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ARTHUR D. LITTLE, INC.
CAMBRIDGE, MASSACHUSETTS

10 May, 1967

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO

TASK NO. 1

Insulation System No. 15 Fabrication

Multilayer Insulation System No. 15 was fabricated onto calorimeter tank No. 1 and completed on April 13. This system consists of 10 doubly aluminized polyester shields and 11 spacers each consisting of two layers of silk netting. Tests with the insulation system were begun on 16 April, 1967.

Tank Calorimeter Test Results

Three tests have been performed with this system during the latter part of April using liquid nitrogen in the calorimeter. In test IV-2A all chamber baffles were maintained at 80°F. Test IV-2B was performed with the upper baffle at -318°F while the lower baffle remained at 80°F. All baffles were maintained at -318°F during the performance of test IV-2C. The calorimeter conditions, heat flow and insulation heat flux results are presented in Table I.

Test IV-2A

The duration of test IV-2A was 90 hours. During this period an average flux of 0.27 Btu/hr ft^2 was measured. This value is comparable to the value predicted in the last monthly report (0.24 Btu/hr ft^2) and to the value of 0.26 Btu/hr ft^2 measured on a sample of the system using the Arthur D. Little, Inc. 12-inch guarded flat plate calorimeter.

Figure 1 presents the temperature distribution in the MLI as measured by copper-constantan thermocouples on foils No. 1, 2, 4, 7 and 10. Exact location of the thermocouples on each foil are shown in Figure 1 of the Monthly Progress Report dated 13 April. Thermocouples at location "a" indicate lower temperatures than thermocouples at locations "b" and "c". Also the temperature distribution in the foils at location "a" is nearly linear, indicating the heat transfer is influenced, to some extent, by thermal conduction. The upper portions of the foils (at and around location "a") are compressed against the tank by the weight of the lower portion of each foil and by the foils above. Also, the edges of the foils are exposed to the tank support shield which is near -320°F and would tend to lower shield temperatures in its vicinity. Thermocouples at locations "b" and "c" are at temperatures close to those predicted from the radiation heat transfer. This observation supports the assumptions that:

(1) the thermocouple readings at these locations are not influenced by the cold neck, and (2) the insulation on the lower portion of the tank is uncompressed. These results are typical of those obtained with previous insulation systems tested and reported under Contracts NAS 3-4181 and NAS 3-6283.

Test IV-2B

In test IV-2B we measured a heat flow rate of 3.8 Btu/hr over a period of 32 hours. This value was used to compute a flux of 0.20 Btu/hr ft^2 over the lower half of the insulation system which alone is exposed to the 80°F environment. This flux value is lower than the average obtained for the entire system in test IV-2A and has its basis in the uncompressed condition of the multilayer in the lower tank half. Test IV-2D with reversed temperature environments is to be performed in May and should indicate higher than average heat flux value, i.e., greater than .27 Btu/hr ft^2.

The temperature distribution of the foils are shown in Figure 2 for test IV-2B. The thermocouples at location "a" show, as expected, nearly liquid nitrogen temperatures. Thermocouples at location "b" are influenced by the boundary between cold and warm baffles and, therefore, indicate temperatures intermediate to those exposed entirely to either warm or cold baffle areas. The thermocouples at location "c" maintained temperatures similar to those obtained during test IV-2A. A comparison of these temperature profiles is shown in Figure 3.

Test IV-2C

Test IV-2C was conducted with all baffles and cold guard cooled with liquid nitrogen. Because of a rising barometer during the test period the calorimeter was operated with a closed vent. The heat flow was computed from the liquid mass and the pressure rise occurring from the beginning to the end of the test. This latter data is directly proportional to the temperature rise of the liquid (it is assumed stratification effects are negligible because of the significant equilibrating effect of the copper wall of the tank).

In this test we measured a heat flow rate into the system of 0.2 Btu/hr over a period of 28 hours. Inspection of the temperature profiles in the multilayer system indicate that temperature equilibrium had not been completely established in the shields. This information is presented in Figure 4 where the temperatures are shown at three time intervals. Operation of the system for longer periods to permit equilibration to take place become exceedingly costly because of the larger quantities of liquid nitrogen required. However, while

the calorimeter system is capable of resolving smaller heat leak rates, the resolution obtained is sufficient for the requirements of the current test series.

Penetration Fabrication

After completion of test IV-2D in early May, the six-inch pipe penetration will be installed into the bottom of the calorimeter and insulated in accordance with Drawing 3522-091 (see Monthly Report dated 13 April, 1967). This work will be completed by mid-May and system tests will be performed in the latter half of May.

Analytical Study of Pipe Penetration

During the past month the thermal-computer model of the pipe penetration was modified to include a finite conductance between the cold-end plate and the wall of the liquid nitrogen filled tank. Previously the cold end of the pipe was assumed to be at 139°R. Experimental results had showed that the temperature of the cold-end plate did increase as the heat flow to the cold end increased. (See Figure IV-25 on page IV-110 of the final report for Contract NAS 3-6283.) With this added thermal resistance in the heat flow path, the computed temperature distribution in the pipe wall showed a small increase in temperature level near the cold end and the overall fit between the measured and computed temperature distribution was improved when compared to the earlier results without the added resistance.

During the next month the thermal-computer model will be run to simulate the present experimental conditions (with the sandblasted interior) and the temperature distributions and heat leaks will be predicted for the upcoming series of tests.

TASK NO. 2

No work was performed on this task during April.

MISCELLANEOUS

Emissometer Data

We measured a number of emittances of the material used for radiation shields in System 15. As we have done before, we will measure emittance of two samples (one for each side of the sheet) cut from the edge of each radiation shield. Table II shows the measurements which were performed during month of April.

TABLE I

TANK INSULATION PROGRAM

DATA SUMMARY, INSULATION SYSTEM NO. 15, TEST SERIES IV-2, CALORIMETER NO. 1

Insulation System:	Ten radiation shields of polyester film aluminized on both sides and eleven spacers each consisting of two layers of silk netting
Test Facility:	Arthur D. Little, Inc.
Penetrations or Gaps:	None
Tank Surface Area:	38.14 ft^2 based on calorimeter tank surface area
Tank Liquid:	Liquid Nitrogen

Test No.	Data Period: Date & Time	to Date & Time	Test Duration (hrs)	Ave. Vac. (mm Hg)	Guard Liq/Temp (°F)	Upper Baffle (°F)	Lower Baffle (°F)	Total Heat Flow (Btu/hr)	Measured Heat Flux ($Btu/hr\ ft^2$)	Ave. Baffle Temp (°F)	Adjusted Heat Flux ($Btu/hr\ ft^2$)
IV-2A	Apr 16/1430	Apr 20/830	90	8×10^{-6}	318	80	80	10.3	0.27	80	0.27
IV-2B	Apr 25/830	Apr 26/1630	32	6×10^{-7}	318	-320	80	3.8	0.20	80 (1)	0.20
IV-2C	Apr 28/800	Apr 29/1200	28	4×10^{-7}	318	-320	-320	0.2	0.005	-320	NA

(1) Baffle temperature surrounding one half of calorimeter tank.

TABLE II

EMISSOMETER DATA SUMMARY

Test Date	Disc No.	Test No.	Sample No.	Sample Description	Envir. Code/Hrs	Emittance
4-18-67	6	714	401	Vaporized Al/Fiberglass Board, 1/16 inch	-	.028
4-24-67	6	715	382	Al, 455 Å, Hastings/Mylar, 1/4 Mil	-	.028
4-26-67	6	716	314	Chromate, M.I.T./Al 2.5 dia. x .125 thick	-	.049
4-26-67	6	717	362	Au, Hastings/Mylar, 1/4 Mil	-	.017
4-27-67	6	718	384	Al, 590 Å, Hastings/Mylar, 1/4 Mil	-	.023
4-28-67	6	719	386	Al, 556 Å, Hastings/Mylar, 1/4 Mil	-	.029
5-2-67	6	720	387	Al, 479 Å, Hastings/Mylar, 1/4 Mil	-	.024

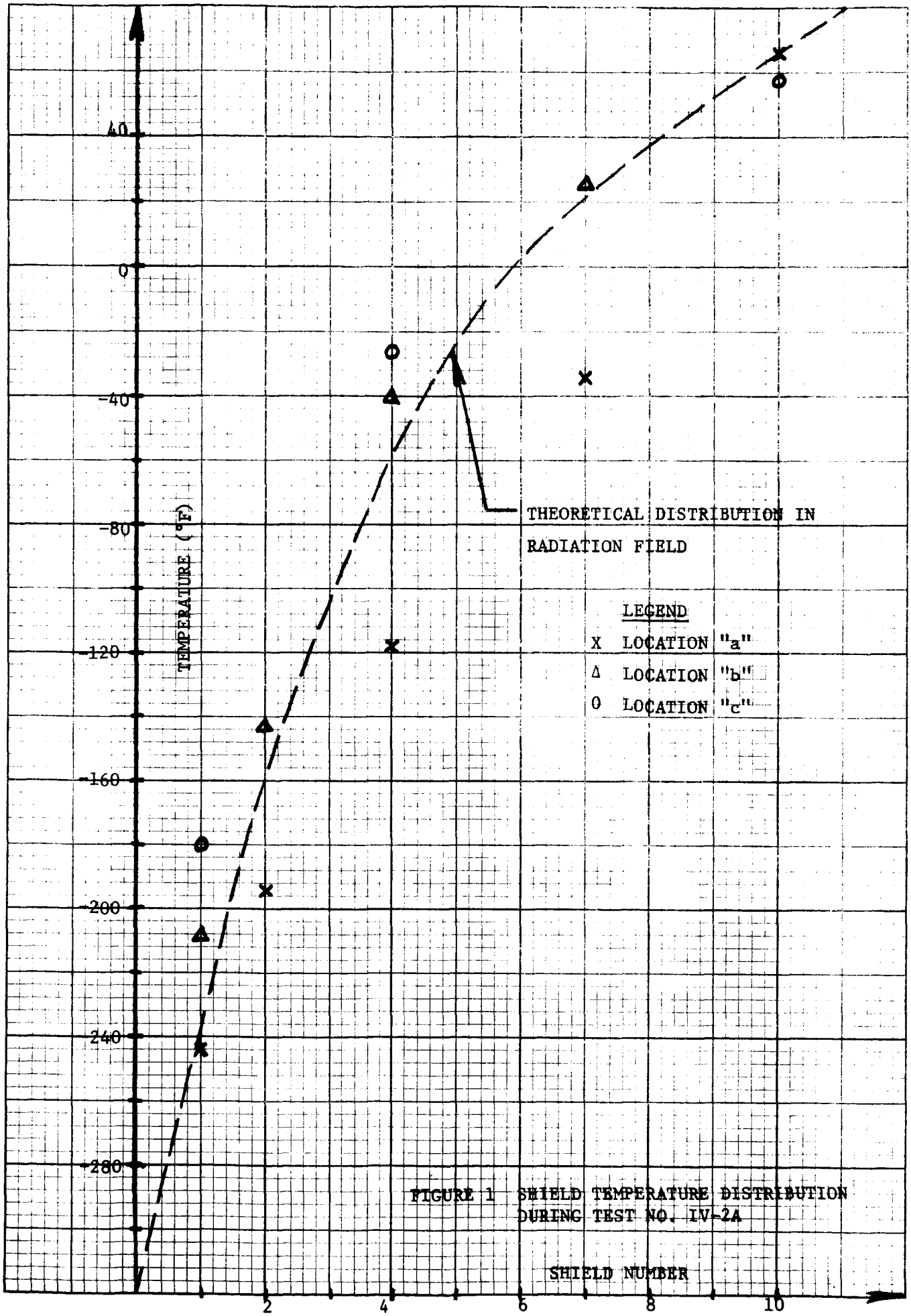

FIGURE 1 SHIELD TEMPERATURE DISTRIBUTION DURING TEST NO. IV-2A

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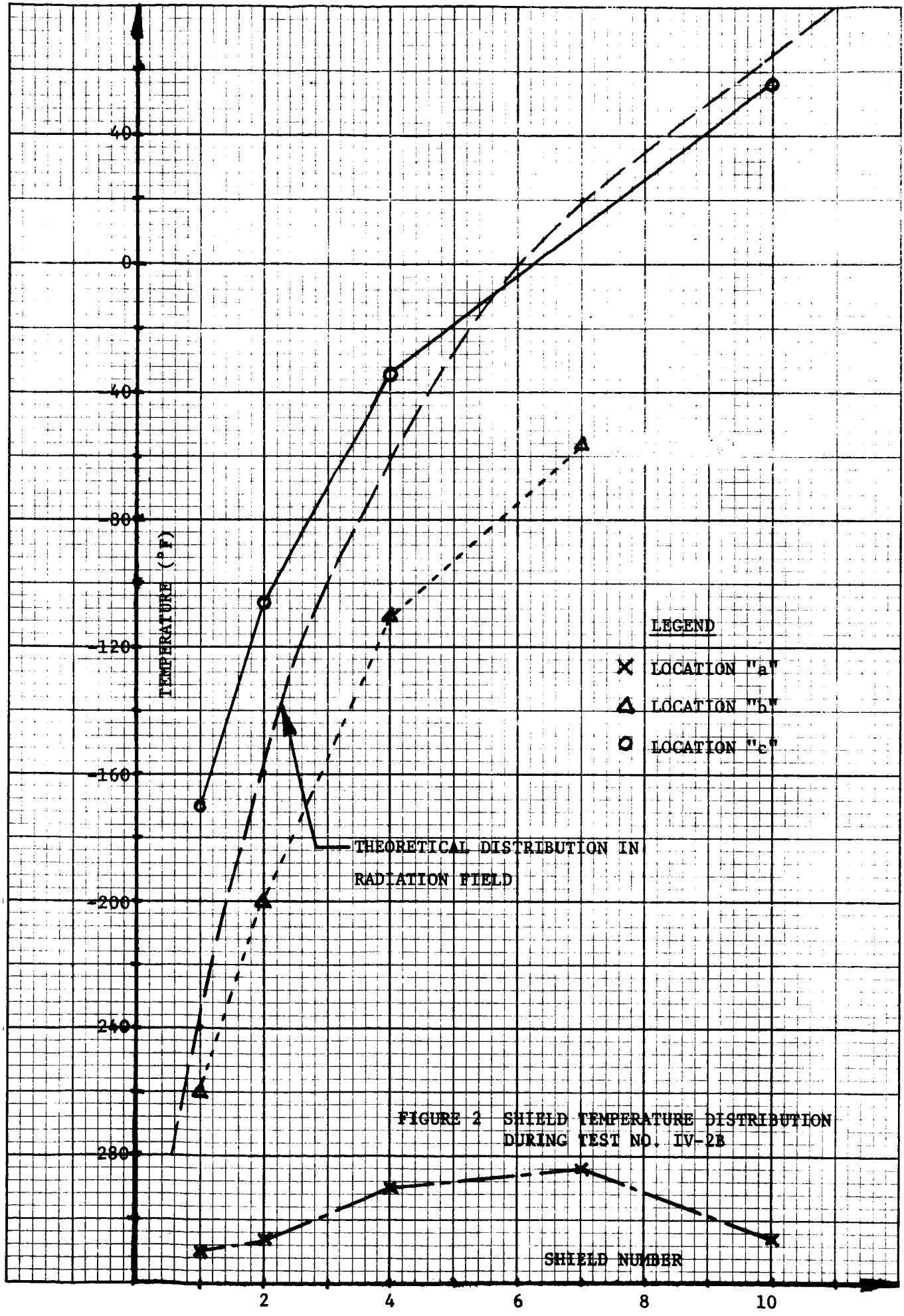

FIGURE 2 SHIELD TEMPERATURE DISTRIBUTION DURING TEST NO. IV-2B

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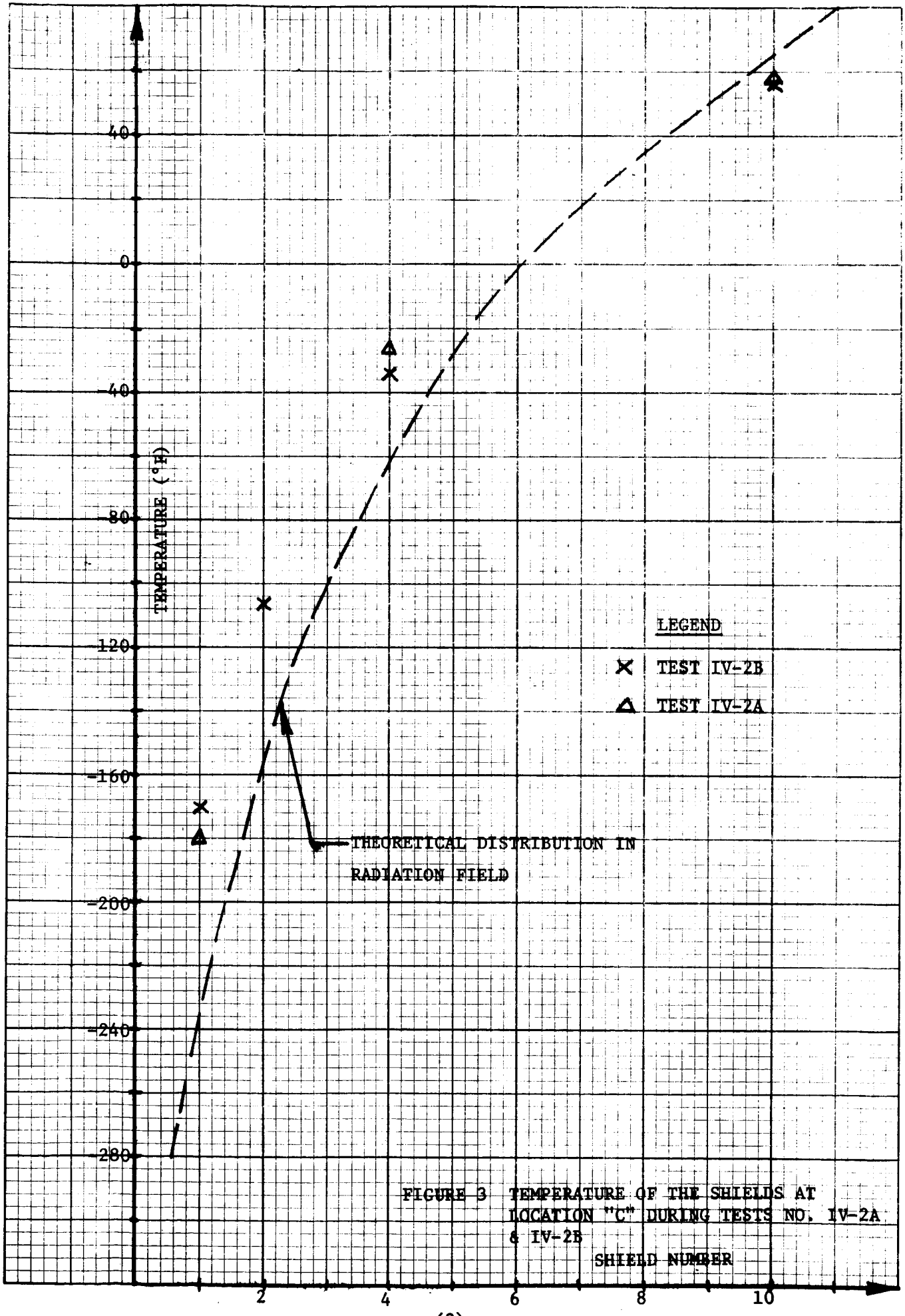

FIGURE 3 TEMPERATURE OF THE SHIELDS AT LOCATION "C" DURING TESTS NO. IV-2A & IV-2B

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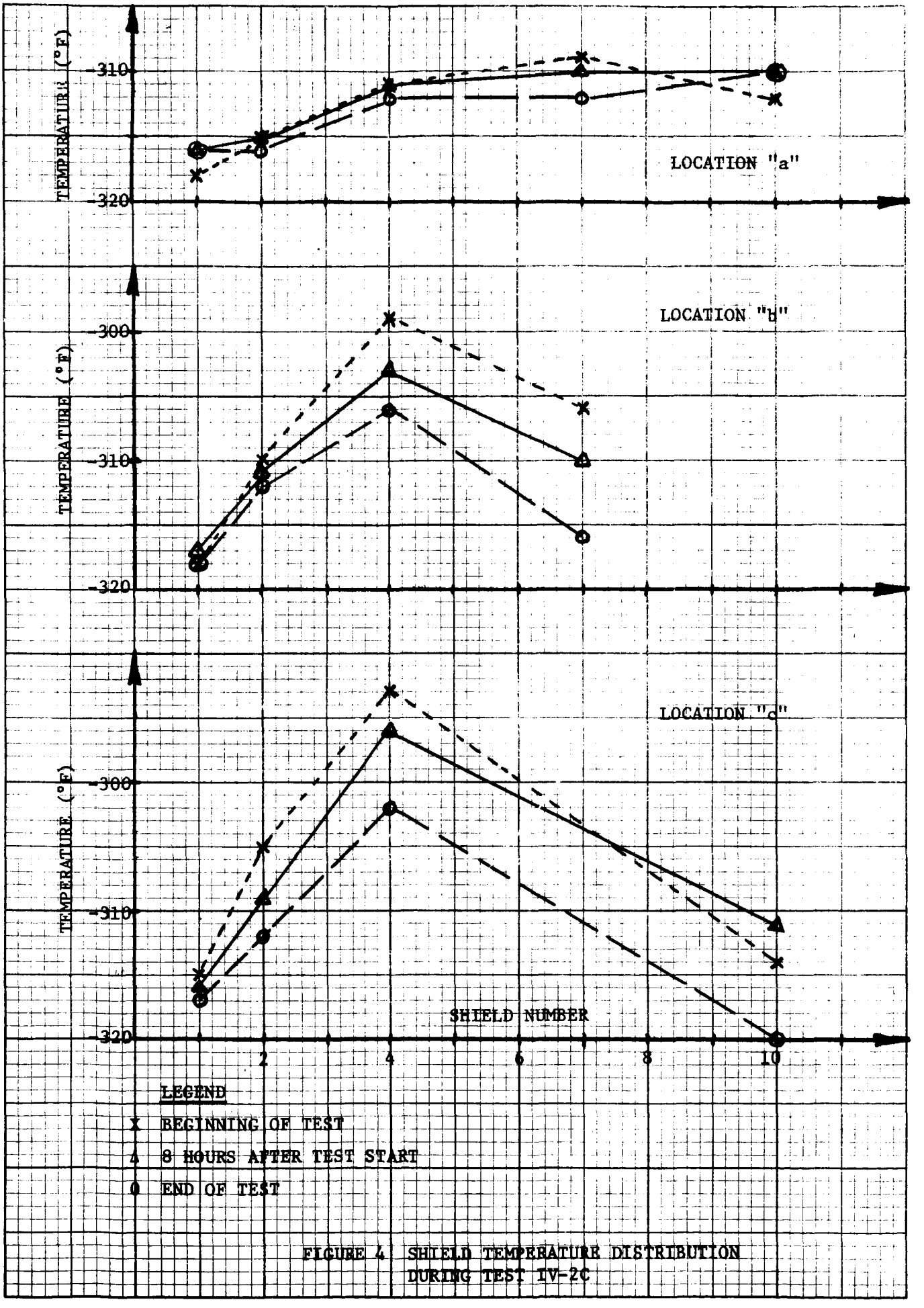

FIGURE 4 SHIELD TEMPERATURE DISTRIBUTION DURING TEST IV-2C

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