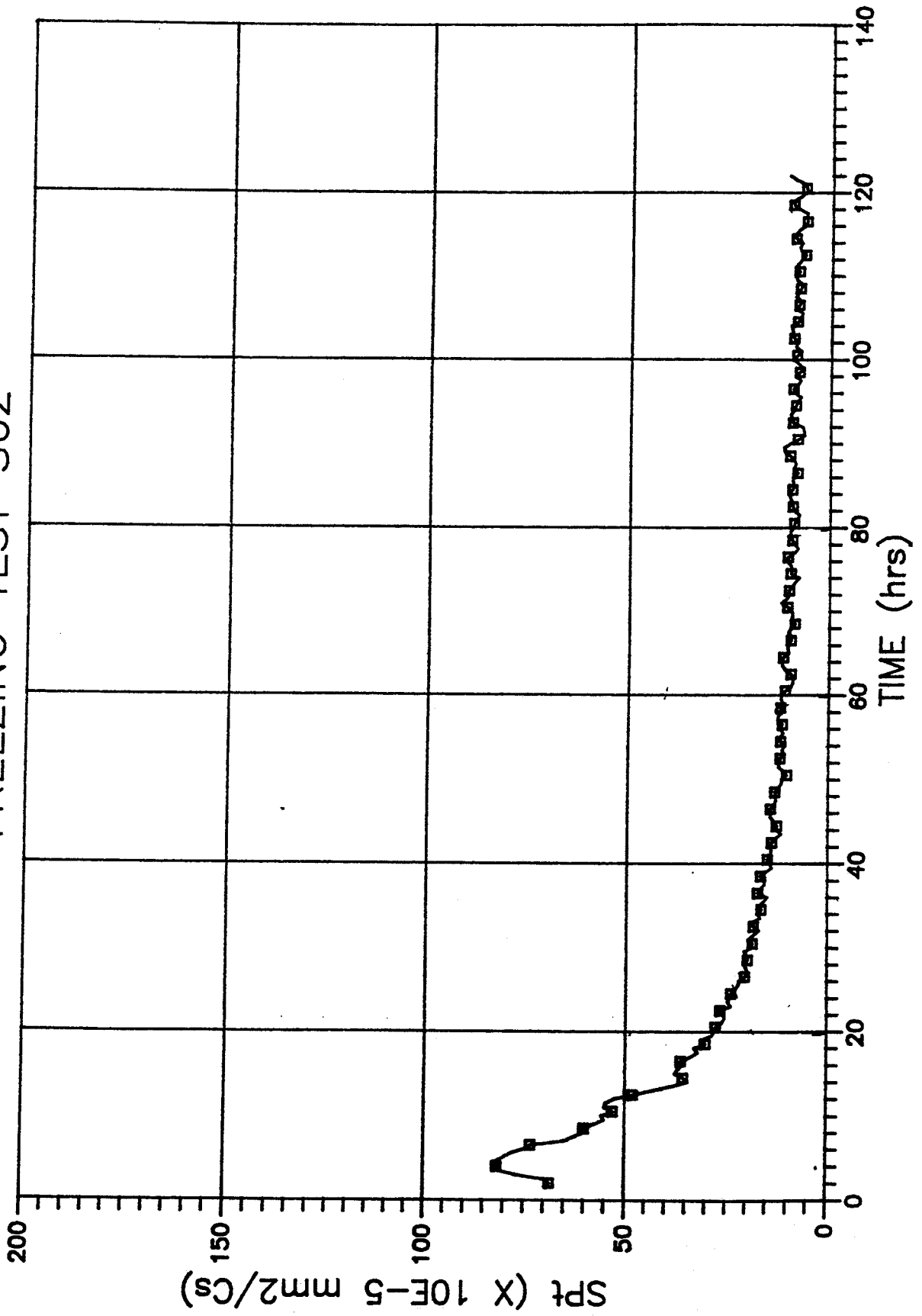
FREEZING TEST S62



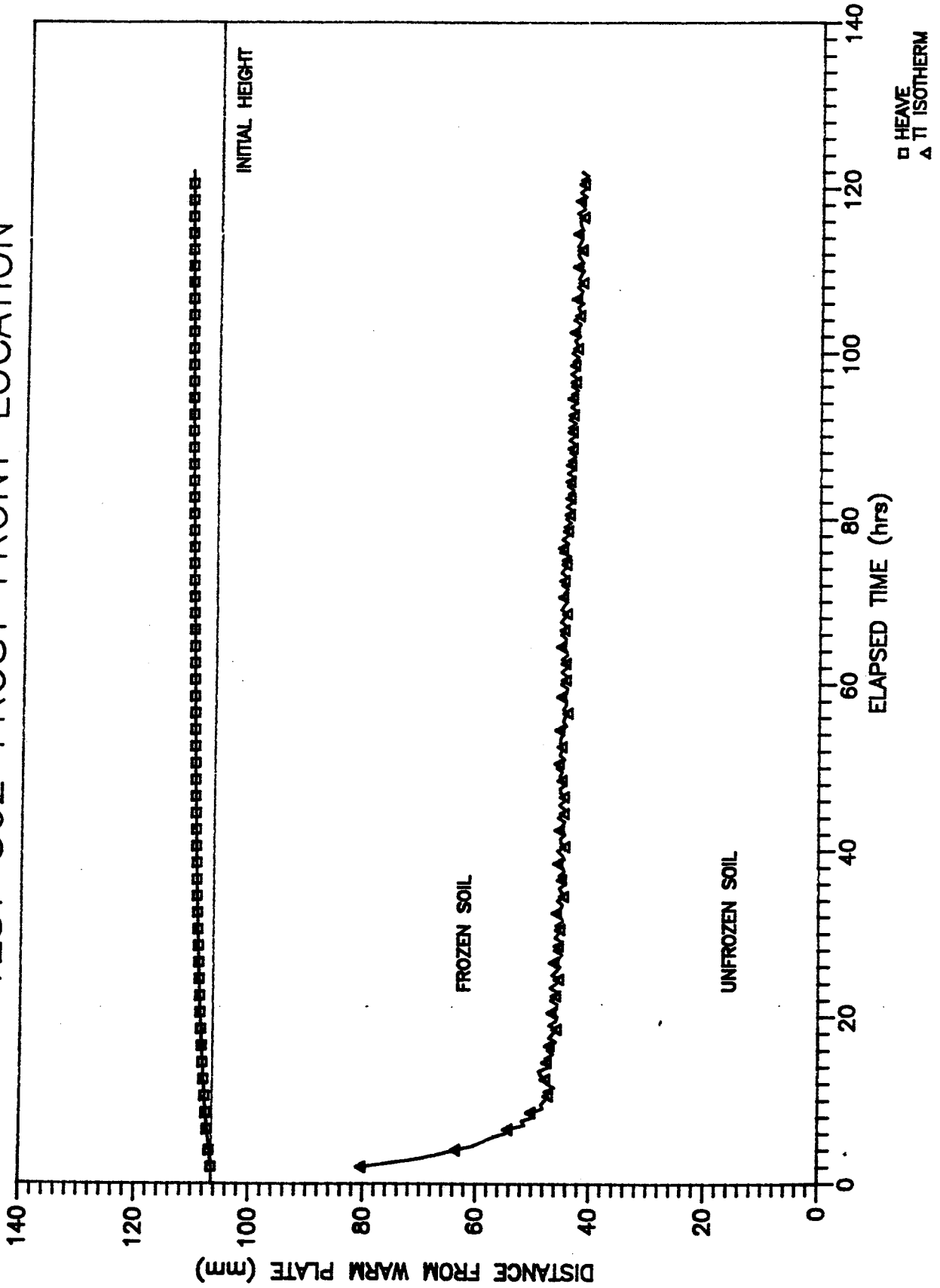
FREEZING TEST S62



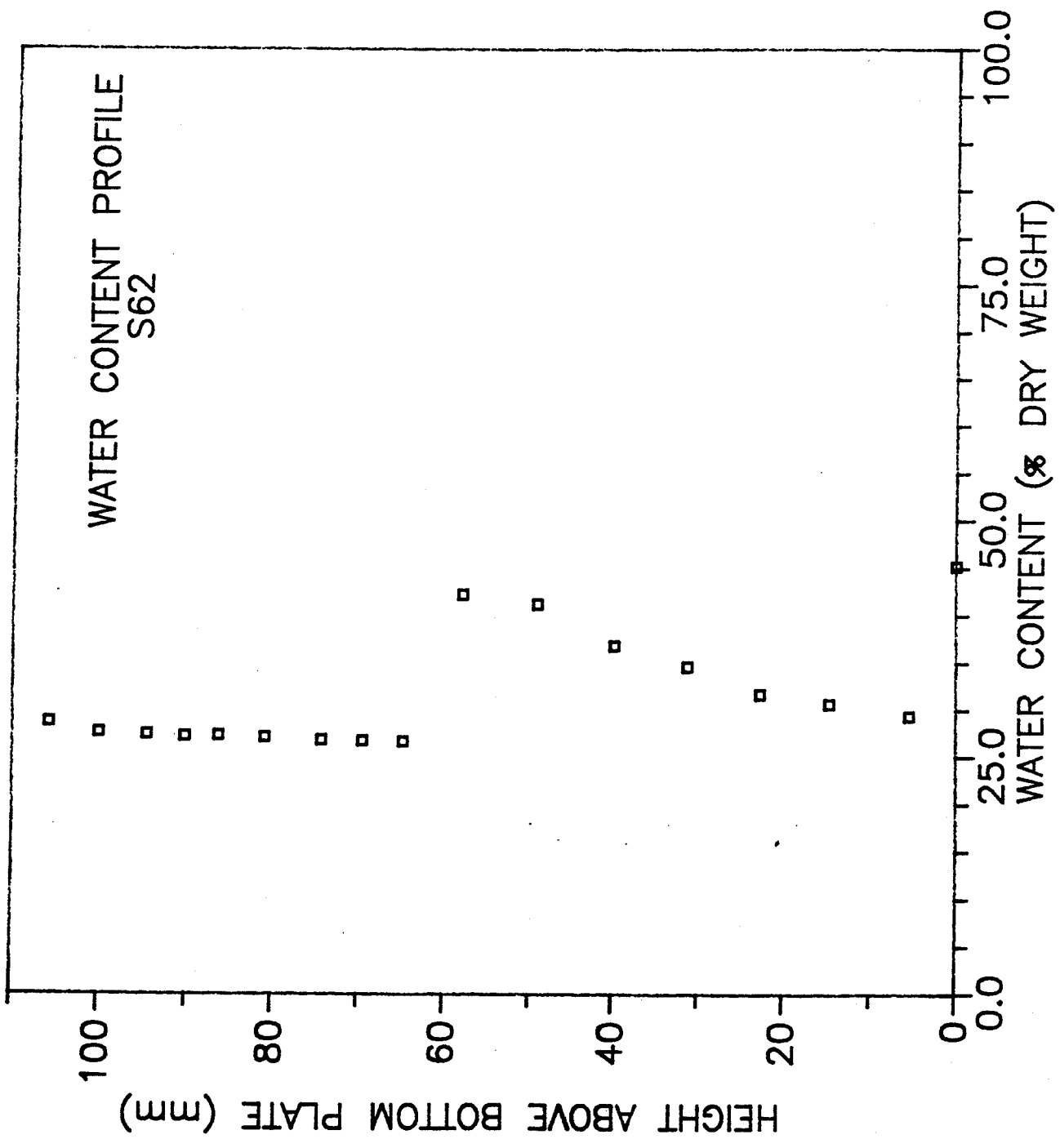
FREEZING TEST S62



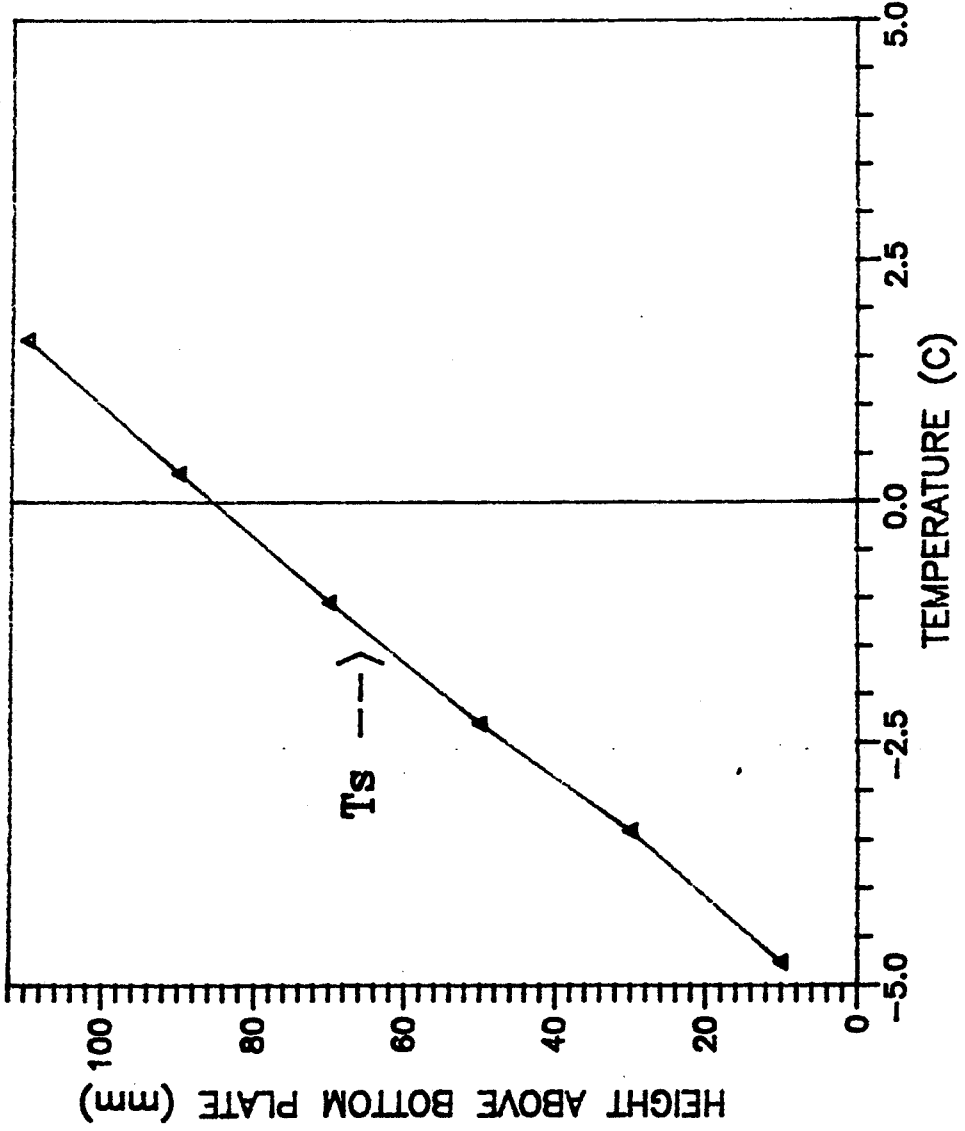
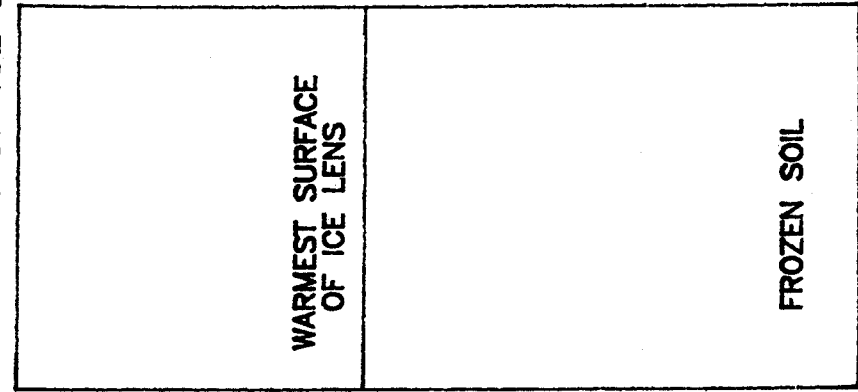
TEST S62 FROST FRONT LOCATION



WATER CONTENT PROFILE
S62

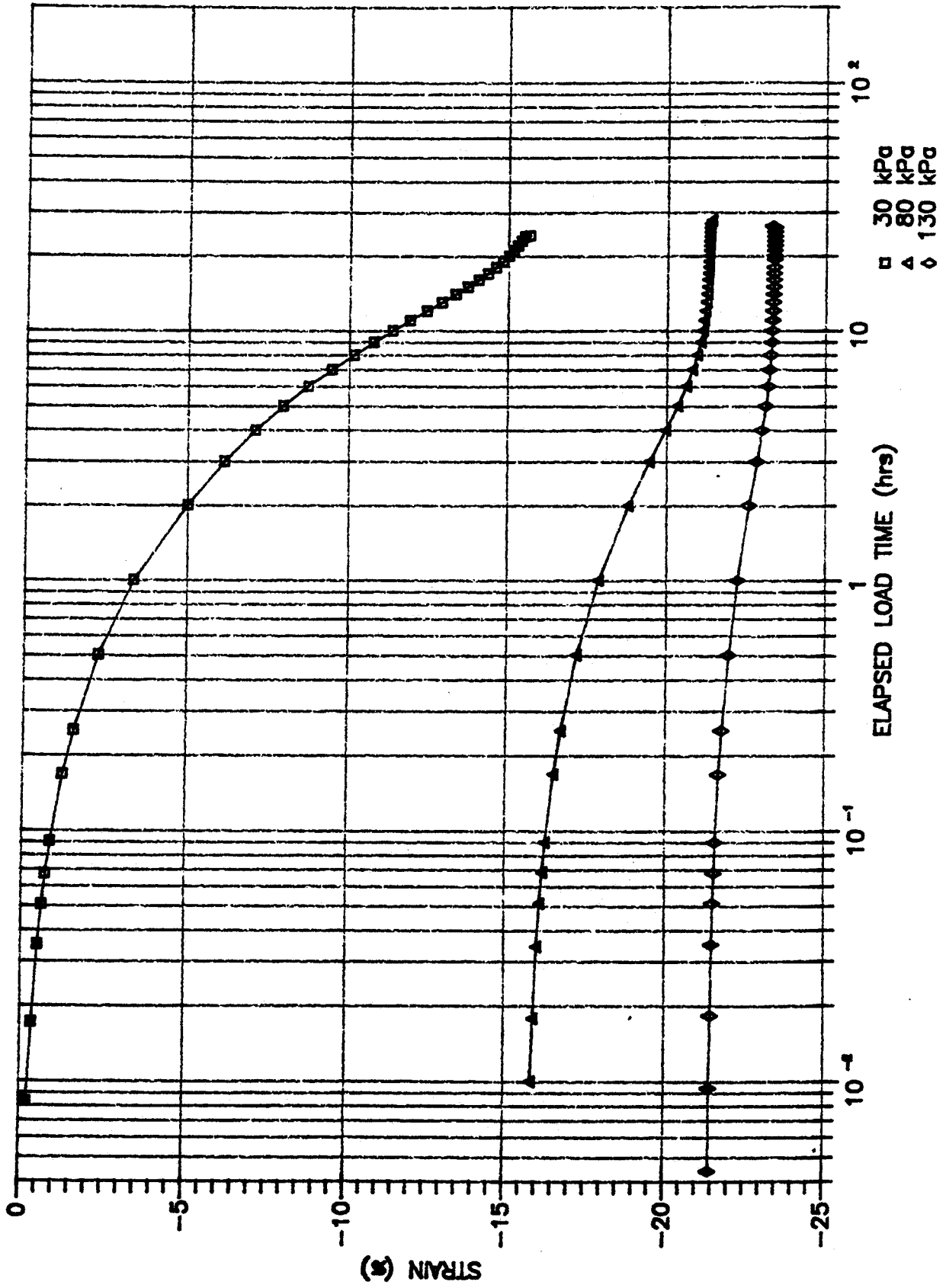


OBSERVED POSITION OF ICE LENS

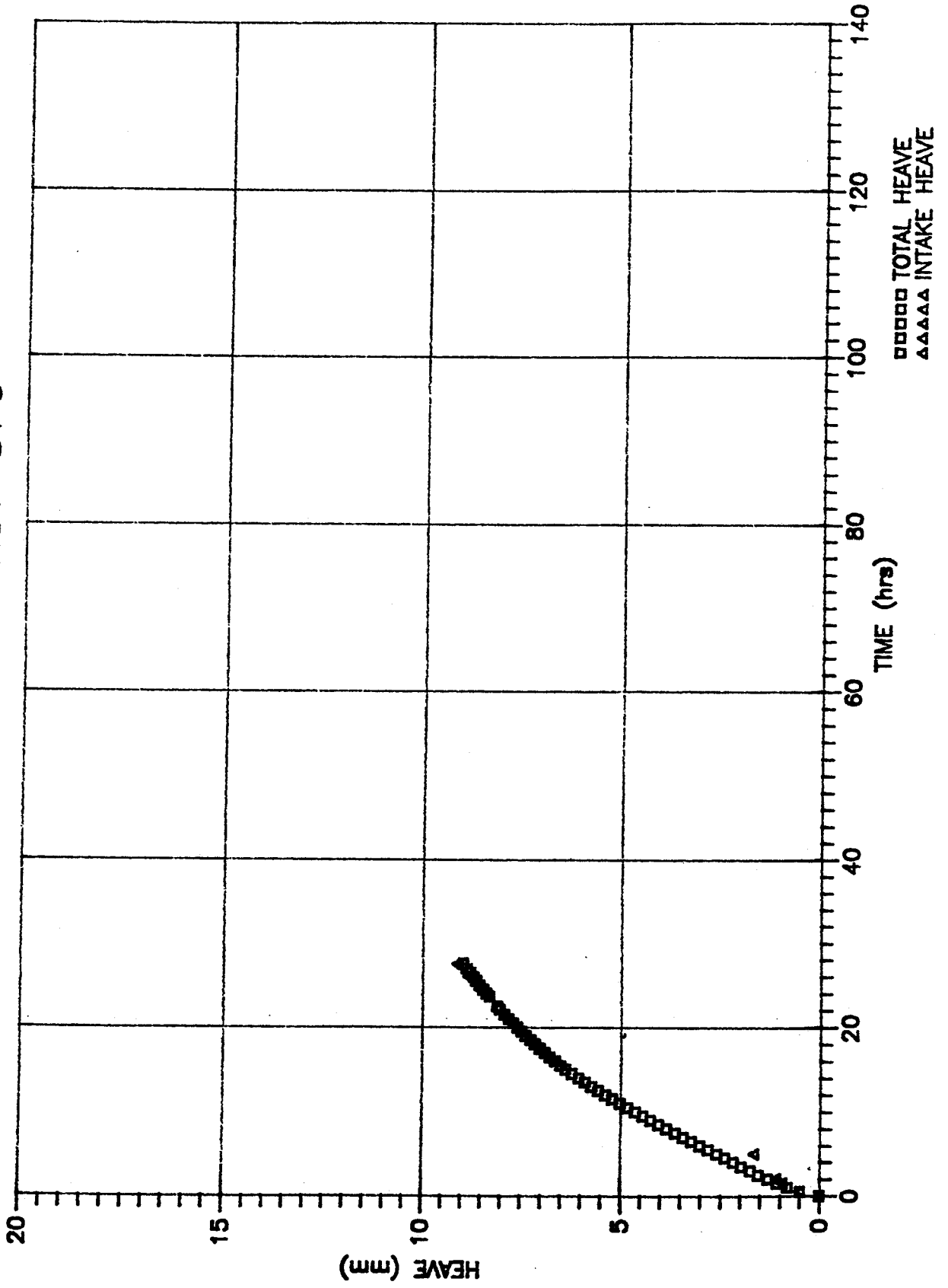


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S62

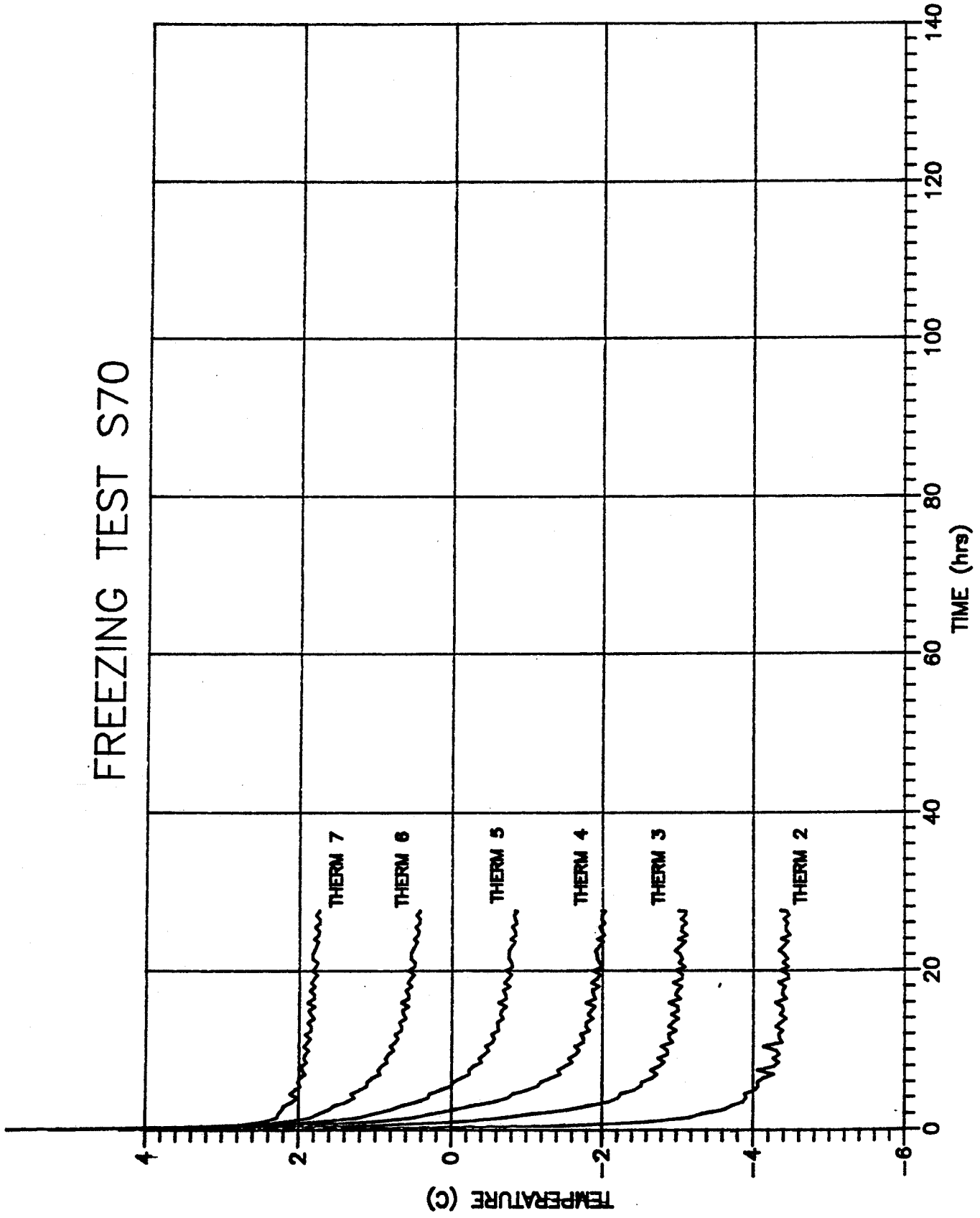
CONSOLIDATION TEST S70



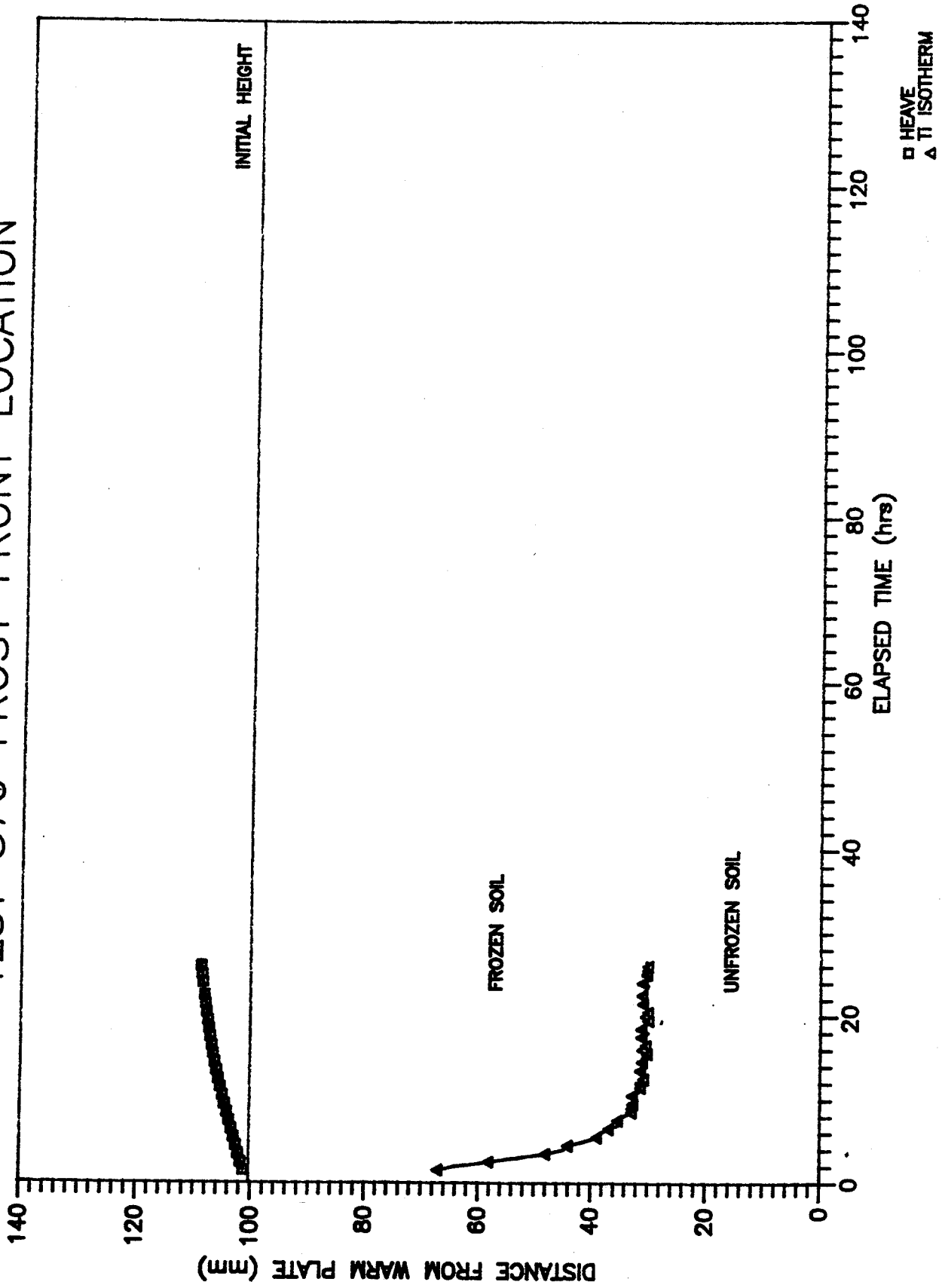
FREEZING TEST S70



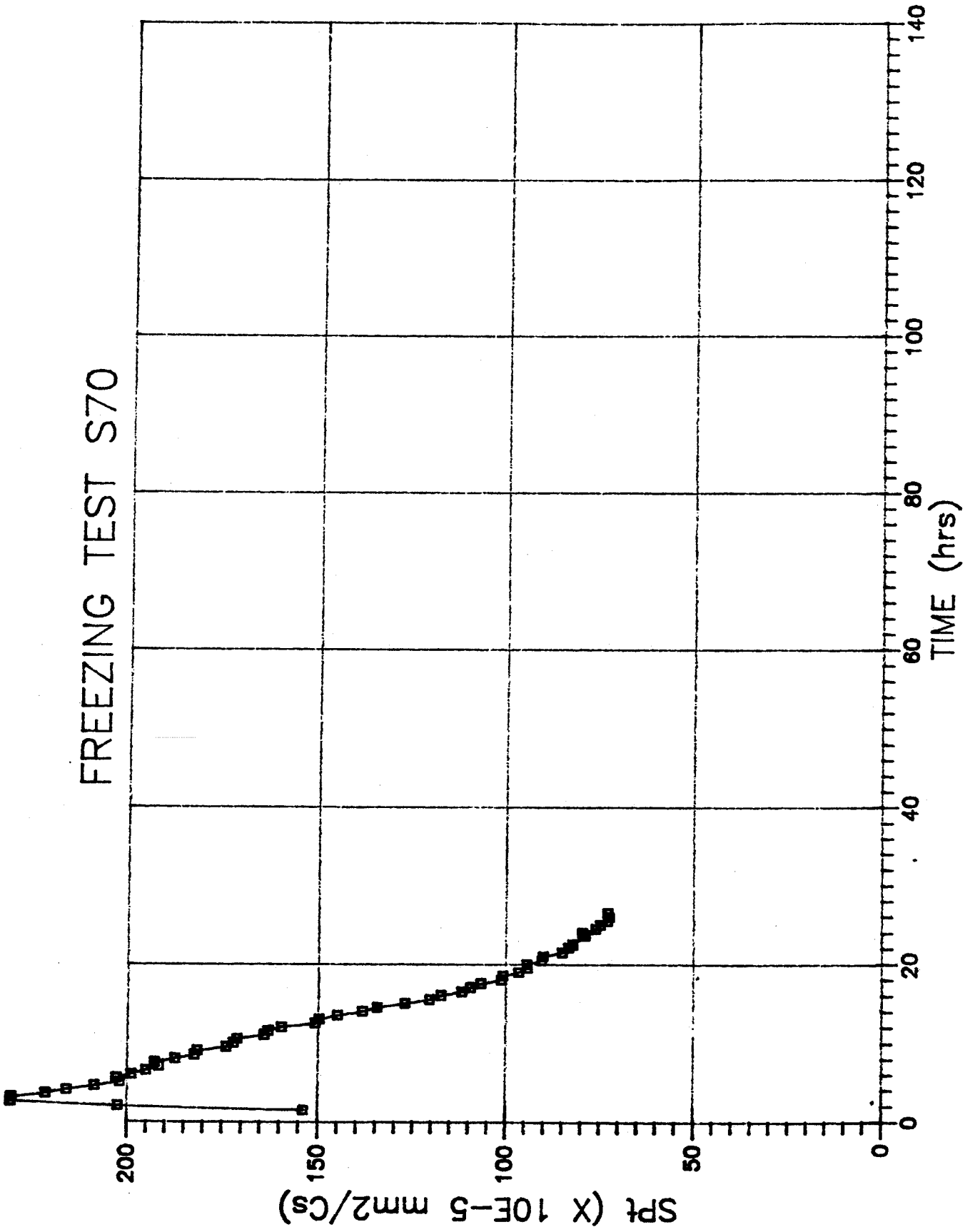
FREEZING TEST S70



TEST S70 FROST FRONT LOCATION

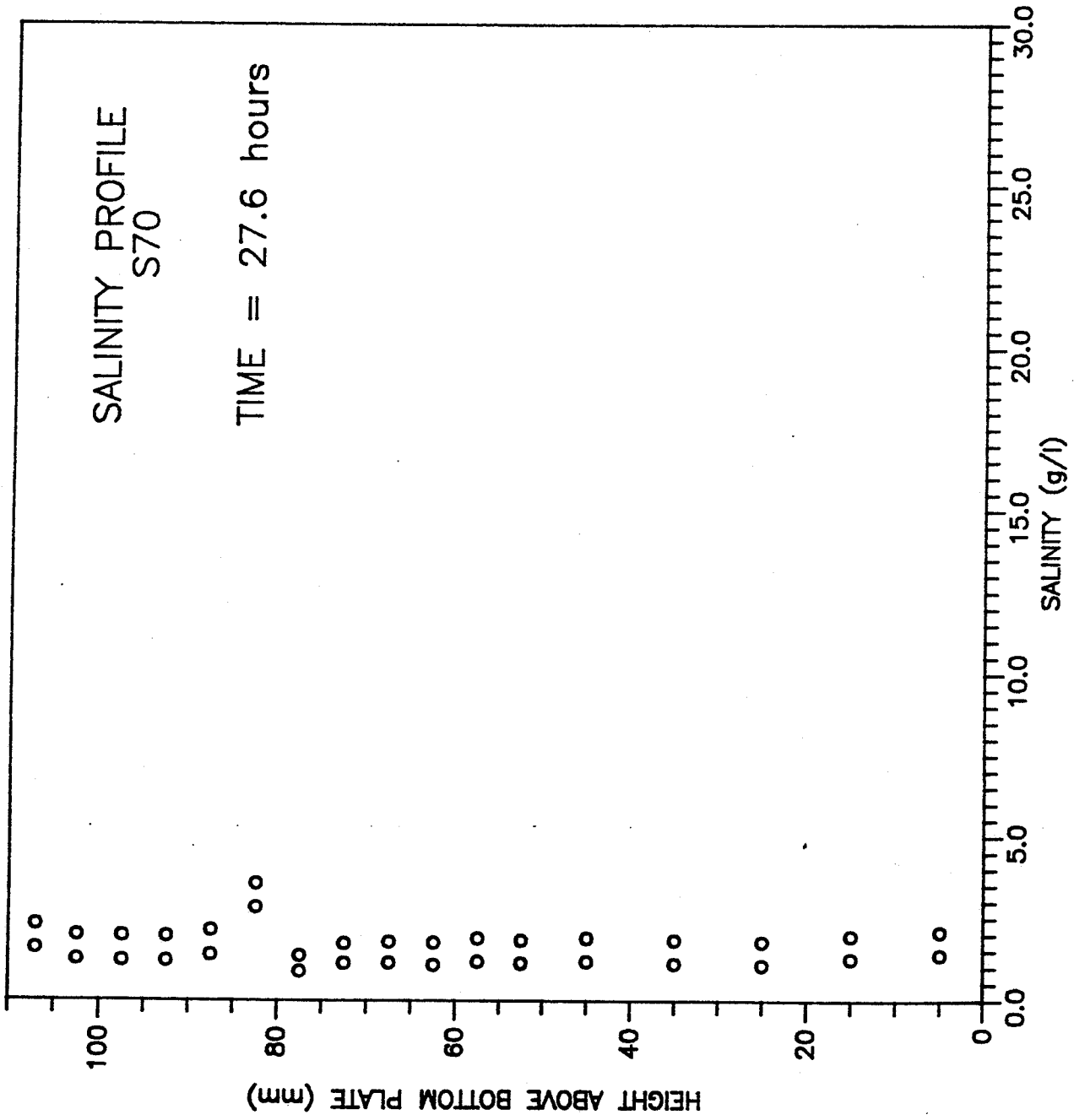


FREEZING TEST S70

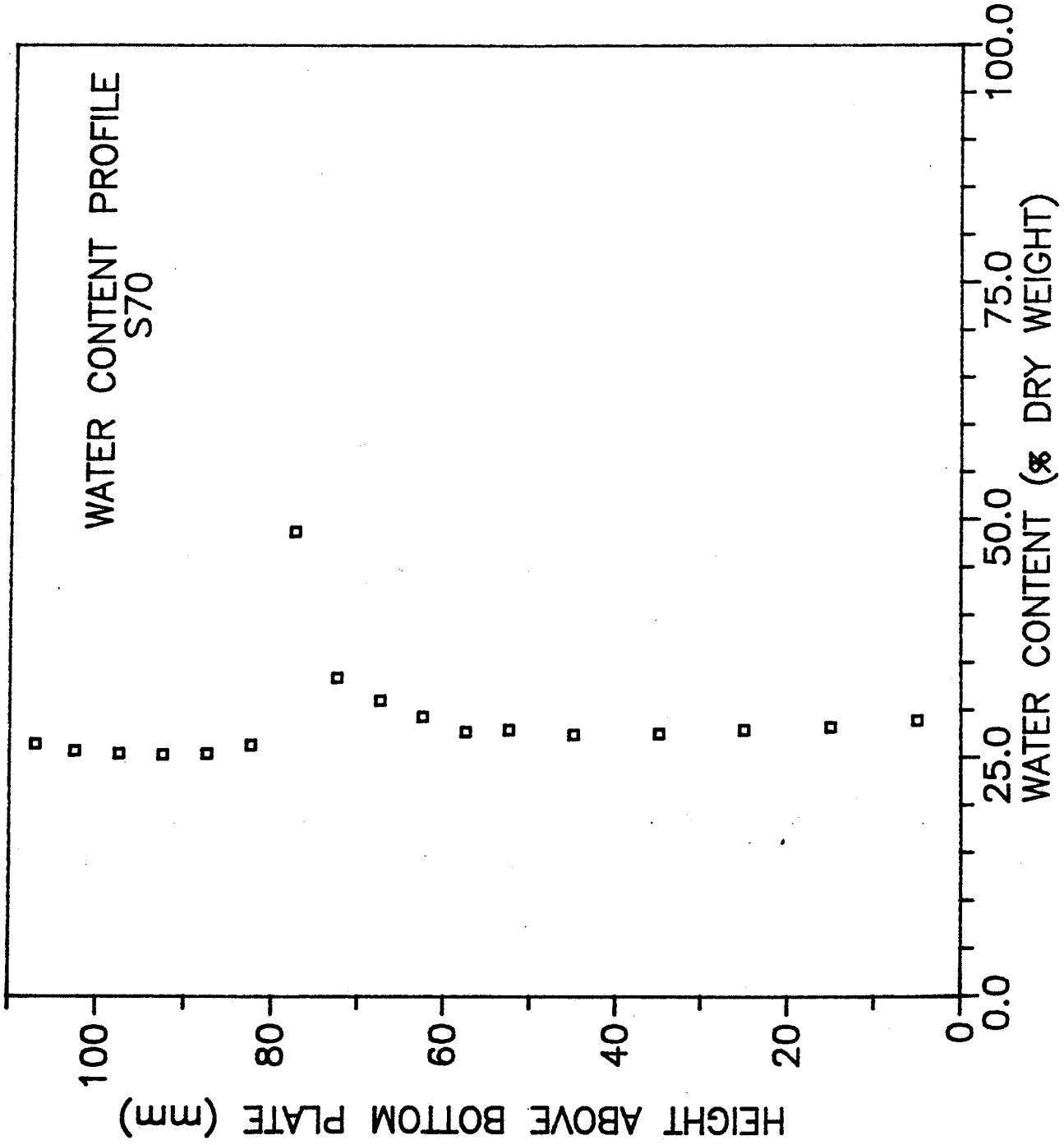


SALINITY PROFILE
S70

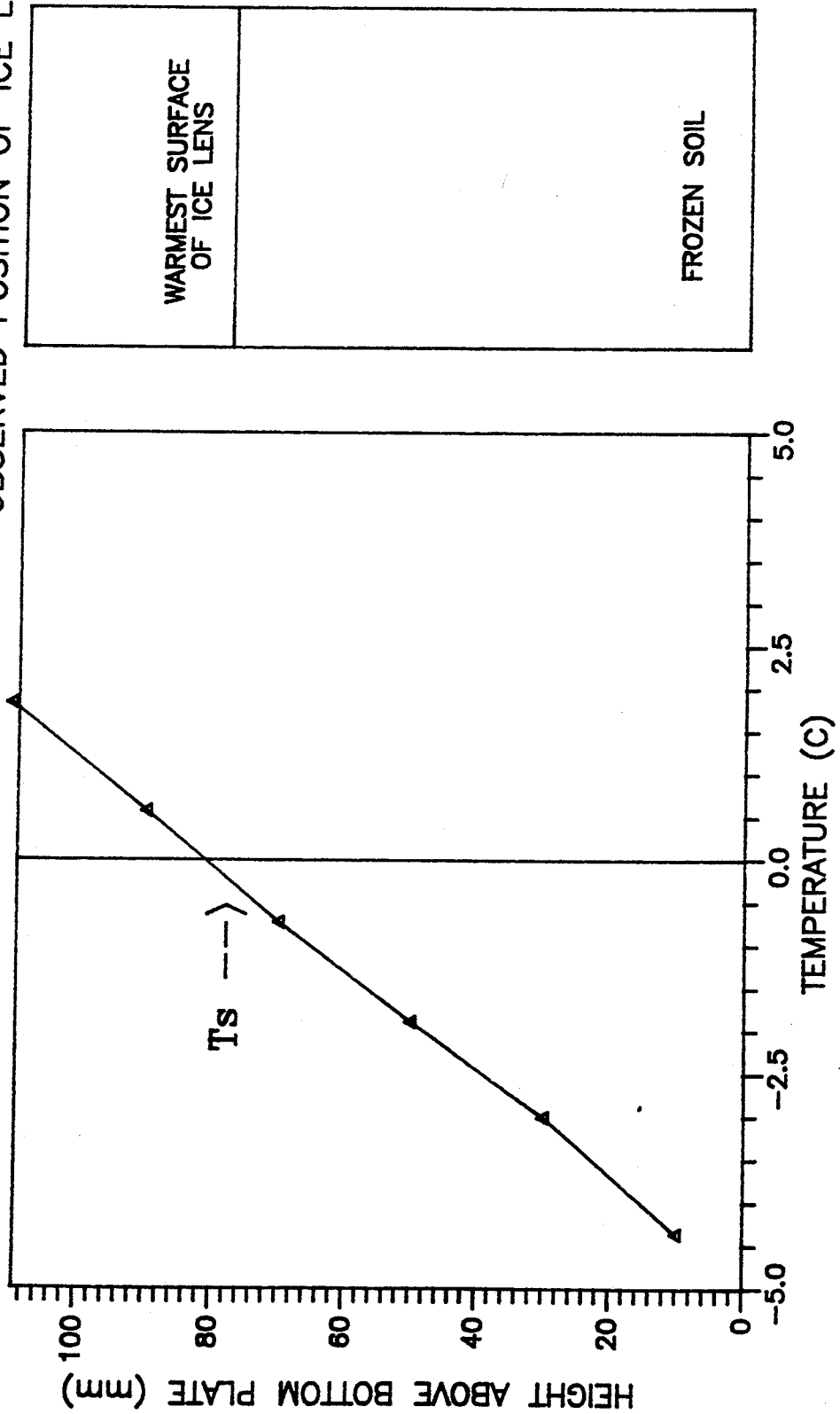
TIME = 27.6 hours



WATER CONTENT PROFILE
S70

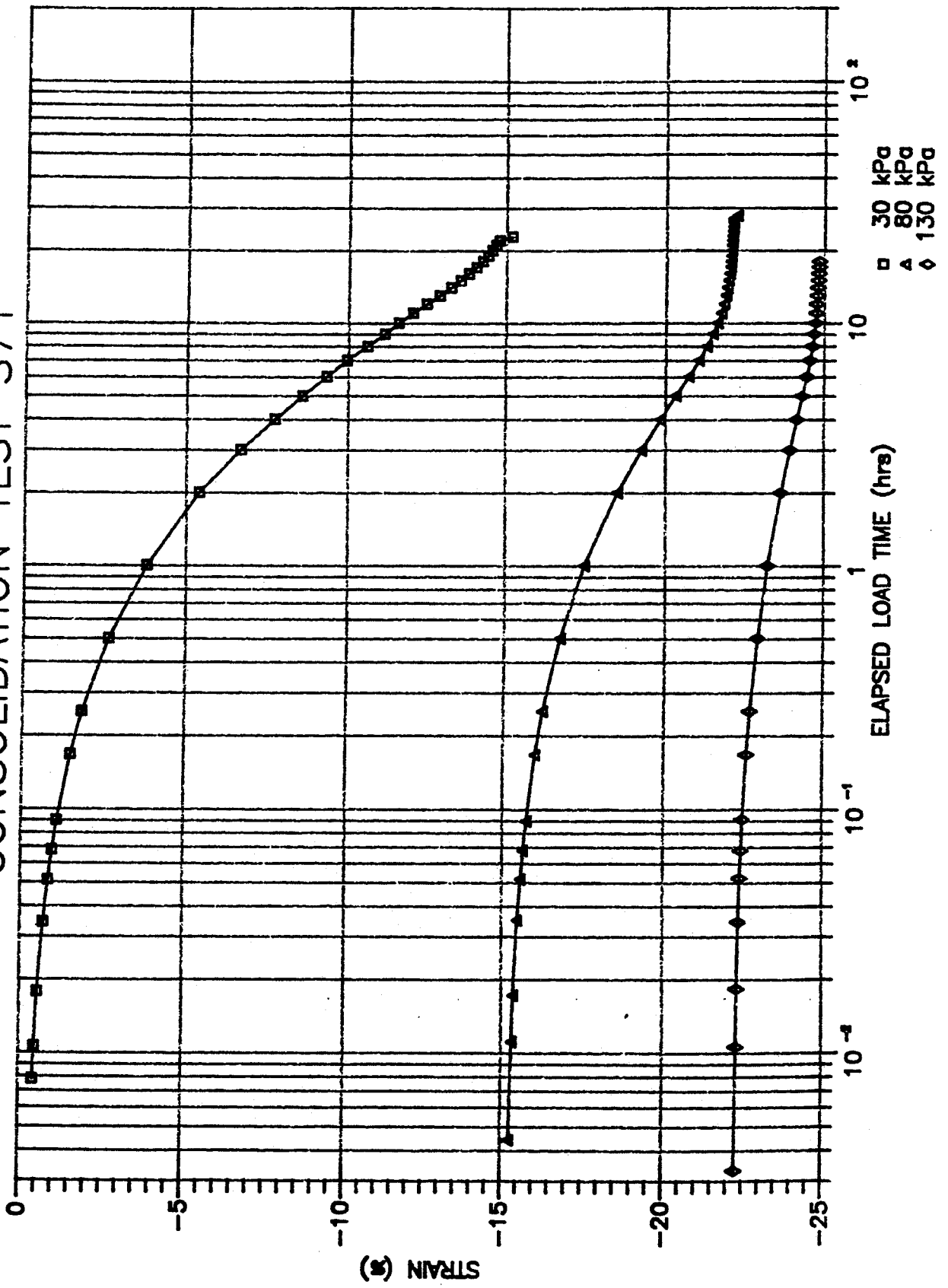


OBSERVED POSITION OF ICE LENS

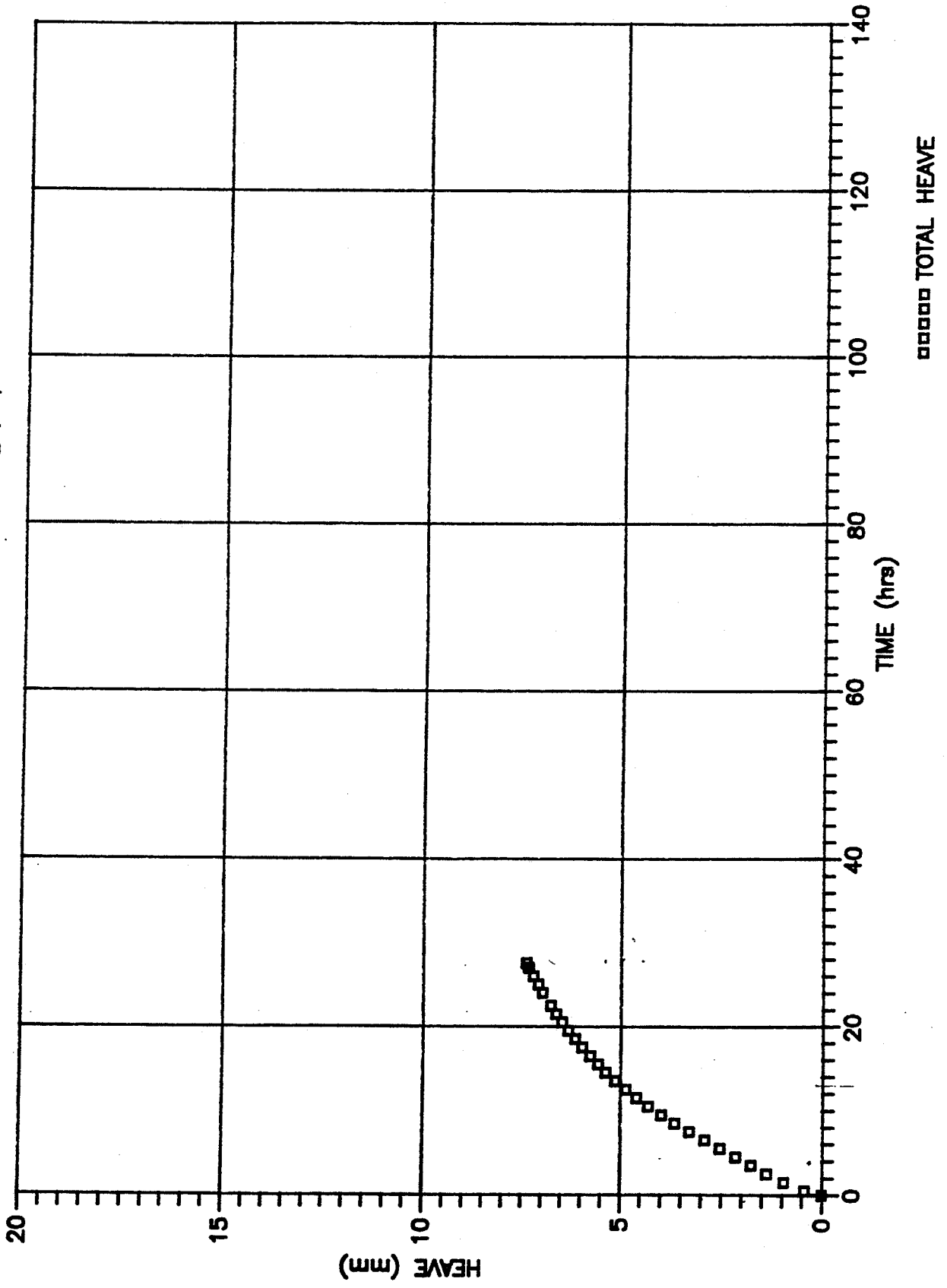


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S70

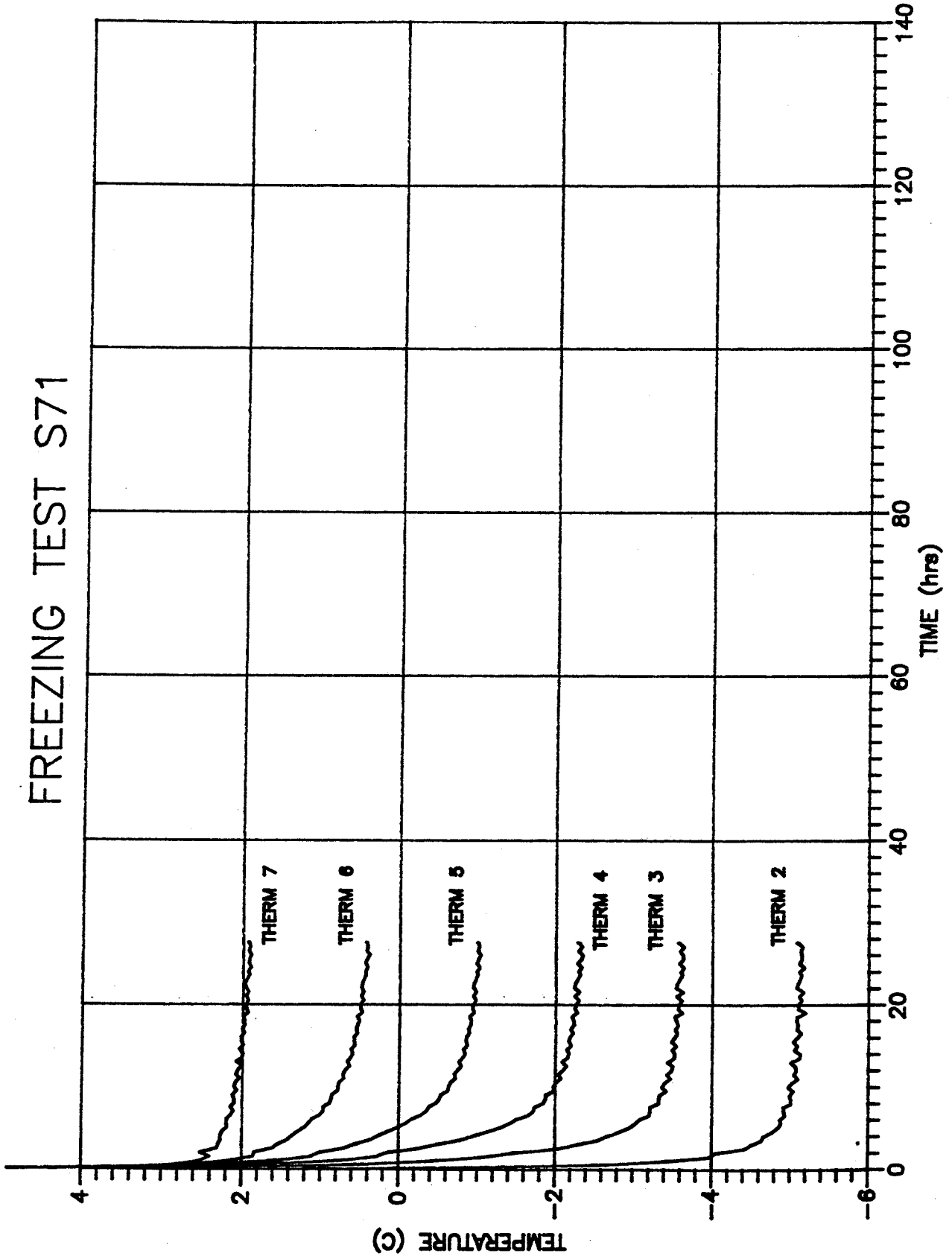
CONSOLIDATION TEST S71



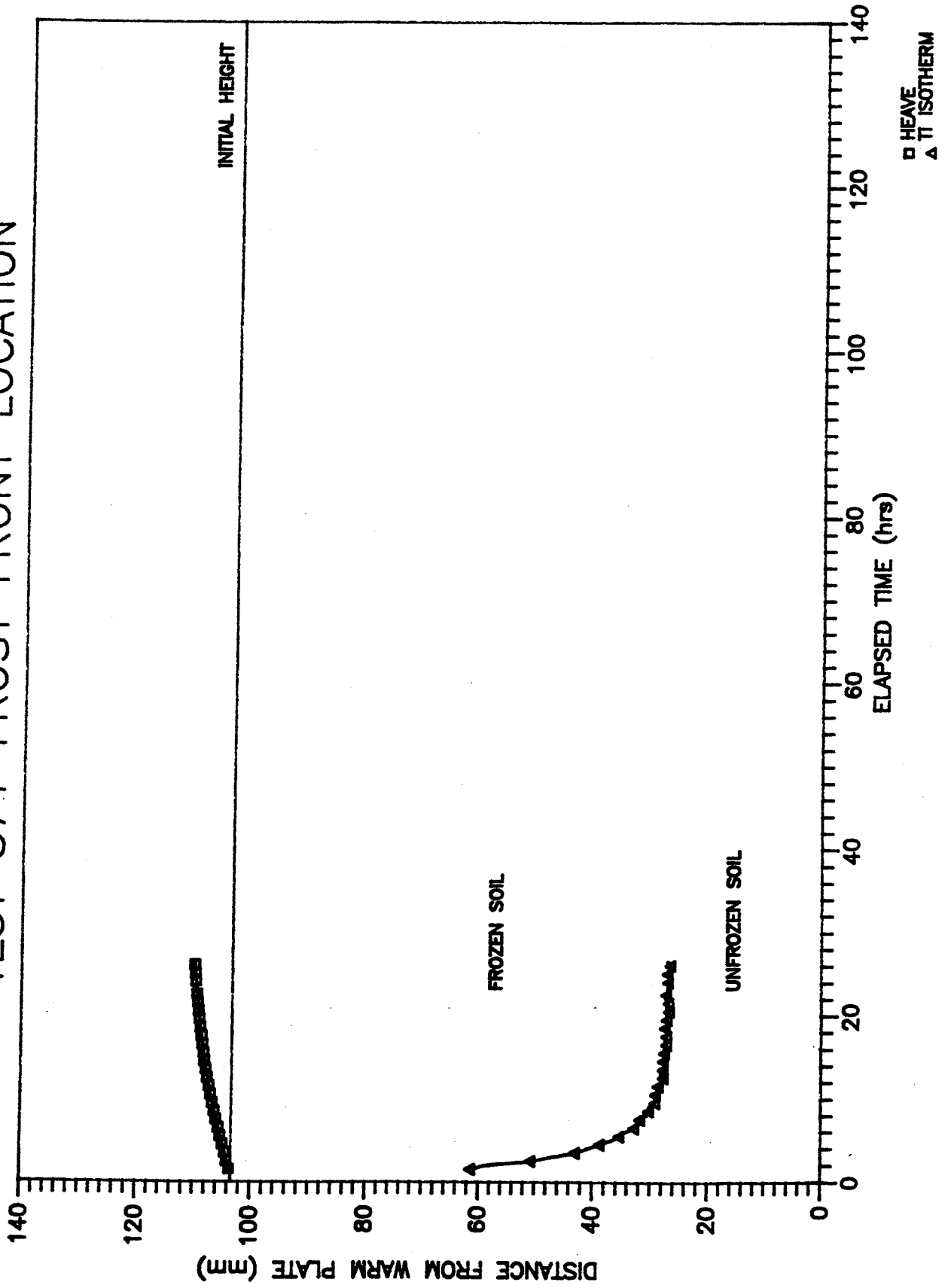
FREEZING TEST S71



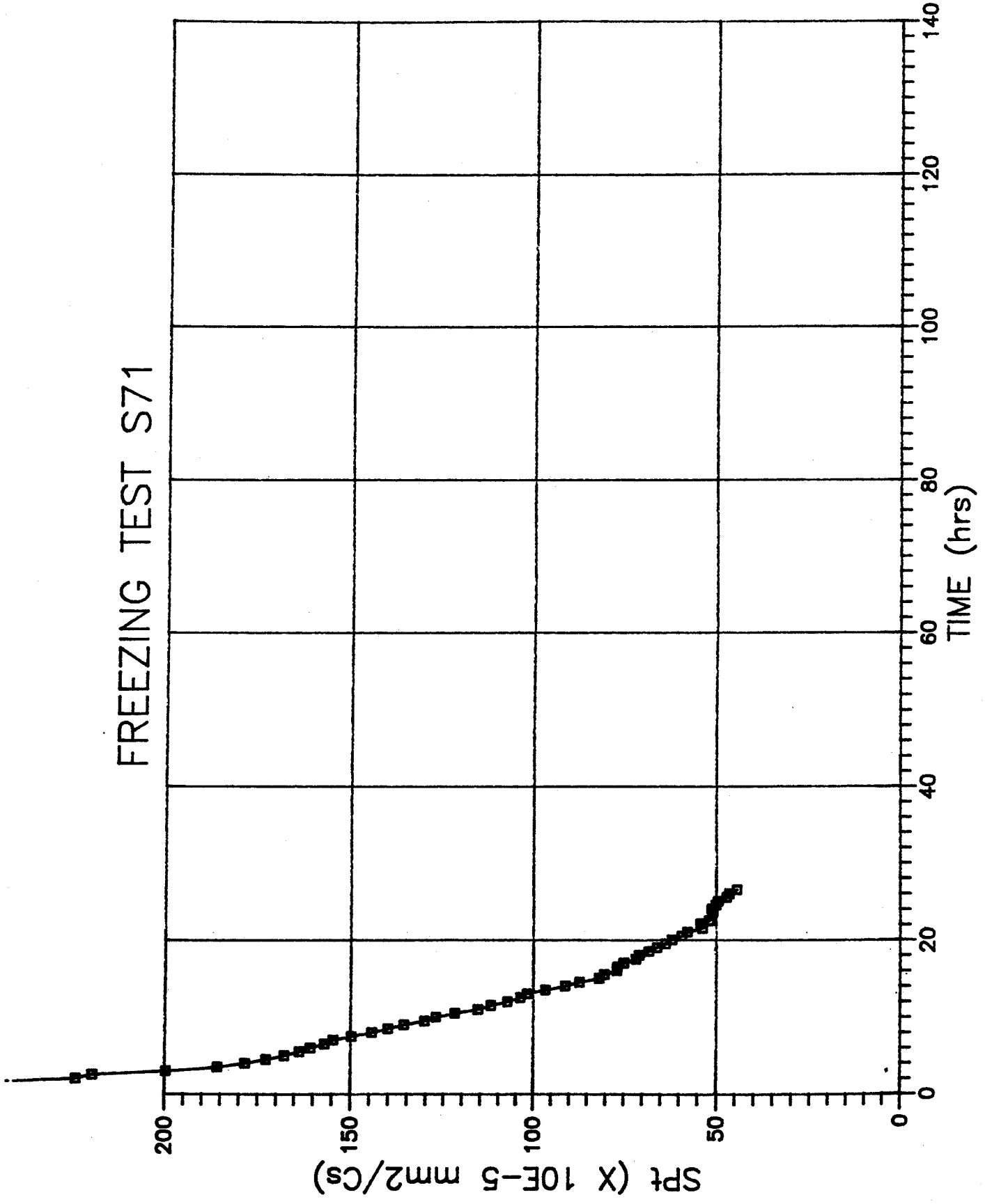
FREEZING TEST S71



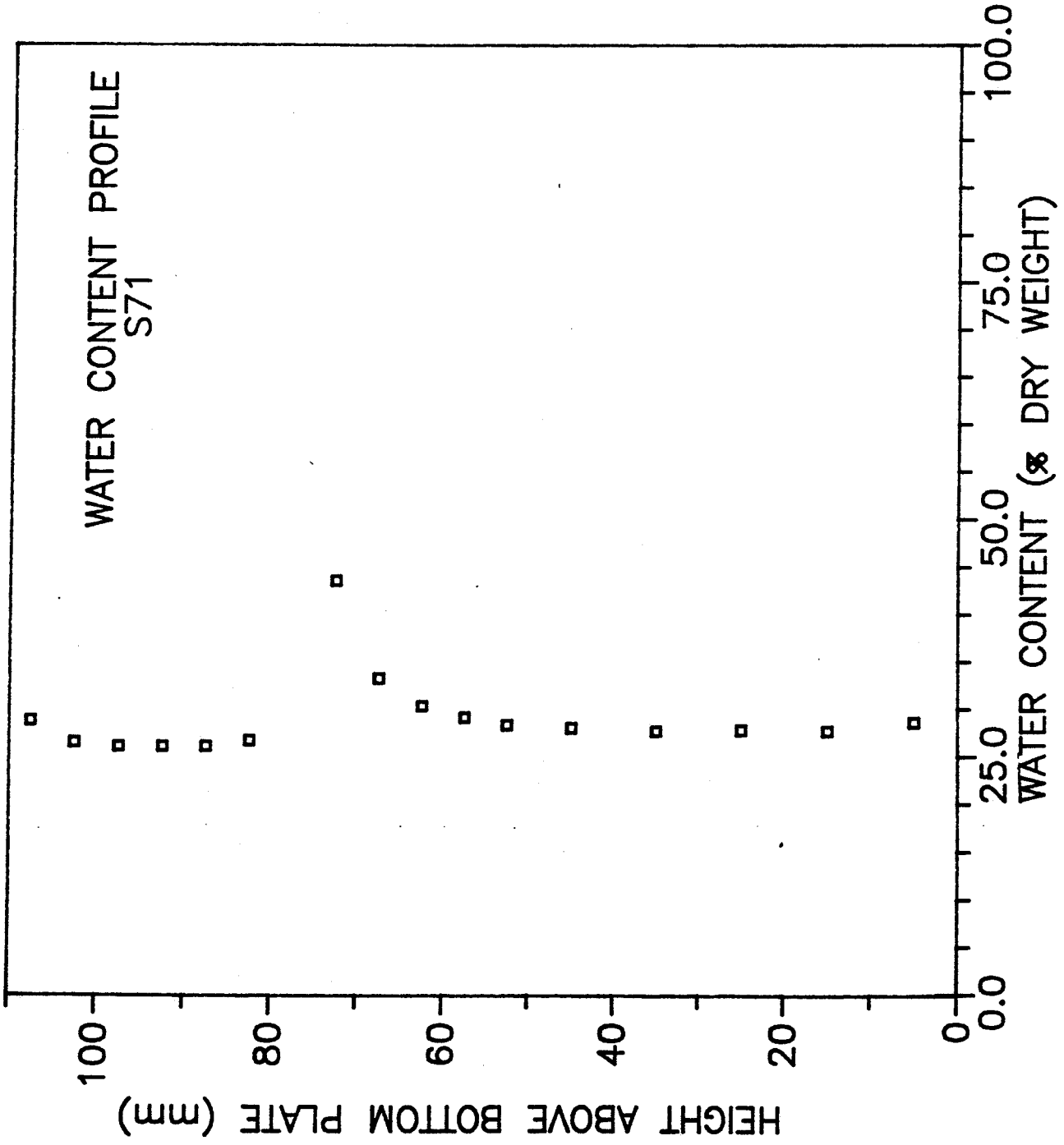
TEST S71 FROST FRONT LOCATION



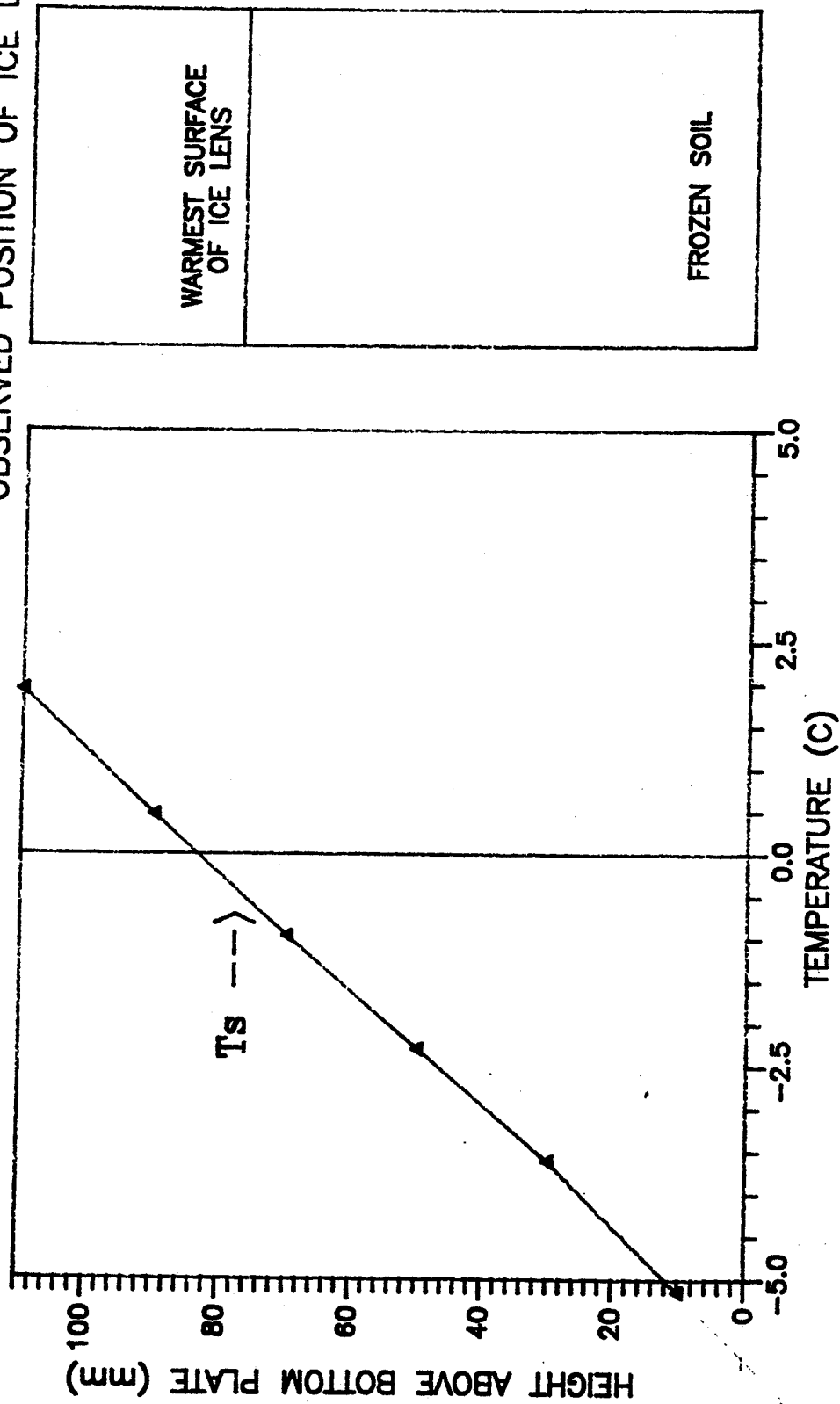
FREEZING TEST S71



WATER CONTENT PROFILE
S71

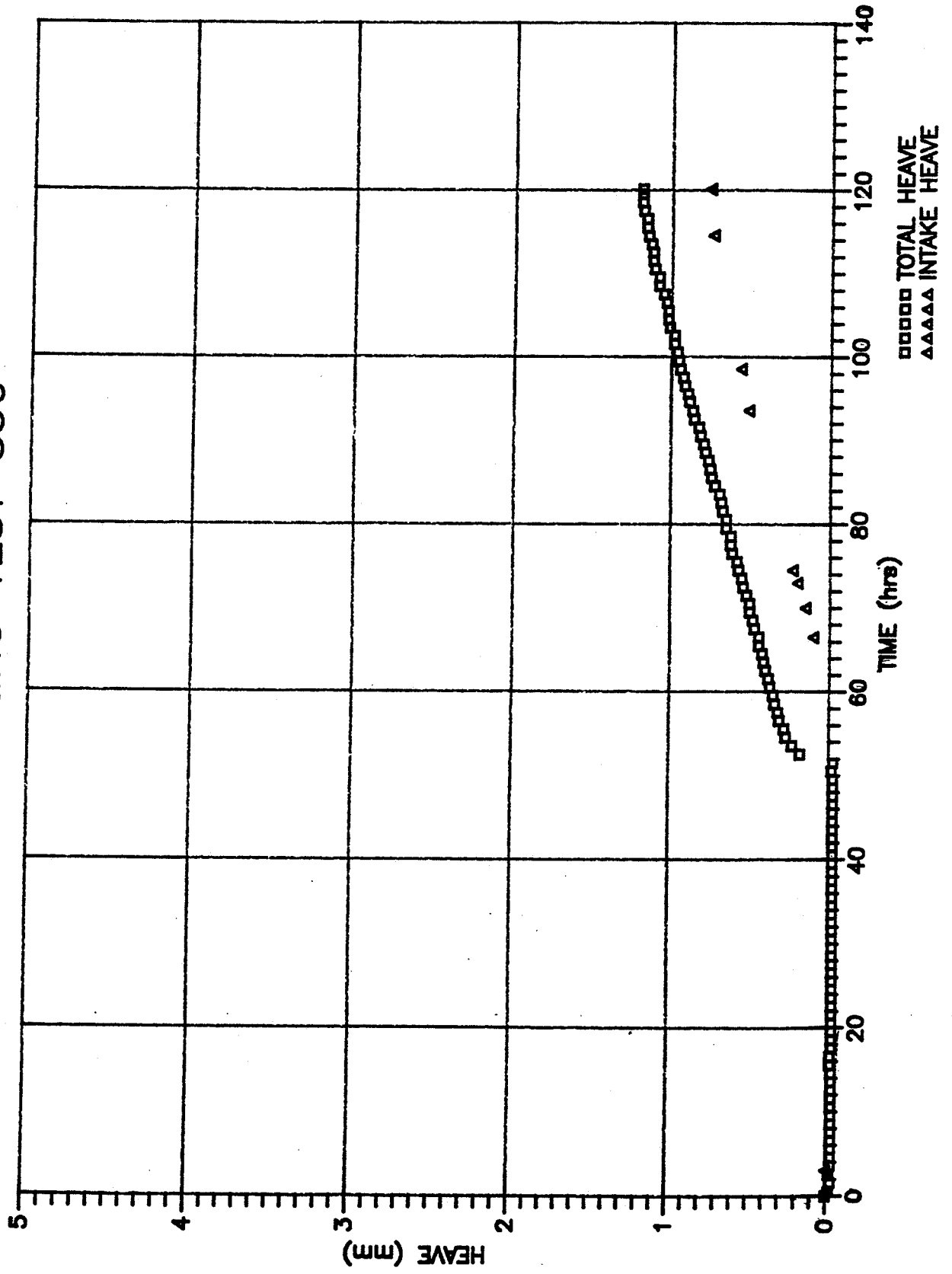


OBSERVED POSITION OF ICE LENS

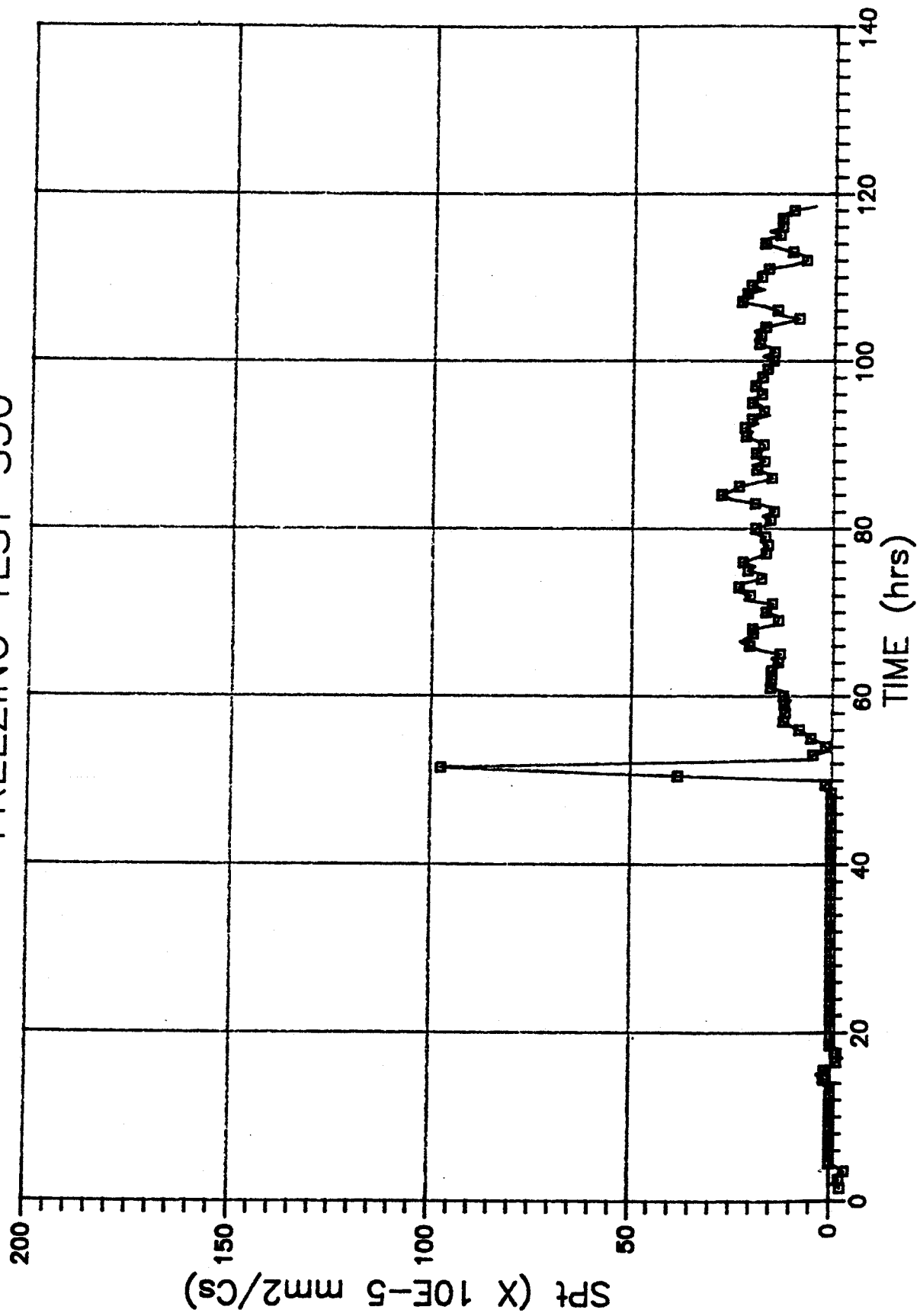


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S71

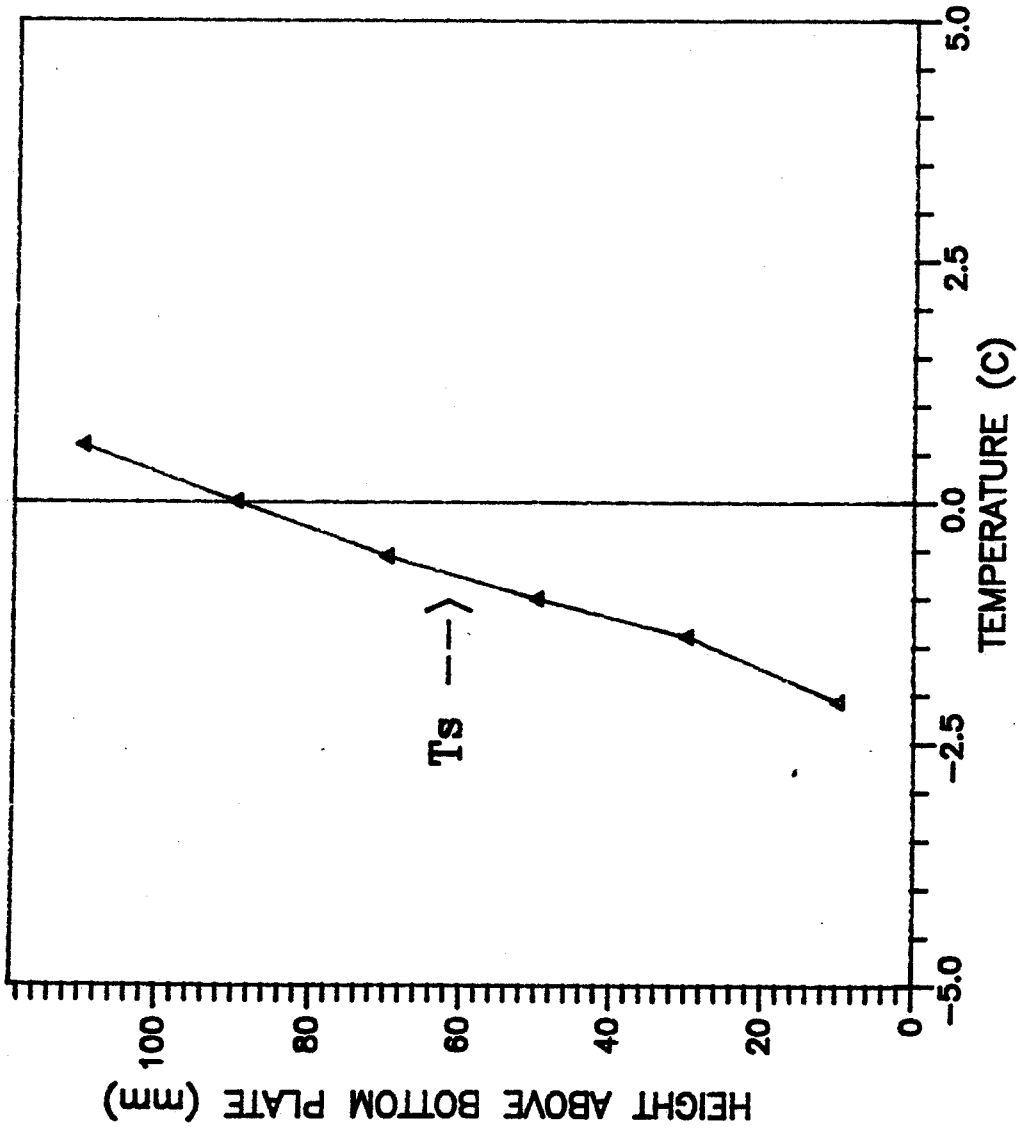
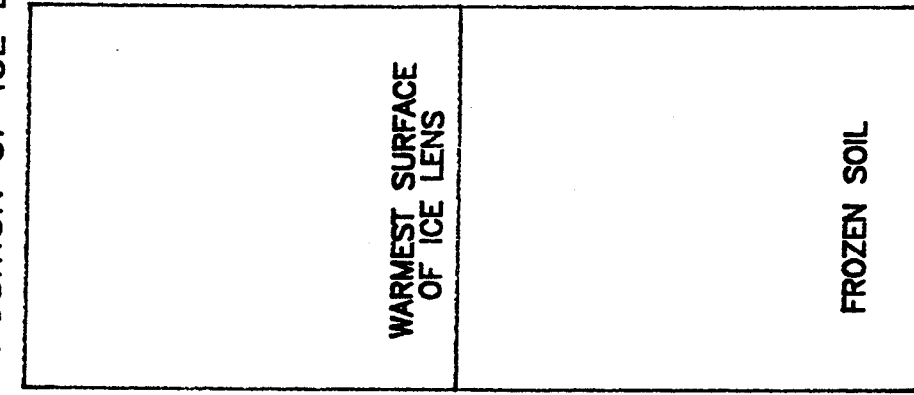
FREEZING TEST S50



FREEZING TEST S50

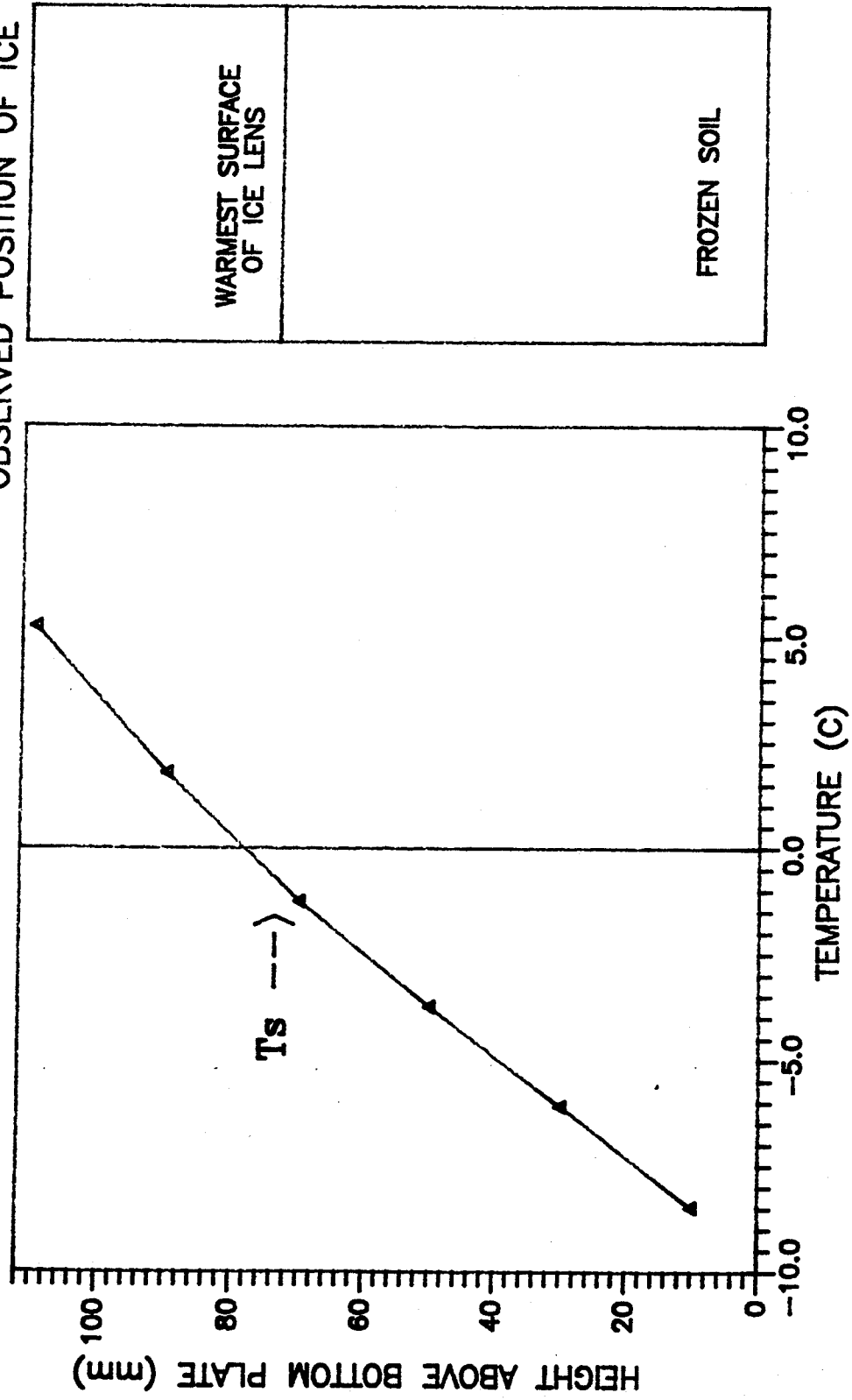


OBSERVED POSITION OF ICE LENS



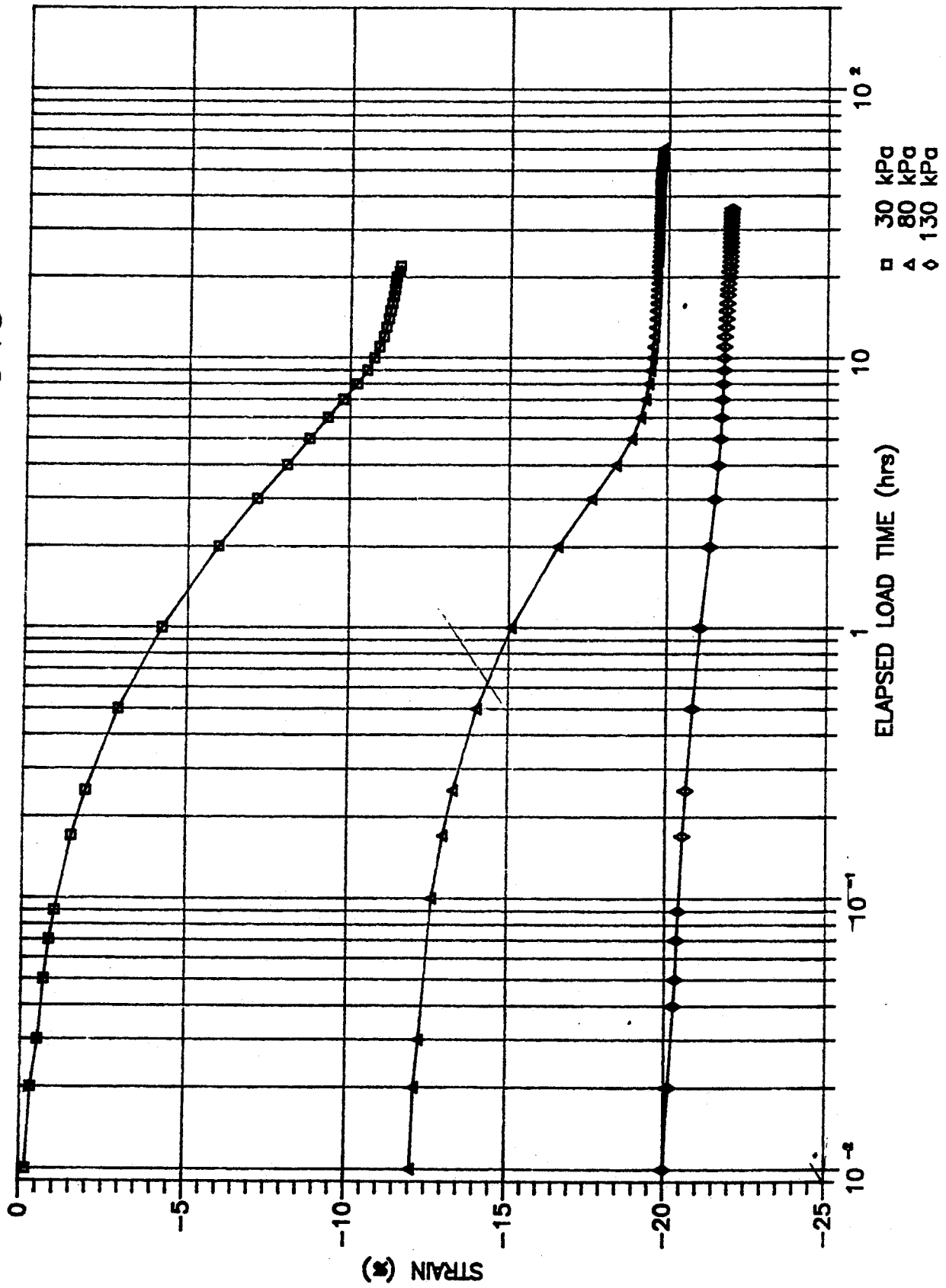
TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S50

OBSERVED POSITION OF ICE LENS

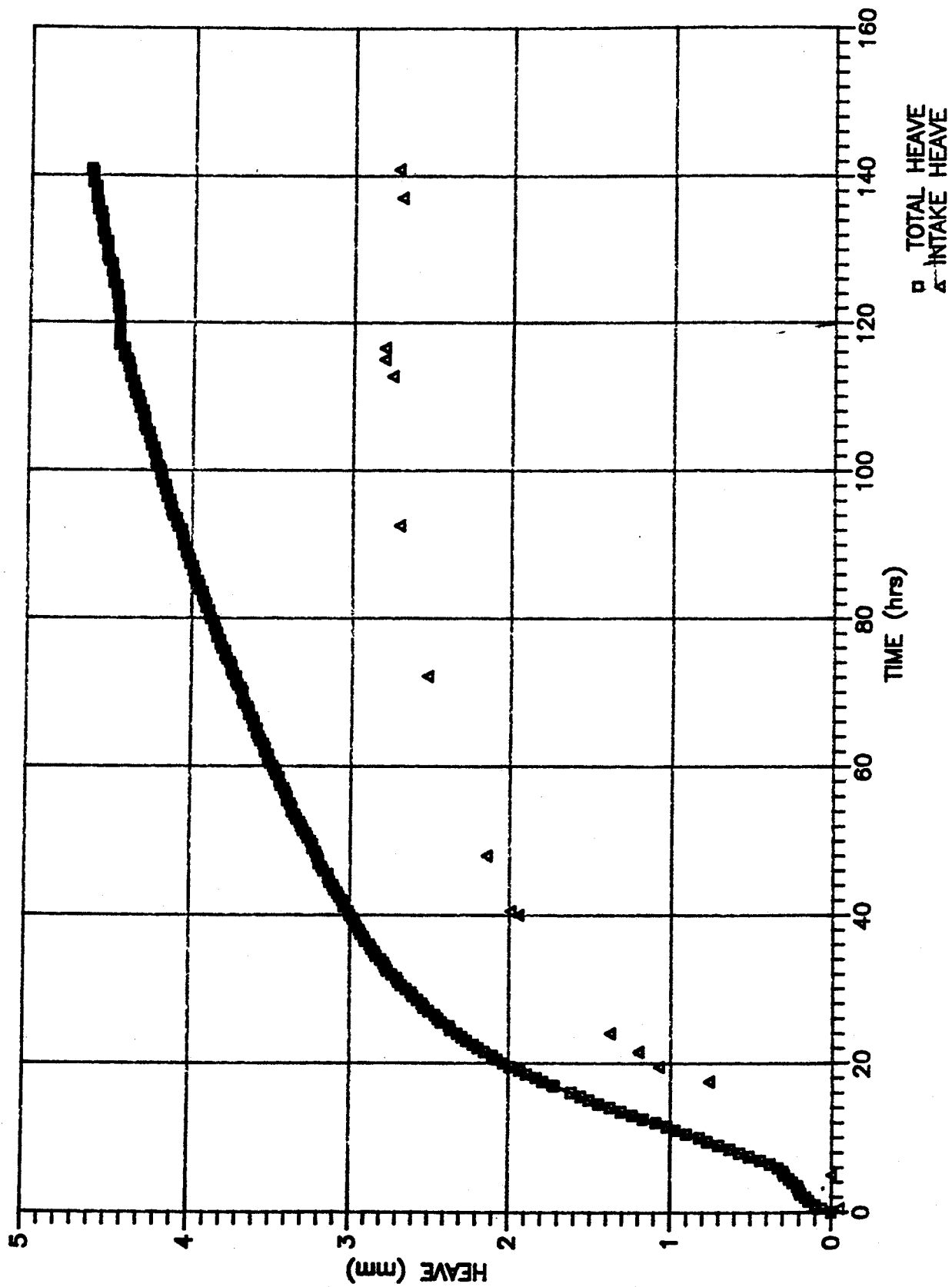


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- S42

CONSOLIDATION TEST S43

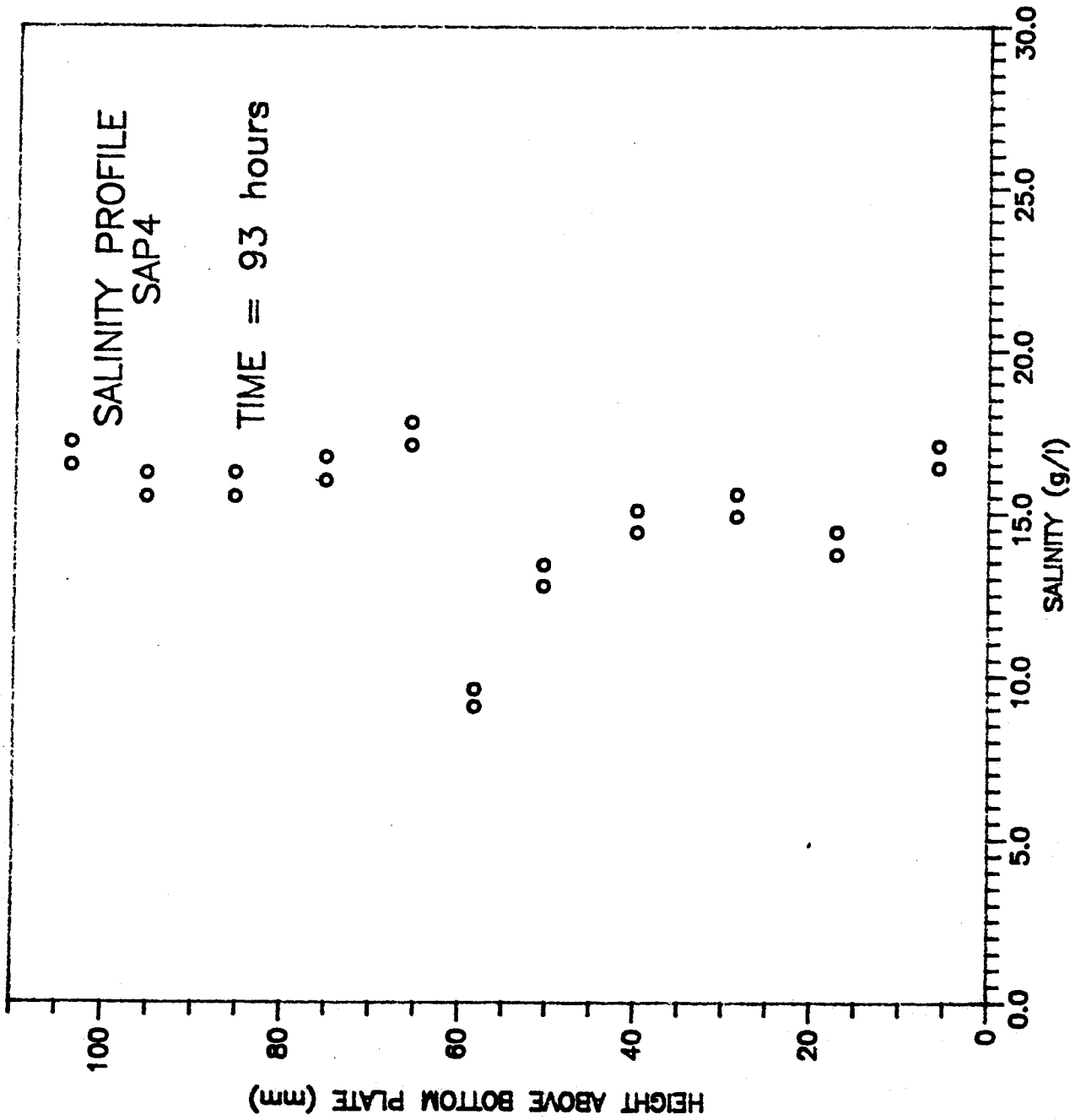


FREEZING TEST S43

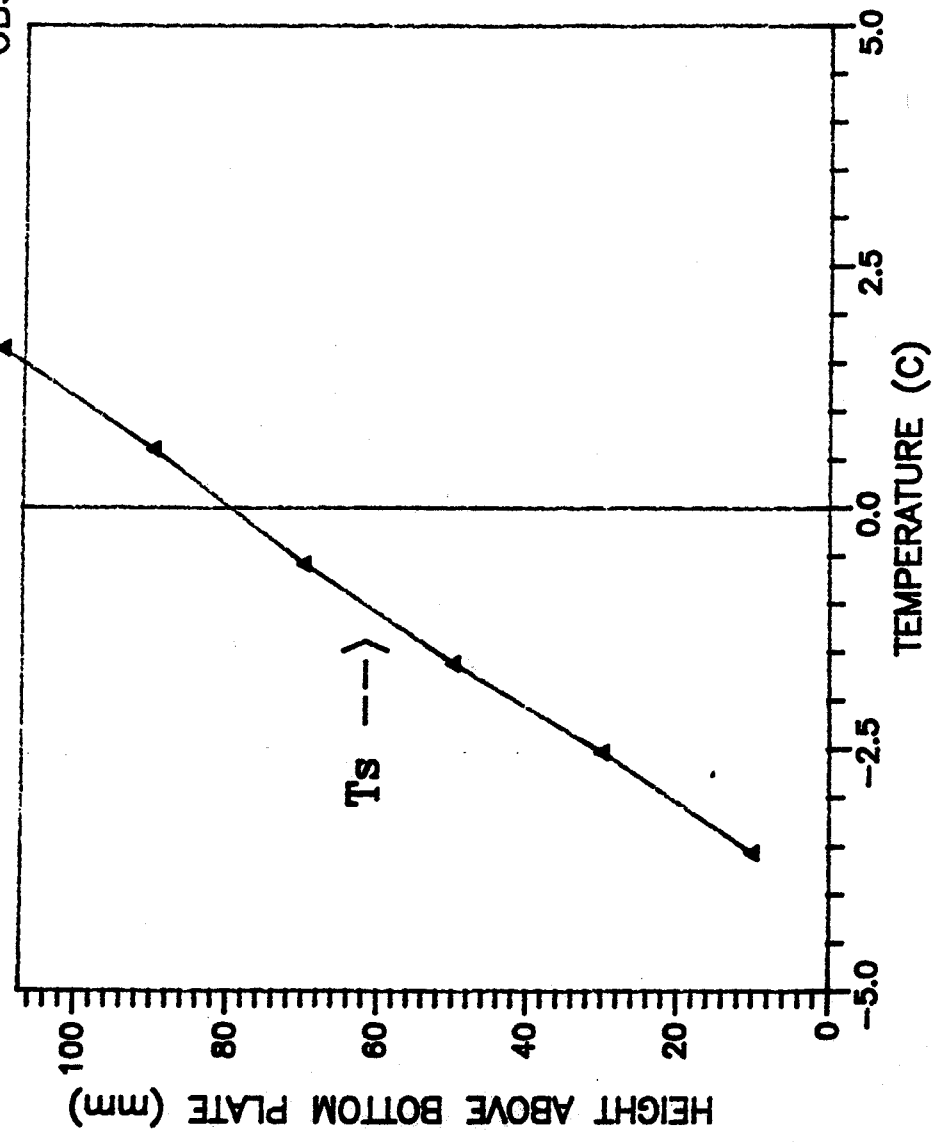
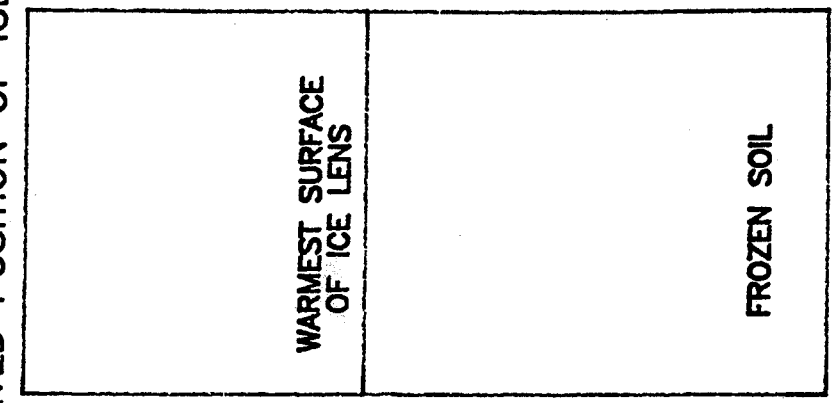


SALINITY PROFILE
SAP4

TIME = 93 hours

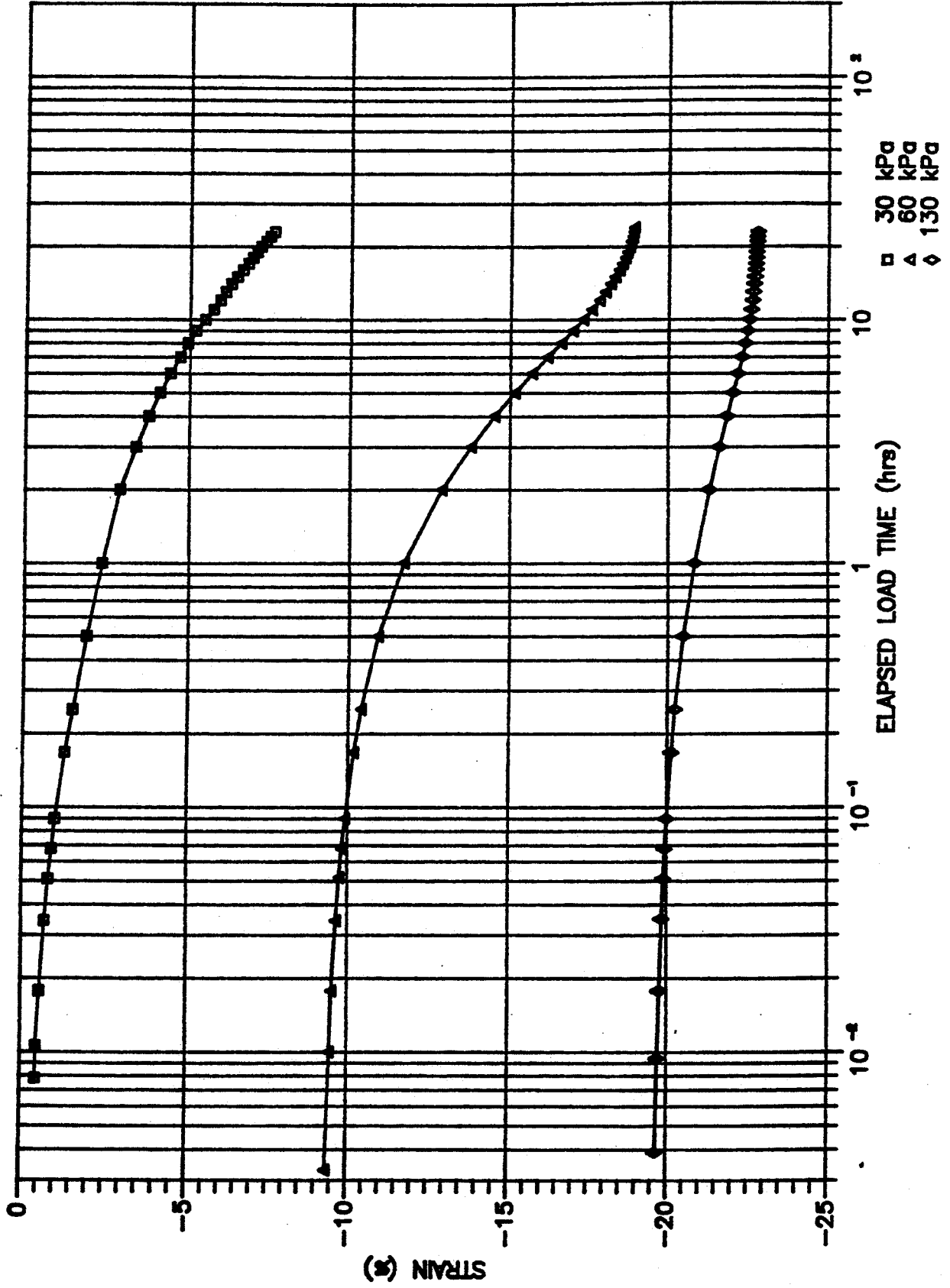


OBSERVED POSITION OF ICE LENS

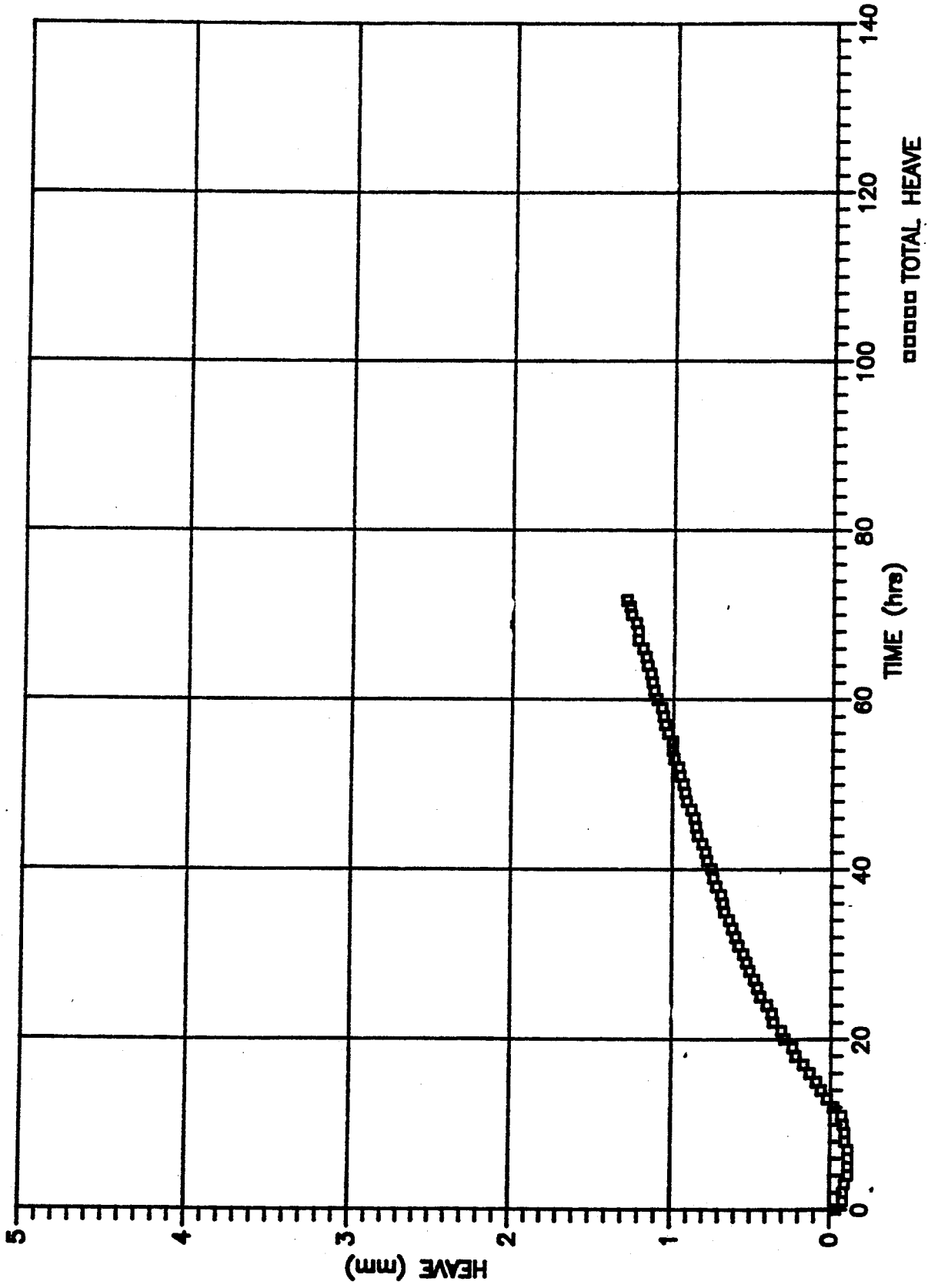


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP4

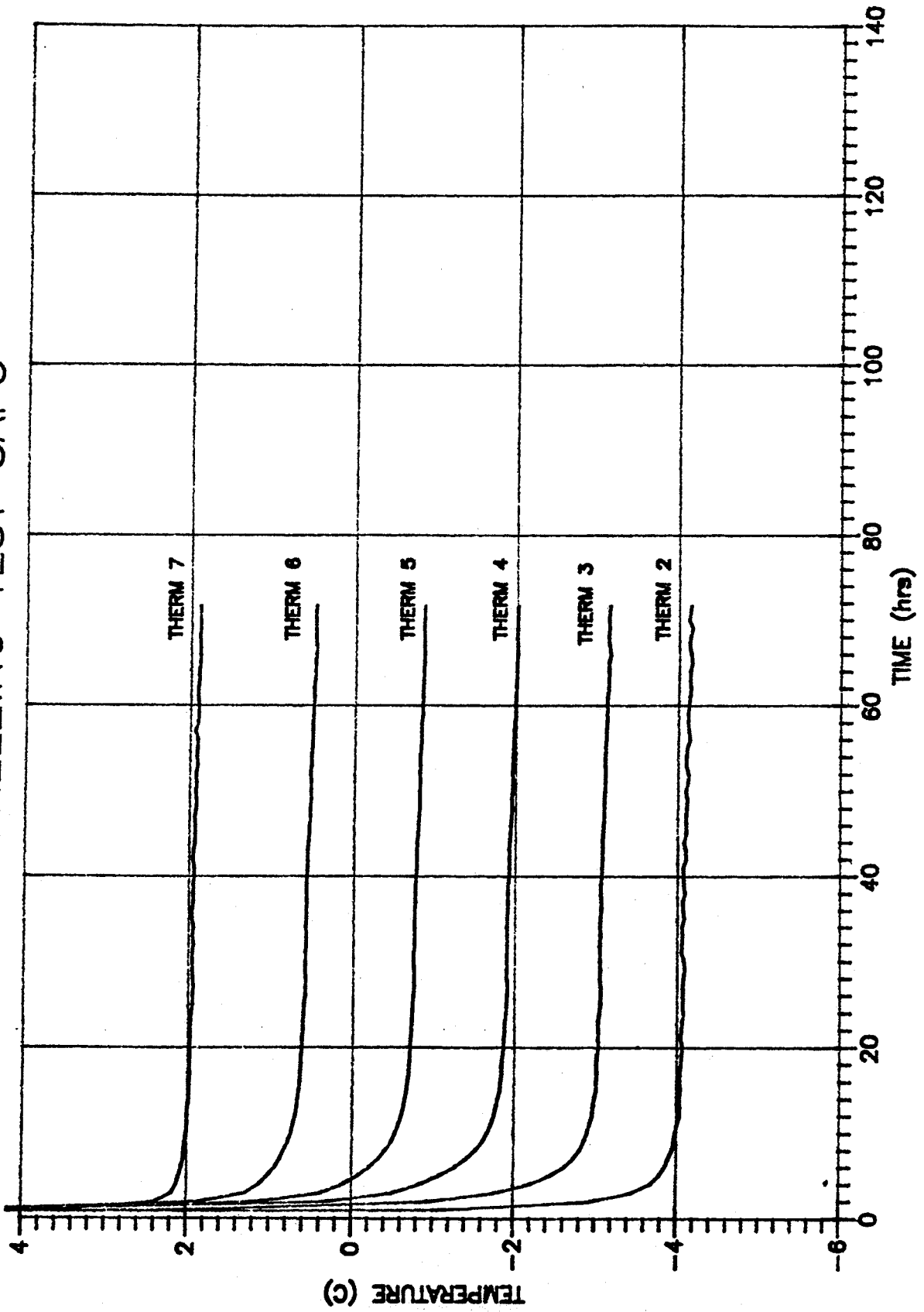
CONSOLIDATION TEST SAP5



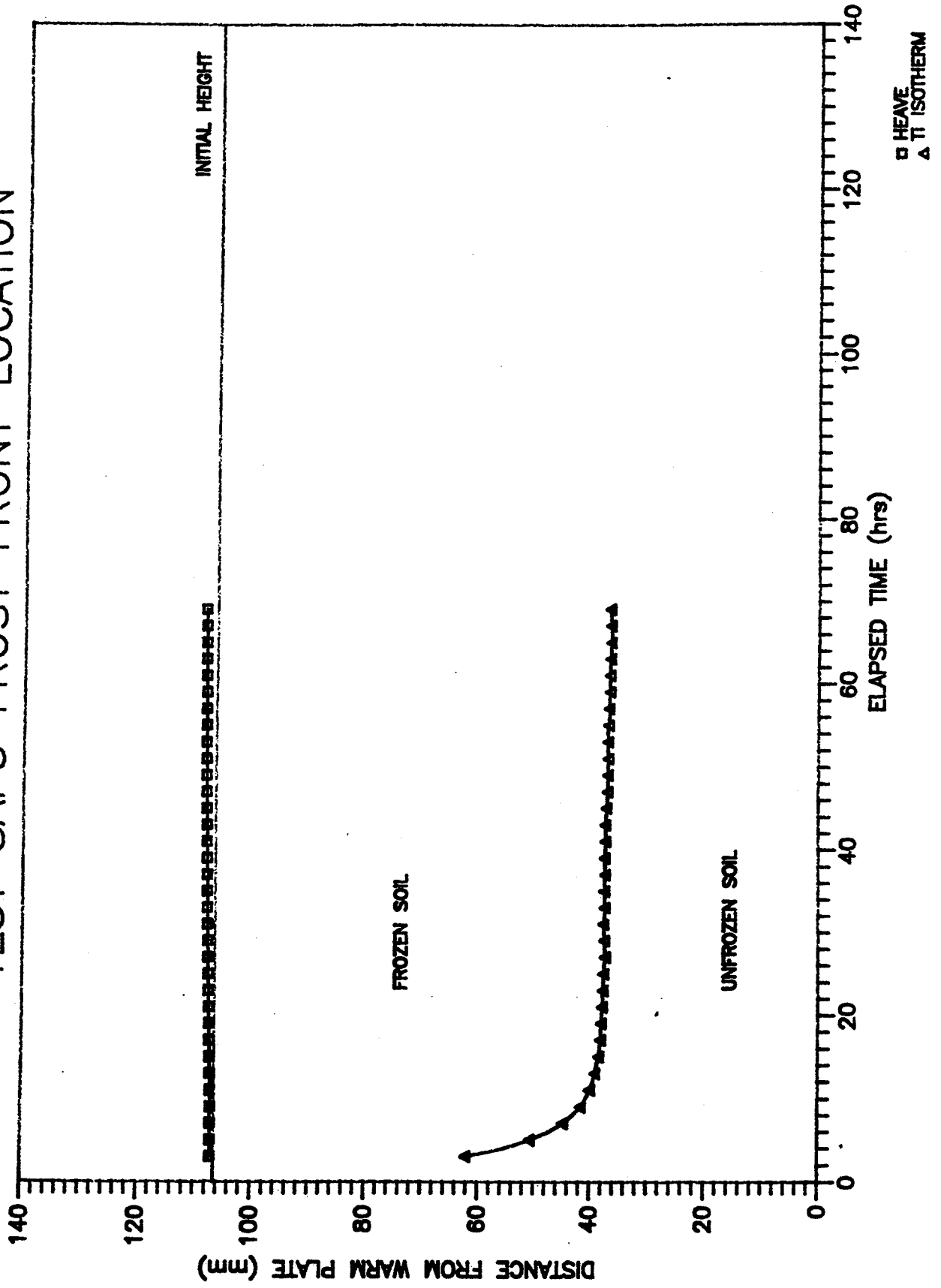
FREEZING TEST SAP5



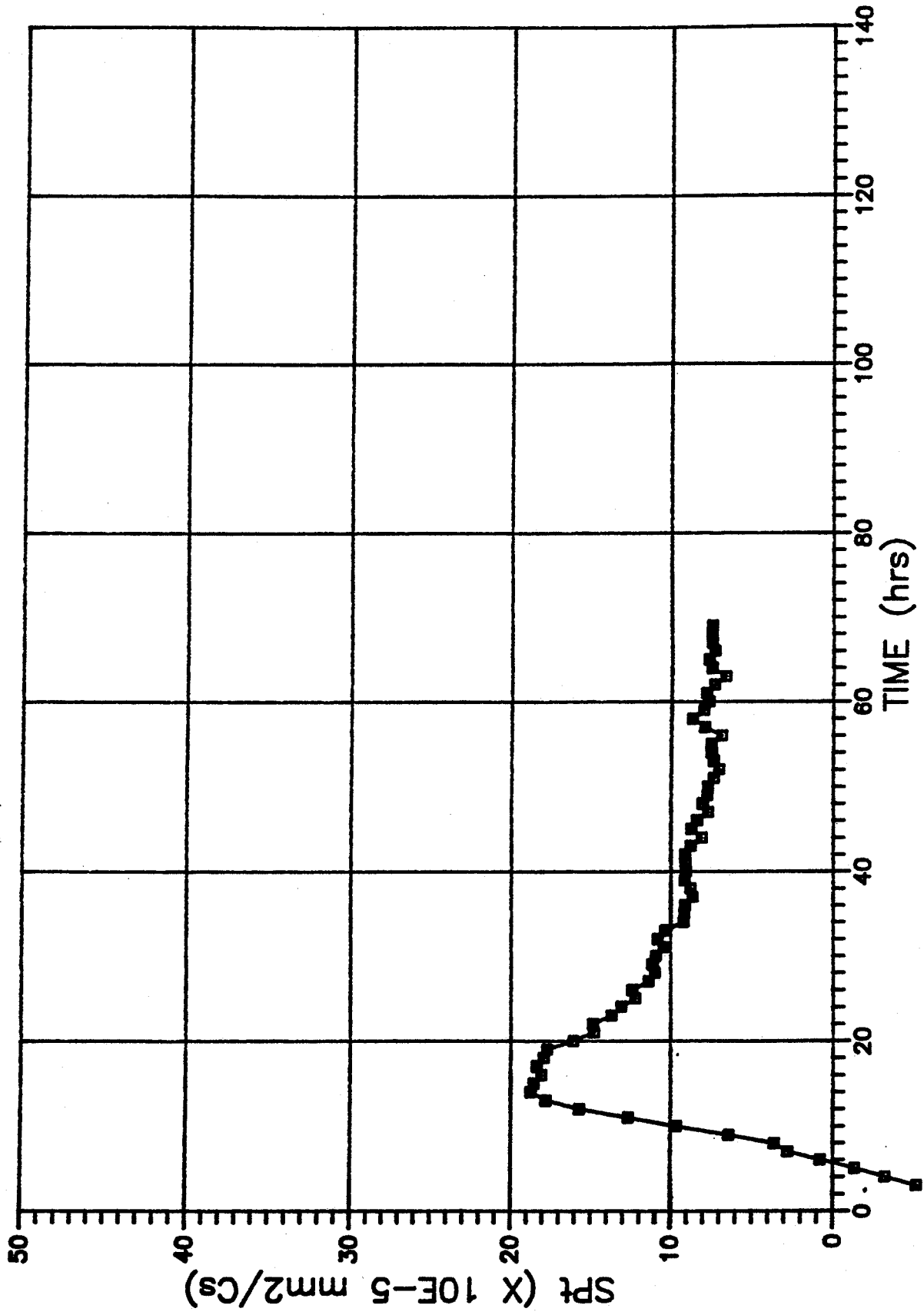
FREEZING TEST SAP5



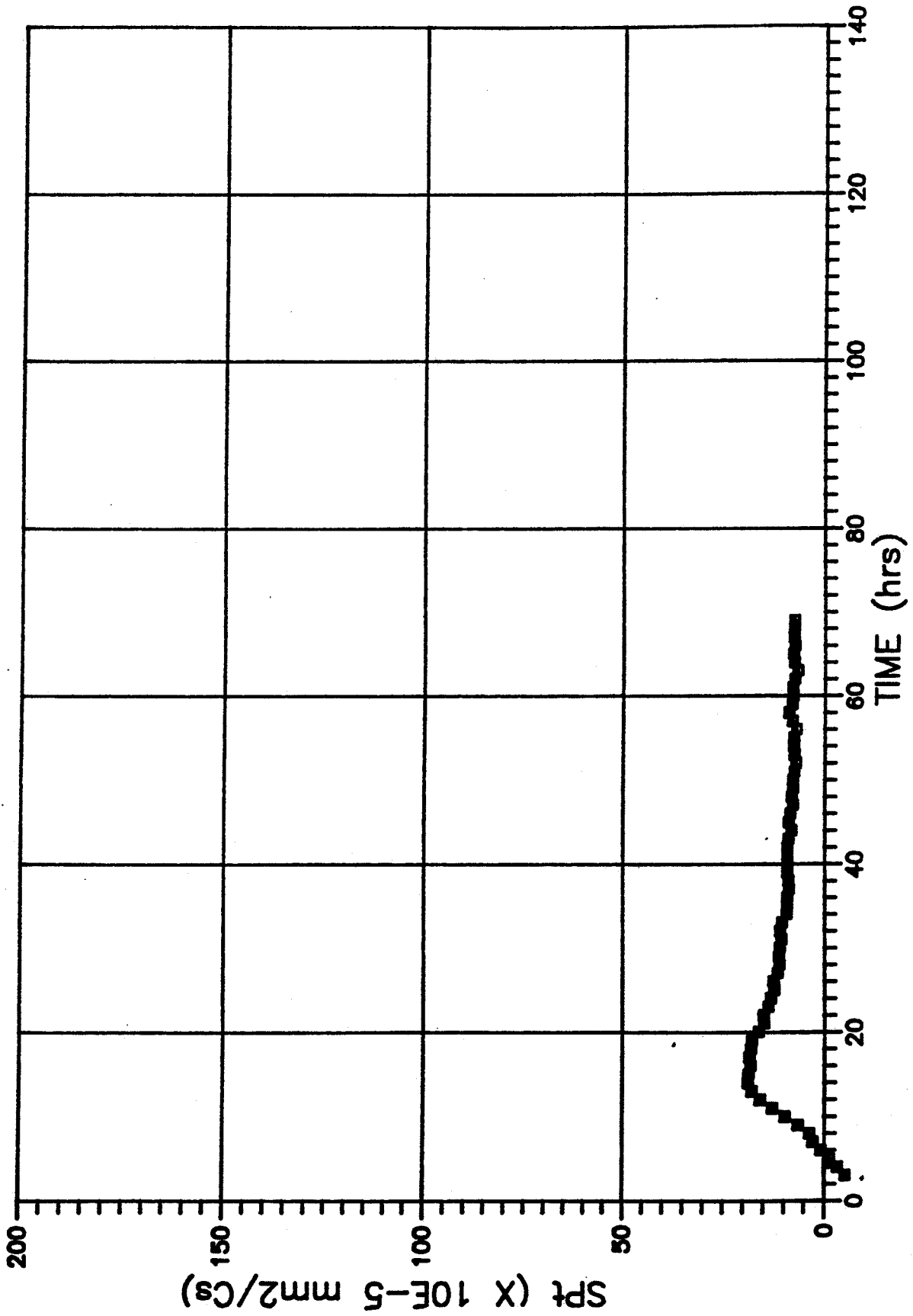
TEST SAP5 FROST FRONT LOCATION



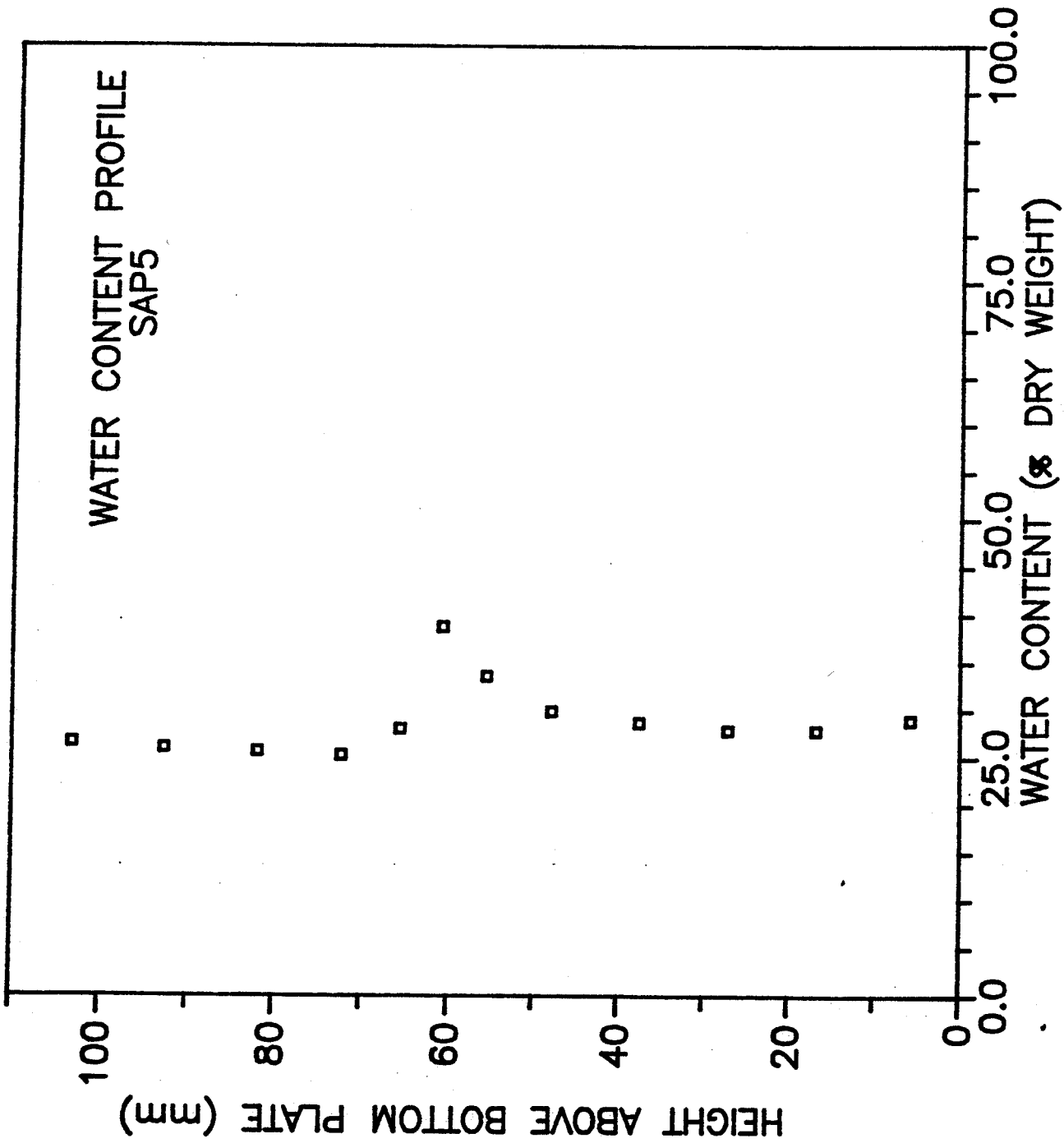
FREEZING TEST SAP5



FREEZING TEST SAP5

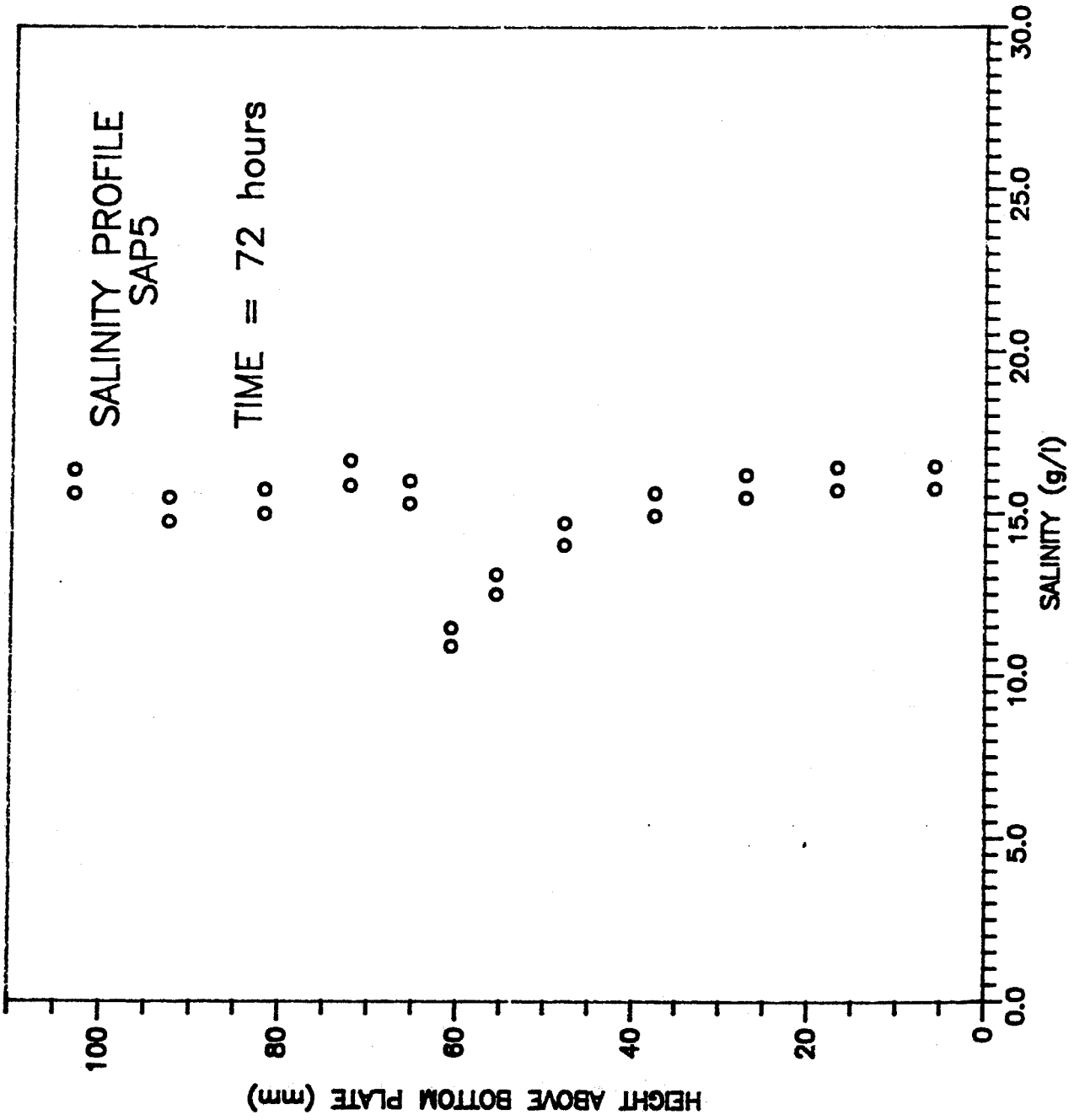


WATER CONTENT PROFILE
SAP5

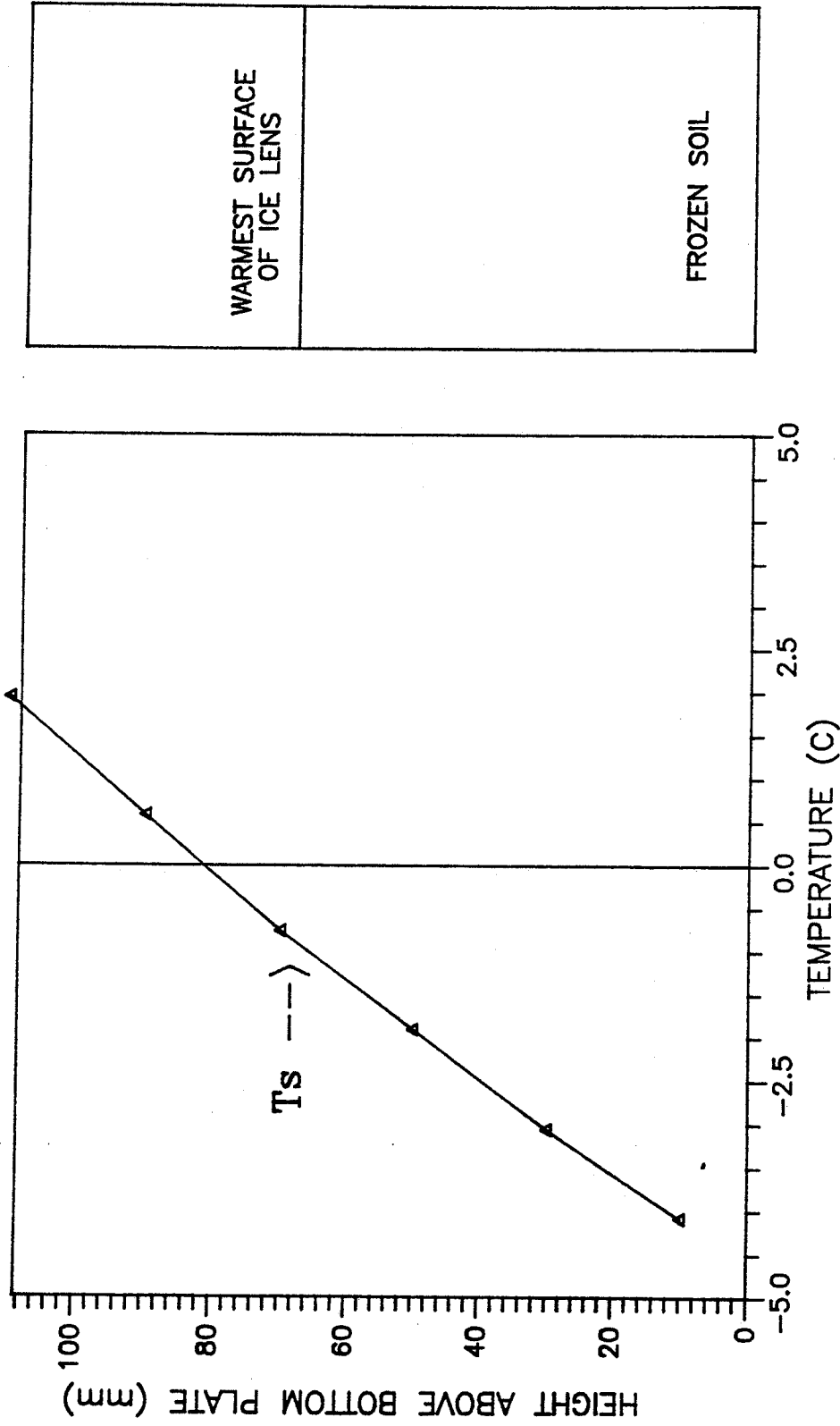


SALINITY PROFILE
SAP5

TIME = 72 hours

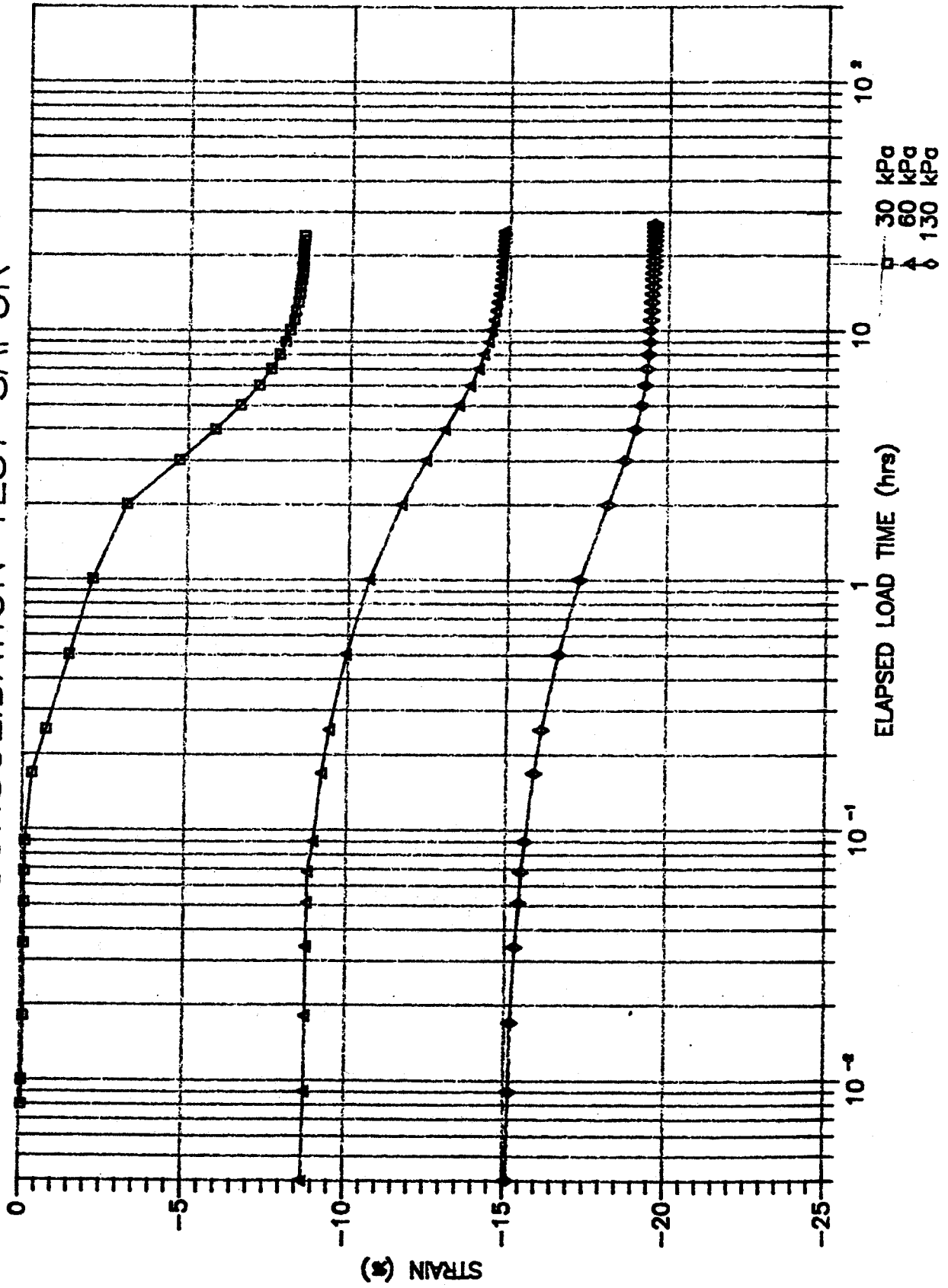


OBSERVED POSITION OF ICE LENS

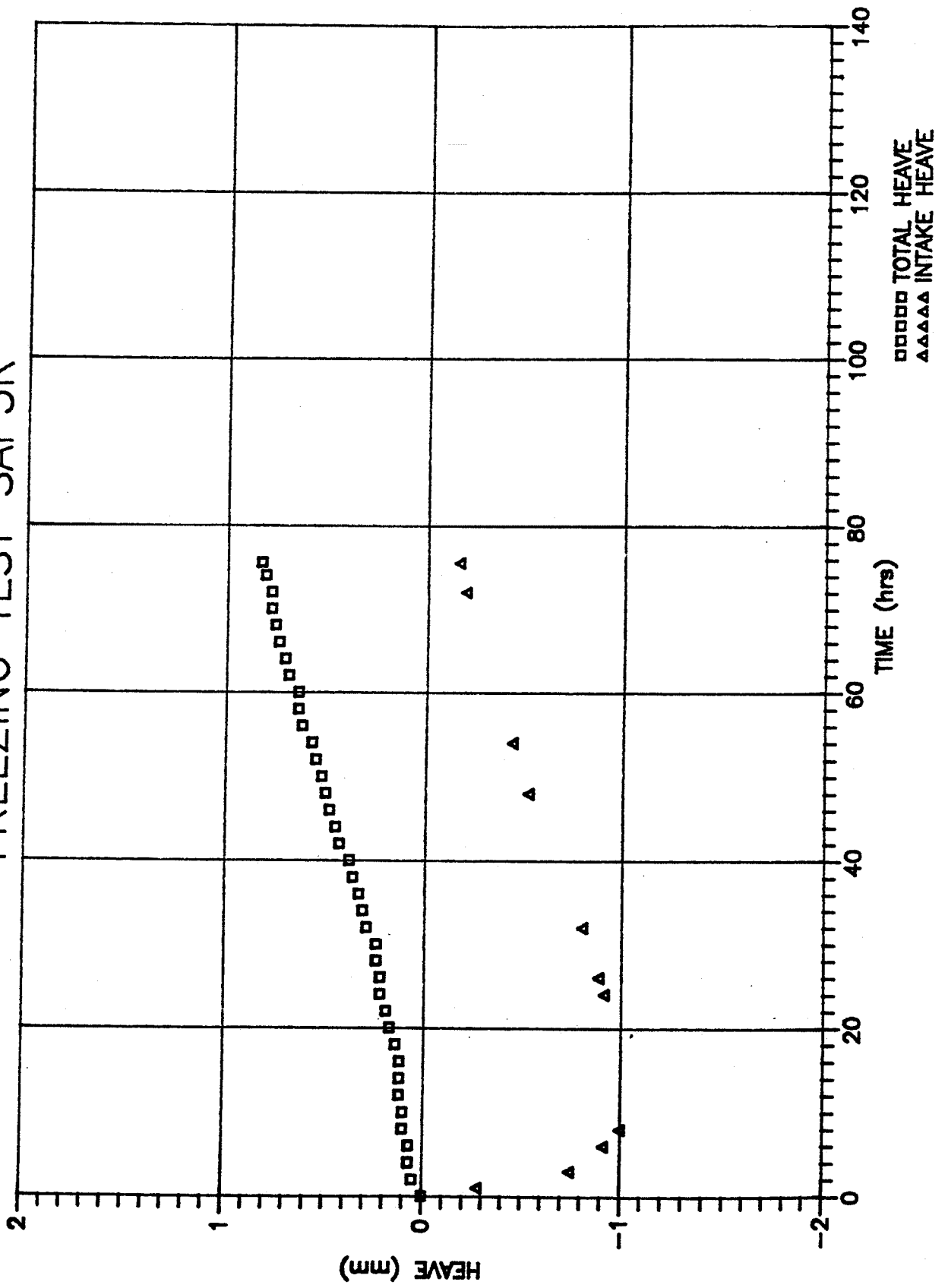


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP5

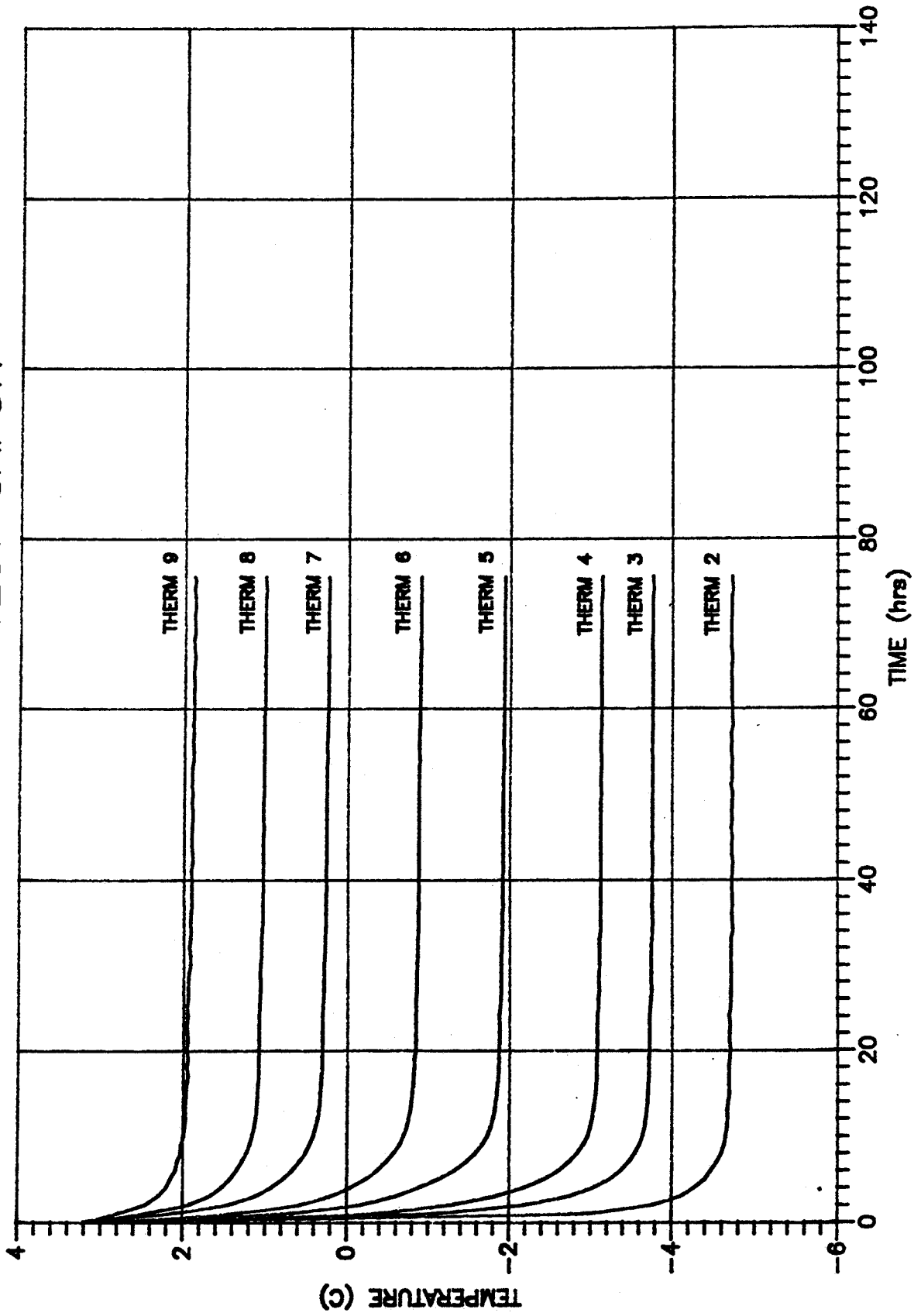
CONSOLIDATION TEST SAP5R



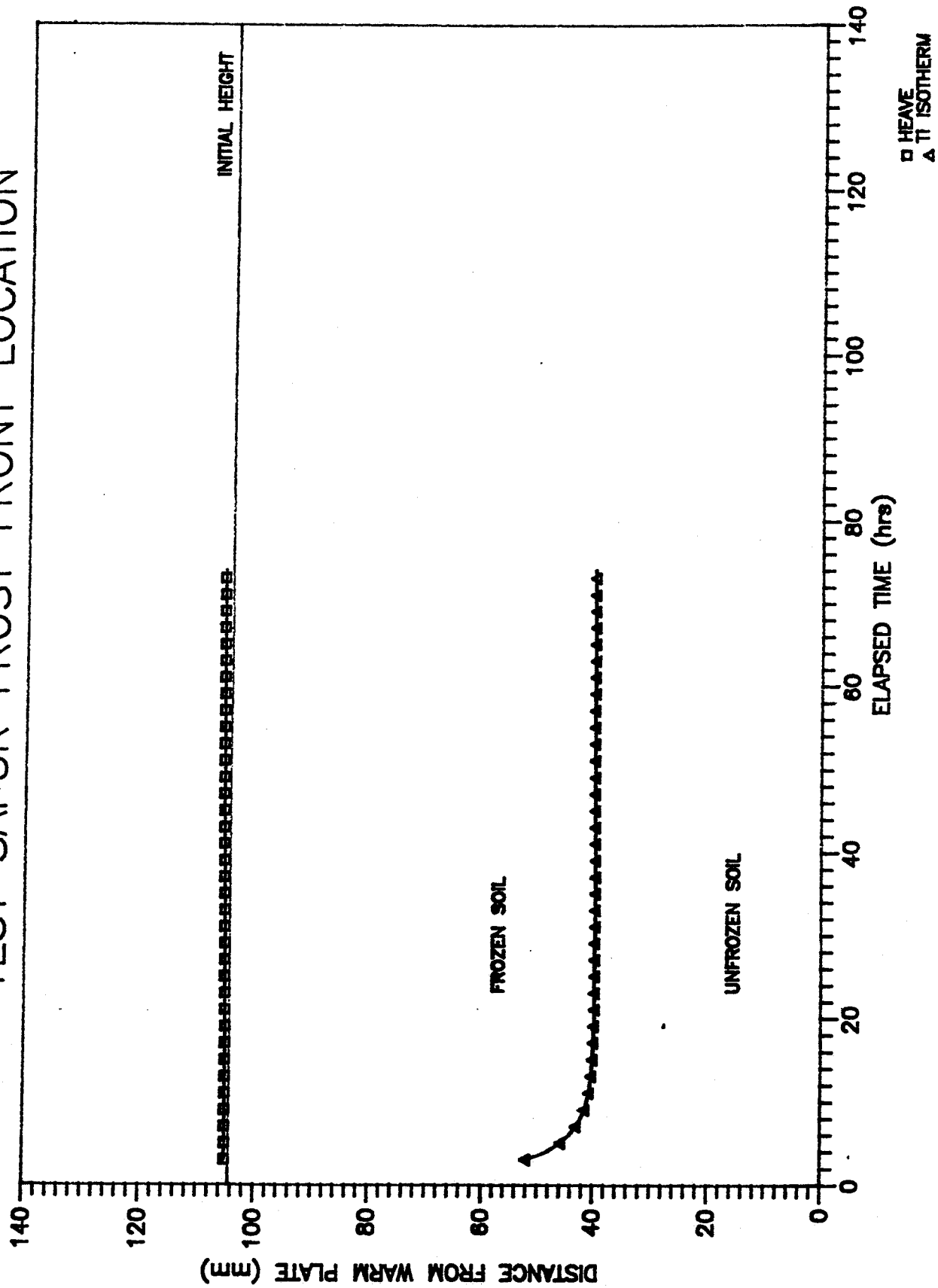
FREEZING TEST SAP5R



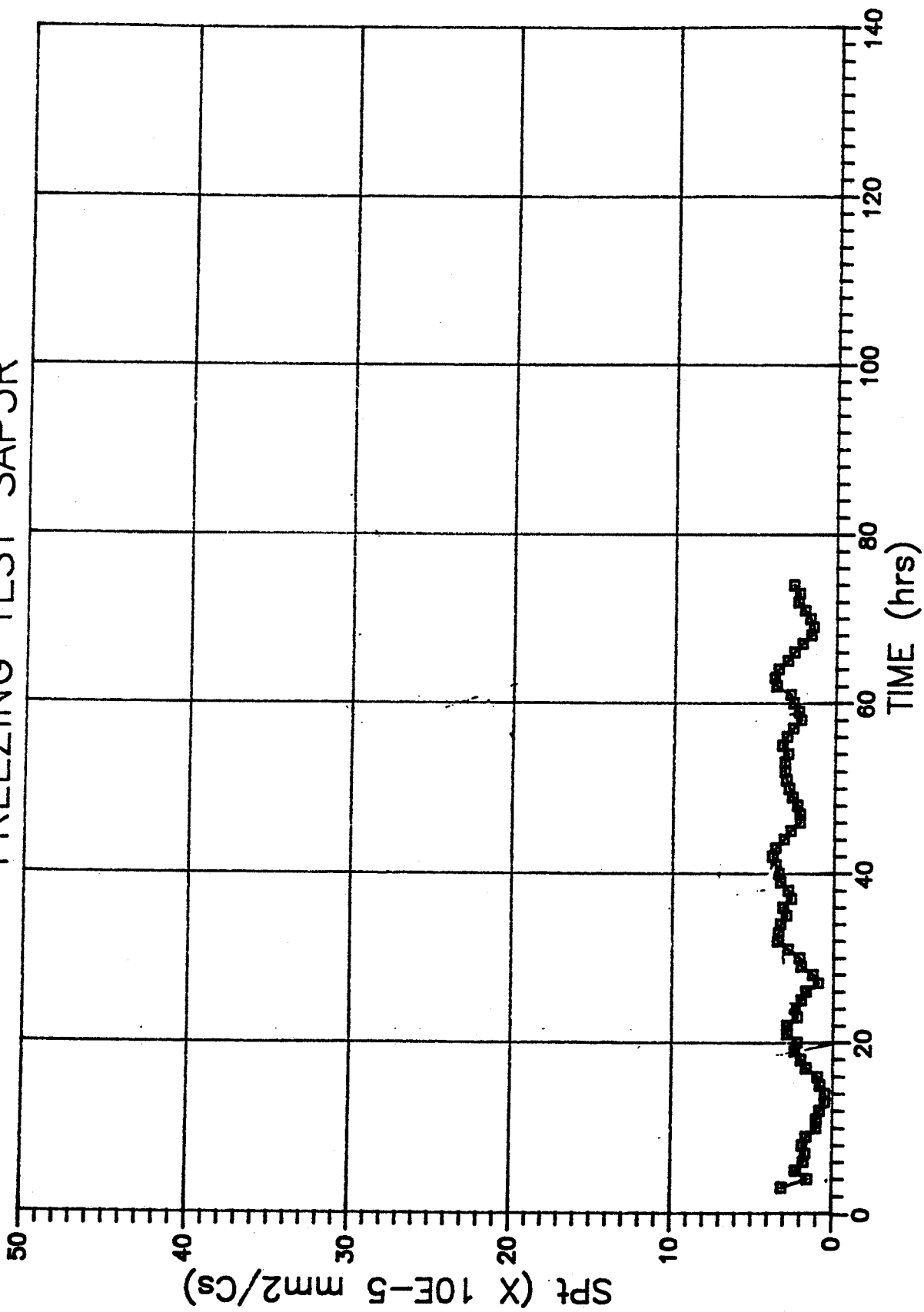
FREEZING TEST SAP5R



TEST SAP5R FROST FRONT LOCATION

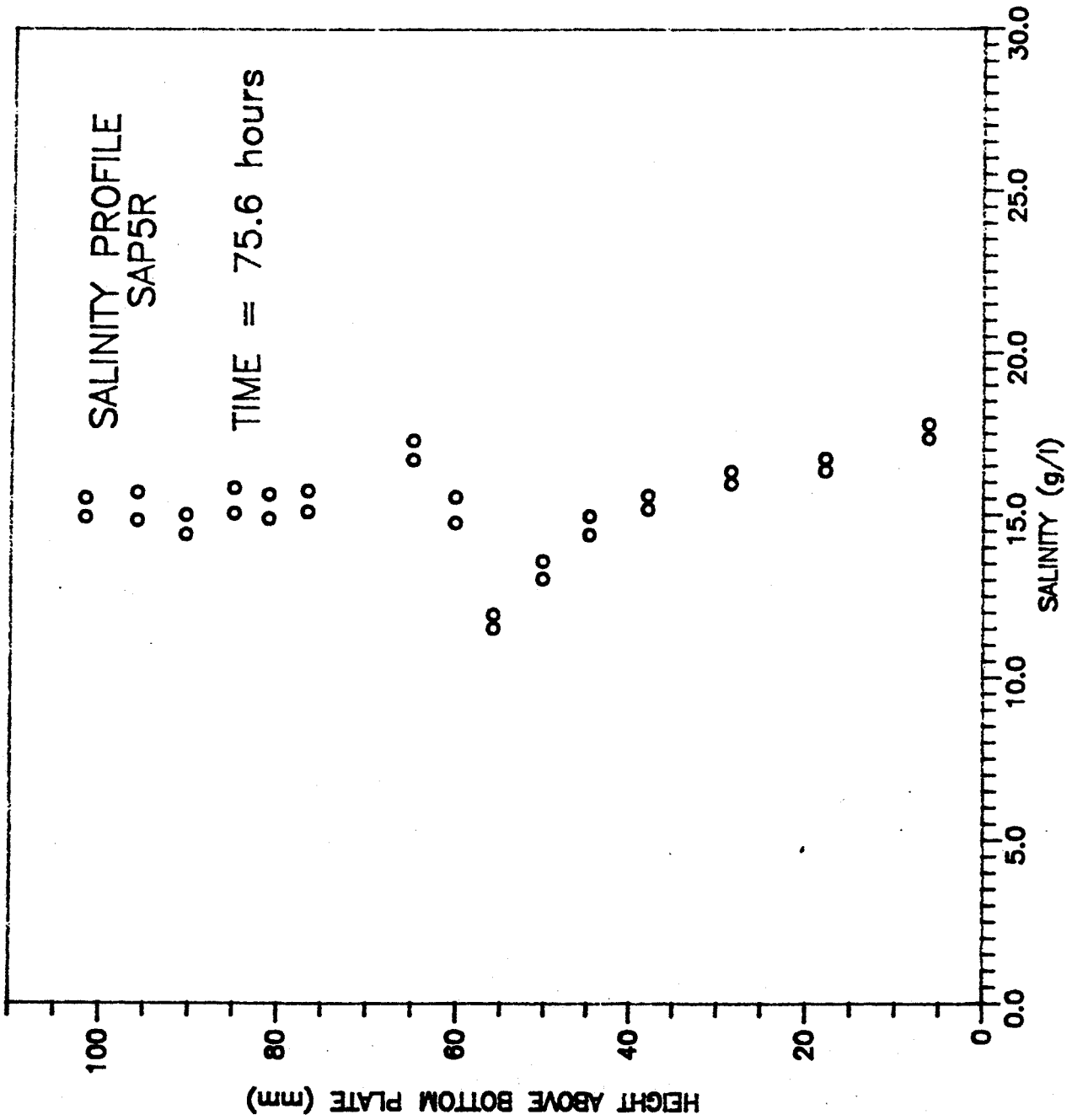


FREEZING TEST SAP5R

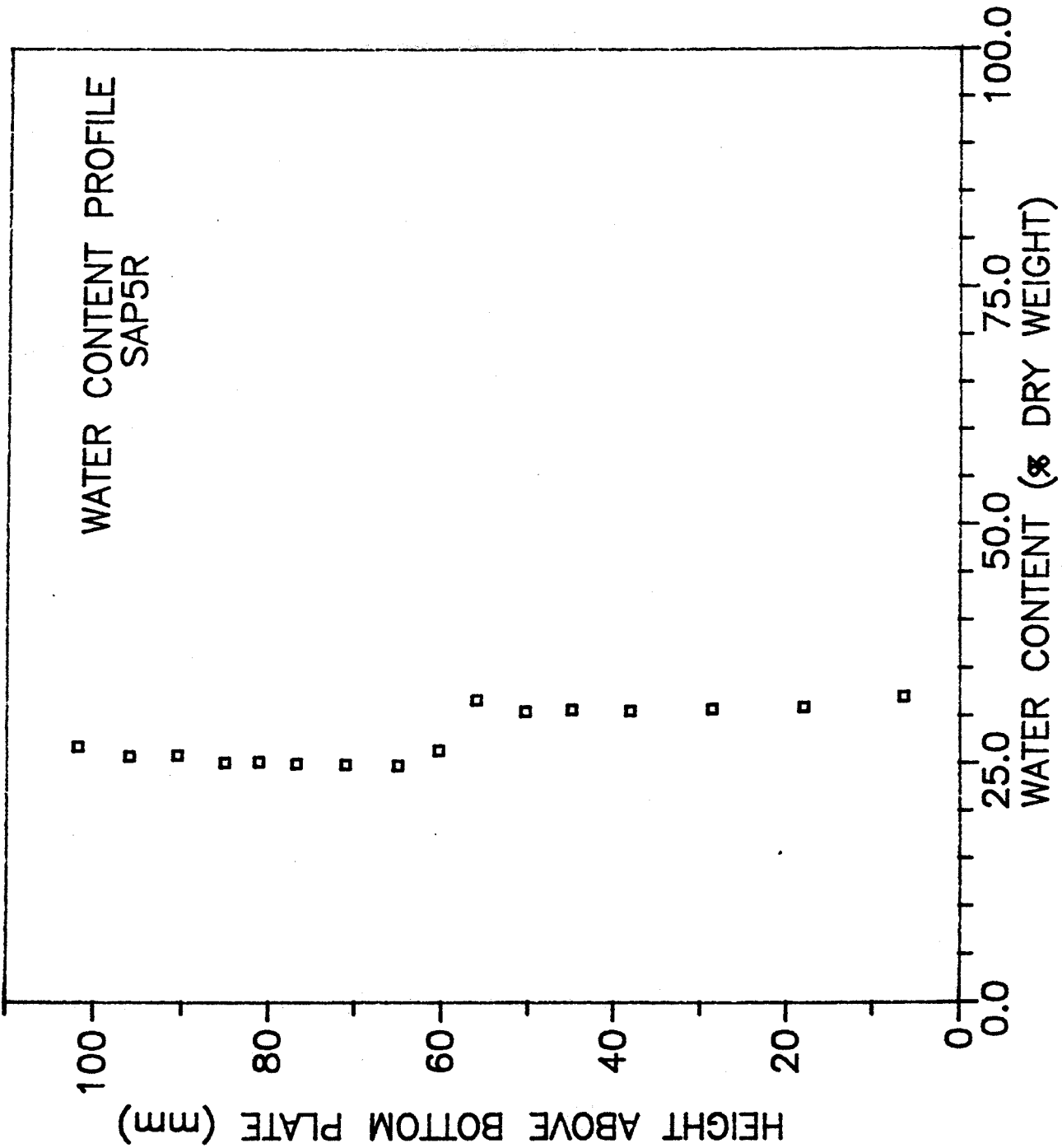


SALINITY PROFILE
SAP5R

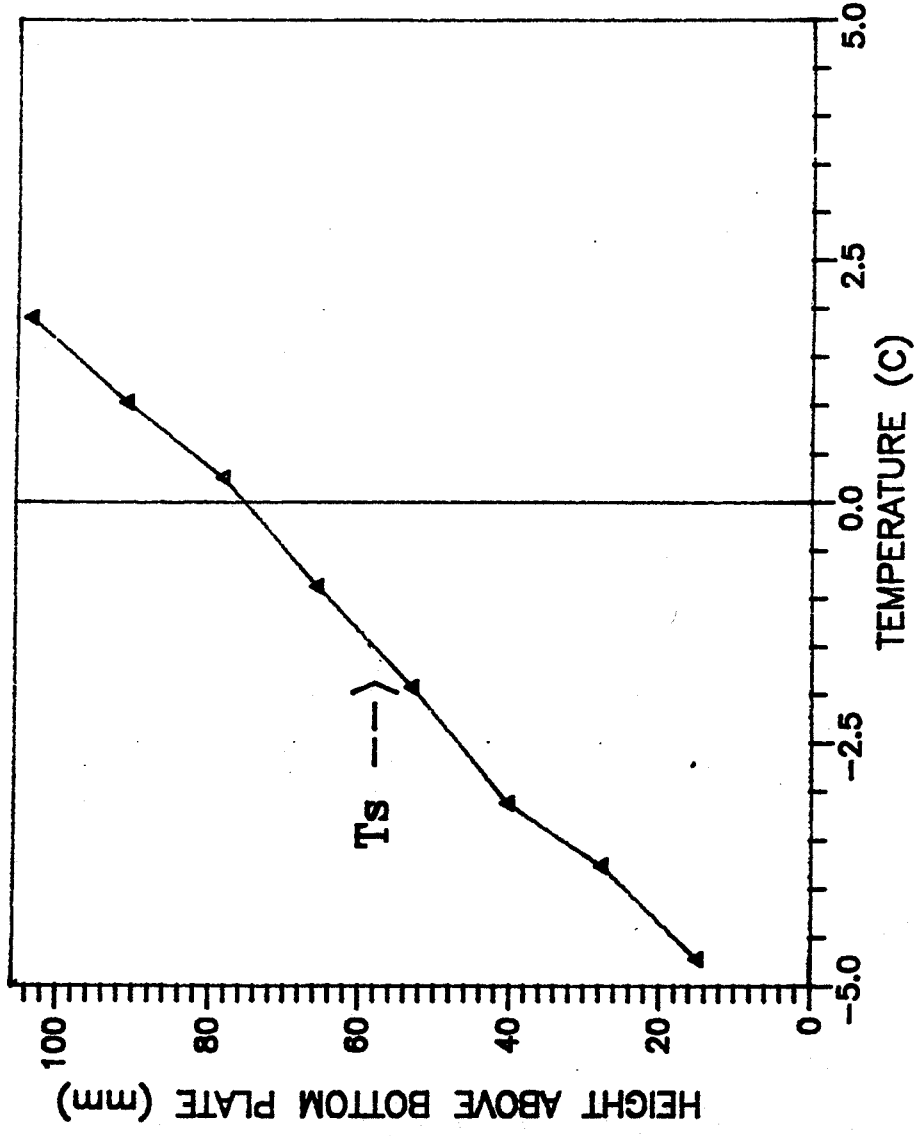
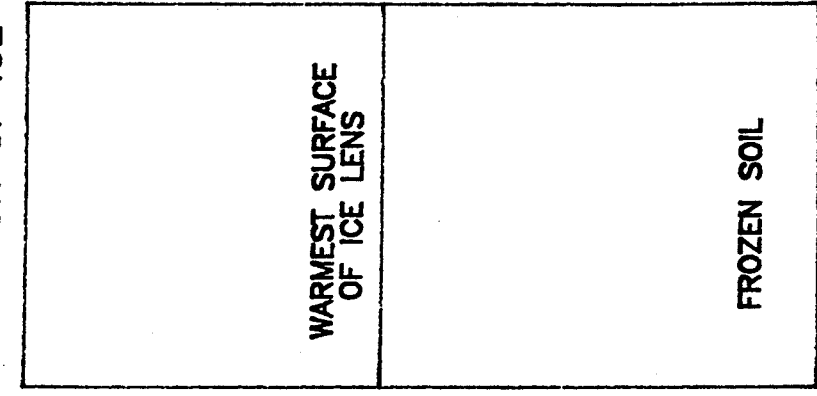
TIME = 75.6 hours



WATER CONTENT PROFILE
SAP5R

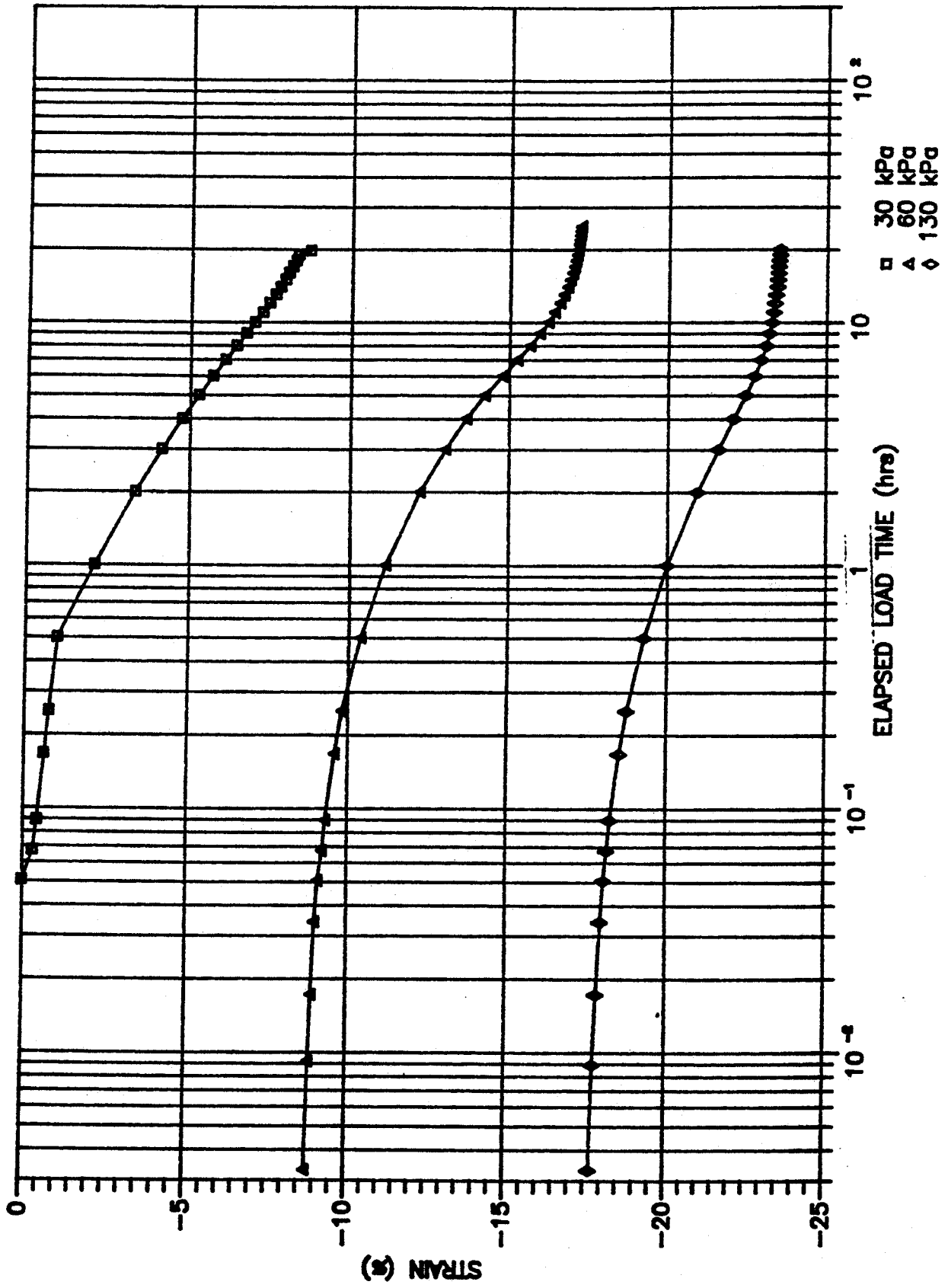


OBSERVED POSITION OF ICE LENS

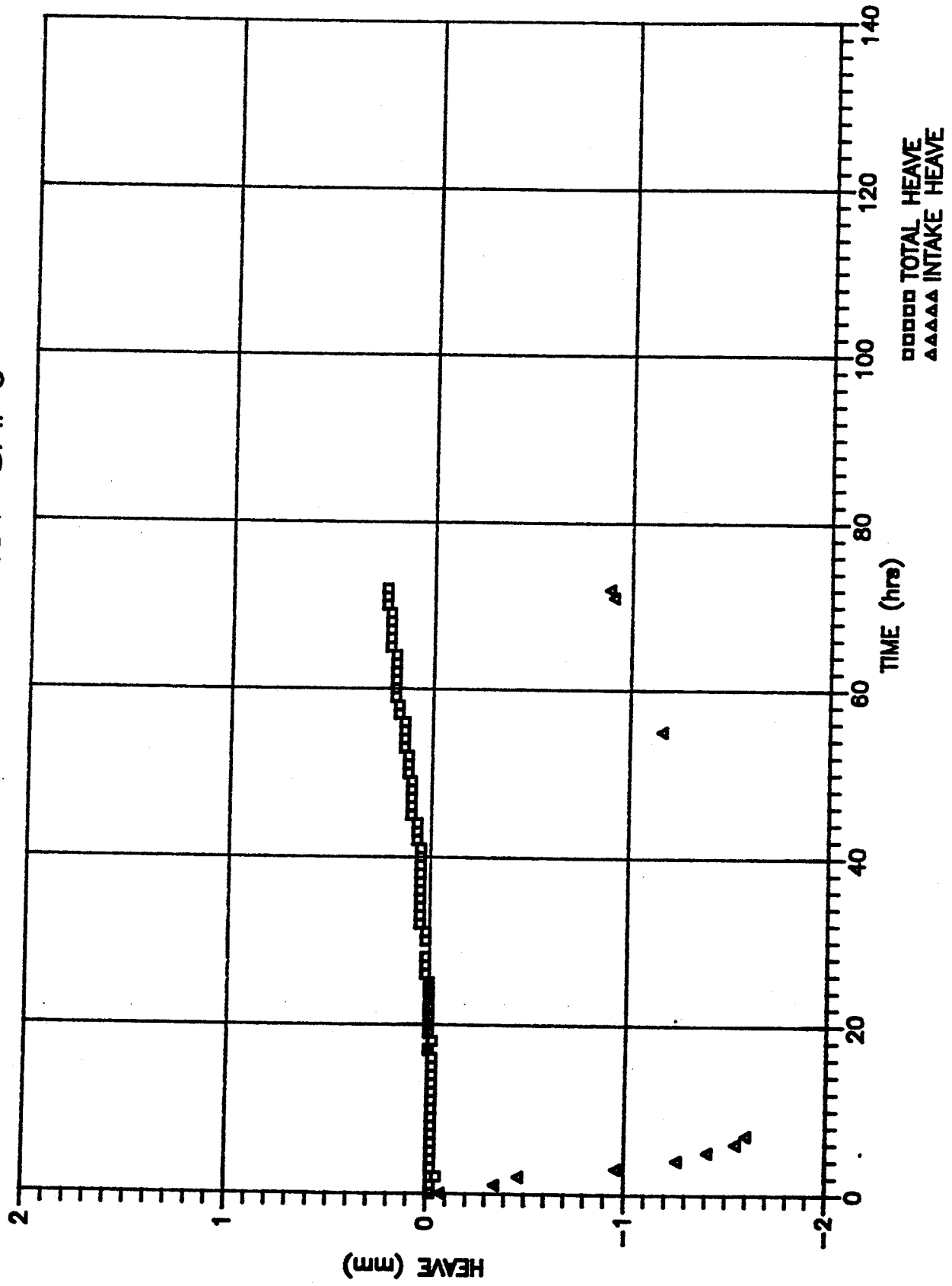


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP5R

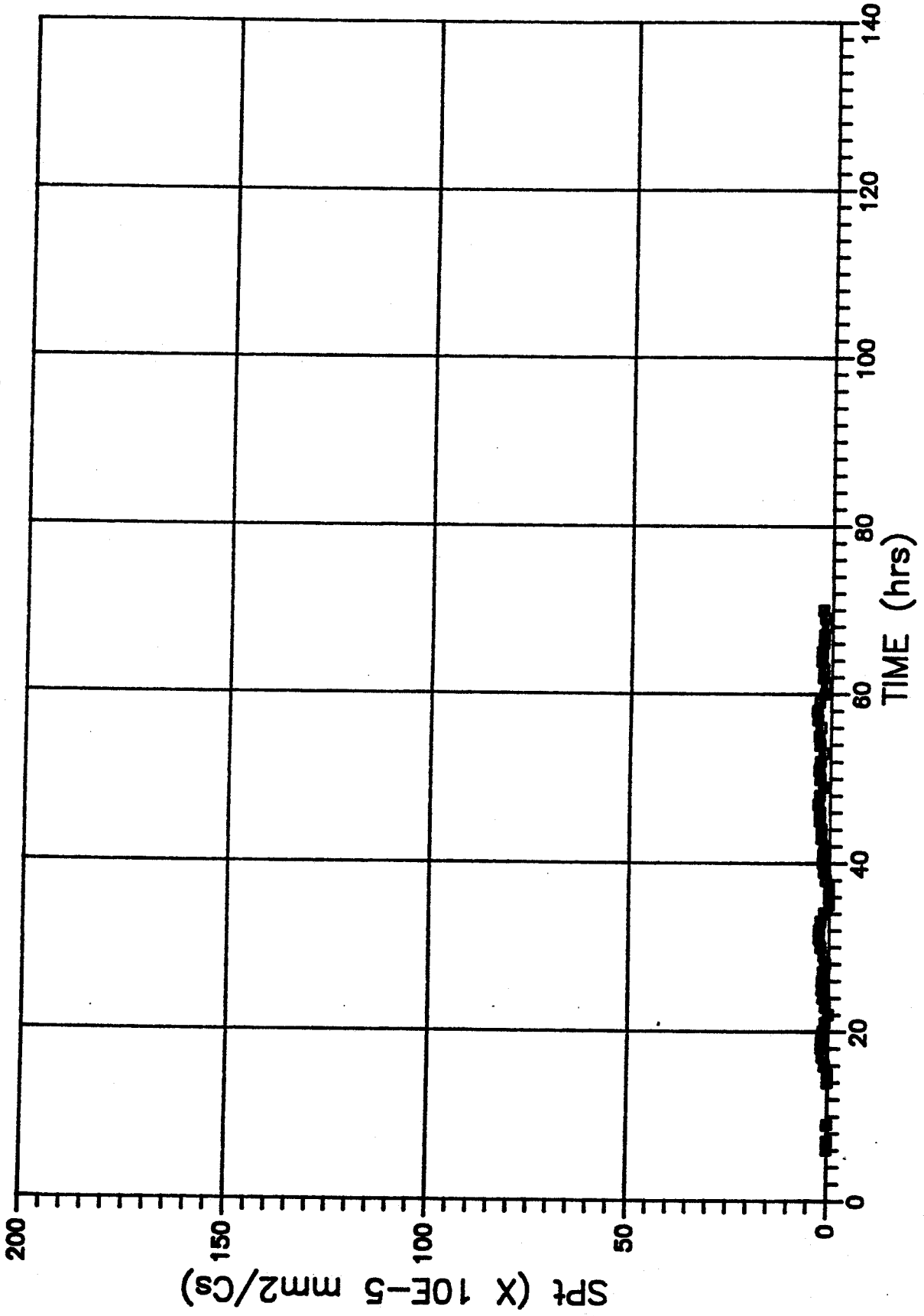
CONSOLIDATION TEST SAP6



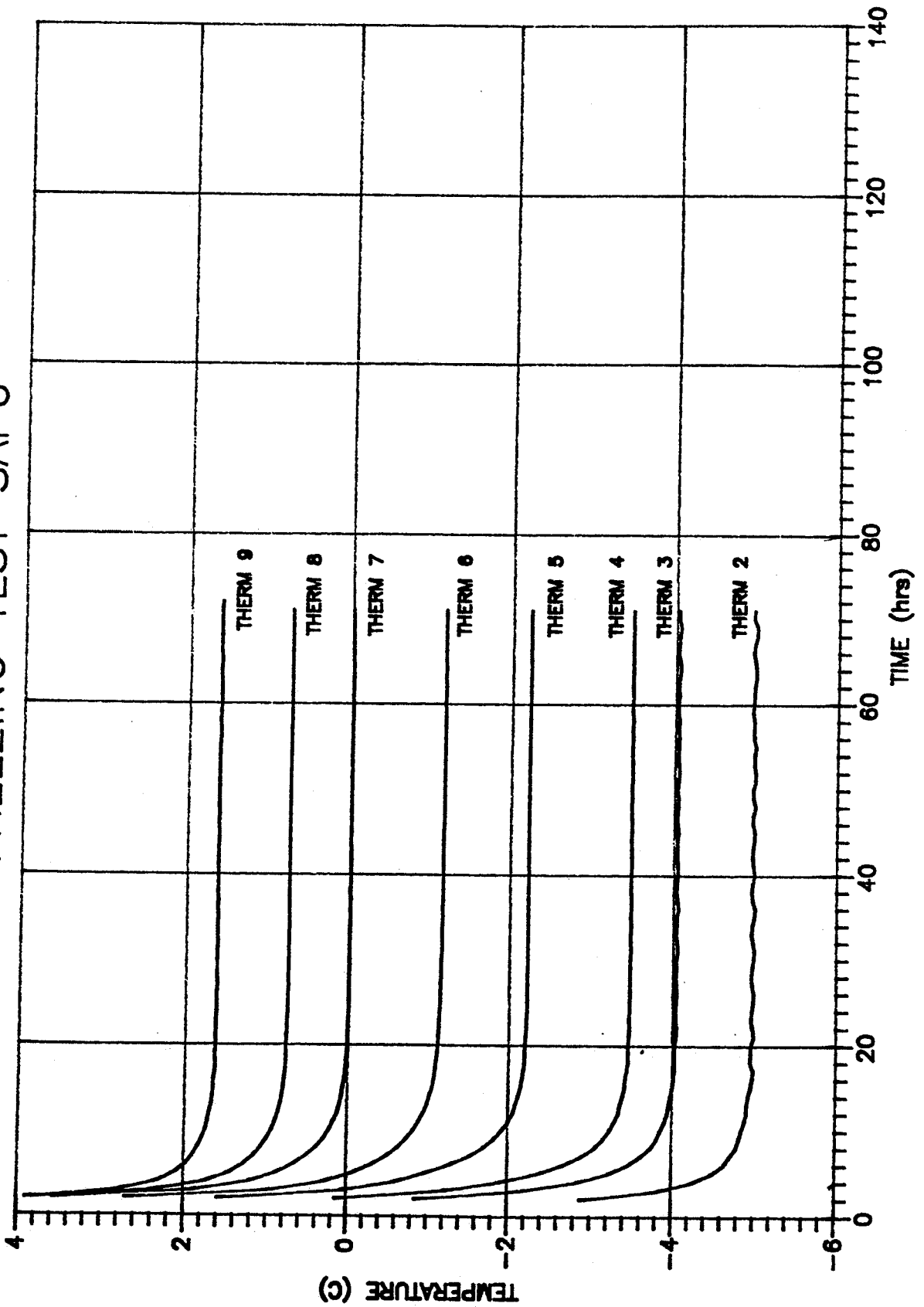
FREEZING TEST SAP6



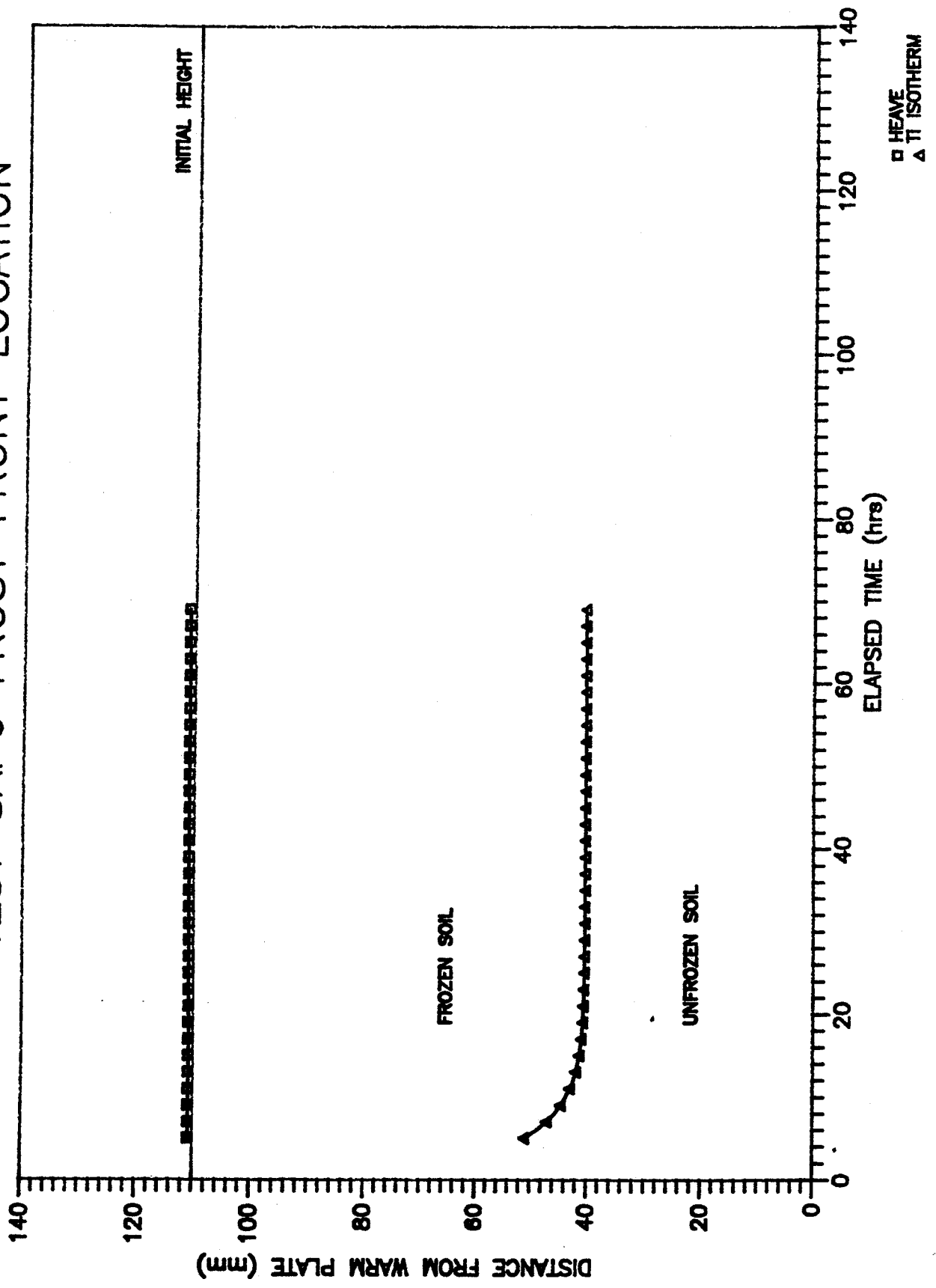
FREEZING TEST SAP6



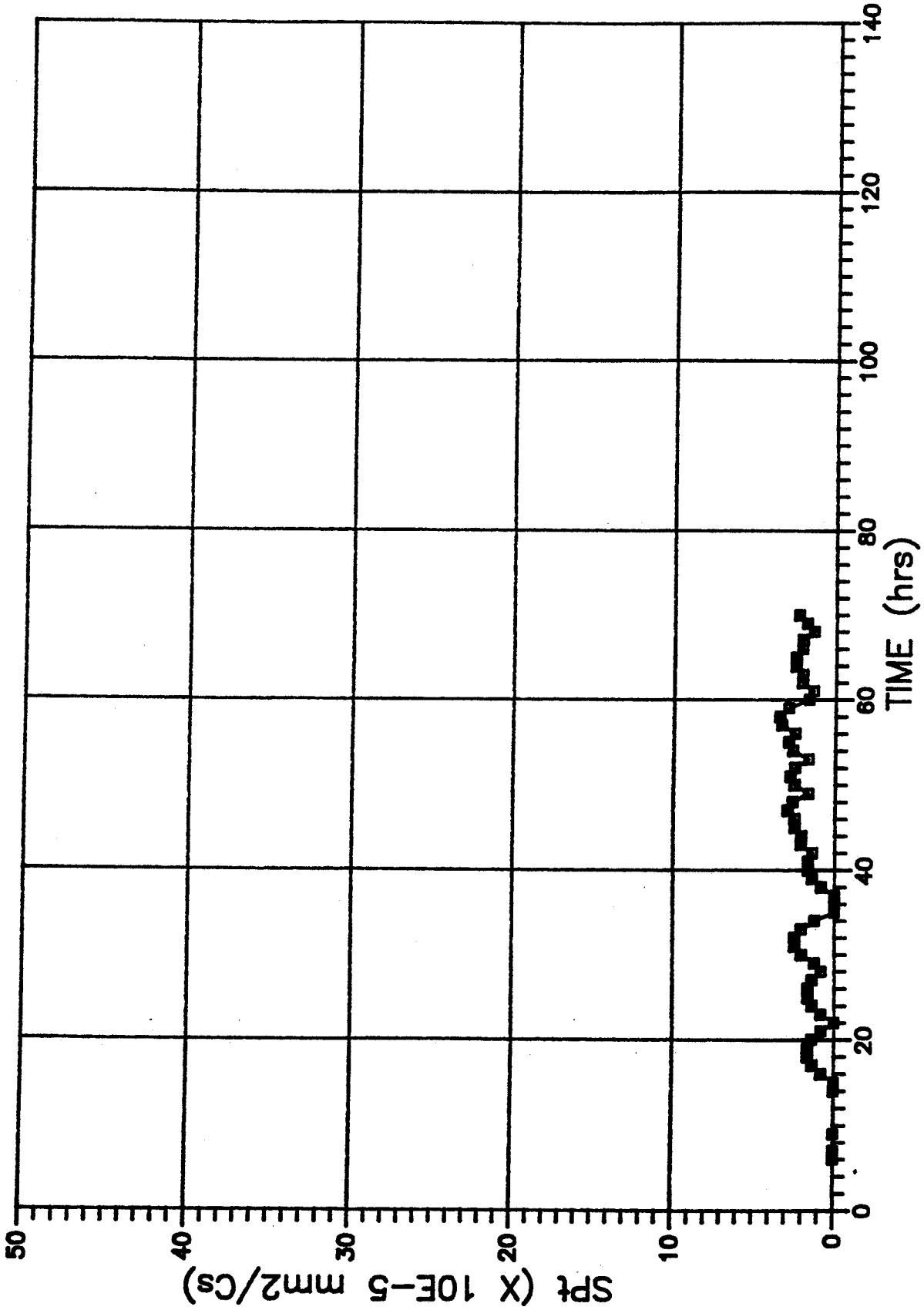
FREEZING TEST SAP6



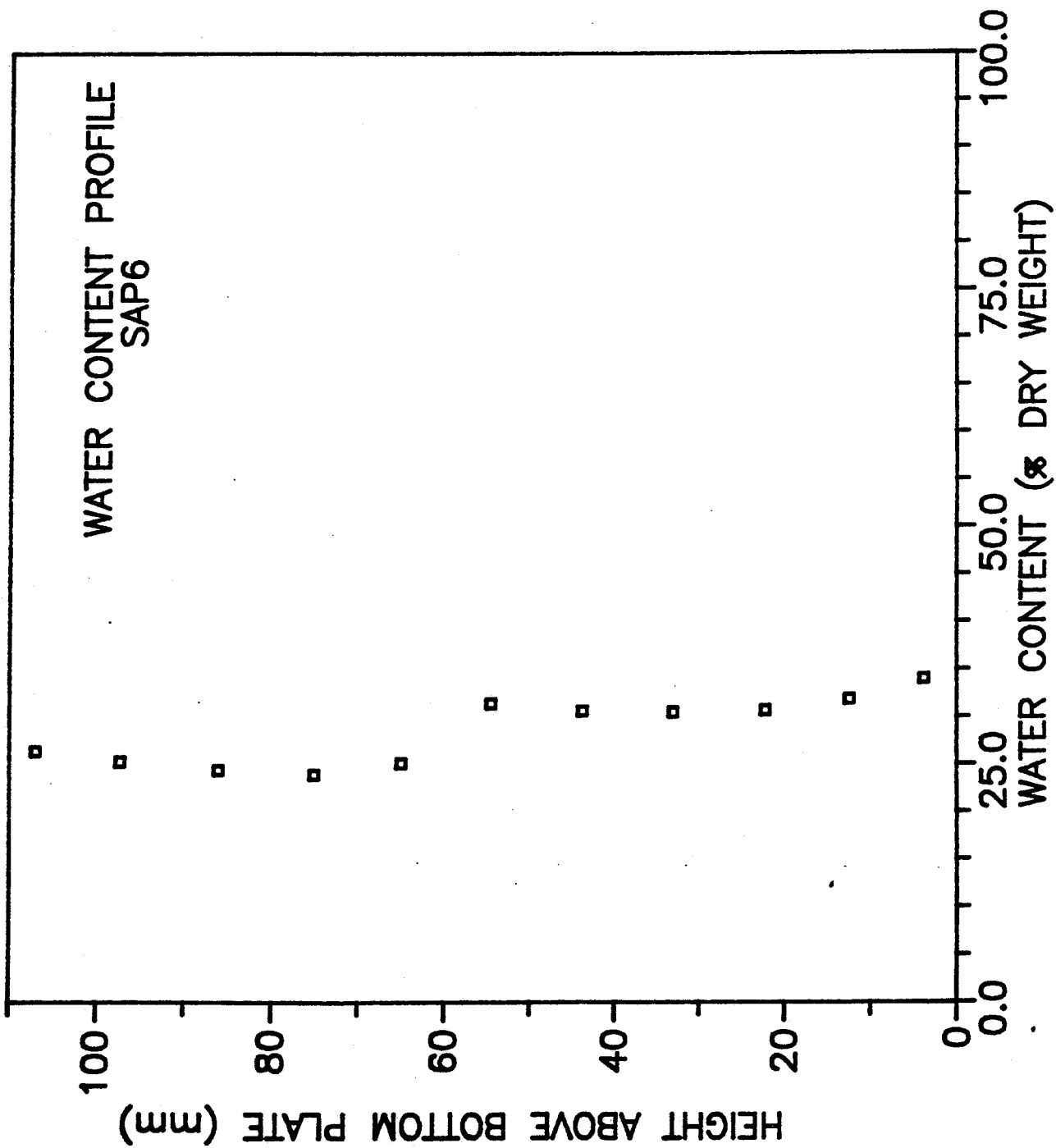
TEST SAP6 FROST FRONT LOCATION



FREEZING TEST SAP6

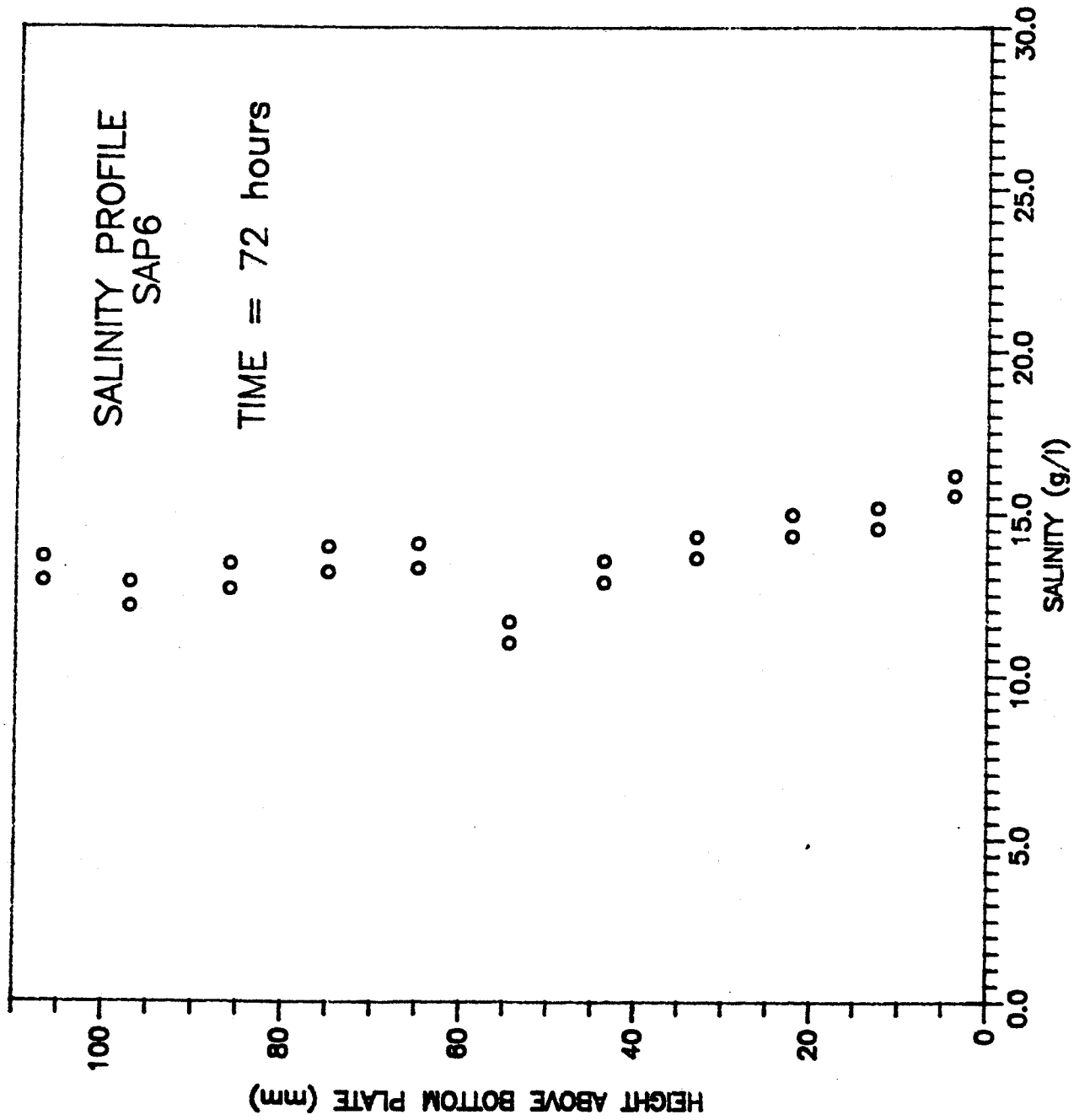


WATER CONTENT PROFILE
SAP6

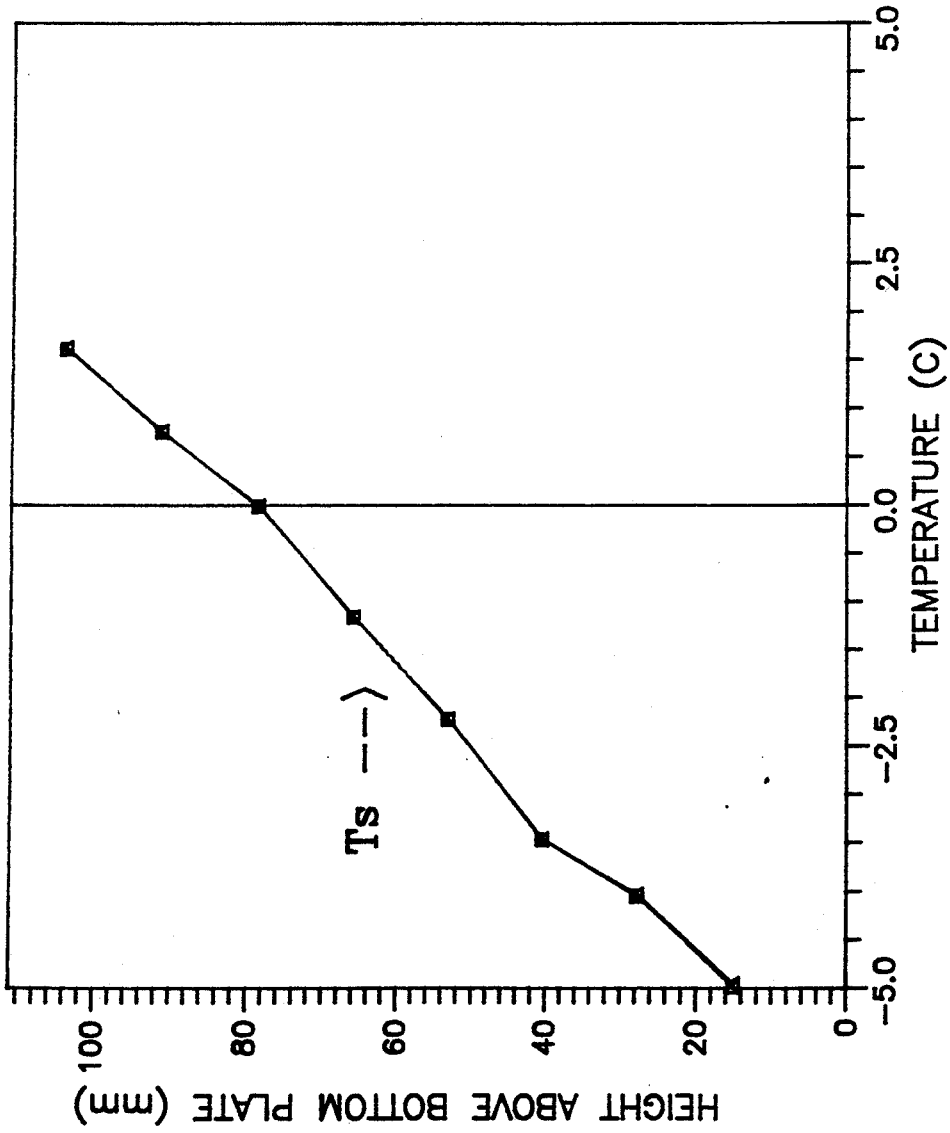
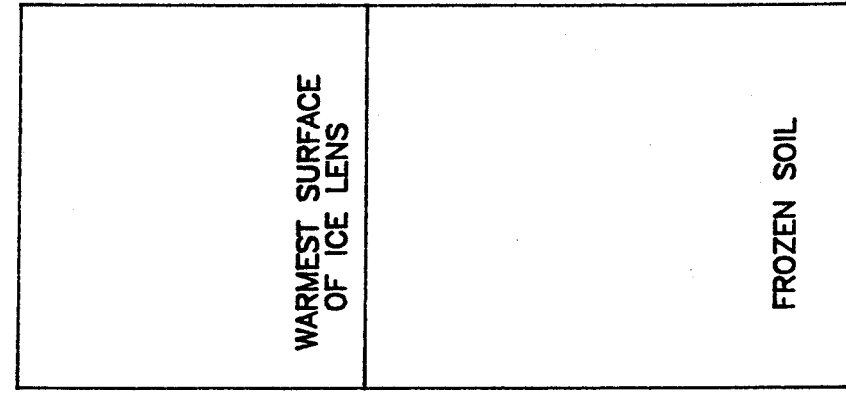


SALINITY PROFILE
SAP6

TIME = 72 hours

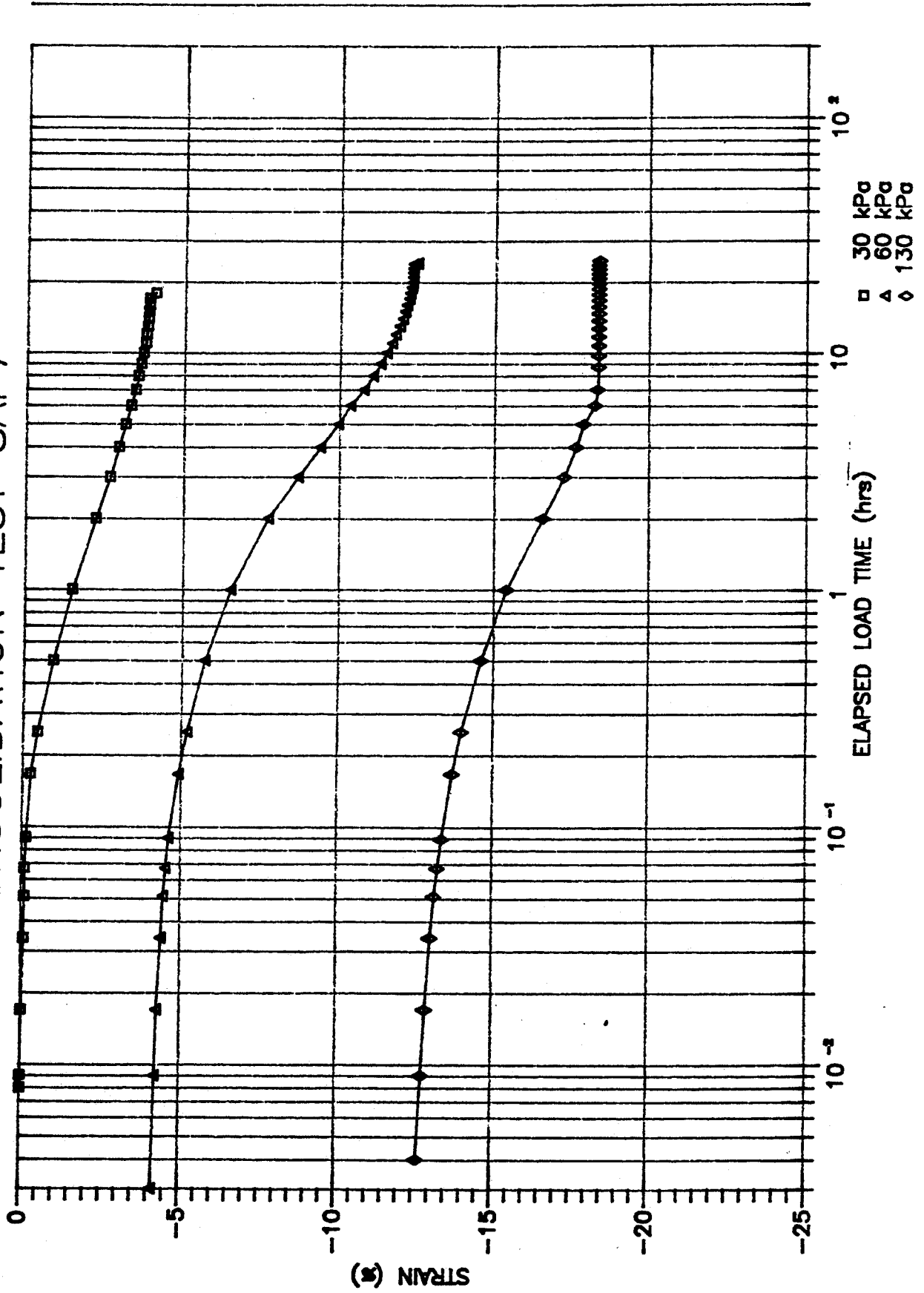


OBSERVED POSITION OF ICE LENS

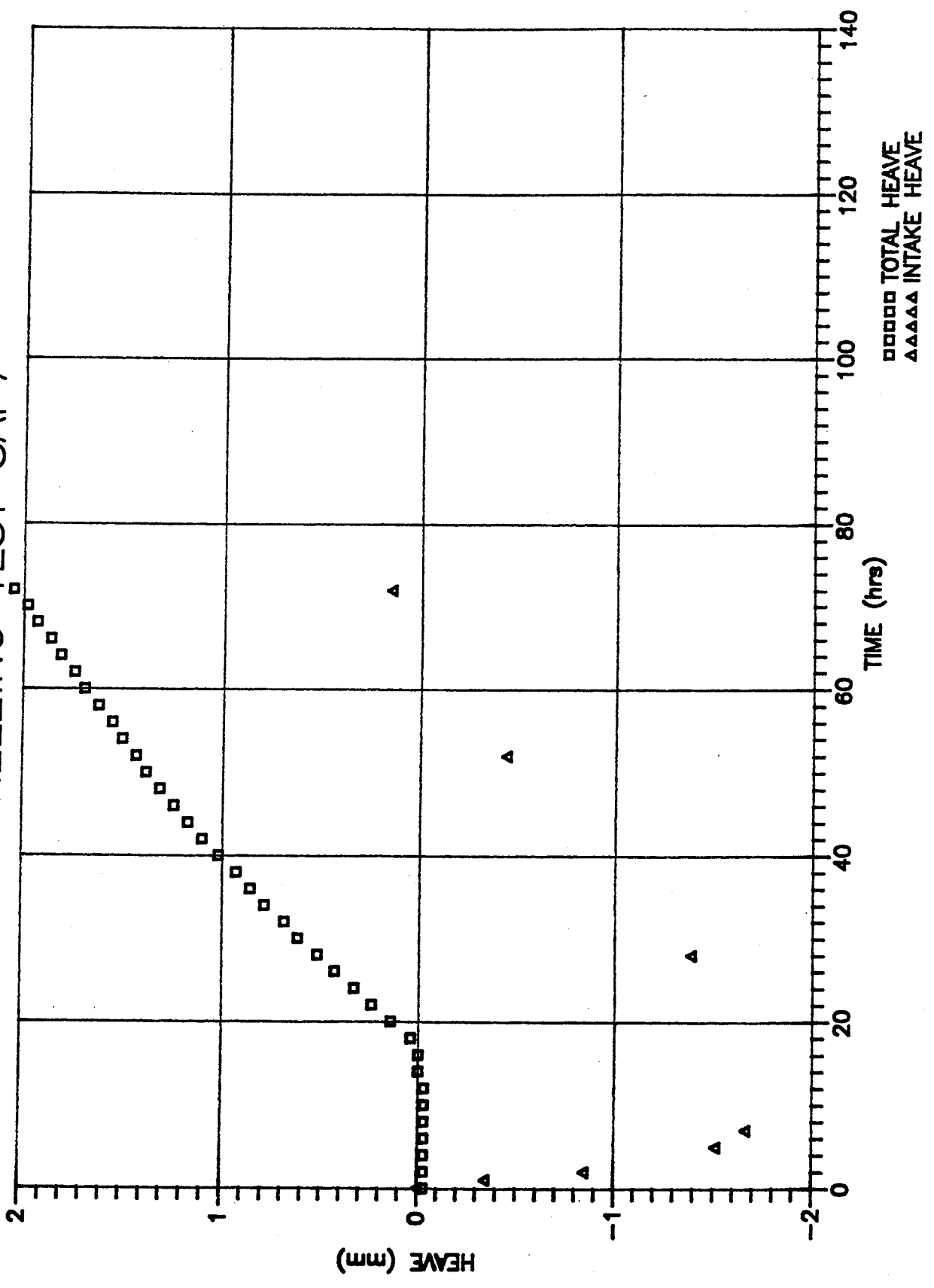


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP6

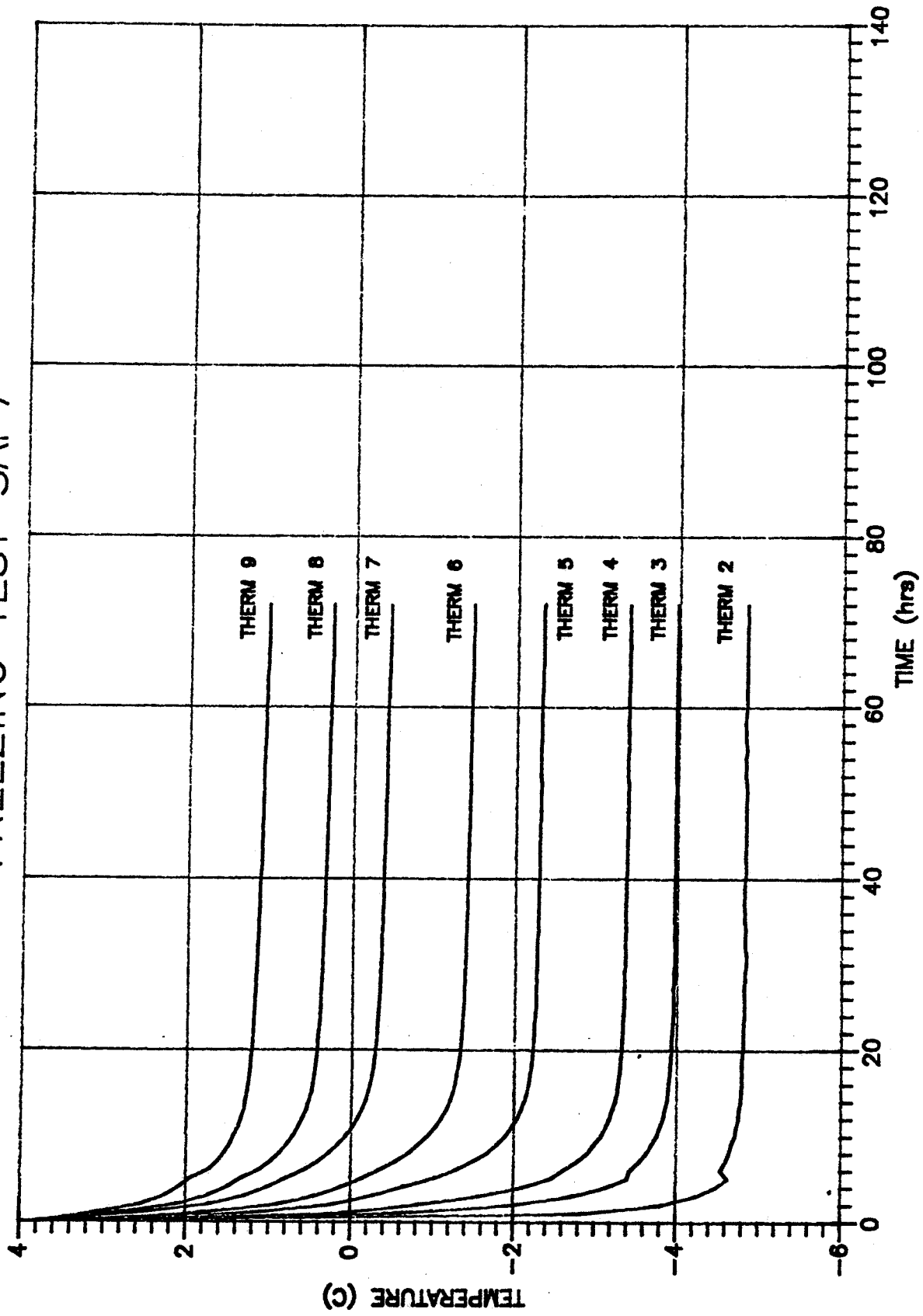
CONSOLIDATION TEST SAP7



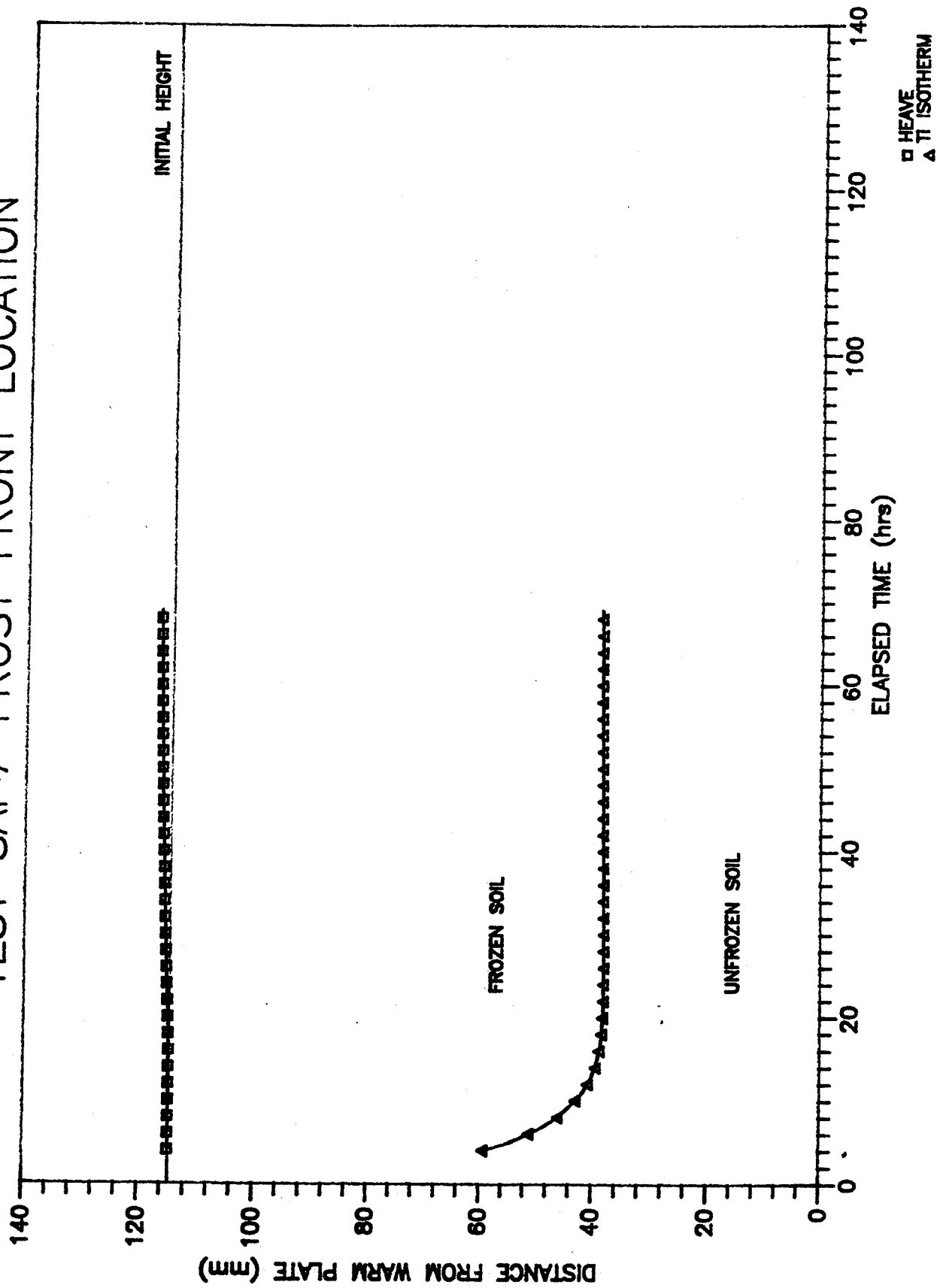
FREEZING TEST SAP7



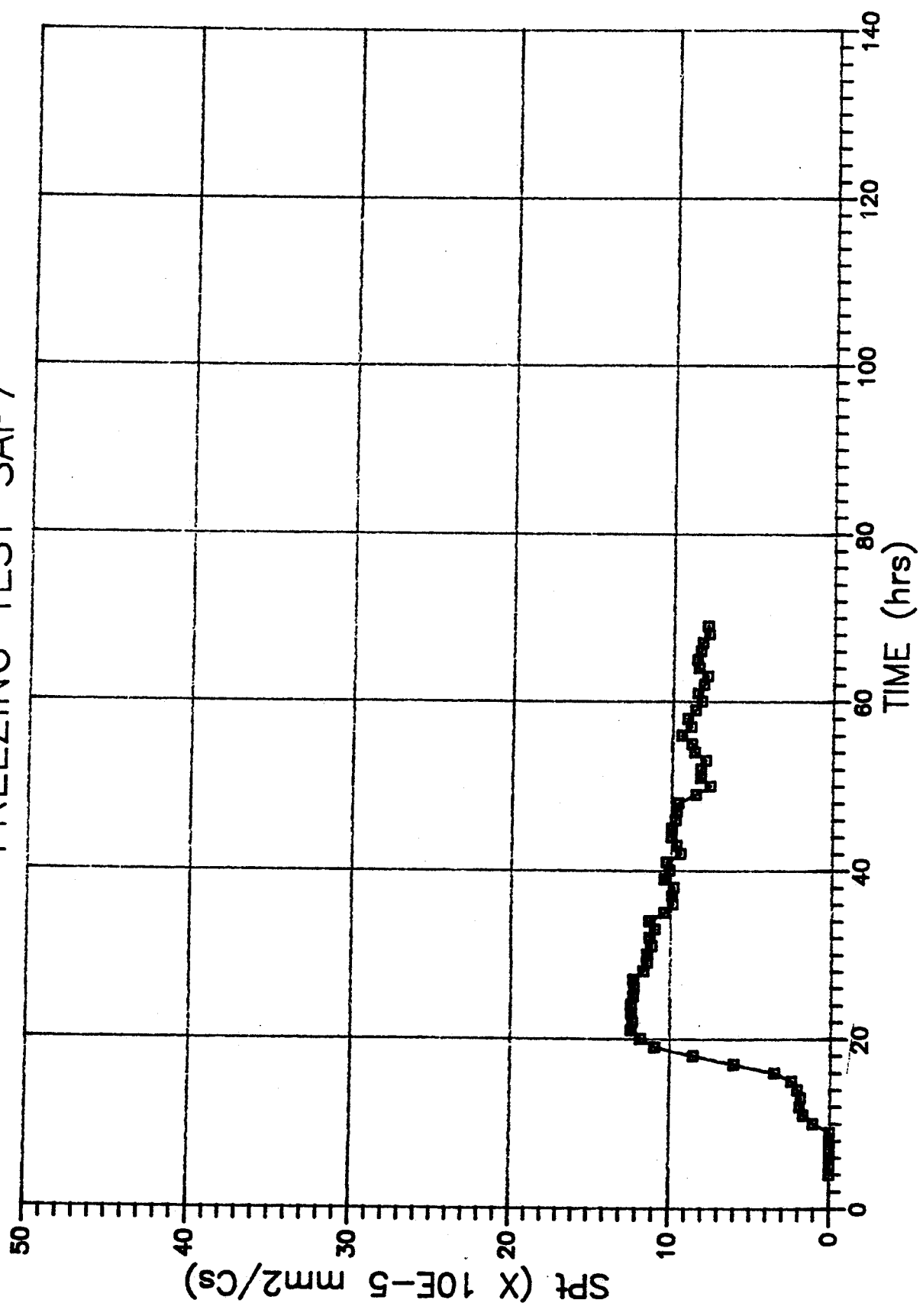
FREEZING TEST SAP7



TEST SAP7 FROST FRONT LOCATION



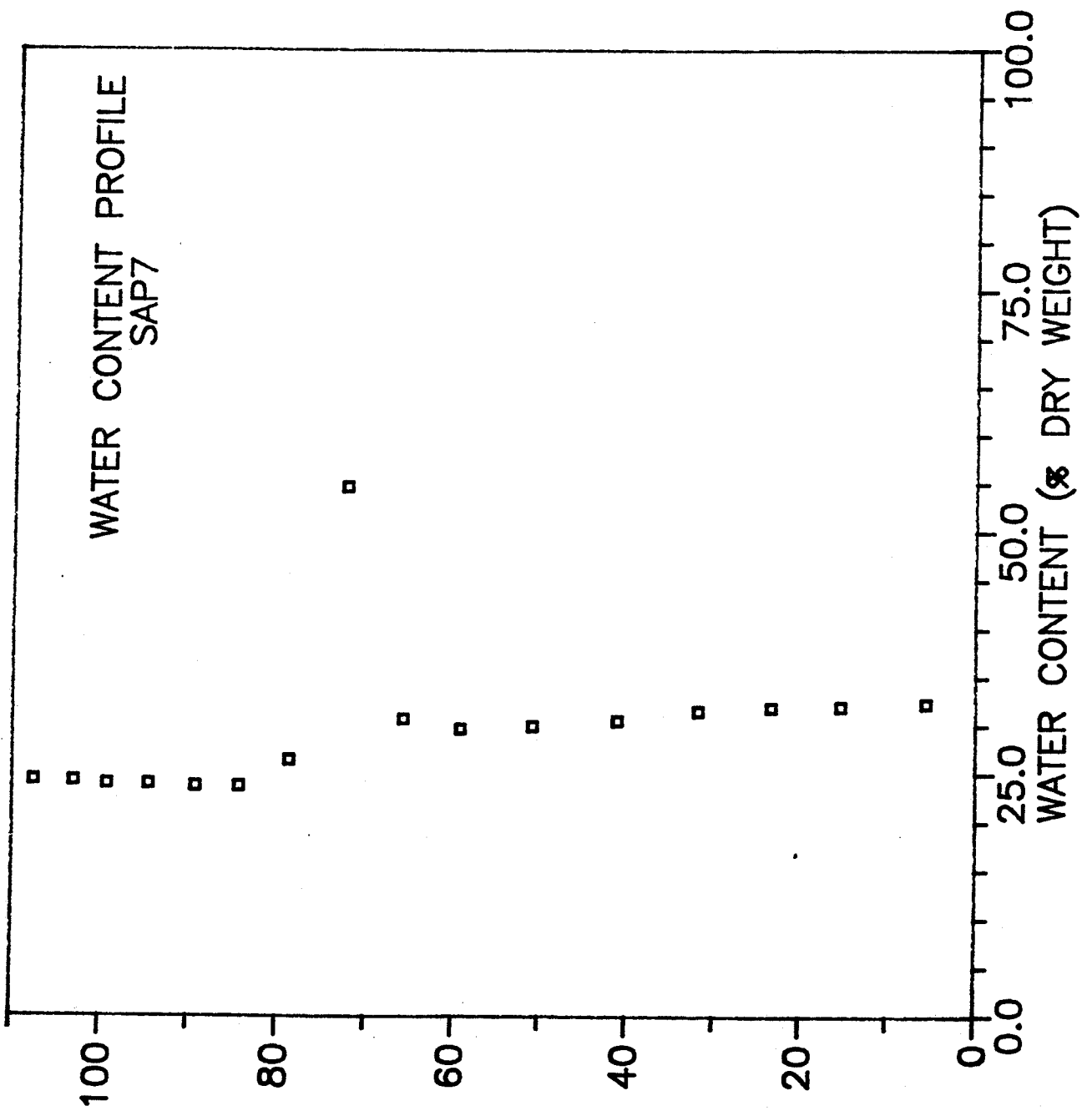
FREEZING TEST SAP7



WATER CONTENT PROFILE
SAP7

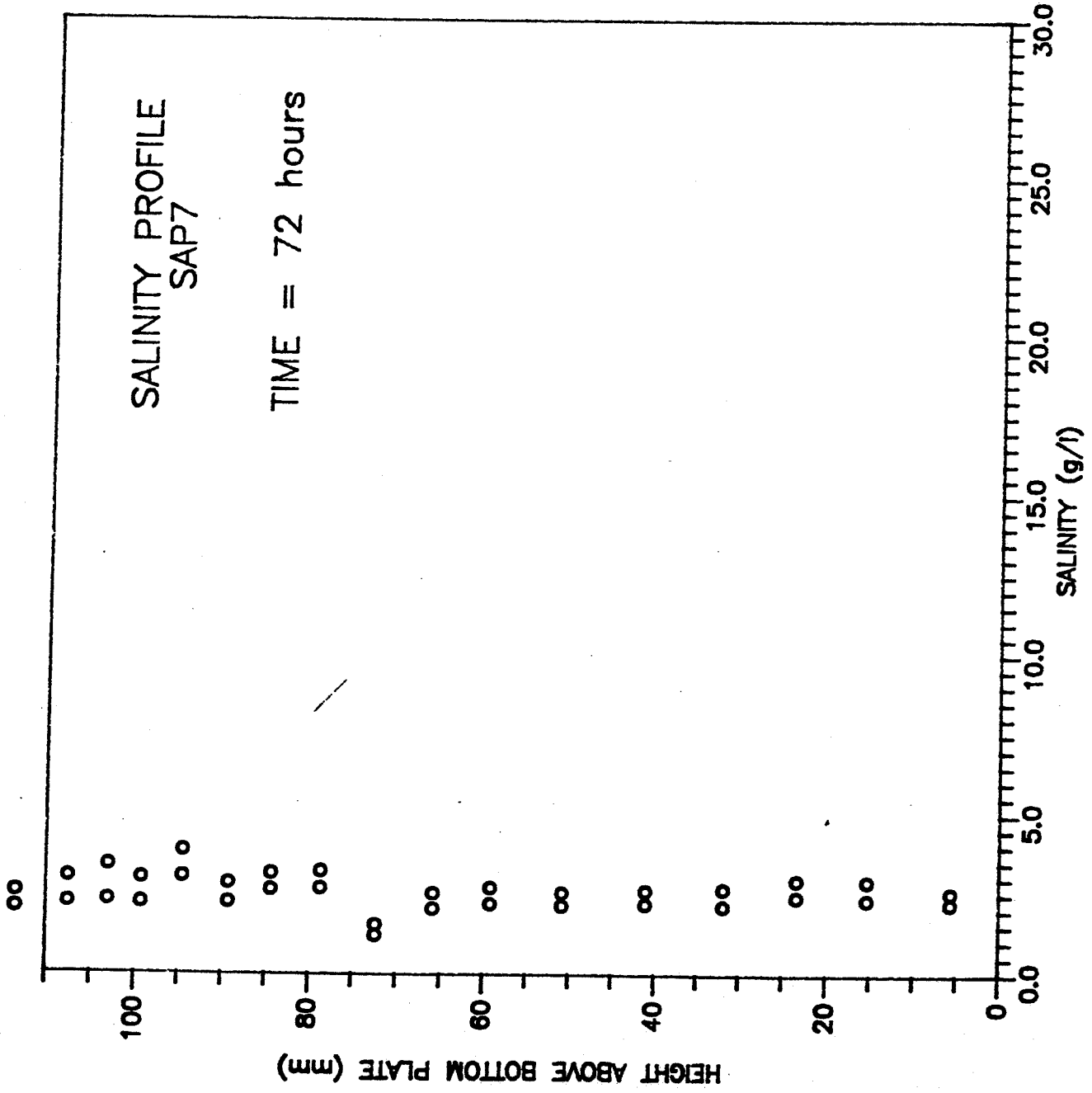
HEIGHT ABOVE BOTTOM PLATE (mm)

WATER CONTENT (% DRY WEIGHT)

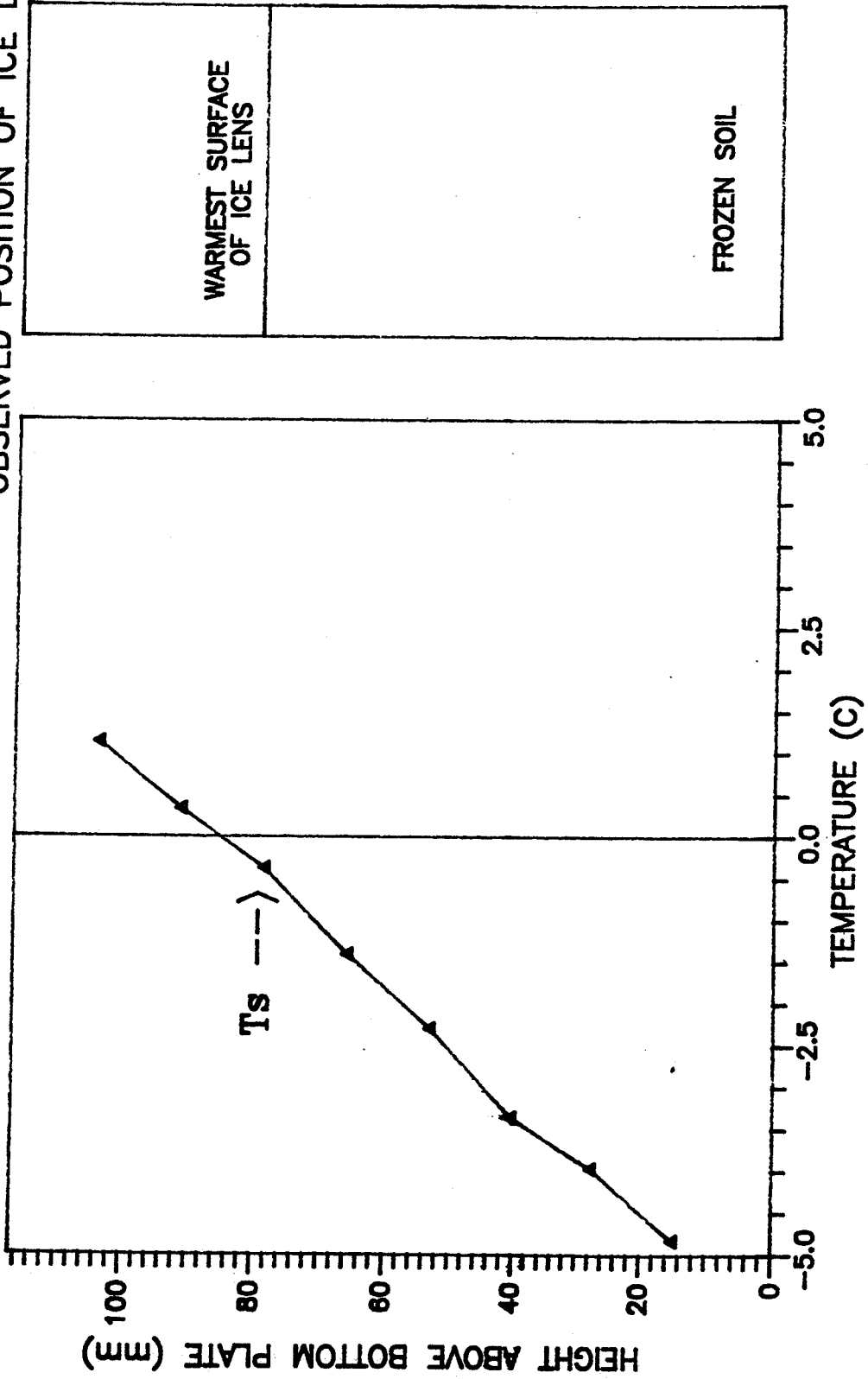


SALINITY PROFILE
SAP7

TIME = 72 hours

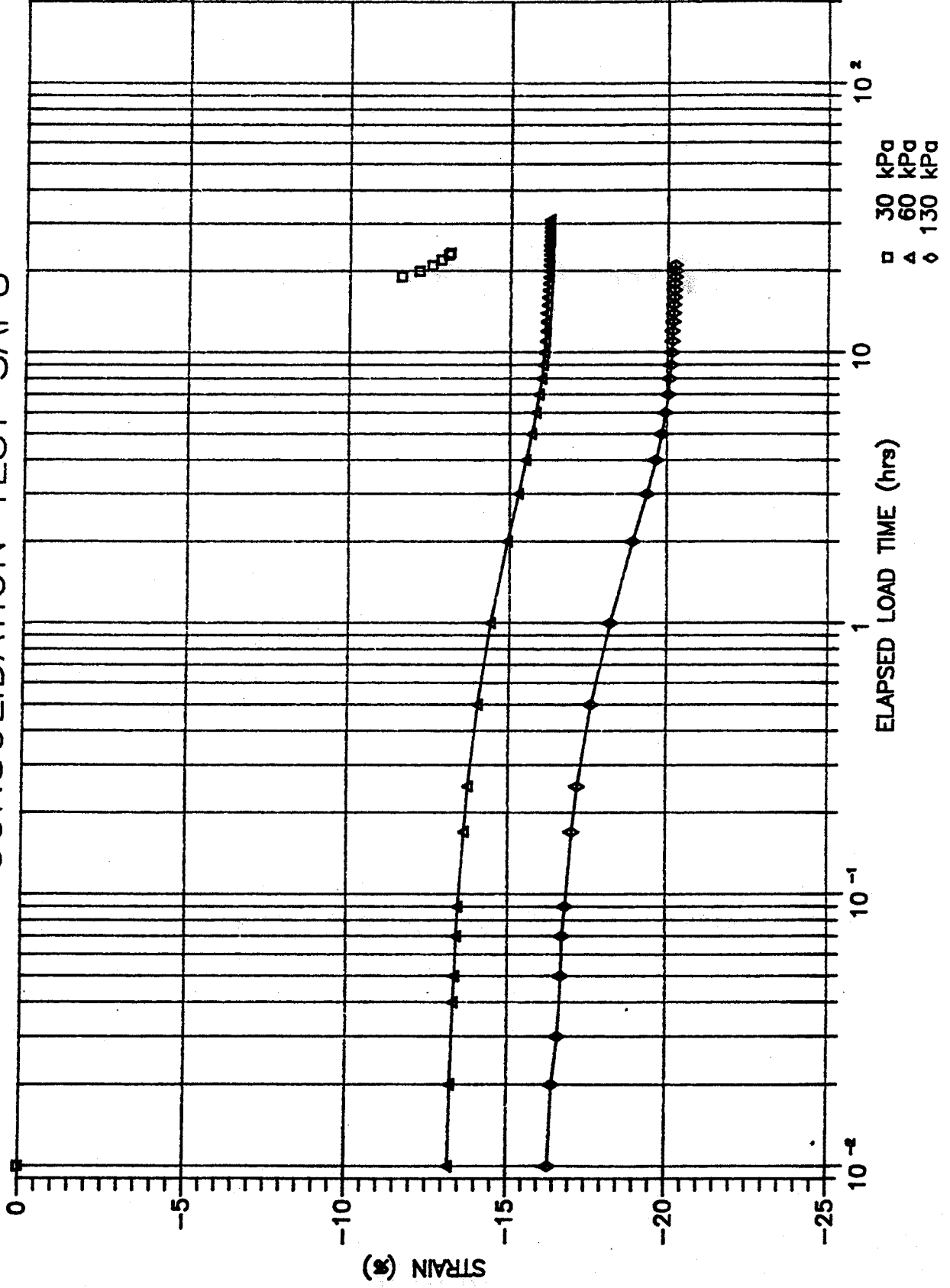


OBSERVED POSITION OF ICE LENS

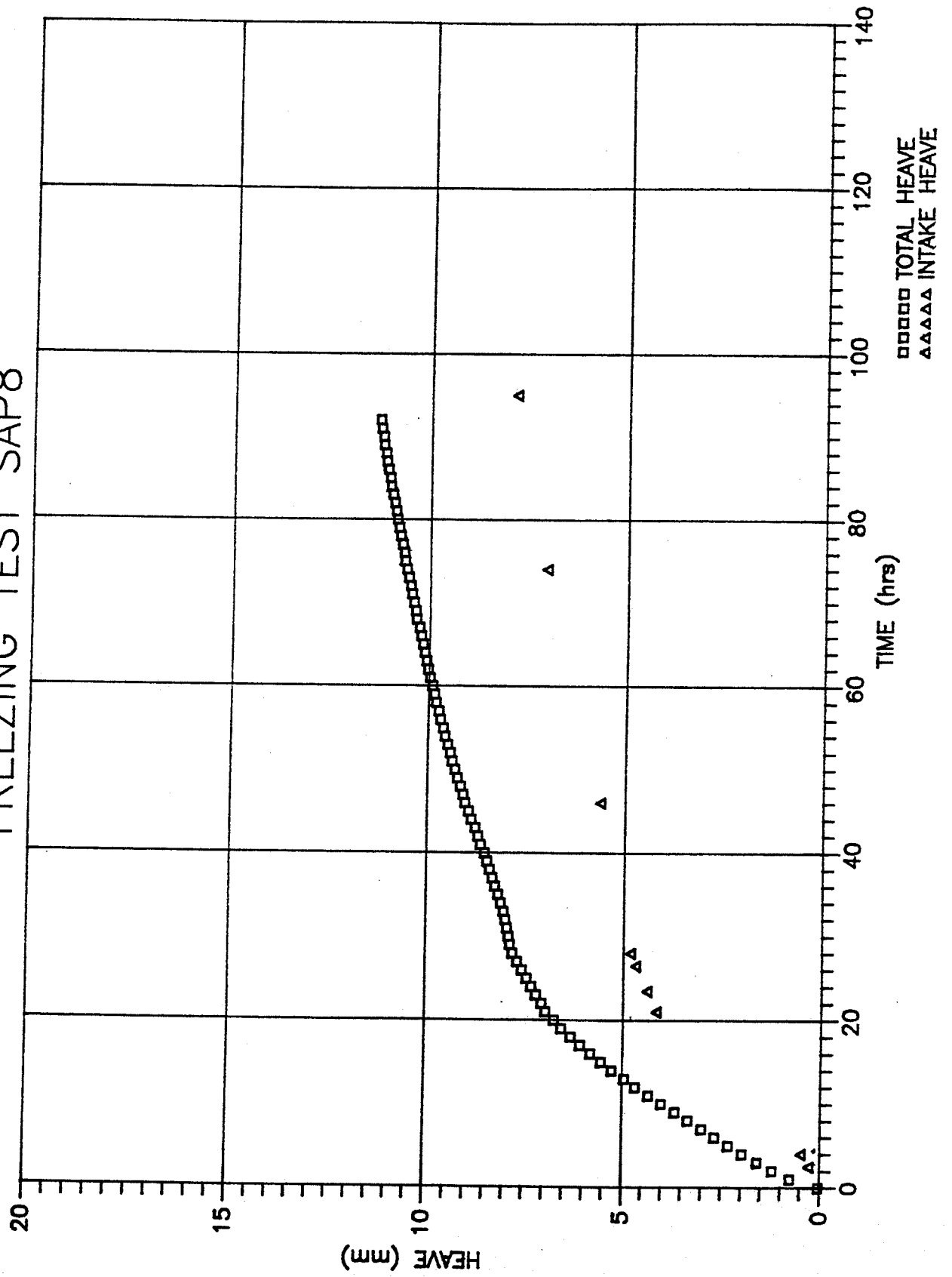


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP7

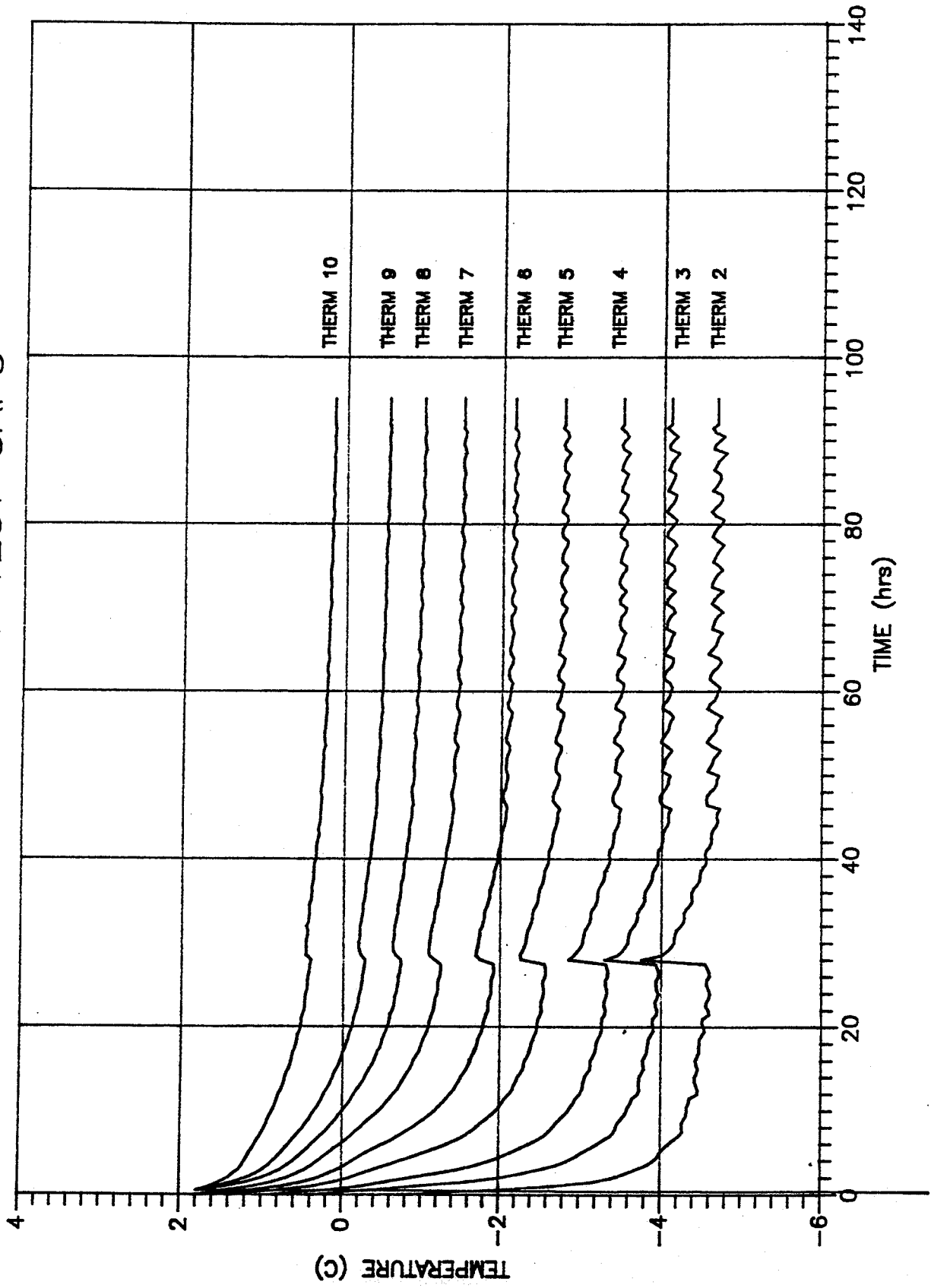
CONSOLIDATION TEST SAP8



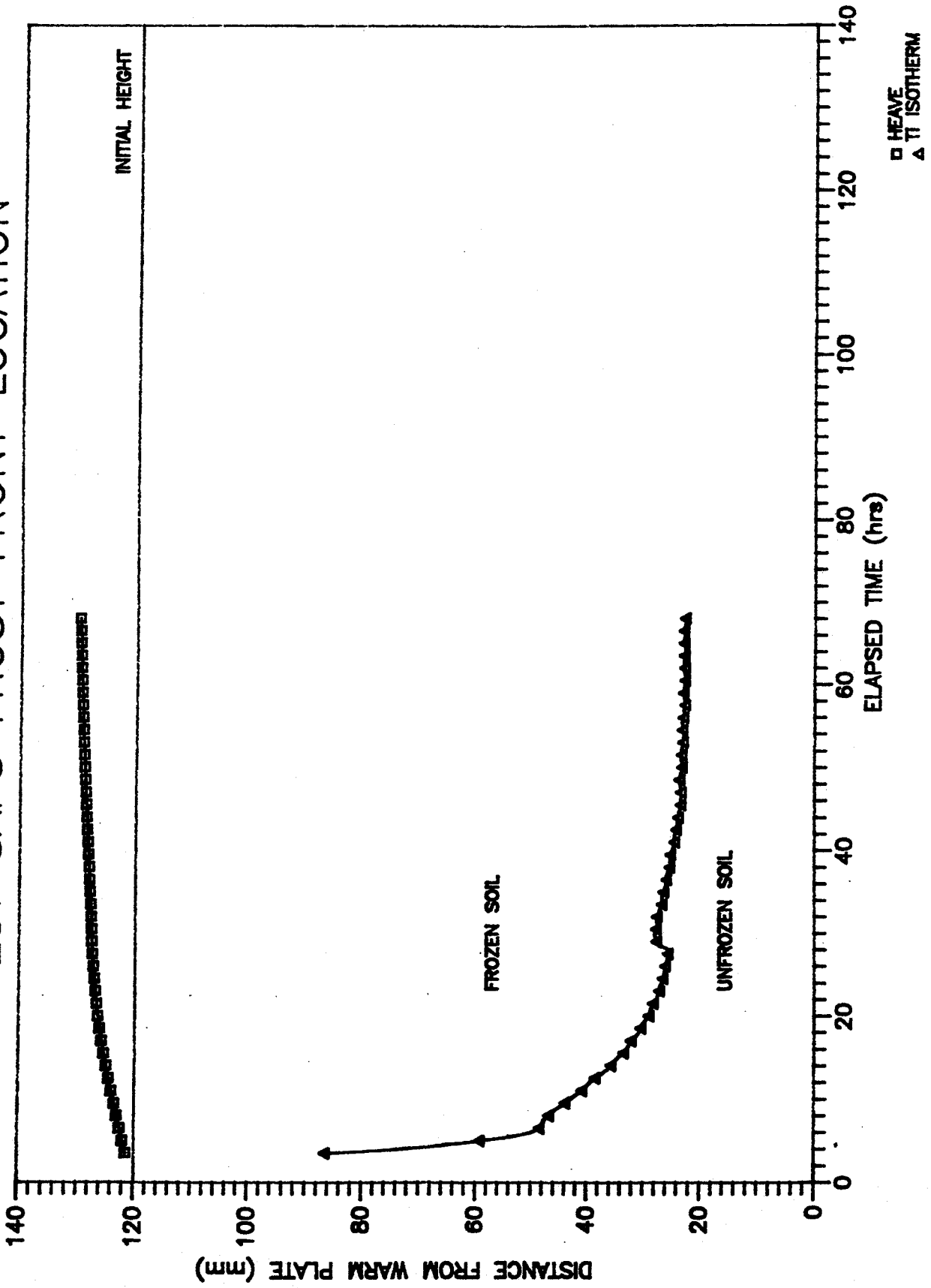
FREEZING TEST SAP8



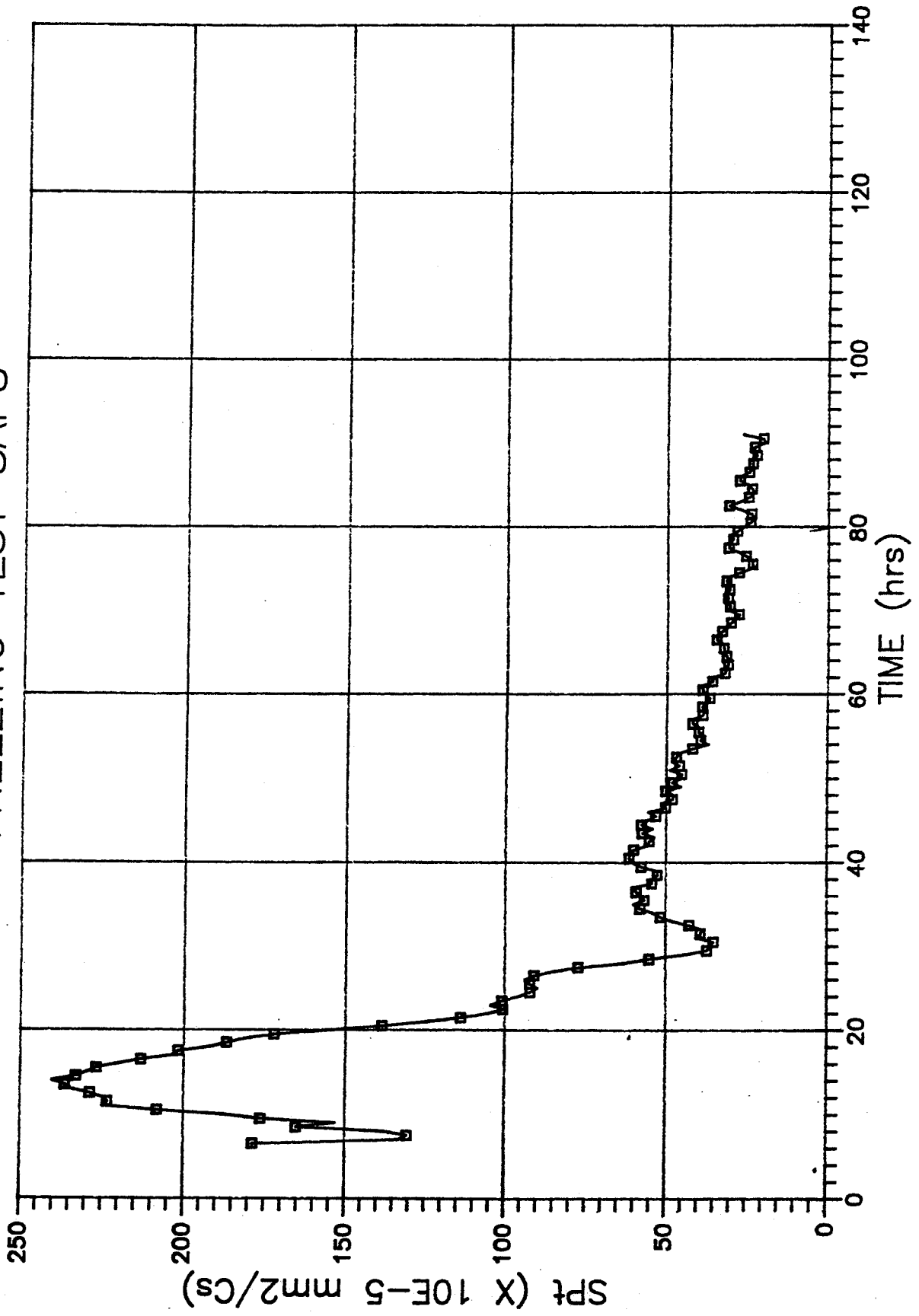
FREEZING TEST SAP8

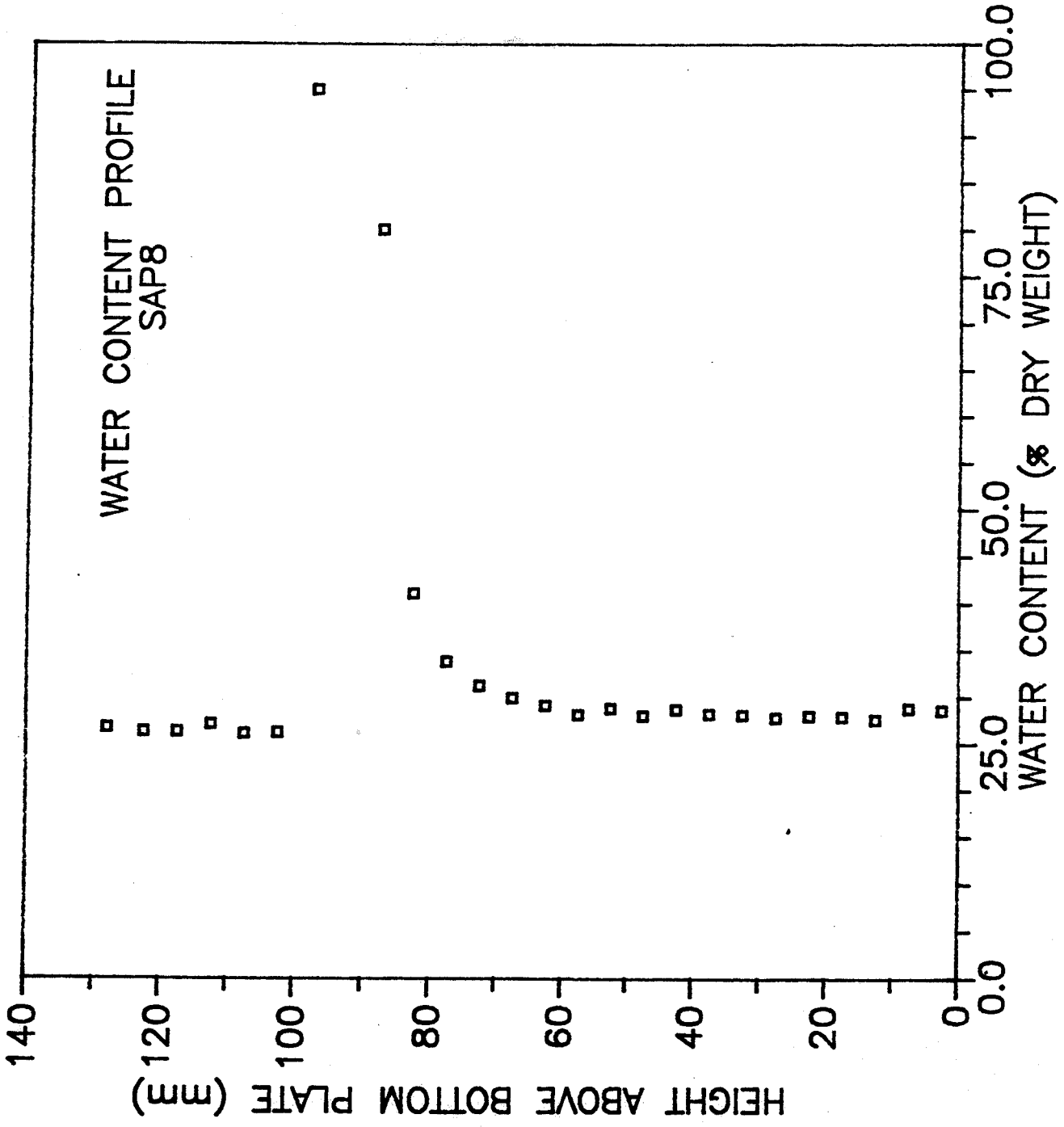


TEST SAP8 FROST FRONT LOCATION



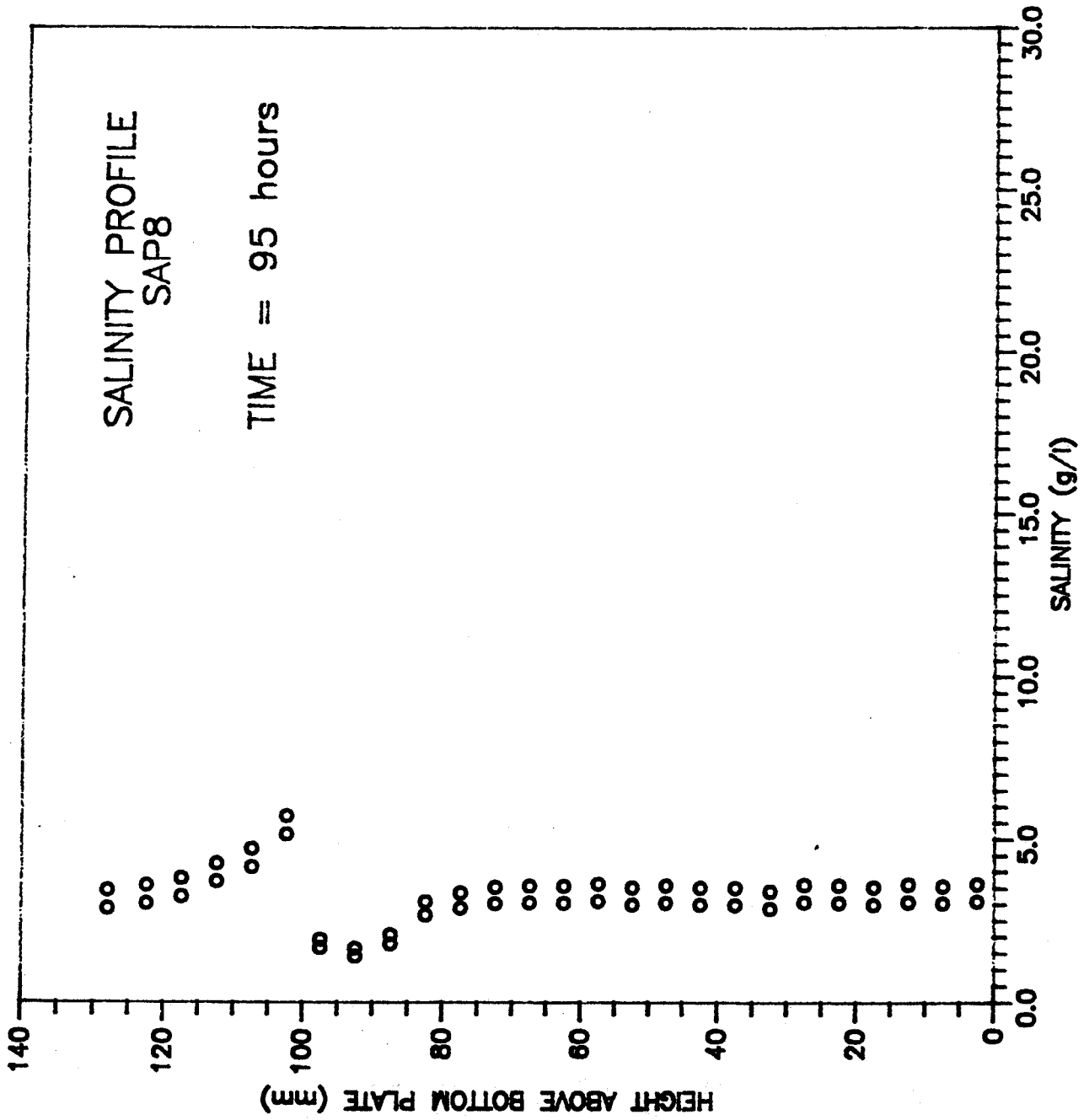
FREEZING TEST SAP8



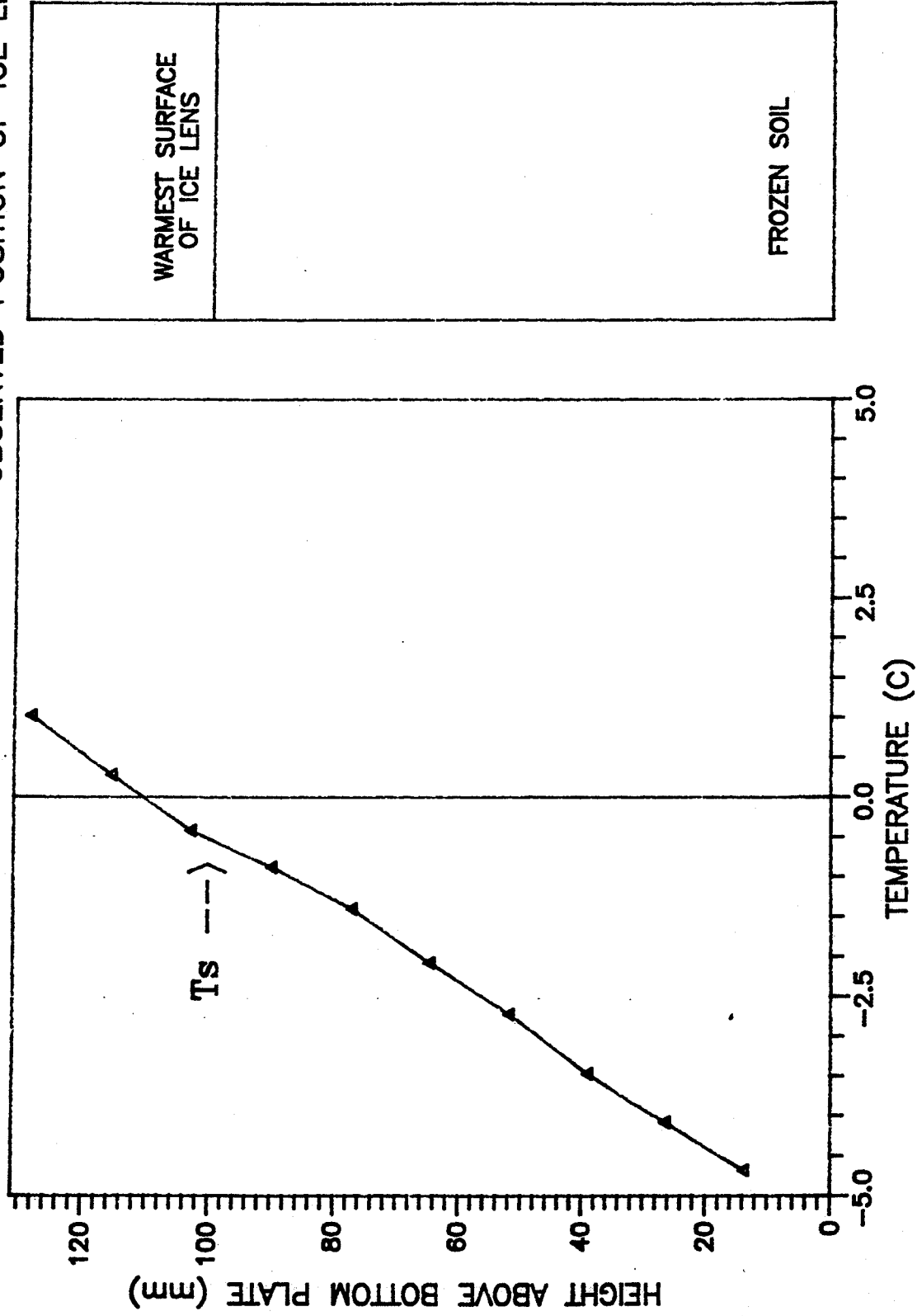


SALINITY PROFILE
SAP8

TIME = 95 hours

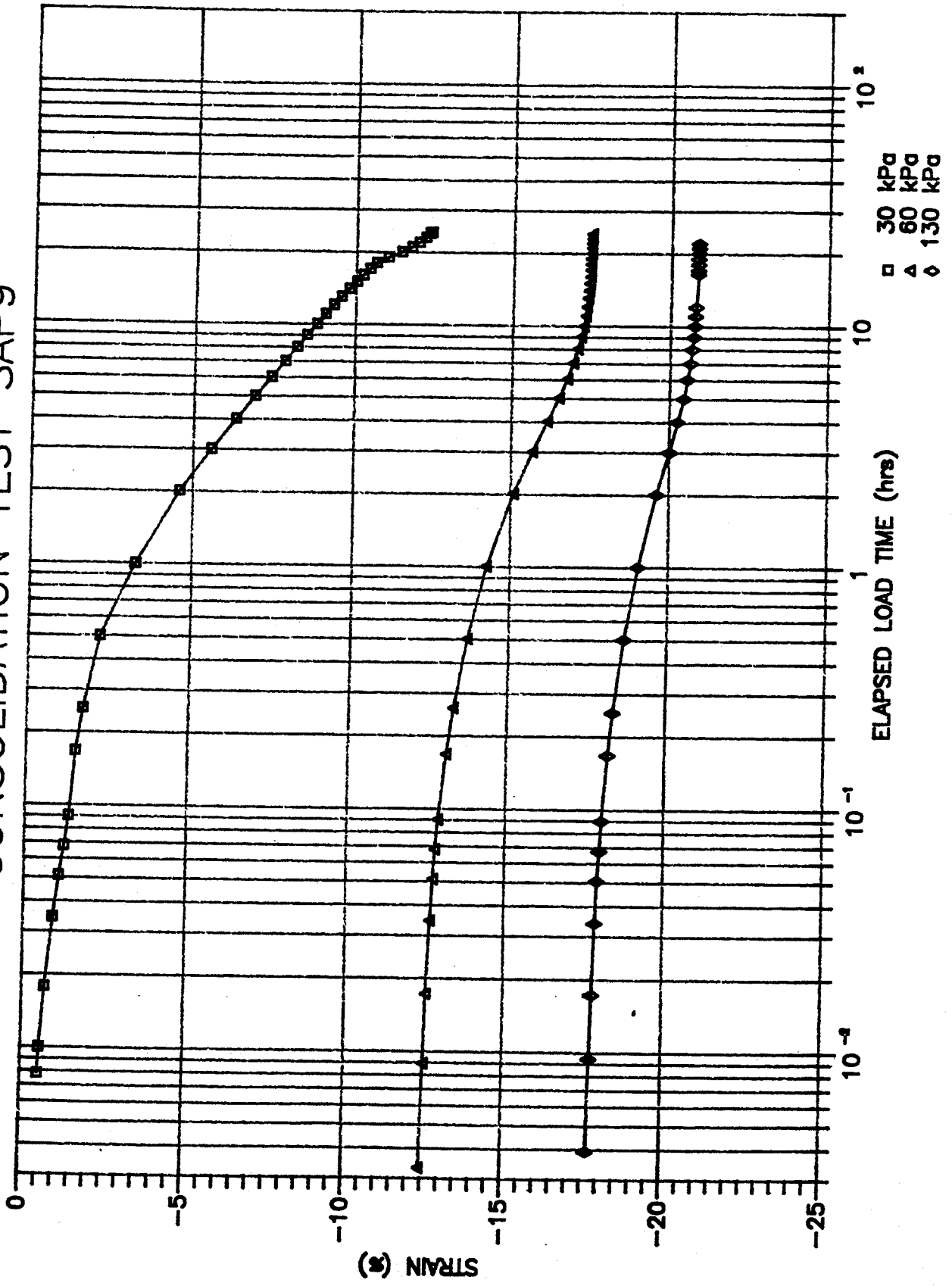


OBSERVED POSITION OF ICE LENS

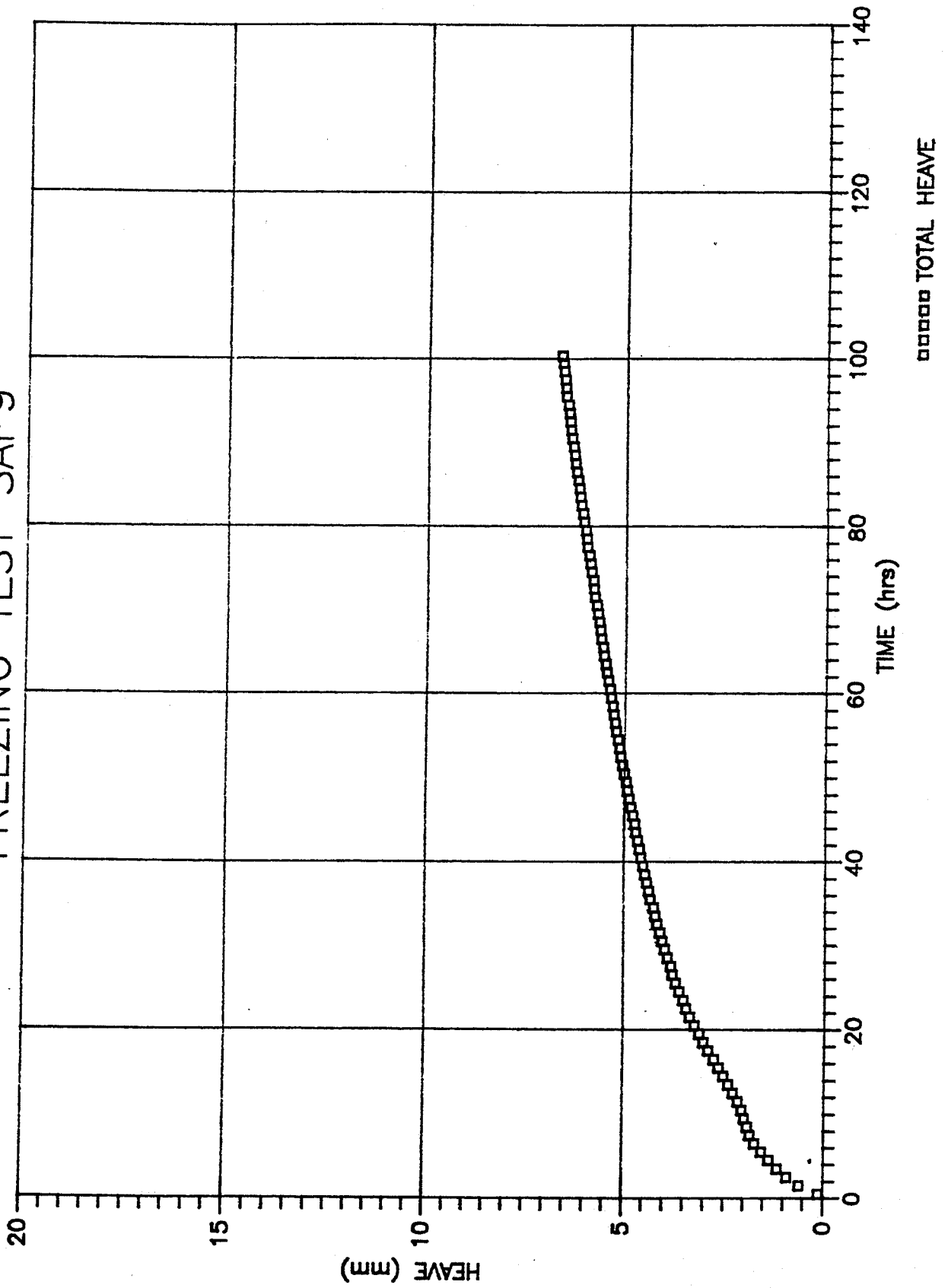


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP8

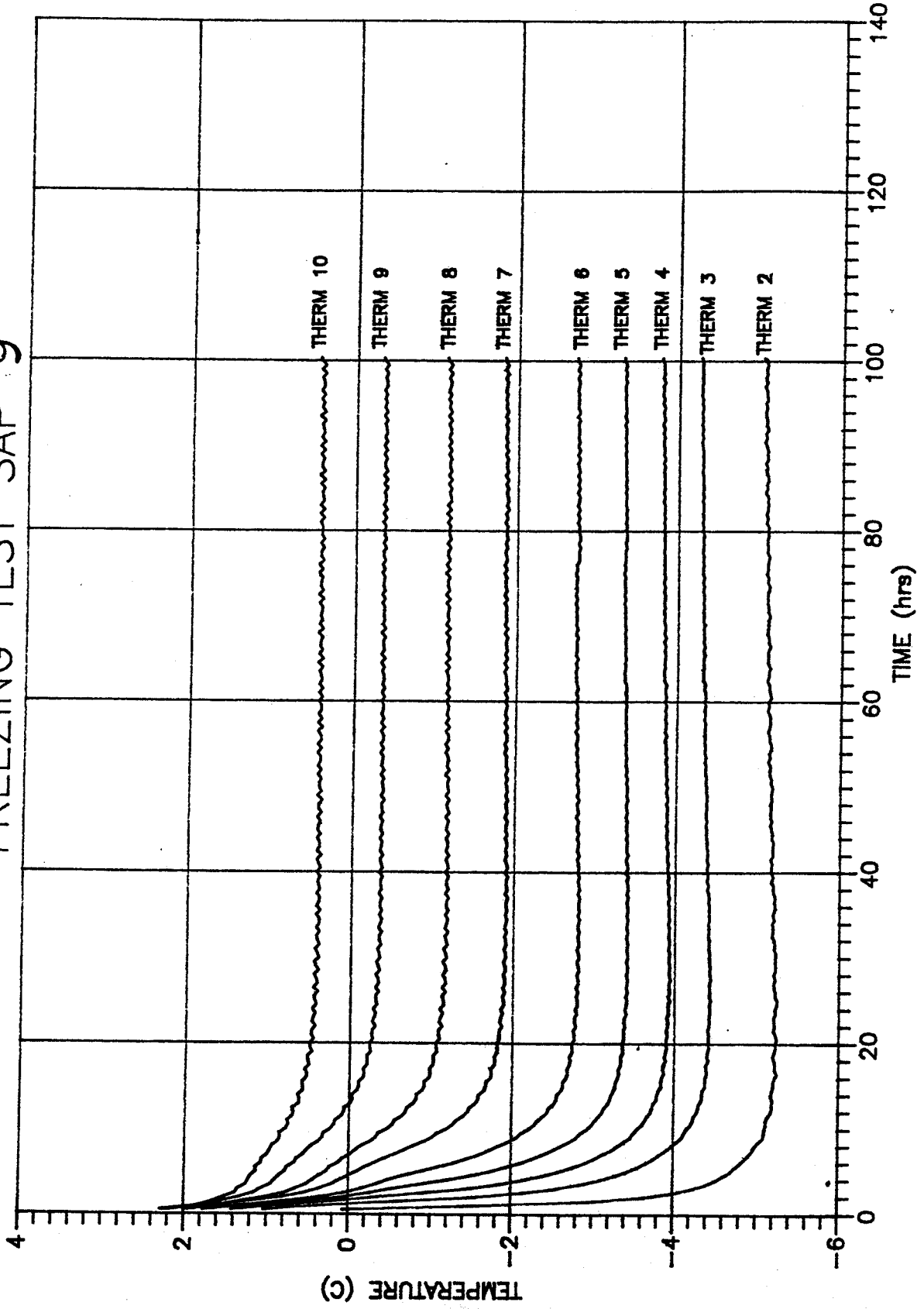
CONSOLIDATION TEST SAP9



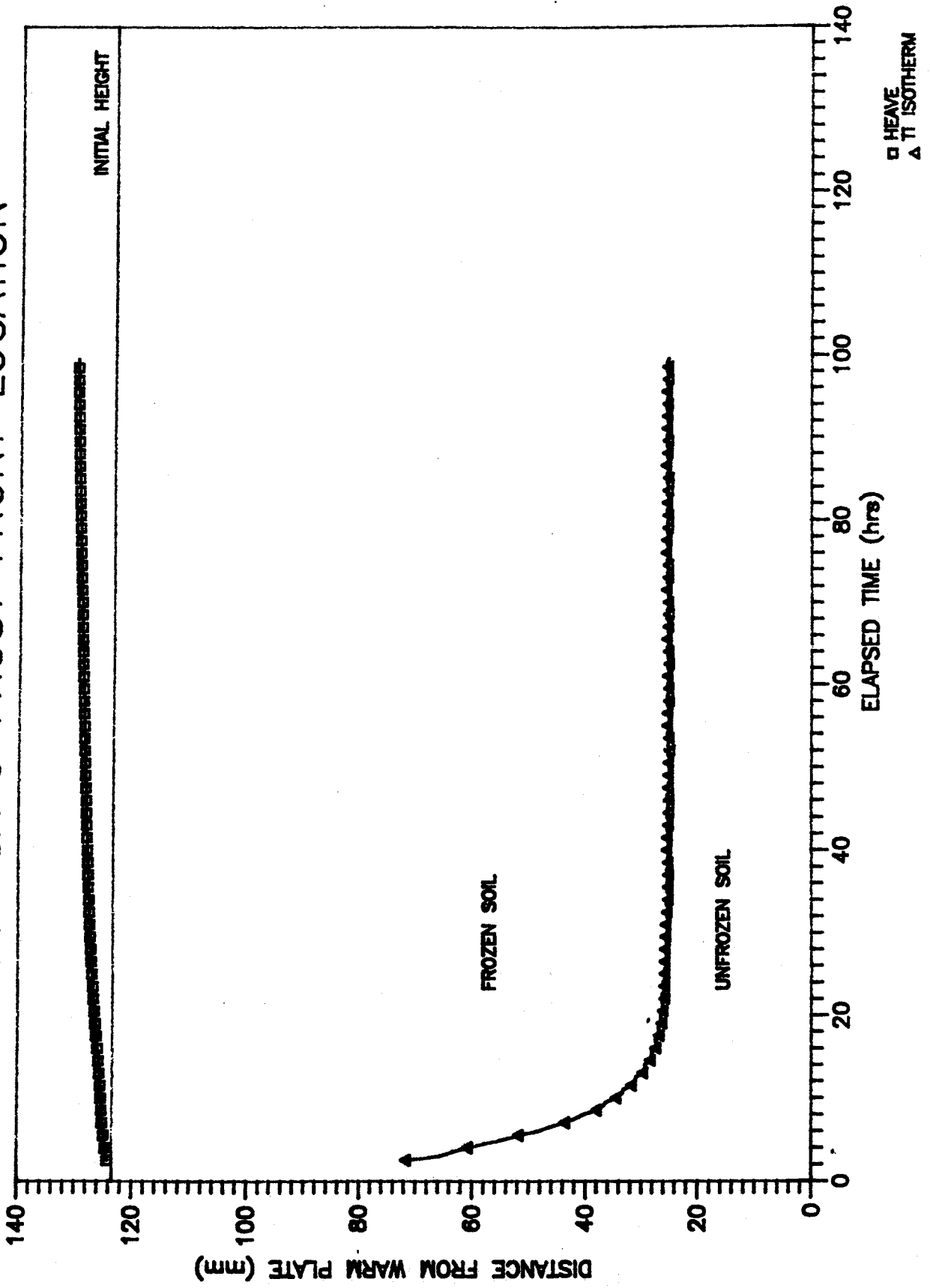
FREEZING TEST SAP9



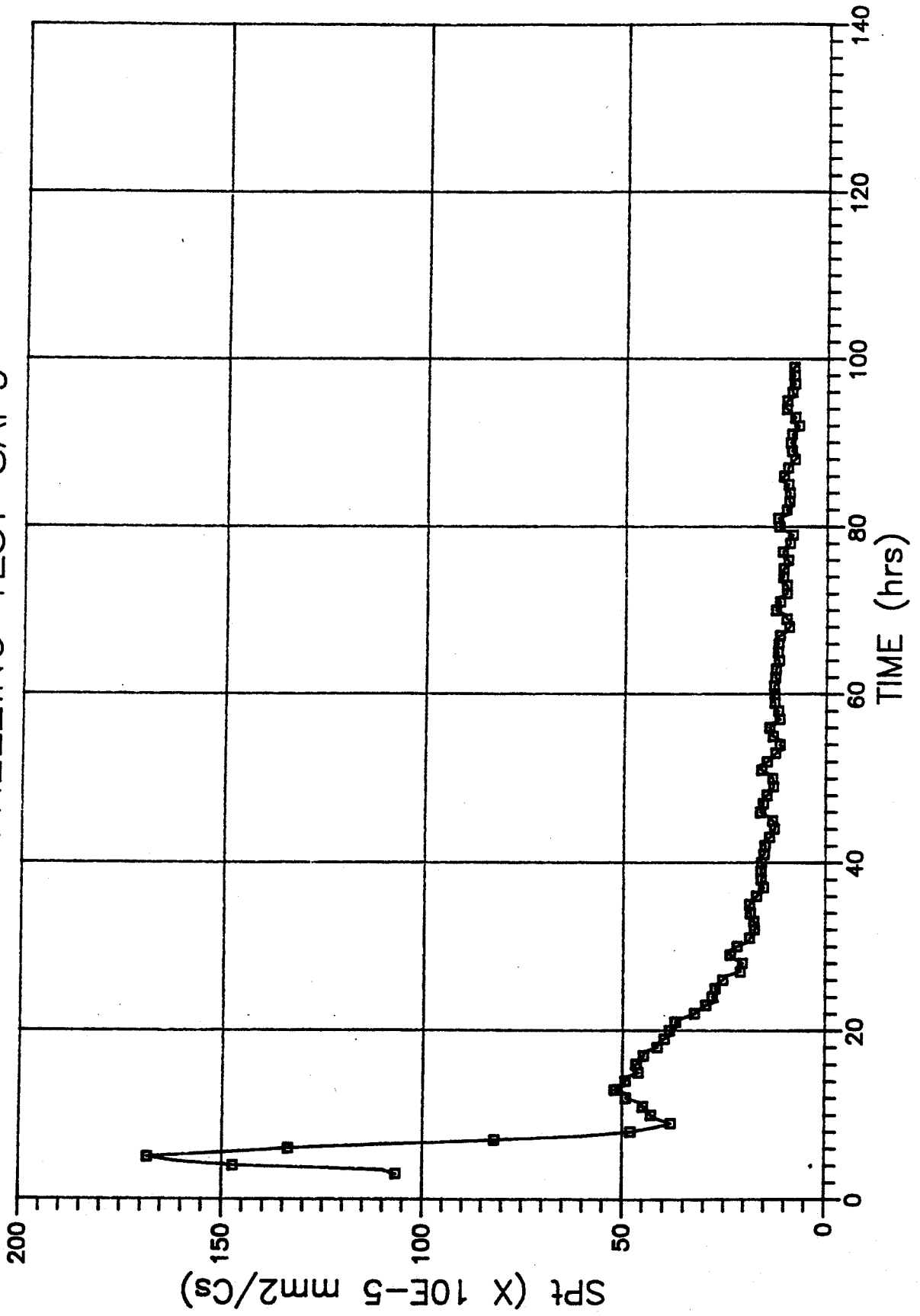
FREEZING TEST SAP 9



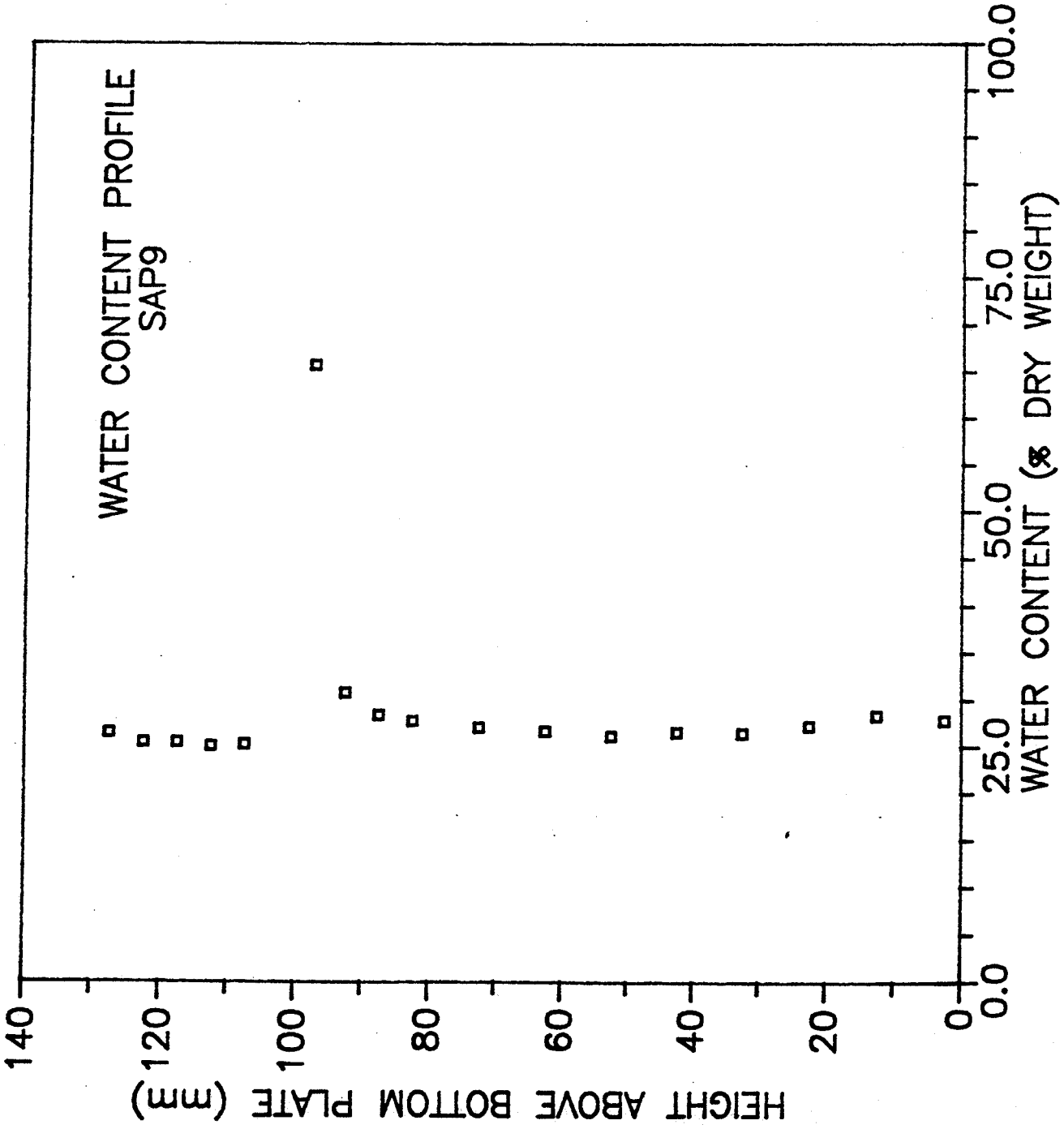
TEST SAP9 FROST FRONT LOCATION



FREEZING TEST SAP9

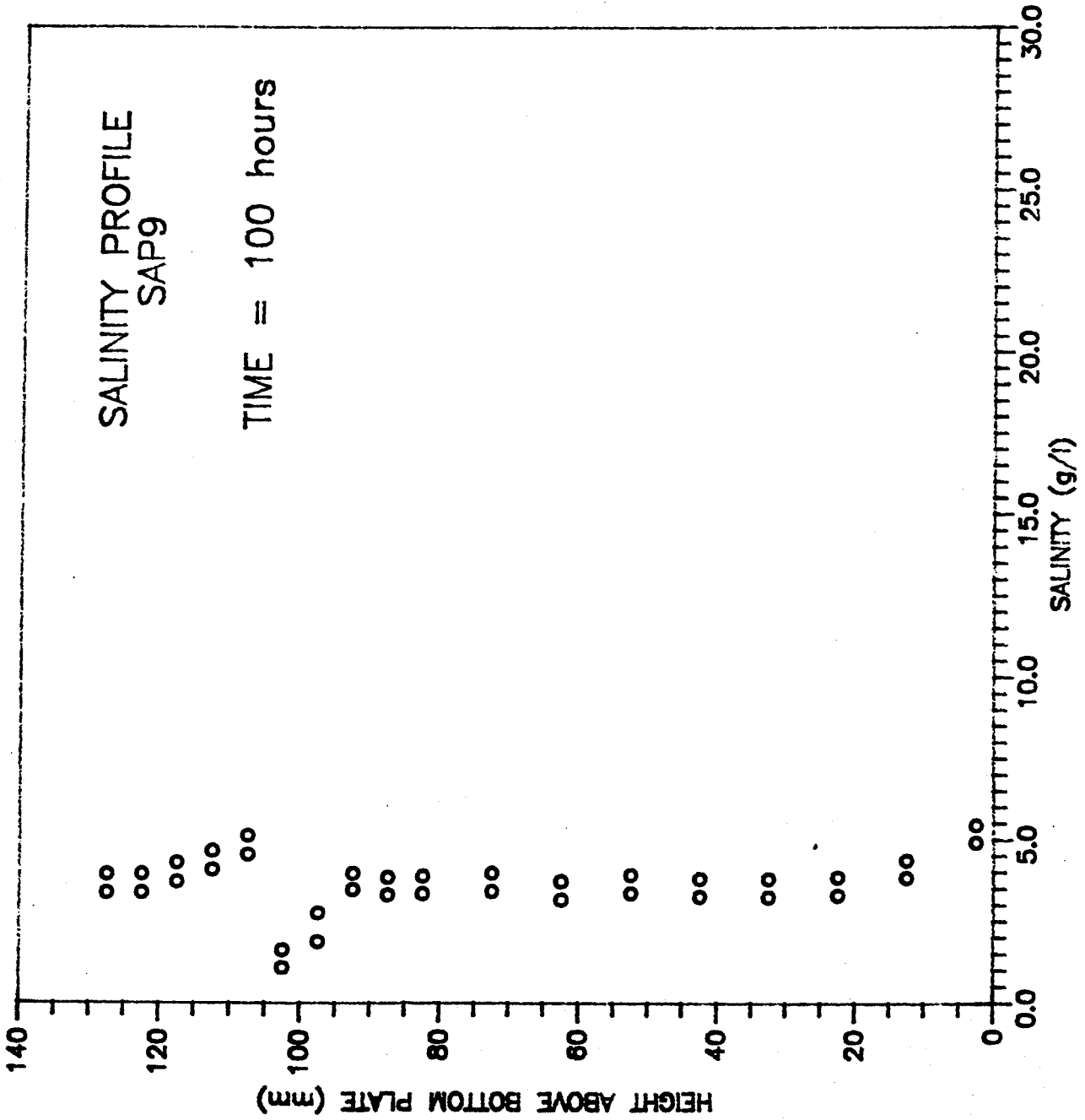


WATER CONTENT PROFILE
SAP9

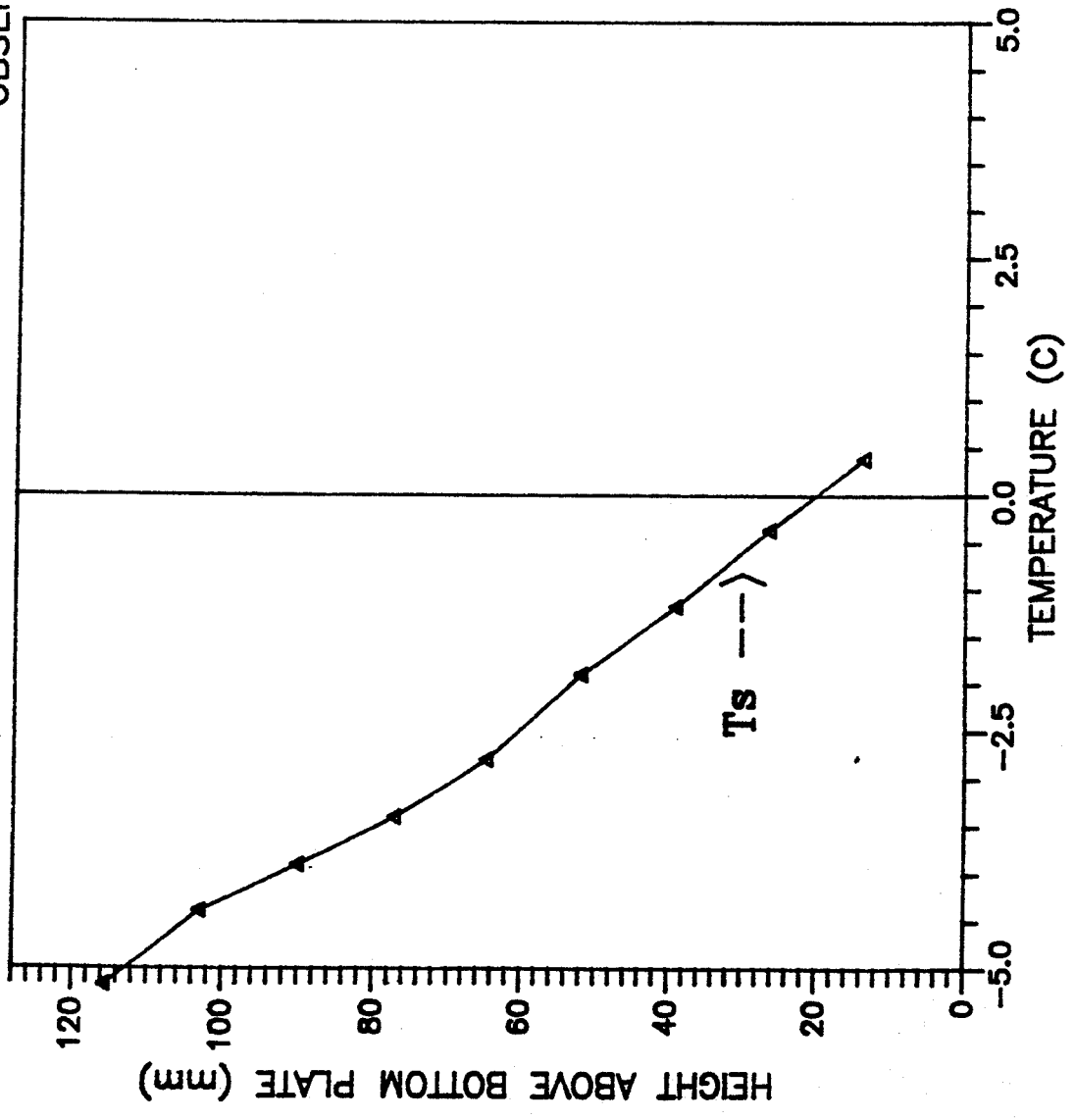
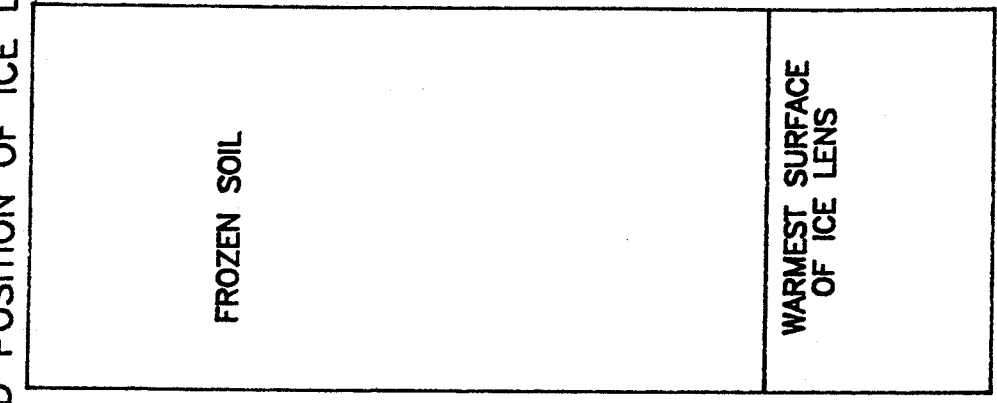


SALINITY PROFILE
SAP9

TIME = 100 hours

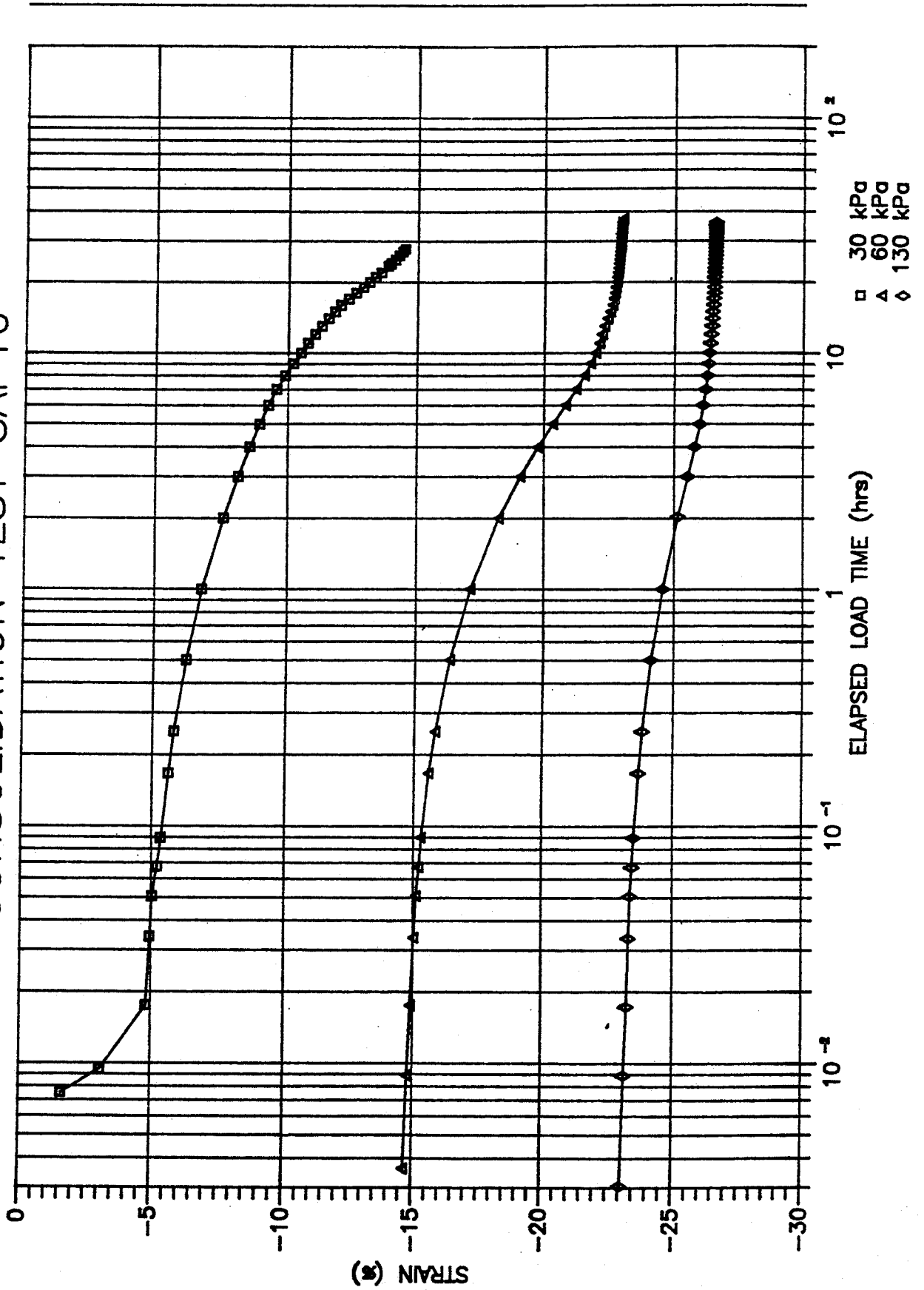


OBSERVED POSITION OF ICE LENS

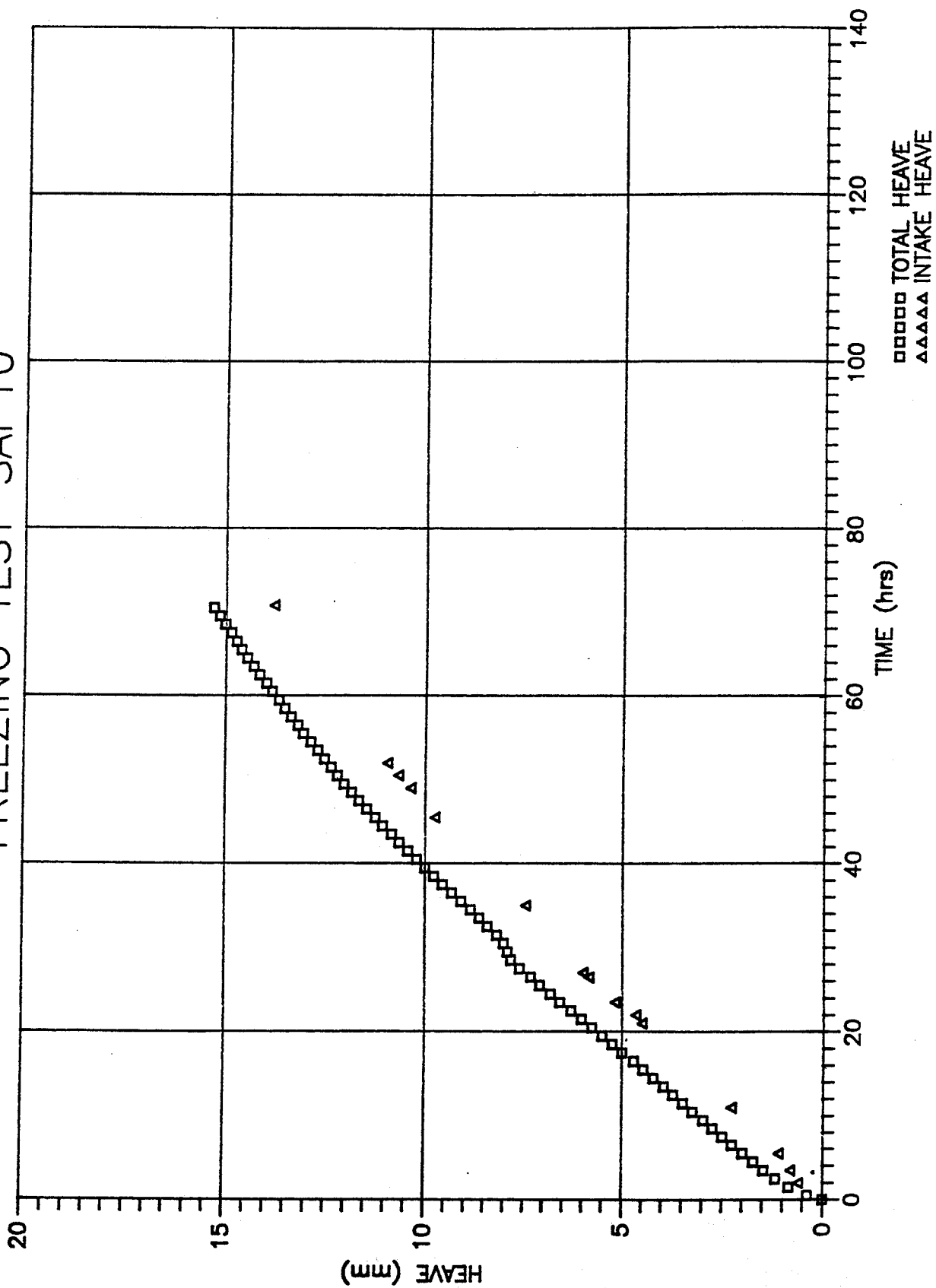


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP9

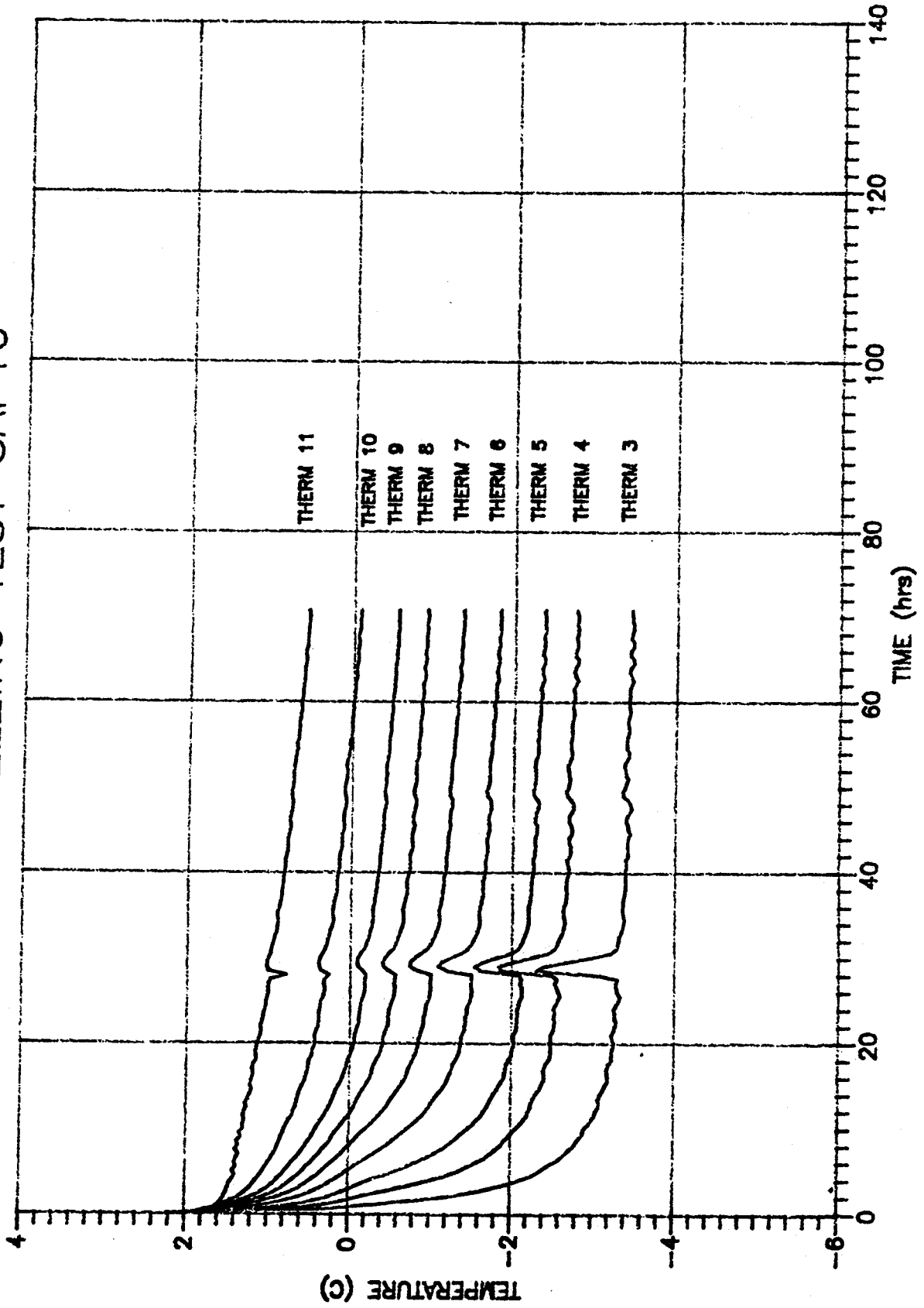
CONSOLIDATION TEST SAP10



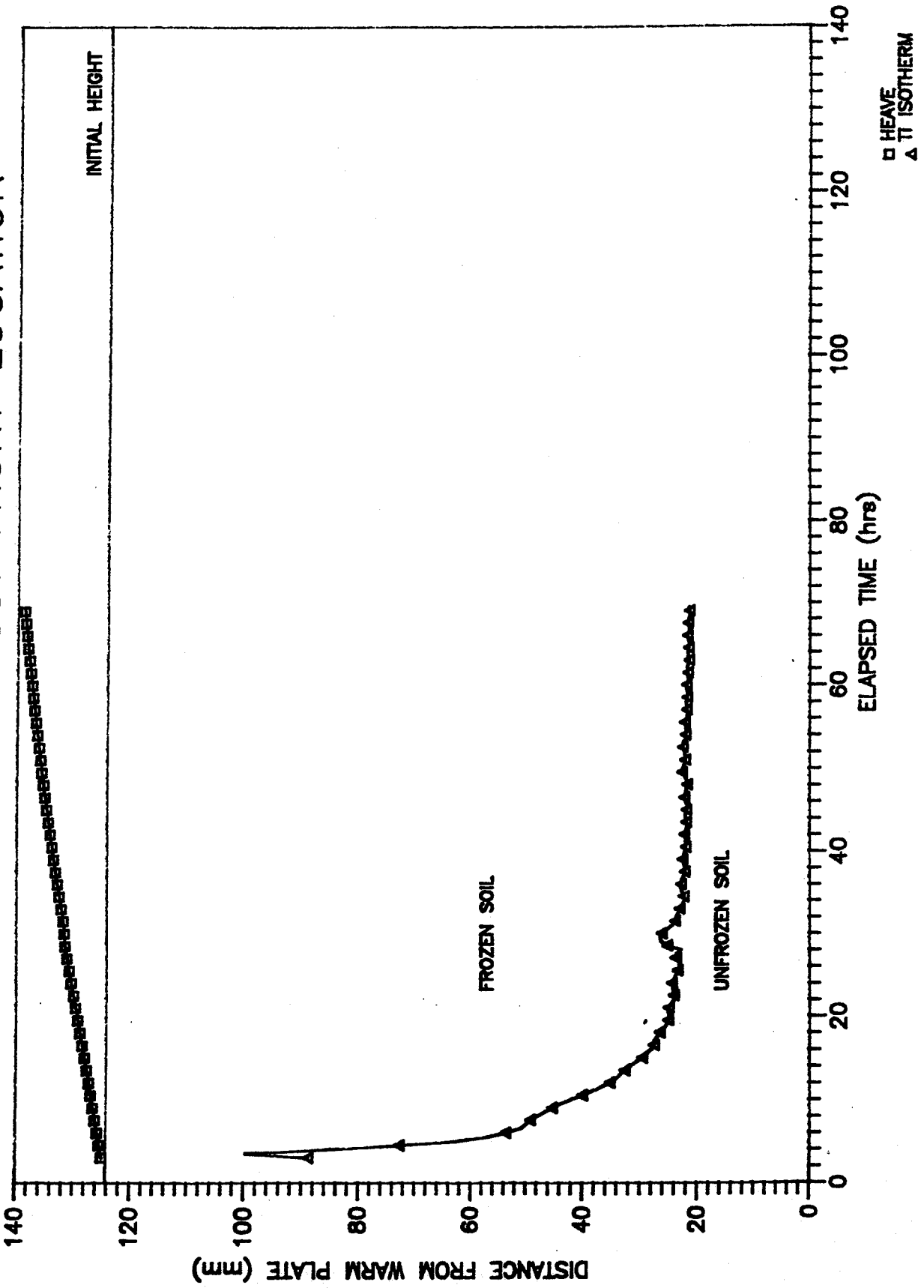
FREEZING TEST SAP10



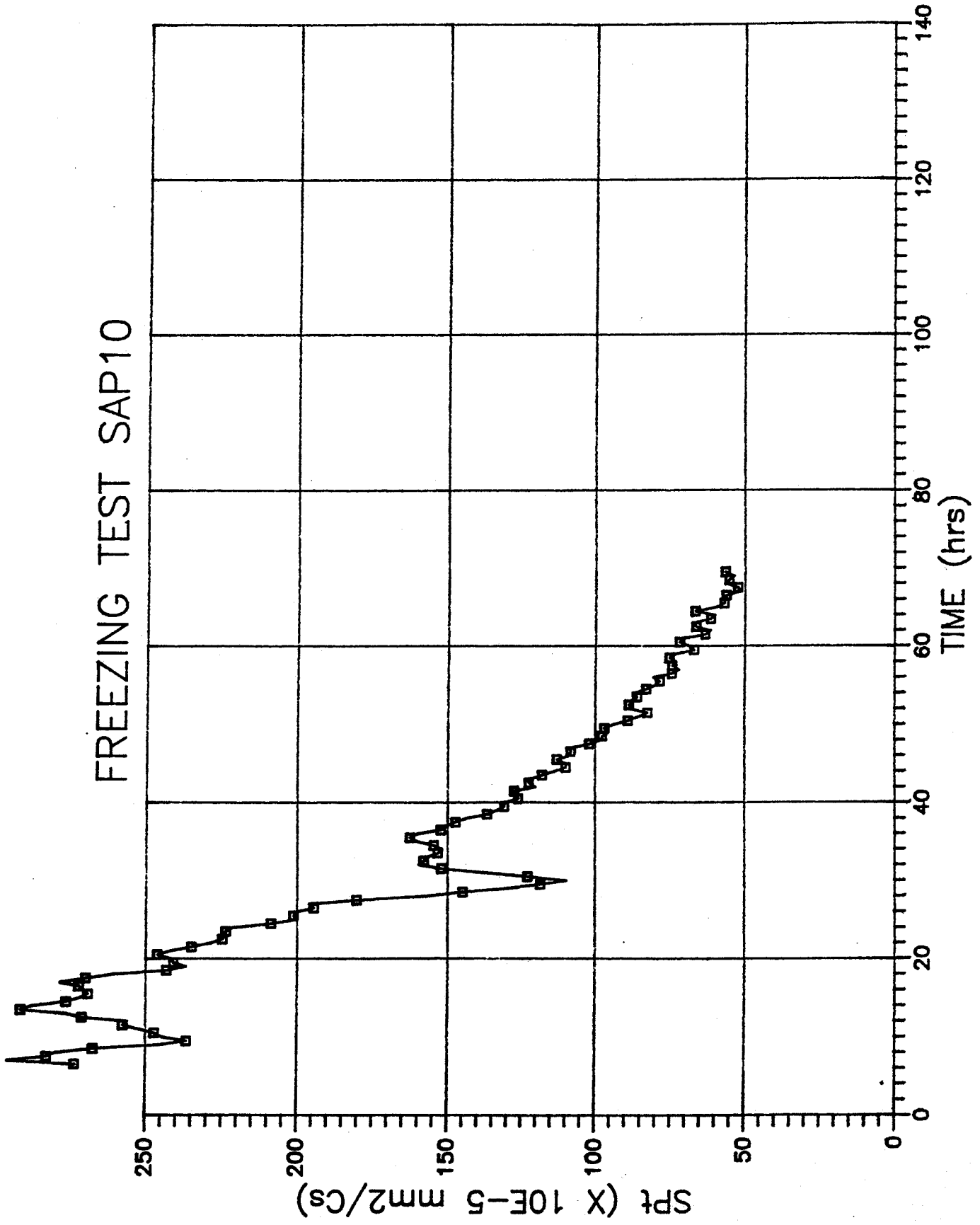
FREEZING TEST SAP10



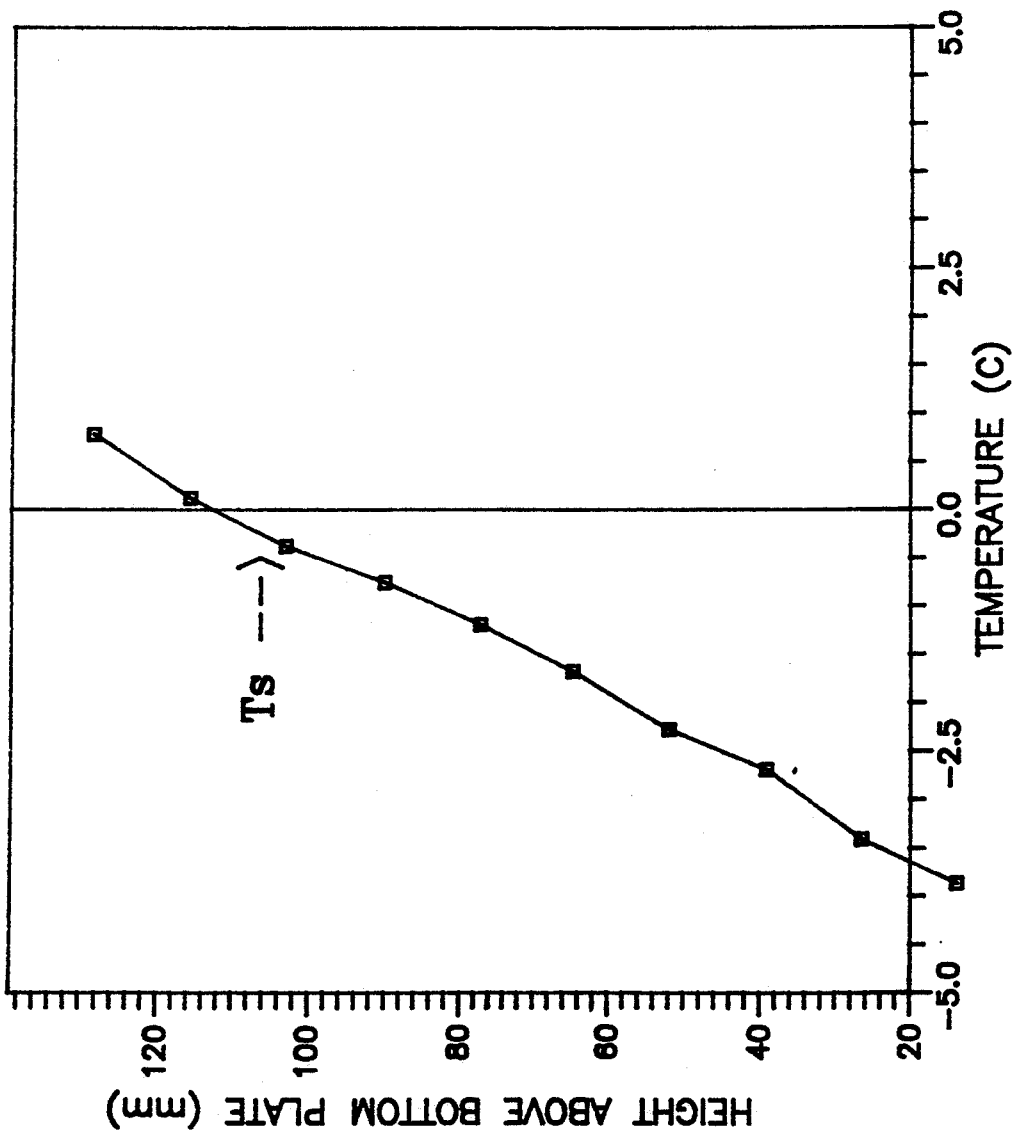
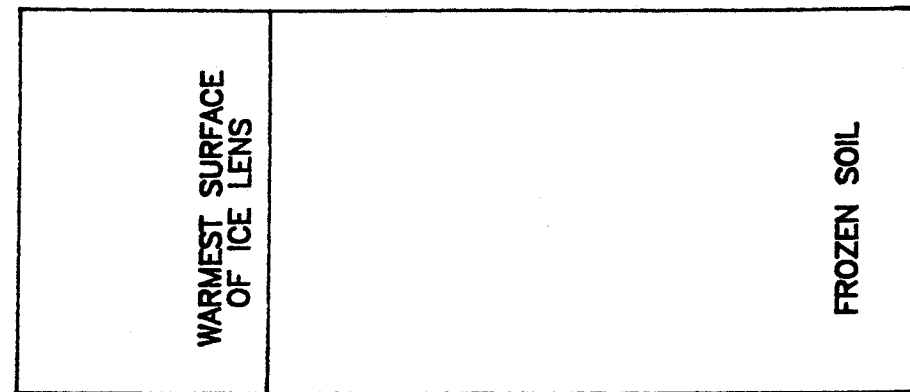
TEST SAP10 FROST FRONT LOCATION



FREEZING TEST SAP10

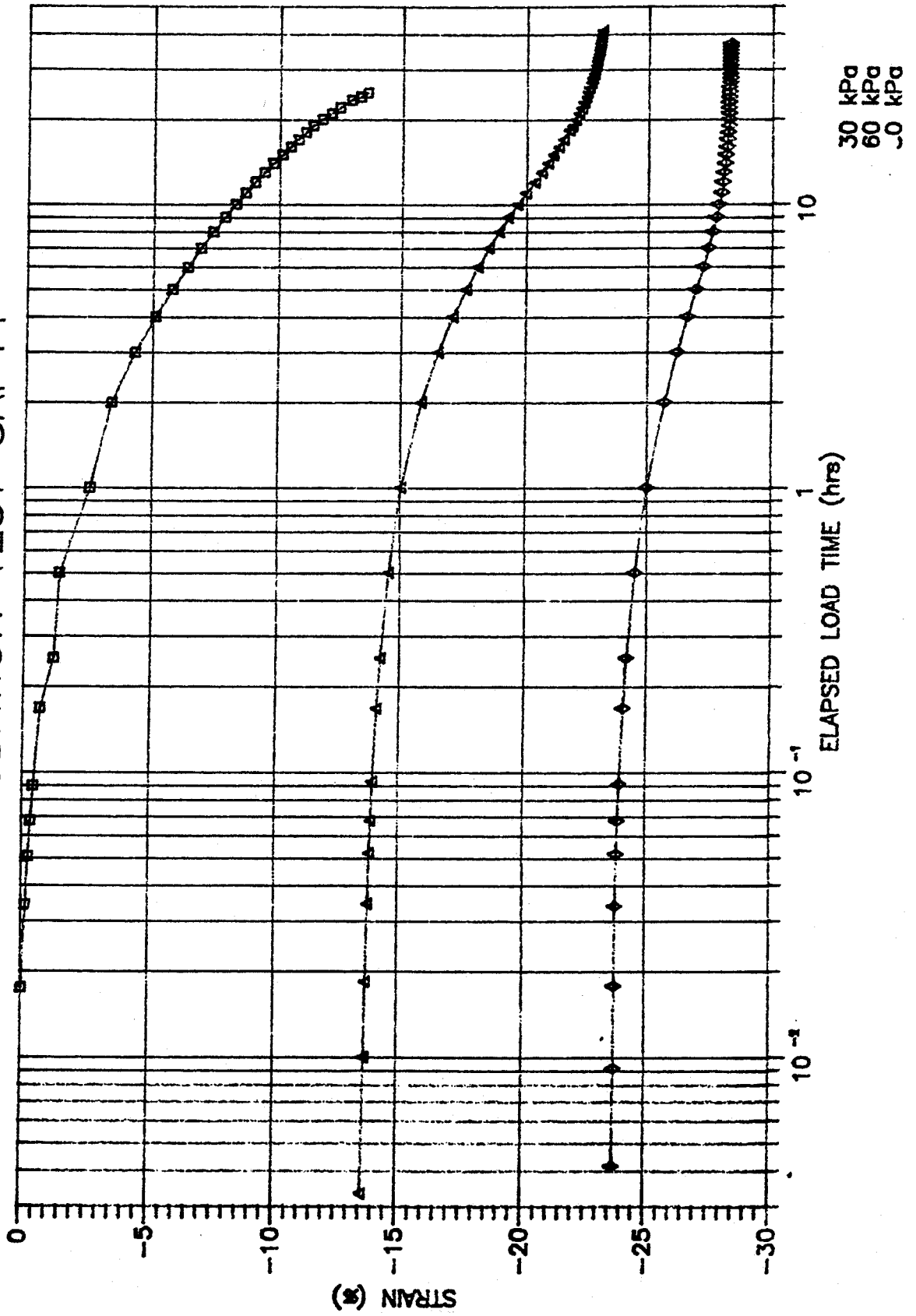


OBSERVED POSITION OF ICE LENS

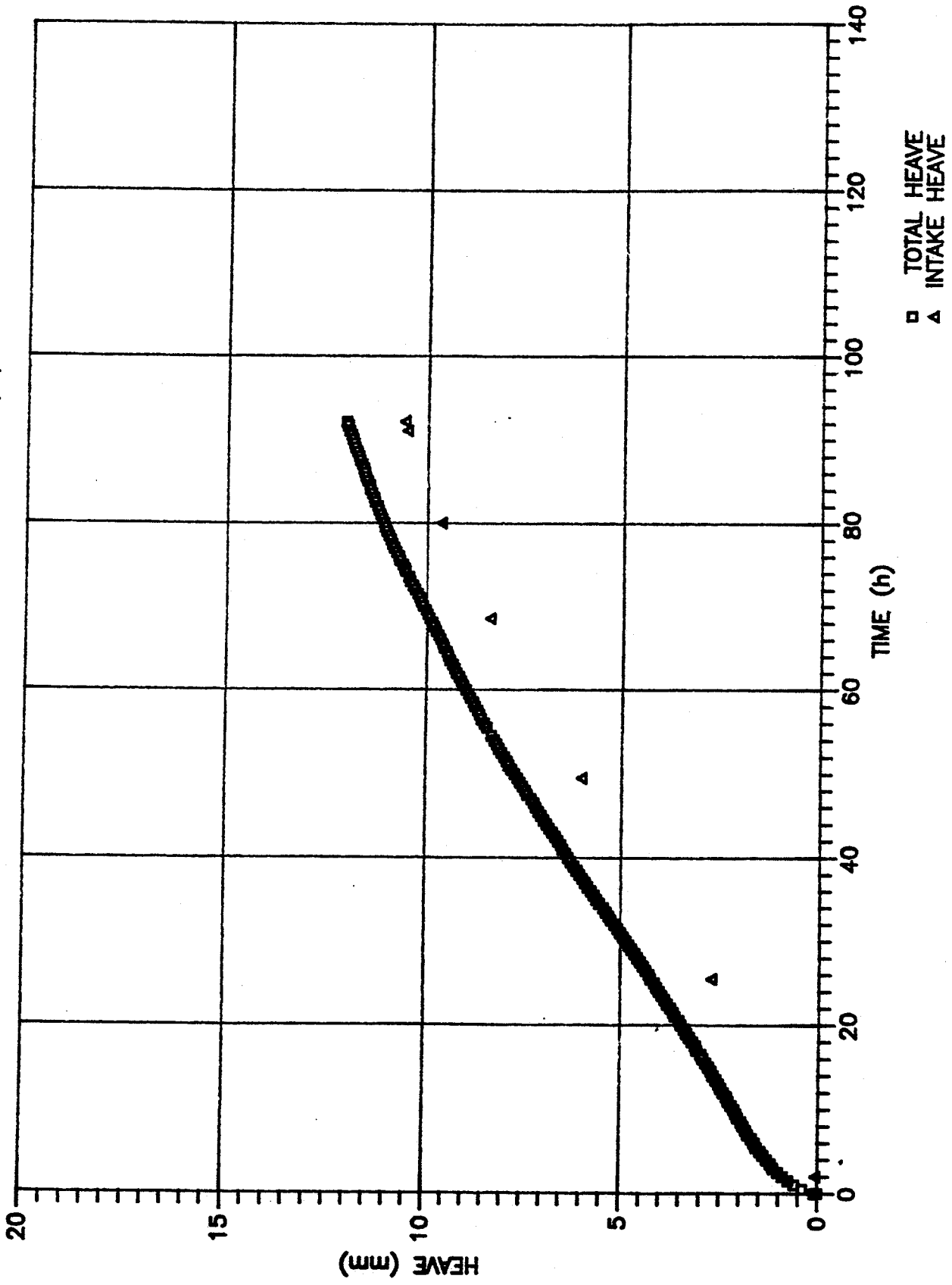


TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP10

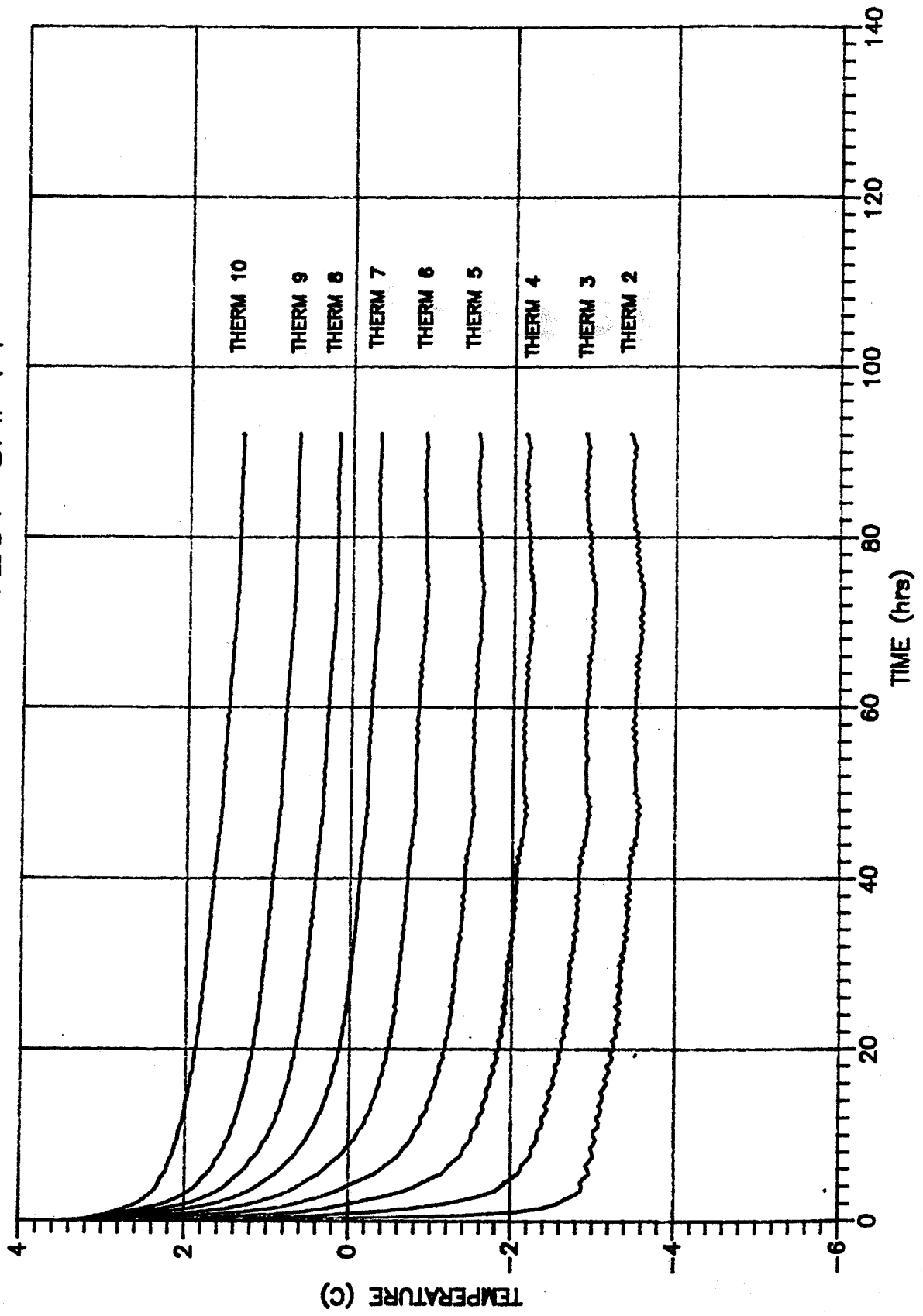
CONSOLIDATION TEST SAP11



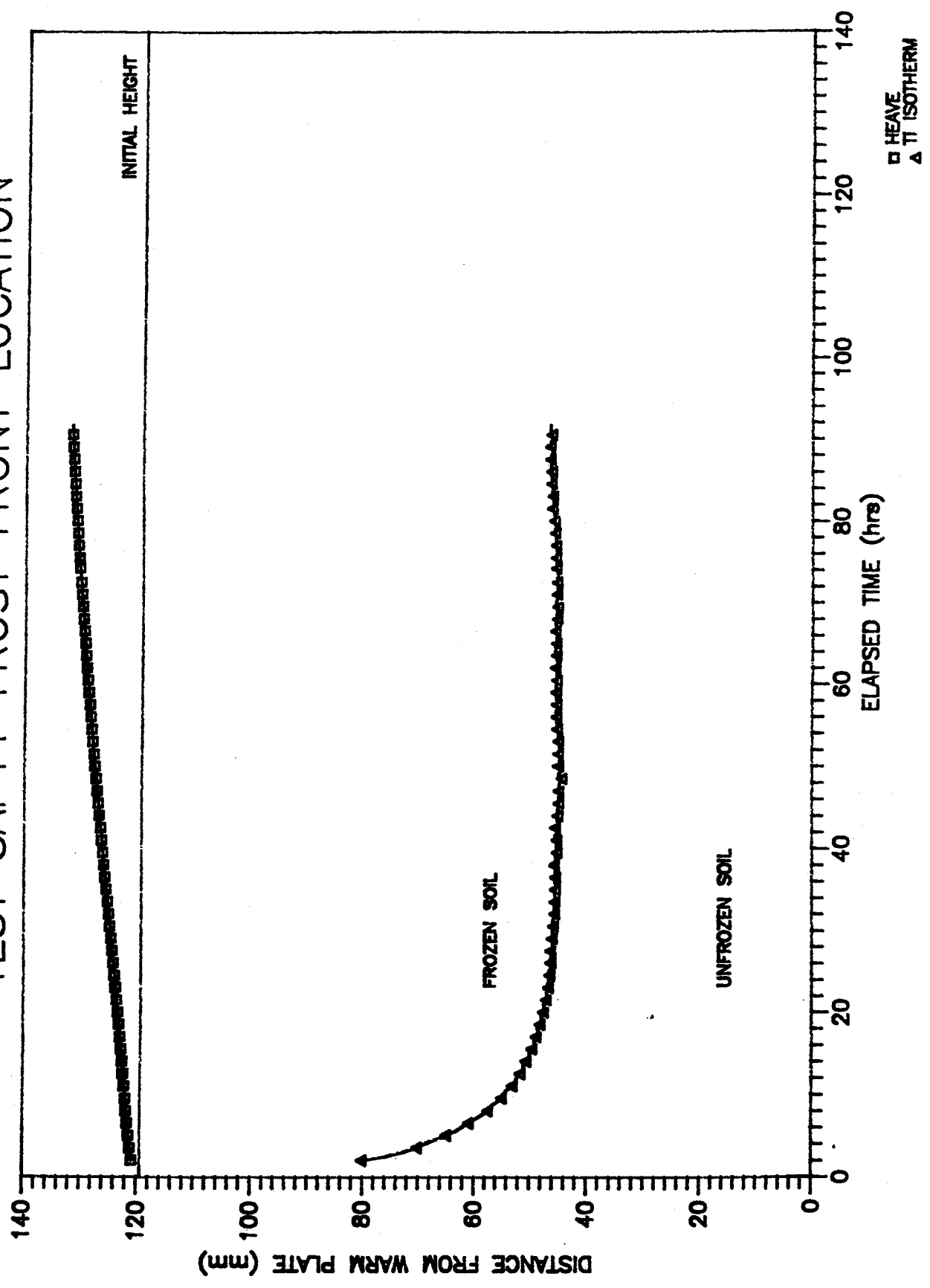
FREEZING TEST SAP11



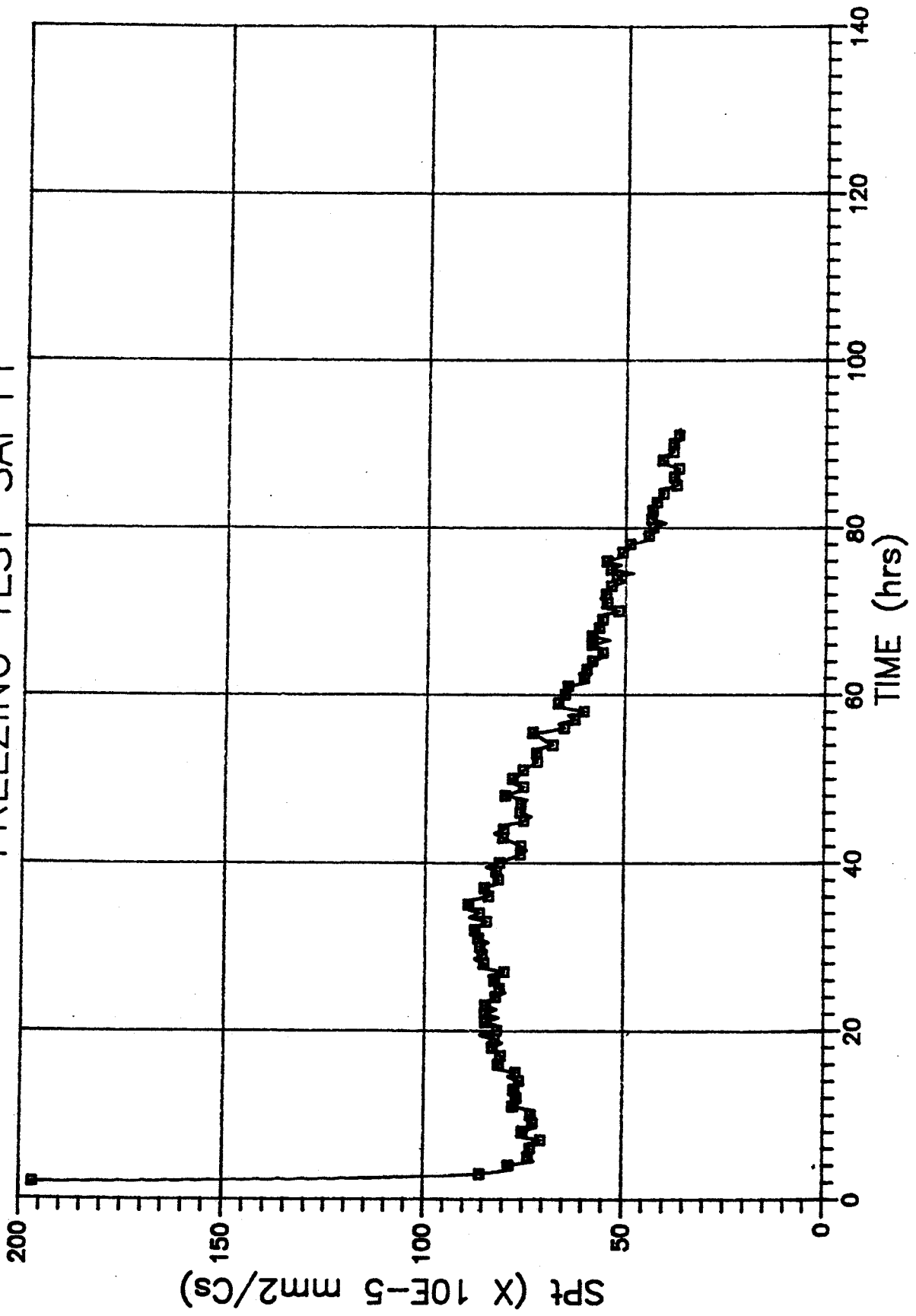
FREEZING TEST SAP11



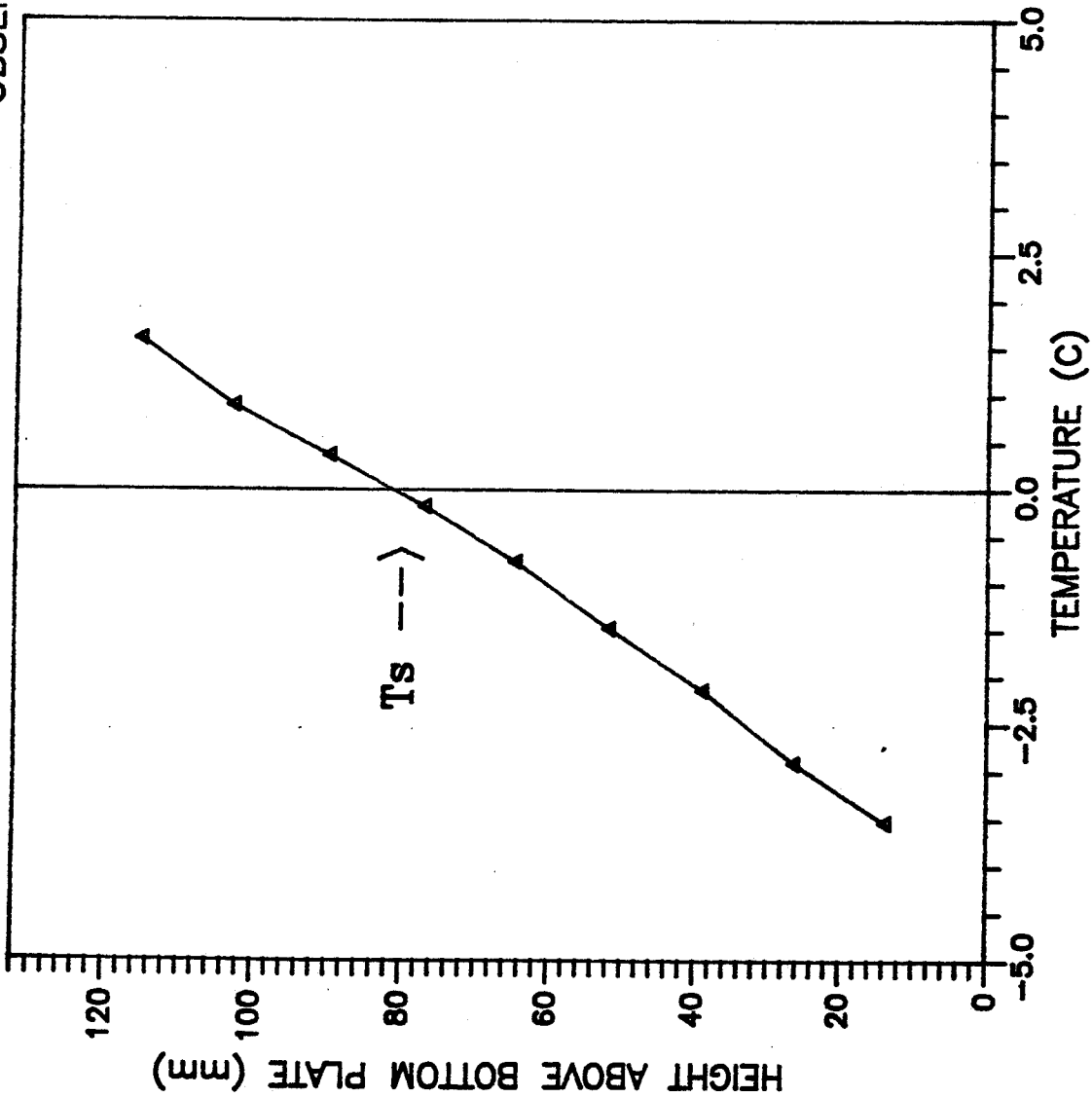
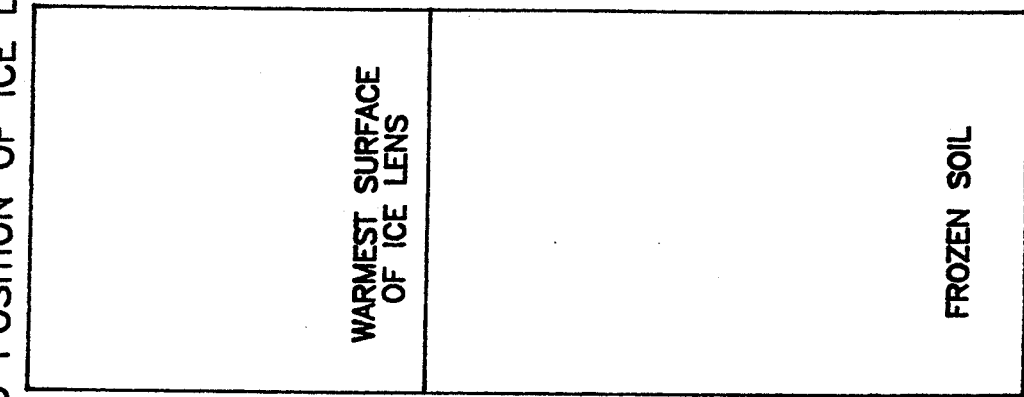
TEST SAP11 FROST FRONT LOCATION



FREEZING TEST SAP11



OBSERVED POSITION OF ICE LENS



TEMPERATURE PROFILE AT ONSET OF WARMEST ICE LENS --- SAP11

WATER CONTENT PROFILE
SAP4

