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SECOND INTERIM FLIGHT REPORT
AIMP-I
EXPLORER XXXIII

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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SECOND INTERIM FLIGHT REPORT
AIMP-I
EXPLORER XXXIII

by
Jeremiah J. Madden

May 1967

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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SECOND INTERIM FLIGHT REPORT
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I. INTRODUCTION

This is the second Interim Flight Report on the AIMP-1 (Explorer XXXIII), which was launched on 1 July 1966. The report deals with the spacecraft from 1 October 1966 to 31 March 1967. Earlier data is included for comparison. The AIMP-I is in an orbit about the earth in which the perigee position varies from 26,000 km to 130,000 km and the apogee position from 400,000 km to 530,000 km. On January 1, 1967 the AIMP-D mission was declared a success—the spacecraft having past its sixth month of active life.

II. SPACECRAFT PERFORMANCE

a. Status

The present status of the spacecraft is all systems operational except for the University of California's Geiger tubes and the spacecraft battery. The failure of California's Geiger tubes, which failed about 23 August, was reported in the first Interim Flight Report (reference 1). The battery failure will be discussed below.

b. Battery Failure

It was stated in the earlier report that the battery temperature had exceeded tolerances and that the battery life was being shortened. On or about the 343rd day of the year* (15 December) the performance parameter (PP-03) which monitors battery charge current from 0 to 200 milliamps began to have sporadic readings indicating a battery charge current of 1 to 15 milliamps. These readings, which were initially hours apart, became more frequent until day 348.81657 when the battery started to continually accept a charge. Initiation of the charge was abnormal in all instances as the battery had not been discharged since the initial shadow, which occurred on 1 July. The spacecraft had been in total sunlight up to this time and no anomalies were noted in spacecraft current requirements.

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*Day of the year numbers are based on a system where January 1 is day 0. This convention is used throughout this report.

Table I lists the events in the deterioration of the battery. The spin rate of the spacecraft was affected by the loss of mass of the electrolyte from the battery. The spin rate (see figure 1) was most affected on day 351 and this was two days prior to the development of a major short in the battery. The battery temperature (see figure 2) had its most dramatic rise from day 349 to day 354.

The AIMP-I battery is a silver-cadmium battery consisting of 13 cells (see illustrations 1 and 2) connected in series. A silver-cadmium cell is characterized by a positive electrode consisting of six sintered silver plates and a negative electrode consisting of seven pasted cadmium plates separated by a composite separator system of four layers of silver-treated cellophane and two layers of non-woven nylon coupled with a 40% potassium hydroxide (KOH) electrolyte solution. Potassium hydroxide is a white salt which in the dry state is a non-conductor.

The cellophane in the presence of the electrolyte and the silver species dissolved in the electrolyte, slowly deteriorates. This situation is aggravated as the temperature increases. Batteries operated or stored charged at 50°C will have a lifetime of 2,000 hours whereas at room temperature or below lifetimes of from three to four years are common. The deterioration of the cellophane permits a silver deposit shorting from the positive to the negative plate. One cell shorting, even if it is a high resistance short, will drop the terminal voltage of the battery. This lower voltage, at constant potential charging, will cause additional charge current to flow. Persistence of this condition on a fully charged battery results in the unshorted cells evolving gas (oxygen). Evolution of the gas is exothermic and a temperature rise of the battery will occur. Subsequently, the internal pressure will rupture the cells, the water will evaporate from the electrolyte (lower the temperature, as can be seen from table 1), and the battery will cease to function. The defunct battery has a high impedance which will prevent charge or discharge, i.e., effectively it is an open circuit.

A test battery has been subjected to the same temperature regime as the flight battery but to date (1 April) has not evidenced any degradation. It was put on test about one month after the AIMP-D launch.

c. Turn-on Anomalies

The AIMP-I spacecraft entered the earth's shadow for the first time on 22 December at 1149Z. It exited at about 1239Z and turned on briefly (a few seconds). It then remained off for 3 hours and 50 minutes (an undervoltage timer cycle), turning on again at 1638Z. The prime power voltage was varying between 9 and 18 volts. The spacecraft remained on since the variation was rapid enough that the voltage did not remain below 12 volts for 2 seconds (the time delay associated with the undervoltage circuit). The output of the prime converter was affected with the 12-volt bus telemetry data indicating readings from 7 to 14 volts and the 28-volt bus 24 to 34 volts. The validity of these voltage readings is questionable since at these levels the encoder output is not reliable. At 2151Z, the spacecraft prime power voltage clamped at 18.3 volts and the other voltages returned to normal. This anomaly was initially thought to be associated with a short in the battery that had burnt itself out in the interim.

The spacecraft entered the shadow of the earth for a second time on 6 January 1967 at 0031Z and exited at 0111Z. The spacecraft came on and remained on. It was again in the oscillatory mode of operation with respect to the spacecraft voltages, however, the prime power voltage varied between 12 and 17 volts, the 12-volt bus remained between 11.7 and 11.9 volts and the 28-volt bus between 27 and 31 volts except for a few sporadic readings (most of which were associated with a GSFC or Ames flipper pulse or short undervoltage cycles).

The spacecraft appeared not to be recovering from the oscillatory mode and it did not appear to be associated with a battery short. A battery short would probably have been burnt clear in less than a day. It now was thought to be related to some turn-on phenomena of the spacecraft under full load in the absence of a battery. It was decided that the command to turn the transmitter off should be sent to see if removing half the spacecraft load would correct the problem. On 13 February the command was sent. Upon turn on of the transmitter after an off time of half an hour the voltages had all returned to normal, i.e., the prime power voltage 18.3 volts, 12-volt bus 12.0 volts, and the 28-volt bus 28.0 volts. Table II contains a list of times that the field stations reported loss of spacecraft signal.

To determine the cause of this anomaly the AIMP-I prototype components of the power system (except for the battery) were tested in the laboratory using a solar array simulator as the source of power input and a resistive load on the prime converter to simulate the spacecraft. The solar array simulator was programmed using the flight data from the AIMP-I (see figure 3). A spin rate of 17.9 rpm and solar sun angles of 30, 90 and 120 were simulated. The test was run at room ambient.

The system on turn-on from power supplied by the solar simulator using programmed data, on three different sun angles, went into the oscillatory mode of operation. Only in the 90 and 120 degree case could normal operation be restored by briefly removing the 20-volt line load (7.2 watts). The 30° case required brief removal of the 28-volt line load (20 watts) instead of the 20-volt load.

Turn on characteristics of the prime converter and solar array regulator were analyzed (see illustration 3). The spacecraft came on when the input voltage exceeded 17.7 volts. The prime converter immediately loaded the system, dropping the input voltage to 9 volts and started charging its input capacitors. The prime converter began to seek its steady state operating point with respect to the solar array, considering no pre-regulation, which is approximately 22 volts. The solar array regulator failed to clamp the voltage at 18.3 volts because of a delay built into the system for noise suppression during thermal vacuum chamber testing. The solar array regulator reacted to the high voltage by regulating hard and dumping current which resulted in the discharge of the prime converter input capacitors. This caused the input voltage to drop to 9 volts and the cycle repeated.

By changing a capacitor value in the solar array regulator from 68μf to 10μf, the system remained stable in all cases tested. The faster response of the solar array regulator permitted the solar array to start to clamp much closer to 18.3 volts, thus turning on softer and not discharging the prime converter input capacitors. A longer delay would have had the effect of having the solar array regulator act more slowly causing the voltage to slowly come back near 18.3 before the regulator was on full. Unfortunately, the value of 68μf is almost optimum in the AIMP-I case for the system to go into this oscillatory mode.

d. Spin Axis/Sun Angle and Spin Rate

The spin axis/sun angle has followed its predicted course from launch to the turn-around point (see figure 4). The returning plot should be a mirror image of the first half however it is not. The slope of the upward curve is different from the downward curve. The reason for this slight variation has not as yet been determined.

The right ascension and declination of the spacecraft as determined from the optical aspect system are given in table III.

The effects of the battery failure on the spin rate are seen in figures 2 and 4. Other than the battery effect, the spin rate has reacted to the sun angle as predicted since the last reporting period.

e. Performance Parameters

There are 26 analog performance parameters.

PP-1 12-Volt Bus—The value of the voltage monitor remained within the 1% tolerance until the termination of the first shadow when the first reducible telemetry data gave values from 7.3 to 14.1 volts. This condition lasted from day 355.69747 to 355.91241. The validity of these values is questionable since the encoder would not function correctly for these voltage excursions. After termination of the second shadow, the telemetry data showed the 12 volts to be slightly out of tolerance (11.8 to 11.9 volts) from day 5.05216 to 12.92729 of 1967 for the majority of the time. Sporadic values of 14.1 to 7.3 appeared which were associated with either a magnetometer flip pulse or a short duration undervoltage turn-off. The 12-volt has been in tolerance since day 12.9729.

PP-2 Prime Power Voltage—The input voltage remained at 18.3 from day 183 to approximately day 350. Afterwards, every time the battery charge current would exceed 100 milliamps, the voltage would switch to 19.6 volts, which is a normal function. The battery did not load the system down to the point that it lowered the voltage until day 354.01813 (sporadic readings did occur prior to this but they appear to be the result of noisy data). On day 354 the prime voltage slowly went down (see figure 5). The spacecraft went into about a half-hour undervoltage cycle and the value returned to 19.6 upon turn-on at 354.17899. The prime power voltage again remained within limits until turn-on of the spacecraft after the first shadow (see turn-on anomalies and 12 volts, above). The prime power voltage variation is the cause of the variations of the other voltages. Since day 12.9729 it has remained at 18.3 volts.

PP-3 Battery Current—The battery current sensor measures battery input or output current from 0 to 200 milliamps. (See battery failure for details on readings during the time period day 350 to day 354 of 1966.) The battery continued to take a charge, i.e., a reasonable short remains in what used to be a battery until about day 20 of 1967. During this period the current to the battery location had values predominately between 50.0 and 90.0 milliamps. After this date (day 20) the current remained below 15 milliamps.

PP-4 Solar Array Current—The solar array current varies with sun angle and orientation of the spacecraft to the sun. The current readings for this period, like those of the first report, varied from 3.0 to 5.0 amps. The solar array has degraded about 5% since launch.

PP-5 Spacecraft Current—As far as can be ascertained, the spacecraft current has been nominal. Large variations have been a function of prime input voltage changes and not the spacecraft prime converter load. The spacecraft current has been consistent with the input voltage.

PP-6 28-Volt Bus—The value remained 28.0 volts from liftoff to exit from the first shadow. The same times of variability associated with the 12-volt bus are associated with the 28-volt bus. During these erratic periods the 28-volt bus would vary from about 24 to 34 volts for the first period and 27 to 31 volts for the second period. The voltage from day 12.92729 of 1967 has been within tolerance.

PP-7 7-Volt Supply—The 7-volt supply, except for the times noted in table 1, has read 7.0 volts. The effect of grounding or loading down the supply caused the loss of all temperature data except for the encoder during the times noted in table 1.

PP-8, 9, 10, 11 and 12 - Iowa Voltage and Solar Cell Damage Experiment—This data is not reported in this document.

PP-13, 14, 17, 18, 19 and 21 through 26 Standard Temperature Measurements—The following is a list of the temperatures monitored along with the corresponding figure number on which the data for this period is shown.

Temperature Monitored	Figure No.
PP13 Solar Cell Damage Experiment	6
PP14 Thermal Ion Temperature	7
PP17 Transmitter Temperature	8
PP18 Battery Temperature	9
PP19 Prime Converter Temperature	10
PP21 Ames Boom Temperature	11
PP22 Ames Electronics Temperature	12
PP23 GSFC Boom Temperature	13
PP24 University of California Temperature	14
PP25 Massachusetts Institute of Technology Temperature	15
PP26 University of Iowa Temperature	16

The temperatures on all systems are high but are satisfactory for operation except for the battery which has failed from storage at too high a temperature. The temperatures were expected to increase about 5° on the second reading at the same spin axis/sun angle on the top cover due to degradation of the thermal coatings. The bottom did not suffer from contamination, therefore, closer agreement was expected at the same sun angles.

A close examination of the temperatures measured in the on-board packages (figures 7, 8, 9, 10, 12, 14, 15, 16 and 17) shows a slight bump due to the increase in temperature of the battery on day 351. The battery temperature curve (figure 6) is most dramatic at this time. Other than this instance, the curves follow their expected paths.

•PP-15 Fourth Stage High Temperature/Fourth Stage Firing Duration—The data output of this sensor has remained constant since fourth stage burnout.

•PP-16 Encoder Temperature and Calibration—The encoder has two temperature sensors both of which have had values within 1/2 a degree of each other since launch. The output of one sensor is given in figure 17.

The encoder calibration consists of two ground readings, a 4-volt divider, a 4-volt standard, a 2.5-volt divider, and a 5-volt reading. A table below gives the decimal output associated with each value.

Input	Output	Note
Ground	220	Steady, no variations
2.5 Volts	121-122	Value almost constantly 122
4-Volt Divider	60-61	Value almost constantly 61
4-Volt Standard	61	Steady
5-Volt	19	Steady

•PP-20 Solar Array Temperature—This data is plotted in figure 18. The difference in temperature at the same sun angle is due to a slight decrease in efficiency of the cells and some darkening of the cover glass.

III. AIMP-D ORBIT

a. Orbital Characteristics

The AIMP-D orbit is highly perturbed by the moon. The predictions presented in the first Interim Flight Report (reference 1) were valid during the period covered by both it and this report. These first predictions, however, began to lose their accuracy after the close approach to the moon in March. A new set of predictions is given in table IV which is estimated to be valid to about August of this year.

In order to obtain as much telemetry (scientific) data as possible, the use of the tracking transponder (which caused a 30 db antenuation of the telemetry signal) is kept to a minimum consistent with experimental position accuracy requirements. This results in the starting vector used in the orbit prediction not being as accurate as would be desirable for long range predictions.

IV. ACKNOWLEDGEMENTS

The following personnel contributed data or information contained in this report. Messrs. Philip Jones, G. Ernest Rodriguez, and Thomas Hennigan of GSFC on the power system; Mr. Jerome Barsky of GSFC on the orbital data; and Mr. Thomas Hollis of Westinghouse contributed general information.

The report was prepared with the assistance of Mr. Warren Bailey and Mrs. D. B. Matters.

REFERENCES

1. Madden, J. J., Interim Flight Report Anchored Interplanetary Monitoring Platform, AIMP-1 - Explorer XXXIII, NASA X-724-66-588, 1966.

2. Salay, J., Laboratory Test Evaluation A-IMP Electric Power System, NASA X-716-67-12, 1967.

3. Rodriguez, G. Ernest, Combined Operation of the AIMP Prime Converter and Solar Array Shunt Regulator from a Solar Array Simulated Source, NASA X-716-67-162, 1967.

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TABLE I

Time	Temp. (C°)	Charge Milliamps	Battery Events
348.81657	49	1.5	Battery goes on continual charge.
349.01920	50	200.0	Battery charges sensor saturates for first time. Voltage switches from 18.1 to 19.4 on main bus.
349.05803 from above to	50	192.4	Battery charge sensor no longer saturated. Becomes sporadic for short periods saturating charge sensor.
351.42428	50	200.0	Battery charge sensor saturates.
351.54075	57	128.6	Battery charge sensor no longer saturated. Performance parameter 7-volt power supply grounded indicating battery electrolyte has ground battery thermistor to the case.
352.32193 to		186.1	Battery charge sensor sporadically saturated.
352.32382 from above to	57	200.0	Battery charge sensor saturated. Temperature returned, i.e., 7-volt supply no longer grounded. Battery sensor remains saturated. Temperature varies between 59° and 60°C.
353.37297	60	200.0	
353.37486 from above to		67.6	Battery sensor no longer saturated. Temperature no longer valid, i.e., 7-volt supply grounded again.
353.60969	9	121.5	Battery temperature returns, however; a few sporadic readings.
353.85020	50	200.0	Battery charge sensor saturates.
353.94773	52	190.2	Battery charge sensor no longer saturated.
354.01117 to	49	182.3	Battery charge sensor sporadically saturated.
354.01495	50	200.0	Battery charge sensor saturated. Spacecraft voltage begins to drop.
354.05600	55	200.0	

TABLE I (Continued)

Time	Temp. (C°)	Charge Milliamps	Battery Events
354.06943	55	200.0	Spacecraft goes into undervoltage momentarily.
354.07132	55	200.0	Spacecraft goes into undervoltage.
354.07502	56	200.0	First data after turn-on.
354.08070	56	200.0	Spacecraft goes into undervoltage.
354.11117	55	200.0	First data after second turn-on.
354.12348	54	200.0	Spacecraft goes into undervoltage for less than a minute.
354.15419	54	200.0	Spacecraft goes into undervoltage for one-half hour.
354.17899	20	200.0	First data after turn-on. Battery temperature decreasing.
354.0550	9	195.1	Battery charges, sensor no longer saturated. Sensor never saturated after this time.
354.23770	6	139.0	Battery thermistor lowest temperature reading.
354.30208	50	85.4	Battery temperature back to normal.

NOTE: Turn on and off of spacecraft are extracted from processed data. Actual spacecraft on and off cycles were more numerous. It is estimated that in one frame six rapid on-off's actually occurred.

TABLE II
Station Reported Loss of Signal AIMP-D

Date	Time Z From To	Time Off Minutes	Notes
21 Dec 1966	0356Z-0414Z	18	Battery short
22 Dec 1966	1149Z-1618Z	269	1st shadow and undervoltage cycle
30 Dec 1966	2012Z-2015Z	3	Battery short
	2116Z-2117Z	0.5	Battery short
	2152Z-2154Z	2	Battery short
	2204Z-2205Z	1	Battery short
	2311Z-2312Z	0.5	Battery short
6 Jan 1967	0031Z-0111Z	40	2nd shadow
13 Jan 1967	2120Z-2200Z	40	Transmitter commanded off and on
18 Jan 1967	1403Z-1811Z	248	3rd shadow and undervoltage cycle
	2102Z-2114Z	12	Transmitter commanded off and on
2 Feb 1967	0140Z-0345Z	125	Transmitter turned off 1 hour prior to entrance to 4th shadow and on half an hour after exit
14 Feb 1967	1612Z-2151Z	339	Transmitter commanded off 1 hour prior to entrance to 5th shadow and on 3 hours and a half after exit

TABLE III
AIMP-D Spin Axis vs. Time

Days	Right Ascension	Declination
182.0	225.2	-21.3
190.0	225.1	-21.3
200.0	224.7	-21.3
210.0	224.3	-21.2
220.0	223.7	-21.2
230.0	223.0	-21.1
240.0	222.2	-21.1
250.0	221.3	-21.2
260.0	220.2	-21.2
270.0	219.2	-21.1
280.0	218.0	-21.0
290.0	216.7	-20.7
300.0	215.5	-20.2
305.0	215.2	-20.0
310.0	215.5	-19.7
320.0	216.4	-19.0
330.0	217.6	-18.2
340.0	219.3	-17.2

TABLE IV
Orbital Elements for AIMP-D

DATE	PERIGEE RADIUS	APOGEE RADIUS	INCLINATION	C.A.M.
2/21/67		451,200	45.6	
3/1	51,300		44.9	
3/6			49.9	58,400
3/7		436,700	53.5	
3/15	108,270		49.6	
3/21		445,400	49.3	
4/1	119,700		48.1	
4/10		442,300	48.5	
4/18	111,900		48.6	
4/26		436,600	48.7	
4/30			49.5	115,000
5/4	80,300		47.8	
5/11		428,200	48.4	
5/19	73,300		48.7	
5/25		418,700	50.3	
5/27			48.1	45,900
5/31	36,500		30.6	
6/7		427,500	30.9	
6/13	32,100		31.0	
6/19		422,400	31.0	
6/23			30.5	111,800
6/26	22,500		29.0	
7/1		407,300	29.2	
7/7	20,300		29.3	
7/13		408,200	28.9	
7/19	22,300		28.7	
7/25		418,900	27.7	
7/31	27,300		27.6	
8/6		423,500	27.3	
8/12	30,600		26.8	
8/16			42.6	28,800
8/19		424,200	38.4	
8/25	63,200		37.4	
9/2		430,000	37.3	
9/8	68,500		37.0	
9/13			38.9	81,800
9/16		459,900	38.0	
9/25	119,400		38.0	

TABLE IV (Continued)
Orbital Elements for AIMP-D

DATE	PERIGEE RADIUS	APOGEE RADIUS	INCLINATION	C.A.M.
10/4/67		467,000	37.8	
10/10	130,600		37.8	
10/23		476,000	38.6	
11/2	122,300		38.9	
11/12		487,600	39.3	
11/21	129,600		39.3	
12/1		499,500	39.4	
12/11	107,200		40.7	
12/21		523,700	40.6	
12/31/67	103,100		40.6	
1/11/68		530,600	40.5	
1/21	96,000		40.7	
1/26			42.1	80,900
1/28		470,000	40.1	
2/6	69,500		39.9	
2/14		480,000	39.5	

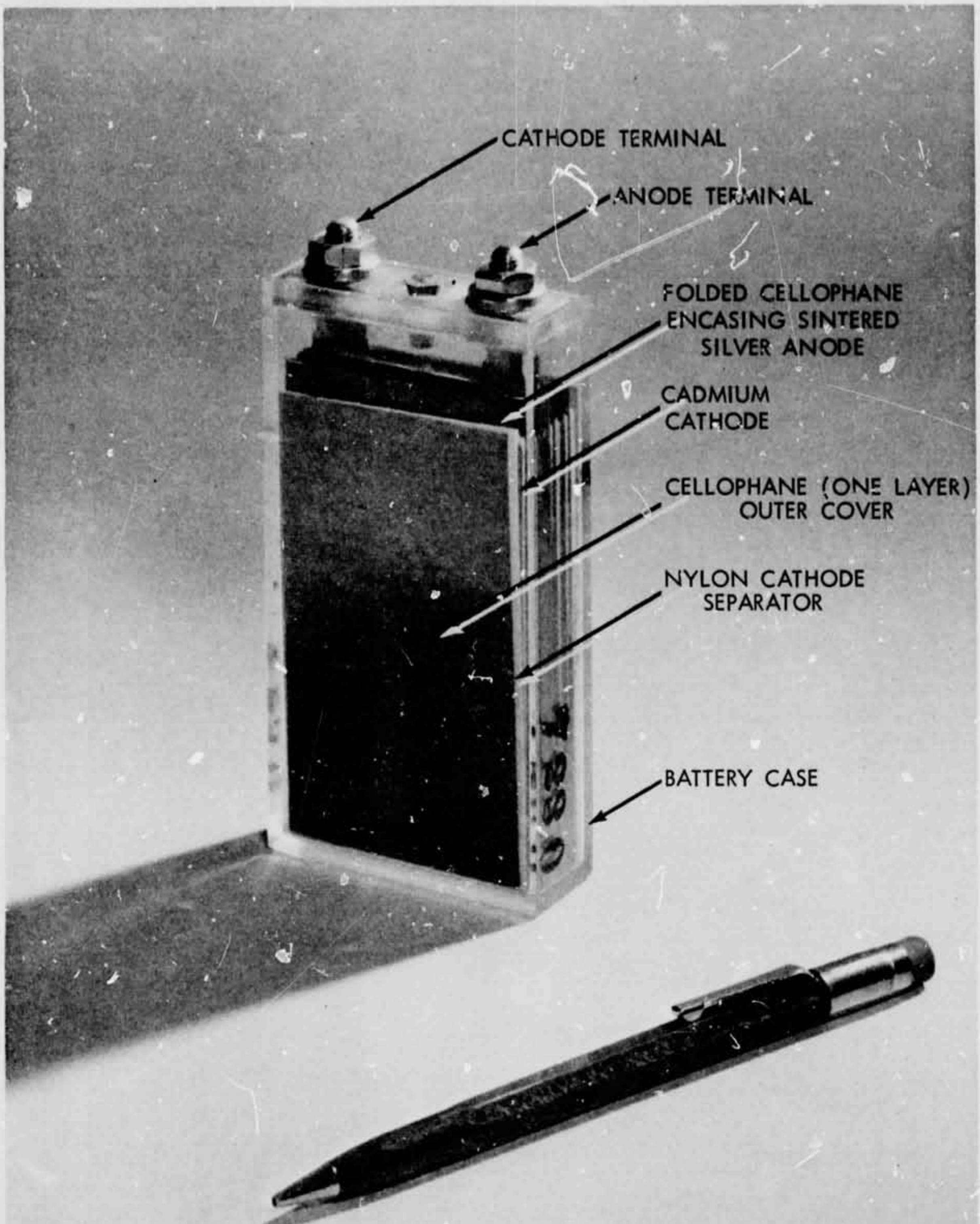

Illustration 1. AIMP Battery Cell

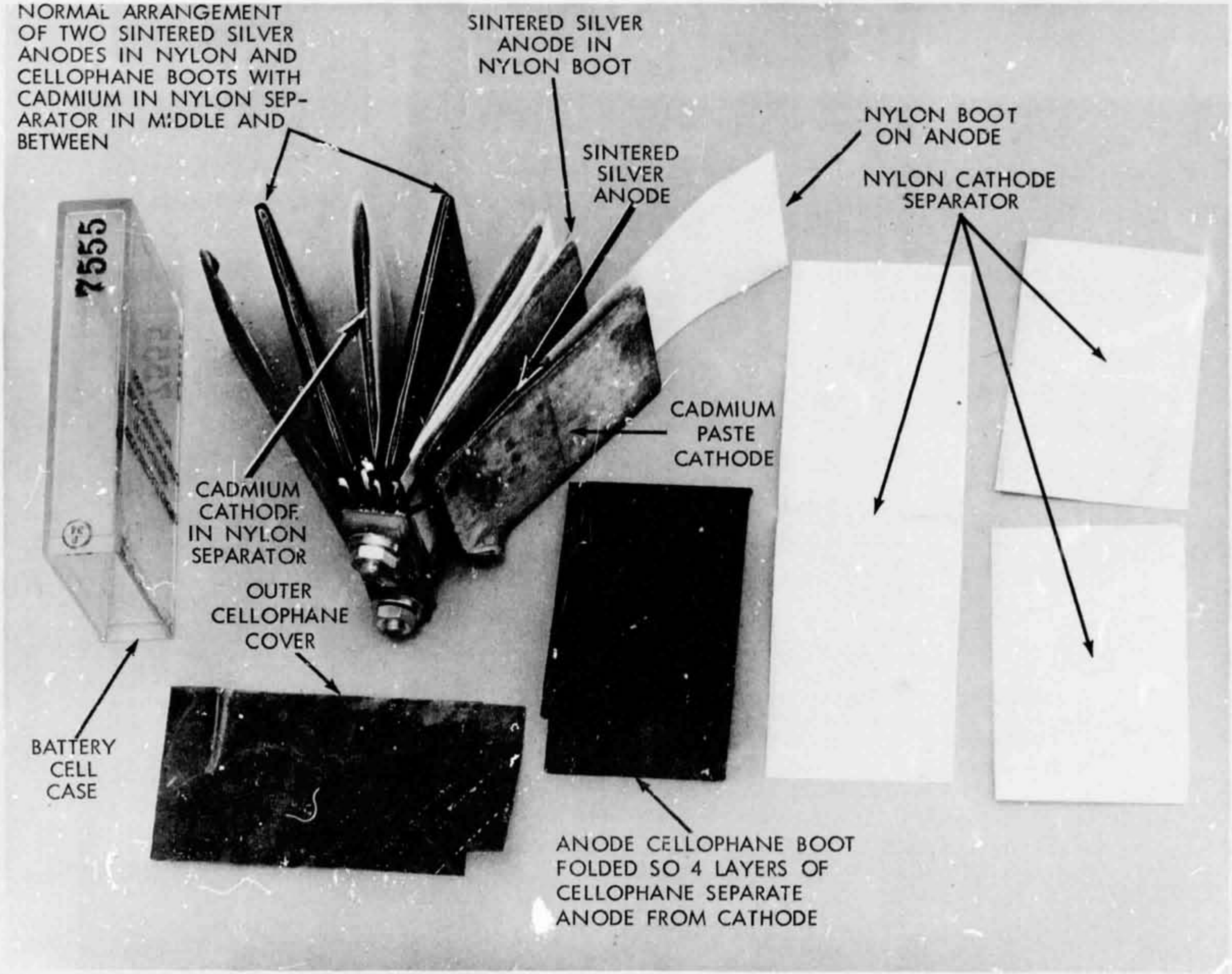

Illustration 2. Silver Cadmium Cell Construction

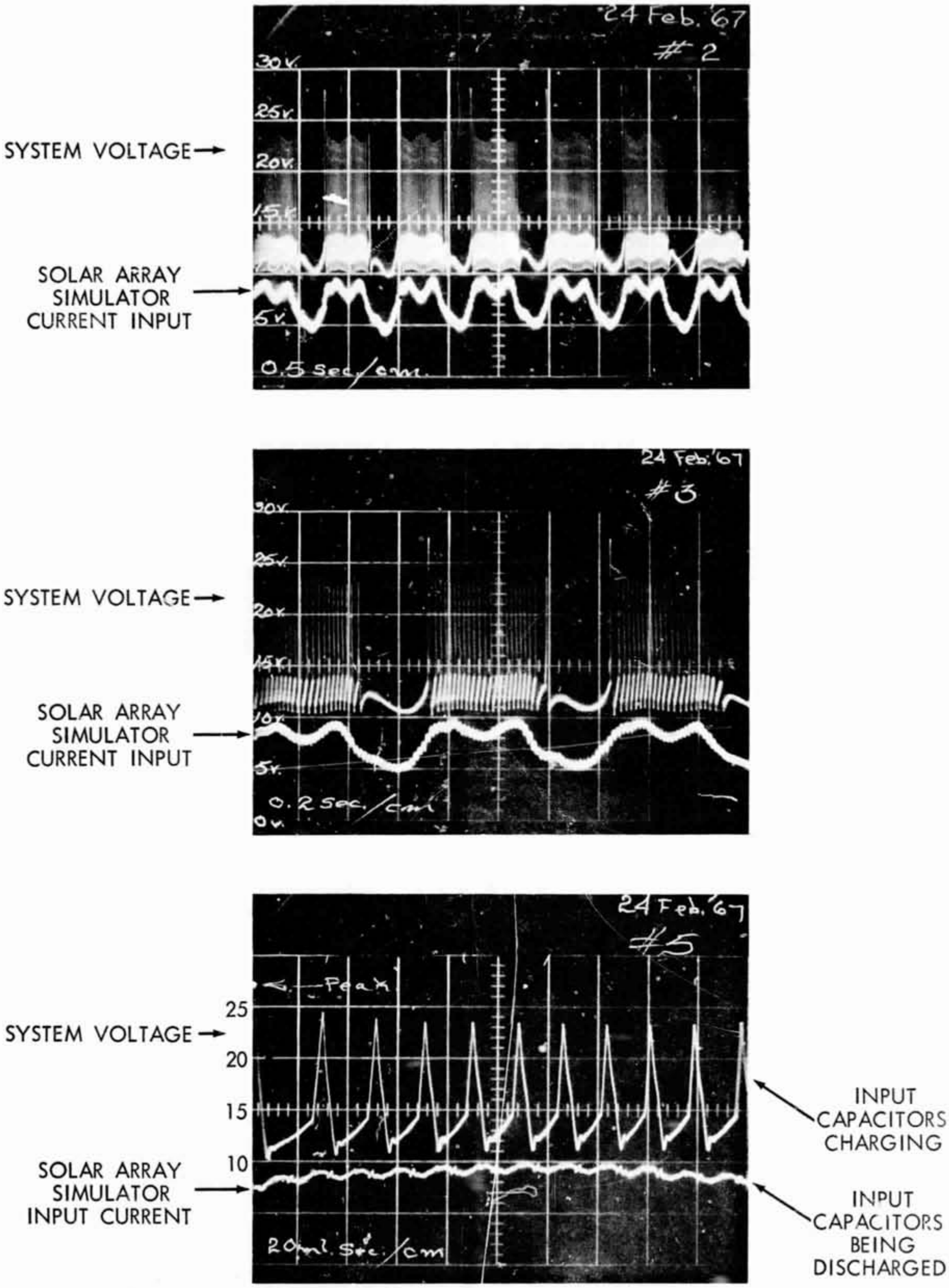

Illustration 3. Turn on Characteristic of System Without Battery for 90° Case

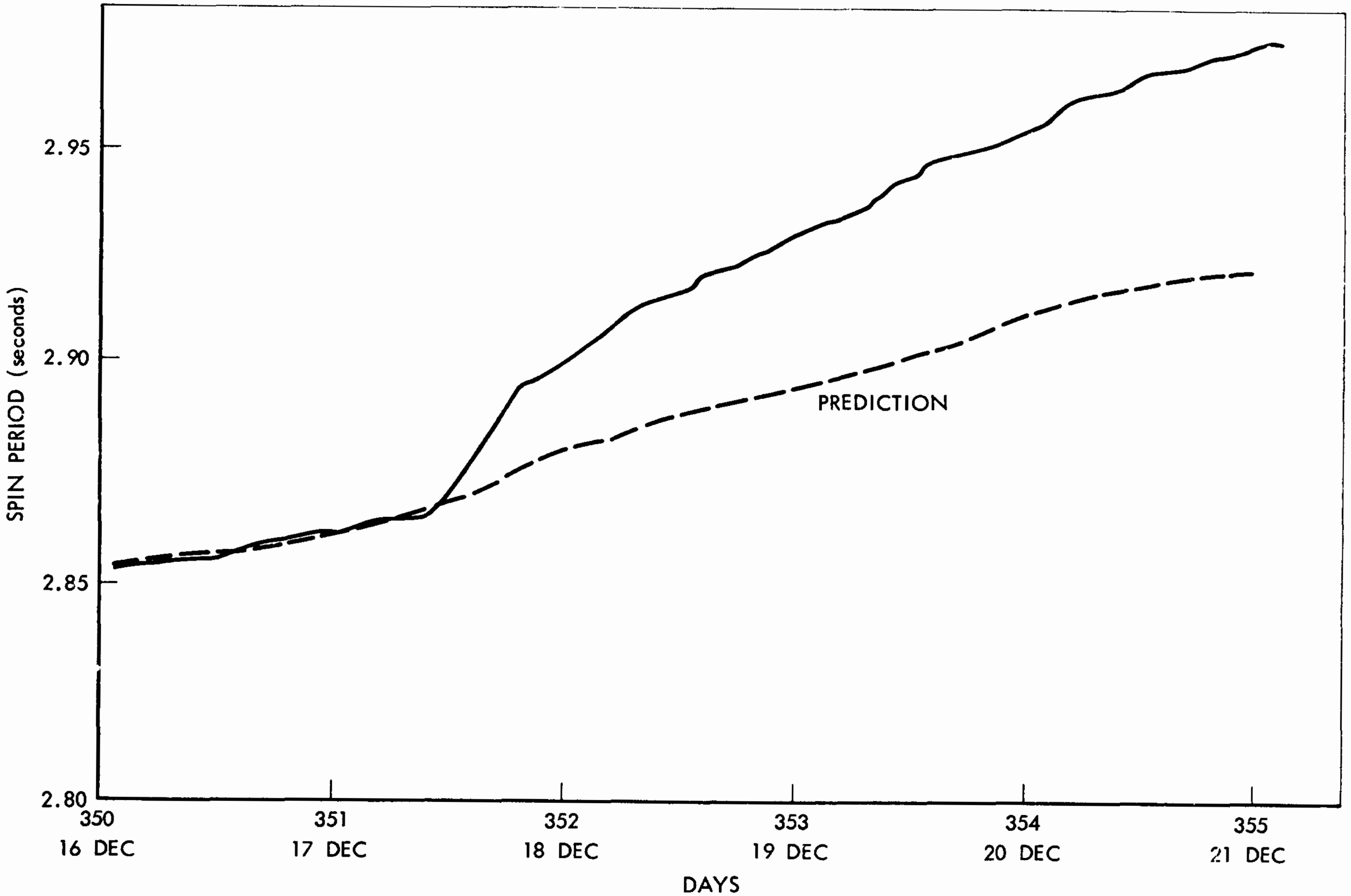

Figure 1. AIMP-D Exp. XXXIII

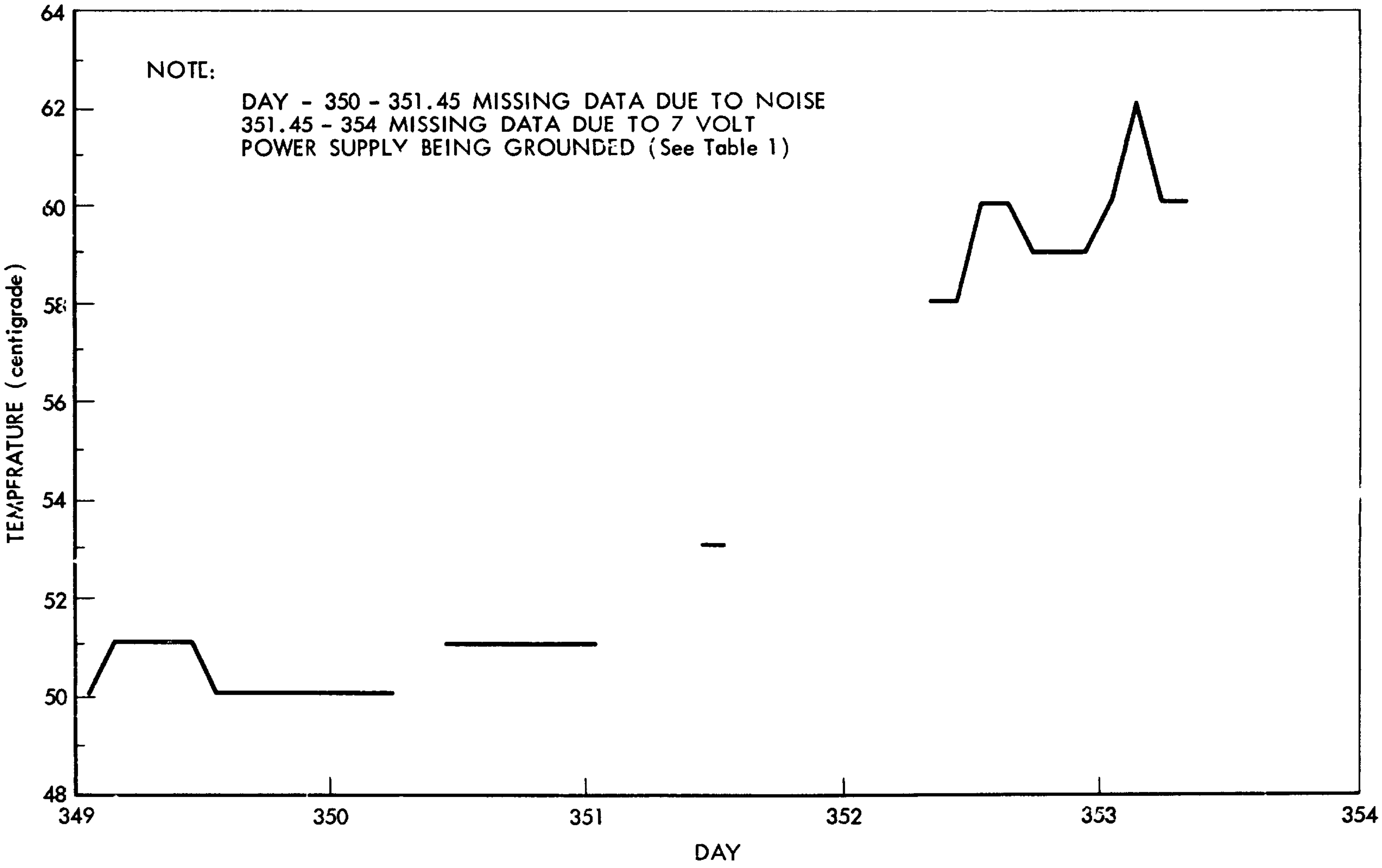

Figure 2. AIMP-D Exp. XXXIII Battery Temperature PP-18

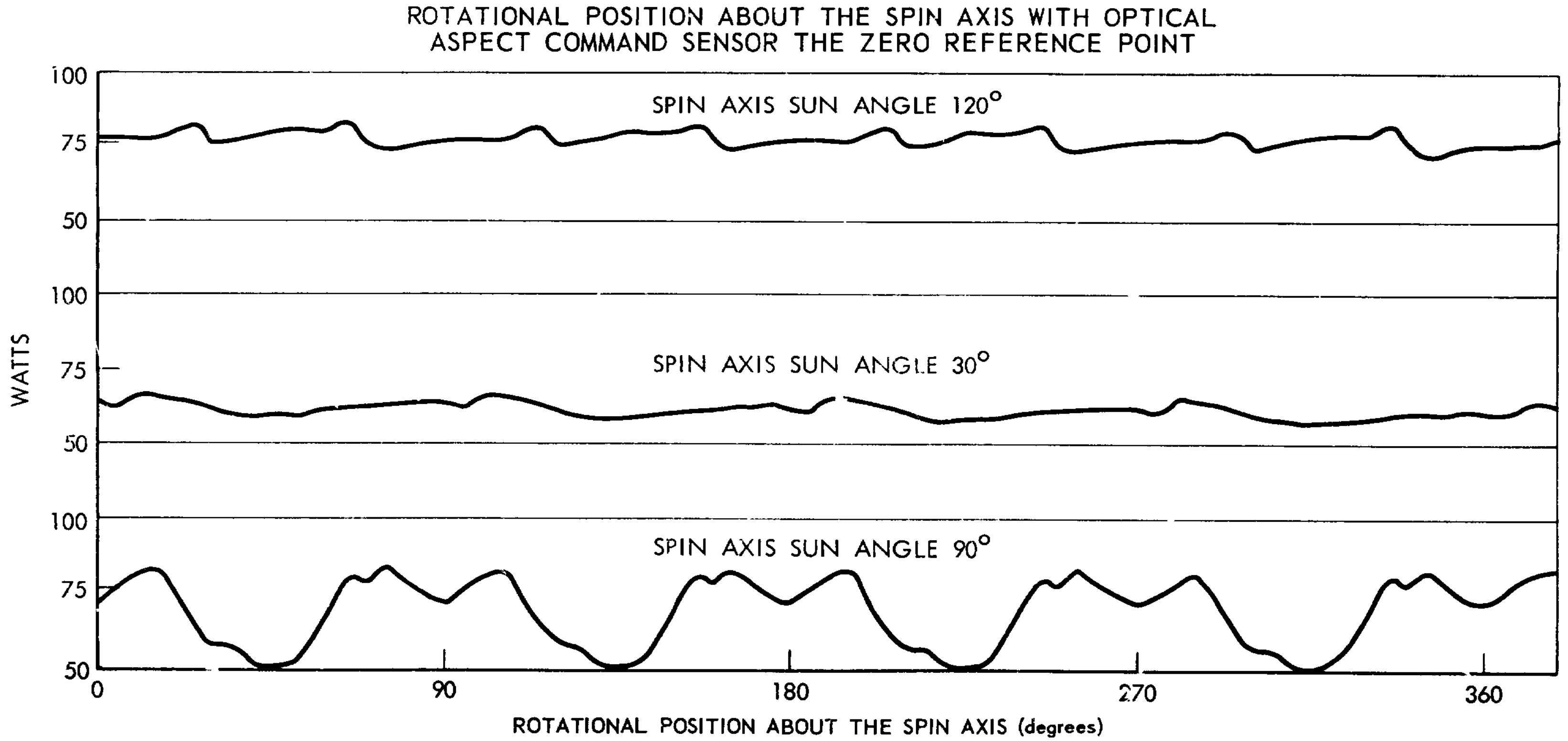

Figure 3. Power Output AIMP-D Solar Array as Determined from Telemetry Data

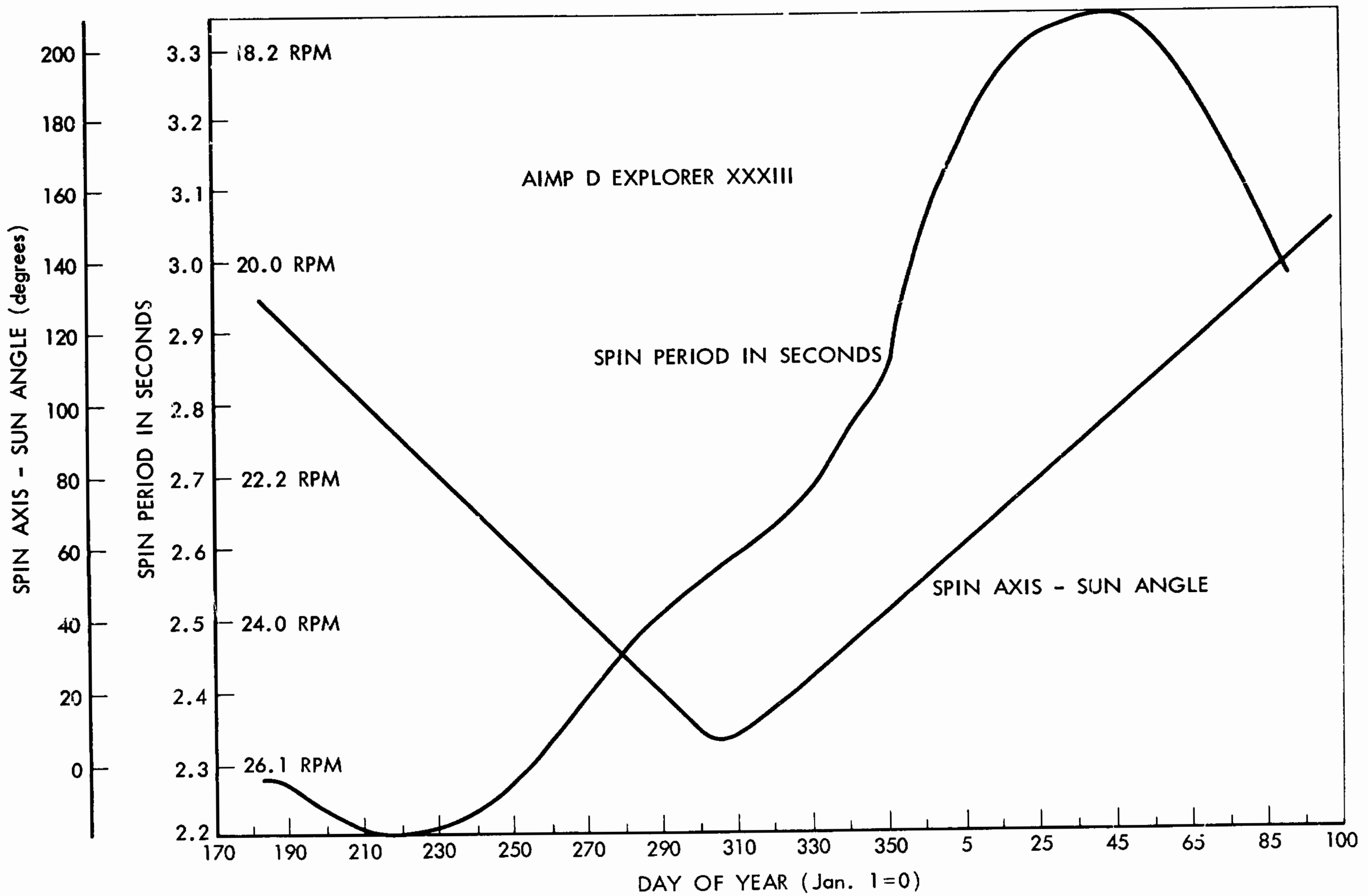

Figure 4. AIMP-D Exp. XXXIII

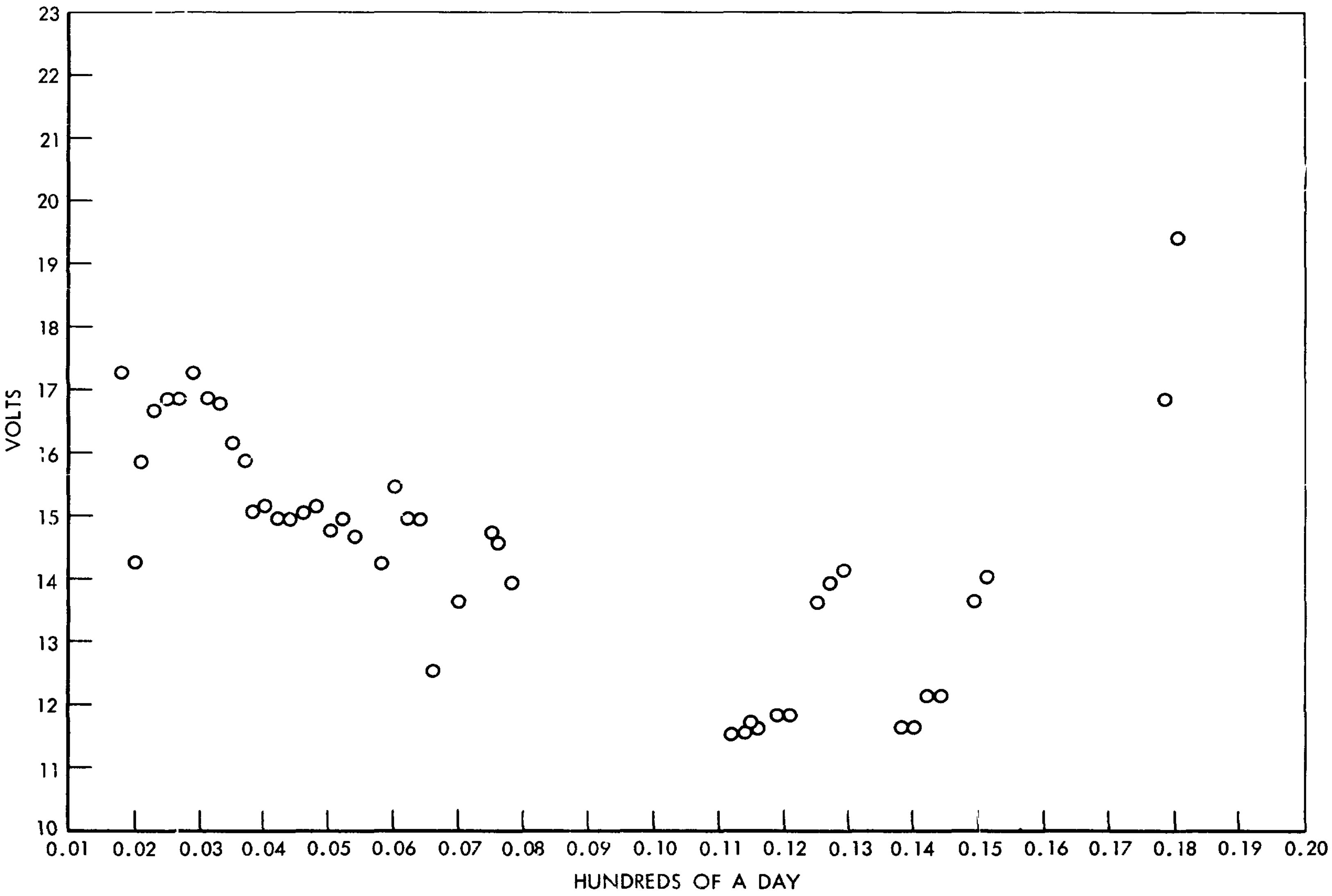

Figure 5. AIMP-D Exp. XXXIII Prime Power Voltage Day 354

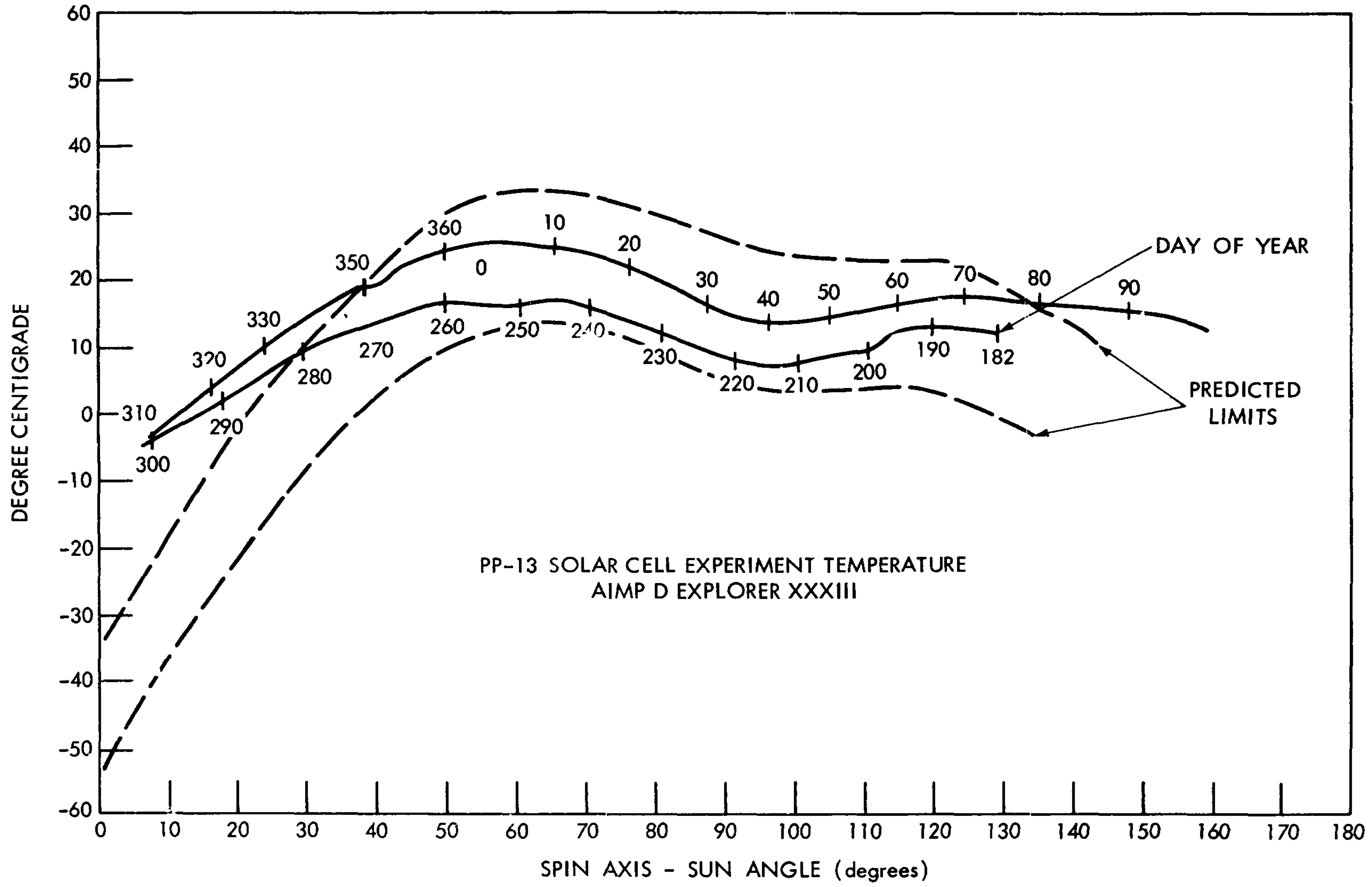

Figure 6. PP-13 Solar Cell Experiment Temperature AIMP-D Exp. XXXIII

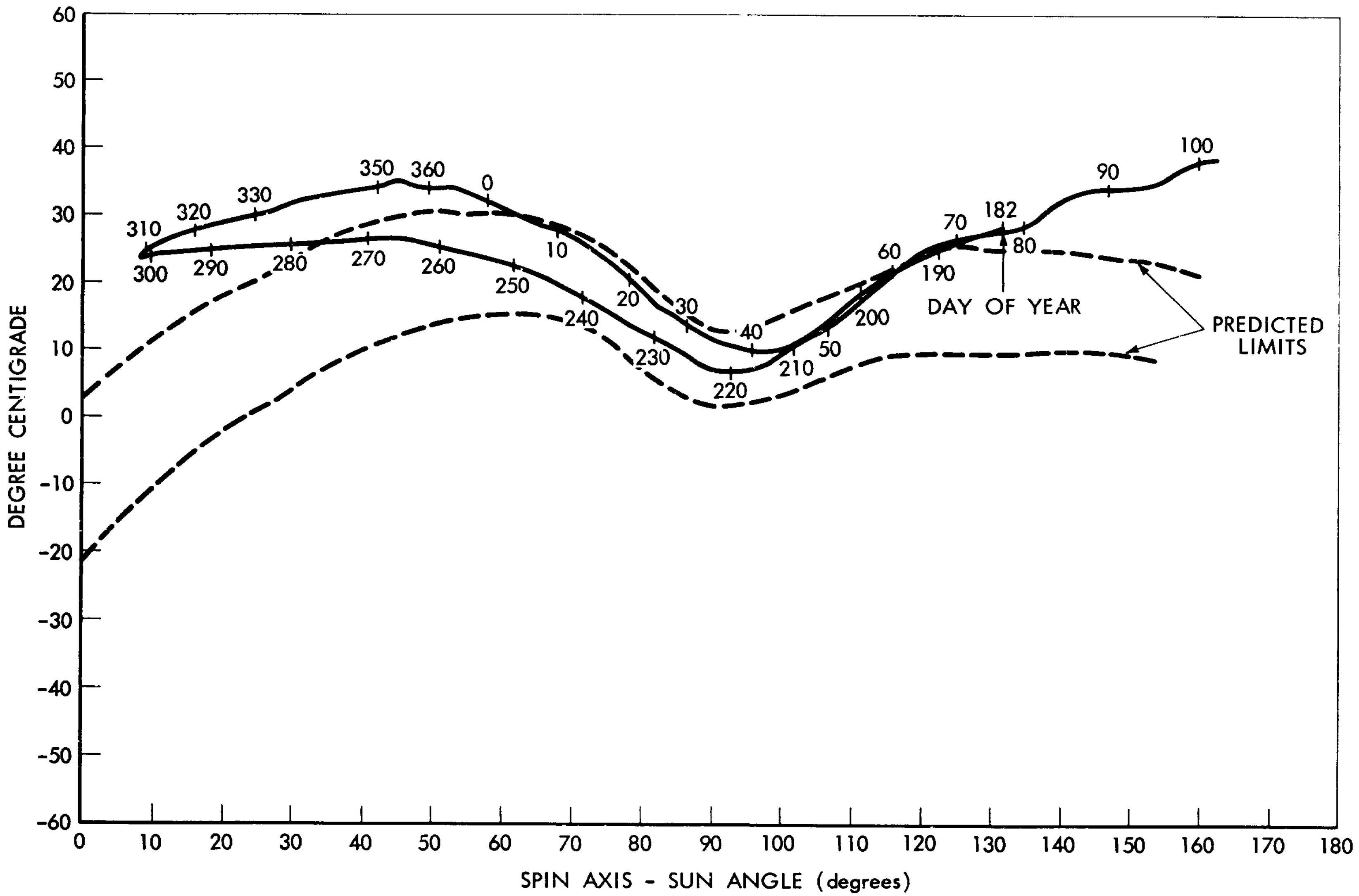

Figure 7. AIMP-D Exp. XXXIII PP-14 Thermal Ion Temperature

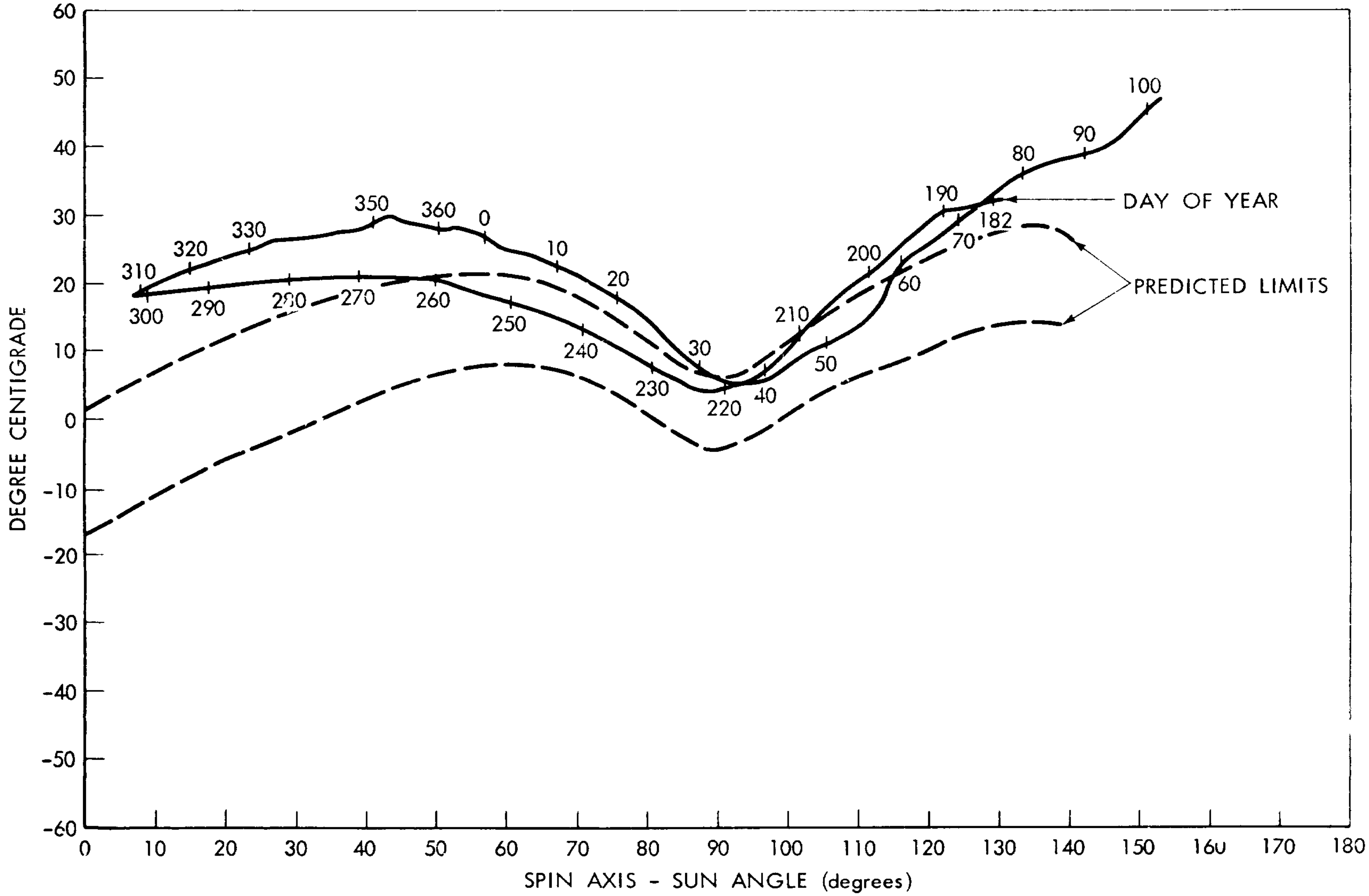

Figure 8. AIMP-D Exp. XXXIII PP-17 Transmitter Temperature

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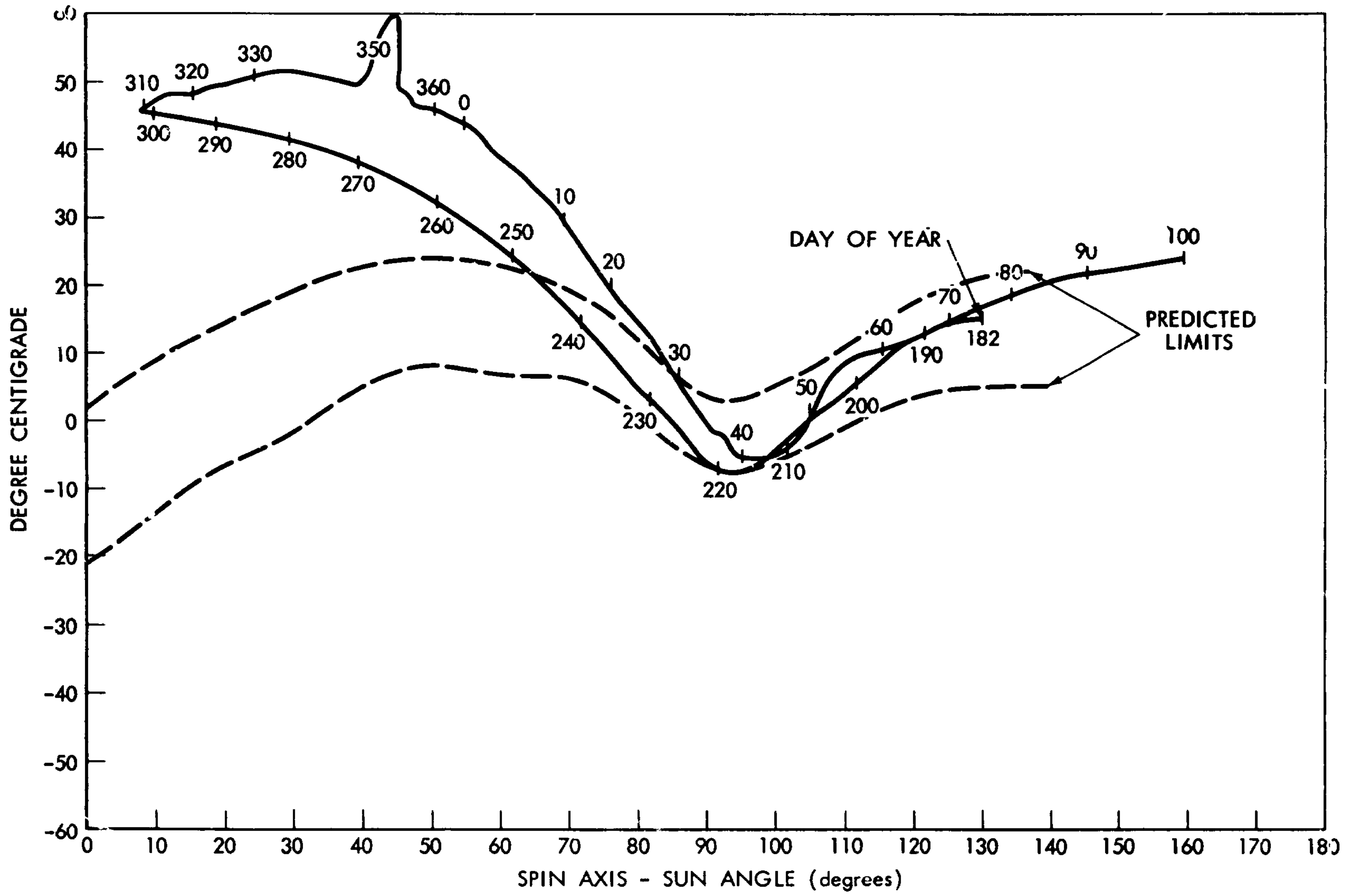

Figure 9. AIMP-D Exp. XXXIII PP-18 Battery Temperature

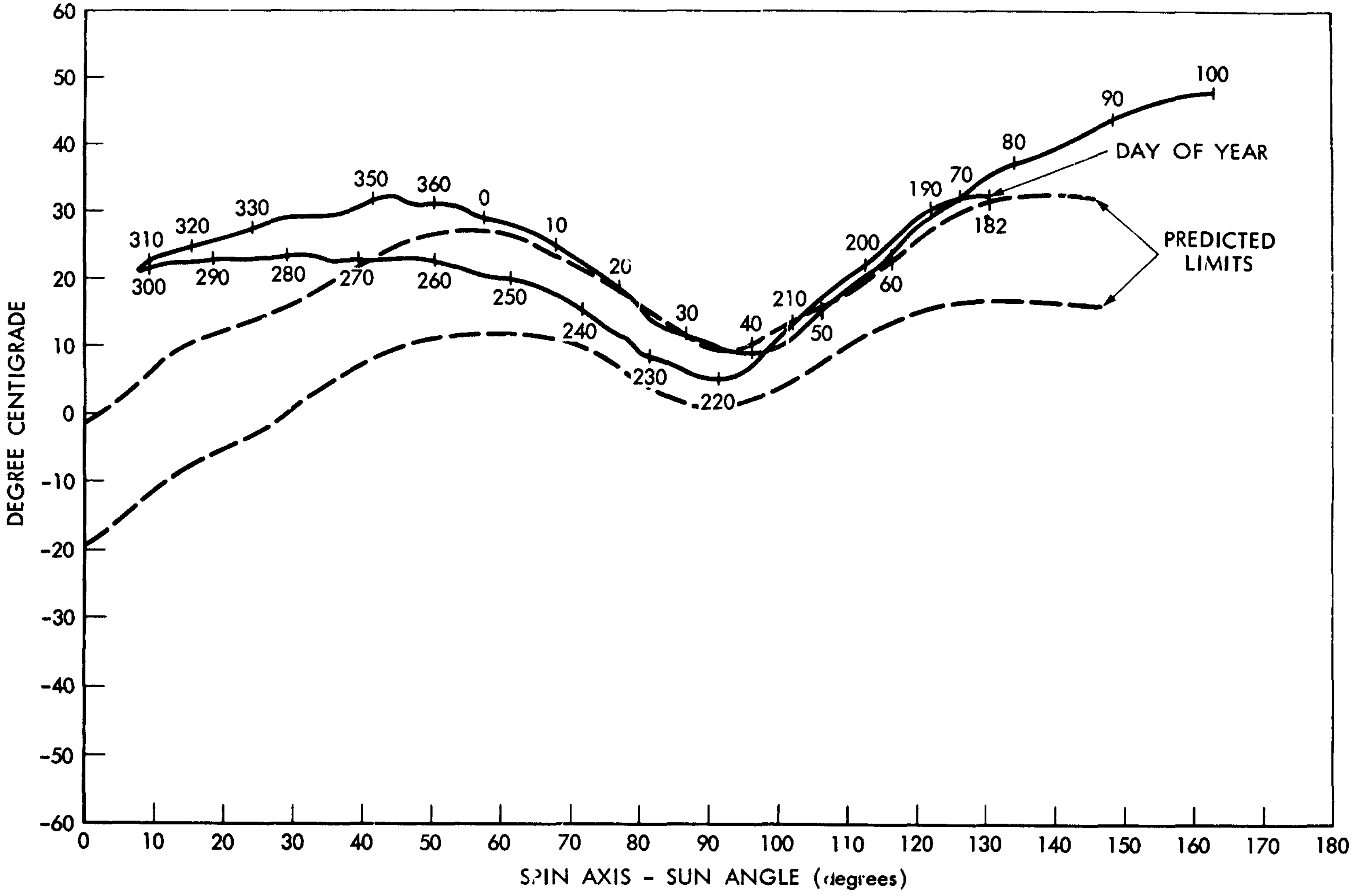

Figure 10. AIMP-D Exp. XXXIII PP-19 Prime Converter Temperature

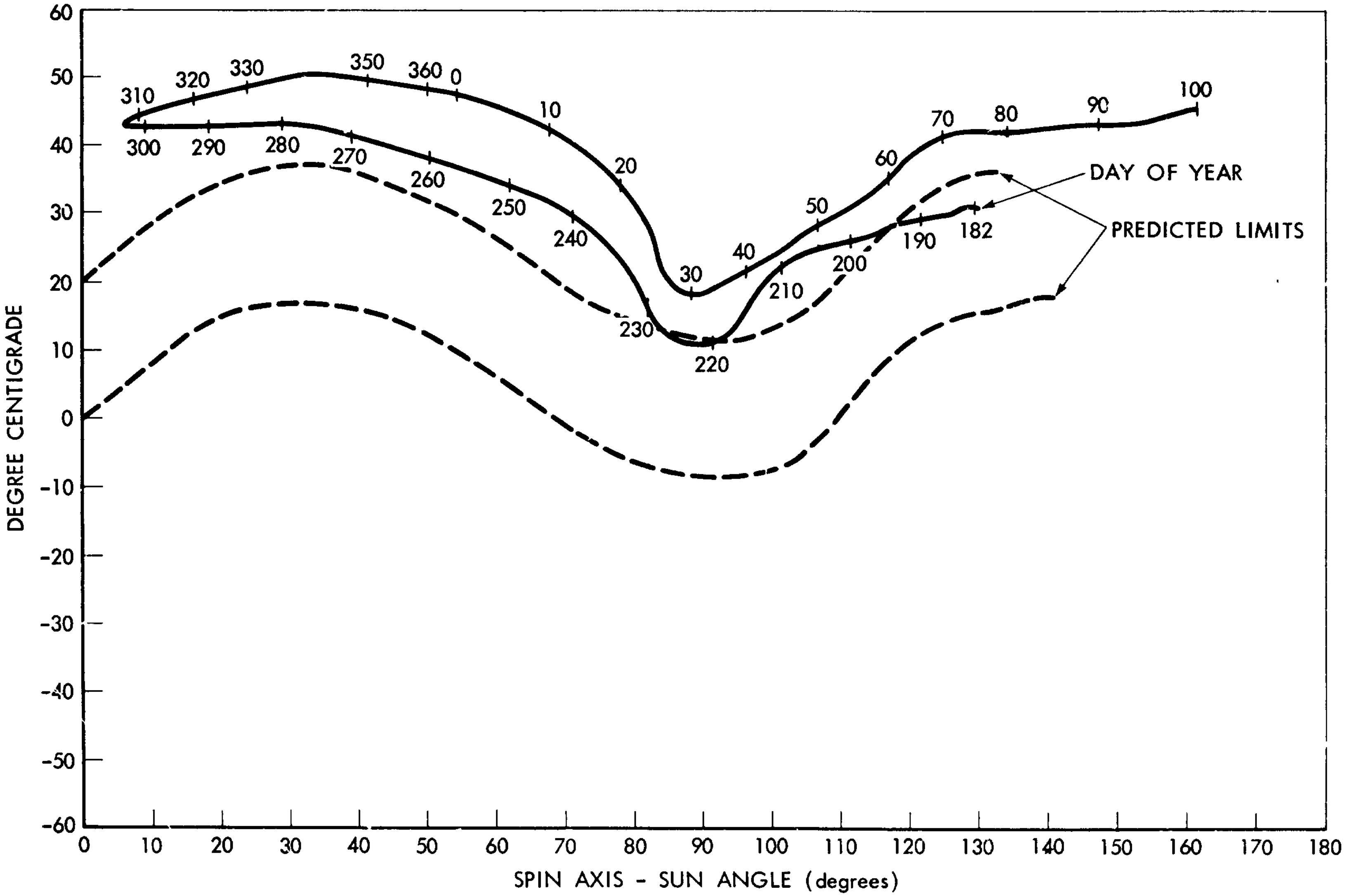

Figure 11. AIMP-D Exp. XXXIII PP-21 Ames Magnetometer Temperature

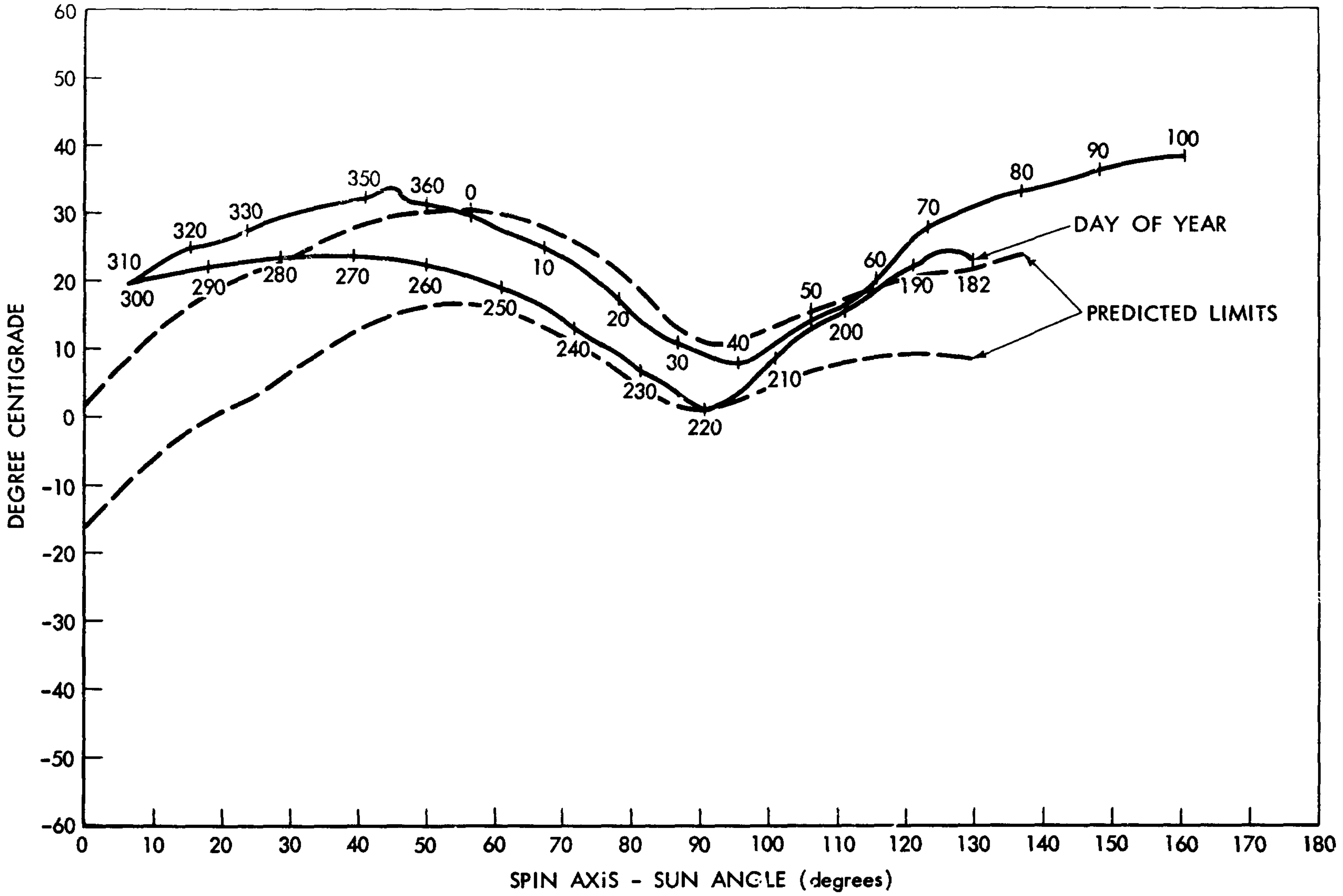

Figure 12. AIMP-D Exp. XXXIII PP-22 Ames Electronic Temperature

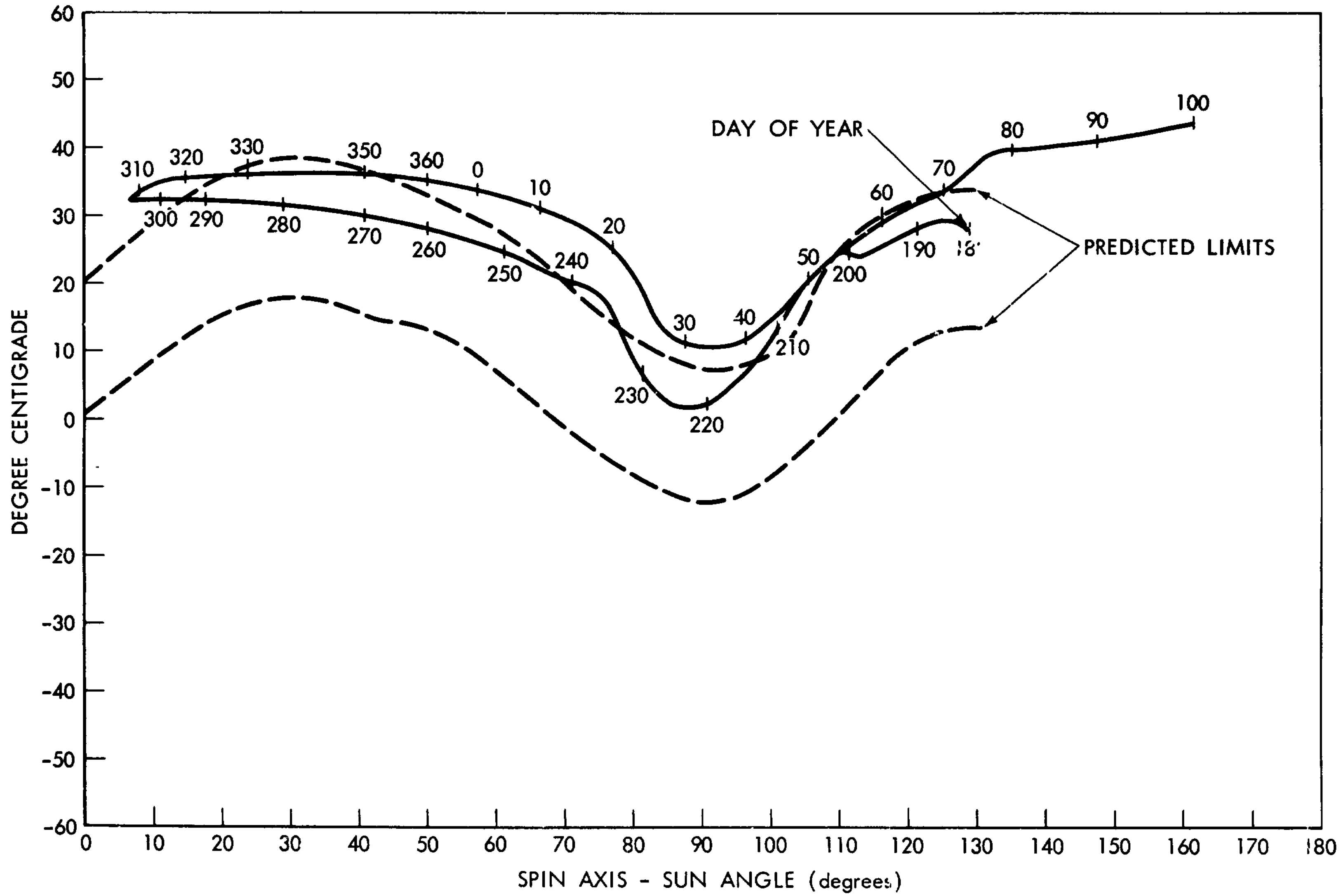

Figure 13. AIMP-D Exp. XXXIII PP-23 GSFC Magnetometer Temperature

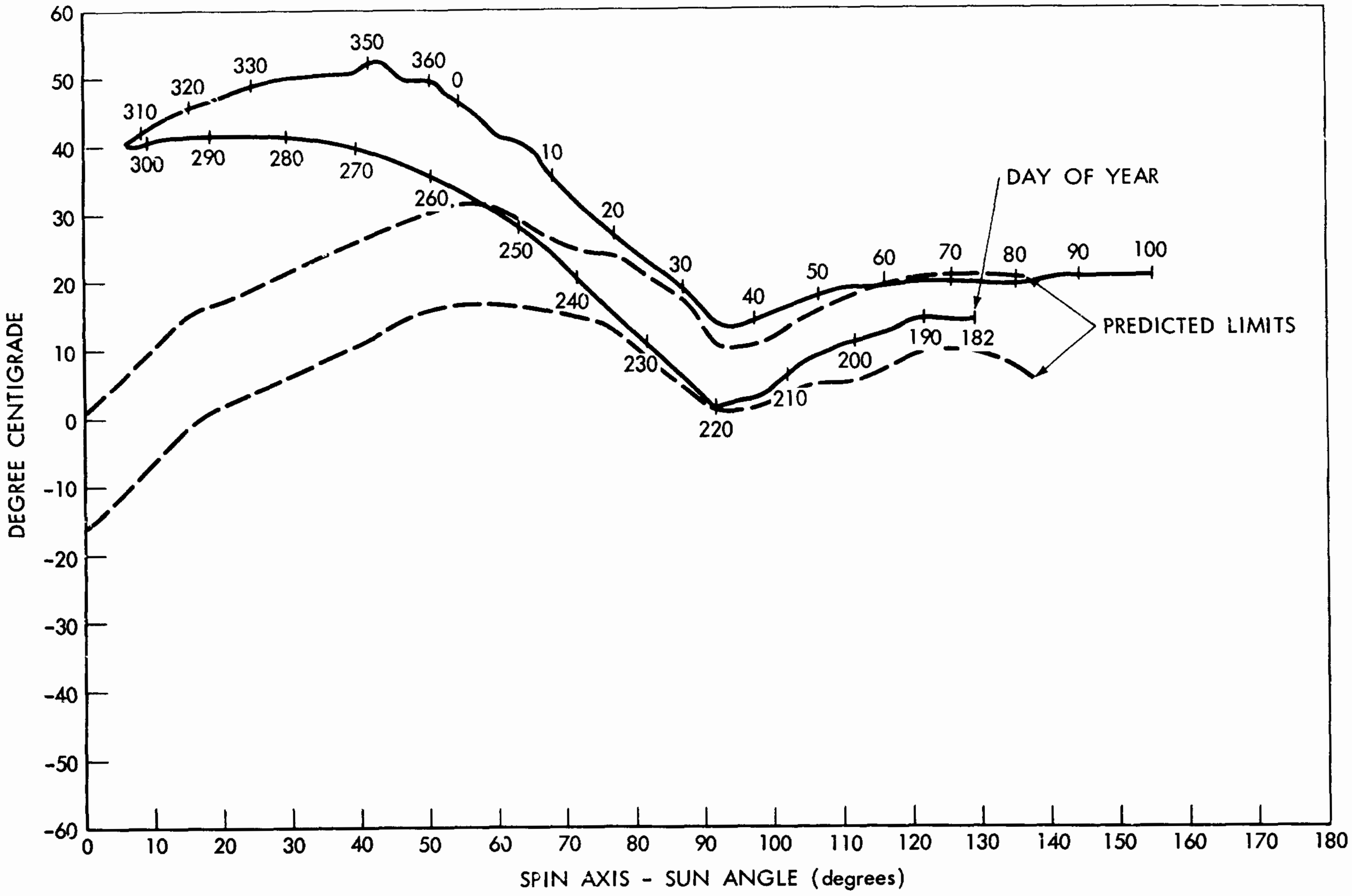

Figure 14. AIMP-D Exp. XXXIII PP-24 University of California

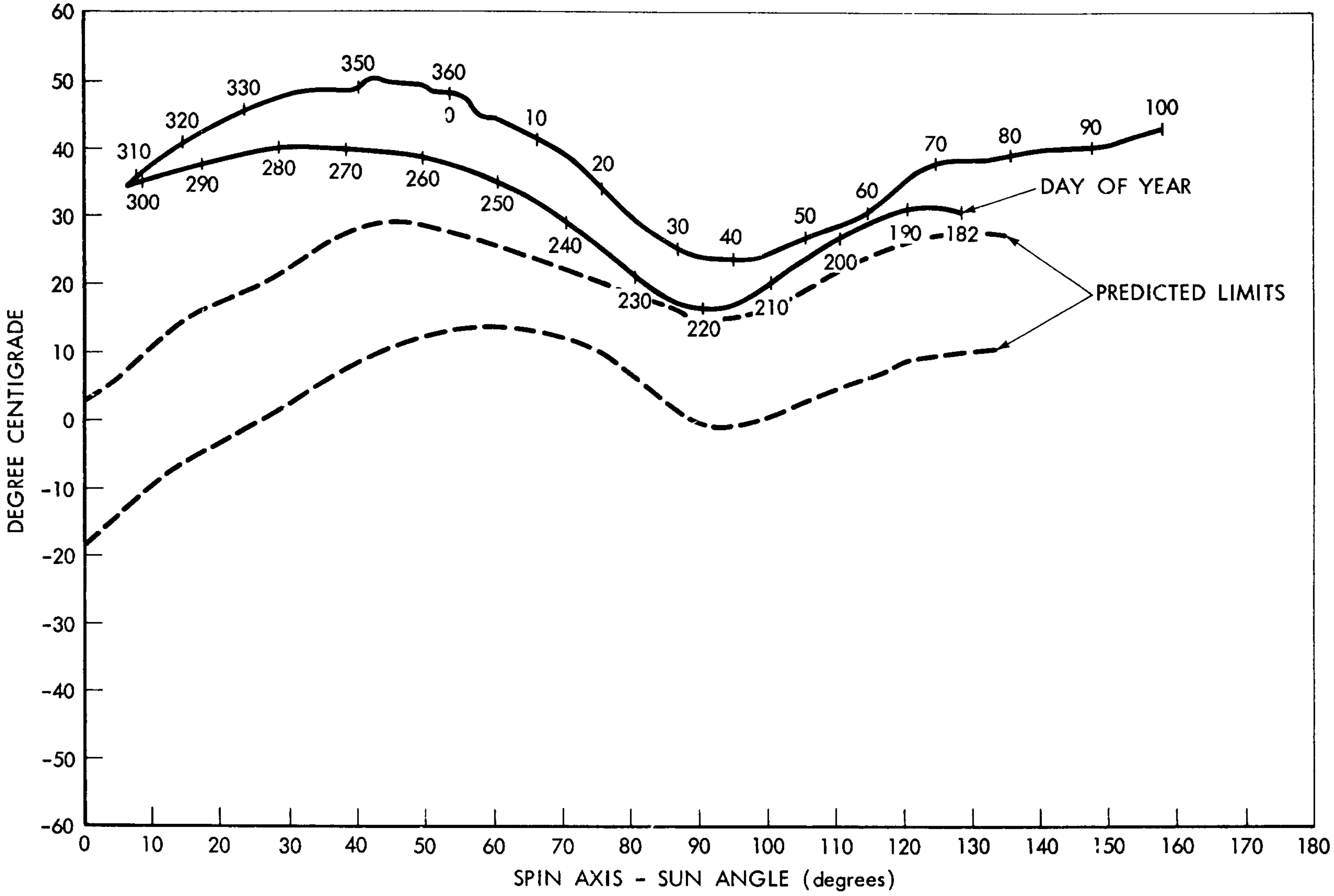

Figure 15. AIMP-D Exp. XXXIII PP-25 MIT Temperature

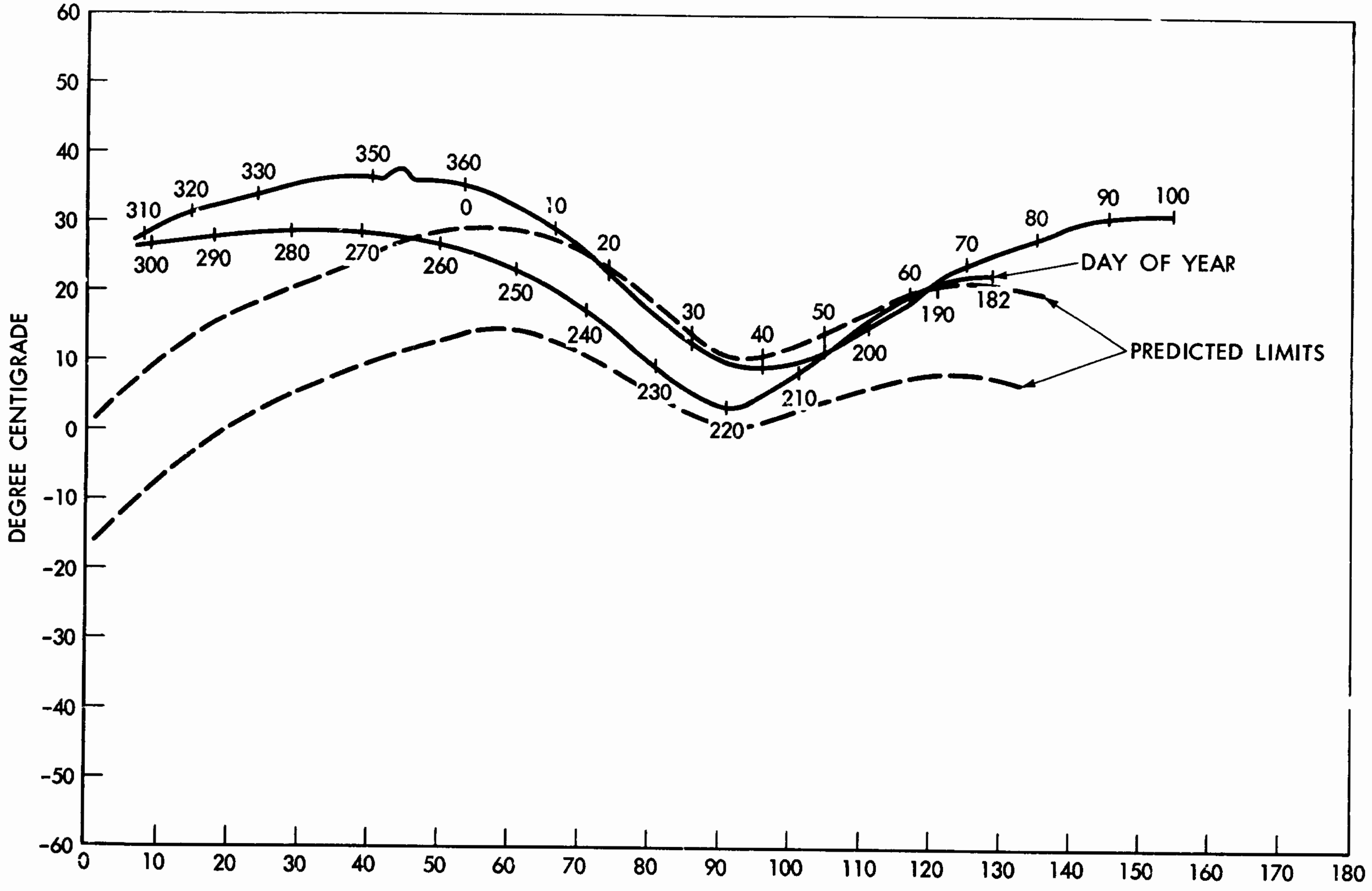

Figure 16. AIMP-D Exp. XXXIII PP-26 University of Iowa Temperature

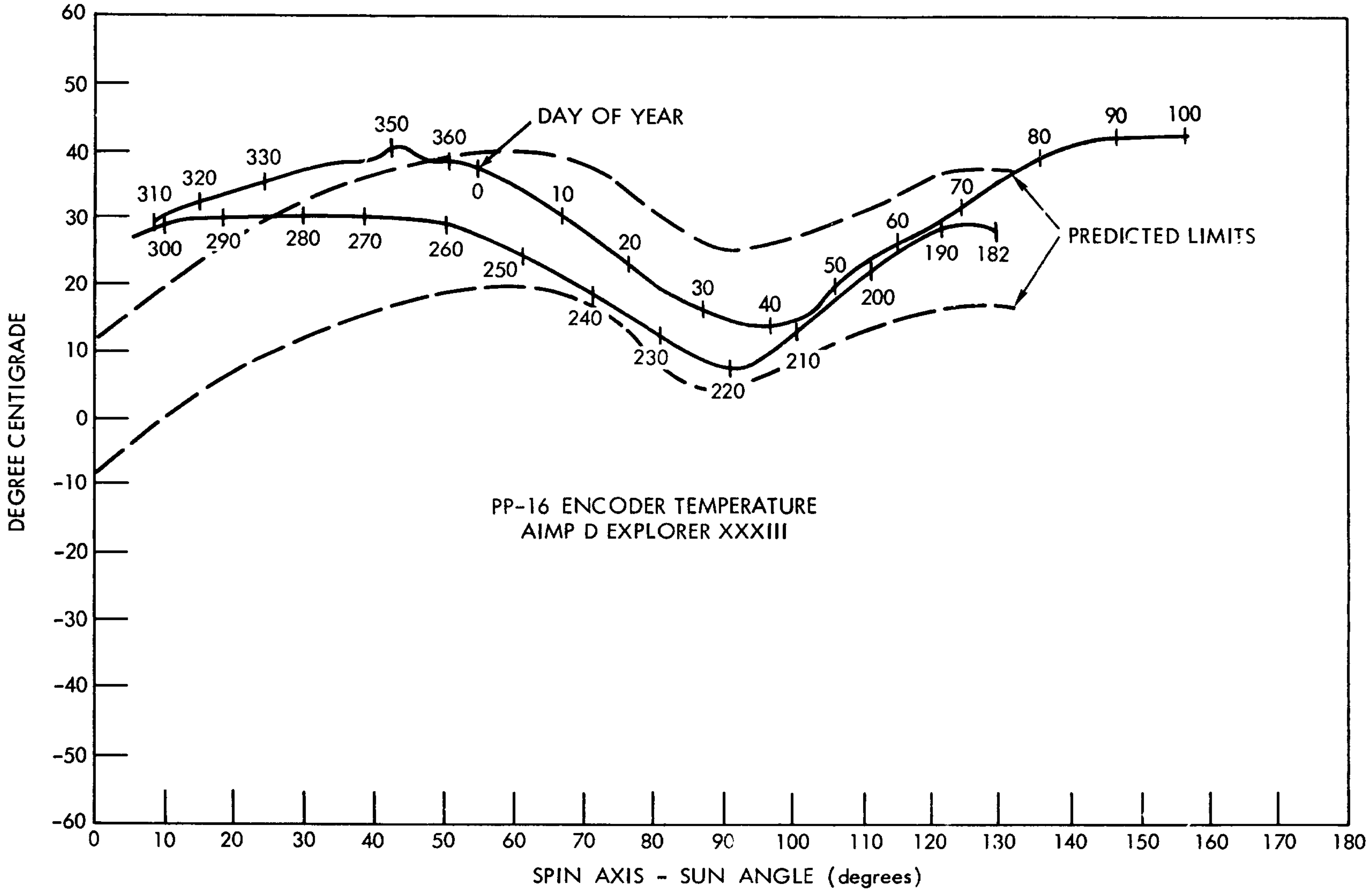

Figure 17. PP-16 Encoder Temperature AIMP-D Exp. XXXIII

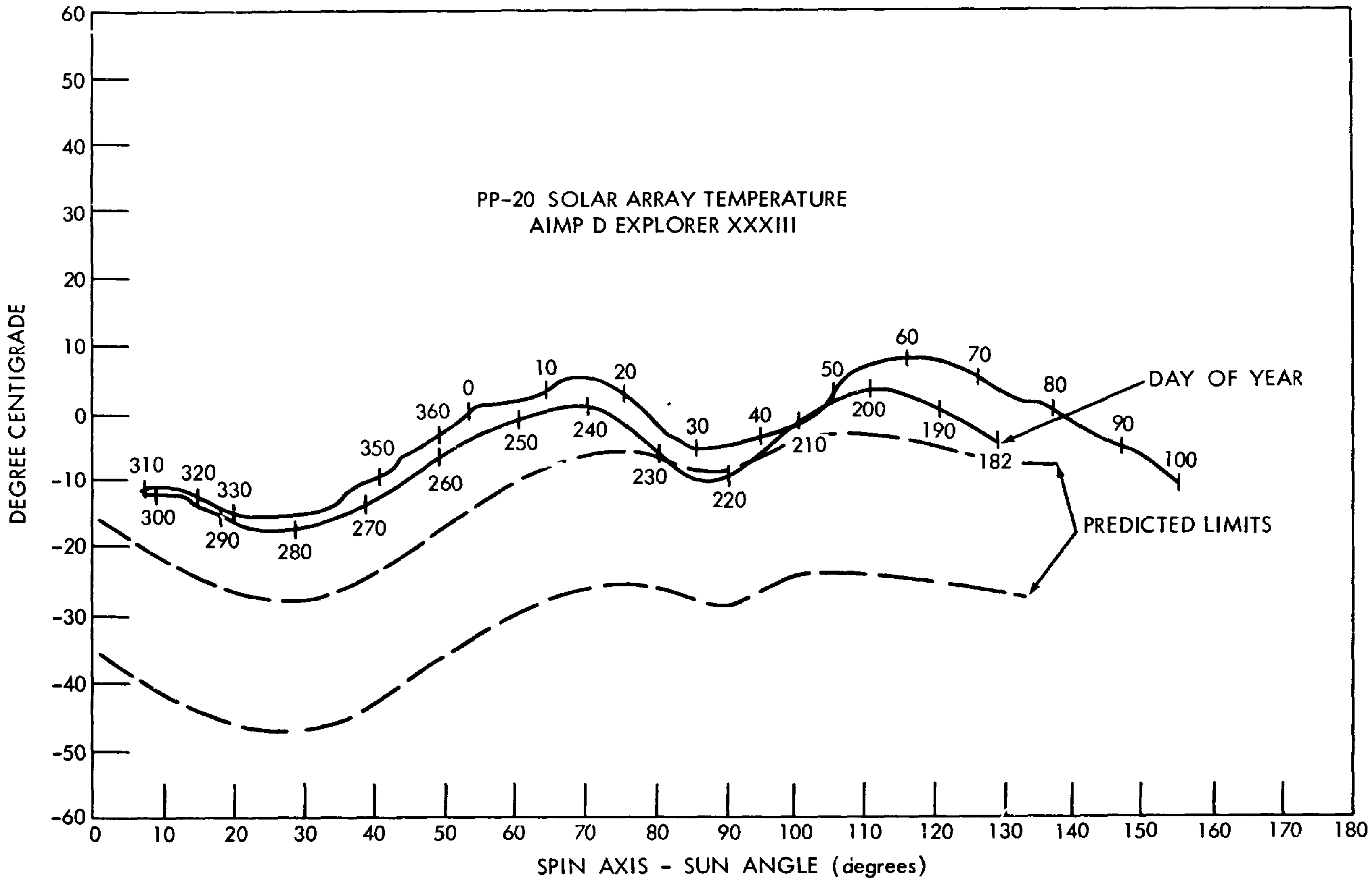

Figure 18. PP-20 Solar Array Temperature AIMP-D Exp. XXXIII