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THERMAL DESIGN AND ANALYSIS ON THE TIMATION III A SATELLITE.(U)
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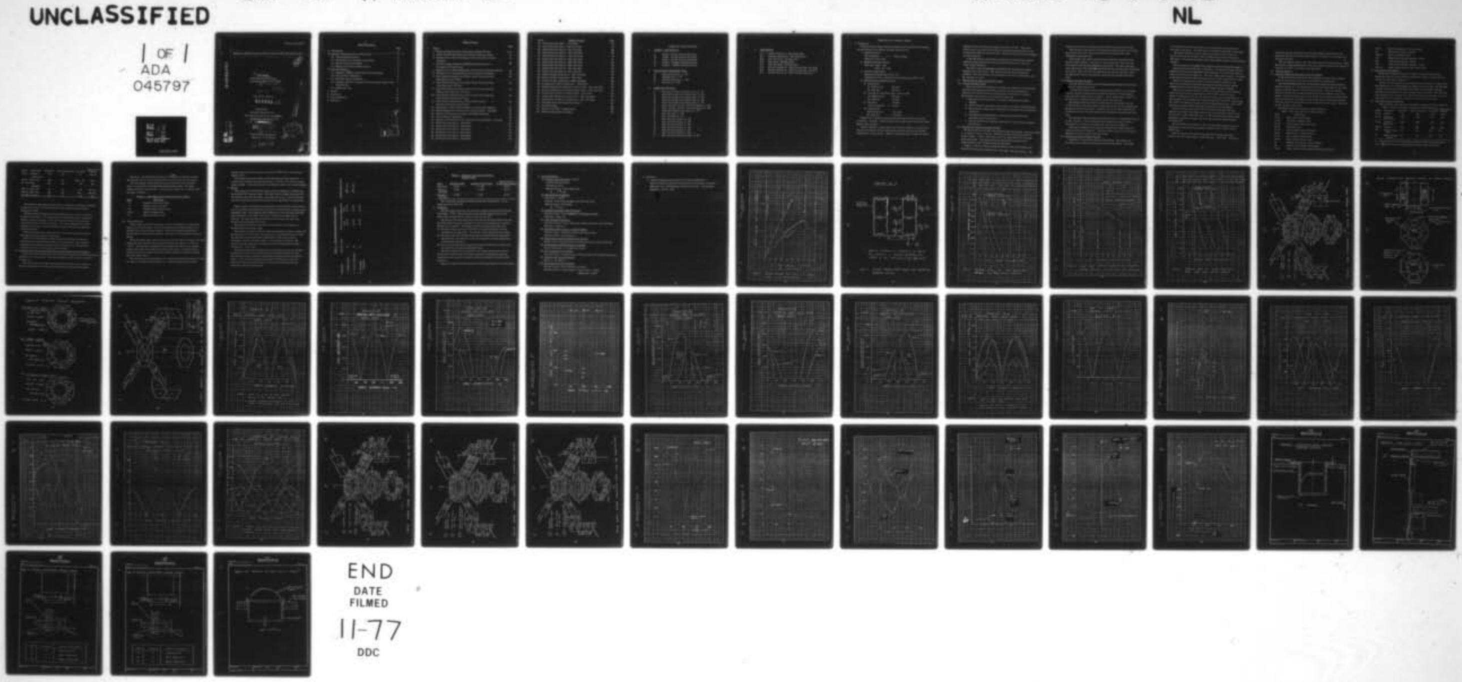

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THERMAL DESIGN AND ANALYSIS ON THE TIMATION III A SATELLITE.

Final Report.

Naval Research Laboratory

Contract No. N00173-72-C-0301

511253

Submitted By

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Fairchild Space and Electronics Division

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Approved: J. F. Parmer

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TIMATION III A THERMAL DESIGN

1. Introduction

Phase II thermal design study and analysis on the Timation III A satellite were performed in accordance with NRL specifications;

1. Orbit parameters

   145° inclination — 125° inclination

   7500 NM circular orbit

2. Satellite structural details

   NRL dwg. 79R04 - 16A

   2 X0 - 19 - 0 X0

3. Thermal requirements

   Battery pack temperature $25^{\circ}C \pm 15^{\circ}$

   Oscillator/T. E. D. assembly heat sink temperature 20° C $\pm 12^{\circ}$

4. Internal power dissipation factors

   A. Initial orbits

(1) Minimum sun	82 watts
(2) 100% sun	92 watts

   B. Allowing for degradation after 1 year in orbit

(1) Minimum sun	66 watts
(2) 100% sun	74 watts

   C. Oscillator — 2 watts

   T. E. D. assembly — 0 - 4 watts

   D. Battery pack

(1) Minimum sun	9.0 watts
(2) 100% sun	7.0 watts

Timation III A satellite is gravity gradient stabilized with a preferred orientation. However, original capture may be upside down for several weeks before a flip maneuver.

Phase I study (1), based on the 36 node thermal analysis on Timation III, shows the feasibility, that the initial design criteria will meet the thermal requirements of the satellite. However, during the Phase II effort the orbital inclination of the satellite was changed from $90^{o} \pm 5$ to 145^{o}. Therefore, Phase II study was aimed to reevaluate the thermal design parameters such as selection of thermal control coatings, location and sizing of thermal radiator and solar absorber.

A 128 node thermal math model was generated to determine the detailed orbital average temperatures in the spacecraft structures for "hot" and "cold" orbital situations.

The solar panel position angle was optimized for the maximum orbital sunlight on the solar panels. The orbital variations of the temperature gradients in the solar panels were predicted for the noon, the maximum, and the minimum sun orbit.

2. Thermal Design Approach and Optimization

2.1 Thermal Design Concept

Since most of power dissipating components are mounted on the mid-shelf, the thermal design approach will be to maintain the shelf temperatures within thermal requirements by employing super insulation and radiators. The design concept consists of essentially the following:

1. Both cylindrical surfaces are covered by multilayered insulation blankets.
2. Fixed radiator areas (silver teflon coats) are located at both end plates.
3. Solar absorber strips may be employed to compensate for environmental variations.
4. The equipment mounting shelf is conductively isolated from both end plates and the outer shell.
5. Internal surfaces are coated by black paint ($\epsilon = .9$) to increase radiation heat transfer.

2.2 The Maximum and the Minimum Sun Orbit

The spacecraft receives 100% sun during the flight of the orbits, whose sun angles, β, are greater than 18. degrees. However, the spacecraft experiences the earth's shadow, while it drifts from the 18^{o} sun angle orbit to 0^{o} sun angle orbit (noon orbit). The maximum time the spacecraft will spend in the earth's shadow is 48.7 minutes during the noon orbit.

Figure 1 shows the orbital average heat fluxes on the top and bottom surfaces of the spacecraft as functions of λ, sun angle with orbit normal. The maximum sun orbit for the spacecraft was defined as the orbit with $\lambda = 72^{o}$.

The maximum temperature in the equipment mounting shelf occurs during the maximum sun orbit, when the maximum internal power (92 watts) dissipates in the spacecraft.

Two possible cold cases in the spacecraft should be considered in the thermal design analysis. One cold case occurs during the noon orbit with the minimum internal power dissipation of 66 watts. The other case may occur during the $\lambda = 32^{o}$ orbit (100% sun time) with the internal power dissipation of 74 watts. The $\lambda = 32^{o}$ orbit was defined as the minimum sun orbit, since the spacecraft receives the minimum orbital average sunlight during this orbit.

2.3 Radiator and Solar Absorber

A 9 node thermal analysis on the Timation satellite (Figure 2) was made to size the initial radiator area.

From the THT computer solution of the thermal model the total radiator areas for the three design cases are plotted as functions of the equipment mounting shelf themperatures in Figure 3. Three design cases include one hot case and two cold cases discussed in the previous section.

The design condition in Figure 3 shows that the total radiator area of 3. Ft^2 will barely meet the thermal requirement of the T. E. D. assembly and the battery pack mounting shelf. Therefore, the use of solar absorber was considered to narrow the shelf temperature differences between hot and cold case.

The cylindrical strips of the top and bottom shells can be goldplated to serve as solar absorber. The net absorbed solar energy by the solar absorber was plotted as a function of sun angle with orbit normal in Figure 4.

Utilizing the goldplated solar absorber the optimum radiator area was computed and shown in Figure 5. The total radiator area of 3. 5 Ft^2 may be adaquate for thermal control of the spacecraft.

2.4 Optimization of Solar Paddle Position

Timation III A satellite has 4 solar array paddles. The paddle axes are attached to the top shell of the spacecraft by hinge fitting. The paddle is 23 inches wide and 52 inches long and is an aluminum-honeycomb sandwich type construction. The solar cells are attached to both sides of the paddle.

The total projected area of the solar array panels in the direction of the sun varies around the orbit, and it changes from one orbit to the other. Therefore, it is necessary to optimize the solar paddle position for the maximum sunlight.

For the purpose of the optimization study the solar paddle position angle ψ and initial attitude angle θ are introduced. The spacecraft initial attitude angle θ is defined as the angle between the spacecraft +X axis and the velocity vector of the spacecraft (Figure 6). The solar paddle position angle ψ is defined as the angle between the solar panel plane normal and the spacecraft X-Y plane.

Based on the spacecraft coordinate systems defined in Figure 6, the total orbital projected areas of the solar panels in the direction of sun are computed from the orbital heat flux and the shadow computer program.

For the noon orbit the orbital variations of the total solar panel projected area towards the sun are compared for $\psi=20^{\circ}$, $\psi=30^{\circ}$, and $\psi=40^{\circ}$ cases. Figure 7 and Figure 8 show the orbital projected area of the solar panels for the noon orbit with the paddle initial attitude angle $\theta=0^{\circ}$ and $\theta=45^{\circ}$, respectively. The $\psi=40^{\circ}$ case shows the largest orbital average projected area, while $\psi=30^{\circ}$ case shows smaller orbital variations for both initial attitude angles.

For the minimum sun orbit ($\lambda=32^{\circ}$) the orbital variations of the total projected area of the solar panels towards the sun are shown in Figure 9 and 10 for $\psi=20^{\circ}$, $\psi=30^{\circ}$, and $\psi=40^{\circ}$ cases. $\psi=20^{\circ}$ case shows the largest orbital average projected area among 3 cases for both spacecraft attitude angles, $\theta=0^{\circ}$ and $\theta=45^{\circ}$.

For the maximum sun orbit ($\lambda=72^{\circ}$), the total orbital projected area of solar panels towards the sun are plotted in Figure 11 for $\psi=20^{\circ}$, $\psi=30^{\circ}$, $\psi=40^{\circ}$ cases.

After the launch of the spacecraft on the initial orbit the spacecraft drifts in the orbit range between $\lambda=32^{\circ}$ orbit and $\lambda=90^{\circ}$ orbit. Therefore, the orbital average projected area of the solar panels towards the sun are plotted as functions of the solar paddle angle ψ in Figure 12 for the noon and minimum sun orbit.

The solar paddle angle $\psi = 40^{o}$ was selected as the optimum position. Hence the orbital average projected area of the solar panels towards the sun will be no less than 14.6 Ft^2 for any orbit of the spacecraft.

3. Thermal Analysis

3.1 Computer Model for Steady State Thermal Analysis

A 128 node thermal math model was developed to determine the detailed temperature gradients in the frames and shells of the spacecraft.

The nodal designations for the thermal math model of the spacecraft are depicted in Figure 13. The spacecraft is divided into three shelves, the inner and outer cylinder shells, and the shelf frame nodes. The outer cylinder shells are divided into 32 nodes (16 shell nodes and 16 insulation outer cover nodes). The top and bottom shelves are divided into 16 nodes (8 radiator nodes and 8 insulator/solar cell nodes), while the mid shelf is divided into 8 nodes. The inner and outer midshelf frames are divided into 8 nodes each. There are 16 inner cylinder shell nodes.

The detailed nodal descriptions are given in Table 1.

Table 1 Nodal Description for 128 Node Model

Node	Description
1—16	Outer cylinder shell nodes
17-24	Top shelf - radiator nodes
25-32	Inner cylinder upper shell nodes
33-40	Mid shelf nodes
41-48	Inner cylinder lower shell nodes
49-56	Bottom shelf - radiator nodes
57-64	Inner midshelf frame nodes
65-72	Outer midshelf frame nodes
73	Bottom cover plates - Laser reflector
74	Bottom cover cylinder shell-flange
75-90	Outer cylinder shell insulation-Kapton cover nodes

91-98	Top shelf insulation - solar cell nodes
99	Upper boom housing - outside
100-117	Solar array/panel nodes
118	Upper boom housing insulation - inside
119	Lower boom housing - outside
120	Lower boom housing insulation - inside
121-128	Bottom shelf insulation outer cover nodes

3.2 Internal Power Dissipation

Based on the equipment location in Figure 14 and the internal power dissipation data for Timation III A the nodal power loads are chosen for one hot and two cold cases in Figure 15.

The hot case corresponds to the maximum sun orbit (100% sun time), when the equipments on the shelf dissipate 92 watts in the spacecraft. The cold case 1 occurs at the noon orbit (89.8% sun time after 1 year in orbit), when the internal power dissipation is at the minimum level of 66 watts. The cold case 2 corresponds to the 53 degree sun angle orbit (100% sun time) after 1 year in orbit when the internal power dissipation is at the level of 74. watts.

3.3 The Nodal Thermal Properties

Thermal finishes and properties of the external nodes are listed in Table 2.

Table 2 Thermal Radiation Properties of External Surfaces

Nodes	Description	Emittance	Solar Absorptance	Area (Ft^2)	Shape Factor to Space
17-24	Radiator	.78	.08	.225	.99-1.
25-32	Insulator-Inner shell	.013	.007	.72	.29
41-48	Insulator-Inner shell	.013	.007	.72	.22
49-56	Radiator	.78	.08	.225	.96
73*	Bottom Flange disk	.18	.12	5.17	1.0
74	Bottom Flange cylinder	.06	.17	2.5	1.0

* Effective emittance and absorptance values are based on the white paint ($\frac{\epsilon}{\alpha} = \frac{.85}{.17}$) finishes at the top side and bare aluminum base of Node 73.

Nodes	Description	Emittance	Solar Absorptance	Area (Ft^2)	Shape Factor to Space
75-90	Insulator outer cover	.80	.40	1.5	.86-.97
91-98	Solar Cell	.83	.70	.166 - .68	.99
99, 119	Boom housings	.96	.98	.38	.99
100-111	Solar Cell	.83	.70	1.38	.85-.99
112-117	Solar Cell	.83	.70	8.3	.93-.97
121-128	Insulator	.80	.40	.79	.98

The detailed nodal radiation shape factors to space are computed by CONFAC program and listed on the attached THT computer input data for 128 node Timation III model.

All the internal surfaces are covered by black paint (ϵ =.9) to increase the radiation heat transfer. The internal radiation shape factors are computed by CONFAC computer program. The nodal effective emittance data are again computed by Script F computer program. 599 nodal couplings and effective emittances are listed on the attached THT computer input data for 128 node Timation III model.

Three shelf areas were reduced by 15% to take into account the radiation blockings by internal harnesses and cables.

Based on the NRL drawings, 79R04-16A and 2X0-19-0X0, the thermal conductances and capacities of Timation III are calculated. 188 conduction coupling pairs and their conductance values are listed on the attached THT computer input data for 128 node Timation III model.

3.4 Computer Model for Transient Thermal Analysis of Solar Cell Array Panels

A 29 node thermal math model was developed to determine the orbital temperature gradients in the solar panels. The nodal designations of the model are depicted in Figure 16.

The model consists of 1 spacecraft node and 28 external nodes, which are directly comparable to the external surface nodes of the 128 thermal model.

Therefore, the orbital heat flux data for 128 Node model are obtained by taking the average value of the corresponding heat flux data for the 29 node model.

The solar paddle, which experiences the worst orbital solar shadowing effect, is chosen for the detailed temperature gradient study. The solar paddle consists of 12 panel nodes. The nodal descriptions of the 29node model are given in Table 3.

Table 3 Nodal Description for 29 Node Thermal Model

Node	Description
1-8	Insulation outer cover nodes
9	Radiator node on top shelf
10	Radiator node on bottom shelf
11-28	Solar Cell panel nodes
29	Spacecraft interior node

3.5 Orbital Heat Flux

The all planet orbit heat flux program was used to generate the orbital heat fluxes on the external nodes. The solar shadowing on the nodal surfaces were obtained from the orbit shadow program, which was specially developed for a gravity gradient stabilized spacecraft in a circular orbit with extended solar cell panels.

The nodal orbital solar heat fluxes for noon orbit are shown in Figure 17 through Figure 23, when the solar cell array panel positions are fixed at $\psi = 40^{o}$ and $\theta = 0^{o}$. The solid lines represent the real orbital solar fluxes on the exposed nodes by taking the nodal shadow percentages into account. The dotted curves with the primed node numbers are for the orbital solar fluxes without including the solar shadow effects.

The orbital solar heat flux data for the maximum sun and the minimum sun orbit are shown in Figure 24 through Figure 32. It was assumed for the thermal analysis that the solar cell panels were fixed at $\psi = 40^{o}$ and the initial attitude angle at $\theta = 0^{o}$.

The albedos and earth's shines on the spacecraft and solar panels are comparatively smaller than solar heat fluxes. Therefore, the orbital average value of albedo. and earth's shine for each node was used in the thermal analysis.

4. Results

The results from the 128 node computer thermal analysis are tabulated on the attached THT computer output. The nodal orbital average temperature for the maximum sun orbit (hot case), noon orbit (cold case 1), and the minimum sun orbit (cold case 2) are shown in Figure 33 through Figure 35 respectively.

Table 4 shows the orbital average temperatures of the battery packs and the T.E.D. assembly mounting shelves during the maximum and the minimum power dissipation orbit. The maximum shelf temperature occur during the maximum power dissipation of 92 watts, and when β =18 degree sun angle orbit is obtained. The minimum shelf temperatures occur during noon orbit with internal power dissipation of 66 watts.

The results from 29 node transient thermal analysis are tabulated on the attached THT computer output.

The orbital variations of the solar panel temperature are shown in Figure 36 through Figure 38 for the noon, the maximum sun, and the minimum sun orbit. The minimum average solar panel temperature ($-91^{o}C$) occurs during occultation, when the sun/orbit angle, β , is 0. degree (noon orbit). The maximum average solar panel temperatures for the noon and the minimum sun orbit (β = ^{o}) are $48^{o}C$.

The orbital temperature gradients of the solar panels are shown in Figure 39 through 41 for the noon, the maximum sun, and the minimum sun orbit. The maximum orbital temperature gradients for the three orbits are shown in Table 5. The worst axial temperature gradient ($57^{o}C$) of the solar panel occured during the maximum sun orbit, when part of the solar panel was shadowed by the other solar panels.

Table 4 Equipment Mounting Shelf Temperature

Equipment	Location # Node	Orbital Average Temperature Max.	Orbital Average Temperature Min.	Control Requirement
1. Battery packs	35	29.4°C	14.5°C	25°C ± 15
2. T.E.D. Assembly	38	28.5°C	12.0°C	20°C ± 12
3. Navigation Subsystem	33	33.4°C	14.2°C	

Table 5 Maximum Temperature Gradients of Solar Panels

Orbit	Orbit/Sun Angle	Location of Orbit Angle	Maximum Axial Temperature Gradient
Noon Orbit	$\beta = 0^o$	$\alpha = 150^o$	46. ^oC
Maximum Sun Orbit	$\beta = 18^o$	$\alpha = 130^o$	57. ^oC
Minimum Sun Orbit	$\beta = 58^o$	$\alpha = 90^o$	54. ^oC

The temperature gradient through the honeycomb solar panels (.5 inch depth) were less than 2.5^{o}C.

5. Conclusion

The solar panel position for the maximum sunlight was optimized and fixed at the angle $\psi = 40^o$. Hence the total orbital average projected area of the solar panels towards the sun will be no less than 14.6 Ft^2.

The results of the both steady state and transient thermal analysis show that the present thermal design is adaquate for the required temperature control of Timation III A satellite. The design essentially consists of the following:

(1) The total radiator area of 3.6 Ft^2 will be evenly distributed at the both end plates of the spacecraft. The radiator will be coated by silver teflon.

(2) The side strips of the top and bottom honeycomb shells will be gold plated and utilized as solar absorber to help the equipment mounting temperature in cold orbital situations.

(3) The rest of the top and the bottom plates and both cylindrical surfaces will be covered by multilayered insulation blanket.

Since both radiator and solar absorber are equally divided and located at the top and the bottom shell, no serious impacts on the equipment mounting temperatures are expected by letting the spacecraft upside down before a flip maneuver.

Based on the present thermal analysis the following designs are recommended.

6. Recommendations

(1) TOTAL RADIATING AREA: 3.60 Ft^2

Location: Both end plates

Distribution: Even

Material Finish: Silver teflon coats

$\frac{\alpha}{\epsilon}$: $(^{.08}/.78)$

(2) SOLAR HEAT ABSORBER

Total Area: 1.65 Ft^2

Location: Both honeycomb plate ends (3/4 inch strip)

Material Finish: Gold plated

$\frac{\alpha}{\epsilon}$: $(^{.3}/.03)$

(3) GRAVITY GRADIENT BOOM HOUSING

Thermal Design: Boom housing to be thermally insulated

Reference: Figure 42

(4) TOP AND BOTTOM SHELL

Thermal Design & Finish: Thermally isolated from outer shell and frame

Reference: Figure 43

(5) BOTTOM COVER PLATE - FLANGE DESIGN

Thermal Design: Thermally isolated from bottom plate

Thermal Finish: Refer Figure 44

(6) SOLAR CELLS ON TOP HONEYCOMB PLATE

Design: To be mounted outside the blanket by means of plastic stand-offs

(7) SPACECRAFT INTERIOR SURFACE FINISH

Coats: Black paints $\epsilon = .9$ (3M velvet black)

(8) S/C CYLINDRICAL SURFACES

Thermal Design: Covered by super insulation blanket with Kapton outer cover

(9) POSITION OF SOLAR PADDLES

Angle ψ : 40. degree

(10) RADIATION COUNTER/SENSOR

Thermal Design: Hard mounting on top shell

Thermal Finishes: Refer Figure 45 Silver teflon - outside

Black paint - inside

7. Reference

1. "Thermal Design and Analysis on the Timation III Satellite," Phase I Preliminary Report to Naval Research Laboratory, Fairchild Industries, Inc. Fairchild Space and Electronics Div., Germantown, Maryland, June 23, 1972.

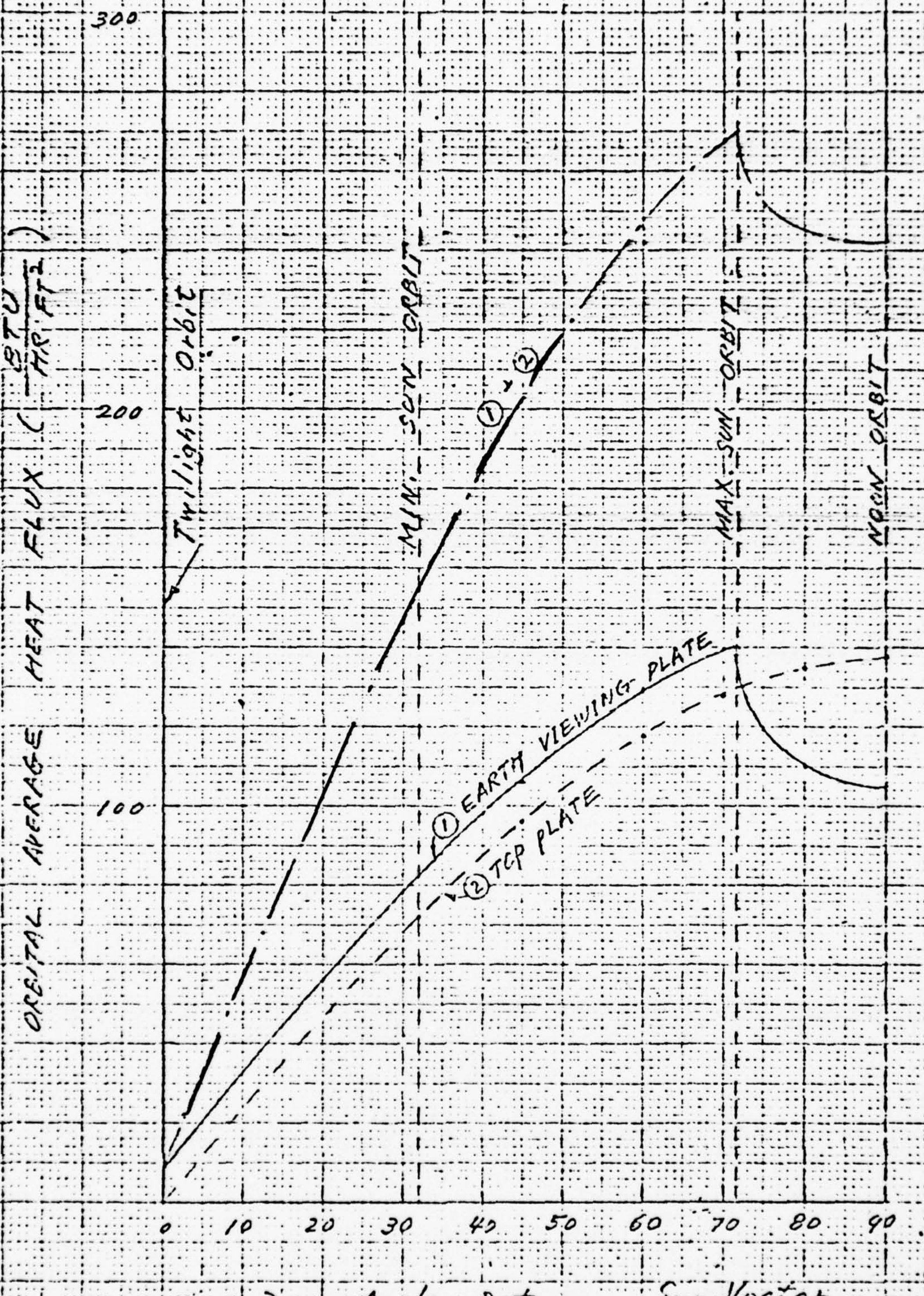
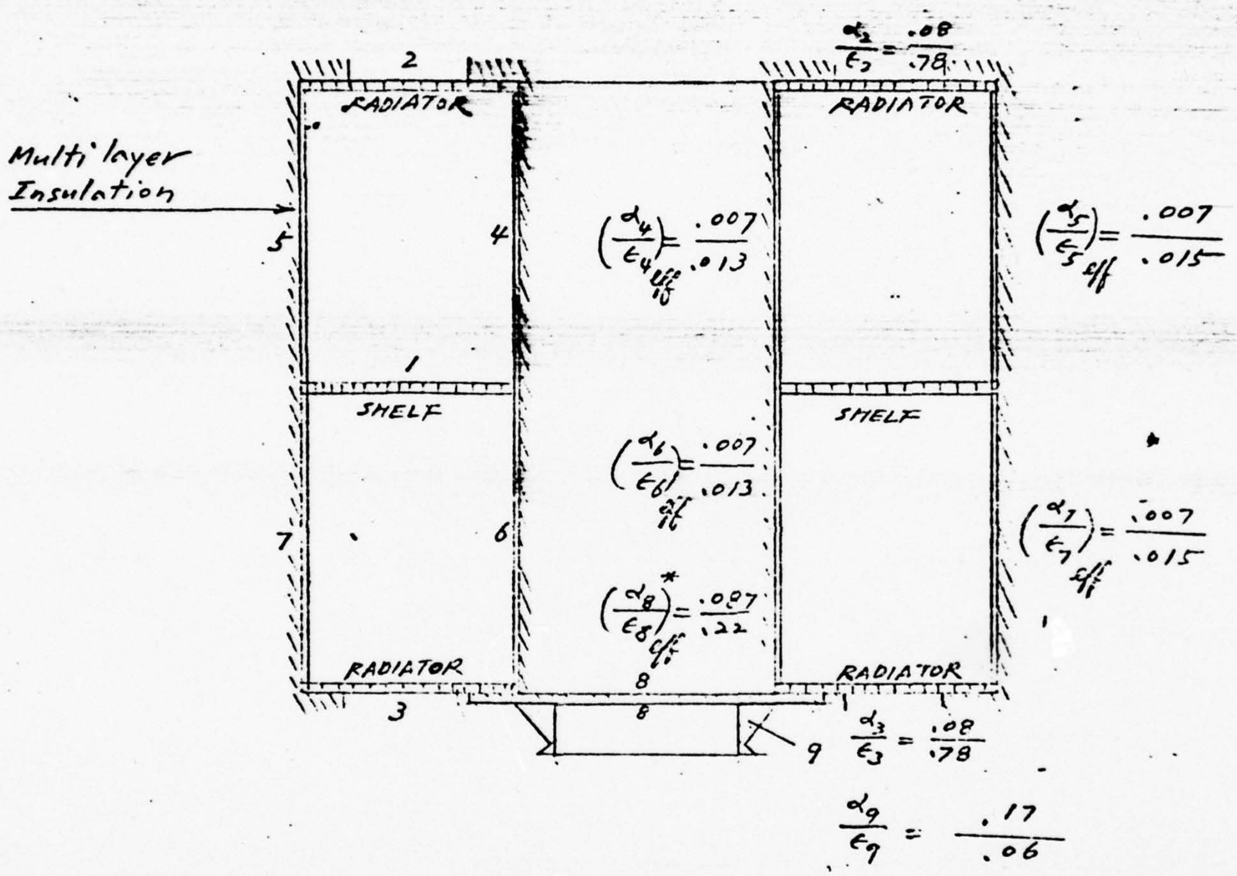


FIG. 1 Orbital Average Heat Flux VS Sun Angle with Orbit Normal.

TIMATION III A



* Effective emittance and absorbtance of node 8 are obtained by script F computation, when surface 8 has white paint ($\frac{\alpha}{\epsilon} = \frac{.17}{.85}$) finish.

FIG. 2 9 NODE THERMAL MATH MODEL FOR TIMATION III RADIATOR DESIGN

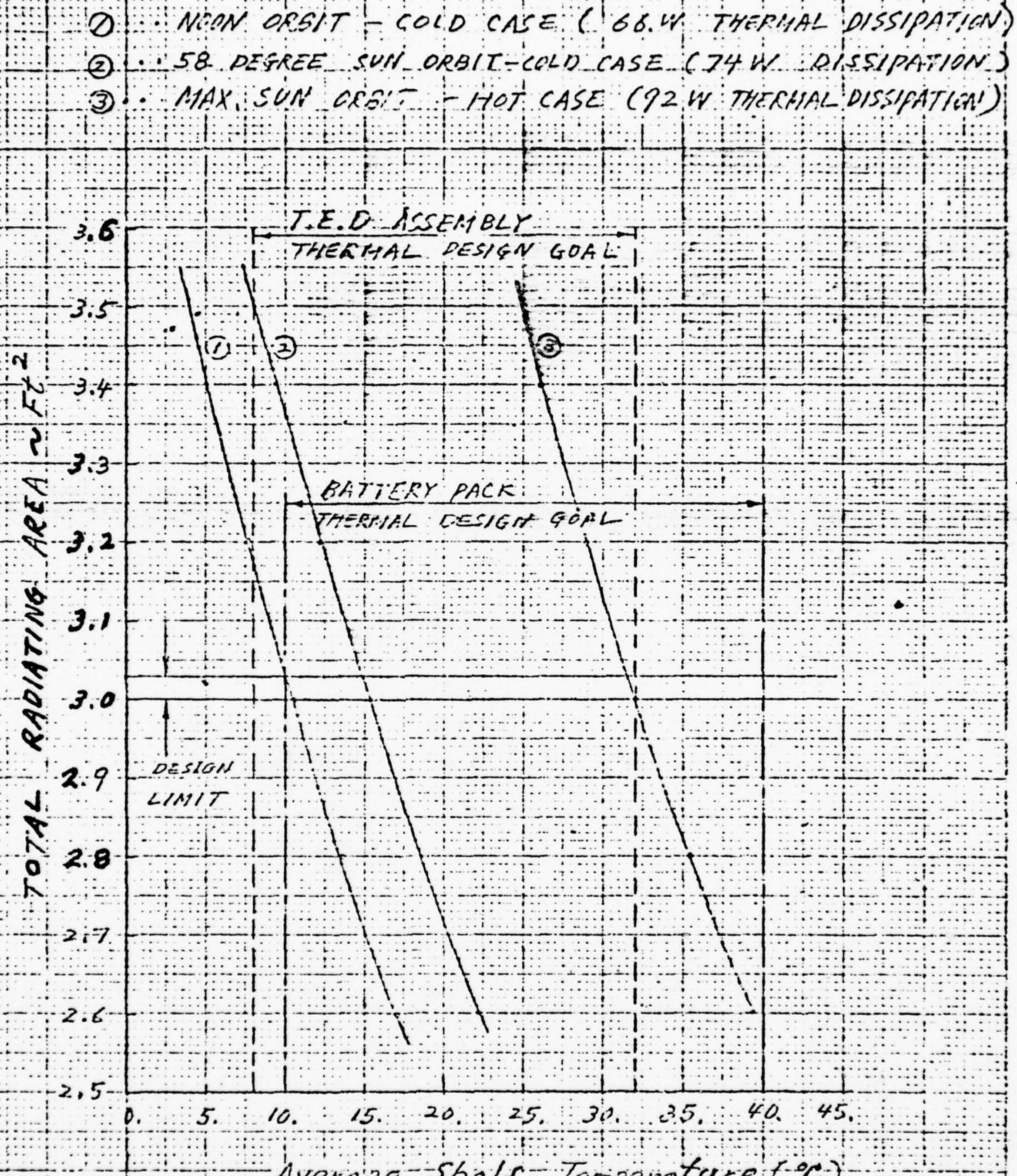


Fig. 3 Radiator Area vs Shelf Temperature Without Gold Strip Thermal Absorber

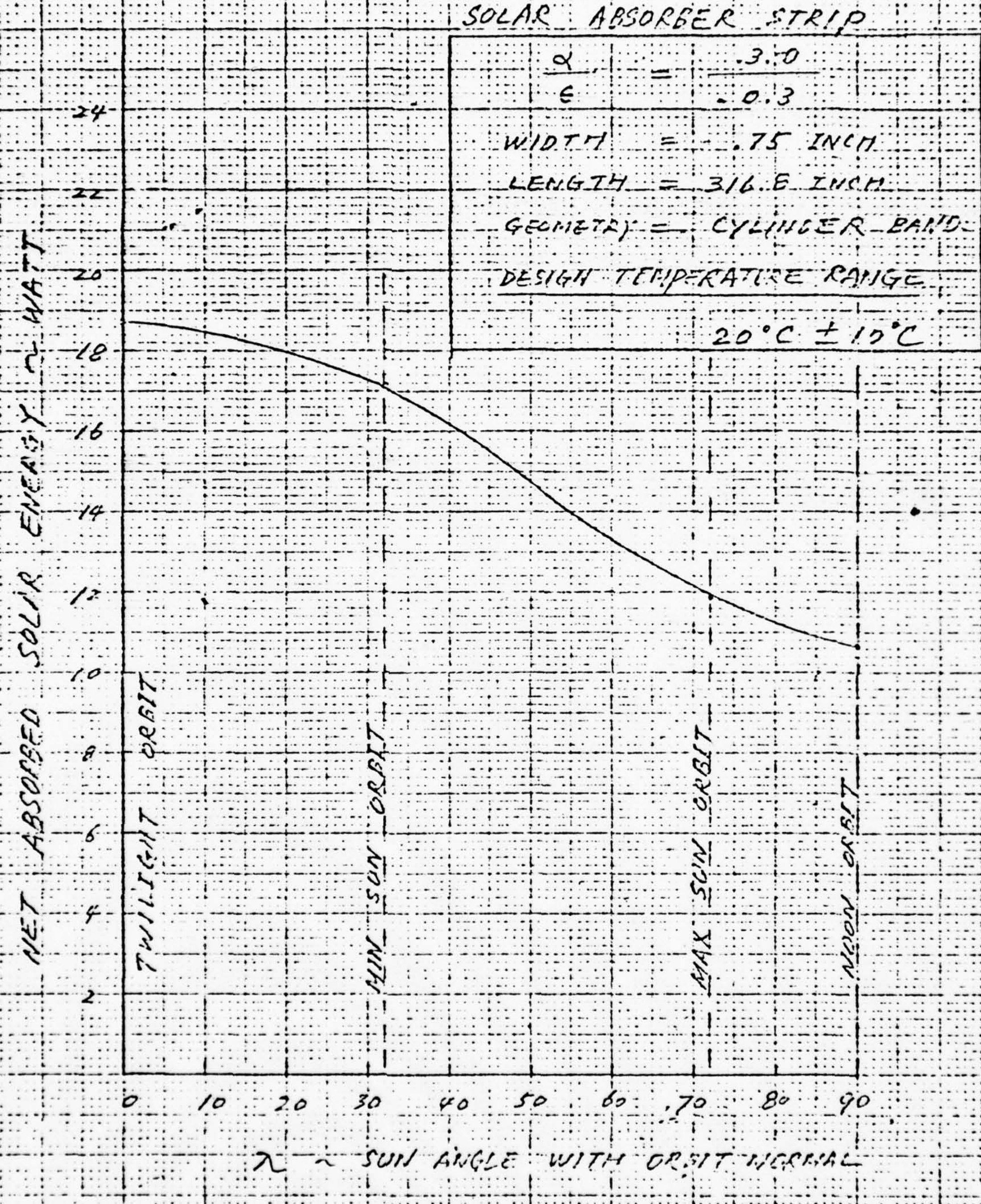


FIG. 4 NET SOLAR ENERGY ABSORBED BY GOLDPLATED STRIP ABSORBER VS SUN ANGLE WITH ORBIT NORMAL

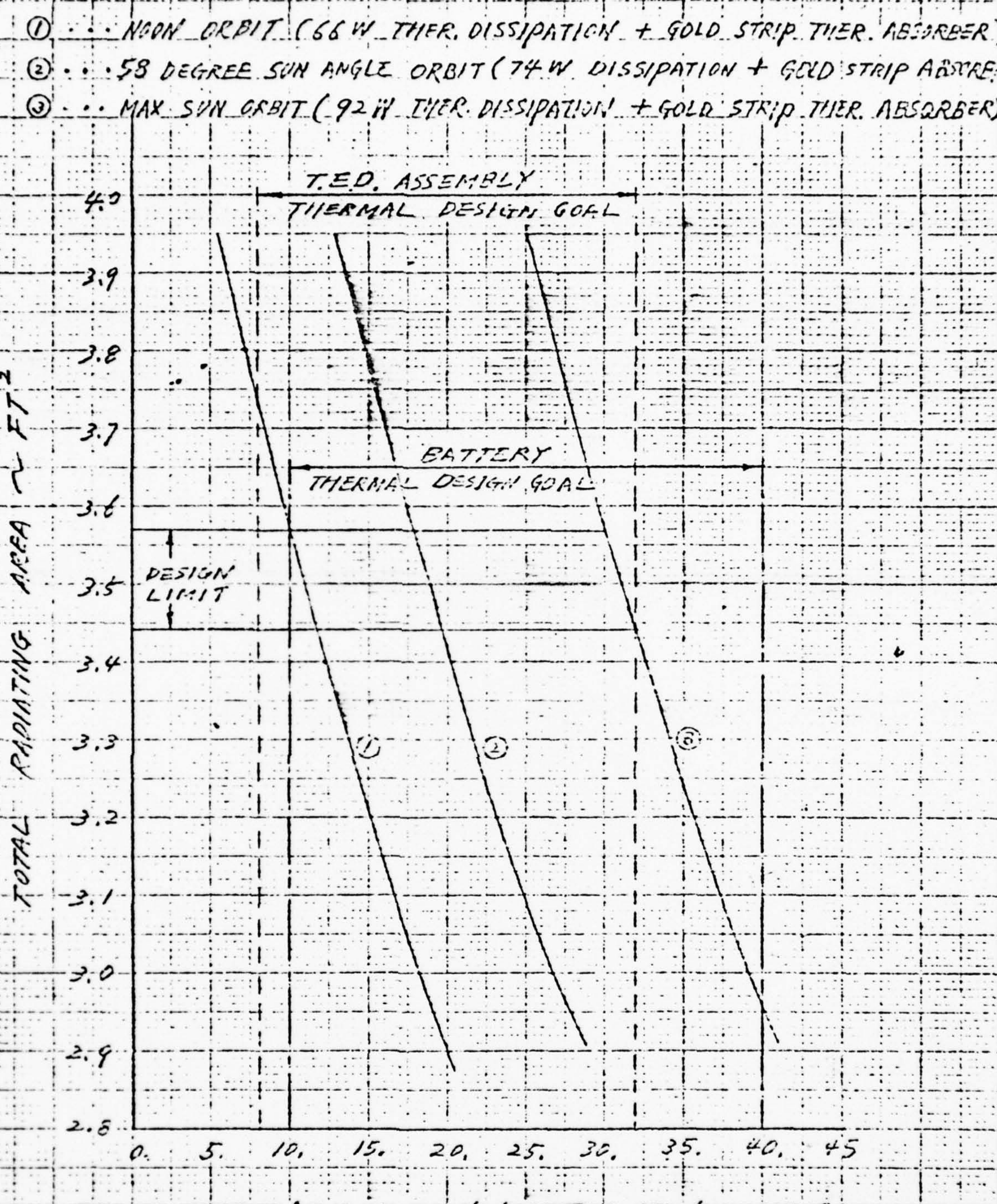


FIG. 5 Radiator Area VS. Shelf Temperature With Gold Strip Thermal Absorber

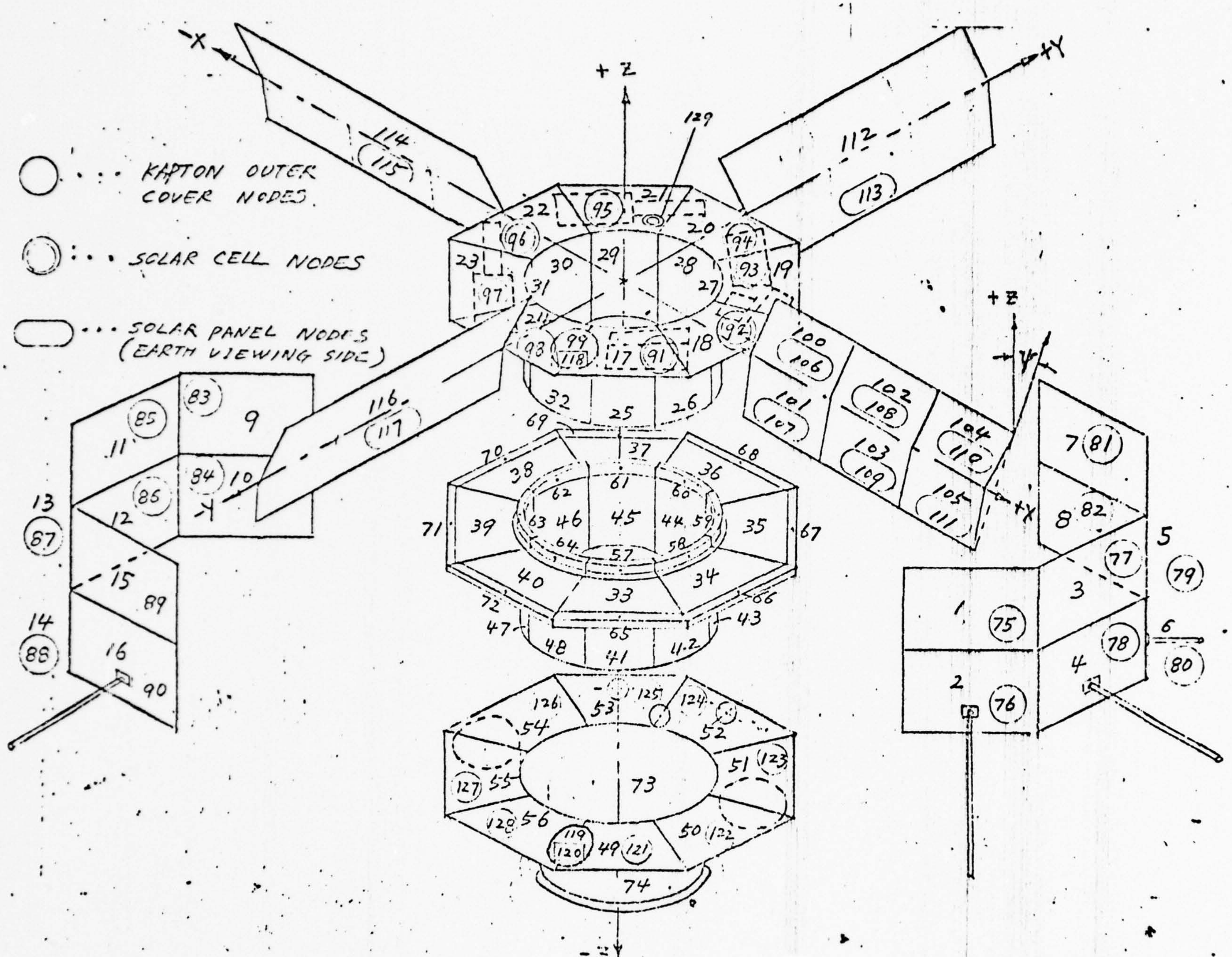


FIG. 13 NODAL CONFIGURATION OF TIMATION III A THERMAL MODEL

FIG. 14 TIMATION III A EQUIPMENT LOCATION AND WEIGHT BREAKDOWN

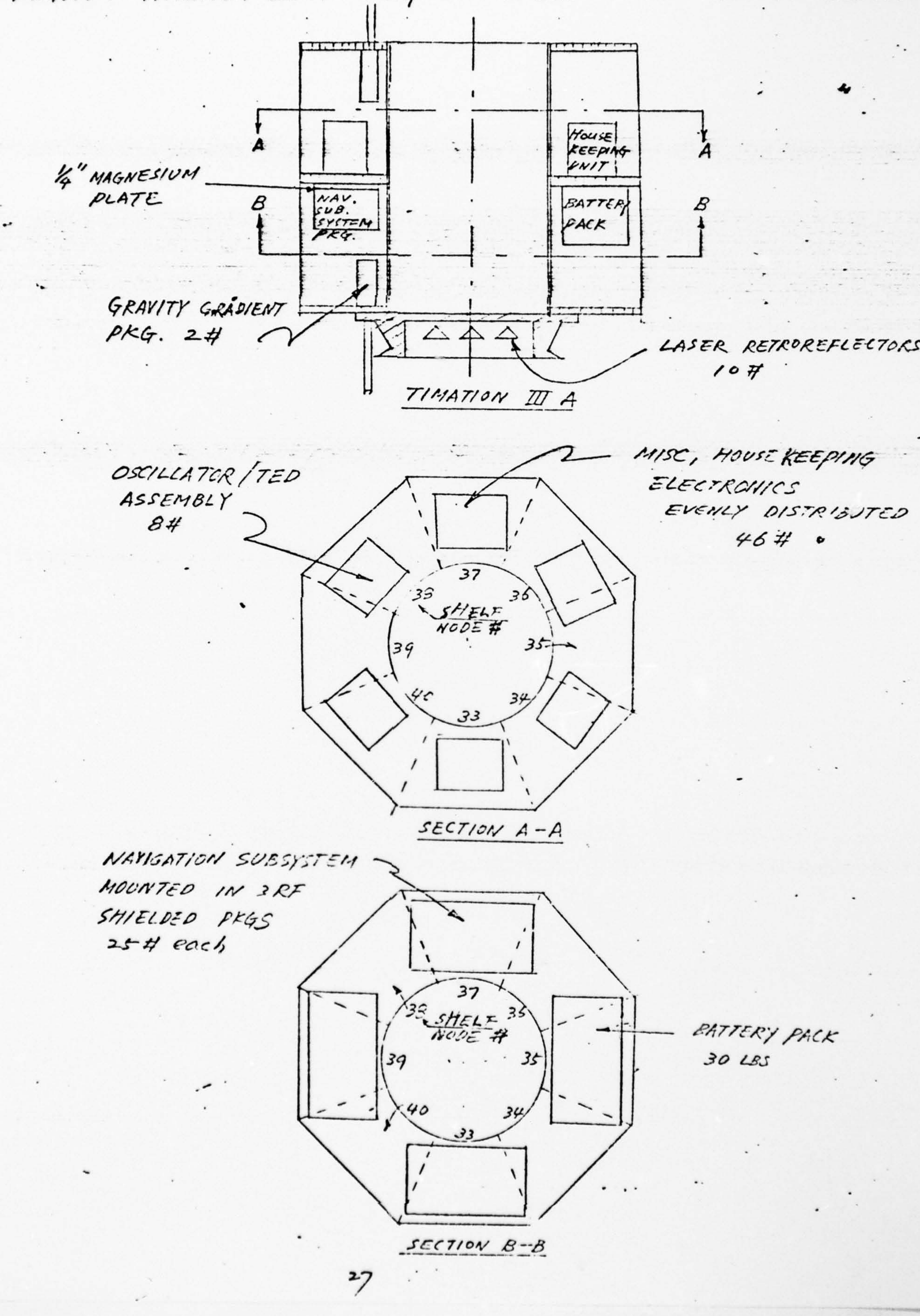


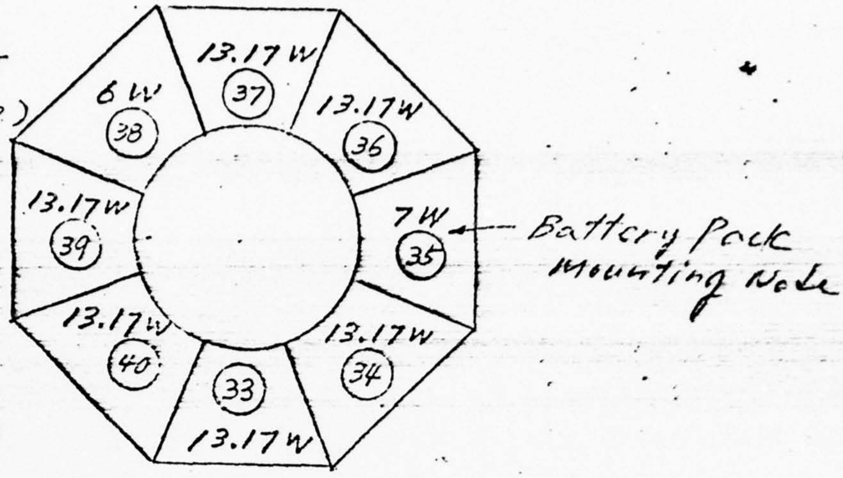
Figure 15 Internal Thermal Dissipation

(1) MAX. SUN ORBIT
(β = 18. degree)
100 % SUN

INITIAL ORBIT

92 WATTS
DISSIPATION

(HOT CASE)



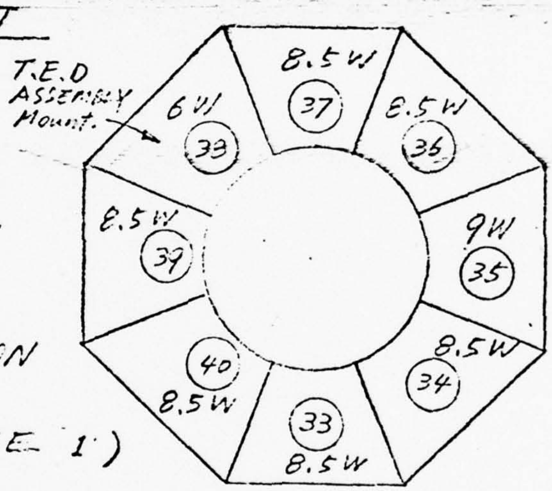
(2) NOON ORBIT

MINIMUM SUN

AFTER 1 YEAR

66 WATTS
DISSIPATION

(COLD CASE 1)



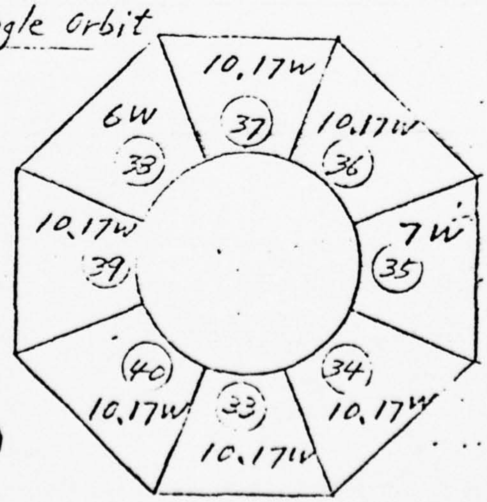
(3) 58 degree Sun Angle Orbit

100 % SUN

AFTER 1 YEAR

74. WATTS
DISSIPATION

(COLD CASE 2)



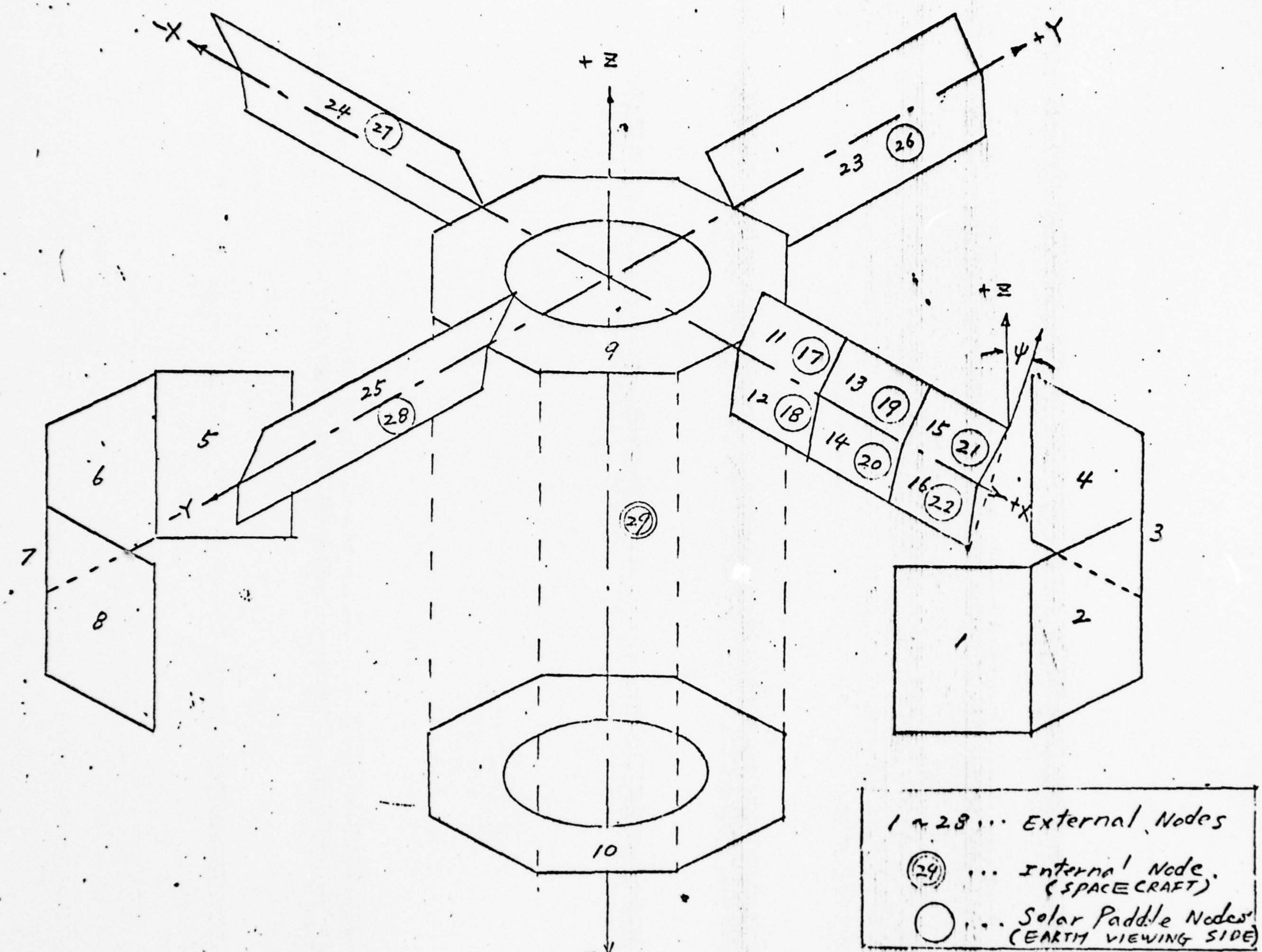


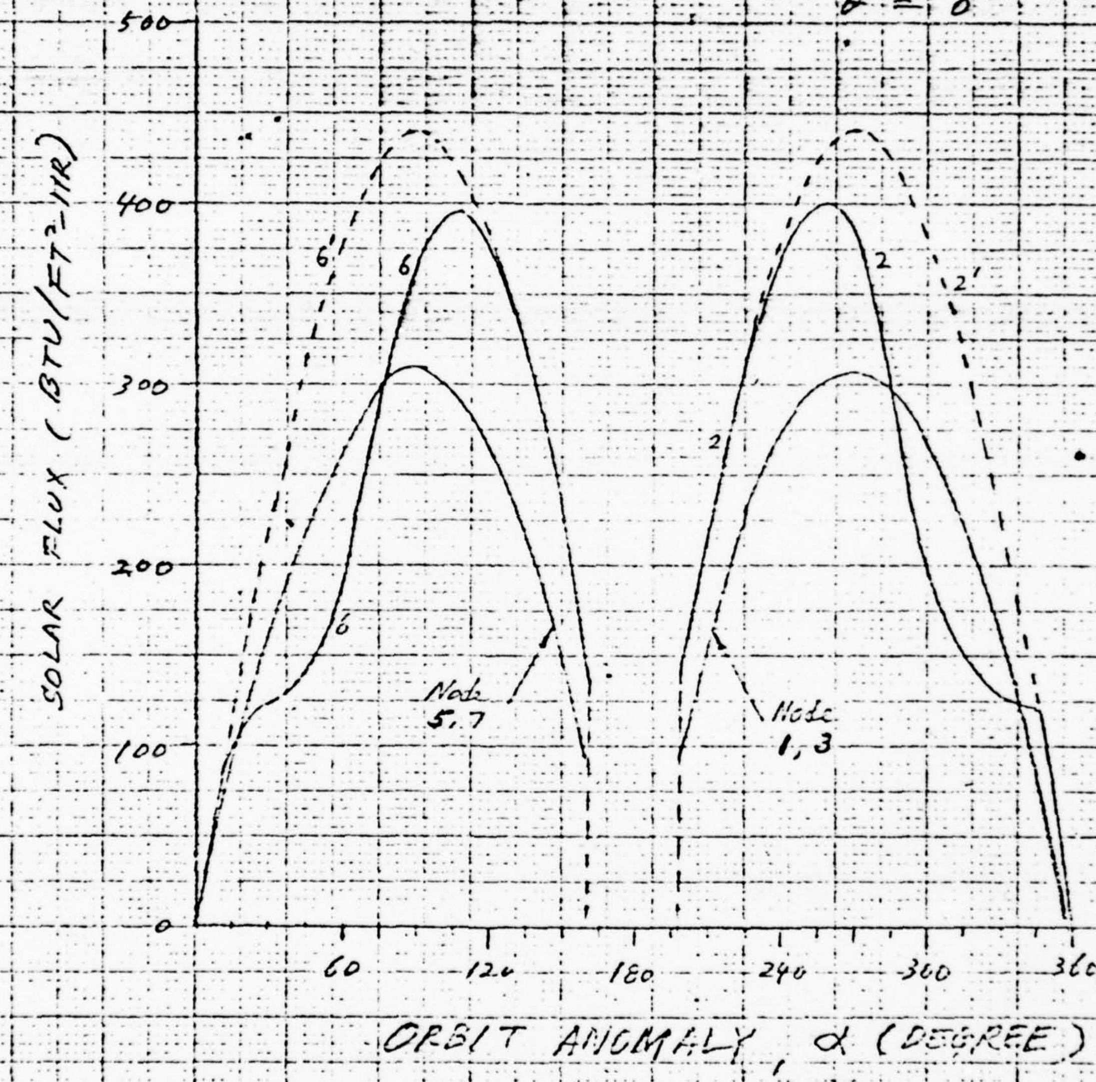
FIG. 16 Schematic of Timation III A For Transient Thermal Analysis

TIMATION III - A

FIG. 17 ORBITAL HEAT FLUX DATA 1

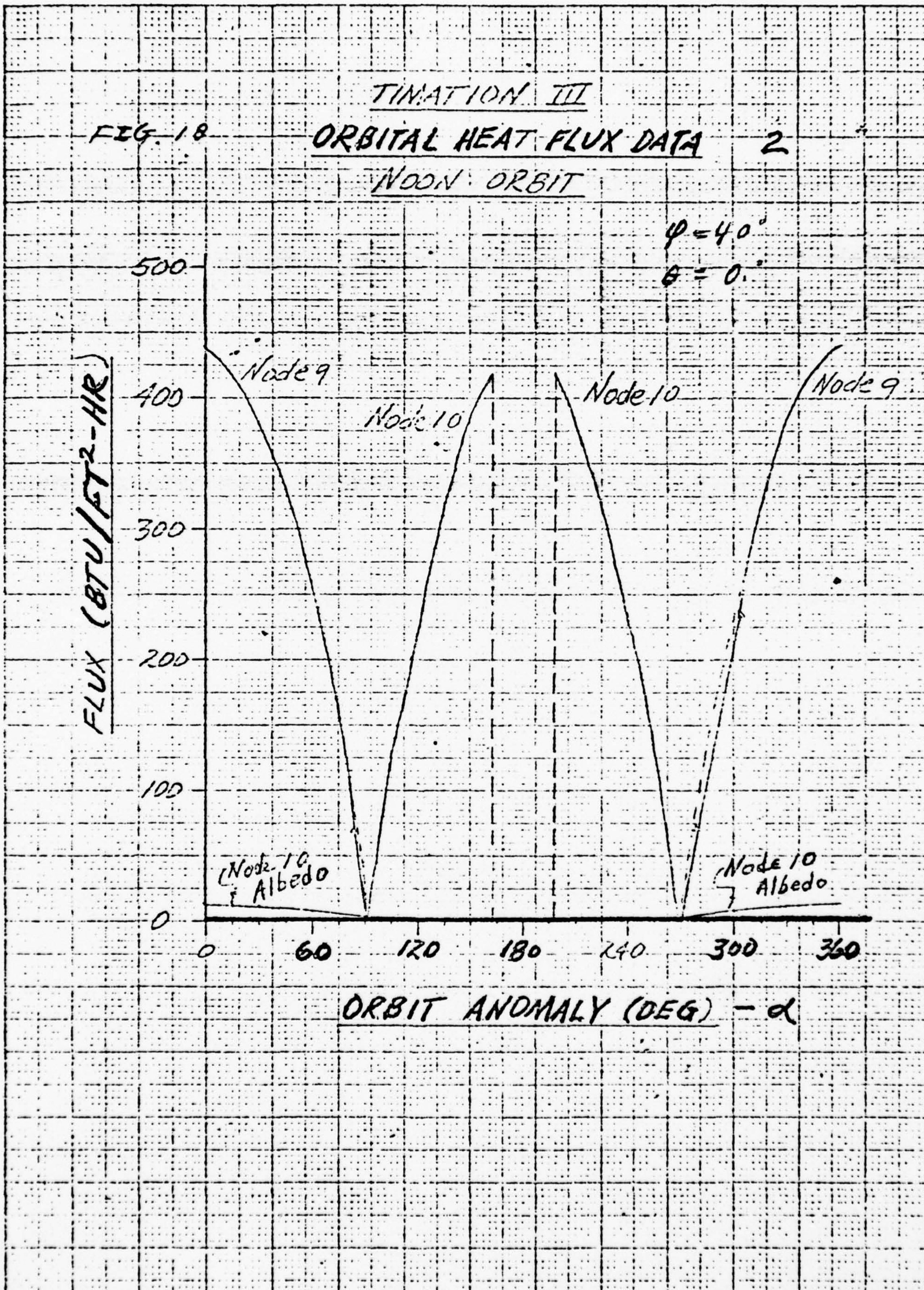
NOON ORBIT $\psi = 40°$

$\beta = 0°$



NOTE 1. NODE 4 & 8 DO NOT RECEIVE SUNLIGHT FOR ENTIRE ORBIT

2. NUMBERS ON CURVES CORRESPOND TO THE NODE DESIGNATIONS FOR 29 NODE MODEL



TINATION III
FIG. 18
ORBITAL HEAT FLUX DATA 2
NOON ORBIT
φ = 40°
θ = 0°
FLUX (BTU/FT²-HR)
500
400
300
200
100
0
Node 9
Node 10
Node 10
Node 9
Node 10 Albedo
Node 10 Albedo
0
60
120
180
240
300
360
ORBIT ANOMALY (DEG) – α

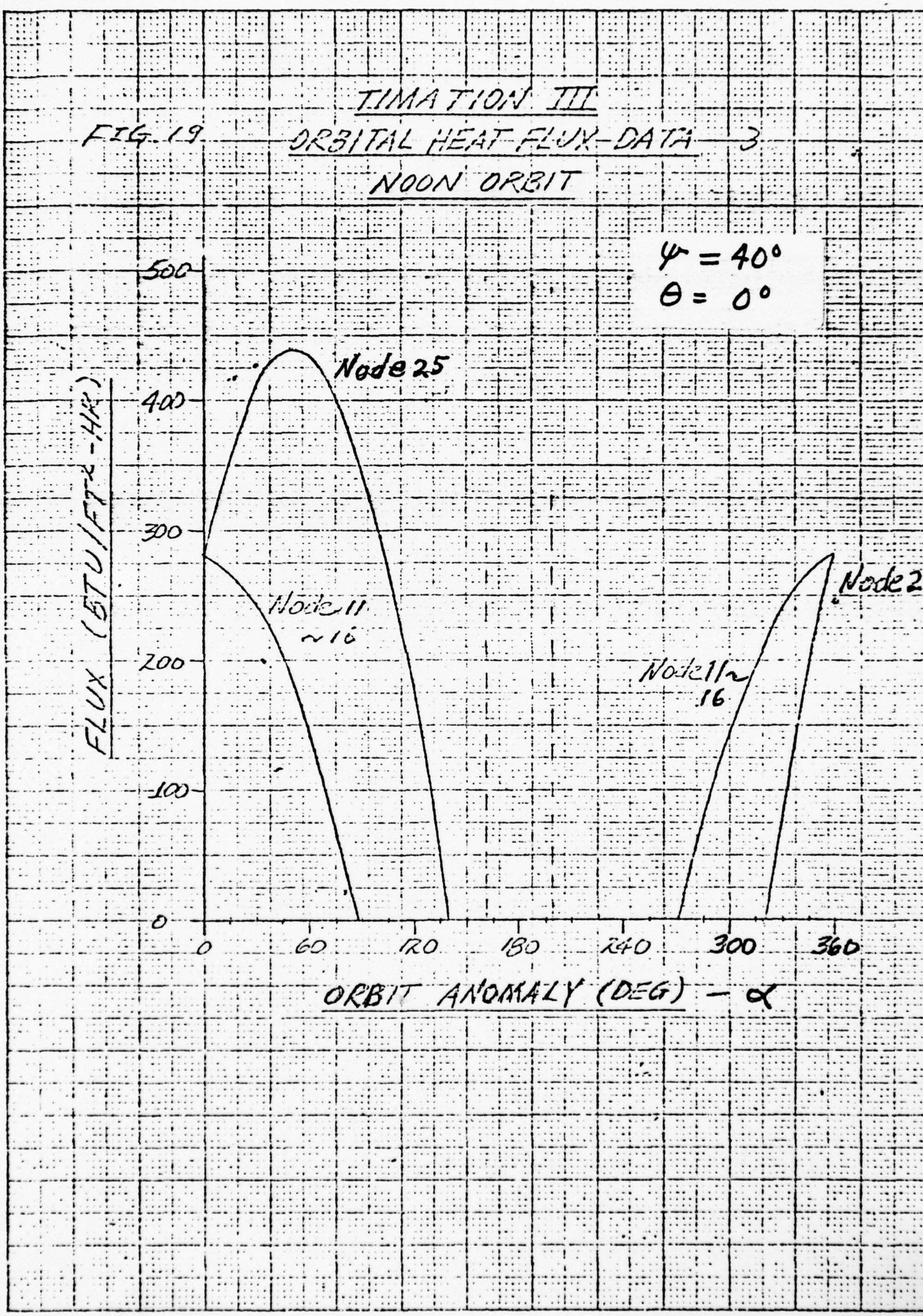

TIMATION III
FIG. 19 ORBITAL HEAT FLUX-DATA 3
NOON ORBIT
Ψ = 40°
θ = 0°
Node 25
Node 11 ~16
Node 11~ 16
Node 25
FLUX (BTU/FT² -HR)
500
400
300
200
100
0
0
60
120
180
240
300
360
ORBIT ANOMALY (DEG) - α

FIG. 20 ORBITAL HEAT FLUX DATA

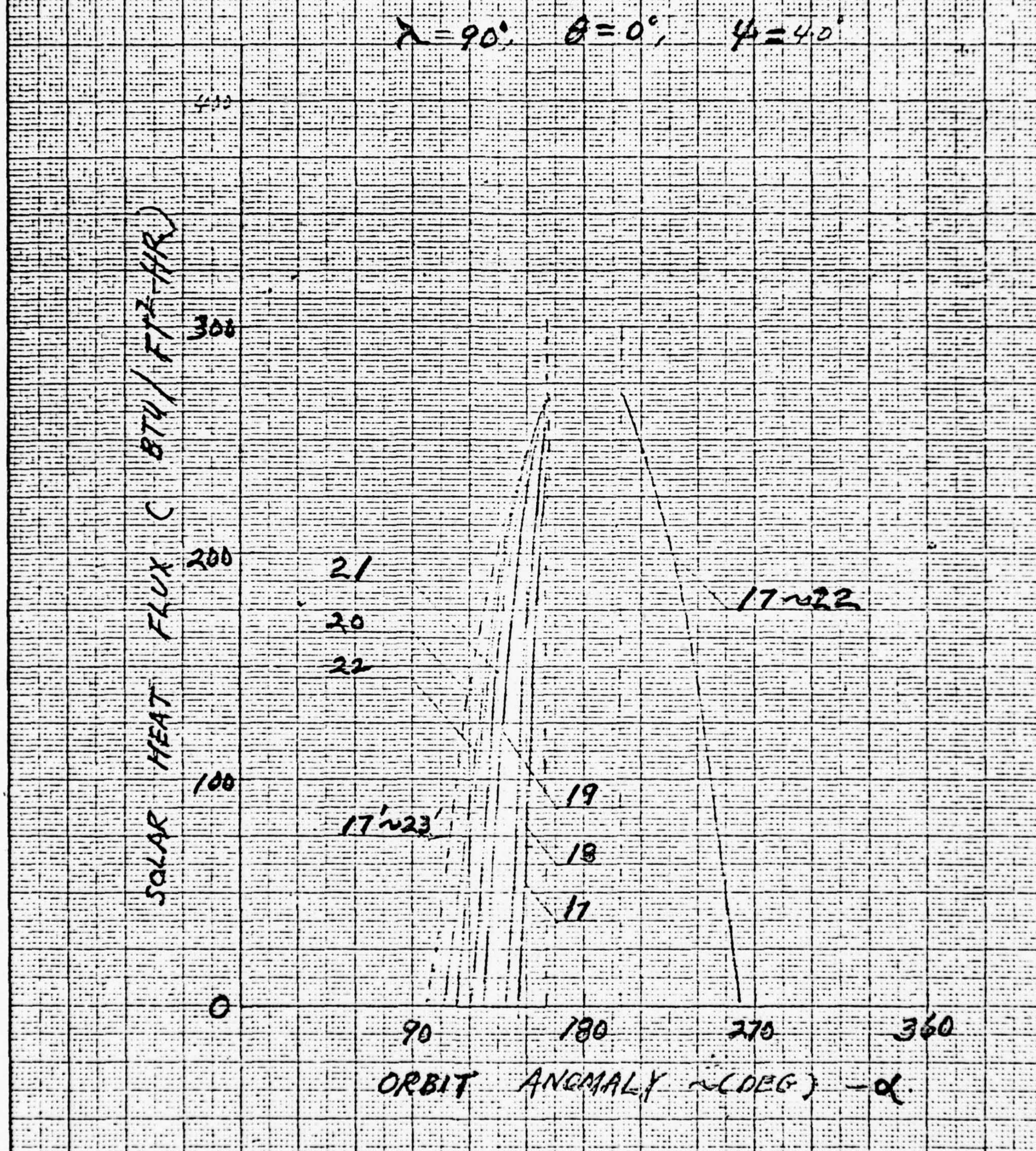
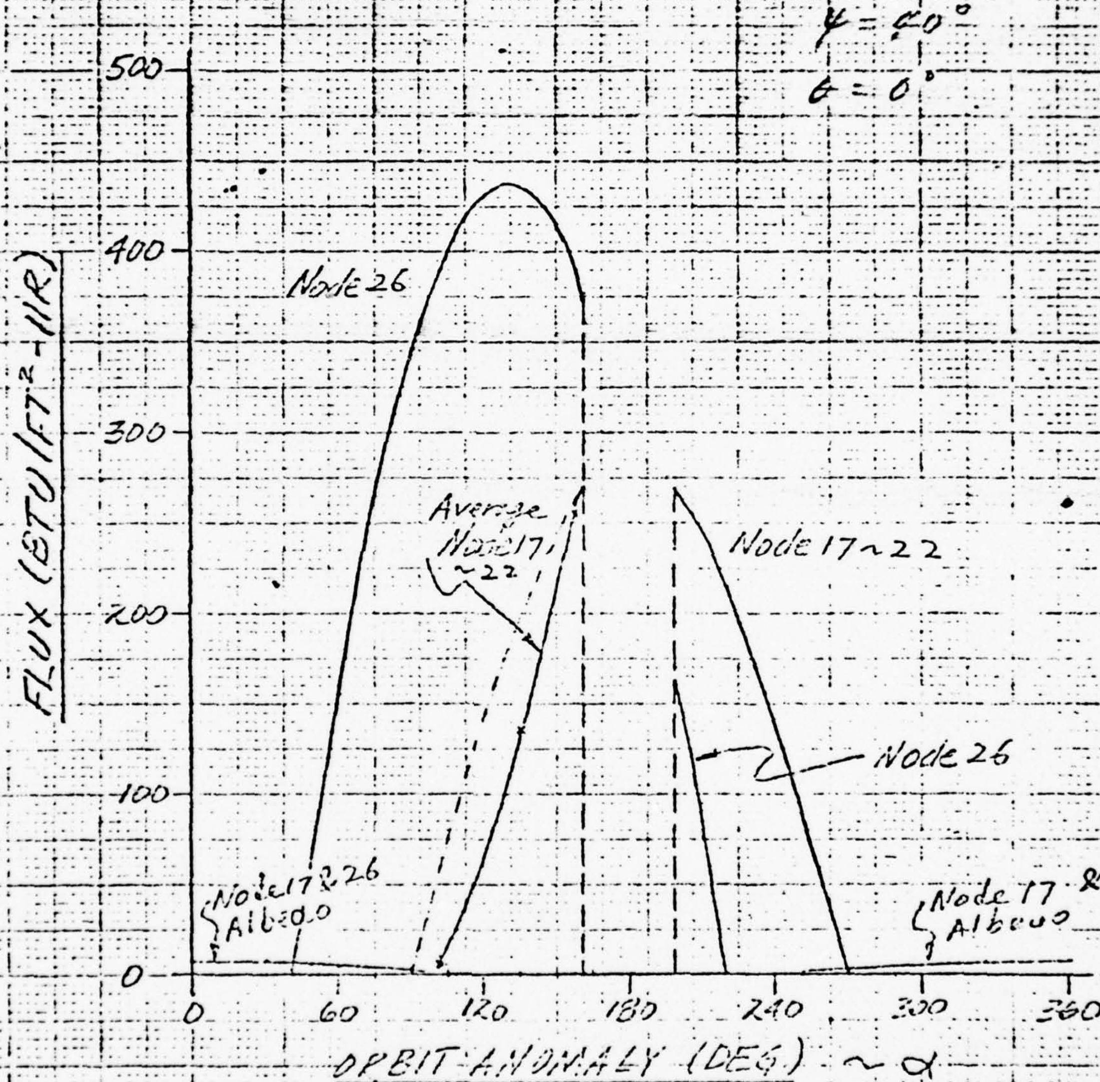


FIG. 21

TIMATION III

ORBITAL HEAT FLUX DATA

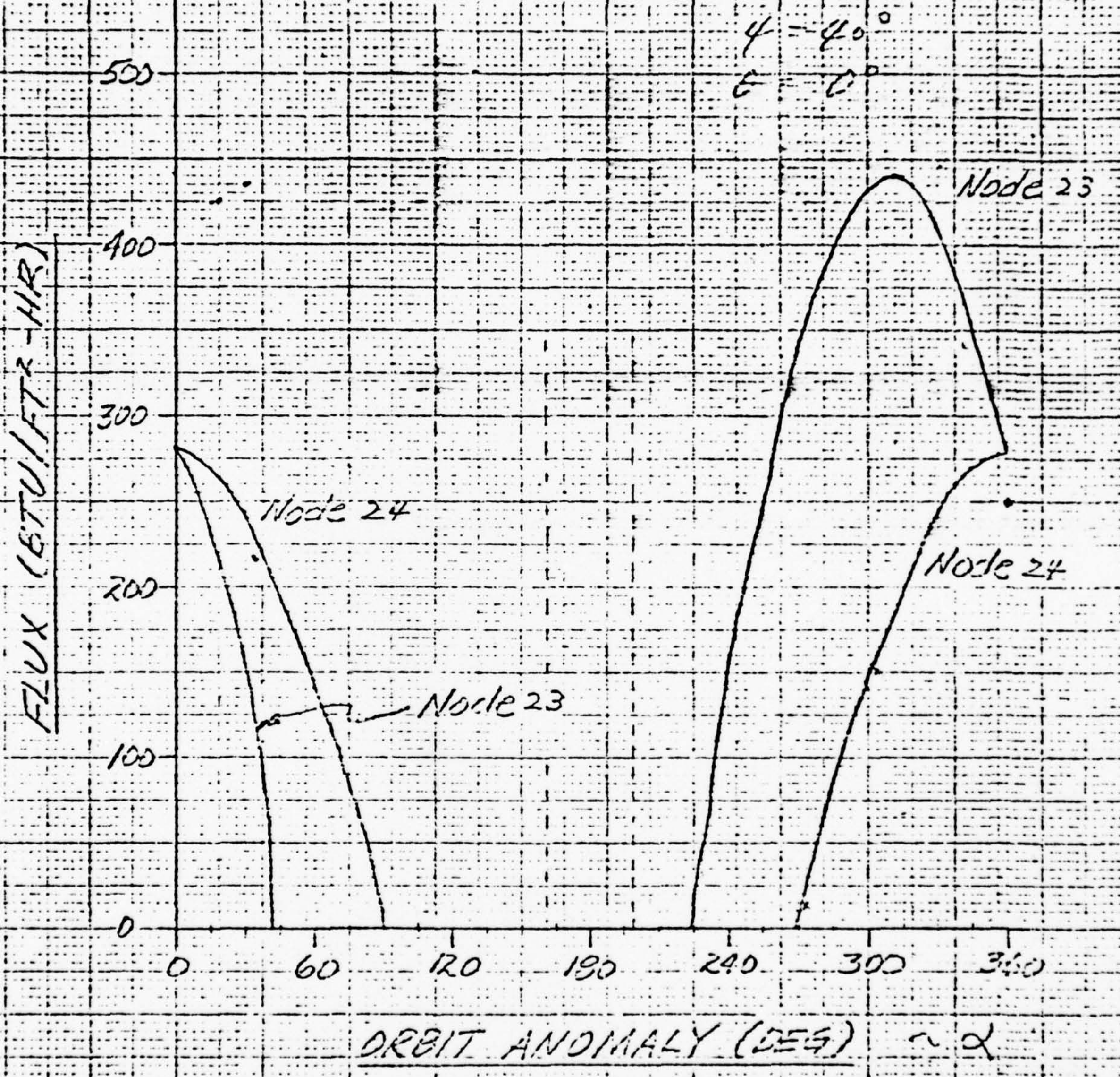
NOON ORBIT

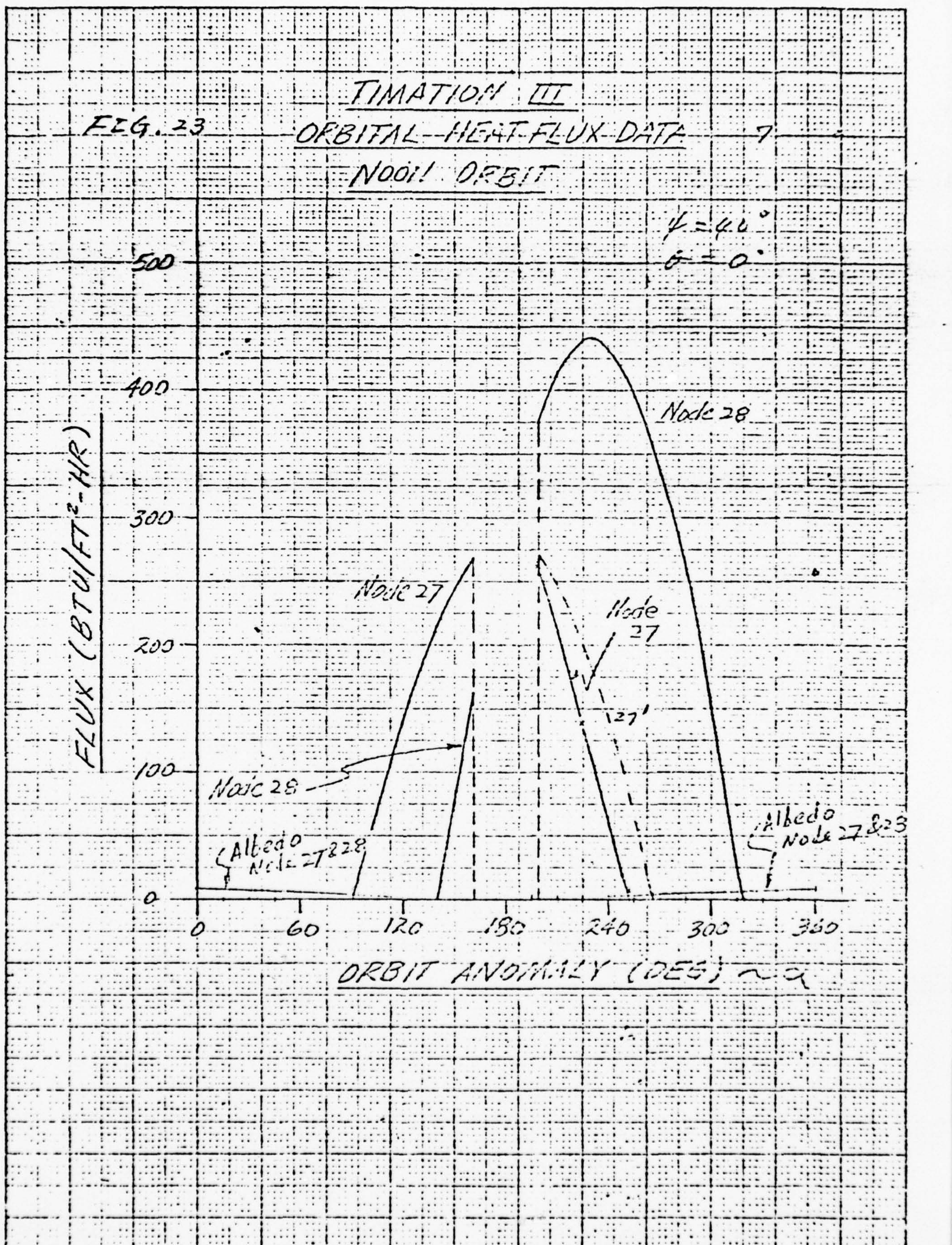


TIMATION III

FIG. 22 ORBITAL HEAT FLUX DATA 6

NOON ORBIT

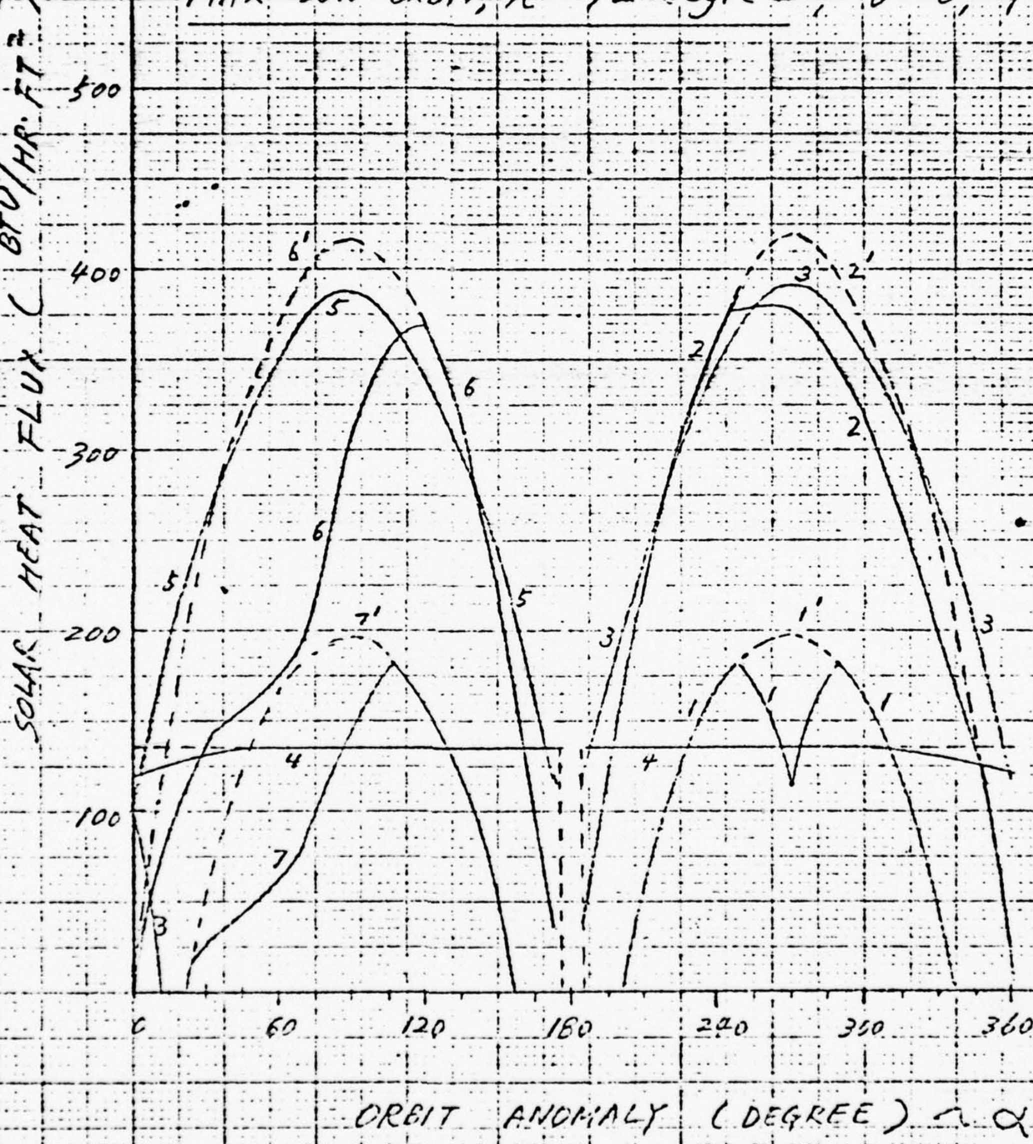



TIMATION III
FIG. 23
ORBITAL HEAT FLUX DATA
NOON ORBIT
ψ = 40°
θ = 0°
500
400
300
200
100
0
FLUX (BTU/FT²-HR)
Node 28
Node 27
Node 27
27'
Node 28
Albedo Node 27&28
Albedo Node 27&28
0
60
120
180
240
300
360
ORBIT ANOMALY (DEG) ~ α

TIMATION III A

FIG. 24 ORBITAL HEAT FLUX DATA 8

MAX SUN-ORBIT, $\lambda = 72$ degree, $\theta = 0°$, $\psi = 40°$



NOTE: NODE 8 DOES NOT RECEIVE SUNLIGHT FOR ENTIRE ORBIT

NUMBERS ON CURVES DESIGNATE THE NODE NUMBERS FOR 29 NODE MODEL

MAX. SUN ORBIT

FIG. 25 ORBITAL HEAT FLUX DATA 9 "1

λ=72, θ=0, ψ=40°

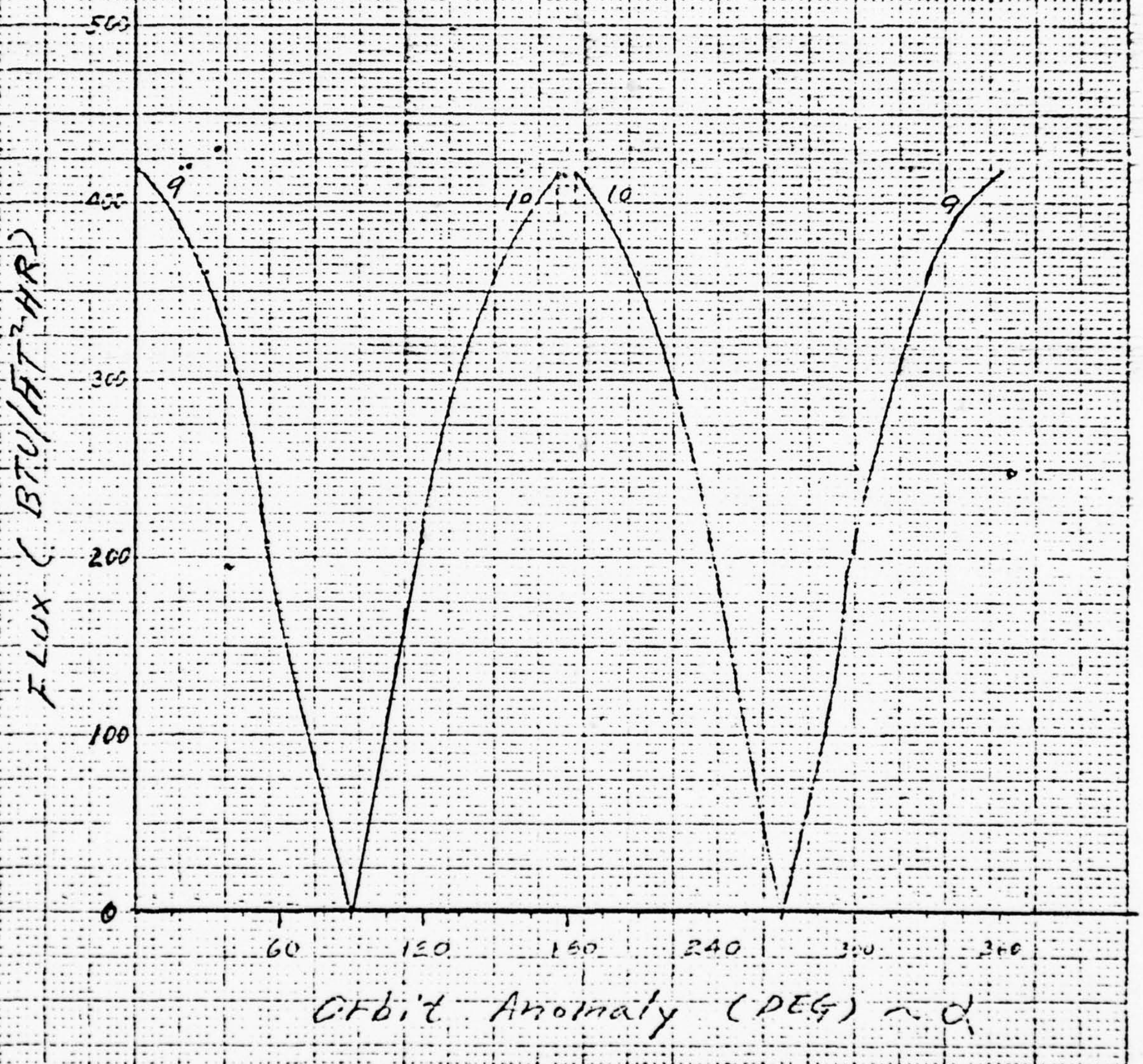
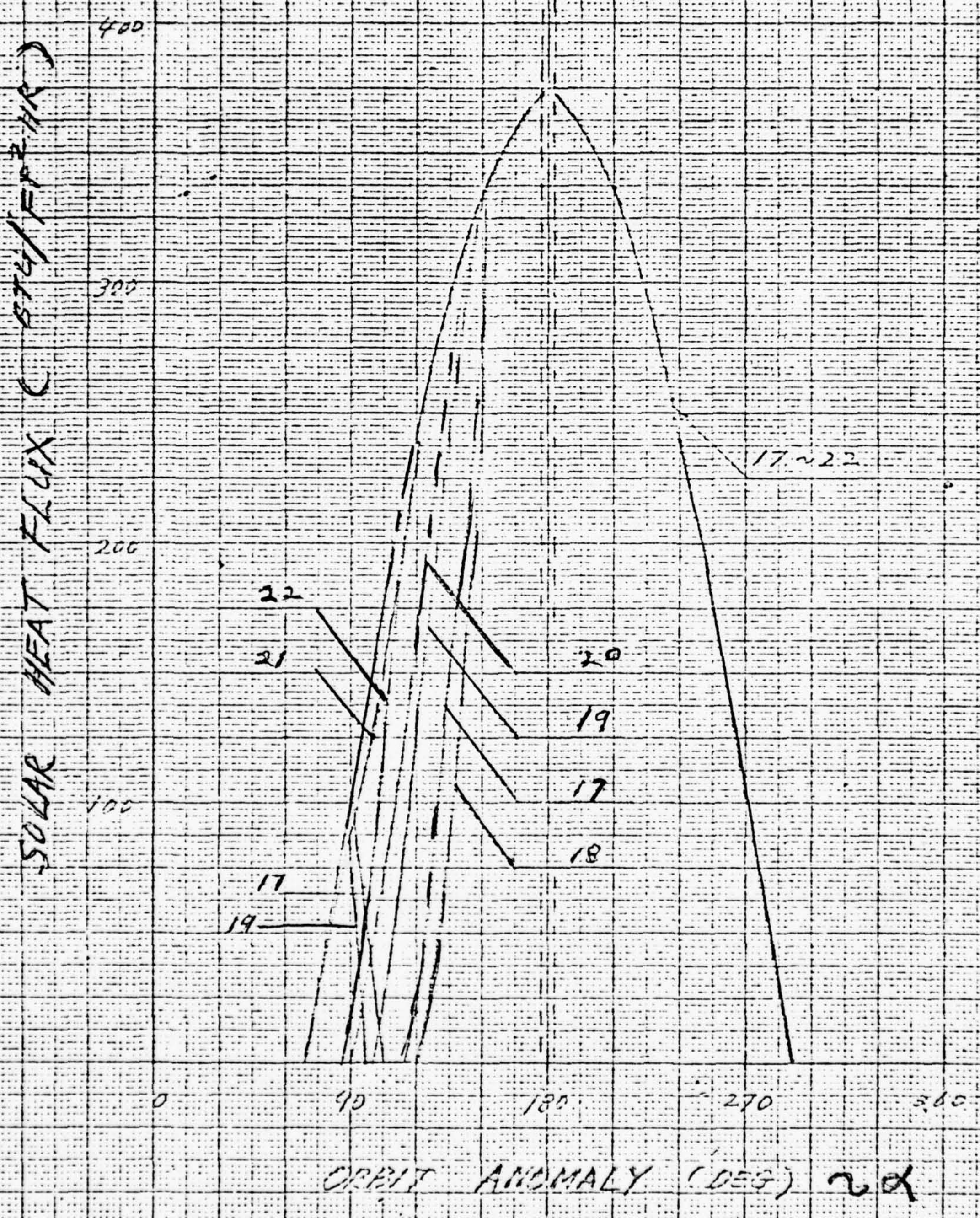


FIG. 26 ORBITAL HEAT FLUX DATA

$\lambda = 72°, \theta = 0, \psi = 40°$



λ = 72°, = 0°, ψ = 40°

FIG. 27 ORBITAL HEAT FLUX DATA 11° MAY SUN ORBIT

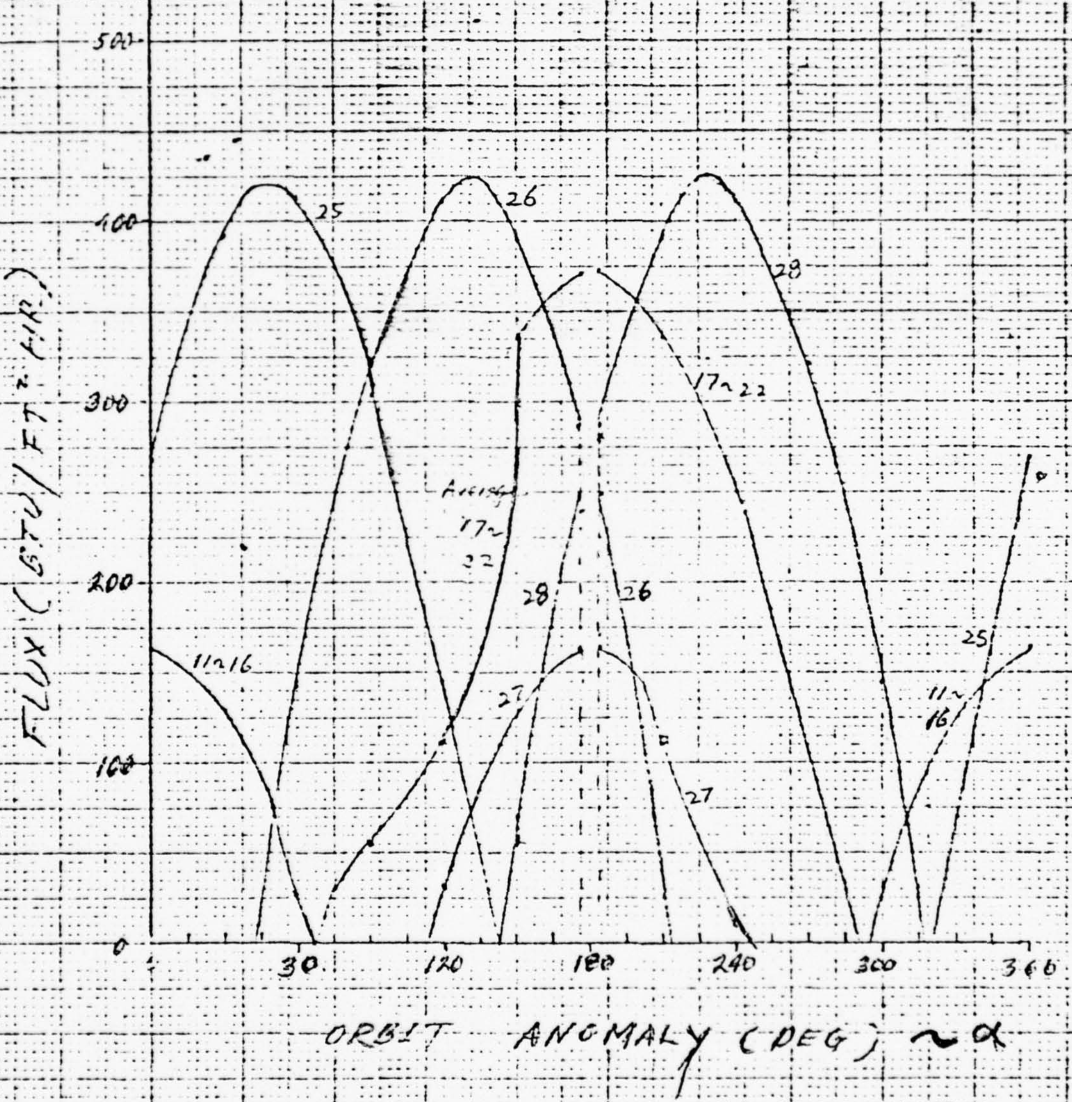
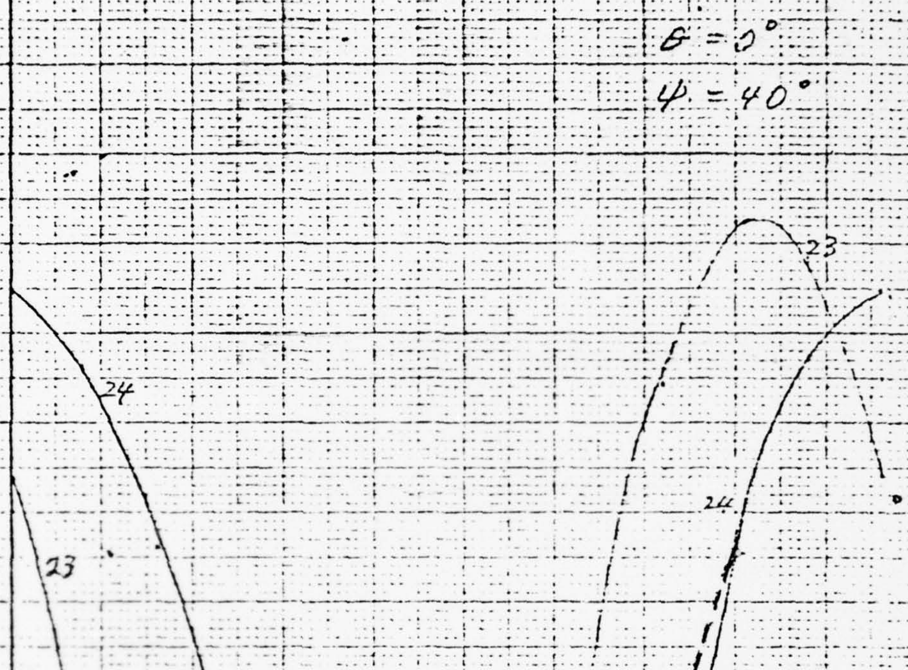


FIG. 28 ORBITAL HEAT FLUX DATA

Maximum Sun Orbit, $\lambda = 72°$



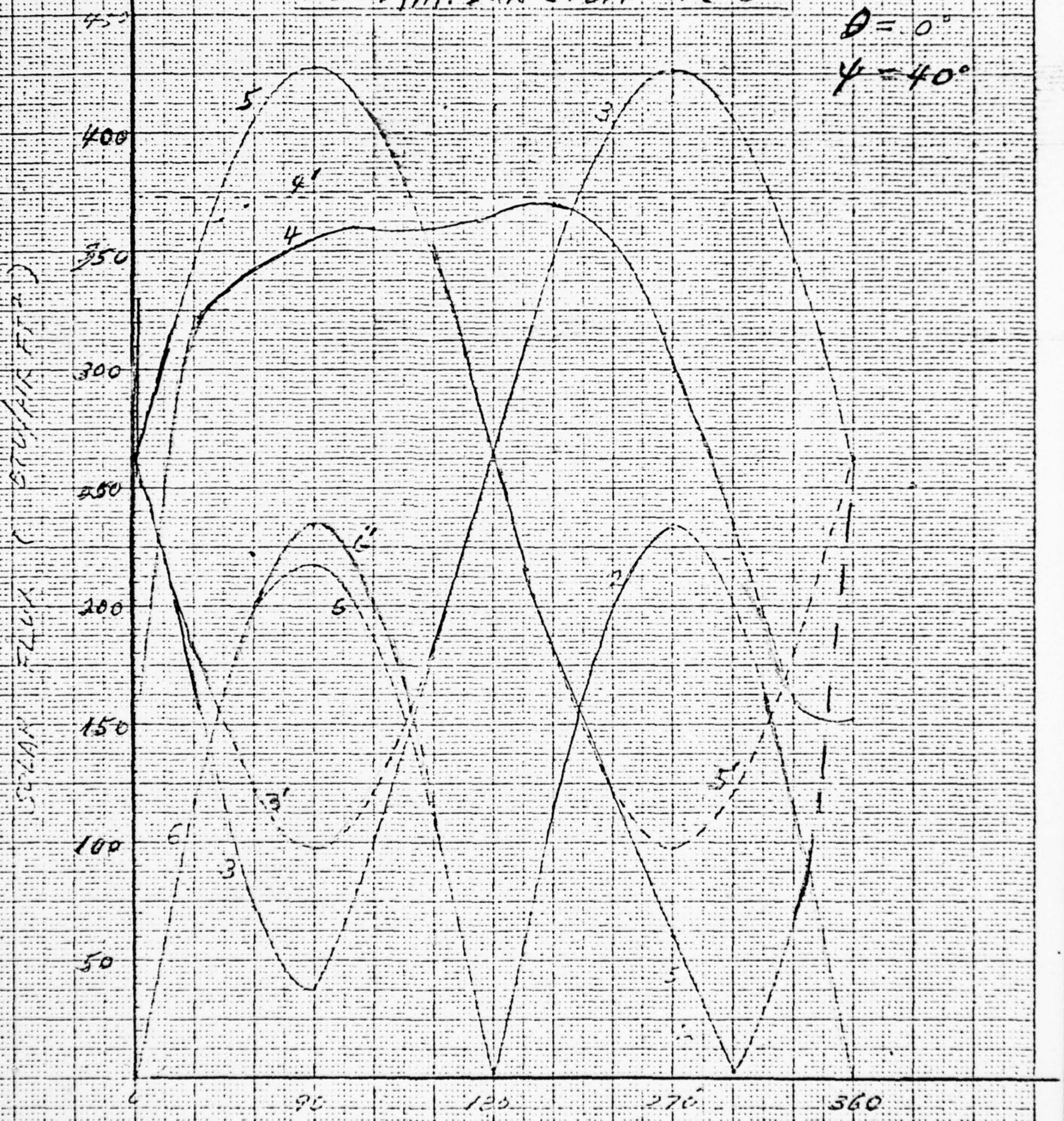
TIMATION III A * CYLINDRICAL SURFACES

FIG. 29 ORBITAL SOLAR HEAT FLUX DATA 13

The Min. Sun Orbit $\lambda = 32°$

$\theta = 0°$

$\psi = 40°$



NOTE 1 : NODES 1,7 &8 DO NOT RECIEVE SUNLIGHTFOR ENTIRE ORBIT

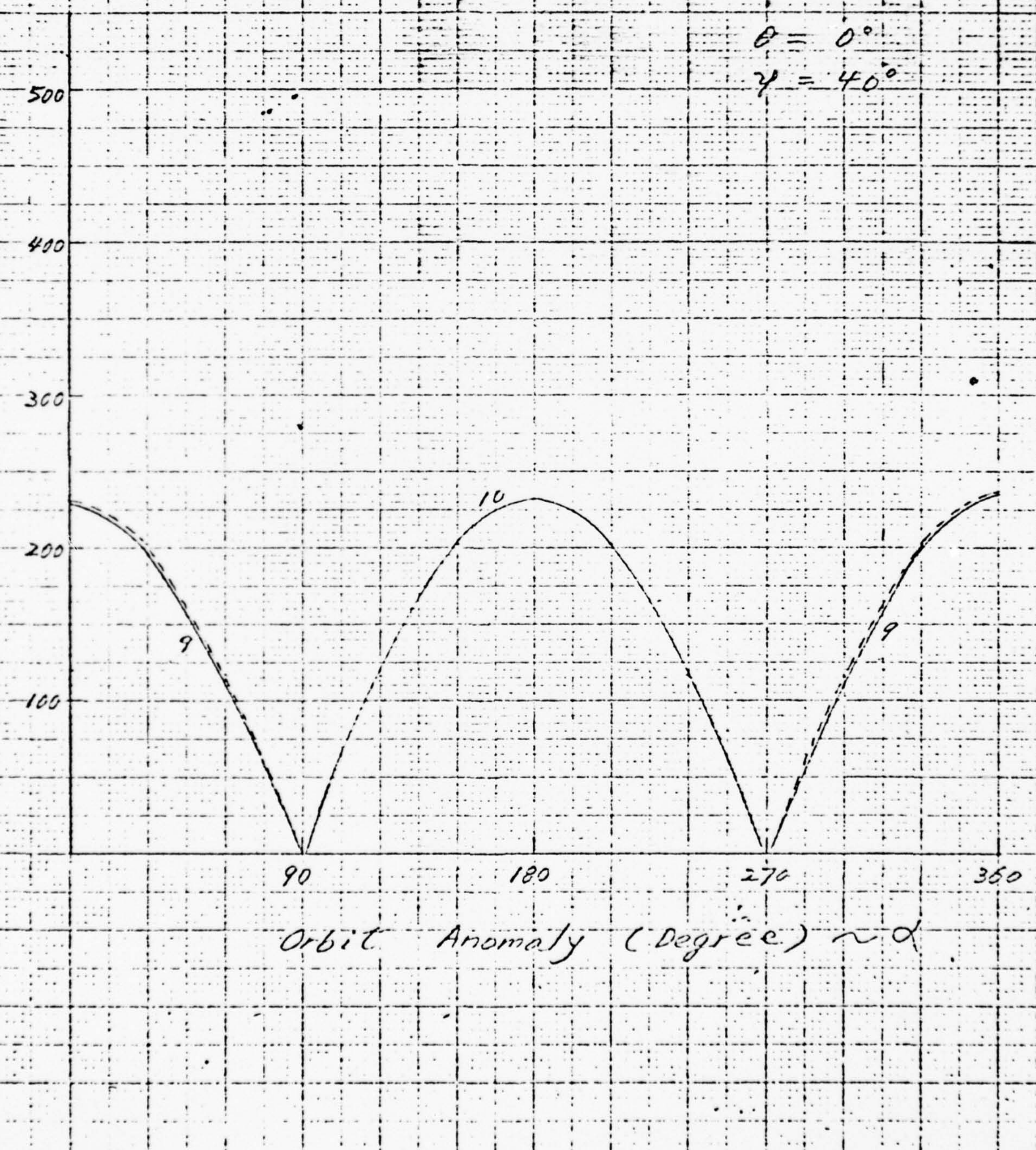
TIMATION - III

FIG. 30 ORBITAL SOLAR HEAT FLUX DATA 14

The Min. Sun Orbit, $\lambda = 32°$

$\theta = 0°$

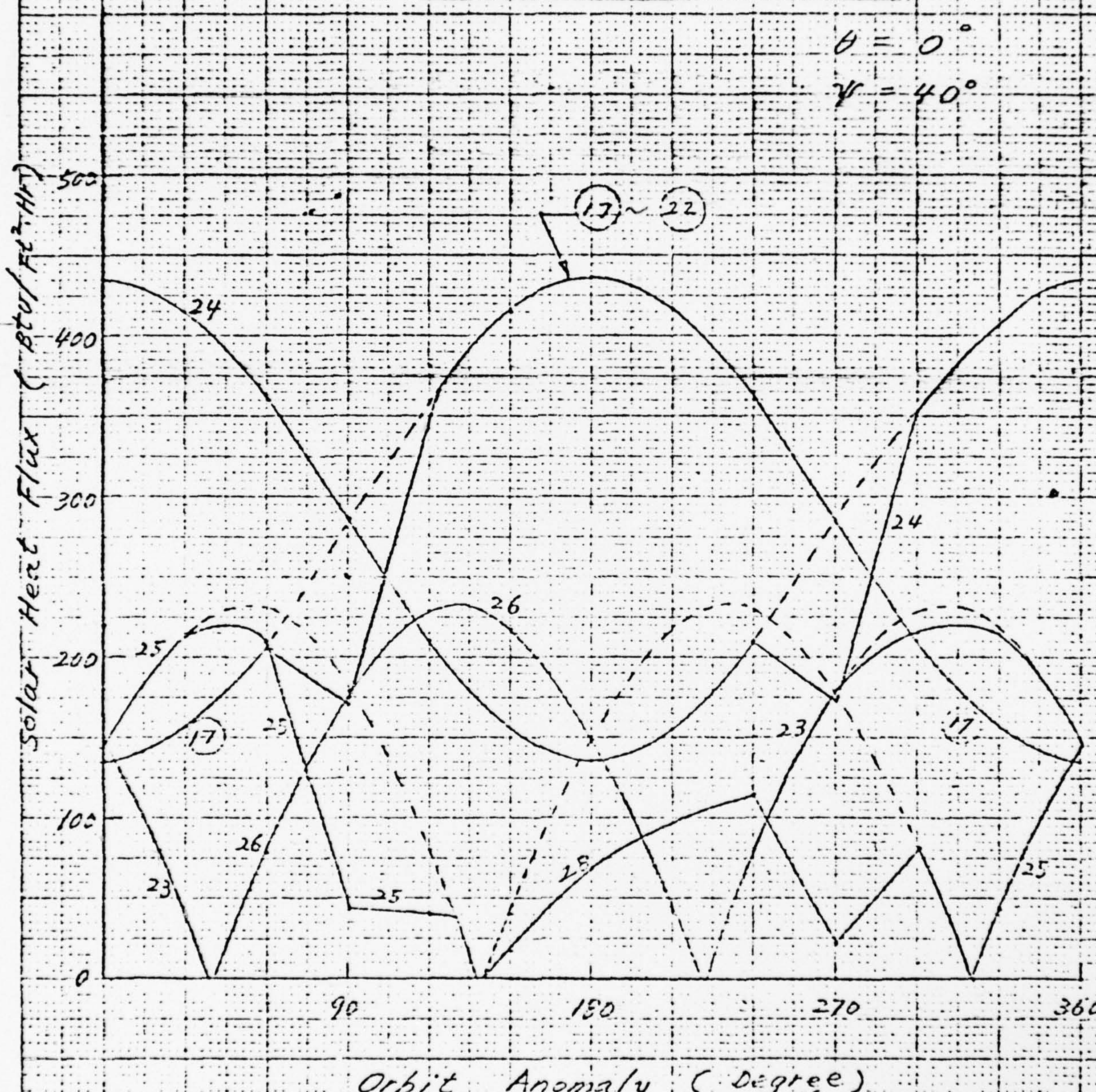
$\psi = 40°$



TIMATION II - SOLAR PANELS'

FIG. 32 ORBITAL SOLAR HEAT FLUX DATA

The Min. Sun Orbit $\lambda = 32°$



NOTE : NODES 11, 12, 13, 14, 15, 16, & 27 DO NOT RECEIVE SOLAR HEAT FLUX FOR ENTIRE ORBIT.

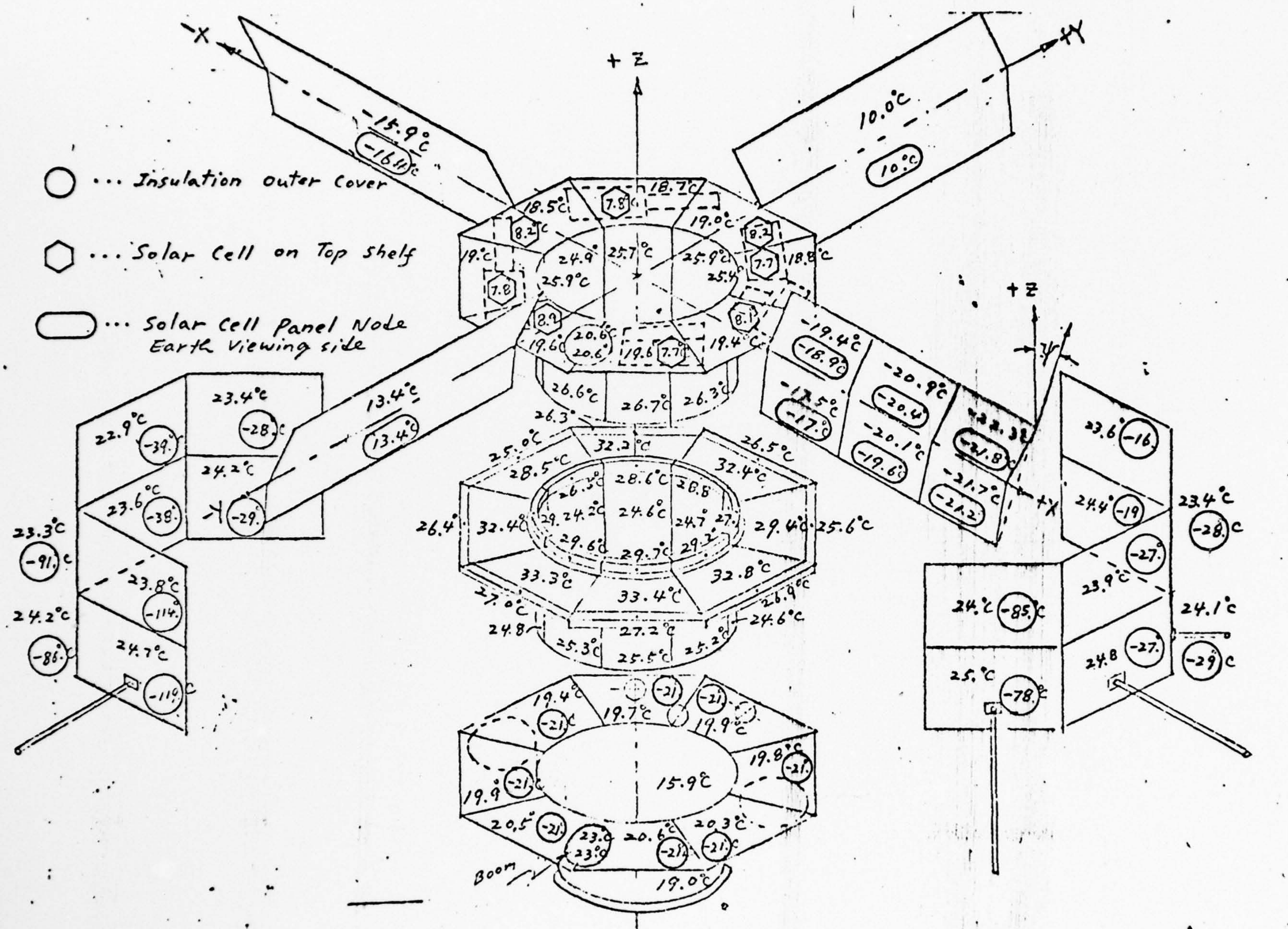


FIG. 33 ORBITAL AVERAGE TEMPERATURE (°C) — MAXIMUM SUN ORBIT (λ = 72°)

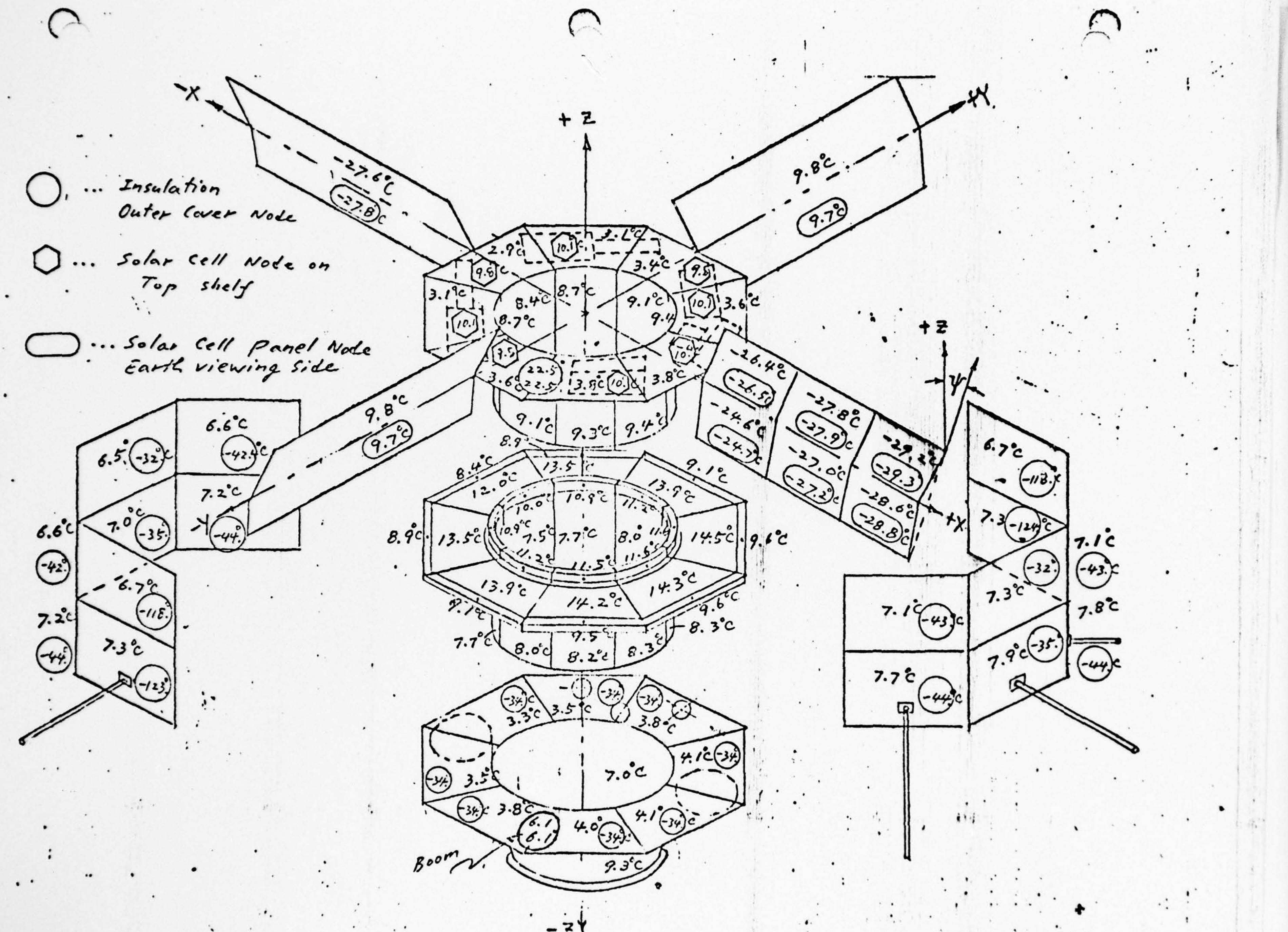


FIG. 34 ORBITAL AVERAGE TEMPERATURE (°C.) - NOON ORBIT (λ=90°).

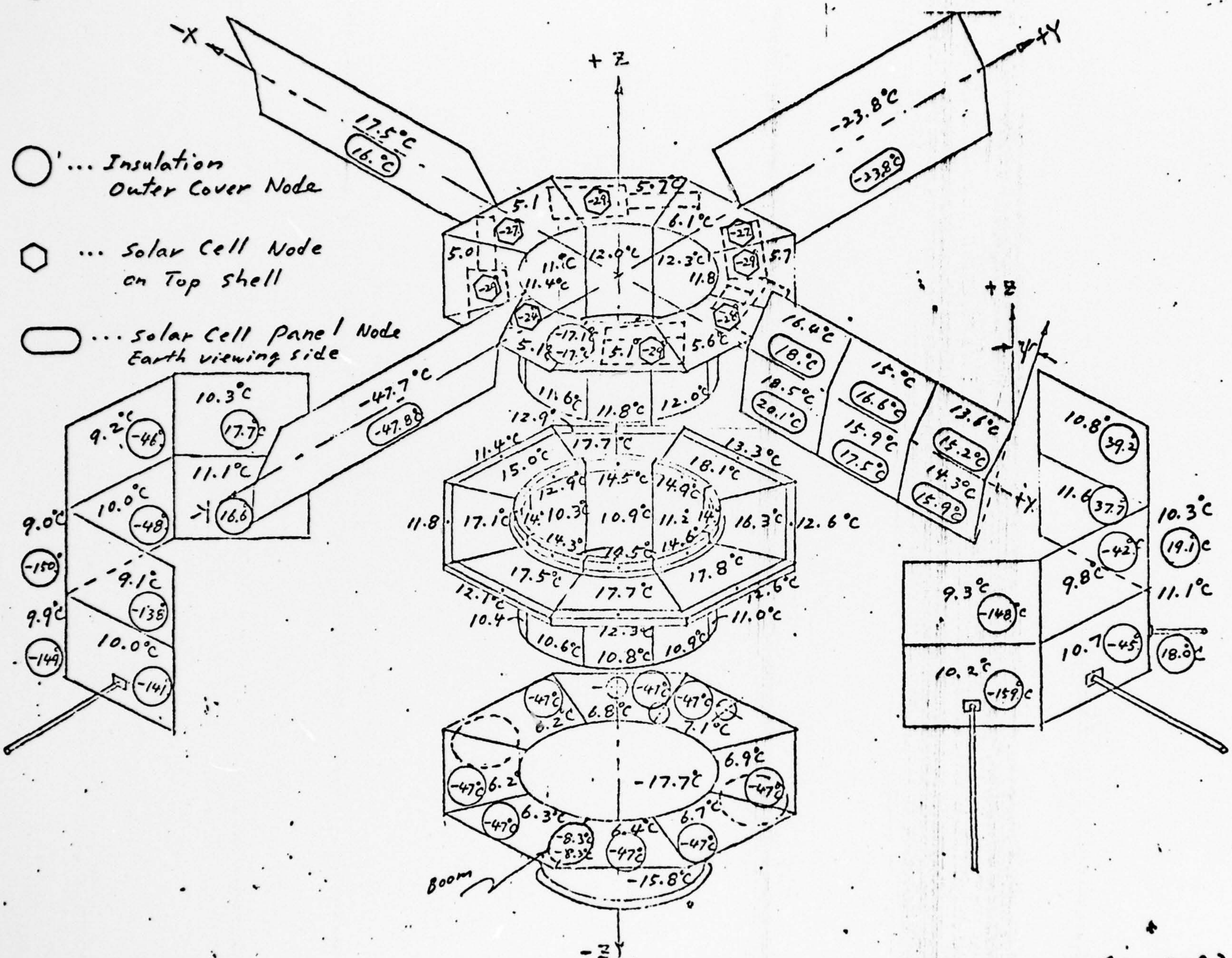


FIG. 35 Orbital Average Temperature ~(°C) — Min. Sun Orbit (λ=32°)

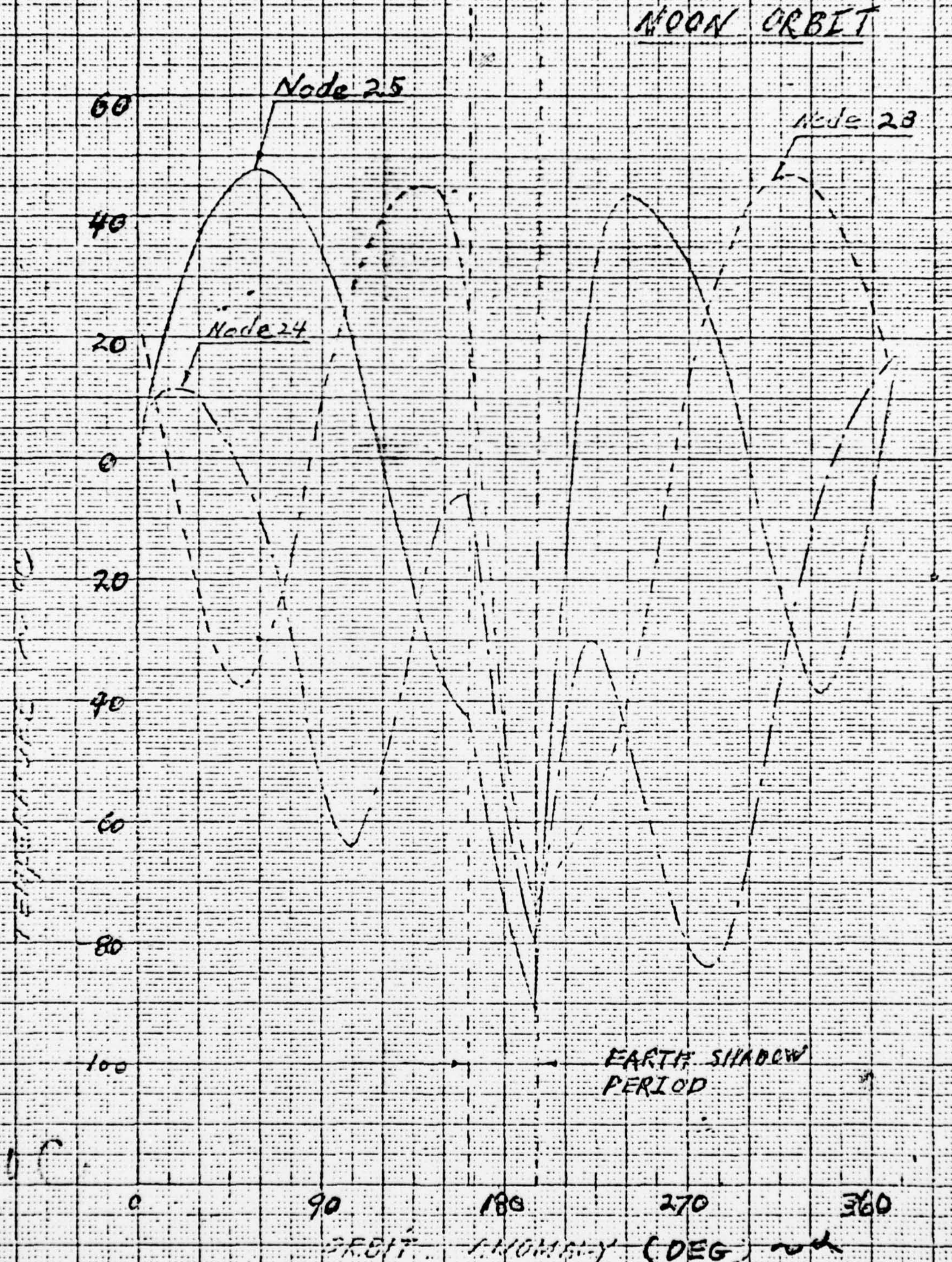


FIG. 36 AVERAGE SOLAR PADDLE TEMPERATURE ~ °C

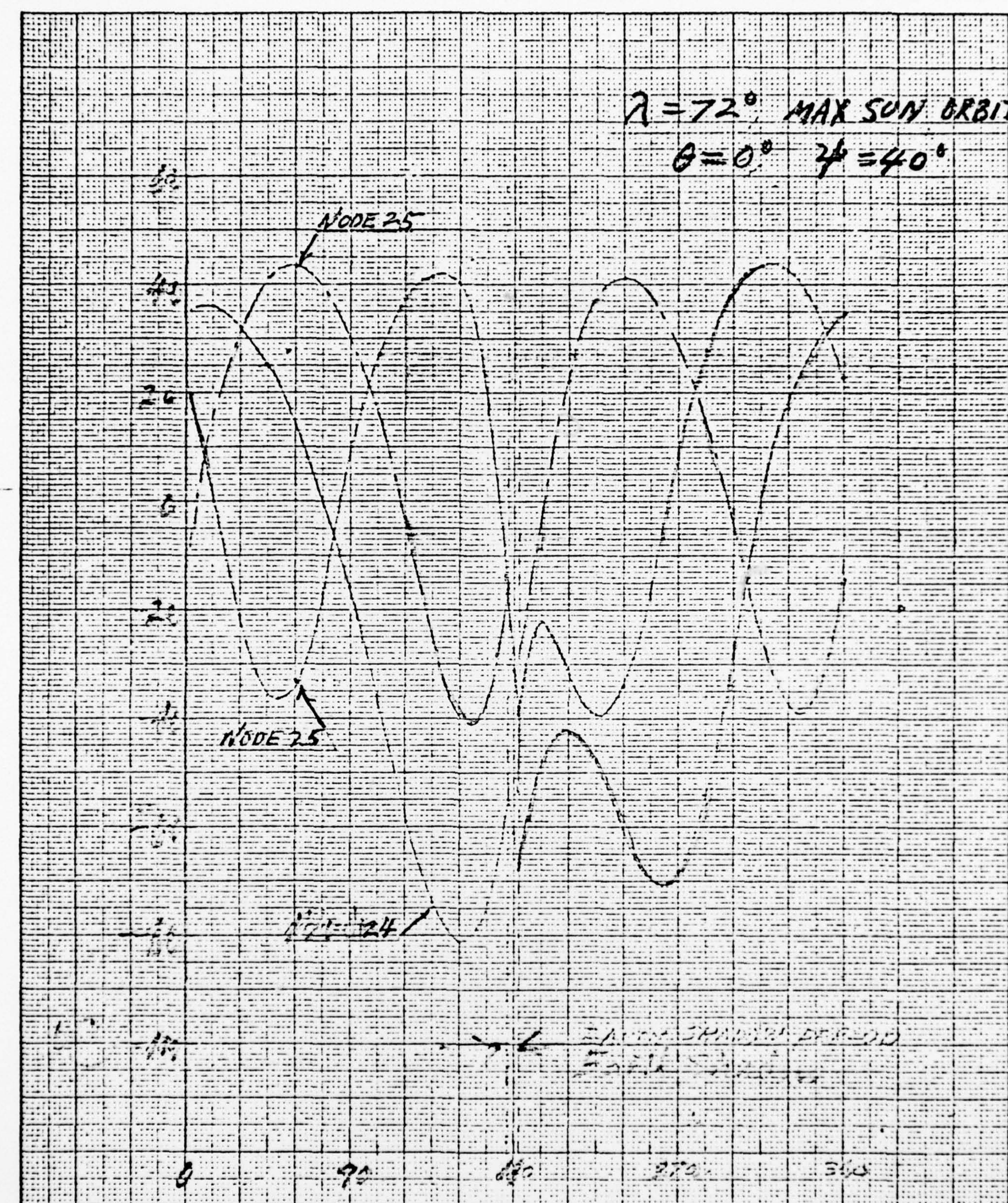


FIG. 37 ORBITAL TEMPERATURE DISTRIBUTION OF SOLAR PANEL

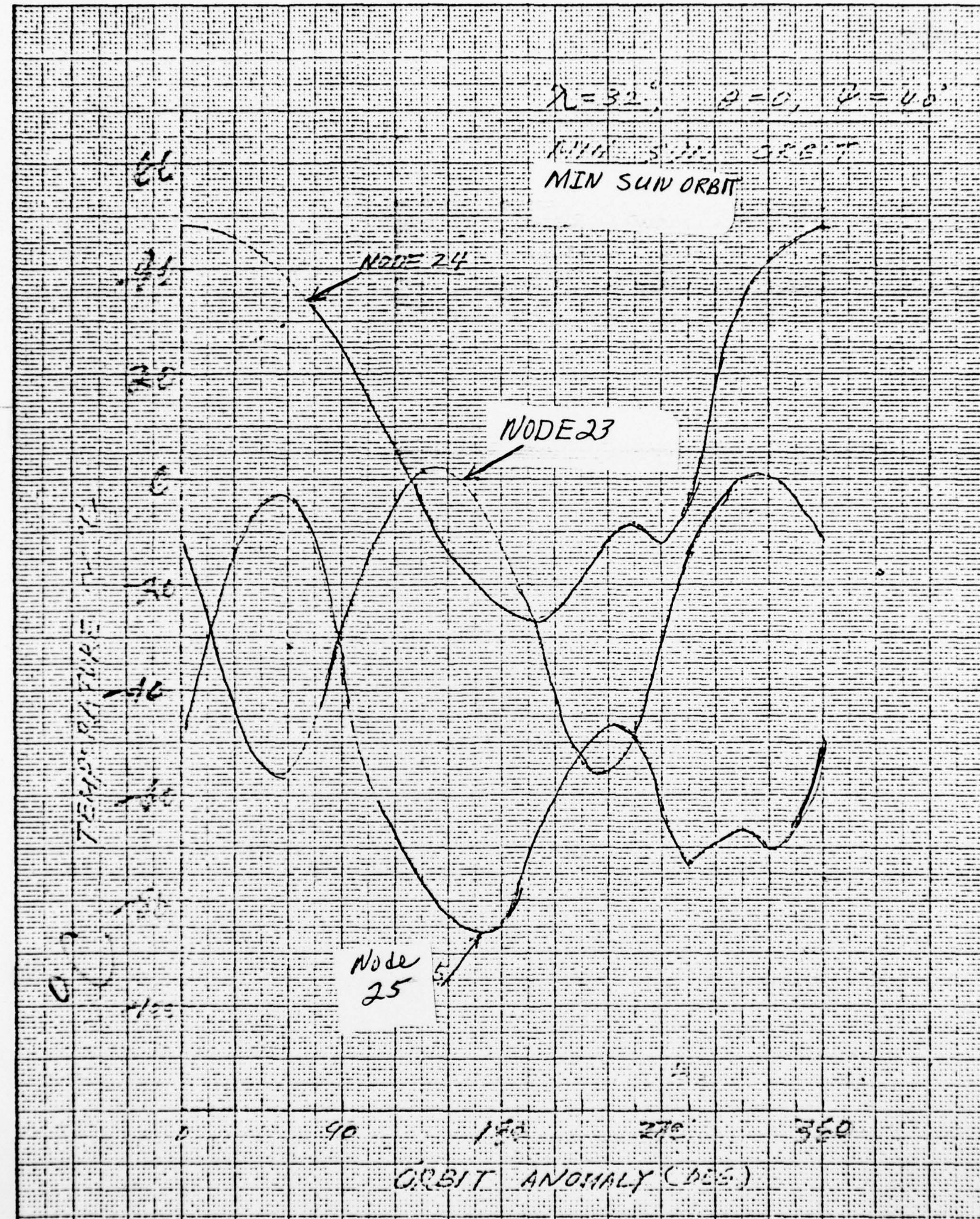


FIG. 38 ORBITAL TEMPERATURE DISTRIBUTION OF SOLAR PANEL

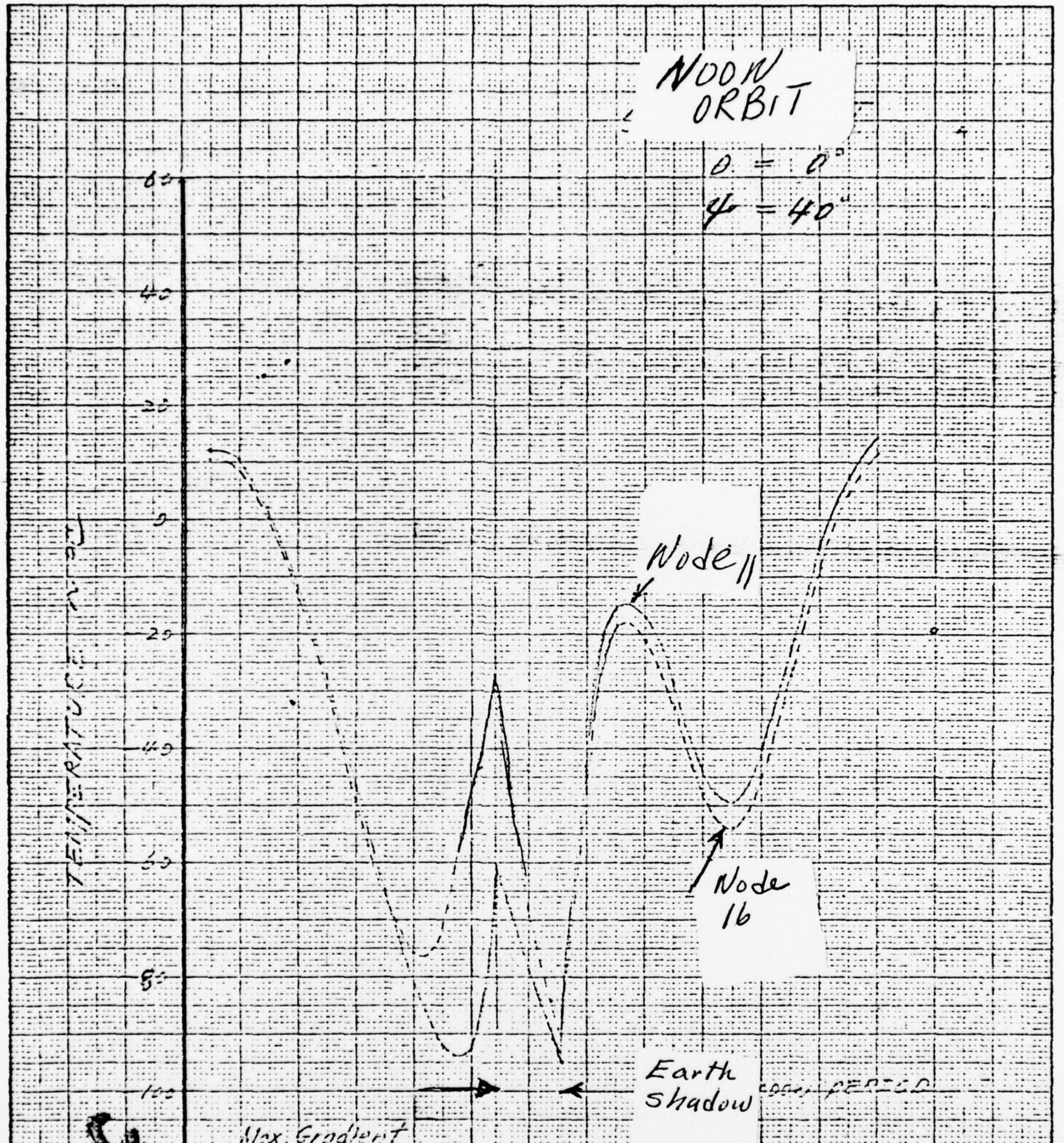


FIG. 39 TEMPERATURE GRADIENT OF A SOLAR PADDLE

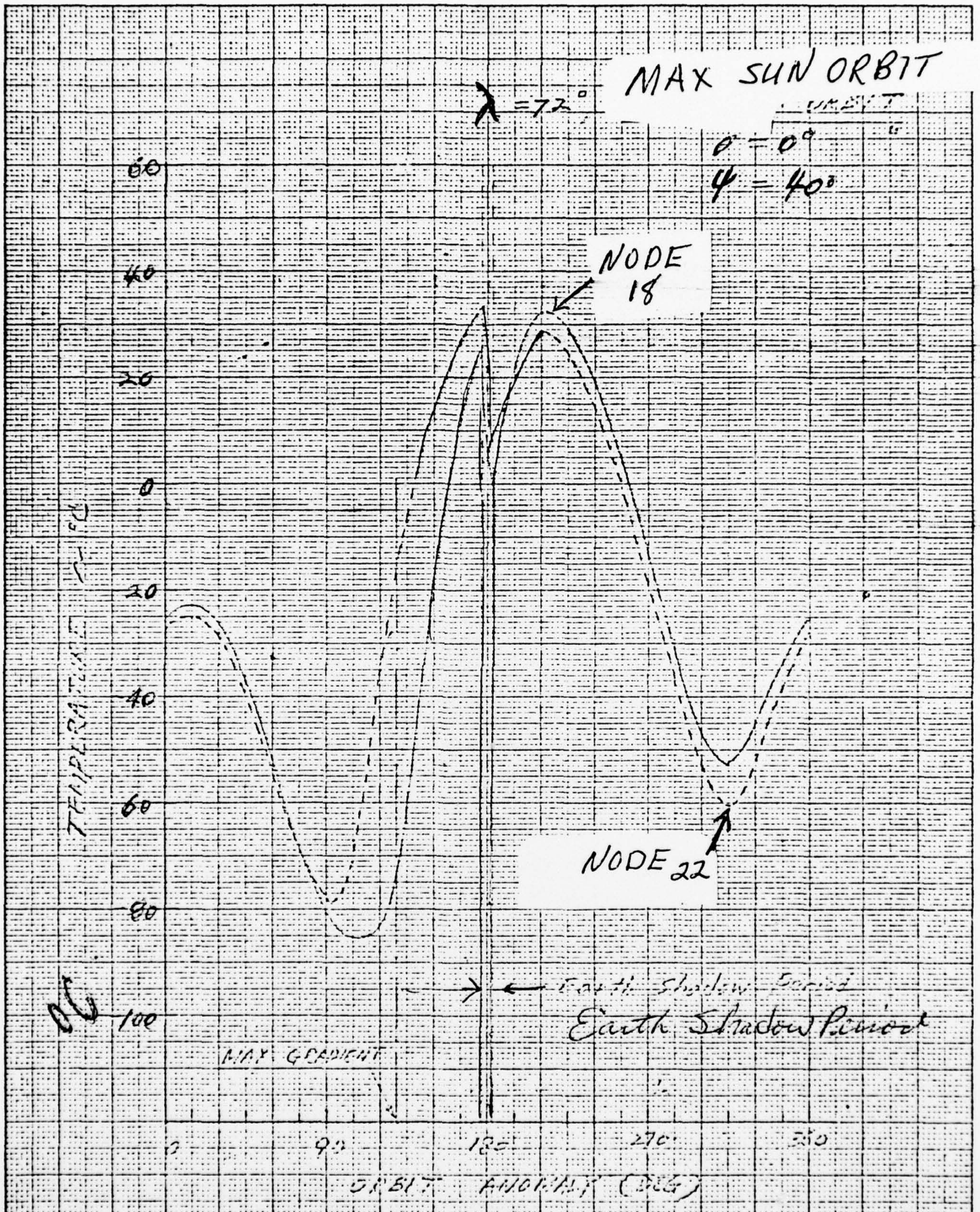
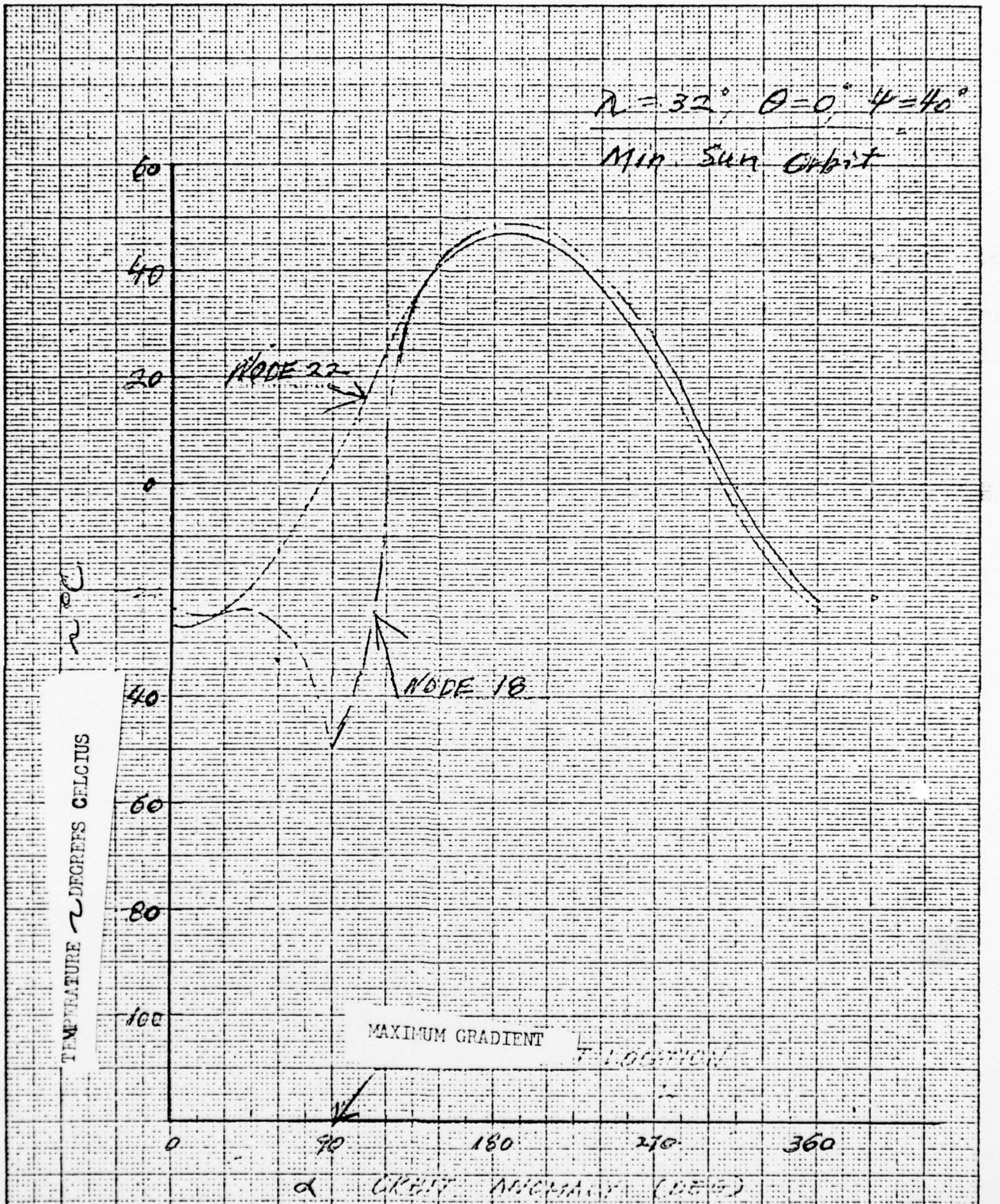


FIG 40 TEMPERATURE GRADIENT OF A SOLAR PANEL



TEMPERATURE GRADIENT OF SOLAR PANEL

Figure 42 EXTENDIBLE BOOM HOUSING THERMAL DESIGN

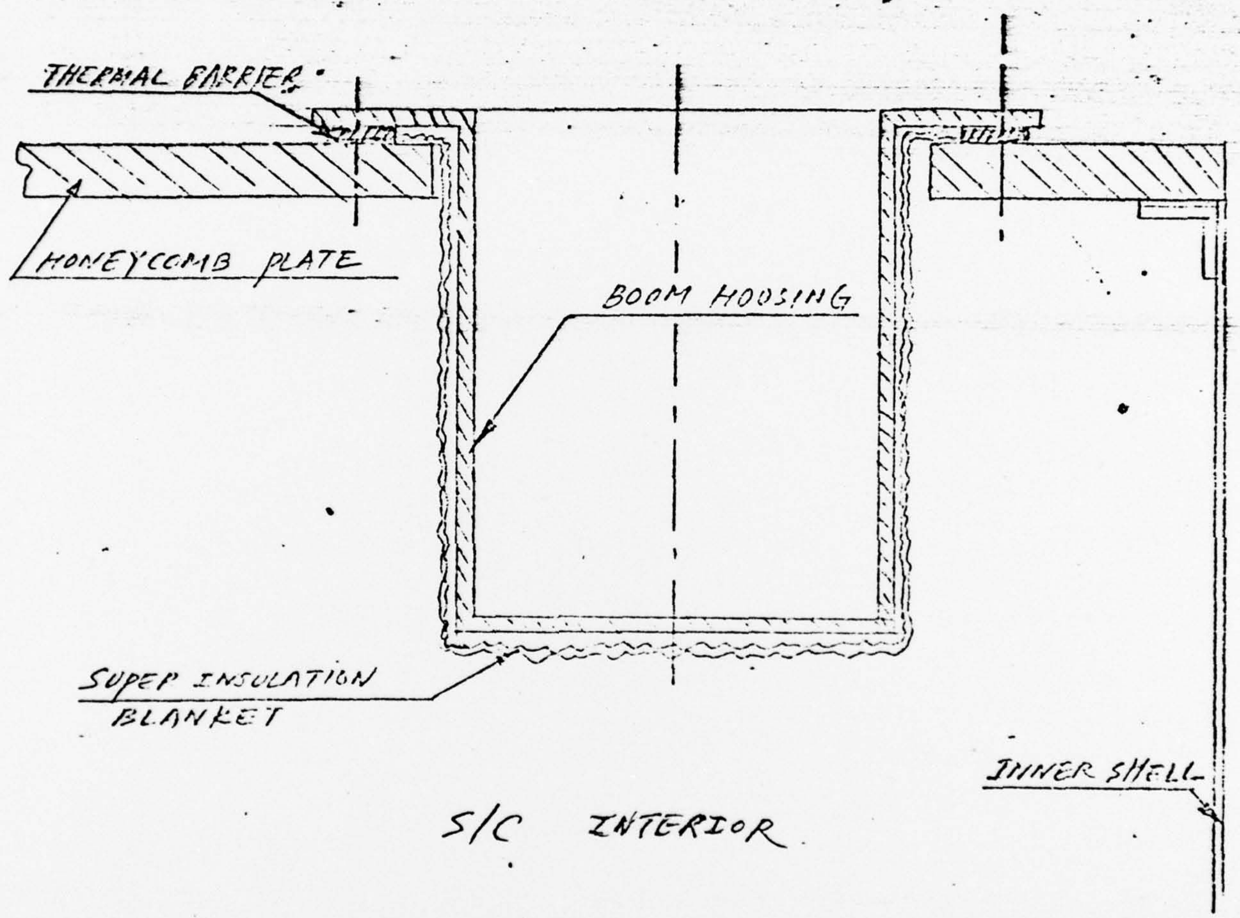


Figure 43. TOP SHELL DESIGN

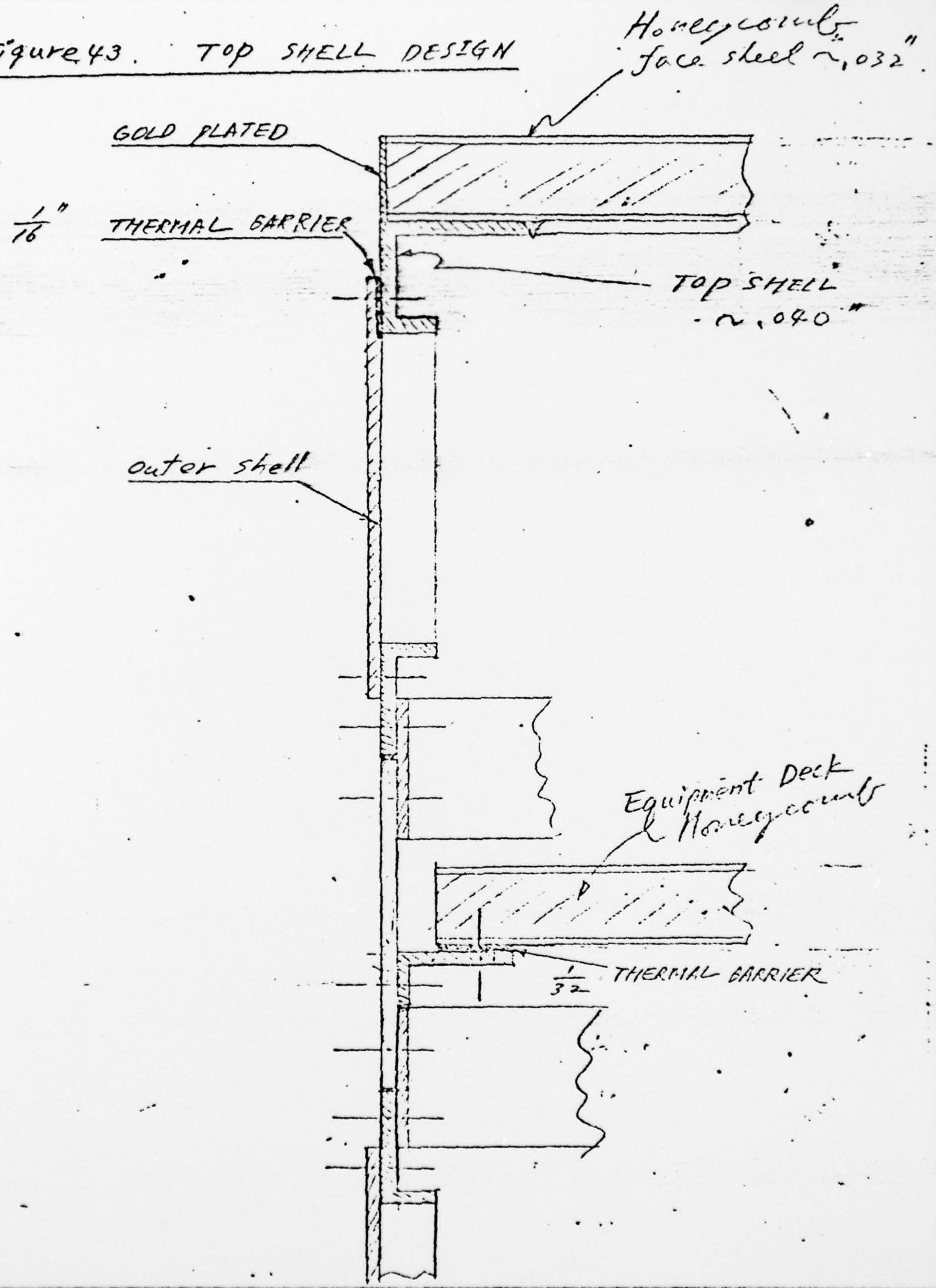
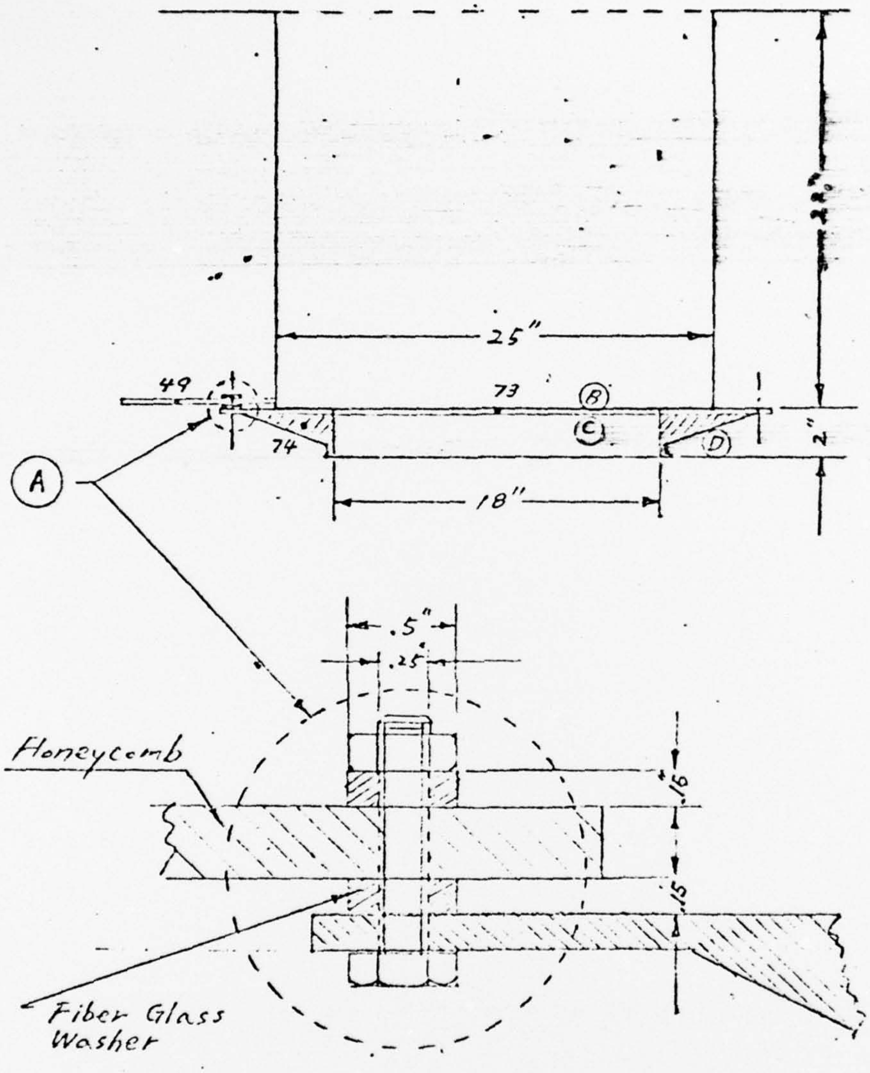
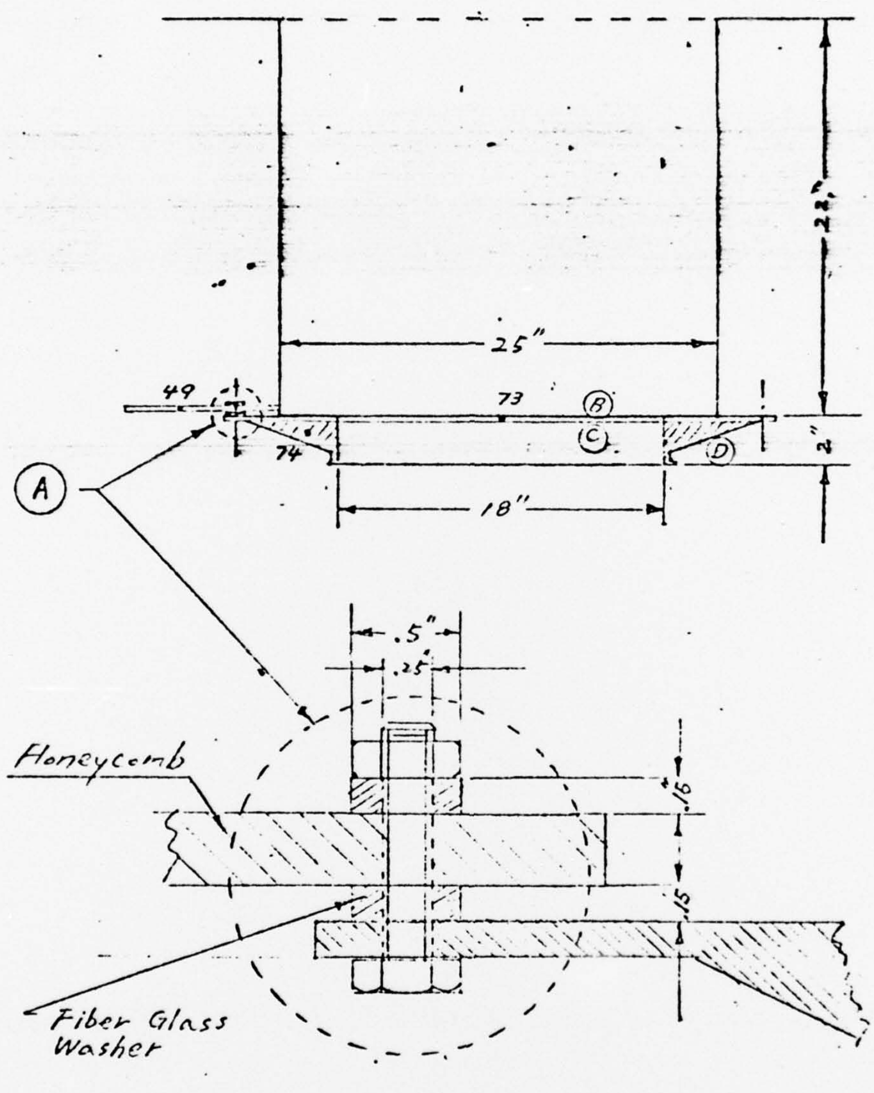


Fig. 44. Bottom cover plate - Flange Design



Node	Surface	Thermal Finisher
73	B	White Paint
73	C	Bare Aluminum
74	D	Bare Aluminum

Fig. 44. Bottom Cover plate - Flange Design



Node	Surface	Thermal Finisher
73	B	White Paint
73	C	Bare Aluminum
74	D	Bare Aluminum

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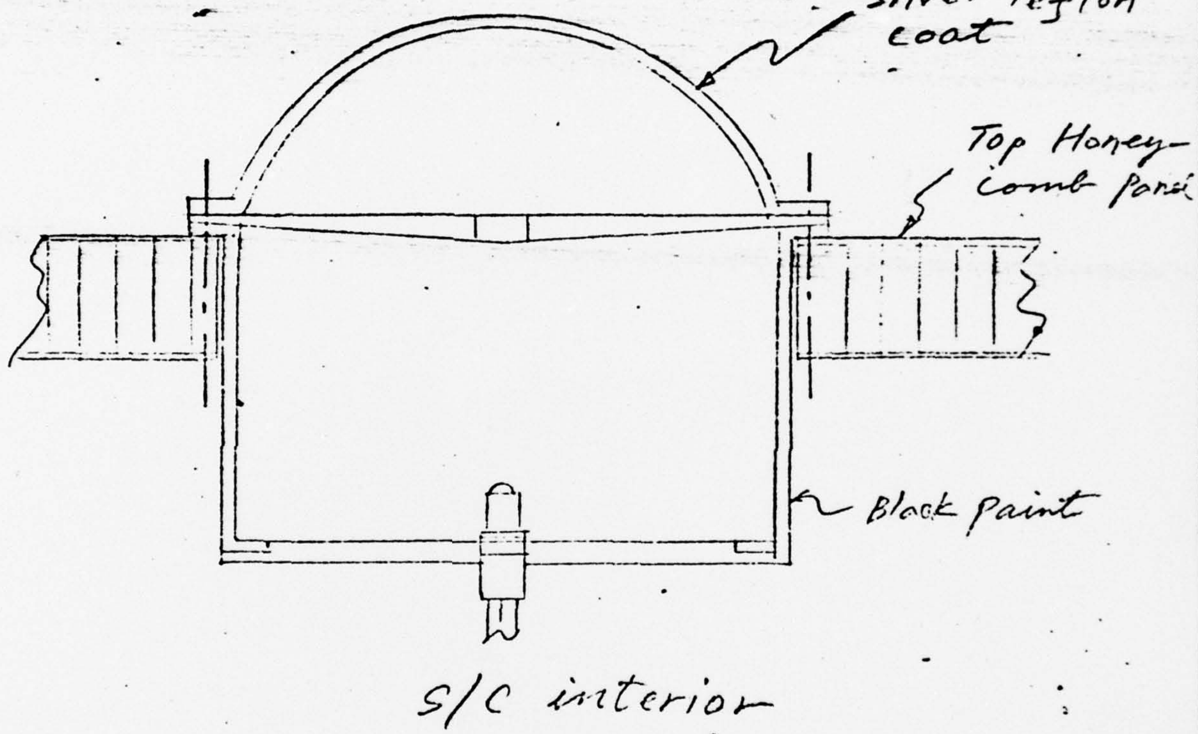
Figure 45 Radiation Counter / Sensor Design



PREPARED BY	CHECKED BY 58	DATE	REV.

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