TEST OF CABLE PENETRATION FIRE STOPS FOR PILGRIM I NUCLEAR POWER GENERATING STATION

FRC Final Report
F-C5159-3

Prepared for

Stone & Webster Engineering Corporation
245 Summer Street
Boston, Massachusetts 02107

As Agents for:

Boston Edison Company
800 Boylston Street
Boston, Massachusetts 02119

April 1980

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

TEST OF CABLE PENETRATION FIRE STOPS FOR PILGRIM I NUCLEAR POWER GENERATING STATION

FRC Final Report
F-C5159-3

Prepared for

Stone & Webster Engineering Corporation
245 Summer Street
Boston, Massachusetts 02107

As Agents for:

Boston Edison Company
800 Boylston Street
Boston, Massachusetts 02119

April 1980

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

CONTENTS

FIGURES

TABLES

1. SUMMARY OF SALIENT FACTS

FRC Project Number: C5159

Test Program Conducted for:

Boston Edison Company
800 Boylston Street
Boston, MA 02199

Test Program Conducted and Reported by:

Franklin Research Center
The Parkway at Twentieth Street
Philadelphia, PA 19103

Subcontractor for Fire Stop Test:

Construction Technology Laboratories
Div. of Portland Cement Association
5420 Old Orchard Avenue
Skokie, IL 60076

Date of Test:

September 7, 1979

Objective of Test Program

To determine the fire resistance of cable tray penetration fire stops fabricated to simulate existing fire stops in the Pilgrim I Nuclear Power Generating Station located in Plymouth, MA.

Test Specimens

Two tray penetration fire stops were tested within a single concrete test slab. Test slab dimensions were 4 ft by 4 ft by 9 in thick. Specifications for the slab and penetrations were prepared by Stone & Webster Engineering Corporation (SWEC) in accordance with information supplied by Boston Edison Company (BECO) to represent typical penetrations existing within the Pilgrim I Nuclear Power Generating Station. Illustrations of the penetrations tested are included in the body of the report, in Figures B-3 and B-4.

Elements of Test Program

A 4 ft by 4 ft concrete test slab was constructed with a fire rating of at least 3 hours. Two cable tray penetrations were constructed within the test slab in accordance with information supplied by SWEC. Cable supports were provided on the cold side of the test slab by a structure of welded 3-in angle iron. A total of 33 thermocouples (TCs) were used to monitor temperatures of the penetrations on the cold side of the slab. Placement of TCs was in accordance with the requirements of IEEE Std 634-1978 (Ref. 1).

After all preparations were completed, the test slab was mounted horizontally upon the floor furnace, hot side down, and the test was initiated. The fire stop test was run in accordance with the requirements of IEEE Std 634-1978. The temperature-vs-time profile as required by IEEE Std 634-1978 was produced in the furnace for a period of 3 hours. All thermocouple readings were recorded every 15 s throughout the 3 h test. The cold side of each penetration was under direct observation throughout the test, while the hot side was observed through two small observation windows. Visual observations were made every 5 to 10 min.

At the end of the 3-h fire stop test, a nuclear generating station hose stream test was performed in accordance with IEEE Std 634-1978.

Summary of Test Results

Tray Penetration #2 exhibited temperatures in excess of 700°F, the maximum temperature limit specified in IEEE Std 634-1978, at 1 h 40 min after test initiation, and physical burn-through at 1 h 47 min after test initiation. Tray Penetration #1 exhibited no physical burn-through or excessive temperatures.

2. IDENTIFICATION OF TEST SPECIMENS

The test slab was of reinforced concrete construction with dimensions of 4 ft by 4 ft by 9 in thick, and was constructed in accordance with SWEC instructions. Figure B-2 is a picture of the test slab just prior to the fire stop test.

The test specimens are defined as the two tray-penetration fire stops constructed within the test slab. These penetrations were constructed to represent penetrations presently existing in the BECO Pilgrim I Nuclear Power Generating Station at Plymouth, MA. The penetrations were constructed with cables, supplied by BECO, representative of those employed in the Pilgrim I Nuclear Power Generating Station plus modifications to improve fire stop performance. The main components used to construct the fire stops within the penetrations were: Kaowool refractory fiber, Instafoam polyurethane foam material, Flamemastic refractory coating, and Chemcomp shrink-compensating grout. The cable penetrations were marked on the cold side of the test slab as Tray 1 and Tray 2. Detailed representations of the tray penetrations are presented in Figures B-3 and B-4 of Appendix B.

3. DESCRIPTION OF TEST FACILITY

3.1 TEST FURNACE

The fire stop test was performed at the Fire Test Laboratory of Portland Cement Association, in Skokie, Illinois. The 4 ft by 4 ft "floor test" furnace, pictured in Figure B-1, was used for the fire stop test. This gas-fired furnace produces a "standard" fire, as defined by IEEE Std 634-1978, (Ref. 1), beneath a horizontal concrete test slab (the test slab simulating a "floor" section in a building). In operation, the test slab itself forms the upper surface of the furnace test volume, with an area 32 in by 32 in being exposed to the fire test conditions.

3.2 FURNACE CONTROL

Three thermocouples (TC) were used to control the fire intensity to produce the required time-vs-temperature profile of Ref. 1. A tabulation of this required temperature profile is presented in Table C-1 of Appendix C. The output signals from the three control TCs were averaged together to form the temperature servo-control signal. These control TCs were located 1 ft away from the hot surface of the test slab, within the area of the furnace proper, in conformity with requirements of IEEE Std 634-1978. Each control TC signal was recorded on a Minneapolis Honeywell Brown Electronic temperature recorder, and the averaged servo-control signal was recorded on a Minneapolis Honeywell Brown circular chart temperature recorder.

3.3 DATA ACQUISITION SYSTEM

Temperatures produced during the fire stop test were monitored by a total of 33 chromel-alumel thermocouples placed at various positions on the cold side of the penetrations in accordance with FRC TC drawings of Ref. 3. Figures B-3 and B-4 illustrate in detail the TC positions. The temperature measurements obtained were used to define the maximum cold side penetration temperatures produced and also, to define the temperature gradient existing across the penetrations.

Three Minneapolis Honeywell Brown Electronic temperature recorders were used to monitor the cold side temperatures. Recorder information is presented in Appendix A.

4. TEST PREPARATIONS

4.1 TEST SLAB CONSTRUCTION

The test slab was constructed of reinforced concrete, of dimensions 4 ft by 4 ft by 9 in thick. Two cable tray penetrations were constructed in accordance with SWEC instructions. Natural curing plus drying with artificial heat ensured that correct concrete strength existed prior to penetration construction.

Samples of concrete were taken and later tested to ascertain that the 28-day concrete strength was a minimum of 4000 lb/in^2. Test results indicated a strength of 5025 psi, thus meeting this requirement. The fire rating required for the test slab was a minimum of 3 hours. Because the fire rating of a concrete wall is a direct function of wall thickness, as related in the American Insurance Association Fire Resistance Ratings of Ref. 2, it was readily established that the 9-in slab thickness employed in the test more than met the 3-h fire rating requirement.

Verification of test slab characteristics was carried out via use of the FRC Quality Assurance (QA) procedures: Materials Inspection and Documentation Requirements for Cable Penetration Fire Stop Test, (Ref. 4) and Inspection Procedure for Completed Fire Stop Test Slab and Cable Penetration Fire Stops (Ref.5).

4.2 CABLES AND CABLE SUPPORT SYSTEM

A tabulation of test cables used in the penetrations is presented in Table C-2. These cables were provided by BECO and were installed in accordance with SWEC instructions to simulate existing penetration configurations in the Pilgrim I Nuclear Plant.

The cables were supported by a welded structure of 3-in angle iron bolted to the cold side of the slab, as shown in Figure B-5. The tray and cables extended 3 ft 6 in beyond the cold side of the test slab. On the hot side of the slab the tray and cables extended 12 in into the furnace.

4.3 FIRE STOP CONSTRUCTION

Detailed representations of the six fire stops tested are presented in Figures B-3 and B-4 of Appendix B. A picture of the completed tray penetration installation is included in Figure B-2.

Four basic components were utilized in construction of the fire stops:

1) Kaowool: a 6-lb/ft^3 density ceramic fiber material placed within the penetrations in a 2-in-thick layer.

2) Instafoam #180: a polyurethane foam material foamed-in-place within the penetrations to a thickness of 6 in.

3) Chemcomp Grout: a shrinkage-compensating grout hardened within the penetrations with a thickness of 1 in.

4) Flamemastic 77: a water-soluble refractory coating sprayed on the penetration and cables. This coating covered the 12 in of cables extending through the hot side of the test slab and extended to the full length of the cables on the cold side.

Figures B-3 and B-4 of Appendix B show the arrangement of fire stop components used in the two tray penetrations.

Verification of fire stop characteristics was performed via use of FRC QA procedures in Ref. 5.

5. FIRE STOP TEST DESCRIPTION

The FRC Test Procedure for Cable Penetration Fire Stop Test (Ref. 6) was the control document for activities carried out during the fire stop test. The test itself can be summarized as follows.

After all QA requirements had been met, in accordance with FRC Refs. 4 and 5, the test slab was placed in position on top of the floor furnace. The test slab in position just prior to test initiation is shown in Figure B-2. Thermocouple leads were then connected to the thermocouples mounted on the penetrations, and the furnace was ignited. The time of furnace ignition was recorded. Within the Control Lab, the furnace operators adjusted furnace draft as required to obtain optimum burning conditions. The furnace servo-controller started tracking the required temperature profile, defined beforehand by the curve of IEEE Std 634-1978 (Ref. 1). The average of the three servo TC temperatures was recorded over a plot of the Ref. 1 curve to give a direct visual presentation of furnace temperature variations from the specified profile for the 3-h test.

A detailed log of observable events on both the cold side and the hot side of the test slab was maintained throughout the 3-h fire stop test. In addition all test slab temperature measurements were monitored throughout the test by test personnel in the Control Lab.

After the IEEE Std 634-1978 fire test was completed, the furnace was extinquished, and the still-hot slab was lifted from the furnace with an overhead crane. A view of the test slab in this position can be seen in Figure B-7. The slab was then placed on its side outside the test building. A 1-1/2-in, high-pressure (75 psig, 75 gal/min) water hose was directed at the cold side of the slab from a distance of 10 ft, in accordance with the requirements of IEEE Std 634-1978 for the nuclear generating station hose stream test. A picture of the hose stream test is shown in Figure B-8.

6. FIRE STOP TEST RESULTS

A summary of test observations and instrumentation results are presented below.

6.1 FURNACE PERFORMANCE

Figure B-6 presents the furnace temperature profile obtained for the test, recorded over the IEEE Std 634-1978 temperature profile. Furnace temperature variations during the 3-h fire stop test were within IEEE Std 634-1978 requirements.

6.2 HOT SIDE TEST OBSERVATIONS

Two small mica windows in the furnace wall permitted observation of the hot side of the test slab. After approximately 40 min of burning, surfaces of penetration components and cables exposed to the flames began to exhibit a uniform, dull orange glow. This condition remained constant throughout the remainder of the test.

6.3 COLD SIDE TEST OBSERVATIONS

Minimal activity was observed on the cold side of the slab throughout the test. At 1 h and 10 min after test initiation a small amount of smoke was seen to seep through Tray Penetration #2. At 1 h and 47 min after test initiation, Tray Penetration #2 was observed to burn through to the cold side. By the end of the test, portions of the central area of the bottom and top of Tray Penetration #2 were seen to be buckled inward approximately a maximum of 3/8 to 1/2 in due to the intense heat. Tray Penetration #1 appeared to be totally unaffected.

6.4 THERMOCOUPLE TEMPERATURE MEASUREMENTS

Cold side thermocouple temperatures for the two tray penetrations were observed to climb slowly throughout the 3-h fire stop test. At 1 h 40 min after test initiation TC 16 of tray penetration #2 exceeded the 700°F temperature limit of IEEE Std 634-1978. Shortly thereafter, at 1 h 53 min, TC 14

exceeded the 700°F limit, followed by TC 13 at 1 h 55 min, TC 20 at 2 h 10 min, TC 15 at 2 h 12 min, TC 17 at 2 h 48 min, TC 12 at 2 h 48 min, and TC 11 at 2 h 57 min, all from Tray Penetration #2. No cold side TC temperatures for Tray Penetration #1 exceeded the 700°F limitations imposed by IEEE Std 634-1978.

Table C-3 presents a tabulation of the 700°F temperature crossover points, plus end-of-test temperatures for the test (temperatures 3-h after initiation of the IEEE Std 634-1978 fire stop test). It should be noted that furnace burning was extended one recorder cycle (i.e., 3 min) beyond 3 h to ensure that all TC channels were fully represented for the test.

6.5 IEEE Std 634-1978 HOSE STREAM TEST

After completion of the 3-h fire test the test slab was removed from the furnace and the IEEE Std 634-1978 hose stream test was performed outside the building. Elapsed time between the end of the fire test and initiation of the hose stream test was approximately 5 min. There was no observable projection of water through the penetrations in the test slab during the hose stream test.

7. CONCLUSIONS

The results of the test can be summarized by the following:

- Tray Penetration #1 remained physically intact throughout the fire stop test. Tray Penetration #2 failed physically 1 h and 47 min after test initiation.
- Both penetrations passed the required IEEE Std 634-1978 nuclear power plant hose stream test performed just after the fire test.
- Cold side temperatures for Tray Penetration #1 remained below the 700°F temperature limit specified by IEEE Std 634-1978. Tray Penetration #2 cold side TC temperatures exceeded the 700°F limit at the times noted below:

  TC 16 at 1 h, 40 min
  TC 14 at 1 h, 53 min
  TC 13 at 1 h, 55 min
  TC 20 at 2 h, 10 min
  TC 15 at 2 h, 12 min
  TC 17 at 2 h, 40 min
  TC 12 at 2 h, 48 min
  TC 11 at 2 h, 57 min

8. CERTIFICATION OF TEST RESULTS

The undersigned certify that this report is a true account of the test conducted and the results obtained.

James Munson
Project Engineer

Approved:

M.M. Reddi, Vice President
Engineering

S.P. Carfagno, Manager
Performance Qualification

9. REFERENCES

1. ANSI/IEEE Std 634-1978, IEEE Standard Cable Penetration Fire Stop Qualification Test. The Institute of Electrical and Electronics Engineers, Inc,. 343 East 47 Street, New York, N.Y. 10017.

2. American Insurance Association, Fire Resistance Ratings, December 1964. American Insurance Association, successor to the National Board of Fire Underwriters, Engineering and Safety Department, 85 John Street, New York, N.Y. 10038.

3. FRC QA Document C5159-3-2, Thermocouple Location and Designation Drawings for Cable Penetration Fire Stop Test, August 1979, Rev., 8/8/79.

4. FRC QA Document C5159-3-3, Materials Inspection and Documentation Requirements for Cable Penetration Fire Stop Test, FRC Project C5159, August 1979, Rev. 0, 8/8/79.

5. FRC QA Document C5159-3-4, Inspection Procedure for Completed Fire Stop Test Slab and Completed Fire Stop, FRC Project C5159, August 1979, Rev. 0, 8/8/79.

6. FRC QA Document C5159-3-5, Cable Penetration Fire Stop Test Procedure, August 1979, Rev. 0, 8/8/79.

7. SWEC Drawing 13201-SK-E1, Penetration Seals Test Slab Layout, 4/2/79.

8. SWEC Drawing 13201-SK-E4. Fire Stop Construction Details. Test slab #3. Boston Edison Co. Pilgrim Unit No 1.

F-C5189-3

DATA ACQUISITION SYSTEM

APPENDIX A

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

DATA ACQUISITION SYSTEM

INSTRUMENTATION AND FURNACE CONTROL THERMOCOUPLES	K20-2-305 "special limits" 20 gage insulated TC wire, chromel alumel Claud S. Gordon Company Instrument Society of America (ISA) error limits: (0 to 530°F) ± 2°F; (530 to 2300°F) ± 3/8% of reading Reference: ISA Recommended Practice RPI3
TEMPERATURE RECORDERS	Minneapolis Honeywell Brown Electronic Temperature Recorders Error Limits: ± 1/4% over full range

Recorder Designation	Model No.	Parameter Measured
Zone 1	152p13ps.196-III-13 Circular Chart	Furnace Control Temperature
Frame 4	Y153X(67)-P16-II-III-(26)-A8M4	Individual Control TC Temperatures
Frame 11	Y153X(67)-P12-II-III-(101)-A8	Cold Side TC Temperatures
Frame 12	Y153X(67)-P12-II-III-(101)-A8	Cold Side TC Temperatures
Frame 13	Y153X(67)-P12-II-III-(101)-A8	Cold Side TC Temperatures

F-C5159-3

ILLUSTRATIONS

APPENDIX B

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

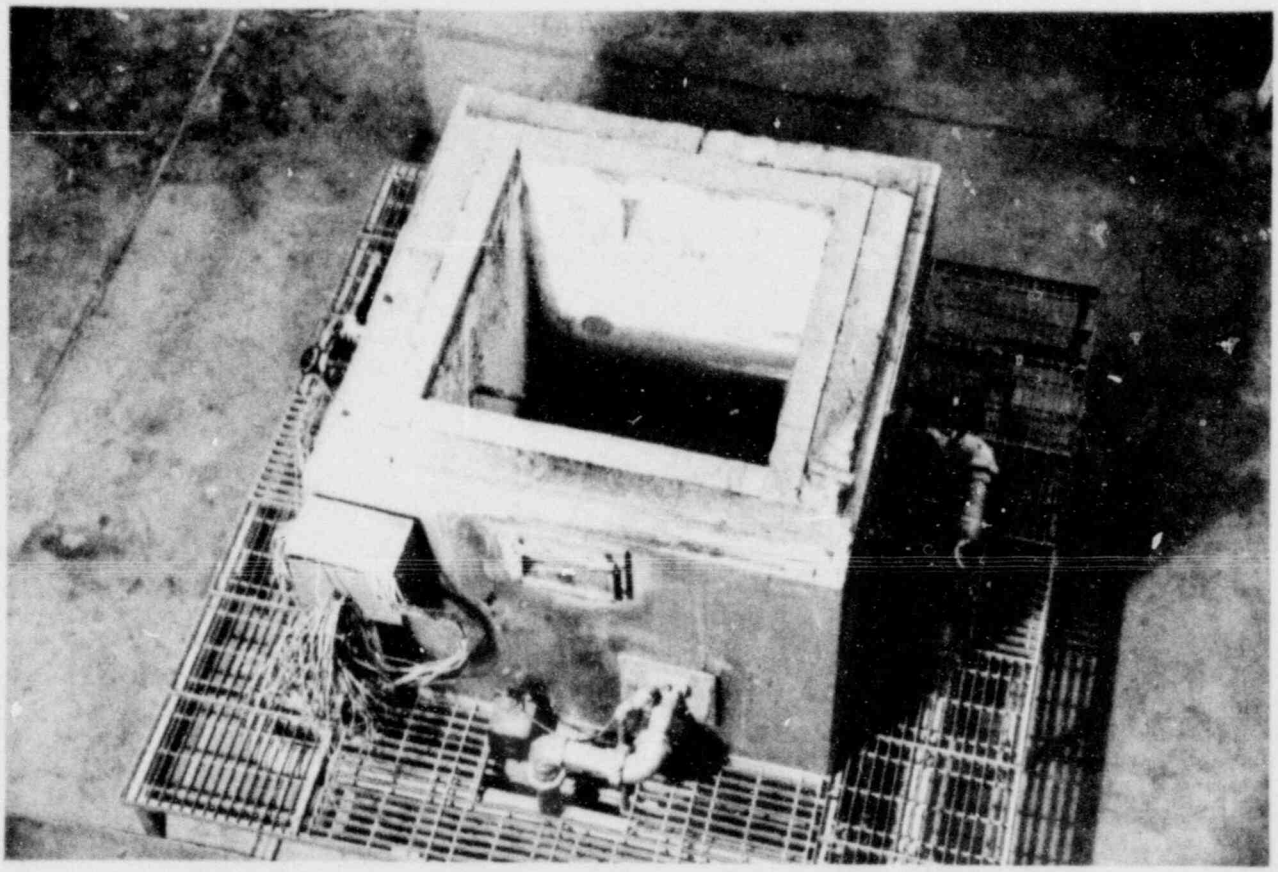


Figure B-1. 4 Ft by 4 Ft Floor Test Furnace

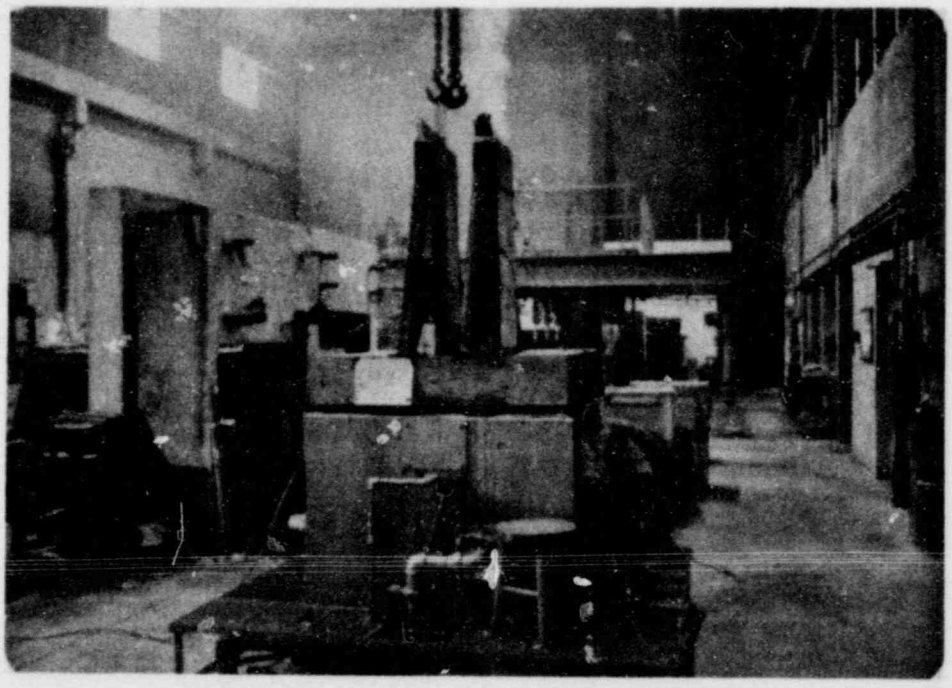
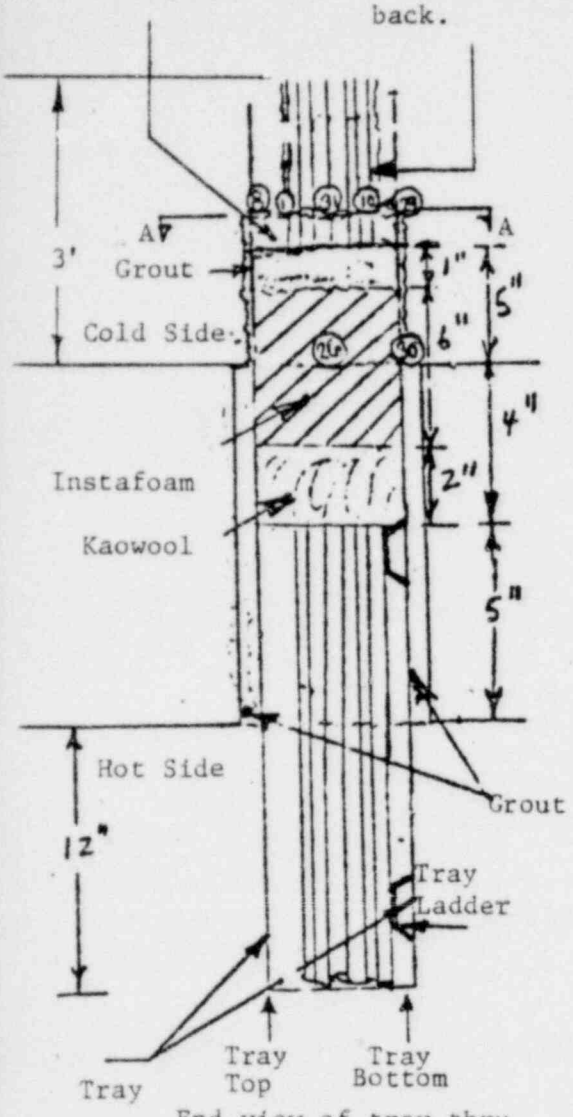


Figure B-2. Fire Stop Test Slab Prior to Test

1" coating of Flamemastic 77 over grout

1/8" coating of Flamemastic over wires in tray 3' back.

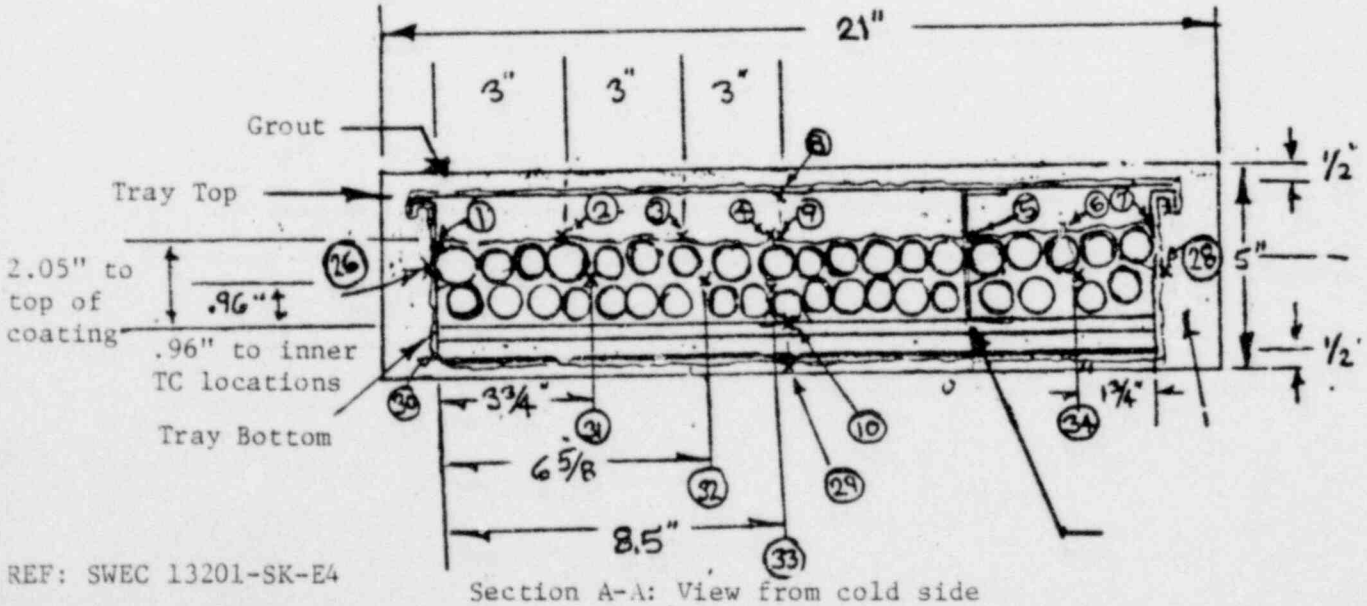
Cable fill: 17 cables of C12
22 cables of 912-27



End view of tray thru test slab.

NOTES:

1. On the cold side of the penetration a 1" thick coating of Flamemastic 77 applied over 1" grout layer, as shown.
2. TCs 2, 3, 4, & 6 are wired to cable jackets in positions shown at level of the 1" Flamemastic-to-cable interface.
3. TC 9 is mounted 3" above TC 4 on the same cable, for temp. gradient information.
4. TCs 1, 5, 7, & 10 are wired to cable jackets, and cable-plus-TCs are wired to adjacent tray metal through two adjacent holes drilled into tray metal for mounting purposes, i.e., TC is firmly sandwiched between metal and cable. This is done at level of the 1"-Flamemastic-to-cable interface.
5. TC 8 is mounted to the inside of tray top with wire thru two mounting holes.
6. All cables to be coated 1/8" wet all the way back to the cold end of the tray (3').
7. The sides, bottom, and top of the tray itself are to be coated 5" from the face of the slab, 1/8" wet.
8. There was no TC#27 included in the test.
9. TCs 26, 28, 29 and 30 are wired to the surface of the dry coating of Flamemastic 77 applied to the outer surface of the tray.
10. TCs 31, 32, 33, and 34 were mounted at the level between the two cable layers at positions indicated in the drawing.



REF: SWEC 13201-SK-E4

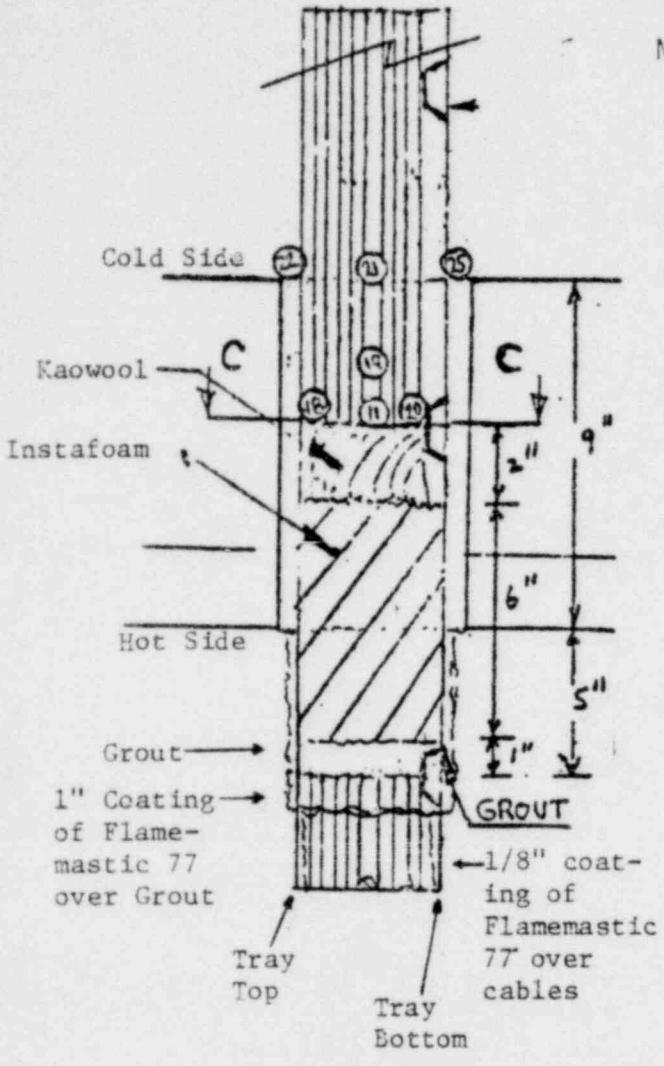
Section A-A: View from cold side

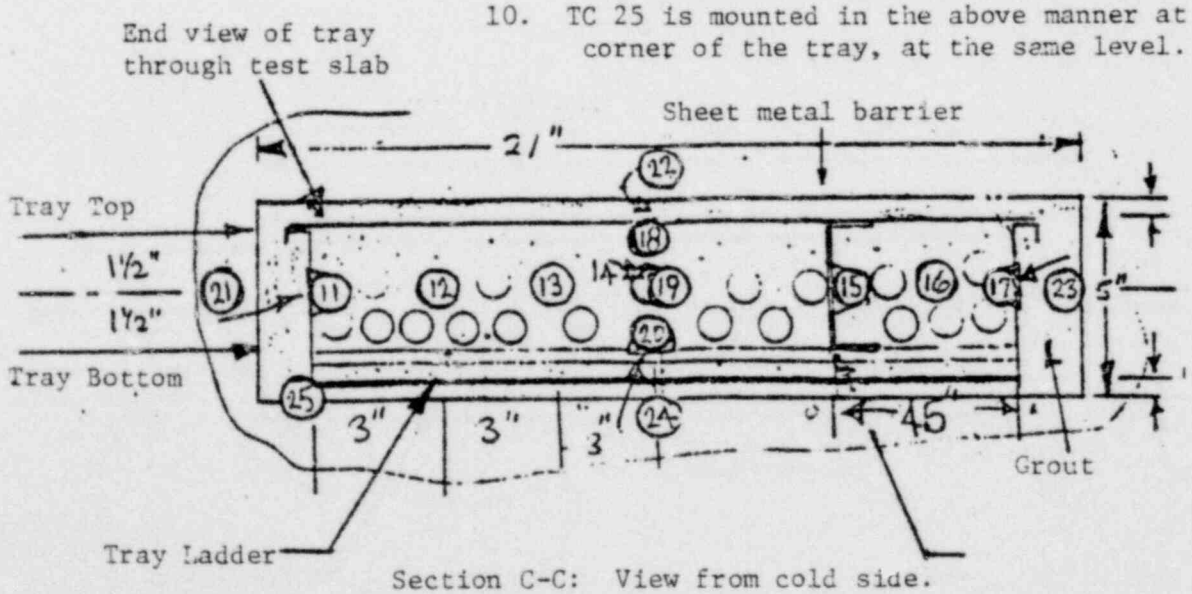
Figure B-3. Tray Penetration #1 Construction Details and Thermocouple Locations.

Cable fill: 17 cables of C12
: 22 cables of 912-27

NOTES:

1. On the hot side of the penetration a 1" thick coating of Flamemastic 77 applied over the 1" grout layer, as shown.
2. All cables to be coated 1/8" wet on the hot side, as shown.
3. The sides, bottom, and top of the tray itself are to be coated 5" from the face of the slab on the hot side.
4. TCs 12, 13, 14 and 16 are wired to cables inside cable bundles in positions shown, at level of grout-to-air-interface.
5. TC 19 is mounted in the same manner, however 3" above TC 4 for temperature gradient information.
6. TCs 11, 15, 17 and 20 are wired to outermost cable surfaces, and cable-plus-TC are wired to adjacent cable metal through two adjacent holes drilled into the tray metal for mounting purposes, i.e., TC is sandwiched between metal and cable, at Kaowool/air interface.
7. TC 18 is mounted to inside of tray top with wire through two mounting holes.
8. TCs 21, 22, 23, 24, and 25 are located on outside of tray at grout-to-tray interface. Each TC is wired to outside of tray through two adjacent mounting holes added for this purpose.
9. TC 22 is mounted with wire through two mounting holes on the top cover at the level of the surface of the cold side of the slab.
10. TC 25 is mounted in the above manner at the corner of the tray, at the same level.





Section C-C: View from cold side.

REF: SWEC 13201-SK-E4

Figure B-4. Tray Penetration #2 Construction Details and Thermocouple Locations

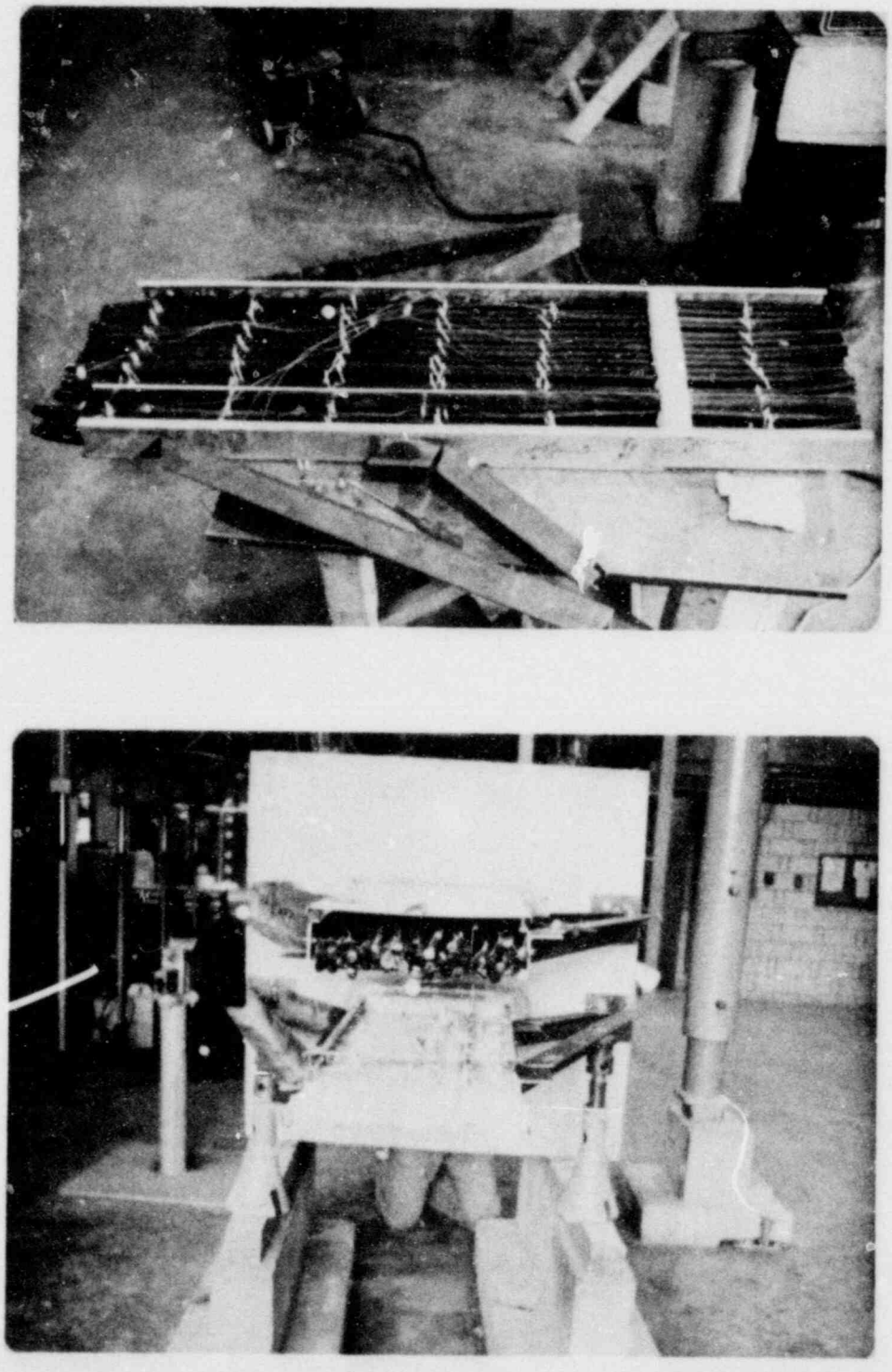


Figure B-5. Tray Supports on Cold Side of Test Slab

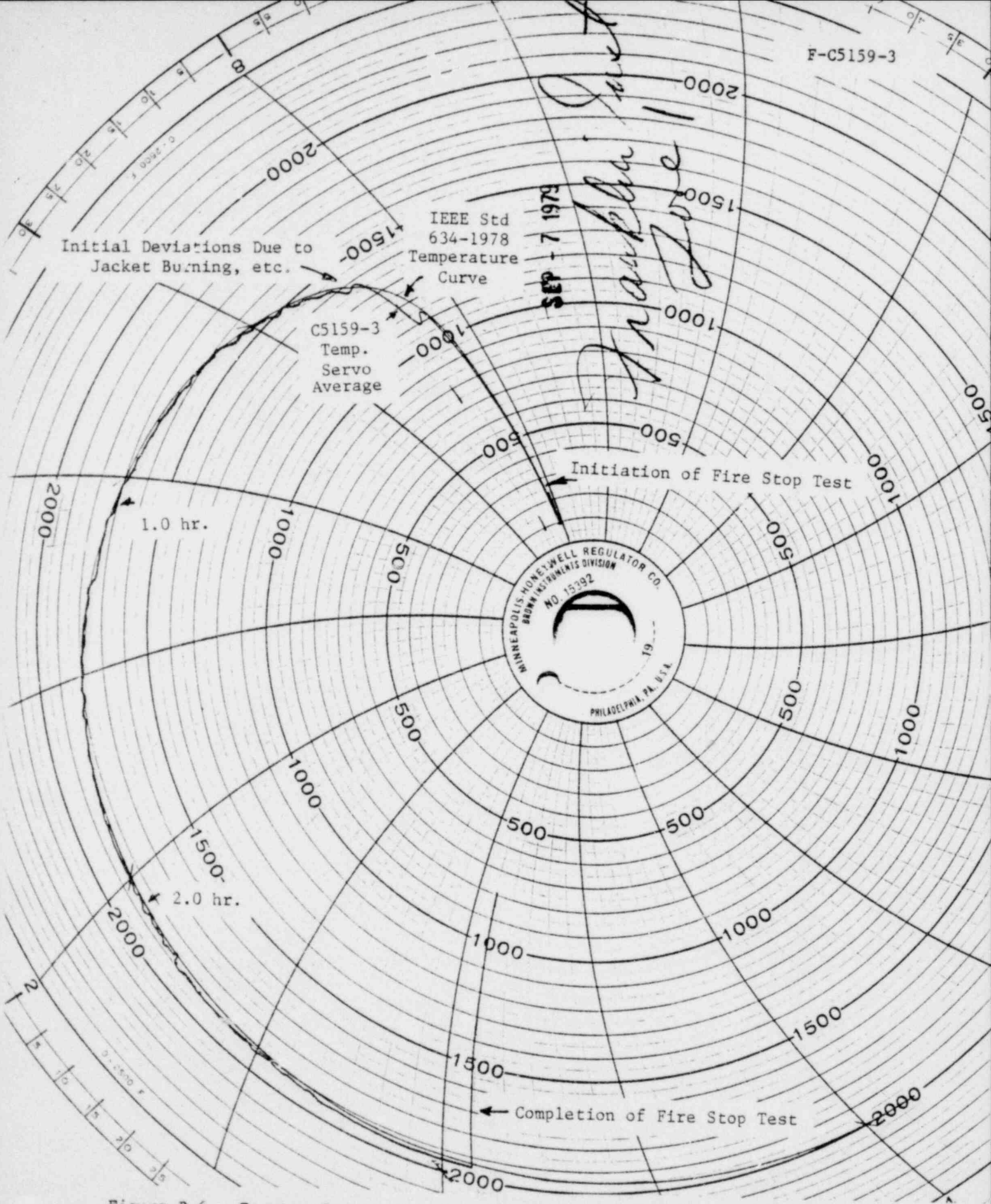


Figure B-6. Furnace Temperature vs. Time Profile Obtained for Fire Stop Test C5159-3, September 1979

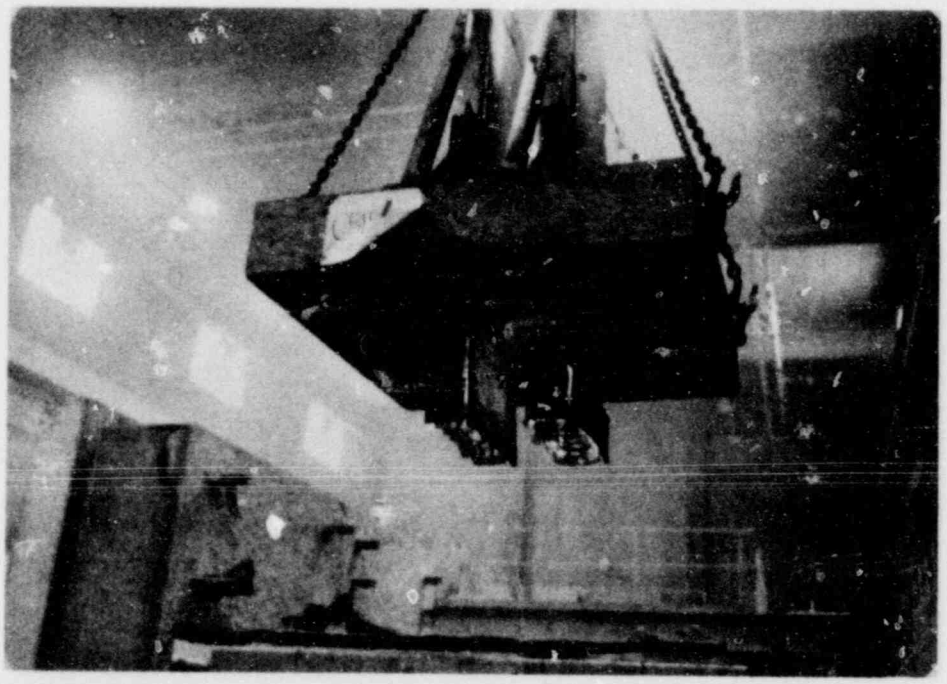


Figure B-7. Test Slab in Raised Position Just After Completion of IEEE Std 634 - 1978 3 Hour Fire Test

Figure B-8. Hose Stream Test of Test Slab C5159-3, September 7, 1979

TABLES

APPENDIX C

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

Table C-1. Standard Time-Temperature Curve for Control of Fire Test from Appendix IEEE 634.1978

Time (h:min)	Temperature (°F)	Area Above 68° F Base (°F-min)	(°F-h)	Temperature (°C)	Area Above 20° C Base (°C-min)	(°C-h)
0:00	68	00	0	20	00	0
0:05	1 000	2 330	39	538	1 290	22
0:10	1 300	7 740	129	704	4 300	72
0:15	1 399	14 150	236	760	7 860	131
0:25	1 510	28 050	468	821	15 590	260
0:30	1 550	35 360	589	843	19 650	328
0:35	1 584	42 860	714	862	23 810	397
0:40	1 613	50 510	842	878	28 060	468
0:45	1 638	58 300	971	892	32 390	540
0:50	1 661	66 200	1 103	905	36 780	613
0:55	1 681	74 220	1 237	916	41 230	687
1:00	1 700	82 330	1 372	927	45 740	762
1:05	1 718	90 540	1 509	937	50 300	838
1:10	1 735	98 830	1 647	946	54 910	915
1:15	1 750	107 200	1 787	955	59 560	993
1:20	1 765	115 650	1 928	963	64 250	1 071
1:25	1 779	124 180	2 070	971	68 990	1 150
1:30	1 792	132 760	2 213	978	73 760	1 229
1:35	1 804	141 420	2 357	985	78 560	1 309
1:40	1 815	150 120	2 502	991	83 400	1 390
1:45	1 826	158 890	2 648	996	88 280	1 471
1:50	1 835	167 700	2 795	1 001	93 170	1 553
1:55	1 843	176 550	2 942	1 006	98 080	1 635
2:00	1 850	185 440	3 091	1 010	103 020	1 717
2:10	1 862	203 330	3 389	1 017	112 960	1 882
2:20	1 875	221 330	3 689	1 024	122 960	2 049
2:30	1 888	239 470	3 991	1 031	133 040	2 217
2:40	1 900	257 720	4 295	1 038	143 180	2 386
2:50	1 912	276 110	4 602	1 045	153 390	2 556
3:00	1 925	294 610	4 910	1 052	163 670	2 728
3:10	1 938	313 250	5 221	1 059	174 030	2 900
3:20	1 950	332 000	5 533	1 066	184 450	3 074
3:30	1 962	350 890	5 848	1 072	194 940	3 249
3:40	1 975	369 890	6 165	1 079	205 500	3 425
3:50	1 988	389 030	6 484	1 086	216 130	3 602
4:00	2 000	408 280	6 805	1 093	226 820	3 780
4:10	2 012	427 670	7 128	1 100	237 590	3 960
4:20	2 025	447 180	7 453	1 107	248 430	4 140
4:30	2 038	466 810	7 780	1 114	259 340	4 322
4:40	2 050	486 560	8 110	1 121	270 310	4 505
4:50	2 062	506 450	8 441	1 128	281 360	4 689
5:00	2 075	526 450	8 774	1 135	292 470	4 874
5:10	2 088	546 580	9 110	1 142	303 660	5 061
5:20	2 100	566 840	9 447	1 149	314 910	5 248
5:30	2 112	587 220	9 787	1 156	326 240	5 437
5:40	2 125	607 730	10 129	1 163	337 630	5 627
5:50	2 138	628 360	10 473	1 170	349 090	5 818
6:00	2 150	649 120	10 819	1 177	360 620	6 010
6:10	2 162	670 000	11 167	1 184	372 230	6 204
6:20	2 175	691 010	11 517	1 191	383 900	6 398
6:30	2 188	712 140	11 869	1 198	395 640	6 594

Table C-2. Cable Descriptions for C5159-3 Fire Stop Test, September 7, 1979

Cable Code	Description	Outside Diameter
912-27	9/C, #12 American Wire Gage (AWG), STR 3/64" FR Insulation, FR Jacket, Kerite - 600 volt rating	0.84 in
C12	12/C, #12 AWG, STR 3/64", FR Insultion, FR Jacket, Kerite - 600 volt rating	0.96"

Table C-3. Tabulation of 700° F Temperature Crossover Points Plus End-of-Test Penetration Temperatures for Fire Stop Test C5159 2, September 7, 1979

Tray No.	TC No.	Time at 700° F Crossover	3-h Temp, °F
1	1	-	190
	2	-	380
	3	-	420
	4	-	350
	5	-	320
	6	-	330
	7	-	260
	8	-	195
	9	-	280
	10	-	350
	26	-	231
	*	-	-
	28	-	271
	29	-	185
	30	-	280
	31	-	438
	32	-	429
	33	-	385
	34	-	374
2	11	2 hr - 57 min	710
	12	2 hr - 48 min	820
	13	1 hr - 55 min	1032 (Max 1056)
	14	1 hr - 53 min	942
	15	2 hr - 12 min	886
	16	1 hr - 40 min	1010
	17	2 hr - 40 min	818
	18	-	512
	19	-	640
	20	2 hr - 10 min	910
	21	-	290
	22	-	268
	23	-	314
	24	-	327
	25	-	300

* There was no TC number 27 in the fire stop test.

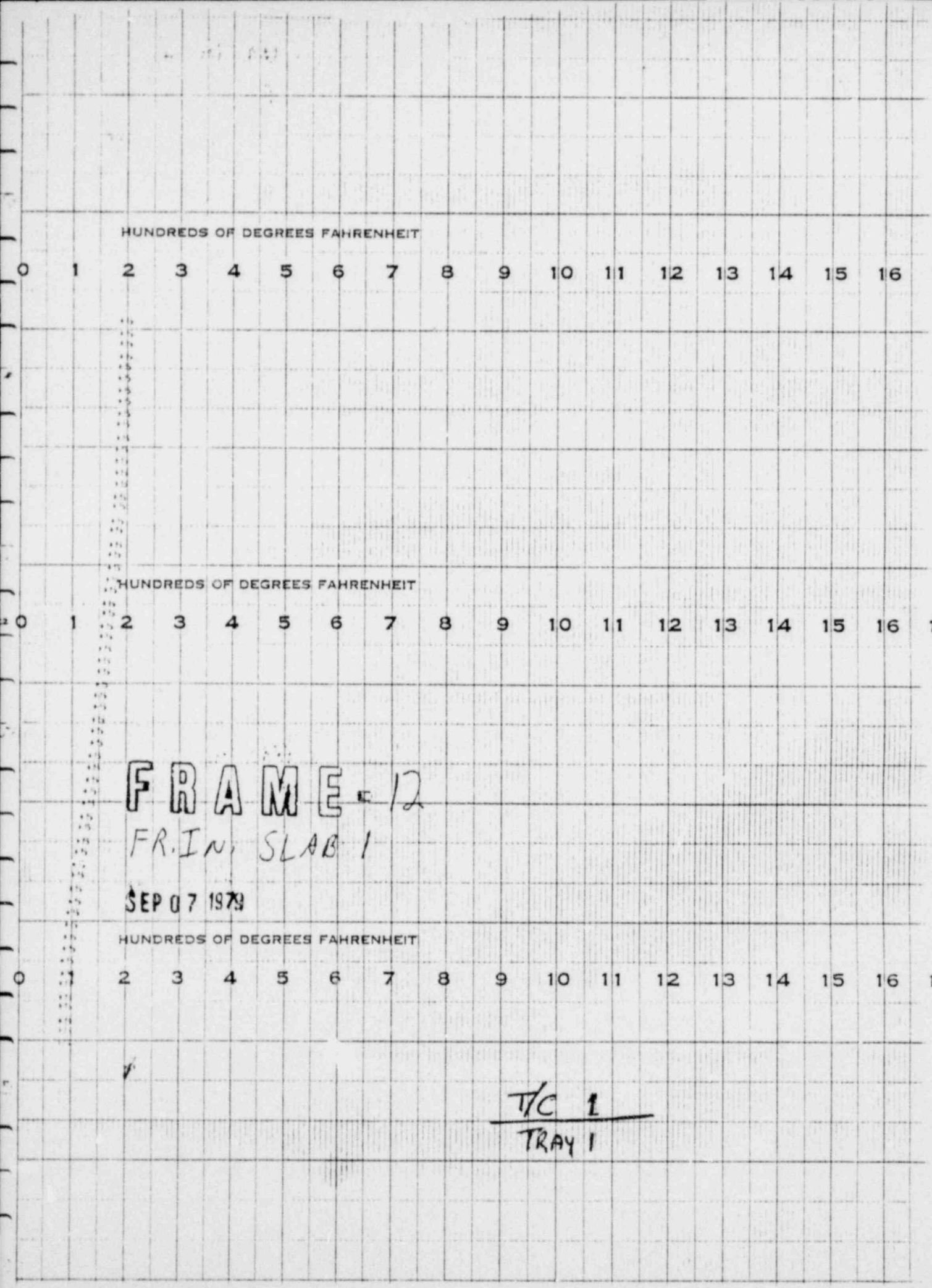
TEST SLAB THERMOCOUPLE DATA

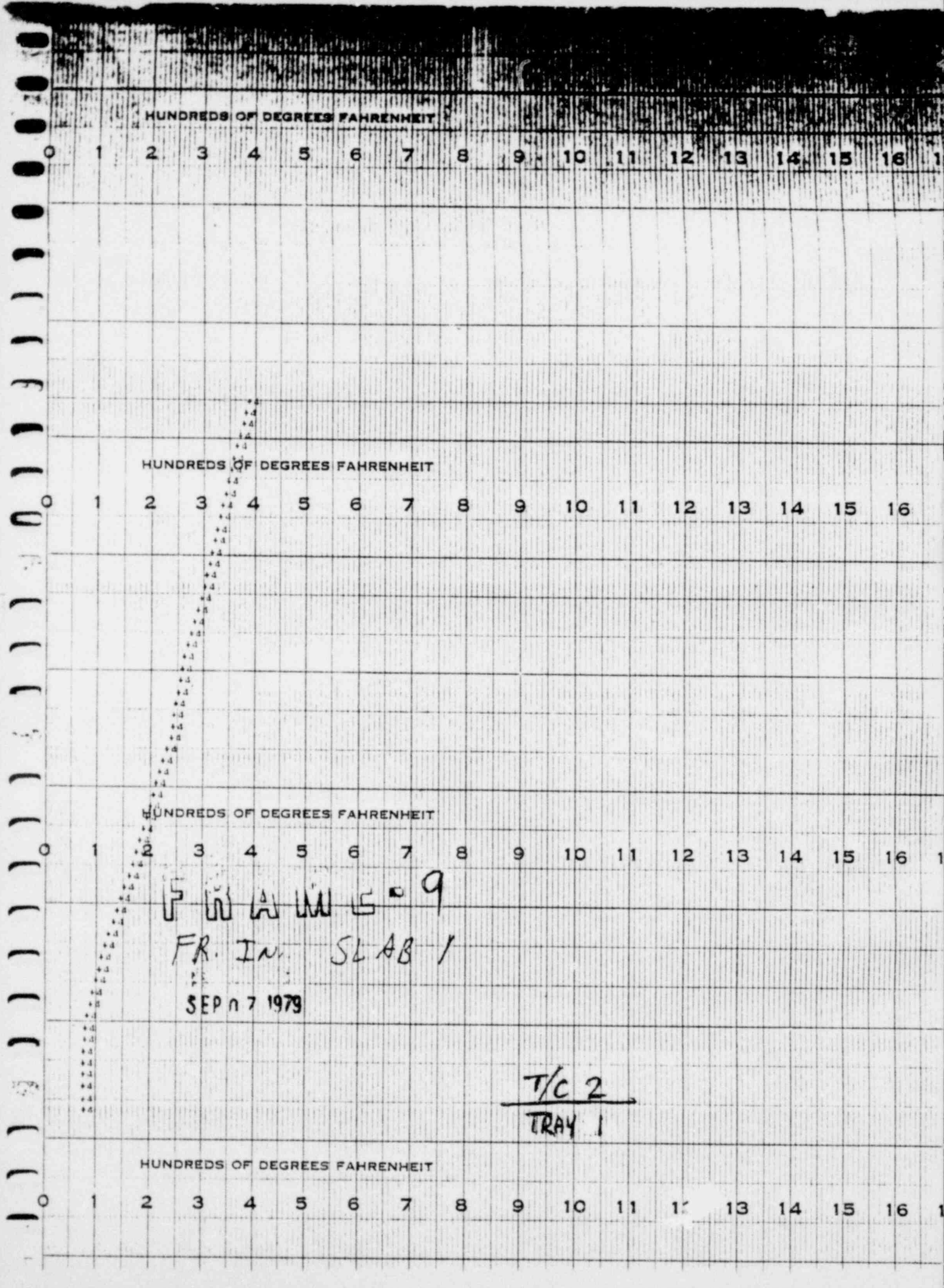
APPENDIX D

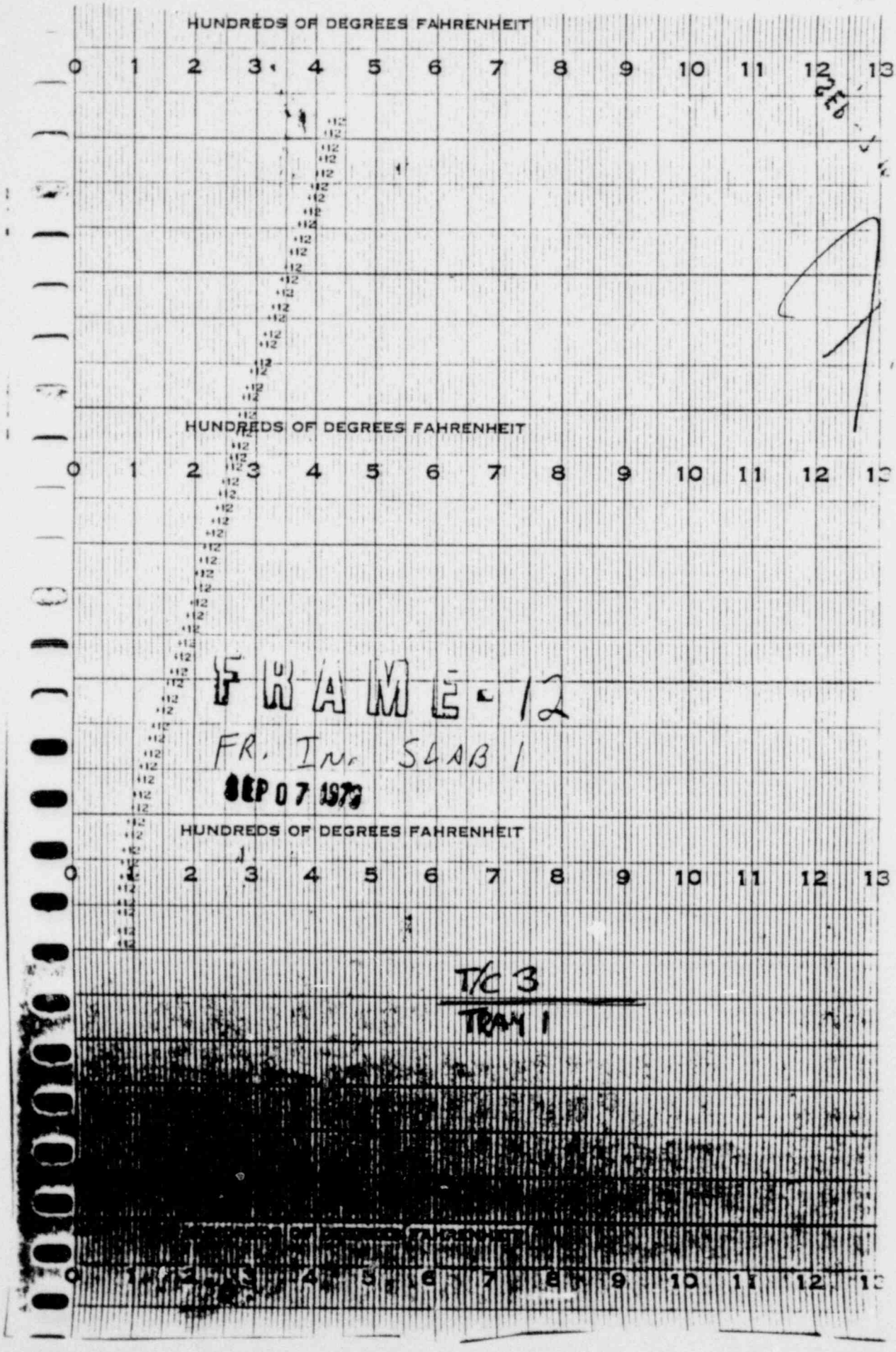
Test C5159-3, September 7, 1979
TC 1 to 26 and TC 28 to 34
Data in Ascending Order

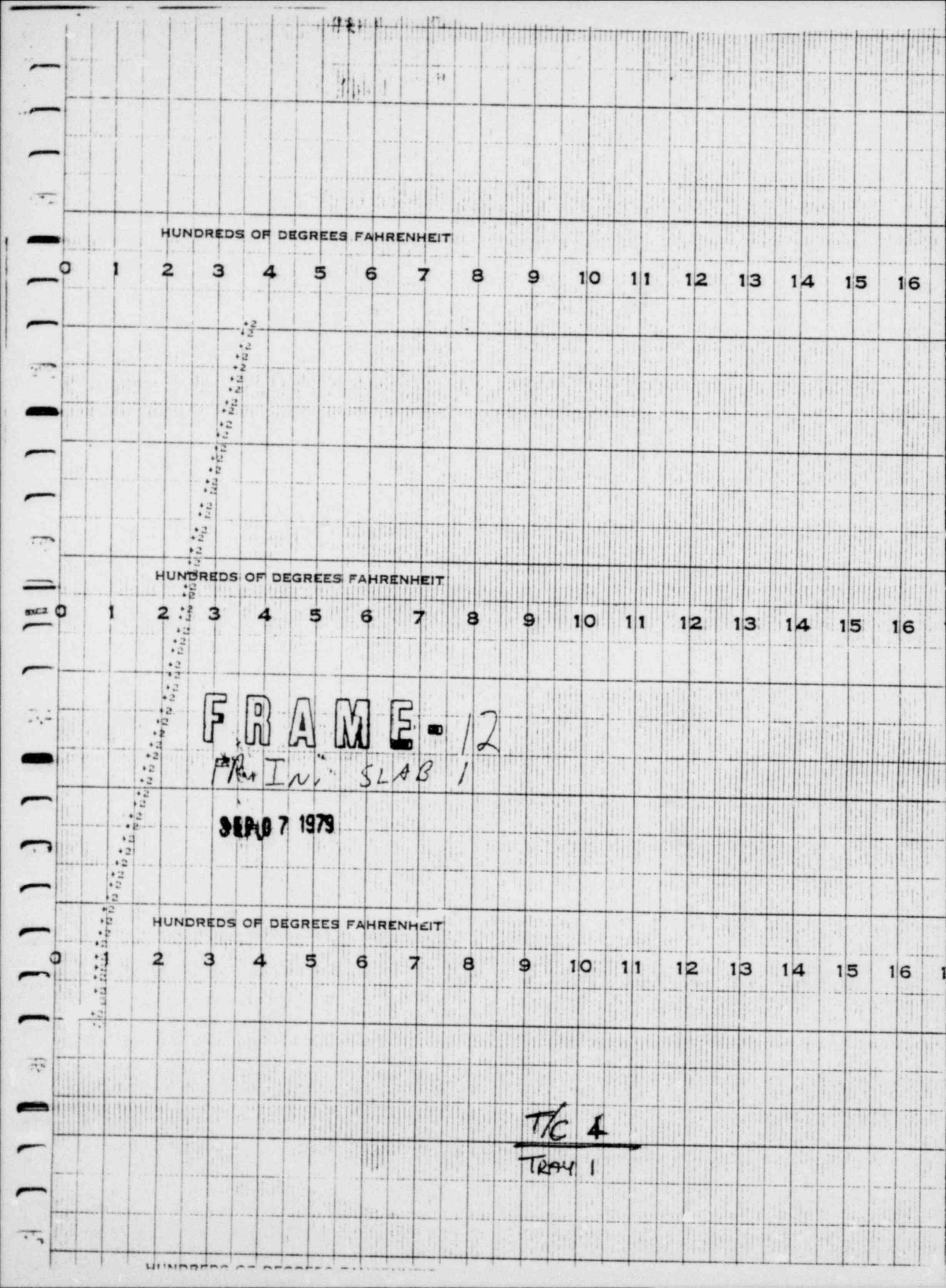
Note: There was no TC number 27
in the fire stop test.

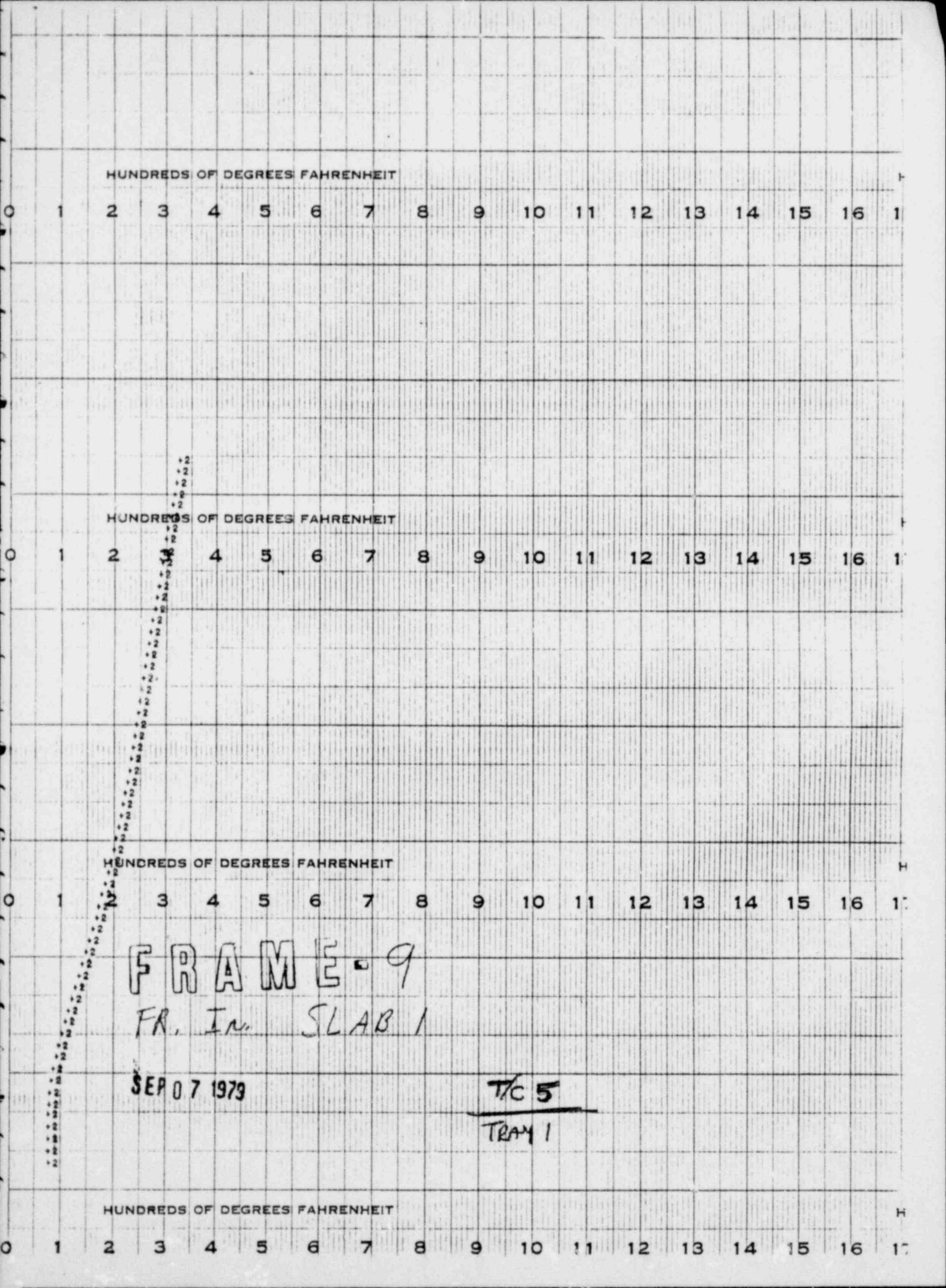
Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

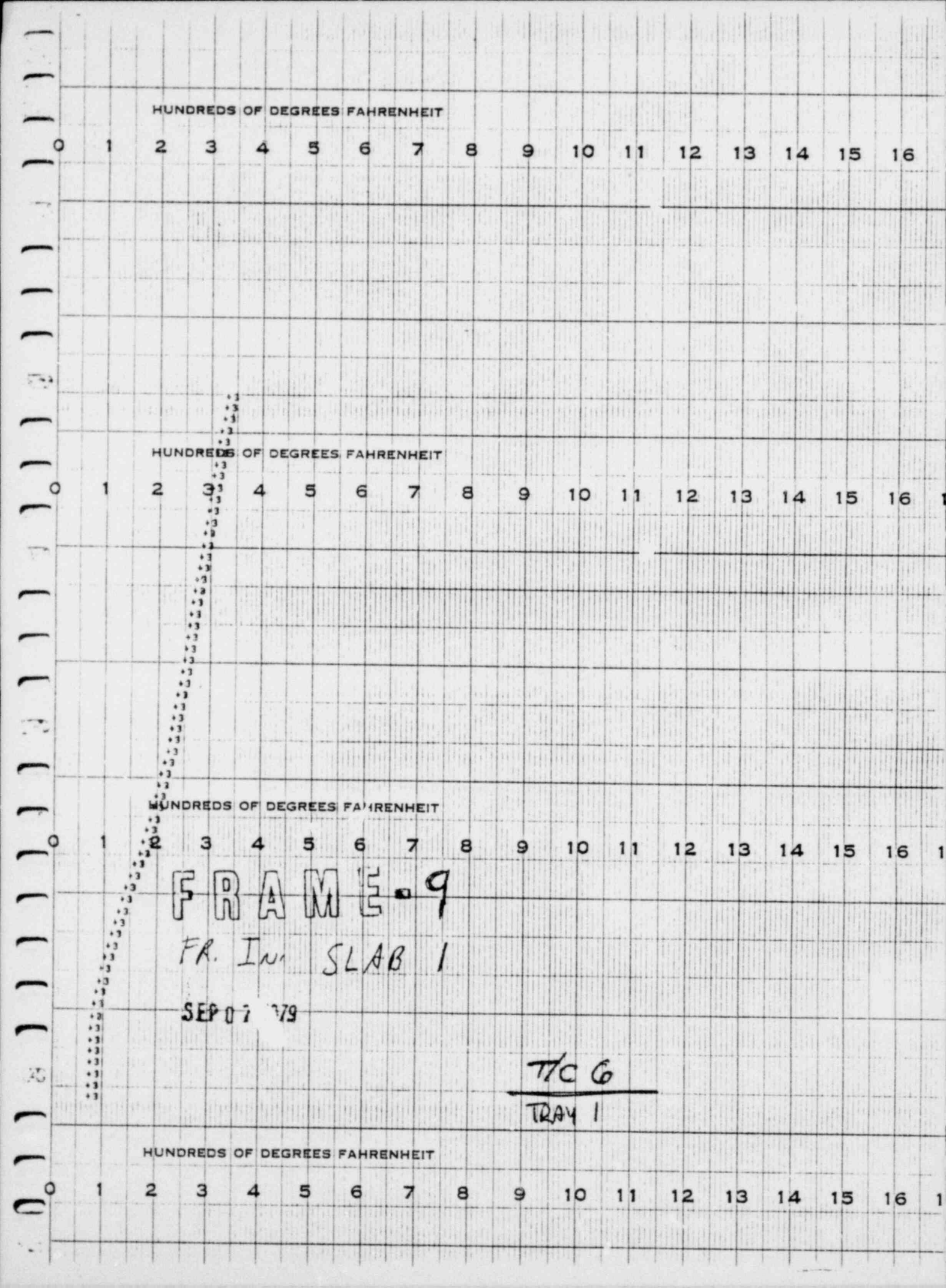

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR.IN, SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 1
TRAY 1

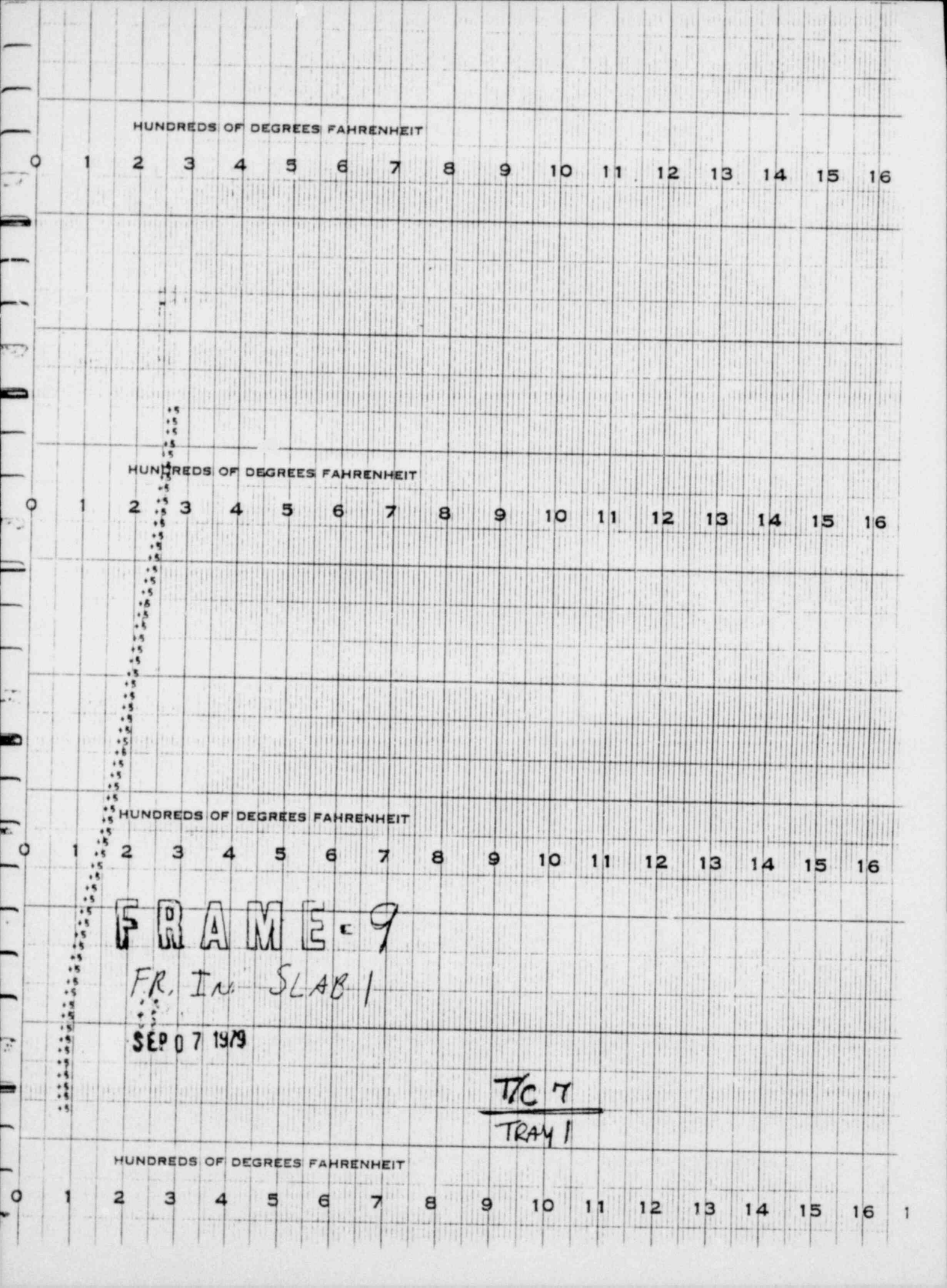

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME 9
FR. IN. SLAB 1
SEP 7 1979
T/C 2
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

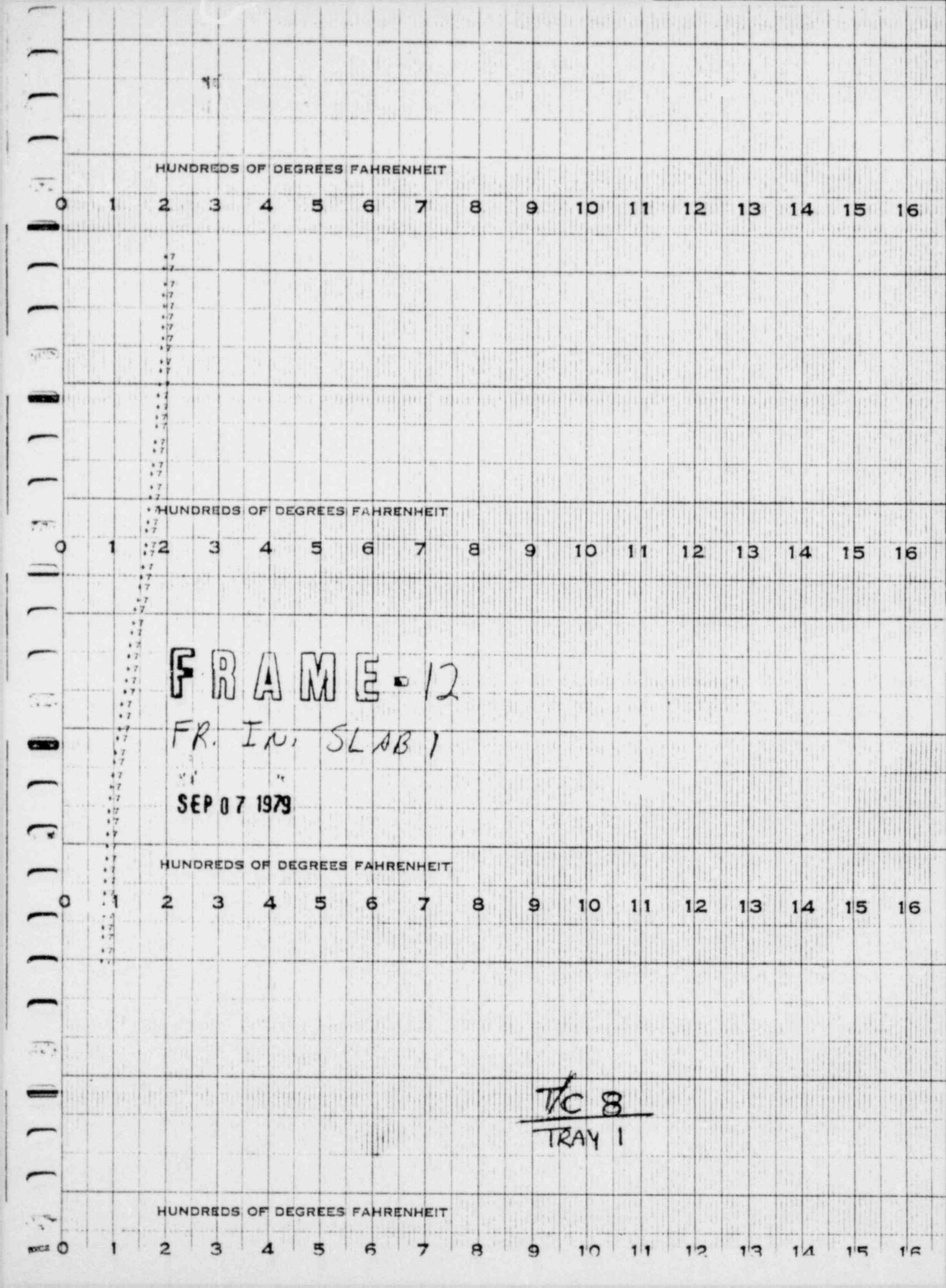

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
FRAME-12
FR. IN. SAAB 1
SEP 07 1978
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
T/C 3
TRAM 1
0 1 2 3 4 5 6 7 8 9 10 11 12 13

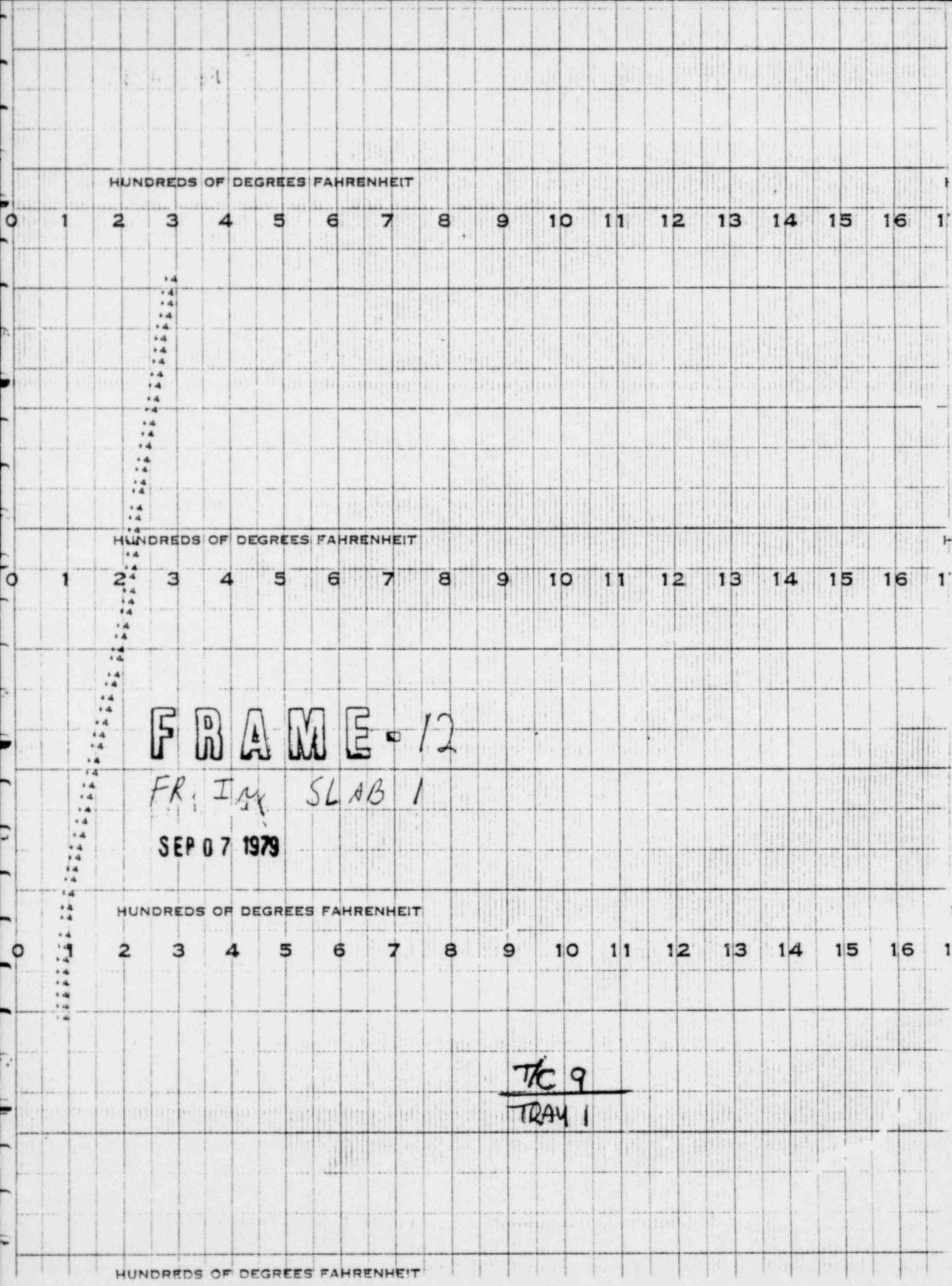

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
PRIN, SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 4
TRAY 1

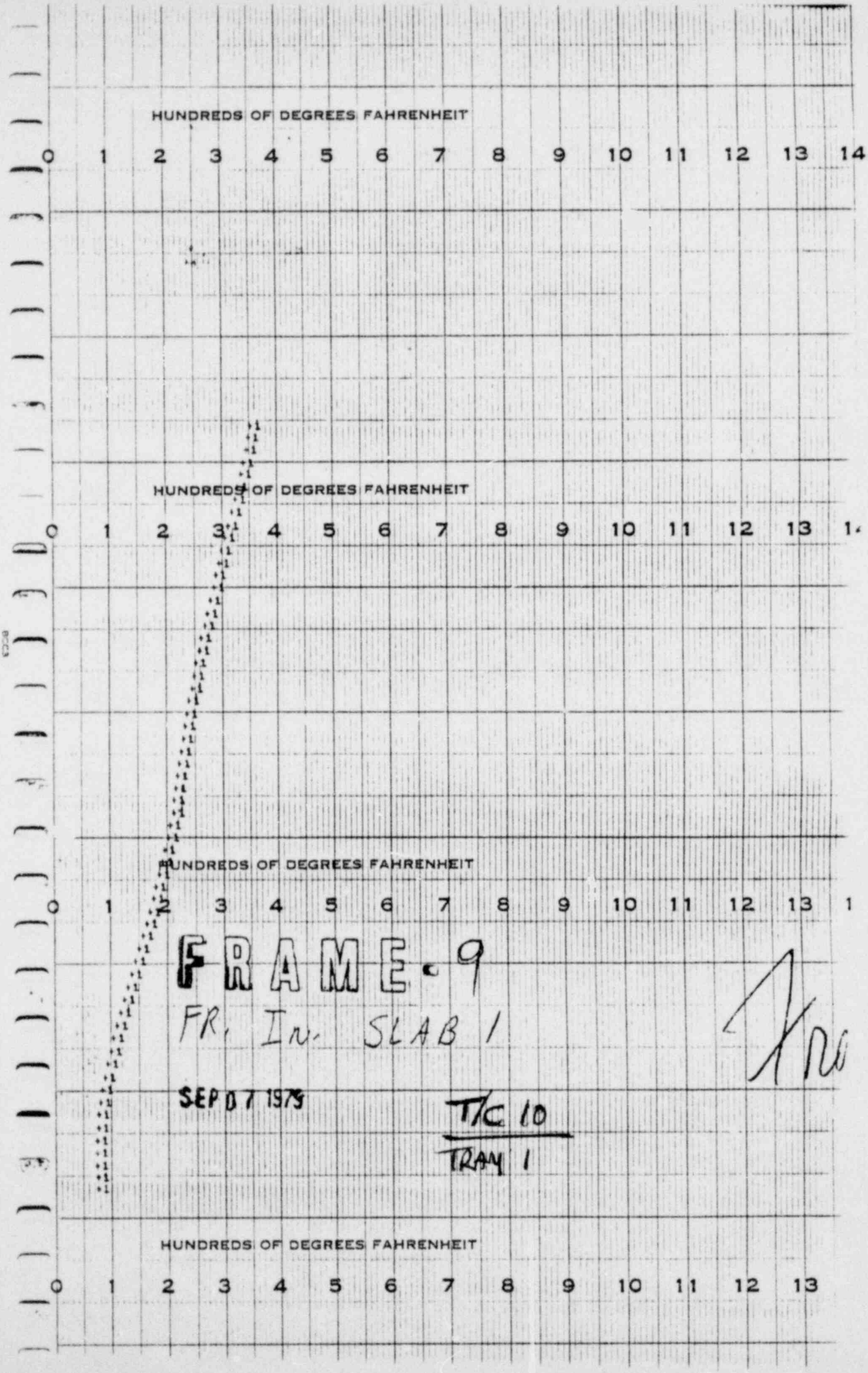

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-9
FR. IN. SLAB 1
SEP 07 1979
T/C 5
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

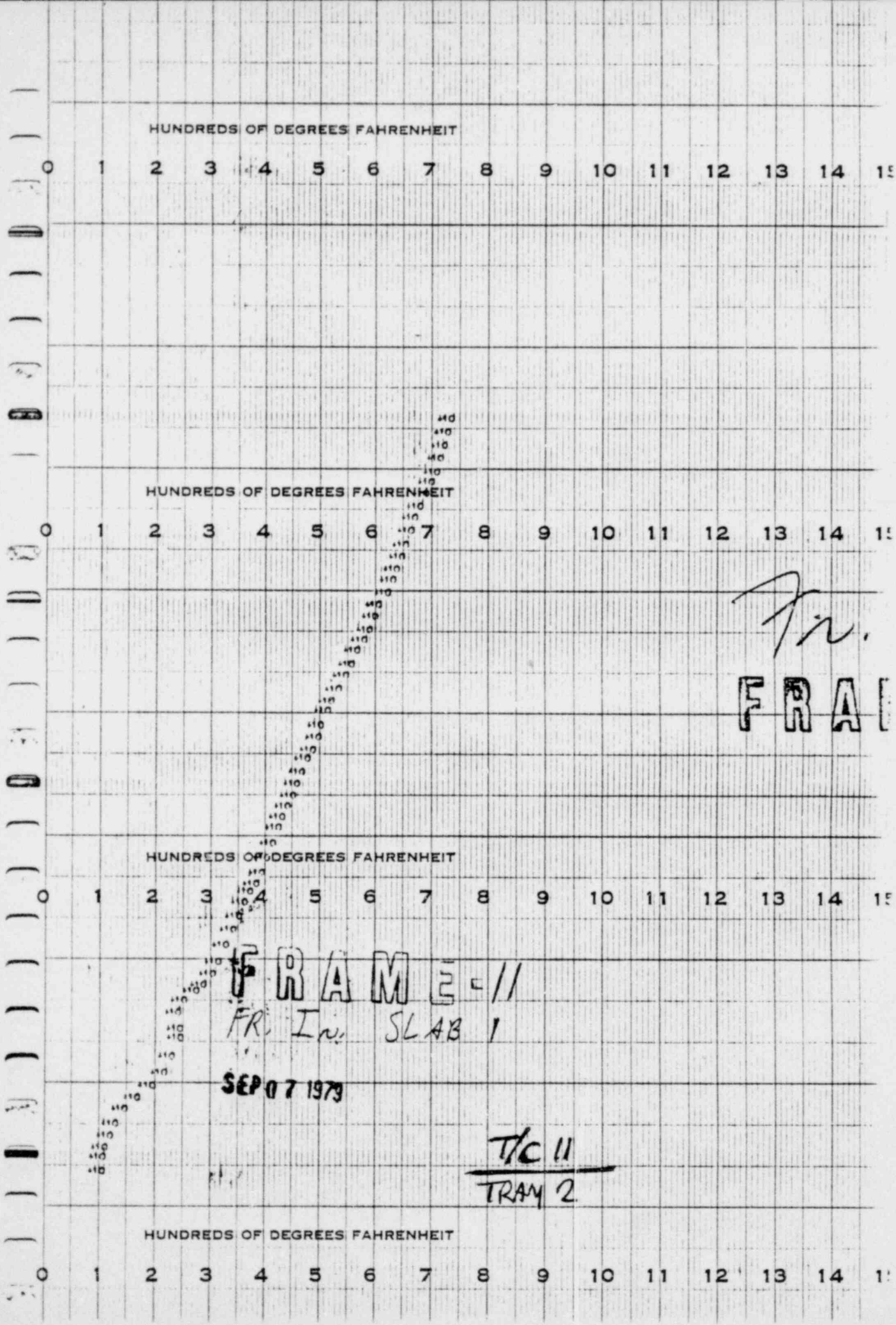

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-9
FR. IN SLAB 1
SEP 07 '79
T/C 6
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

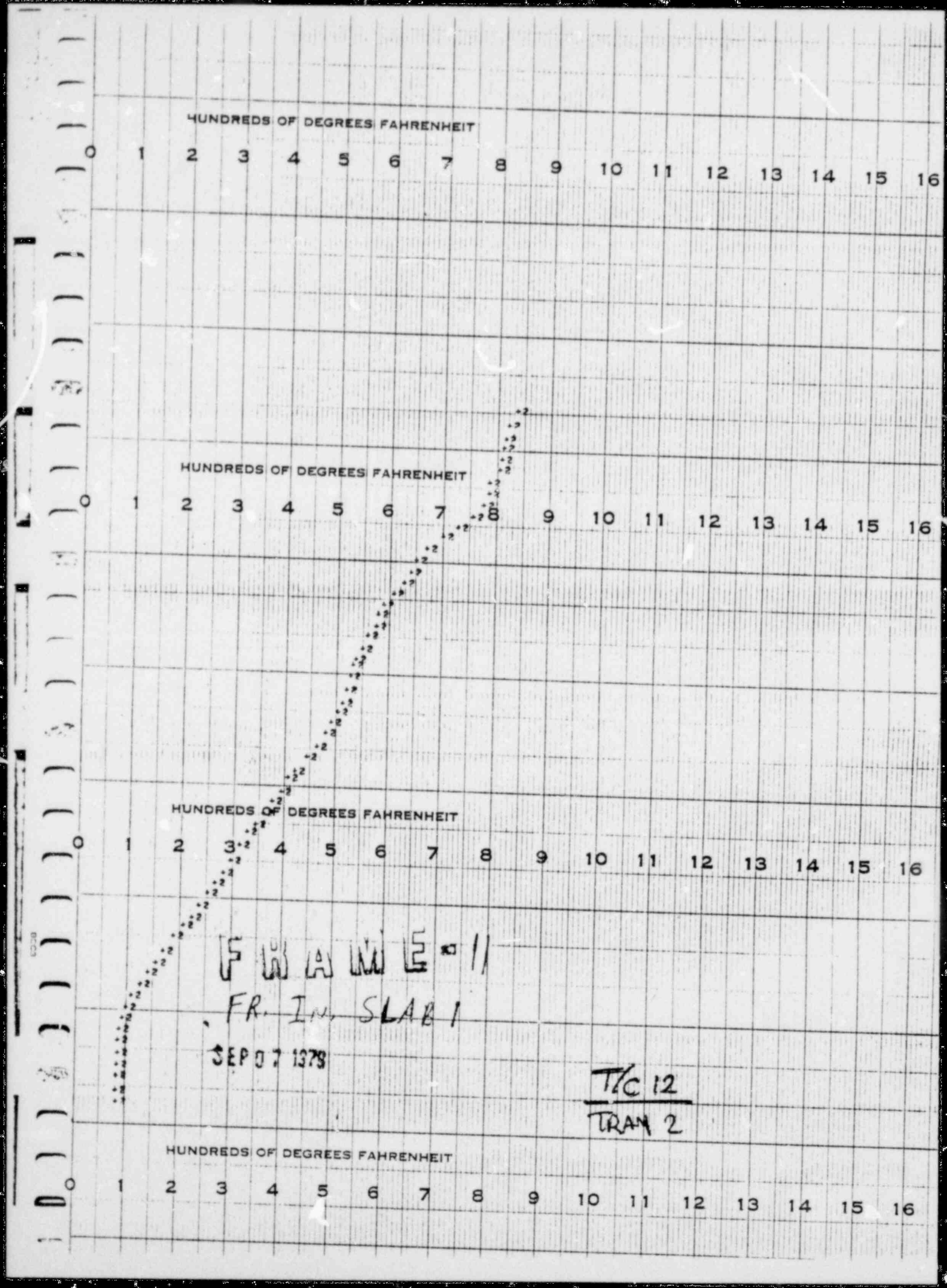

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME 9
FR. IN. SLAB 1
SEP 07 1979
T/C 7
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

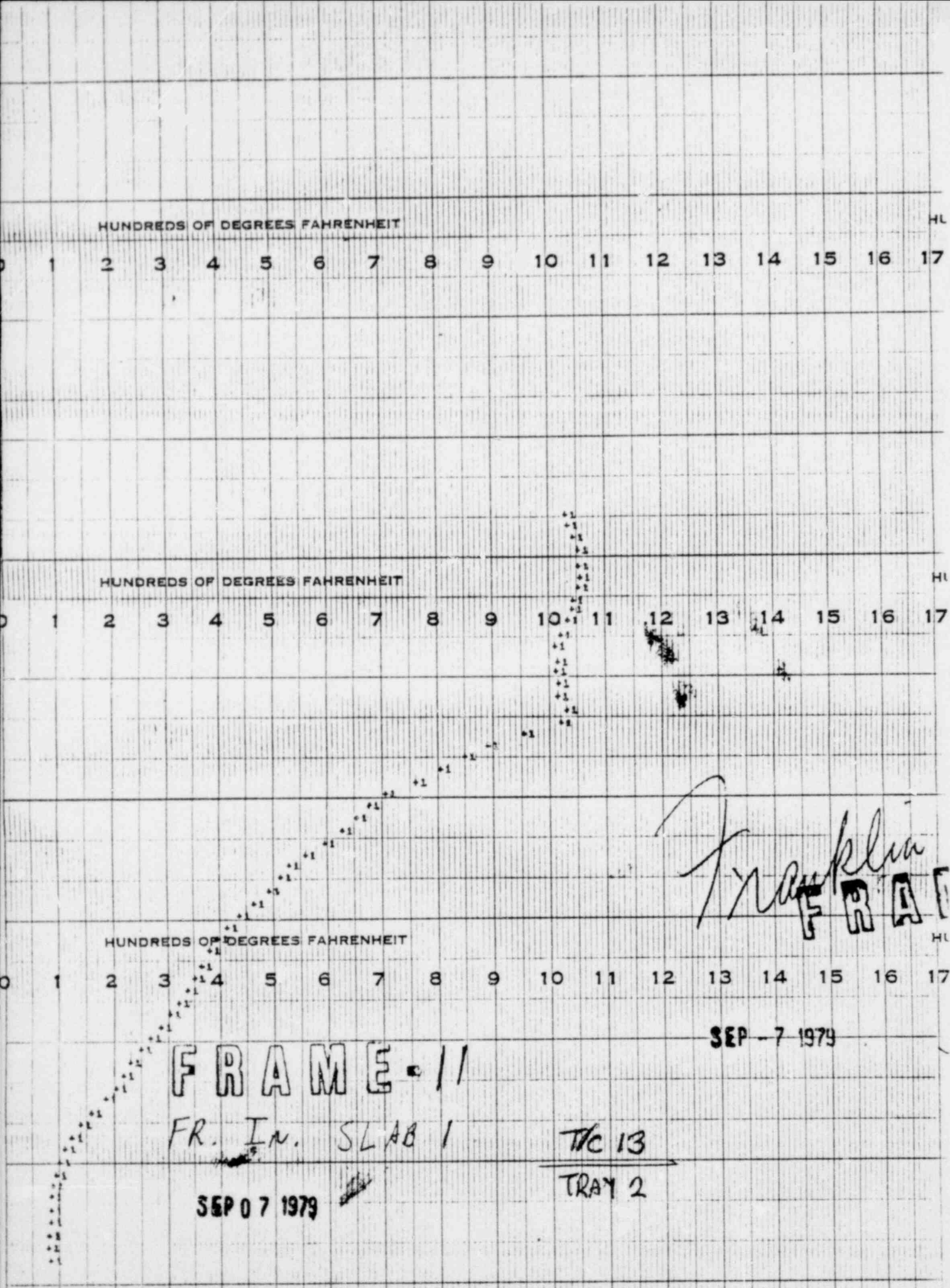

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 8
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

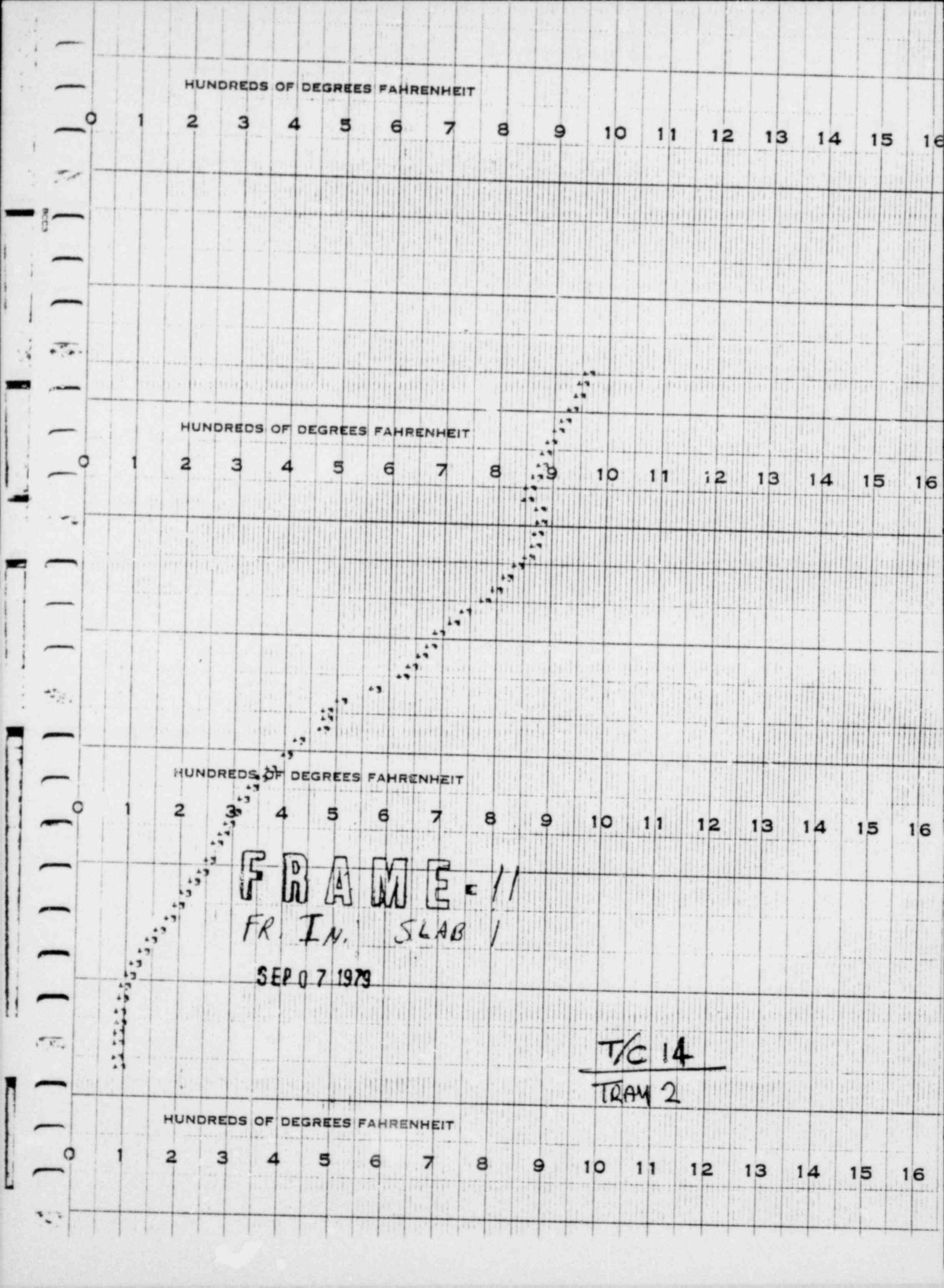

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 9
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT

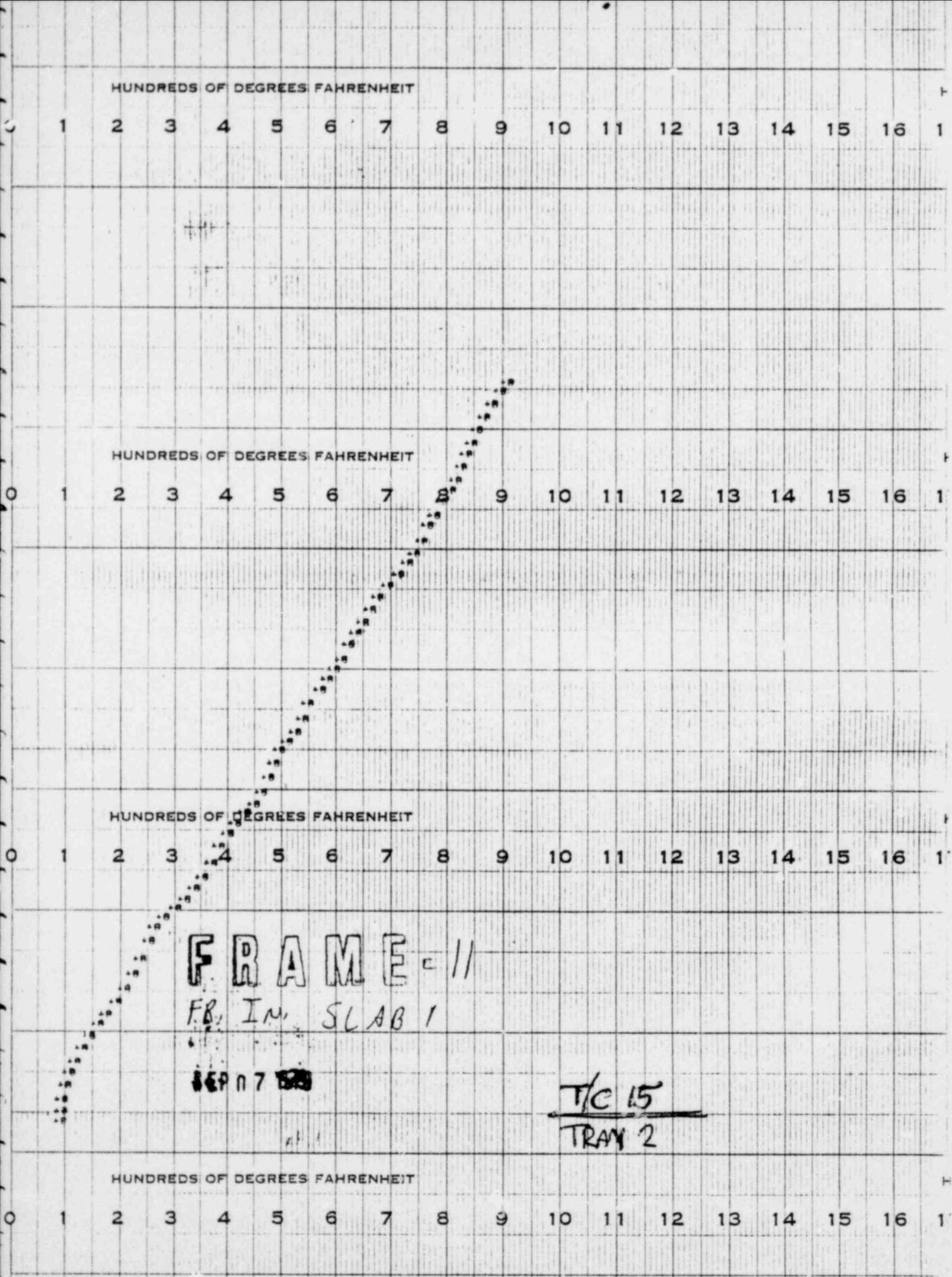

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
FRAME. 9
FR. IN. SLAB 1
SEP 07 1979
T/C 10
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13

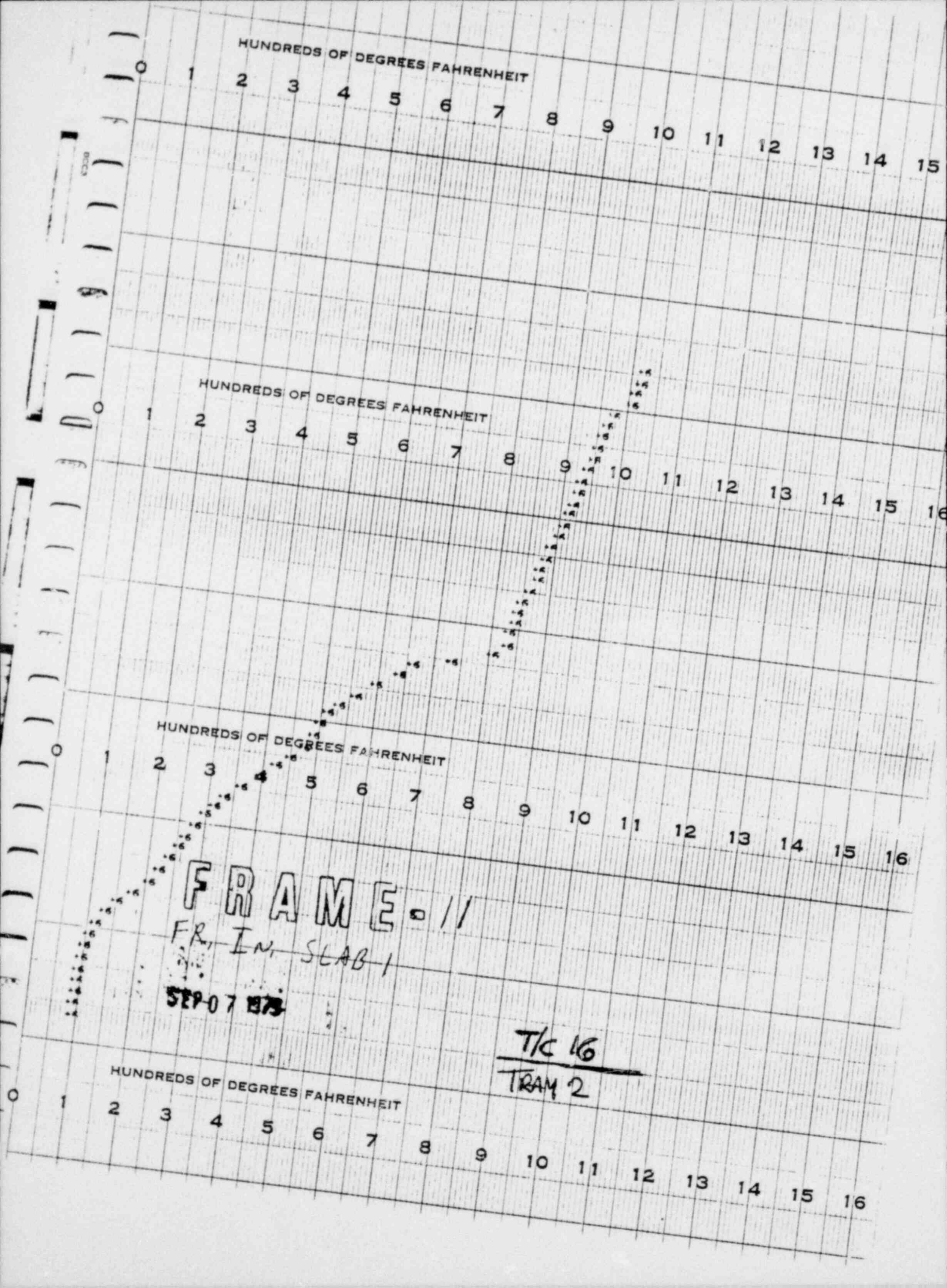

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
FRAME 2-11
FR. In. SLAB 1
SEP 07 1979
T/C 11
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

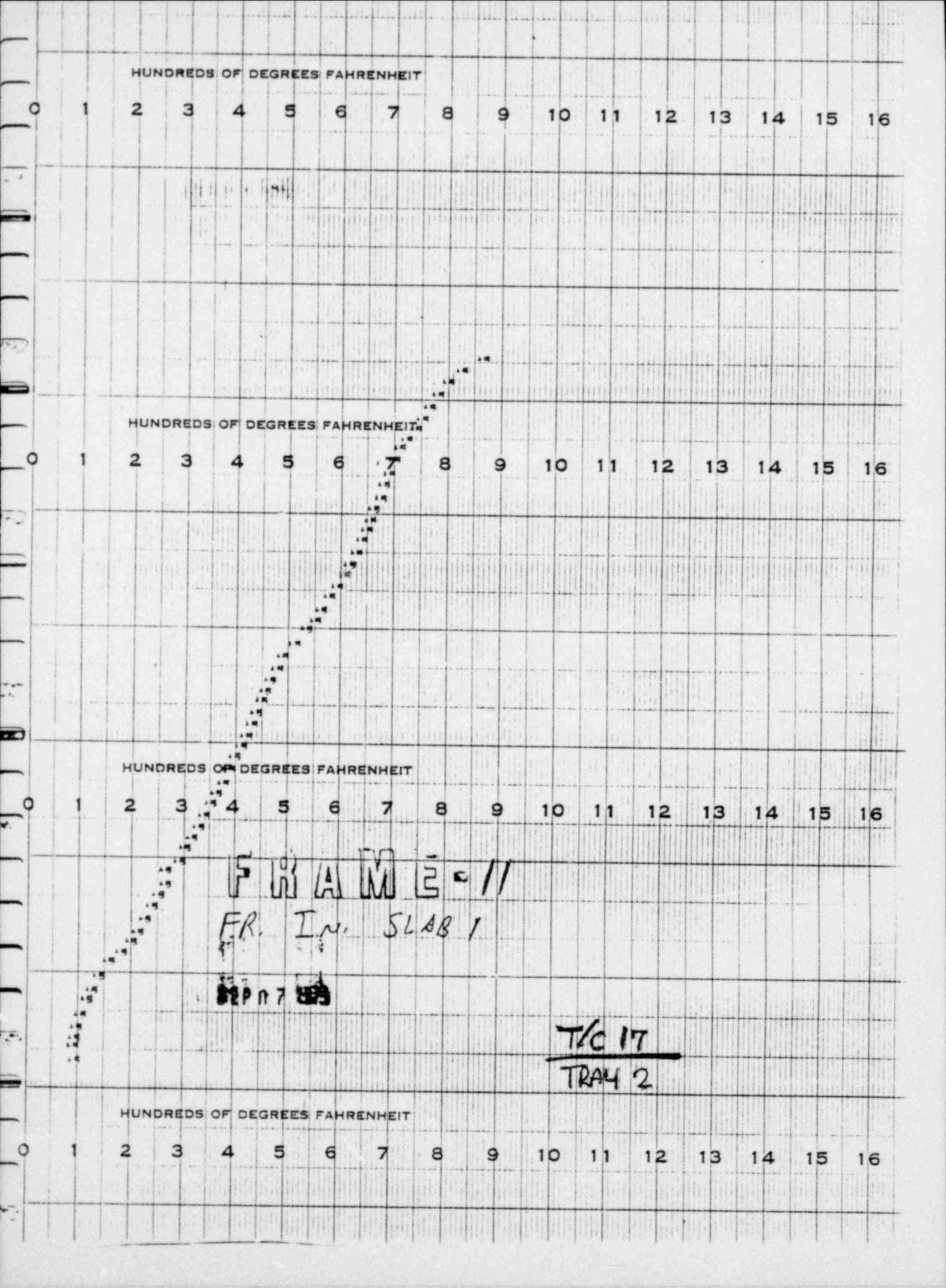

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FWAME=11
FR. IN. SLAB 1
SEP 07 1979
T/C 12
TRAN 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

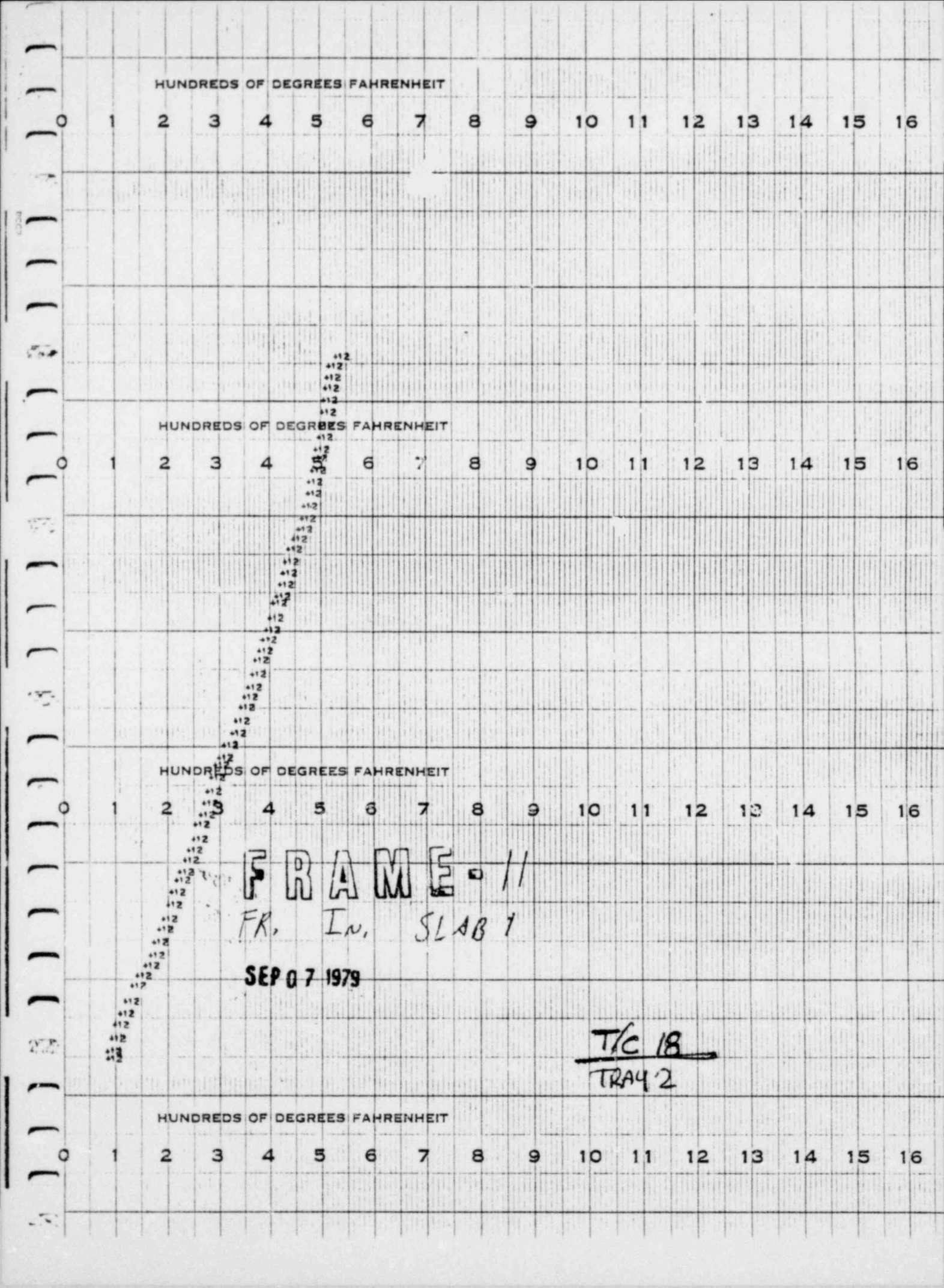

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Franklin
FRA
SEP - 7 1979
FRAME - 11
FR. IN. SLAB 1
T/C 13
TRAY 2
SEP 0 7 1979

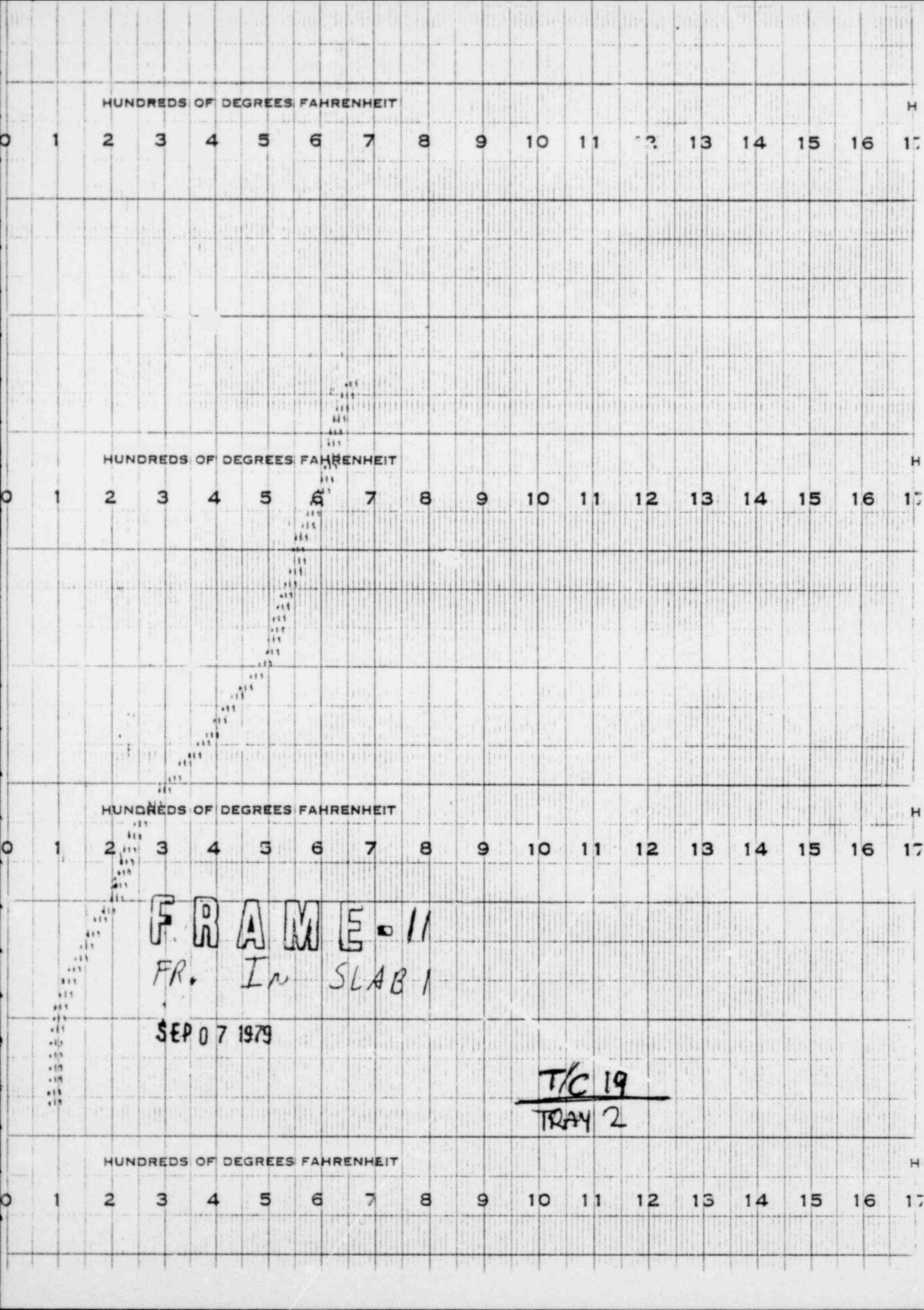

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-11
FR. IN. SLAB 1
SEP 07 1979
T/C 14
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

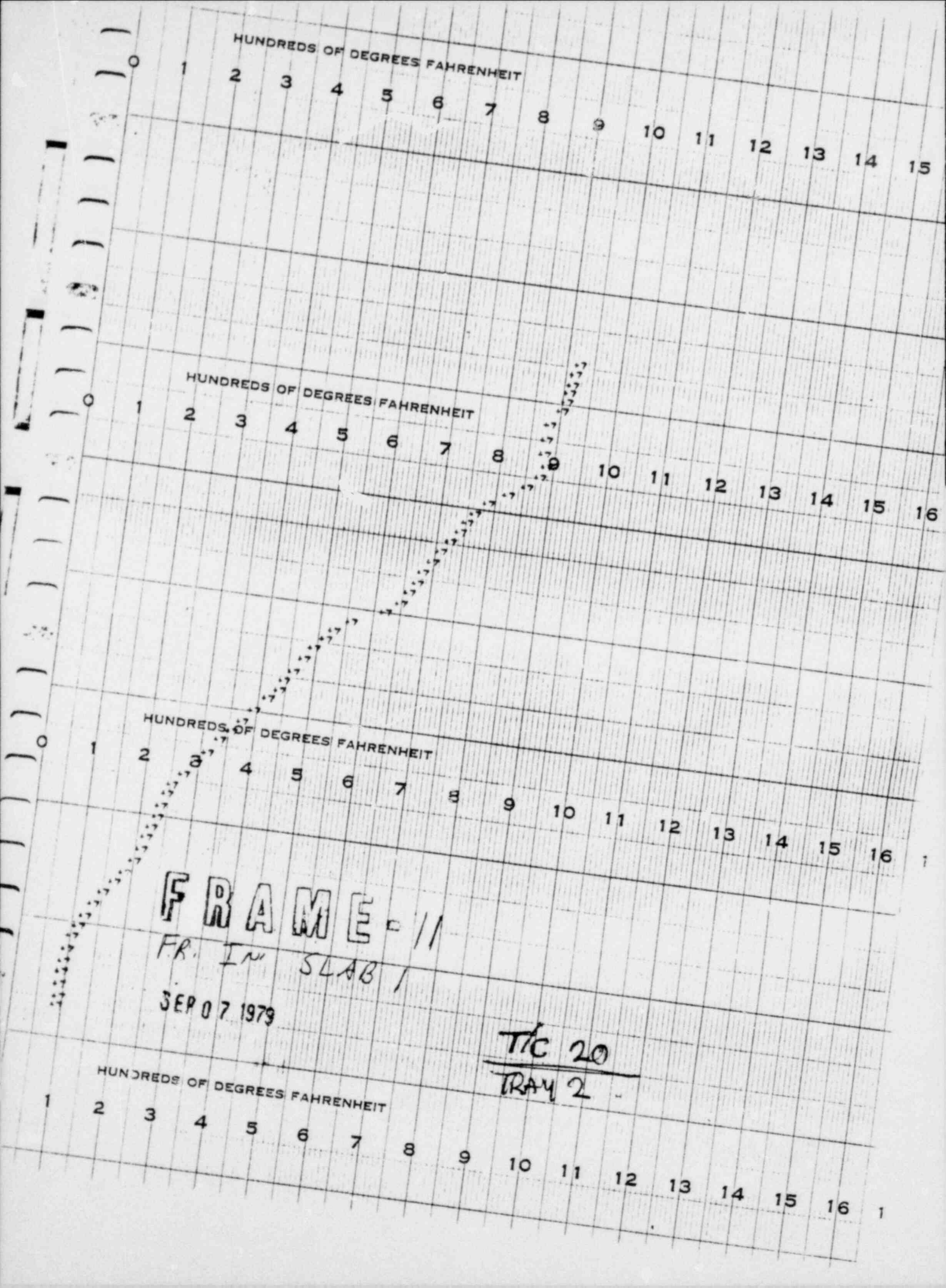

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1
FRAME-11
F.B. IN SLAB 1
T/C 15
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1

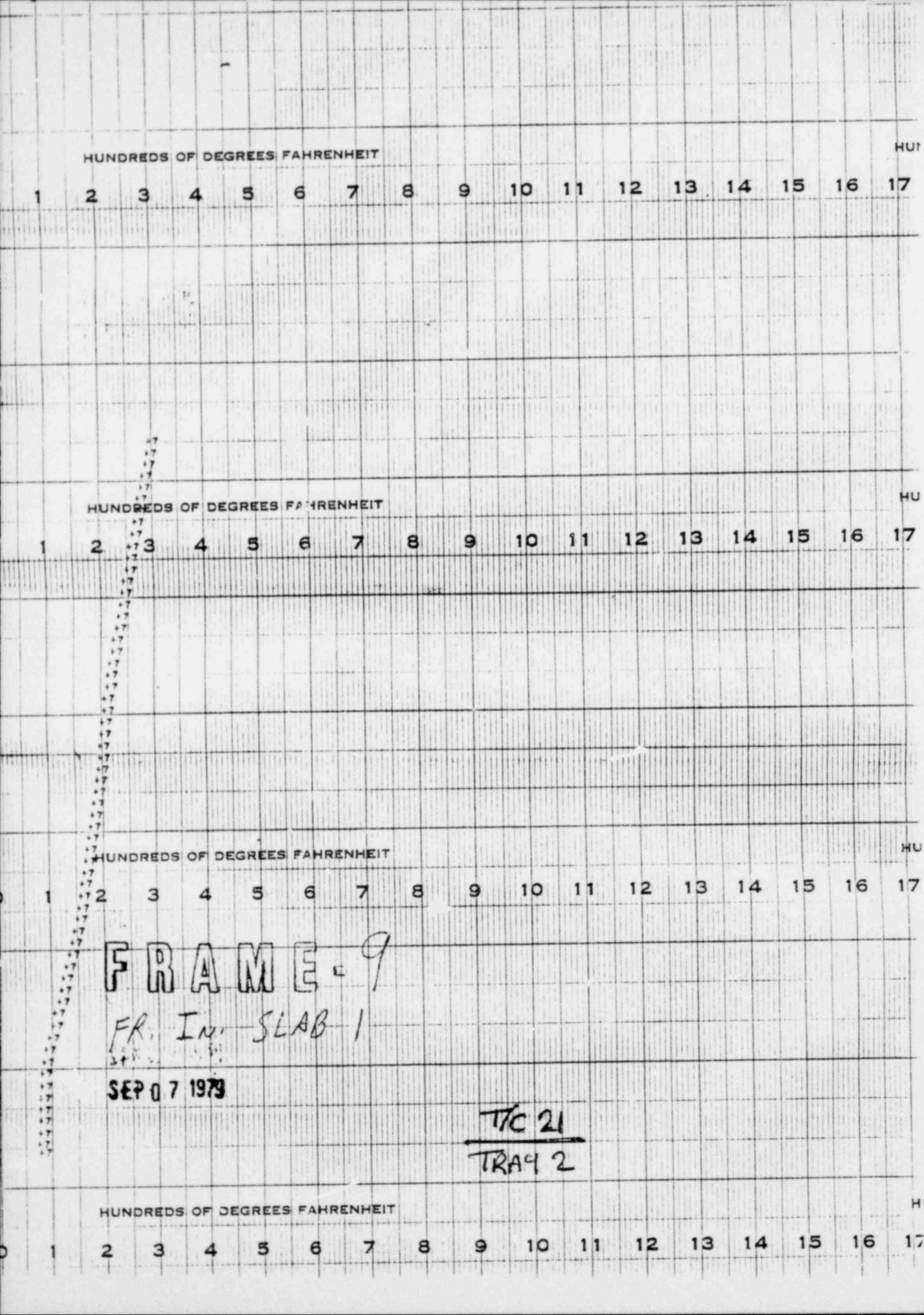

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-11
FR, IN, SLAB 1
SEP 07
T/C 16
TRAM 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

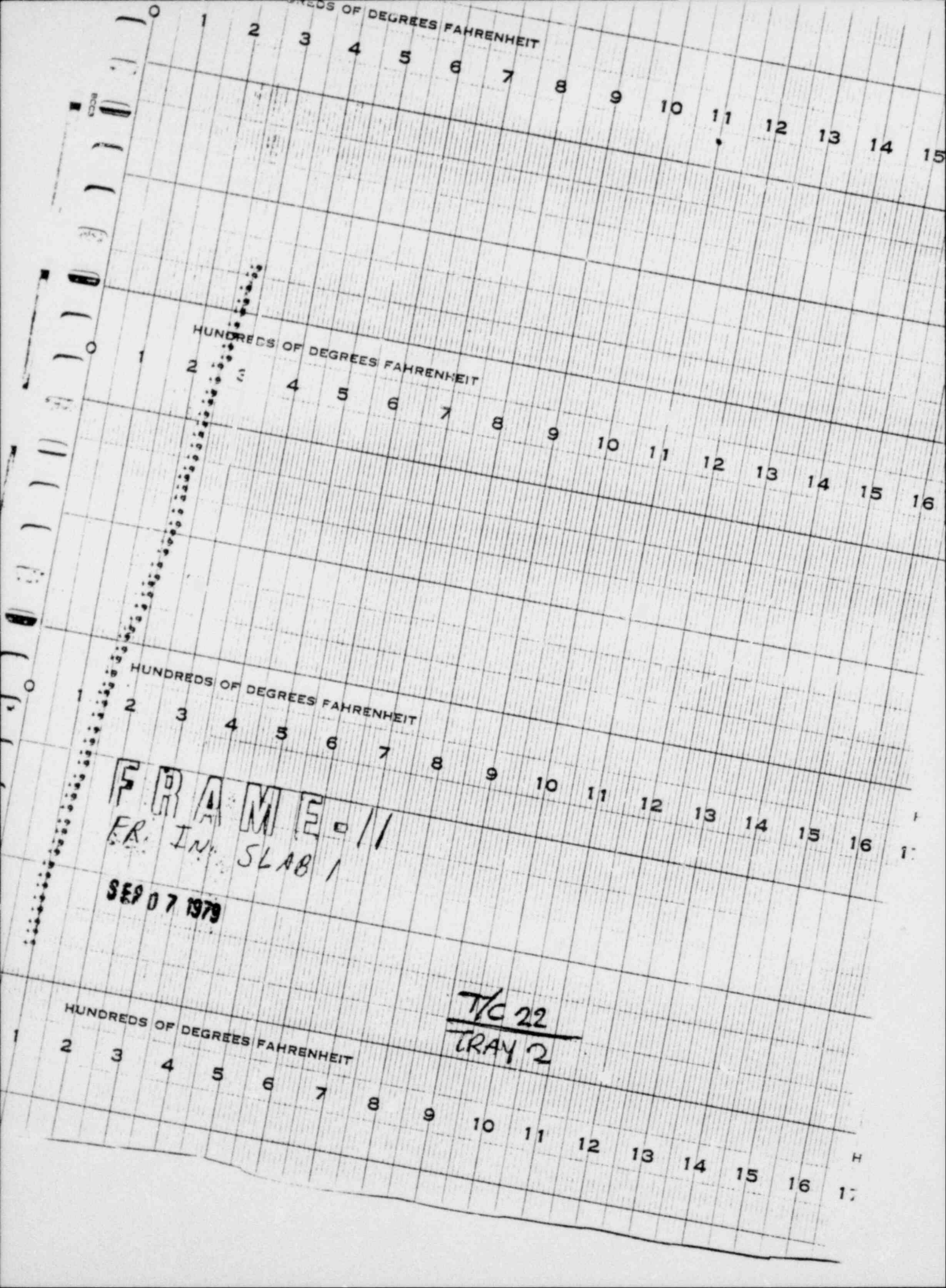

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-11
FR. IN. SLAB 1
T/C 17
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

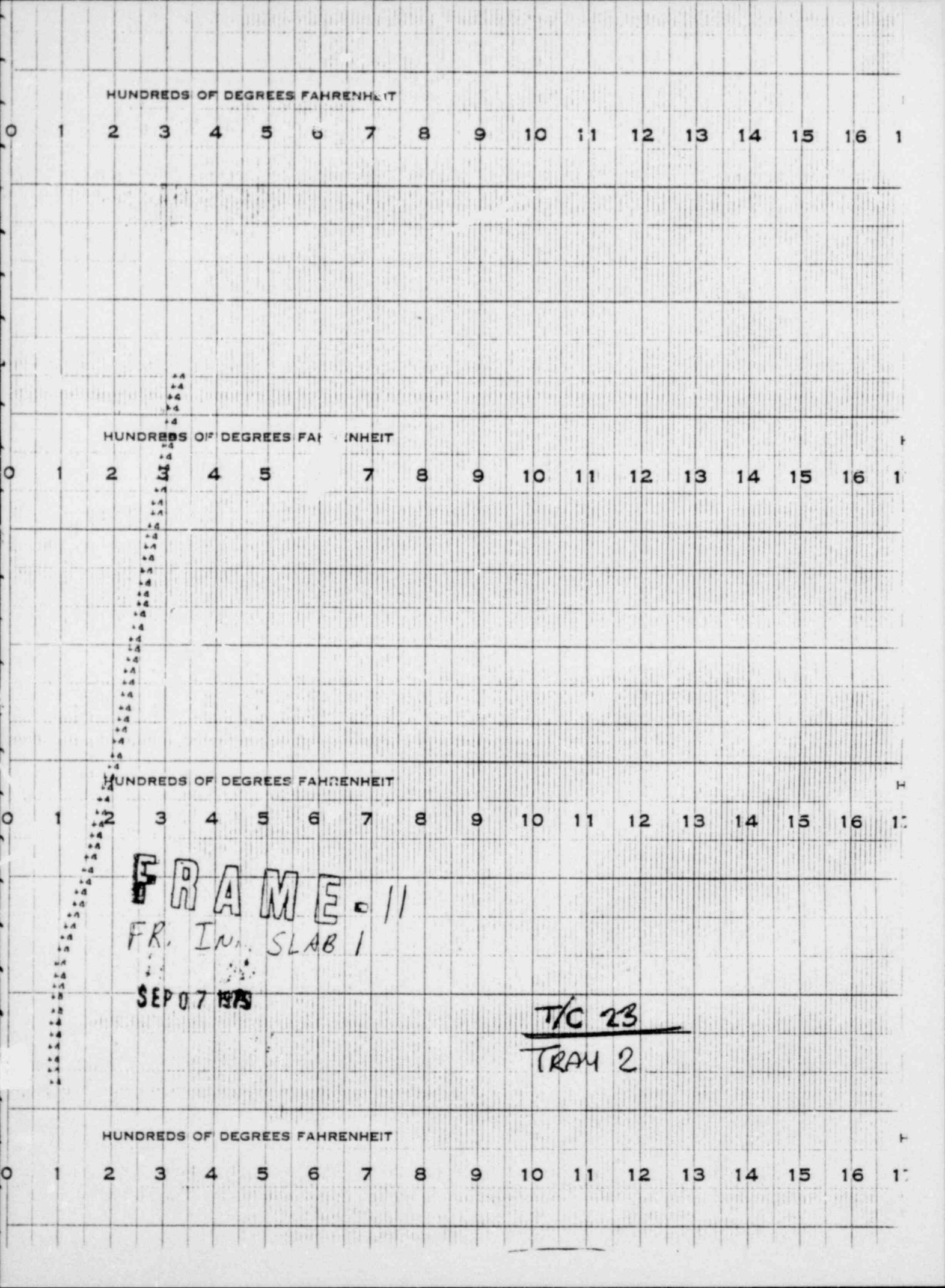

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-11
FR, IN, SLAB 1
SEP 07 1979
T/C 18
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

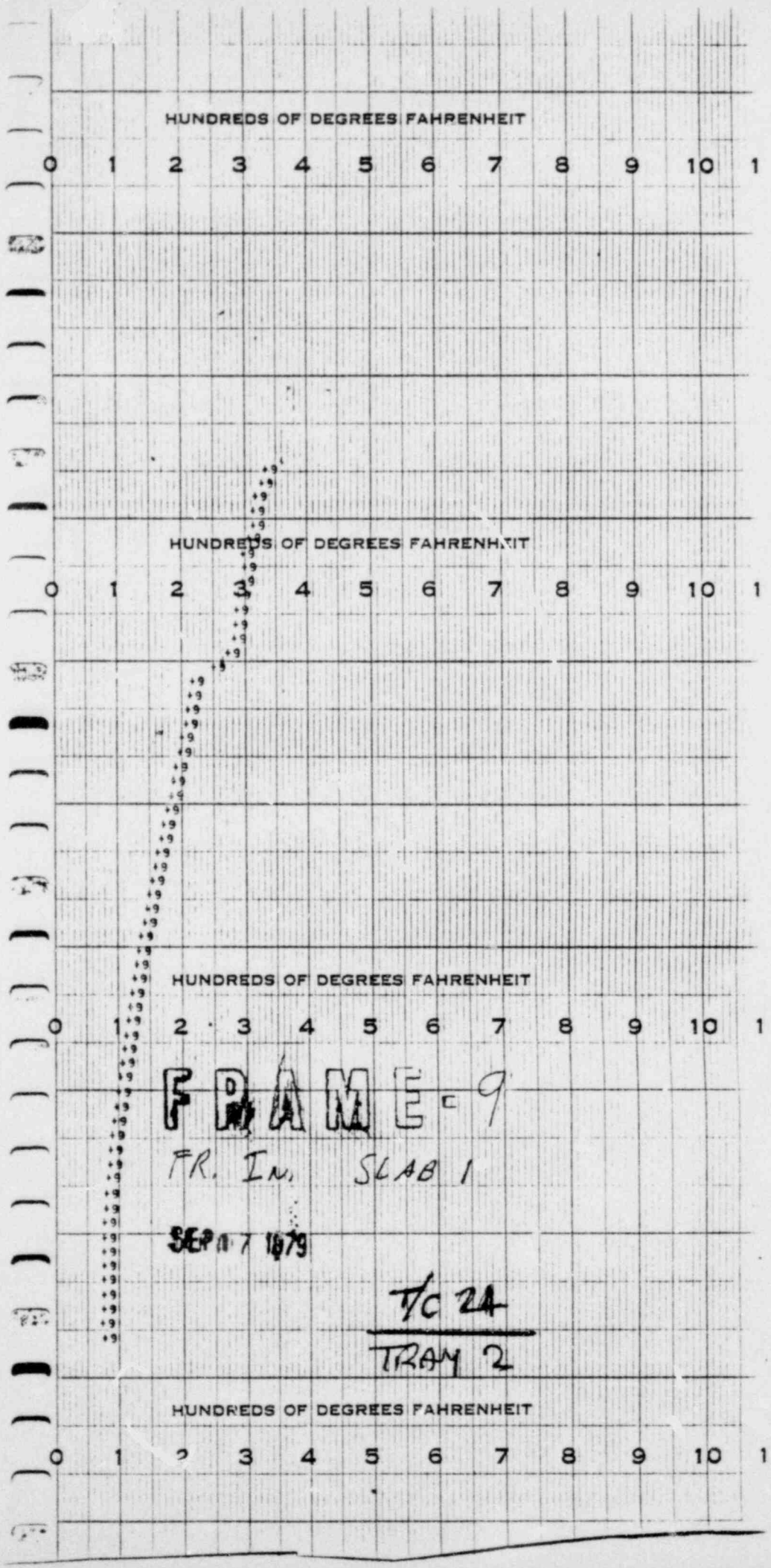

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
FRAME-11
FR. IN SLAB 1
SEP 07 1979
T/C 19
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

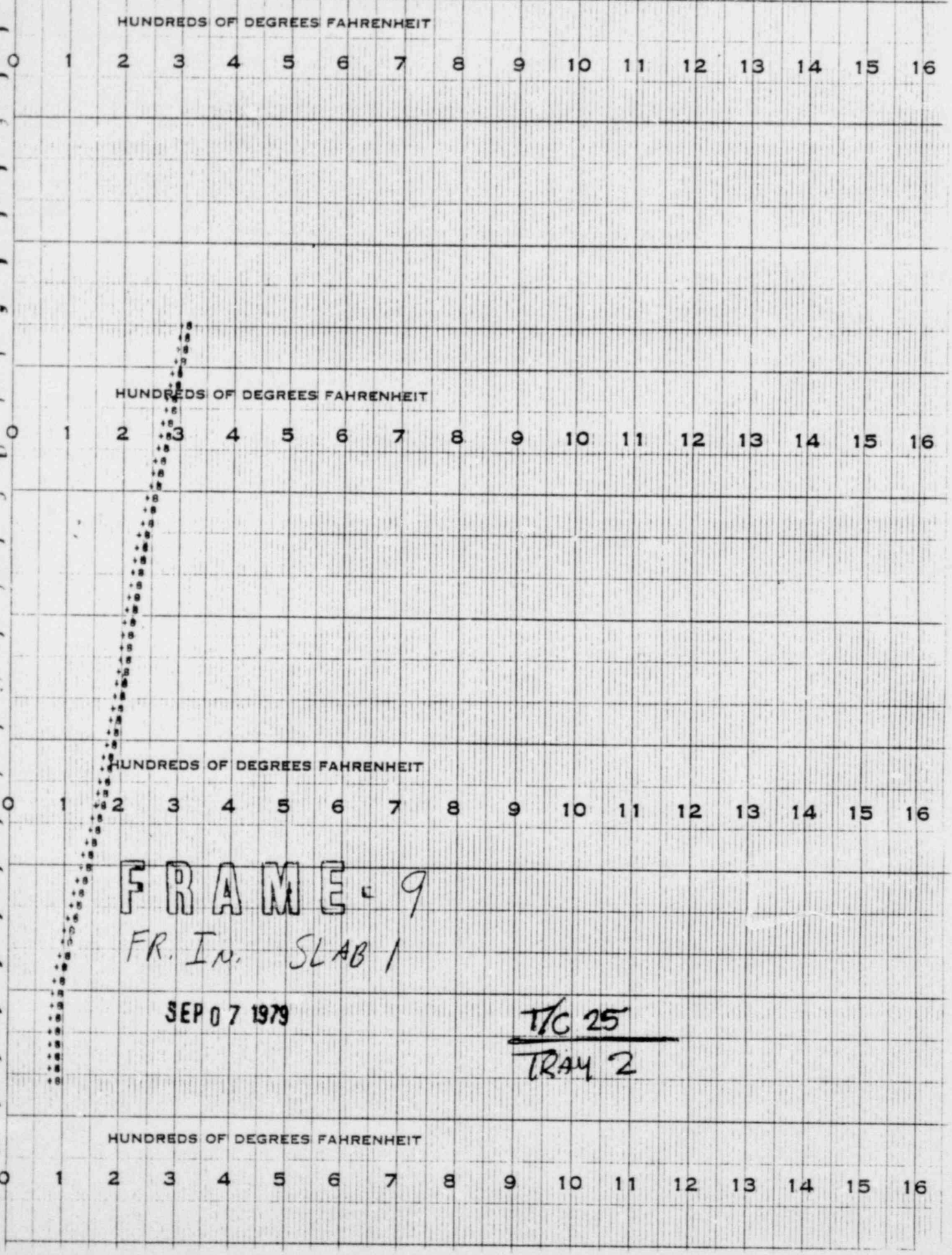

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME - 11
FR. IN SLAB 1
SEP 07 1979
T/C 20
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

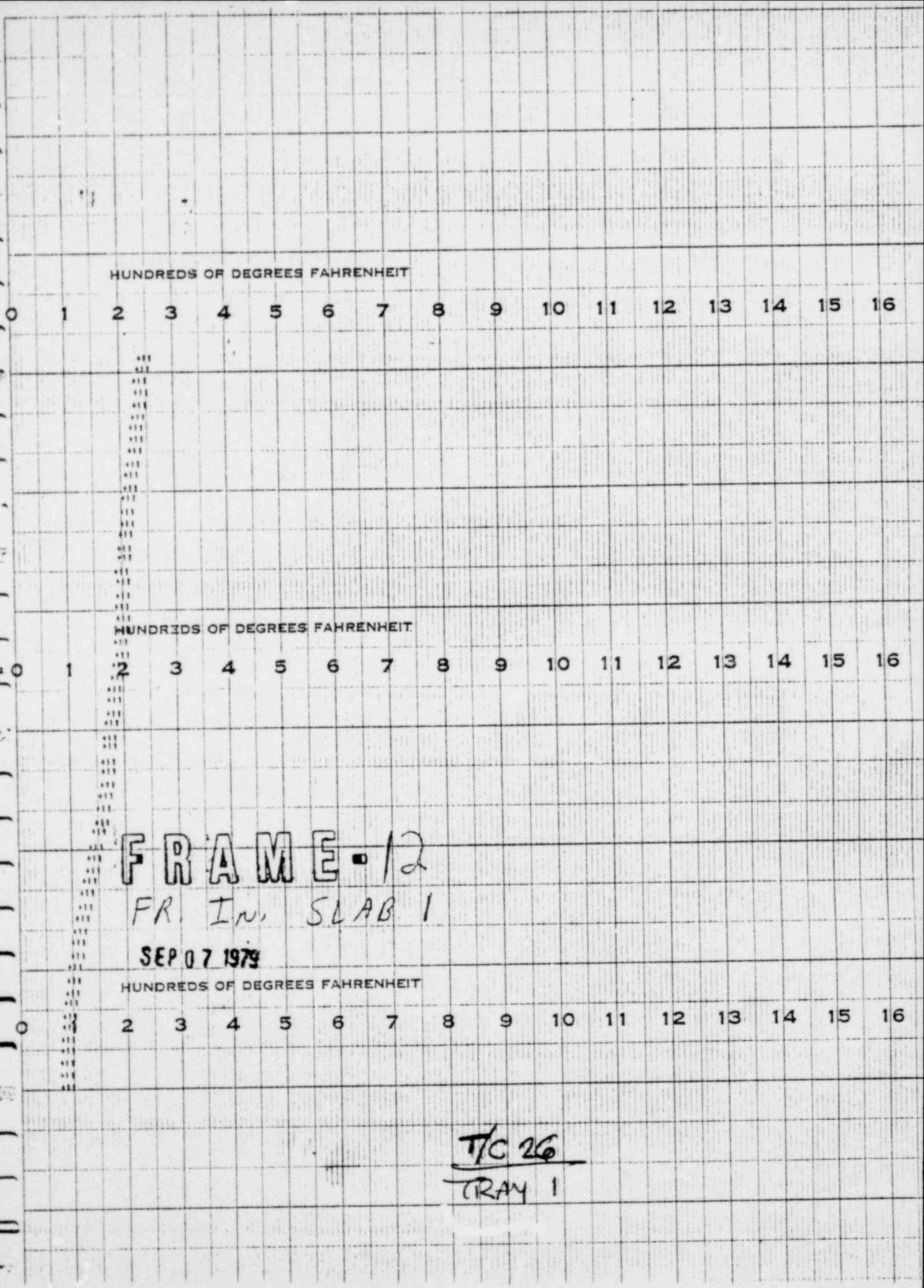

HUNDREDS OF DEGREES FAHRENHEIT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
HUNDREDS OF DEGREES FAHRENHEIT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
FRAME 9
FR. IN. SLAB 1
SEP 07 1979
T/C 21
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

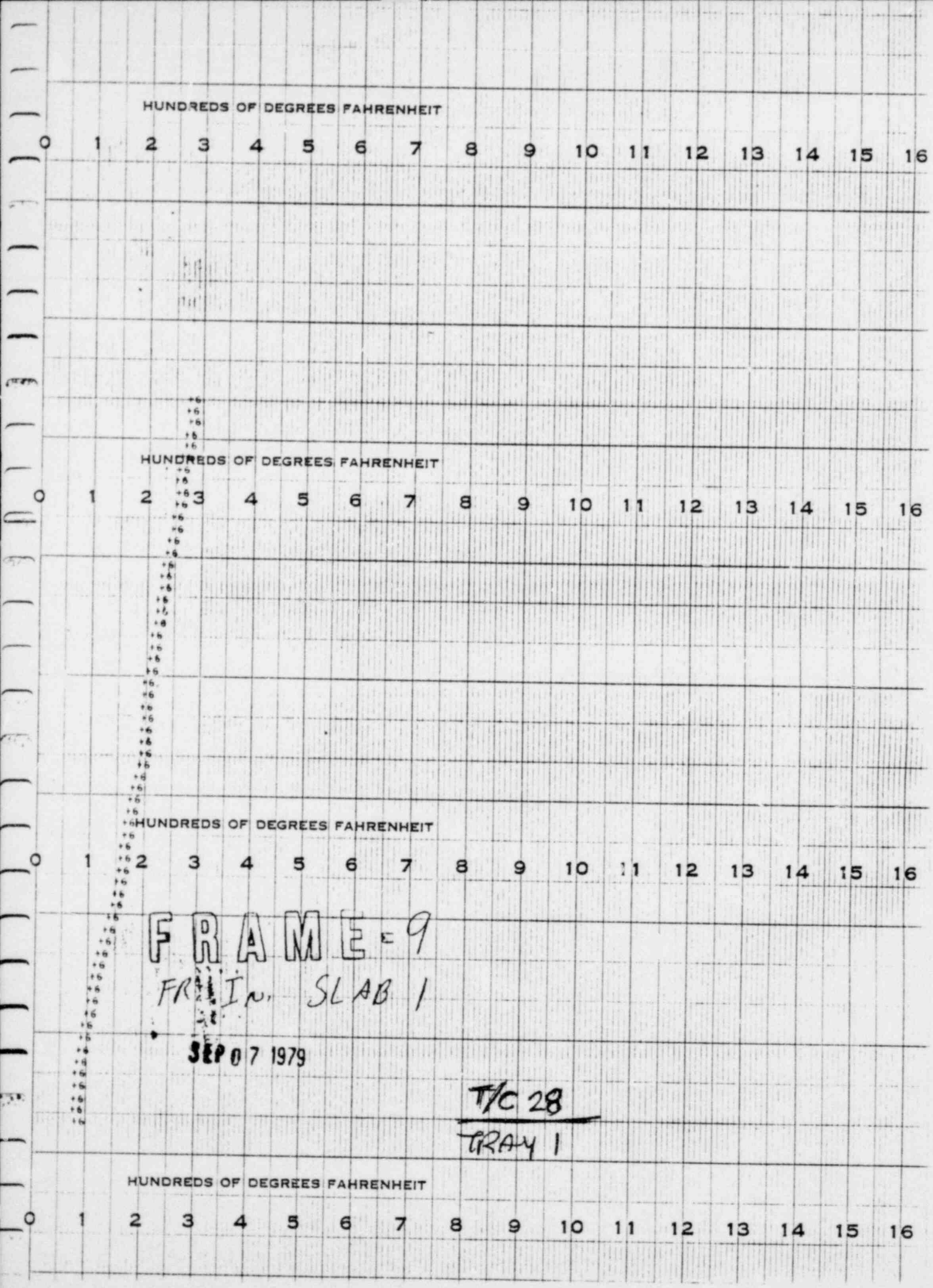

HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
FRAME-11
FR. IN. SLAB 1
SEP 07 1979
T/C 22
TRAY 2

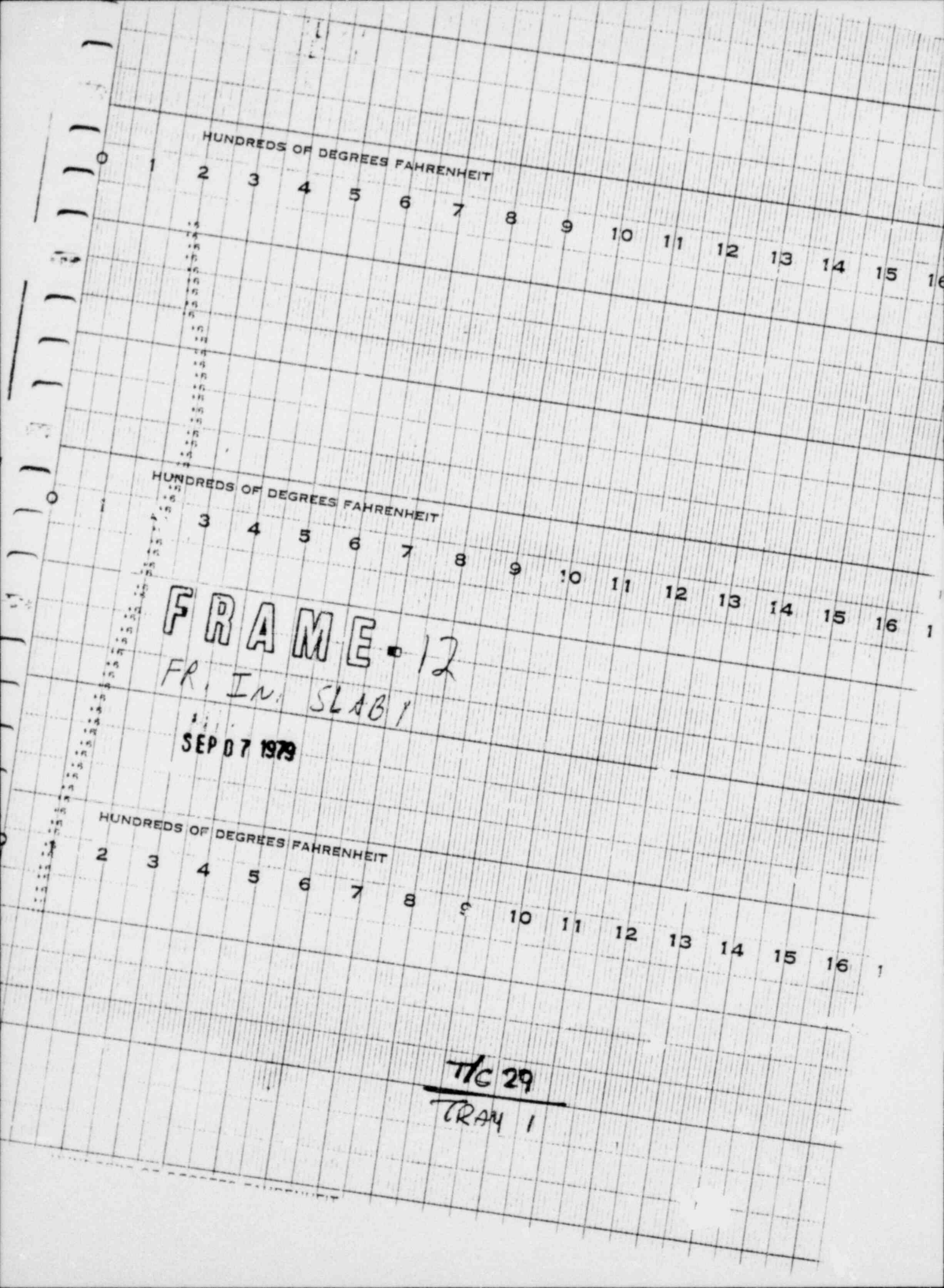

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME 11
FR. IN. SLAB 1
SEP 07 1975
T/C 23
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

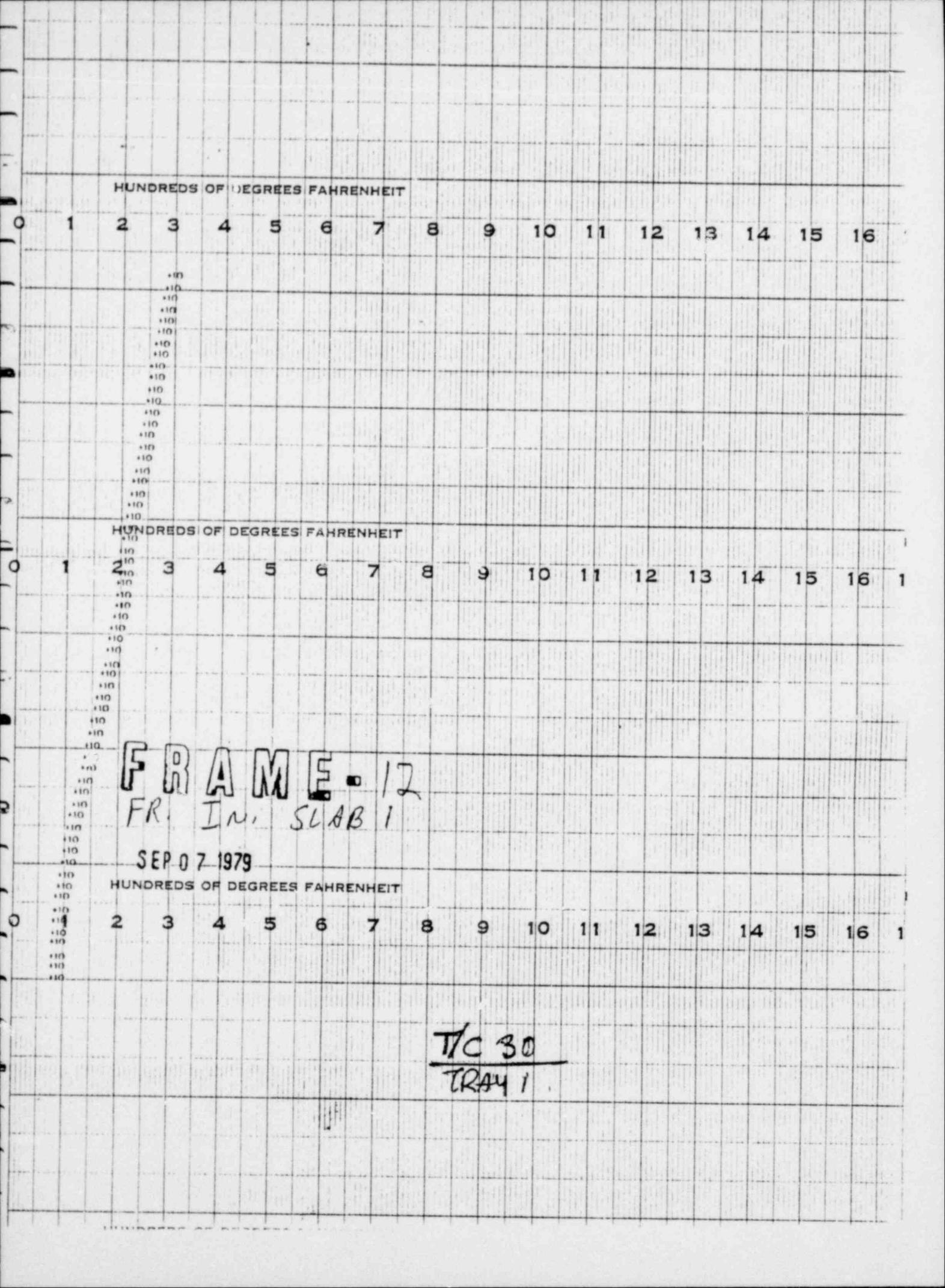

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 1
FRAME 9
FR. IN. SLAB 1
SEP 7 1979
T/C 24
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 1

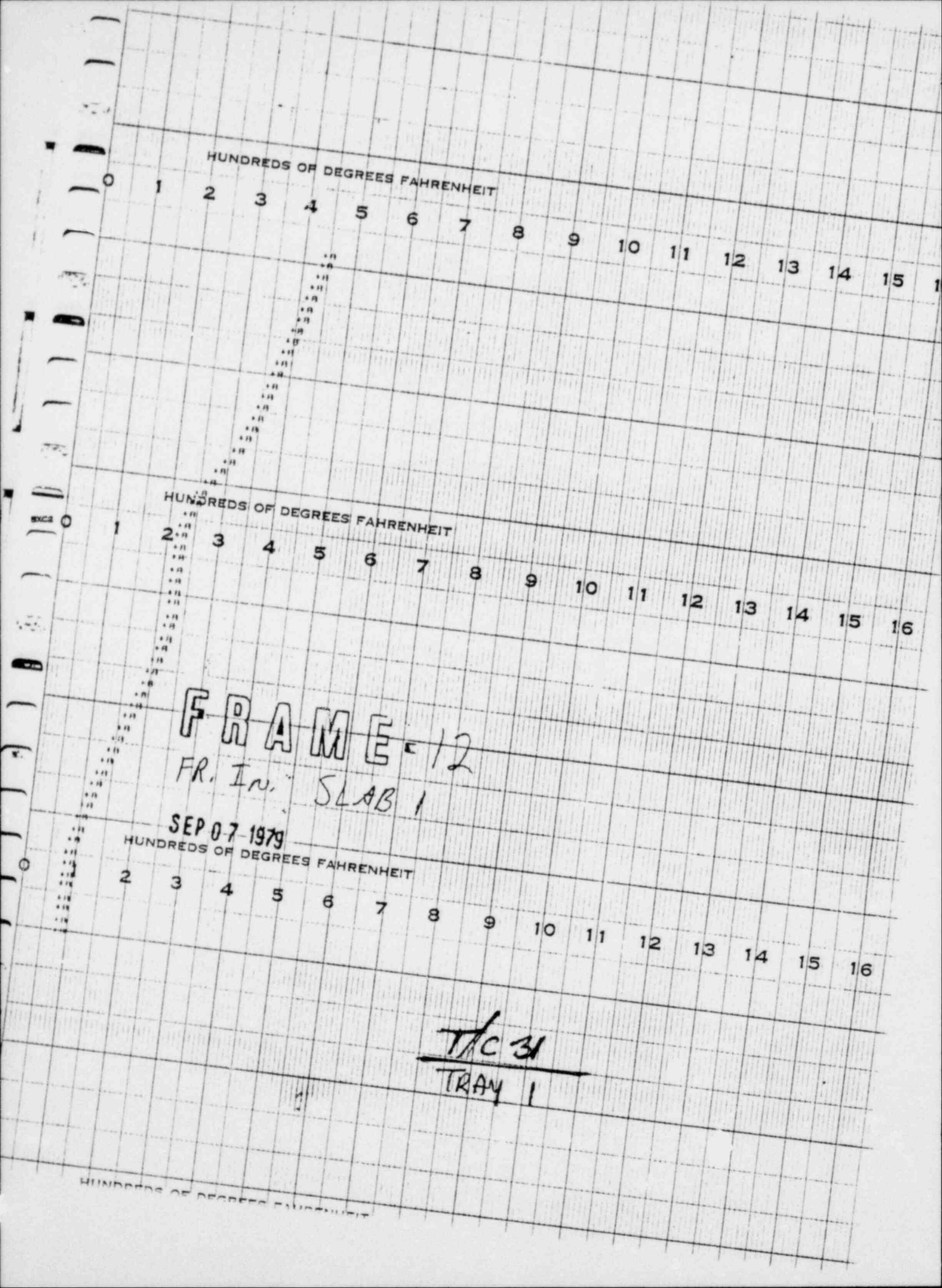

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME 9
FR. IN. SLAB 1
SEP 07 1979
T/C 25
TRAY 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

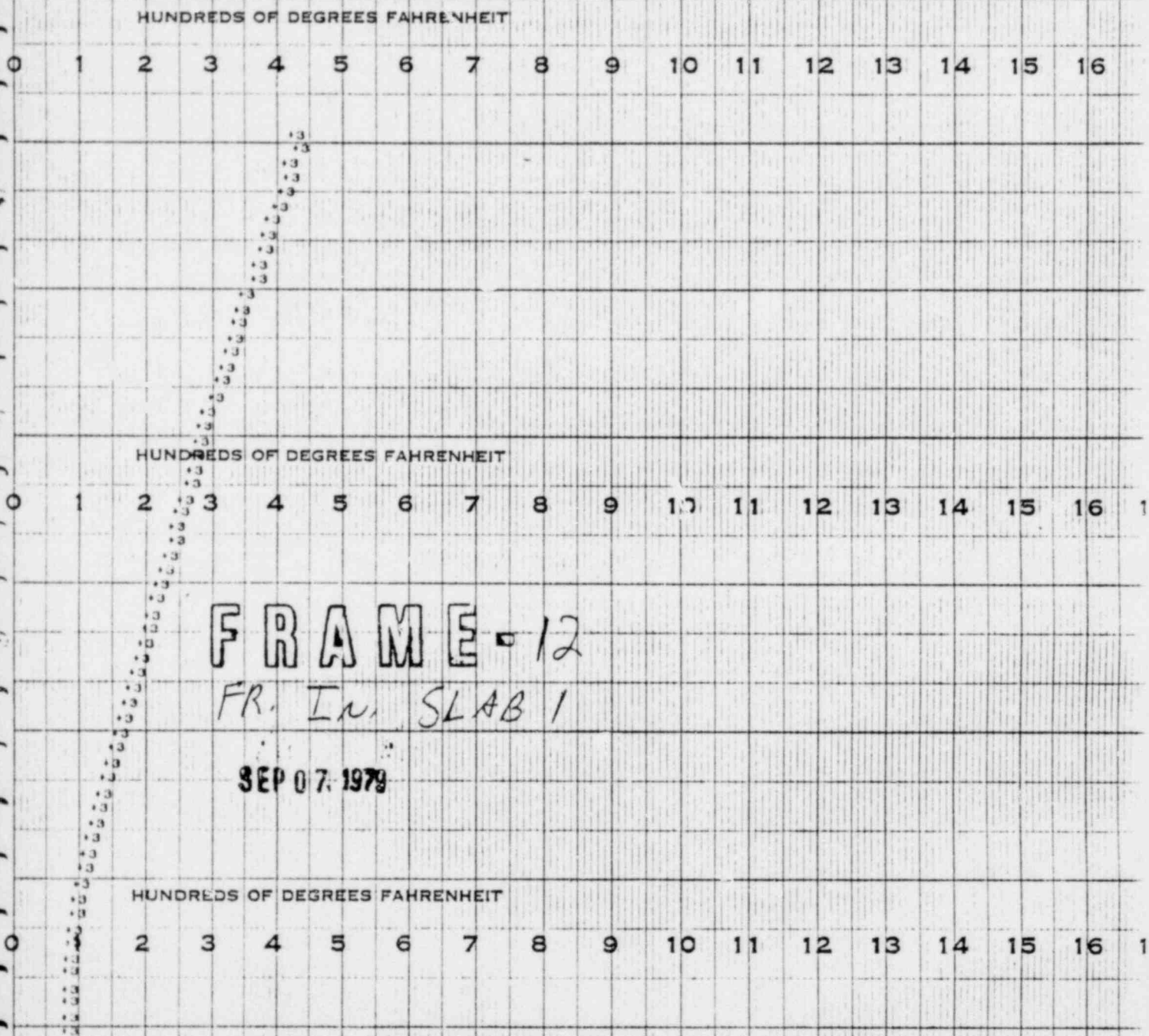

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDRIDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 26
TRAY 1


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME=9
FRAME, SLAB 1
SEP 07 1979
T/C 28
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
2 3 4 5 6 7 8 10 11 12 13 14 15 16
TC 29
TRAY 1


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 30
TRAY 1


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 31
TRAY 1



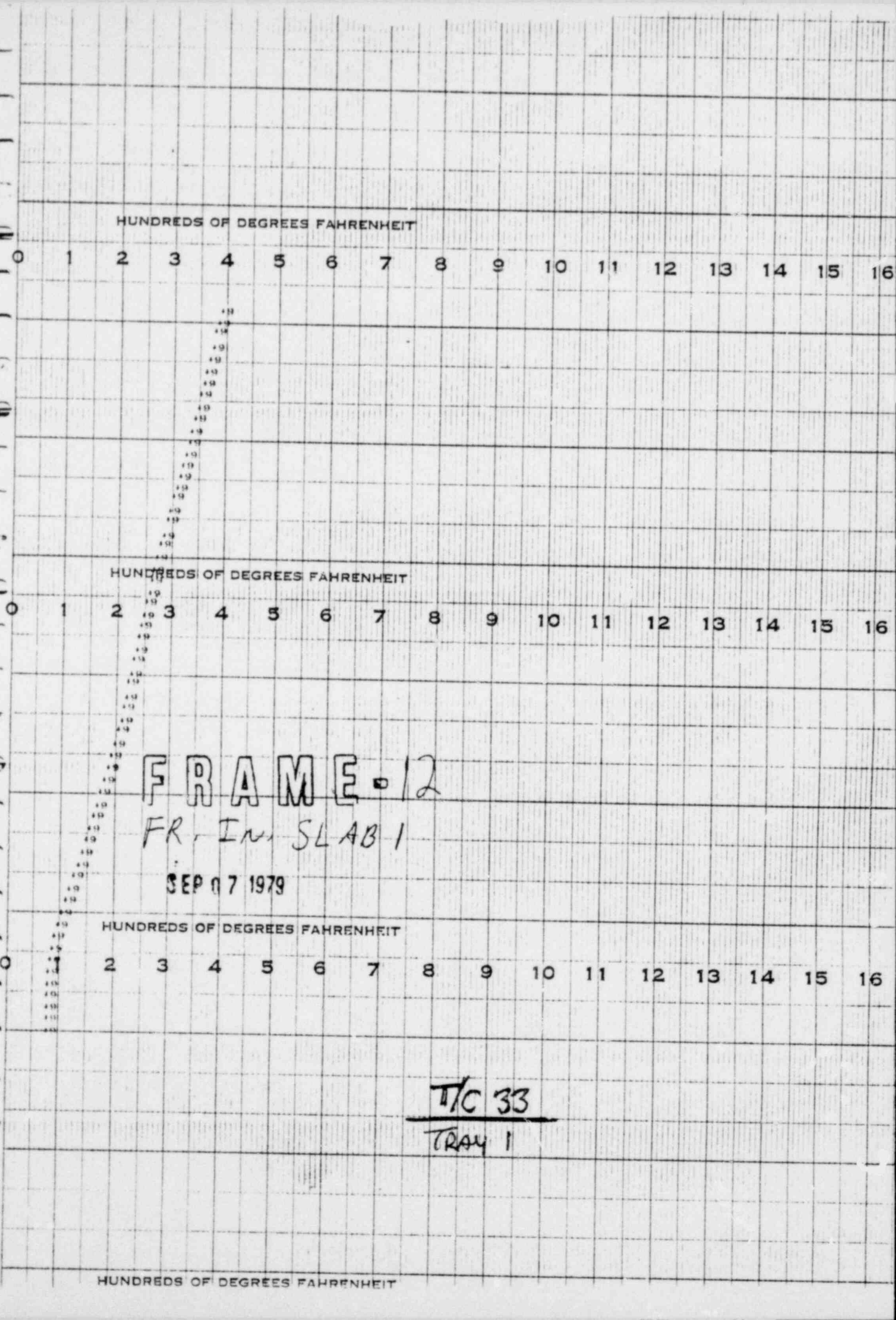
FRAME-12

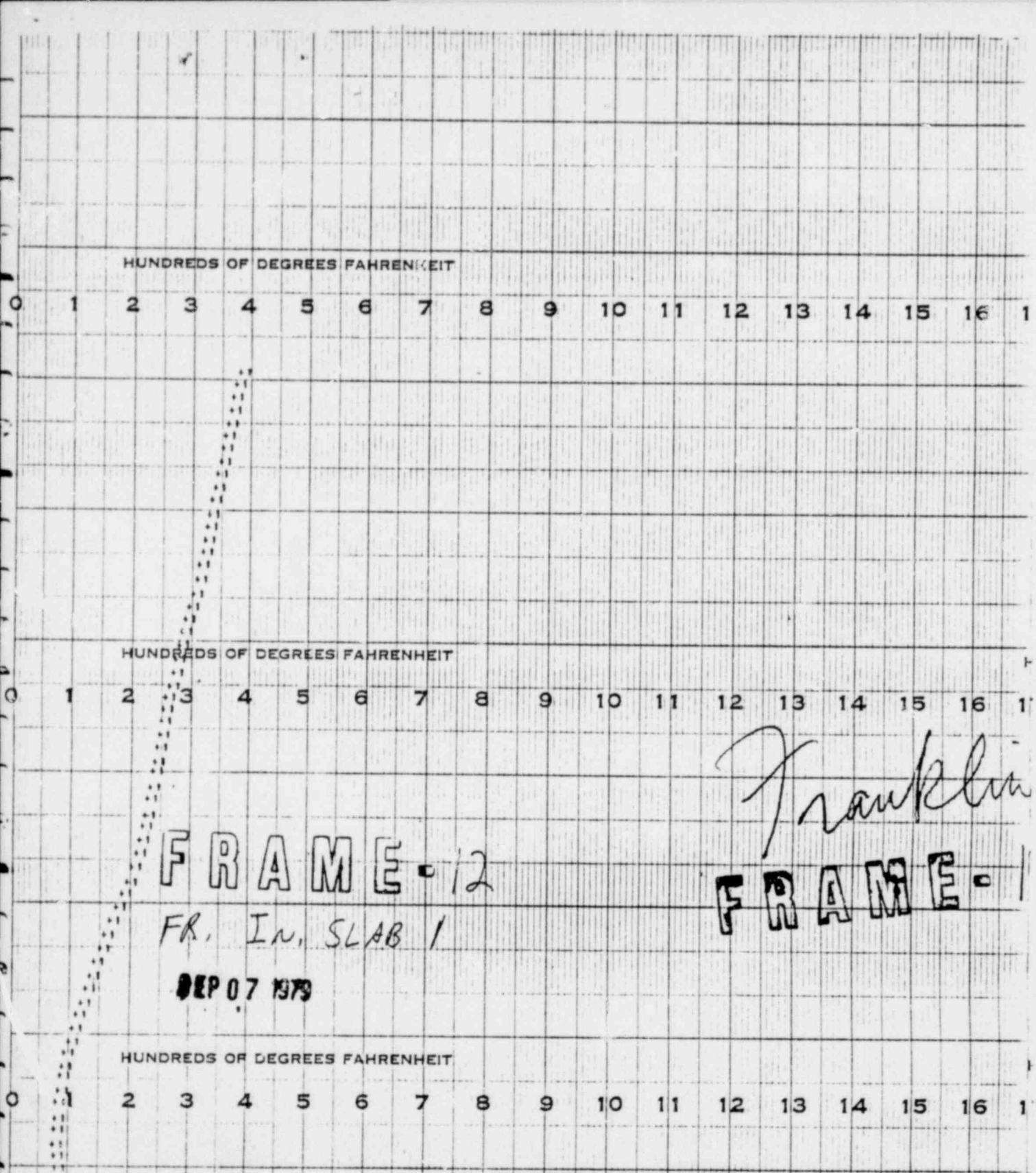
FR. IN. SLAB 1

SEP 07 1979

T/C 32

TRAY 1


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FRAME-12
FR. IN. SLAB 1
SEP 07 1979
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
T/C 33
TRAY 1
HUNDREDS OF DEGREES FAHRENHEIT



Franklin

FRAME-1

T/C 34

TRAY 1

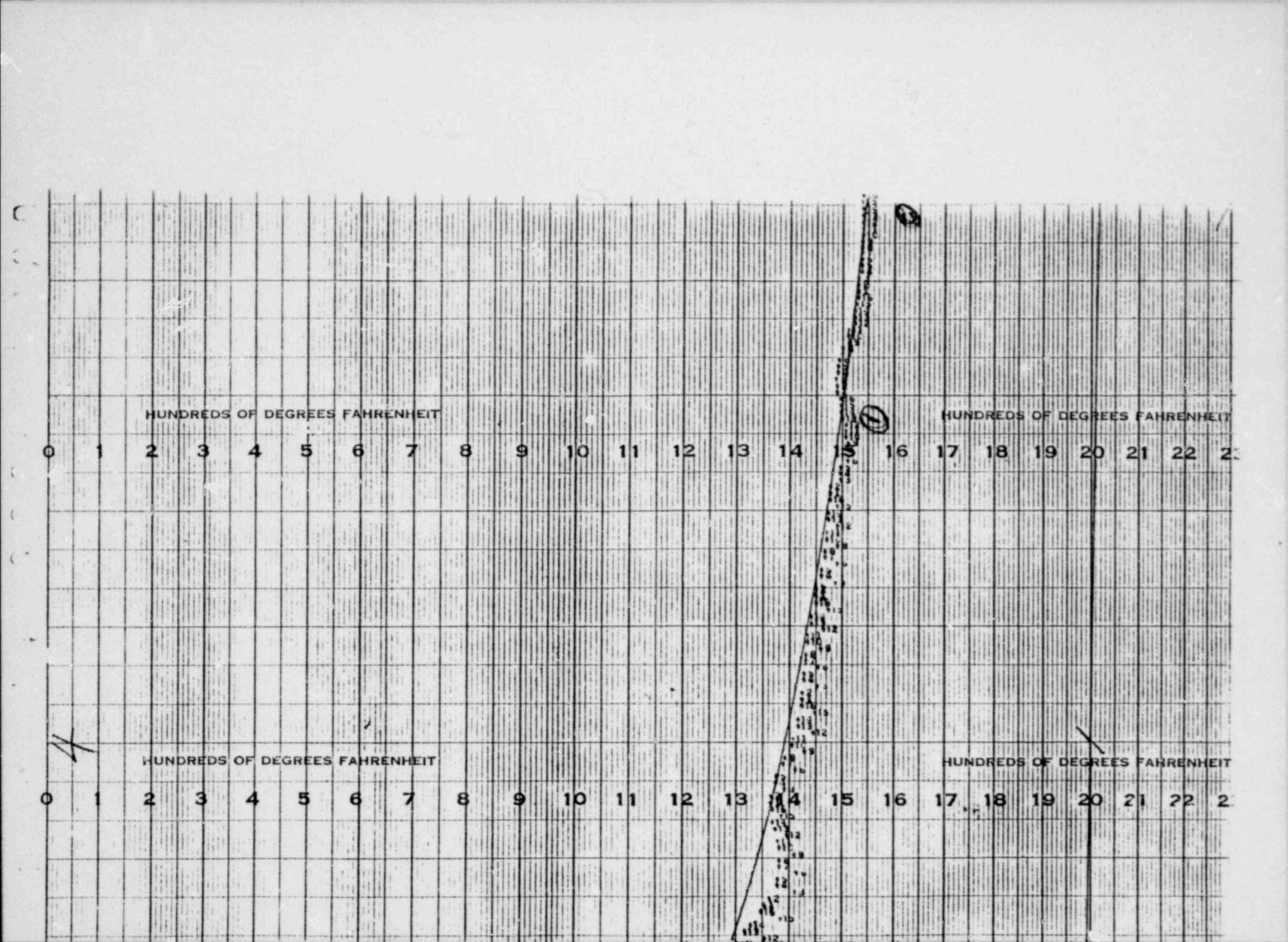
F-C5159-3

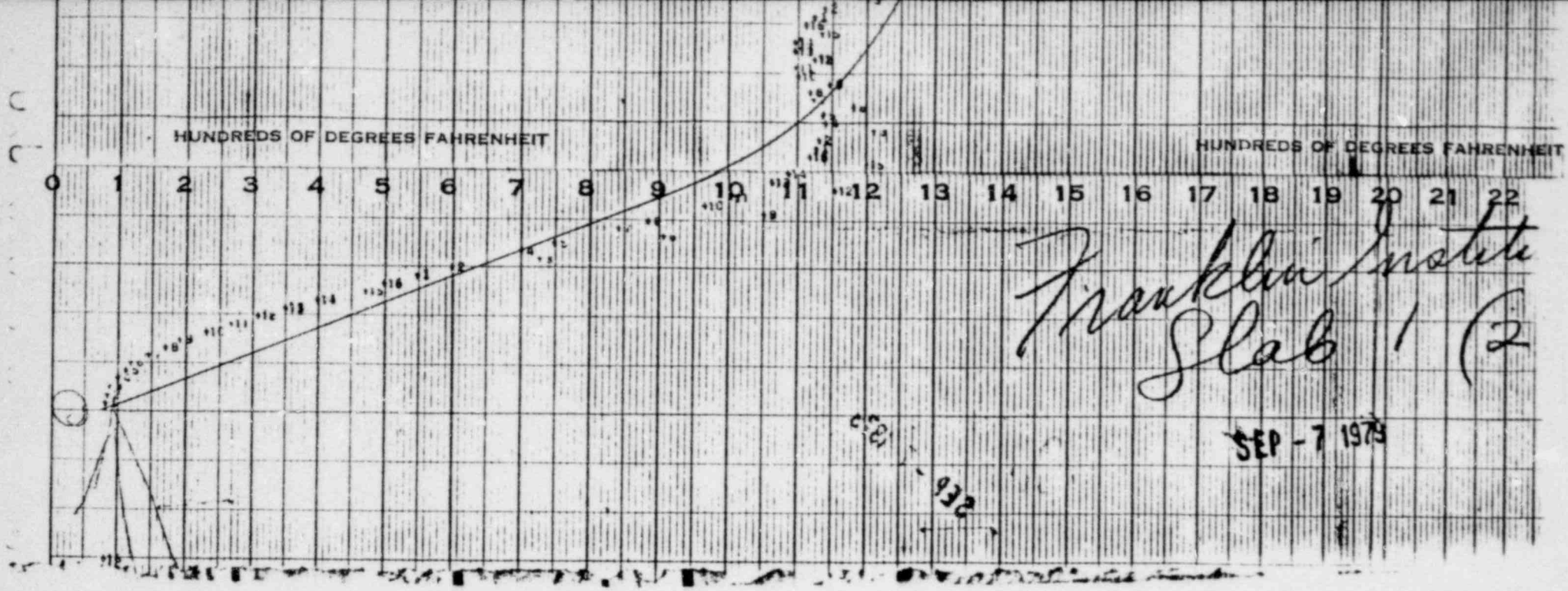
FURNACE SERVO THERMOCOUPLE DATA

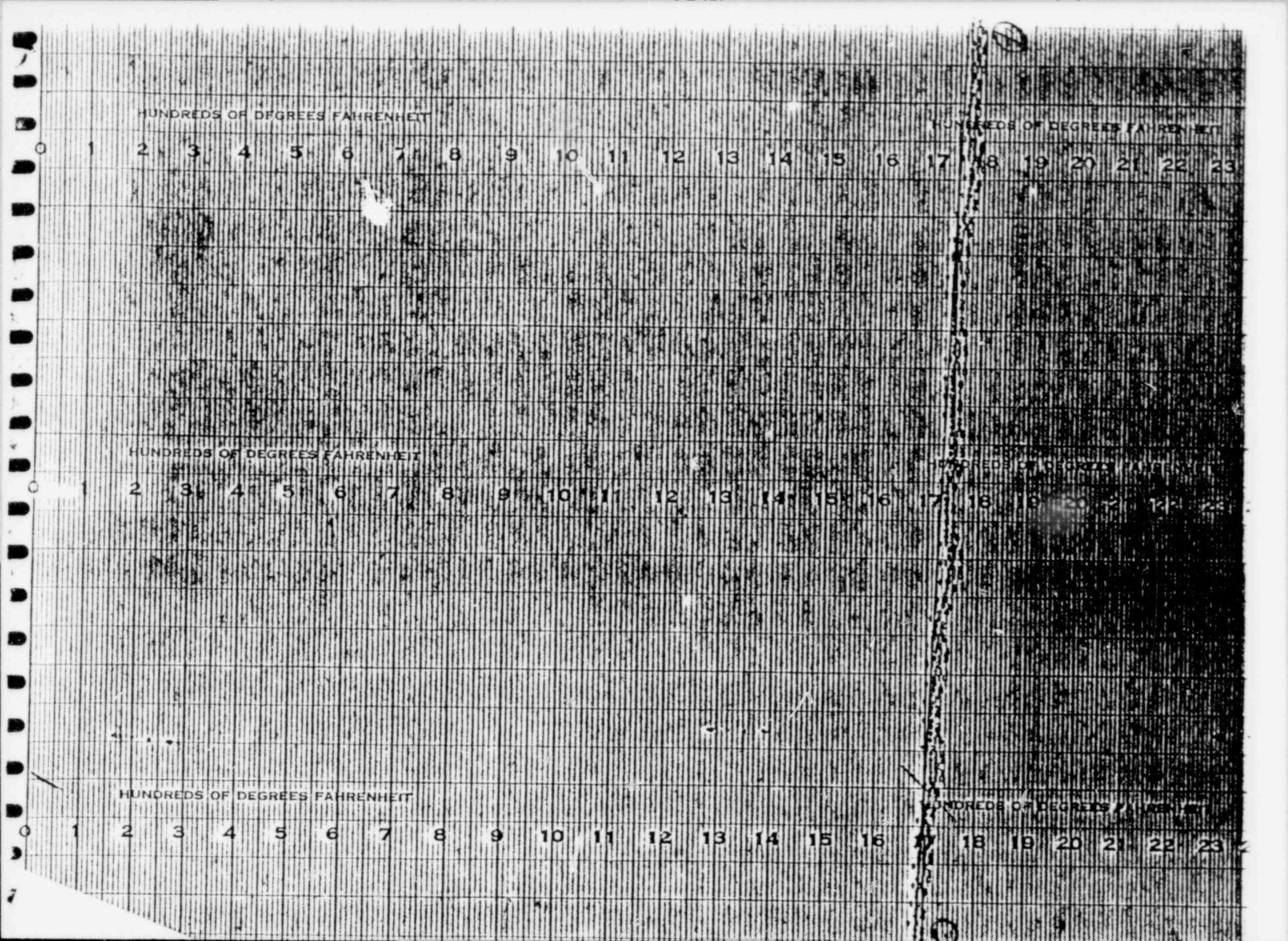
APPENDIX E

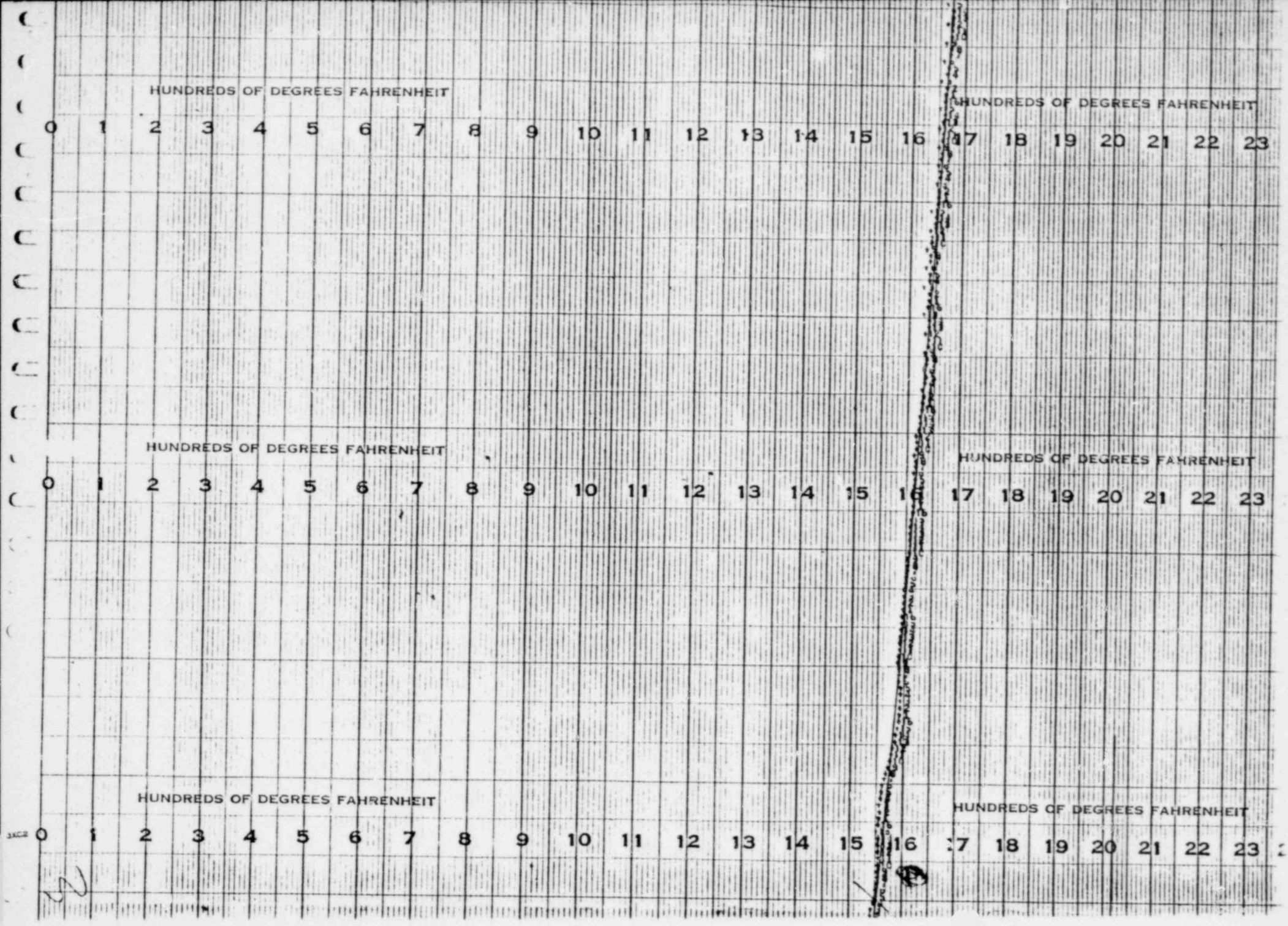
Three Hours of Thermocouple Data
Shown in Eight Contiguous Figures for Clarity
Test C5159-3, September 7, 1979

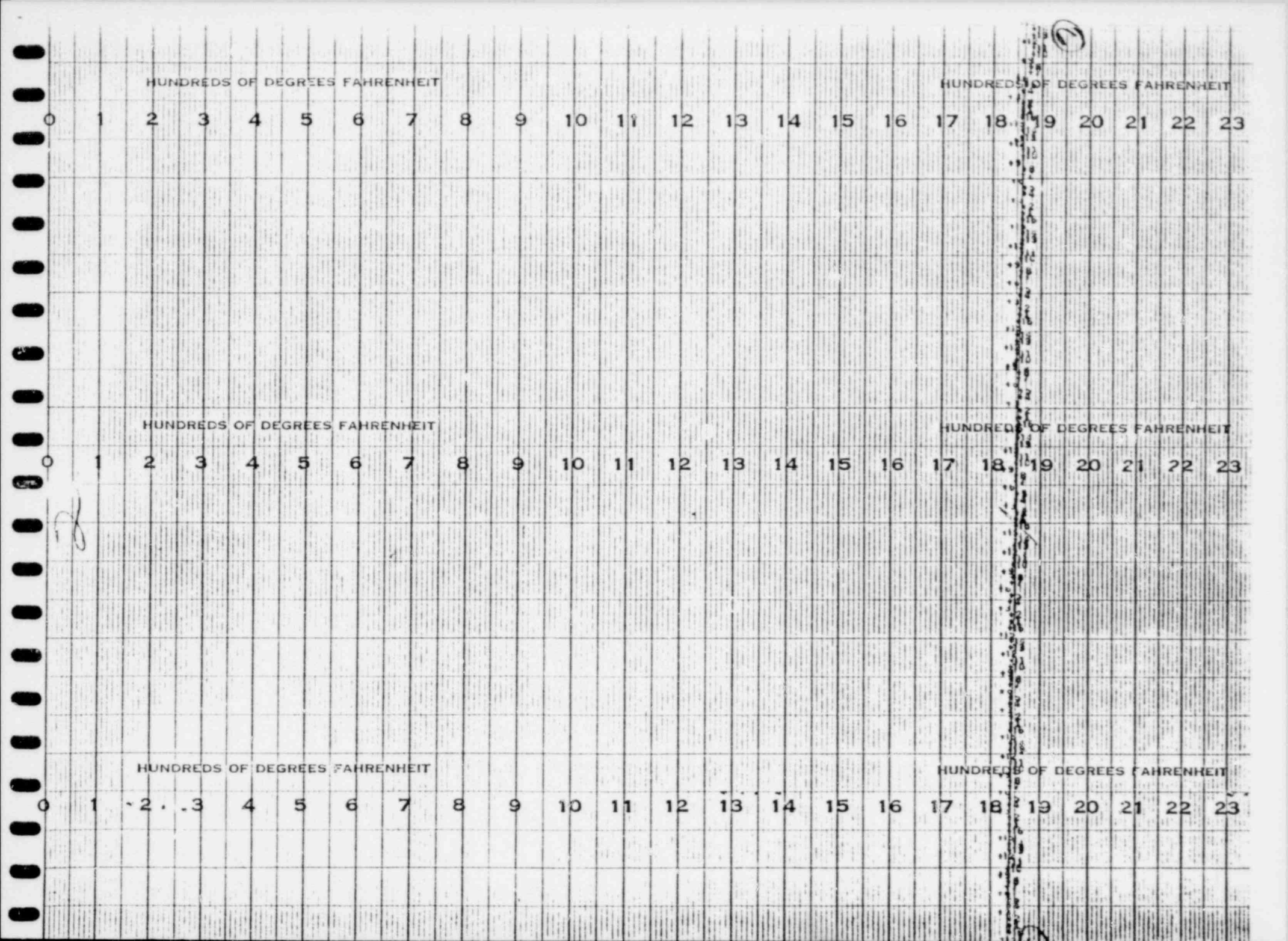
Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

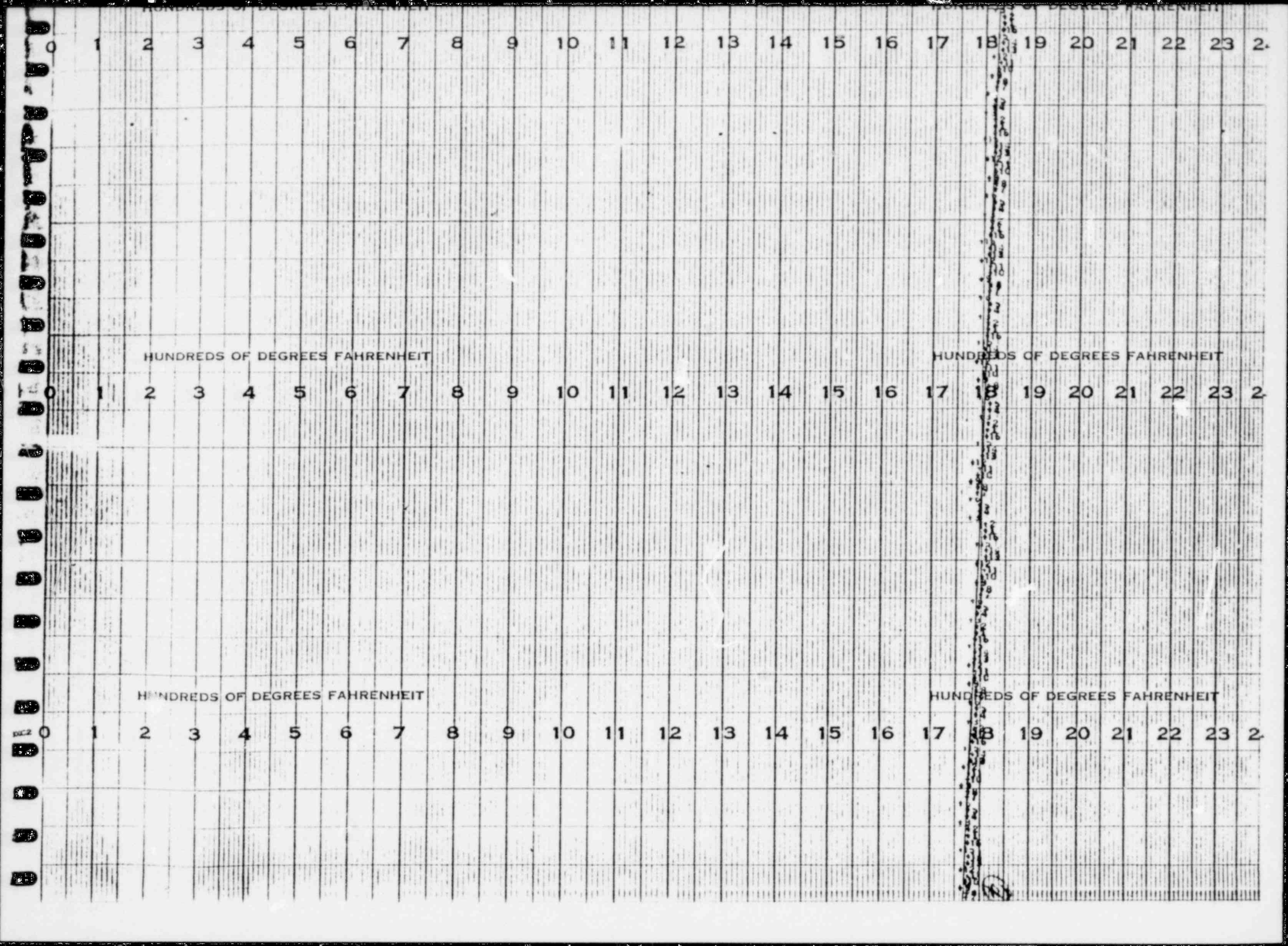

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
HUNDREDS OF DEGREES FAHRENHEIT

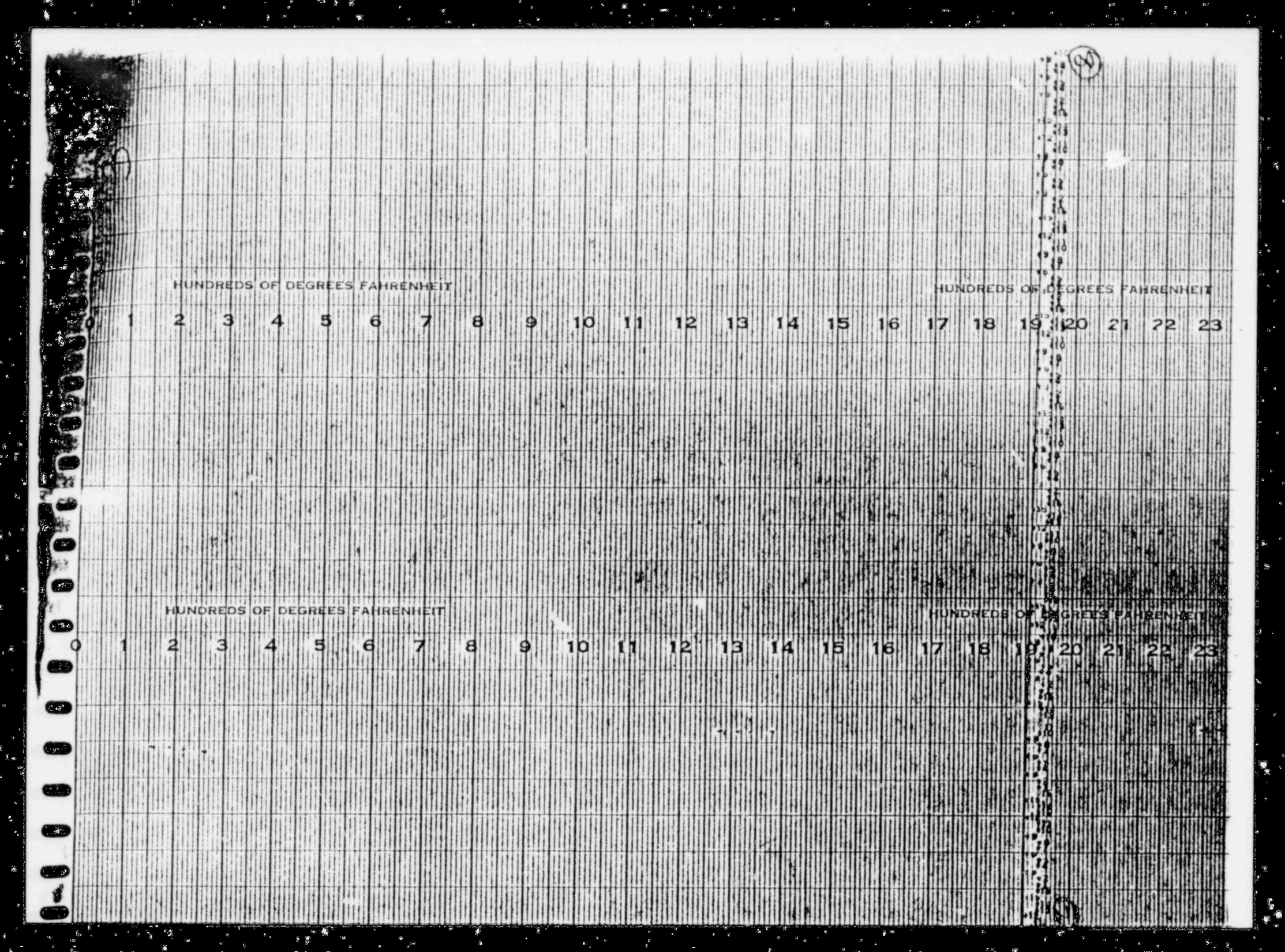

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
HUNDREDS OF DEGREES FAHRENHEIT
Franklin Institute
Slab 1 (2
SEP - 7 1979

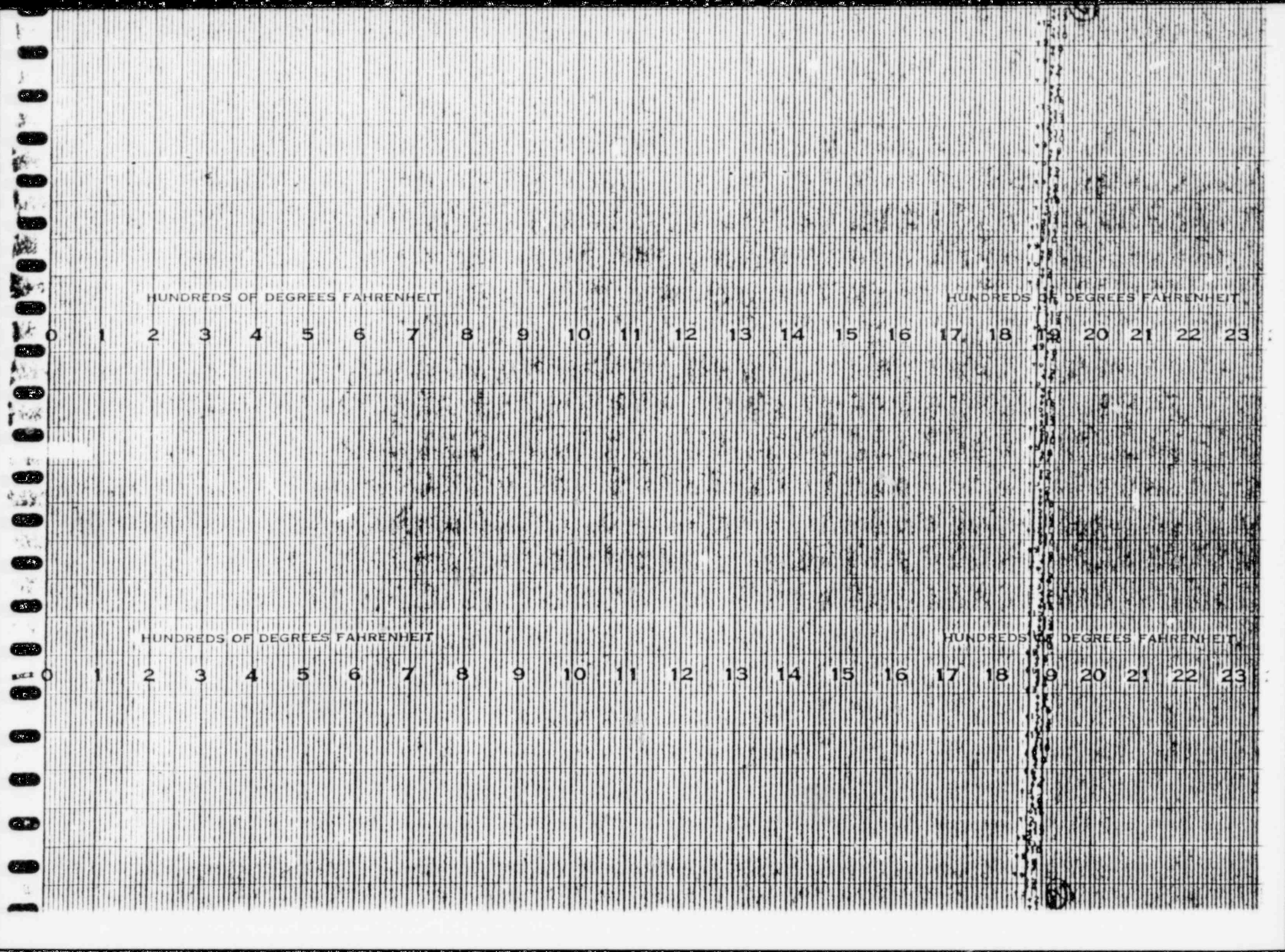

HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 2
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 2


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HUNDREDS OF DEGREES FAHRENHEIT
HUNDREDS OF DEGREES FAHRENHEIT