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NASA CR-167784
2-53200/2R-53333

ORBITER RADIATOR PANEL SOLAR FOCUSING TEST

(NASA-CR-167784) ORBITER RADIATOR PANEL SOLAR FOCUSING TEST (Vought Corp., Dallas, Tex.) 200 p HC A09/MF A01 CSCL 20D

N83-20028

Unclas
G3/34 03020

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For

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
JOHNSON SPACE CENTER
HOUSTON, TEXAS

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR167784		

4. Title and Subtitle	5. Report Date
Orbiter Radiator Panel Solar Focusing Test	December 1982
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Harold R. Howell	2-53200/2R-53333
9. Performing Organization Name and Address	10. Work Unit No.
Vought Corporation P.O. Box 225907 Dallas, Texas 75265	11. Contract or Grant No. NAS9-14907
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058	Contractor Report
	14. Sponsoring Agency Code

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15. Supplementary Notes

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16. Abstract

A test has been conducted to determine the solar reflections from the Orbiter radiator panels. The concave shape of the panels and their specular silver/Teflon coating can cause focusing of solar energy which could have adverse heating effects on equipment or astronaut Extra-Vehicular Activity (EVA) in the vicinity of the radiator panels. A one-tenth scale model of the forward and mid-forward radiator panels in the deployed position was utilized in the test. Test data has been obtained to define the reflected one-sun envelope for the embossed silver/Teflon radiator coating. The effects of the double contour on the forward radiator panels was included in the test. Solar concentrations of 2 suns were measured and the one-sun envelope was found to extend approximately 86 inches above the radiator panel.

A limited amount of test data was also obtained for the radiator panels with the smooth silver/Teflon coating to support the planned EVA on the Orbiter STS-5 flight. Reflected solar flux concentrations as high as 8 suns were observed with the smooth coating and the one-sun envelope was determined to extend 195 inches above the panel. It is recommended that additional testing be conducted to define the reflected solar environment beyond the one-sun boundary. Analysis of reflections from the embossed coating is difficult due to the specular reflection characteristics of the silver, the embossing pattern and the curved surface of the radiator panel. The ambient environment testing method established herein provides the most cost effective method of determining the needed panel solar reflection data.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Orbiter Radiators Solar Testing Solar Environment	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	198	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

ORBITER RADIATOR PANEL
SOLAR FOCUSING TEST

REPORT NO. 2-53200/2R-53333

3 December 1982

Submitted to:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Johnson Space Center
Houston, Texas

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VOUGHT CORPORATION
Dallas, Texas

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0933B

ACKNOWLEDGEMENT

The work reported herein was performed under contract NAS9-14907, for NASA Johnson Space Center. Mr. Gary Rankin of the Crew Systems Division of JSC was the contract technical monitor and provided many valuable suggestions and guidance throughout the conduct of the program. Special thanks is extended to Mr. Chuck Wheelwright of the Spacecraft Design Division of JSC, who provided the test equipment, assisted in the test set-up and checkout and insured that equipment modifications were completed in a timely manner.

The author would also like to express his appreciation to the Hughes Aircraft Company and in particular to Dr. Dick Bobco for allowing Mr. Rankin and the author to attend a Hughes in-house seminar on the photometric method of solar simulation. The background information received and review of previous problem areas saved considerable time and allowed the test program to be initiated on a short schedule.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF TABLES

1.0 SUMMARY

A test has been conducted to determine the solar reflections from the Orbiter radiator panels. The concave shape of the panels and their specular silver/Teflon coating can cause focusing of solar energy which could have adverse heating effects on equipment or astronaut Extra-Vehicular Activity (EVA) in the vicinity of the radiator panels. A one-tenth scale model of the forward and mid-forward radiator panels in the deployed position was utilized in the test. The model was illuminated with a xenon arc sun gun and the brightness of a small diffuse target located in the reflection was measured. The target brightness is compared to the brightness of a target directly illuminated by the sun gun to determine the "number of suns" in the reflected light.

Test data has been obtained to define the reflected one-sun envelope for the embossed silver/Teflon radiator coating. Thirty different solar attitudes were tested and sufficient data was obtained to establish the reflected one-sun boundary at any attitude by interpolation. The effects of the double contour on the forward radiator panels was included in the test. Solar concentrations of 2 suns were measured and the one-sun envelope was found to extend approximately 86 inches above the radiator panel. The one-sun envelope does not extend beyond the panel longitudinal edges and does not include the payload bay area.

A limited amount of test data has also been obtained for the radiator panels with the smooth silver/Teflon coating to support the planned EVA on the STS-5 flight. An interim report (reference 1) describing only the smooth coating test results was released prior to the STS-5 flight. Although no other flights will be made with the smooth silver/Teflon, this data has also been included in this report for informational purposes. Reflected solar flux concentrations as high as 8 suns were observed with the smooth coating and the one-sun envelope was determined to extend 195 inches above the panel. The one-sun boundary extends approximately 25 inches inboard of the panel hinge-line edge but does not infringe on the payload bay area.

Although the present investigation was constrained (due to time limitations) to establishing the reflected one-sun boundary, less than one-sun environments can have significant thermal impacts on payloads particularly if

one side of the payload is designed to face away from the sun. It is therefore recommended that additional testing be conducted to completely define the reflected solar environment around the radiators. Analysis of reflections from the embossed coating is difficult due to the specular reflection characteristics of the silver, the embossing pattern and the curved surface of the radiator panel. The ambient environment testing method established herein provides the most cost effective method of determining the needed panel solar reflection data.

2.0 INTRODUCTION

The Orbiter radiator panels are mounted on the inside of the payload bay doors for protection during ascent and re-entry and thus conform to the shape of the doors to minimize stowage volume. While in orbit the payload bay doors are open, exposing the radiators to space as shown in Figure 1. The forward and mid-forward panels can be deployed away from the doors to provide additional radiation area to space as illustrated in Figure 1. The aft and mid-aft panels remain attached to the payload bay doors. For missions which do not require the additional radiator area, the forward and mid-forward panels are not deployed and remain stowed against the payload bay doors. Figure 2 shows the radiator/door cross-section and the coordinates of major points in both the deployed and stowed positions.

The external surface of the payload bay door flares inward at the forward end to provide an aerodynamically smooth interface with the cabin fuselage as illustrated by Figure 3. Since the radiator conforms to the shape of the door, there is a portion of the forward panel which also curves inward. This double curvature portion extends approximately 70 inches from the forward edge of the panel and is referred to as the "double contour" area of the panel. Figure 3 also shows the panel contour at various X locations.

The radiator panels are coated with a high solar reflectance silver/Teflon coating in order to maximize heat rejection in solar environments. Two types of coatings are used; the smooth coating used on the first five Shuttle flights is nearly 100% specular. An embossed coating used on subsequent flights reduces the specularity to roughly 50%. The specularity of the coatings in combination with the radiator panel parabolic shape results in focusing of solar energy in the area above the radiator panels. Ray trace analyses have indicated that for 100% specular reflections, a major portion of the reflected solar energy is focused in a small area resulting in solar intensities considerably greater than one-sun. The embossed coating will reduce the focused solar flux, but intensities greater than one-sun are still expected. These high intensity areas could result in thermal problems for payloads and astronaut activity around the radiators. Of particular interest is the envelope in which the reflected solar is equal to one sun or more. A limiting acceptable solar environment of one-sun from two different directions (direct and reflected) was originally established by NASA/JSC for EVA by the astronauts. Later information indicates higher solar environments can be tolerated. However, the determination of the reflected one-sun envelope has been retained as the primary test objective to aid in EVA mission planning.

The test utilized the photometric solar simulation method developed by Bobco (Reference 2), and more recently used by Hughes to determine the solar flux reflected from the radiator panel onto the Ku Band Antenna (Reference 3). A one-tenth scale model of the number 1 and number 2 forward radiator panels in the deployed position was built by NASA JSC and used in the test (Figures 4a thru 4c). The model was tested with the two different types of thermal control coating used on the radiators: the smooth silver/Teflon and the embossed silver/Teflon. Figure 5a shows the lay-up of the silver/Teflon on the radiator panel. An embossing pattern shown in Figure 5b is used to scatter the reflections and reduce the specularity. The smooth silver/Teflon was applied to the model in 4 inch tape widths as is used on the flight vehicle (See Figure 4a). The embossed tape was also applied in 4 inch widths, but was then cut into 0.4 inch widths to better simulate the gap between adjacent tape strips (See Figure 6). The model door simulator was covered with the smooth silver/Teflon in 4 inch widths, with the strips running along the vehicle X axis. Thus the door was simulated as a smooth uniform surface covered with the silver/Teflon, whereas the actual vehicle door has radial beams and various equipment (deployment motors, drives, etc.) mounted on it. A smooth uniform door surface will result in more solar energy reflected out of the hinge-line gap between the panel and door than the actual door which would tend to absorb more and scatter the incident solar. Therefore, the model will yield more conservative (worst case) results than the vehicle.

The Orbiter attitude relative to the sun is defined by the vehicle pitch angle and roll angle as illustrated by Figure 7. The pitch angle (θ) is the angle between the Orbiter X axis ($+X = 0^{o}$) and the line-of-sight vector to the sun. It ranges from 0^{o} to 180^{o}. The roll angle (ϕ) is the angle of rotation, clockwise, around the +X Orbiter axis ($-Z = 0$) to the line-of-sight vector to the sun. The roll angle ranges from 0^{o} to 360^{o}. It should be noted that the pitch and roll rotations must be performed in order, i.e., pitch first, then roll.

3.0 TEST METHOD

The general test method involves illuminating the scale model with a xenon "sun gun" lamp and measuring the brightness of a small target in the reflected light. The brightness of the target is compared to the brightness of a target directly illuminated at the model surface to determine the "number of suns" on the target in the reflected light. Figure 8 shows a sketch of the test arrangement.

Figures 9 thru 11 are photographs of the test set-up. The radiator/ door model was mounted on one end of a rotatable platform and illuminated with the sun gun. The platform is scribed with one inch squares to locate the target relative to the model. A wire suspended between two rods supports the target. The rods are moveable outward and inward from the model (along the Orbiter Z-axis) and the target slips along the wire to the right and left of the model to provide movement in the Orbiter Y-axis. The wire is moved up and down the rods to adjust the target position in the Orbiter X-axis. Orbiter pitch angles are simulated by tilting the model as shown in Figure 11. The rods are also tilted and the target is maintained parallel to the model. The Z and X target locations are adjusted by the proper trigonometric relationships and the known tilt angles.

The light reflected from the model coated with the smooth silver/Teflon is not uniform. Numerous dark spots or shadows are present apparently due to small surface irregularities in the silver. Figure 12 shows a photograph of a typical shadow pattern reflected from the smooth coating onto a white scribed surface. The embossed coating reflection is shown in Figure 13 for comparison. Figure 14 is a close-up of the smooth coating reflected shadow pattern and Figure 15 shows a close-up of the embossed reflection. The smooth coating shadow pattern is apparently caused by small silver surface irregularities which causes dark spots in the relected light. Since these surface irregularities are not scaled down, the shadow areas from the model are relatively larger than would occur on a full scale panel. In order to obtain a truer brightness reading on the target, a relatively large target area was used to effectively integrate the bright and dark spots. Figure 16 is a photograph of a typical smooth coating shadow pattern on the target. It should be noted that the contrast between the light and dark spots on the target was much more evident to the naked eye than is depicted in the photo. It can be seen that with the photometer focused on a small shadow area, the true target brightness would not be obtained. The photometer was positioned to subtend a circle of 0.60 inches in diameter on the target to obtain an average brightness reading. Thus the flux data represents the average flux over a 6.0 inch circular area in full scale. This procedure was used for both the embossed and smooth coating. Since the embossed coating reflections are uniform, the measured flux can be used for small items or localized heating rates. However, the smooth coating data does not give the <u>maximum</u> flux on the target and considerably higher localized fluxes are present. This could be significant for small targets or localized areas with a low surface thermal conductance.

3.1 TEST EQUIPMENT

The test was conducted at NASA-JSC in the TRML (Thermal Radiation Measurement Laboratory) in Building 13. This lab has black walls, floor and ceiling to minimize light reflections. The specific equipment used included:

Spectra Brightness Spot Meter
Photo Research Corporation
Burbank, California
Code 1505 UB Serial No. 2182
NASA-JSC 80473

Aerospace Controls Corporation
Type 302 Solar Simulator
Xenon Arc Lamp
SN 8237-1A and -1B

Rotary Table
Optometric Tools
Model 5005-Imperial

Target Material
Munsel Standard - 90% reflective paper

3.2 TEST PROCEDURE

The test was conducted using the following procedure:

1. Activate sun gun (Figure 17) and photometer at least 15 minutes prior to start of test.
2. Align sun gun and model to desired pitch and roll angles.
   - a. Position the model mounting platform normal to the sun gun by aligning the shadows cast by two objects located on the platform centerline.
   - b. Tilt the model to the desired pitch angle.
   - c. Rotate the table to the desired roll angle.
3. Obtain base (one-sun) reading (see Figure 18).
   - a. Place black shield over model.
   - b. Position target in solar beam center at the model plane.
   - c. Take photometer reading with the photometer 68.75 inches from the target and at an angle of less than 45° from the normal.
   - d. Remove black shield.
4. Position target.
   - a. Place target wire holder (goal posts) at the desired Z location on the scribed table.
   - b. Locate the target in the desired X position by adjusting the wire height.
   - c. Use the giant triangle to position the target in the desired Y location on the scribed table (Figure 19).
5. Position the photometer 68.75 inches from the target with the viewing angle approximately 45° from the target normal. When target is close to the model, greater angles will be required. Always minimize the viewing angle.
6. Record the photometer reading on the data sheet. Always zero the meter just prior to the reading and recheck the zero after the reading.
7. Move the target to a new Y position and repeat steps 5 and 6. Continue until all desired Y positions are completed.
8. Move target to a new X position and repeat steps 5, 6 and 7. Continue until all desired X positions are complete.

9. Move the target to a new Z position and repeat steps 5 thru 8. Continue until all desired Z positions are completed.
10. Rotate the table to a new roll angle and repeat steps 4 thru 9 until all desired roll angles are obtained.
11. Move the model to a new pitch angle. Tilt the target wire holders to the same pitch angle as the model. Use a ruler to measure the Z distance from the model reference point to the target for at least one X position for each Z position.
12. Repeat step 3 (baseline reading) and turn off the sun gun and photometer.

4.0 DATA ANALYSIS

Figures 20 and 21 show the test data "number of suns" at various planes above the radiator panel superimposed on a ray trace analysis for a 90° pitch, 0° roll angle. The smooth silver/Teflon coating test results agree very closely with the ray trace analysis. Peak solar constants are within the predicted concentration of solar rays. It is interesting to note that during the test the solar constants obtained near the panel out board edge (at Y stations 220 and greater) were questioned because it did not seem logical that solar reflections would be in this area. However, as seen by the ray trace analysis, approximately 15% of the incident solar flux (6 out of 41 rays) are reflected in this area.

The embossed silver/Teflon coating test results shown on Figure 21 indicate that peak solar constants still occur in the specular focal regions although the peaks are reduced and the solar constants outside the specular focal region are increased.

Figures 22 through 25 compare the embossed coating test data to the specular and diffuse analyses for four different planes (Z = 436, 446, 456 and 466). These figures illustrate that the solar reflections have been significantly reduced from the completely specular but are higher than the completely diffuse results.

Figure 26 summarizes the embossed coating average number of suns as a function of distance from the radiator panel. Specular and diffuse analyses results are also shown for various absorptivities. Based on the assumption of

50% specular reflections from the embossed coating, an absorptivity of 0.125 appears to best agree with the test data. This verifies that the sun gun spectral output combined with the photometer wave length sensitivity and coating reflectance yields an absorptance close to the radiator panel solar absorptance. The embossed coating is expected to have an initial solar absorptivity of 0.08, and degrade to 0.11 after 100 missions. Thus, the test data are more representative of the end of life values and the reflected solar intensities on the initial flights should be approximately 4.5% greater than the test data.

A comparison of the smooth silver/Teflon coating data with the specular analysis at three different planes is shown in Figures 27 through 29. It is evident from these figures that the test data was not taken at close enough intervals to accurately obtain the peak solar reflections. For example, at Z = 456 (Figure 28), a peak solar flux of 11.8 to 17.5 suns occurs between Y 143 and Y 147. Since test data was taken only at 1.0 inch intervals on the one tenth scale model (10 inches on the vehicle) this peak was missed during the test. Due to the high concentration of flux in a small area, it was not possible to obtain an average flux value from the relatively sparse test data over the plane as was done for the embossed coating. The smooth coating should have the same optical properties as the embossed coating and the same absorptance to the xenon sun gun. Thus, the test data for the smooth silver/Teflon can also be assumed to better represent end of life reflections with the initial flight values estimated to be approximately 4.5% higher. It should be noted that the fact that the smooth coating test data were not sufficient to obtain an accurate flux distribution does not compromise the test objective, i.e., to determine the one sun envelope. Sufficient data was taken to determine the one sun boundary within a 10 inch Y axis location.

Throughout the test several test points were repeated after a review of the data indicated possible discrepancies or that additional data were required to complete the mapping. Table 1 summarizes the original and repeated data and the differences. The average difference in the readings was 12.5%. Some of the difference can be attributed to model orientation, sun gun output variation and photometer reading error. It is believed that most of the differences are due to differences in the target locations. During the test it was noticed that slight variations in the target Y position could cause large variations in the photometer readings. However, by systematically varying the X, Y and Z locations a complete flux map is obtained and the exact location of specific flux values are usually not required. Most of the data was taken with 1 inch intervals in the Y direction and 1 to 2 inch intervals in the Z direction with an estimated accuracy of $\pm$ 1/4 inch. Specific X locations were used; however, flux variation in the X direction does not appear to be severe.

5.0 TEST RESULTS

Paragraphs 5.1 and 5.2 discuss the test results for the embossed and smooth silver/Teflon coating respectively. The data is summarized by showing the areas around the panels for which the reflected solar flux is equal to one-sun or more. Specific flux values at each of the tested X, Y and Z locations and pitch and roll angles are presented in the Appendices. An index to the data plots is presented at the beginning of each Appendix to aid the user in finding the specific data of interest. All data is shown for the right side panels as tested. The left side panels one-sun envelope will be the same as the right side panels at corresponding roll angles. For example, data for a 25° roll angle for the right side panels corresponds to a 335° roll angle for the left side panels.

5.1 Embossed Coating Results

Solar flux reflected from the forward radiator panel coated with the embossed silver/Teflon was measured for 30 different solar attitudes. Vehicle pitch angles of 90°, 115°, 140°, and 165° were tested in combination with vehicle roll angles of 0°, 25°, 50°, 75°, 90°, 285°, 310°, and 335°. Sufficient data was obtained to provide a complete map of the one-sun boundary at any vehicle attitude. For most vehicle attitudes, data was taken at 4 locations along the X axis as illustrated by Figure 30. The reflected flux is uniform along the X axis except as influenced by the double contour at the forward end of the number 1 panel. The first X location is aft of station 660 and provides data typical of the entire length of the radiator panels except in the double contour area. The second location is in the double contour area. Data was also taken at the forward edge of the panel (location 3) and forward of the forward edge (location 4). Appendix A contains flux maps for each of the specific attitudes and X locations.

TABLE 1

SOLAR FOCUSING TEST DATA REPEATABILITY

TARGET POSITION			NUMBER OF SUNS		DIFFERENCE	PERCENT DIFFERENCE
Z	X	Y	9/22/82 DATA	9/27/82 DATA		
0	24	29	.89	1.80	.91	102.2
		30	1.32	1.97	.65	49.2
		31	1.91	1.92	.01	.5
		32	1.86	1.46	- .40	- 21.5
		33	.91	.74	- .17	- 18.7
		34	.56	.50	- .06	- 10.7
1	24	29	.52	.66	.14	26.9
		30	.65	1.00	.35	53.8
		31	1.14	1.68	.54	47.4
		32	1.77	1.47	- .30	- 16.9
		33	1.27	.76	- .51	- 40.2
		34	.74	.52	- .22	- 29.7
2	24	29	.45	.48	.03	6.7
		30	.56	.62	.06	10.7
		31	.76	.78	.02	2.6
		32	.91	1.67	.76	83.5
		33	1.50	1.76	.26	17.3
		34	1.05	.84	- .21	- 20.0
3	24	33	.91	1.30	.39	42.9
		34	1.12	1.05	- .07	- 6.3
		35	.89	.69	- .20	- 22.5
4	24	33	.60	.90	.30	50.0
		34	.81	1.02	.21	25.9
		35	.84	.82	- .02	- 2.4
		36	.65	.53	- .12	- 18.5

AVERAGE = 12.5%

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Figure 31 summarizes the one-sun envelope for a pitch (θ) of 90° and a roll (ϕ) of 0° at the four X locations in the Y-Z plane. As shown, the double contour has the effect of reducing the one-sun envelope for the 90° pitch attitude. Therefore, data was taken at only one X location (X = 722) for the other roll angles with a 90° pitch angle. Figure 32 shows the deployed forward panels one-sun envelope for roll angles from 0° to 335° with a 90° pitch angle. The aft panels or stowed forward panels one-sun envelope is shown in Figure 33.

Also of interest is the solar flux reflected out of the hinge-line gap between the deployed radiator and the door. Figure 34 shows the maximum flux observed in the gap area for roll angles of 80° to 110°. As indicated, the gap solar flux is less than one sun. Therefore, gap solar fluxes were not measured at other pitch angles. As previously discussed, the modeling of the door as a smooth, continuous, silver/Teflon coated surface should provide the maximum (worst case) gap solar fluxes.

The double contour on the forward panel has the effect of expanding the one-sun envelope for a vehicle pitch of 115°. This is illustrated by Figure 35 which shows the 0° roll angle envelope at four different X locations. Figures 36 through 39 present the one-sun boundaries from data taken at roll angles from 0° to 335° at each of the X locations for the deployed panel configuration. The aft panel or stowed forward panel envelopes are shown in Figures 40 through 43.

Data taken at a vehicle pitch angle of 140° indicates a diminished one-sun envelope although the envelope forward of the radiators is increased. Reflected solar fluxes of one-sun or more were measured only in the double contour region and forward of the panels. Figure 44 shows the one-sun envelope for four X locations and the specific roll angles. The stowed forward panel configuration envelope is shown in Figure 45.

Figure 46 summarizes the one-sun envelope in the XZ plane for the deployed forward panel configuration. The envelopes shown are the maximum Z-axis envelope from the various roll angles. Thus Figure 46 represents the maximum one-sun envelope for all roll angles. Figure 47 shows the one-sun boundary for the stowed forward panel configuration.

All of the previously discussed test data was taken for a nose down pitch direction (90° to 180°). The nose up pitch attitudes (0° to 90°) should yield symmetric results except in the double contour area. Figure 48 compares test data taken at pitch angles of 65° and 115° (25° off normal in either direction) for a roll angle of 0° at X station 722, aft of the double contour area. It is seen that the one-sun envelopes compare very closely, with the differences attributed to the expected test data repeatability inaccuracies. A comparison of data taken at pitch angles of 65 and 115° in the double contour area is shown on Figure 49. As expected, the one-sun envelope is smaller for the 65° pitch angle. This verifies that the maximum one-sun envelope in the double contour region occurs in the tested nose down pitch attitude.

5.2 Smooth Coating Results

Solar flux reflected from the forward radiator panel coated with the smooth (specular) silver/Teflon coating was measured for the following Orbiter attitudes in relation to the sun:

1. pitch = 90°, roll = 0°
2. pitch = 90°, roll = 25°
3. pitch = 90°, roll = 50°
4. pitch = 90°, roll = 70°
5. pitch = 90°, roll = 75°
6. pitch = 90°, roll = 80°
7. pitch = 90°, roll = 90°
8. pitch = 90°, roll = 100°
9. pitch = 90°, roll = 105°
10. pitch = 90°, roll = 310°
11. pitch = 90°, roll = 335°
12. pitch = 115°, roll = 0°
13. pitch = 115°, roll = 335°

Appendix B contains flux maps for each of the specific attitudes and X locations.

Figure 50 summarizes the one-sun envelope for the 90° pitch attitude. Figure 51 shows the one-sun envelope for the aft panels or the forward panels not deployed. The test data indicates a reflected one-sun environment out to a maximum Z station of 588 inches with the Y station ranging from 93 to 238 inches. Figure 50 also shows that the test data compares favorably with analyses done by Lockheed. The analyses apparently had the radiator panel in a slightly different position than the test as shown on Figure 50. Rotation of the analysis panel to the test position would tend to make the analyses and test envelopes agree more closely except for the "fingers" that extend beyond the analysis envelope at 310° and 335° roll angles.

All of the data shown in Figure 50 were taken at station X = 719.5 inches. Data were also taken at various X locations for the 0° sun angle at the maximum reflected solar point (Z = 496.5, Y = 111.9). These data are presented in Table 2. They show that the maximum reflection begins to decrease (or the maximum point is moved to a different Y station) at about midway between the double contour and the forward end of the panel. The one sun envelope appears to extend beyond Z = 496.5 at X = 659.5 to 679.5 but is not as large forward of X station 639.5. Again, this is attributed to the double contour. It is expected that similar results would be obtained for other sun angles.

Figure 52 shows the estimated 90° pitch one sun envelope in the Orbiter ZX plane based on the complete mapping data taken at X station 719.5 and the data from Table 2.

The initial data for the "sun in cavity" test points indicated that less than "one sun" was emitted from the hinge-line gap between the panel and door. A one-sun environment was observed near the outboard edge of the panel for roll angles of 100° and 105° (see Appendix B). These envelopes are due to reflections from the panel convex side to the door and then out the cavity plus the direct solar incident on the target.

In order to measure the environment closer to the panel-door gap, the model was modified by cutting away part of the support structure (payload bay sill) forward of X station 780. This allowed the photometer line-of-sight to the target to be maintained with the target closer to the gap. Figure 53 shows the gap solar flux as a function of roll angle. For roll angles less than approximately 83°, the sun illuminates the top of the panel, and the gap flux is due to reflections from the top of the panel rather than reflections through the cavity. The high reflected flux, shown on Figure 53,

TABLE 2
VARIATION OF SOLAR REFLECTIONS ALONG THE X-AXIS
PITCH = 0°, ROLL = 0°

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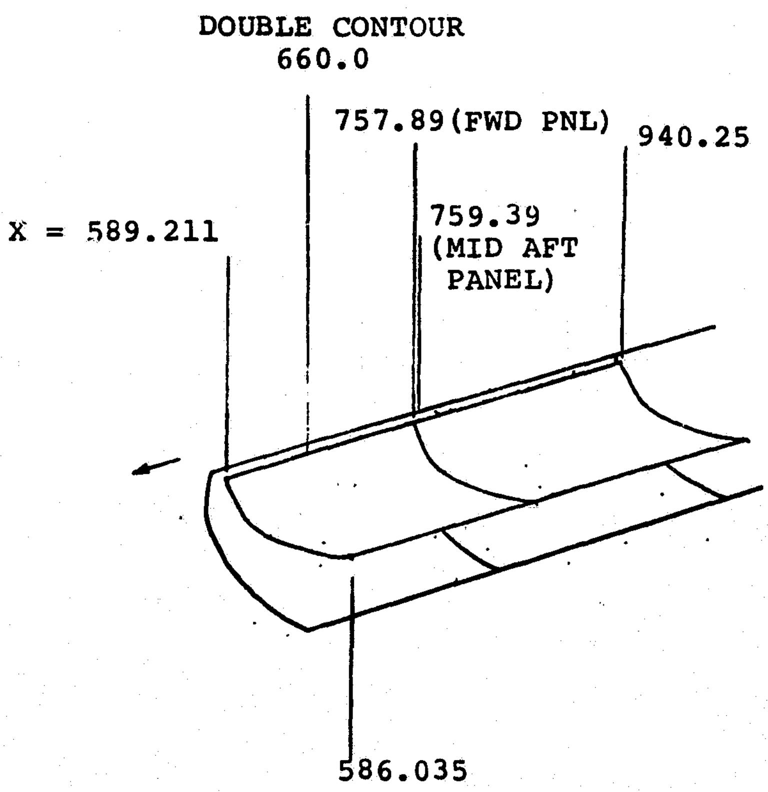
	MAXIMUN OBSERVED SOLAR REFLECTION (Z = 446.5, Y = 153.15)	ONE SUN ENVELOPE (Z = 496.5, Y = 111.9)
X-AXIS	SUNS	SUNS
719.5	7.36	.99
699.5	-	.95
679.5	-	1.03
659.5	7.52	1.30
649.5	7.52	-
639.5	8.00	.78
629.5	8.00	-
624.5	7.28	-
619.5	7.20	.50
609.5	6.24	-
599.5	5.28	-
589.5	2.88	-
579.5	.34	-



at the forward end of the panel (X = 605) is attributed to the panel double contour in that area.

Figure 54 shows the one sun envelope at various X stations for the 115° pitch, 0° roll attitude. The double contour on the forward panel reflects the sun outward and towards the aft end of the Orbiter in this attitude. Thus the one sun envelope tends to shrink towards the forward edge of the panel and is considerably diminished beyond the panel forward edge.

Figure 55 presents the one sun envelope data for the 115° pitch, 335° roll attitude. In this attitude the double contour of the forward panel reflects the sun forward so that the one-sun envelope extends to at least X station 490 or about 100 inches beyond the forward panel edge.

Figure 56 shows the one sun envelope in the ZX plane derived from the data for pitch = 115°, roll = 0° and 25°.

6.0 CONCLUSIONS

Test data has been obtained to define the reflected one-sun boundaries for the radiator panels coated with the embossed silver/Teflon. Limited data was also obtained for the panels coated with the smooth silver/Teflon. The embossed coating significantly reduces the reflected solar environment. The maximum observed solar concentration for the embossed coating was 2 suns, whereas the smooth coating yielded a maximum of 8 suns. Figure 57 compares the one sun envelope of the two coatings for a 90° pitch attitude. As indicated the one-sun boundary is reduced considerably with the embossed coating.

The test equipment and procedures appear to provide reasonable accuracy; a rigorous error analysis has not been done. Location of the target in the three axes is the most probable source of error. Model orientation, sun gun output variation and photometer reading errors are expected to have a smaller contribution to the error. For much of the data the flux was found to vary considerably with target position and precise target location is required for repeatability. However, by systematically varying the X, Y and Z locations a complete flux map is obtained and the exact location of specific flux values are usually not required. Most of the data was taken at 1 inch intervals in the Y direction, 2 inch intervals in the Z direction and 1 to 2 inch intervals in the X direction with an estimated accuracy of ± 1/4 inch. Thus in full scale, flux values are known every 10 to 20 inches within ± 2.5 inches. Mission planning and analyses efforts at specific locations should use the maximum flux values within a 2.5 inch radius of the desired location.

It is recommended that additional testing be done to completely define the reflected solar environment around the radiators. The present test program was concerned only with determining the reflected one-sun envelope around the radiators. However, less than one-sun environments can have significant thermal impacts particularly if the spacecraft is not designed for solar from two directions. For example, the shadeside of a solar oriented satellite with an α/ϵ = 1.0 would reach an equilibrium temperature of 180°F in a 0.25 sun environment with an earth-space equivalent radiation sink temperature of -20°F. Analysis of the radiator embossed coating solar reflections is difficult and has not been accomplished to date. The embossing pattern re-directs a portion of the specular reflections due to the orientation of the embossing facets. On the curved radiator surface the facet orientations relative to the incident solar is not constant which complicates the analysis procedure. The room ambient test method established herein provides the most direct and cost effective method of determining the needed panel solar reflection data.

REFERENCES

(1) Howell, H. R., "Orbiter Radiator Panel Solar Focusing Test-Interim Report - Specular Silver/Teflon Coating" Vought Corporation Report No. 2-53200/2R-53250, 17 September 1982.

(2) Bobco, R. P., "An Experimental Technique for Measuring Local Solar Irradiation with A Model Spacecraft", AIAA Paper No. 68-770, presented at AIAA Third Thermophysics Conference, Los Angeles, California, 24-26 June 1968.

(3) Drolen, B. L. and Friedman, A. S., "Ku-Band/Space Transportation System Attitude Constraint Study", Hughes Aircraft Co. Report No. IDC 4132.15/2110 (HS-237-4091), 20 May 1982.

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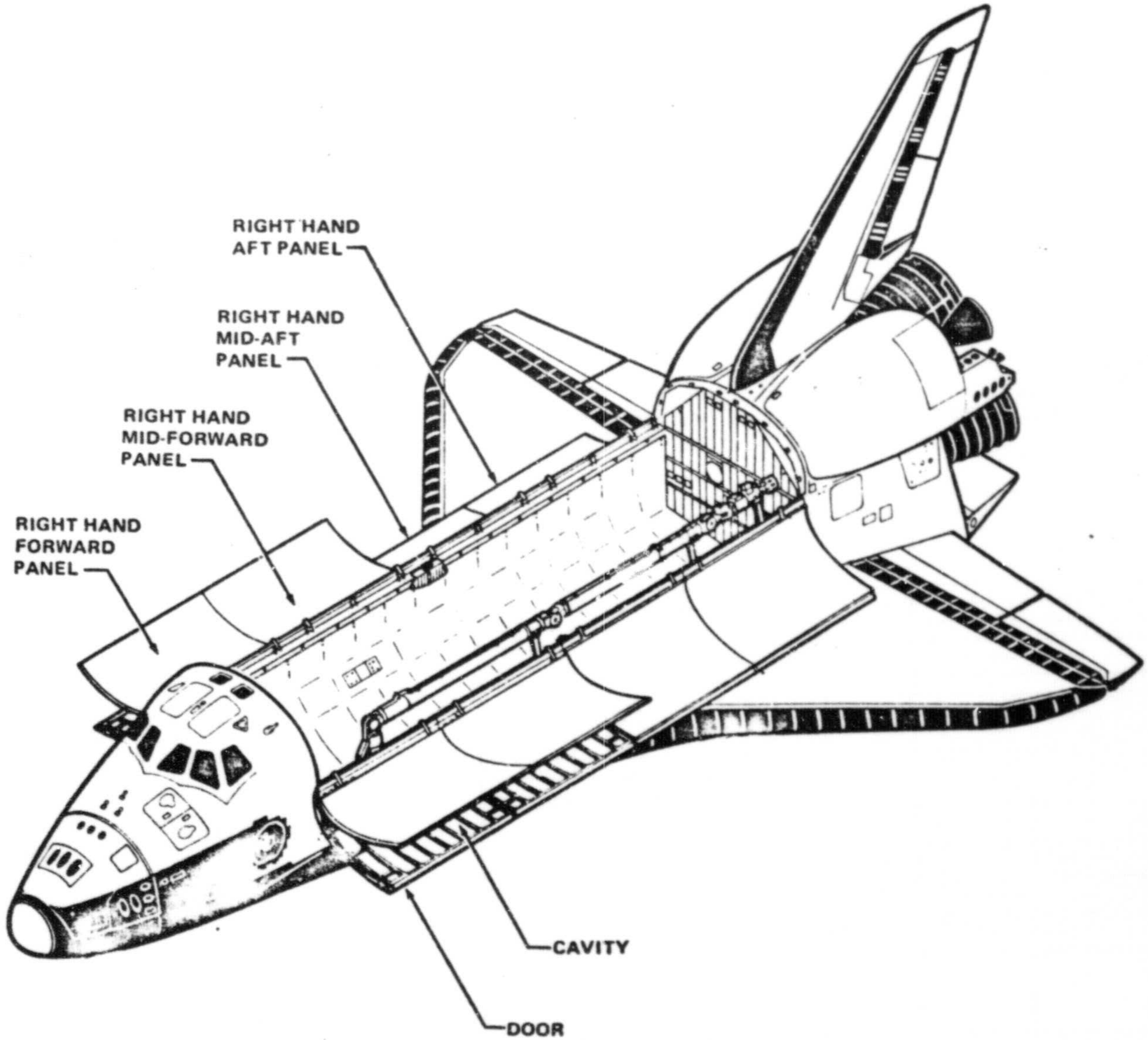

FIGURE 1 ORBITER RADIATOR ON-ORBIT CONFIGURATION

	P/L BAY DOOR CLOSED		P/L BAY DOOR OPEN 178°		P/L BAY DOOR OPEN 176°	
	Y_0	Z_0	Y_0	Z_0	Y_0	Z_0
P/L BAY DOOR POINTS						
A	0	500.0000	215.2872	343.7579	217.8816	347.6086
B	0	495.2500	215.1214	348.5050	217.5503	352.3470
C	100.2500	429.5000	112.6379	410.7162	112.9580	410.9438
D	102.3500	420.5000	110.0252	419.6305	110.0358	419.7614
E	105.0000	420.5000	107.5767	419.5450	107.5918	419.5905
FWD RADIATOR PANEL POINTS - PANEL CLOSED						
H	100.7500	423.0000	111.9113	417.1948	112.0058	417.3931
J	3.0000	494.7111	212.1045	348.9388	214.5200	332.6753
K	3.0000	492.9505	212.0434	350.6884	214.3979	354.4217
L	98.0000	429.0000	114.8691	411.2945	115.1676	411.5995
M	99.7500	429.0000	113.1201	411.2334	113.4219	411.4774
FWD RADIATOR PANEL POINTS - PANEL OPENED MAX						
H					112.0058	417.3931
J					232.9569	425.6624
K					231.8275	427.0000
L					117.9778	414.5828
M					116.6407	413.4538

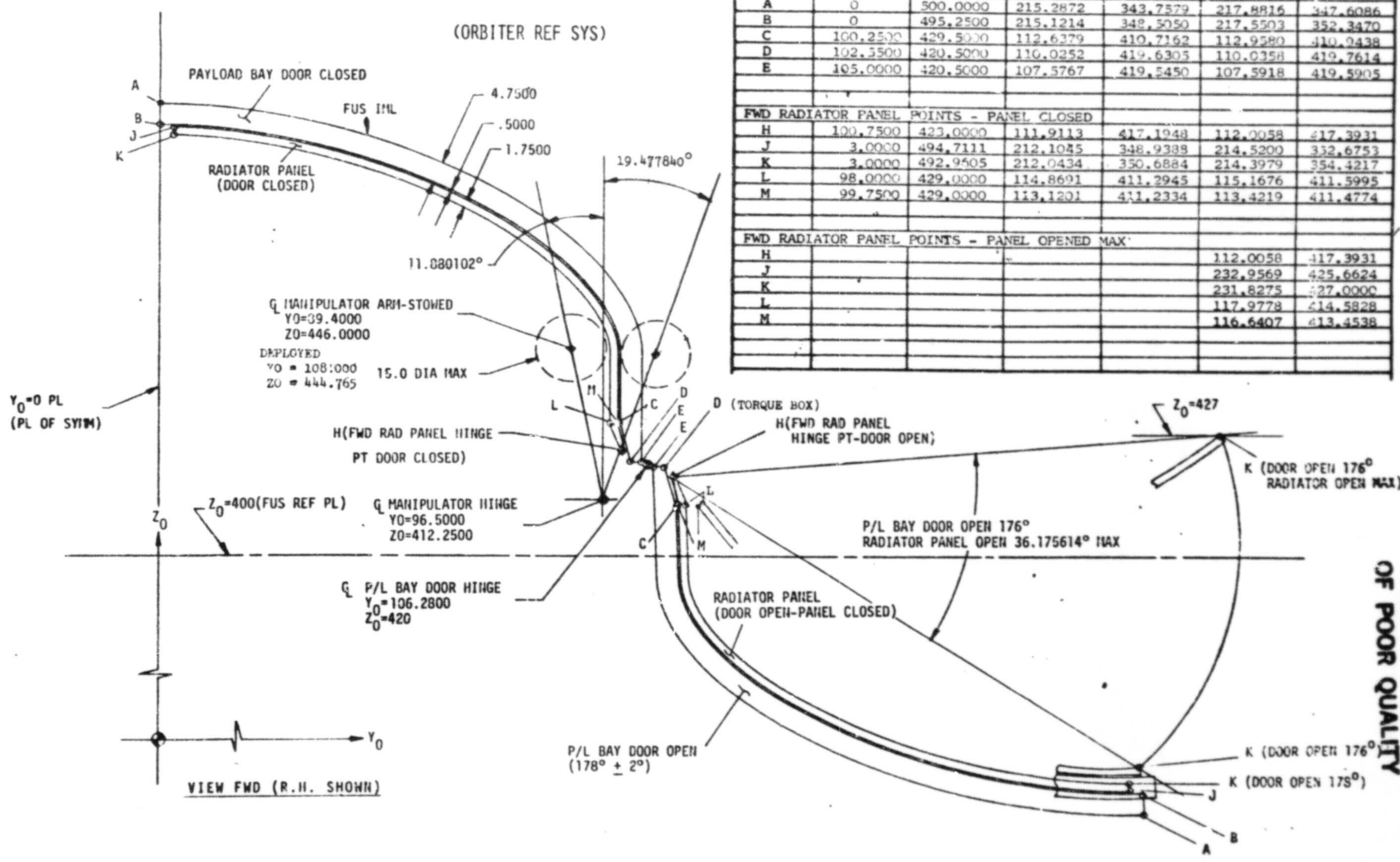

FIGURE 2 ORBITER RADIATOR COORDINATES

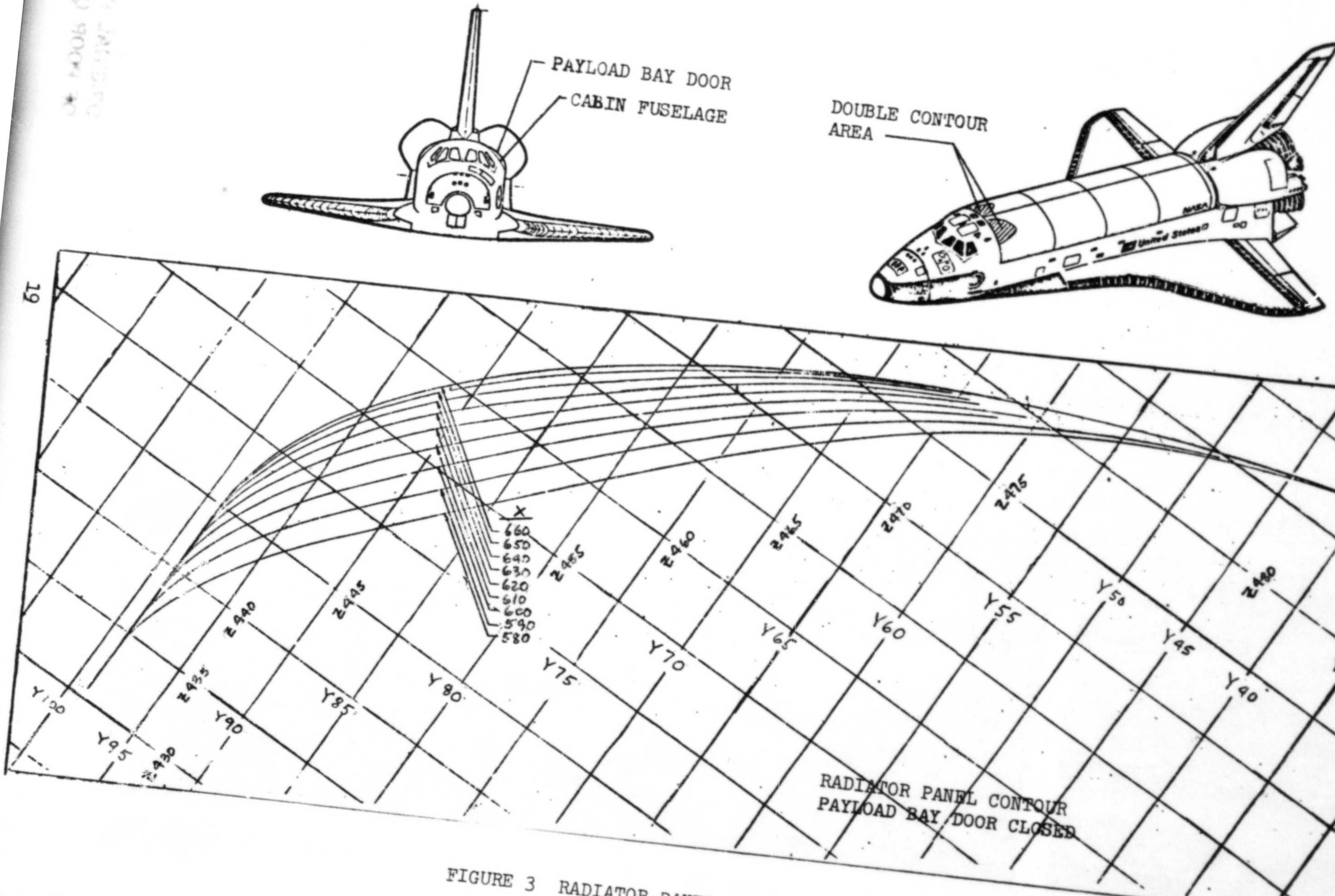

FIGURE 3 RADIATOR PANEL DOUBLE CONTOUR

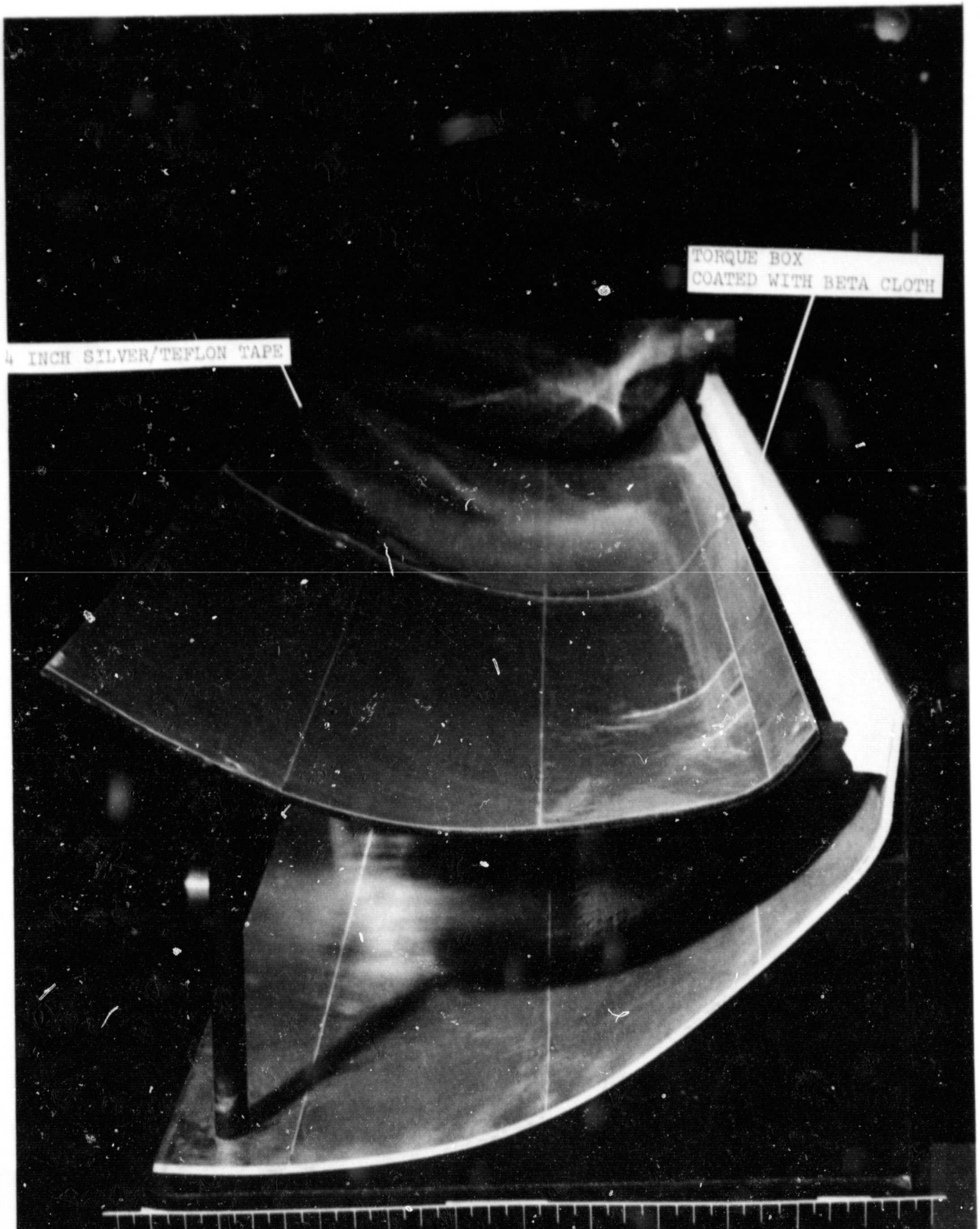

FIGURE 4a PANEL/DOOR ONE-TENTH SCALE MODEL - END VIEW

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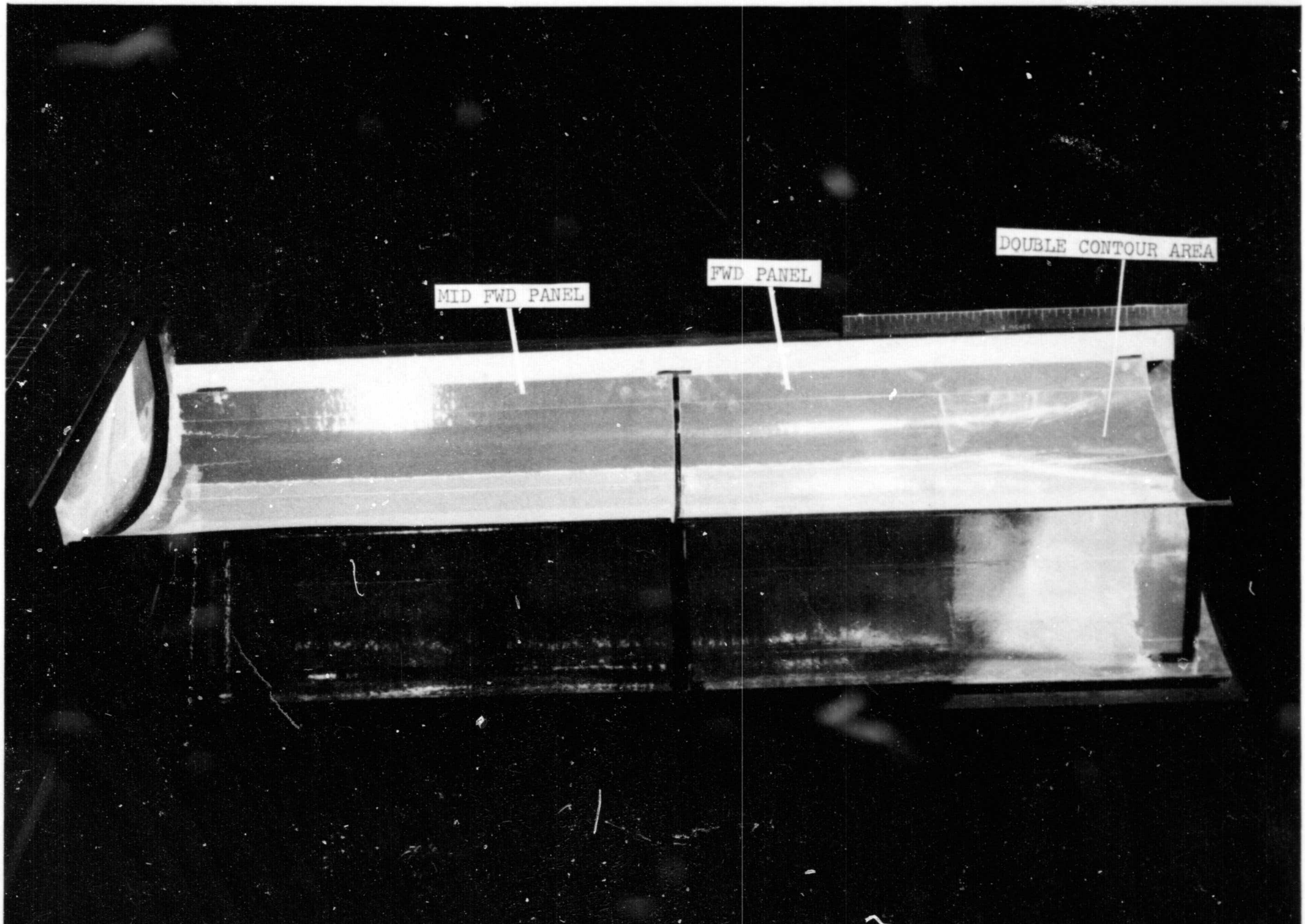

FIGURE 4b PANEL/DOOR ONE-TENTH SCALE MODEL - TOP/CAVITY VIEW

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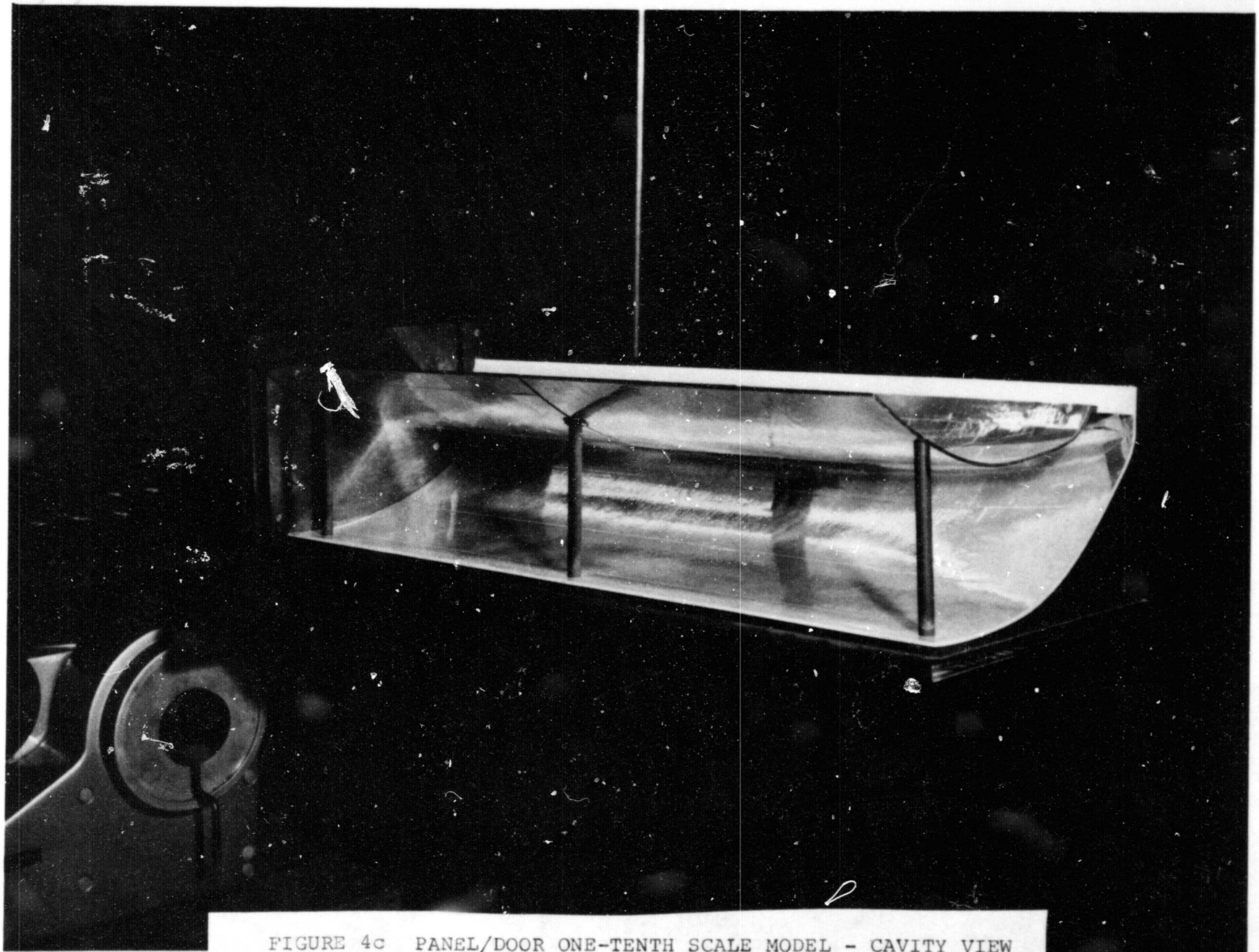


FIGURE 4c PANEL/DOOR ONE-TENTH SCALE MODEL - CAVITY VIEW

FIGURE 5a SILVER TEFLON BONDED TO TYPICAL RADIATOR PANEL

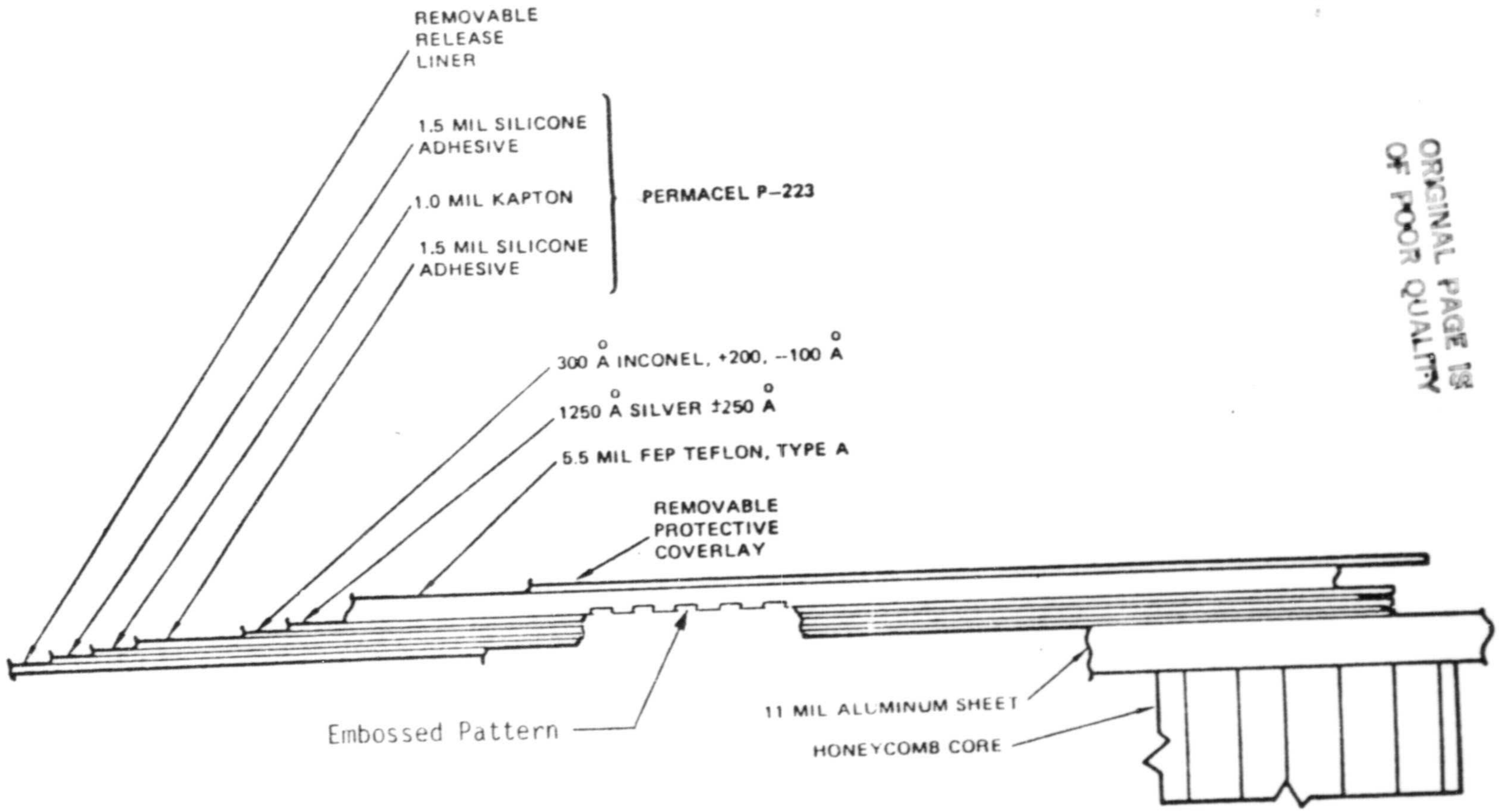
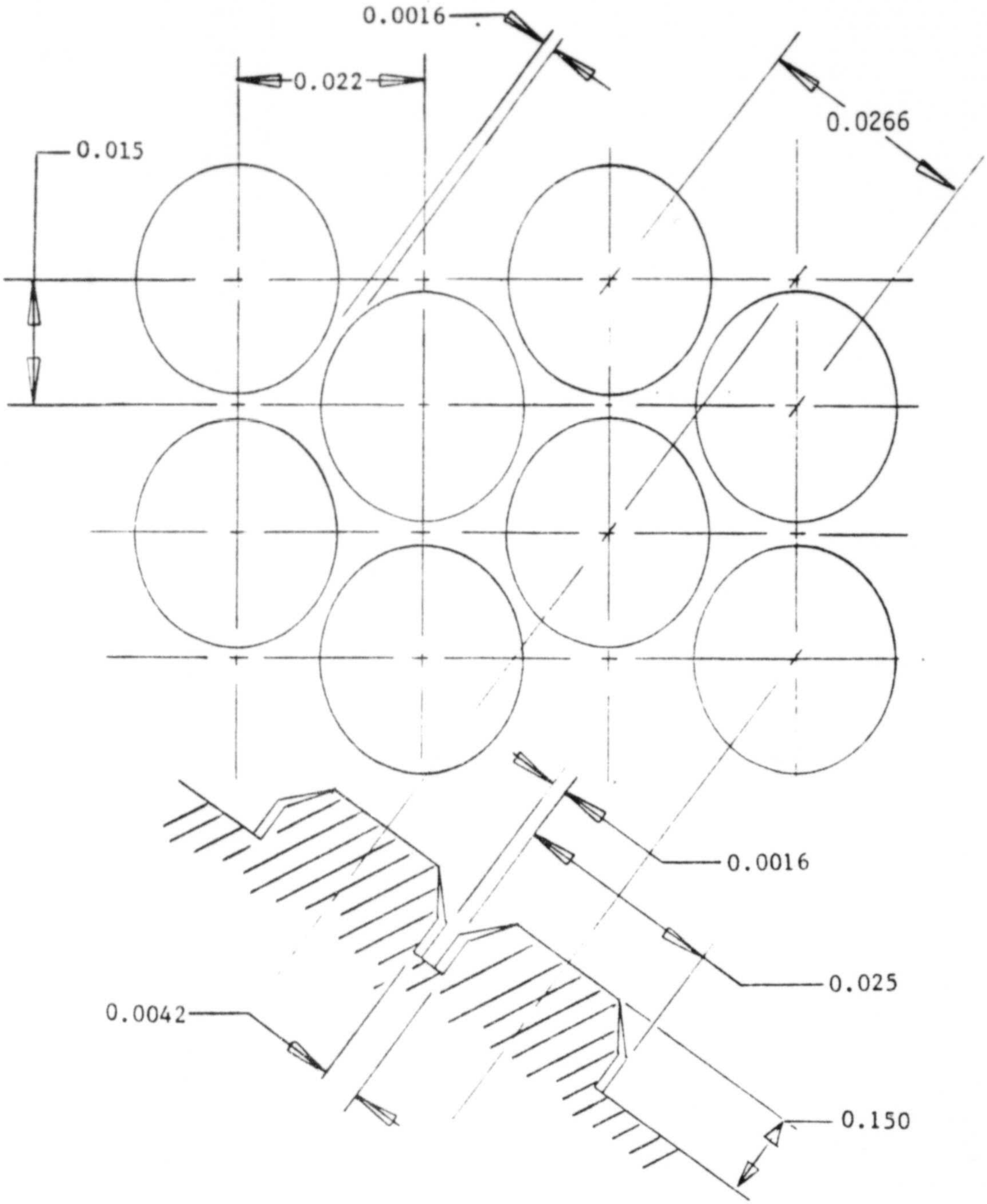


FIGURE 5b EMBOSSING TOOL PATTERN FOR TEFLON FILM



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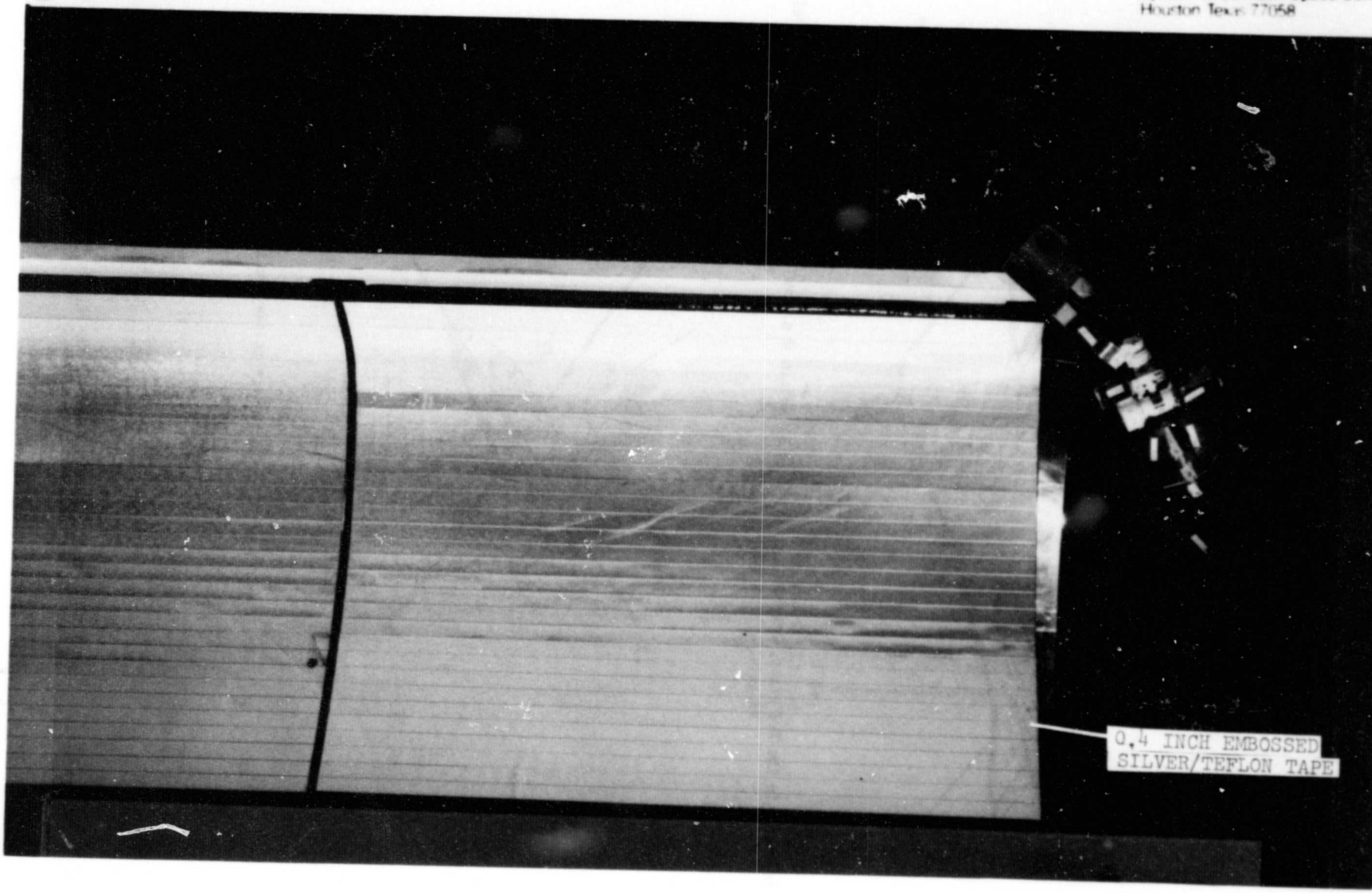

FIGURE 6 EMBOSSED SILVER/TEFLON TAPE CUT TO 0.4 INCH WIDTHS

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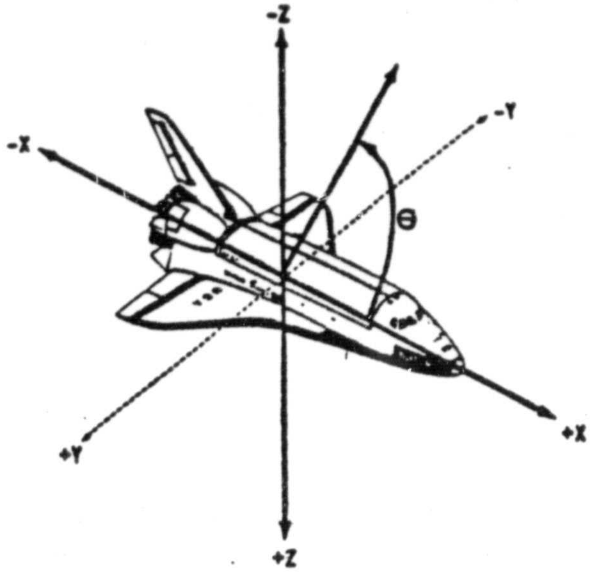
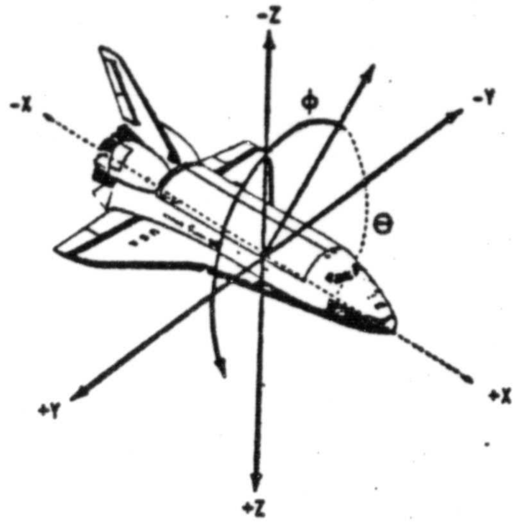
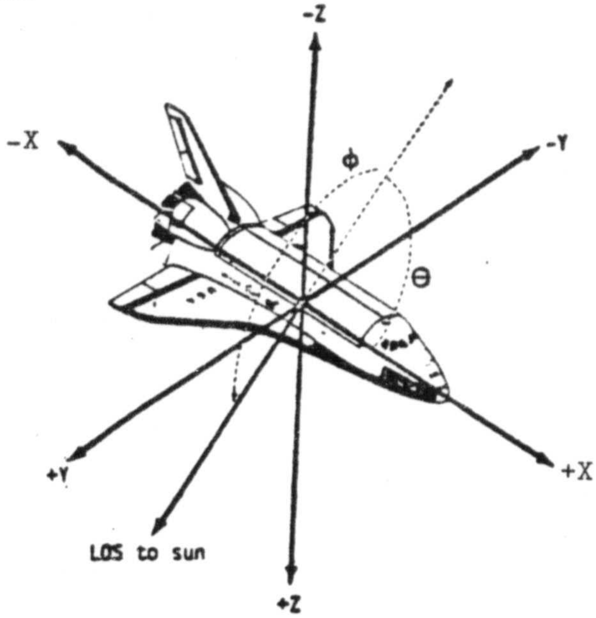


(a) Rotate Θ in the X-Z plane, originating at the +X axis.



(b) Rotate ϕ clockwise around the +X axis parallel to the Y-Z axis.



(c) The location of Sun with respect to the Orbiter.

FIGURE 7 STEPS TO DETERMINE LOCATION OF THE SUN WITH RESPECT TO THE ORBITER

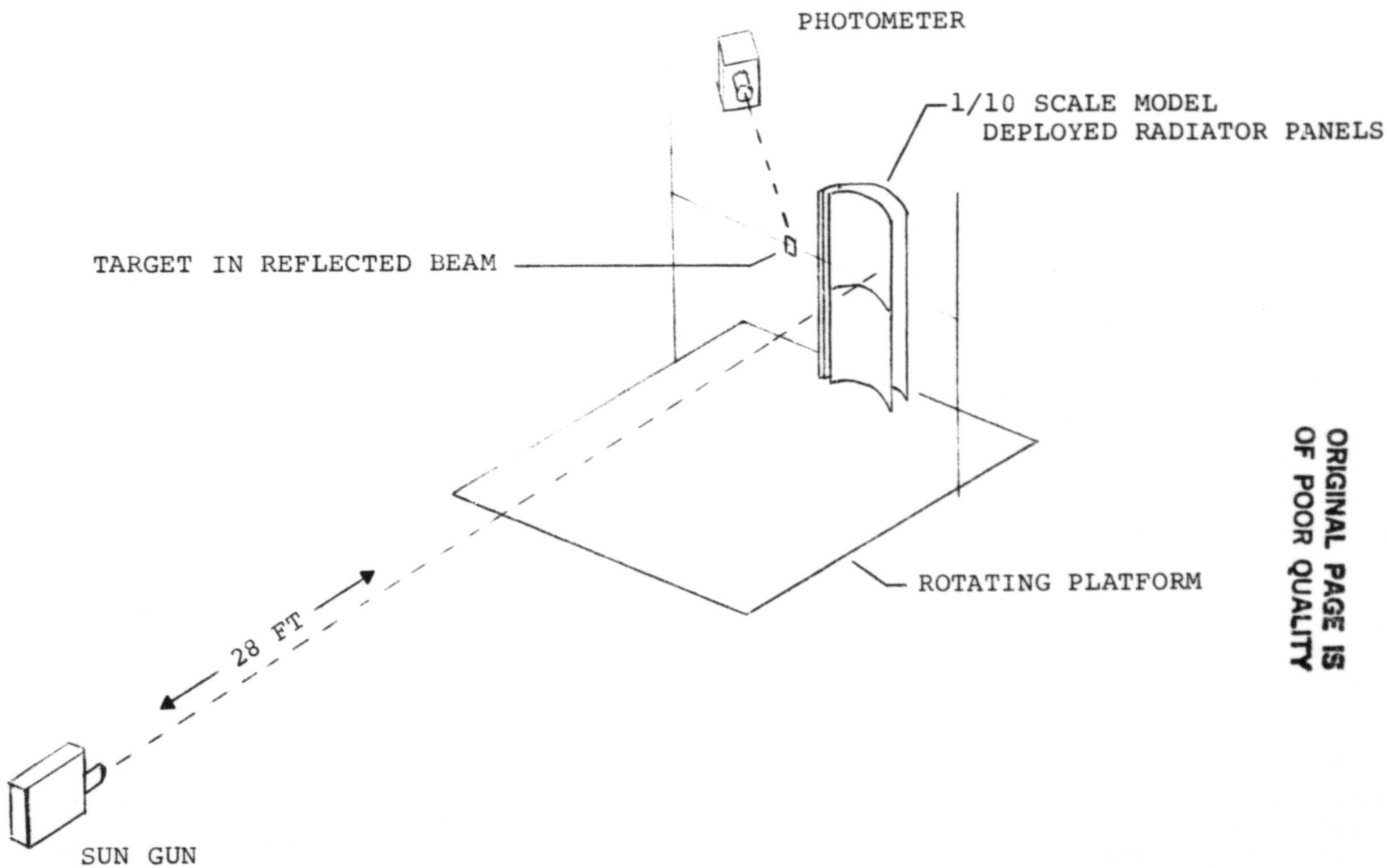


FIGURE 8 TEST SET-UP

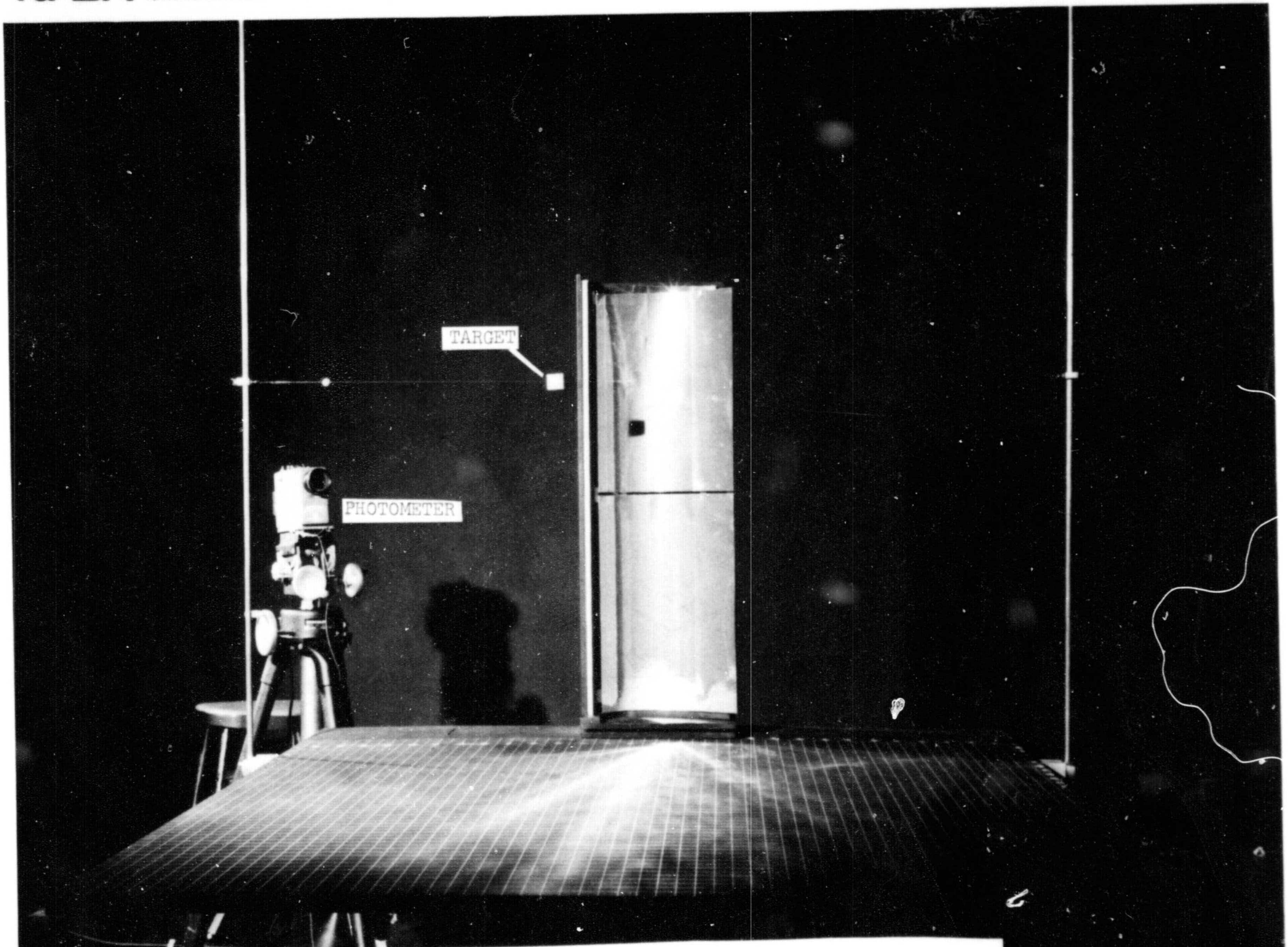


FIGURE 9 TEST ARRANGEMENT - FRONT VIEW

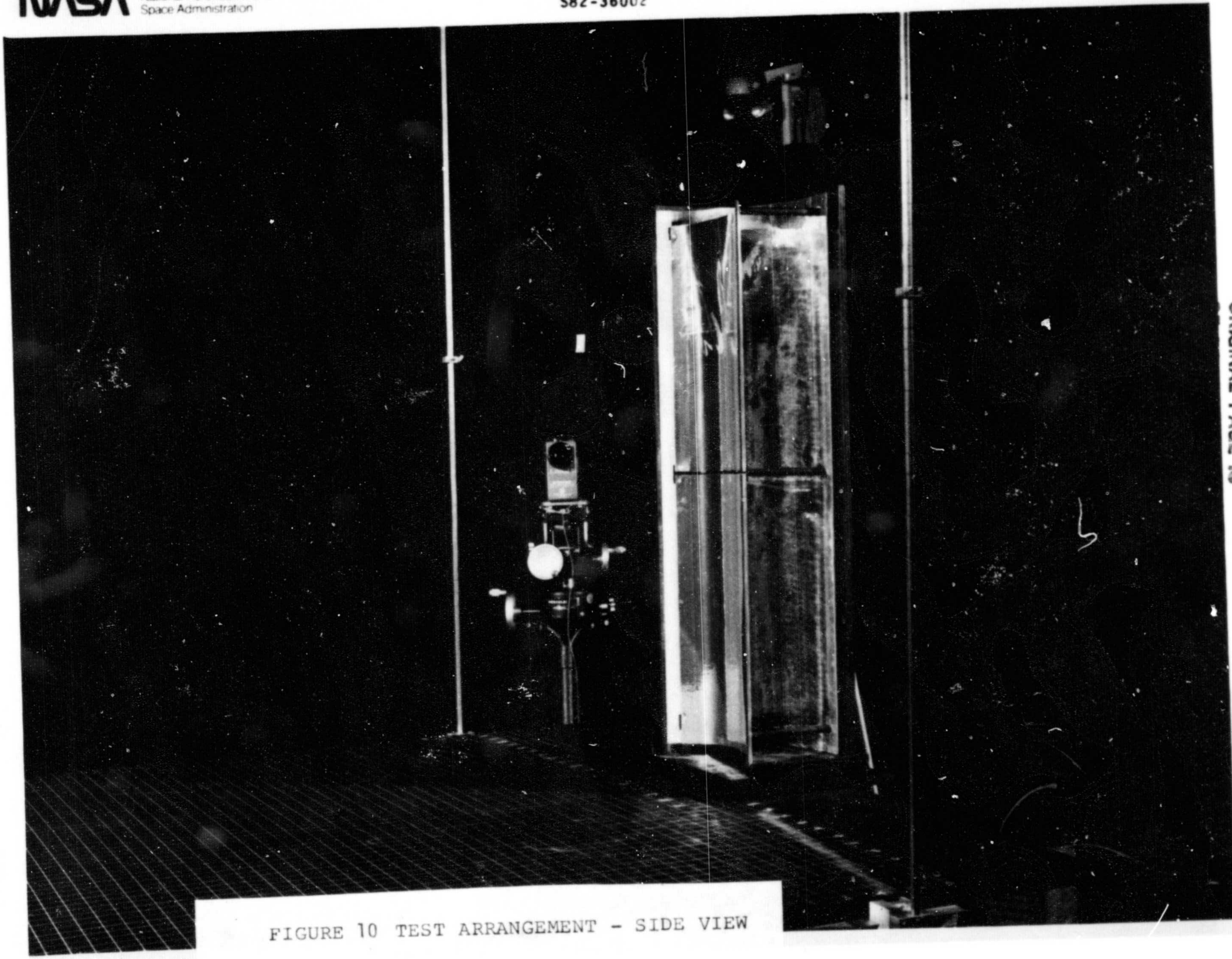


FIGURE 10 TEST ARRANGEMENT - SIDE VIEW

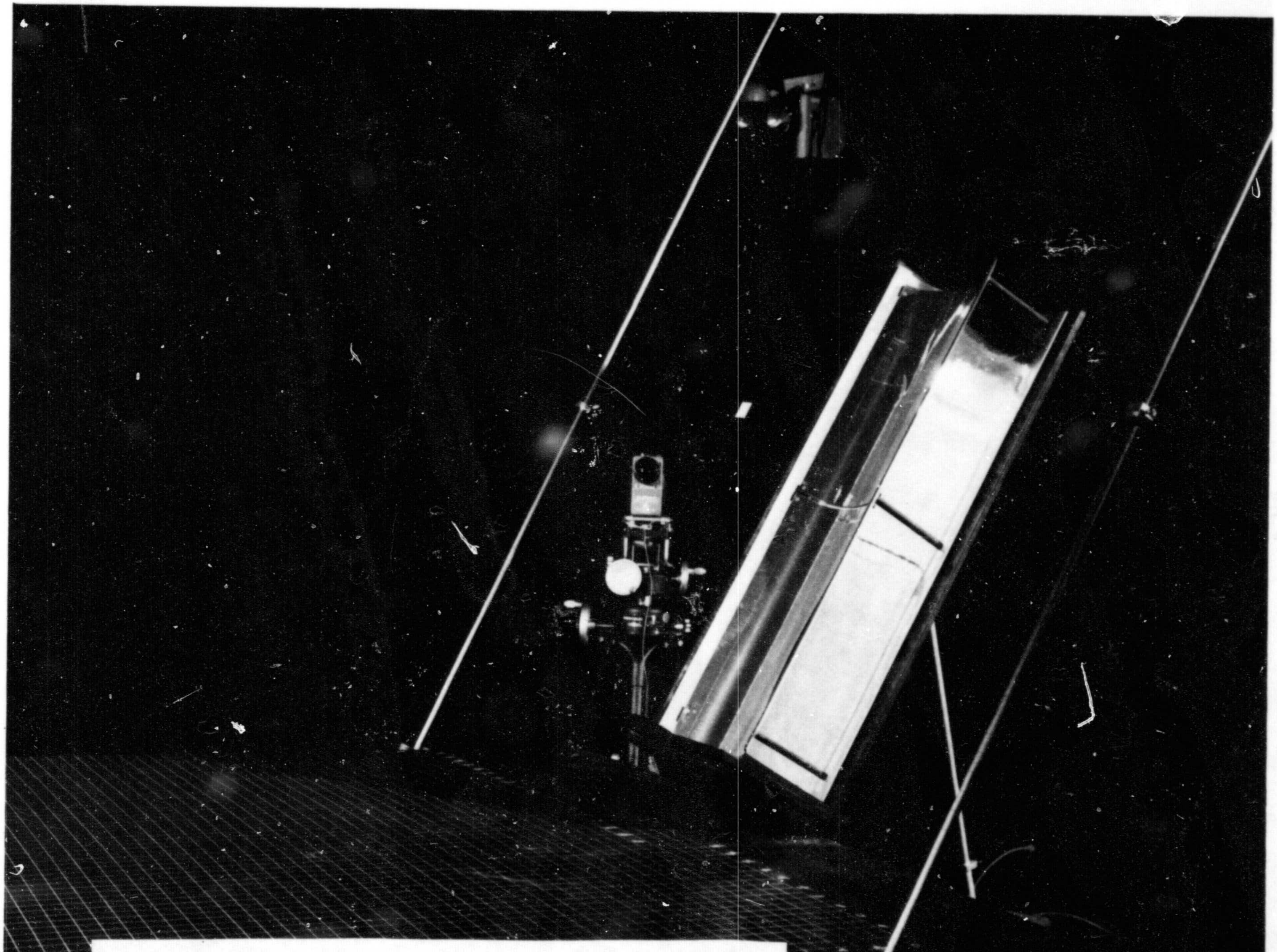


FIGURE 11 TEST ARRANGEMENT -115° PITCH ANGLE

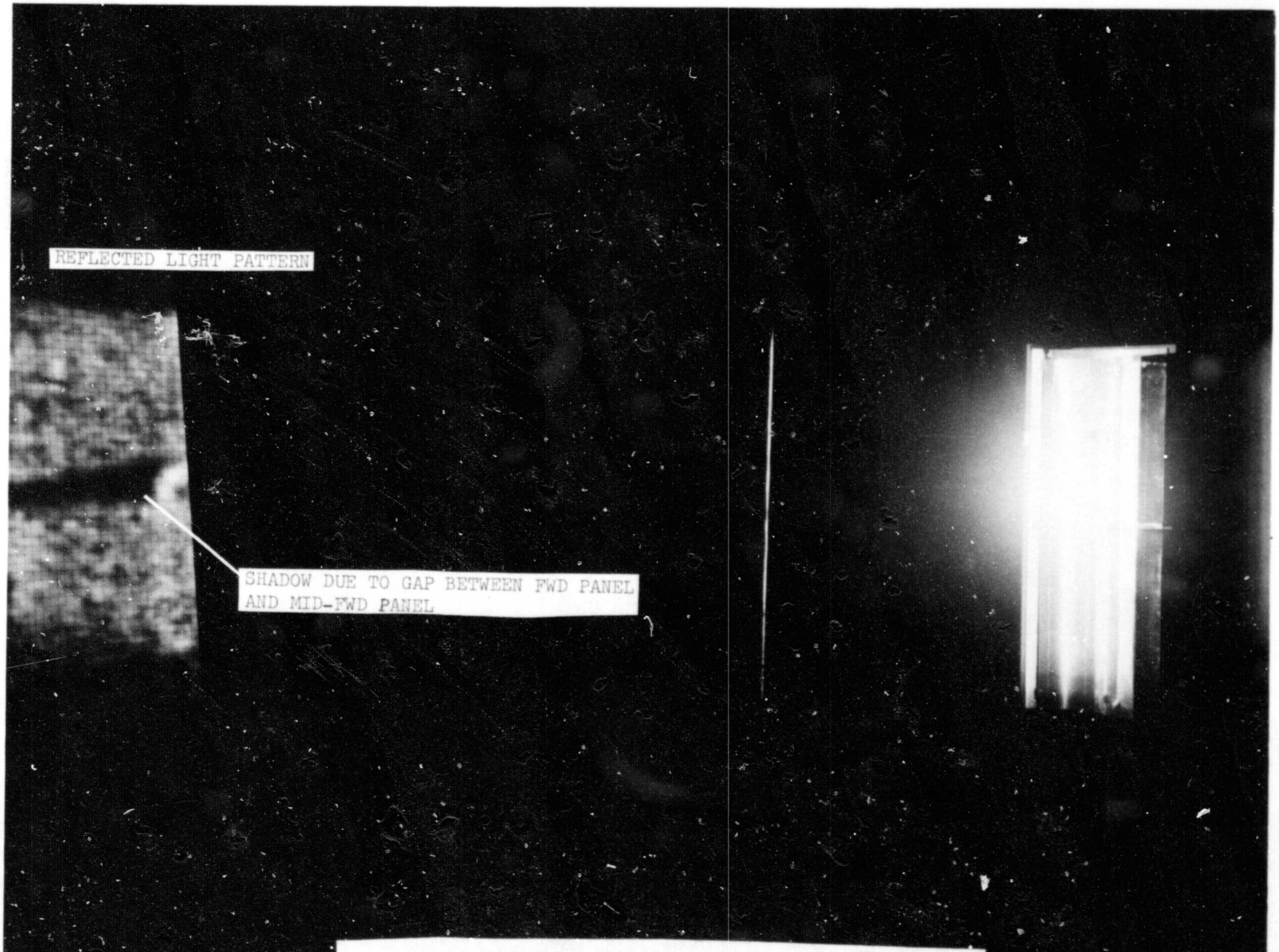


FIGURE 12 SMOOTH SILVER/TEFLON REFLECTED LIGHT SHADOW PATTERN

FIGURE 13 EMBOSSED SILVER/TEFLON REFLECTED LIGHT SHADOW PATTERN

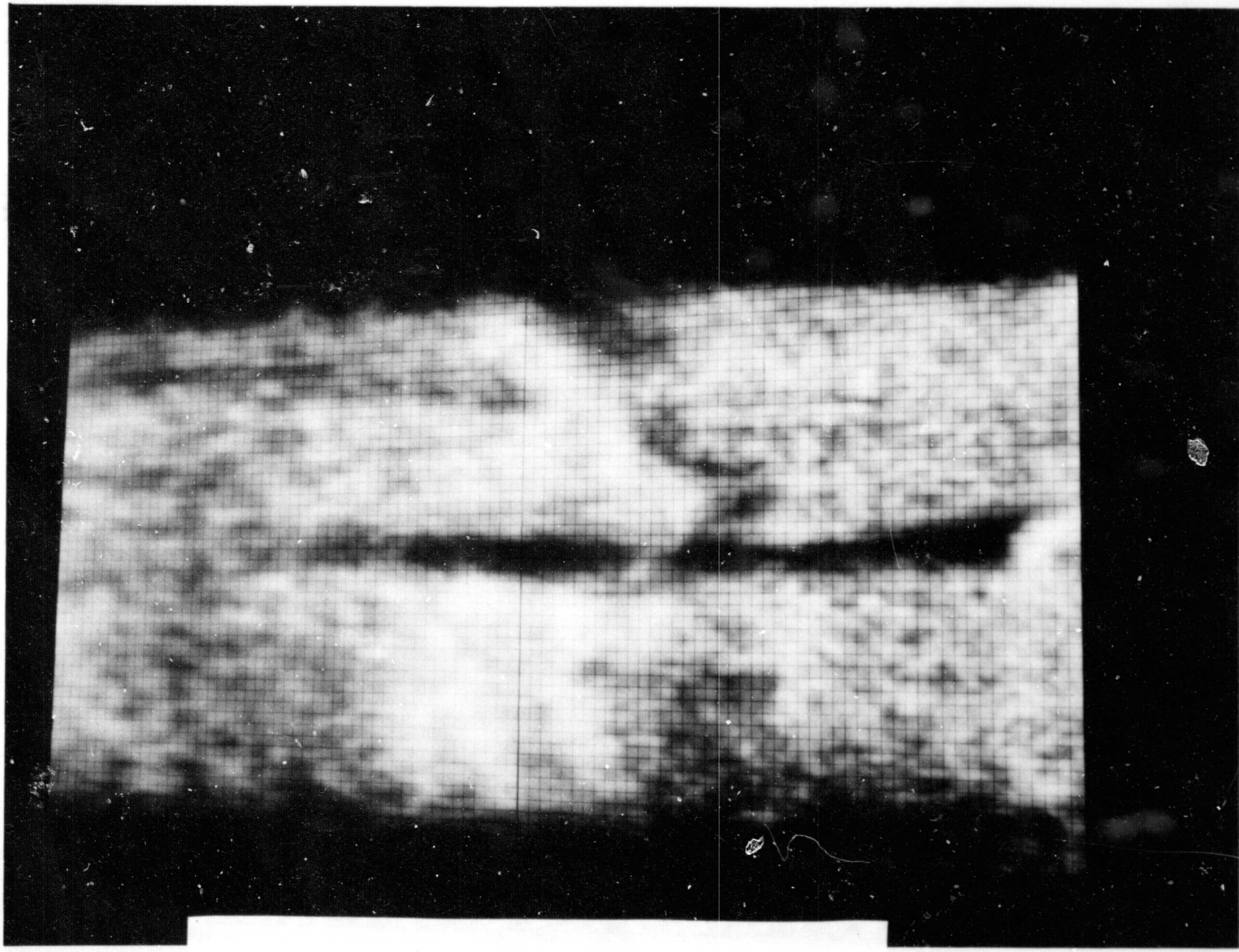


FIGURE 14 CLOSE-UP OF SMOOTH SILVER/TEFLON REFLECTED SHADOW PATTERN

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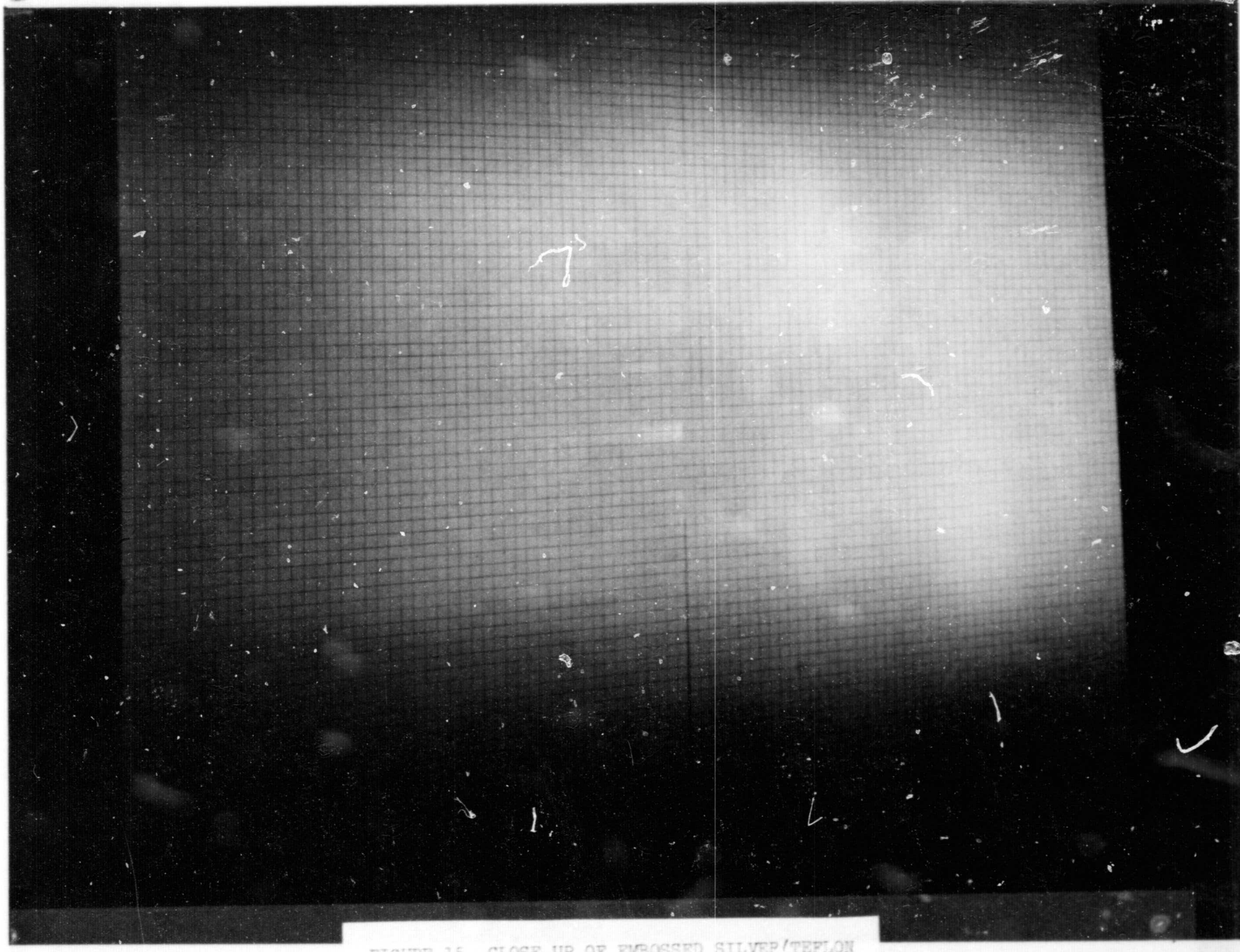

FIGURE 15 CLOSE-UP OF EMBOSSED SILVER/TEFLON
REFLECTED SHADOW PATTERN

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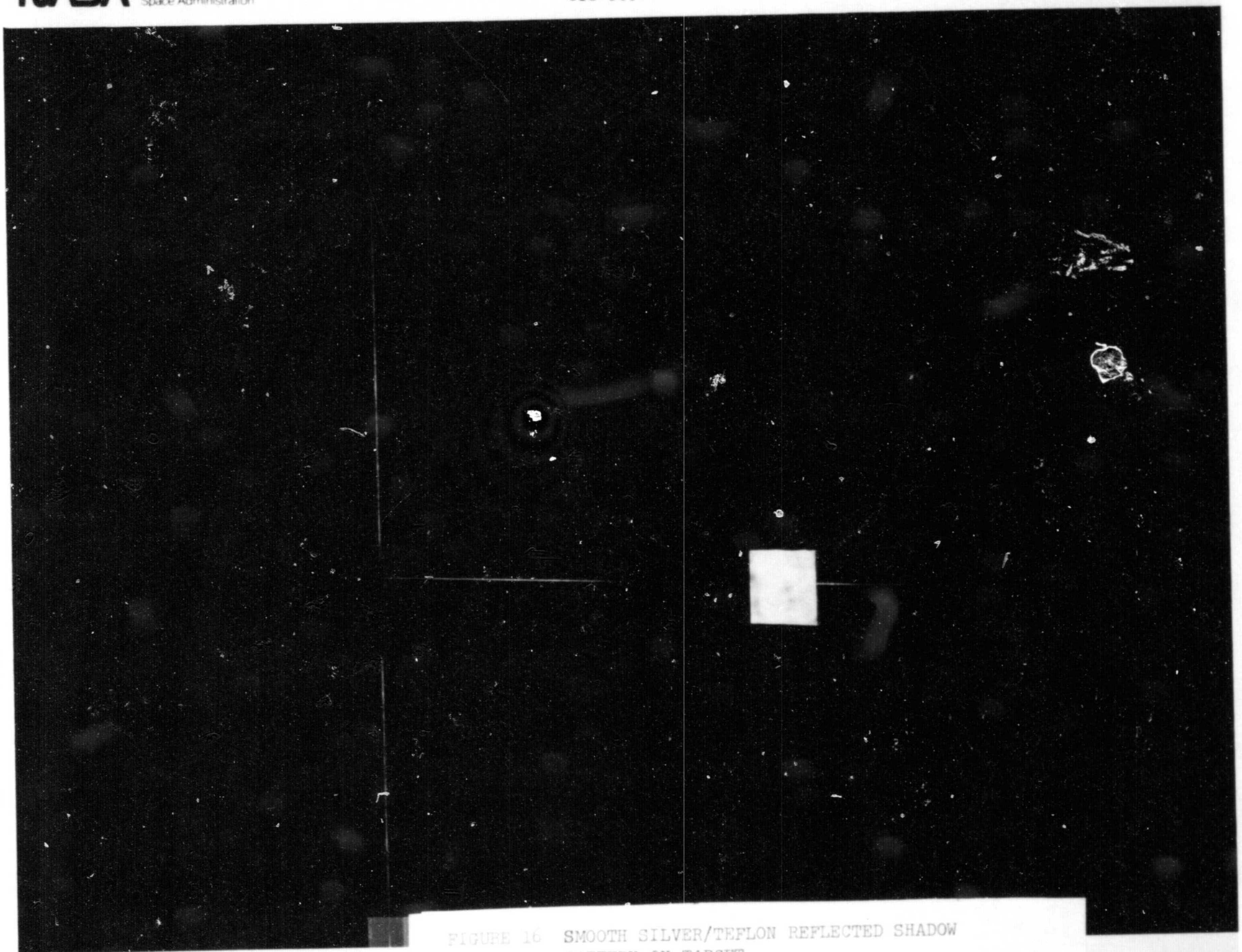

FIGURE 16 SMOOTH SILVER/TEFLON REFLECTED SHADOW PATTERN ON TARGET

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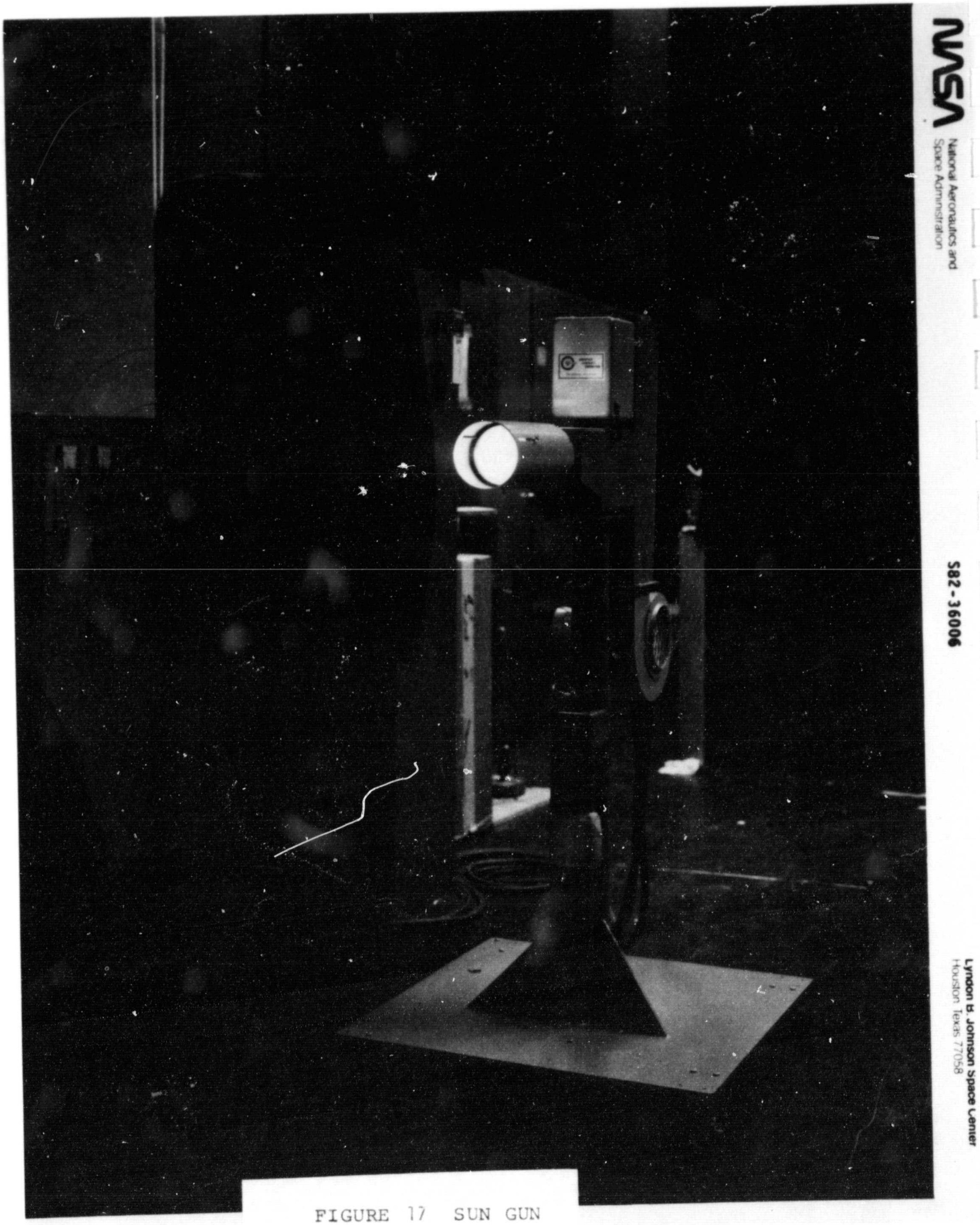

FIGURE 17 SUN GUN

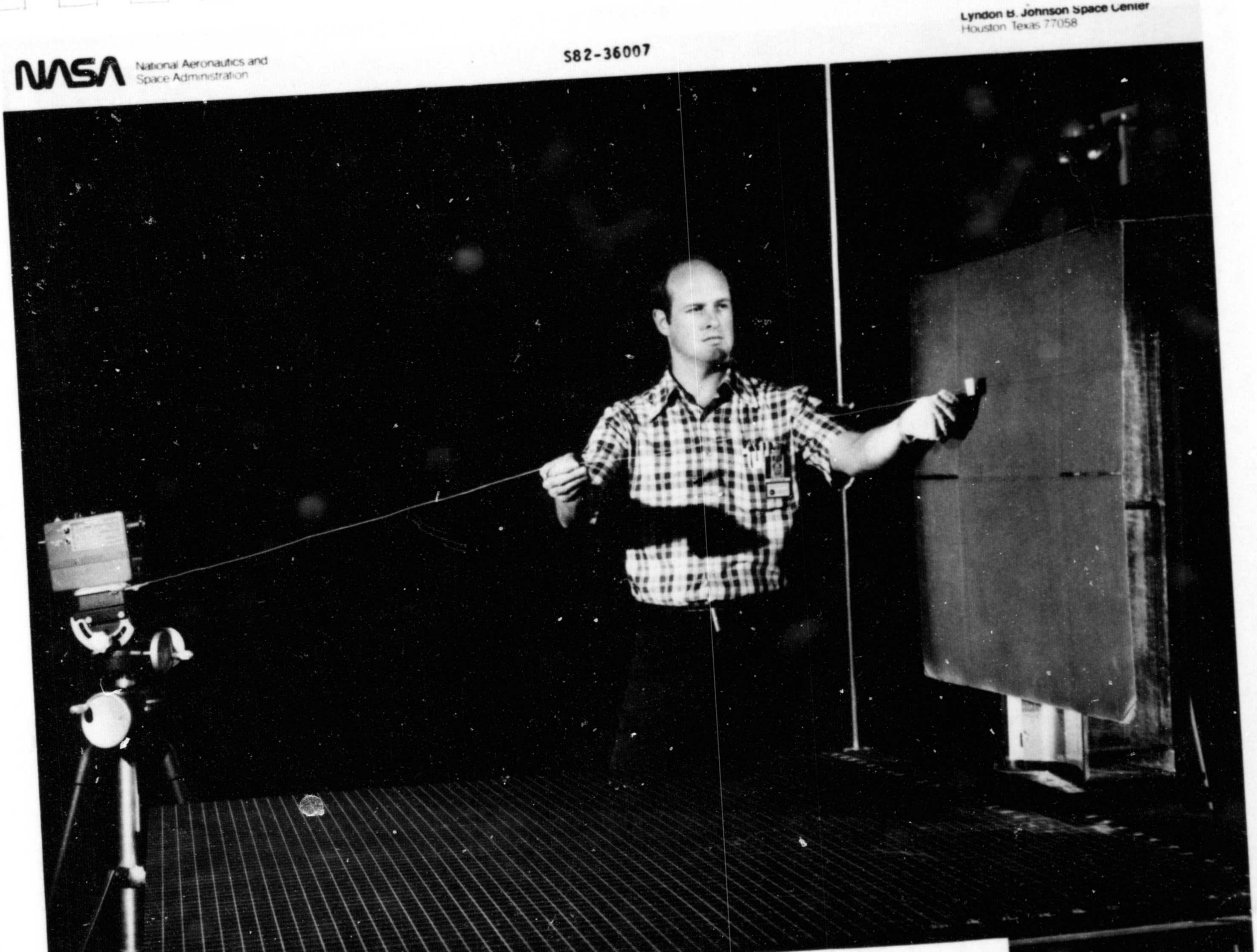

FIGURE 18 PHOTOMETER LOCATION FOR BASELINE ONE-SUN READING

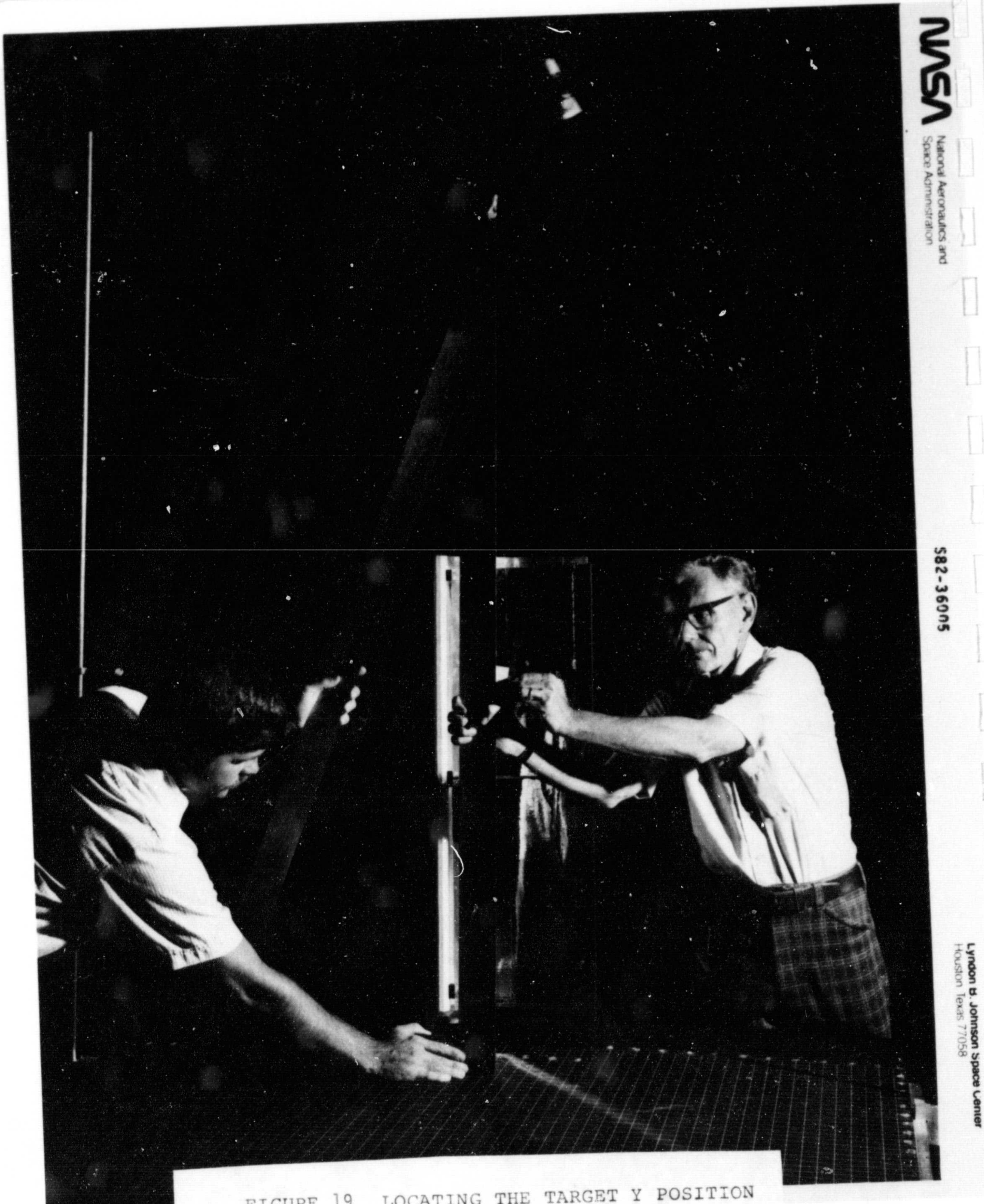

FIGURE 19 LOCATING THE TARGET Y POSITION

FIGURE 20

COMPARISON OF TEST DATA AND RAY TRACE ANALYSIS
SMOOTH SILVER/TEFLON COATING

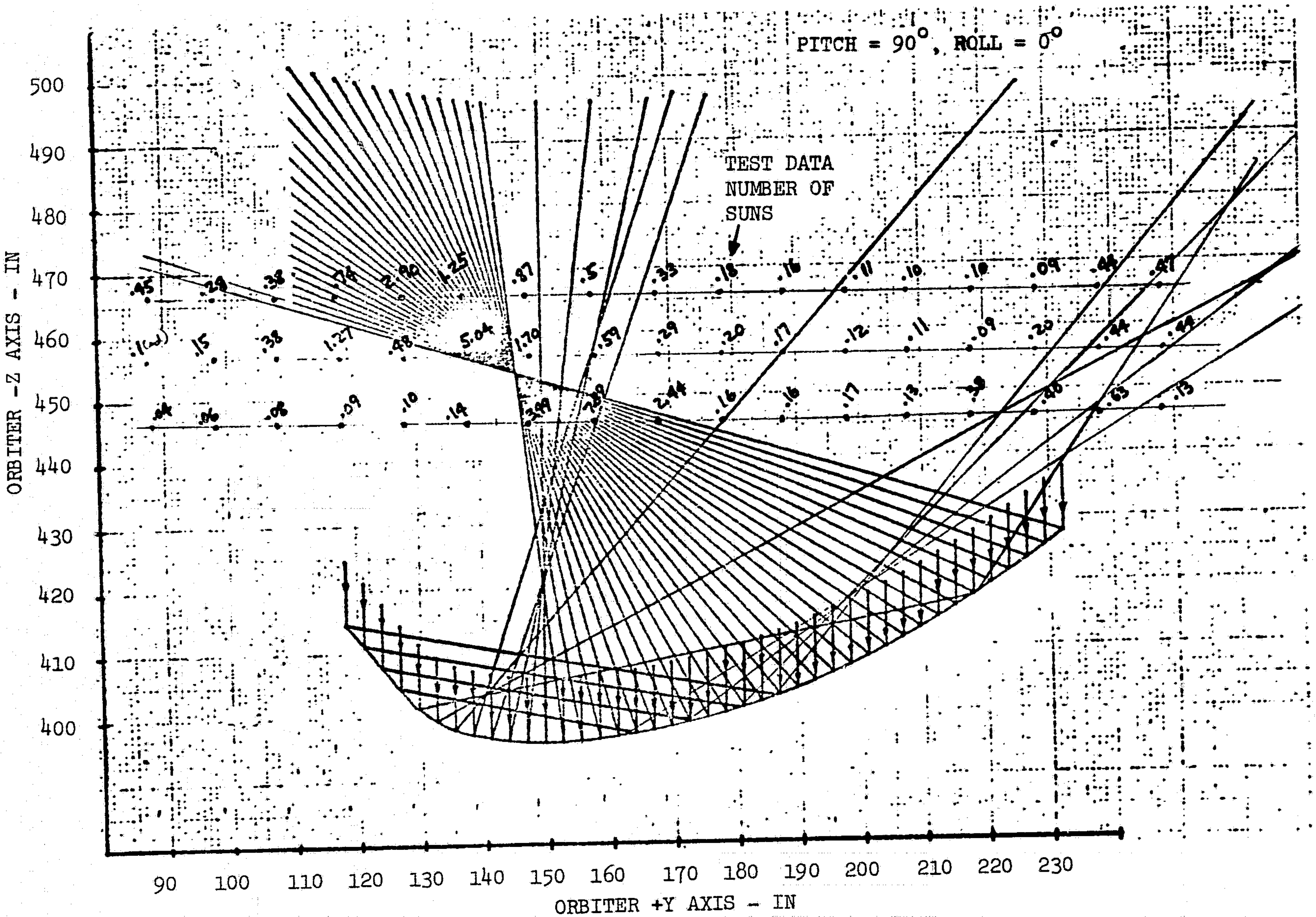

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FIGURE 21

COMPARISON OF TEST DATA AND RAY TRACE ANALYSIS
EMBOSSED SILVER/TEFLON COATING

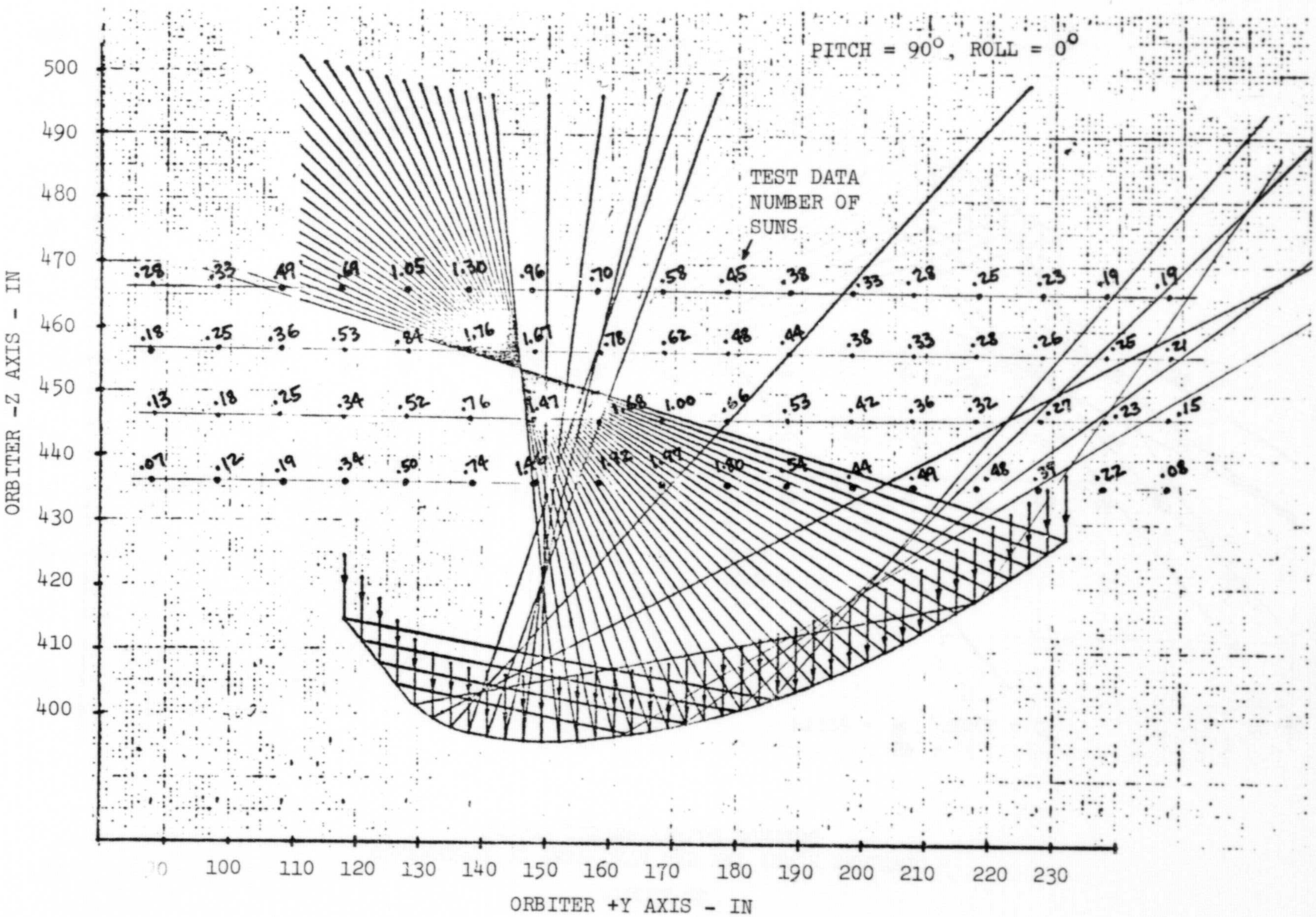

FIGURE 22

EMBOSSED COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 436

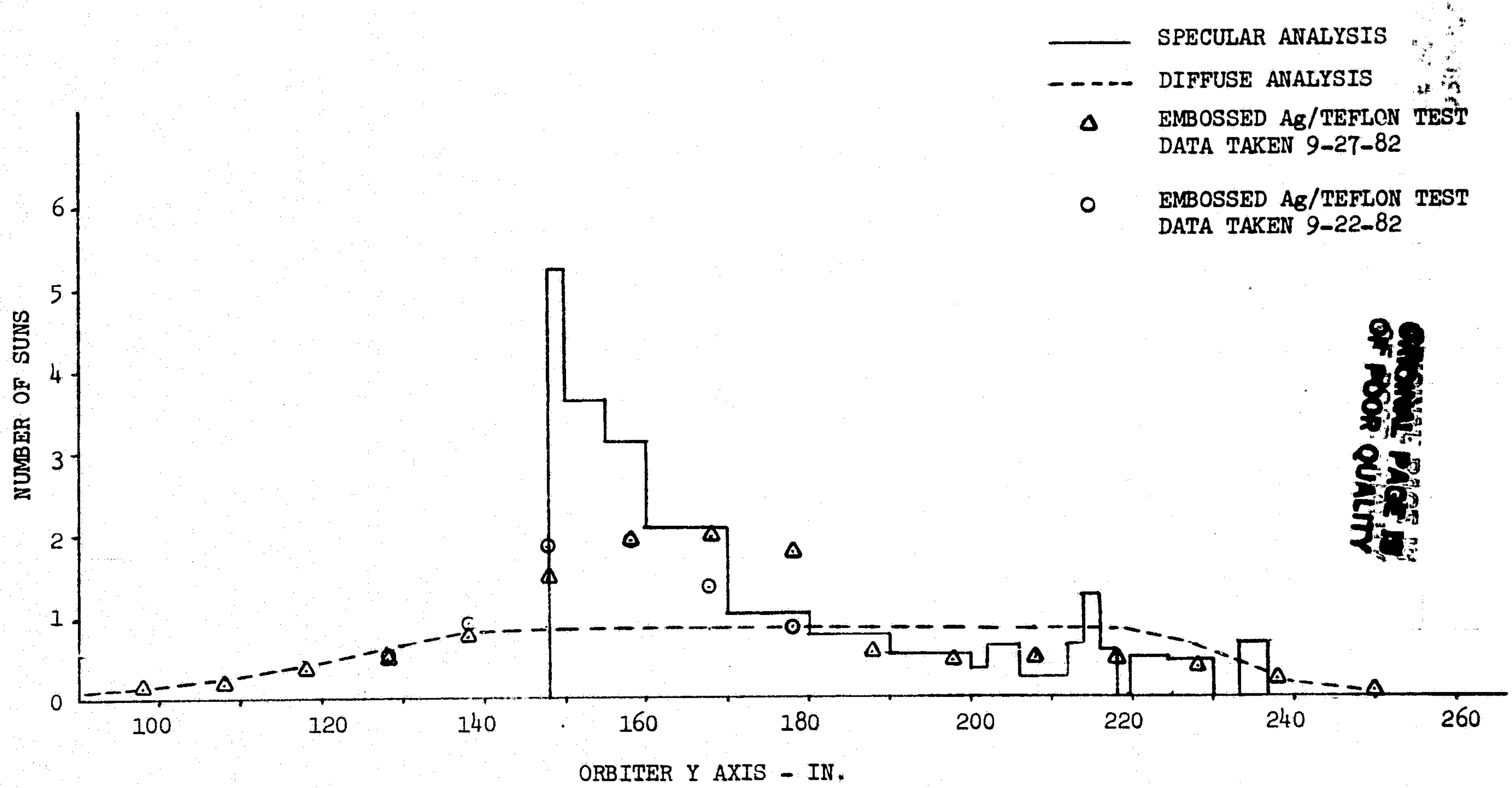

FIGURE 23

EMBOSSED COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 446

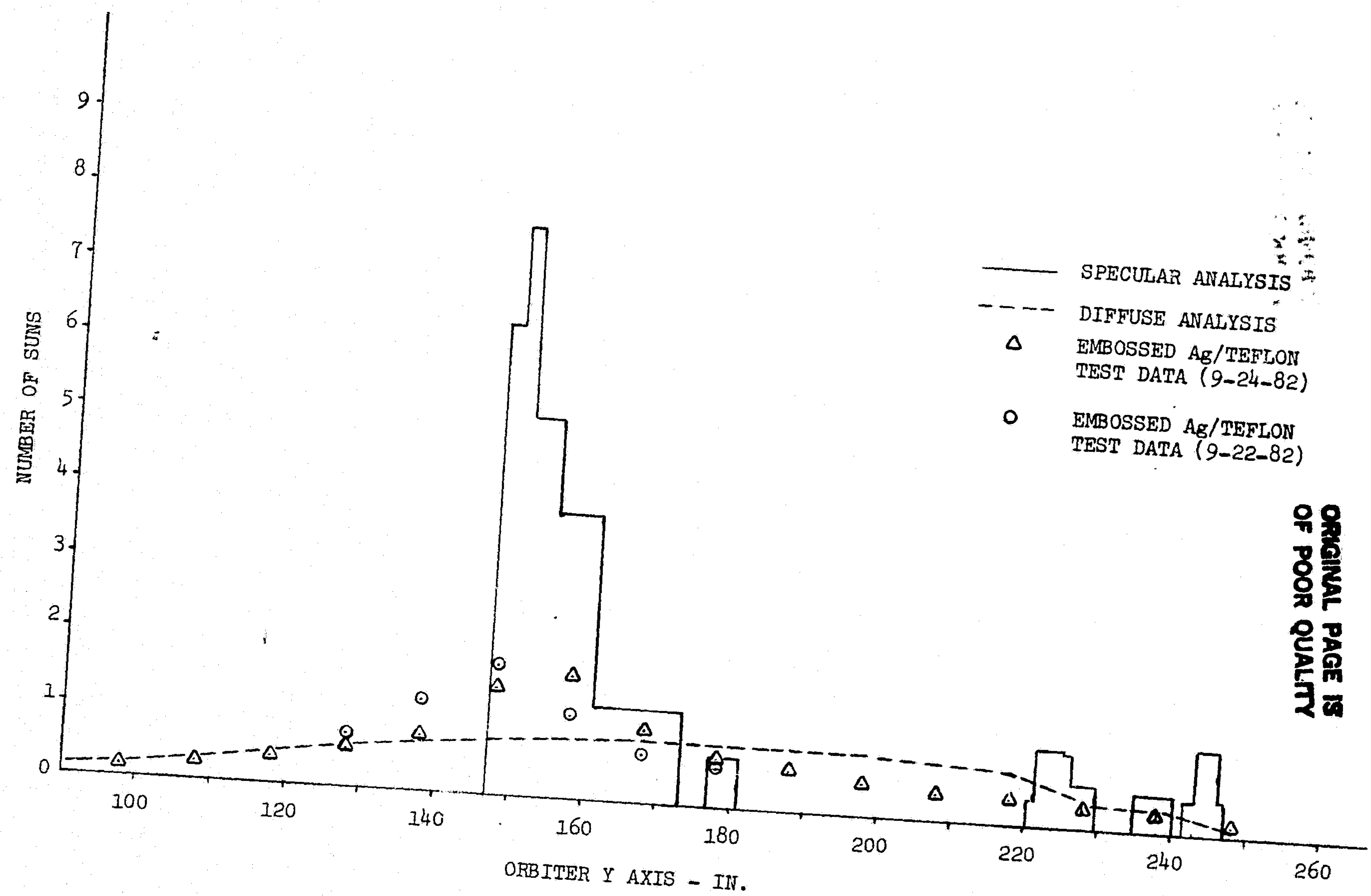

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FIGURE 24

EMBOSSED COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 456

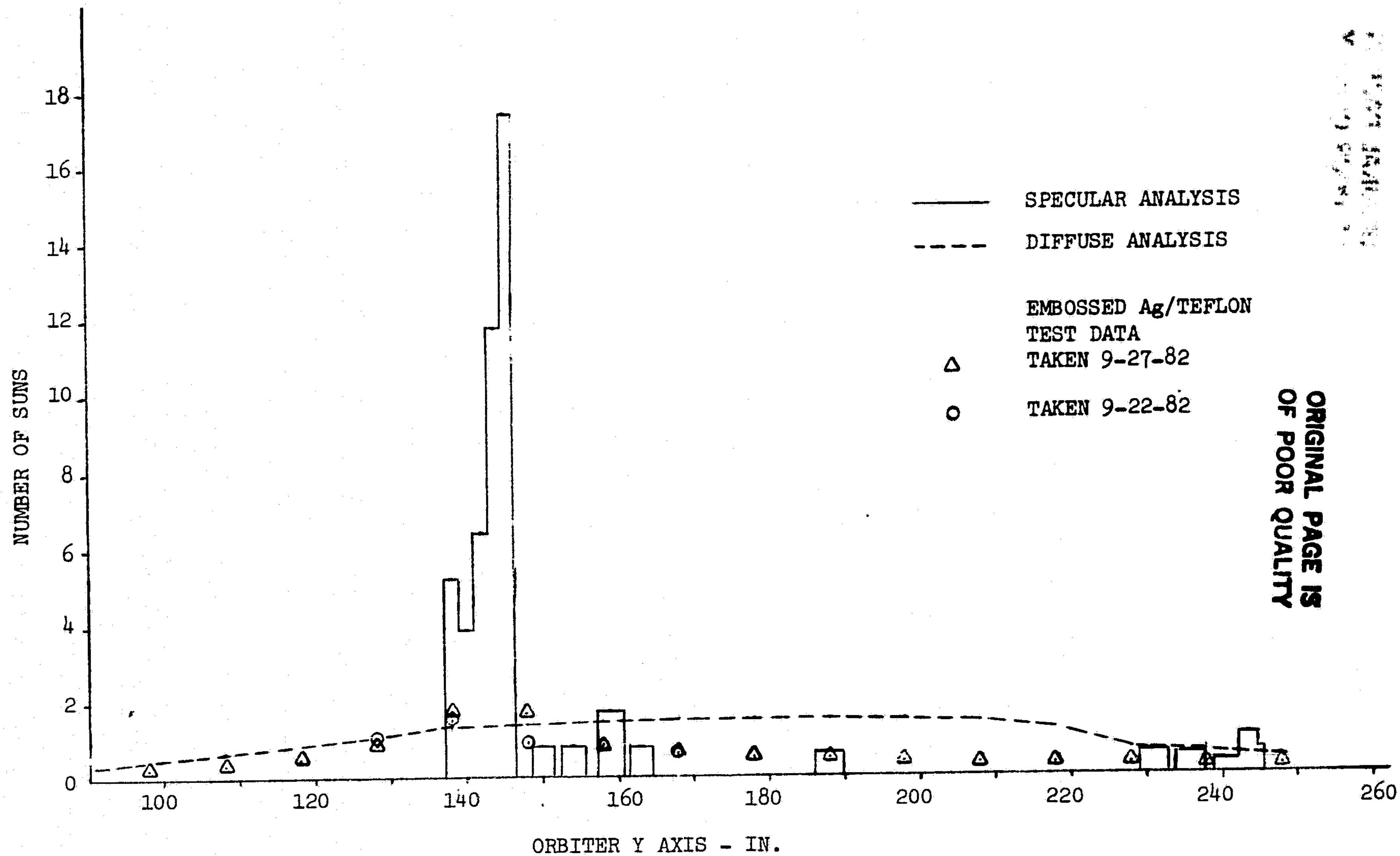

FIGURE 25

EMBOSSED COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 466

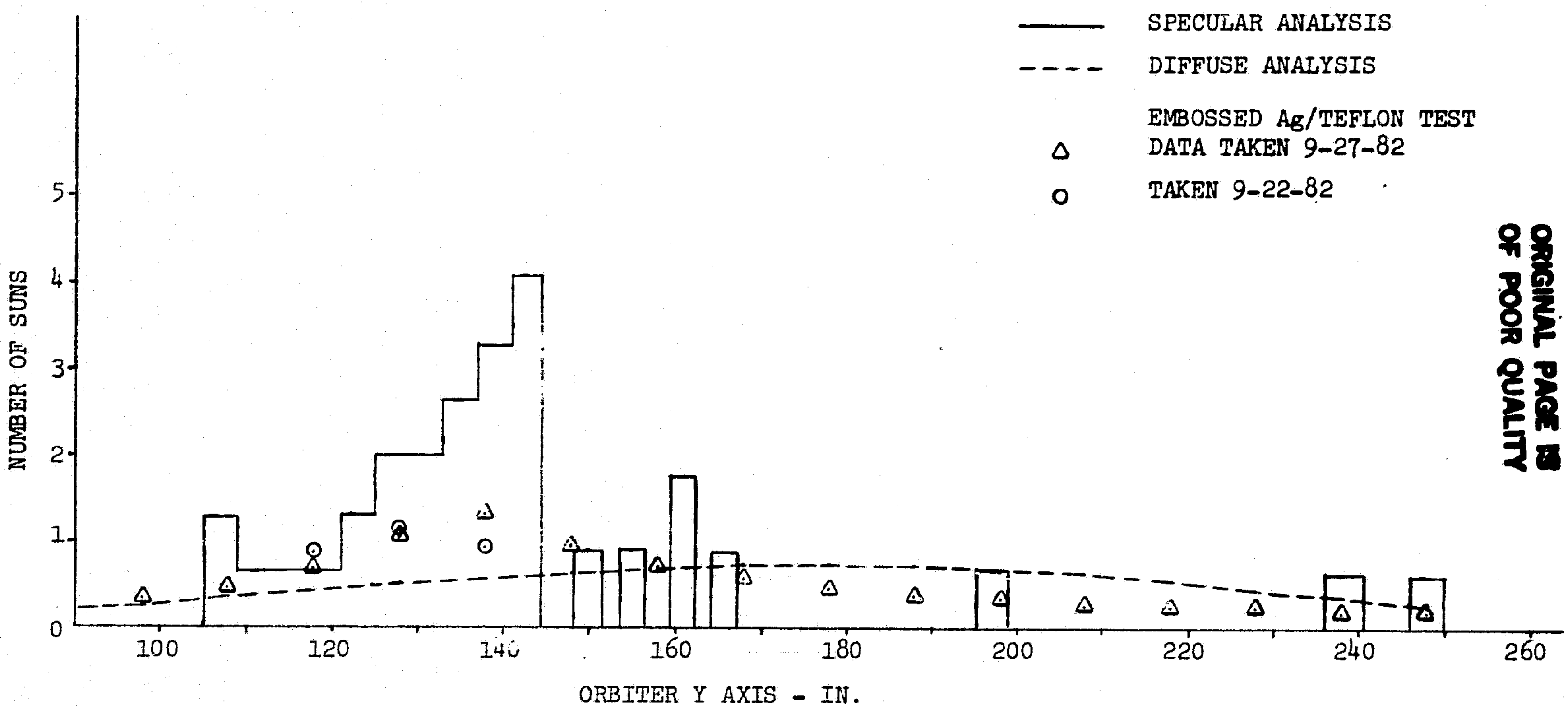

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FIGURE 26

EMBOSSED COATING EFFECTIVE SOLAR ABSORPTANCE

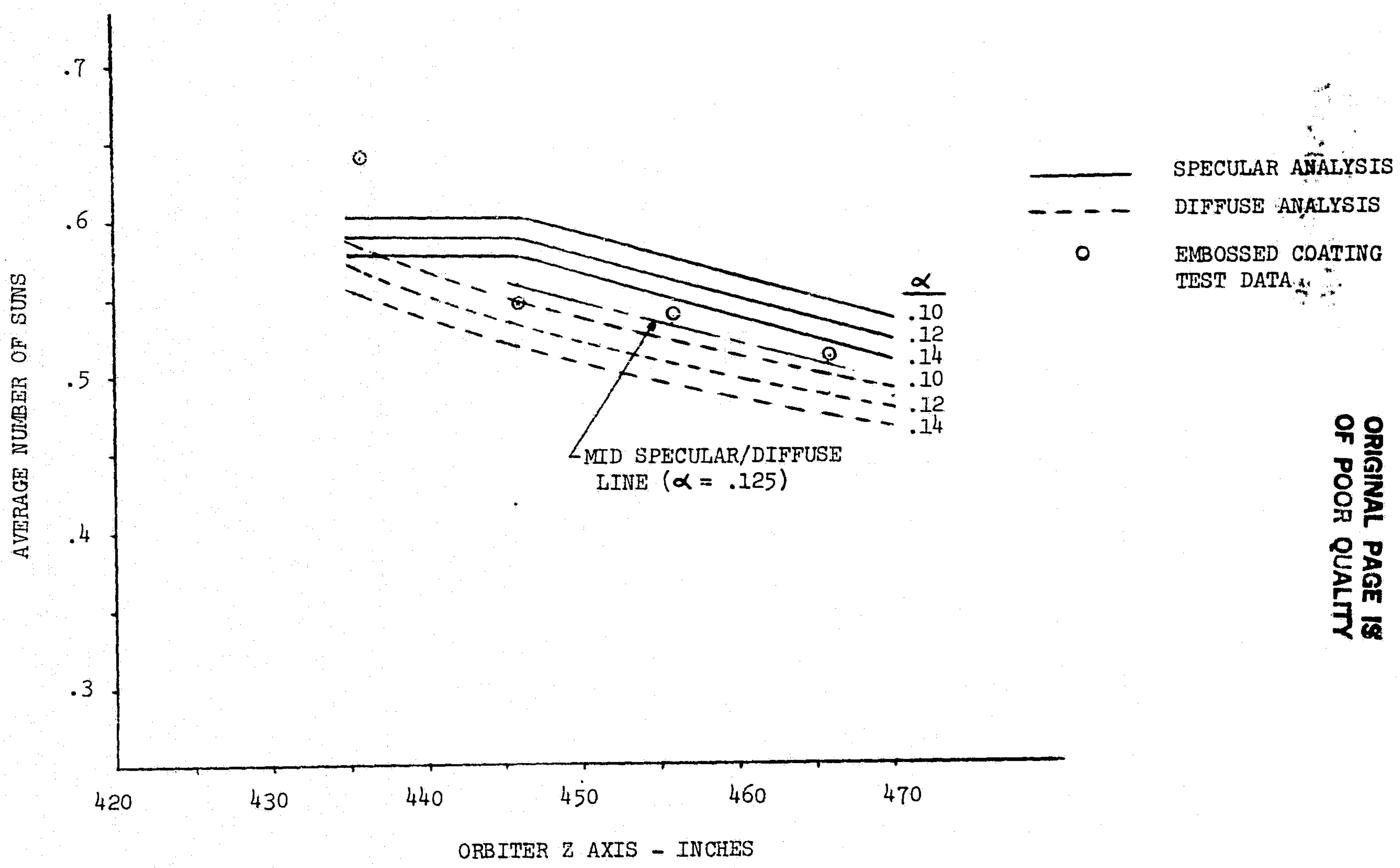

FIGURE 27

SMOOTH COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 446

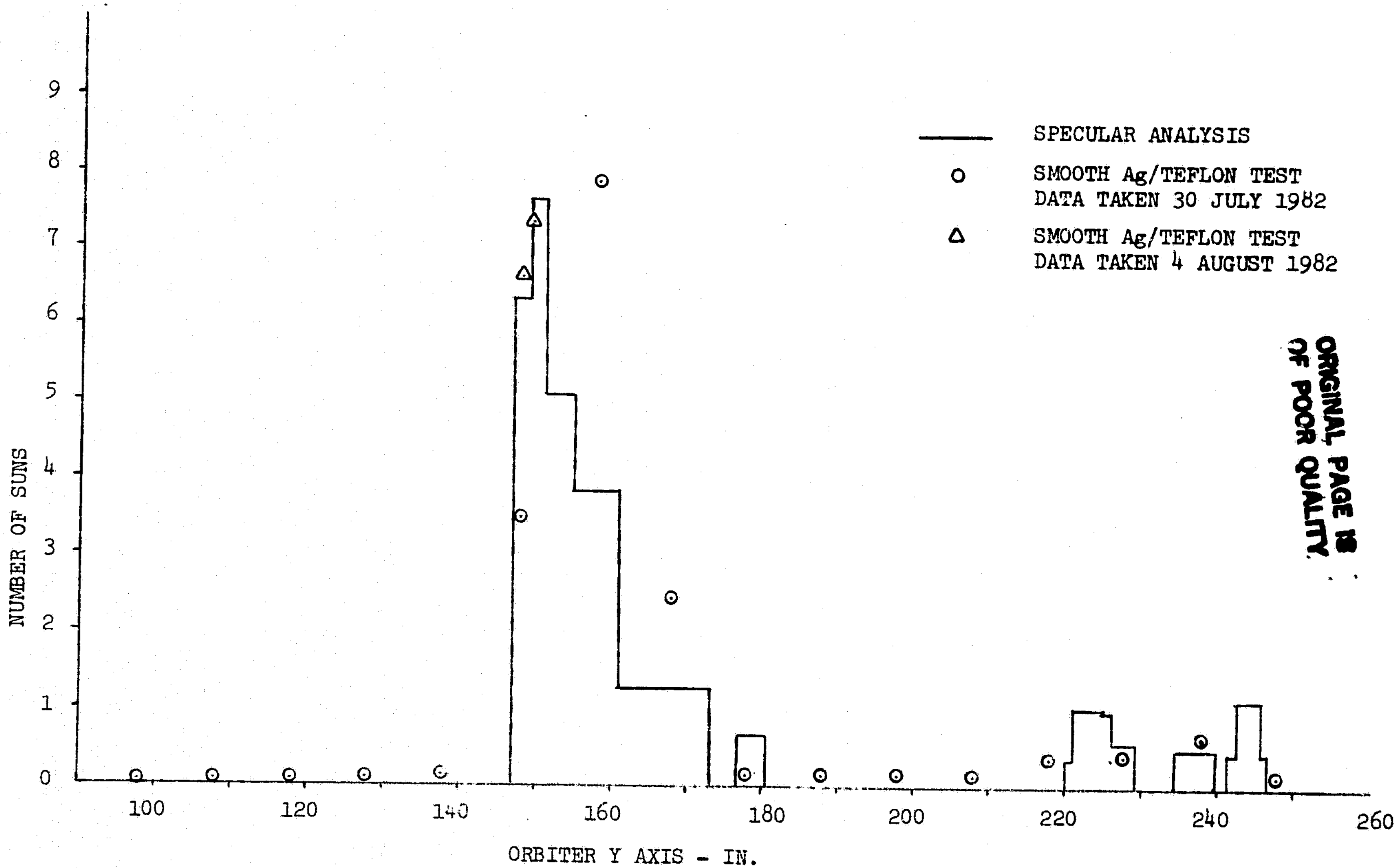

FIGURE 28

SMOOTH COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 456

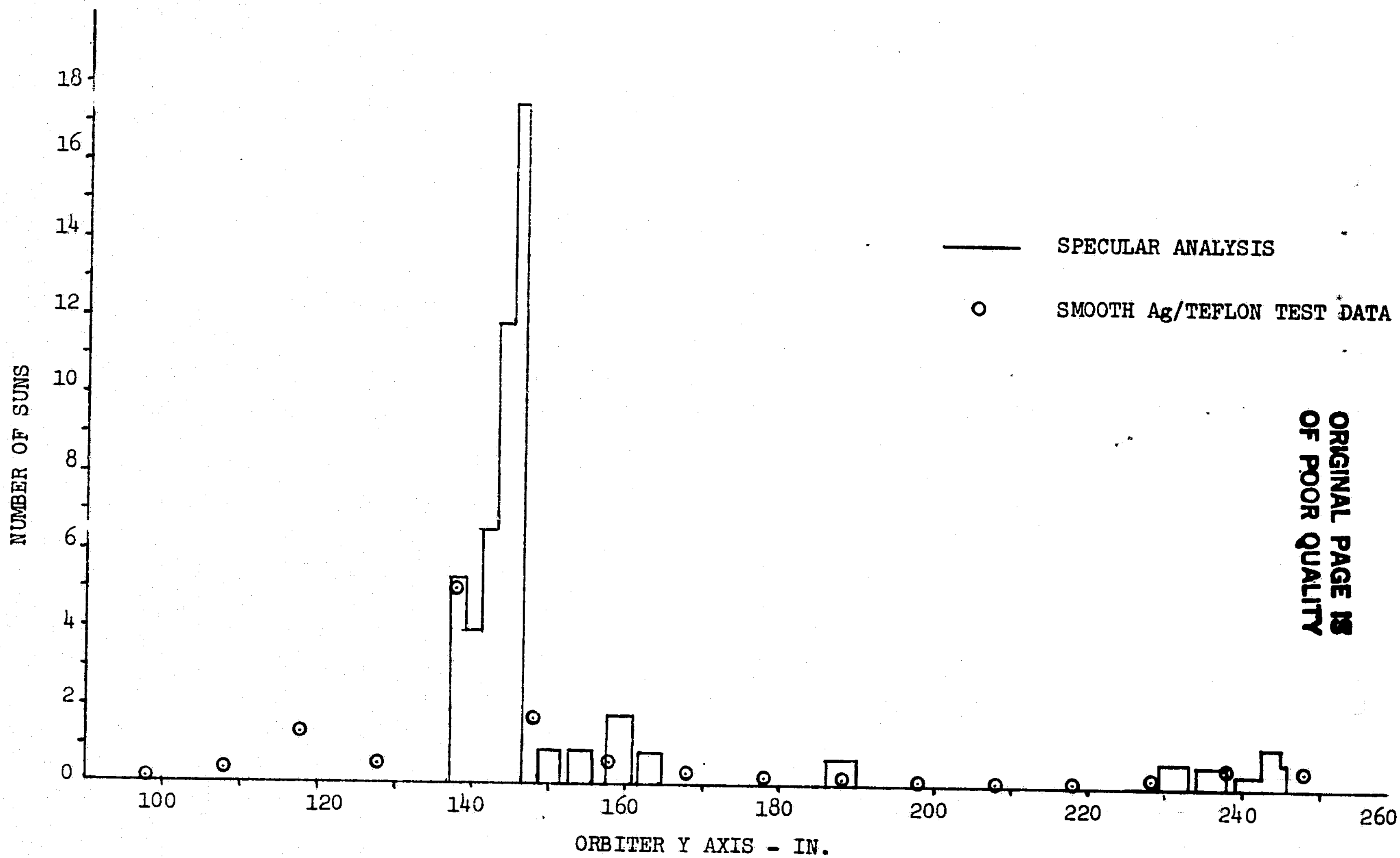

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FIGURE 29

SMOOTH COATING REFLECTED SOLAR FLUX DISTRIBUTION AT Z = 466

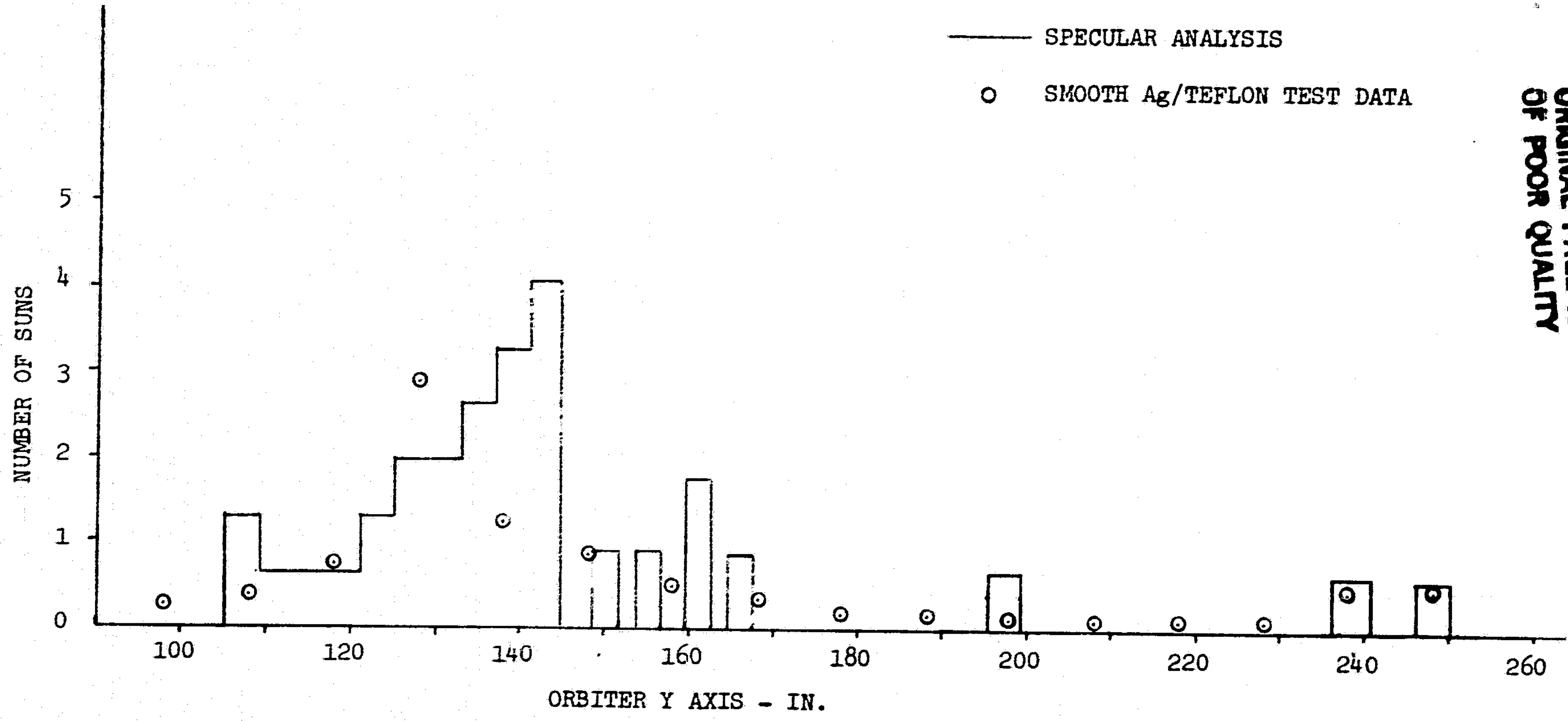

FIGURE 30 X-AXIS DATA LOCATIONS

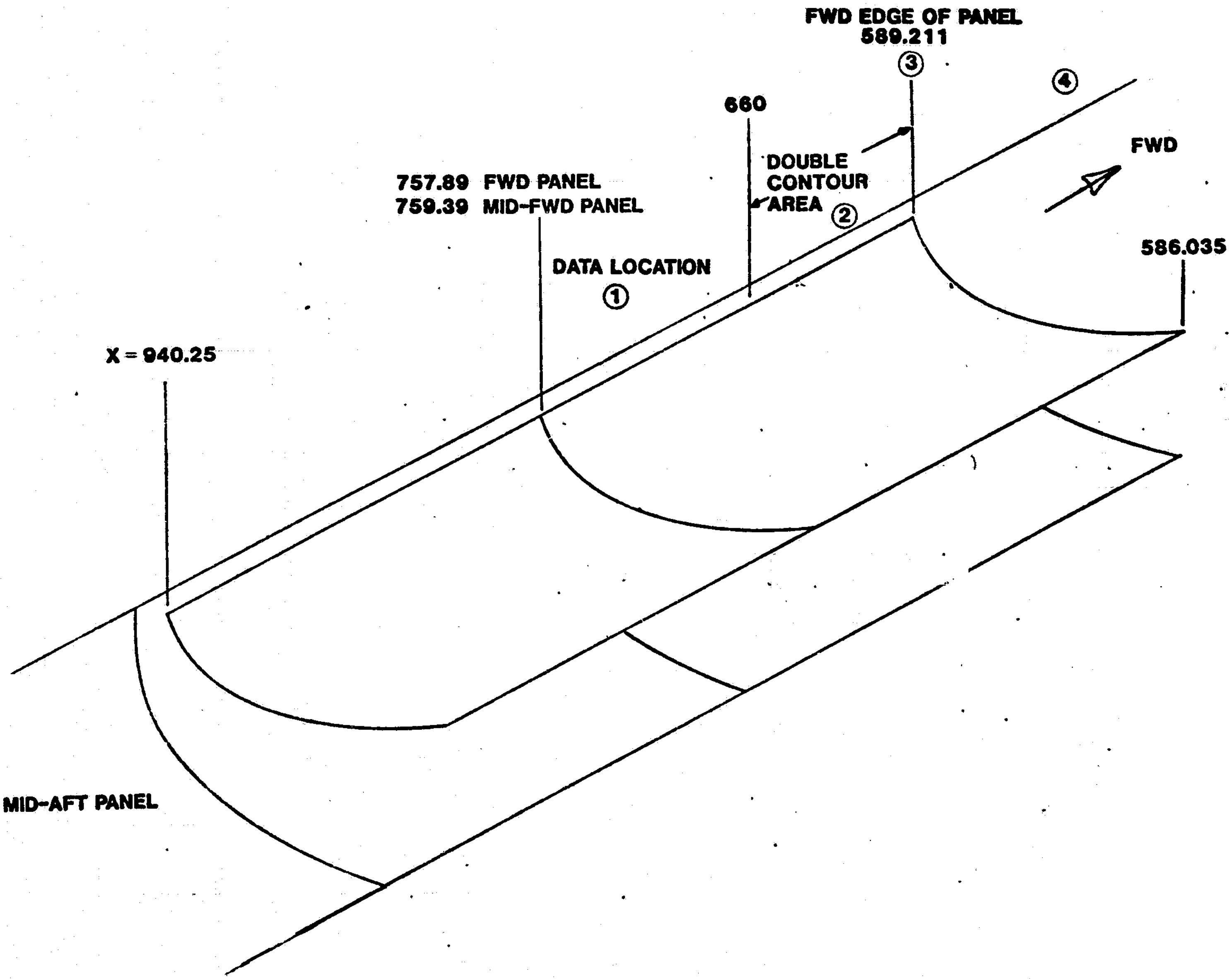

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FIGURE 31

EMBOSSED COATING ONE-SUN ENVELOPE
VARIATION IN X AXIS - PITCH = 90°

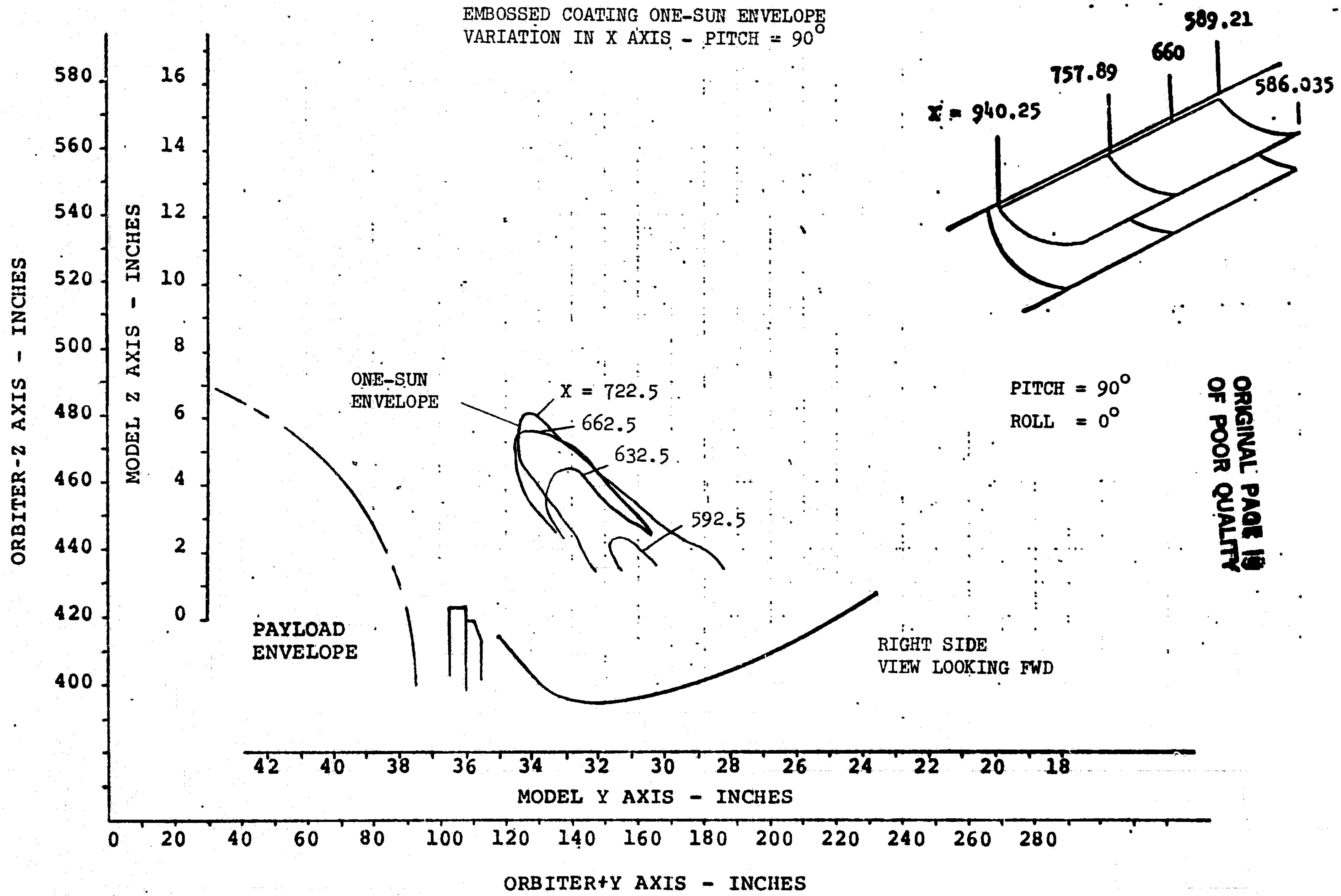

FIGURE 32

EMBOSSED COATING ONE-SUN ENVELOPE - PITCH = 90°

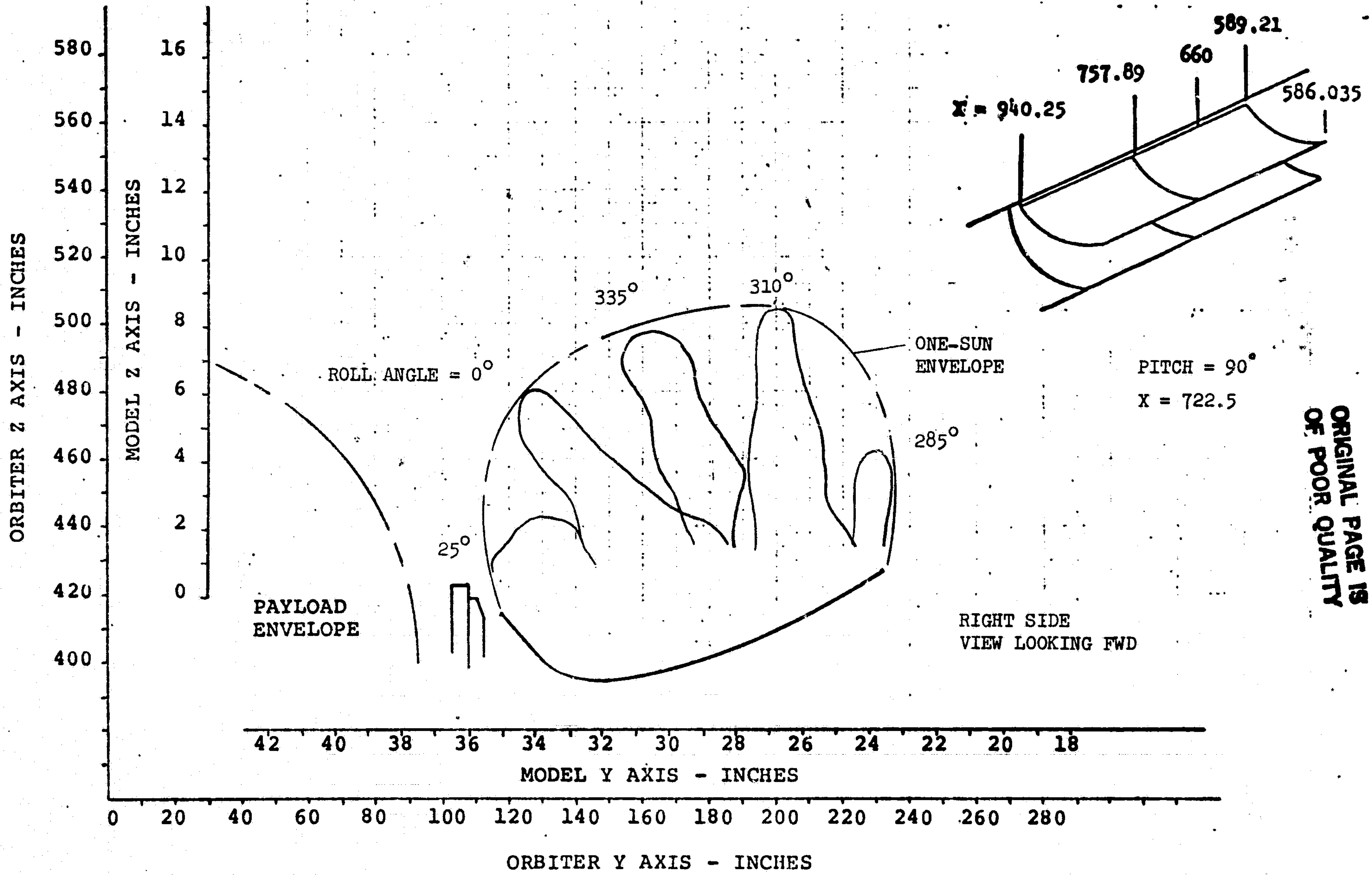

FIGURE 33

EMBOSSED COATING ONE-SUN ENVELOPE - PITCH = 90°
STOWED FWD PANELS AND AFT PANELS

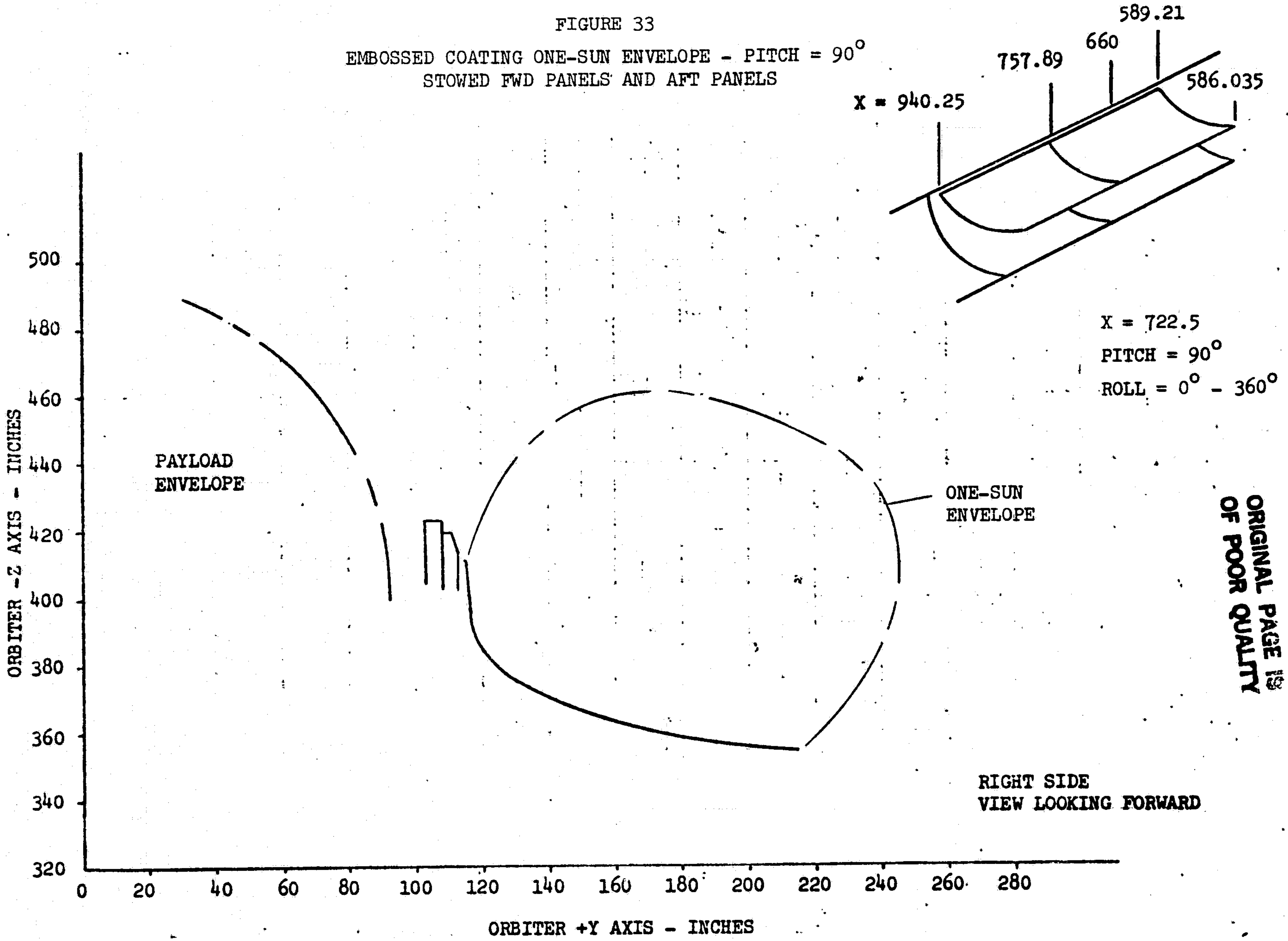

FIGURE 34 REFLECTED SOLAR-FLUX NEAR RADIATOR/DOOR GAP-EMBOSSED COATING

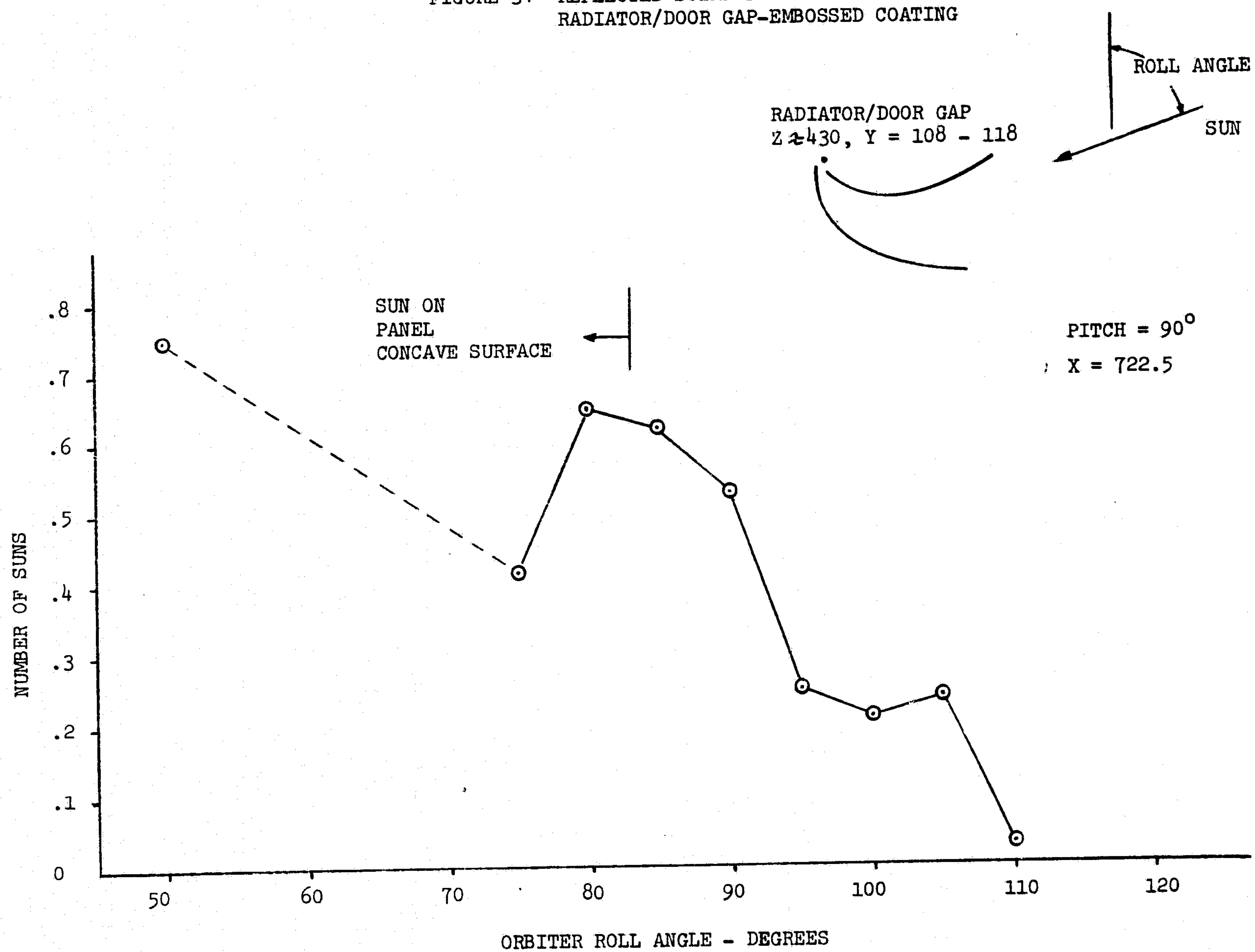

FIGURE 35

EMBOSSED COATING ONE-SUN ENVELOPE VARIATION IN X-AXIS
PITCH = 115°

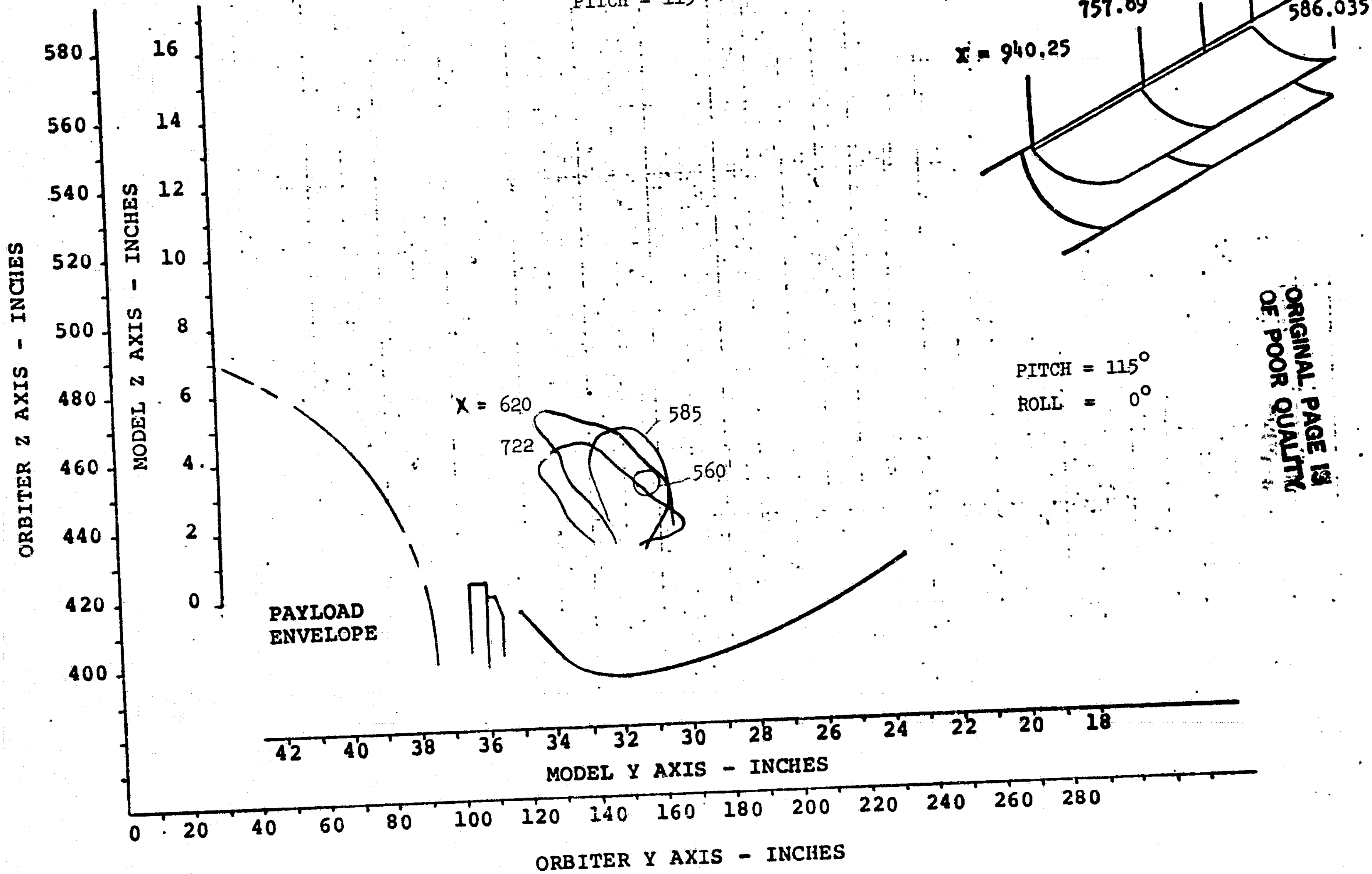

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FIGURE 36

EMBOSSED COATING ONE-SUN ENVELOPE
AFT OF DOUBLE CONTOUR - PITCH = 115°

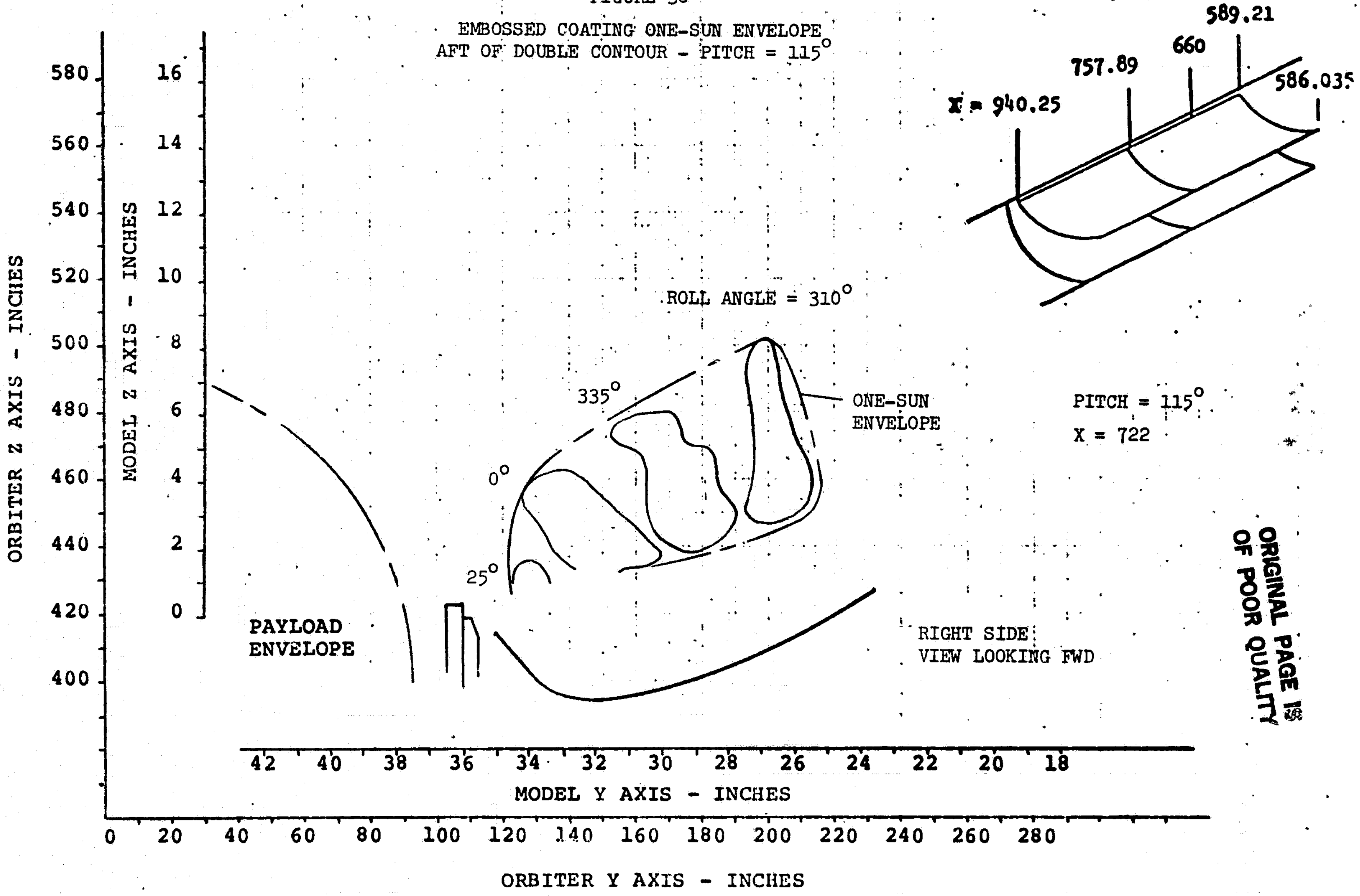

FIGURE 37

EMBOSSED COATING ONE-SUN ENVELOPE
IN DOUBLE CONTOUR AREA - PITCH = 115°

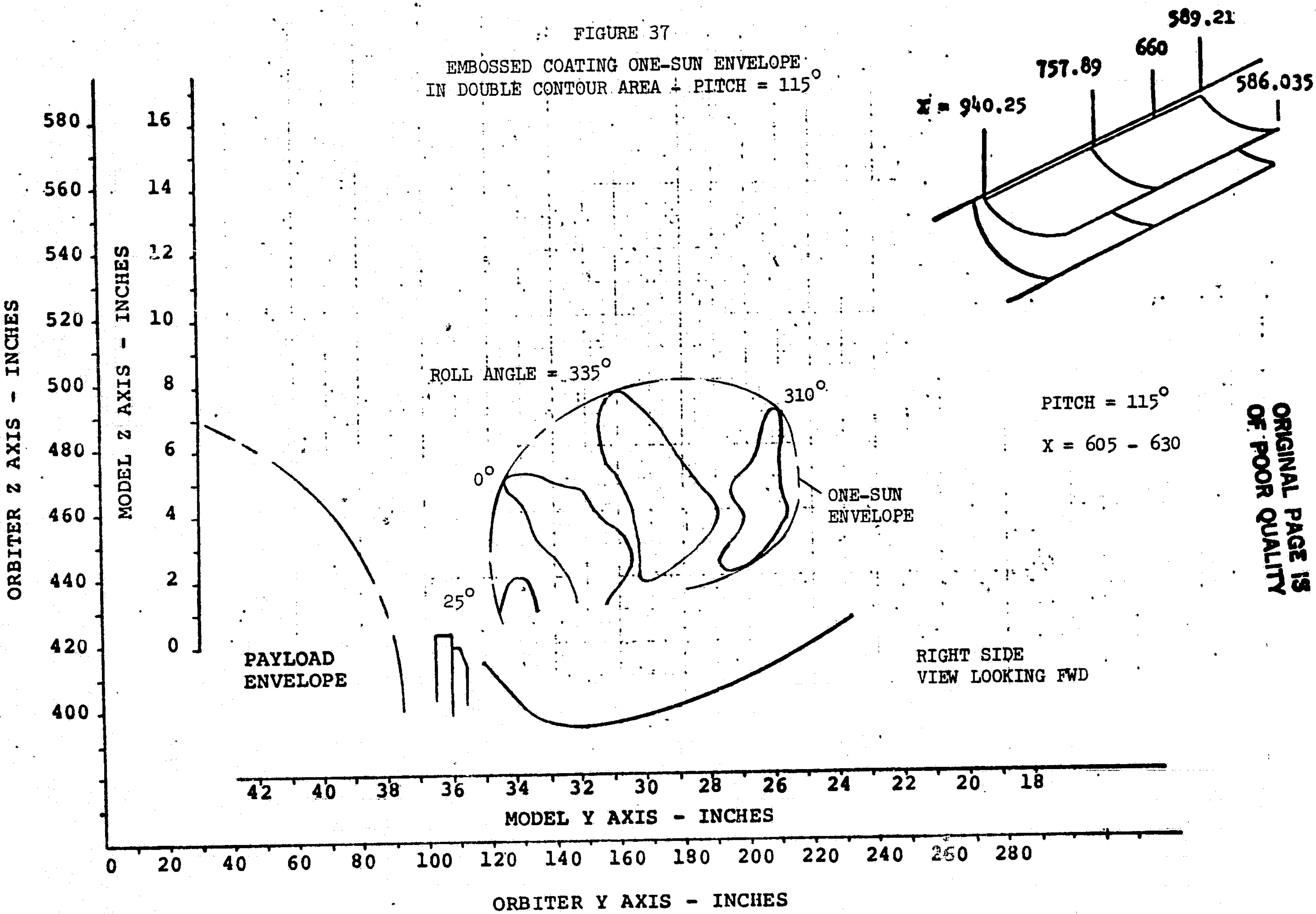

FIGURE 38

EMBOSSED COATING ONE-SUN ENVELOPE
AT PANEL FORWARD EDGE - PITCH = 115°

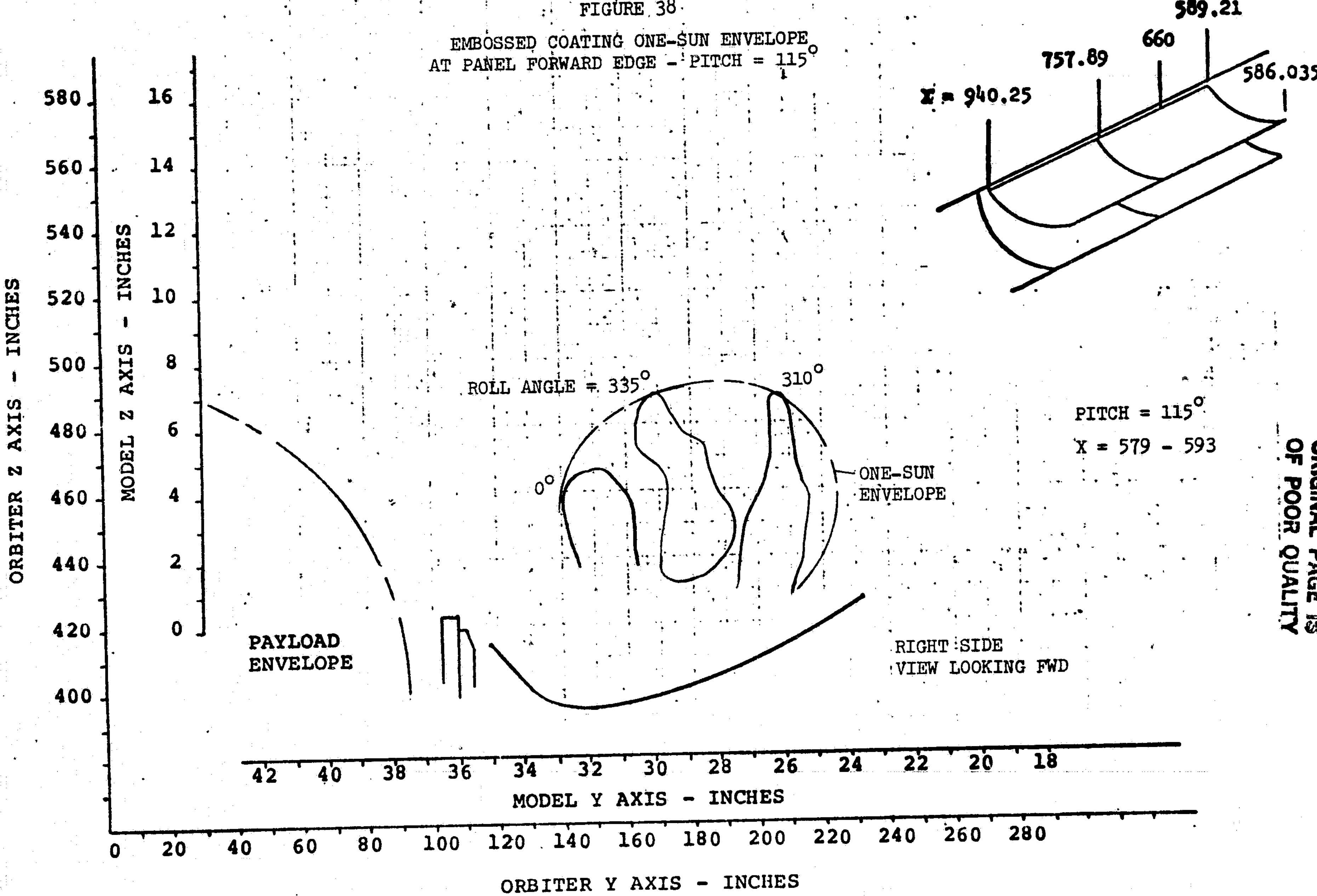

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FIGURE 39

EMBOSSED COATING ONE-SUN ENVELOPE
FORWARD OF FWD PANEL EDGE - PITCH = 115°

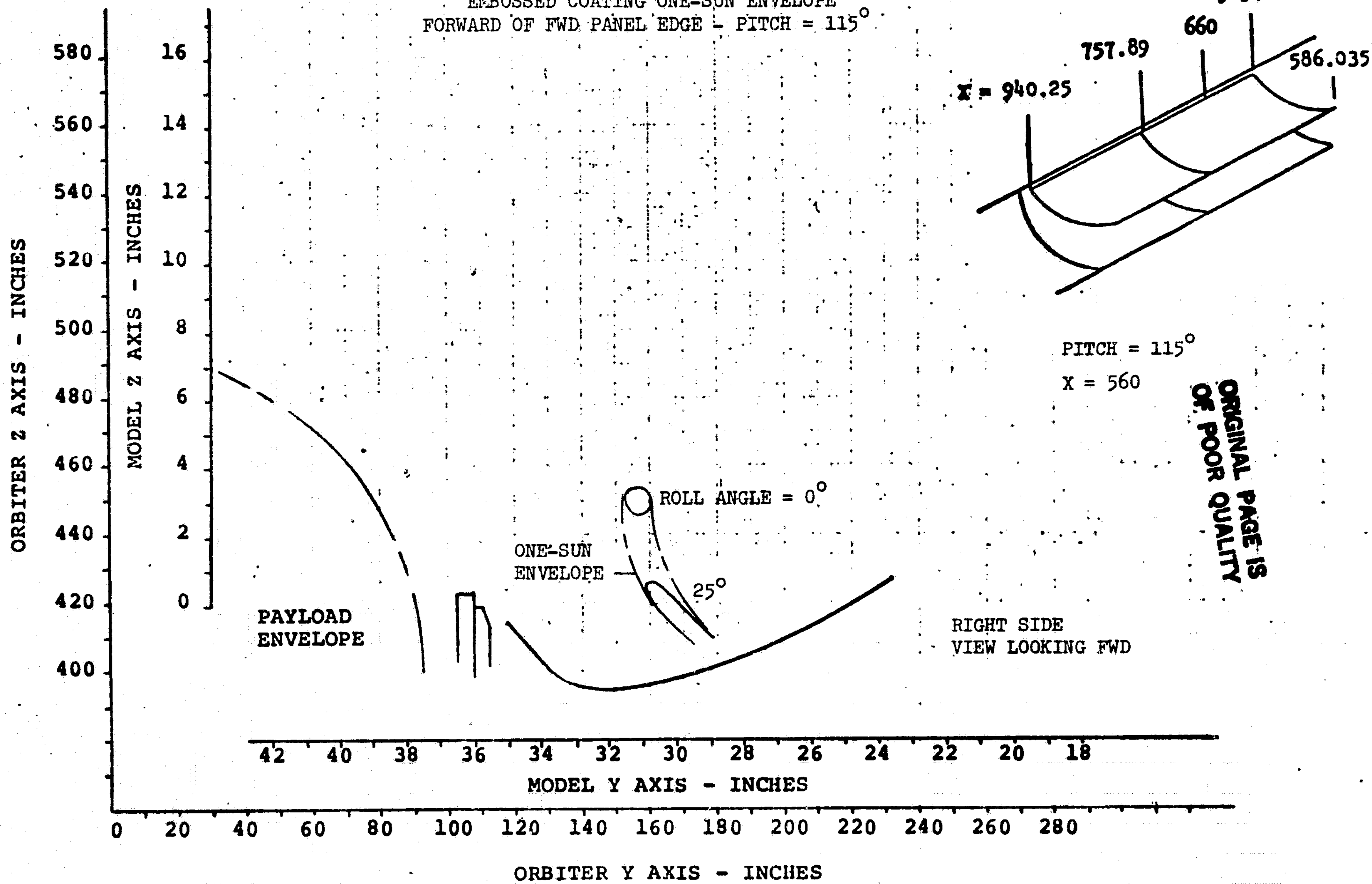

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FIGURE 40

EMBOSSED COATING ONE-SUN ENVELOPE
AFT OF DOUBLE CONTOUR - PITCH = 115°
STOWED FWD PANELS AND AFT PANELS

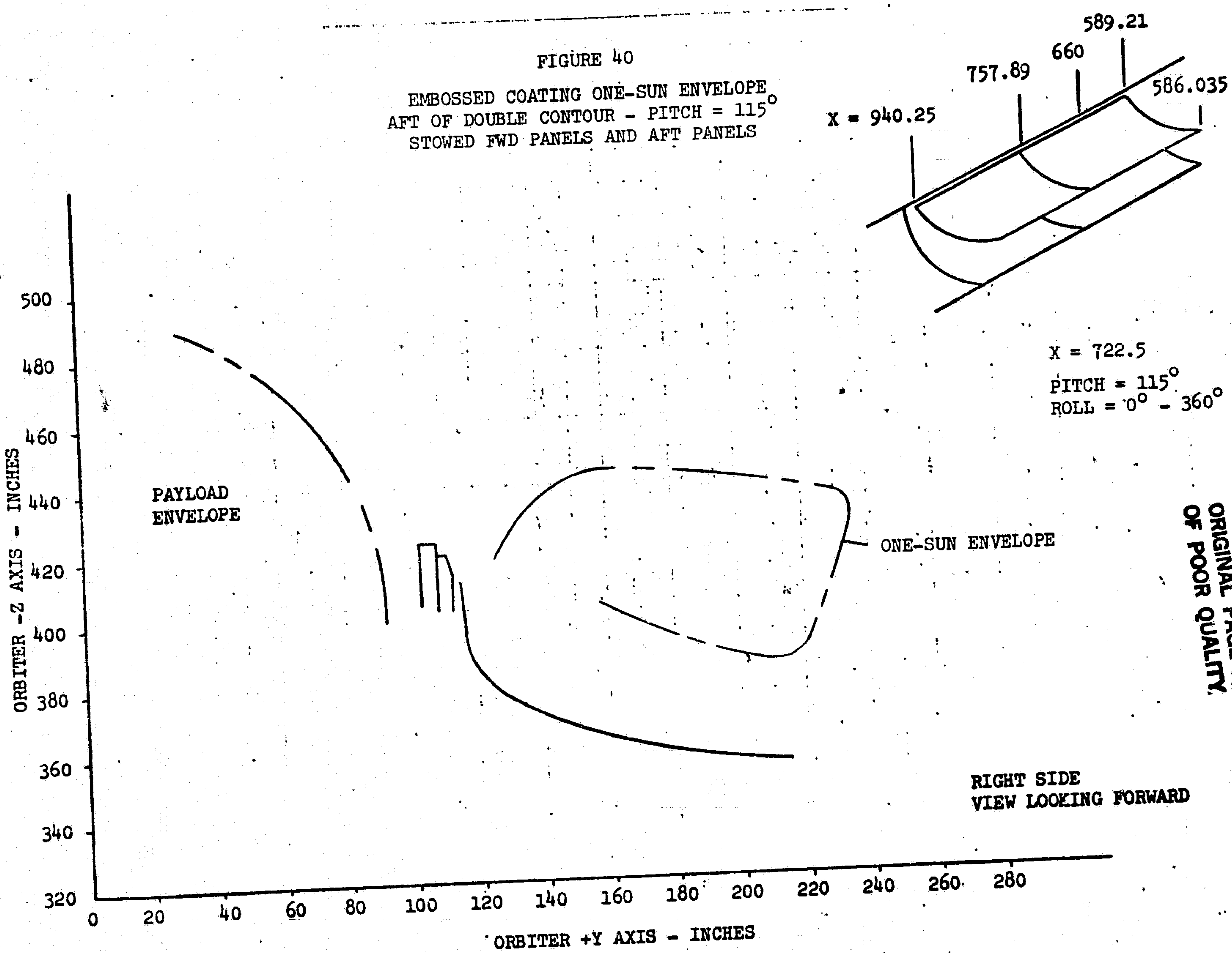

FIGURE 41

EMBOSSED COATING ONE-SUN ENVELOPE IN DOUBLE CONTOUR AREA - PITCH = 115°
STOWED FWD PANELS

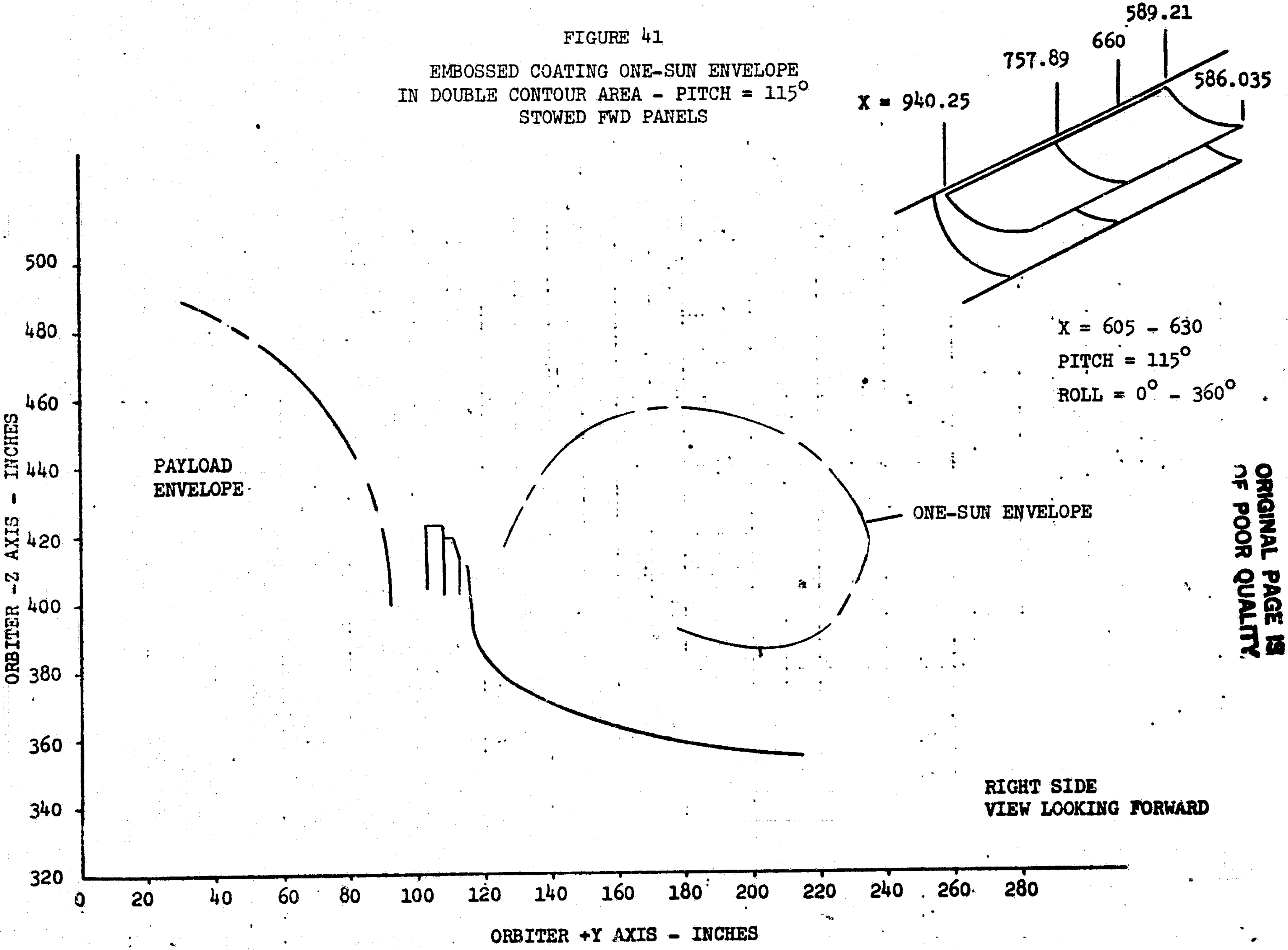

FIGURE 42

EMBOSSED COATING ONE-SUN ENVELOPE
AT PANEL FORWARD EDGE - PITCH = 115°
STOWED FWD PANELS

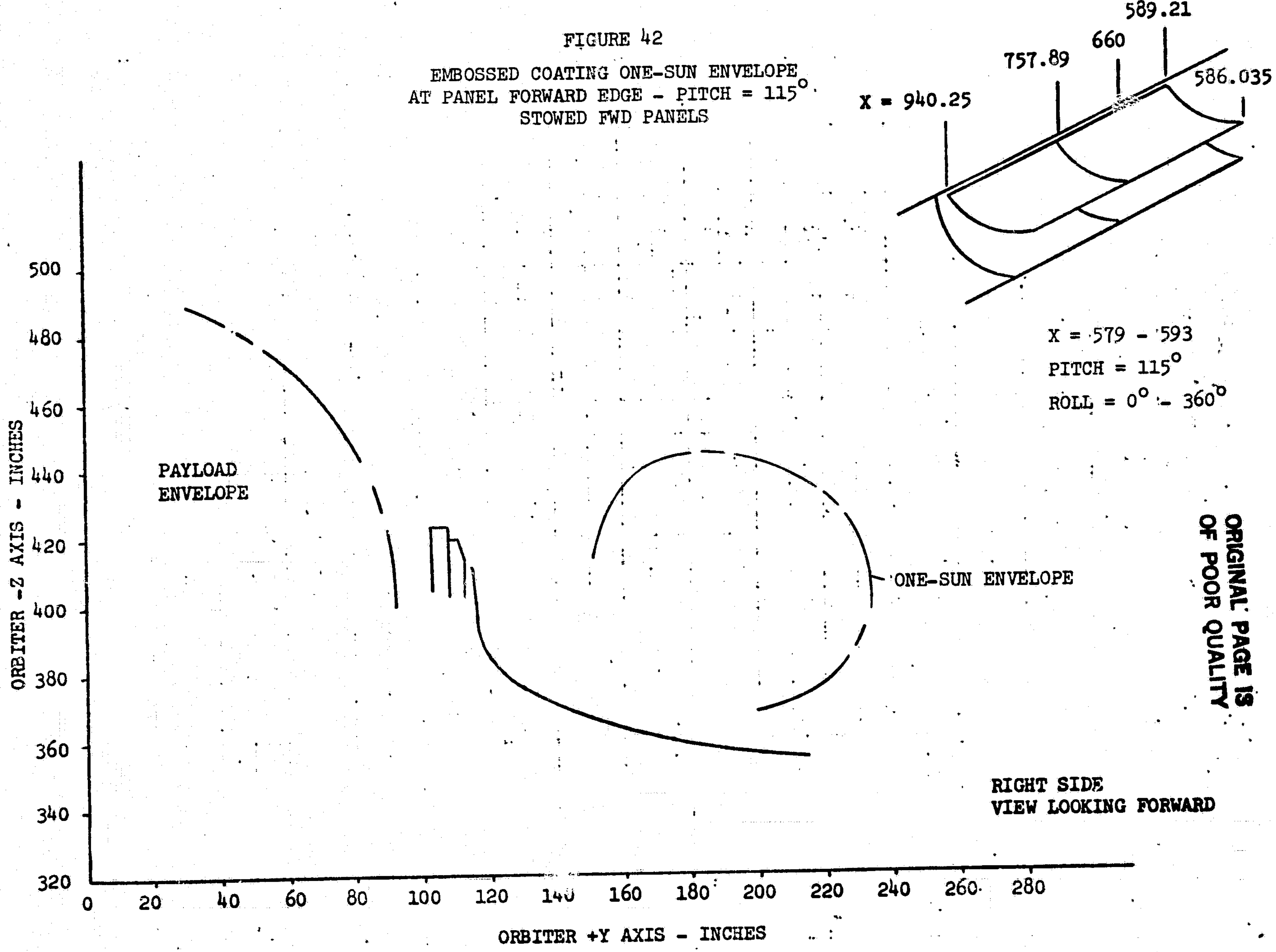

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FIGURE 43

EMBOSSED COATING ONE-SUN ENVELOPE
FORWARD OF FWD PANEL EDGE - PITCH = 115°
STOWED FWD PANELS

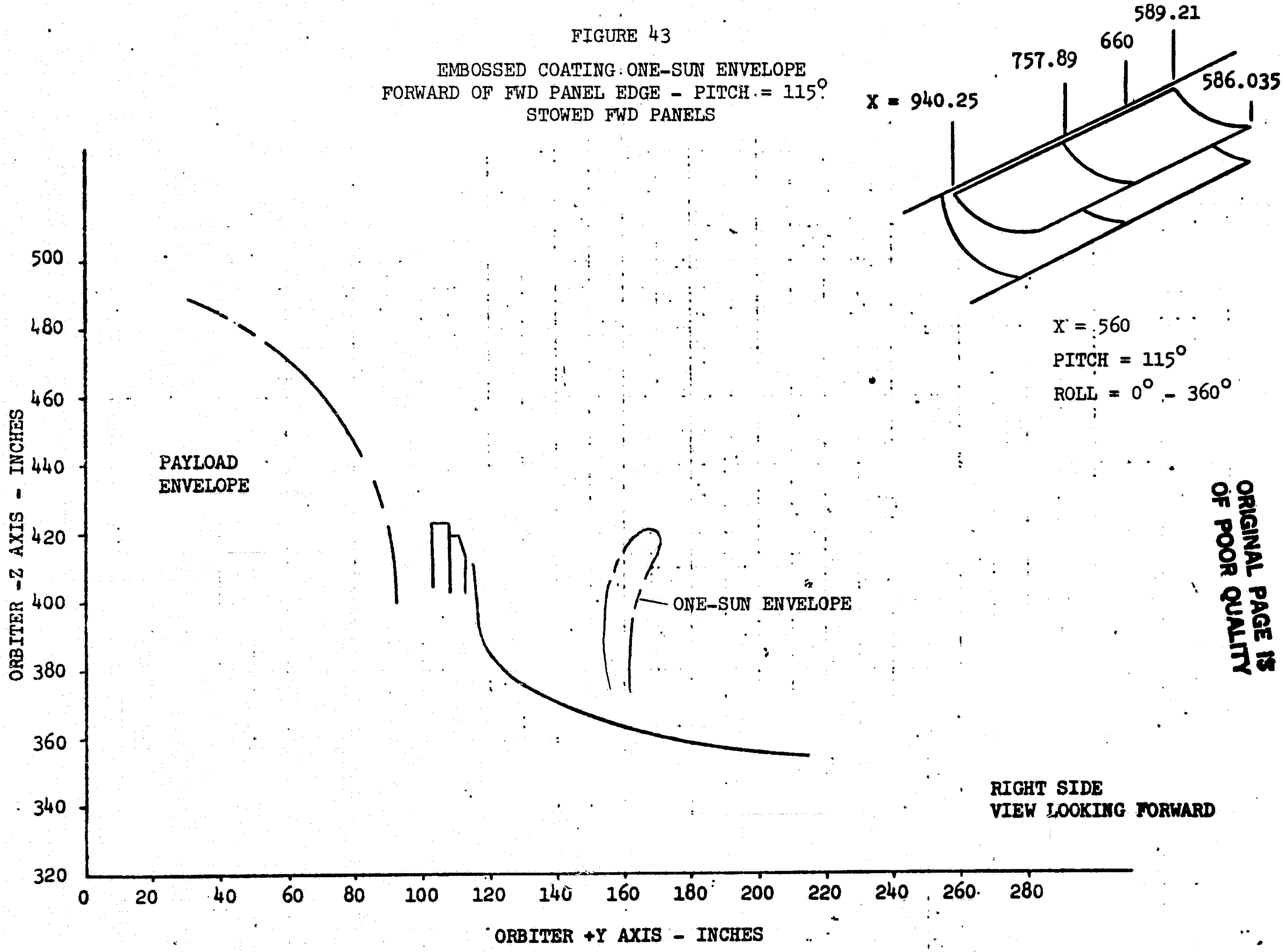

FIGURE 44

EMBOSSED COATING ONE-SUN ENVELOPE
PITCH = 140°

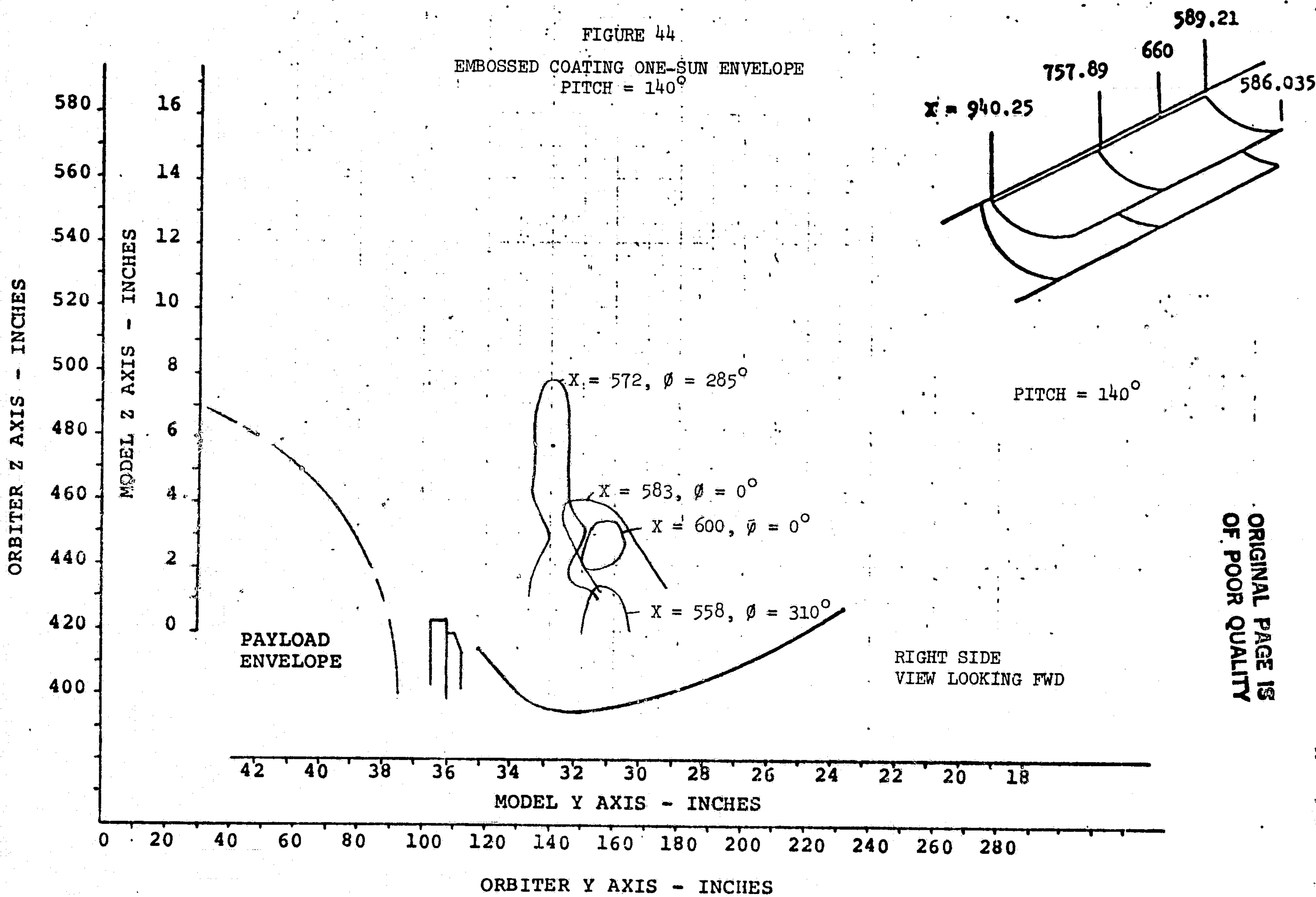

FIGURE 45

EMBOSSED COATING ONE-SUN ENVELOPE
PITCH = 140°, FWD PANELS STOWED

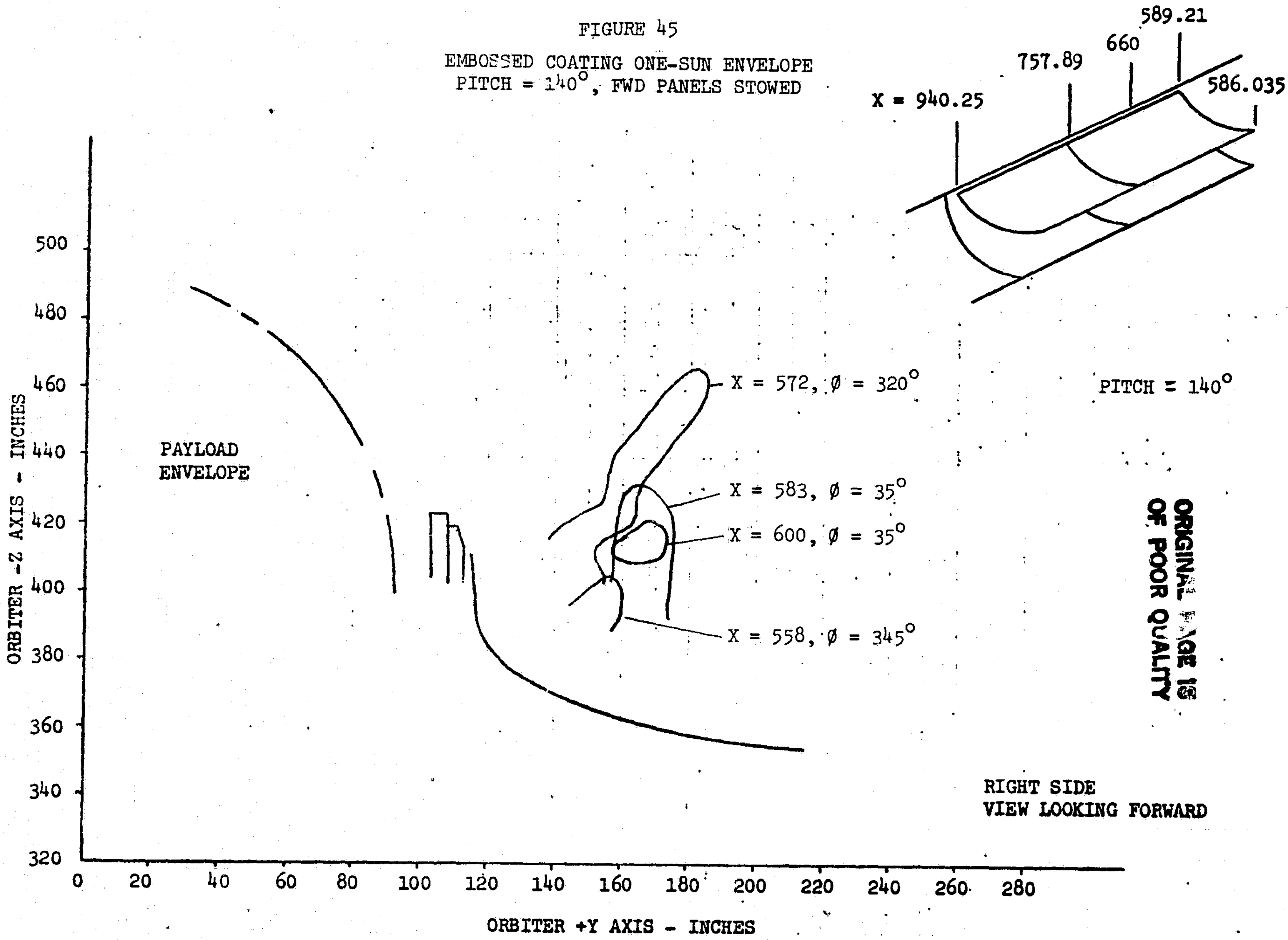

FIGURE 46

EMBOSSED COATING MAXIMUM ONE-SUN ENVELOPE IN XZ PLANE

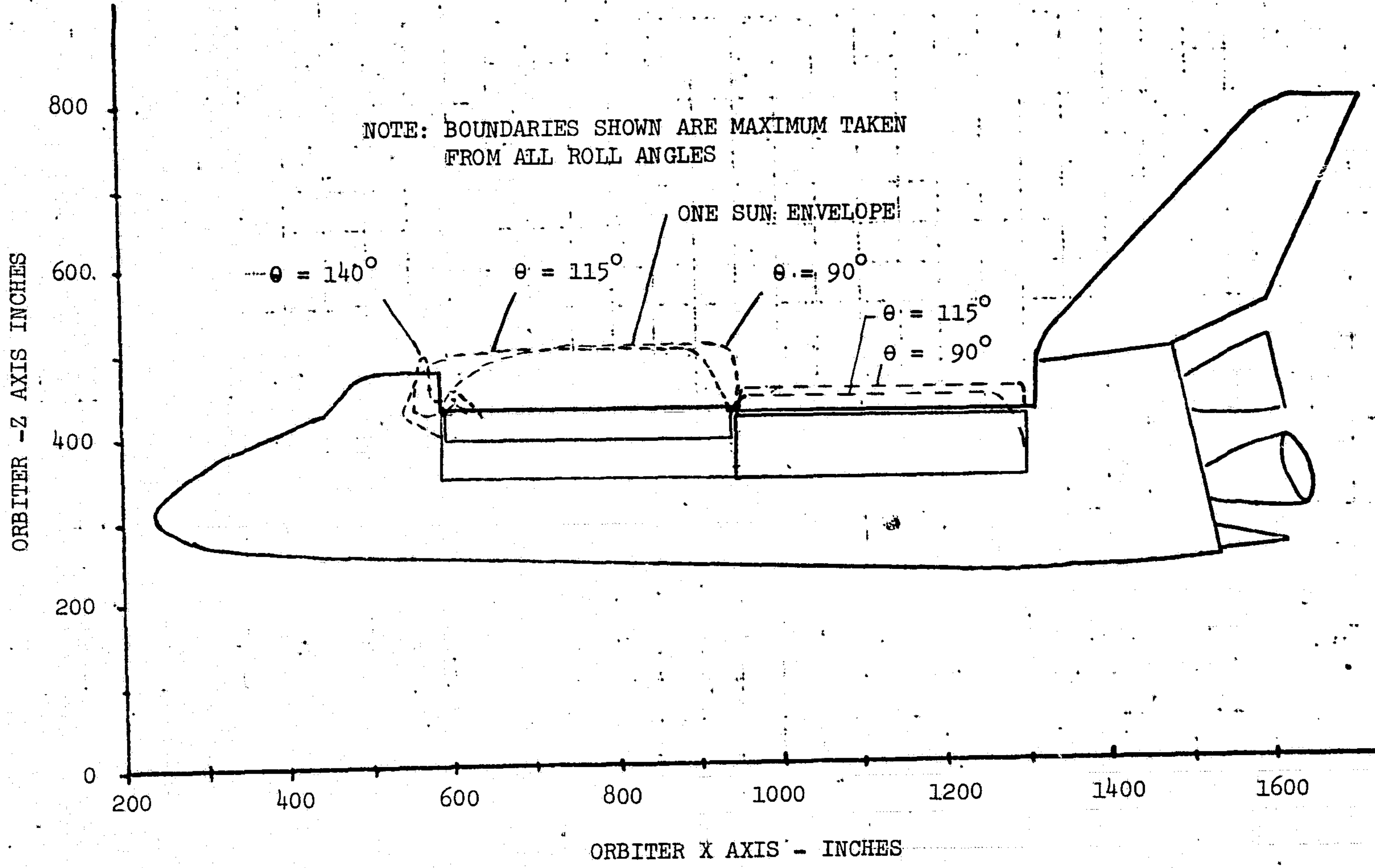

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FIGURE 47

EMBOSSED COATING MAXIMUM ONE-SUN ENVELOPE IN XZ PLANE
STOWED FWD PANELS

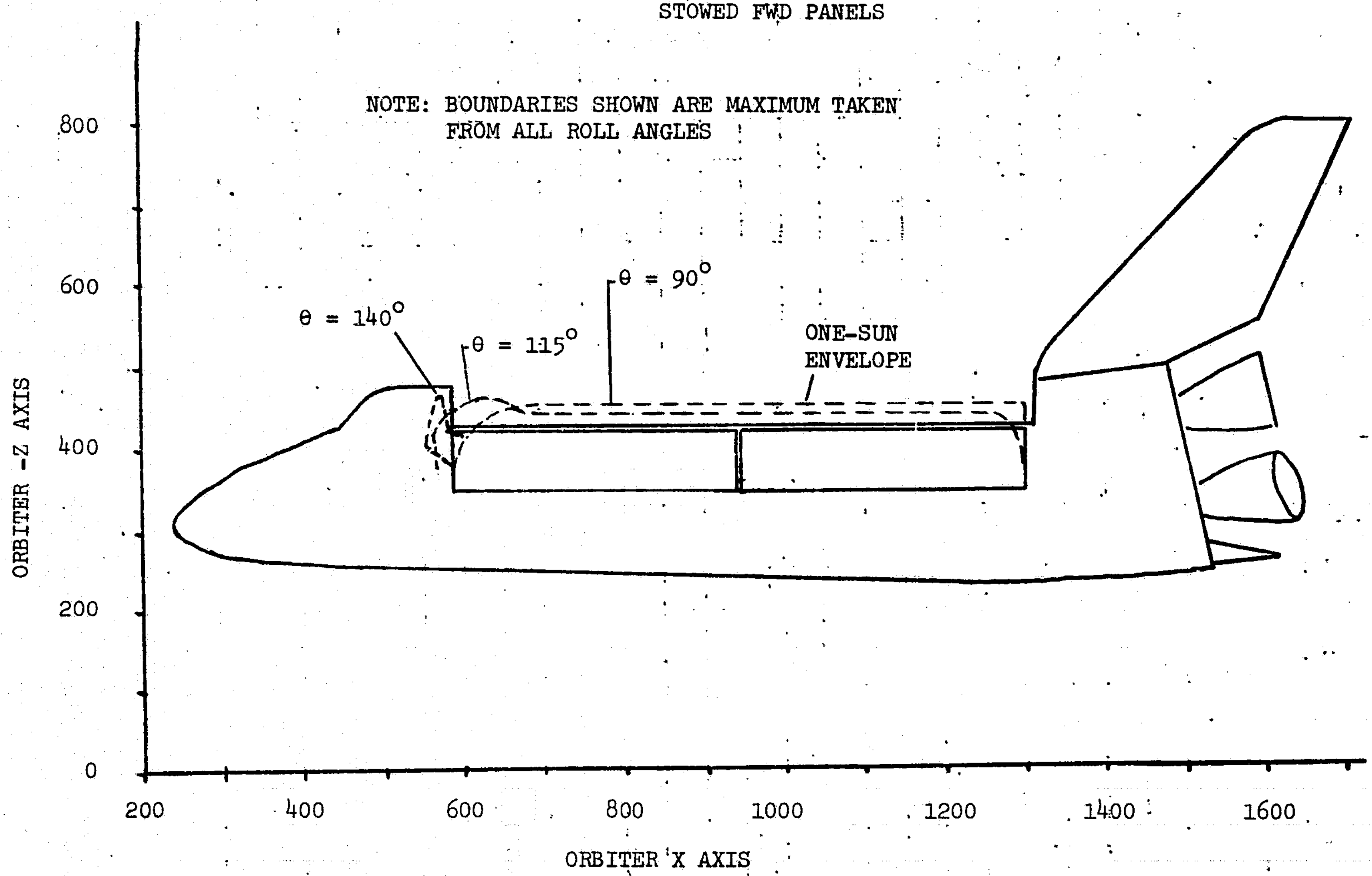

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FIGURE 48

COMPARISON OF ONE SUN ENVELOPE AT PITCH = 65° AND 115°
AFT OF DOUBLE CONTOUR REGION

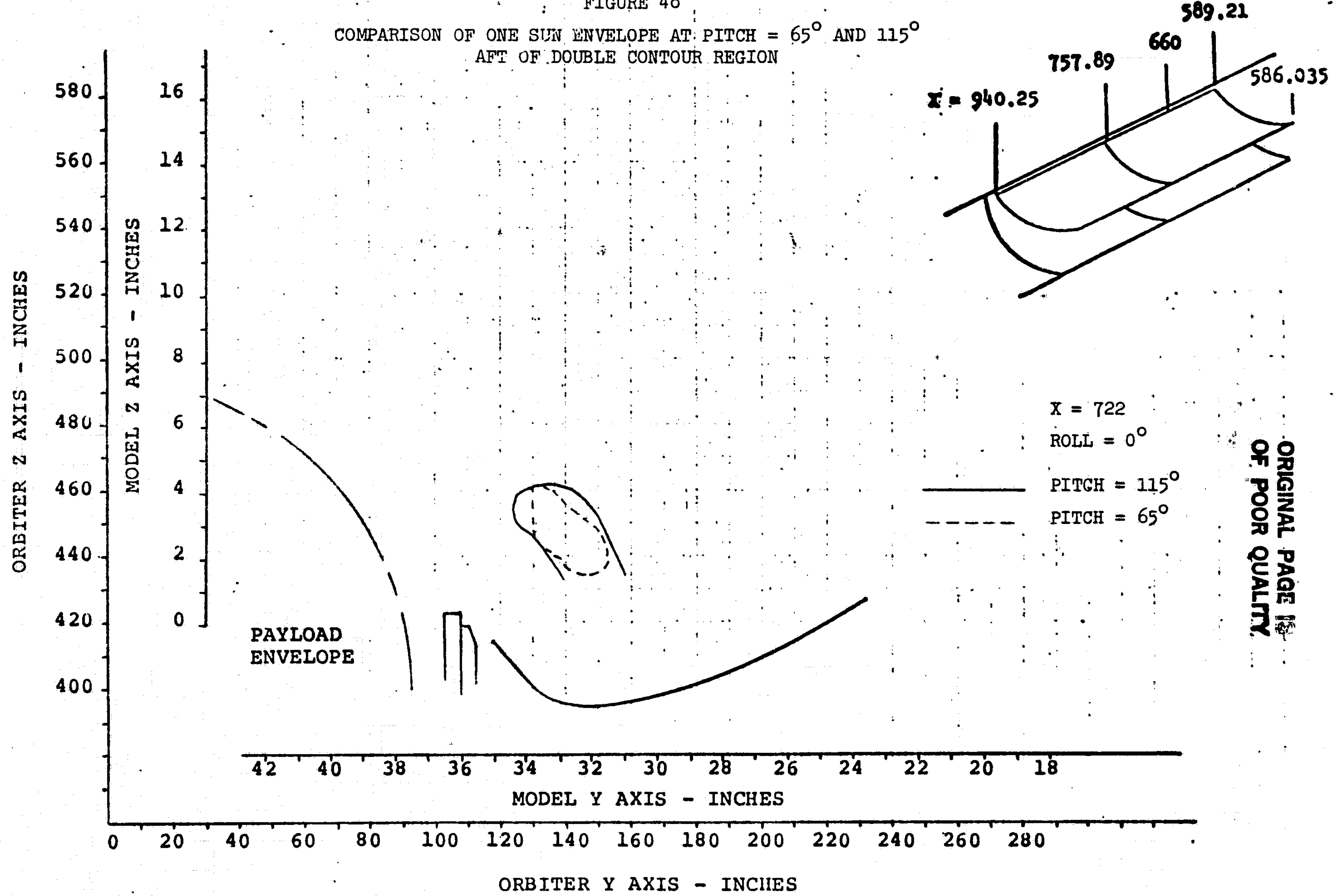

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FIGURE 49

COMPARISON OF ONE-SUN ENVELOPE AT PITCH = 65° AND 115° IN DOUBLE CONTOUR REGION

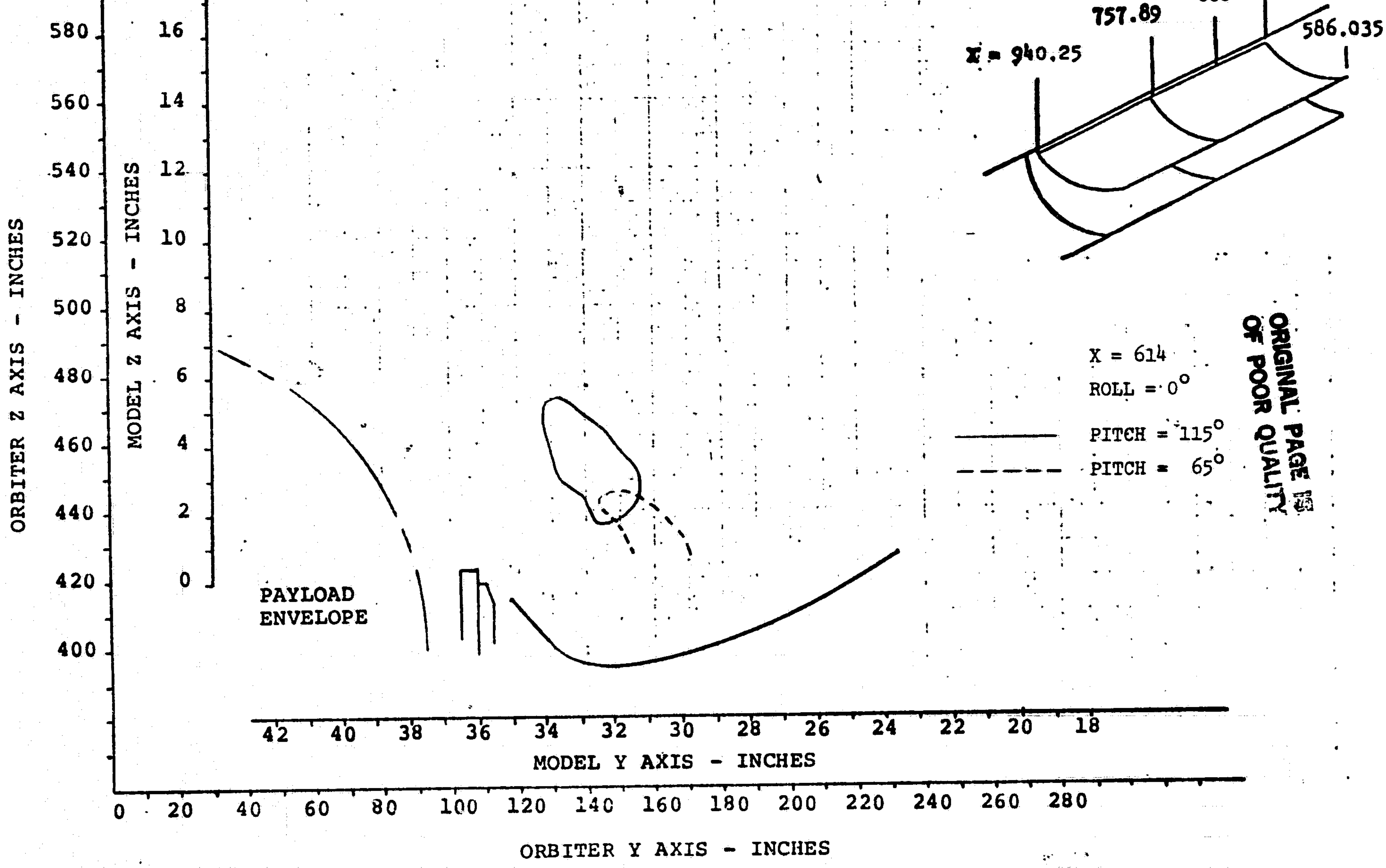

FIGURE 50
SMOOTH COATING ONE-SUN ENVELOPE
PITCH = 90°

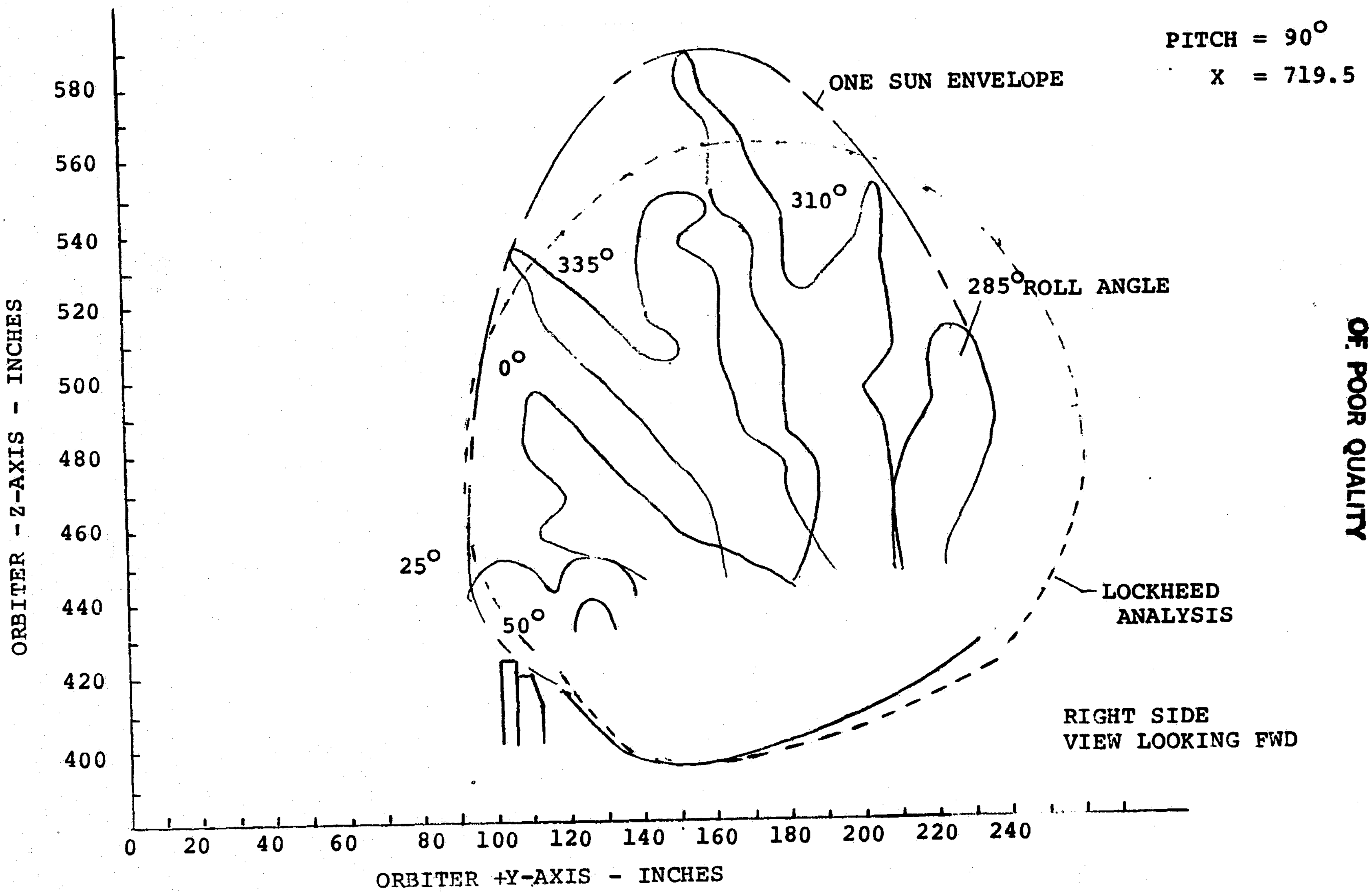

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FIGURE 51

SMOOTH COATING ONE-SUN ENVELOPE - PITCH = 90°
STOWED FORWARD PANELS AND AFT PANELS

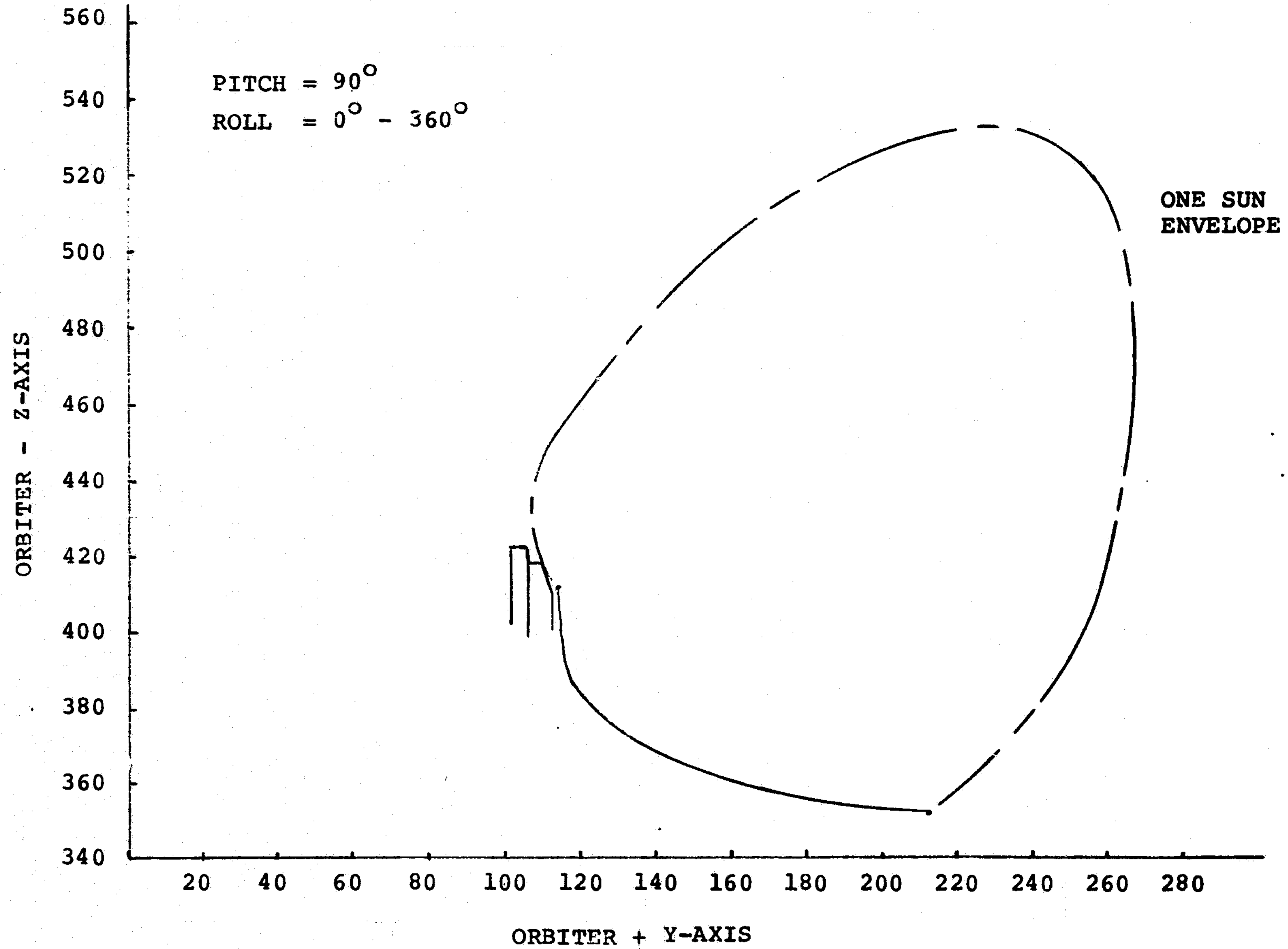

FIGURE 52

SMOOTH COATING ONE SUN ENVELOPE IN ZX PLANE
PITCH = 90°

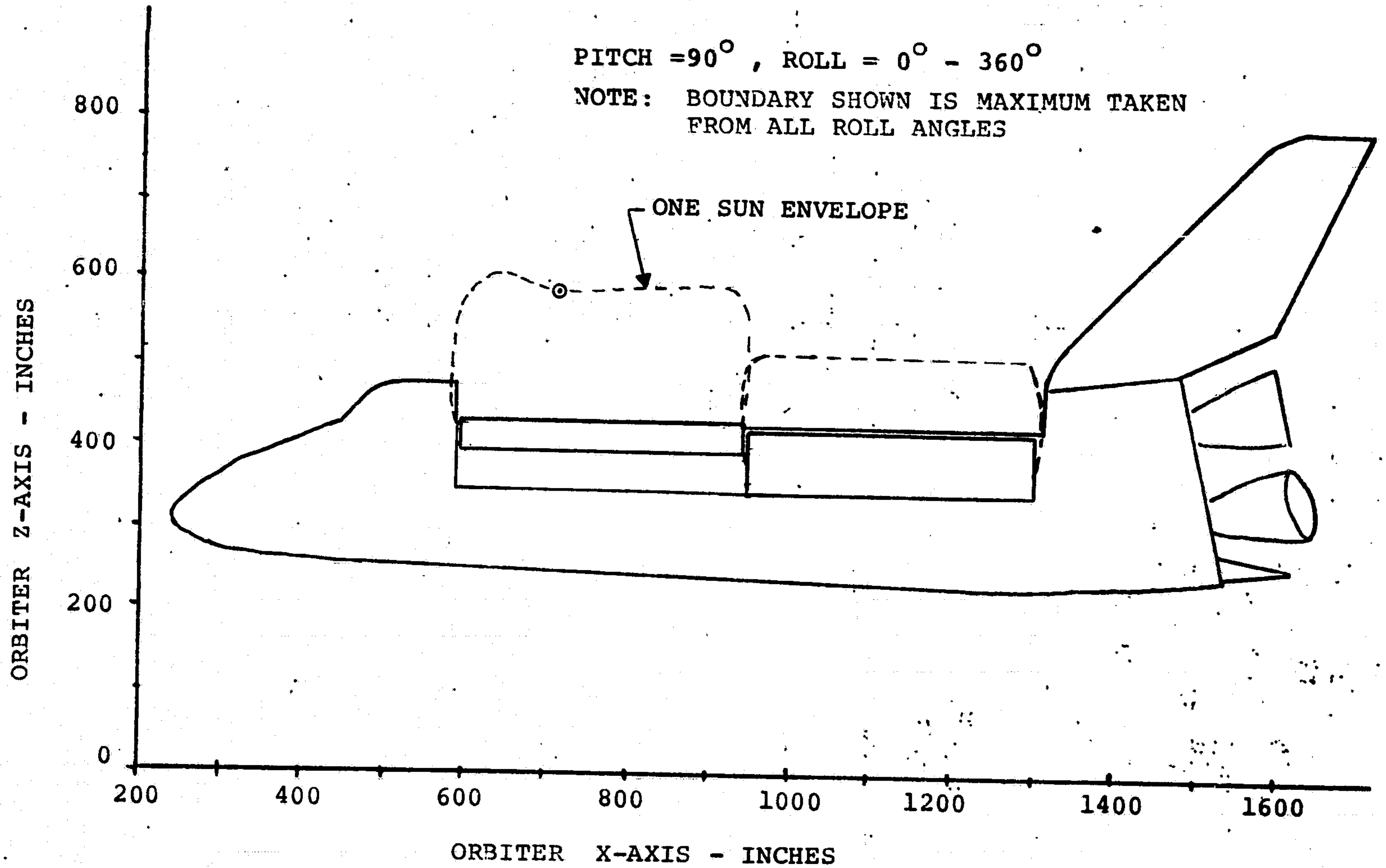

FIGURE 53

REFLECTED SOLAR FLUX NEAR
RADIATOR/DOOR GAP - SMOOTH COATING

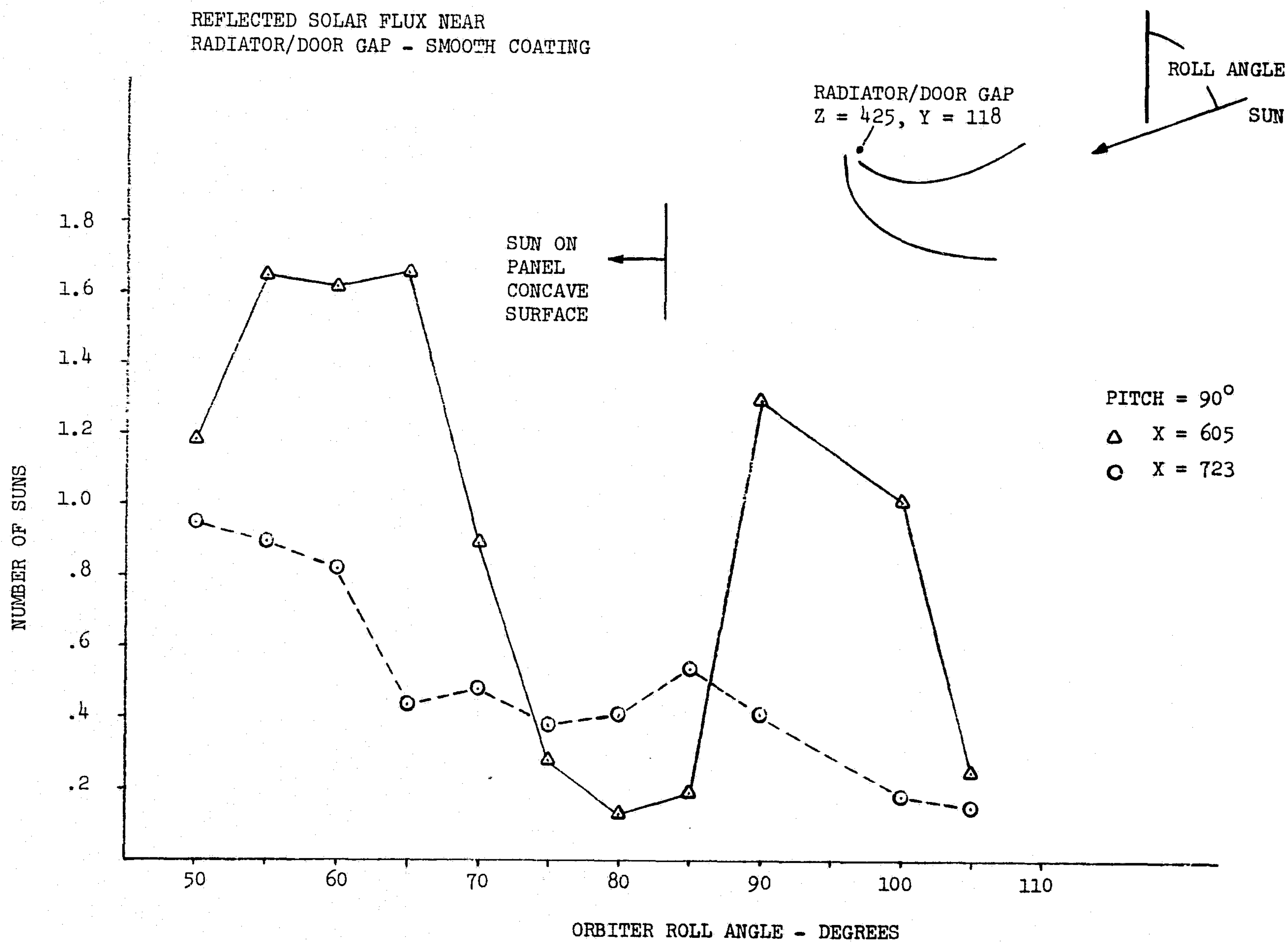

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FIGURE 54

SMOOTH COATING ONE SUN ENVELOPE - PITCH = 115°, ROLL = 0°

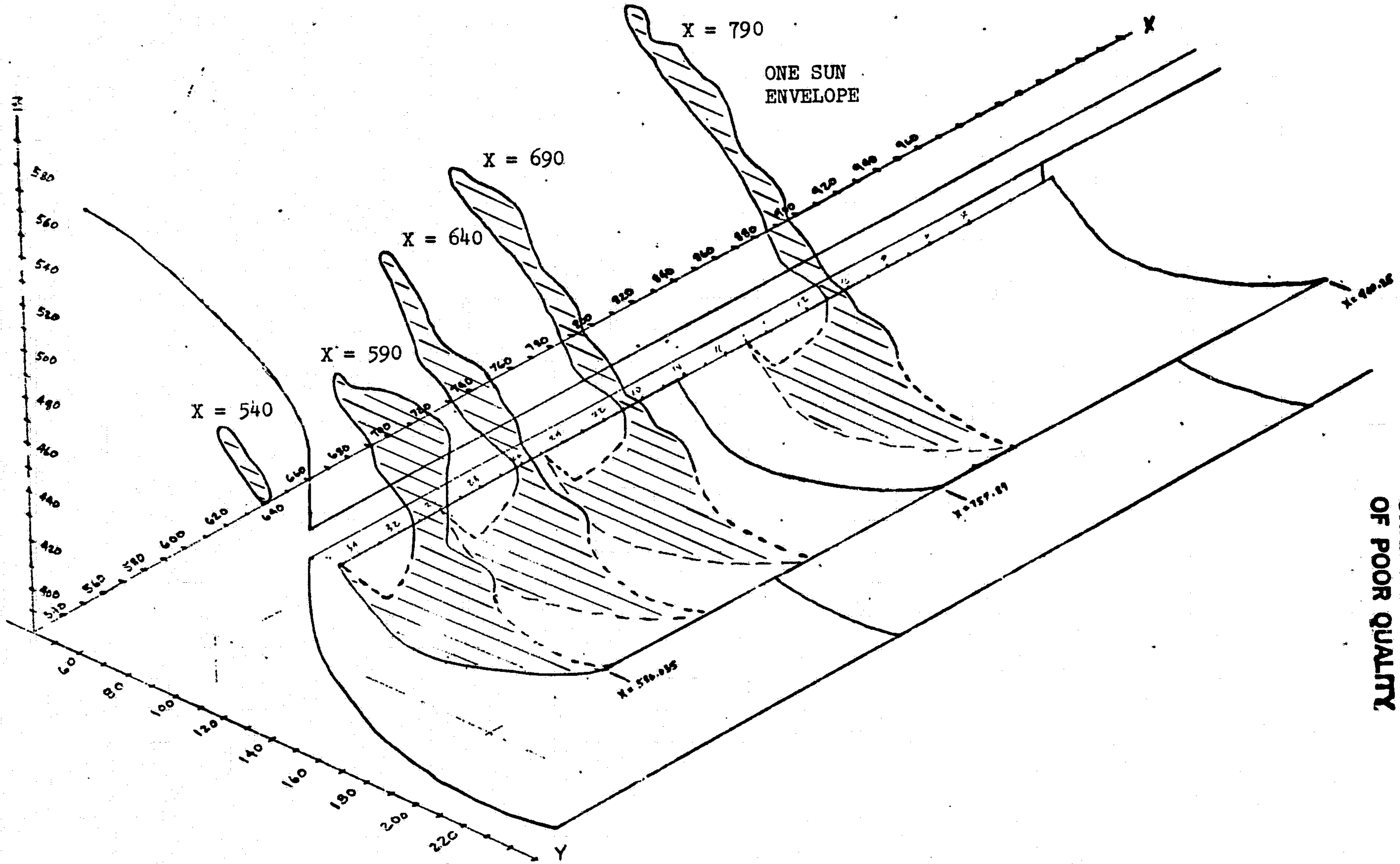


FIGURE 55

SMOOTH COATING ONE SUN ENVELOPE - PITCH = 115°, ROLL = 335°

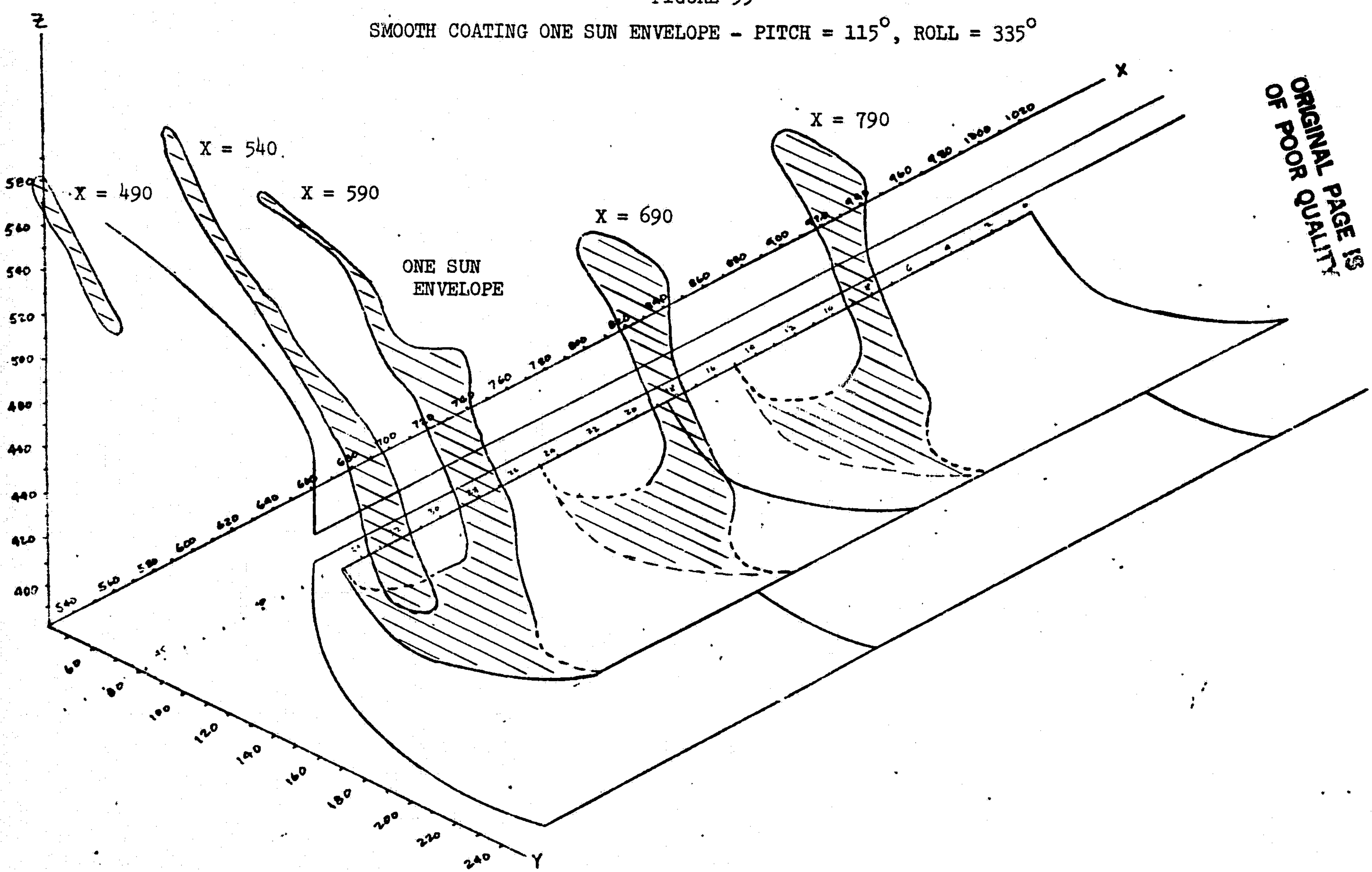


FIGURE 56

ONE SUN ENVELOPE IN ZX PLANE

PITCH =115°

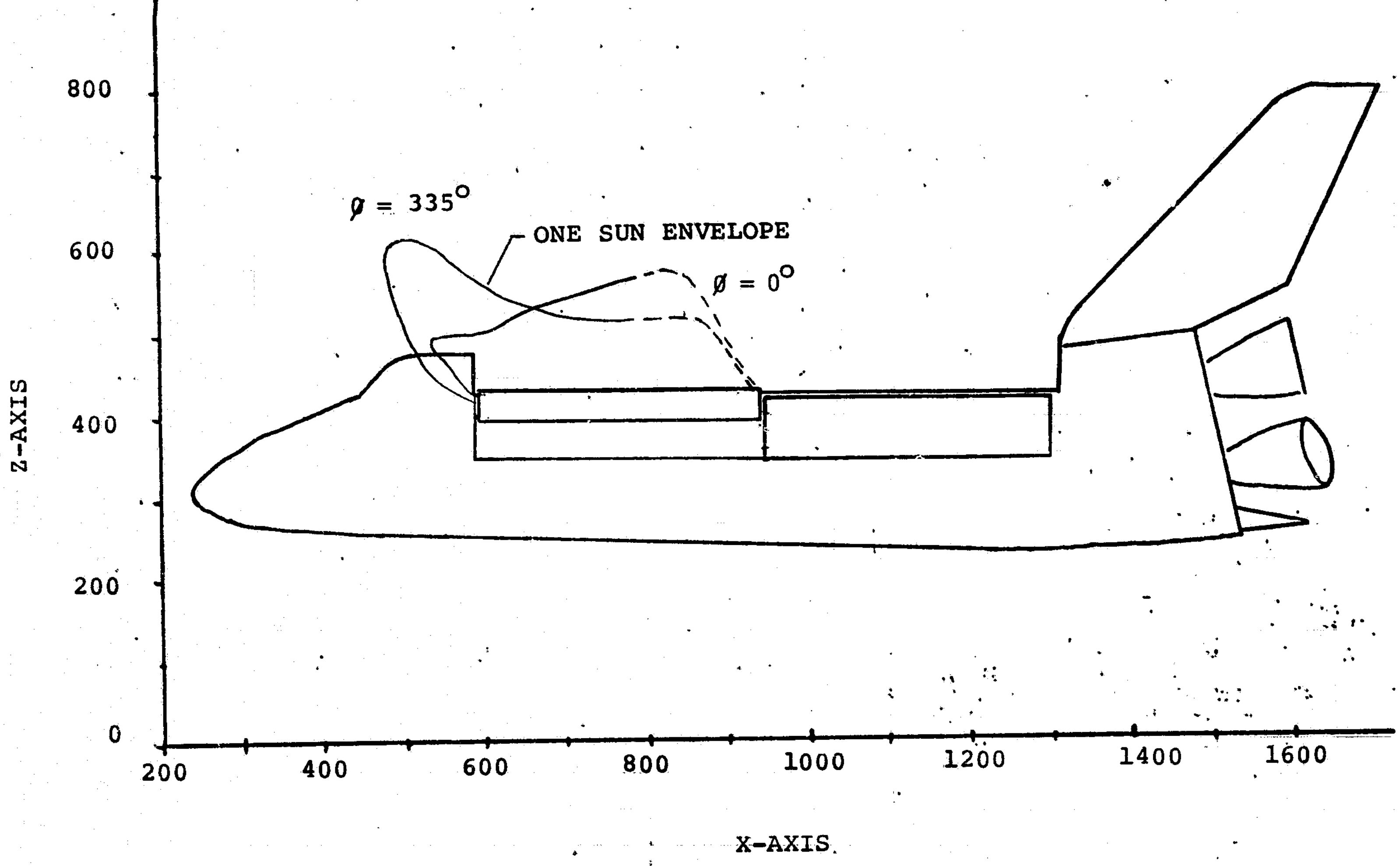
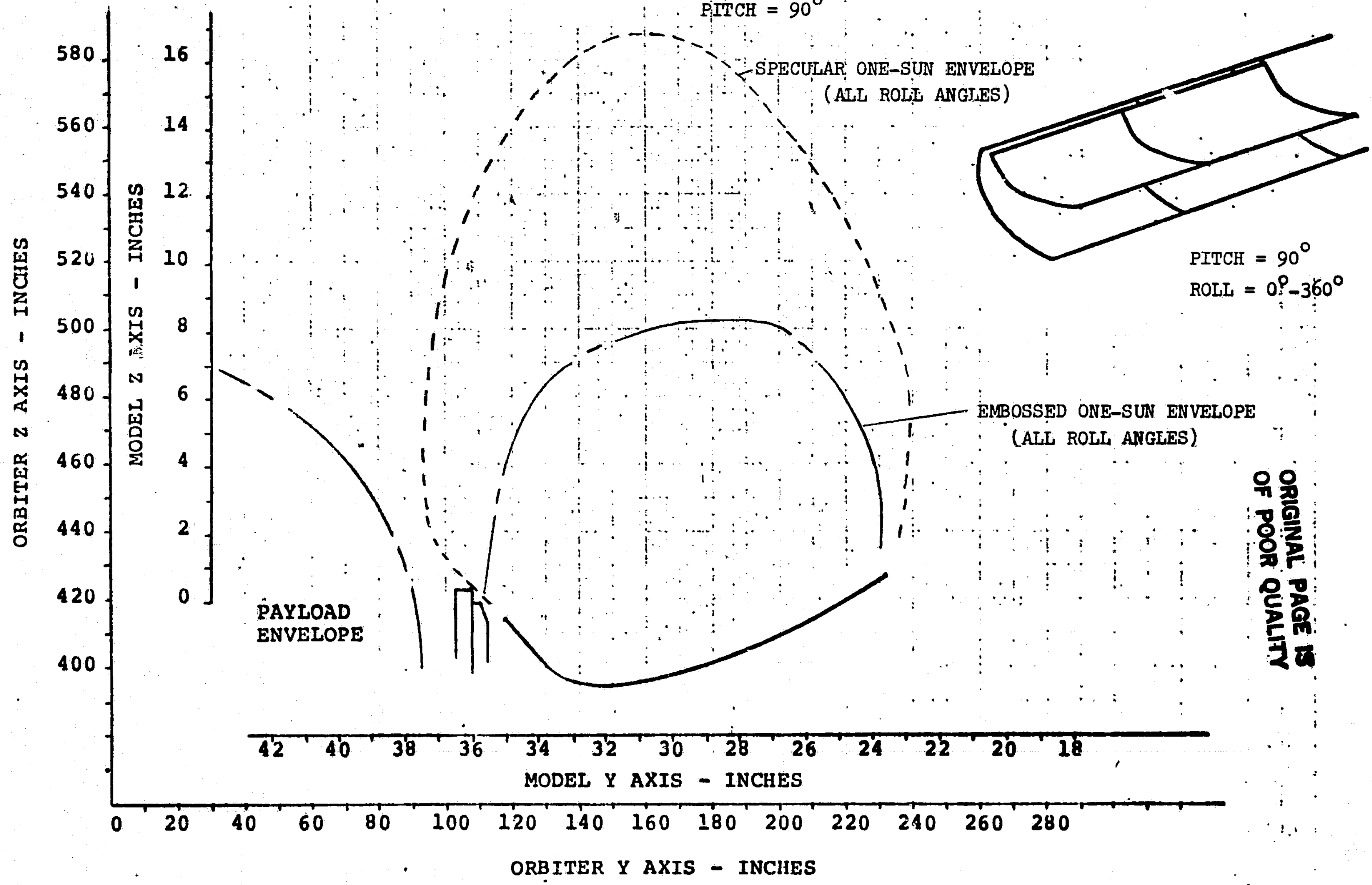


FIGURE 57

COMPARISON OF SMOOTH AND EMBOSSED ONE-SUN ENVELOPE
PITCH = 90°



APPENDIX A

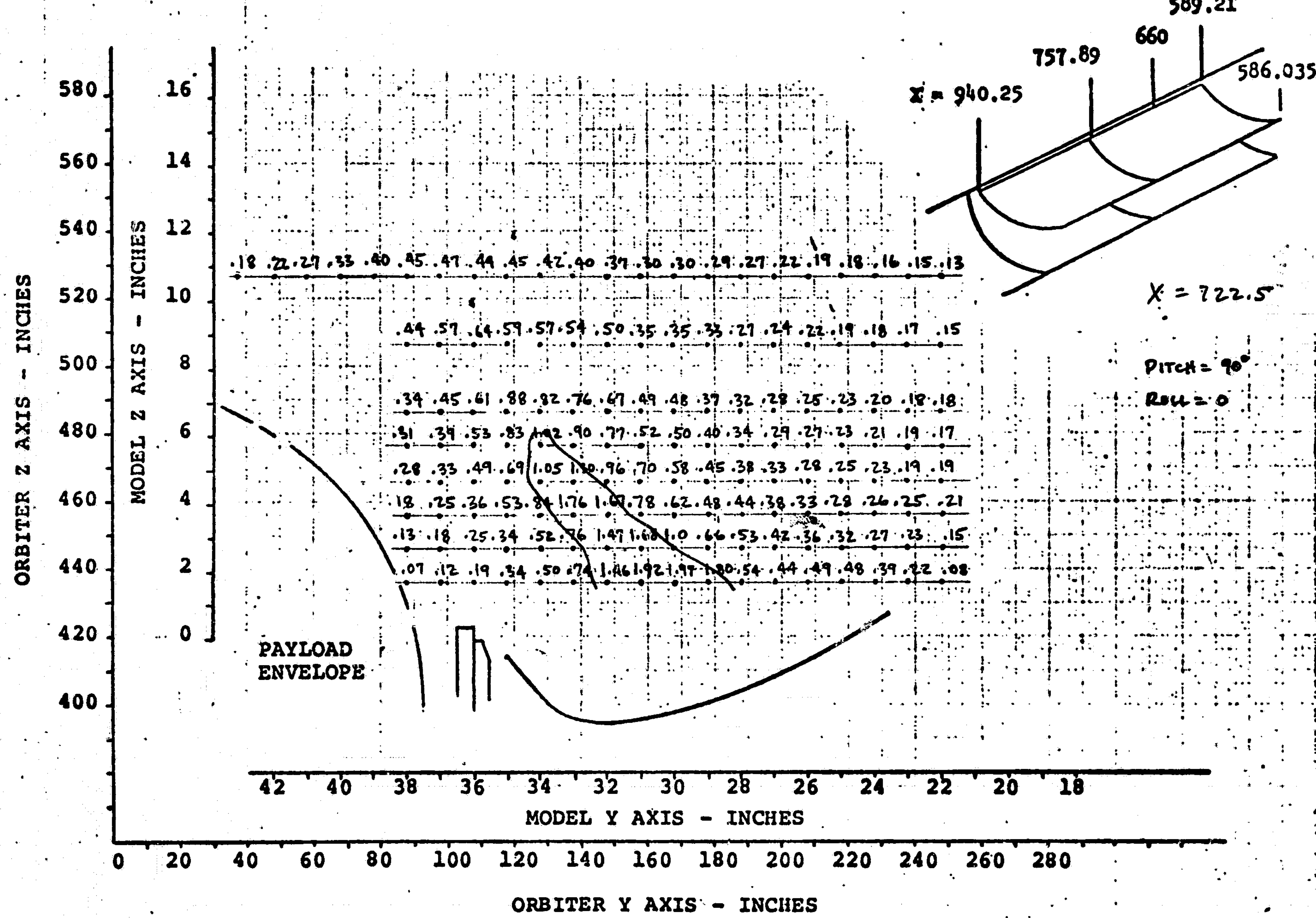
EMBOSSED SILVER/TEFLON TEST DATA

(See Page A-2 for Index to Data Plots)

TABLE A-1 INDEX TO PAGE NUMBERS FOR TEST DATA PLOTS

Pitch Angle	Roll Angle	X AXIS LOCATION			
		Aft of Double Contour	Double Contour Area	Fwd Edge of Panel	Fwd of Fwd Edge
90	0	A-3	A-4, A-5	A-6	
	25	A-7			
	50	A-8			
	75	A-9			
	80	A-10			
	85	A-11			
	90	A-12			
	95	A-13			
	100	A-14			
	105	A-15			
	110	A-16			
	285	A-17			
	310	A-18			
	335	A-19			
115	0	A-20	A-21	A-22	A-23
	25	A-24	A-25	A-26	A-27, A-28
	50	A-29	A-30	A-31	A-32 - A-35
	75	A-36			A-37
	285	A-38	A-39		A-40
	310	A-41	A-42	A-43	A-44
	335	A-45	A-46	A-47	A-48
140	0	A-49	A-50	A-51	A-52
	25	A-53		A-54	A-52 - A-59
	50	A-60	A-61		A-62 - A-66
	75	A-67	A-68		A-69 - A-71
	285	A-72	A-63		A-74, A-75
	310	A-76	A-77		A-78, A-79
	335	A-80	A-81	A-82	A-83, A-84
165	0	A-85			
65	0	A-86	A-87, A-88		A-89

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



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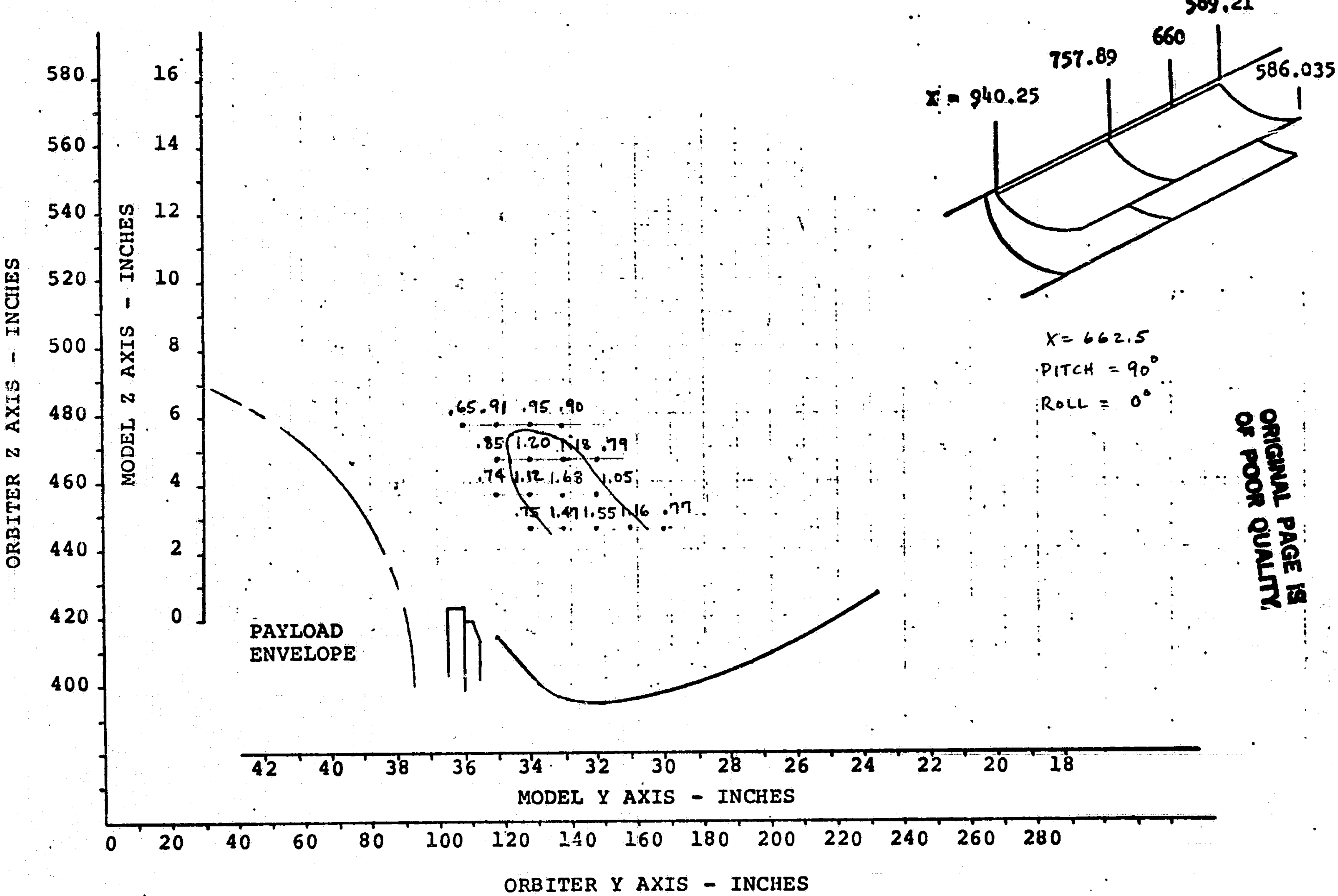
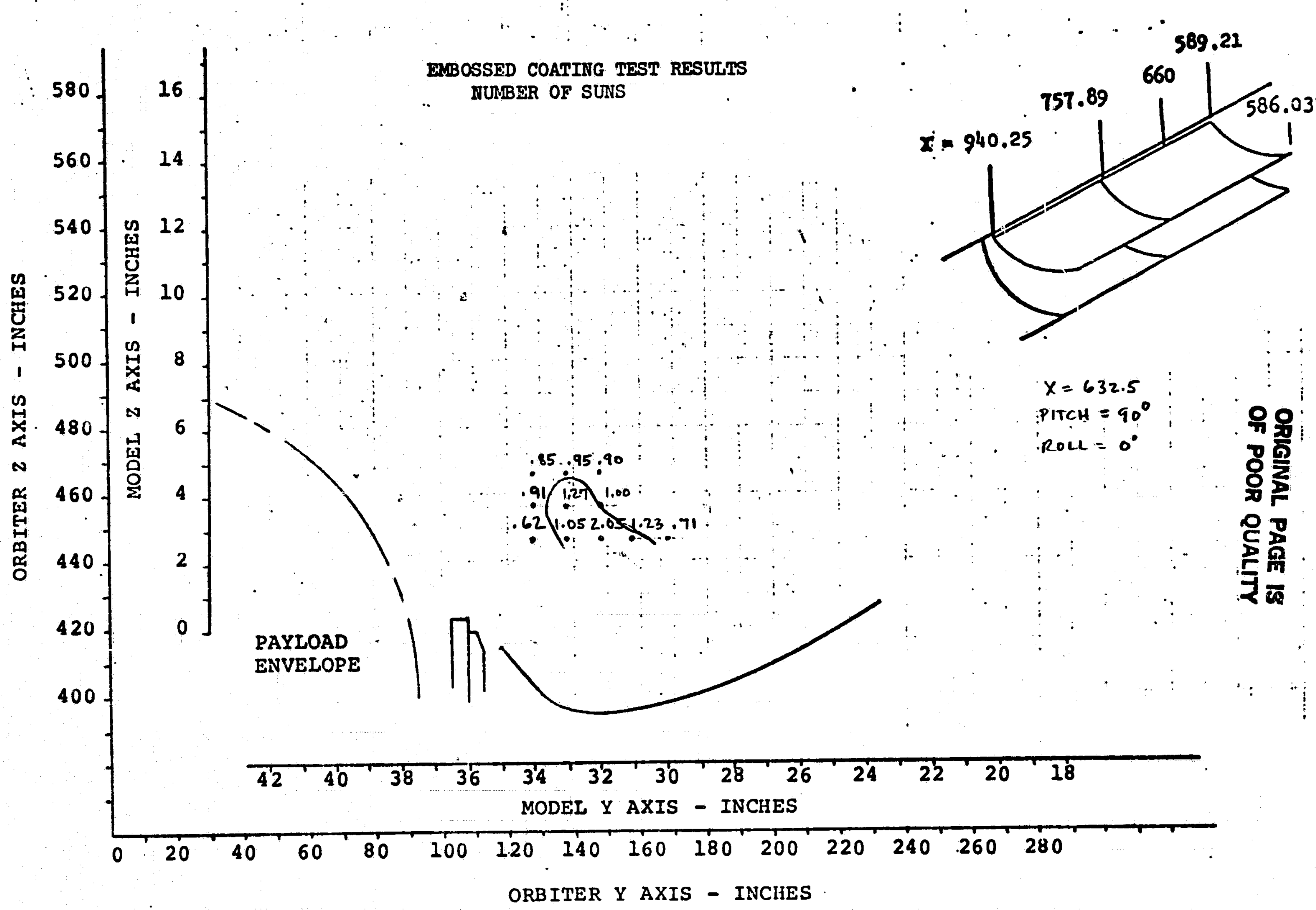
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





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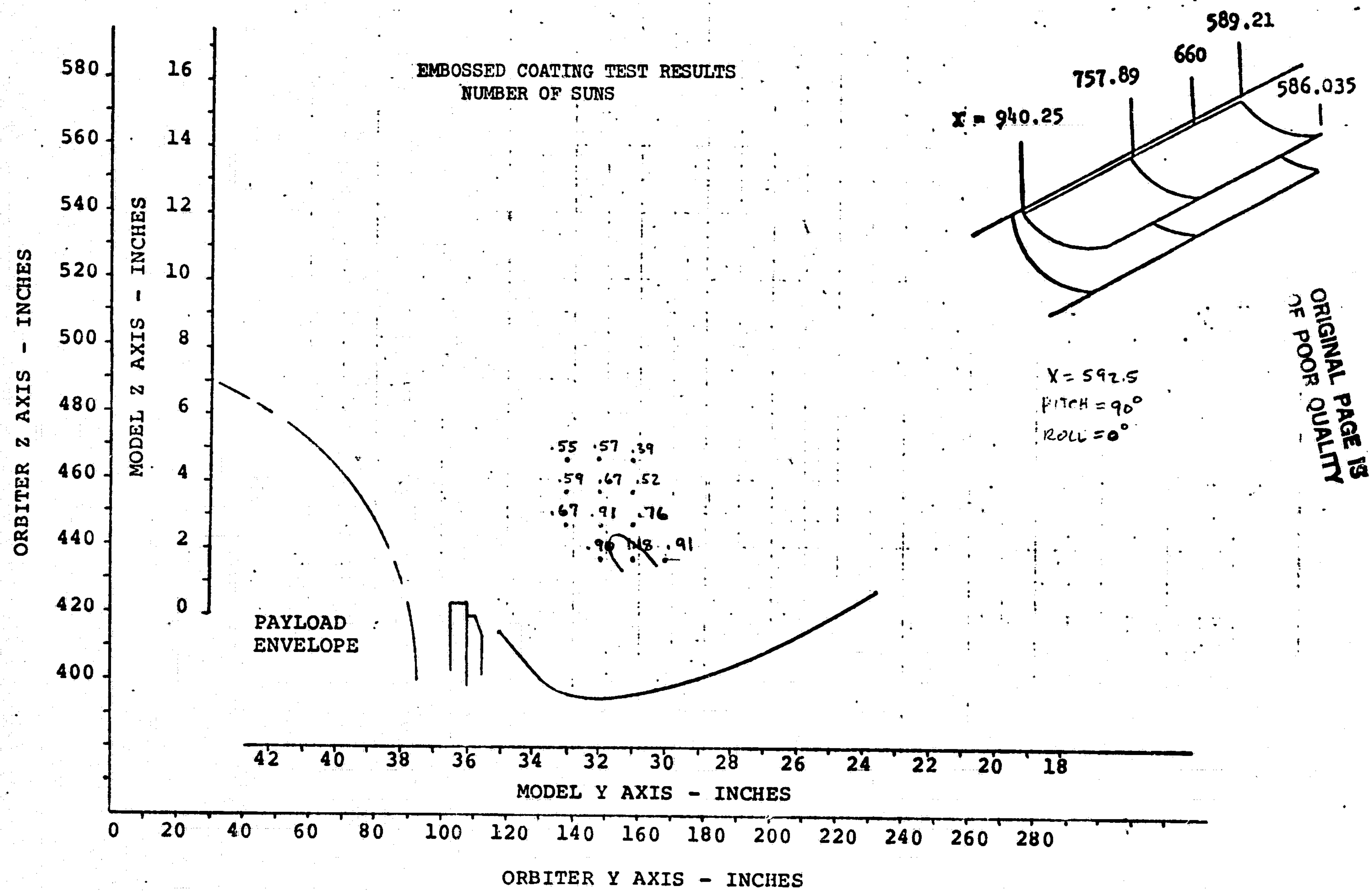
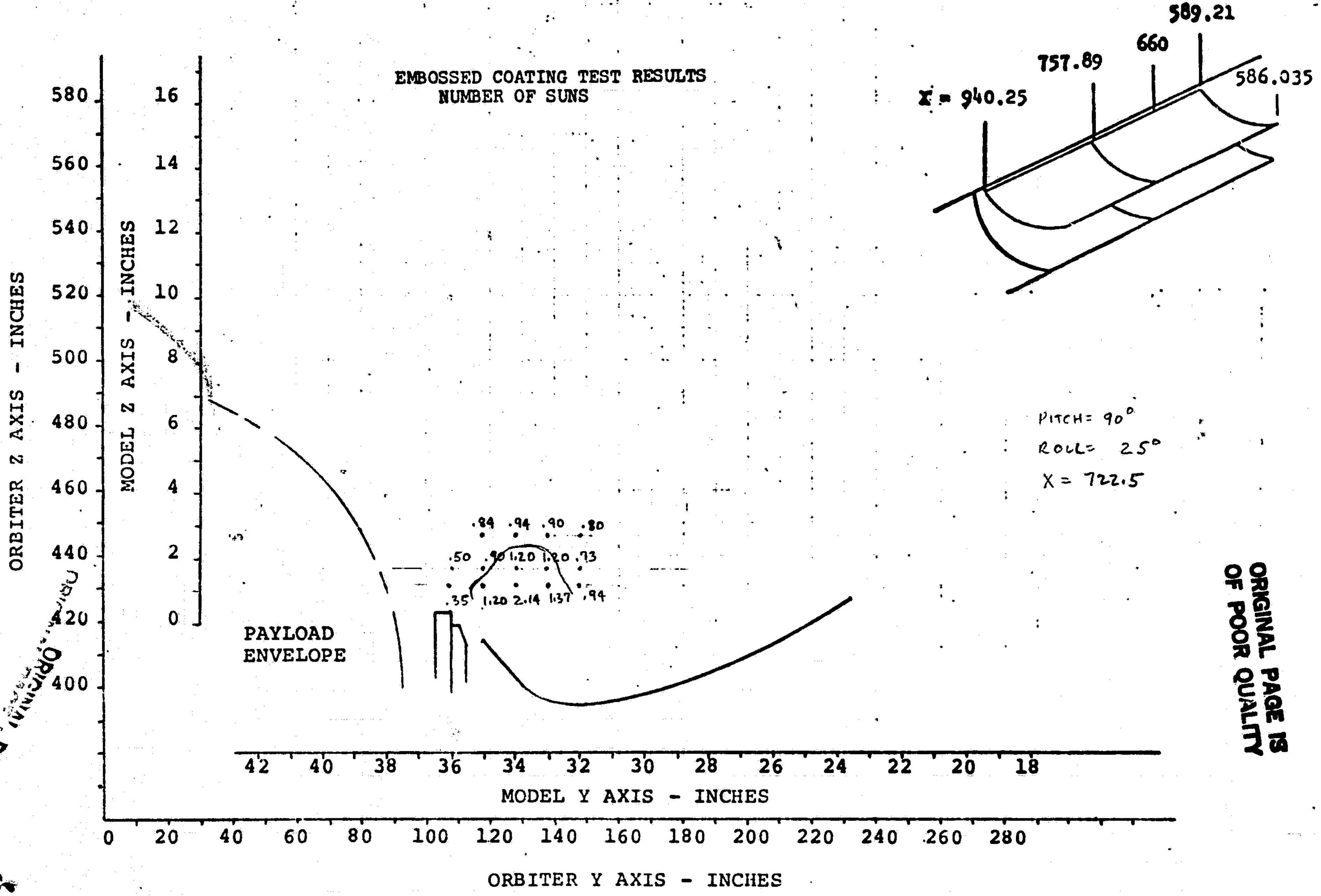

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
X = 592.5
PITCH = 90°
ROLL = 0°
.55 .57 .39
.59 .67 .52
.67 .91 .76
.96 1.18 .91
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES



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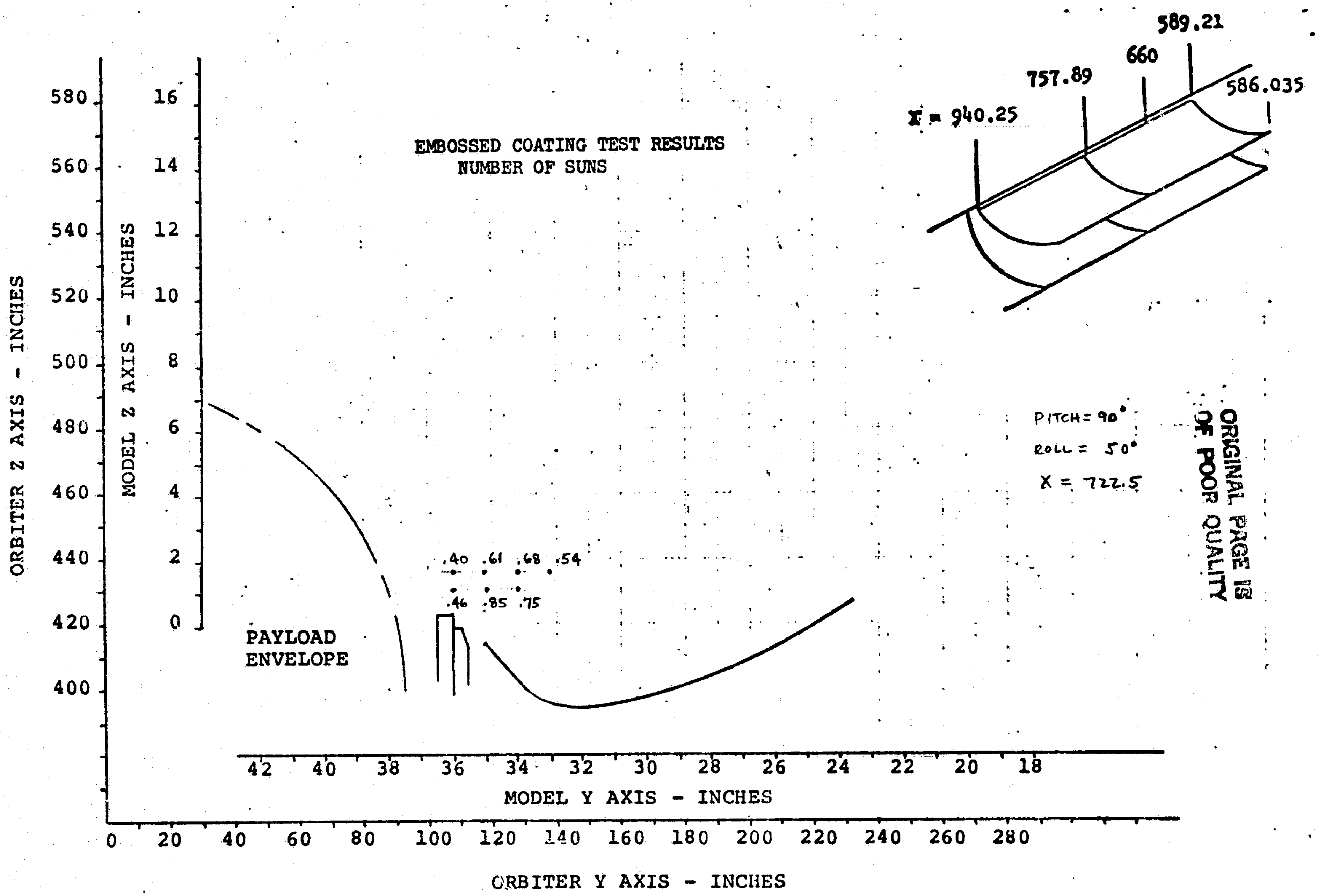

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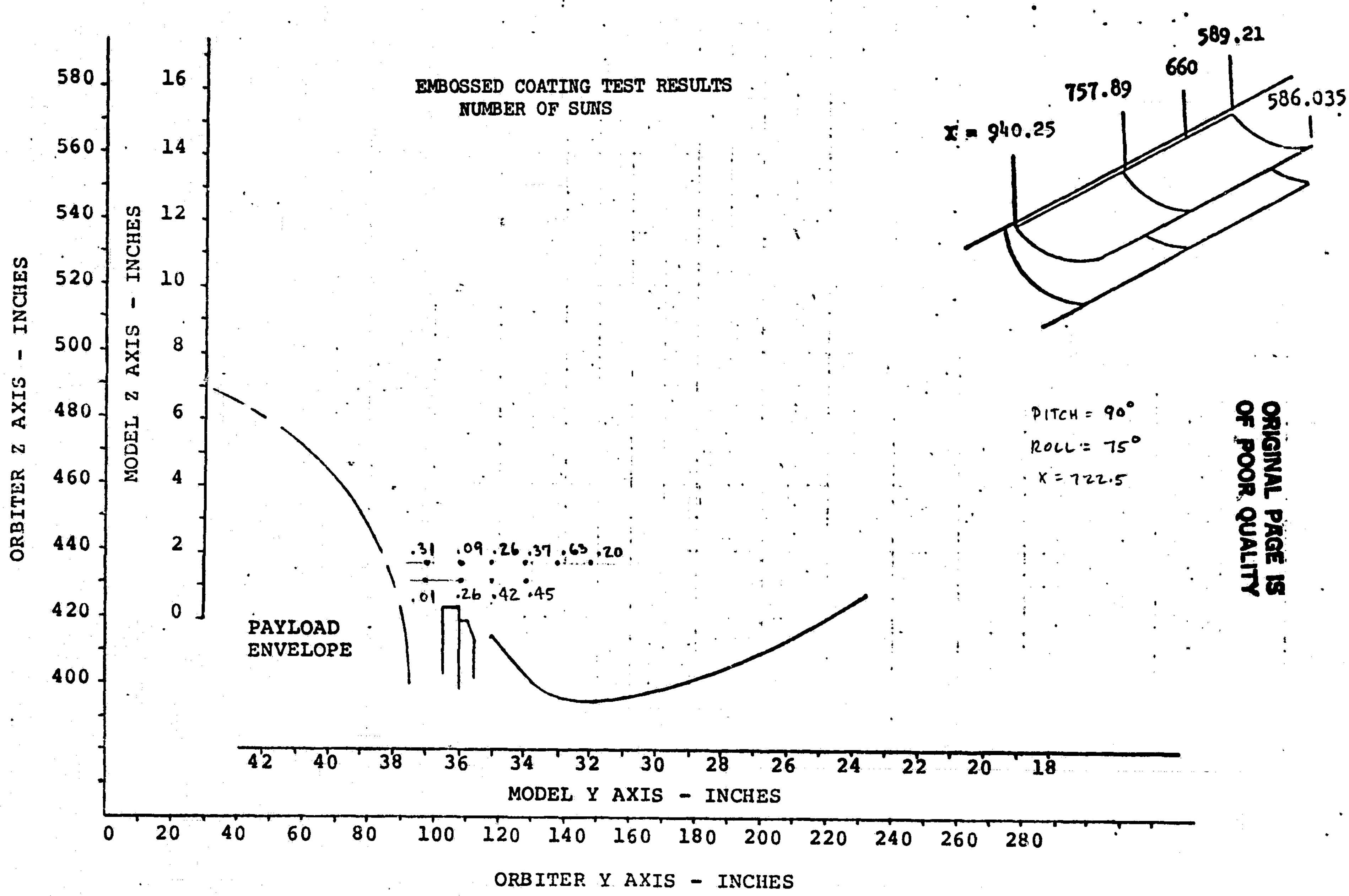

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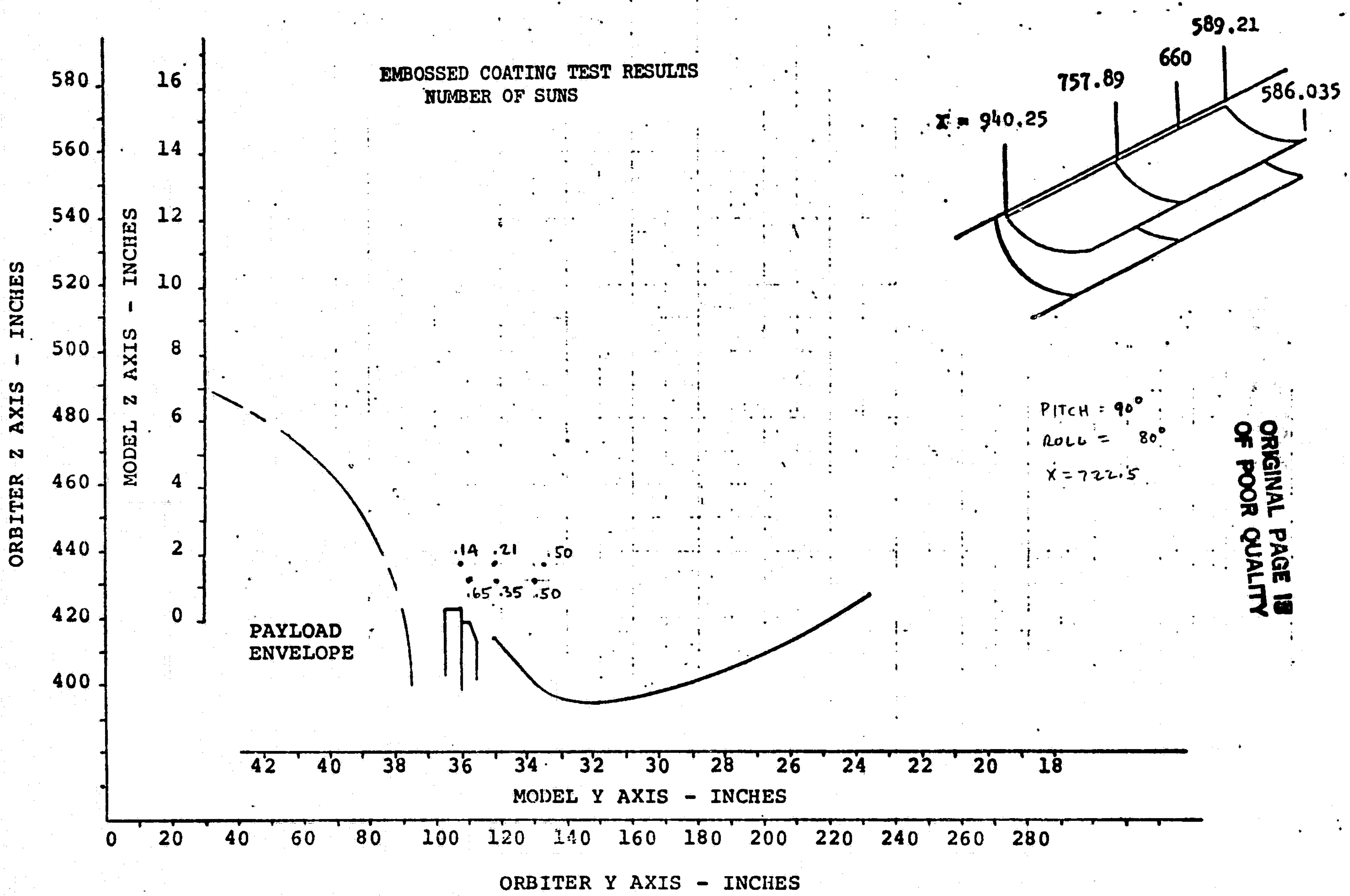
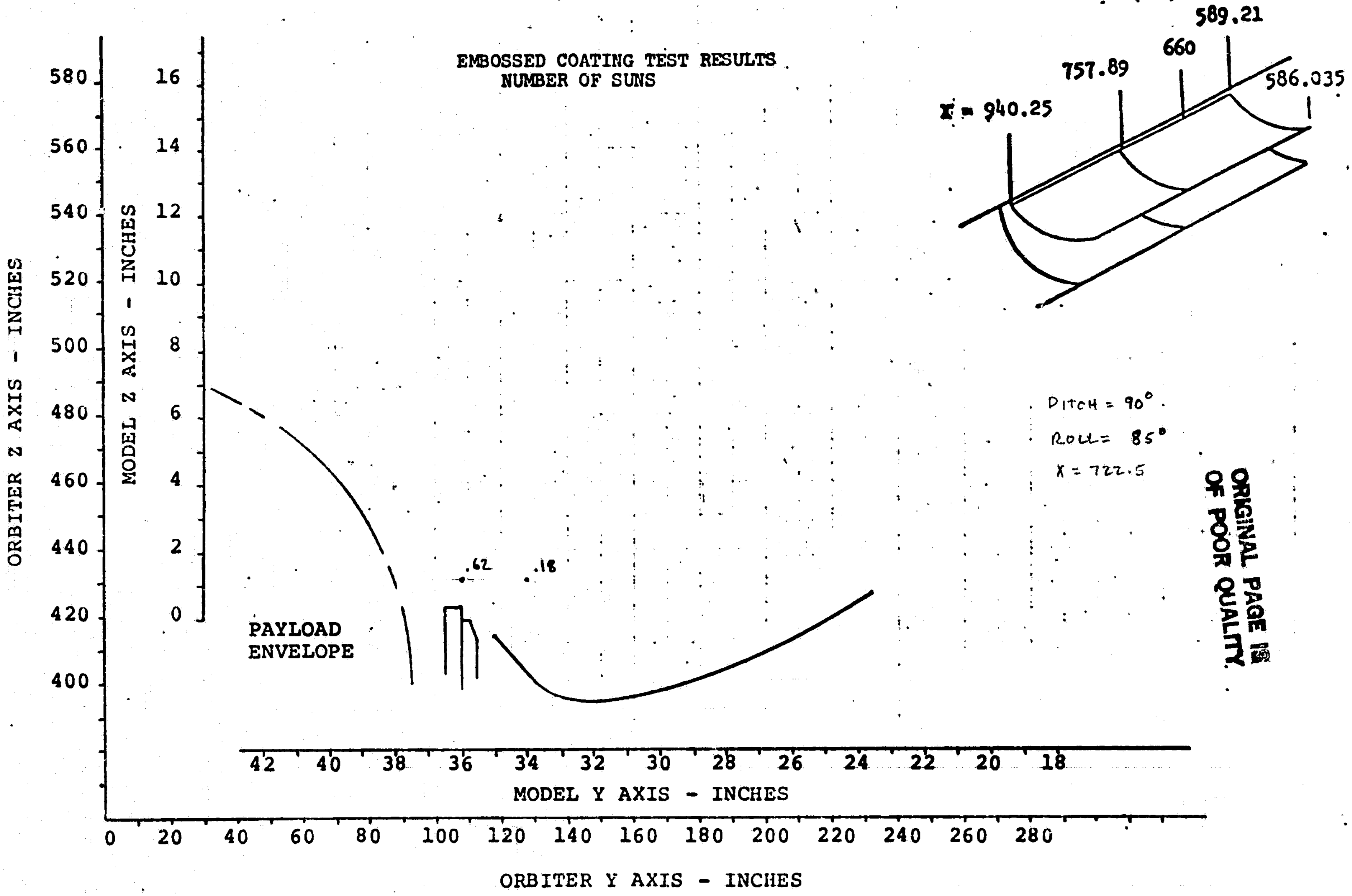
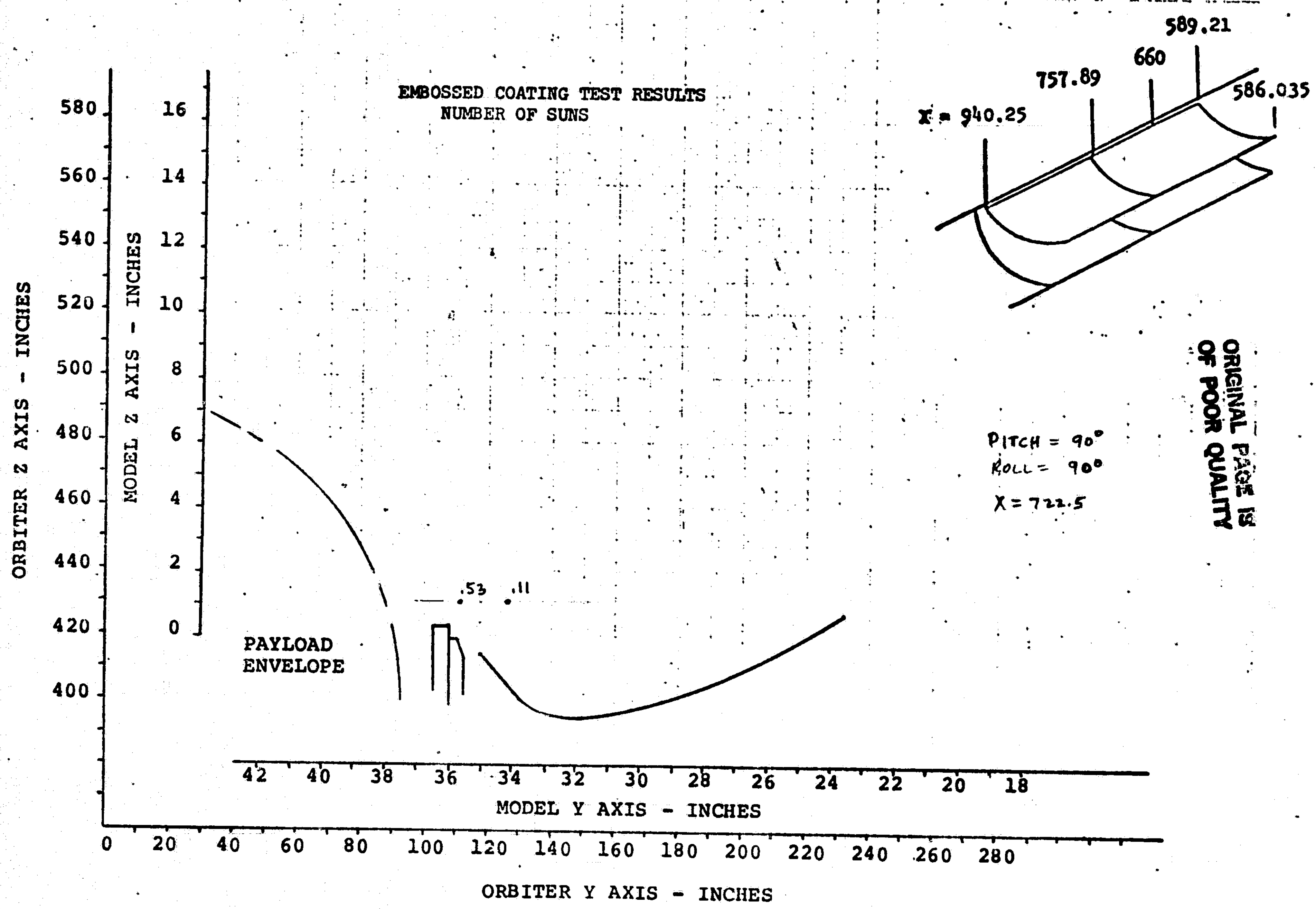
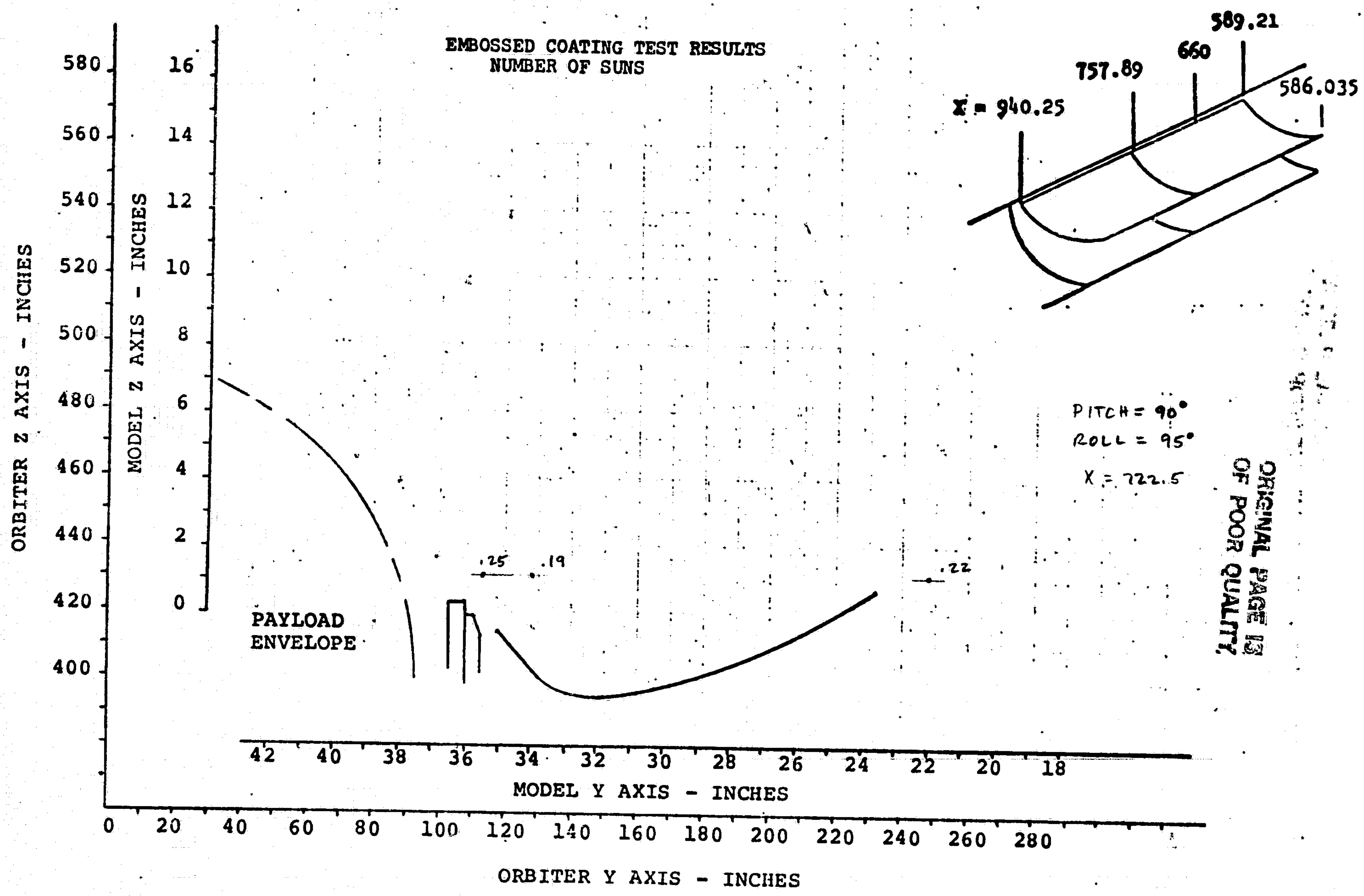
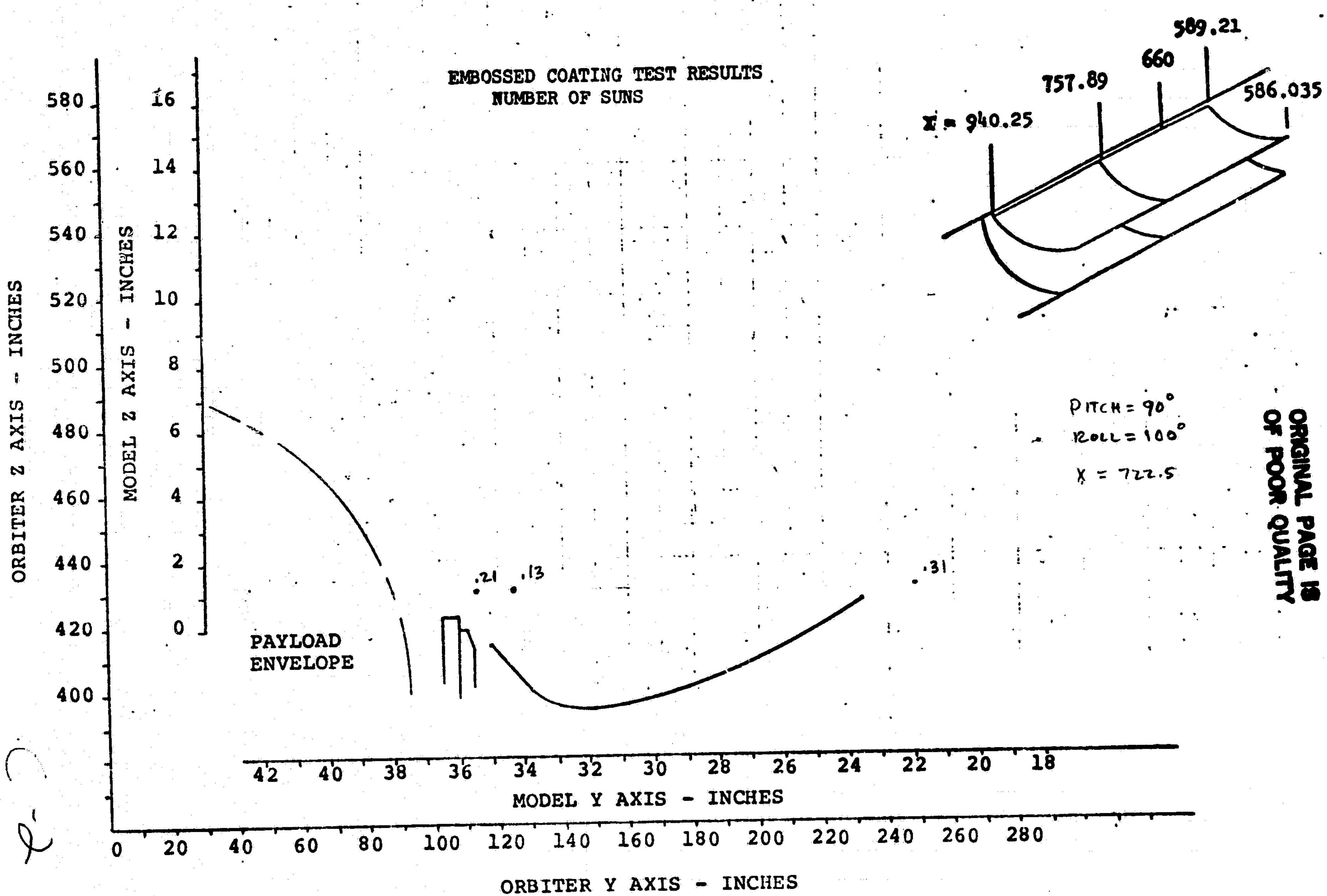

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 80°
X = 722.5
.14
.21
.50
.65
.35
.50
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 85°
X = 722.5
.62
.18
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 90°
X = 722.5
.53
.11
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 95°
X = 722.5
.25
.19
.22
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280



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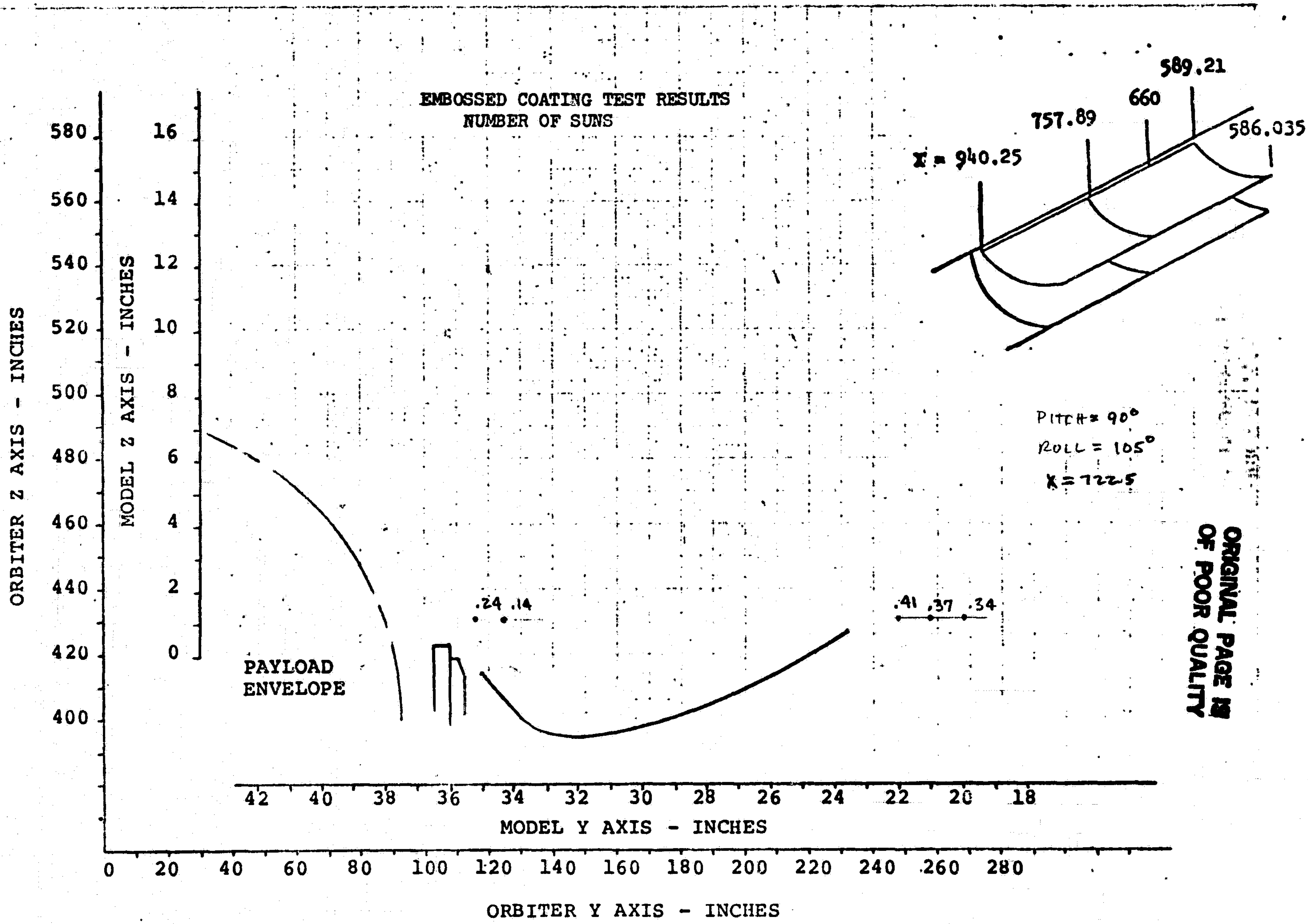

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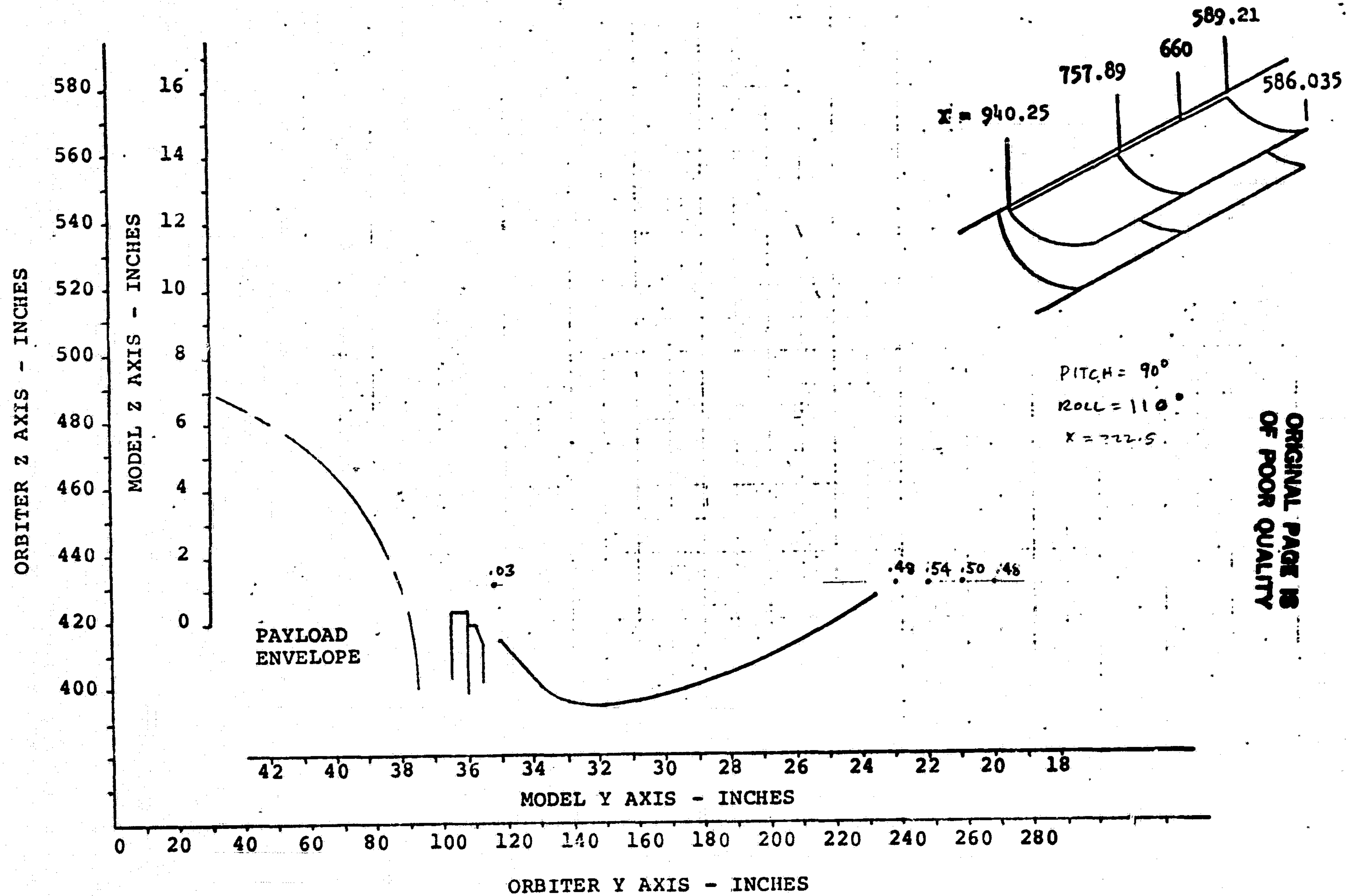
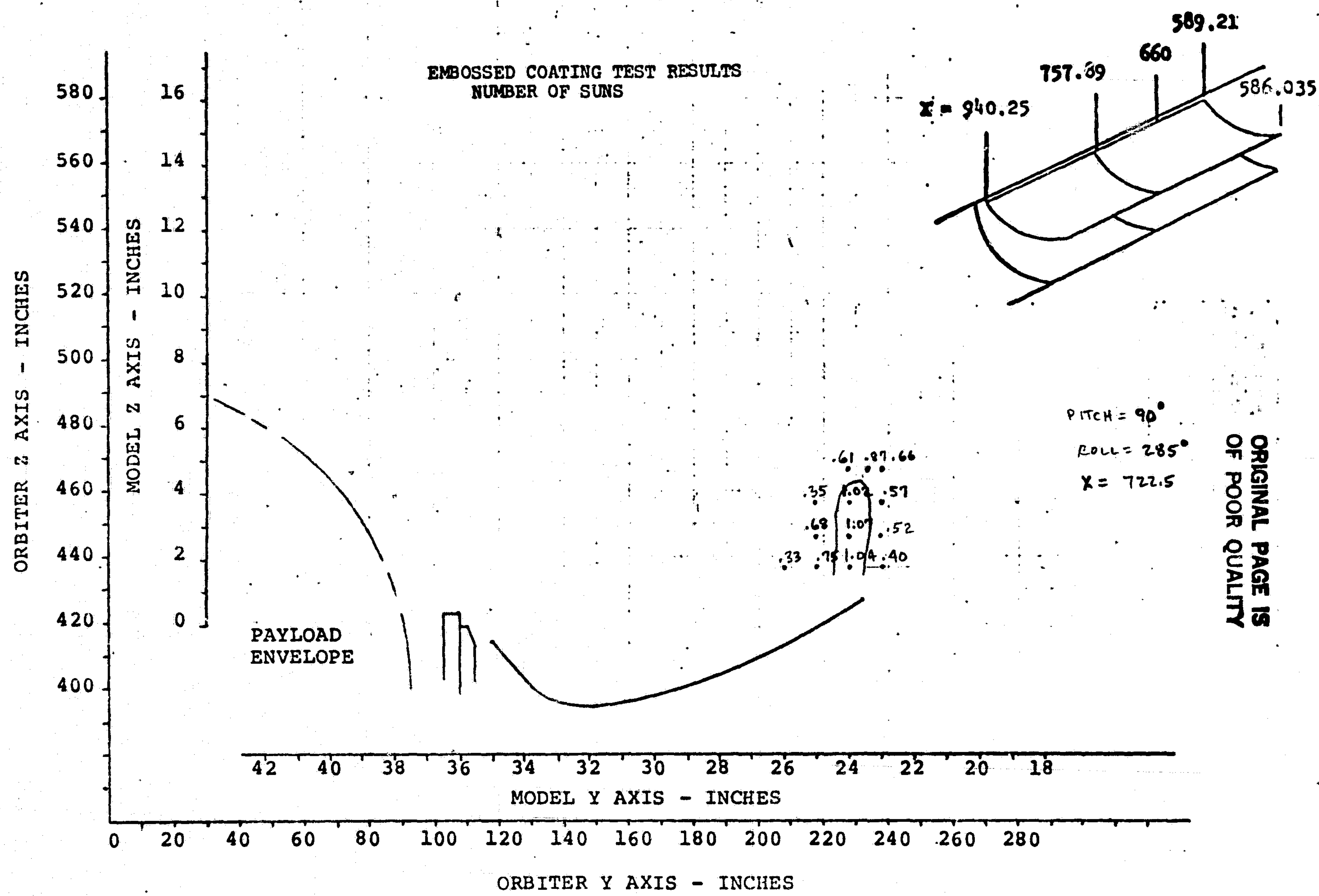
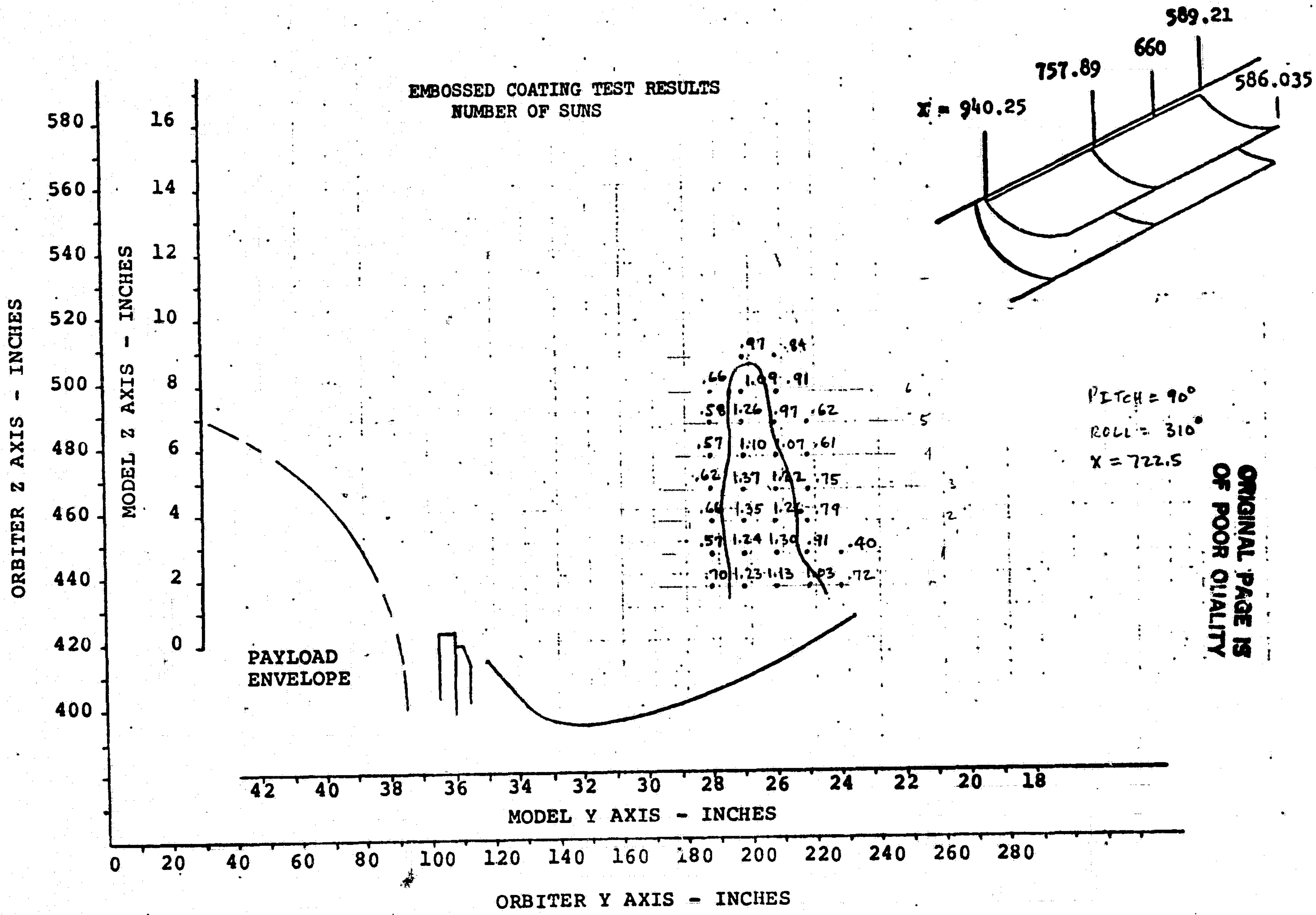
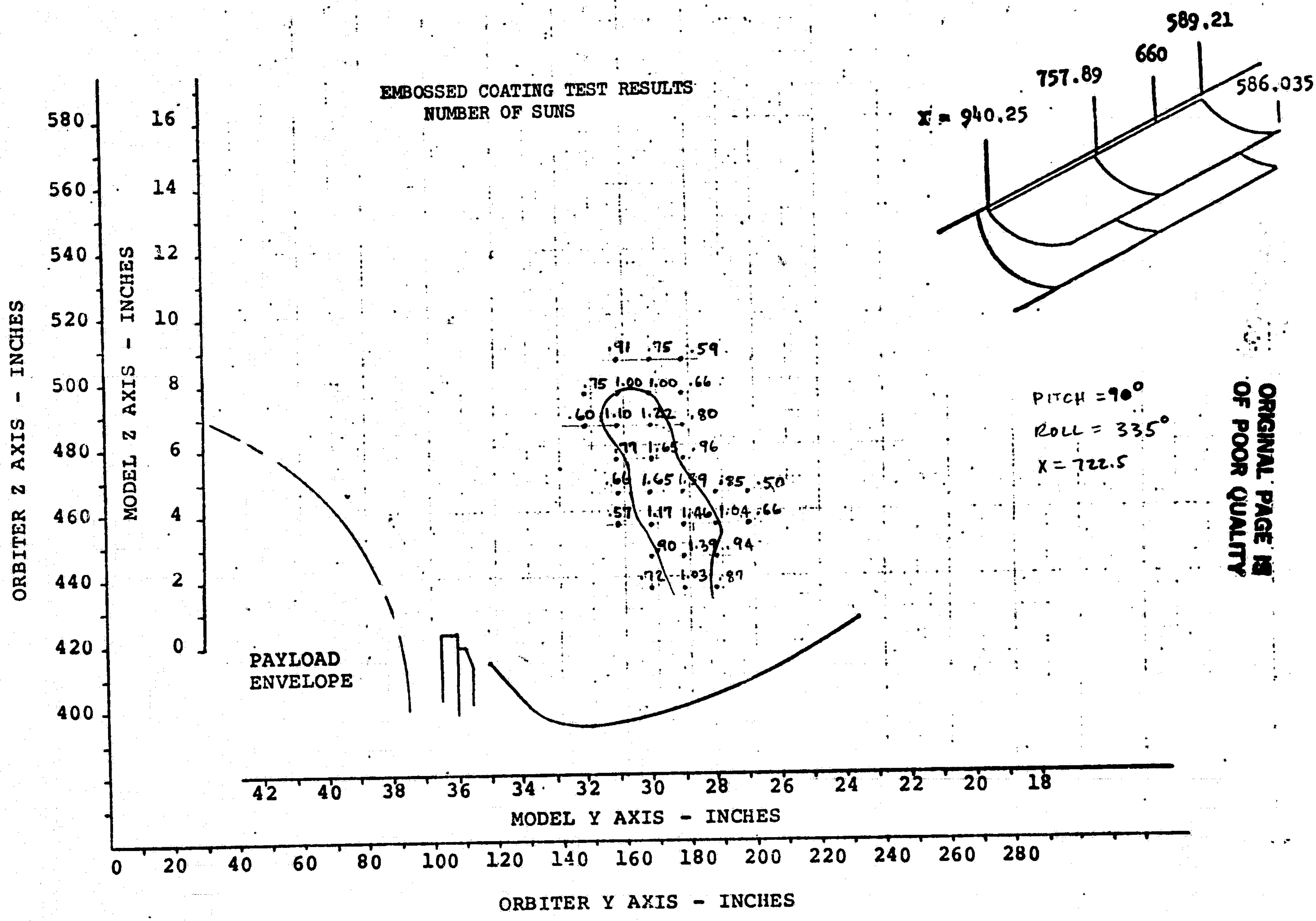


ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
PAYLOAD ENVELOPE
.03
.49 .54 .50 .48
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 110°
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 285°
X = 722.5
.61 .87 .66
.35 1.02 .57
.68 1.07 .52
.33 .75 1.04 .40
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 90°
ROLL = 310°
X = 722.5
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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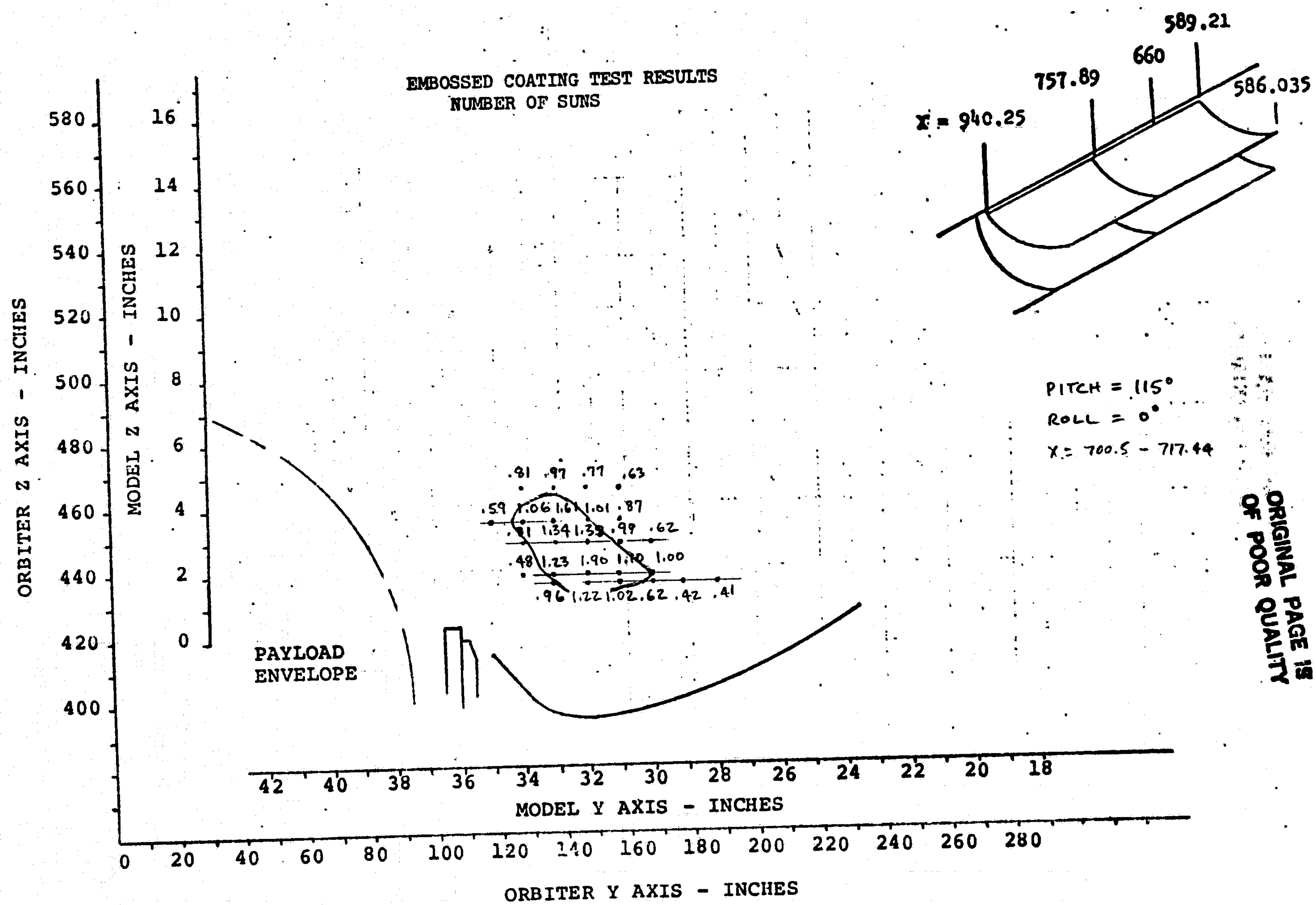
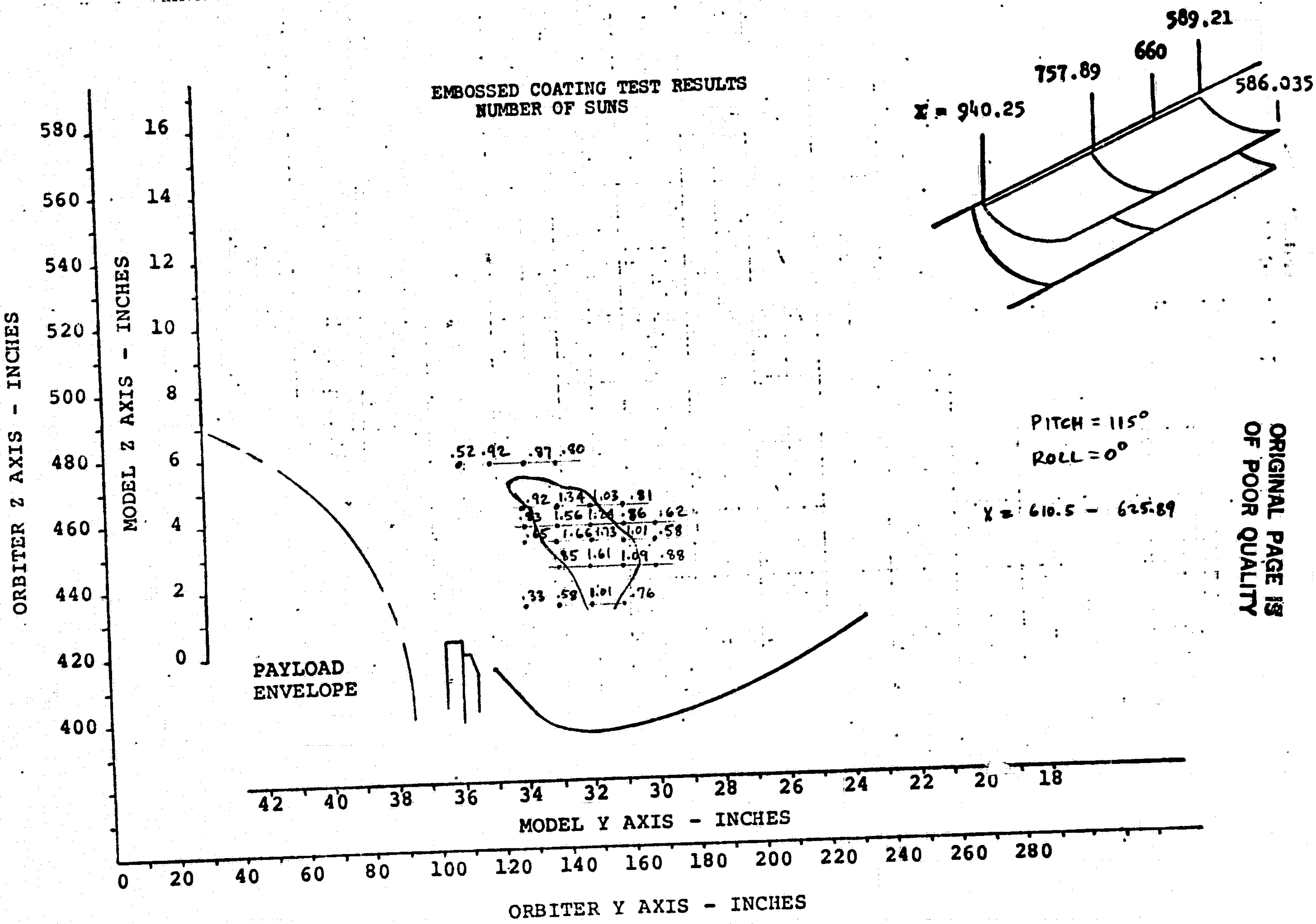
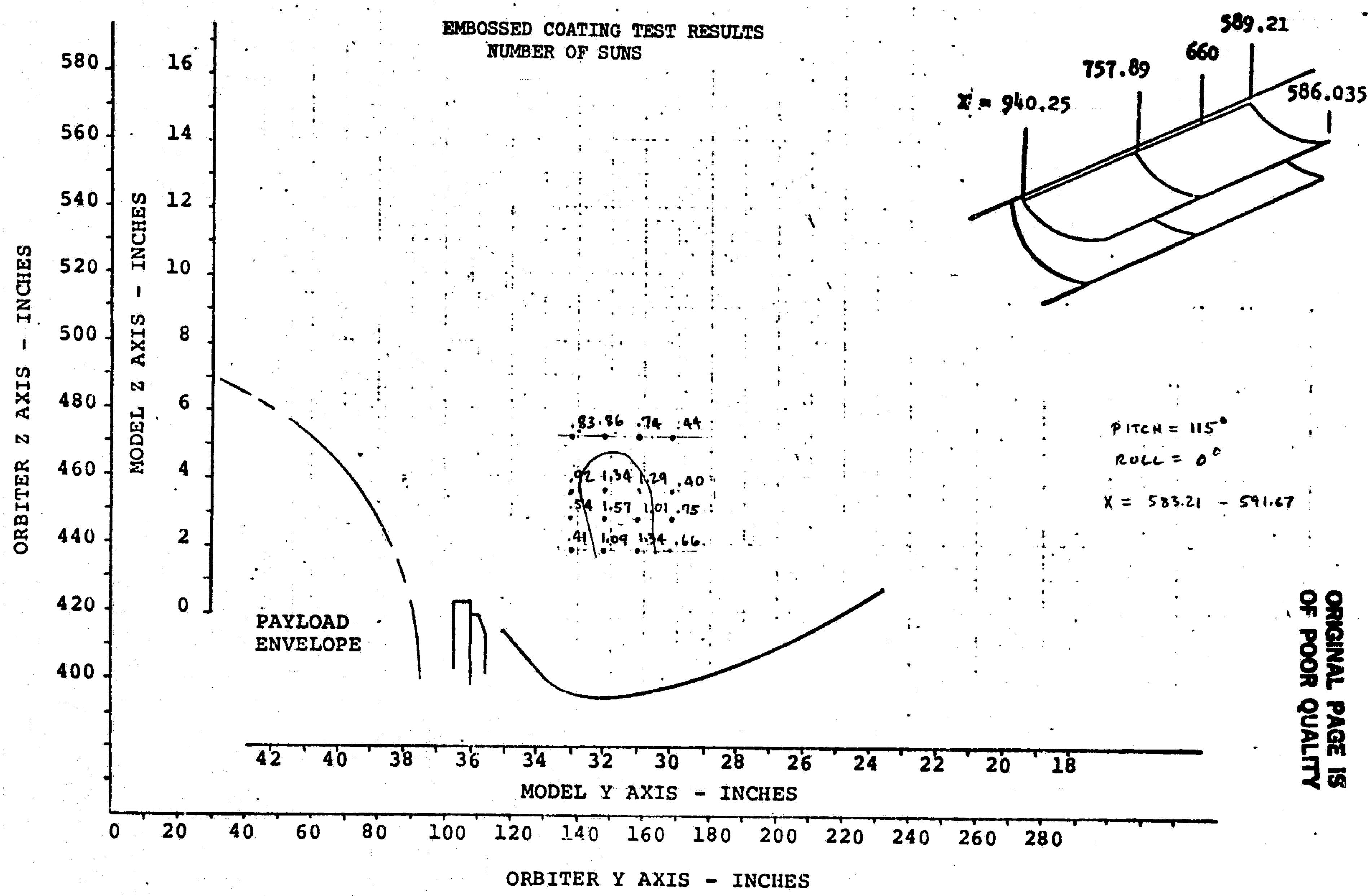
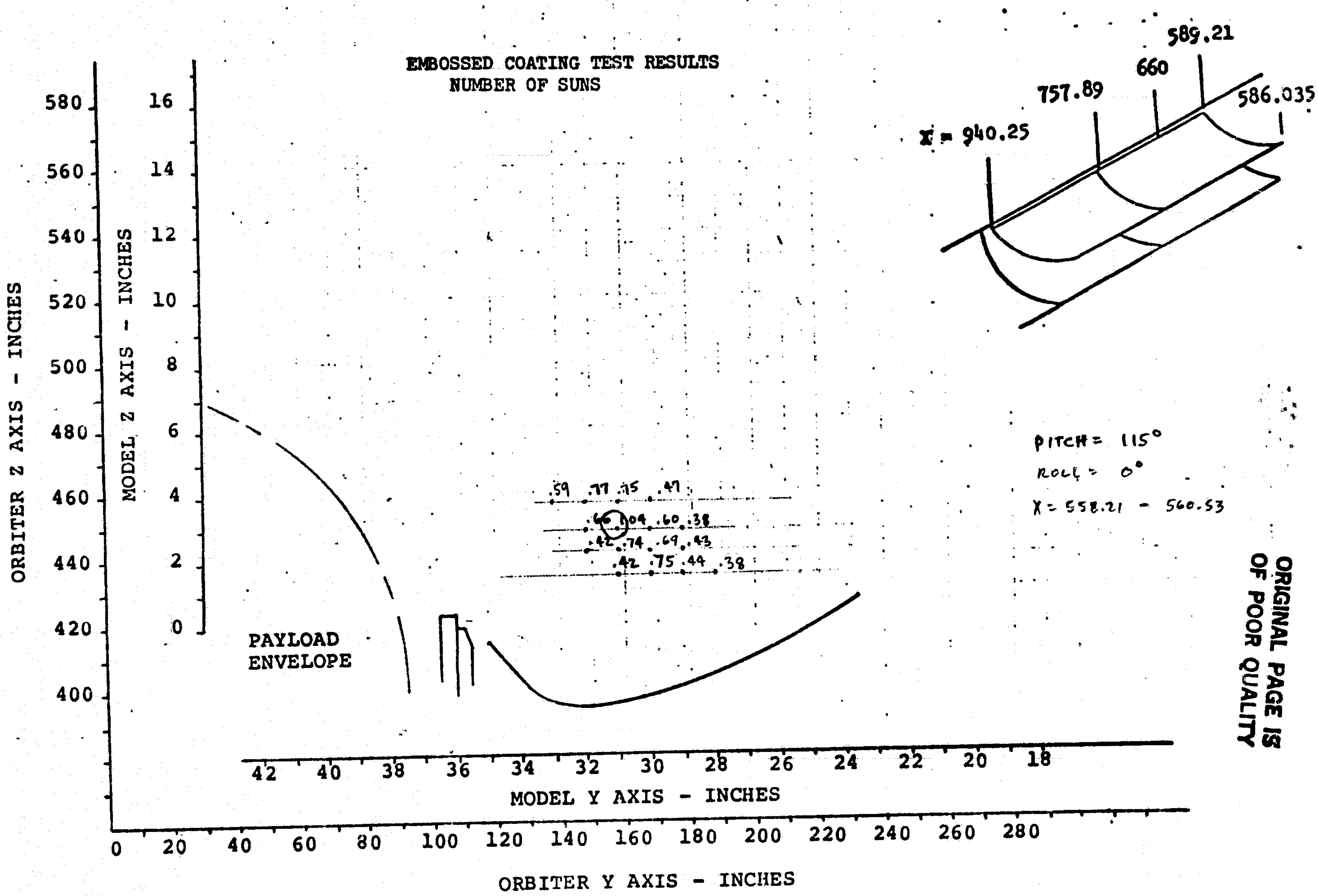


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 0°
X = 700.5 - 717.44
.81 .97 .77 .63
.59 1.06 1.61 1.01 .87
.81 1.34 1.33 .99 .62
.48 1.23 1.90 1.10 1.00
.96 1.22 1.02 .62 .42 .41
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 0°
X = 610.5 - 625.89
PAYLOAD ENVELOPE
.52 .92 .87 .90
.92 1.34 1.03 .81
.83 1.56 1.24 .86 .62
.65 1.66 1.73 1.01 .58
.85 1.61 1.09 .88
.33 .58 1.01 .76
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
MODEL Y AXIS - INCHES
42
40
38
36
34
32
30
28
26
24
22
20
18
ORBITER Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 0°
X = 583.21 - 591.67
.83 .86 .74 .44
.92 1.34 1.29 .40
.54 1.57 1.01 .75
.41 1.09 1.34 .66
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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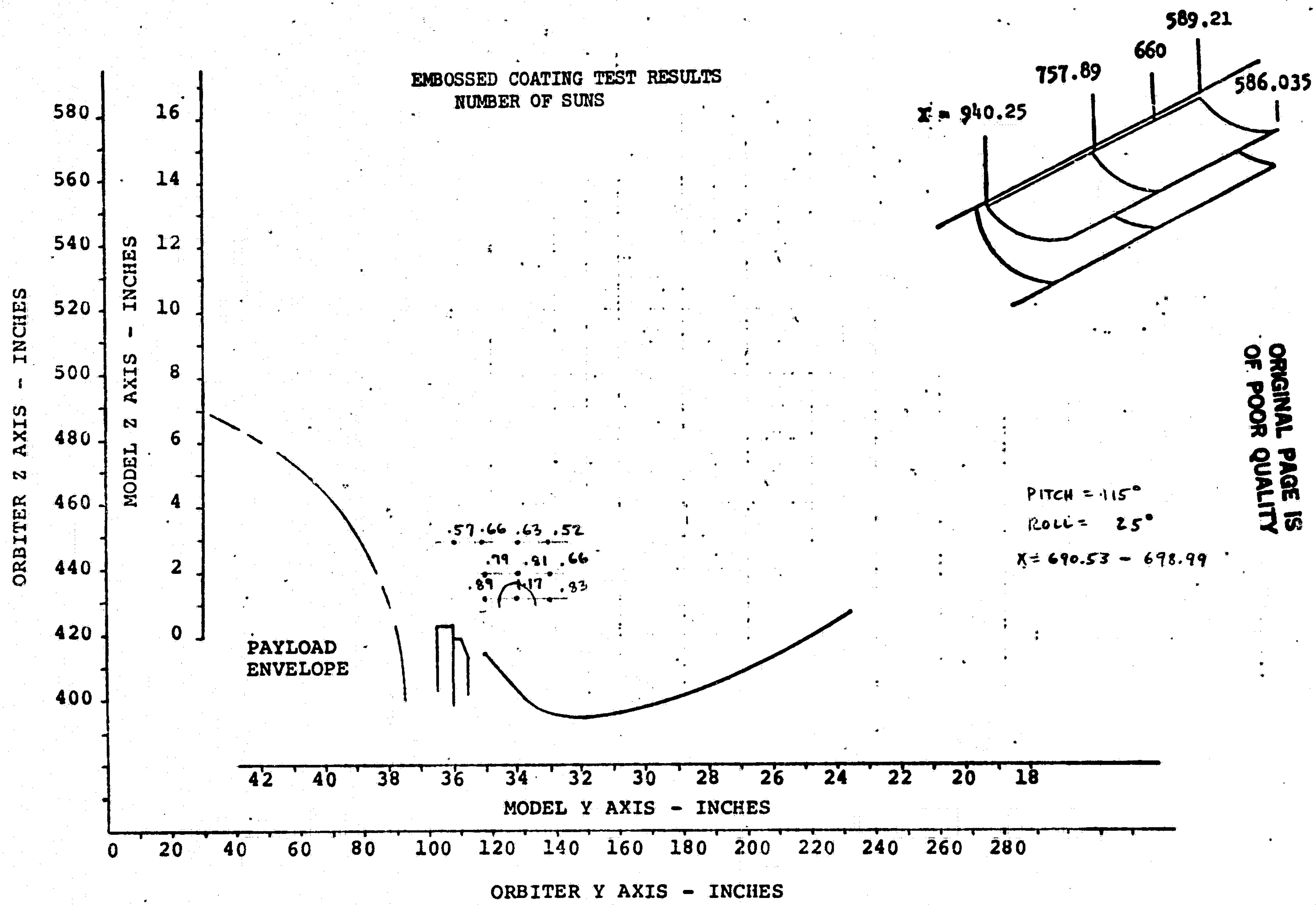
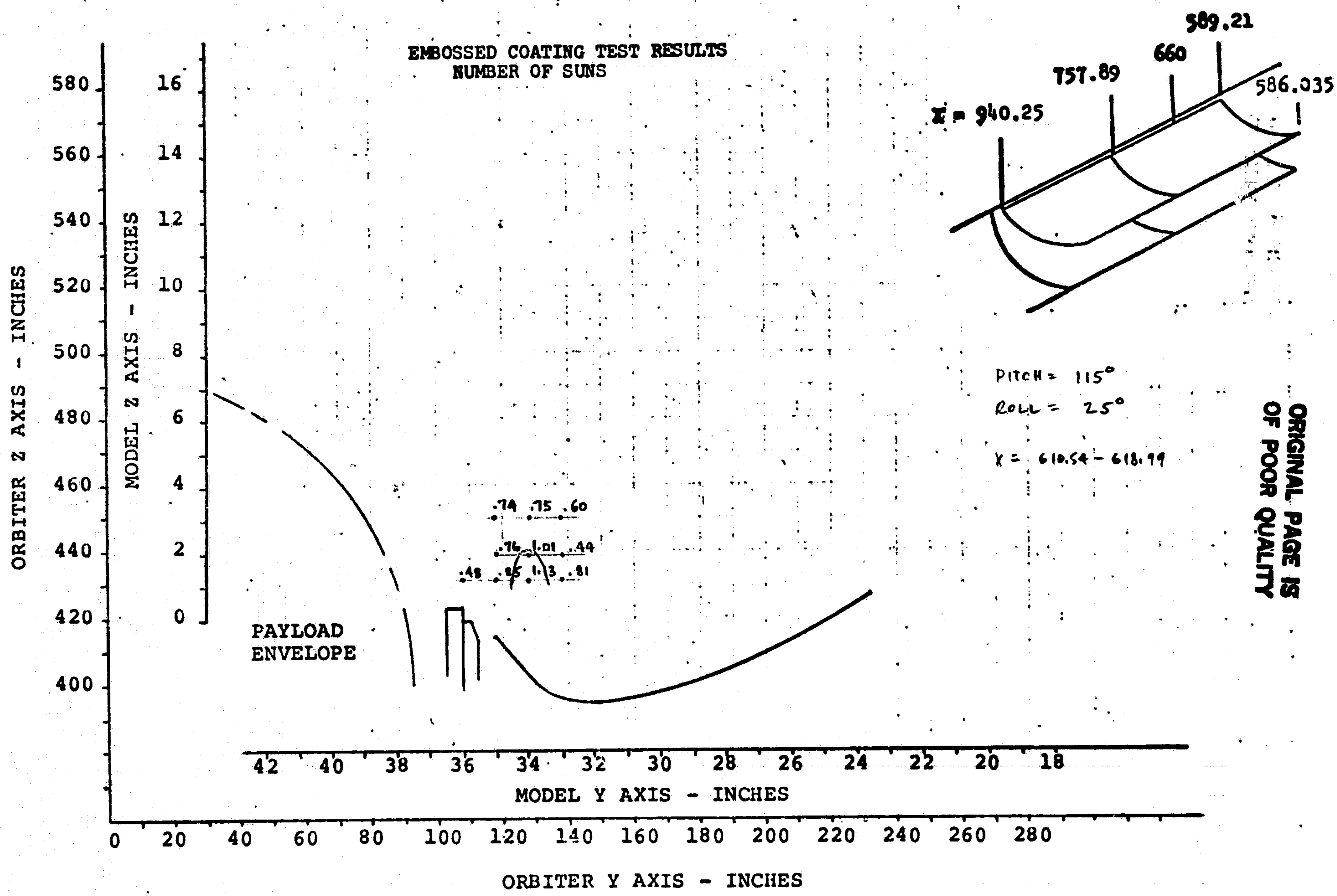

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 25°
X = 690.53 - 698.99
.57 .66 .63 .52
.79 .91 .66
.89 1.17 .83
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES



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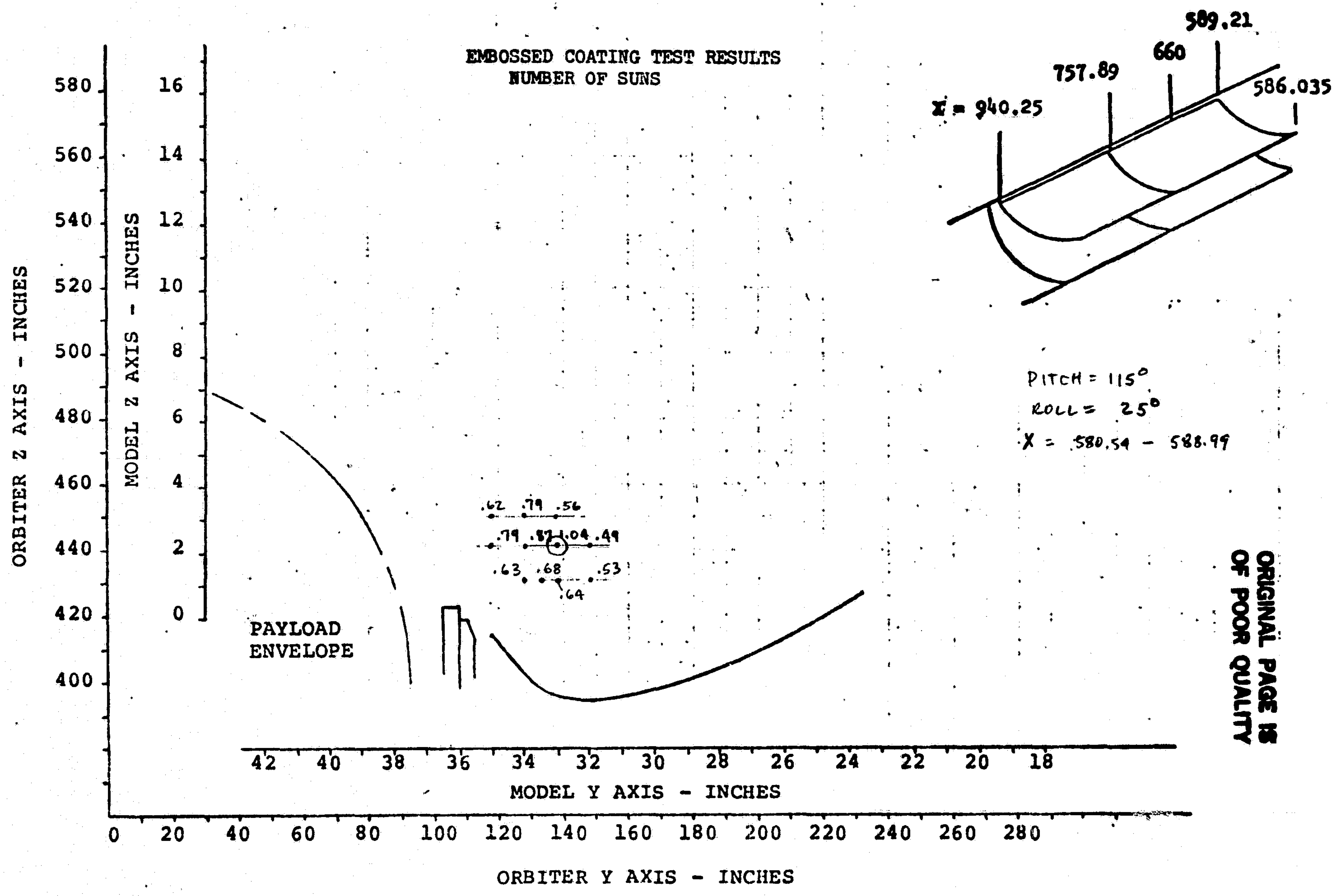

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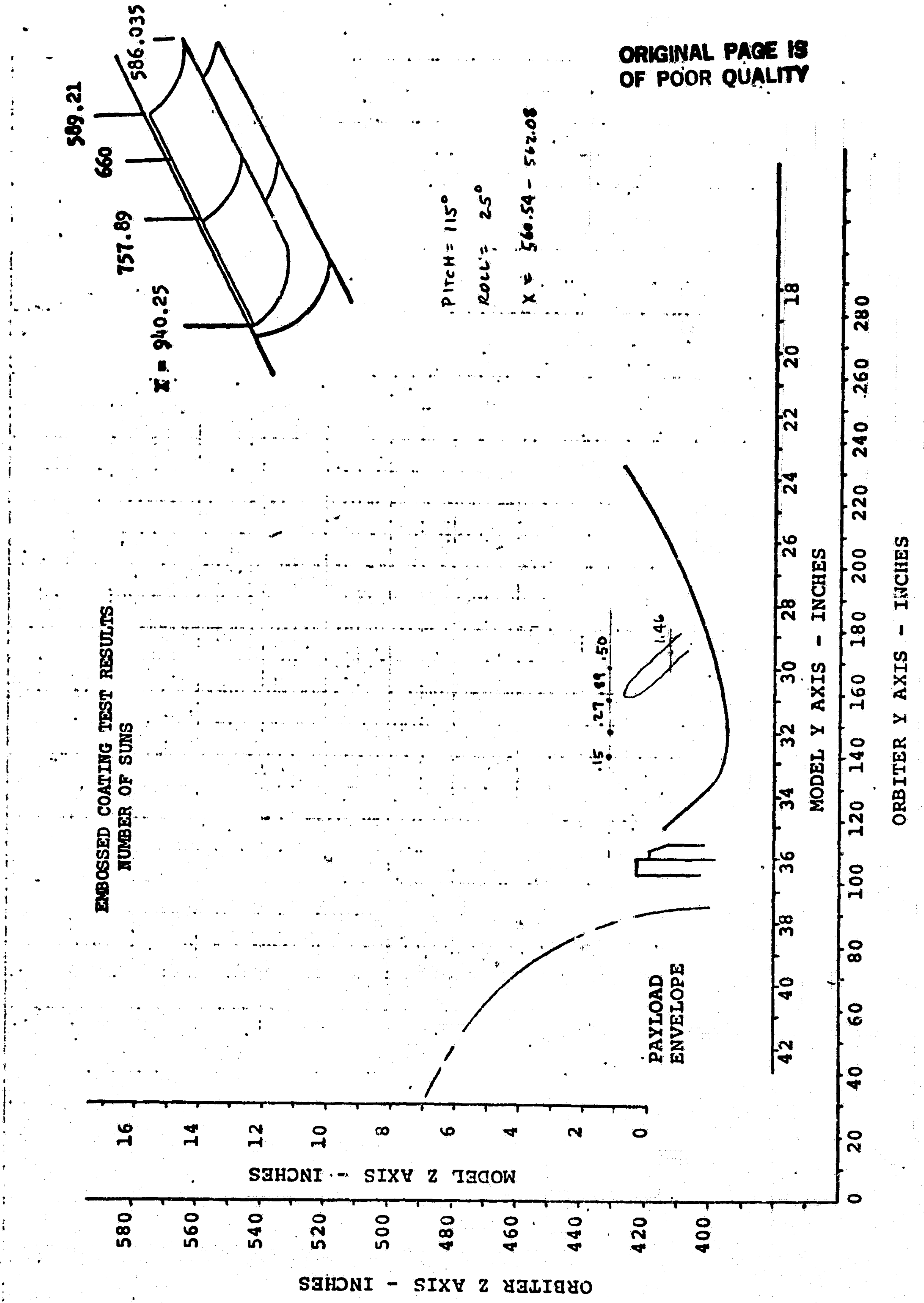
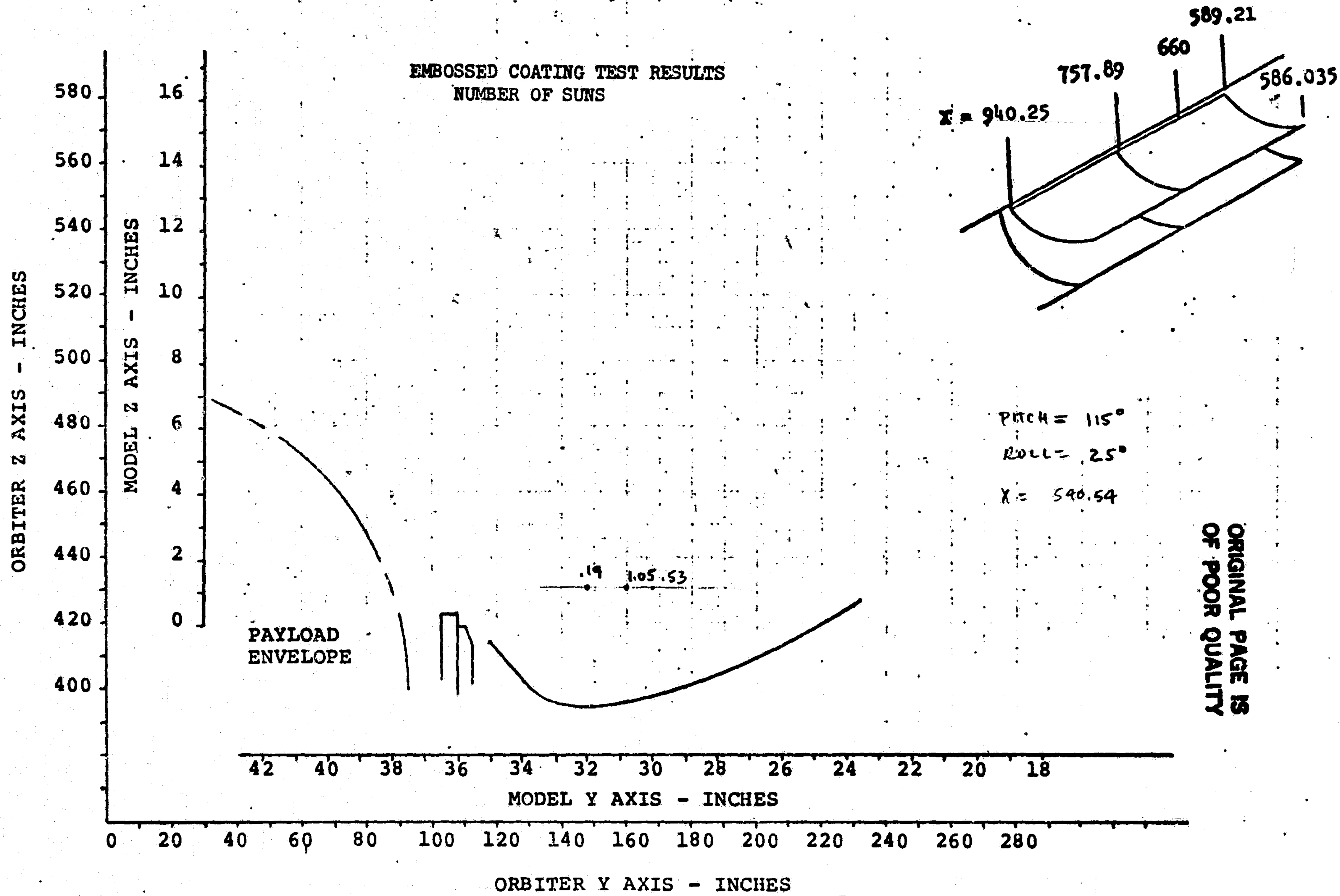

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
PITCH = 115°
ROLL = 25°
X = 560.54 - 562.08
X = 940.25
757.89
660
589.21
586.035
.15
.27
.49
.50
1.46
PAYLOAD ENVELOPE
MODEL Y AXIS - INCHES
18 20 22 24 26 28 30 32 34 36 38 40 42
ORBITER Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
MODEL Z AXIS - INCHES
0 2 4 6 8 10 12 14 16
ORBITER Z AXIS - INCHES
400 420 440 460 480 500 520 540 560 580



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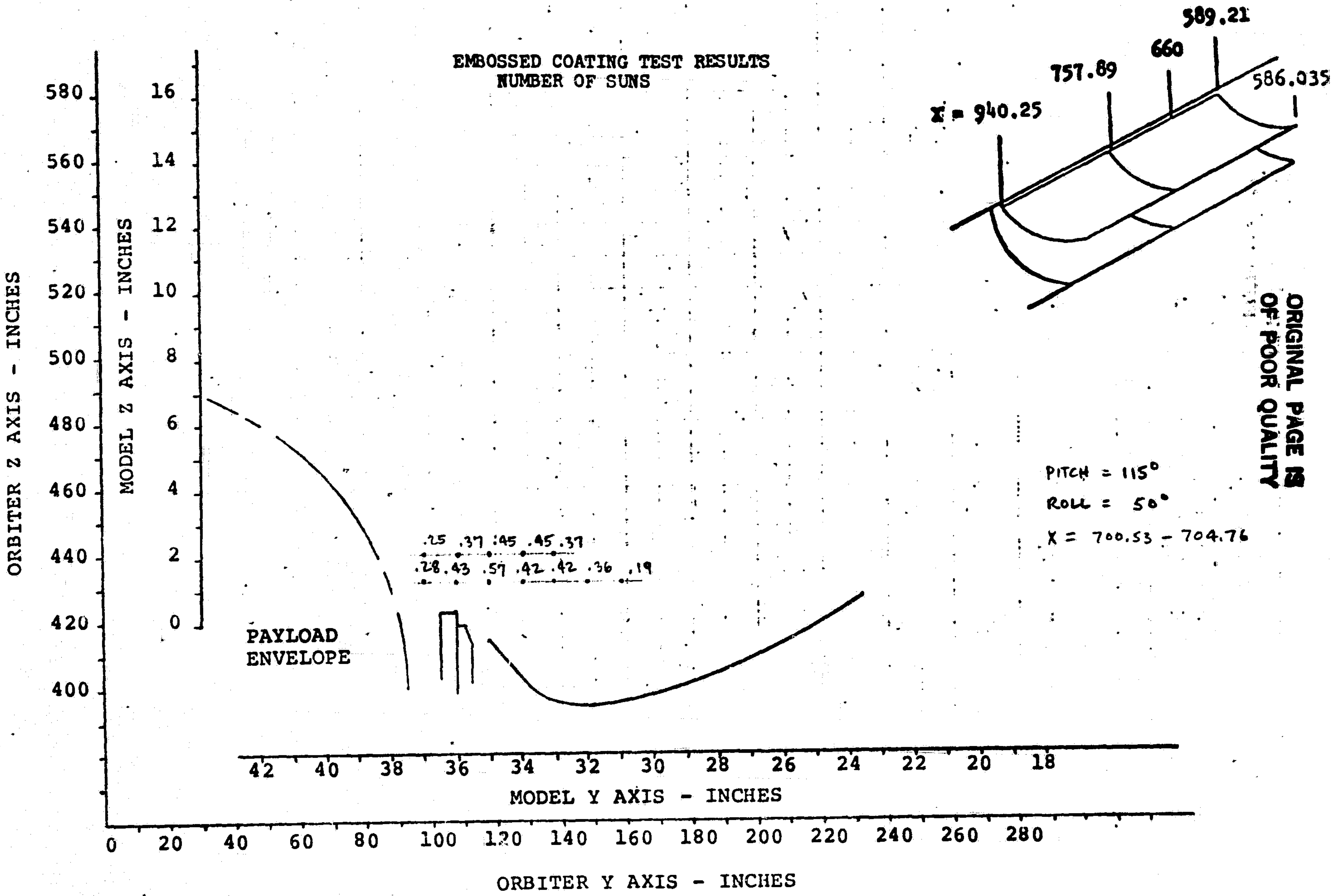
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
ORIGINAL PAGE IS
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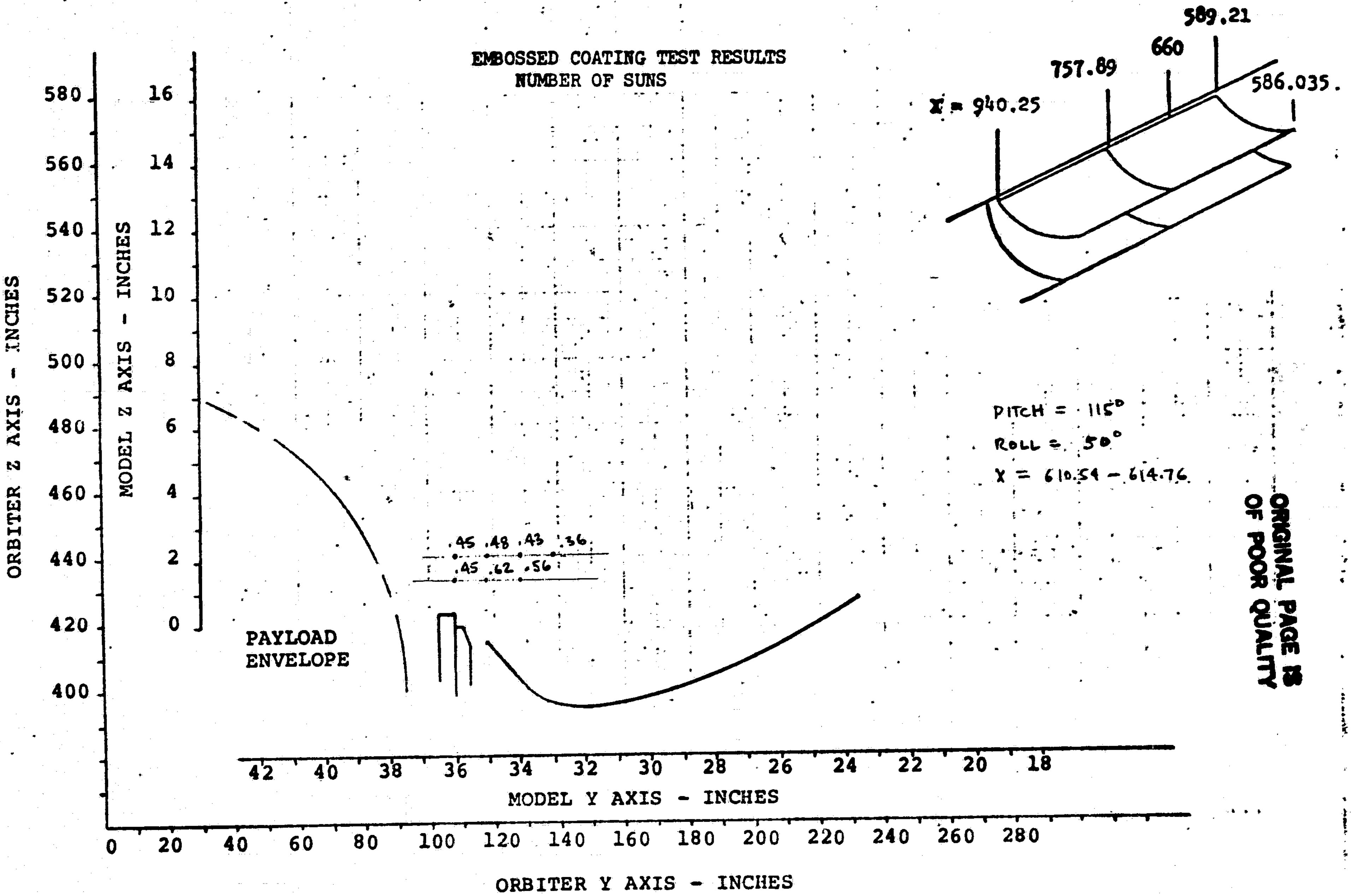
PITCH = 115°
ROLL = 50°
X = 700.53 - 704.76
.25 .37 .45 .45 .37
.28 .43 .57 .42 .42 .36 .19
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES



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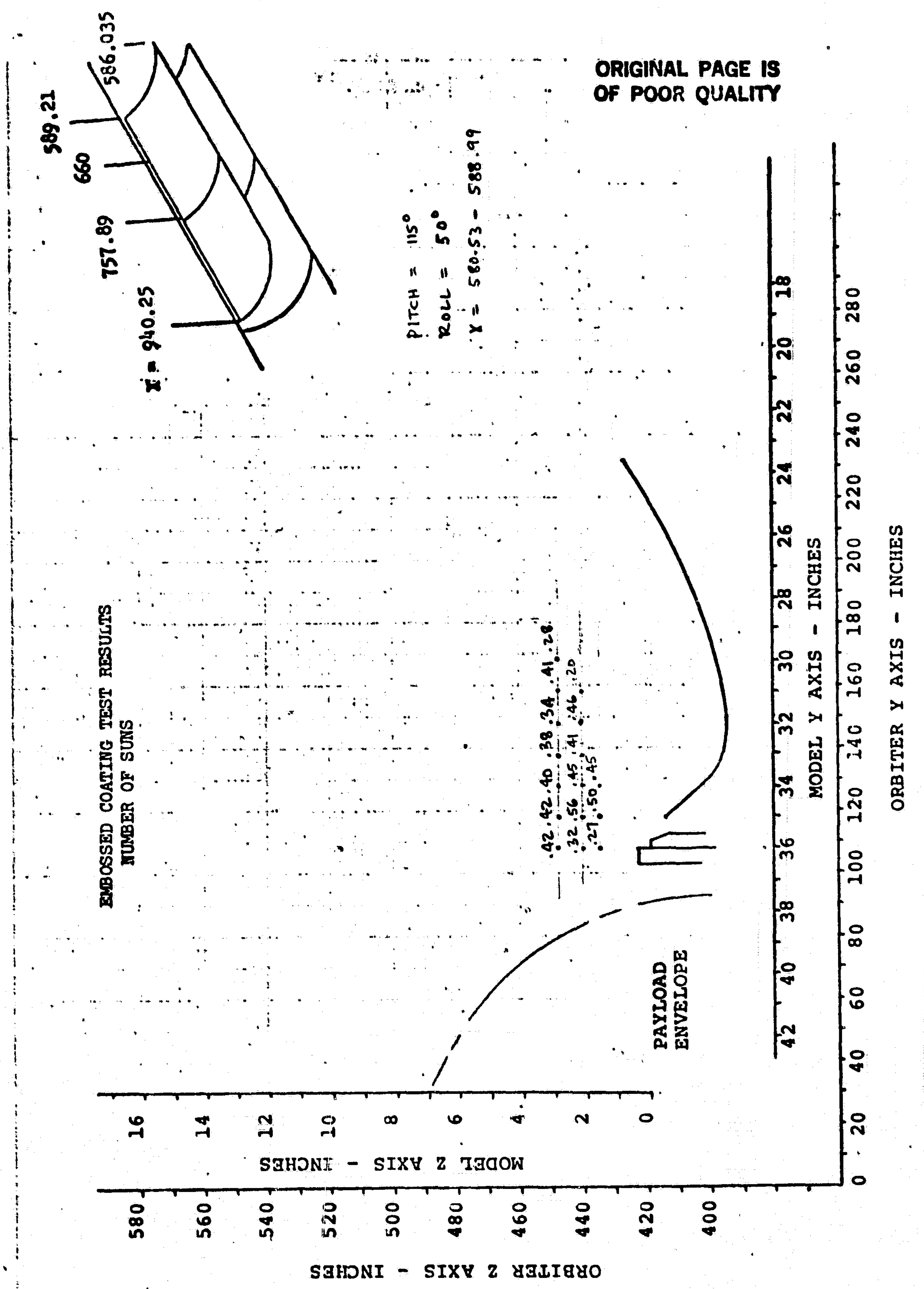
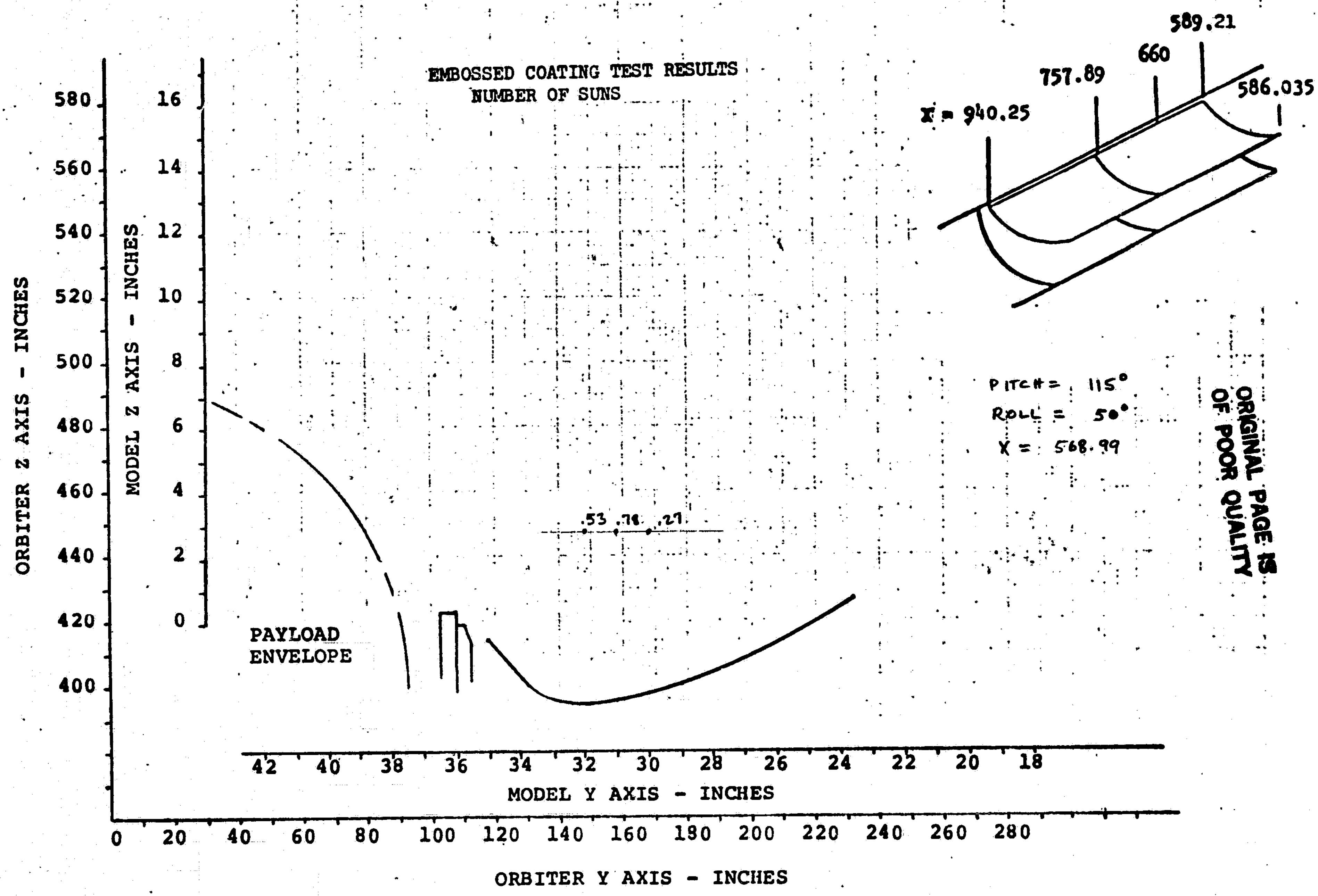

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
PITCH = 115°
ROLL = 50°
Y = 580.53 - 588.99
X = 940.25
757.89
660
589.21
586.035
.42 .42 .40 .38 .34 .41 .28
.32 .56 .45 .41 .46 .20
.27 .50 .45
PAYLOAD ENVELOPE
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES
0 2 4 6 8 10 12 14 16
MODEL Z AXIS - INCHES
400 420 440 460 480 500 520 540 560 580
ORBITER Z AXIS - INCHES



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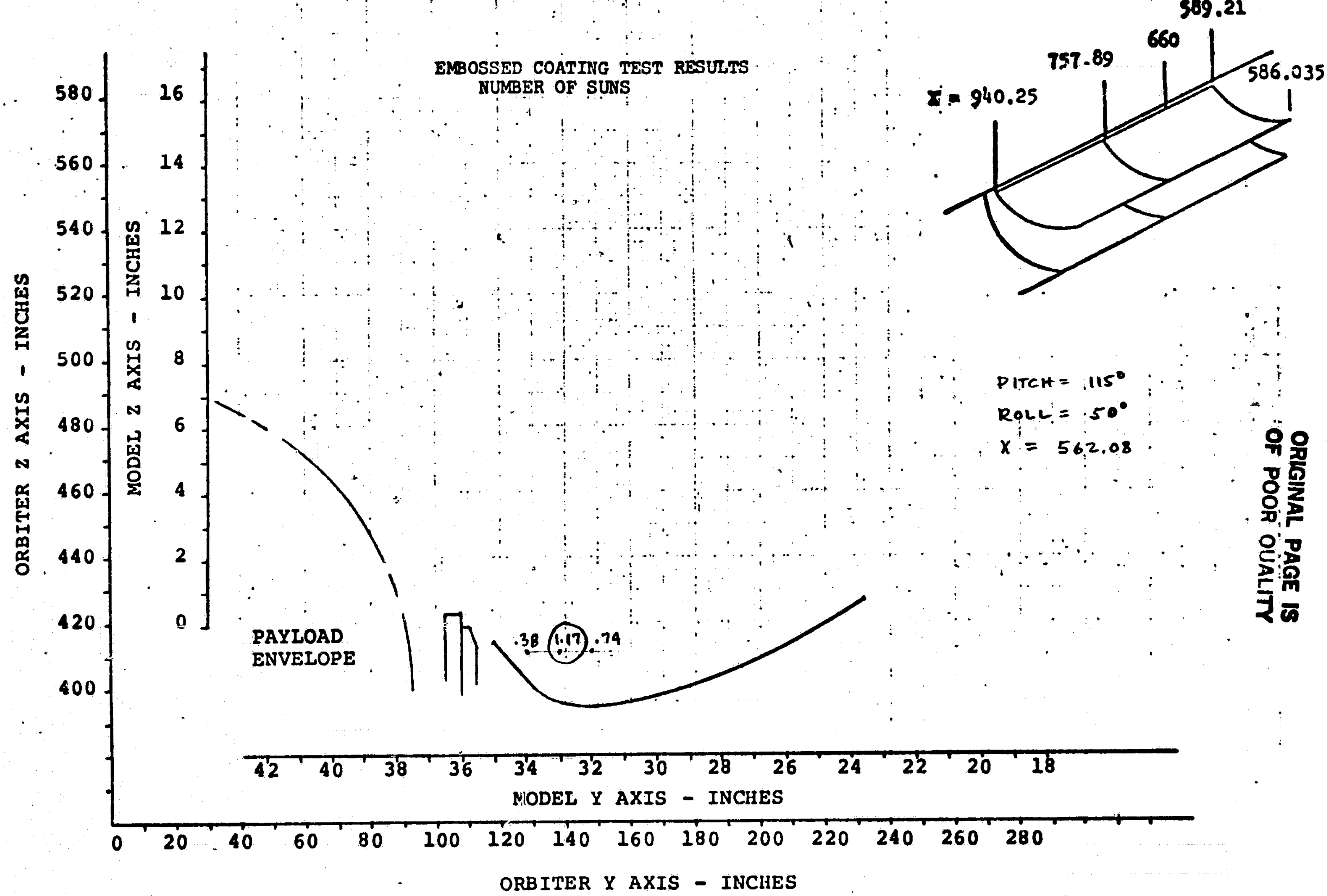
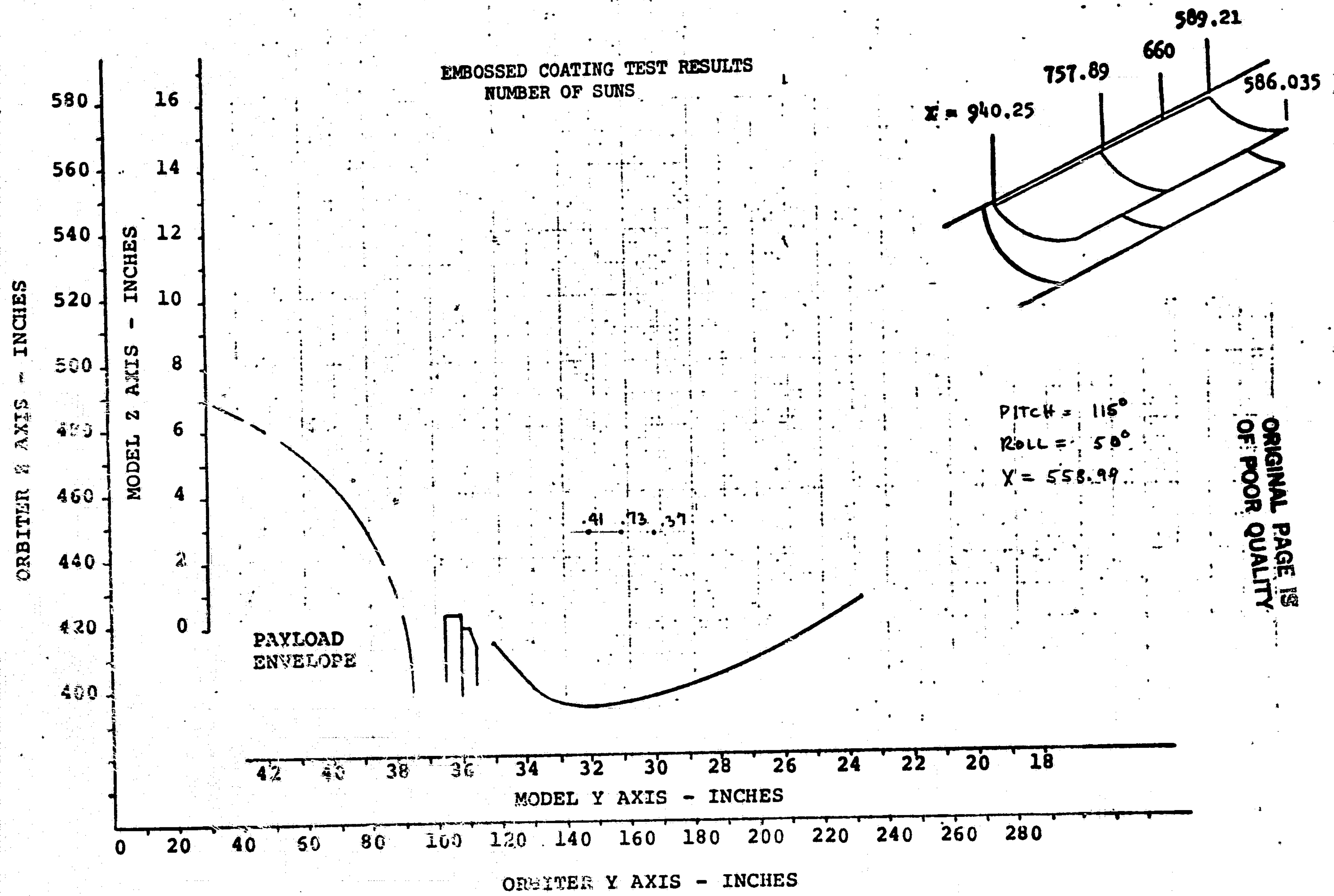

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 50°
X = 562.08
PAYLOAD
ENVELOPE
.38
1.17
.74
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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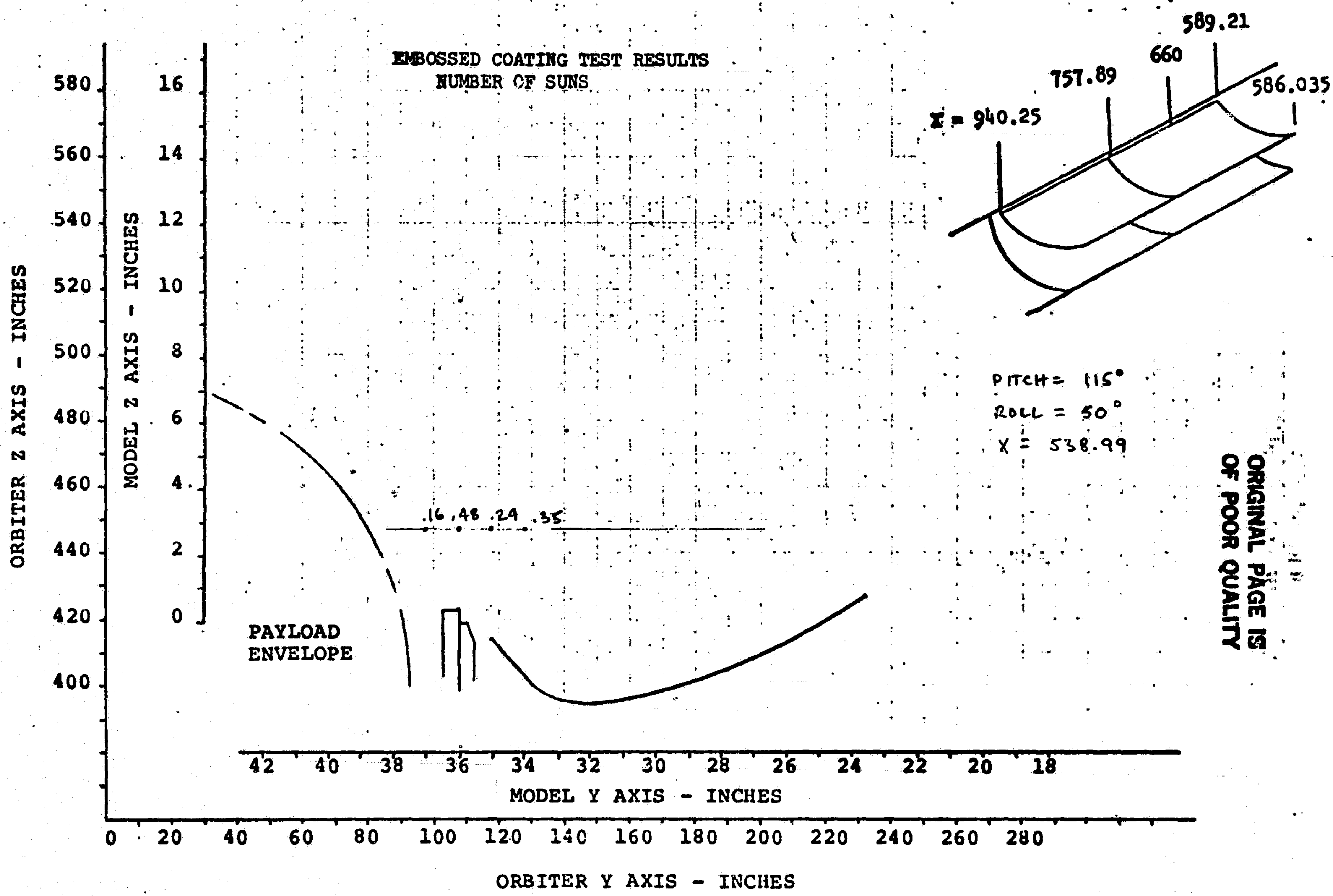
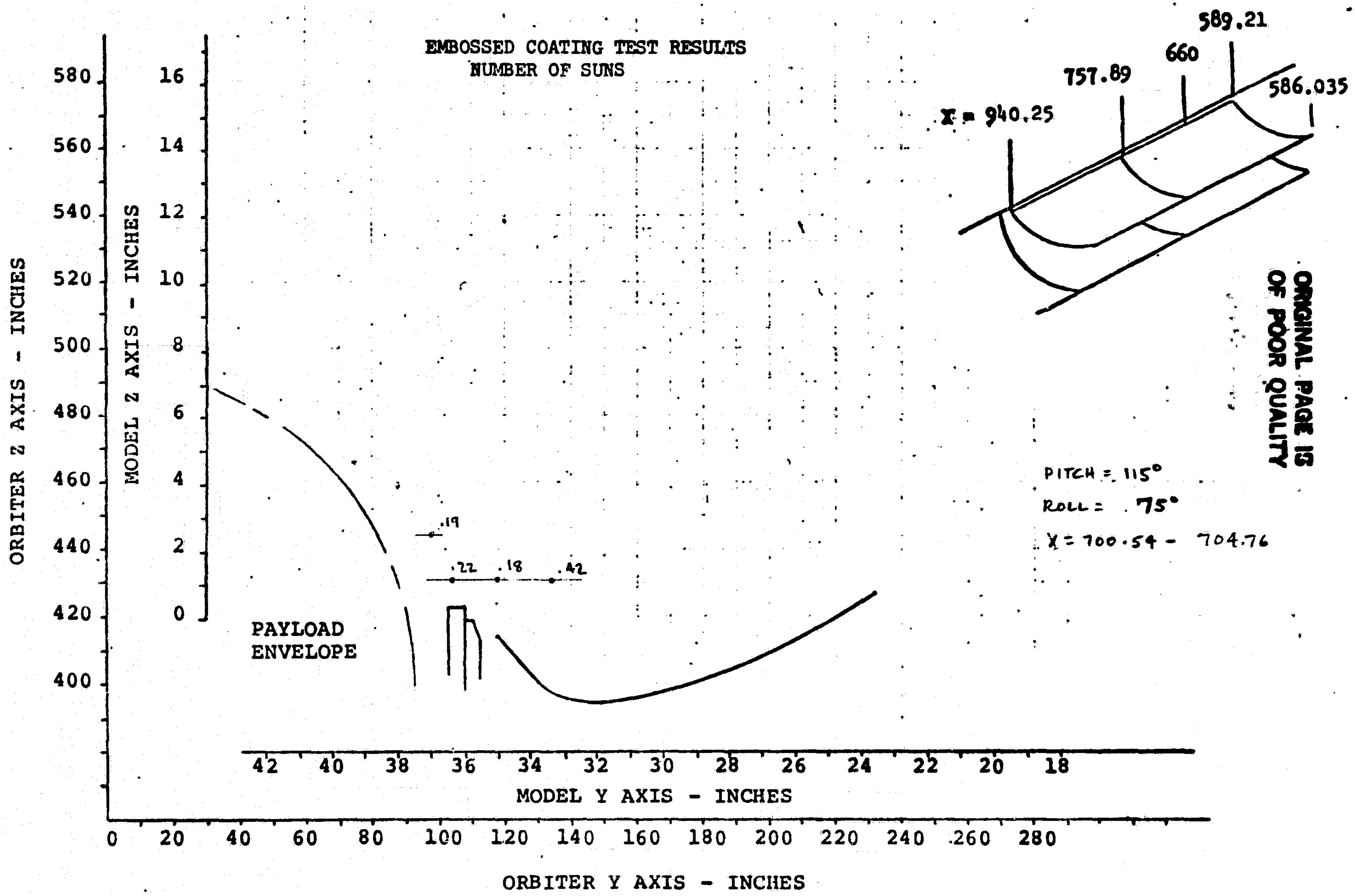
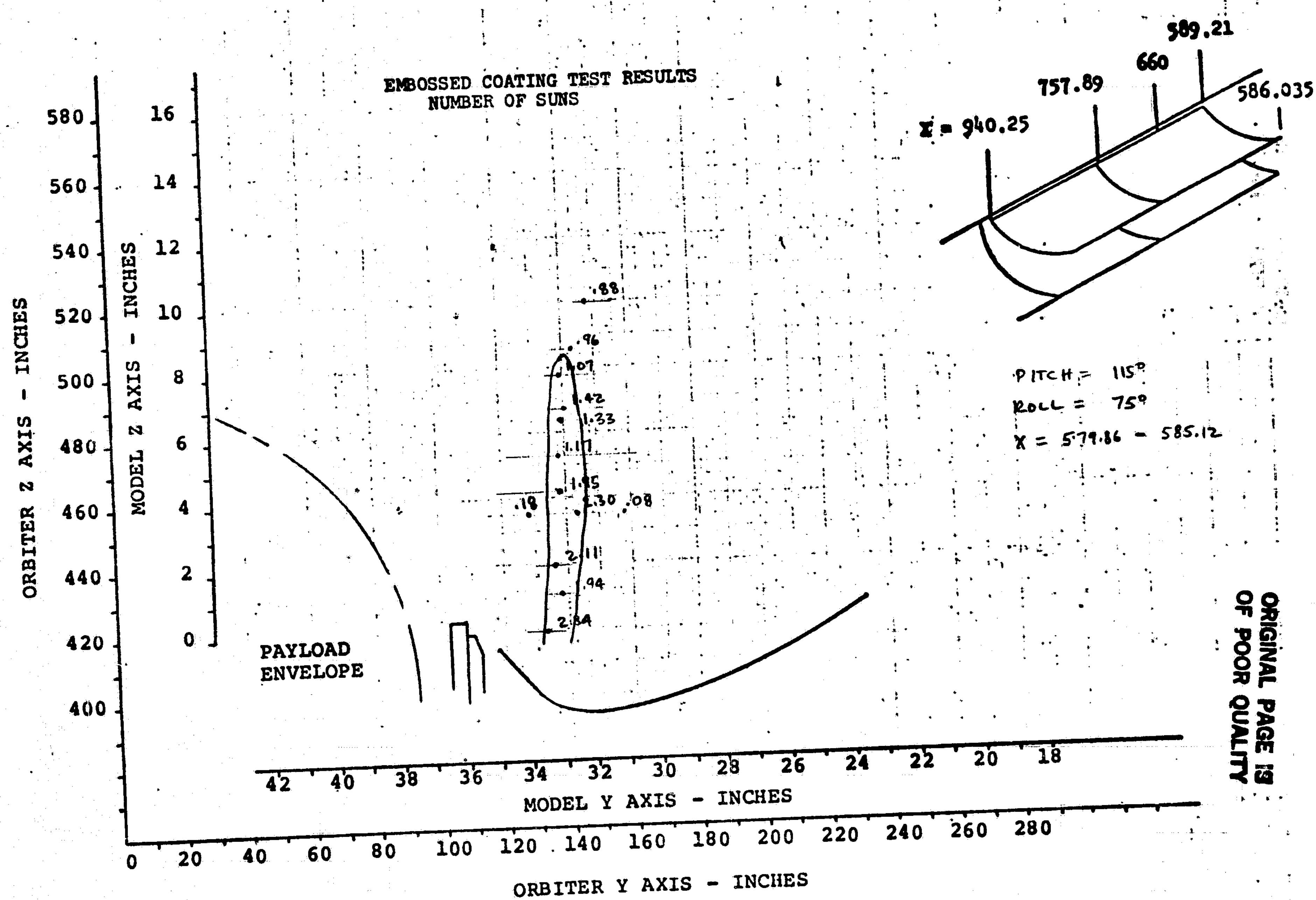
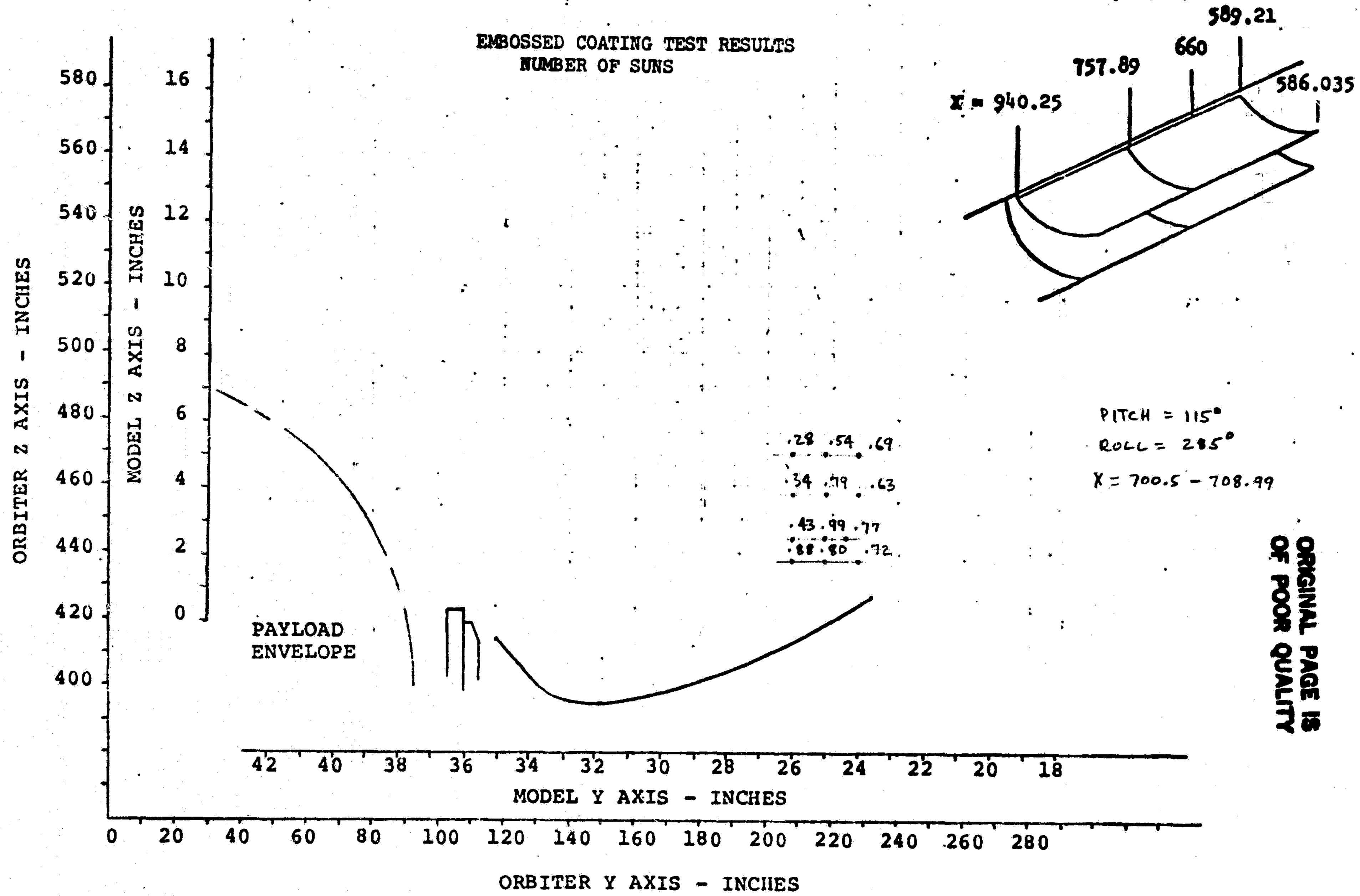

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 50°
X = 538.99
.16
.48
.24
.35
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
MODEL Y AXIS - INCHES
42
40
38
36
34
32
30
28
26
24
22
20
18
ORBITER Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
PAYLOAD
ENVELOPE
.19
.22
.18
.42
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 75°
X = 700.54 - 704.76



EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 75°
X = 579.86 - 585.12
.88
.96
1.07
1.42
1.33
1.17
1.85
.19
2.30
.08
2.11
.94
2.34
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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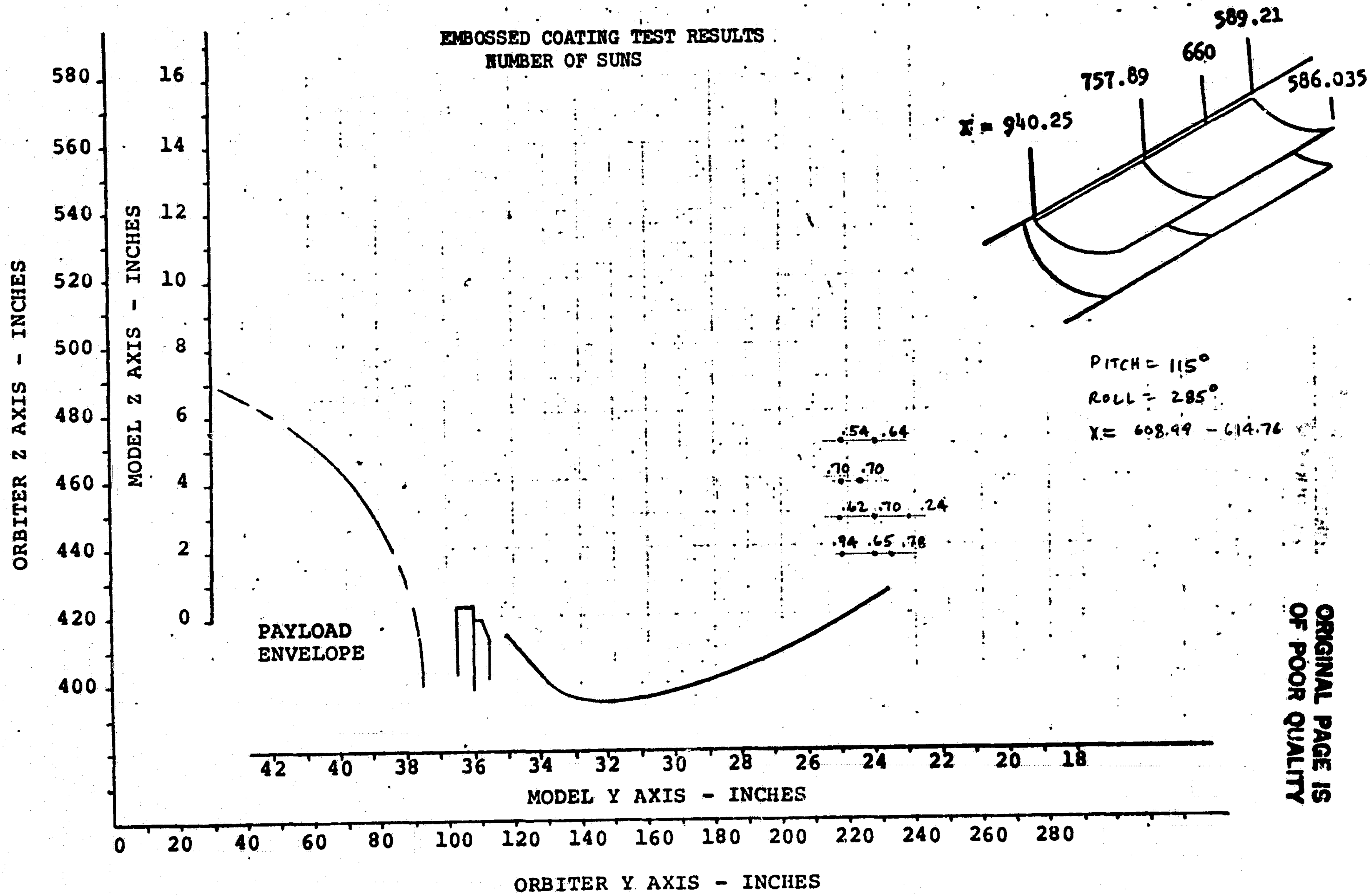

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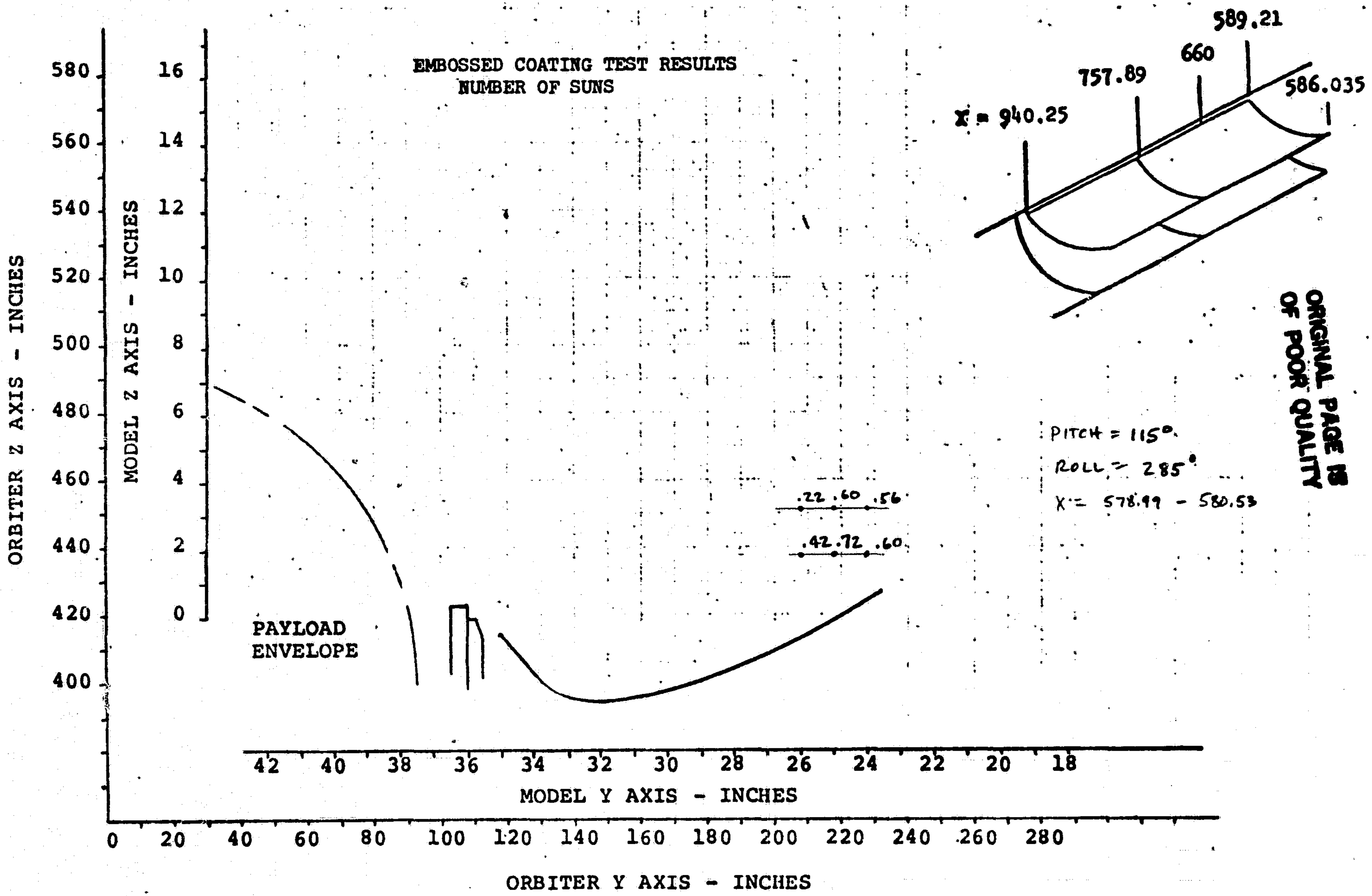
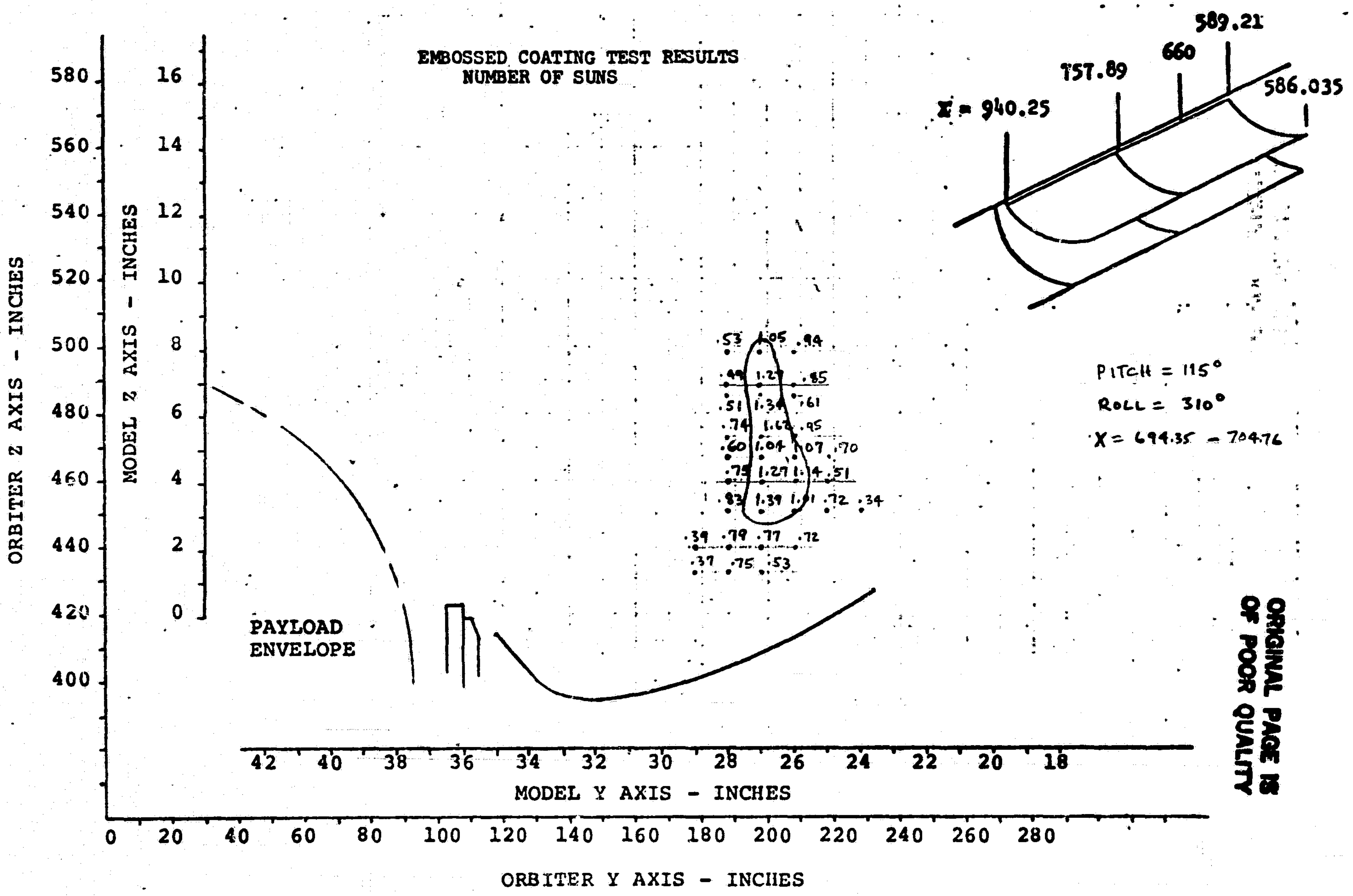


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 285°
X = 578.99 - 580.53
.22 .60 .56
.42 .72 .60
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES



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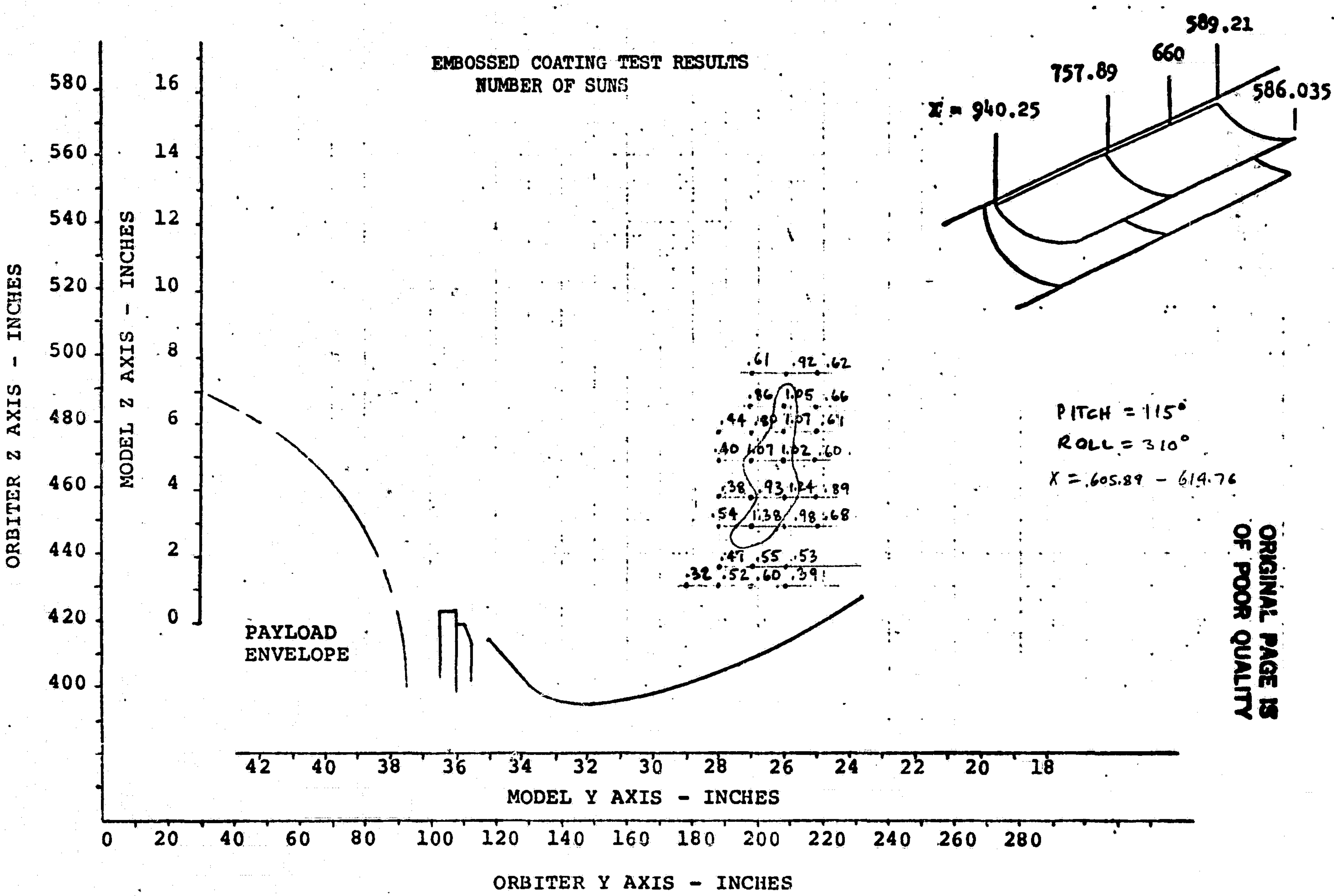
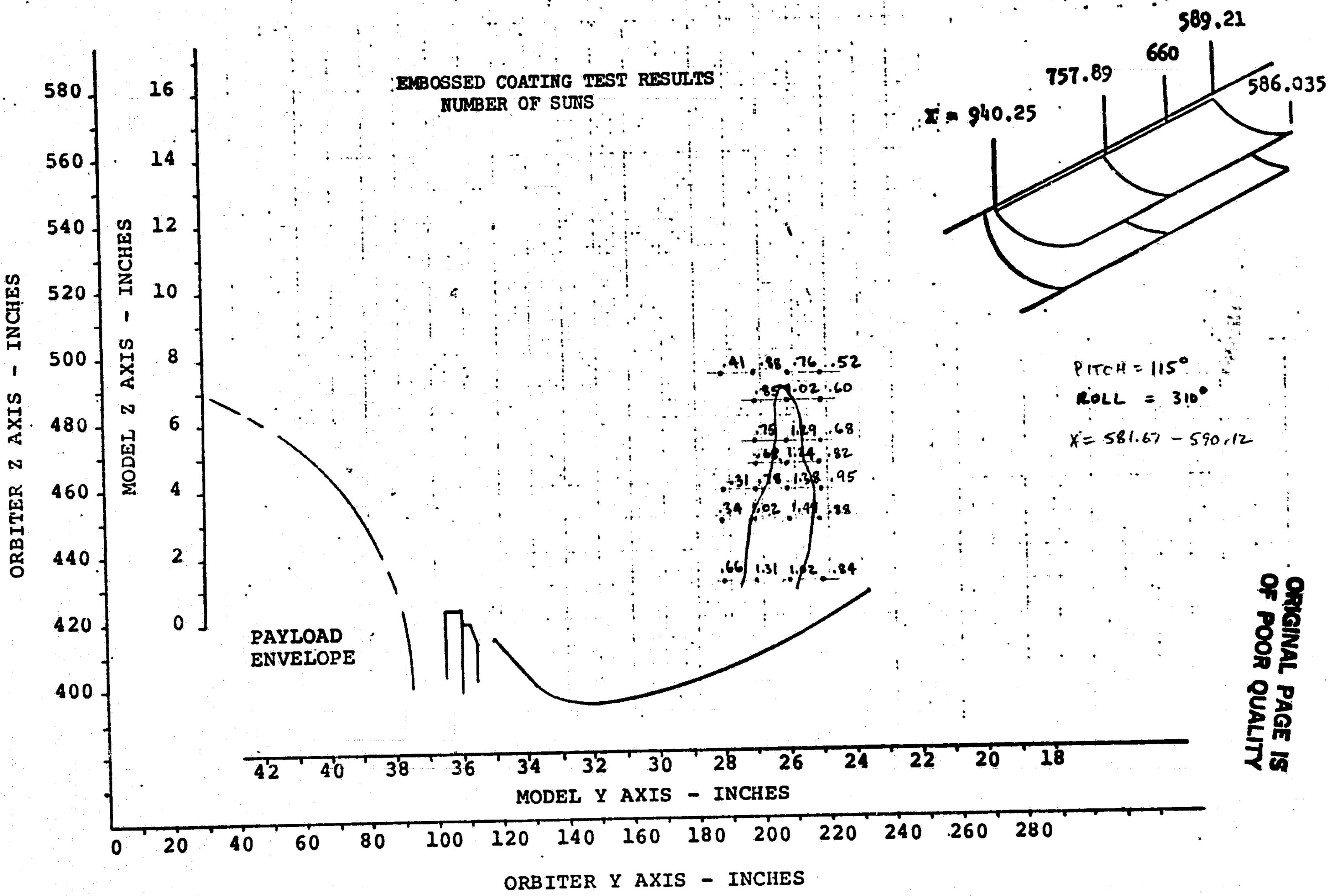

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 310°
X = 605.89 – 614.76
.61 .92 .62
.86 1.05 .66
.44 .80 1.07 .61
.40 1.07 1.62 .60
.38 .93 1.24 .89
.54 1.38 .98 .68
.47 .55 .53
.32 .52 .60 .39
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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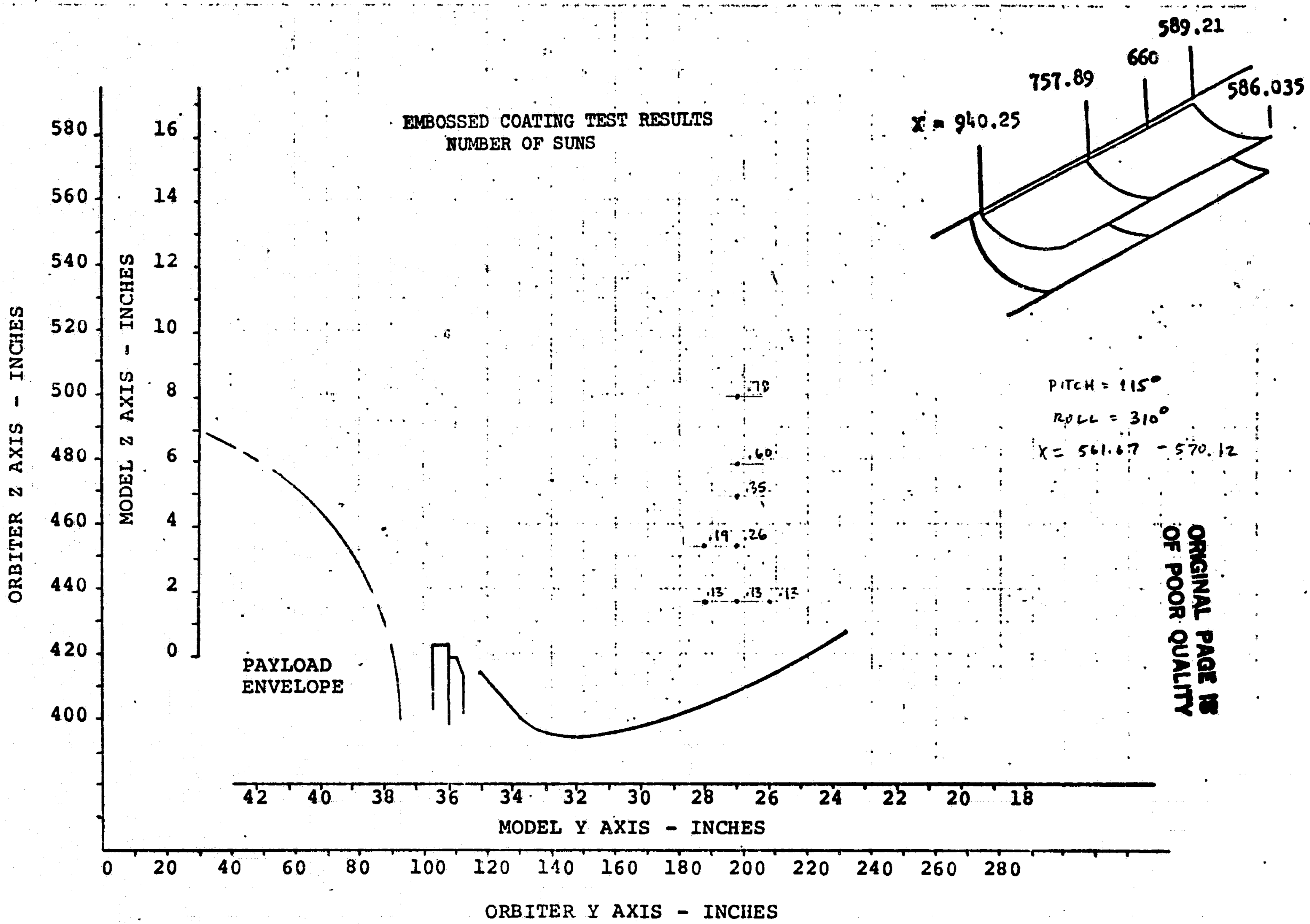

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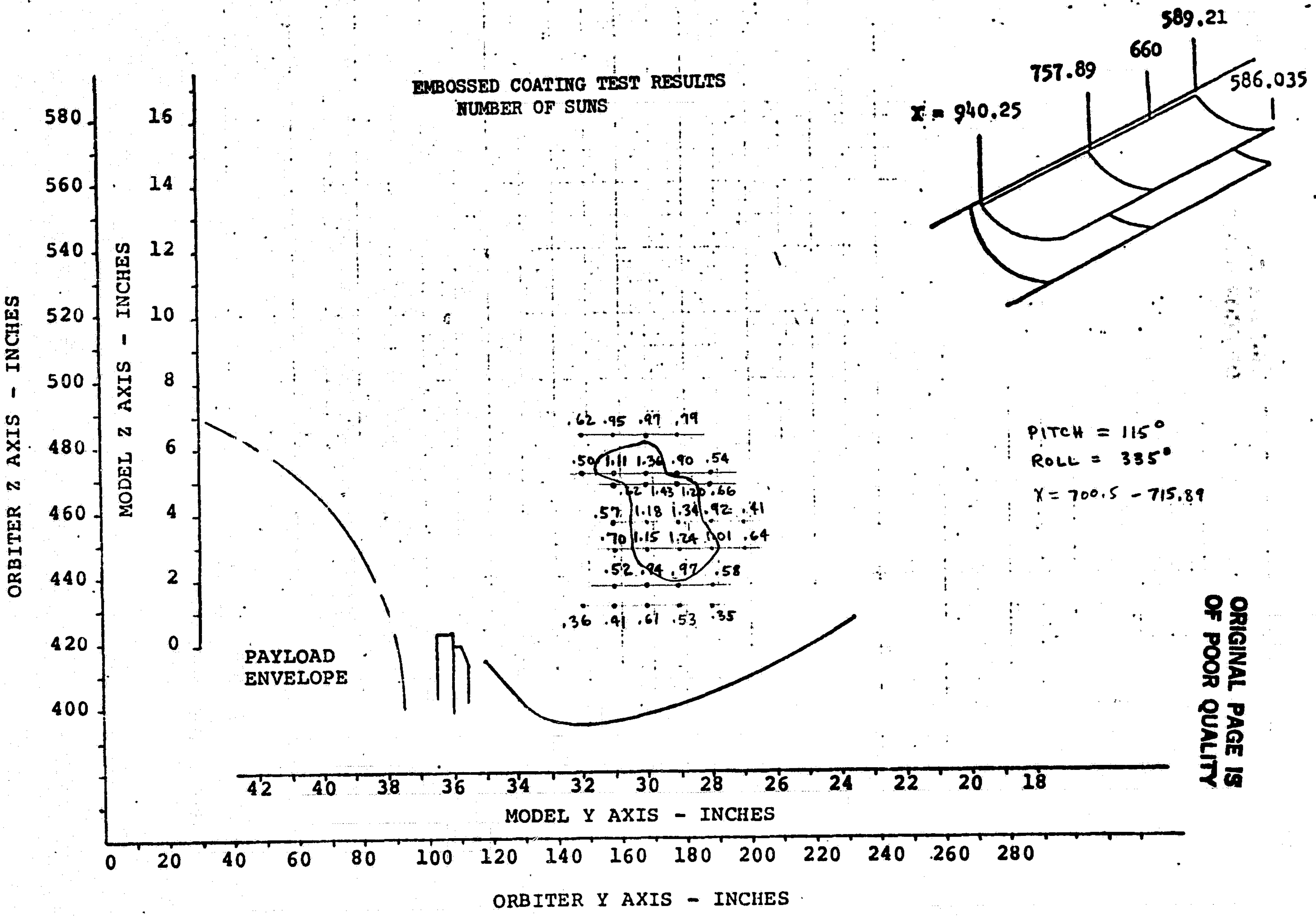
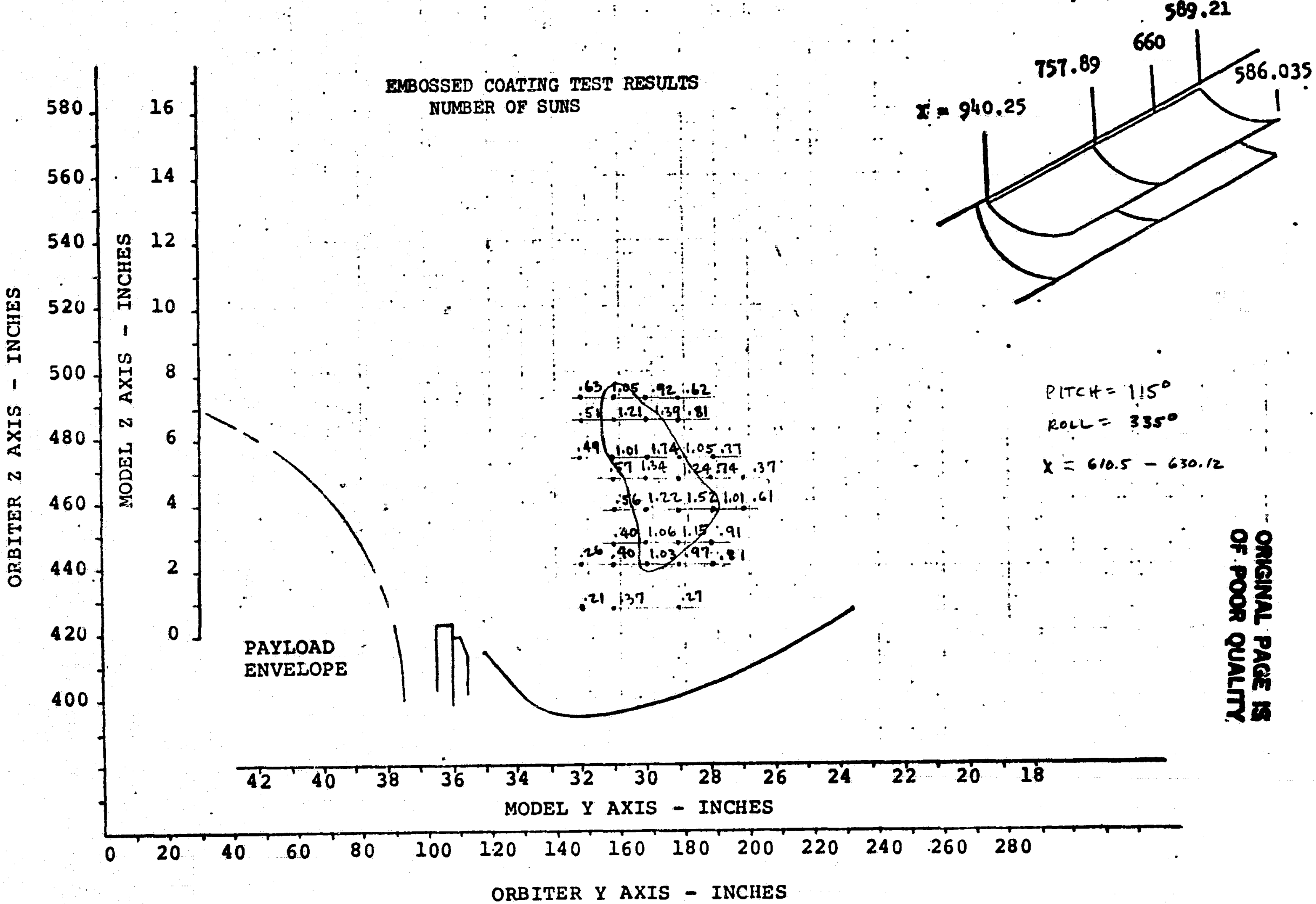

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 335°
X = 700.5 - 715.89
.62 .95 .97 .99
.50 1.11 1.36 .90 .54
.62 1.43 1.20 .66
.57 1.18 1.34 .92 .41
.70 1.15 1.24 1.01 .64
.52 .94 .97 .58
.36 .41 .61 .53 .35
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES



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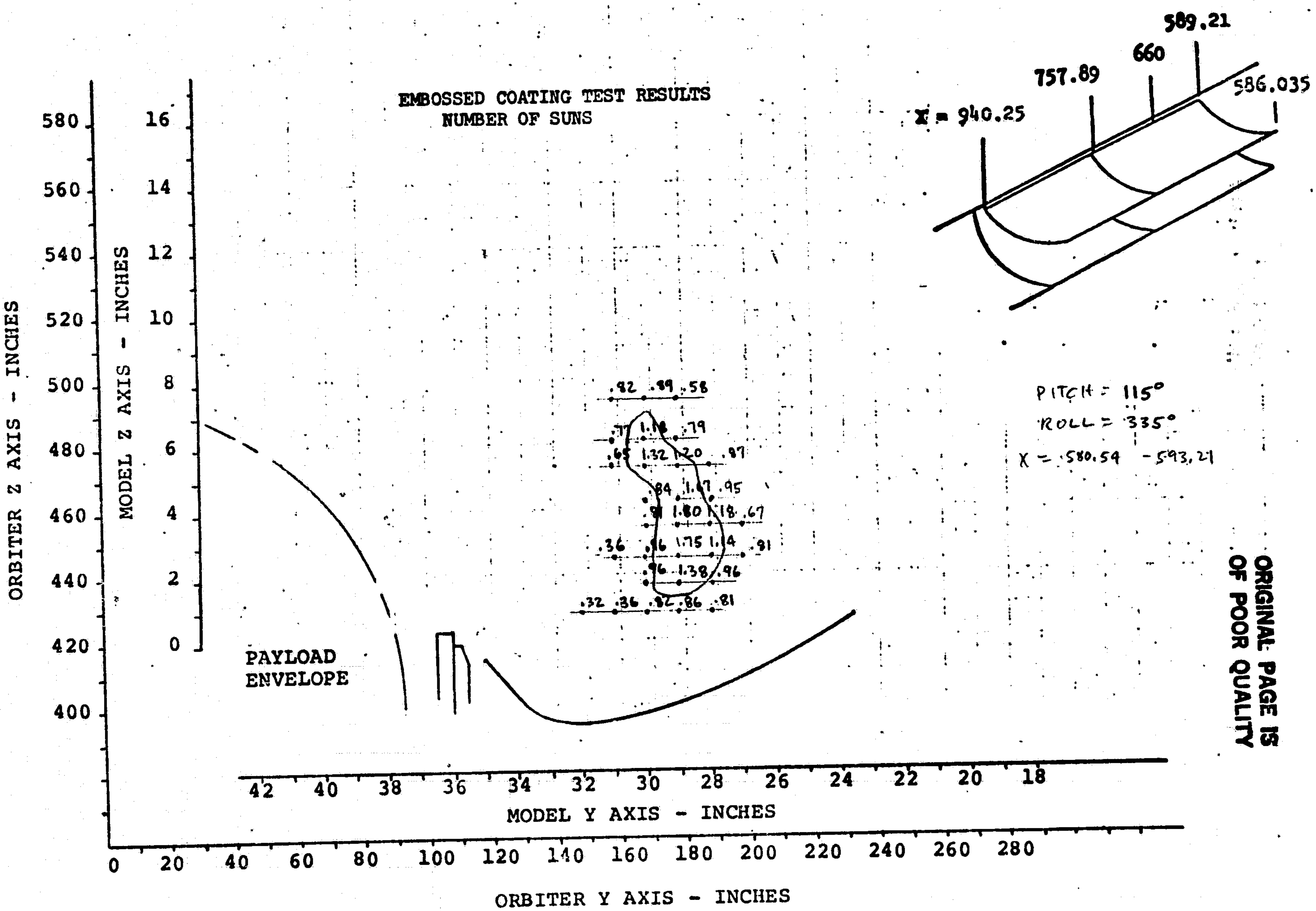
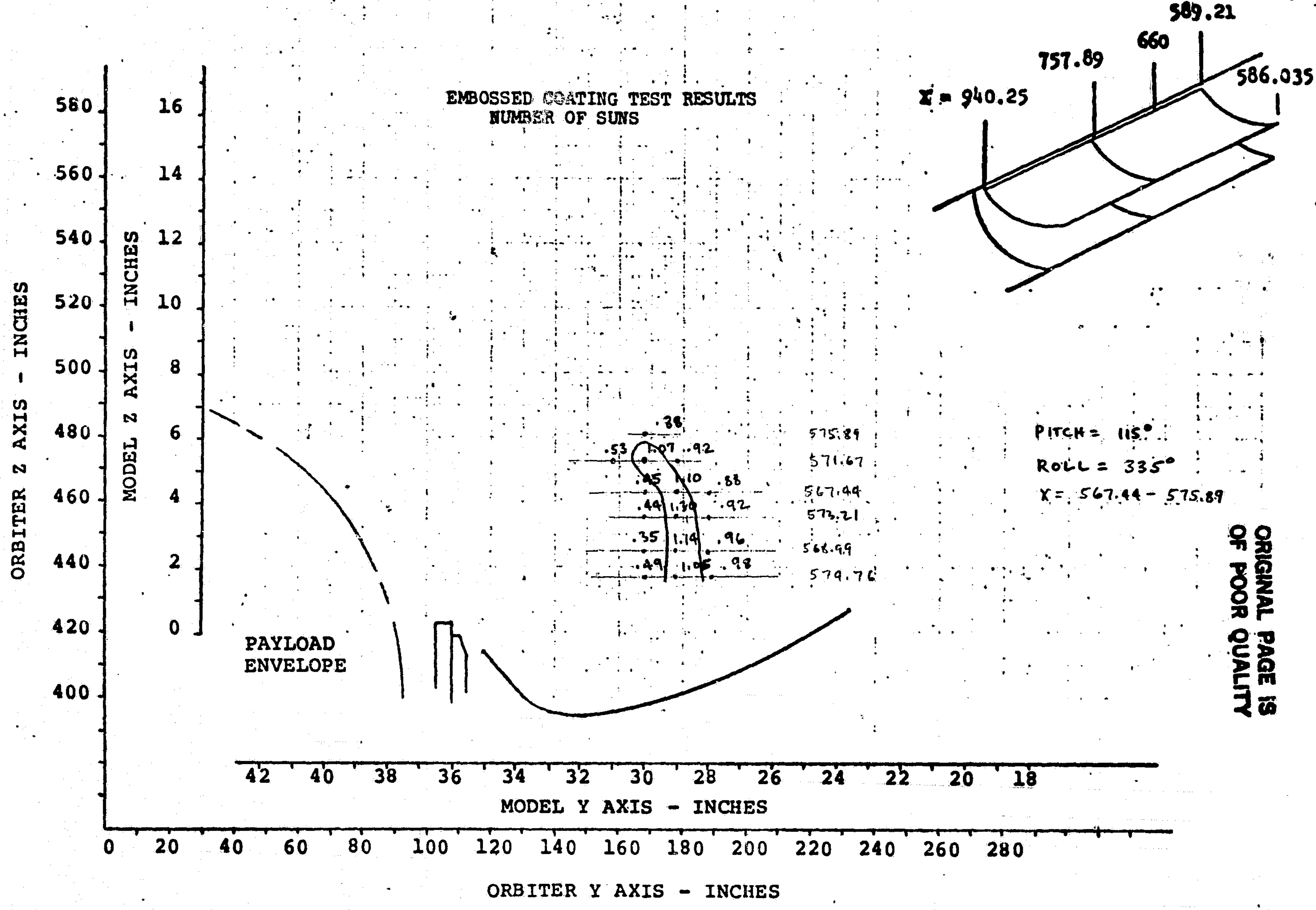

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 115°
ROLL = 335°
X = 580.54 - 593.21
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES



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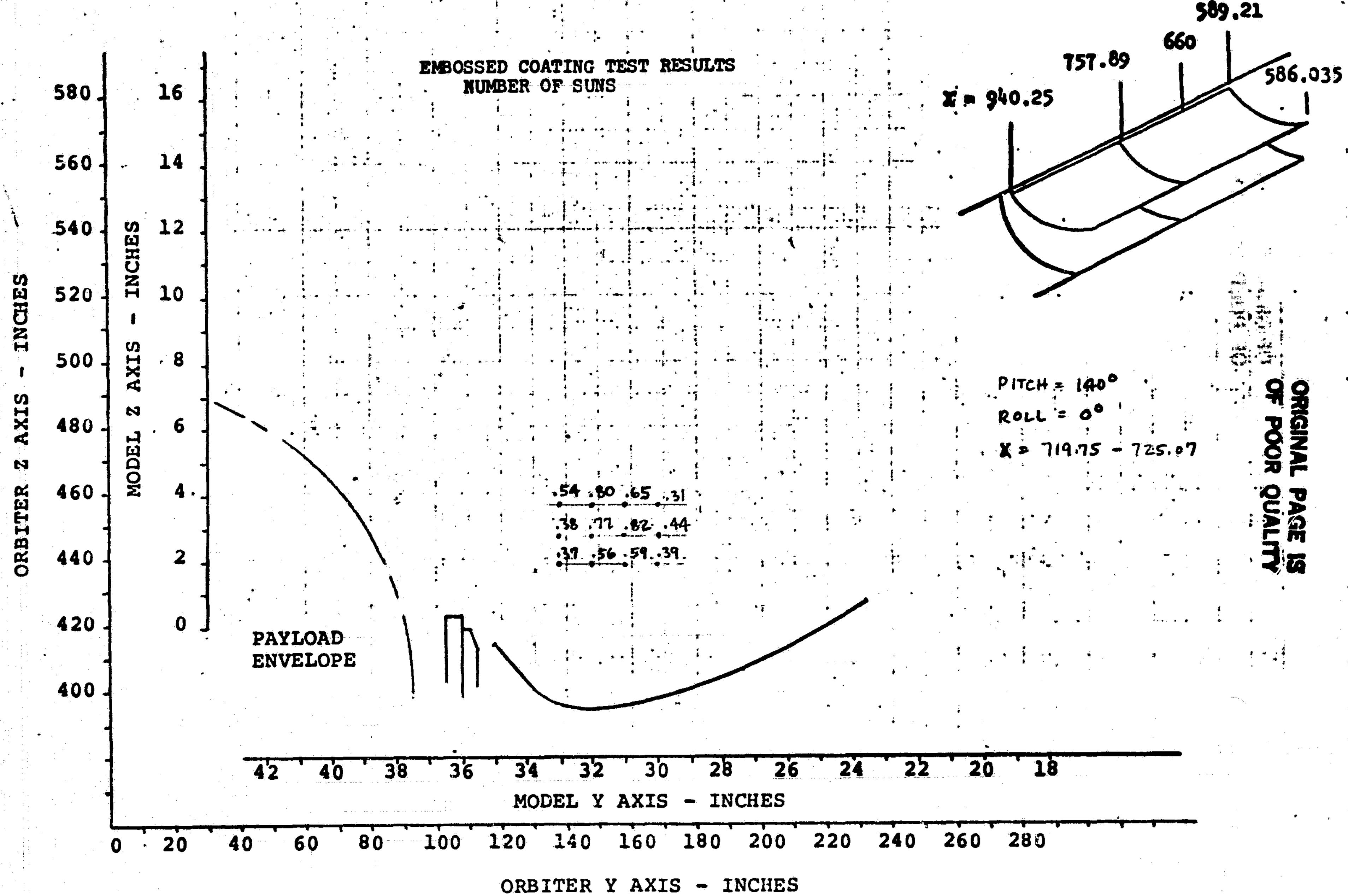
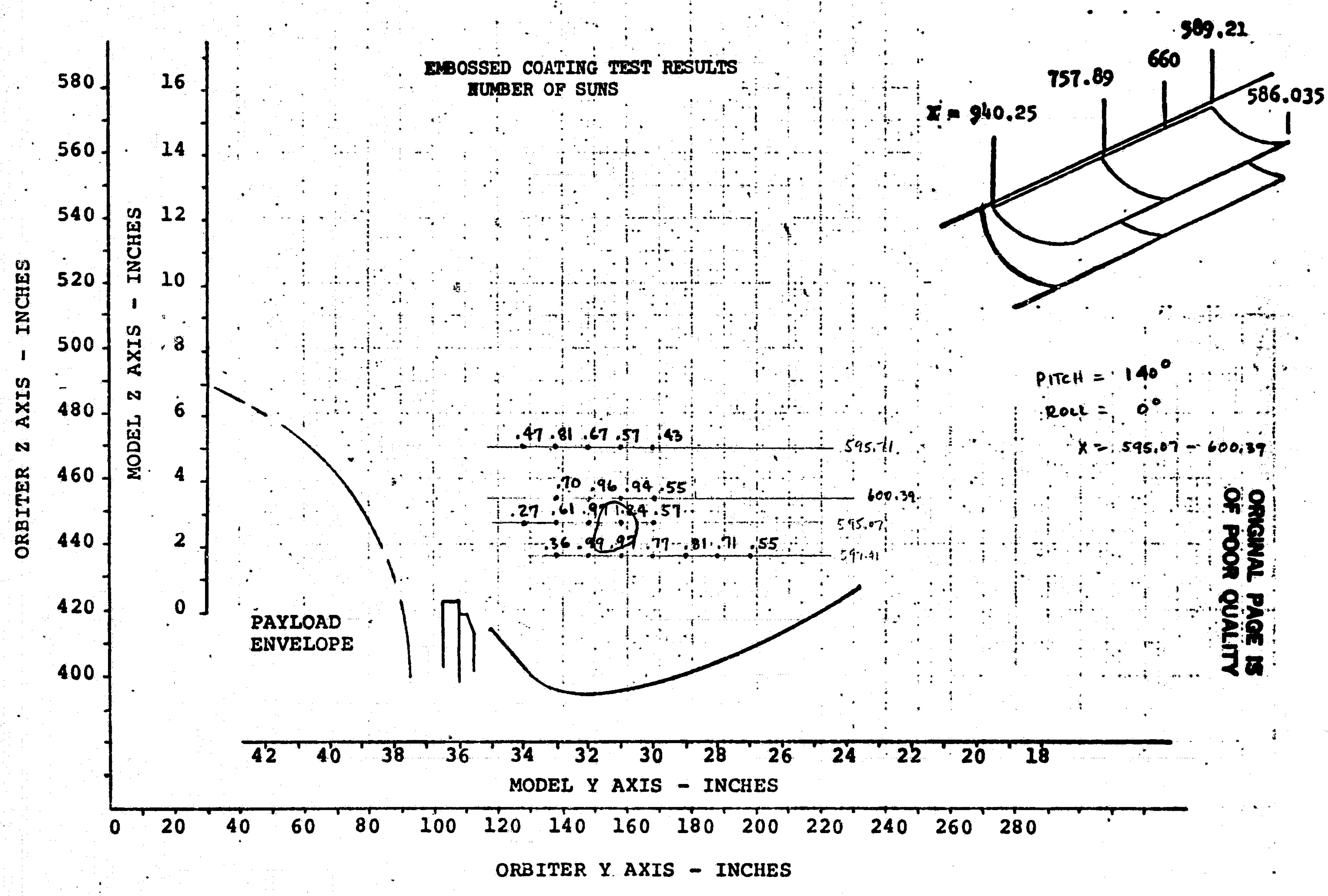
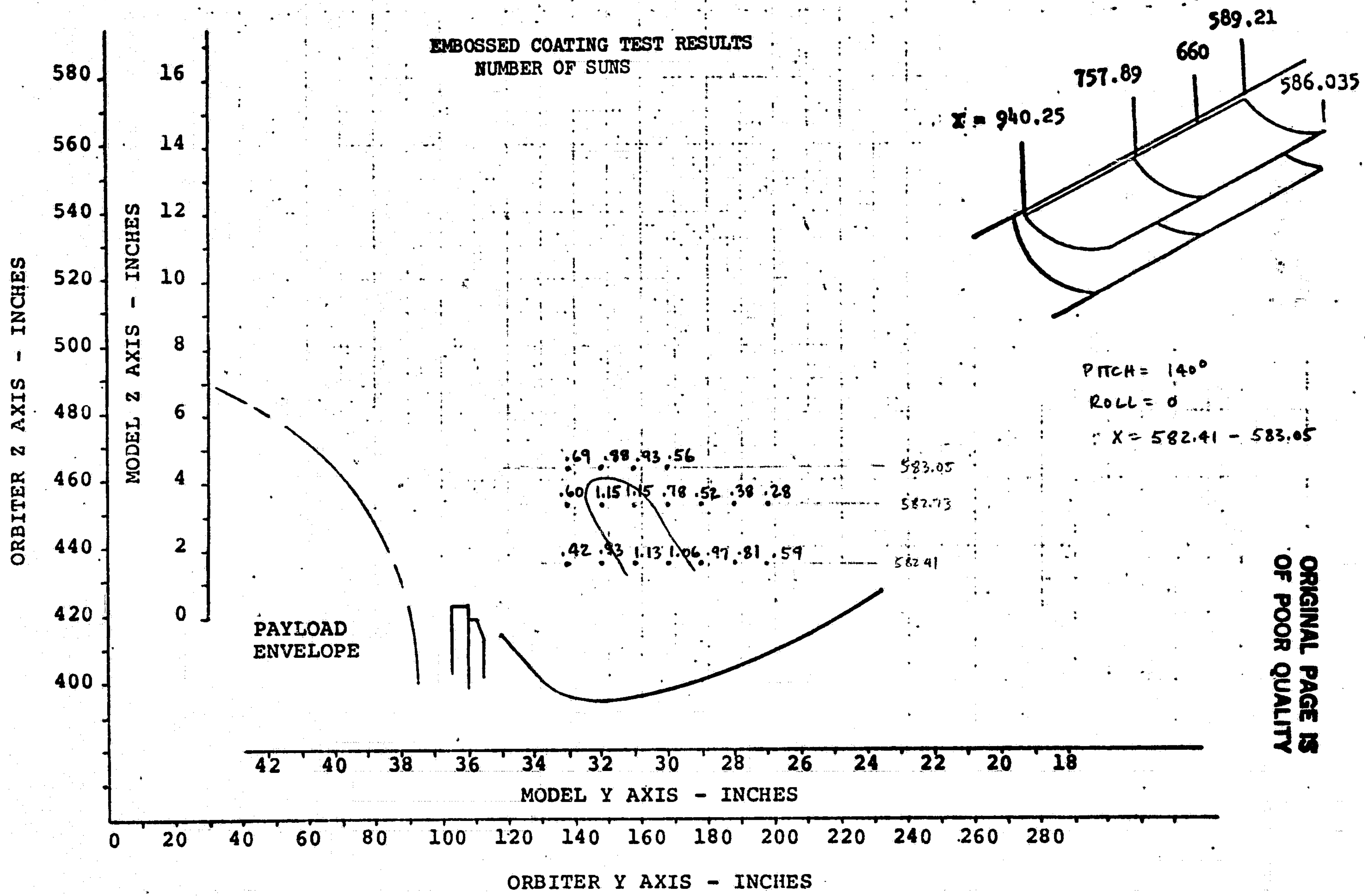
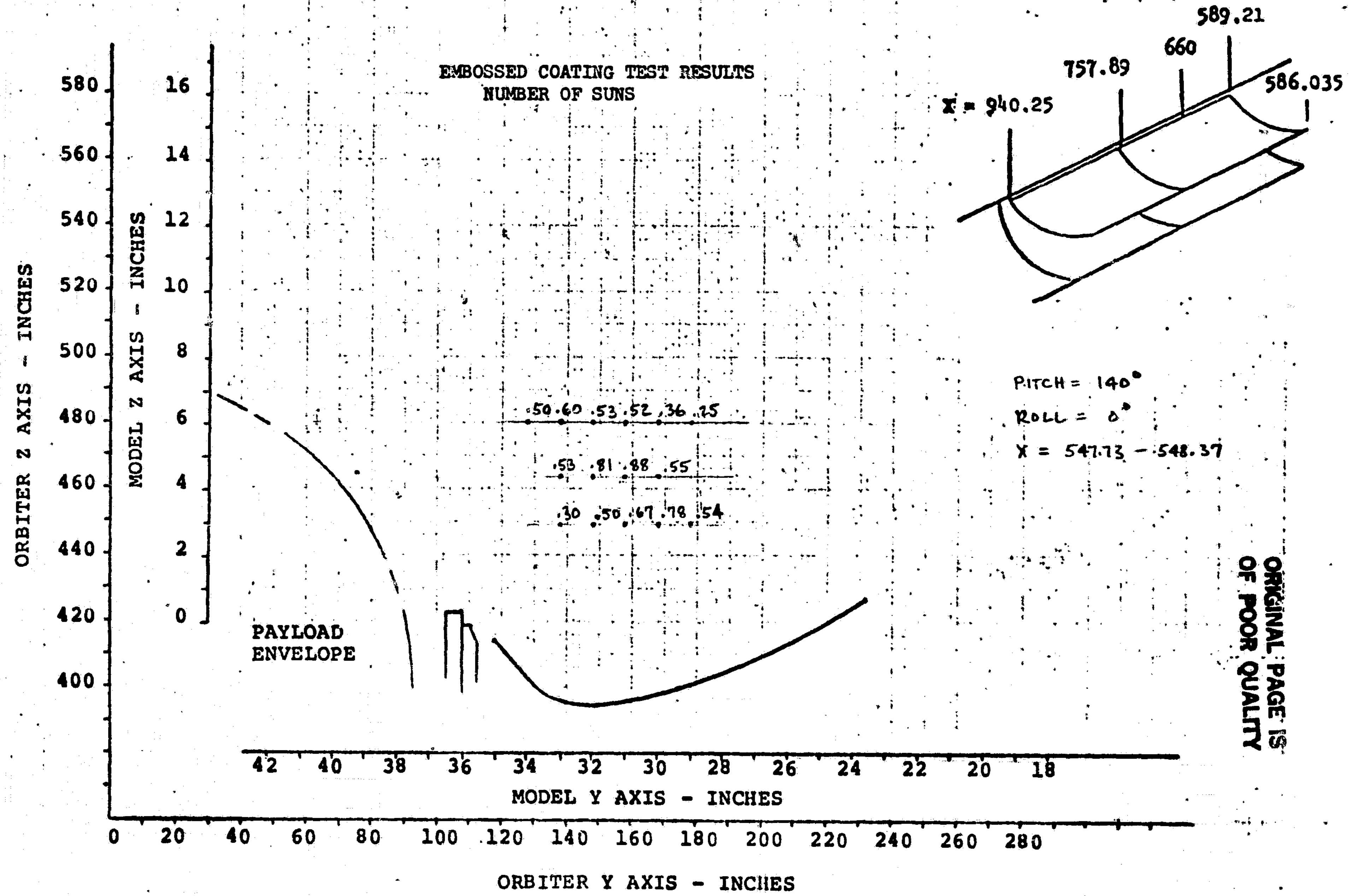


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 0°
X = 719.75 - 725.07
.54 .80 .65 .31
.38 .77 .82 .44
.37 .56 .59 .39
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 0°
X = 595.07 – 600.39
.47 .81 .67 .57 .43
595.11
.70 .96 .94 .55
600.39
.27 .61 .97 1.24 .57
595.07
.36 .99 .97 .77 .81 .71 .55
591.41
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 0
X = 582.41 - 583.05
.69 .88 .93 .56
.60 1.15 1.15 .78 .52 .38 .28
.42 .93 1.13 1.06 .97 .81 .59
583.05
582.73
582.41
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
.50 .60 .53 .52 .36 .25
.53 .81 .88 .55
.30 .50 .67 .78 .54
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 0°
X = 547.73 - 548.37
ORIGINAL PAGE IS
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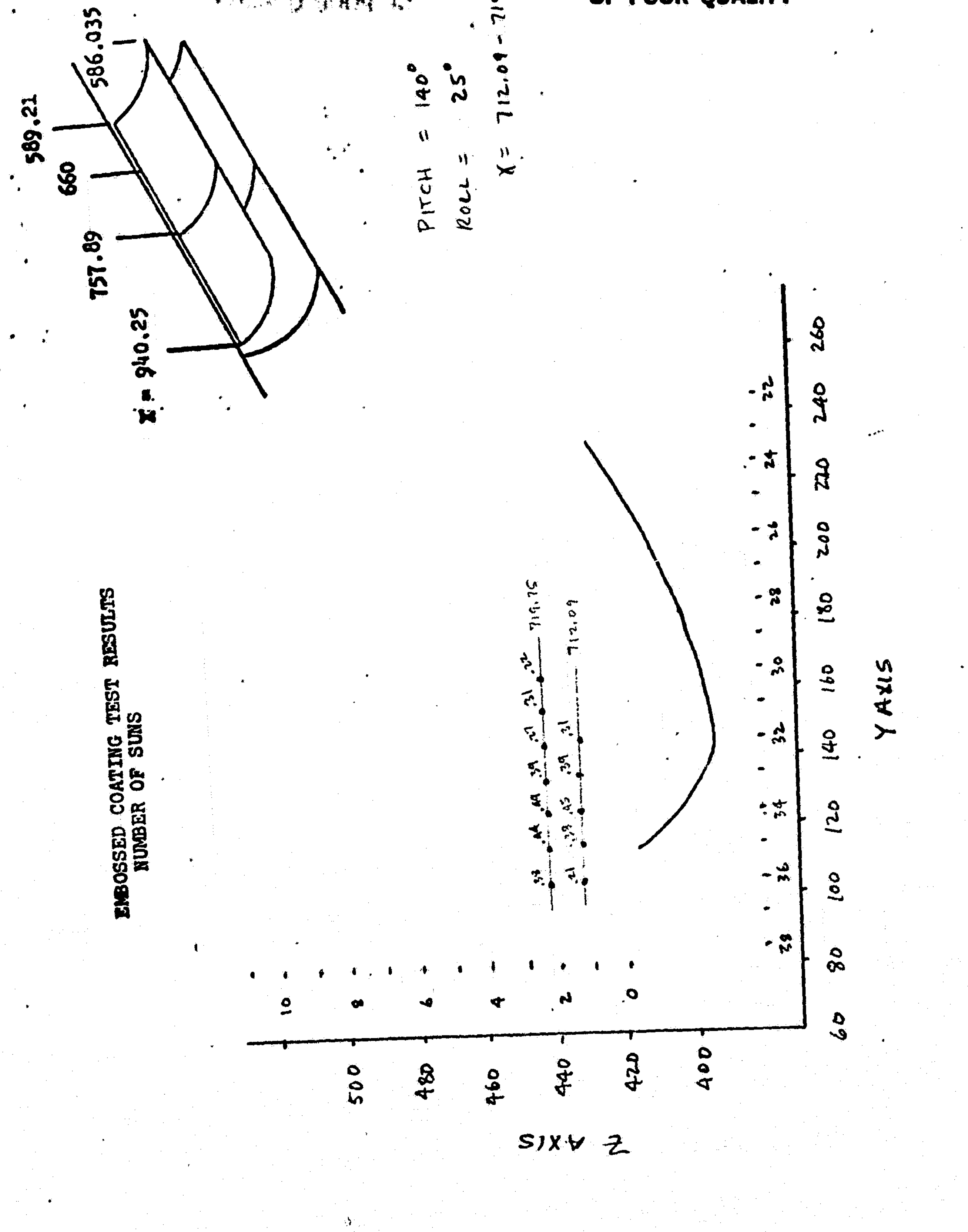
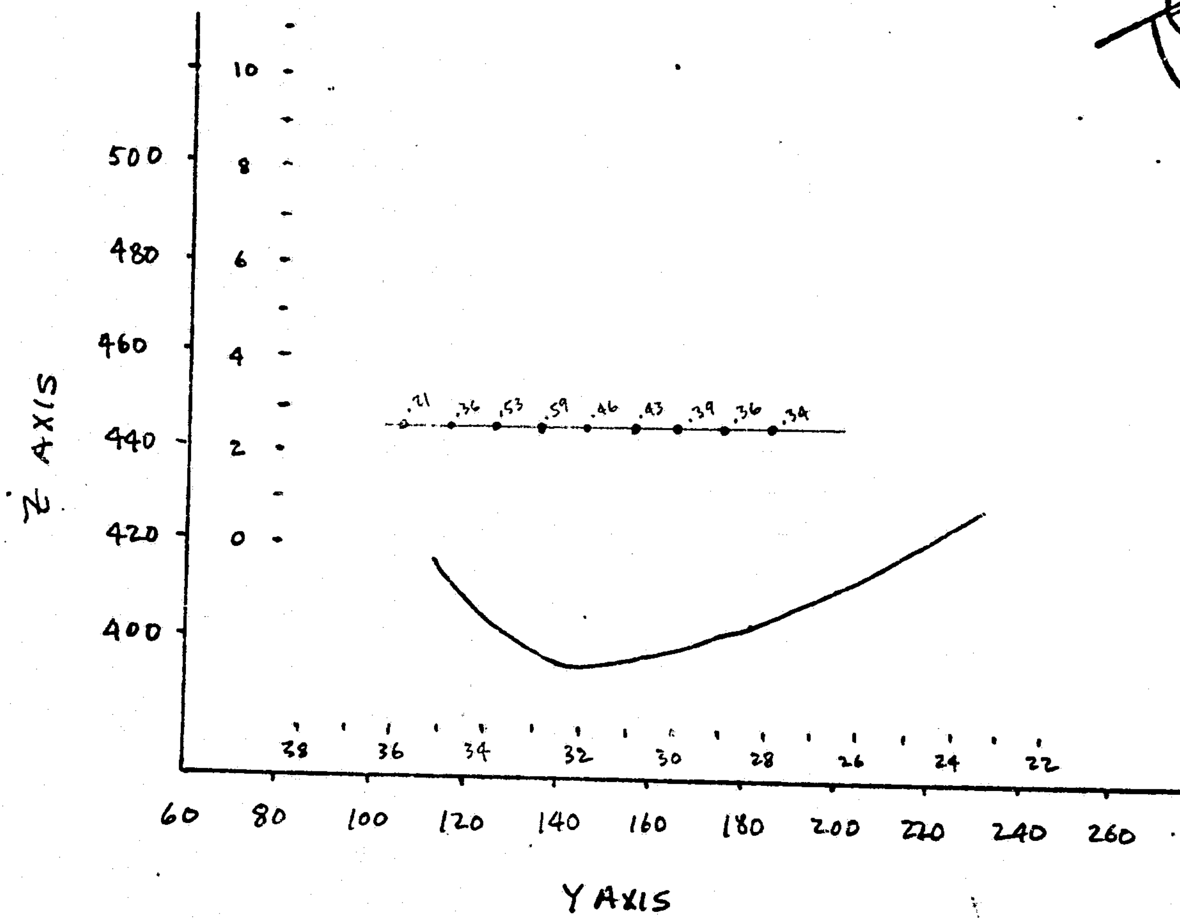
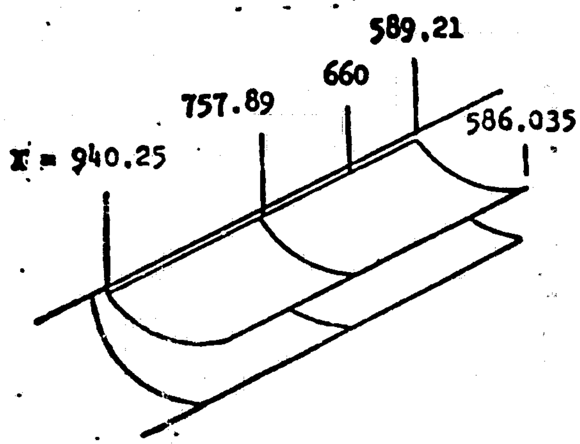
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES

ORIGINAL PAGE IS
OF POOR QUALITY



EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 140°
ROLL = 25°
X = 589.75

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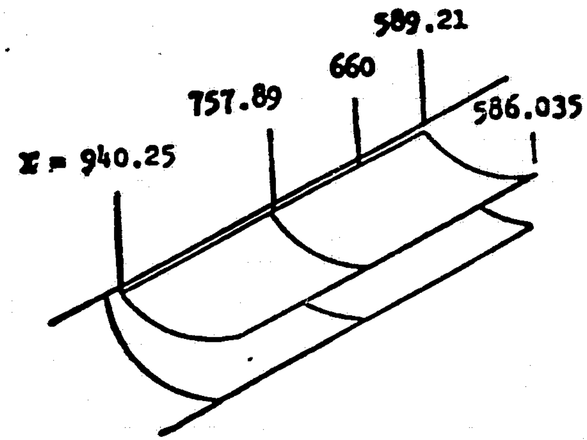
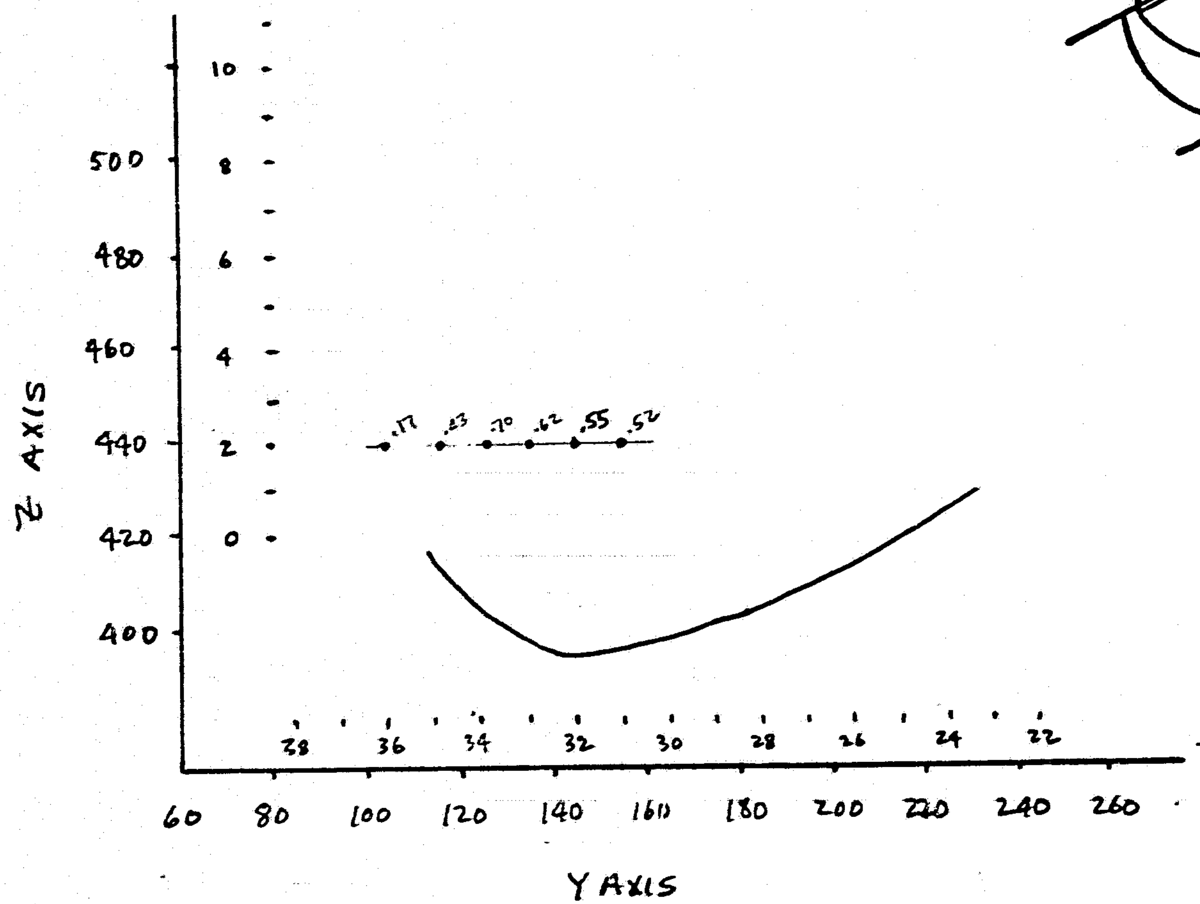
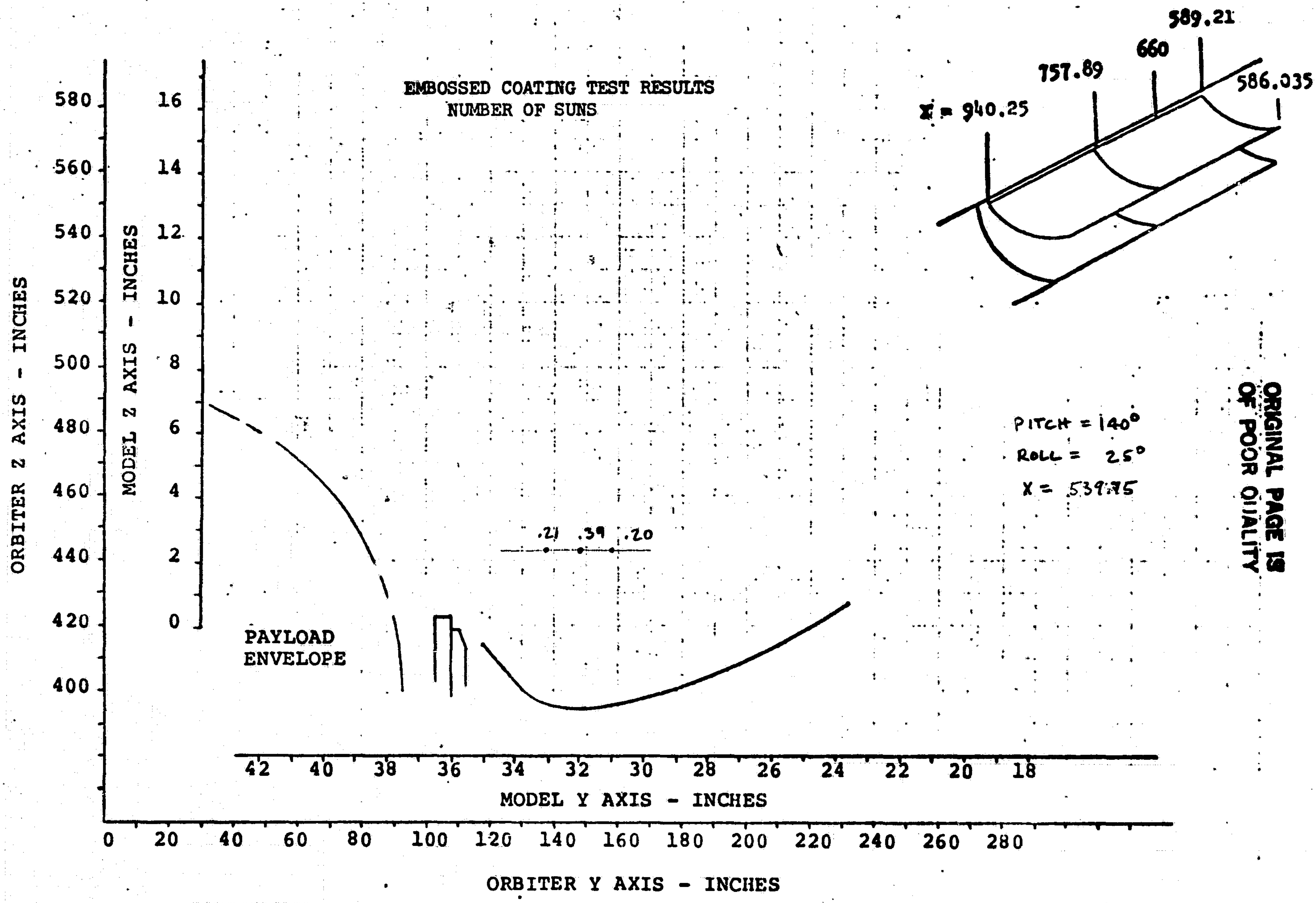
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



PITCH = 140°
ROLL = 25°
X = 582.09





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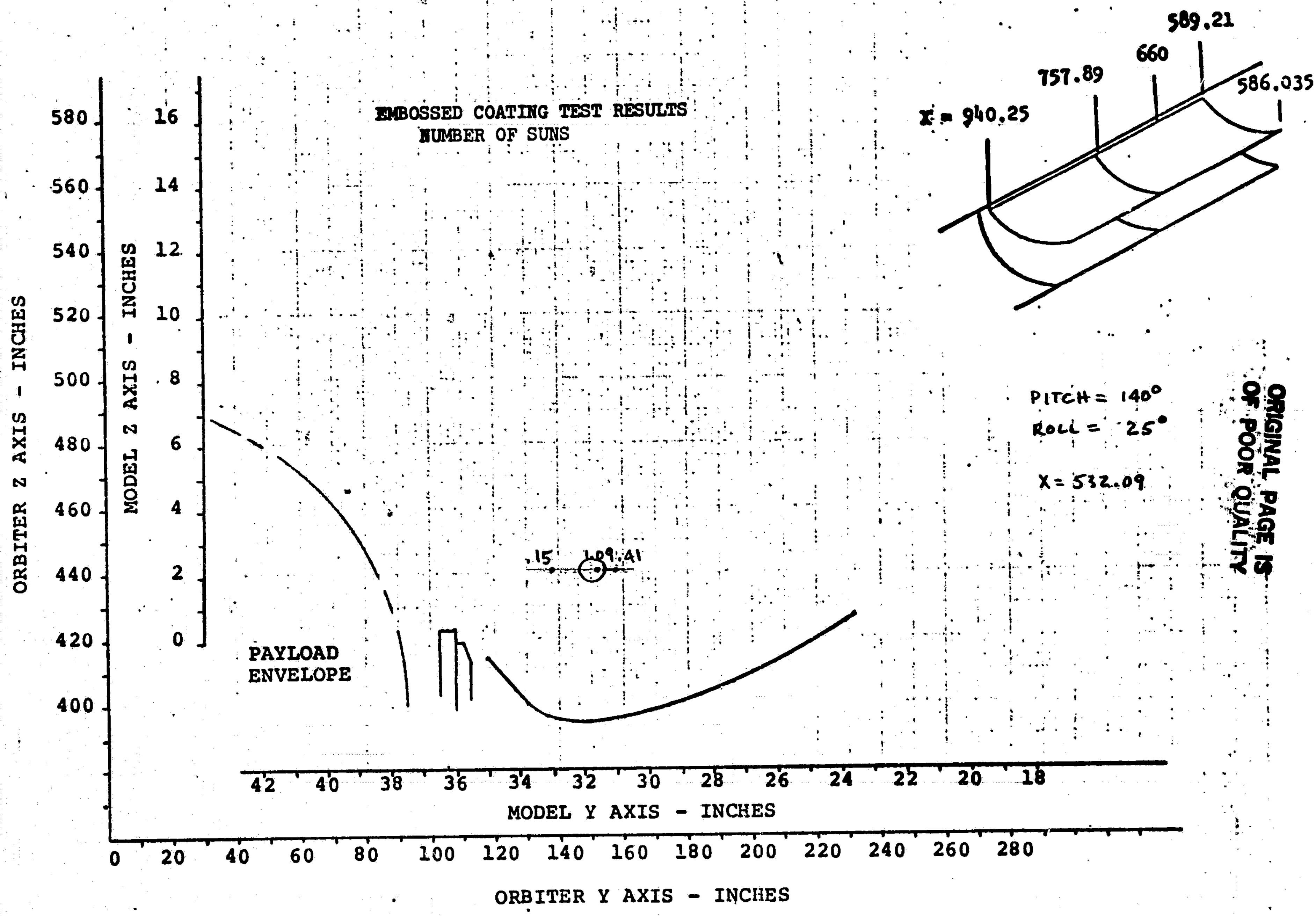

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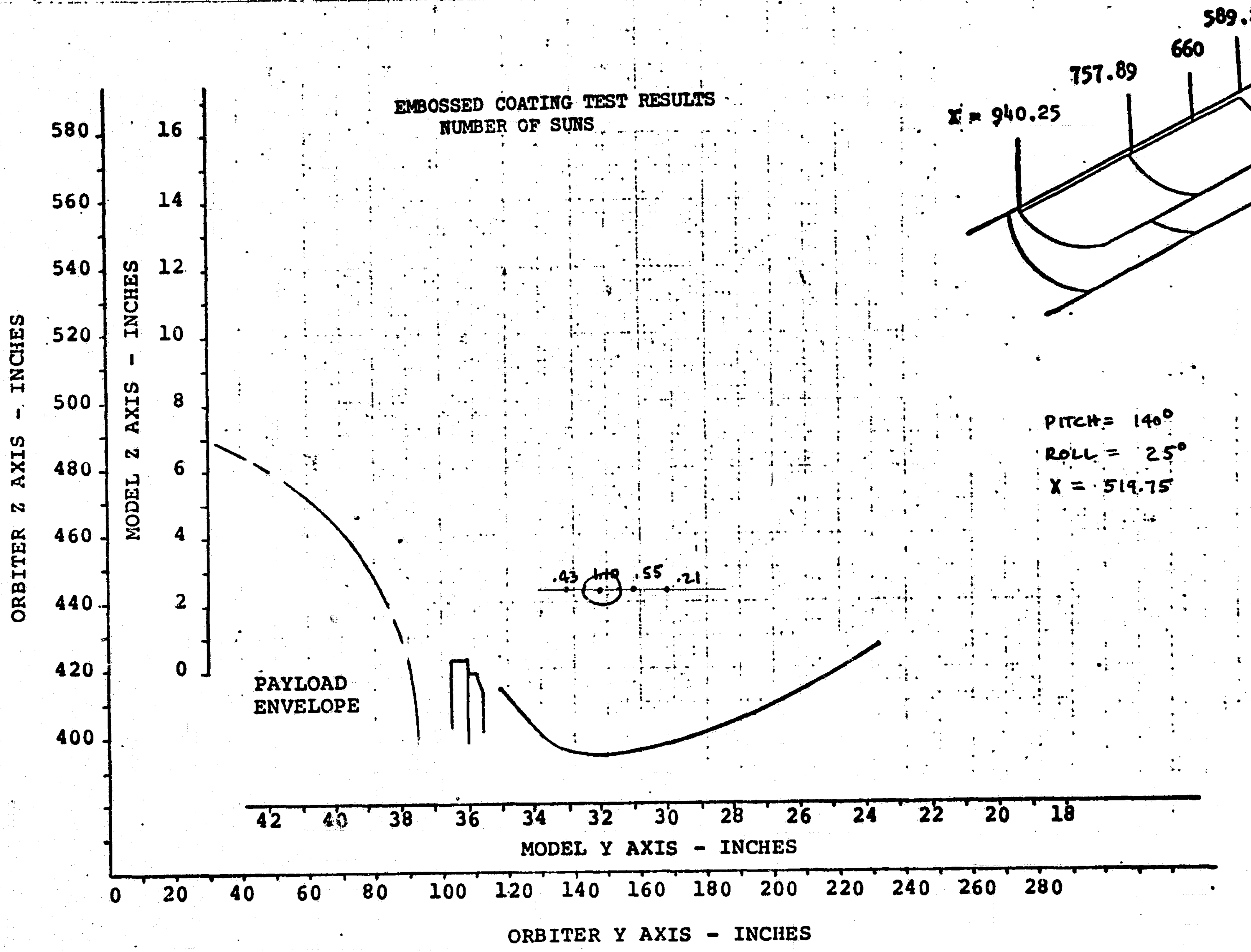
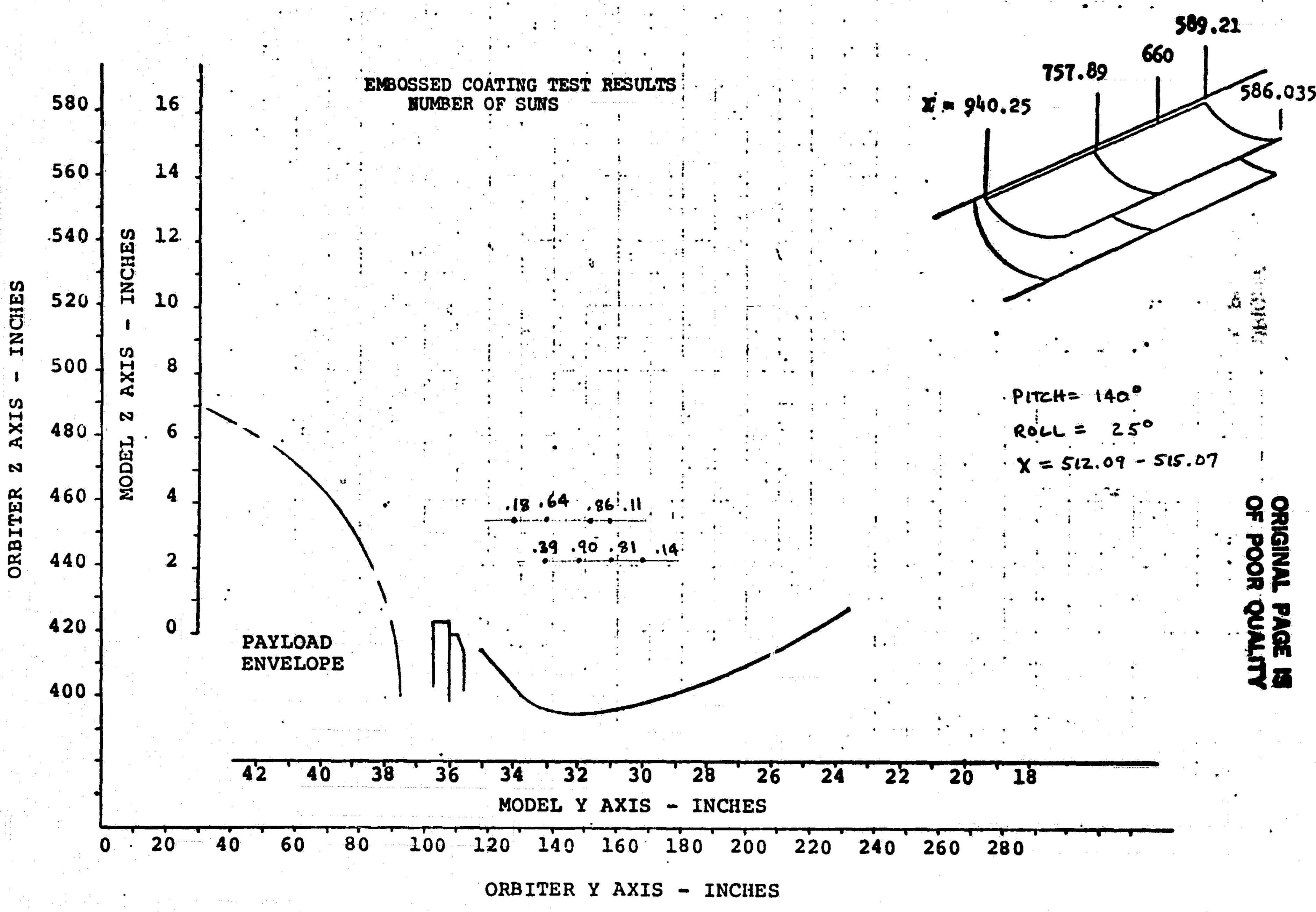

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 25°
X = 519.75
.43
1.10
.55
.21
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES



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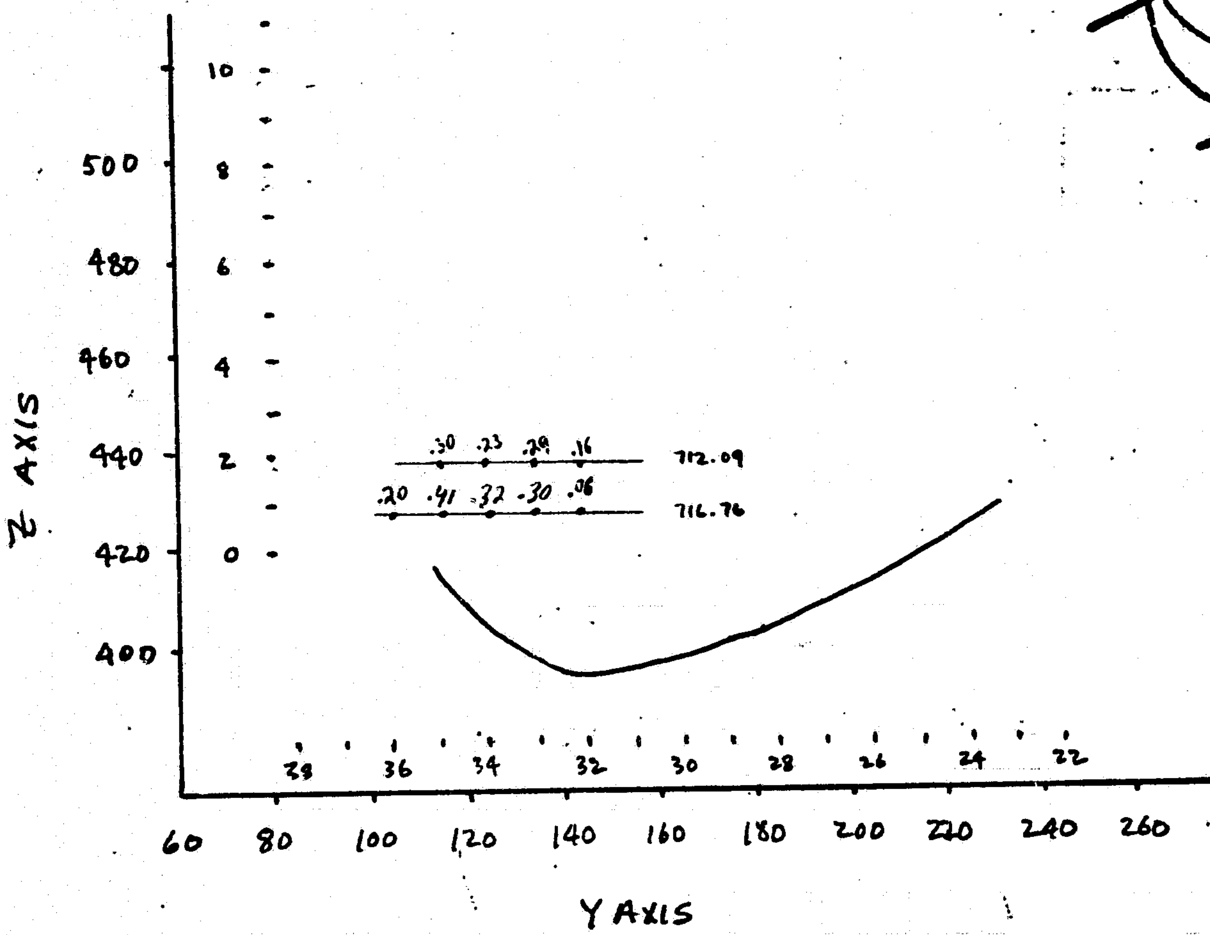
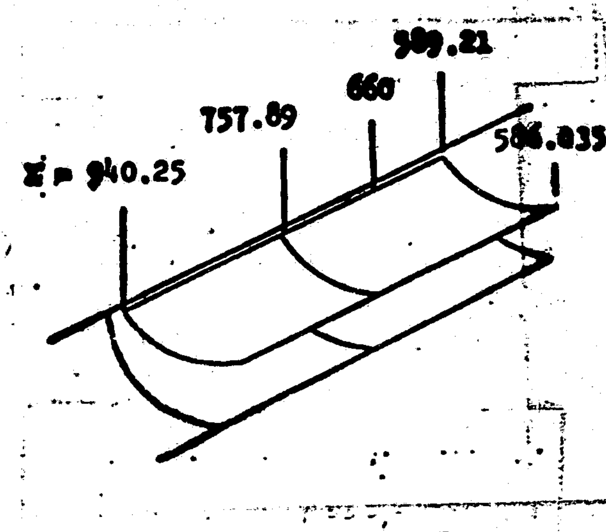
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 140°
ROLL = 50°
X = 712.09 – 716.76

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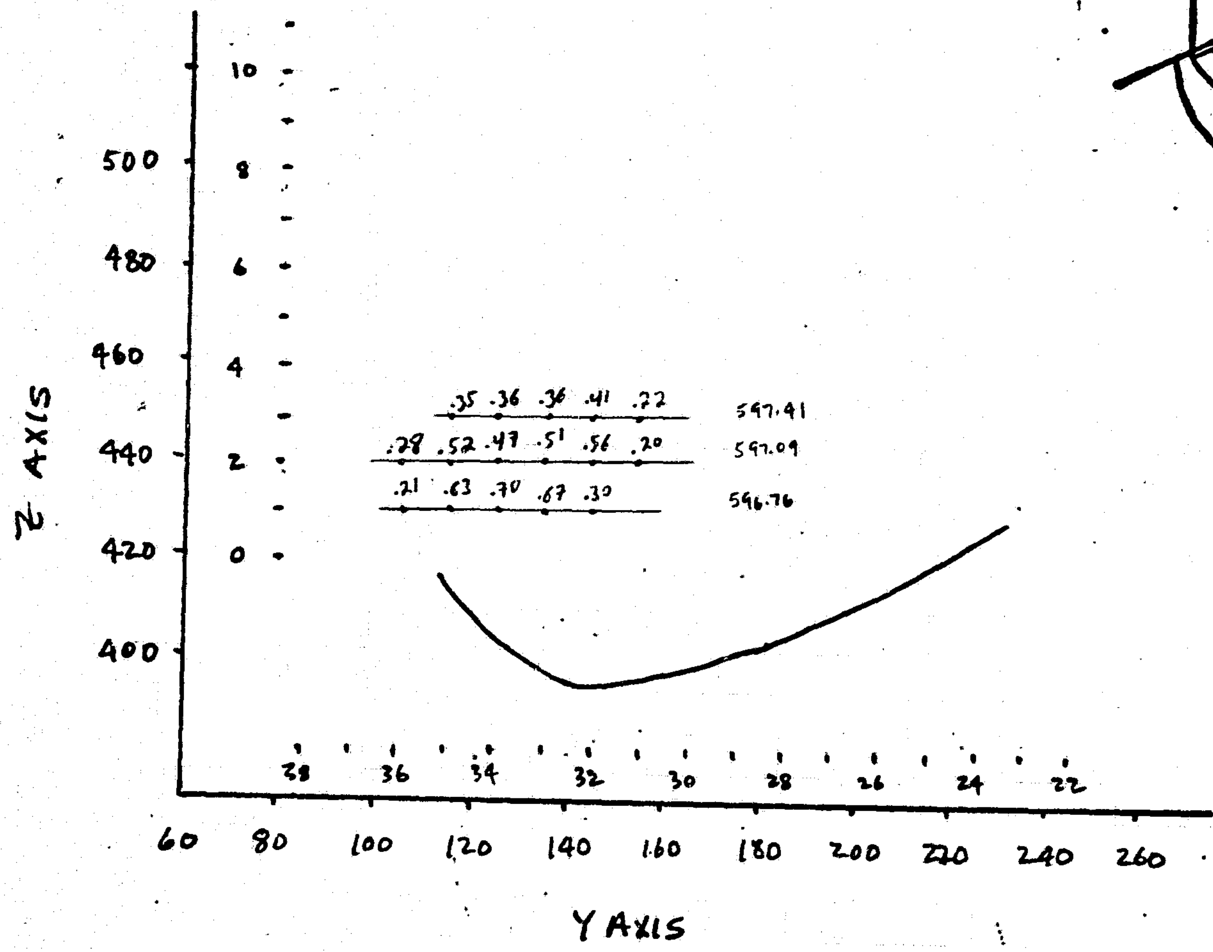
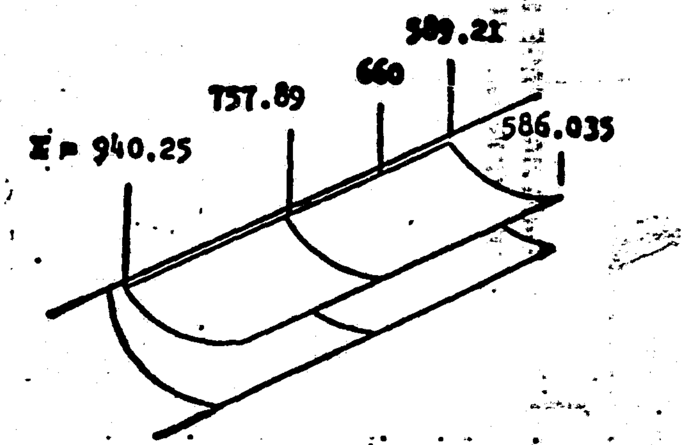
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 140°
ROLL = 50°
X = 596.76 - 597.41

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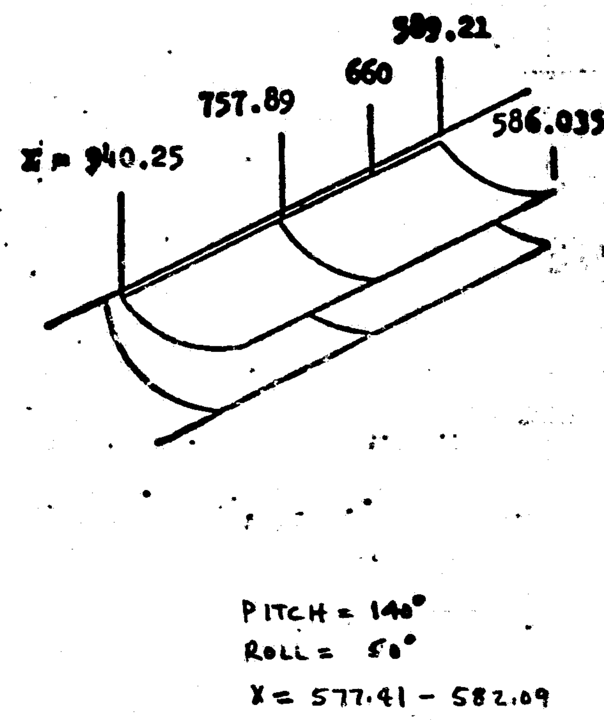
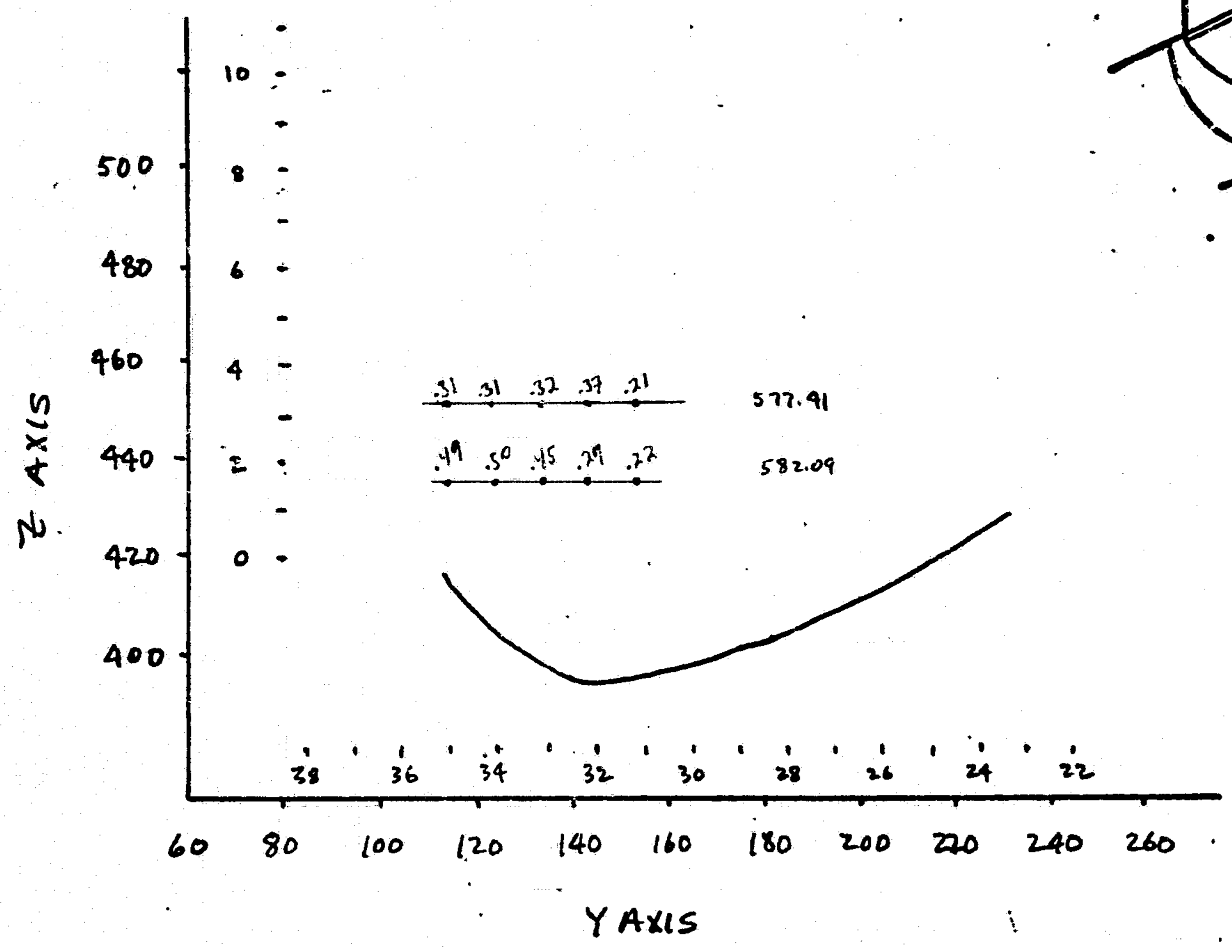
OF POOR QUALITY

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





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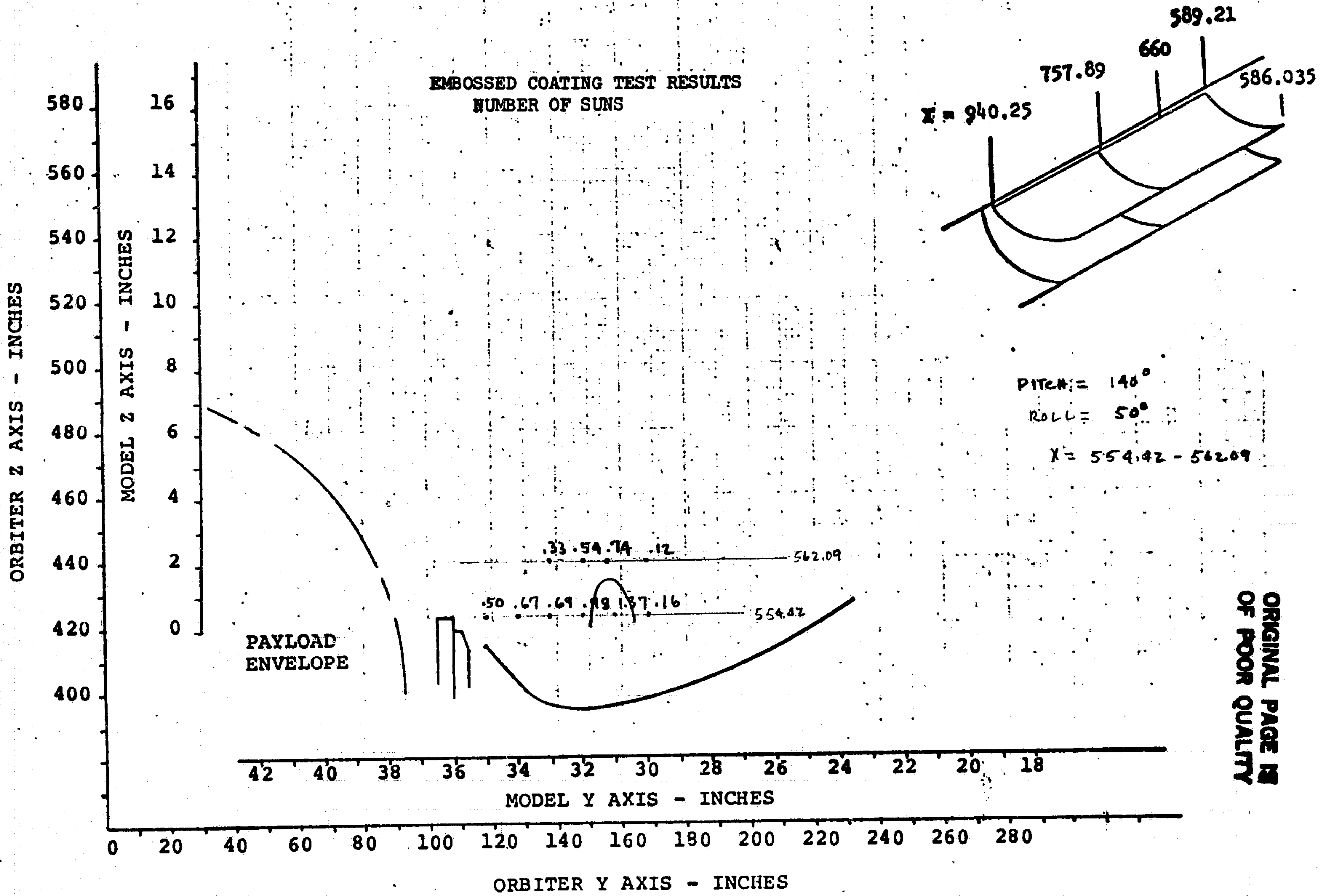

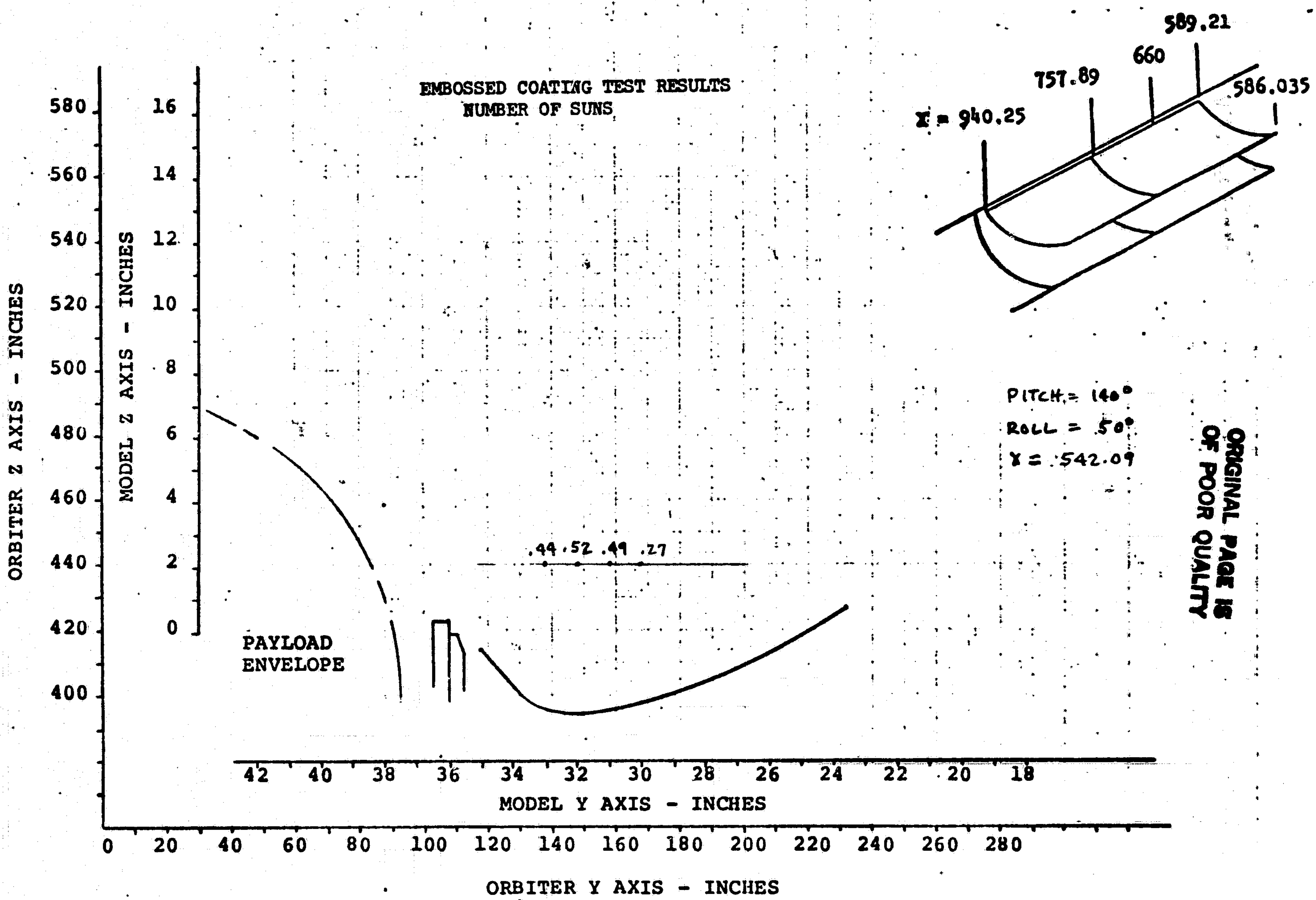

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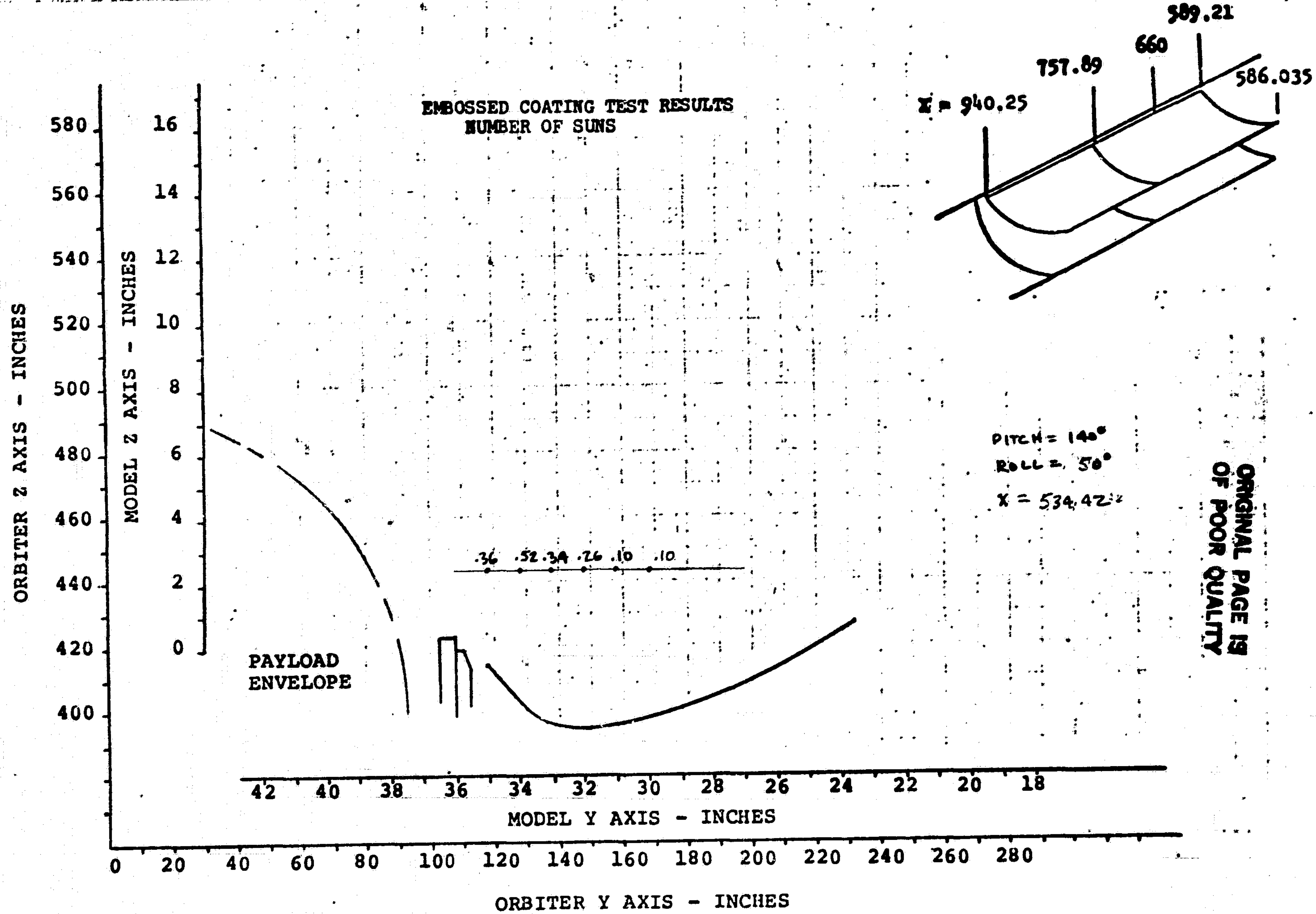

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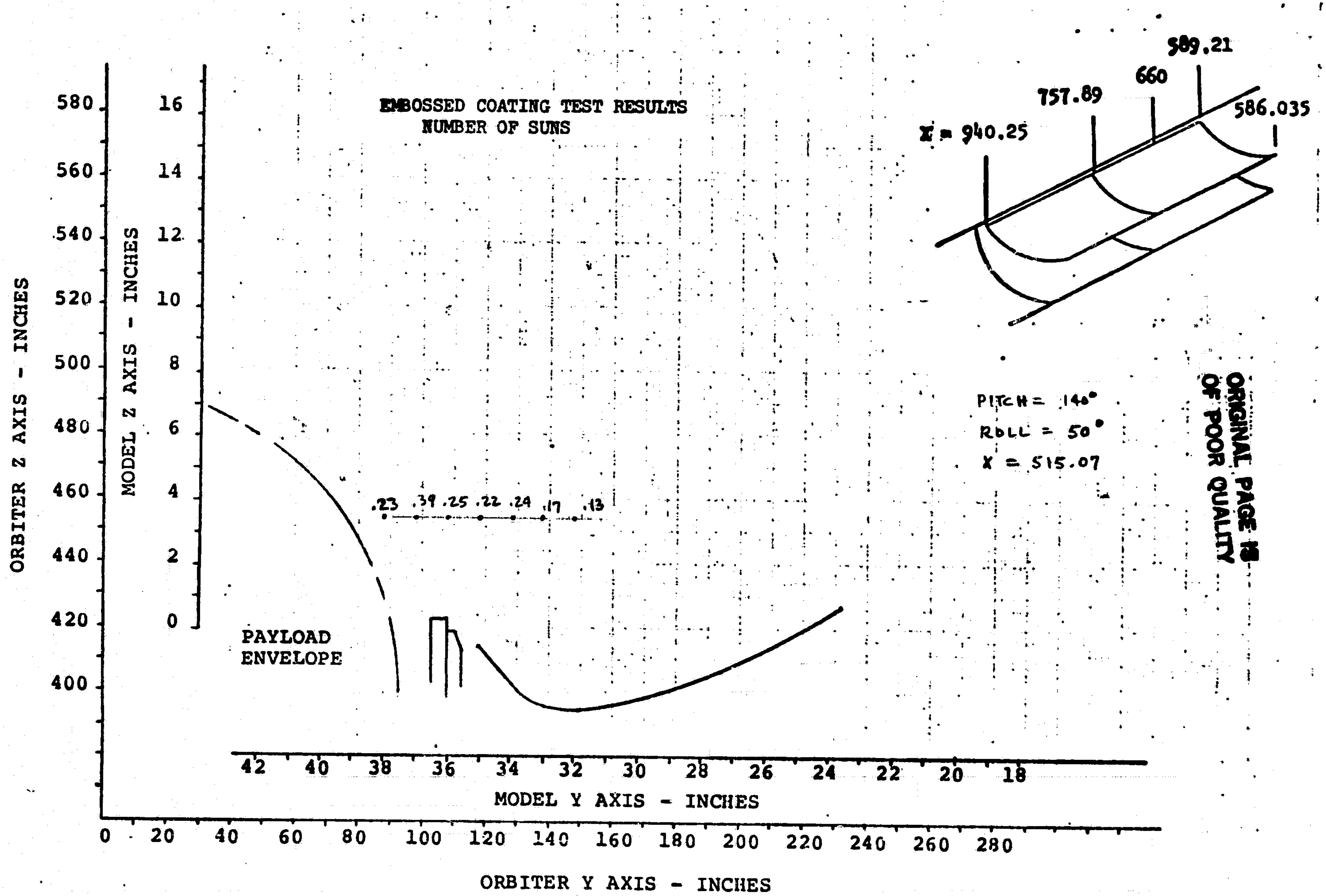
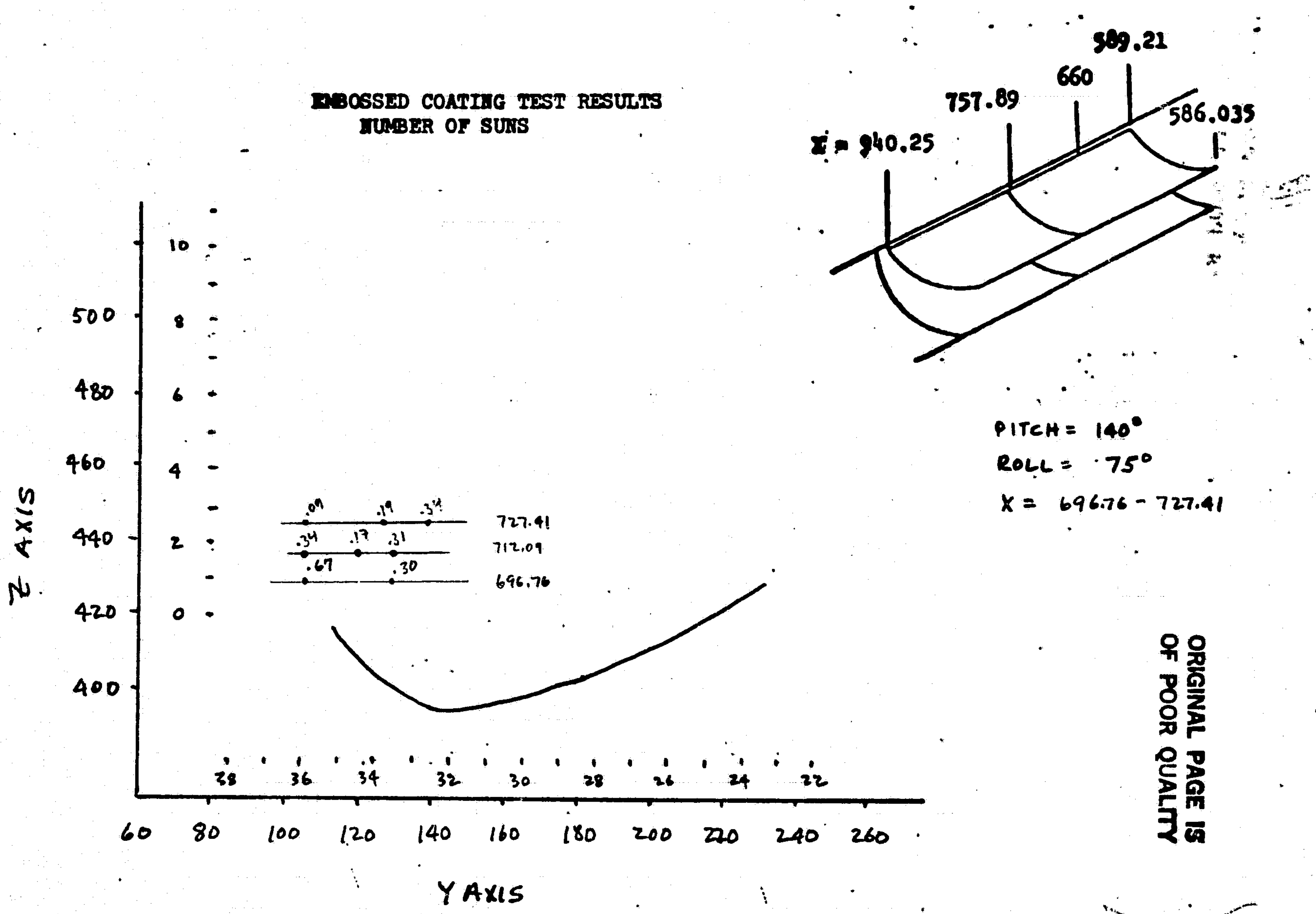


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
.23 .39 .25 .22 .24 .17 .13
PAYLOAD
ENVELOPE
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 50°
X = 515.07
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



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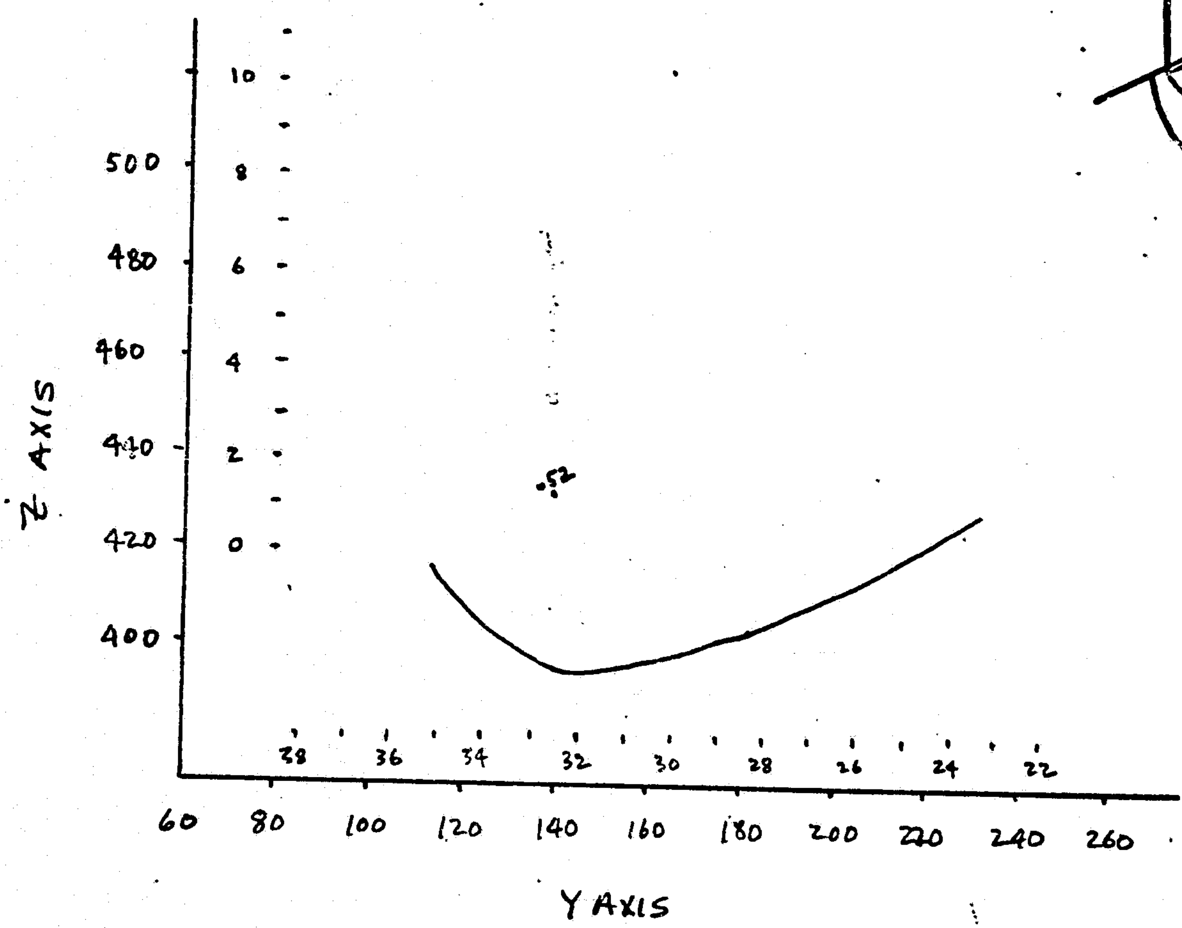
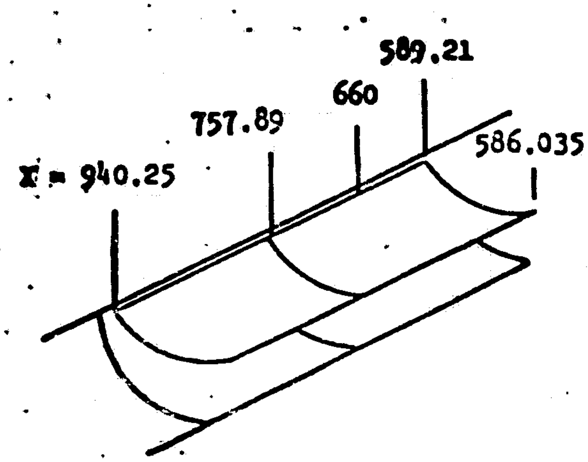
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 140°
ROLL = 75°
X = 606.76

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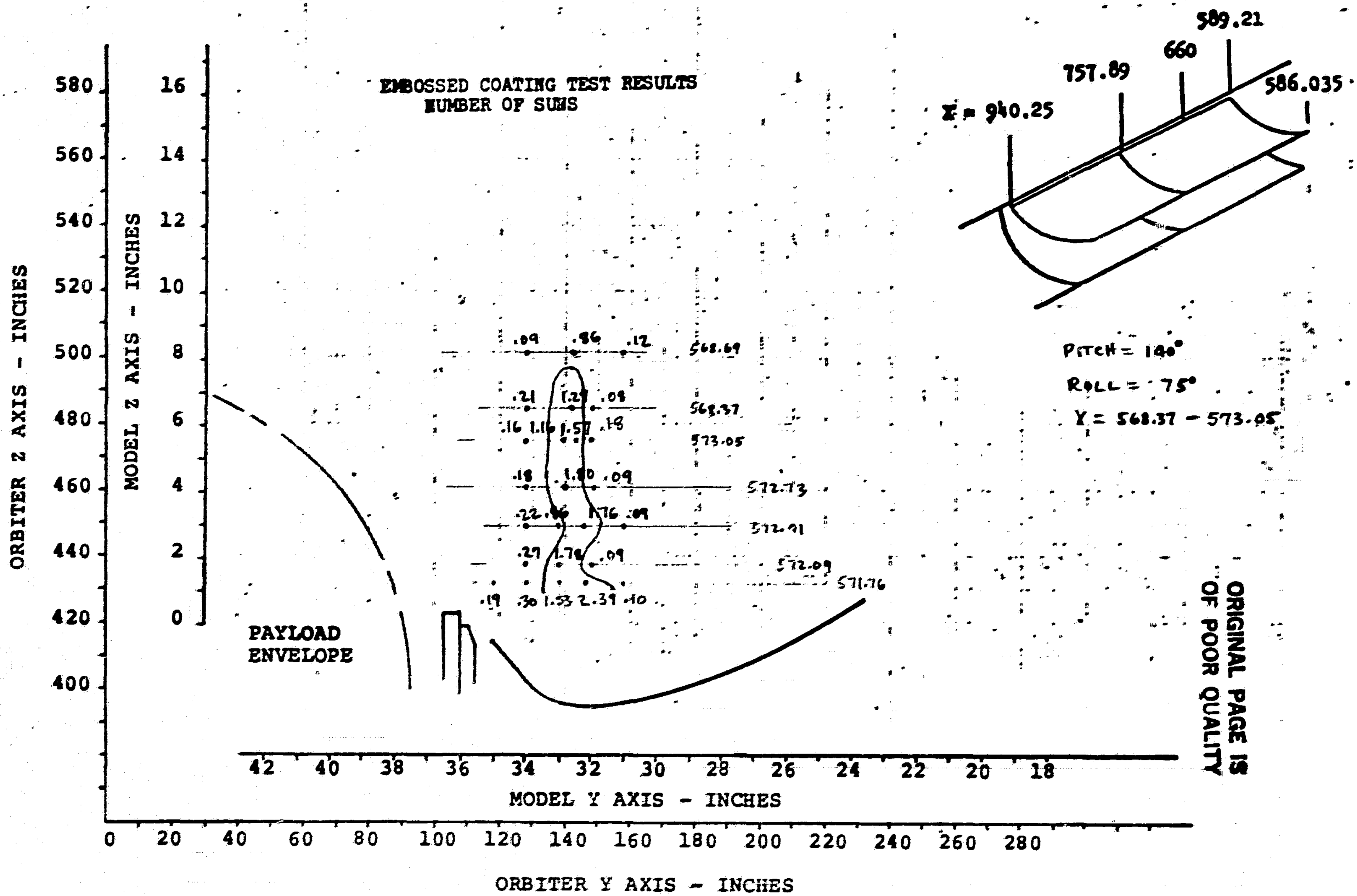

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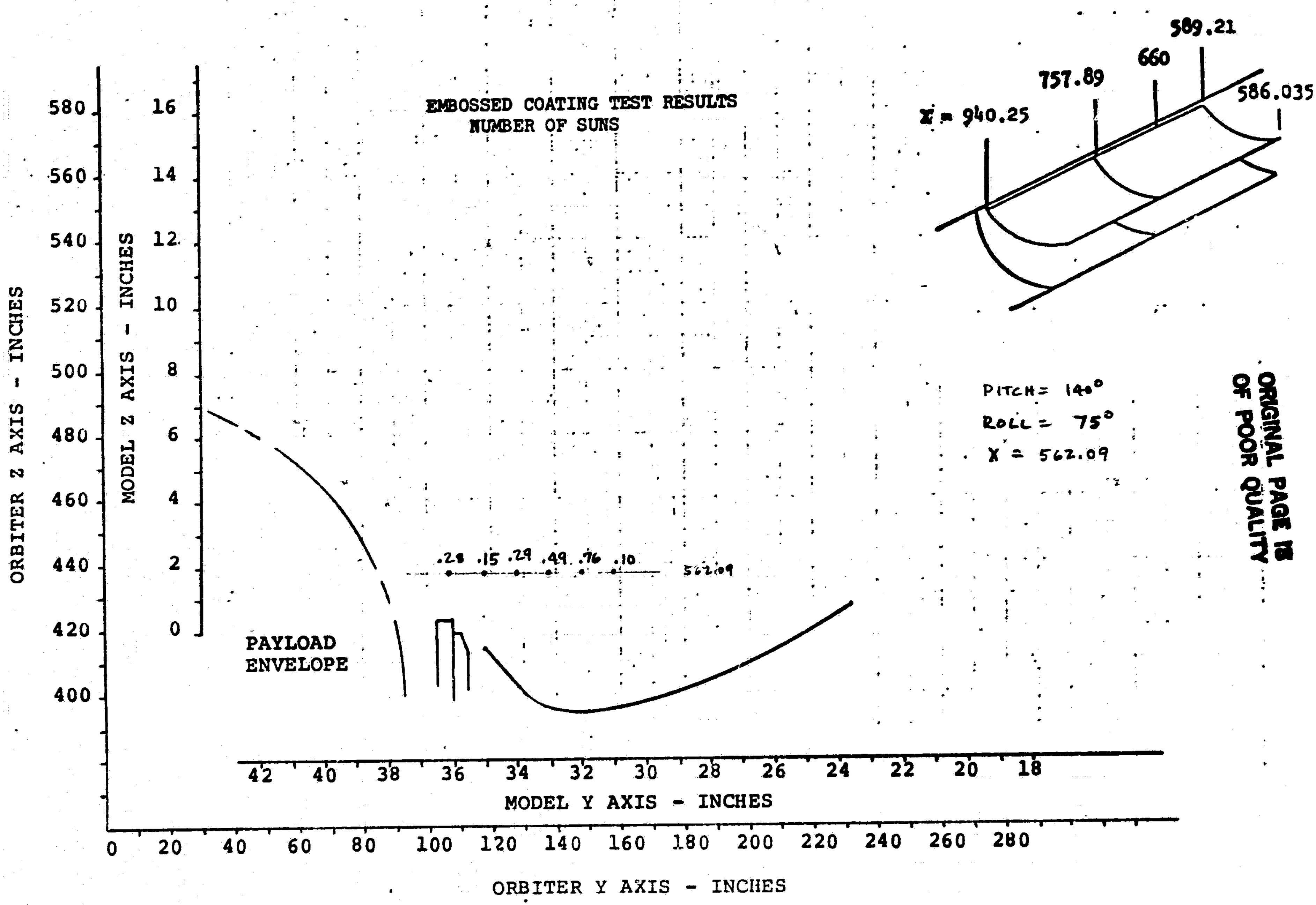
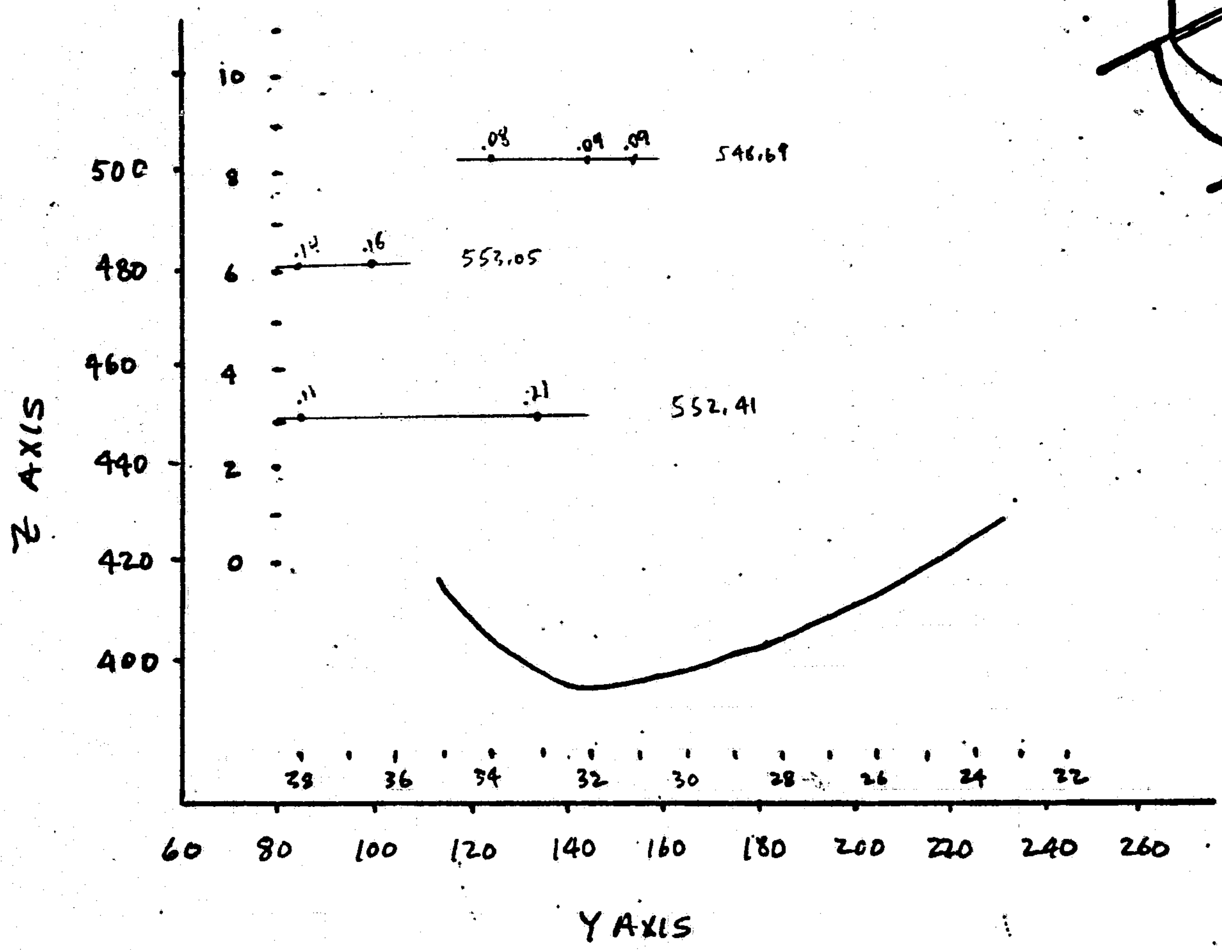
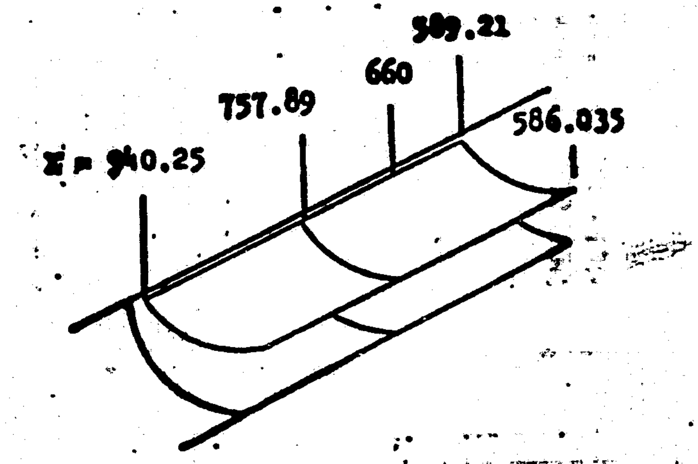


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 140°
ROLL = 75°
X = 562.09
.28 .15 .29 .49 .76 .10
562.09
PAYLOAD ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
MODEL Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
ORBITER Y AXIS - INCHES

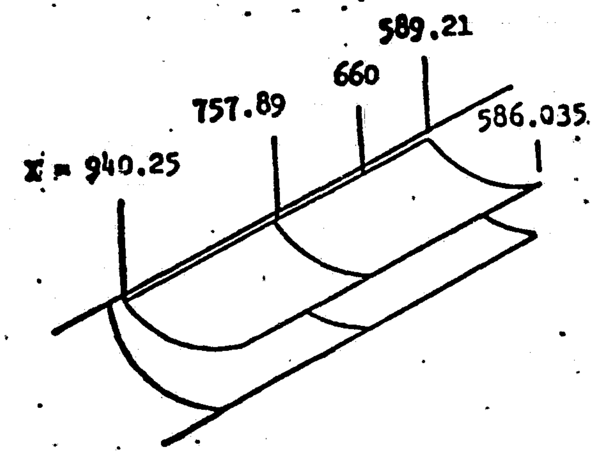
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS

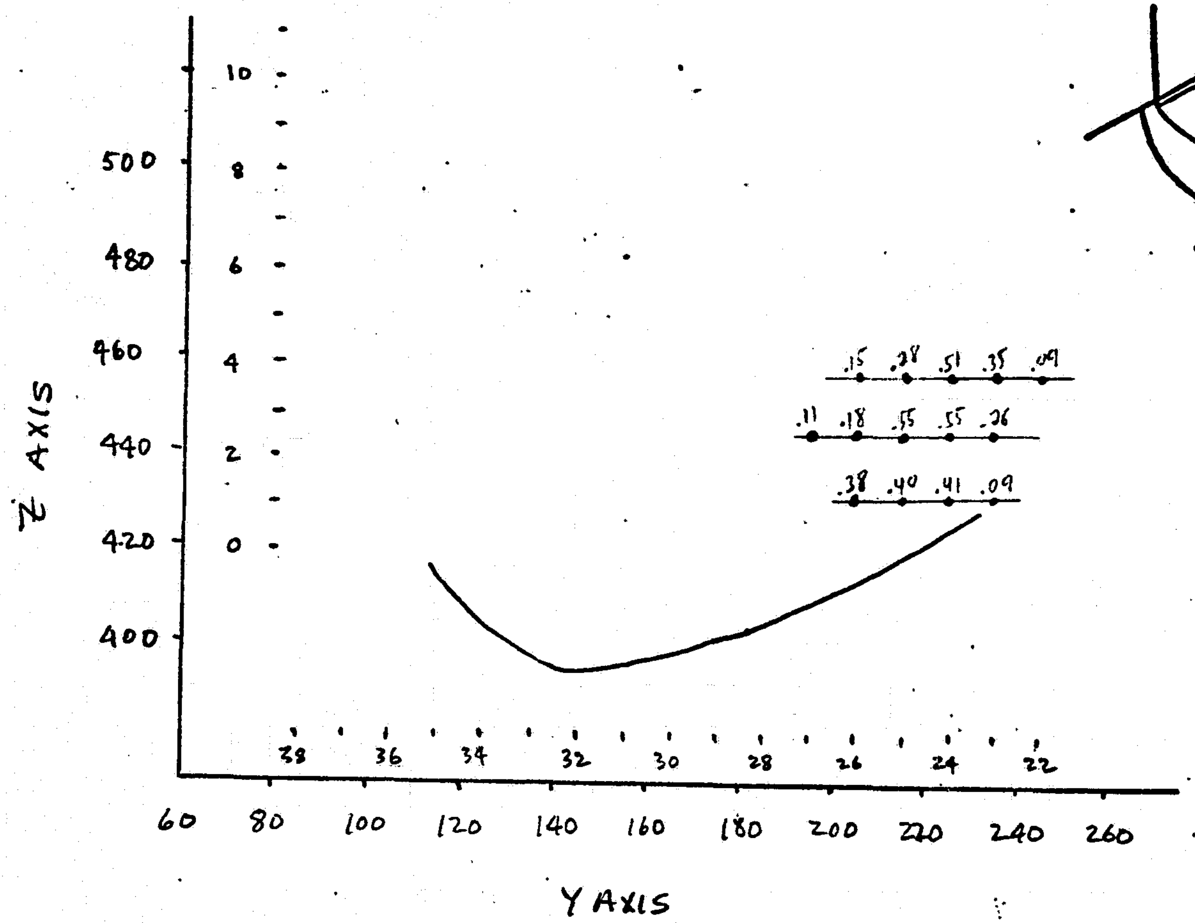




PITCH = 140°
ROLL = 75°
X = 548.69 - 553.05

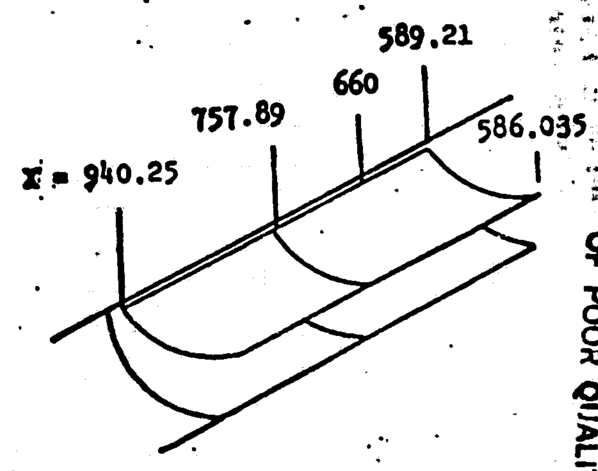
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



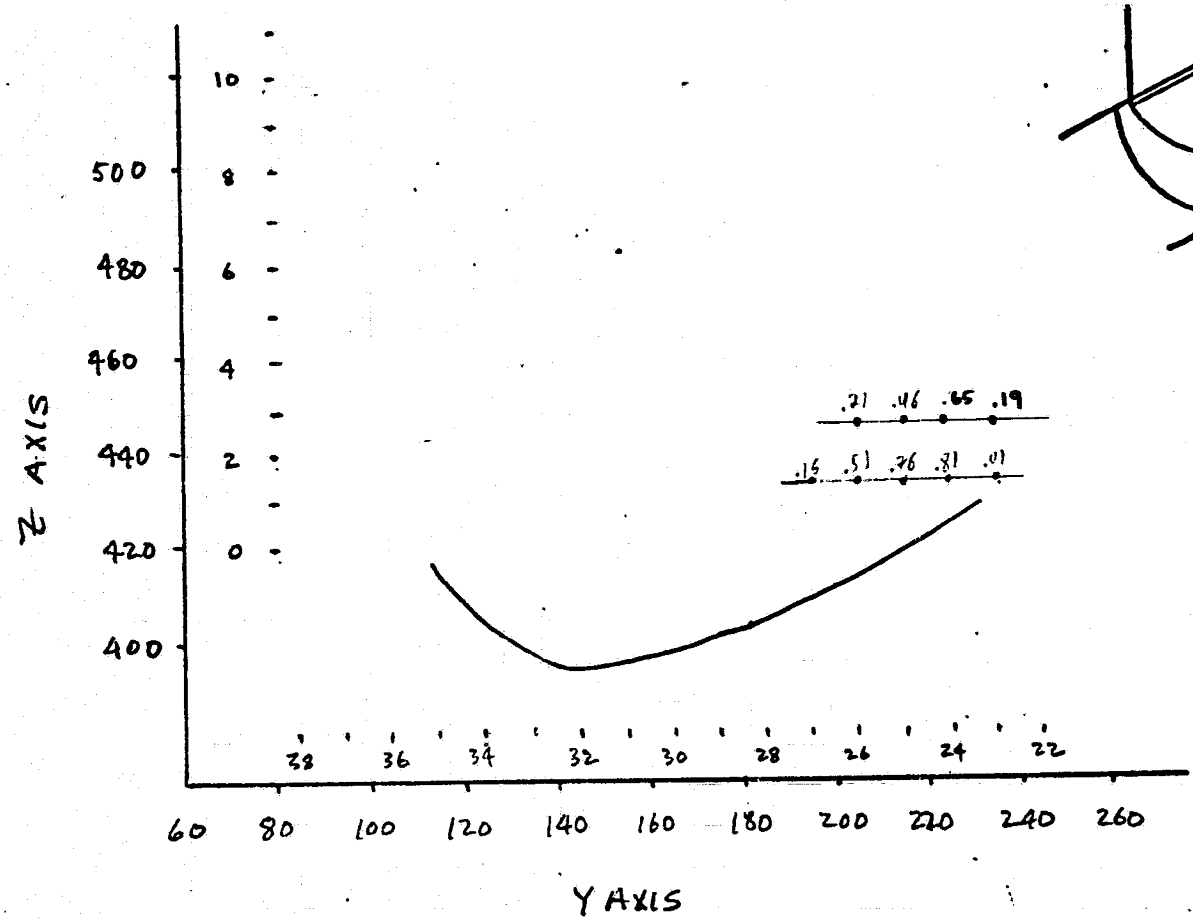


PITCH = 140°
ROLL = 285°
X = 714.43 – 719.75

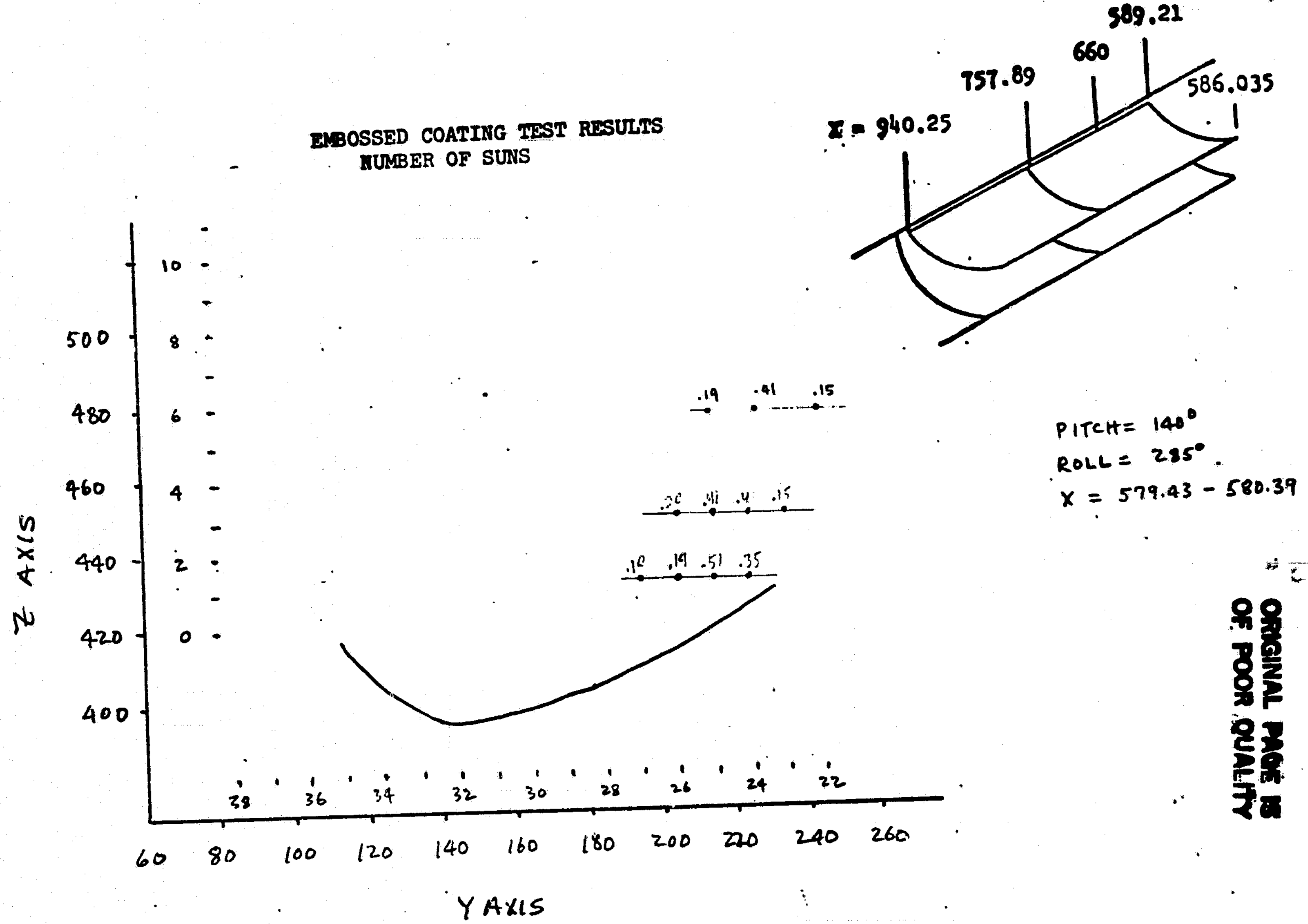
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



PITCH = 140°
ROLL = 285°
X = 594.43 - 599.75



EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



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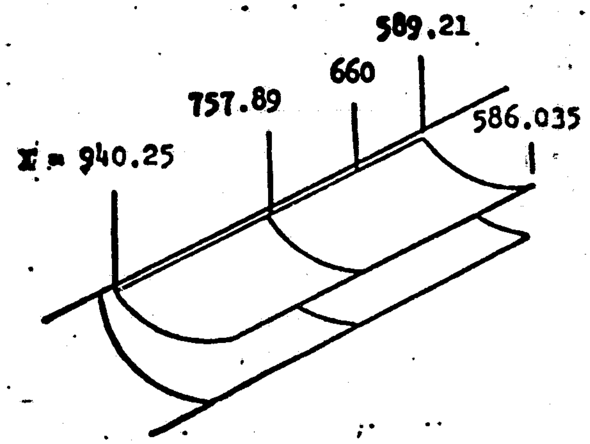
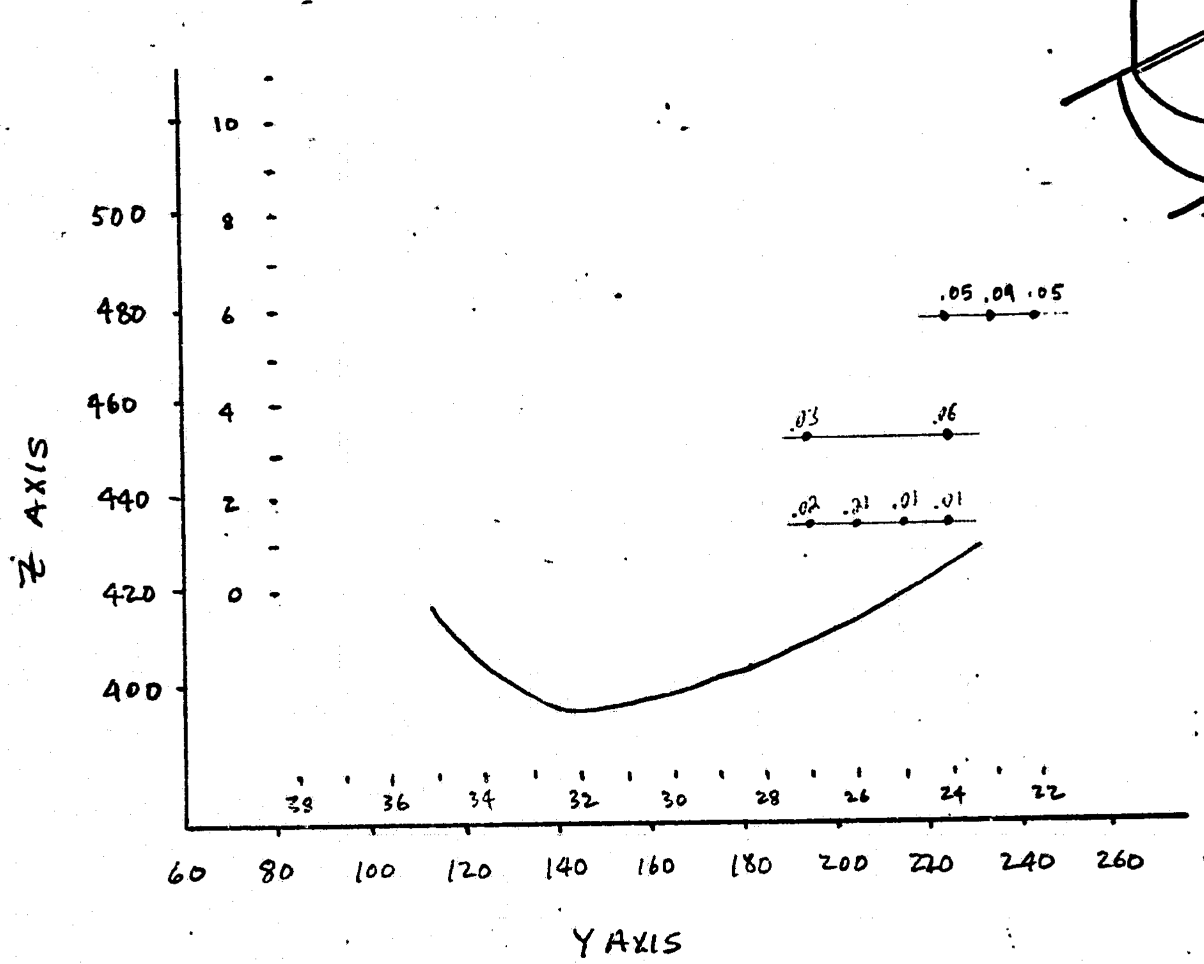
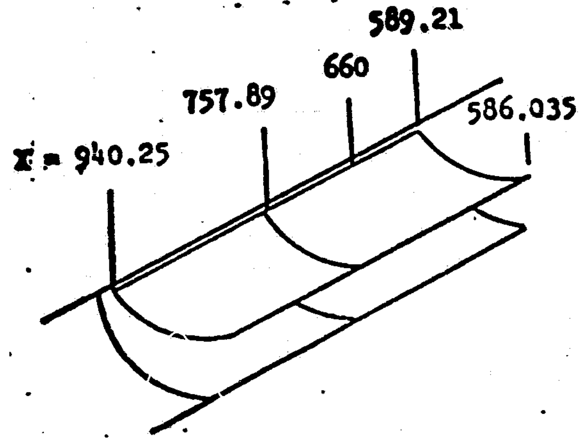
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



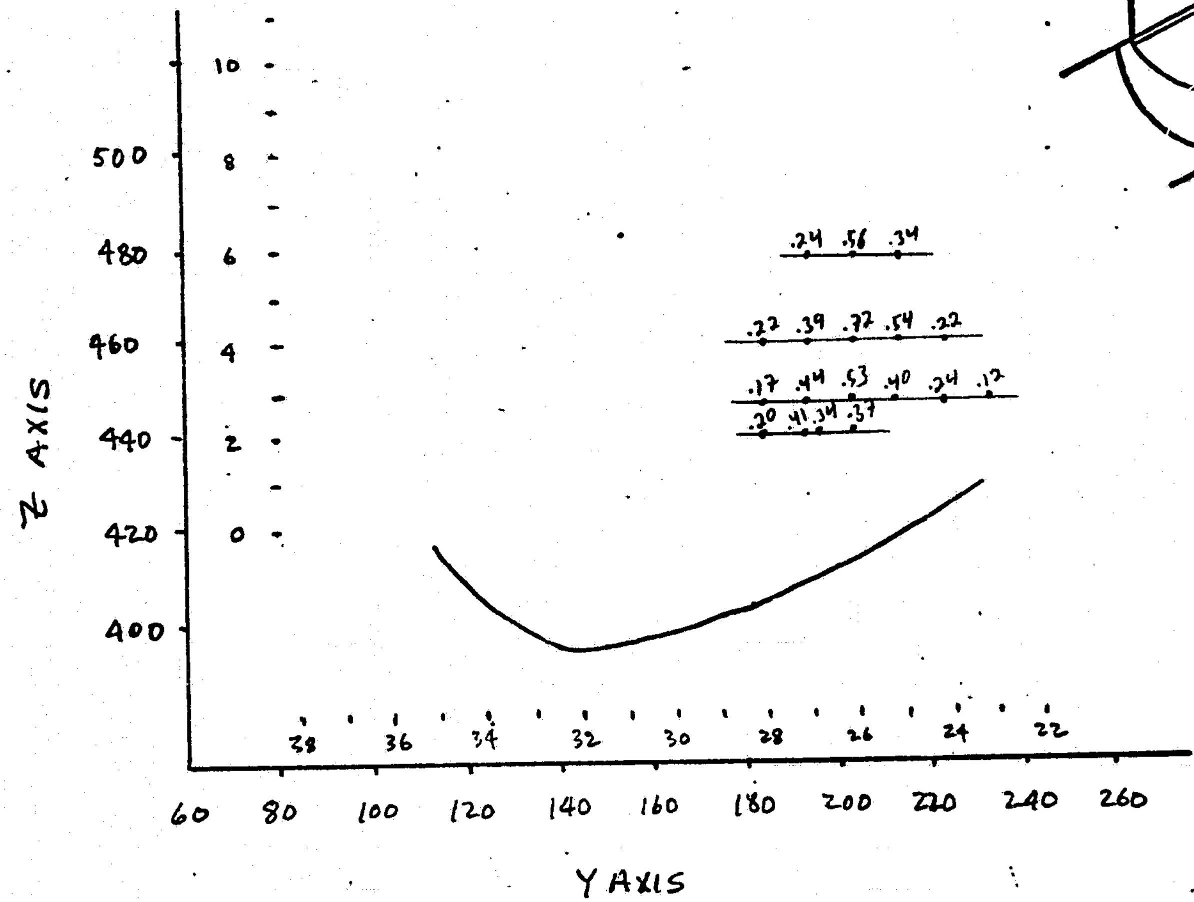


PITCH = 140°
ROLL = 285°
X = 555.39 - 559.75

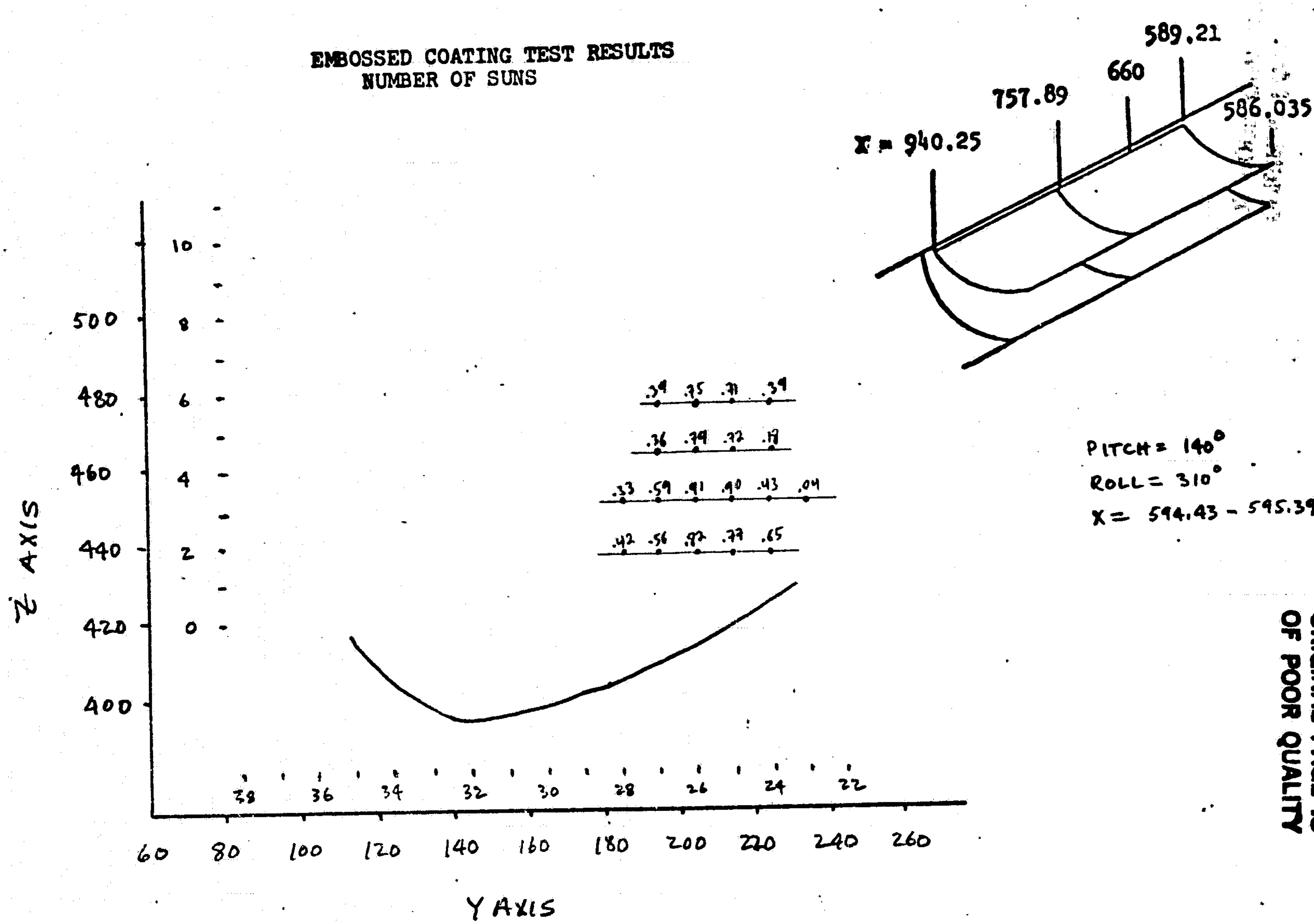
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



PITCH = 140°
ROLL = 310°
X = 710.39 – 719.75



EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS



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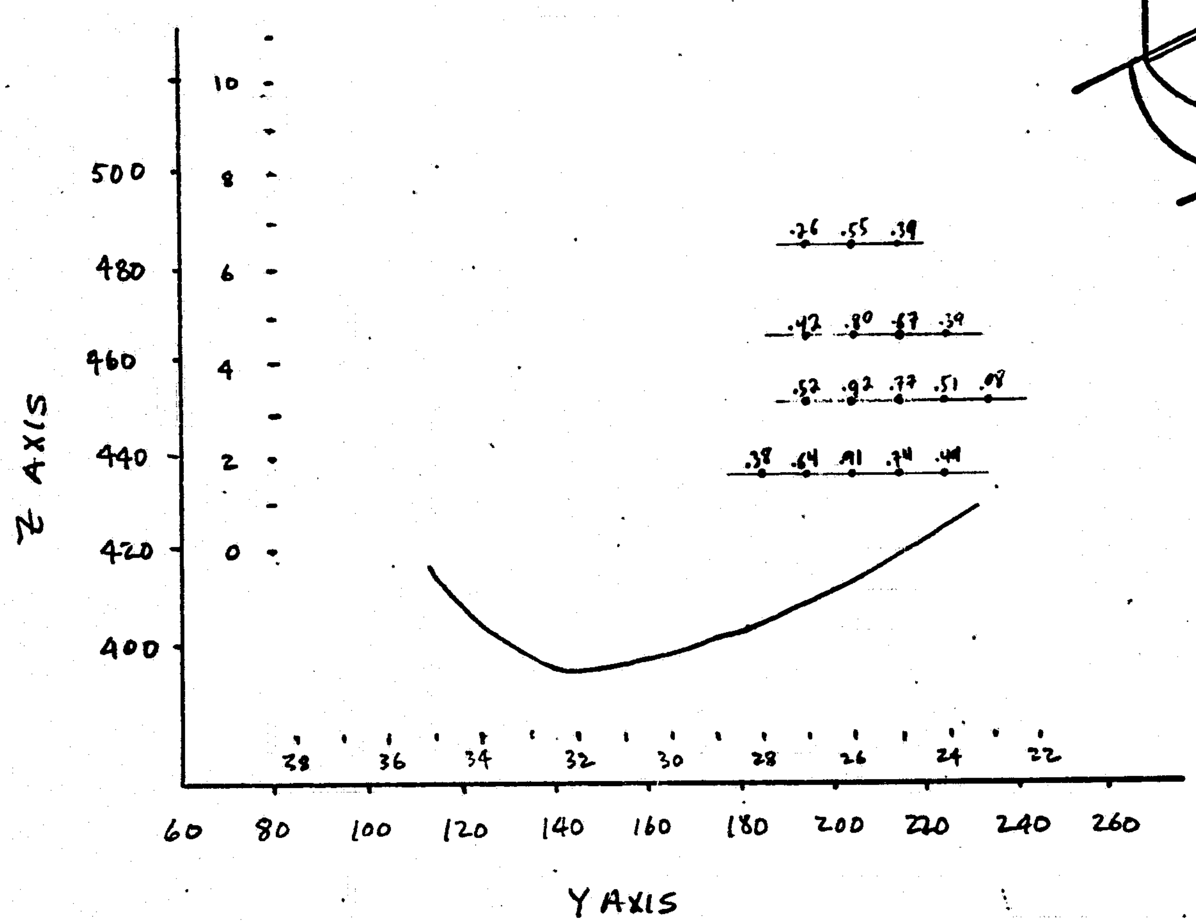
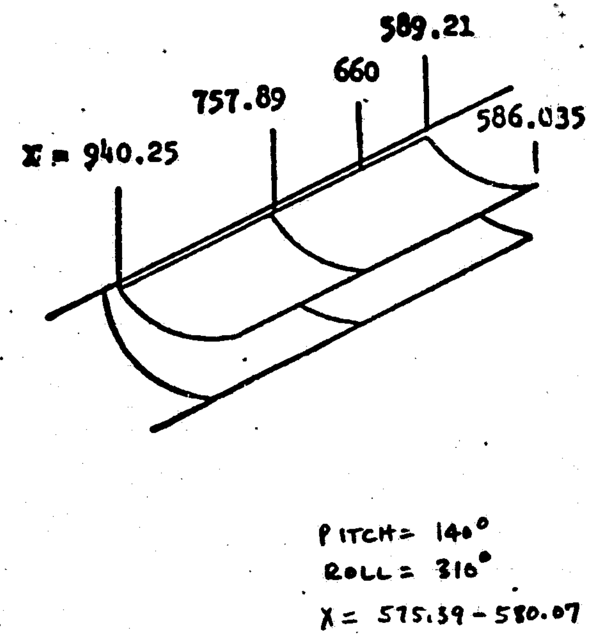
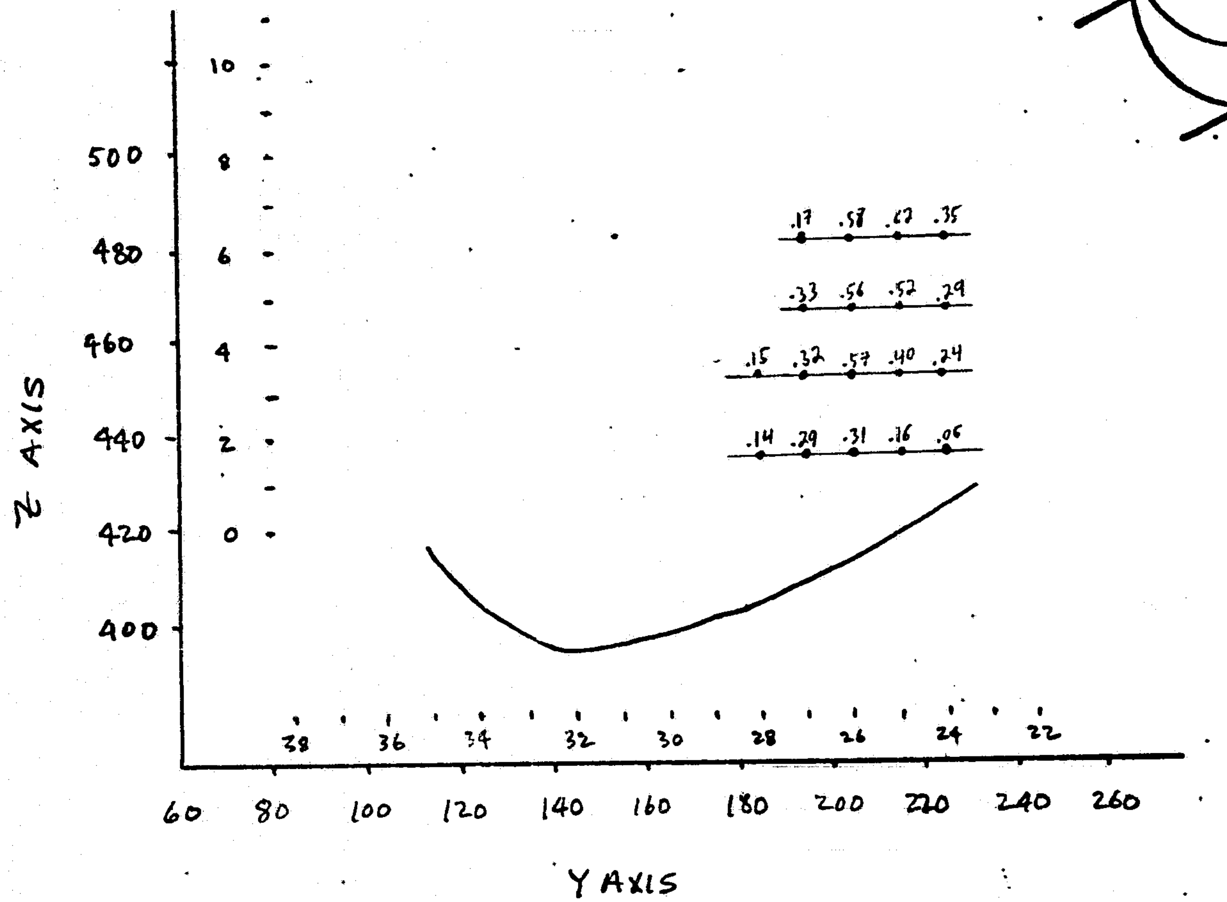
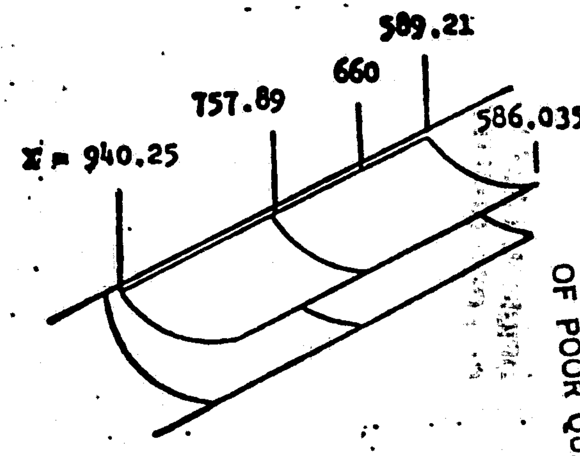
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





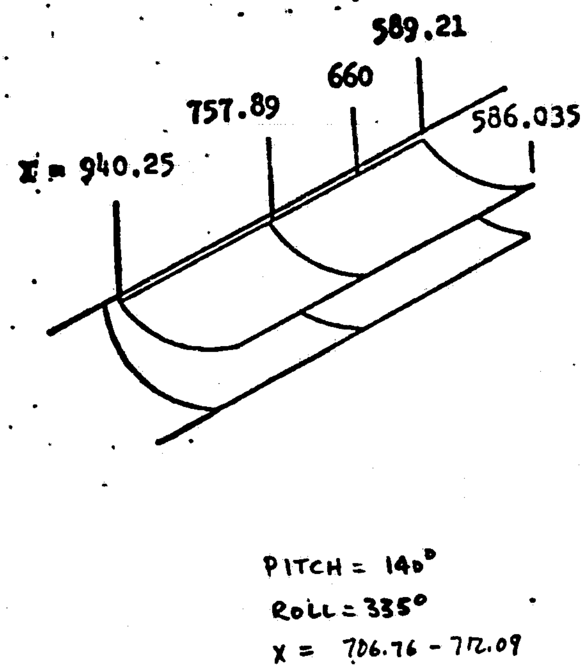
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS

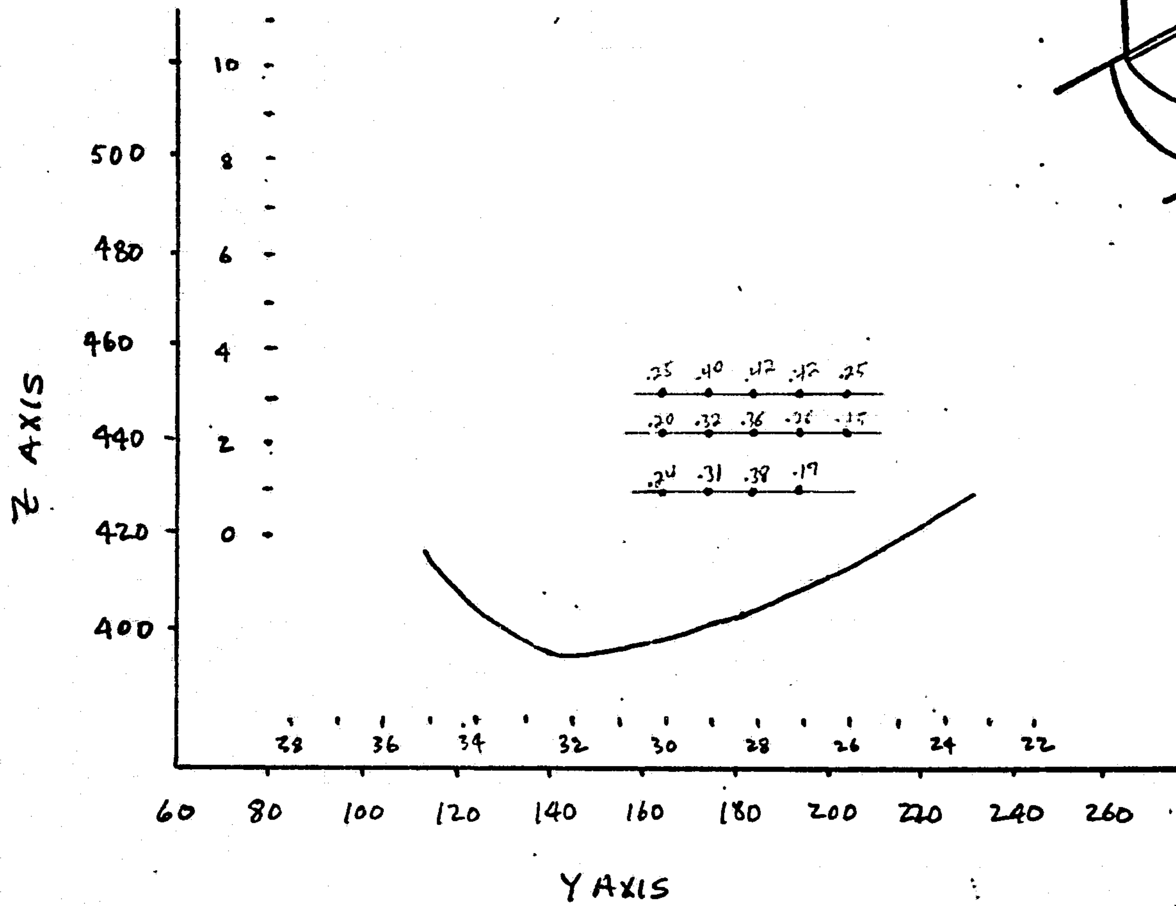


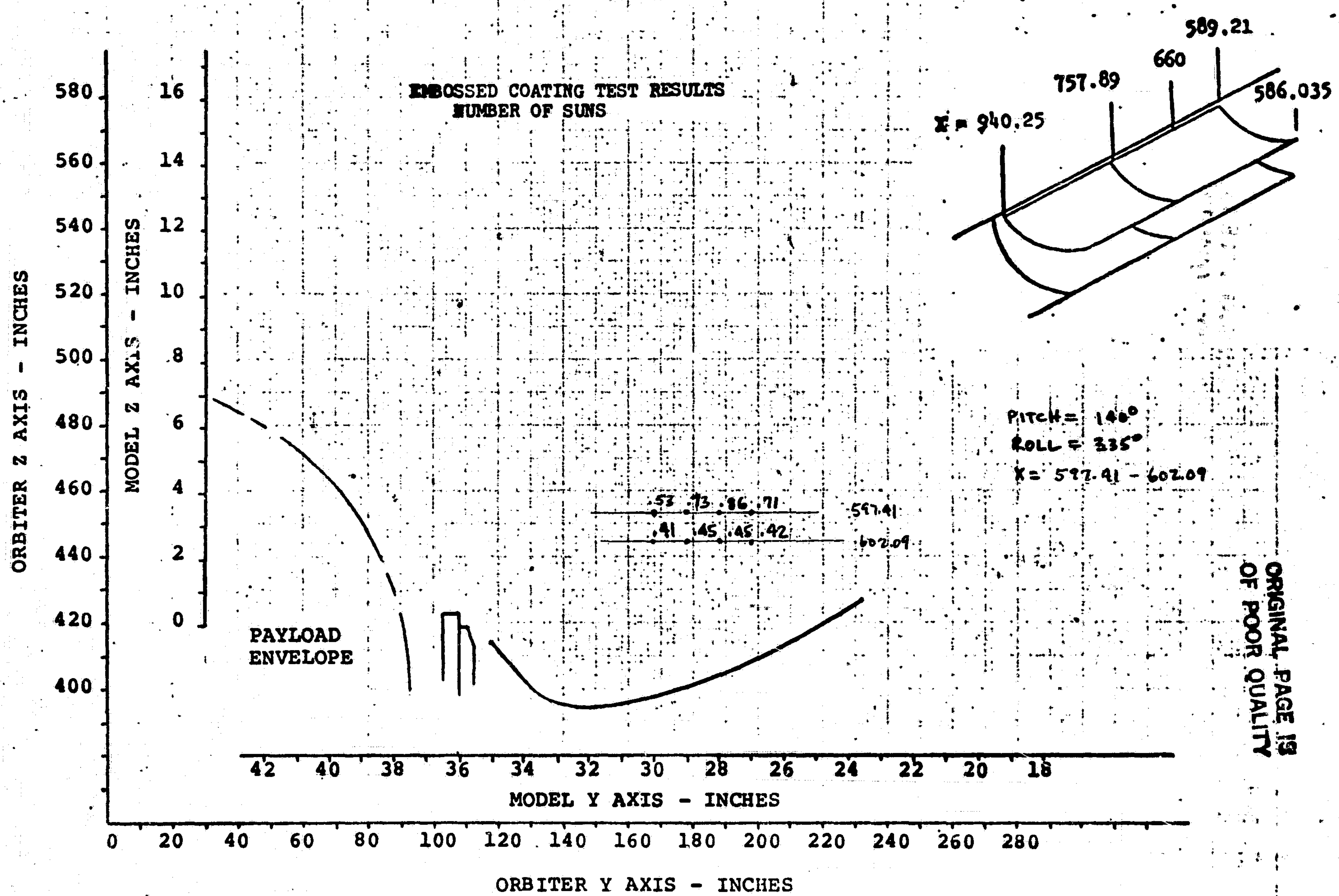


PITCH = 140°
ROLL = 310°
X = 555.39 - 560.07

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS







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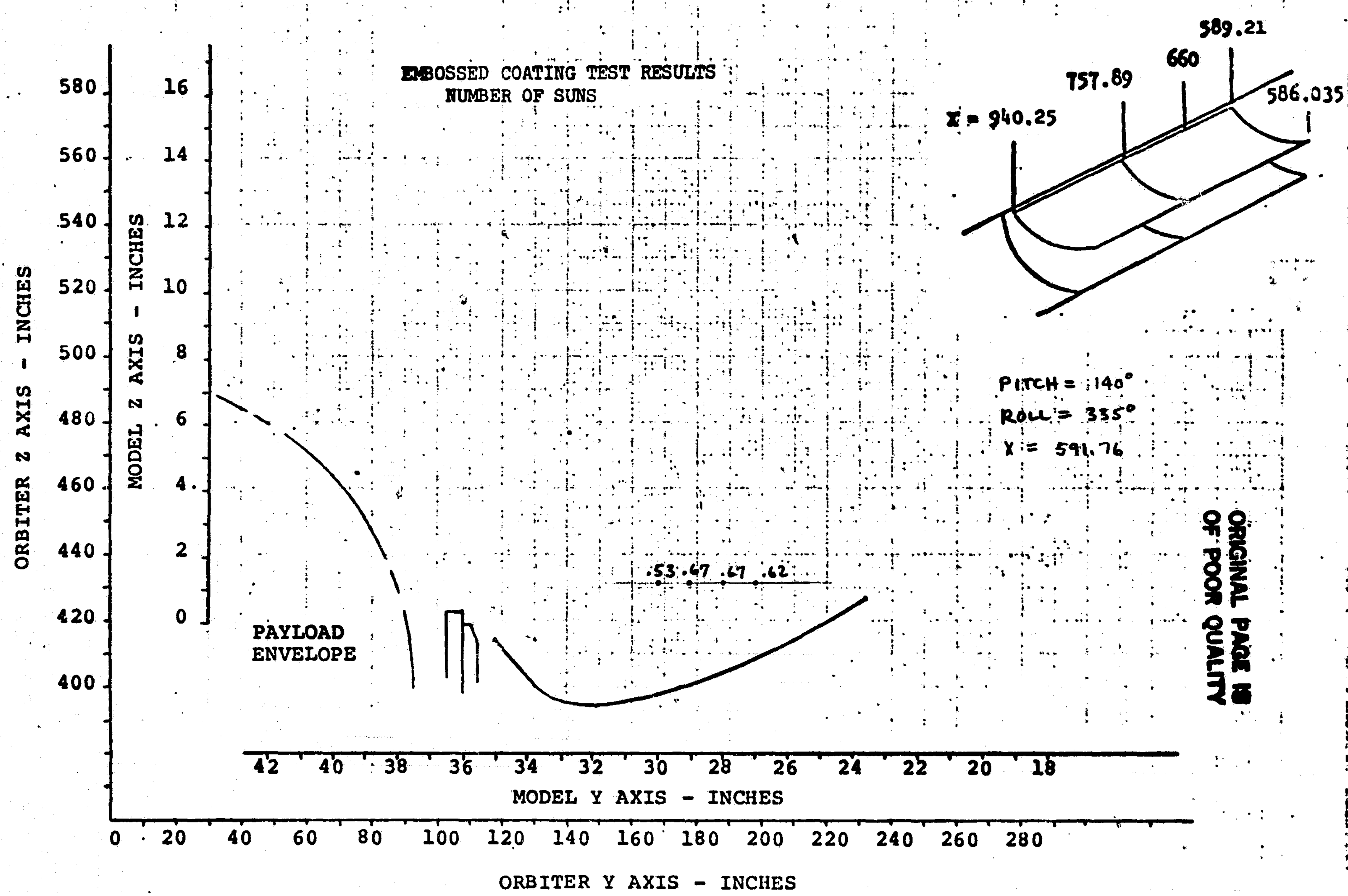

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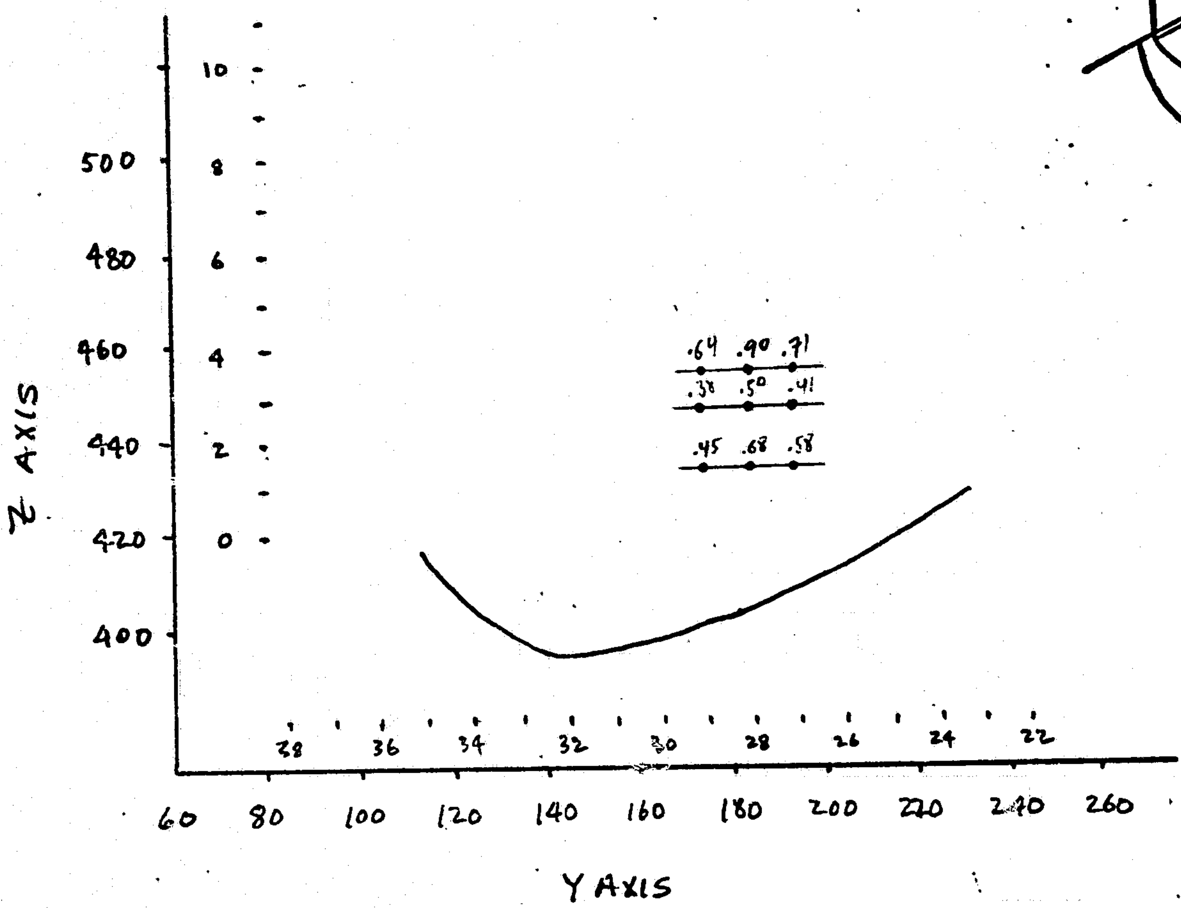
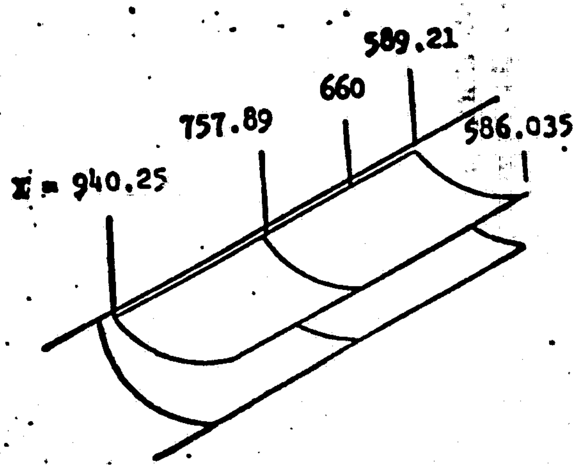
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 140°
ROLL = 335°
X = 572.41 - 577.09

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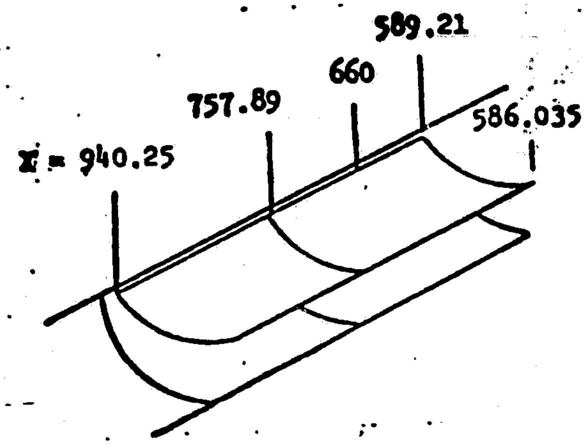
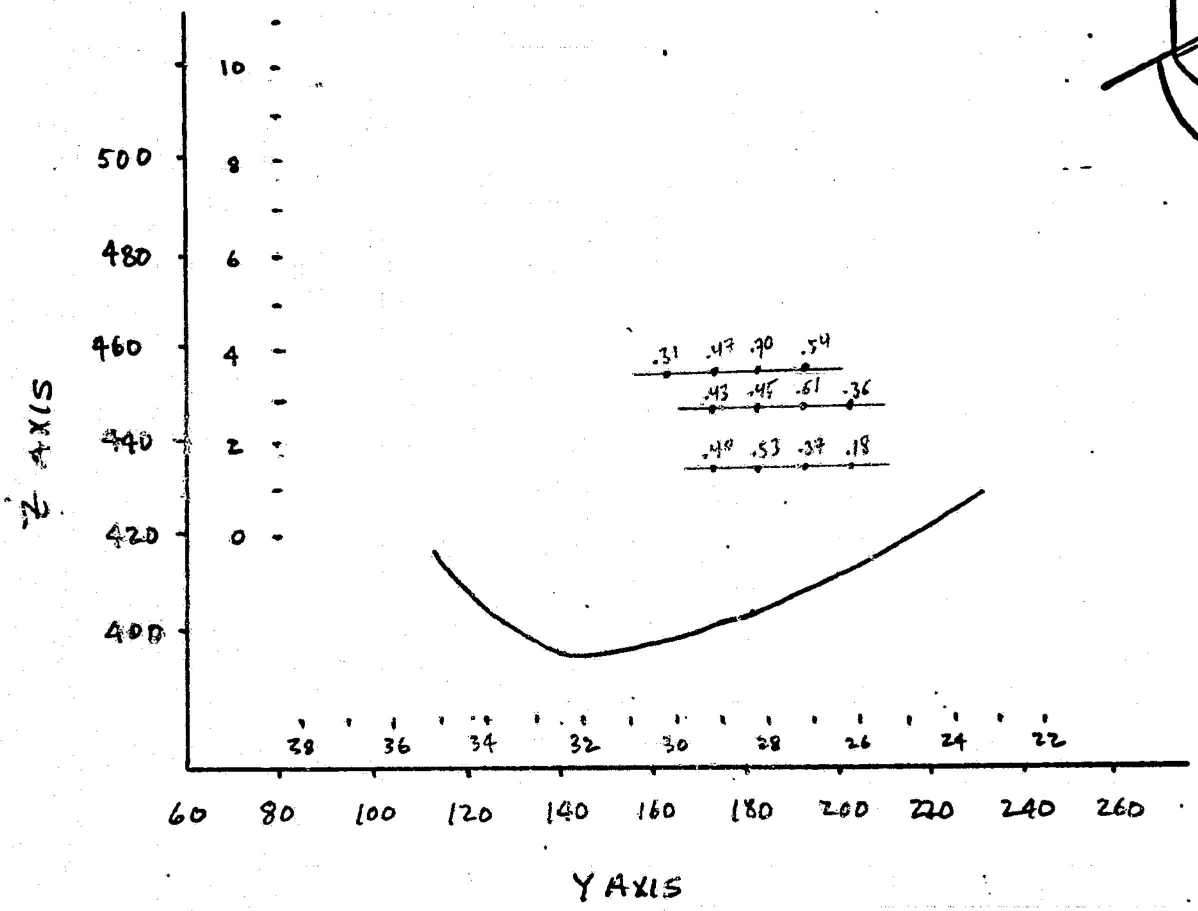
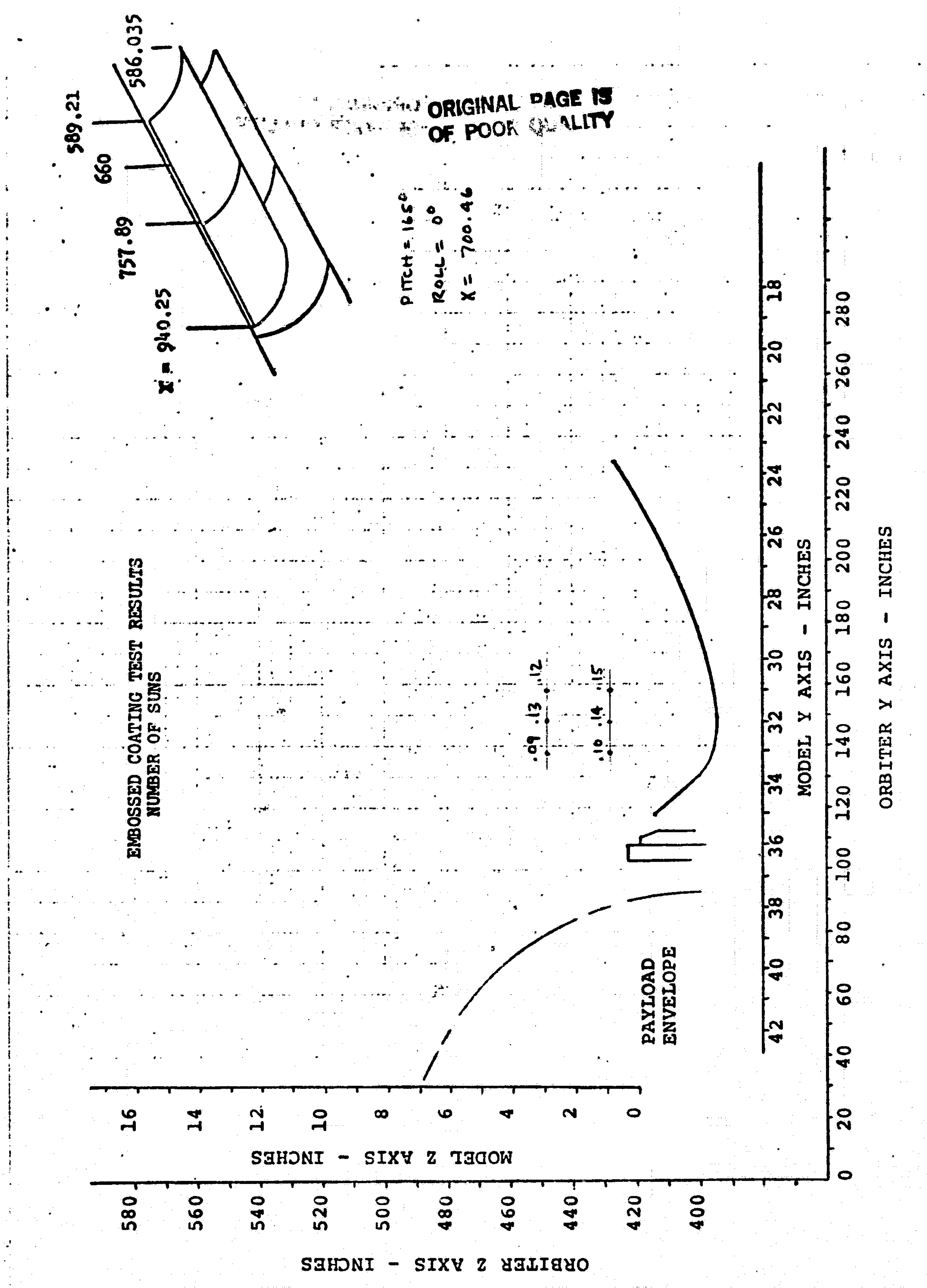
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS

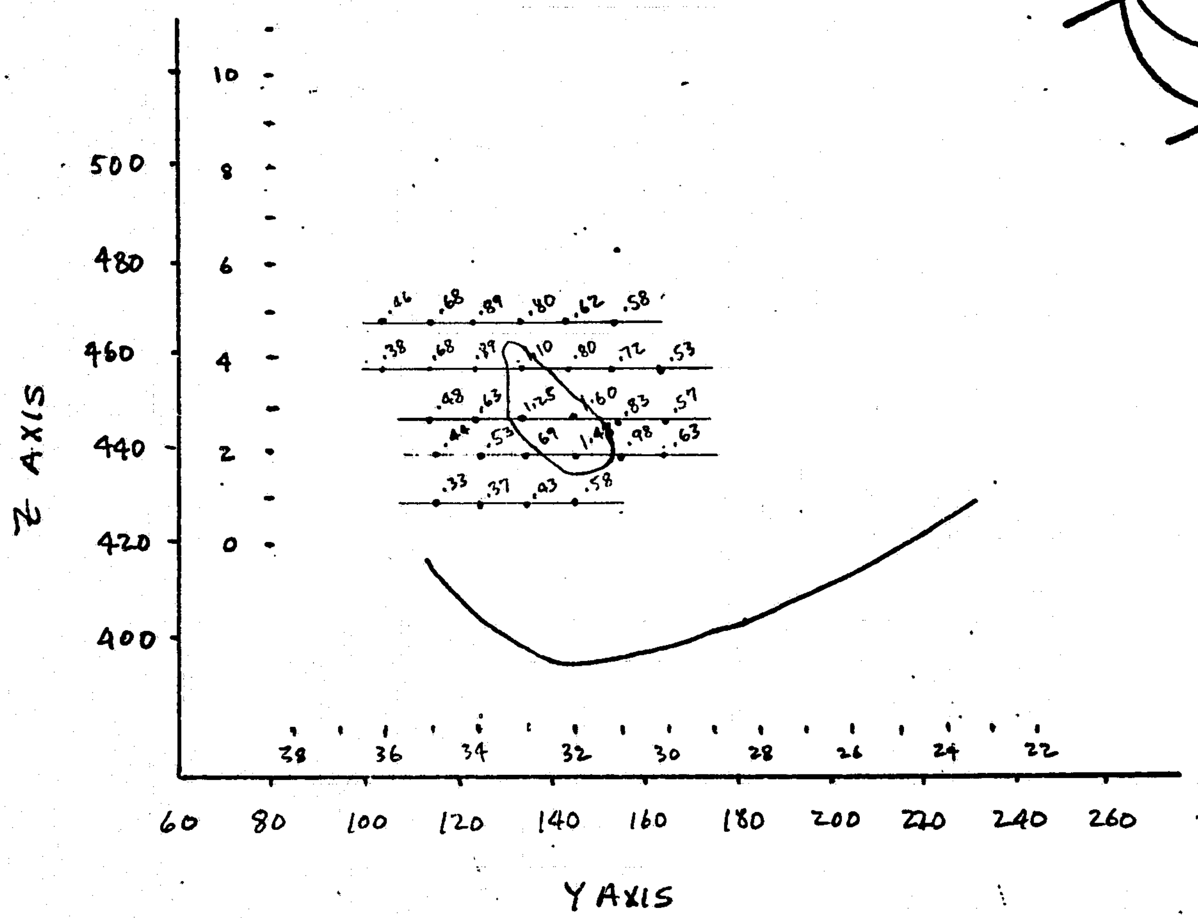


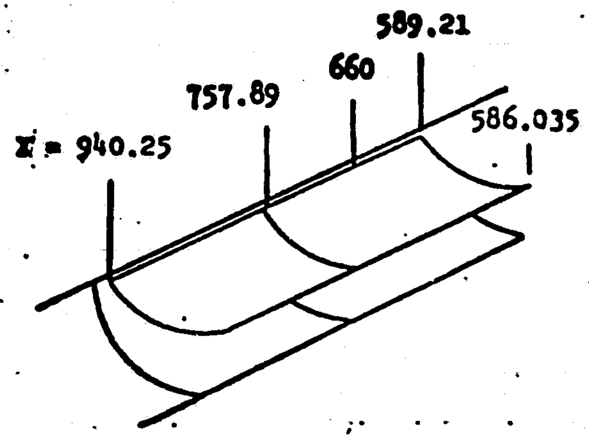


PITCH = 140°
ROLL = 335°
X = 552.41 – 557.09


EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
PITCH = 165°
ROLL = 0°
X = 700.46
X = 940.25
757.89
660
589.21
586.035
PAYLOAD ENVELOPE
.09 .13 .12
.10 .14 .15
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
MODEL Z AXIS - INCHES
ORBITER Z AXIS - INCHES
ORIGINAL PAGE IS OF POOR QUALITY

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS





PITCH = 65°
ROLL = 0°
X = 722.5

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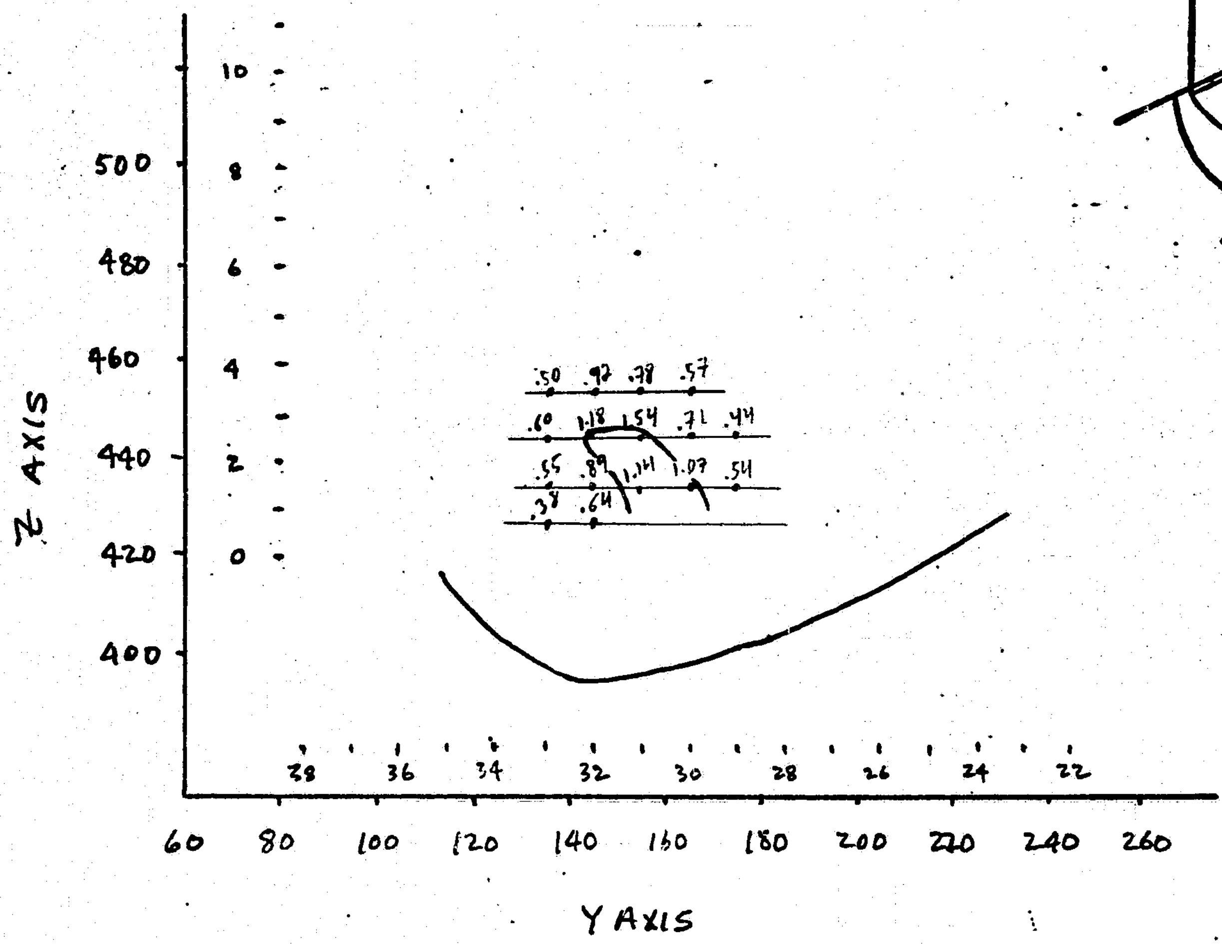
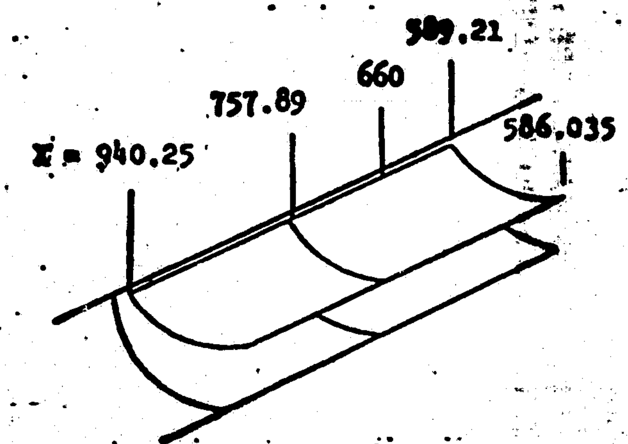
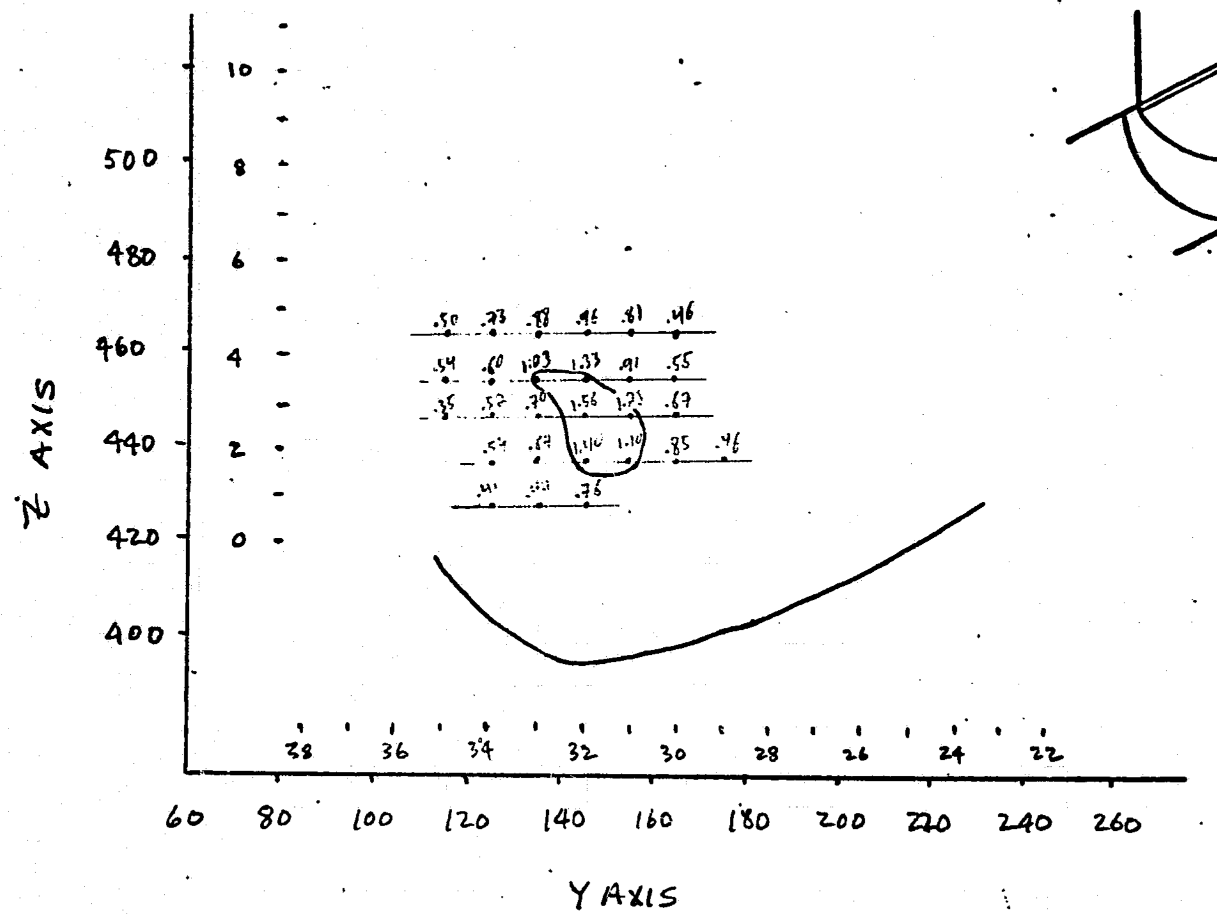
EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS

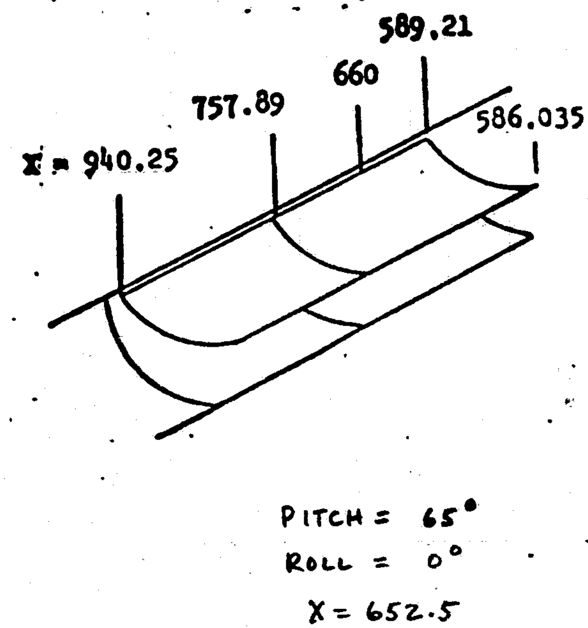


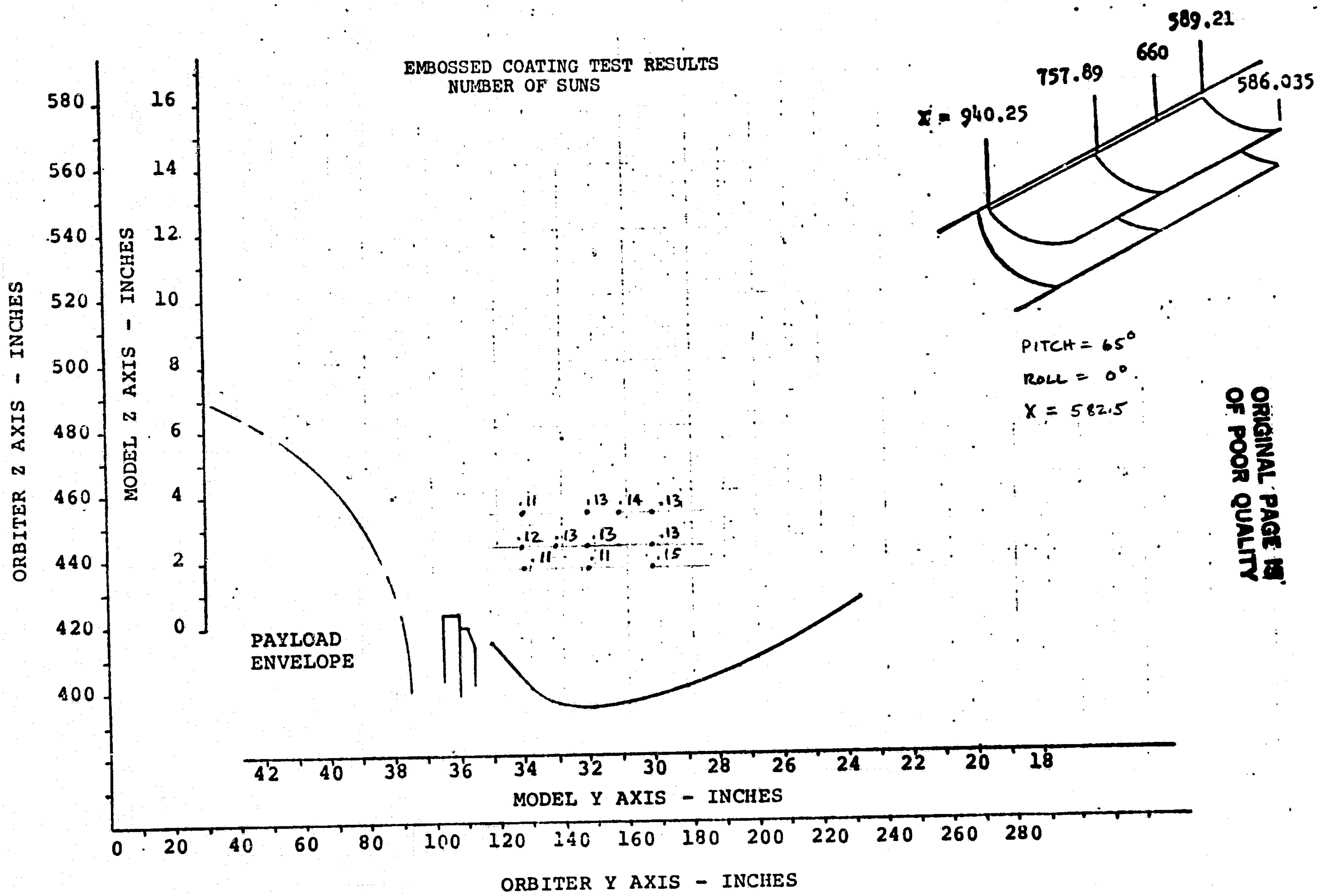


PITCH = 65°
ROLL = 0°
X = 612.5

EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS






EMBOSSED COATING TEST RESULTS
NUMBER OF SUNS
X = 940.25
757.89
660
589.21
586.035
PITCH = 65°
ROLL = 0°
X = 582.5
PAYLOAD
ENVELOPE
.11
.13
.14
.13
.12
.13
.13
.13
.11
.11
.15
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
42
40
38
36
34
32
30
28
26
24
22
20
18
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

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APPENDIX B

SMOOTH SILVER/TEFLON TEST DATA

(See Page B-2 for Index to Data Plots)

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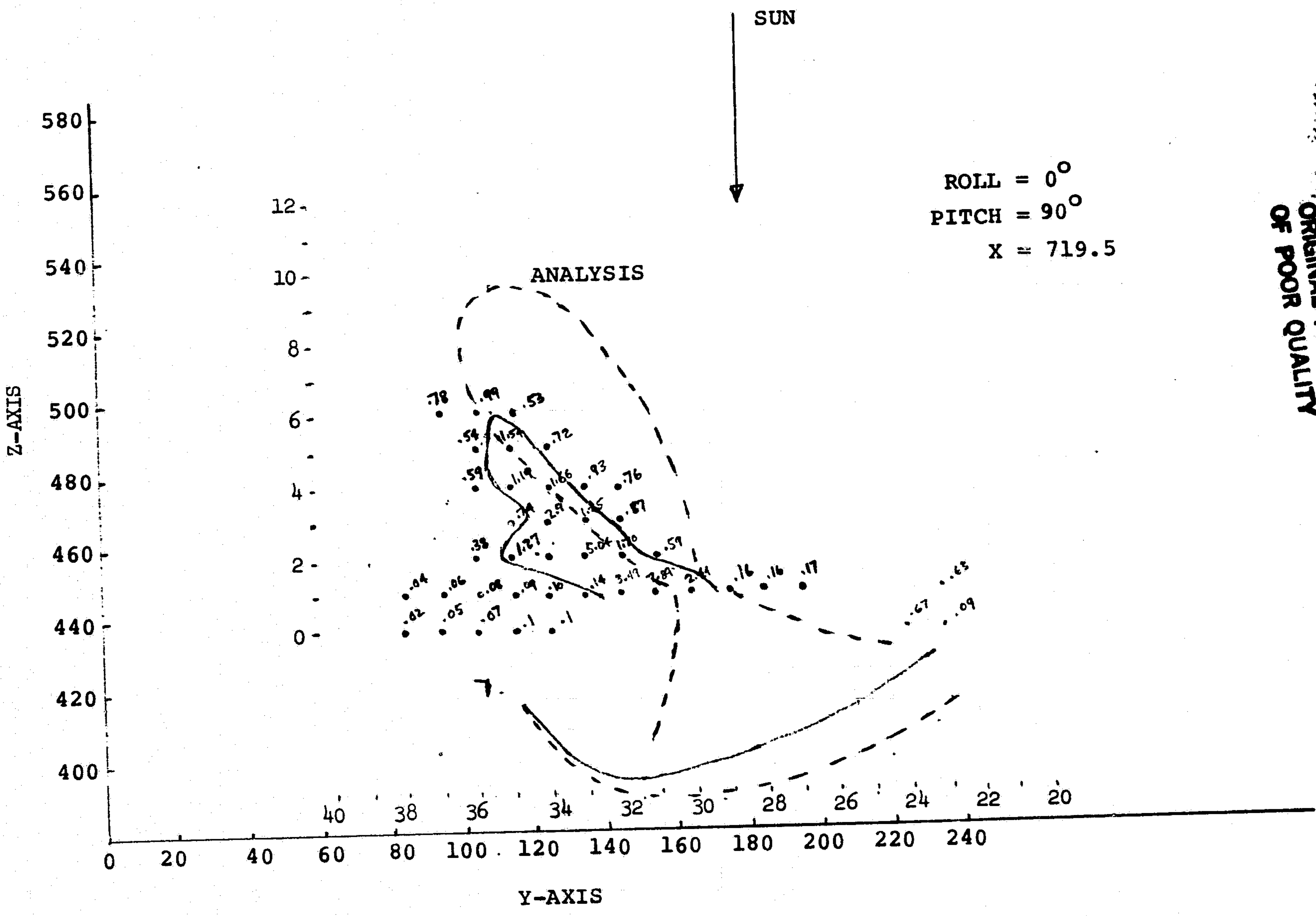
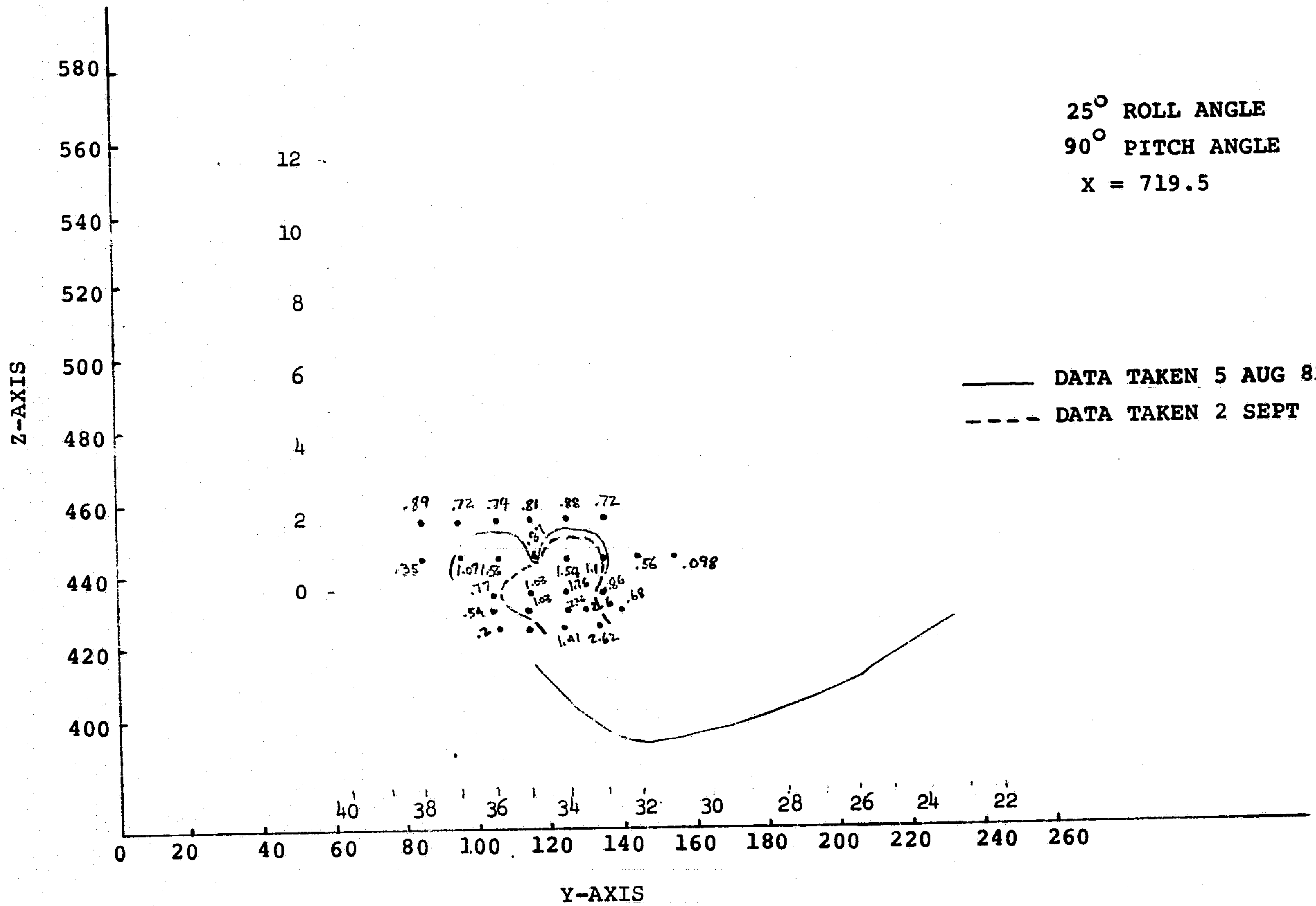
TABLE B-1 INDEX TO PAGE NUMBERS FOR SMOOTH SILVER/TEFLON TEST DATA PLOTS

		X AXIS LOCATION			
Pitch Angle	Roll Angle	Aft of Double Contour	Double Contour Area	Fwd Edge of Panel	Fwd of Fwd Edge
90	0	B-3			
	25	B-4			
	50	B-5			
	70	B-6			
	75	B-7			
	80	B-8			
	90	B-9	B-10, B-11		B-12
	100	B-13			
	105	B-14			
	285	B-15			
	310	B-16			
	335	B-17			
115	0	B-18, B-19	B-20	B-21	B-22
	335	B-23, B-24		B-25	B-26, B-27

SOLAR FOCUSING TEST RESULTS



SOLAR FOCUSING TEST RESULTS



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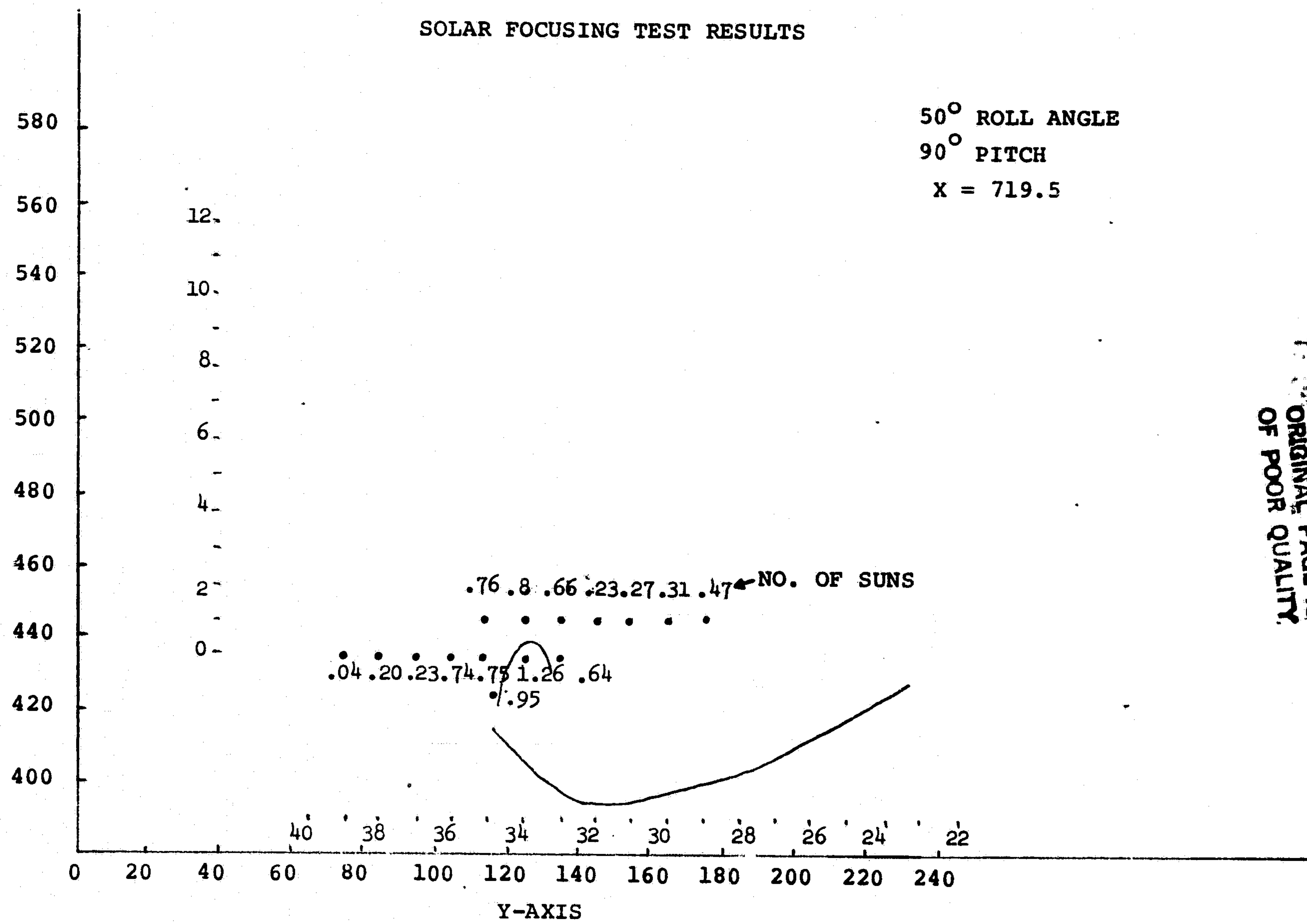
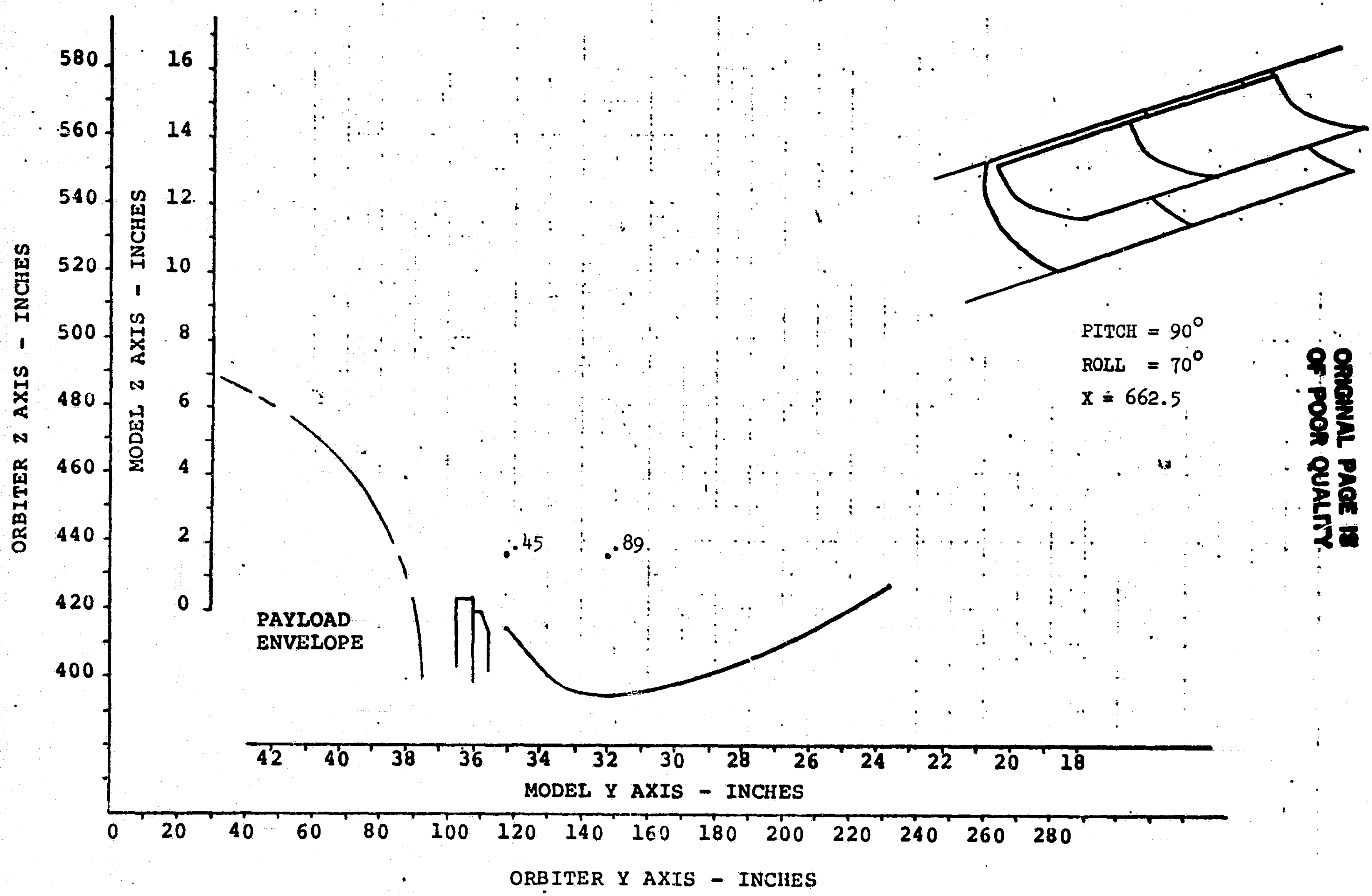
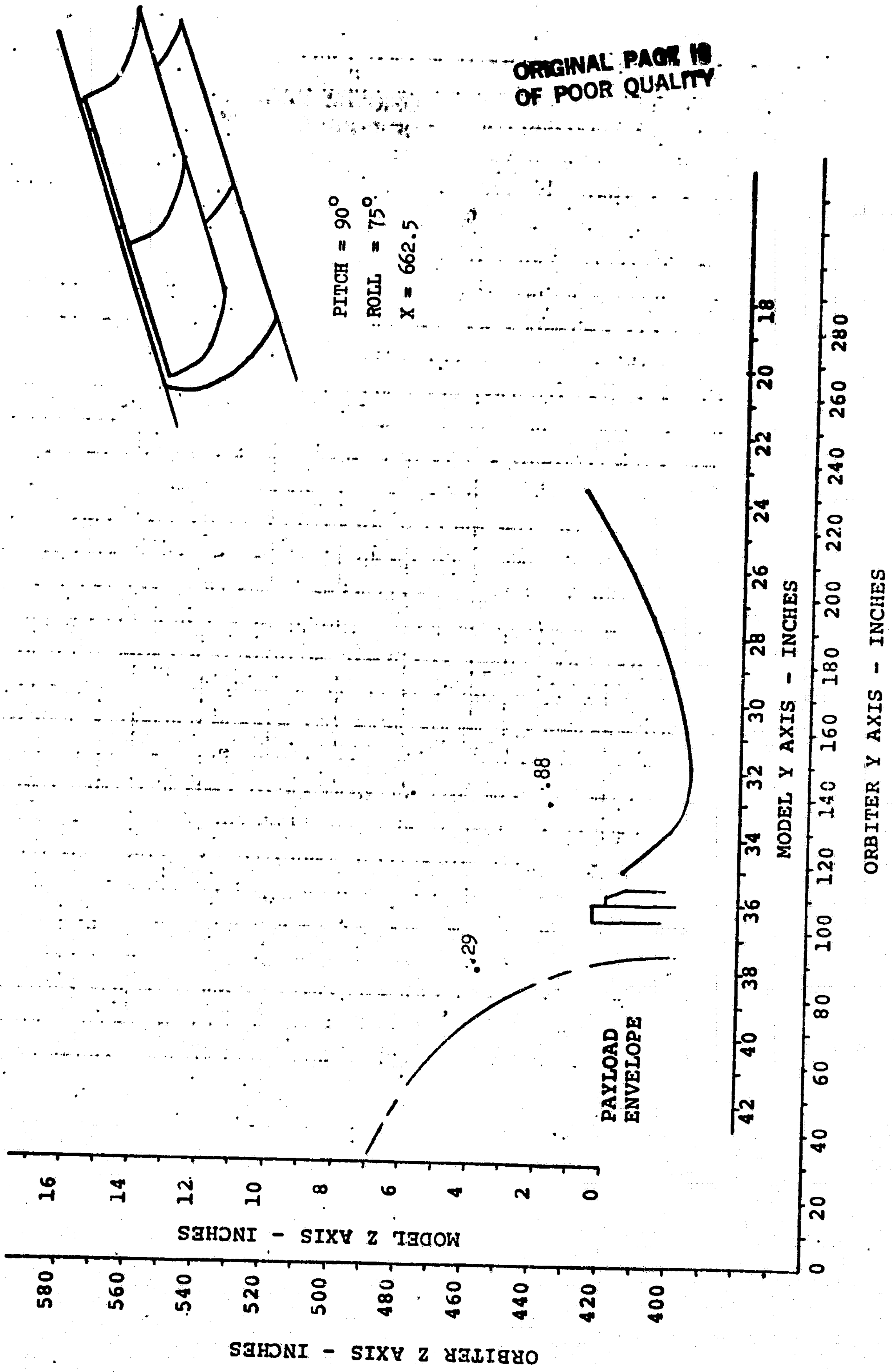
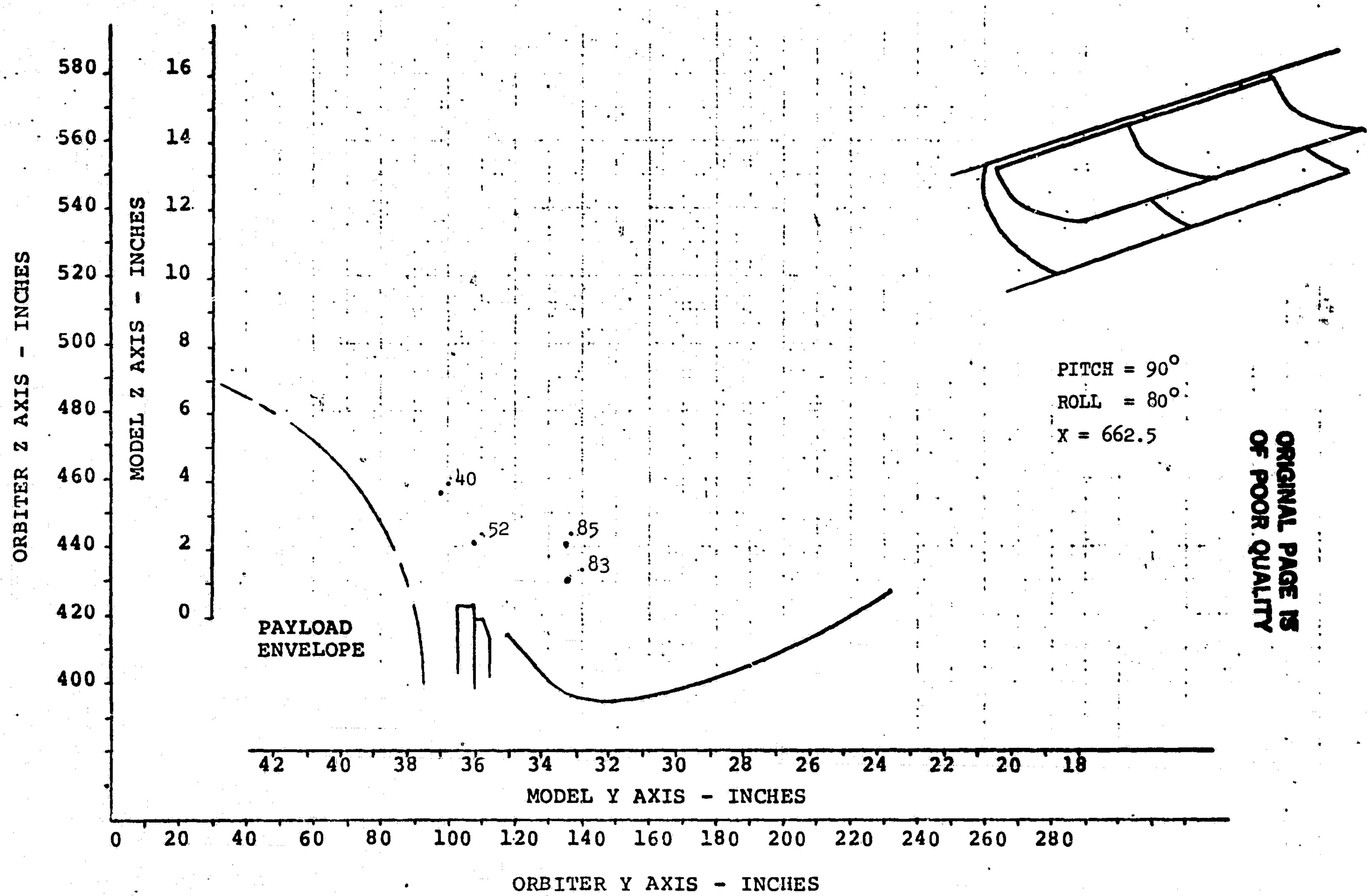


SOLAR FOCUSING TEST RESULTS
50° ROLL ANGLE
90° PITCH
X = 719.5
580
560
540
520
500
480
460
440
420
400
Z-AXIS
12
10
8
6
4
2
0
.76 .8 .66 .23 .27 .31 .47
NO. OF SUNS
.04 .20 .23 .74 .75 1.26 .64
.95
40 38 36 34 32 30 28 26 24 22
0 20 40 60 80 100 120 140 160 180 200 220 240
Y-AXIS



ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
PAYLOAD
ENVELOPE
.45
.89
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES
PITCH = 90°
ROLL = 70°
X = 662.5


PITCH = 90°
ROLL = 75°
X = 662.5
.88
.29
PAYLOAD
ENVELOPE
MODEL Y AXIS - INCHES
18 20 22 24 26 28 30 32 34 36 38 40 42
ORBITER Y AXIS - INCHES
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
MODEL Z AXIS - INCHES
0 2 4 6 8 10 12 14 16
ORBITER Z AXIS - INCHES
400 420 440 460 480 500 520 540 560 580



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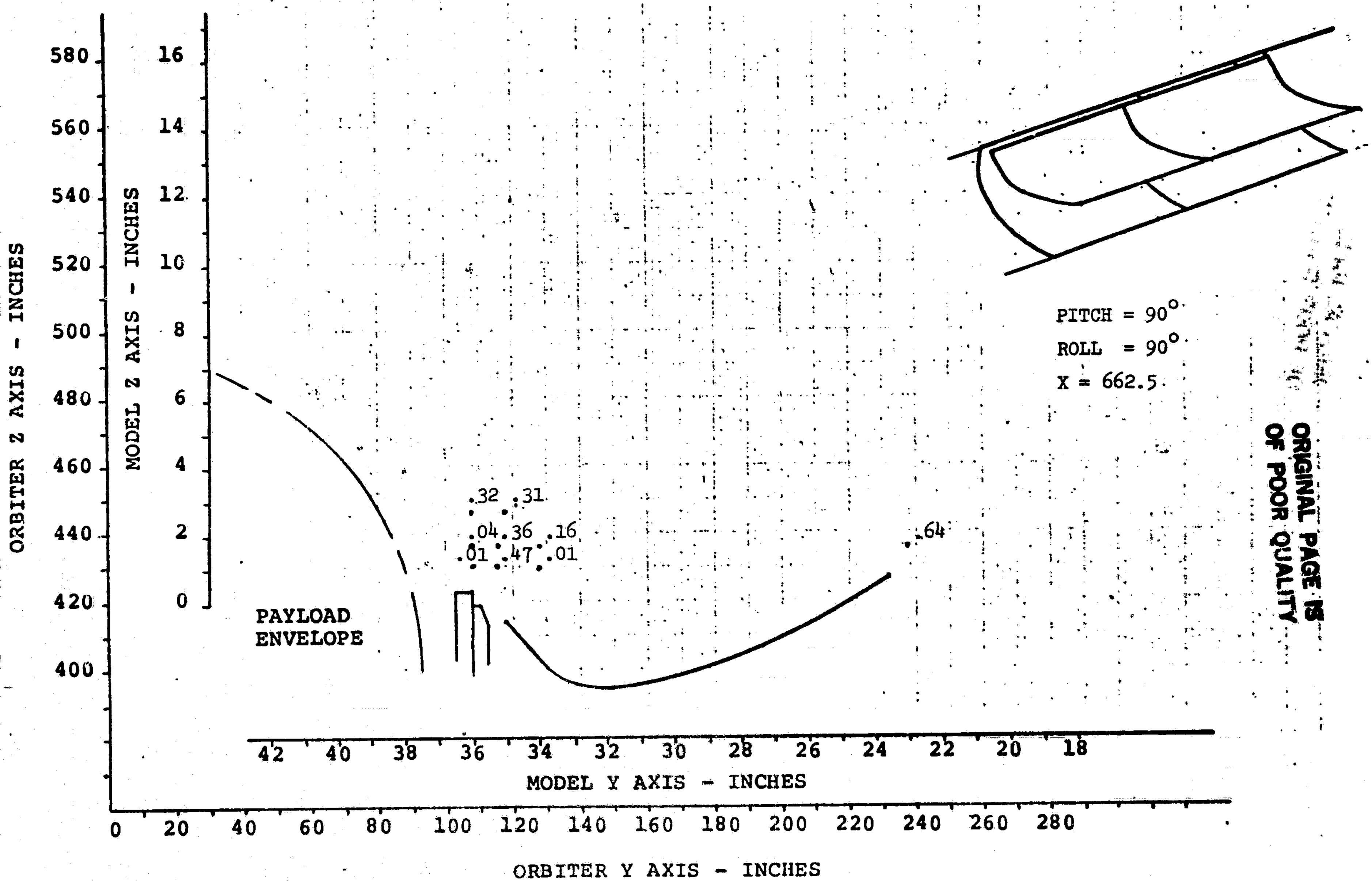
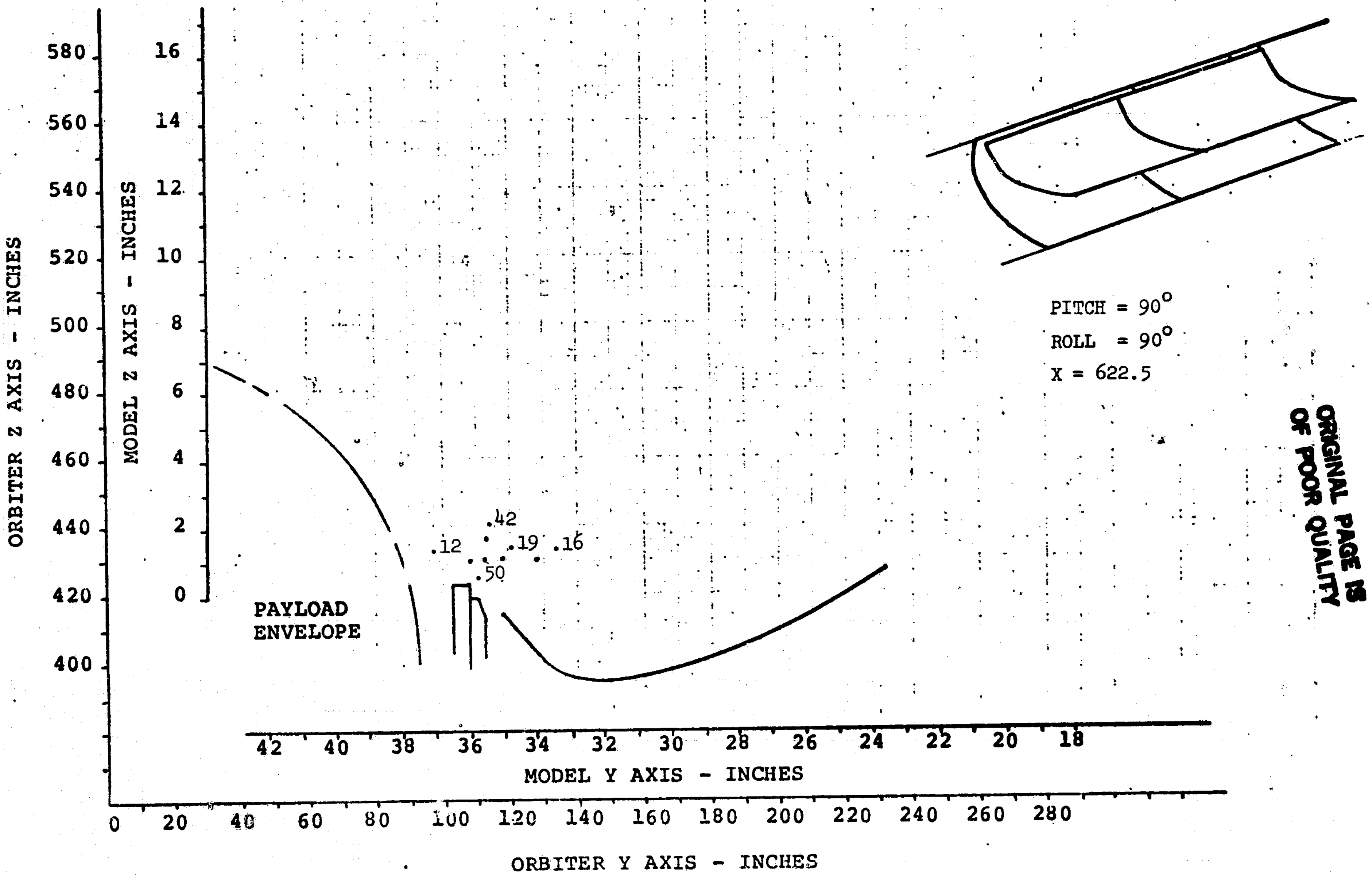
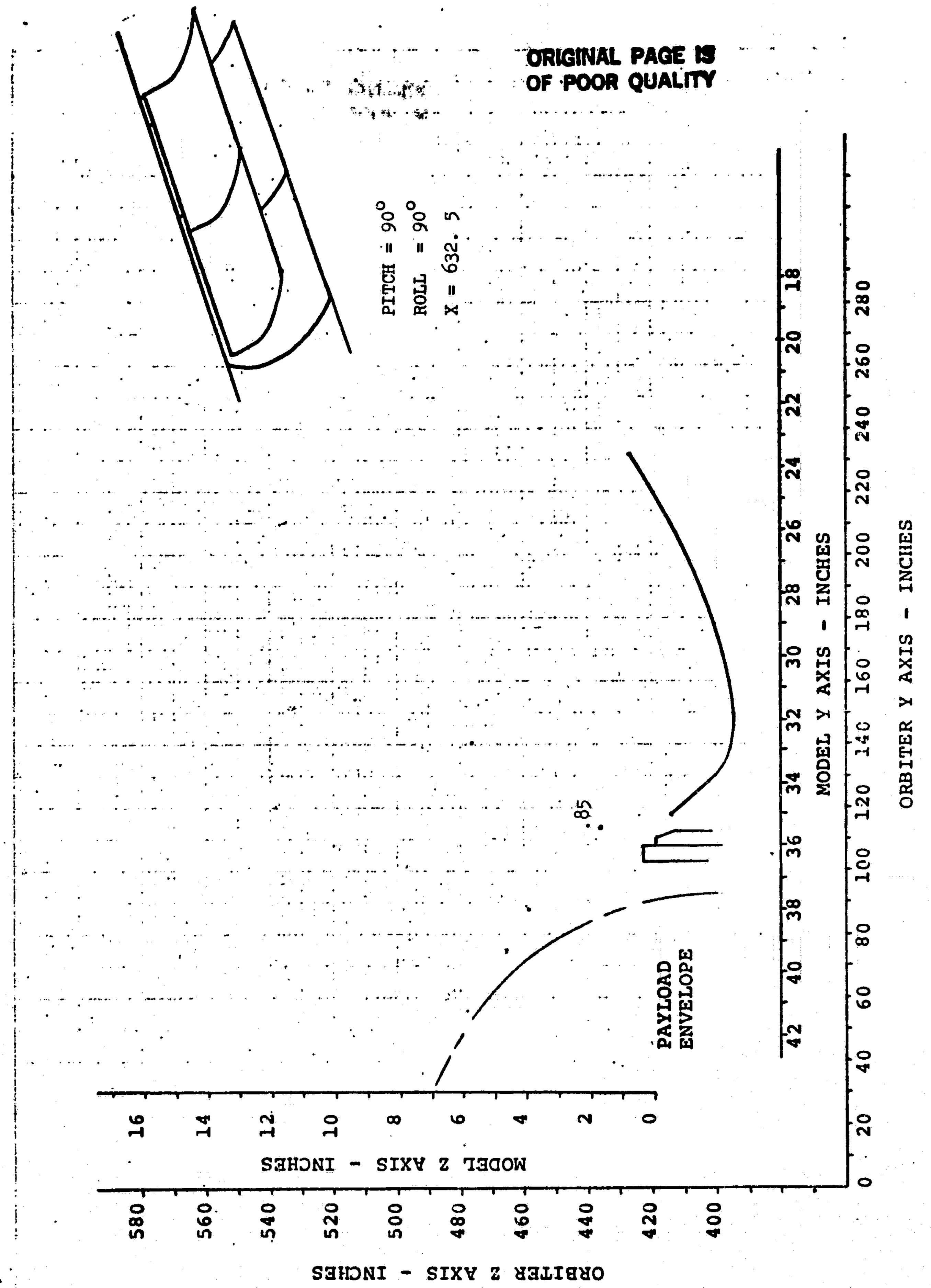
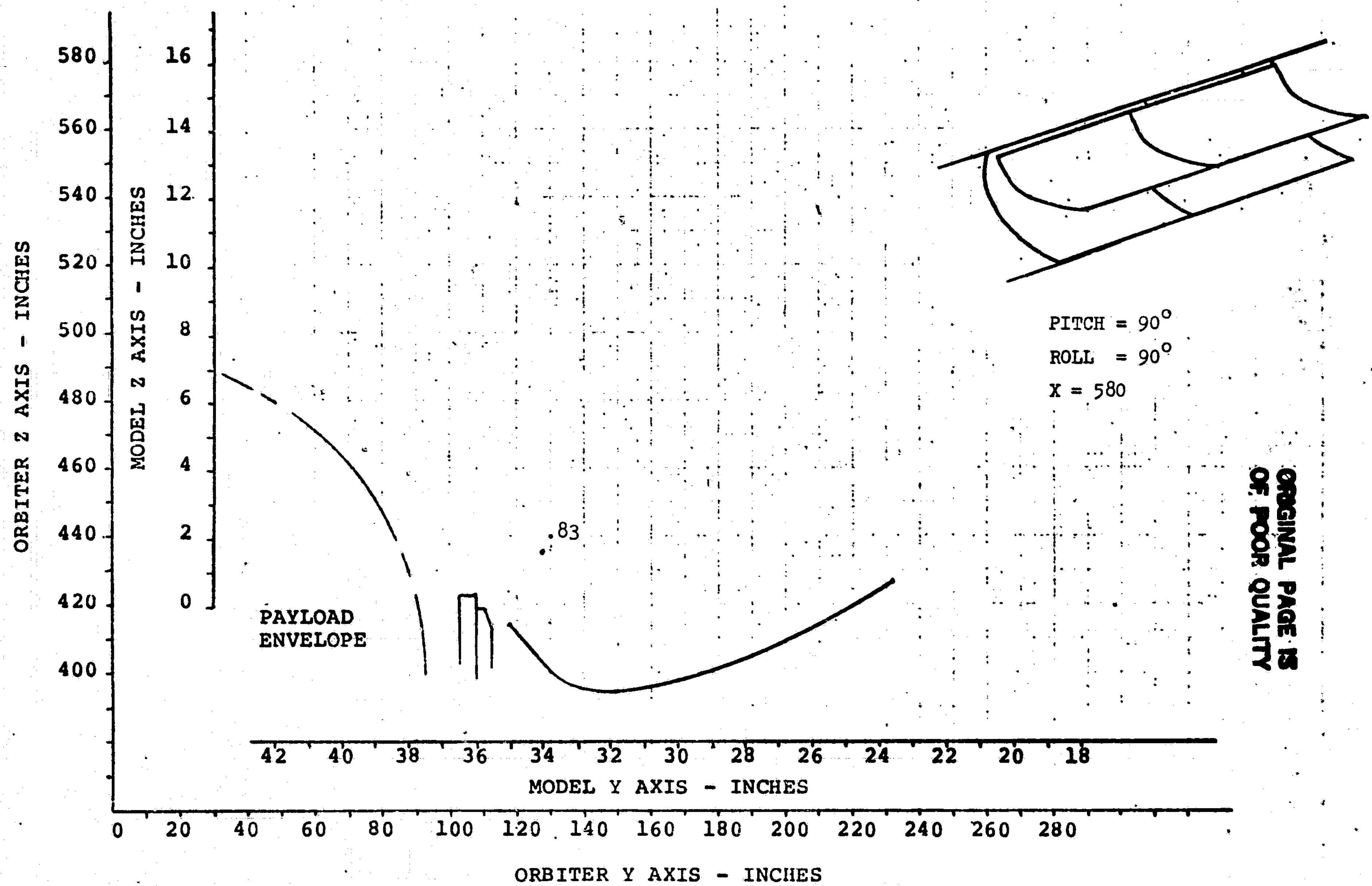

PITCH = 90°
ROLL = 90°
X = 662.5
PAYLOAD ENVELOPE
.32 .31
.04 .36 .16
.01 .47 .01
.64
ORBITER Z AXIS - INCHES
MODEL Z AXIS - INCHES
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
16
14
12
10
8
6
4
2
0
42 40 38 36 34 32 30 28 26 24 22 20 18
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280


ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
PAYLOAD
ENVELOPE
.42
.12
.19
.16
.50
42
40
38
36
34
32
30
28
26
24
22
20
18
MODEL Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
ORBITER Y AXIS - INCHES
PITCH = 90°
ROLL = 90°
X = 622.5

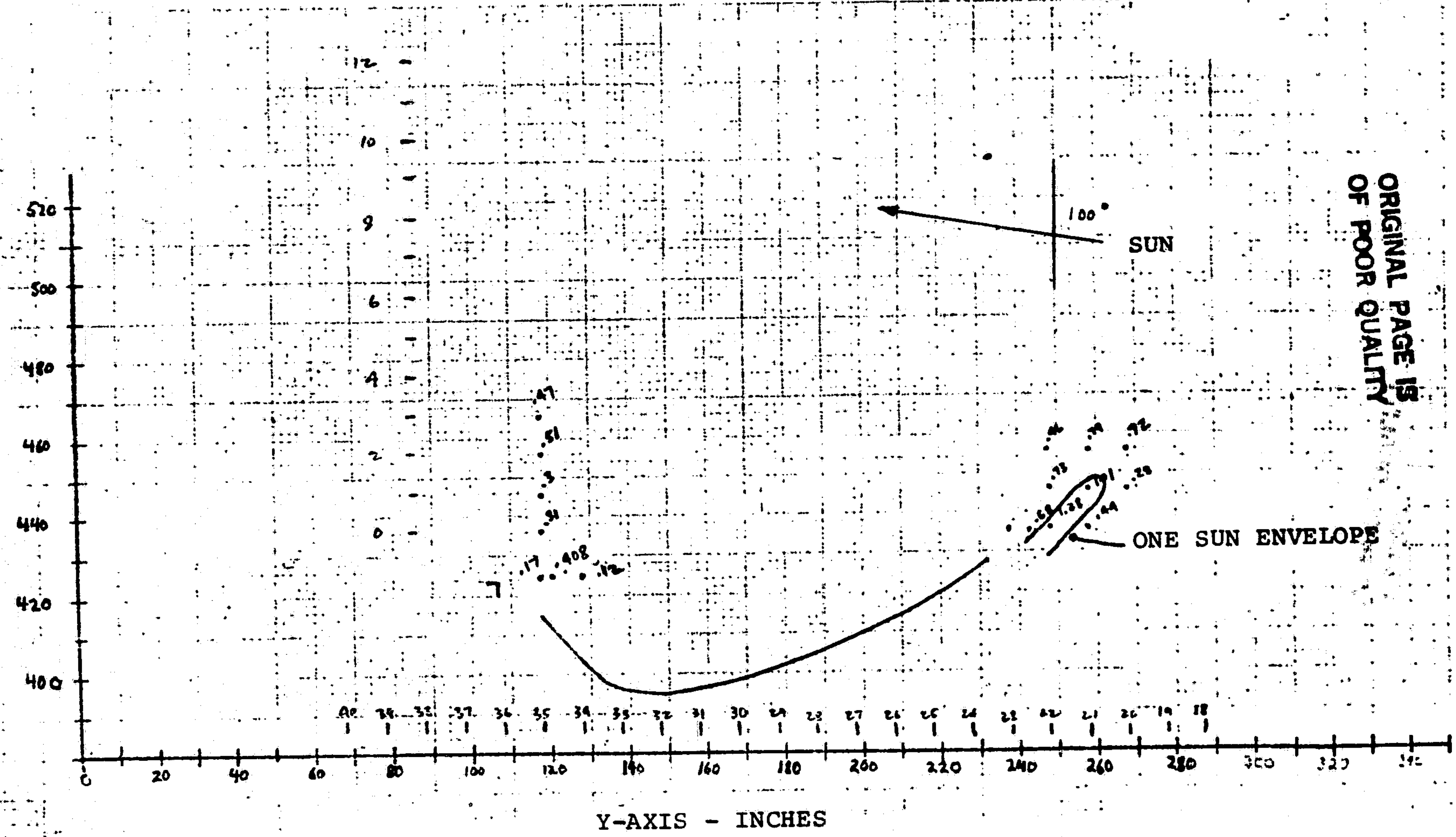

PITCH = 90°
ROLL = 90°
X = 632.5
PAYLOAD ENVELOPE
.85
MODEL Y AXIS - INCHES
ORBITER Y AXIS - INCHES
MODEL Z AXIS - INCHES
ORBITER Z AXIS - INCHES
18 20 22 24 26 28 30 32 34 36 38 40 42
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
0 2 4 6 8 10 12 14 16
400 420 440 460 480 500 520 540 560 580


PITCH = 90°
ROLL = 90°
X = 580
.83
PAYLOAD
ENVELOPE
ORBITER Z AXIS - INCHES
580
560
540
520
500
480
460
440
420
400
MODEL Z AXIS - INCHES
16
14
12
10
8
6
4
2
0
MODEL Y AXIS - INCHES
42
40
38
36
34
32
30
28
26
24
22
20
18
ORBITER Y AXIS - INCHES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

SOLAR FOCUSING TEST RESULTS

SUN IN CAVITY - ROLL = 100°

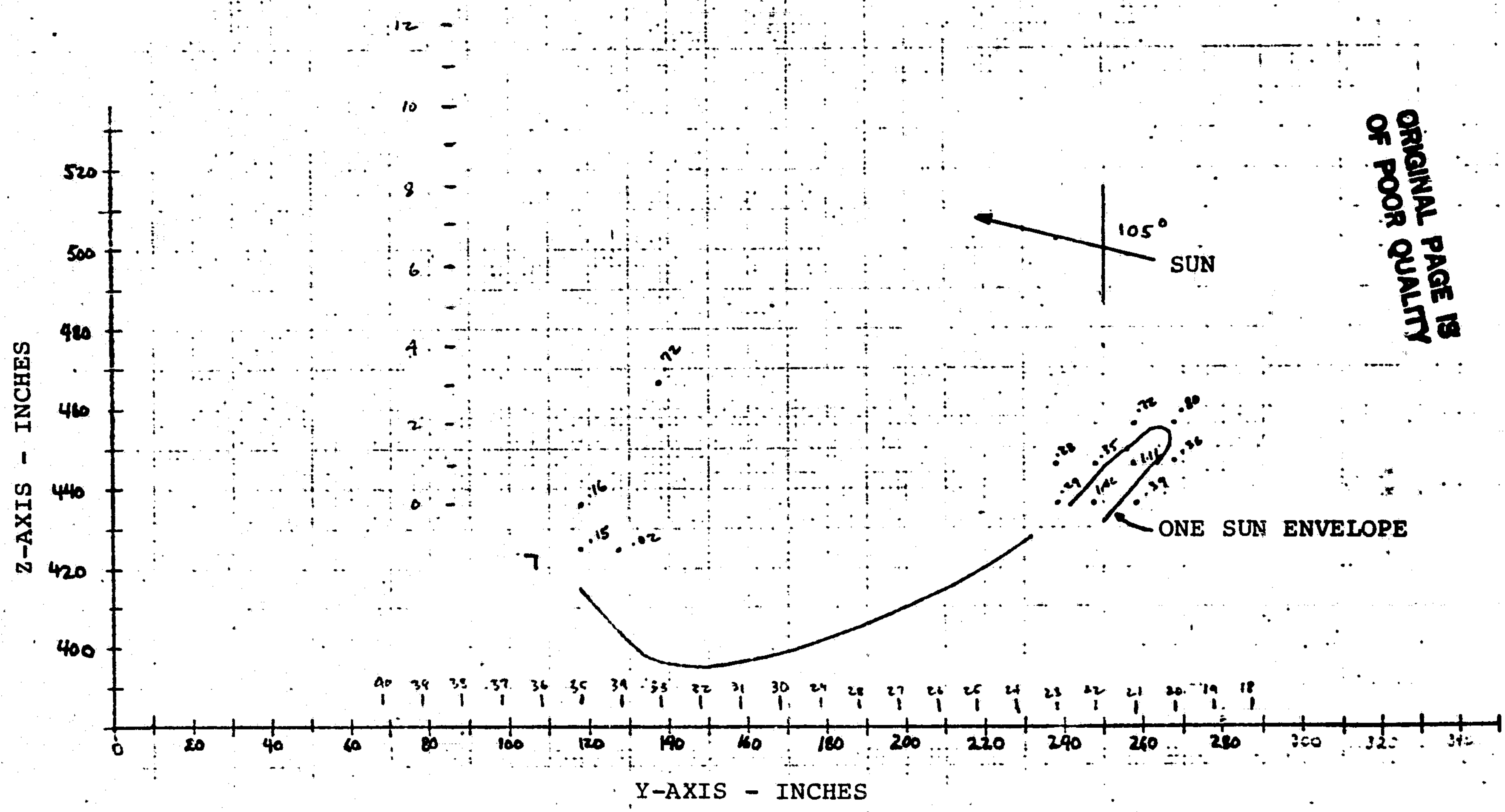
X = 727.5 - 682.5



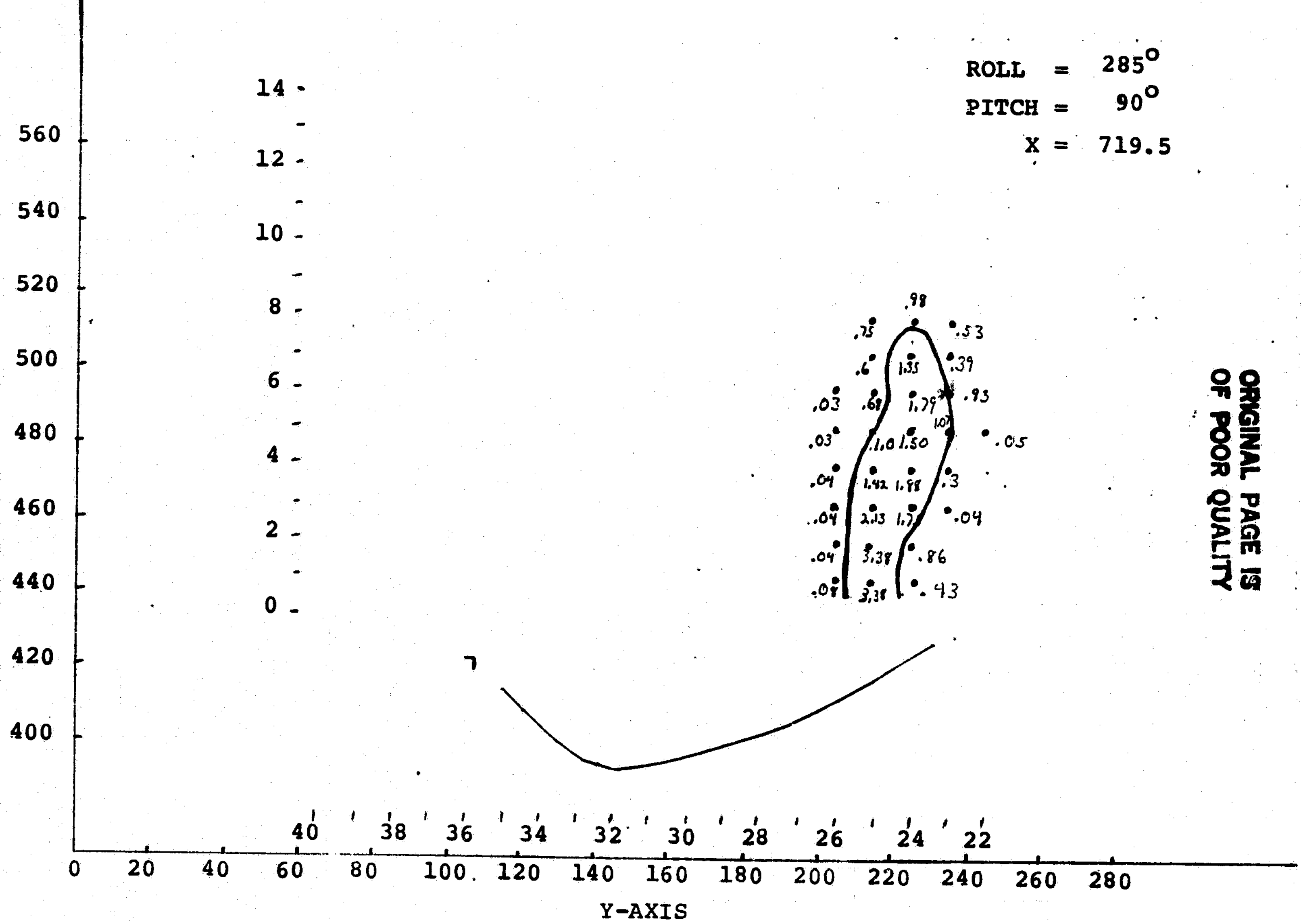
SOLAR FOCUSING TEST RESULTS

SUN IN CAVITY - ROLL = 105°

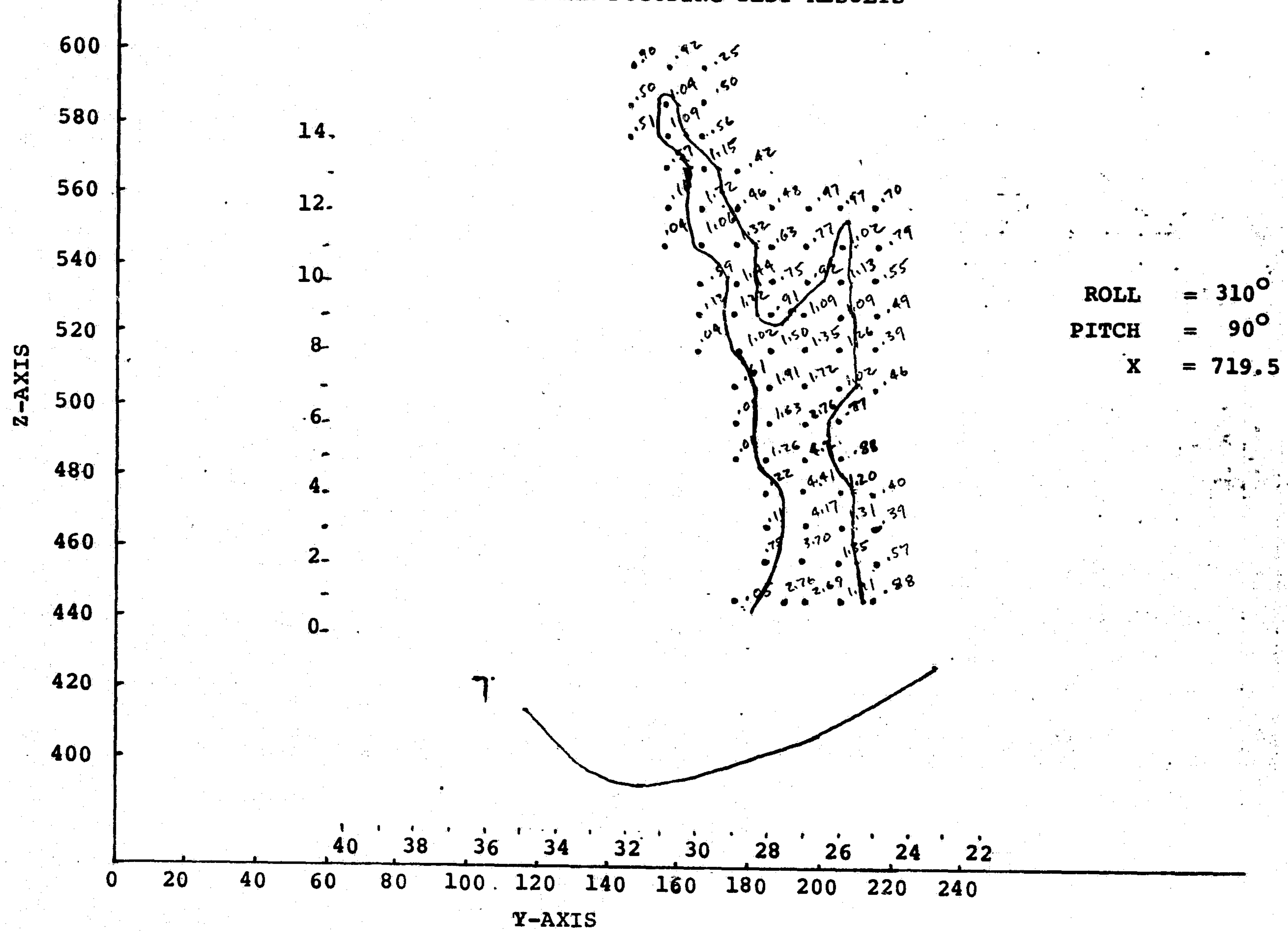
X = 662.5



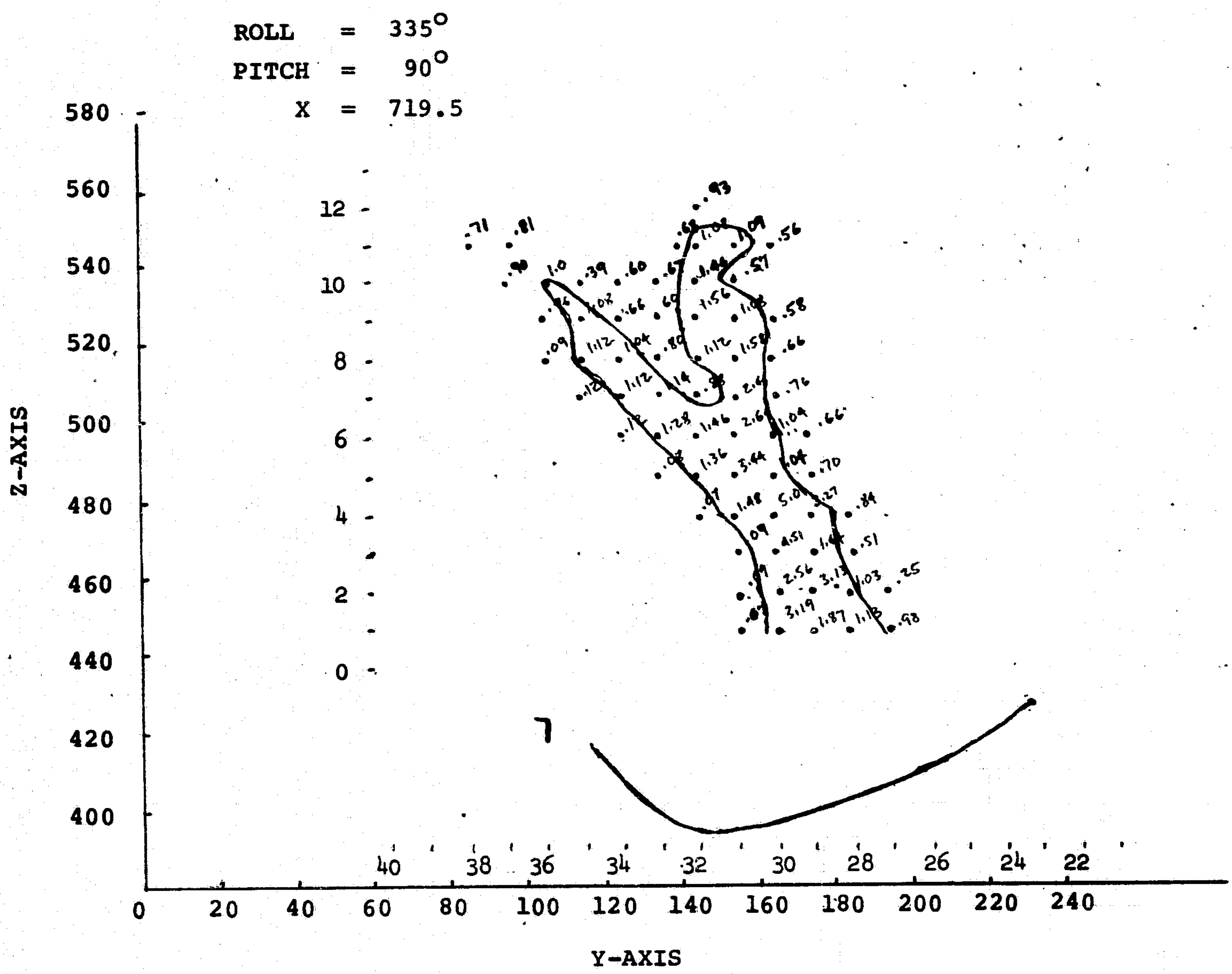
SOLAR FOCUSING TEST RESULTS



SOLAR FOCUSING TEST RESULTS



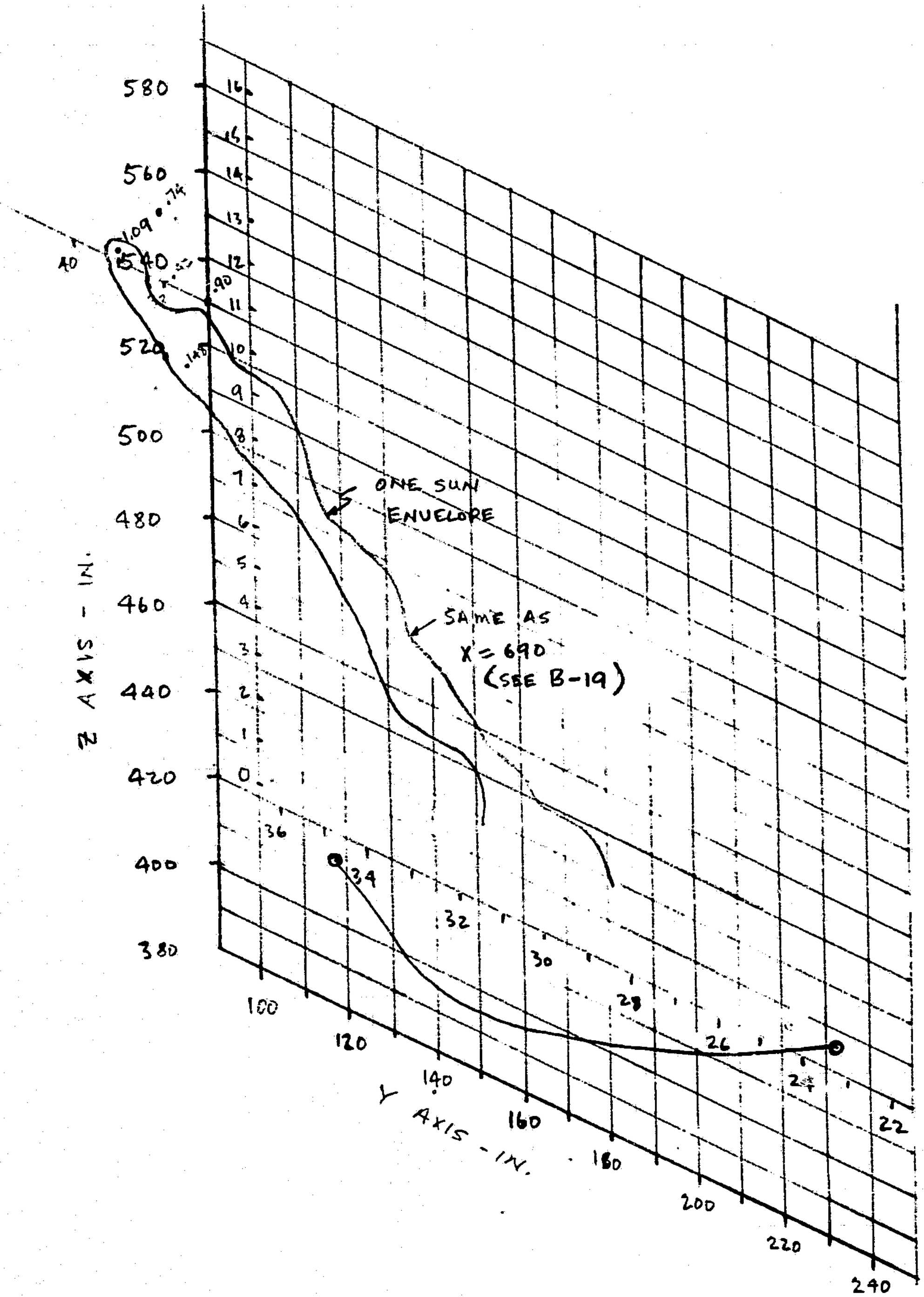
SOLAR FOCUSING TEST RESULTS



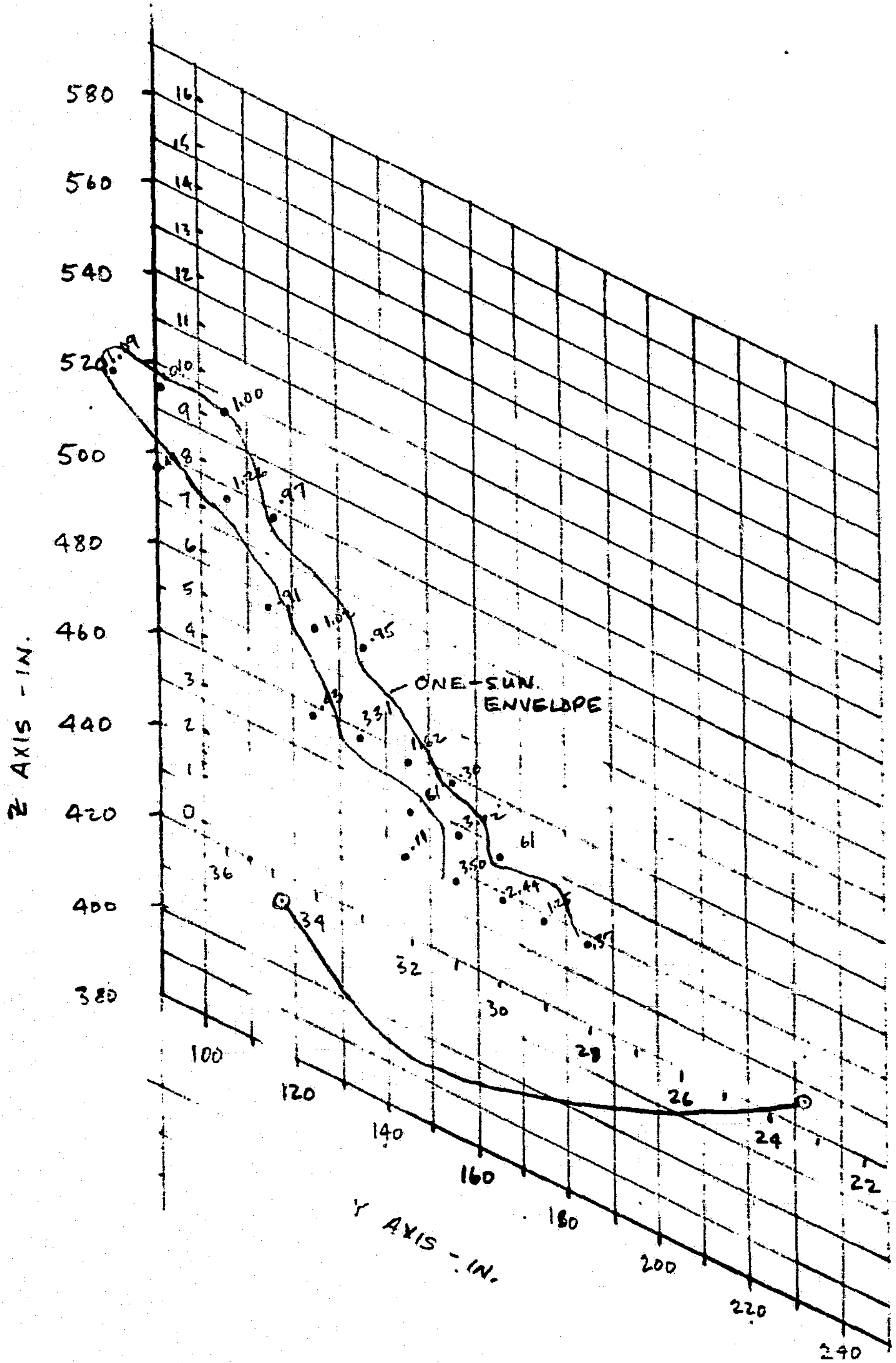
ORIGINAL PAGE IS OF POOR QUALITY

SOLAR FOCUSING TEST RESULTS

ROLL = 0°
PITCH = 115°
X = 790



ORIGINAL PAGE IS OF POOR QUALITY



SOLAR FOCUSING TEST RESULTS

ROLL = 0°

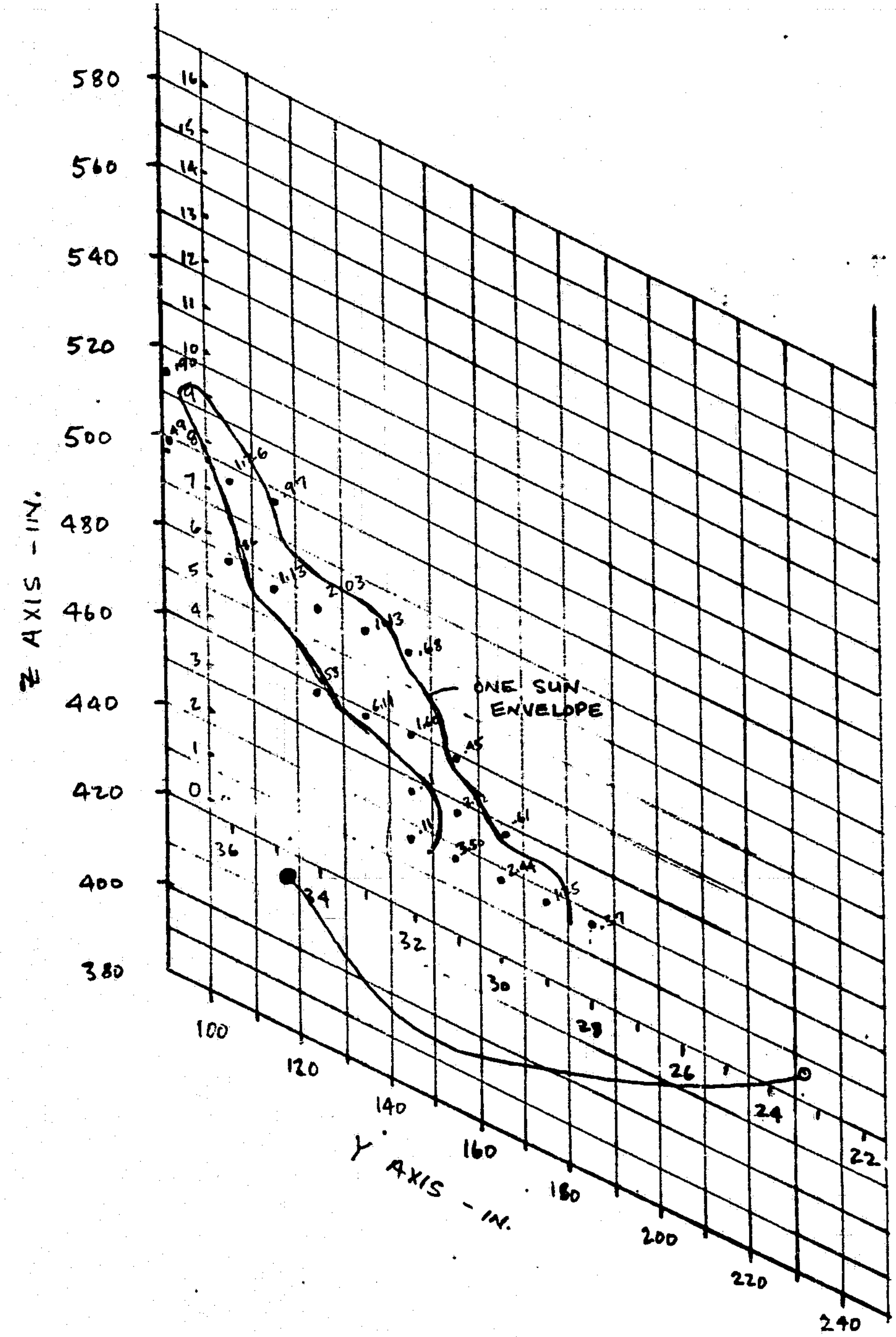
PITCH = 115°

X = 690

ORIGINAL PAGE IS
OF POOR QUALITY

SOLAR FOCUSING TEST RESULTS

ROLL = 0
PITCH = 115°
X = 640



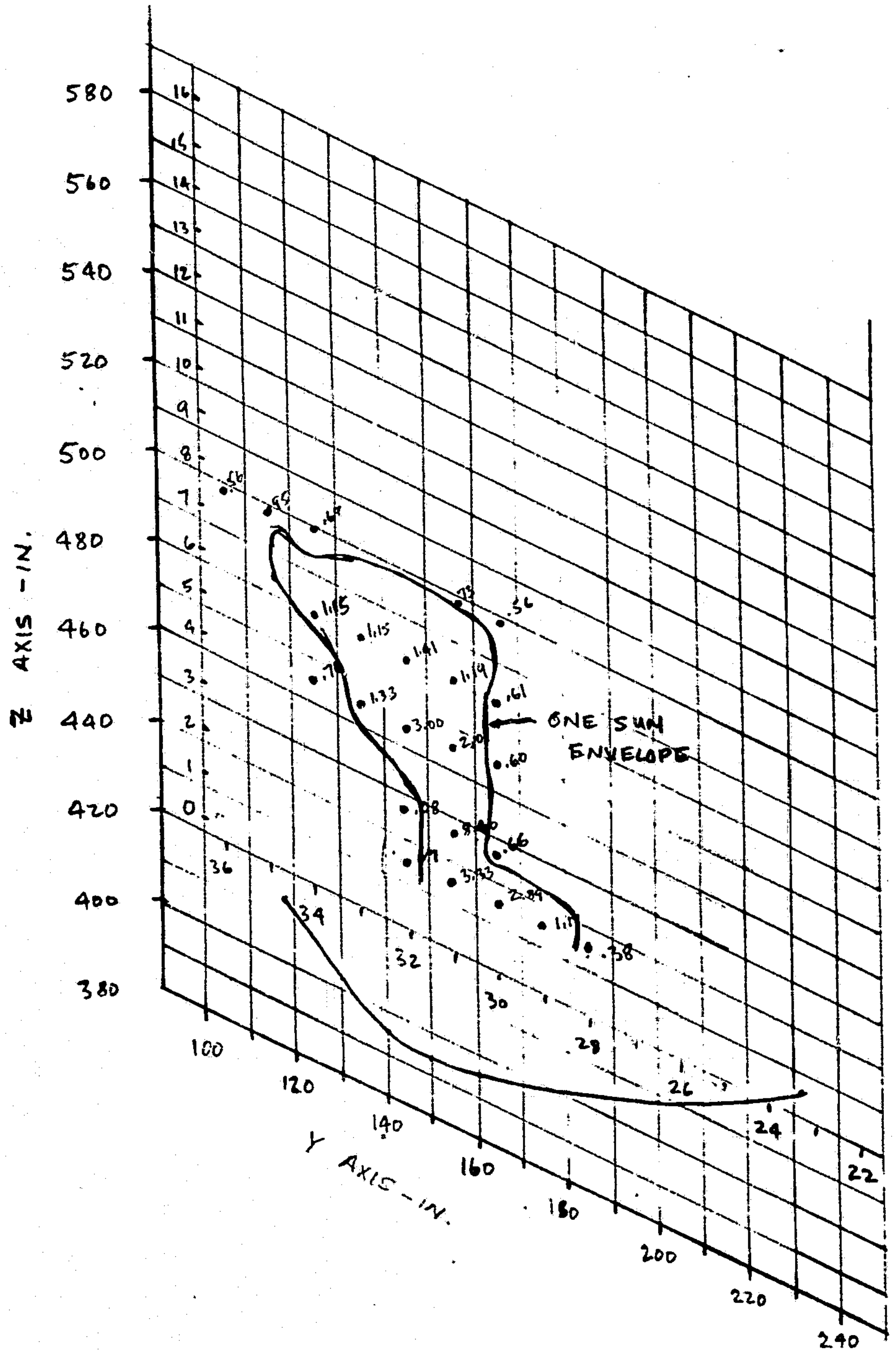
ORIGINAL PAGE IS OF POOR QUALITY

SOLAR FOCUSING TEST RESULTS

ROLL = 0°

PITCH = 115°

X = 590

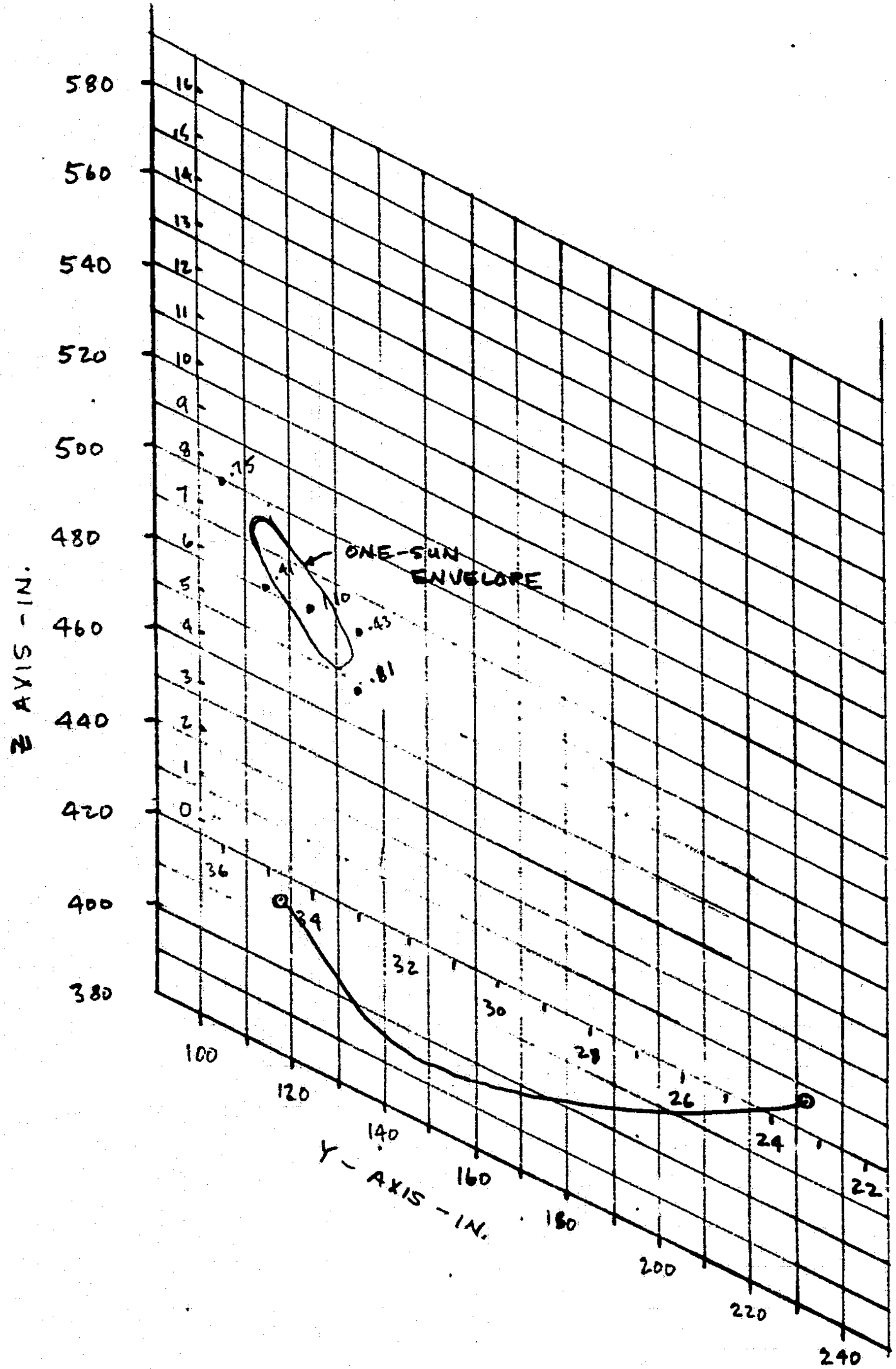


SOLAR FOCUSING TEST RESULTS

ROLL = 0°

PITCH = 115°

X = 540



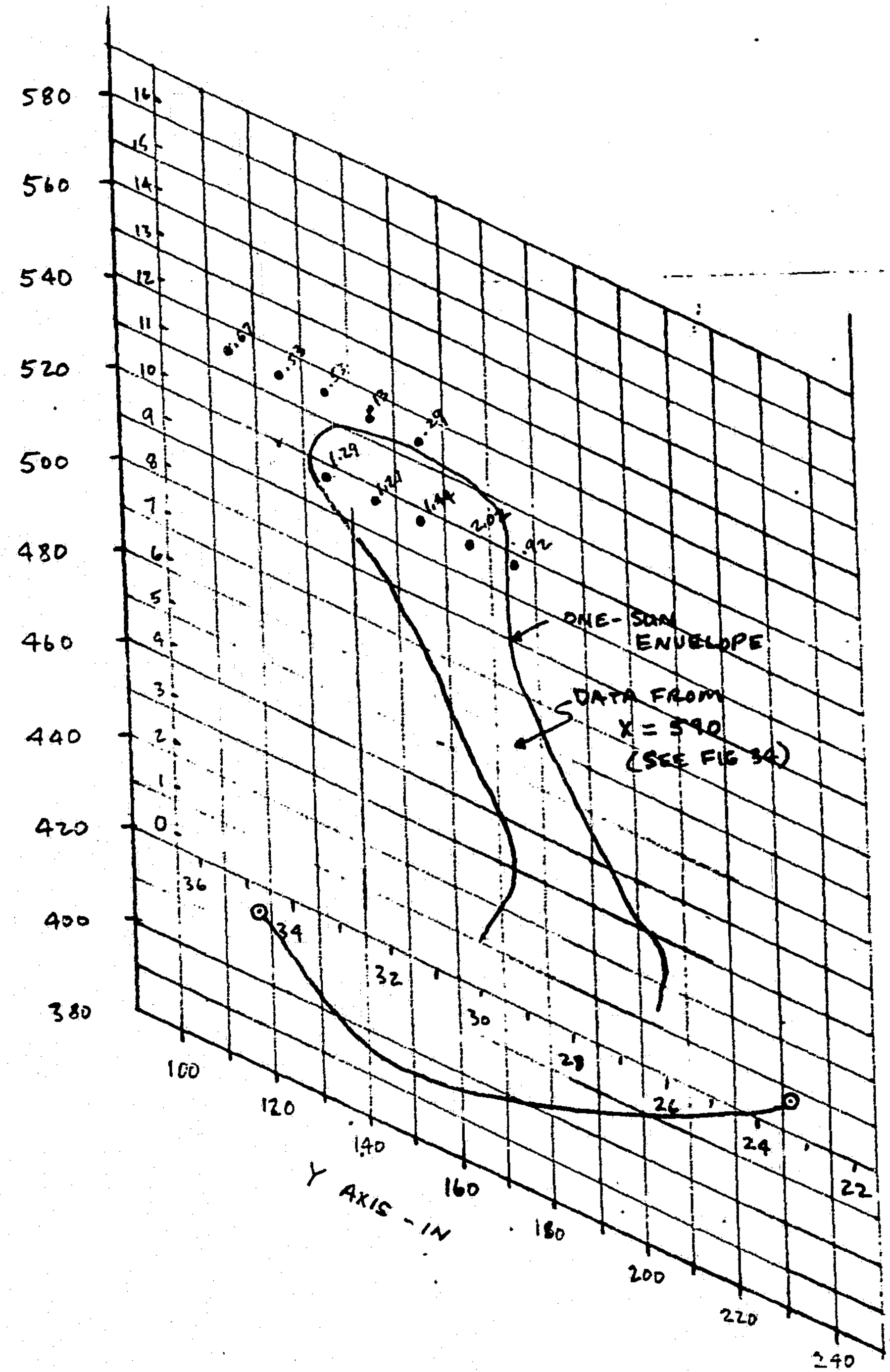
C - 3

SOLAR FOCUSING TEST RESULTS

ROLL = 335°

PITCH = 115°

X = 790 & 690



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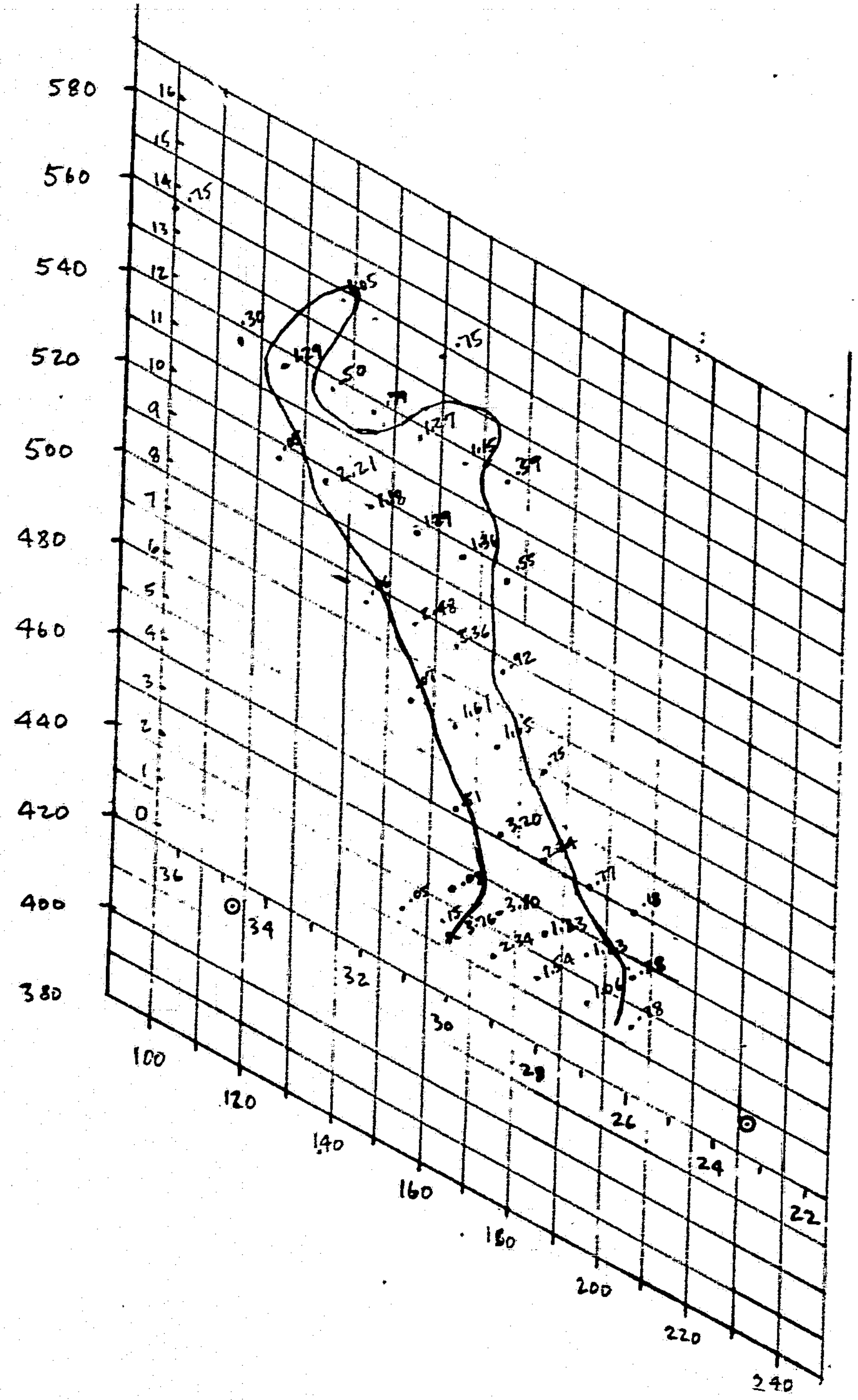
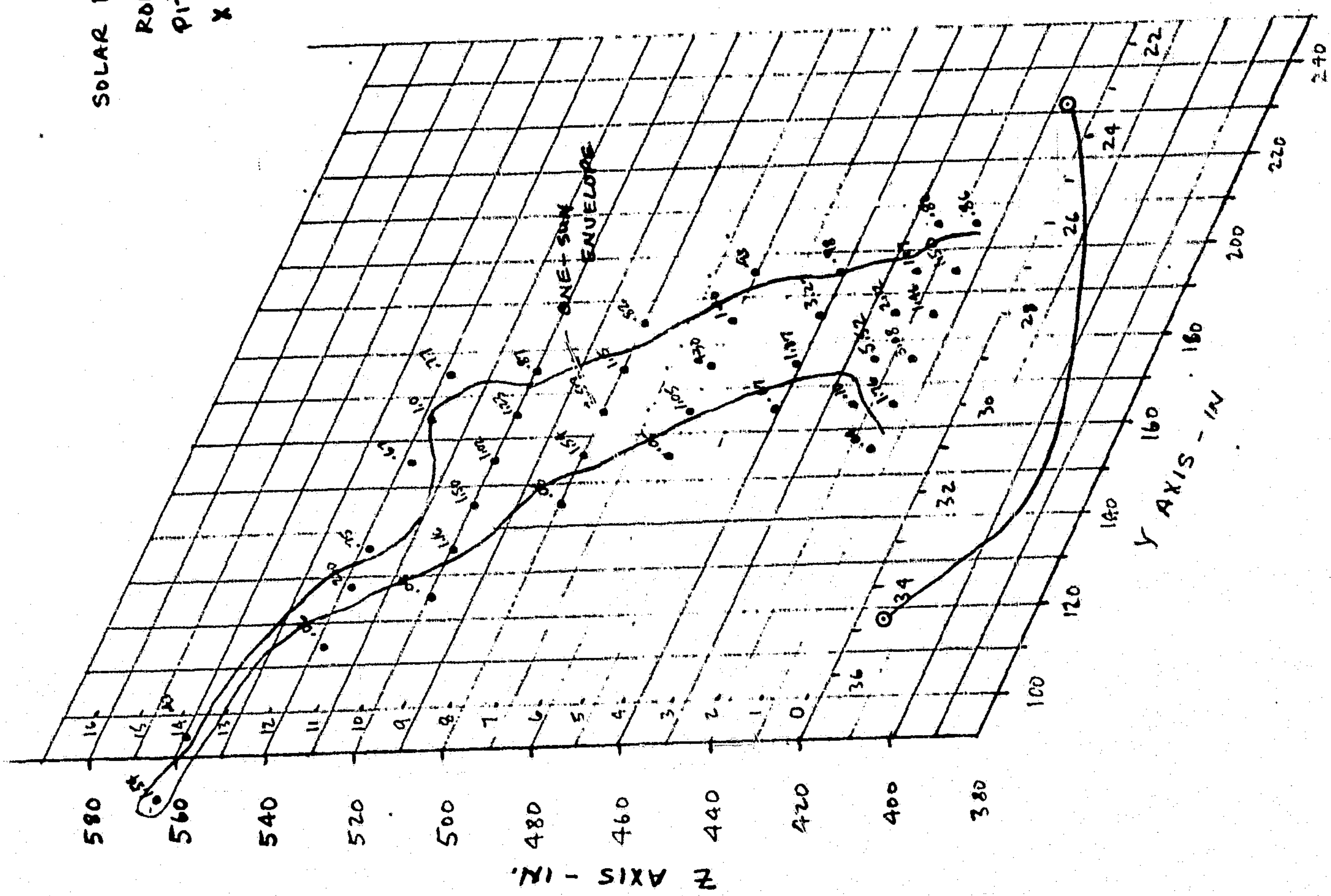
SOLAR FOCUSING TEST RESULTS
ROLL = 335°
PITCH = 115°
X = 662.5



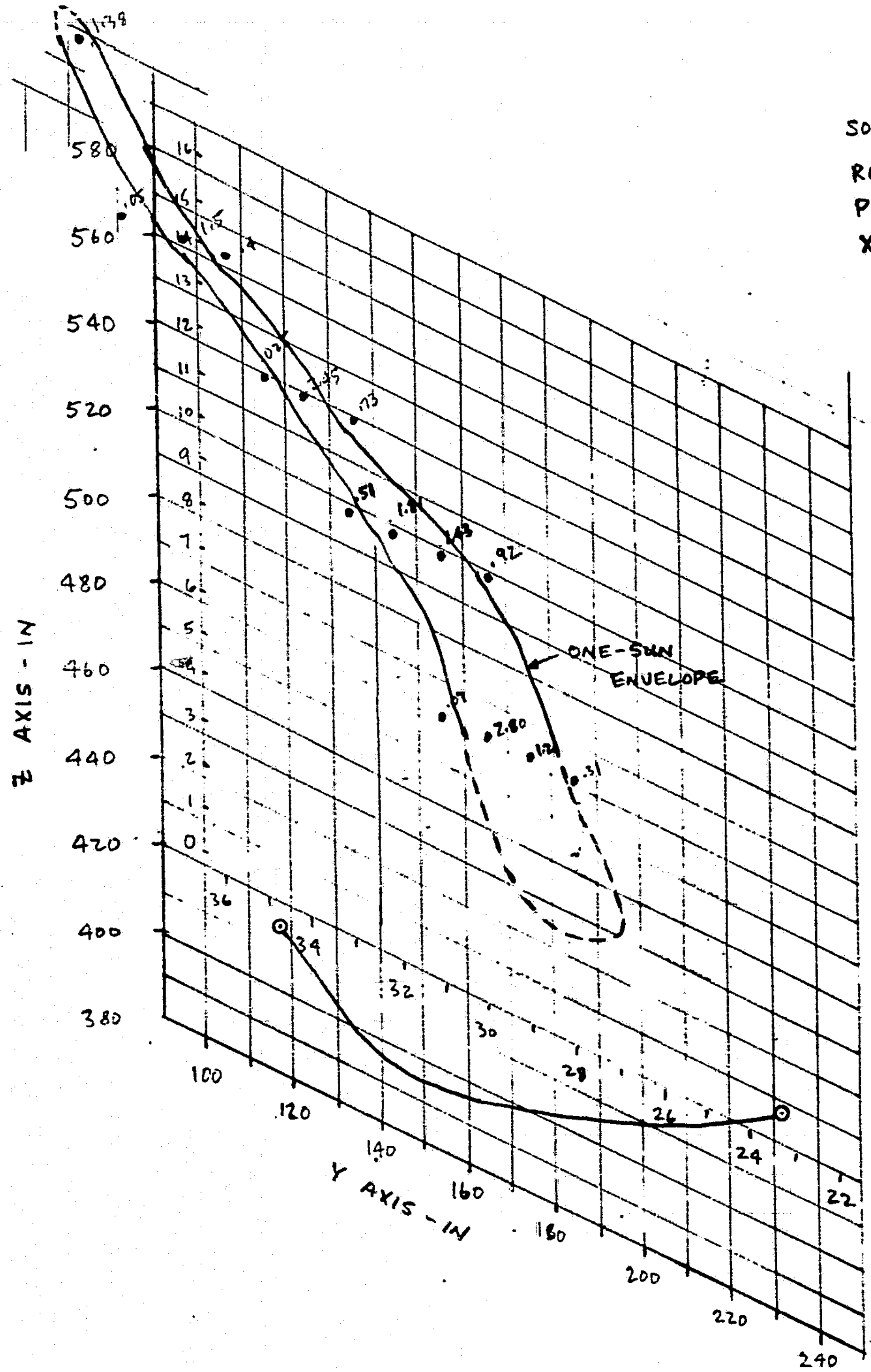
ORIGINAL PAGE IS
OF POOR QUALITY

SOLAR FOCUSING TEST DATA
ROLL = 335°
PITCH = 115°
X = 590



SOLAR FOCUSING TEST RESULTS

ROLL = 335°
PITCH = 115°
X = 540



ORIGINAL PAGE IS OF POOR QUALITY