DEPLOYABLE REFLECTOR DESIGN

FOR

KU-BAND OPERATION

NAS1-11444

SEQUENCE NUMBER 4317-01

PREPARED FOR

LANGLEY RESEARCH CENTER

PREPARED BY

ELECTRONIC SYSTEMS DIVISION OF

HARRIS CORPORATION

P.O. BOX 37

MELBOURNE, FLORIDA 32901

SEPTEMBER, 1974

HARRIS
COMMUNICATIONS AND INFORMATION HANDLING

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*(formerly RADIATION)

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INTRODUCTION

1.0 INTRODUCTION

In the past, operation at Ku-band frequencies (11 to 18 GHz) was considered possible only with solid surface reflectors due to surface tolerance requirements. However, the packaging and weight restrictions of such reflectors limit their practicality in the larger sizes, particularly where severe volume limitations are imposed. The objective of this program was to extend the deployable antenna technology state-of-the-art through the design, analysis, construction, and testing of a lightweight (31 pounds maximum with a 25 pound goal) high surface tolerance (0.020 inches rms surface error) 12.5-foot diameter reflector for Ku-band operation. A secondary objective of the program was to ensure, to the extent possible, the applicability of the reflector design to the Tracking and Data Relay Satellite (TDRS) Program.

This final report presents a complete documentary of the total program. The remainder of this section presents a results summary. Section 2.0 describes the performance requirements used to guide and constrain the design. Section 3.0 presents a detailed description of the design. Section 4.0 presents RF, structural/dynamic, and thermal performance results and includes analysis/test correlation where applicable. Section 5.0 discusses the applicability of the reflector design to the TDRS Program. Section 6.0 presents the conclusions and recommendations of the program. Appendices are utilized to provided detailed test data and the detailed fabrication drawings for the reflector.

Results Summary

The reflector design is illustrated in Figure 1.0-1. The parabolic reflective surface consists of 12, 1.5-inch diameter, tubular aluminum ribs which shape and support the metallic mesh. The choice of 12 ribs was based on a trade-off study considering weight, surface tolerance, and deployed dynamic performance. The "double mesh" technique is used to obtain the high surface accuracy required for Ku-band operation. This technique consists of two mesh surfaces which are separated by the rib thickness and tee bars and connected by tensioned metallic ties. By properly tensioning the connecting tie wires, the reflector surface (front mesh) can be contoured to a precision parabolic shape.

The conical feed support structure is the primary structural member of the stowed antenna. A conical structure was chosen because, in this application, the RF aperture blockage is no more severe than that of a spar support and the conical structure is more efficient than a spar system from weight and structural standpoints. A dielectric ogive radome is provided as an enclosure for the RF feed. The ogive geometry was selected because of its high electrical efficiency over other geometries.

The stowed antenna is restrained by top and midsection restraint systems which force the stowed antenna to act as a single stiff structural member, thereby providing a high stowed resonant frequency. The reflective surface is deployed at a controlled rate by the mechanical deployment system (MDS) (Figure 1.0-2). The MDS consists of a disc-shaped carriage mounted to the moving section of a recirculating ball nut on a ball screw shaft. The carriage and the ribs are connected by linkages that transmit the force and motion required for deployment to the ribs. Redundant drive system power is supplied to the ball screw by a spring motor and

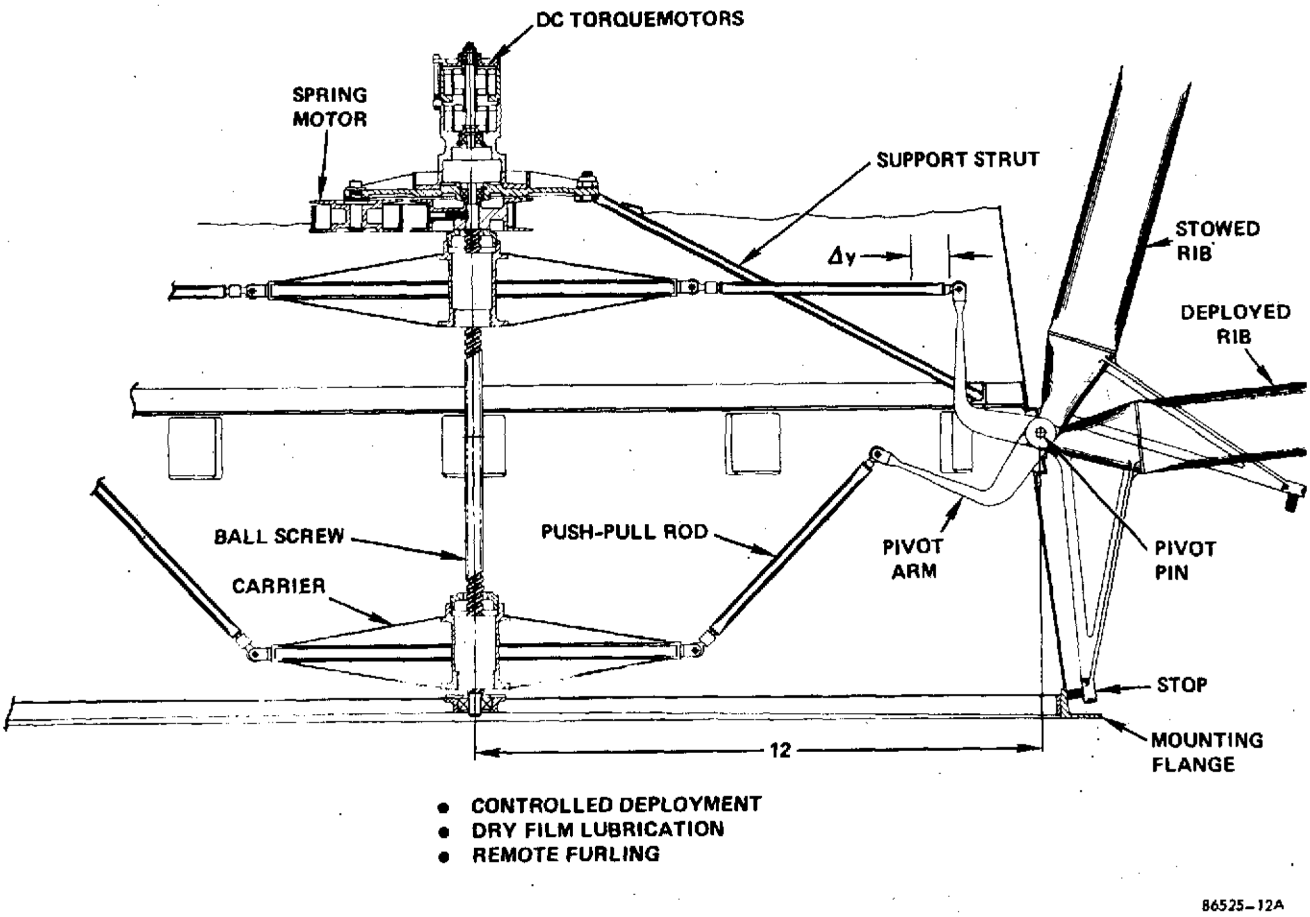

Figure 1.0-2. The Mechanical Deployment System (MDS) Provides Controlled Deployment, Redundant Drive Power, and Is Self-Locking in the Deployed Condition

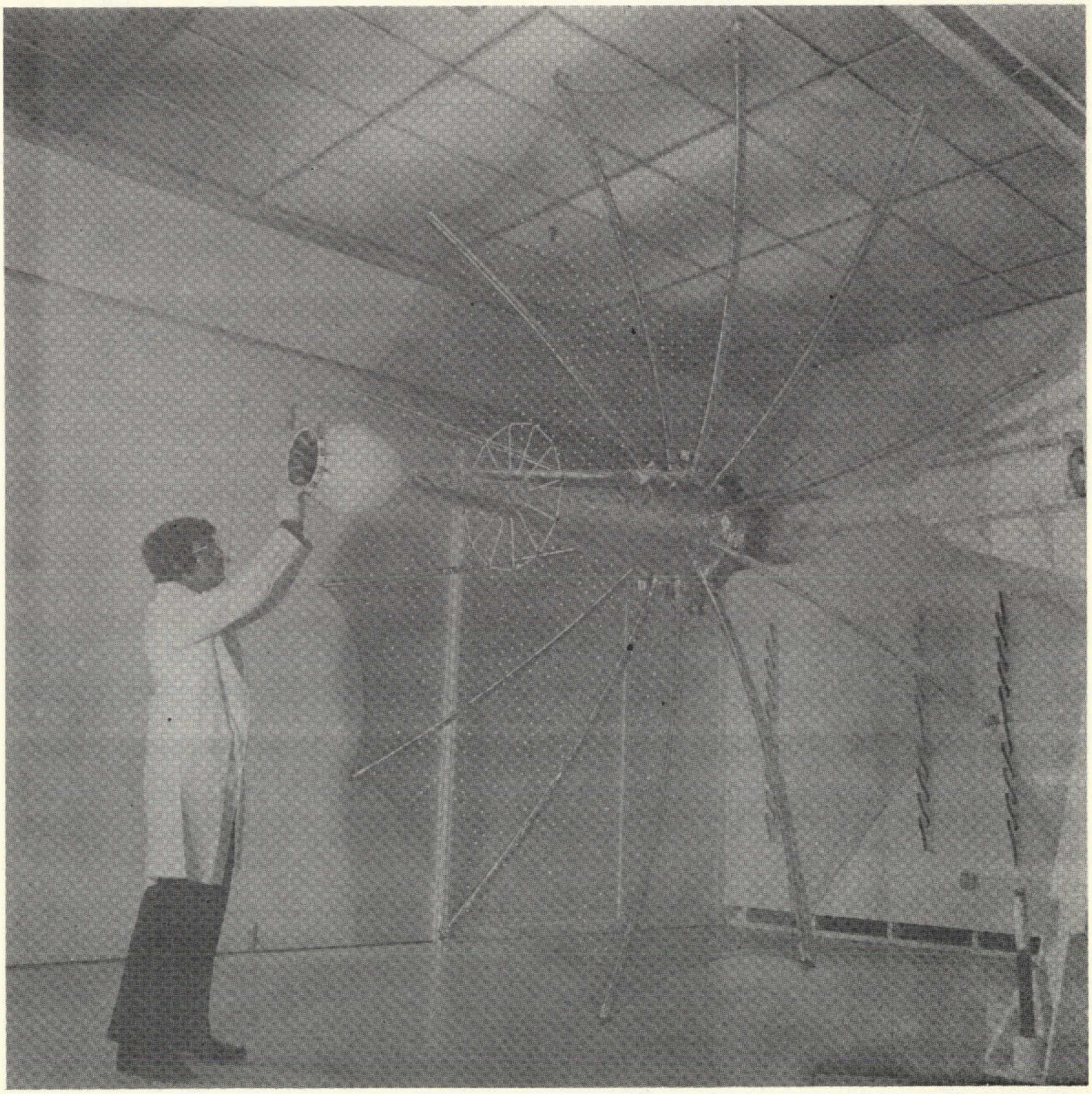

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Figure 2.2. 12.5 Foot Reflector

two electric torque motors. The probability of successful reflector deployment is 0.993 as based on test data from this and previous programs. The controlled deployment rate eliminates the transfer of any deployment forces to the spacecraft and also prevents impact loading of the ribs and mesh, thus, assuring the preset parabolic surface is not distorted by the deployment action. Repeatability of the reflector surface over successive deployments was measured as ±0.002 inches rms (see Appendix B).

The measured weight of the completed reflector (reflective surface, feed support, and deployment system) is 26.2 lbs. Previous technology would have resulted in a total weight of no less than 40 lbs.

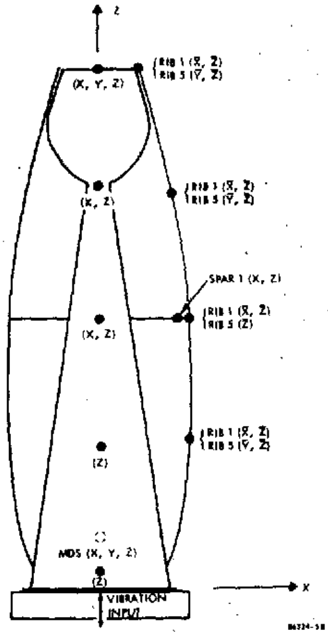
The projected surface error under worst-case orbital conditions is 0.022 inches rms as shown in Figure 1.0-3. The manufacturing error of 0.020 inches is a measured value. The thermal error contribution is determined by analysis (see Section 4.3). The gravity deflection error occurs in orbit once the gravity force is removed. Upon removal of the gravity force, the mesh assumes an equilibrium position different from that in the gravity field. This error is minimized by setting the reflector along horizontal radial lines where the gravity effects are essentially nullified. The surface error when the reflector is oriented in the face-side range test condition (as shown in Figure 1.0-5) is 0.030-inches rms.

Error Source	Magnitude, Inches RMS
Thermal	0.008
Manufacturing	0.020
Gravity	0.006
Total RSS Error	0.022

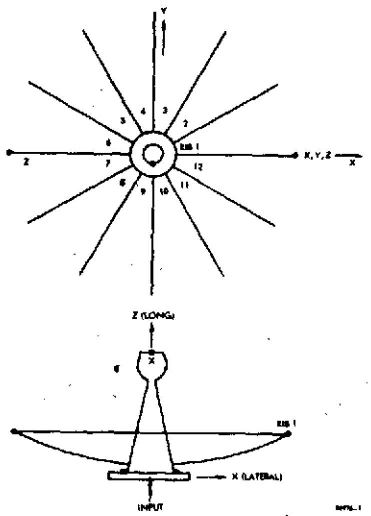
Figure 1.0-3. Surface Error Budget for Worst-Case Orbital Conditions

The minimum lateral frequency of the stowed reflector is 57 Hz and the minimum longitudinal frequency of the stowed reflector is 93.1 Hz. These high stowed resonant frequencies minimize deflections and structural coupling with the lower frequencies of excitation introduced by the launch vehicle. They also allow the reflector to be structurally qualified as a component in dependent of the total spacecraft. The minimum resonant frequency of the deployed reflector is 8.3 Hz. This high deployed resonant frequency ensures minimal structural coupling of the deployed reflector with the spacecraft attitude control system or with other large flexible structures, e.g., antenna support booms, solar panels, etc. Figure 1.0-4 shows the test configurations during stowed and deployed vibration testing of the reflector.

Figure 1.0-5 shows the RF test arrangement for the reflector. Figures 1.0-6 and 1.0-7 show the measured reflector patterns at 2 GHz and 15 GHz respectively. Figure 1.0-8 summarizes the RF range gain measurement results.



Stowed Vibration Test Configuration



Deployed Vibration Test Configuration

Figure 1.0-4. High Stiffness in the Stowed and Deployed Conditions Allows Qualification of the Reflector as a Component

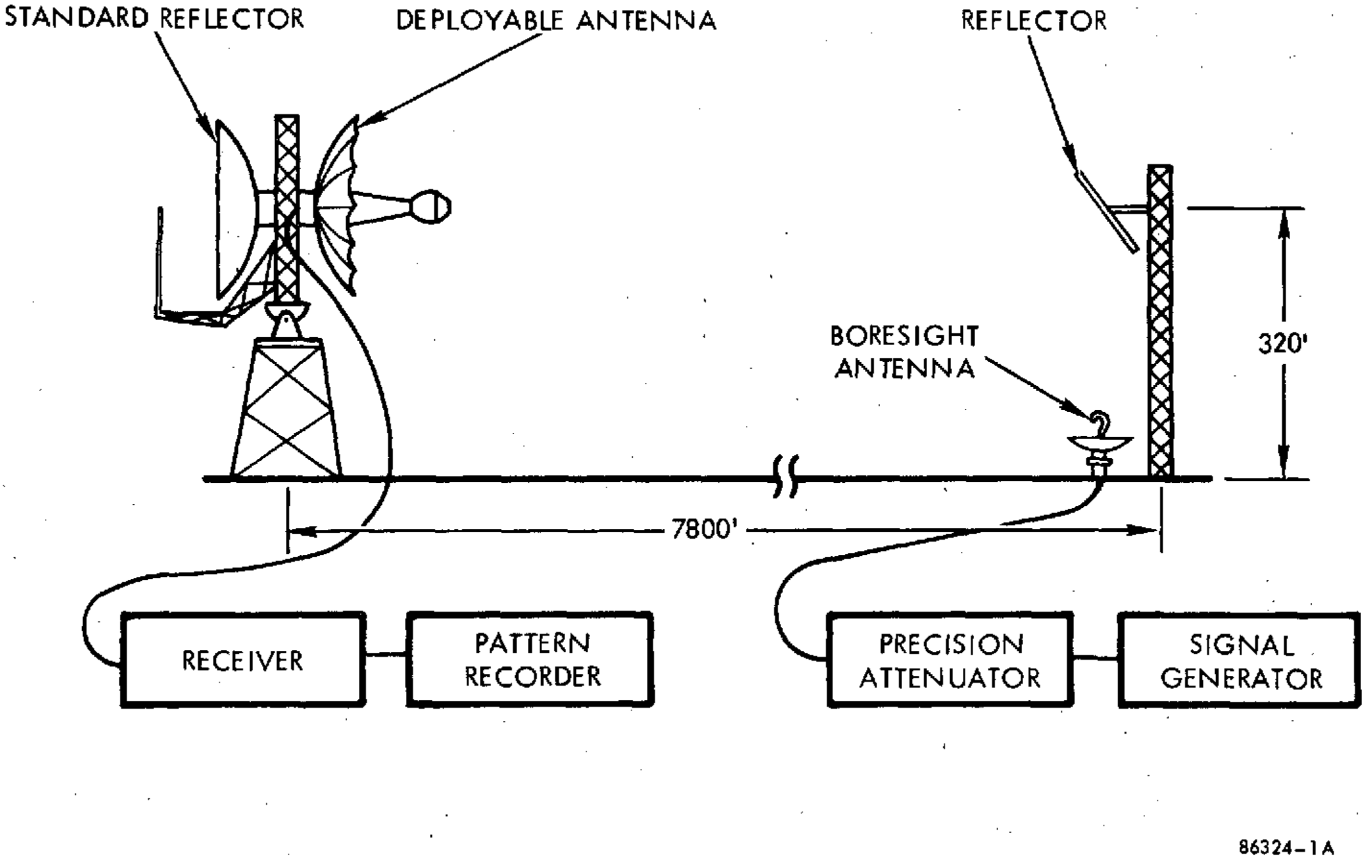


Figure 1.0-5. RF Range Measurements Validate Ku-Band Performance

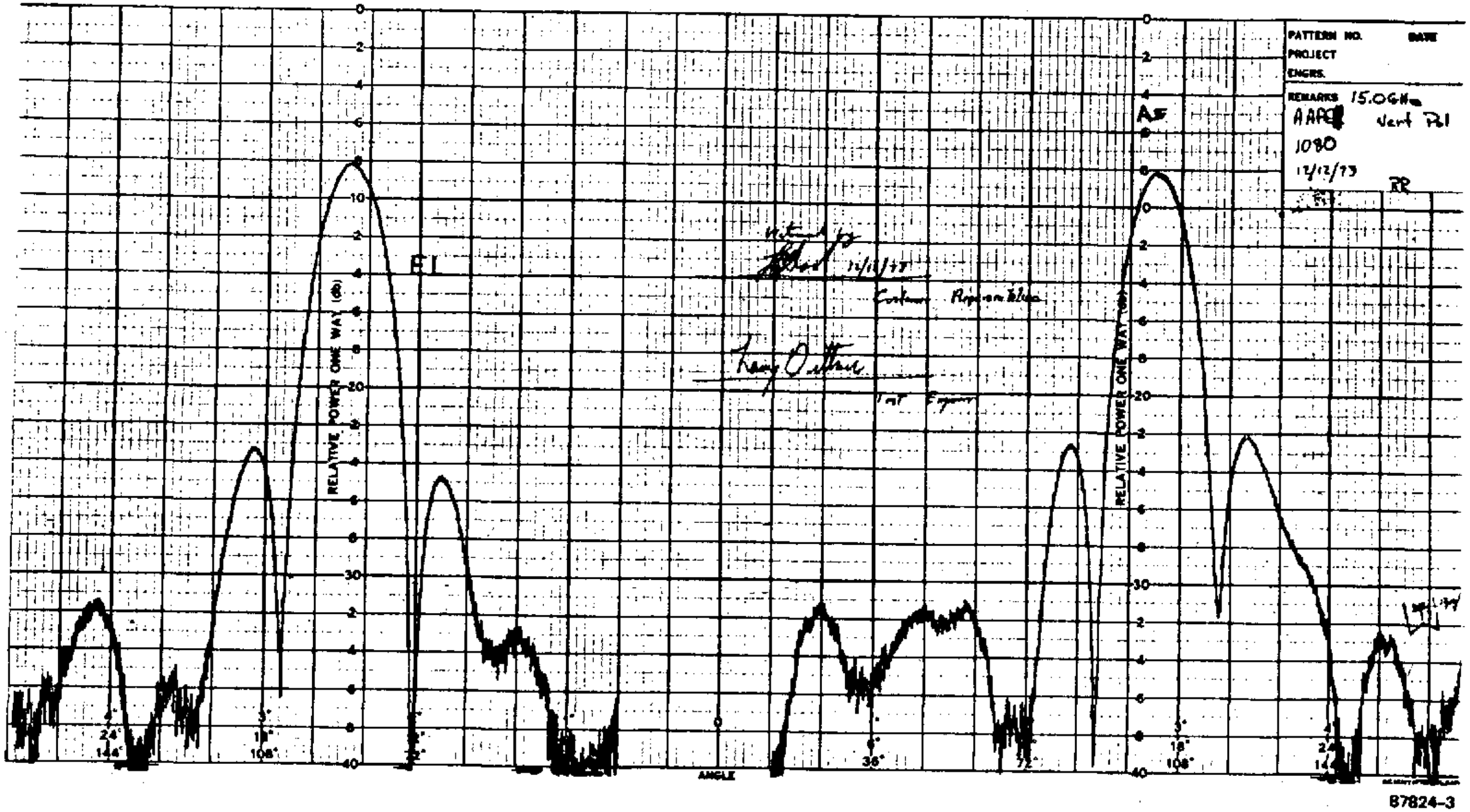


Figure 1.0-6. Reflector Patterns at 15 GHz

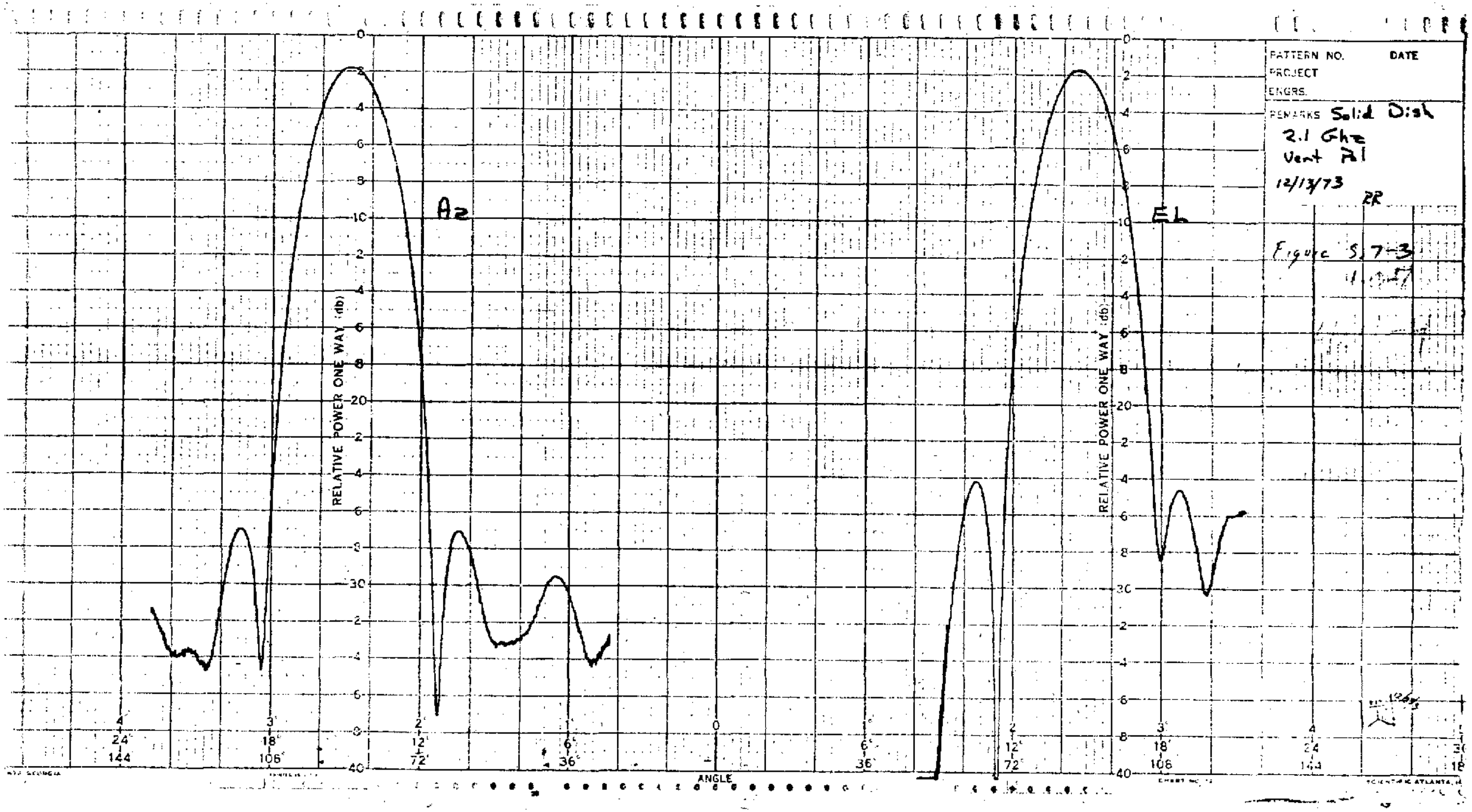


Figure 1.0-7. Reflector Patterns at 2.1 GHz

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	GAIN	
FREQUENCY	AAFE[1]	TDRS[2]
2.1 GHz	35.3 dB	35.3 dB
15.0 GHz	51.5 dB	51.9 dB

[1]MEASURED GAIN IN GRAVITY

[2]PROJECTED ORBITAL GAIN

CONCLUSION:

RF PERFORMANCE IS ADEQUATE TO MEET TDRS REQUIREMENTS.

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Figure 1.0-8. Gain Measurement Summary at S- and Ku-Band

SECTION 2.0

DESIGN PERFORMANCE REQUIREMENTS

2.0 DESIGN PERFORMANCE REQUIREMENTS

This section presents the basic performance requirements, constraints, and philosophies considered essential in the 12.5-foot diameter model antenna development to ensure a coordinated electrical/structural/mechanical design.

Contained in this section are the following:

a. Applicable documents and definition of terms

b. Basic objectives and philosophy of design

c. Conditions and environments for which the antenna is analyzed and designed

d. Load requirements and other factors used for design

e. Environmental and stiffness criteria

f. Weight and balance criteria

g. Structural/mechanical performance requirements

h. Electrical performance criteria

2.1 Applicable Documents

The following documents of the issue and date indicated form a part of these requirements to the extent specified herein. In the case of conflict between this document and the documents referenced herein, this document governs:

MIL-HDBK-5B Metallic Materials and Elements for Aerospace Vehicle Structures

Delta Launch Vehicle Interface and Environment, December, 1970.

NASA SP-3024 Models of Trapped Radiation Environment, Volumes I and II, 1962

2.2 Design Philosophy and Definition of Terms

2.2.1 Design Philosophy

Nonflight conditions and environments influenced the design to the minimum extent. Where practicable, means were devised for assembling, handling, transporting, and storing which do not require an increase in the flight weight over that for the flight conditions.

The allowable stress values and materials properties used to substantiate the performance of the antenna were obtained from MIL-HDBK-5B or from test values when appropriate. Strength allowables and other mechanical properties are consistent with the loading conditions, design environments, and stress states for each structural member.

The materials of construction were chosen for compatibility with the space environment. Materials with low levels of outgassing have been utilized.

2.2.2 Structural Design Procedures

The following procedures, material allowables, and strength requirements were used as guidelines for all structural design and analysis. Procedures for all stress calculations are consistent with those in MIL-HDBK-5B.

2.2.2.1 Definition of Terms

Limit Loads - The maximum loads the antenna is expected to experience for the design condition under consideration

Yield Design Loads - Limit loads multiplied by the yield design load factor of safety

Ultimate Design Load - Limit loads multiplied by the ultimate design load factor of safety

2.2.2.2.1 Allowable Stress Values

For antenna members that are critical in buckling, the minimum guaranteed properties (A values in MIL-HDBK-5B) and minimum thicknesses were used for stress calculations. For all other conditions, the minimum guaranteed properties and the nominal thickness were used.

2.2.2.2.2 Margin of Safety

To achieve a lightweight structure, the antenna is designed to attain the smallest practical margin of safety greater than zero, except where stiffness requirements dictate additional structure. The following structural elements, which are susceptible to random type failures due to manufacturing and load distribution inconsistencies, were restricted to have the following margins of safety:

Antenna Part	Minimum Margin of Safety
Fasteners in Shear	+.15
Bolts in Tension	+.50
Fittings	+.15
Lugs	+.25
Welds and Brazed Joints	+.50
Epoxied Joints	+.75

In determining the margin of safety, the effect of combined loads or stresses was considered.

2.2.2.3 Factors of Safety

The following factors of safety were applied to the limit loads to obtain the structural design loads.

Yield Design Load	1.15
Ultimate Design Load	1.25

2.2.2.4 Fatigue Considerations

The structural design of the antenna accounts for the effects of repeated loads. Efforts were made to avoid residual stresses and stress concentrations wherever possible.

2.2.2.5 Component Preload Requirements

All joints which depend upon preload for adequate performance are designed with sufficient preload such that no mechanical separation occurs due to limit loads.

2.3 Performance Requirements

This section describes those performance requirements used as a guideline for developing the design. Wherever possible these requirements were based on the Tracking and Delta Relay Satellite mission. As such, launch via a Delta 2914 booster and a synchronous equatorial orbit was assumed.

2.3.1 Weight and Packaging

The 12.5-foot diameter test model weight is not to exceed 31.0 pounds. A weight design goal of 25 pounds was established. The test model includes the following items: rib-and-mesh reflector, feed support structure and radome, mechanical deployment system and central hub, and the launch restraint system.

Maximum packaging envelope dimensions are not to exceed those defined by a right circular cylinder of 75 inches height and 30 inches diameter.

2.3.2 Reflector Tolerance

The antenna gain loss due to reflector surface error shall not exceed 0.50 dB at 15 GHz for a nominal sun angle of 60 degrees to antenna boresight axis. This requirement limits the maximum rms surface error to 0.020 inch.

The antenna gain loss due to feed defocusing for a nominal sun angle of 60 degrees to antenna boresight shall not exceed 0.50 dB at 15 GHz with 0.25 dB budgeted to linear displacement and 0.25 dB budgeted to beam mispointing. The maximum allowable linear displacement tolerance and feed offset angle to achieve this gain loss specification are:

Axial defocusing	0.15 inch
Feed offset angle	0.7°

2.3.3 Reflector f/D

Since no specific mission requirements dictated an f/D value, a trade-off study was conducted to develop a representative value. The evaluation of the f/D ratio involved consideration of three areas: electrical performance, stowed volume, and launch stiffness.

For general application, both broadband and narrowband, the optimum f/D from an electrical standpoint falls between 0.35 and 0.5 with 0.4 a good nominal value.

The maximum physical length of the stowed antenna as described in Paragraph 2.3.1 places an upper bound on the f/D and, likewise, the maximum diameter of the stowed antenna (as per Paragraph 2.3.1) places a minimum bound on the f/D.

For launch (resonance) performance a low value of f/D is desirable to reduce the stowed antenna height.

Based on the above considerations, an f/D range of 0.38 to 0.42, with a nominal value of 0.417 was chosen as a median value satisfying all limiting conditions.

2.3.4 Structural Design Requirements

The launch environment and qualification test requirements for the Delta booster are comprehensively described in Reference 1. The dynamic environment is defined at the interface between the booster and the spacecraft. This information was used to establish environmental design criteria for the antenna.

The TDRS spacecraft is, at this time, not adequately defined to allow an estimate of the transmission of energy through the spacecraft to the antenna. Because of this, the values given in Reference 1 were increased by an appropriate amount to account for unknown effects of the spacecraft. The resulting design criteria for the antenna are given in Table 2.3.4.

Table 2.3.4. Structural Design Criteria

Antenna Configuration	Antenna Axis	Fundamental Frequency, Hz	Maximum Vibration Response G Ultimate	Maximum Shock Response G Ultimate
Stowed	Lateral	40	25	20
	Longitudinal	90	35	20
	Torsional	15	--	10
Deployed	Lateral	4.5	2.2	N/A
	Torsional	4.0	2.0	

The minimum launch frequency requirements for the spacecraft are 40 Hz and 25 Hz in the longitudinal and lateral directions, respectively. The antenna is a component of the spacecraft and requires higher values. The values of 90 Hz and 40 Hz in the longitudinal and lateral directions for the stowed antenna are considered typical values based on the spacecraft requirements. No torsional frequency requirement is given in Reference 1. A value of 15 Hz minimum torsional frequency for the stowed antenna was assigned based on past experience.

The design acceleration values of 25 G laterally and 35 G longitudinally were determined after evaluation of the qualification test requirements for sine and random vibration, steady state accelerations, and pyrotechnic shock from Reference 1. The critical condition was found to be response to sinusoidal vibration. From Table 3-1, Reference 1, in the lateral axis the required input from 14 to 100 Hz is 1.5 G limit. Typical measured amplification by the antenna at resonance is 17, resulting in a maximum response of 25 G ultimate. In the longitudinal axis, the input is 2.3 G ultimate from 23 to 100 Hz. Typical longitudinal amplification at resonance is approximately 15, resulting in a maximum longitudinal response of 35 G limit. The above values assume a rigid spacecraft and attachment fixture. To determine actual response it is necessary to perform a coupled dynamic analysis of the antenna, spacecraft, attachment fixture, and Delta booster. However, based on the data available at this time these values are recommended for use as criteria for sizing the antenna structural members.

The qualification test requirement for random vibration is 9.2 G_{rms} with a PSD of 0.045 from 300 to 2000 Hz and rising from 20 to 300 Hz at +3 dB/octave. The lateral response is approximately 4 G_{rms}. Three sigma values are 12 G_{o-p}. In the longitudinal axis the response is approximately 7 G_{rms} and three sigma values are 21 G_{o-p}. Thus, the random vibration is less severe than sine vibration.

The shock spectra at the spacecraft interface for the marmon-type clamp and the explosive nut separation systems are similar. Values are 1400 G at 0.3 ms and 1600 G at 0.8 ms, respectively. The level is reduced through the interfaces and with distance to the source. This reduction is estimated to be a factor of 0.1 to 0.4. Using a value of 0.3, the amplitudes become 420 G and 480 G, respectively. The estimated maximum response in the antenna is less than 10 G. This, again, is less severe than the sine vibration.

The acoustic overall noise level is 146 dB. This is considered much less severe than the vibration. Tests reported in the Shock and Vibration Bulletin 33, Part III, indicate 146 dB corresponds to approximately 9 G_{rms}.

The deployed frequency values shown were developed based on previous experience. A high deployed resonant frequency, such as shown, is desirable to assure no coupling of the reflector and other deployed structures (e.g., solar panels) occurs.

2.3.5 Other Design Considerations

A number of other environmental considerations are normally applied as design constraints in a flight hardware program. Typical examples of such constraints are given below. While complete satisfaction of such requirements was not to be demonstrated on the present program, they have been given consideration in the antenna design.

2.3.5.1 Deployment Reliability

The antenna design should be such as to provide a probability of proper deployment of 0.99 or greater in the space environment. Proper deployment is defined as release of the launch restraint system and operation of the deployment system which results in a tensioning of the mesh surface to the required levels.

2.3.5.2 Angular Rates and Accelerations

The basic angular rates linking the TDRS to the user spacecraft are low (on the order of 0.75 radian per hour). Slewing maneuvers can increase these rates. Slewing is required when the antenna must sign off one satellite and acquire another. Since the minimum potential communication time to a user satellite is approximately 37 minutes, rapid slewing does not appear to be of great importance. A reasonable slew rate of 0.1 radian per second with potential accelerations of 0.1 radian/sec^2 have been selected. This rate allows the entire field of view to be scanned in 10 seconds.

2.3.5.3 Particle Radiation

Radiation from trapped electrons and protons will be encountered in the space environment. The materials used are such as to ensure that the antenna can perform its intended function under the effects of such radiation for the life of the mission.

2.3.5.4 Life

The antenna design considers a minimum orbital mission life of 5 years.

SECTION 3.0

DESIGN DESCRIPTION

3.0 DESIGN DESCRIPTION

The final 12.5-foot diameter antenna design is illustrated in Figure 3.0-1. The antenna is designed for a nominal f/D of 0.417. The measured weight of the entire antenna is 26.2 pounds. The minimum stowed lateral frequency is 57.0 Hz and the minimum deployed resonance frequency is 8.3 Hz. The high stowed resonant frequency minimizes deflections and structural coupling with the lower frequencies of excitation introduced by the launch vehicle. The high deployed resonant frequency ensures minimal coupling of the deployed reflector with the spacecraft attitude control system or with other large flexible structures such as the antenna support booms and solar panels on a three-axis spacecraft or the antenna support mast and/or booms on a spin stabilized spacecraft.

The major antenna elements can be categorized as:

- Reflective Surface
- Feed Support Structure
- Mechanical Deployment System (MDS)
- Launch Restraint System

Each of these areas is discussed in the following paragraphs. Figure 3.0-2 summarizes the design parameters used in this design. Detailed fabrication drawings are presented in Appendix A.

3.1 Reflective Surface

The parabolic reflective surface consists of 12, 1.5-inch diameter, tubular ribs which support and shape the metallic mesh. The choice of 12 ribs was based on a trade-off study considering weight, surface tolerance, and dynamic performance.

Figure 3.1-1 presents weight and deployed dynamic performance as a function of the number of ribs. All data has been normalized relative to the parameter values for 12 ribs. As shown, increasing the number of ribs improves the deployed resonant frequency; however, the resulting increase in weight is severe. The general conclusion to be derived from the data is to use the minimum number of ribs possible within the surface tolerance and deployed resonant frequency requirements. Based on dynamic analyses, and on achievement of the surface tolerance requirements with the "double mesh" design technique, a selection of 12 ribs was made. The double mesh technique utilizes two mesh surfaces which are separated by the rib thickness and connected to one another by tensioned metallic ties. Prior to the development and demonstration of this concept the surface accuracy of the rib-and-mesh design was directly proportional to the number of ribs. This dependency resulted because the largest contribution to surface error was the reverse bulge effect of the mesh between the ribs. The general nature of this effect is shown in Figure 3.1-2. The mesh membrane is pulled tight between the two curved, relatively rigid ribs. Due to the curvature of the ribs, the mesh takes a doubly curved shape, bowing in

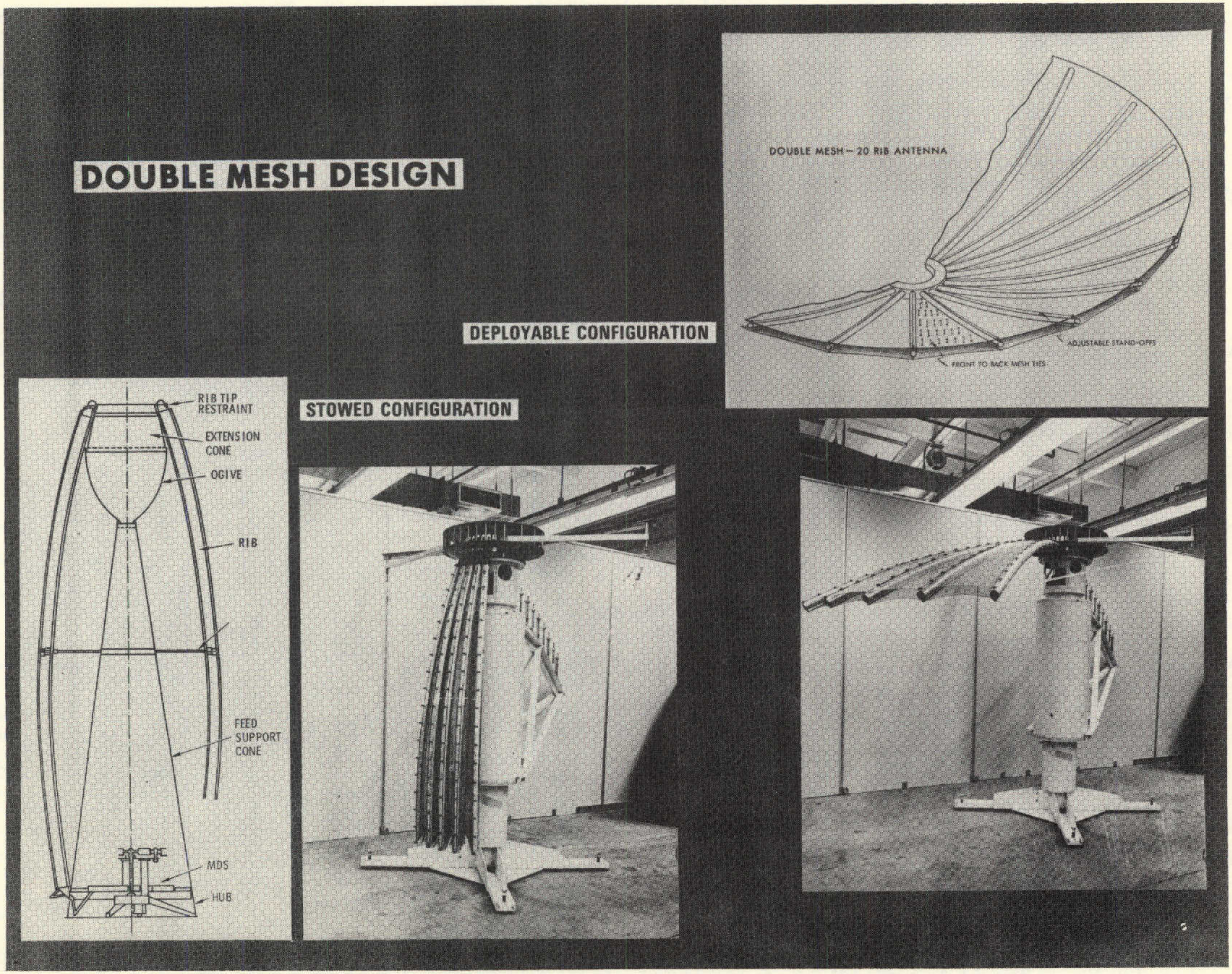

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Figure 3.0-1. The Double Mesh Design Allows Achievement of High Surface Accuracy

Element	Design Parameters
Ribs	• Number: 12 • Diameter: 1.5 inches • Wall Thickness: Tapered from 0.008 (base) to 0.012 (mid) to 0.006 (tip) • Cross Section: Circular • Material: 6061-T6 Aluminum • Shape: Modified parabolic • f/D: 0.417 • Thermal Control: Polished aluminum exterior with three layers of multilayer insulation
Mesh (Front)	• Material: Chromel-R wire, 0.7 mil by 5 strands per end • Geometry: Tricot knit, 14 ends per inch • Coating: Electroless nickel, electroless gold, electrolytic silver and electroless gold • Loading: 0.02 lb./in. tangential 0.01 lb./in. radial
Mesh (Rear)	• Material: Chromel-R wire, 0.7 mil by 5 strands per end • Geometry: Raschel knit, 2 ends per inch • Coating: Electroless nickel covered with electroless gold • Loading: 0.03 lb./in. tangential 0.005 lb./in. radial
Center Support Structure	• Type: Truncated support cone with dielectric ogive radome • Cone Material: 6061-T6 Aluminum, 0.020 inch thick (base), stepping to 0.015 inch from the midsection to the ogive

Figure 3.0-2. Design Description

Element	Design Parameters
	• Radome: 0.01 inch thick, high modulus fiberglass and epoxy laminate skins, with phenolic (1/4-inch cell) honeycomb, 3/8 inch thick.
	• Thermal Control: Three layers of multilayer insulation separated by three layers of nylon net on the cone. White paint (α/ϵ) = 0.28/0.86 on the radome.
	• Attachment to Hub: Removable
Central Hub	• Geometry: Extension of feed support cone geometry
	• Material: 0.050 inch thick 6061-T6 aluminum
	• Thermal Control: 15 layers of multilayer insulation separated by 15 layers of nylon net.
Mechanical Deployment System (MDS)	• Type: Over center type toggle action using a ball screw and carrier with linkages to each rib pivot arm. Over center condition gives positive deployed latching.
	• Drive System: Redundant electric motor and constant torque spring motor.
	Primary - 2.5 inch/pound spring motor direct drive on the ball screw
	Secondary - One synchronous motor integrated with a planetary gear train with 25 inch/pounds of output torque.
	• Redundancy: Either the spring motor or dc motor is capable of deploying the antenna in a 1 G field.
Launch Restraint	• Rib-to-center support cone restraint at rib midpoints using radial spars and a single hoop. Ball-and-socket joint between ribs and hoop. Preloaded by flexing rib.
	• Upper restraint provides moment joint at rib tip. Rib tips restrained and preloaded by a pretensioned, captivated cable.
	• Restraint Release: Two redundant pyrotechnic cable cutters.
Feed System	• Ku-band apex type feed assumed for design. 0.55-pound weight budget assumed for feed, brackets and cabling in all structural and dynamic analysis.

Figure 3.0-2. Design Description (Continued)

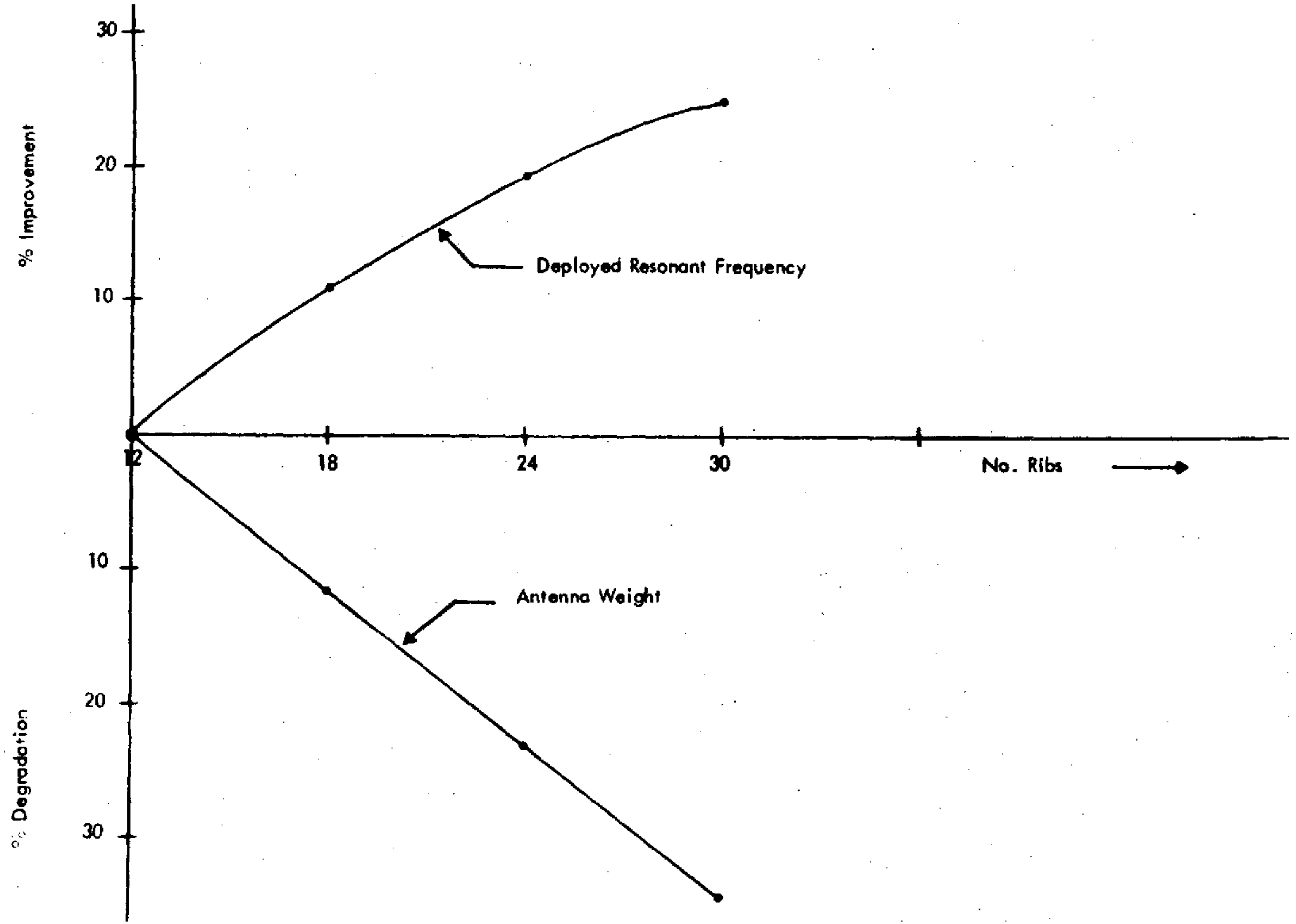


Figure 3.1-1. Weight and Deployed Resonant Frequency Versus Number of Ribs for 12.5-Foot Diameter Antenna

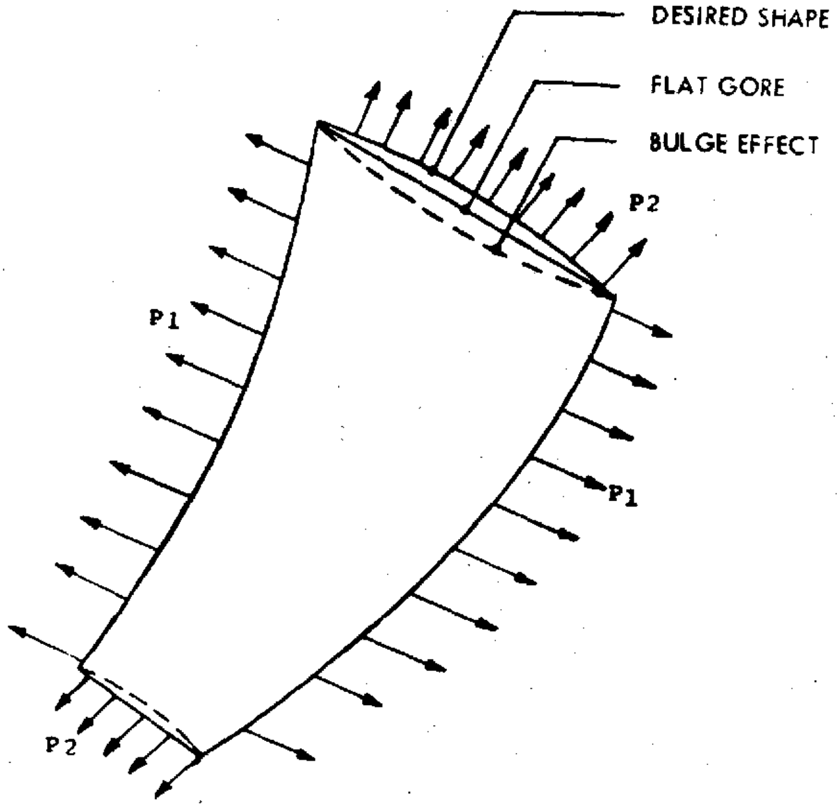


Figure 3.1-2. Reverse Bulge Effect

towards the concave side. This error is essentially eliminated by the double mesh concept as illustrated in Figure 3.1-3. The concept utilizes a second mesh as a drawing surface for contouring the front reflector mesh. The second mesh is attached to the back of the ribs and is tied to the front mesh by tensioned wires. By properly tensioning these tie wires, the reflector surface can be contoured to a precision parabolic shape. A manufacturing surface accuracy of 0.020-inch rms was achieved on the 12.5-foot diameter reflector using this concept. The design eliminates surface tolerance dependency on the number of ribs and thereby provides the flexibility to meet a wide range of structural and surface tolerance requirements with low weight.

A surface accuracy of 0.020-inch rms (representing 0.5 dB loss at 15 GHz) is a goal for the present application. As seen from Figure 3.1-4, the surface accuracy of a single mesh design is dependent on the number of ribs and a surface accuracy of 0.020 inch rms is not possible within the specified weight requirement. Conversely, the surface accuracy of the double mesh design is weight independent since the desired accuracy is achieved through the use of more or less ties between the two mesh layers. To attain the required surface tolerance within the specified weight, it is necessary that the double mesh design be utilized for this application.

The mesh is constructed from 5-strand bundles of 0.7-mil Chromel-R wire which is knitted into a highly elastic wire screen. The front mesh is knitted with 14 ends per inch of width. This size was selected to ensure satisfactory RF reflectivity. The back mesh is knitted with 0.375-inch openings. This size opening is sufficient to allow the back mesh to be utilized as a secondary drawing surface for contouring the front mesh while minimizing the antenna weight. After knitting, the front mesh is plated with electroless nickel, silver, and gold platings, respectively. The nickel/silver/gold plating provides the necessary properties for electrical reflectivity and is also compatible with the thermal control design of the antenna. Figure 3.1-5 shows electron photomicrographs of the plated mesh. As seen in Figure 3.1-5, discontinuities in the plating are few in number and are localized in effect. Similarly plated samples of mesh have exhibited no measurable change in RF reflectivity and thermal surface properties after repeated folding and flexing operations over long periods of time. The finished mesh is a low spring rate, elastic material. The use of this soft mesh with the rigid ribs results in a rib-dominated reflector surface which is relatively unaffected by changing mesh forces and orbital thermal variations throughout the antenna life. The mesh is attached to the ribs in a pretensioned state. The tension levels are based on the value of tension required to maintain a flat, unwrinkled condition throughout the orbital life of the reflector.

The prestress loading on the mesh is 0.02 pound per inch in the circumferential direction and 0.01 pound per inch in the radial direction for the front mesh. The back mesh is pretensioned to 0.03 pound per inch in the circumferential direction by 0.005 pound per inch in the radial direction.

The rear mesh is attached to the rib through a series of fiberglass T-bars. The T-bars are bonded on the rib and the mesh is bonded directly to the bars. The T-bars are necessary to insulate heat flow in the area of the mesh attachment. Figure 3.1-6 shows the attachment technique.

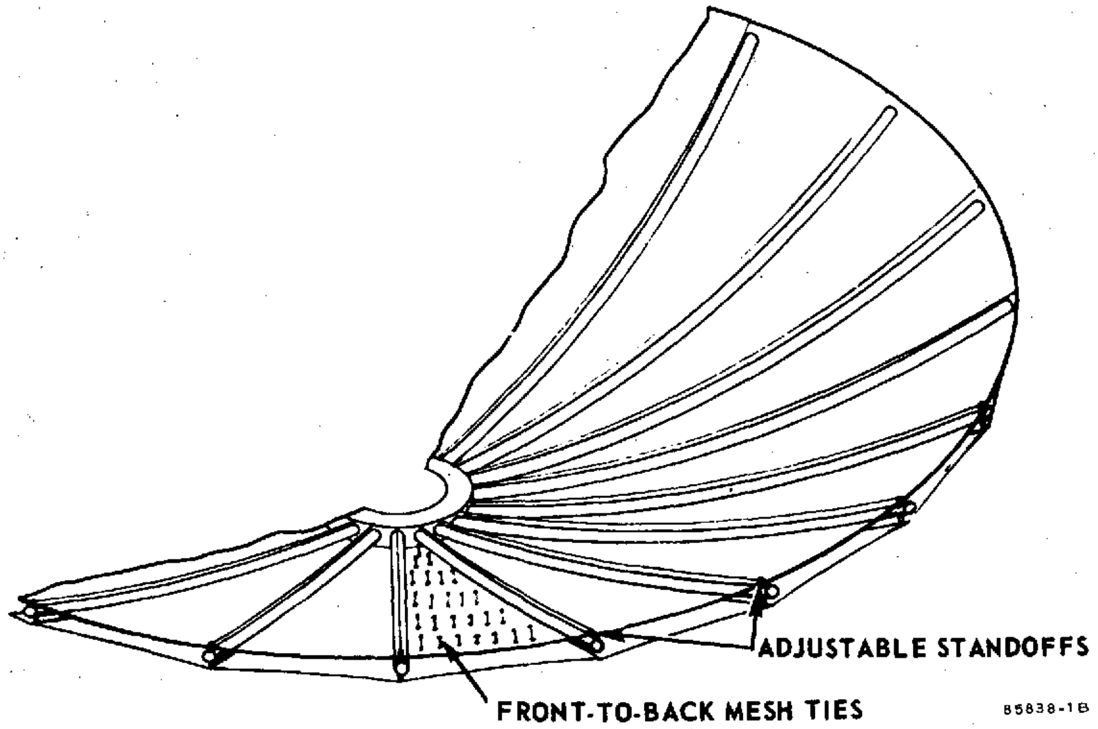


Figure 3.1-3. Double Mesh Concept Design

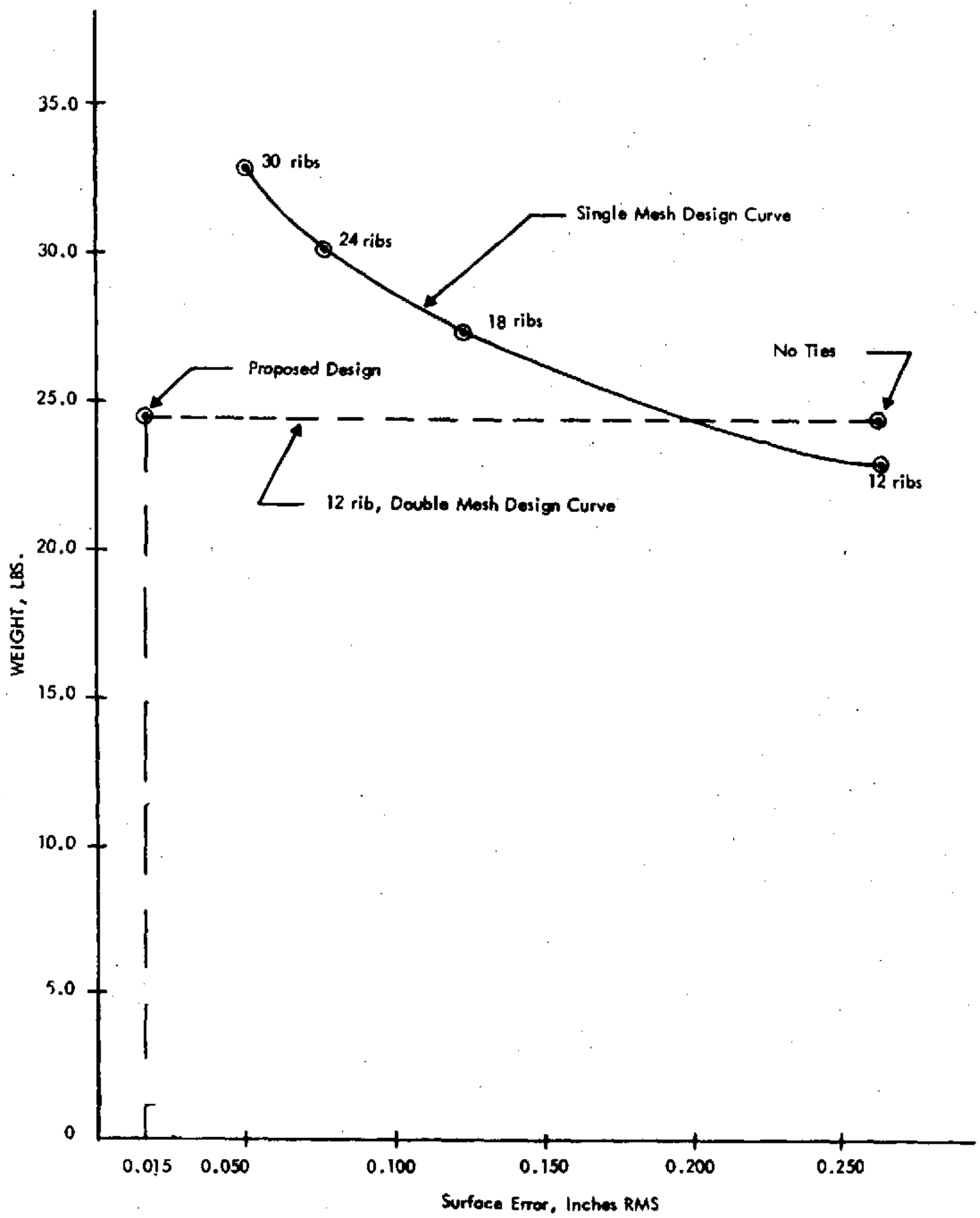
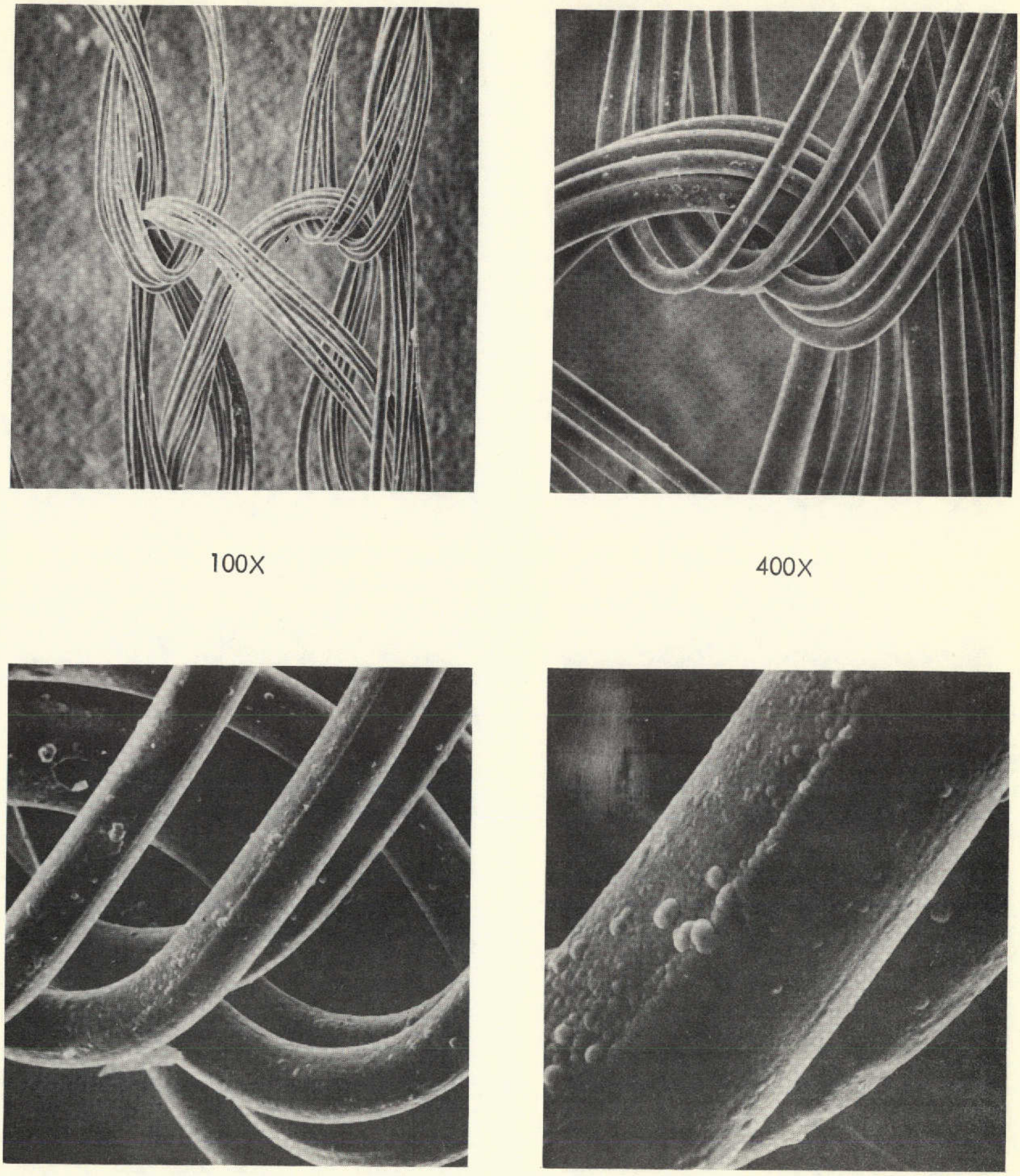


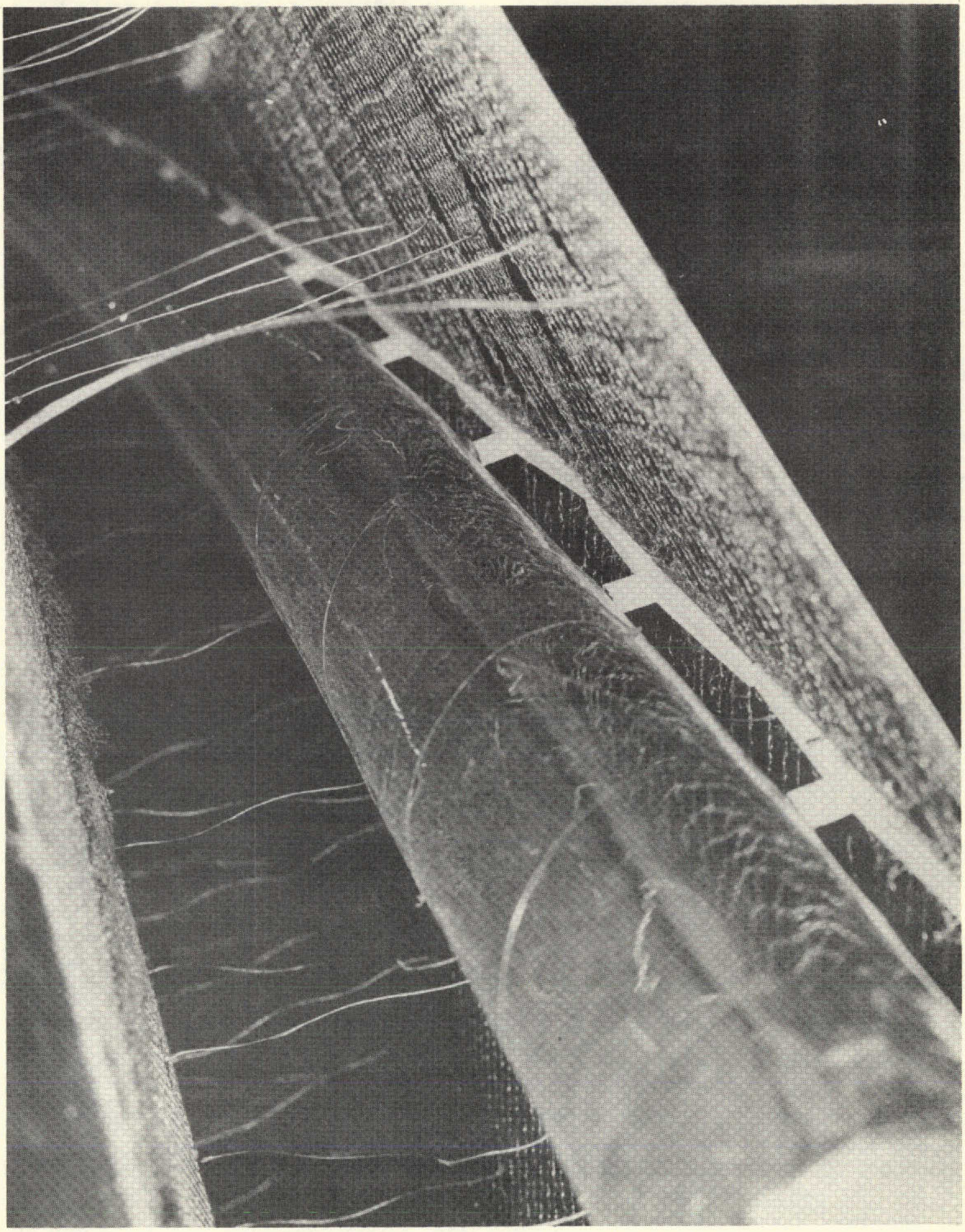
Figure 3.1-4. Weight Versus Surface Error for Single Mesh and 12-Rib Double Mesh Design



100X 400X

1000X 4000X

Figure 3.1-5. Electron Photomicrographs of Ni/Au/Ag Plating



74-0127

Figure 3.1-6. Rear Mesh Attachment

The front mesh is supported by a combination of standoffs and intercostals (Figure 3.1-7) at the rib tips and roots only. In between these areas the mesh is pulled into position by flexible wire threads spaced every 2 inches over the entire mesh surface.

Since the front mesh has a 2:1 stretch ratio and is attached on a bias at each gore interface to the adjacent gore, there is a small shear force introduced at the interface. This shear force is maintained by a sewn wire seam on the front mesh. The load introduced into the wire seam is resisted at the rib tip standoff. The wire seam is stopped 6 inches before the rib root and a zig-zag stitch is used to create an elastic membrane to the rib root. This effect is required to prevent the introduction of a bimetallic differential expansion between the wire seam and the rib. The shear force along the gore interfaces on the back mesh is reacted by attachment to the T-bars.

A 1.5-inch rib tip standoff height was selected for the front mesh as a result of an analysis using the tension values described above. This height is necessary to prevent the front and rear mesh from touching as they are pulled together by the ties in the shaping process.

The ribs are constructed from 6061-T6 aluminum alloy for strength and thermal requirements. The rib diameter of 1.5 inches was based on considerations of deployed resonant frequency, launch stress, and weight. The resulting deployed resonant frequency of 8.3 Hz is sufficiently high to prevent dynamic coupling of the deployed antenna with orbital excitations from the attitude control system or with other large flexible structures such as solar panels or the antenna support booms. The ribs have a variable wall thickness. The midsection thickness of 0.013 inch is linearly tapered to 0.009 inch at the rib root and 0.007 inch at the rib tip. Tapering in this fashion produces an efficient, lightweight structure by matching the rib strength to the moment profile imposed on each rib in the maximum stress condition. Figure 3.1-8 illustrates this profile, which results in the restrained stowed condition. The resulting rib design weighs 0.325 pound per rib and totals 3.9 pounds for the 12 ribs.

Thermal control of transverse rib temperature gradients is accomplished by three layers of a multilayer insulation blanket using three layers of nylon net to separate each film. Thermal analyses (see Paragraph 4.3) of the reflector in the orbital environment indicate this thermal control method is sufficient to meet the required orbital surface tolerance and pointing requirements under worst-case orbital conditions.

The ribs are formed to a shape such that application of the mesh tension loads produces the required parabolic rib curvature. The required rib preshape is illustrated in Figure 3.1-9. This required shape is determined by a computer program which considers the forces resulting from application of the mesh and intercostals to arrive at the correct rib shape. Following forming, the ribs are chemically milled to the required wall thickness and tolerance. Tolerance on rib thickness is critical when dealing with the extremely thin wall conditions. The rib thickness is verified using an ultrasonic instrument for thickness measurements. The holes required for midpoint restraint stems are drilled. After fabrication, the ribs are stored in a clean environment and require white glove handling.

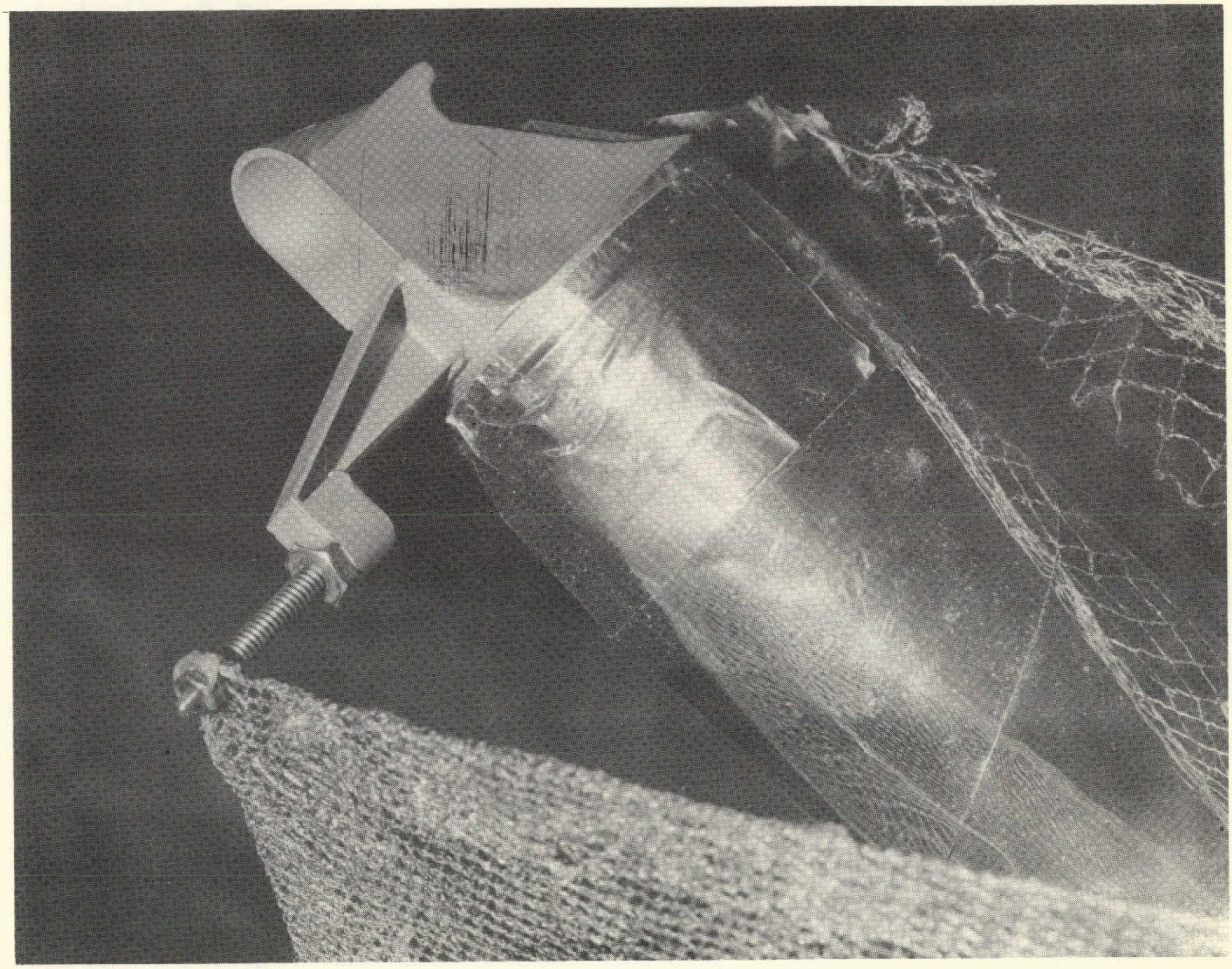


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Figure 3.1-7. Front Mesh Attachment

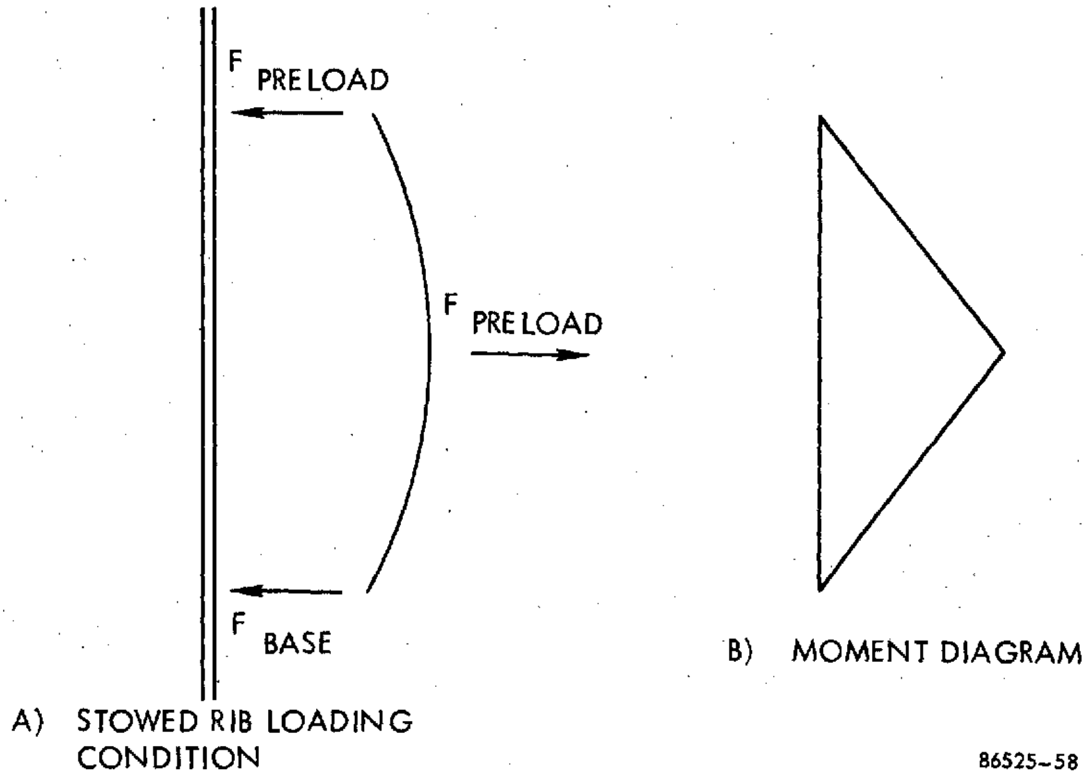


Figure 3.1-8. Loading Condition for Stowed Ribs

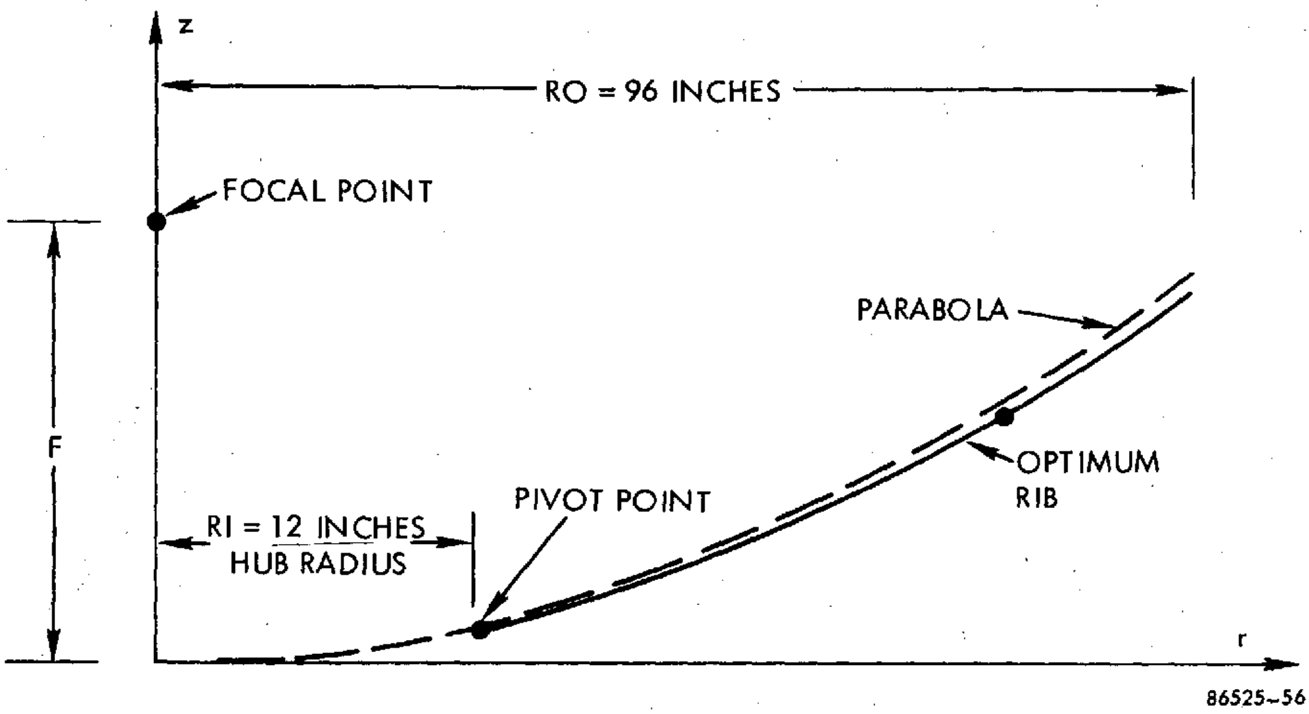


Figure 3.1-9. Sketch of Optimum Rib Shape

The rib pivot arms are considered an integral part of the rib structure. These pivot arms are constructed as castings from K01 aluminum alloy and are bonded into the end of each rib. This alloy was selected due to its high yield strength and good elongation characteristics. Since the flexural portion of the pivot arm acts as a spring to maintain preload against the rib stops and ensures accurate positioning of the deployed ribs, it is important that yielding does not occur. The dimensions of the flexural portion of the pivot arm are determined from consideration of the stress in the arm due to gravity, preload, and travel allowance for adjustment. The deflection of the pivot arm is sufficient to allow final adjustment of the rib position without removing the preload. Figure 3.1-10 is a view of the pivot arm detailed design. Figure 3.1-11 shows the fabricated pivot arm casting.

3.2 Feed Support Structure

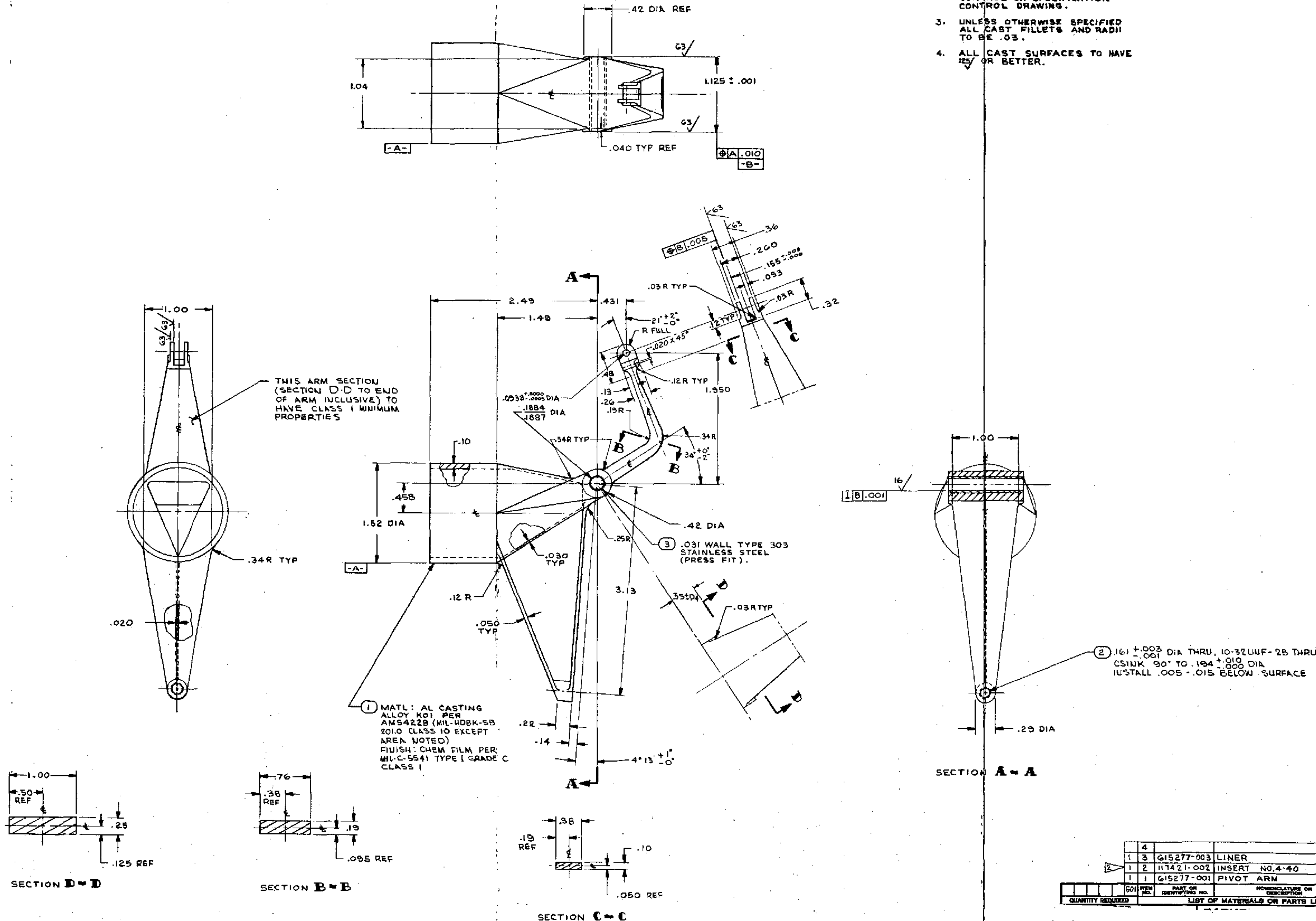
The feed support element is the primary structural member of the stowed antenna. The base diameter of the feed support was selected from a trade-off between electrical performance, stiffness, and weight considerations. A conical structure was chosen because of inherent structural efficiency of this geometry. Past analyses have shown that a truss type support structure is not weight effective in this application due to the high length to small base diameter ratio.

The base of the feed cone is designed to simply unbolt from the hub structure, thus allowing alternate cone and feed designs to be attached. Removal of the cone also allows access to the deployment system, RF feed lines and microwave components within the cone.

The cone is manufactured from 6061 aluminum sheet which is rolled and joined along a vertical seam. After forming, the wall thickness is etched to 0.020 inch for the lower half and 0.015 inch in the upper section. Figure 3.2-1 shows the finished support cone. A stiffener ring is utilized in the cone midsection to support the rib-to-cone restraint system. The hub section is machined from a continuous piece of 6061-T6 aluminum stock. The hub walls are held to 0.050-inch thickness with local stiffening rings, rib ports, and base flange machined into the integral structure. At each rib port, bearing blocks are precisely machined into the surface to locate and support the rib pivot bearings. Figure 3.2-2 shows the finished hub structure. The upper portion of the support cone attaches to a dielectric radome in the shape of an ogive. The ogive geometry was selected due to its high electrical efficiency in the Ku-band region. Figure 3.2-3 shows the fabricated radome and the upper conical section used to attach the rib tips and feed brackets. The dielectric walls are constructed from two skins, 0.010 of an inch thick, high modulus "S" glass and epoxy resin with a 3/8-inch thick, phenolic honeycomb core. The sandwich construction was used because it gave high stiffness to weight and a very low RF loss. Figure 3.2-4 shows the fully assembled feed support system.

NOTES:

1. MARK 91417-G15277-001 PER MIL-STD-130.
2. VENDOR ITEM-SEE SOURCE CONTROL OR SPECIFICATION CONTROL DRAWING.
3. UNLESS OTHERWISE SPECIFIED ALL CAST FILLETS AND RADII TO BE .03.
4. ALL CAST SURFACES TO HAVE 125/ OR BETTER.



	4			
1	3	G15277-003	LINER	
1	2	117421-002	INSERT NO.4-40	
1	1	G15277-001	PIVOT ARM	
QUANTITY REQUIRED / CODE IDENT	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

Figure 3.1-10. Pivot Arm Design

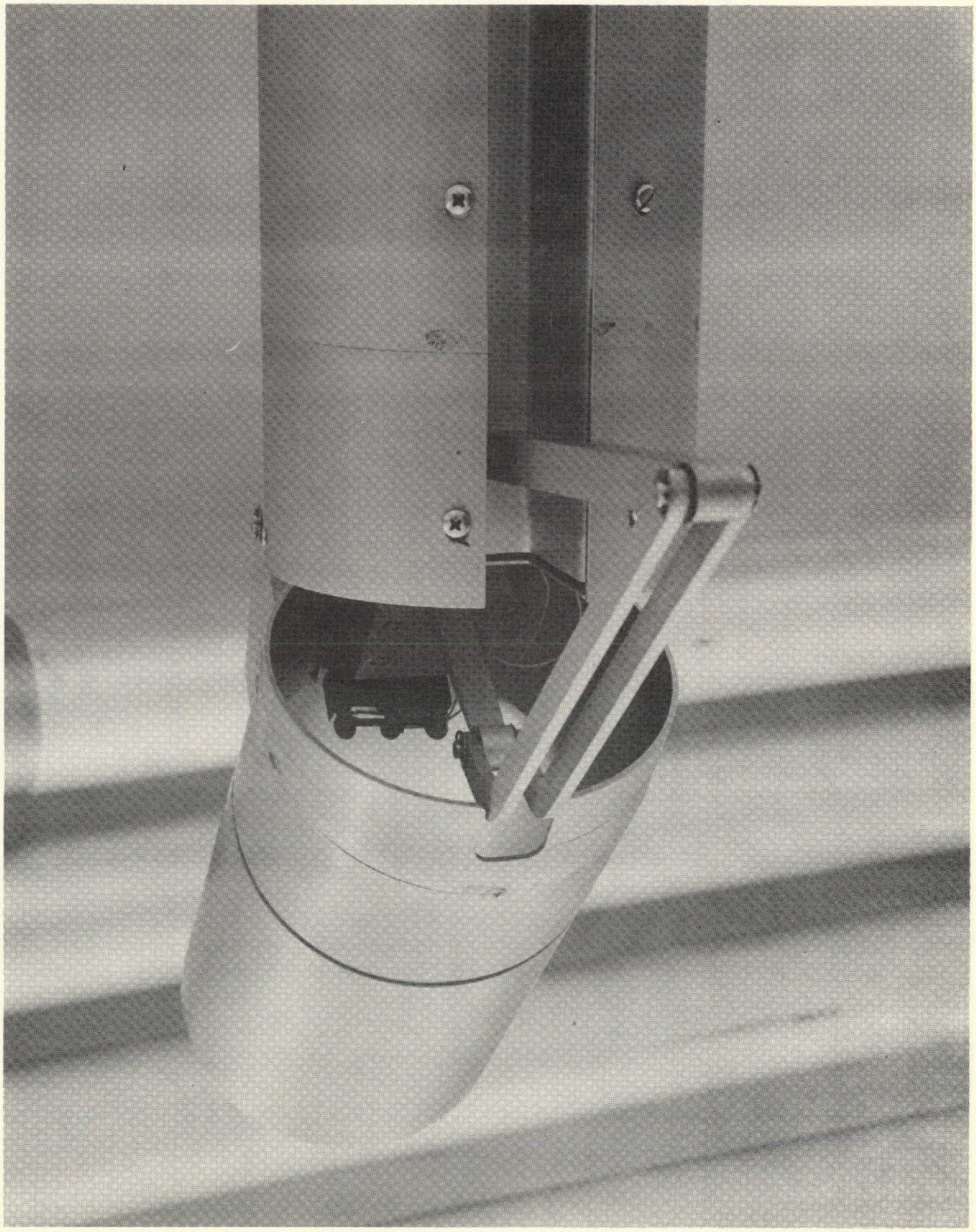


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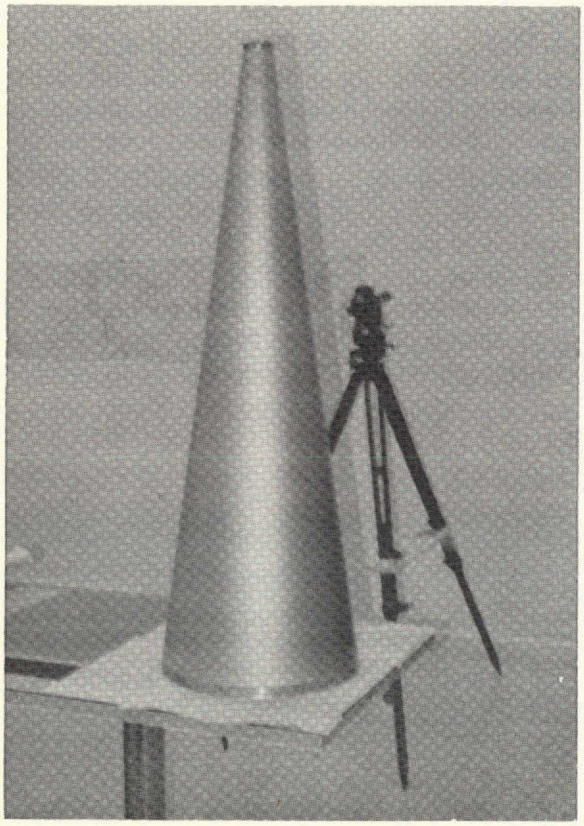
Figure 3.1-11. Pivot Arm Casting



87882-3

Figure 3.2-1. Fabricate Conical Feed Support

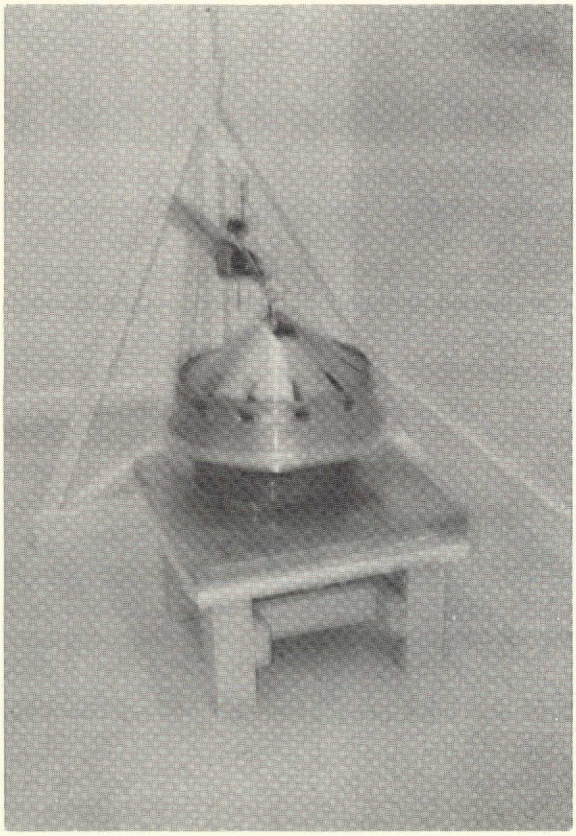


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Figure 3.2-2. Fabricate Hub Structure

87882-5

Figure 3.2-3. Ogive Radome and Fabrication Mold

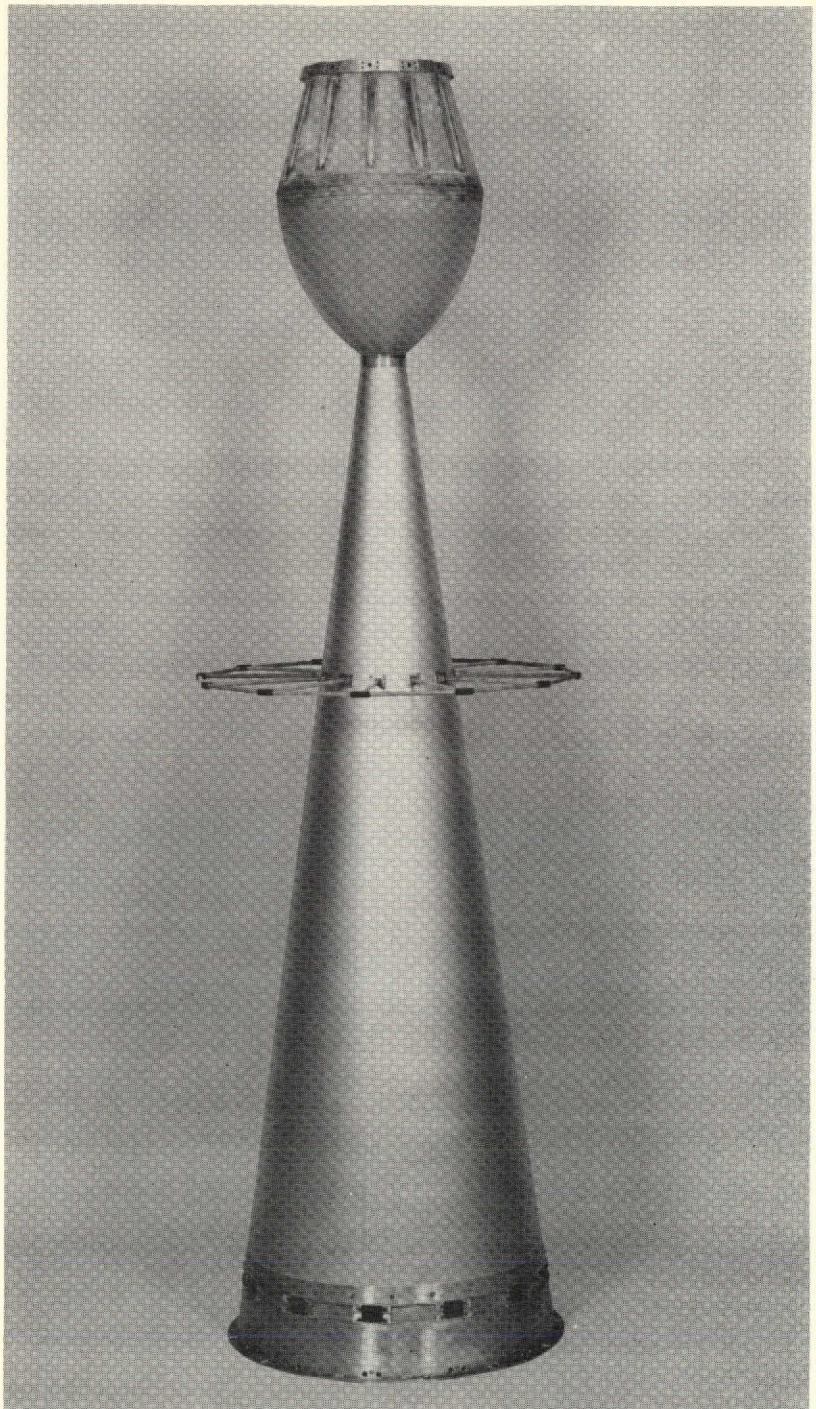

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Figure 3.2-4. Conical Support and Ogive Radome Provides High Stowed Stiffness with Minimal RF Blockage and Radome Loss

3.3 Mechanical Deployment System (MDS)

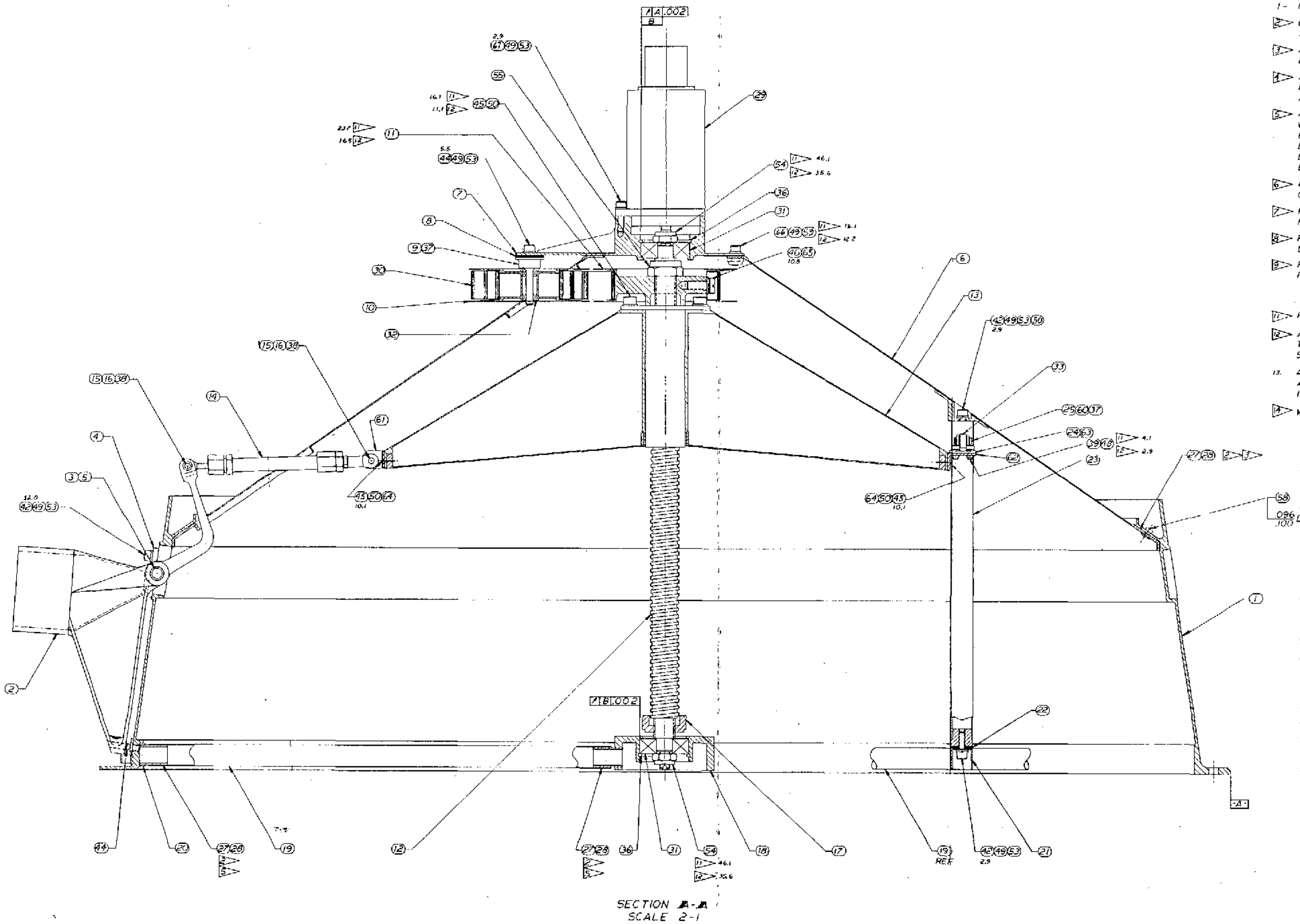
The Mechanical Deployment System (MDS) function is to provide a controlled deployment of the reflector from the stowed to the fully deployed position. This controlled deployment eliminates the transfer of any deployment forces to the spacecraft and also prevents impact loading of the rib structures, thus assuring that the preset parabolic surface is not distorted by the deployment action.

The MDS is located inside the lower section of the feed support cone assembly. Figure 3.3-1 illustrates the mechanism design. The MDS consists of a disc-shaped carriage mounted to the moving section of a recirculating ball nut on a ball screw shaft. Connected between the carriage and the 12 ribs are 12 links that transmit the required force and motion to deploy the individual ribs. Rotation of the ball screw moves the carriage and attached links which, in turn, produces the simultaneous rotation of each rib about its bearing. As the carrier moves 4.25 inches along the screw shaft, the ribs are rotated a total of 68° from their stowed to their fully deployed position. This travel requires approximately 55 seconds. When fully deployed, each connecting link is under 38 pounds compression. This loading holds each rib tightly against an accurately preset stop. The flexural section of the rib pivot arm (located between the rib pivot point and the linkage bearings) acts as a cantilever spring and deflects approximately 0.038 inch due to the 38-pound compression loading. This compliance provides a method for eliminating the effects of minor differences in link adjustments on the final rib position. It also allows for differential expansion and contraction between the various members without resulting in any appreciable movement of the rigid portion of the rib pivot arm.

Latching in the deployed condition is accomplished by driving the ball-nut carrier and linkages through an over center condition (relative to the pivot arms). In this condition the mesh tension forces, rib loads, spring motor, and pivot arm preload all force the carrier against a mechanical stop. Any external loads, such as vibration loads, only serve to further increase the loading of the carrier against the mechanical stop. This toggle action eliminates the requirement for further latching devices in the deployed condition (e.g., a mechanical brake or one-way clutch) thereby improving reliability. A back driving torque of approximately 8-inch pounds to the ball screw is required to back drive the mechanism through the latching toggle action to restow the antenna.

A secondary advantage of this toggle latching is convenience during ground testing and handling. The antenna can be remotely stowed during ground testing by reversing the current to the electric motors.

The MDS utilizes redundant energy drive systems to rotate the ball screw within the ball nut carrier. The primary drive energy is a constant torque (2.5 inch pound) spring motor. A secondary advantage of the spring motor is that it also provides a preload on the mechanism in the stowed position which helps to eliminate any joint looseness in this area. The redundant backup drive system for a flight model version of the design consists of two miniature torque motors driven through a 60:1 ratio high efficiency gear system. For convenience and economy, these motors are replaced on the present ground test model by a 400-cycle, three-phase, ac motor and



NOTES

1 - MARK 91417 6152846I PER MIL-STD-130.

2 BONDING IN ACCORDANCE WITH PROCESS SPEC 5762.

3 APPLY EPOXY ITEMS 27 & 28 TO JOINTS BEFORE RIVETING.

4 ALIGN CUTOUTS IN CONE (ITEM 6) WITH PIVOT ARMS (ITEM 2). USING CONE (ITEM 6) AS TEMPLATE DRILL HOLES FOR RIVETS. } SEE RAD.-SPEC.7905

5 ALIGN LOWER BEARING SUPPORT (ITEM 18) WITH TOP BEARING PLATE (ITEM 7) USING BALLSCREW (ITEM 12) BEFORE BONDING LOWER SUPPORT TUBE (ITEM 19) TO LOWER BEARING SUPPORT (ITEM 18) AND LOWER SUPPORT PADS (ITEM 20). } SEE RAD.-SPEC.7905

6 PURCHASED FROM MPC PRODUCTS CORP. CHICAGO, ILL.

7 PURCHASED FROM HUNTER SPRING CO. HATFIELD, PENN.

8 PURCHASED FROM BARDEN CORP. DANBURY, CONN.

9 PURCHASED FROM MICRO SWITCH, FREEPORT, ILL.

11 FIRST INSTALLATION TORQUE VALUE.

12 AFTER OBTAINING FIRST INSTALLATION TORQUE, BACK OUT SCREW MINIMUM OF 5 TURNS AND RETORQUE TO NEW VALUE.

13. ALL TORQUE VALUES TO BE IN IN.-LBS AND TOLERANCE TO BE ±10% OR .50 IN.-LB WHICHEVER IS LESS.

14 MATERIAL: CORROSION RESISTANT STEEL WITH A TENSILE OF 170,000 PSI.

Quantity Required	Item No	Part or Identifying No.	Nomenclature or Description	
4	67	MS-16995-12	SCREW, SOC. HD. CAP 4-40 X 5/8	
8	66	MS-16995-9	SCREW, SOC. HD. CAP 4-40 X 3/8	
A/R	65	GRADE-A	LOCTITE MIL-S-22473, RED	
26	64	MS35338-136	WASHER, LOCK	NO. 6
1	63	421187-2	CLEVIS, ANTI-TORQUE	
1	62	421220G1	BRKT. ANTI-TORQUE	
12	61	421221-1	CLEVIS, CARRIER	
4	60	308396-2	WASHER	
8	59	MS-21083-C06	NUT LOCKING	NO. 4-40
12	58	MS20604A03T1	RIVET BLIND 3/32 DIA	
8	57	MS21083-C06	NUT LOCKING	6-32
24	56	MS21083-C08		8-32
1	55	MS21083 C6		3/8-24
2	54	MS21083-C3	NUT LOCKING	10-32
57	53	MS35338-135	WASHER - LOCK	NO. 4
6	52	MS35338-134	WASHER - LOCK	NO. 2
24	51	NAS620-8	WASHER FLAT	NO. 8
38	50	NAS620-6		NO. 6
57	49	NAS620-4		NO. 4
10	48	NAS620-2	WASHER - FLAT	NO. 2
24	47	MS16995-27	SCREW SOC HD CAP	8-32 x 9/16
1	46	MS35233-43	SCREW PAN HD	8-32 x 3/8
26	45	MS16995-17	SCREW SOC HD CAP	6-32 x 3/8
17	44	MS16995-11		4-40 x 1/2
52	42	MS16995-10		4-40 x 3/8
2	41	MS16995-4		2-56 x 1/2
4	40	MS16995-3		2-56 x 3/8
4	39	MS16995-1	SCREW SOC HD CAP	2-56 x 3/16
48	38	MS16633-4009	RETAINER RING	
5	37	MS16624-5012	RETAINER RING	
2	36	MS16625-4086	RETAINER RING	
2	35	JS-5	ACTUATOR	
2	34	M8805-8C	SWITCH	
2	33	SR144SS	BEARING	
2	32	SFR144SS	BEARING	
2	31	3755	BEARING	
1	30	40008	SPRING MOTOR	
1	29	04P400-19	DRIVE MOTOR	
A/R	28	117098-001	ADHESIVE	
A/R	27	111053-001	CURING AGENT - RESIN	
2	26	421185G1	BRACKET - SWITCH	
2	25	308373-1	SHAFT - ANTI - TORQUE	
1	24	421187-1	CLEVIS - ANTI - TORQUE	
2	23	421186G1	TUBE - ANTI - TORQUE	
2	22	308398-1	SHIM - ANTI - TORQUE TUBE	
2	21	421188-1	LOWER SUPPORT	
12	20	421191G1	PAD - LOWER SUPPORT	
12	19	308386-1	TUBE - LOWER SUPPORT	
1	18	421189G1	LOWER BEARING SUPPORT	
1	17	421236-1	STOP - LOWER	
24	16	308396-3	WASHER	
24	15	308390-1	SHAFT - ROD END	
12	14	534385G1	COMPRESSION ROD ASSY	
1	13	615287G1	CARRIER	
1	12	534066-1	BALLSCREW AND NUT ASSY	
1	11	534091-1	DRUM - OUTPUT	
1	10	534090-1	DRUM - TAKE - UP	
1	9	308383-1	SHAFT - TAKE - UP DRUM	
1	8	308384-1	SHIM - TAKE - UP SHAFT	
1	7	534381-1	TOP BEARING PLATE	
1	6	615217G1	CONE - SUPPORT - TOP BEARING	
24	5	308396-4	WASHER	
24	4	308391-1	CLAMP - PIVOT SHAFT	
12	3	308389-1	SHAFT - PIVOT	
12	2	615277G1	PIVOT ARM	
1	1	615216G1	HUB	
G1				

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

Figure 3.3-1. MDS Mechanism Design (Sheet 1 of 2)

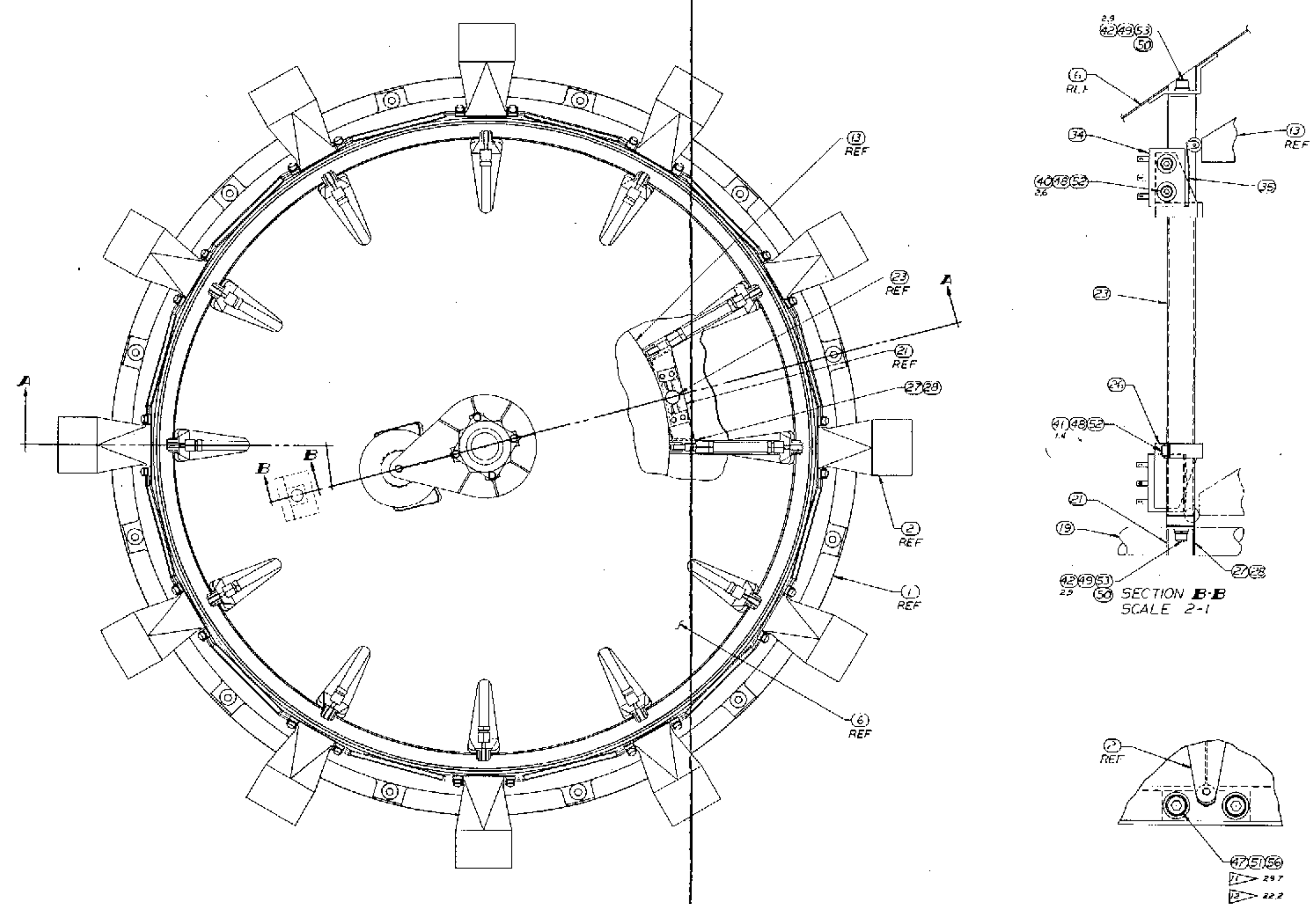


Figure 3.3-1. MDS Mechanism Design
(Sheet 2 of 2)

gear system. The torque motors normally function as dynamic brakes, controlling the deployment rate and requiring no electrical power. If called upon to deliver power (by the deployment control unit) the motors can increase the torque to the ball screw by as much as a factor of five.

Figure 3.3-2 shows the required ball-screw torque in inch-pounds as a function of the number of ball-screw revolutions for both the zero gravity and the face-down gravity conditions. The maximum deployment torque required in the face-down gravity position is approximately 1.8 inch-pounds at 25 revolutions of the ball-screw and this torque requirement is due to the force required to stretch the mesh to the proper tension condition. In zero gravity, only 1.3 inch-pounds are required at this maximum torque.

The constant torque spring motor provides a 2.5 inch-pound torque to the ball screw and thus exceeds the required face-down gravity torque by 40.0 percent and the zero gravity torque by 92 percent. The total deployment torque available is 15.5 inch-pounds and exceeds the face-down gravity requirements by 860 percent and the zero gravity requirements by over 1,000 percent.

All rib and linkage bearings are designed with simple, parallel redundant bearings. This design greatly reduces the probability of any bearing exhibiting undesirable friction changes. In the event of a high friction condition, the deployment system is designed to transfer the full deployment force to the lagging member and overcome the increased friction.

Dry film lubricants are used on the various sliding and rolling surfaces in the MDS. Two basic types of dry film lubricants are used. These consist of transfer film lubricants used in the Bartemp special retainer bearings, and bonded or plated films used on journal shafts and the ball screw. The use of these dry film lubrication techniques allows the deployment mechanism to be operated in space with unsealed components.

The techniques of thin film lubrication involve a hard solid surface covered by a thin film of softer material possessing lower shear strength. The hard underlying substrate acts to support the load and limit the area of contact.

The lubricant system must be compatible with extensive ground testing in an ambient environment in addition to operating in the orbital environment. All of the lubricants used have been previously tested in air and provide satisfactory life in air as well as in a vacuum.

Table 3.3 details the lubricants used. Lubeco 905 is a chemically-bonded, completely inorganic solid dry film made up of molydbenum disulfide and graphite particles of controlled size. The exact chemical binder is vendor proprietary. Lubeco 905 was successfully used on moving mechanical parts of the Surveyor Camera equipment. This lubricant was also used on a previous 12.5-foot diameter test model antenna which was tested under solar-vacuum conditions.

Hi-T-Lube consists of an initial substrate deposition of gold with a film overcoat. The film uses a phenolic binder to adhere the impregnated MoS_2 and graphite. The film coatings are applied in the 0.0003 to 0.0005 inch thickness range. Hi-T-Lube was also used on the

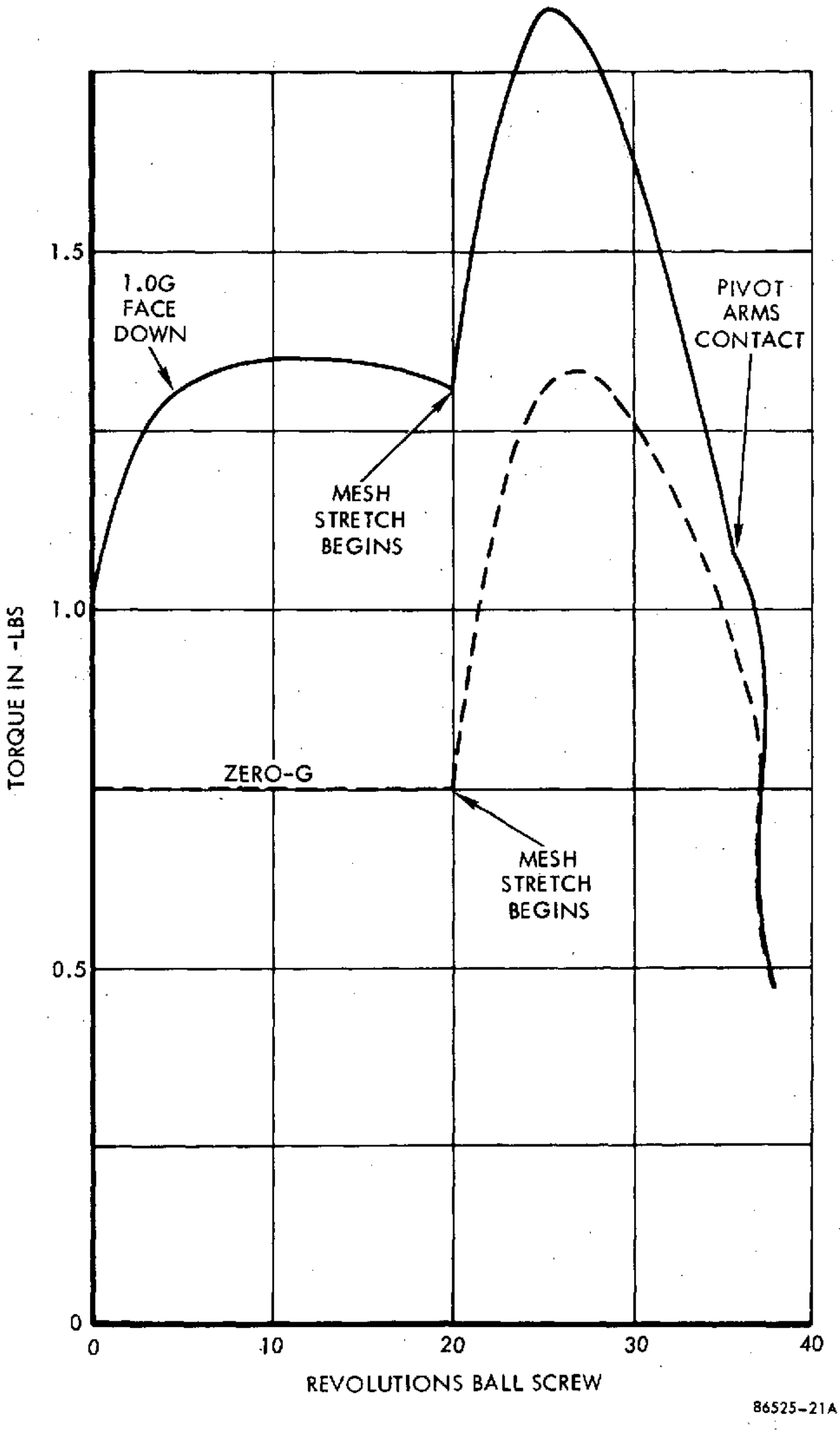


Figure 3.3-2. Deployment Torque Requirements

Table 3.3. Dry Film Lubricant Usage

	Item/Location	Quantity	Material	Lubricant (Vendor)
1.	Pivot Arm Shafts	12	303 Stainless Steel	Hi-T-Lube (General Magnaplate Corp.) Lubeco 905 (Lubeco Inc.)
2.	Rod End Bearings	24	440C Stainless Steel	Lubeco 905 (Lubeco Inc.)
3.	Rod End Shafts	24	416 Stainless Steel	Hi-T-Lube Lubeco 905 (Lubeco Inc.)
4.	Upper Ball Screw Bearing	1	440C Stainless Steel	Hi-T-Lube Lubeco 905 (Lubeco Inc.)
5.	Spring Motor Reels	2	6061-T6 Aluminum	Tufram (General Magnaplate Corp.)
6.	Spring Motor Take-Up	2	440C Stainless Steel	Bartemp (Barden Corp.)
7.	Ball Screw and Nut Returns	1	440C Stainless Steel	Hi-T-Lube
8.	Carrier Antirotation Bearings	2	440C Stainless Steel	Bartemp
9.	Gear Train Bearings	4	440C Stainless Steel	Bartemp
10.	Gear System	4	440C Stainless Steel	Hi-T-Lube Lubeco 905
11.	Electric Motor Brushes	4	Composite	Silver/Graphite (Inland)
12.	Upper Restraint Cable Ferrules and Cable Guide	12	6061-T6 Aluminum	Tufram (General Magnaplate Corp.)
13.	Thrust Washers and Shaft Spacers	24	Duroid 5813	Composite MoS_2, Teflon, Fiberglass (Rogers Corp.)

previous 12.5-foot diameter antenna and this lubricant was flight and ground vacuum tested for the LEM ball nut-screw actuator.

The spring motor reels (and the guide ferrules of the rib tip restraint system) are coated by the Tufram process. This process consists of converting a controlled depth of the surface to aluminum oxide and then impregnating the ceramic surface with TFE particles less than 1 micron in diameter. The combined effect gives a resilient surface having a very favorable coefficient of friction.

3.4 Launch Restraint Design

The launch restraint system serves a dual purpose. First, the restraint system forces the stowed antenna structure to act as a single, stiff, structural element, thereby increasing the stowed resonant frequency of the antenna. Second, the restraint system design is utilized to effectively reduce stresses developed by launch loads in critical areas. Two restraint systems, one at the rib midpoint and one at the rib tip, are utilized to accomplish the above functions.

Each rib is supported at its midpoint in the stowed condition by the midpoint restraint system (see Figures 3.4-1 and 3.4-2). This restraint system is comprised of 12 spars emanating radially outward from the midsection of the feed support cone to a circular hoop. As each rib is stowed, a metal pin protruding from the rib seats into a small conical socket on the hoop. A preload of 15.8 pounds is developed at this point by deflecting the rib tips inward after each pin is seated. This preload assure that no separation of the pin-and-socket joint will occur during the maximum dynamic loading. The pins and sockets are protected from wear and cold welding by plating with Type III hard anodic coating. This system provides rib stability as well as a direct load path from the ribs to the feed support cone.

The midpoint restraint system is entirely passive in performing its function, with no motion involved. Being constructed of dielectric material, its presence does not measurably affect the RF performance of the antenna. The material selected for the radial spars and hoop is a fiberglass and epoxy laminate with undirectional glass fibers. This midpoint restraint system design has been shown by test to produce a 45 percent increase in the stowed antenna resonant frequency with respect to a design without such a restraint.

The upper restraint system provides rib tip restraint and maintenance of the stowed rib preload by a tensioned cable system. An aluminum plug on the tip of each rib contains an accurately machined conical socket (Figure 3.4-3). This socket seats over a mating aluminum cone protruding from the upper restraint ring (Figure 3.4-3). The upper restraint ring is attached to the outer cone of the feed structure. The restraint is illustrated in Figure 3.4-4. When these two parts are mated and held in position by the restraining cable, a moment type connection is achieved. The angles and dimensions of the mating conical parts are chosen to provide resistance to both translational and rotational motion of the ribs while allowing the ribs to easily disengage for deployment when the restraining cable is released.

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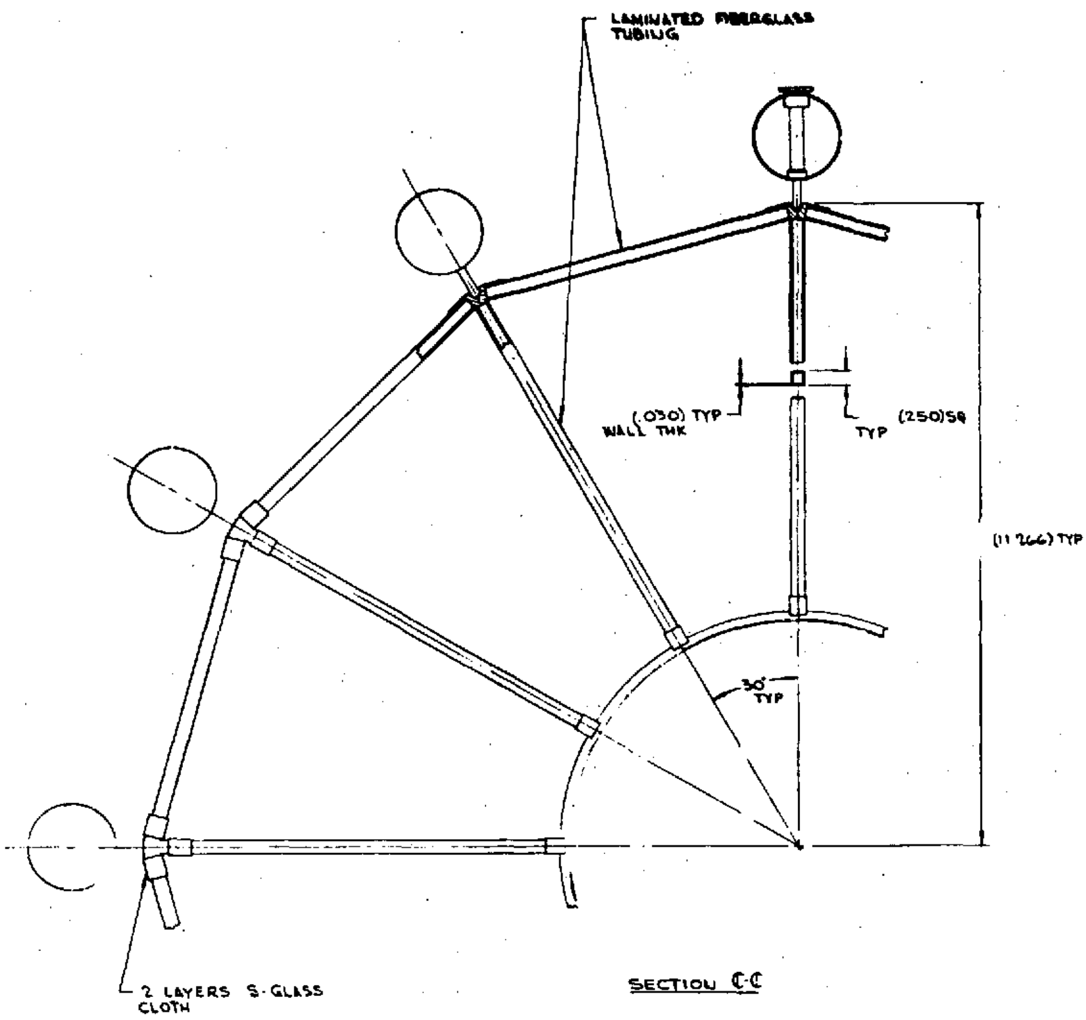

Figure 3.4-1. Midpoint Restraint System

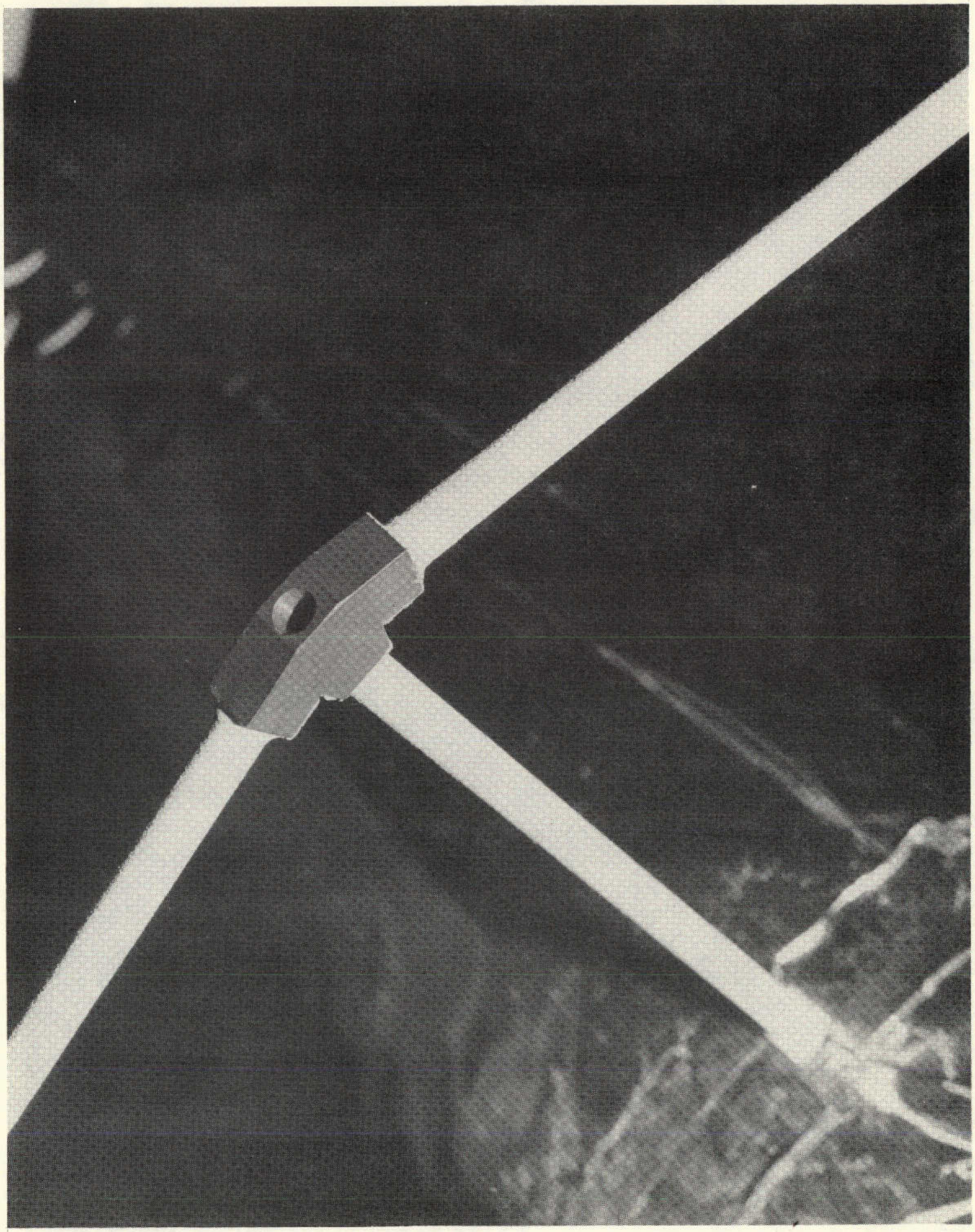

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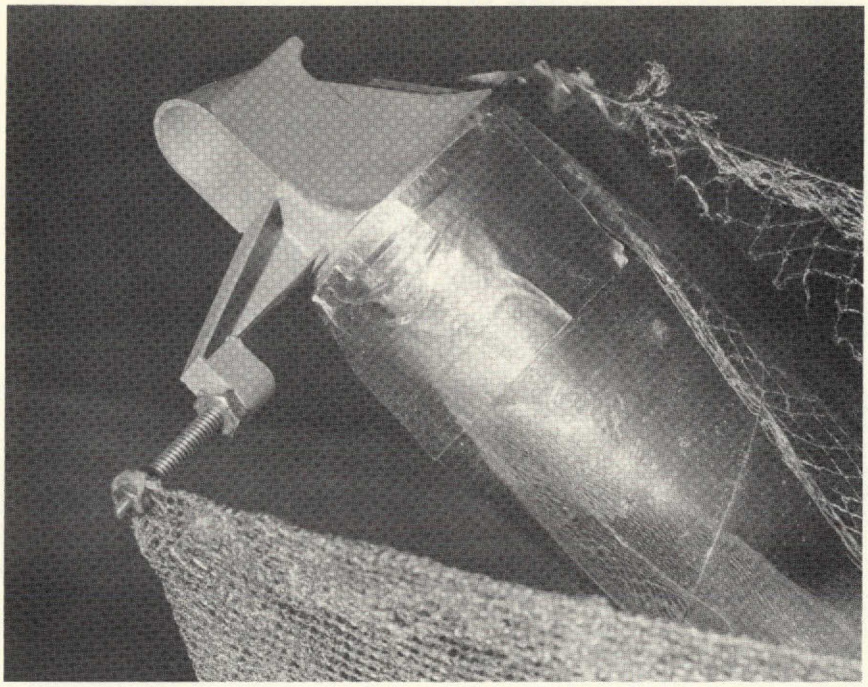
Figure 3.4-2. Midpoint Restraint System



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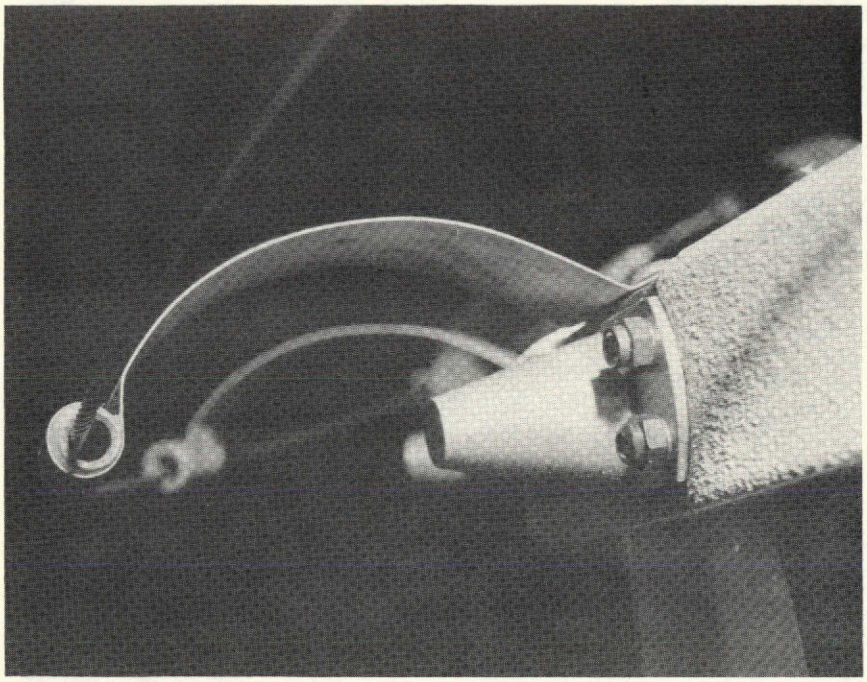

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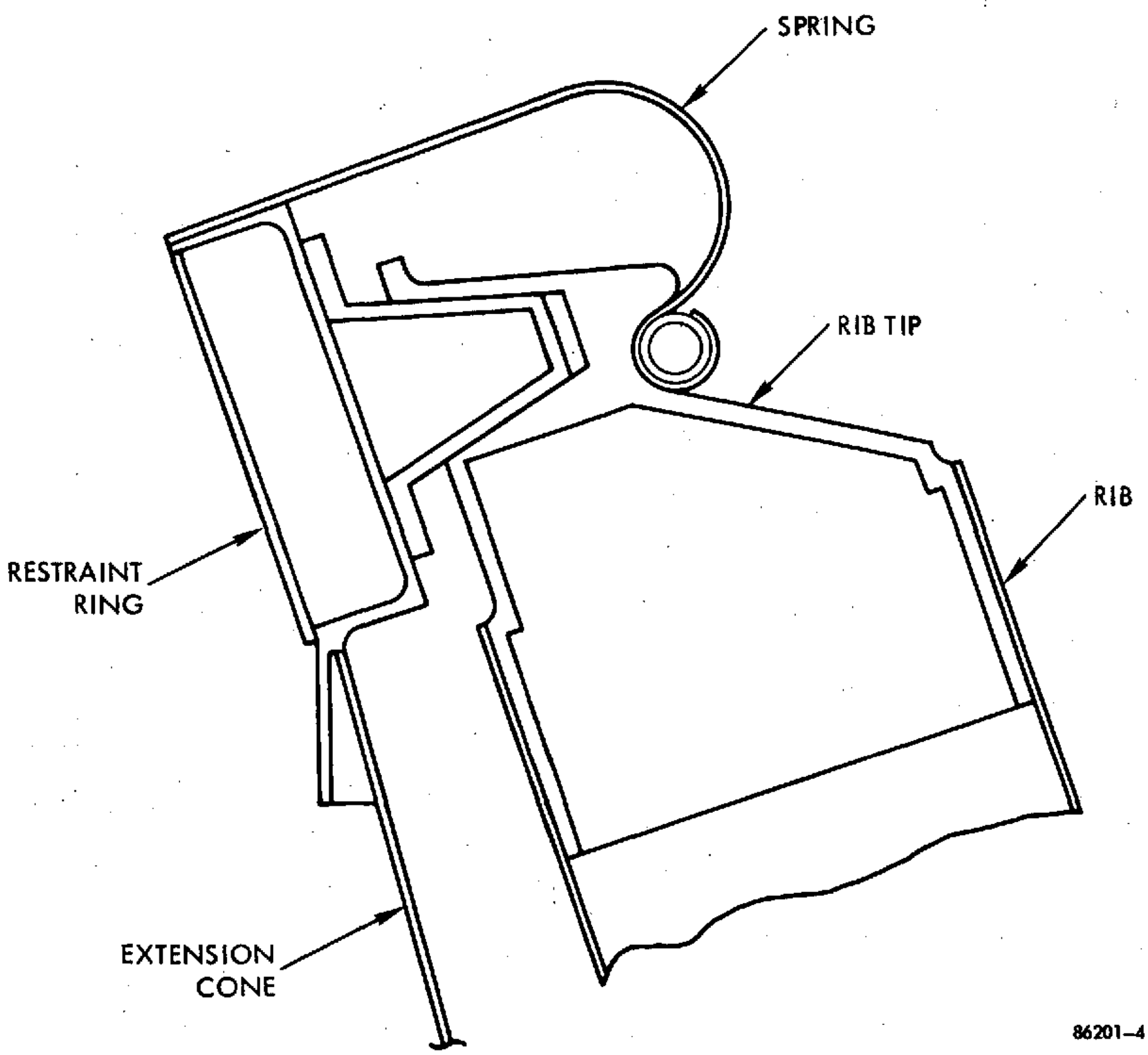
Figure 3.4-3. Rib Tip Restraint Socket and Mating Cone on Feed Support System



- PROVIDES STOWED PRELOAD AND MOMENT CONSTRAINT OF RIBS
- DUAL REDUNDANT PYROTECHNICS
- CAPTIVATED RESTRAINT CABLE
- DEPLOYMENT RELIABILITY: 0.999

Figure 3.4-4. Upper Restraint System Details

To seat the rib tip against the mating cone a preload force of 15 pounds is required. This preload is provided by the tensioned cable around the rib tips. Development of this preload also provides the required midpoint restraint preload.

The restraining cable does not directly contact the rib tips but is threaded through ferrules on the ends of a series of 12 leaf springs. These ferrules seat against the rib tips. The opposite end of the leaf springs are attached to the upper restraint ring. The cable passes through the ferrules and then through a pair of pyrotechnic guillotine cutters. The cable ends terminate in a cable crimp. When the cable is cut, the leaf springs return to their unloaded shape and this action lifts the cable free of the rib tips. The cable slips through the ferrules until the springs are fully extended, and then remains captivated inside the ferrules. The ferrules utilize a hard anodic coating with a proprietary impregnated Teflon coating. This dry film lubrication method provides lubrication for cable sliding while preventing cold welding. With the cable and ferrules now out of the way, the ribs are free to be deployed by the mechanical deployment system.

SECTION 4.0

REFLECTOR PERFORMANCE RESULTS AND PROJECTIONS

4.0 REFLECTOR PERFORMANCE RESULTS AND PROJECTIONS

This section presents measured test results on the reflector and includes analytical projections for orbital performance.

4.1 Weight and Surface Error Budgets

The projected and actual weight and surface error budgets are shown in Tables 4.1-1 and 4.1-2, respectively.

The actual weight increased from the projected weight at CDR by 3.5 pounds from 22.75 pounds to 26.25 pounds. This was due mainly to the use of a nonflight deployment motor (0.75 pound) and 2 mil silver-coated Teflon for the outer layer of the MLI blankets.

The surface error budget for the worst-case orbital condition is shown in Table 4.1-2. The error sources are described in the following paragraphs.

The manufacturing error consisting of mesh attachment, adjustment, and bulge error is the measured value of this error source. Components of this source are a small error associated with the mesh seam along each rib due to the inability to practically achieve a perfect joint; the inherent reverse bulge effect between adjacent mesh tie points as well as a slight "dimpling" of the mesh in the immediate vicinity of each tie point; and one's ability to physically adjust the reflector contour with the mesh ties and adjustable rib standoffs.

The gravity deflection error occurs in orbit as the gravity force is removed from the surface. Upon removal of the gravity force, the mesh surface will assume an equilibrium position different from that in the gravity field. Preliminary efforts to determine the quantity of this error indicate that, if no compensation is built in, the magnitude could be as much as 0.023-inch rms for the present design. By setting each gore in a horizontal position where the gravity effects are partially nullified, the effect of this error can be reduced by 75 percent or more. The 0.006-inch contribution listed in the budget reflects such a value.

The thermal error shown is the worst-case distortion projected by thermal analyses (see Paragraph 4.3).

Table 4.1-3 presents the measured surface error data on the reflector. Two significant results are indicated. First, examination of the first and third measured surface error values shown illustrates that a highly repeatable surface is achieved and maintained over multiple deployments. Second, a comparison of the first and second values in the table bounds the gravity distortion effects on the reflector. The first value of 0.020-inch rms was measured by rotating the reflector past the horizontal sweep template. Thus, gravity effects are partially nullified. The second value of 0.032-inch rms was measured by rotating the sweep template around the reflector with the reflector in the face-side condition. This value thus includes the maximum, or worst-case, effects of gravity distortion. One is therefore assured that the orbital surface error before thermal distortions are included must be less than the measured 0.032 value.

Table 4.1-1. Antenna Weight

Element		Weight, Pounds	
		Calculated	Actual
Feed Support System		7.4	
Hub	2.8		2.8
Cone	3.6		3.7
Ogive	1.0		1.0
Rib Assembly		7.0	
Ribs	4.0		4.3
Midpoint Restraint Pins and Local Reinforcement	0.5		0.5
Standoffs	0.2		0.2
Pivot Arms	1.6		1.9
Rib Tip Restraint	0.7		0.8
Mesh Gore Assemblies		1.7	
Front Gore Assembly	1.2		2.0
Back Gore Assembly	0.2		0.2
Tie Wires	0.1		0.1
Intercostals	0.2		0.2
Mechanical Deployment System (MDS)		2.9	3.8
Restraint System		2.0	
Hoop and Spar Assembly	1.0		1.2
Top Restraint Ring, Cones, and Hardware	0.6		0.6
Cable, Cutter, Spring, Ferrules, and Pyrotechnics	0.4		0.4
Thermal Control		0.9	
Rib Insulation	0.5		0.9
Cone/Hub Insulation	0.4		0.8
Motor Wire and Harness		0.3	0.3
Feed		0.55	0.55
Total Weight		22.75	26.25

Table 4.1-2. Surface Error Budget for Worst-Case Orbital Conditions

Error Source	Magnitude, Inches
Thermal Distortion	0.008
Manufacturing (mesh attachment, adjustment, and bulge)	0.020
Gravity Error	0.006
Total RMS Error	0.022
Measurement Error Effects on Total RMS Error	±0.001

Table 4.1-3. Summary of Surface Error Measurements

Test Condition	Surface Error Inches RMS
Face-side reflector is rotated past horizontal template; gravity effects minimized	0.020
Template is rotated around face reflector; gravity effects included	0.032
Face-side reflector is rotated past horizontal template after pyrotechnic firing and ten stow/deploy cycles	0.019

4.2 RF Performance

4.2.1 RF Range Test Results Summary

Range tests were conducted to evaluate the RF performance of the reflector. Range measurements consisted of pattern measurements at 2.1 GHz and 15 GHz, relative gain measurements at 2.1, 13.4, 15.0, and 15.45 GHz, and an absolute gain measurement at 15.0 GHz.

Figure 4.2.1-1 illustrates the test configuration for the relative gain and pattern measurements. The deployable reflector and a standard 12-foot diameter solid reflector are mounted back to back. The solid reflector has a known surface error of 0.007-inch rms. A standard feed was used for the gain measurements by first placing the feed in the solid reflector and then in the deployable reflector. The feed is supported in the solid, or reference, reflector in such a way that the primary blockage is zero and the secondary blockage is minimal (0.05 dB). The deployable reflector was tested with the complete feed cone, midrib restraint assembly, and radome, thus representing an operational condition. No fixturing was utilized to correct for gravity distortions in the deployable reflector and thus a surface error of 0.032-inch rms existed.

The absolute gain of the deployable reflector at 15 GHz was determined by comparison with an NRL design gain standard horn.

Figure 4.2.1-2 summarizes the gain measurement results. Figures 4.2.1-3 and 4.2.1-4 show the deployable reflector patterns at 2.1 GHz and 15.0 GHz.

Complete details of the range test results are given in Appendix B.

4.2.2 Projected Orbital Performance

To project the orbital performance of the reflector, the worst-case orbital surface error, defocus, and pointing error have been combined with a selected feed concept.

The feed concept selected for these calculations employs a pseudomonopulse tracking Cassegrain Ku-band and programmed-tracking apex S-band implementations. The feed arrangement (see Figure 4.2.2-1) utilizes a frequency sensitive dichroic lens subreflector. The feed is configured to mate with the 12.5-foot rib-and-mesh reflector. Table 4.2.2-1 presents efficiency factors for the feed at Ku-band as well as the overall illumination efficiency. Also, the effects of coupler, bandpass filter, rotary joint, waveguide, diplexer and other losses are reflected by the overall line loss efficiency shown in the table.

The worst-case orbital surface error is 0.024-inch rms, and utilizing Figures 4.3.3-6 and 4.3.3-7, the worst-case axial defocusing and pointing error are 0.065 inch and 0.05 milliradian, respectively. For operation at 15 GHz, these produce a reflector efficiency of 87 percent. Combining these with a measured mesh reflectivity of 93 percent gives an overall reflector efficiency of 81 percent. Table 4.2.2-2 presents the combined feed/reflector or overall antenna efficiency.

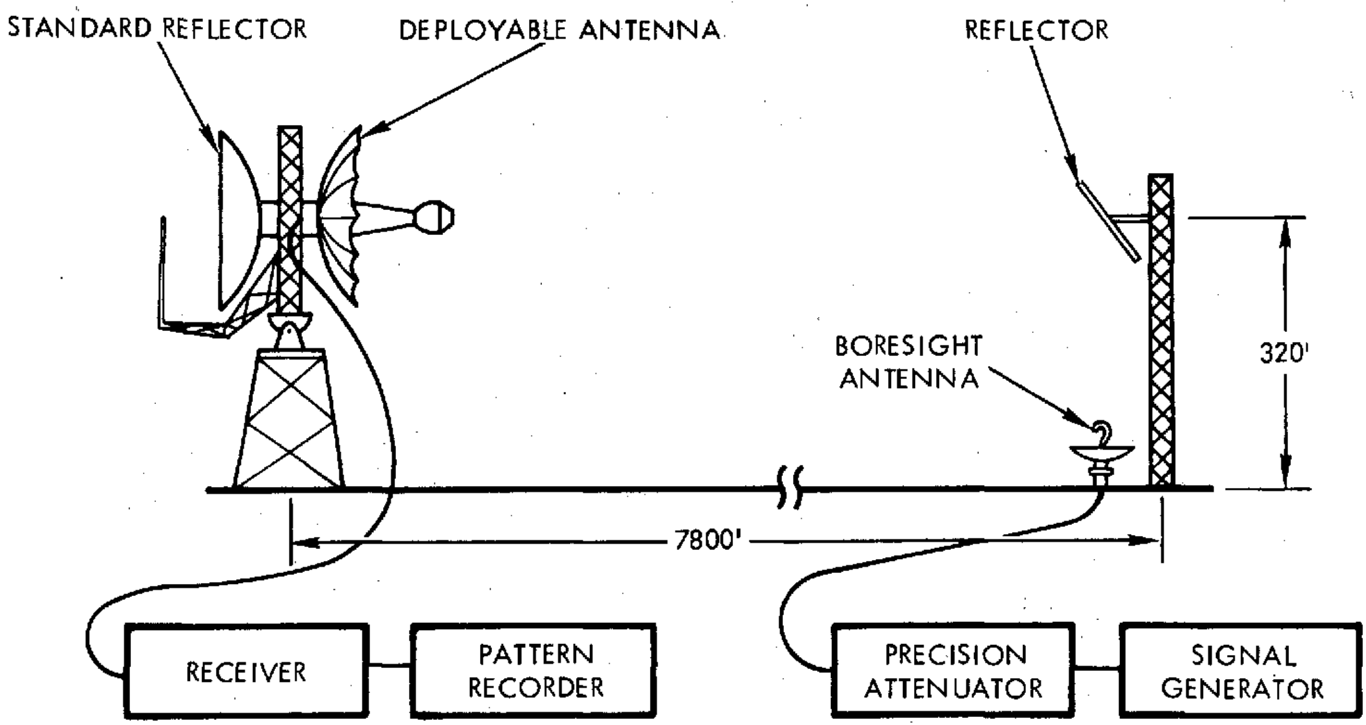


Figure 4.2.1-1. RF Range Test Configuration

- RELATIVE GAIN

FREQUENCY	GAIN DIFFERENCE* MEASURED	GAIN DIFFERENCE* PREDICTED
2.1 GHz	-0.6 dB	-1.2 dB
13.4 GHz	-2.4 dB	-2.5 dB
15.0 GHz	-2.5 dB	-2.5 dB
15.45 GHz	-2.5 dB	-2.5 dB

- ABSOLUTE GAIN

FREQUENCY	GAIN
15.0 GHz	51.5 dB (WITH RESPECT TO GAIN STANDARD)

*GAIN DIFFERENCE IS BETWEEN SOLID REFERENCE REFLECTOR AND DEPLOYABLE REFLECTOR

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Figure 4.2.1-2. Gain Measurement Summary

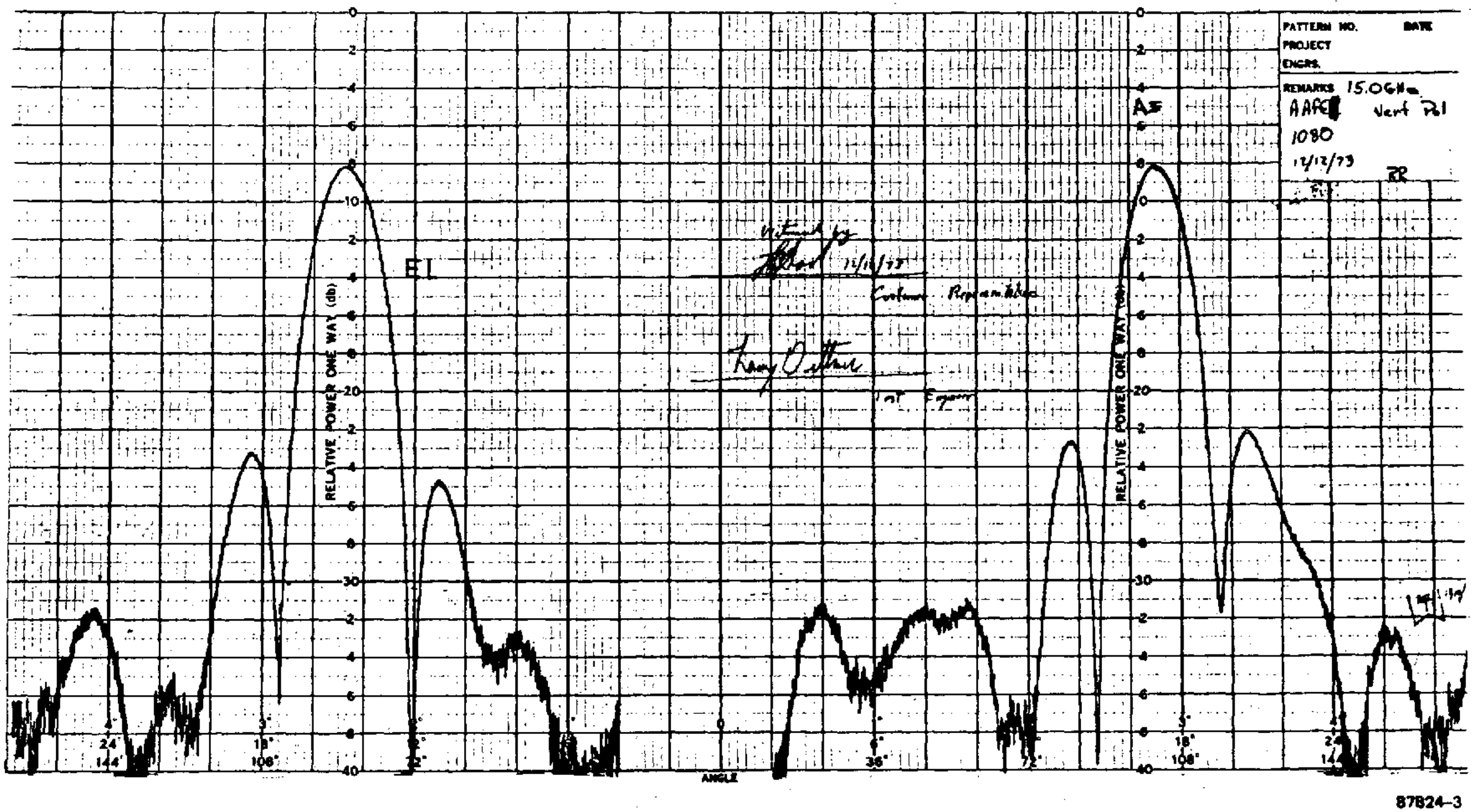

Figure 4.2.1-3. RF Patterns at 15 GHz

Figure 4.2.1-4. RF Patterns at 2.1 GHz

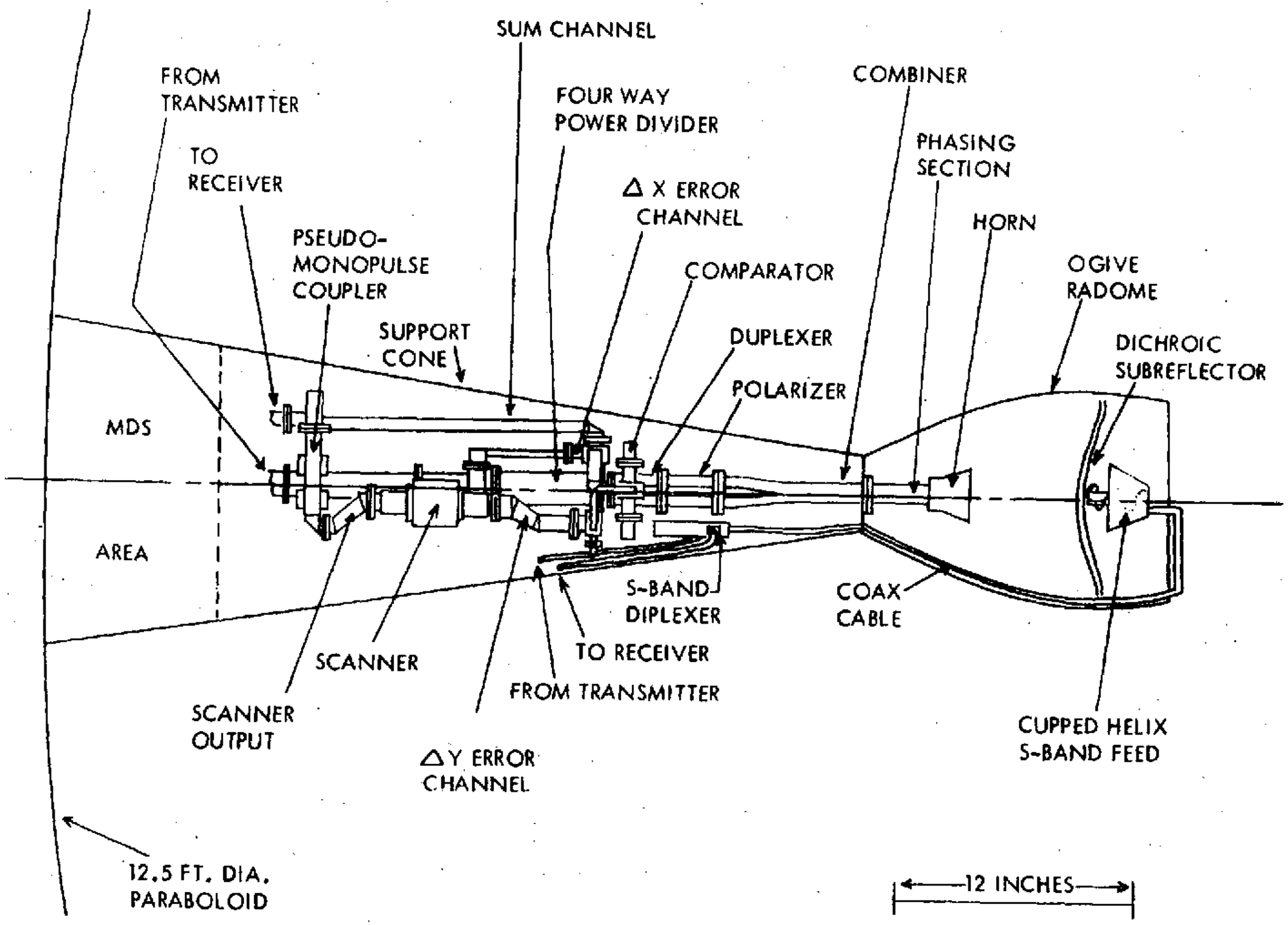

Figure 4.2.2-1. Tracking Cassegrain Ku-Band, Nontracking Apex S-Band Feed Layout

Table 4.2.2-1

Efficiency Factors	Ku-Band	
	Receive	Transmit
Spillover/Amplitude Taper Efficiency	0.800	0.800
Primary Phase Efficiency	0.980	0.980
Blockage Efficiency	0.981	0.981
Primary Cross-Polarization Efficiency	0.990	0.990
Secondary Cross-Polarization Efficiency	0.999	0.999
Dichroic Loss Efficiency	0.940	0.940
A. Illumination Efficiency	0.715	0.715
Horn and Polarizer Loss Efficiency	0.978	0.978
Diplexer Loss Efficiency	0.994	0.994
Four-Way Power Divider Loss Efficiency	---	0.985
Comparator Loss Efficiency	0.982	---
Coupler Loss Efficiency	0.937	---
Bandpass Filter Loss Efficiency	0.966	---
Rotary Joint Loss Efficiency	---	0.955
Waveguide Loss Efficiency	0.946	0.995
Diplex Loss Efficiency	---	---
Coaxial Cable Loss Efficiency	---	---
Cupped Helix Feed Loss Efficiency	---	---
Mismatch and Axial Ratio Loss Efficiency	0.978	0.978
B. Line Loss Efficiency	0.799	0.890

Table 4.2.2-2. Worst-Case Orbital Performance for Ku-Band Operation

Parameter	Efficiency Receive	Efficiency Transmit
Dual Frequency Feed at Ku-Band	0.715	0.715
Line-Loss Efficiency	0.799	0.890
Reflector	0.81	0.81
Total Efficiency	0.462	0.515

4.3 Thermal Design Performance

This section presents the thermal analyses that were performed to verify the adequacy of the antenna design.

4.3.1 Thermal Performance Parameters

The primary parameters affecting the antenna orbital thermal performance are hub temperature gradients, diametral rib gradients, feed support cone gradients, and the rib and feed cone average temperatures. These variations are induced by changes in the solar incidence angle and shadow patterns. Hub distortions are potentially the major contributor to the thermal contribution to surface error, defocusing, and mispointing because of their amplification by the rib length to give large rib tip movements. The hub gradients are effectively controlled by the incorporation of a multilayer insulation blanket around the hub and feed support cone. The diametral rib gradients are directly proportional to the rib solar absorptivity, α_s, and inversely proportional to the diametral thermal conductance. The gradient is therefore minimized by reducing the rib α_s and increasing the wall thickness and thermal conductivity. The feed support cone diametral heat transfer is predominantly by radiation, therefore, the gradients are reduced by incorporating a high infrared emittance interior surface and a multilayer insulation blanket around the exterior.

Thermal analyses were performed to provide sufficient trade-off data for selection of the optimum rib thermal control system. The high surface accuracy required is achieved through thermal control of the antenna rib locations. Though large temperature variations occur in the mesh itself, the mesh spring constant is adequately low to prevent a significant transmission of mesh effects to the rigid ribs. Further, the mesh pretension ratio is such that no "wrinkling" of the mesh occurs due to orbital temperature excursions.

In addition, a thermal analysis was performed for the antenna assembly for a synchronous orbital condition to confirm the operational performance of the antenna thermal control system.

4.3.2 Thermal Analysis Approach

The preliminary thermal analysis was performed using the Antenna Thermal Analyzer Program (ATAP) which performs the following steps:

1. Generates the thermal math model of the antenna including node assignment and distribution
2. Solves for the steady-state temperature distribution for each sun angle and shadow condition
3. Computes the surface distortion caused by the temperature distribution
4. Computes the rms surface accuracy, defocusing, and mispointing of the best-fit paraboloid generated by the deflected rib coordinates.

Since the thermal distortion analysis was performed on this antenna, additional development has led to a thermoelastic distortion model which includes the mesh surfaces using pretensioned, orthotropic membrane elements. Mesh membrane distortions have been determined to be a significant contributor to on-orbit surface distortion of other deployable antennas. The solar vacuum testing and associated analysis of the Ku-band antenna will provide definitive data concerning mesh distortions. Mesh plating, pretension, and stiffness properties are available which are consistent with the thermal distortions listed in surface error budgets. Presentation of additional analysis results within the scope of this report is not possible.

4.3.3 Thermal Control Coatings

Several thermal control coating systems were considered for the antenna ribs. These can be classified in three basic categories: rib surface treatment, adhesive backed tapes, and multilayer insulation (MLI). Figures 4.3.3-1 and 4.3.3-2 present the predicted diametral temperature gradient along the antenna ribs for sun angles of 0° and 180°, respectively, for four configurations. (The rib wall thickness at the hub, midpoint and tip are 0.008, 0.012, and 0.006 inch, respectively.) The surface treatment concept investigated involved polishing the rib exterior to yield a relatively low solar absorptivity (α_s). Past experience in polishing of the 6061-T6 aluminum ribs yielded an emissivity of approximately 0.06 and α_s values in the range of 0.18 to 0.23 with 0.21 being a representative value. The polished aluminum thermal control

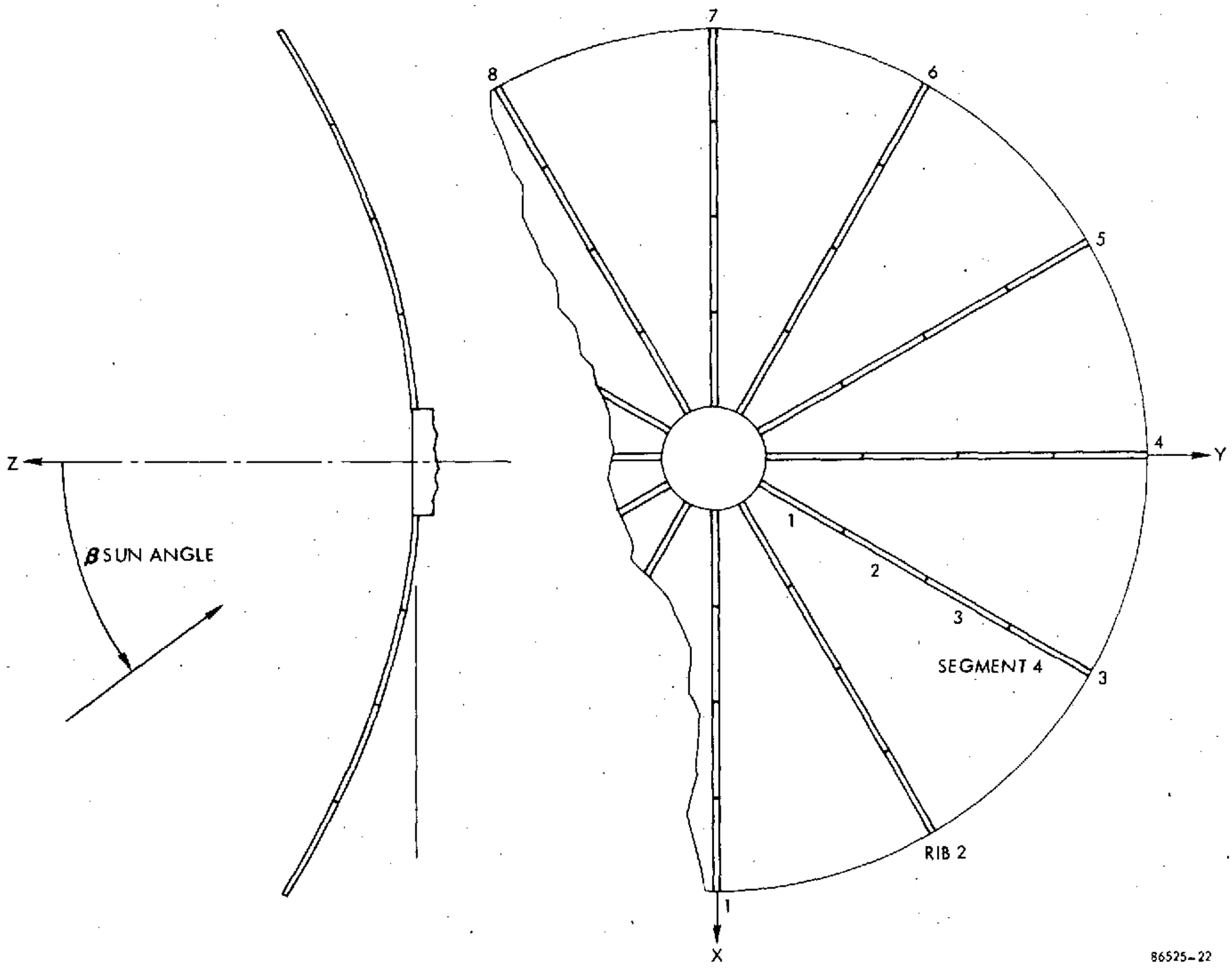

Figure 4.3.2. Antenna Thermal Model and Sun Angle Reference

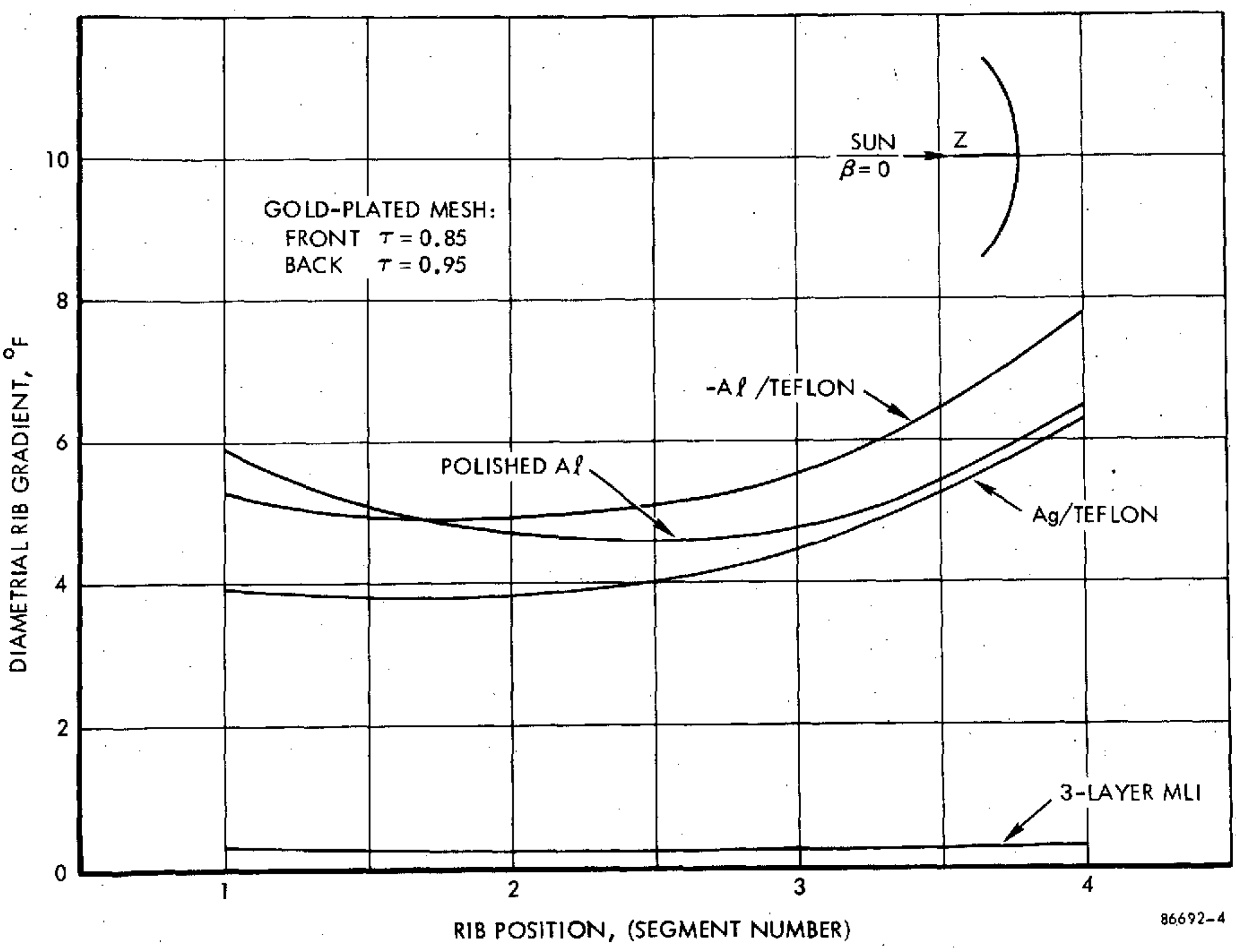

Figure 4.3.3-1. Diametral Rib Gradient Versus Rib Position for Four-Rib Thermal Control Coating Systems

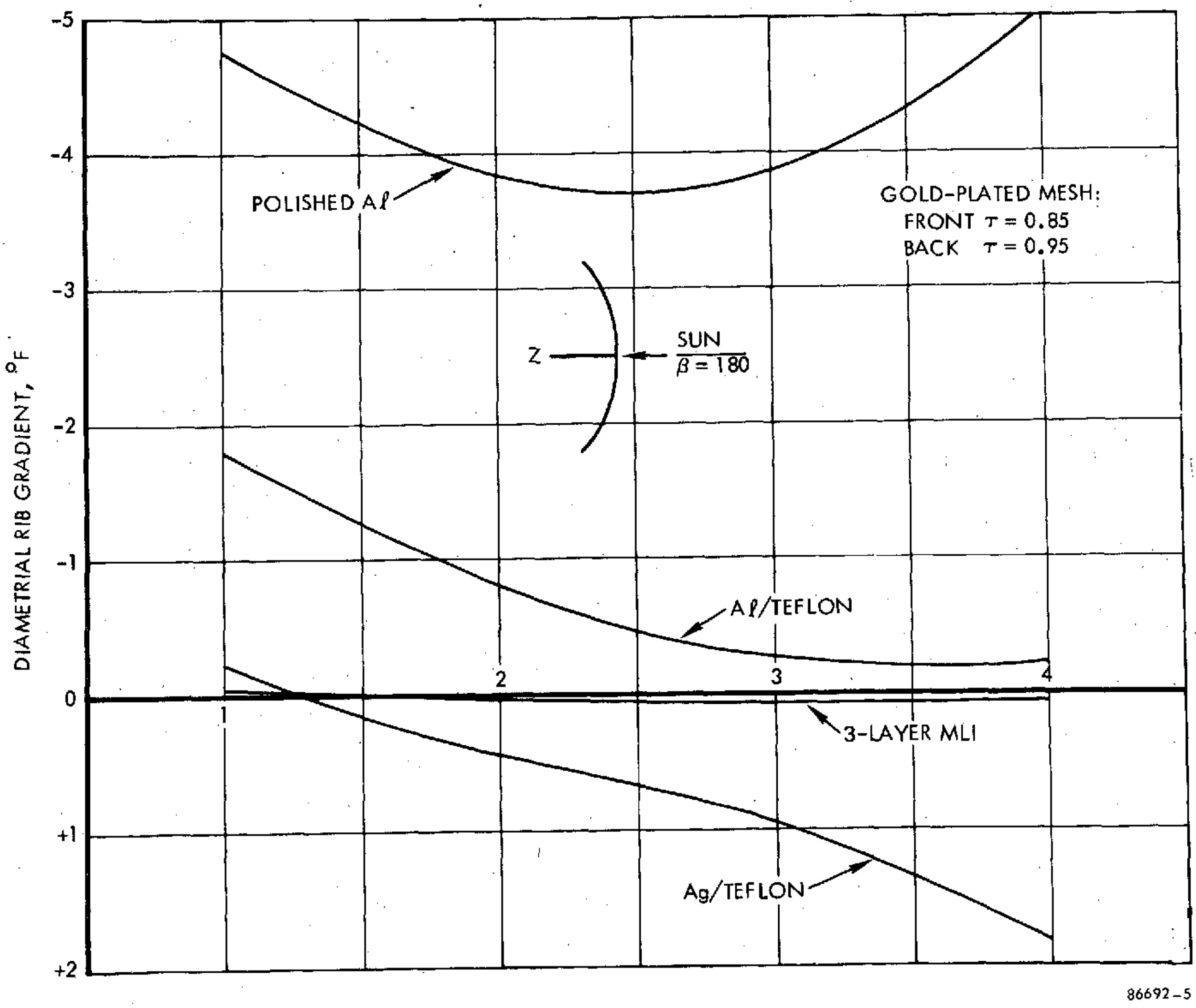

Figure 4.3.3-2. Diametral Rib Gradient Versus Rib Position for Four Thermal Control Coating Systems

surface has the advantage of having the lowest weight possible since it adds no weight to the rib.

Flexible, adhesive-backed, metallized FEP Teflon tapes were also evaluated for use on the antenna ribs. The FEP Teflon tape is readily available with either vapor-deposited aluminum or silver as the solar reflective surface. Solar absorptivity values of 0.08 and 0.14 were assumed for the silverized and aluminized tapes, respectively. An emissivity of 0.55 was used for both tapes (indicative of a 0.001-inch Teflon thickness). A close inspection of Figures 4.3.3-1 and 4.3.3-2 reveals the significant interaction between the Teflon-coated ribs and the gold-plated mesh. The differences in the front and back mesh transmissivity ($\tau_F = 0.85$, $\tau_B = 0.95$) causes a significantly greater thermal loading condition on the front portion of the ribs. This has the effect of increasing the front-to-back diametral rib gradient for sun angles yielding forward insolation and decreasing it for rear insolation.

Multilayer insulation (MLI) is the third category of rib thermal control systems mentioned above. Most MLI configurations can be classified into two basic categories:

1. MLI with interlayer separating spacers, and

2. MLI without an interlayer separating spacer

The spacer is normally made of a lightweight, low conductive material and is used to retard the interlayer thermal conduction. MLI with interlayer spacers is normally used where contact pressure between layers may be significant.

The MLI configurations without the interlayer spacers rely on crinkling or dimpling of the metallized film to interrupt the thermal conduction paths. Crinkled mylar blankets exhibit high thermal insulating properties for relatively low weight. The primary disadvantage of crinkled mylar blankets is ensuring that for relatively small diameter cylinders (such as the 1.5-inch diameter ribs) the interlayer contact pressure is not so great as to flatten out the crinkles, thereby allowing significant thermal conduction to occur.

An MLI configuration was selected which incorporated alternating layers of a lightweight nylon tulle and aluminized 1/4-mil mylar. The blanket is constructed by placing a layer of nylon tulle on the surface of the rib, followed by alternating layers of aluminized mylar and nylon tulle. The final outer layer of insulation is silverized Teflon rather than aluminized mylar. The mylar used in the blanket is aluminized on both sides. The number of layers is defined as the number of layers of nylon tulle. The approximate weights per unit area and thicknesses for the MLI blanket materials are listed in Table 4.3.3.

Figure 4.3.3-3 presents the results of thermal tests which have been performed on this MLI configuration on 1.5-inch diameter cylinders. The model used in the data correlation assumed heat transfer across the blanket to be by both radiation and conduction. These MLI performance data were used together with the basic antenna design to produce the diametral rib gradient data of Figure 4.3.3-4 for different numbers of layers of MLI. It is interesting to compare the temperature gradient of Figure 4.3.3-1 for the adhesive-backed silver-coated Teflon (approximately 4°F at segment No. 1) with the gradient indicated in Figure 4.3.3-4 for one-layer

Table 4.3.3. MLI Material Weights

Material	Thickness, Inches	Weight, Lbs./Ft.^{2}
Nylon Netting	0.0035	2.0×10^{-3}
Aluminized Mylar	0.00025	1.79×10^{-3}
Silverized Teflon	0.001	11.32×10^{-3}

MLI (1.2°F). Physically, this represents simply exchanging the adhesive for a single layer of lightweight nylon tulle. This represents greater than a 3:1 reduction in weight.

The rib diametral gradient data presented above are used to indicate the best thermal control coating configuration for the antenna. The rib temperature distributions are included in Appendix C of the CDR Data Package with the ATAP printouts of the orbital surface accuracy.

4.3.4 Conclusions

The results of the analyses presented confirm the adequacy of the thermal design of the antenna assembly for operation in the synchronous equatorial orbit.

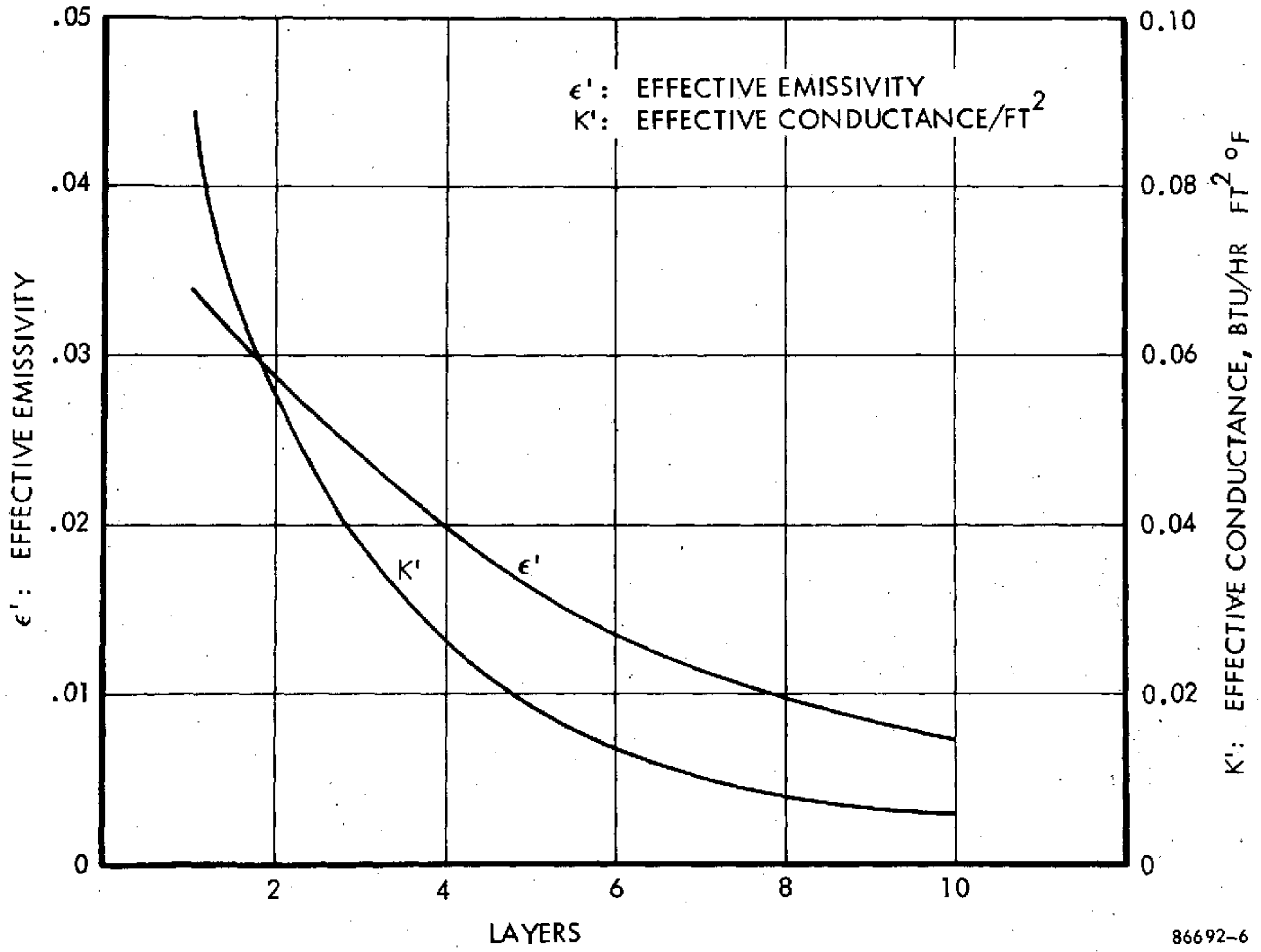

Figure 4.3.3-3. MLI Thermal Performance Versus Number of Layers

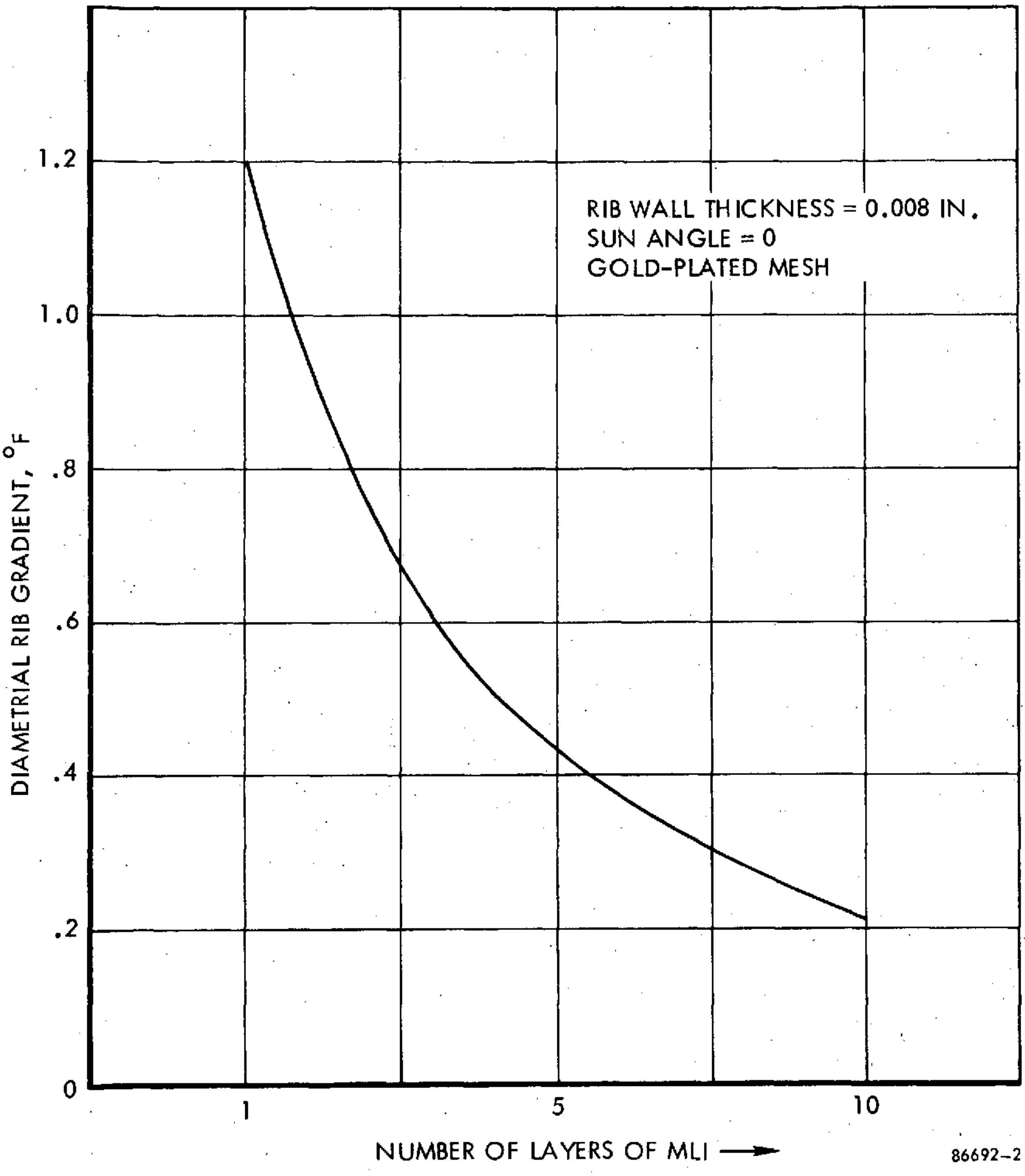

Figure 4.3.3-4. Diametral Rib Gradient Versus Number of Layers of MLI

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4.4 Structural and Dynamic Analyses

Analyses were performed to support design trade-off studies. Of primary concern is attaining a very lightweight antenna that meets the stowed and deployed frequency requirements and can survive the 25 G lateral launch load.

The Rayleigh Method was used in preliminary analysis to calculate fundamental frequencies at a low cost. Eigenvalue solutions were used for final analysis.

4.4.1 Results and Correlation

The final lightweight antenna design meets all frequency and strength requirements as demonstrated in Tables 4.4.1-1 and 4.4.1-2. Table 4.4.1-3 correlates measured stiffness values with calculated values. Detail test results are given in Appendix B.

To aid in the selection of a rib, a parametric analysis was performed by varying the rib thickness and diameter. From these results and considering stresses and thermal requirements, a 1.5-inch diameter rib was selected having a root wall thickness of 0.008 inch, a midpoint wall thickness of 0.012 inch and a tip wall thickness of 0.006 inch.

The selected rib was analyzed more accurately for frequencies by performing an eigenvalue solution and considering the rib parabolic shape and the pivot arm and hub compliance.

A load analysis was performed for the mechanical deployment system for each degree of motion during face-side or face-down deployment in a 1 G field.

Calculations were made for the optimum rib shape that would tend to offset the mesh bulge effects and the zero-G effects of space.

A detail computer model was assembled for the MDS. It included the lower half of the ribs and the lower eight inches of the support cone and hub. A lateral loading of 25 G and a longitudinal loading of 35 G were applied. Stresses due to these launch loads were calculated throughout the MDS and found to be less than 2500 psi limit.

The calculated antenna center of gravity is on the boresight axis and is located 30.29 inches above the base.

4.4.2 Stowed Antenna Dynamic Analysis

4.4.2.1 Description of Computer Model

The nodal topology of the stowed antenna model is shown in Figure 4.4.2.1. This cantilevered antenna was fixed at its base. Each of the 12 ribs was modeled with six straight

Table 4.4.1-1. Comparison of Fundamental Frequencies, Hz

Configuration	Axis	Requirement	Calculated
Stowed Antenna	Torsional	15.	29.4
Stowed Antenna	Lateral	40.	55.6
Stowed Antenna	Longitudinal	90.	141.8
Deployed Antenna	Lateral	4.	7.02
Deployed Antenna	Torsional	4.	7.01
Stowed MDS	Lateral	100.	*648.
Stowed MDS	Longitudinal	100.	*556.

*Values look too high. See discussion in Appendix D.
Section D4.0.

Table 4.4.1-2. Physical Stress Margins of Safety, MS

Element	MS
Rib	0.31
Cone, Node 1	1.44
Cone, Node 2	1.86
MDS Carrier	0.14
MDS Push-Rod	1.78
MDS Ball Screw	1.36
Pivot Arm	2.45

Table 4.4.1-3. Correlation of Analysis and Test Values for Reflector Stiffness

TEST CONFIGURATION	MEASURED VALUE	PREDICTED VALUE*
STOWED, LATERAL AXIS	57.0 Hz	56.8 Hz
STOWED, LONGITUDINAL AXIS	185.0 Hz	141.8 Hz
DEPLOYED, LONGITUDINAL AXIS	8.2 Hz	7.0 Hz

*PREDICTED VALUES AT CRITICAL DESIGN REVIEW

CONCLUSIONS:

- ANTENNA IS SUFFICIENTLY STIFF TO BE TREATED AS A COMPONENT AND QUALIFIED SEPARATE FROM SPACECRAFT.

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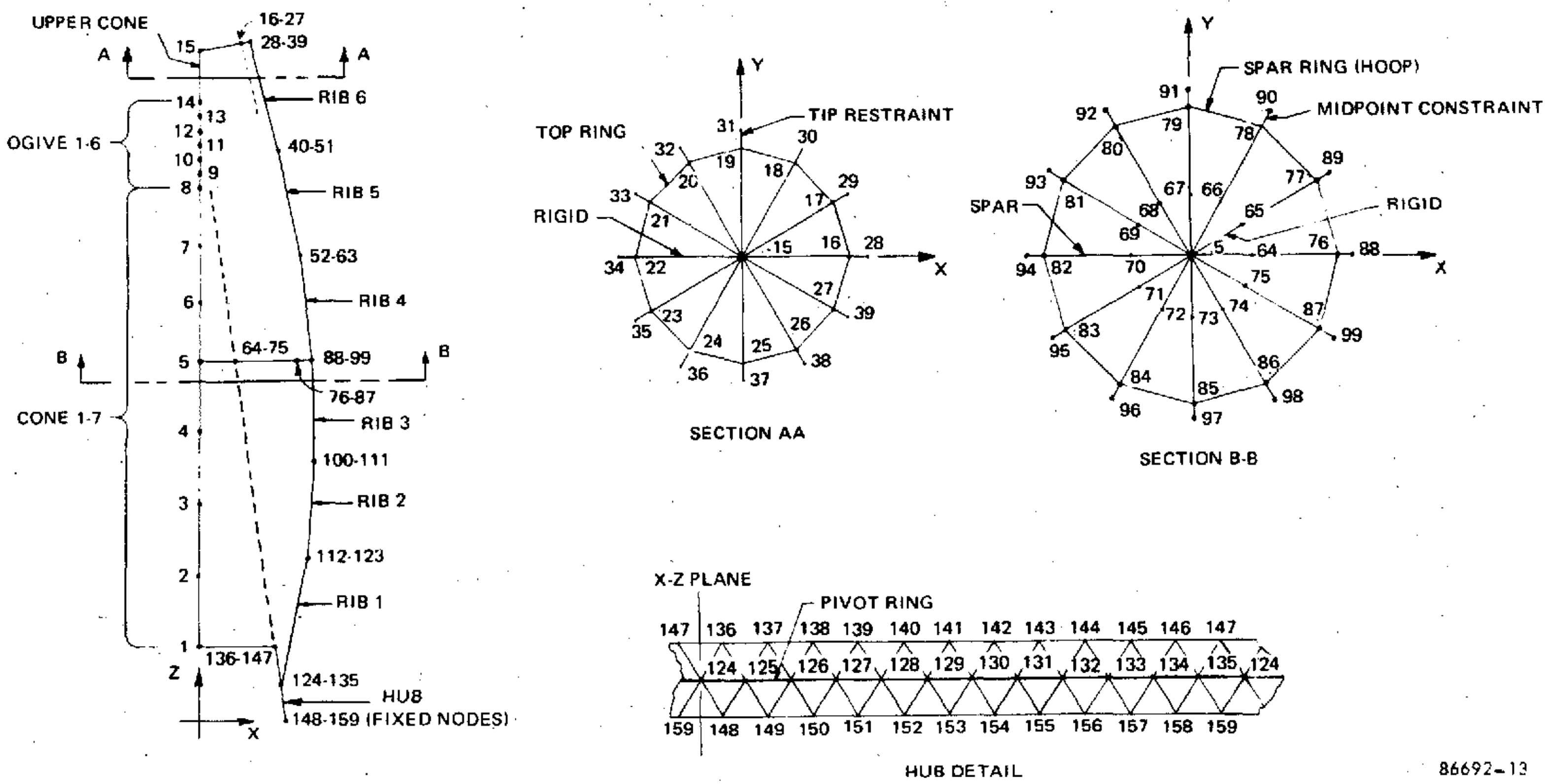


Figure 4.4.2.1. Computer Model of Stowed Antenna Showing Nodal Topology

line beam elements. Each rib was connected at its base by a pinned joint to the antenna hub. The midpoints of the ribs were connected to the support cone by a hoop and spar restraint system. The midpoint restraint is fixed to the rib and ball connected at the spar ring. The rib tips were moment connected about two axes to the top ring with short tip-restraint members that provide the correct amount of eccentricity and no torsional restraint about its axis. The support cone and ogive assembly was modeled as a fourteen member tapered beam. Section property calculations for the support cone and ogive took into account the conical shape, thus, providing effective areas and moments of inertia for each section. In reducing the cone and ogive to a line it was necessary to add rigid members at the midpoint and at the top, e.g., nodes 5-64 and 15-16. Rigid members at the top are fixed at node 15 and ball connected at the top ring.

The hub is 0.050 inch thick up to the pivot pins which are 3.5 inches above the base. The support cone is 0.020 inch thick up to the midpoint and 0.015 inch thick from the midpoint to the neck. The ogive is 0.031 inch thick at the neck and the remaining two-thirds is 0.021 inch thick. Material for the ogive is S-glass having a modulus of elasticity of 3.0×10^6. The upper cone is 0.021 inch thick S-glass. The rib wall thickness is 0.008 ±0.001 inch at root, increasing to 0.012 ±0.001 inch at the midpoint and decreasing to 0.006 ±0.001 inch at the tip. The ribs, hub, and support cone are all made from 6061-T6 aluminum.

The thermal control on the support cone and hub is black anodize on the interior and 14 layers of mylar, 15 layers of nylon net, and one layer of silverized Teflon on the exterior lower eight inches. Five layers of MLI are used on remainder of cone. The ogive and upper cone thermal control is obtained with white paint on its exterior. The thermal control for the ribs consist of two layers of mylar, three layers of nylon net, and one layer of silverized Teflon. The mass of these items was included in the analyses.

Mesh was conservatively assumed to be 100 percent effective as a mass in the stowed and deployed antenna models.

4.4.2.2 Stowed Antenna Analytical Method

Final dynamic analyses were performed using an eigenvalue solution for the antenna. For the stowed antenna an inverse iteration method was used to extract the lowest four frequencies. For the deployed rib, the HQR algorithm was used to solve for all eigenvalues.

The stowed antenna lateral mode shape was used to determine internal loads, deflections and stresses. Knowing that the maximum response is 25 G and that the vibration is harmonic, the acceleration relates to deflection from $G = .1f^2 X$. The solved value of X divided by the normalized deflection of 1.0 inch produces a factor which can be multiplied by the eigenmode solution having internal loads.

Preliminary analyses and trade-off studies were performed using the Rayleigh Method to calculate the fundamental frequencies. In this method, it is assumed that the lowest mode shape is the same as obtained by applying a 1 G field to the model. Deflections at all nodes are calculated using the STARDYNE computer program. The lowest frequency is then calculated from the expression

$$f = 3.13 \sqrt{\Sigma F_i \Delta_{xi} / \Sigma F_i \left(\Delta^2_{xi} + \Delta^2_{yi} + \Delta^2_{zi}\right)}$$

Where: F_i = gravity weights that are lumped at nodes i

Δ_i = deflections in x, y, and z directions at corresponding nodes i

Validity of the Rayleigh Method was verified in prior analyses and tests. A comparison of results with the eigenvalue solution is presented in the next subsection.

4.4.2.3 Stowed Antenna Results

The computer printout of the input and a portion of the results is presented in Section D1.0 of Appendix D of the CDR data package. The primary result is the fundamental frequencies for the stowed antenna which are 29.4, 55.6 and 141.8 Hz for the torsional, lateral, and longitudinal axes, respectively.

Appendix D1.0 of the CDR data package contains additional results on internal loads, stresses, and deflections. This data was used with acceleration load factors to size members and determine the required preload at the rib midpoint, Reference Sections D7.0 and D8.0 of the CDR data package.

Results of the stowed antenna lateral and longitudinal fundamental frequencies as calculated by the Rayleigh Method are presented in Sections D1.3 and D1.4 of Appendix D of the CDR data package. The eigenvalue solutions are presented in Section D1.5 of the CDR data package. The identical model was used in both Rayleigh and Eigenvalue Method solutions. Each method has its advantages. Though the Rayleigh Method can be used to calculate the fundamental frequency with less machine time, the eigenvalue solution is more accurate; especially on mode shapes and stresses. Whereas the Rayleigh Method only provides the lowest frequency, the eigenvalue solution yields the first five natural frequencies.

The Rayleigh Method results in a fundamental lateral frequency of 56.76 Hz. The eigenvalue solution value is 55.61 Hz.

Figure 4.4.2.3 shows the sensitivity of the stowed lateral frequency to additional (in excess of 0.55 pound) weight at the top of the antenna.

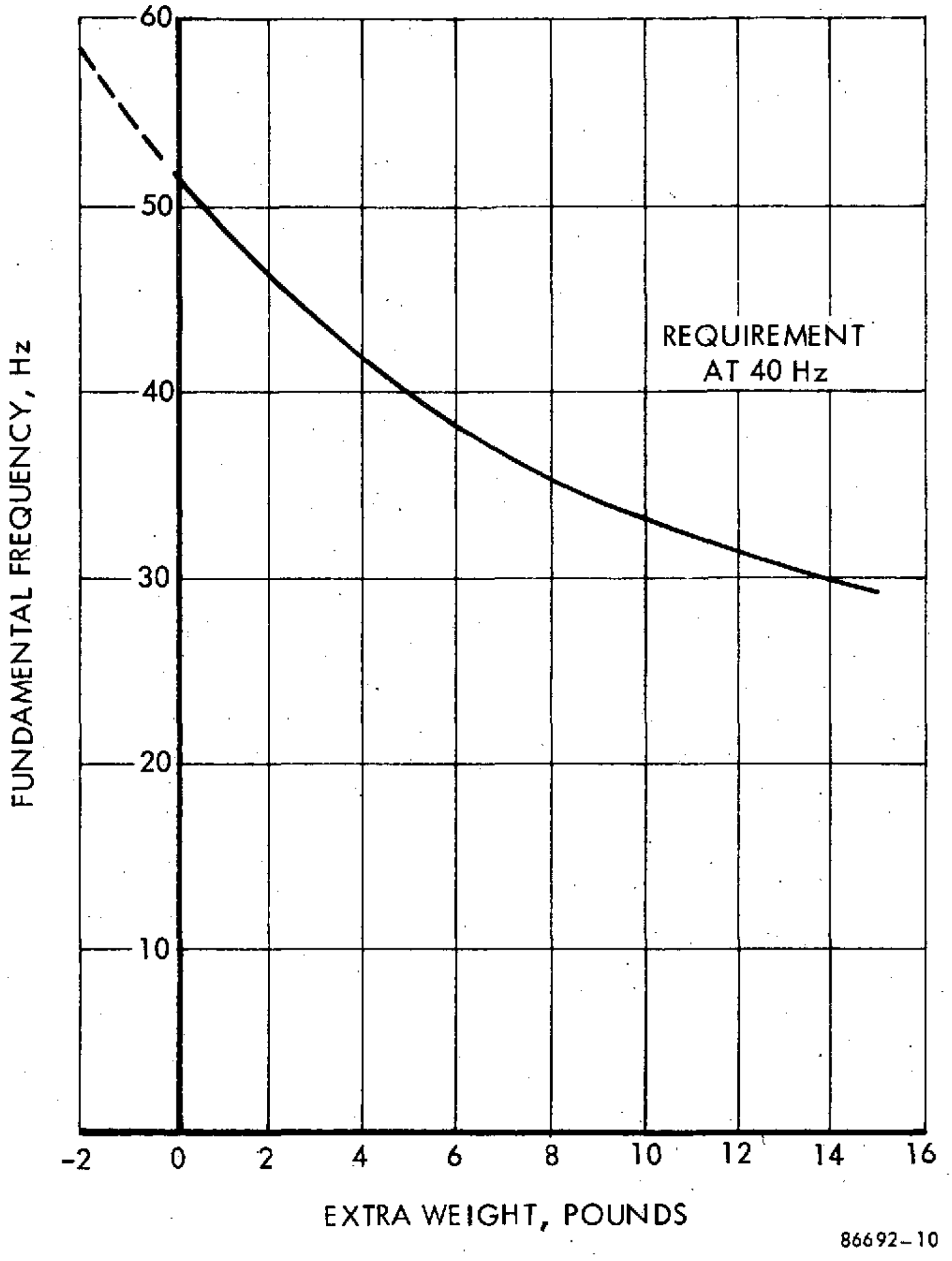


Figure 4.4.2.3. The Final Design Antenna Can Support an Extra Payload of 7.5 Pounds

4.4.3 Deployed Rib

4.4.3.1 Parametric Analysis

Previous analyses and test correlation have revealed that the fundamental frequency of the deployed antenna can be calculated within four percent by using a one rib model. This indicates that the mesh spring rate is relatively low and the mesh stiffness can be ignored to obtain approximate results. This is also a valid assumption in the present design because the ribs are relatively stiff compared to the mesh. The four percent accuracy on frequency applies to the final detailed rib model which includes a pivot arm and a portion of the hub. In this section the presumed accuracy is approximately 15 percent while in Paragraph 4.4.3.2 the presumed accuracy is approximately five percent for the fundamental lateral frequency and 10 percent for the fundamental torsional frequency.

Analyses were made to enable selection of a deployed rib based upon meeting a minimum frequency requirement while minimizing weight and tip deflection. Rib diameters of 1.0, 1.5, and 2.0 inches were analyzed. Rib wall thickness was varied from 0.004 to 0.016 inch in 0.002 inch increments. Because the primary stresses are from preloading the rib, they are a maximum at the rib midpoint and a minimum near the tip and root. The rib thickness was also allowed to be a maximum in the center.

The model consisted of 11 nodes connecting 10 segments. Node 1 at the tip was free and Node 11 at the root was fixed. The arc length of the rib was used but the model was a straight beam. Further details on the model and applied weights and results may be found in Section D2.0 of Appendix D of the CDR data package. A portion of the results is presented in Figures 4.4.3-1 through 4.4.3-3.

The rib parametric analysis results show that none of the 1.0 inch diameter ribs meet the frequency requirements. The 1.5-inch diameter ribs meet frequency requirements when thickness is greater than 0.006. All of the 2.0-inch diameter ribs exceed the frequency requirement.

Analysis indicated that preload stress requires a rib midpoint wall thickness of $t_m = 0.012$ inch. The data used to plot Figure 4.4.3-2 shows that when the tip and root thicknesses are 0.006 the frequency reduces 14 percent while the weight reduces 25 percent. Thus, it is efficient to have a thickness taper of approximately two to one from midpoint to tip or root.

Figure 4.4.3-3 indicates the degree of frequency-to-weight effectiveness. This chart must be tempered with absolute weight, frequency, stress, and thermal requirements. Figure 4.4.3-3 also indicates that the larger diameter thinner walled tubes are best from a frequency or stiffness viewpoint. This is contrary to thermal requirements which are ideal for small diameter thick walled tubes. Moreover, stress buckling must be investigated when using large D/t ratios.

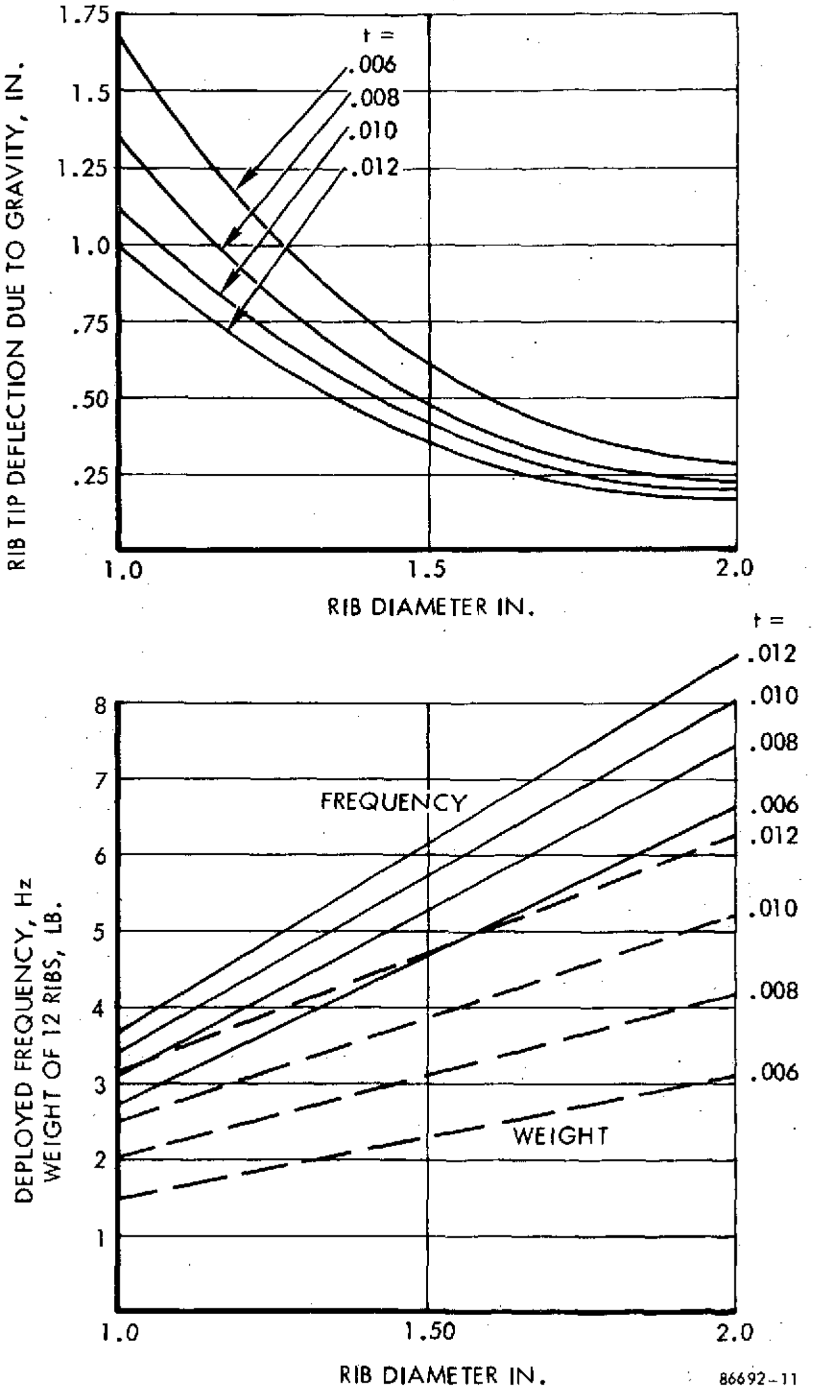


Figure 4.4.3-1. None of 1.0-Inch Diameter Ribs Meet the 4 Hz Requirement But 1.5-Inch Diameter Is Satisfactory When Thicker Than 0.006 Inch

NOTES: 1. TAPER RATIO = RIB WALL THICKNESS AT MIDPOINT, t_m, OVER THICKNESS AT TIP OR ROOT

2. MINIMUM FREQUENCY REQUIREMENT IS 4 Hz.

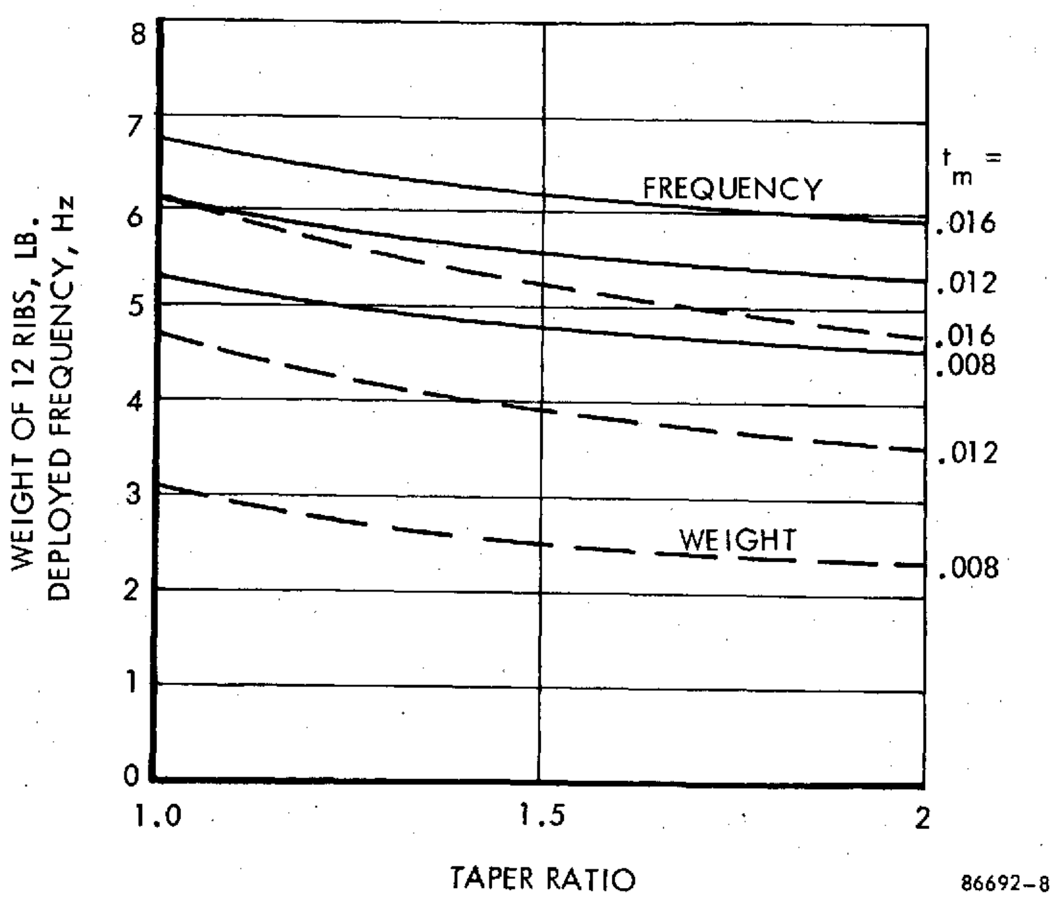


Figure 4.4.3-2. Variation of Rib Frequency and Weight Versus Taper Ratio for a Deployed 12.5-Foot Diameter Antenna

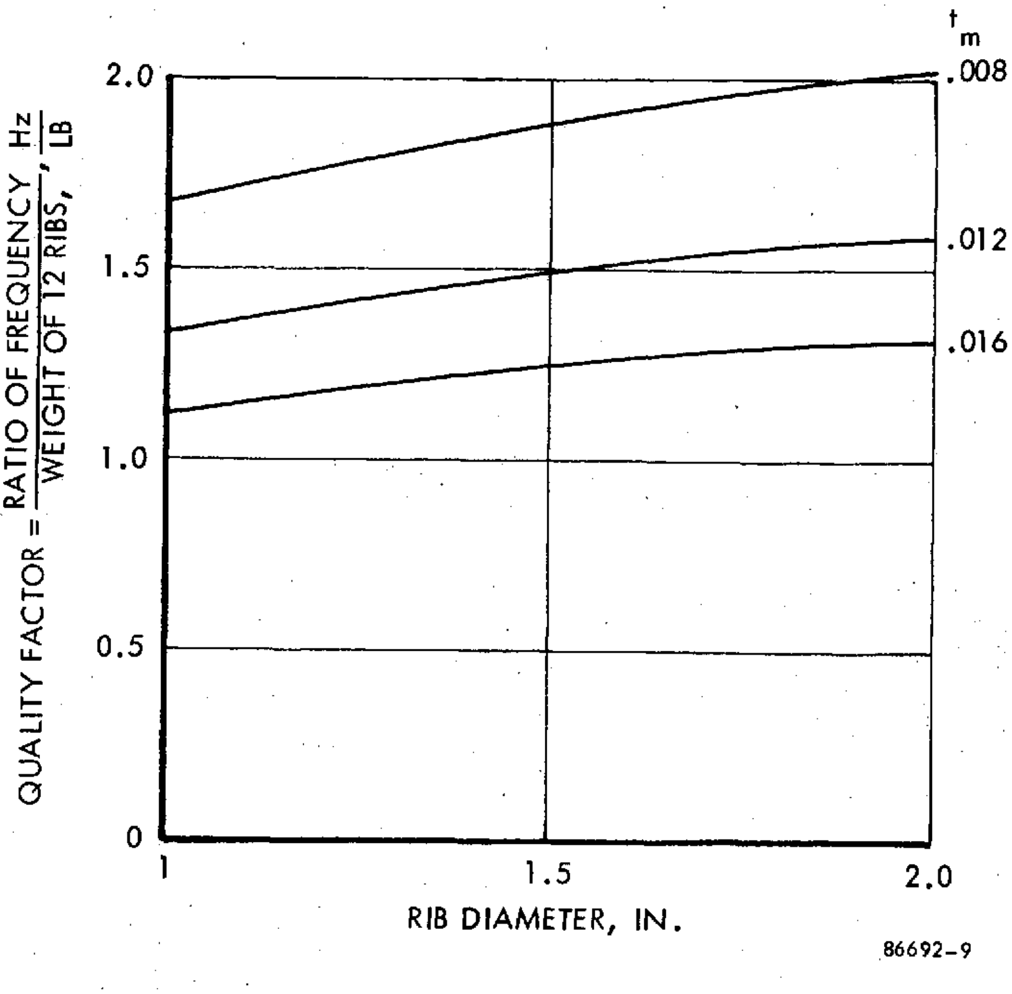


Figure 4.4.3-3. Variation of Quality Factor Versus Diameter for Ribs of a Taper Ratio = 2

Of the analyzed ribs there are a number of candidates that appear satisfactory. Preliminary thermal analysis shows that a 1.50 diameter rib with a constant wall thickness of 0.010 inch is marginally satisfactory.

Therefore, giving consideration to stress, frequency, thermal, weight, cost, and low deflections, a rib size was selected. The selected rib is 1.50 inches diameter with a minimum thickness of 0.008 at the root, 0.012 at the midpoint, and 0.006 at the tip. Using a tolerance of ±0.0010 inch the above nominal thicknesses would all increase 0.001 inch.

4.4.3.2 Detailed Rib Analysis

The selected rib was modeled for a STARDYNE eigenvalue run. The parabolic rib shape was now considered and a pivot arm was connected to the rib at the pivot pin. A sketch of the model and the geometry and other details are presented in Section D6.0 of Appendix D. The rib has 11 nodes and 10 beam segments, the pivot arm had 11 nodes and 11 beams and one plate element. Effective areas and moments of inertia were calculated considering the thickness taper.

The fundamental frequencies in the torsional and lateral axes are 6.97 and 6.91 Hz. The torsional mode shape is out-of-plane bending of the rib about the z axis of the pivot pin. The lateral mode shape is in-plane bending of the rib about the y axis. A summary of frequencies and a comparison between computer models for the structure is shown in Table 4.4.3.2.

Table 4.4.3.2. Summary of Lower Frequencies

	Frequency, Hz	
Mode	Model 1 No HUB	Model 2 With HUB
First Lateral	7.02	6.91
First Torsional	7.02	6.97
Second Lateral	44.0	43.1
Second Torsional	43.9	43.7
Third Lateral	136	132
Third Torsional	137	137

4.4.4 MDS Load Analysis

Forces and torques in the MDS were calculated for antenna deployment in a face-down position and for deployment in a face-side position. These loads were calculated for each 1° increment of deployment. A summary of the maximum limit loads is presented in Table 4.4.4. The complete load calculations are presented in Section D3.0 of Appendix D of the CDR Data Package.

Table 4.4.4. Summary of Maximum Limit Loads in the MDS

a. Face-Down Condition

Angle α, Degrees	Push Rod Force Pounds	Ball Screw Force Pounds	Ball Screw Torque Inch Pound
49	10.55	81.49	1.44
74	13.67	4.5	0.081

b. Face-Side Condition

Angle α, Degrees	Push Rod Force Pounds	Carrier Moment In. Lbs	Ball Screw Moment In. Lbs	Ball Screw Stress psi	Ball Screw Deflection Inches
0	16.43	510	319	70,000	0.00005

Moments were taken about the rib pivot point. The rib weight of 0.6548 pound was concentrated at its CG which has a radius arm of 41.79 inches. Reacting this moment is a push rod force acting on a moment arm of a sin $(\alpha + \beta)$. See Figure 4.4.4 for a sketch of the geometry. This approach is approximately two percent conservative because it excludes the counter-balancing effect of the carrier and push rod weights on their moment arms.

4.4.5 Preload Requirements

Appendix D, Section 7.0 of the CDR Data Package, shows the derivation of preload requirements at the rib midpoint and at the rib tip.

To avoid chatter during vibration at 25 G response it is necessary to preload the rib midpoint with 15.84 pounds. This is accomplished by installing the rib so that it must be deflected 1.604 inches at its tip during final assembly.

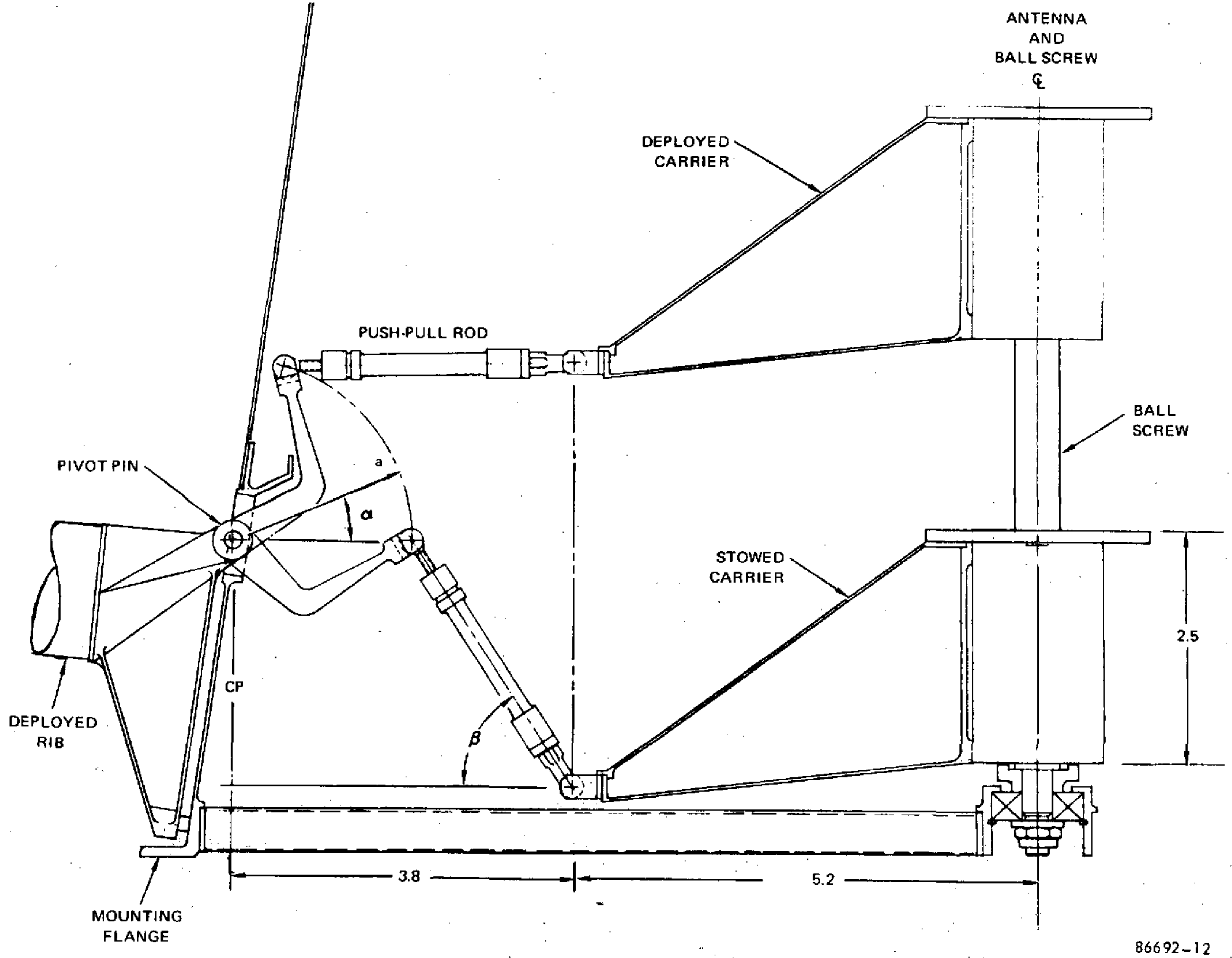


Figure 4.4.4. Geometry of MDS Used in Load Analysis

4.4.6 Stress Analysis

Rib and Support Cone Detail Stress Analysis is included in Appendix D, Section 8.0, of the CDR Data Package.

4.5 Deployment Reliability

An analysis was performed to determine the probability of proper deployment of the antenna in the orbital environment. Proper deployment is herein defined as release of the ribs by the launch restraint system and subsequent operation of the mechanical deployment system (MDS) which results in a tensioning of the mesh surface to the required levels. The approach taken in the analysis was to evaluate the probability of the restraint system release and MDS operation separately, then these values were combined to yield the probability of successful deployment.

4.5.1 MDS Analysis

The results of tests conducted in the design and development phase of a previous program were used to construct a lower bound on the probability of successful operation of the MDS. Succinctly, the MDS was cycled 400 times, under various conditions, to determine what failure modes, if any, would show up. The extensive testing did not produce any failures. The testing can be thought of as representing 400 Bernoulli trials during which 400 successes were observed.

Let

p = probability of successful operation of the MDS on a single trial

then the maximum likelihood estimator for p is

$$\hat{p} = \frac{X_o}{\eta} \qquad (1)$$

where X_o = number of successes

and η = total number of trials.

Using the results of the tests then

$$\hat{p} = 1,$$

which says that the best point estimate for the true probability of success p is $\hat{p} = 1$. A more revealing statistic at this point is the lower bound on the true probability of success (p). The arguments leading up to and development of the following lower bound can be found in

C-2

References 1 and 2. A 95 percent Lower Bound (LB) on the parameter p is given by the following:

$$LB = \frac{X_o}{X_o + (\eta - X_o + 1)\ F_{0.95}\,(2\,(\eta - X_o + 1),\ 2\,X_o)}$$

where $F_{0.95}\,(2\,(\eta = X_o + 1),\ 2\,X_o)$ is a random variable with the variance ratio distribution and is a function of two parameters (degrees of freedom).

Substituting in the above equation for $X_o = 400$ and $\eta = 400$ and using tables for the cumulative F distribution[2]

$$LB = 0.993.$$

Based on the test results we are 95 percent sure that the true probability of successful operation of the MDS is no smaller than 0.993.

4.5.2 Restraint Release Analysis

The problem is one of determining the reliability associated with the deployment of the antenna ribs where each rib is being restrained. The ground rules are that:

1. All 12 ribs must be pulled free.

2. The scope of this analysis is as appears in Figure 4.5.2-1.

3. All system elements exterior to this scope are assumed to function properly.

Approach

The approach consisted of determining the probabilities associated with the successful operation of the pair of redundant guillotines and the freeing of each of the 12 antenna ribs (see Figure 4.5.2-1).

Solution Technique

The probability of successfully cutting the cable by means of the pair of guillotines is

$$PG = 1 - (1 - pg)^2 \qquad (2)$$

[1]Hald, A., 1952, Statistical Theory with Engineering Applications, John Wiley and Sons, New York

[2]Brownlee, K. A., 1960, Statistical Theory and Methodology in Science and Engineering, John Wiley and Sons, New York

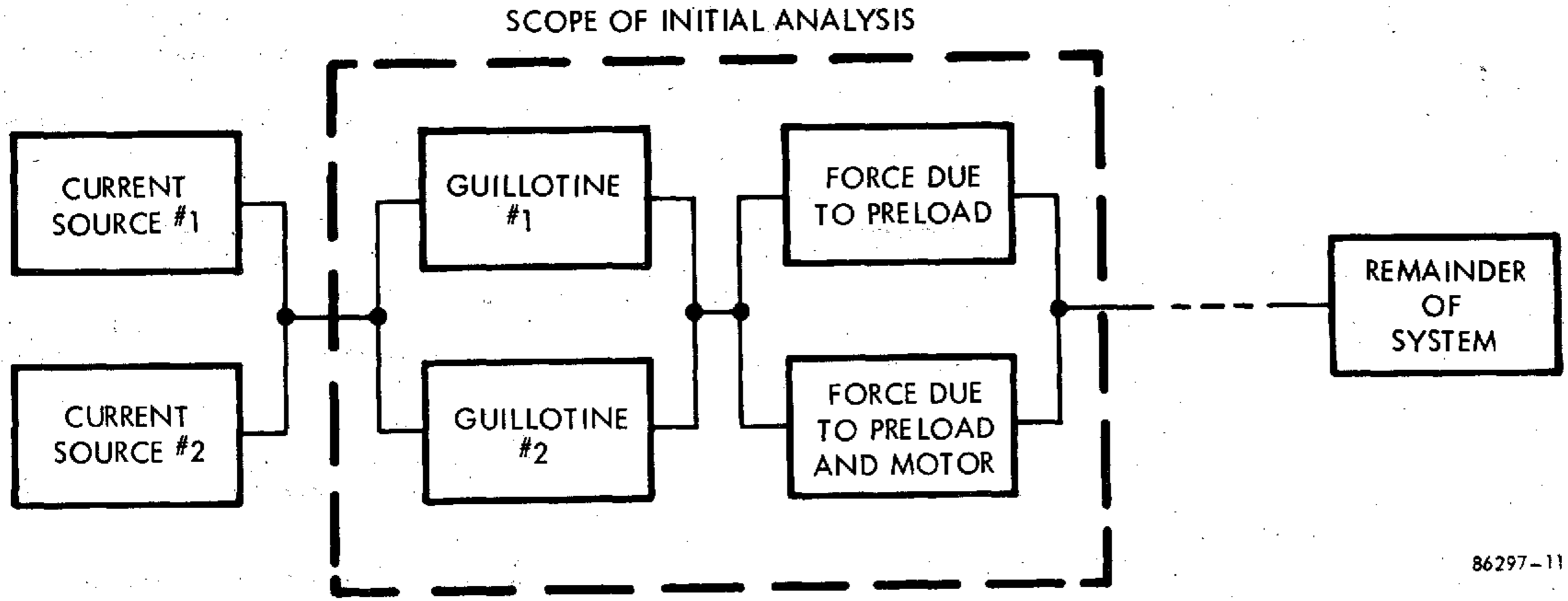


Figure 4.5.2-1. Simplified Model for Antenna Deployment

where pg = the probability that a single guillotine will successfully cut the cable and PG is the desired probability. The values of pg used in the analysis were

$$pg = \begin{array}{l} .99, \text{ conservative estimate} \\ 0.9999, \text{ vendor quoted estimate} \end{array}$$

The probability that each rib would be free if the cable were cut, depends on the forces acting to pull each rib from the restraining mechanism. There are two components of force acting to free each rib - a force due to preload and a force due to the torque motors. The forces due to preload and torque motors are random variables which are assumed to be normally distributed. This assumption is based on engineering judgement as opposed to mathematical convenience. It is further assumed that each of the 12 ribs is identical from a freeing and restraining force viewpoint.

Let x_1 be the amount of force on each rib due to preload where x_1 is a random variable assumed to be normally distributed with mean μ_1, and standard deviation σ_1. The probability that the preload force will be greater than the restraining force (k) is

$$Pr\left\{x_1 < k\right\} = \left\{1 - Pr\, x_1 \leq k\right\}$$

or in terms of the standard cumulative normal

$$Pr\left\{x_1 > k\right\} = 1 \Phi \frac{k - \mu_1}{T_1} \tag{3}$$

Based on design values and engineering estimates μ_1 was determined to be 5.15 pounds and the three Sigma limits were ±1.50 pounds which implies $\overline{V}_1 = 0.5$ pound. The value of k (restraint force) was not easily quantifiable, ergo k was treated as a parameter and allowed to range over 0 to 200 percent of μ_1.

The amount of freeing force (x_2) acting on each rib due to the torque motors was assumed to be normally distributed with the mean ($\mu_2 = 2.75$ pounds) and standard deviation ($\overline{\mu}_2 = 0.2750$ pound) determined by design values and engineering judgement. The combined forces ($x_1 + x_2$) will act to free each rib, hence

$$Pr\left\{x_1 + x_2 > k\right\} = 1 - Pr\left\{x_1 + x_2 \leq k\right\}$$

or in terms of the cumulative unit normal

$$Pr\left\{x > k\right\} = 1 - \underline{\overline{\Phi}}\left(\frac{k - \mu}{\sigma}\right) \tag{4}$$

where $x = x_1 + x_2$ and is a random variable normally distributed with $\mu = \mu_1 + \mu_2$ and $\sigma = (\overline{V}_1^{\,2} + V_2^{\,2})^{1/2}$. Performing the indicated operation yields $\mu = 7.90$ and $\overline{V} = 0.5706$.

Since each rib can be freed if either the preload or the combined preload plus torque motor force is greater than the restraining force computations were carried out to gain insight into the effect of restraint force on the freeing force with and without the torque motor. Using Equation (3) for preload force only, let

$P_i = \left\{Pr\ X_1 > k\right\}$ where P_i is the probability that the freeing force on the ith rib will be greater than the restraint force.

Then

$$\underline{P} = Pg \prod_{i=1}^{18} P_i \tag{5}$$

where PG is defined by Equation (2) and $\underline{P}$ is the Probability that the cable will be cut and all 12 ribs will be released.

When the introduction of the freeing force due to the torque motor and assuming statistical independence

$$P_i = 1 - Pr\left\{x_1 \leq k\right\} \cdot Pr\left\{x \leq k\right\}. \tag{6}$$

Hence, substituting Equation (6) for P_i in Equation (5) will yield the probability that the cable will be cut and all 12 ribs will be released when both the preload and torque motor force are considered.

Results

Computations were carried out with PG = .9999 (i.e., pg = .99) and PG = .999999 (i.e., pg = 9999) and for values of k = 0, 10, ... 200 percent of μ_1 under both the preload only and preload plus torque motor freeing force. These computations in essence involved the operations depicted by Equation (5). Extreme precautions were taken so as not to introduce round-off or truncation errors in the computations. The numerical integration of the unit normal density, for example, was executed using the Hewlett-Packard Calculator with 100 subdivisions per integration. This allowed for the computation of very small probabilities (i.e., in the tails of the unit normal density) which are not readily available in table form. The final results are shown in graphic form in Figure 4.5.2-2. The curves marked preload force correspond to removing the block titled "Force Due to Preload and Motor" from Figure 4.5.2-1 which in essence removes a redundant success path. The set of curves marked preload + torque motor force corresponds to the situation enclosed by the dotted region in Figure 4.5.2-1. For the preload force only condition and PG = .9999, the probability of freeing all the ribs ($\underline{P}$) is virtually .9999 for a restraint force less than 50 percent of $\mu = 5.15$. The addition of the force due to the torque motor will allow a k of approximately 90 percent or less to be overcome with probability = .9999. The curves can be used to determine the probability that a given restraint force can be overcome by the forces acting to free the ribs. For example, if k = 5.12 pounds (100 percent of μ_1) then P = 0.50 (not shown on graph) for the preload force only but when the force due to the torque motor is considered, $\underline{P}$ = .9998 when PG = .9999.

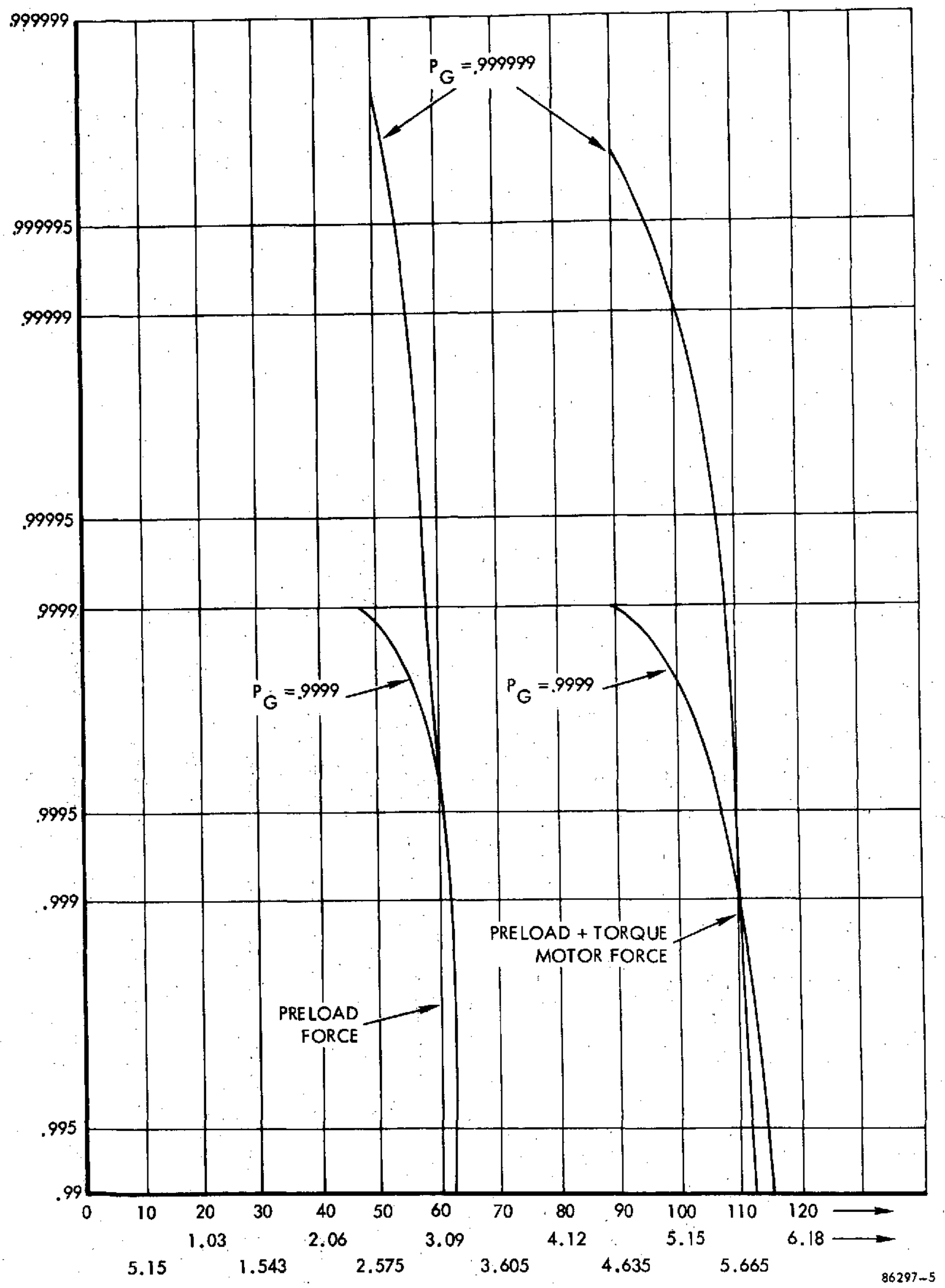


Figure 4.5.2-2. Probability of Antenna Deployment (P) Versus Restraint Force (K)

Conclusions

The present design with redundant guillotines and preload and torque motor forces acting to free the antenna ribs, possesses a probability of deploying greater than .999. This conclusion assumes a priori that all other events necessary for antenna deployment will occur with probability one.

4.5.3 Probability of Successful Deployment

From the previous section, P was conservatively estimated at 0.9999 where

P = the probability that the cable will be cut and all 12 ribs will be released.

Combining this estimate with the results for the MDS from Paragraph 4.5.1 yields

$$P_s = 0.9999\,(0.9926) = 0.9925$$

Where P_s is the probability of successful operation of the MDS and deployment of the antenna ribs.

Conclusion

Based on the above analyses, the probability of successful deployment of the antenna is estimated conservatively at 0.9925.

SECTION 5.0

APPLICATIONS STUDIES TASK

5.0 APPLICATIONS STUDIES TASK

The objective of the Applications Studies Task was to investigate the applicability of the 12.5-foot deployable reflector to the requirements of the Tracking and Data Relay Satellite (TDRS) Program. To accomplish this investigation, the following subtasks were conducted:

- Establish baseline system parameters
- Select and analyze two practical feed concepts
- Perform typical link analyses
- Establish pointing error budgets and perform servo analyses
- Develop relationship of reflector weight and surface accuracy as a function of antenna diameter

The following paragraphs describe the results of these activities. However, the applicability of the 12.5-foot reflector design to the TDRS Program is, undoubtedly, best demonstrated by the fact that the reflector design (with only slight modifications) has been cited as the selected baseline design by both contractors in the recently completed TDRSS Definition Phase Studies (see References 2 and 3 and Figure 5.0).

5.1 Baseline Systems Parameters Definition

The first subtask of the Applications Studies Task was the definition of the baseline system parameters on the basis of NASA furnished data. This data was received and evaluated with respect to the antenna system. This section includes a summary of the NASA data, link tables, and an assessment of user satellite antenna gains required to support various data bandwidths for a range of TDRS Ku-band and S-band sizes.

The pertinent antenna parameters may be classified as RF or mechanical. The RF parameters (performance) are fixed by link analyses and required link performance. The mechanical parameters are developed from the selected pointing philosophy, required tracking accuracy, and TDRS and user spacecraft ephemeris and attitude accuracies. The antenna RF parameters supplied by NASA are:

• Transmit Frequency	13.4 ⟶ 14.2 GHz
• Receive Frequency	14.4 ⟶ 15.35 GHz
• Bandwidth	20 MHz
• Receiver Sensitivity (G/T)	$\geq$10 dB/$^{\circ}$K (Boresight)

TDRS BASELINE CONFIGURATION

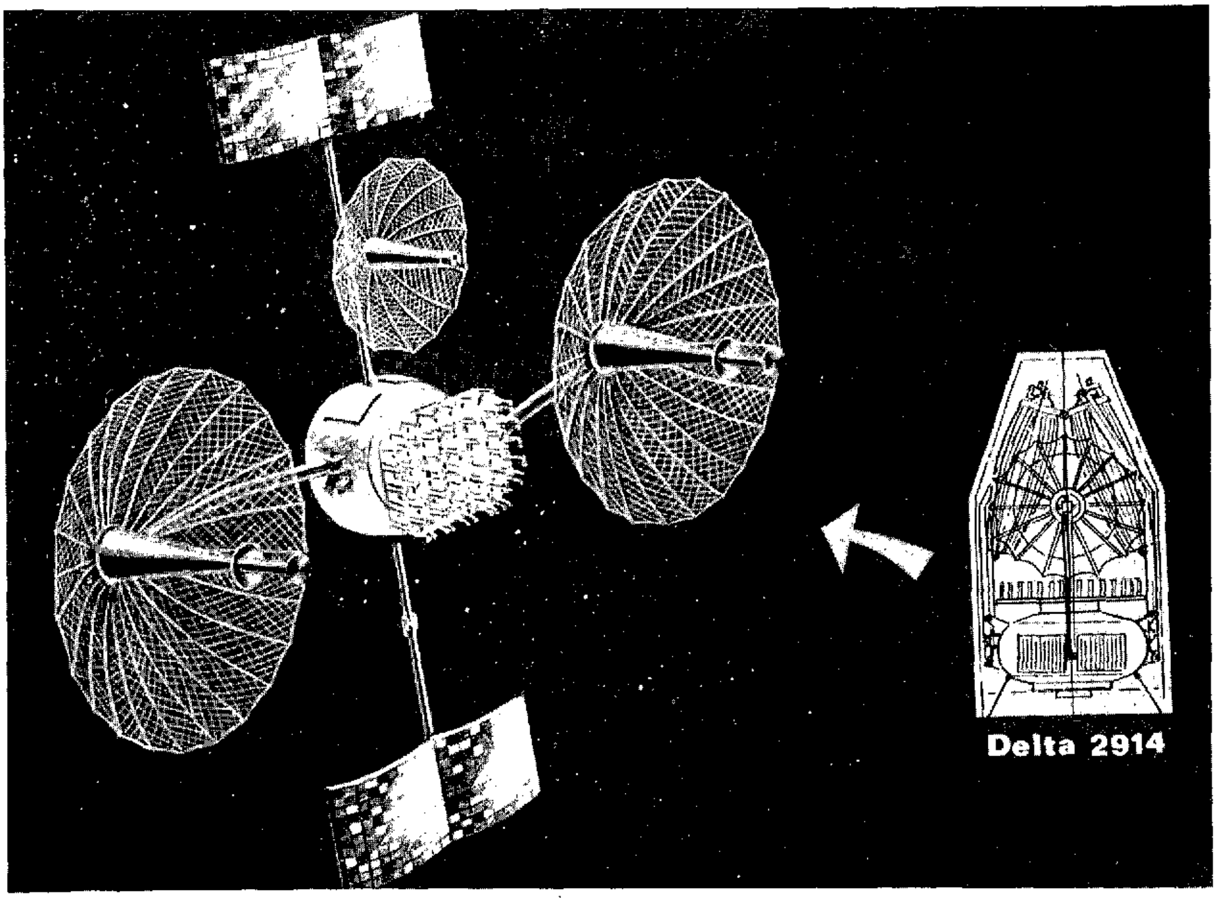


Figure 5.0. TDRS Baseline Configuration

- Effective Radiated Power — 40 dBW
- Power Output — 20 watts
- Transmit Losses — 2.0 dB
- Pointing Loss — ≤ 1.0 dB

Assuming that solid state Ku-band receivers will be used on the TDRS, the noise temperature will be approximately 1000°K or 30 dB/°K. The minimum antenna gain required, assuming 1 dB circuit losses, is therefore 41 dB and the effective radiated power is 52 dBw with a 20 watt RF source and 2.0 dB losses. The 42 dB gain corresponds to an antenna diameter of approximately 3 feet. As illustrated in Table 5.1, a 3-foot dish provides sufficient margin to support a 20 Mb link to the ground. A conservative noise temperature for a ground based receiving system is 500°K and the 28 dB/°K. The G/T shown in Table 5.1 reflects such a temperature. For completeness, the links corresponding to a range of TDRS antennas are shown for both the TDRS ground and TDRS user satellite links in Table 5.1, although the 3-foot reflector would probably be dedicated to the ground link.

The parameter values shown in Table 5.1 represent gross estimates and this table is included to illustrate the difficulty of maintaining a 20 Mb link between the TDRS and the user satellites.

The NASA supplied user satellite parameters are:

- Antenna Gain — 16 dB
- Transmitter Power — 6 dBW
- Transmitter Losses — 2 dB
- Pointing Loss — ≤ 1.0 dB
- Receiving Temperature (assumed) — 30 dB/°K

Radiation's assumptions which are reflected in this table are:

- TDRS Receiver Noise Temperature — 30 dB/°K
- User Satellite Noise Temperature — 30 dB/°K
- Ground Station Noise Temperature — 27 dB/°K

Table 5.1. Ku-Band TDRS Link Tables

13.5 GC Down-Link \ Dish Diameter Link –	3' Gnd	3' User	6' Gnd	6' User	12' Gnd	12' User	20' Gnd	20' User
Antenna Gain (dB)	39.5	39.5	45.5	45.5	51.5	51.5	56.0	56.0
Transmitter Power (20 watts) (dBw)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Transmitting Circuit Losses (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Transmitter EIRP (dB)	51.5	51.5	57.5	57.5	63.5	63.5	68.0	68.0
Space Loss (dB)	207.26	207.9	207.26	207.9	207.26	207.9	207.26	207.9
Receiver Antenna Gain (dB)	56.0	16.0	56.0	16.0	56.0	16.0	56.0	16.0
Receiver Temperature (dB °K)	27.0	30.0	27.0	30.0	27.0	30.0	27.0	30.0
Receiver Losses	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Receiver G/Ts dB/°K	+28.0	-15.0	+28.0	-15.0	+28.0	-15.0	+28.0	-15.0
P/KT (dB/Hz)	100.84	57.2	106.84	63.2	112.84	69.2	117.34	73.7
Margin @ ZOMB and Eb/No = 9.6	+18.24	-25.4	+24.24	-19.4	+30.24	-13.4	+34.74	- 8.9
User Dish Rqd.		41.4 dB~4'		35.4 dB 2'		29.4 dB 1'		24.9~3"
15.0 GC Up-Link \ Dish Diameter Link –	**3' Gnd**	**3' User**	**6' Gnd**	**6' User**	**12' Gnd**	**12' User**	**20' Gnd**	**20' User**
Transmitter Antenna Gain (dB)	57.0	17.0	57.0	17.0	57.0	17.0	57.0	17.0
Transmitter Power (dBw)	10.0	6.0	10.0	6.0	10.0	6.0	10.0	6.0
Transmitting Circuit Losses (dB)	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
Transmitter EIRP (dBw)	66.0	20.0	66.0	20.0	66.0	20.0	66.0	20.0
Space Loss (dB)	208.18	208.82	208.18	208.82	208.18	208.82	208.18	208.82
Receiver Antenna Gain (dB)	40.5	40.5	46.5	46.5	52.5	52.5	57.0	57.0
Receiver Temperature (dB °K)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Receiver Losses (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Receiver G/Ts (dB °K)	9.5	9.5	15.5	15.5	21.5	21.5	26.0	26.0

Table 5.1. Ku-Band TDRS Link Tables (Continued)

15.0 GC Up-Link	Dish Diameter Link -	3'		6'		12'		20'	
		Gnd	User	Gnd	User	Gnd	User	Gnd	User
P/KT dB/Hz		95.92	59.28	101.92	65.28	107.92	71.28	112.42	75.78
Margin @ 20 MB and Eb/No = 9.6 dB		13.32	-23.32	19.32	-17.32	25.32	-11.32	29.82	- 6.82
User Dish Rqd.			39.32~2.5'		33.32~1.25'		27.32~7.5"		27.82

- Ground Station Maximum Space Loss at 15 GHz — 208 dB

  (Assumes 65° longitude separation and Wallops Island ground station latitude)

- User Satellite Maximum Space Loss at 15 GHz — 209 dB

  (Assumes 3000 mile altitude orbit and a 5° cutoff angle)

- Required Bit Error Rate — 10^{-5}

Because of the negative link margins for the TDRS User Satellite Links, Figure 5.1-1 was developed to illustrate the bit rate that can be supported with the specified 16 dB gain user satellite antenna for a range of TDRS antenna diameters as well as the additional channel capacity resulting from increased user satellite antenna gain. Because the TDRS antenna system will support many users it is probably advantangeous to place most of the link gain requirements on that antenna rather than on the users.

In a similar manner, the possible support of user satellites at S-band frequencies is shown parametrically in Figure 5.1-2. The user satellites are baselined with a 1.5-foot dish, a 10 watt power amplifier and a 500°K noise temperature. The supportable bit rate is shown as the TDRS antenna diameter is increased from 3 feet to 20 feet and the user satellite antenna diameter is increased from 1.5 feet to 6 feet. As in the previous link analysis, the link parameters values represent preliminary estimates and assumptions, and the actual link tolerances are probably in the neighborhood of ±3 to 6 dB. The assumptions made to develop Figure 5.1-2 are:

- TDRS S-band Noise Temperature — 500°K (27 dB-°K)
- User Satellite S-band Noise Temperature — 500°K
- TDRS S-band Power Output — 40 watts
- User Satellite S-band Power Output (Expandable to 40 watts) — 10 watts
- Maximum User Satellite Antenna Diameter — 6 feet
- Required E_b/N_o (Corresponding to 10^{-5} Bit Error Rate) — 9.6 dB

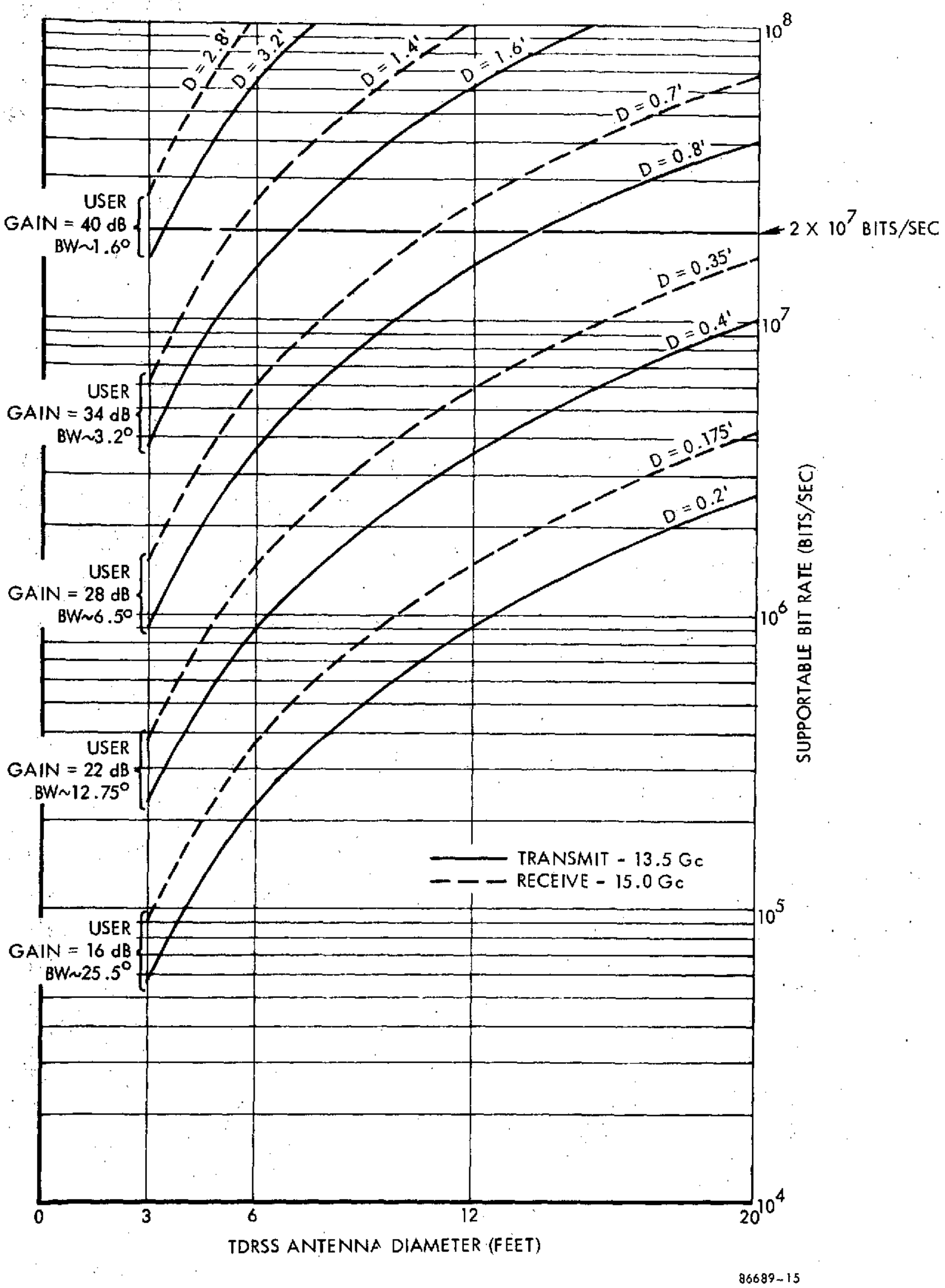


Figure 5.1-1. Supportable Bit Rate at Ku-Band as Function of Antenna Diameters

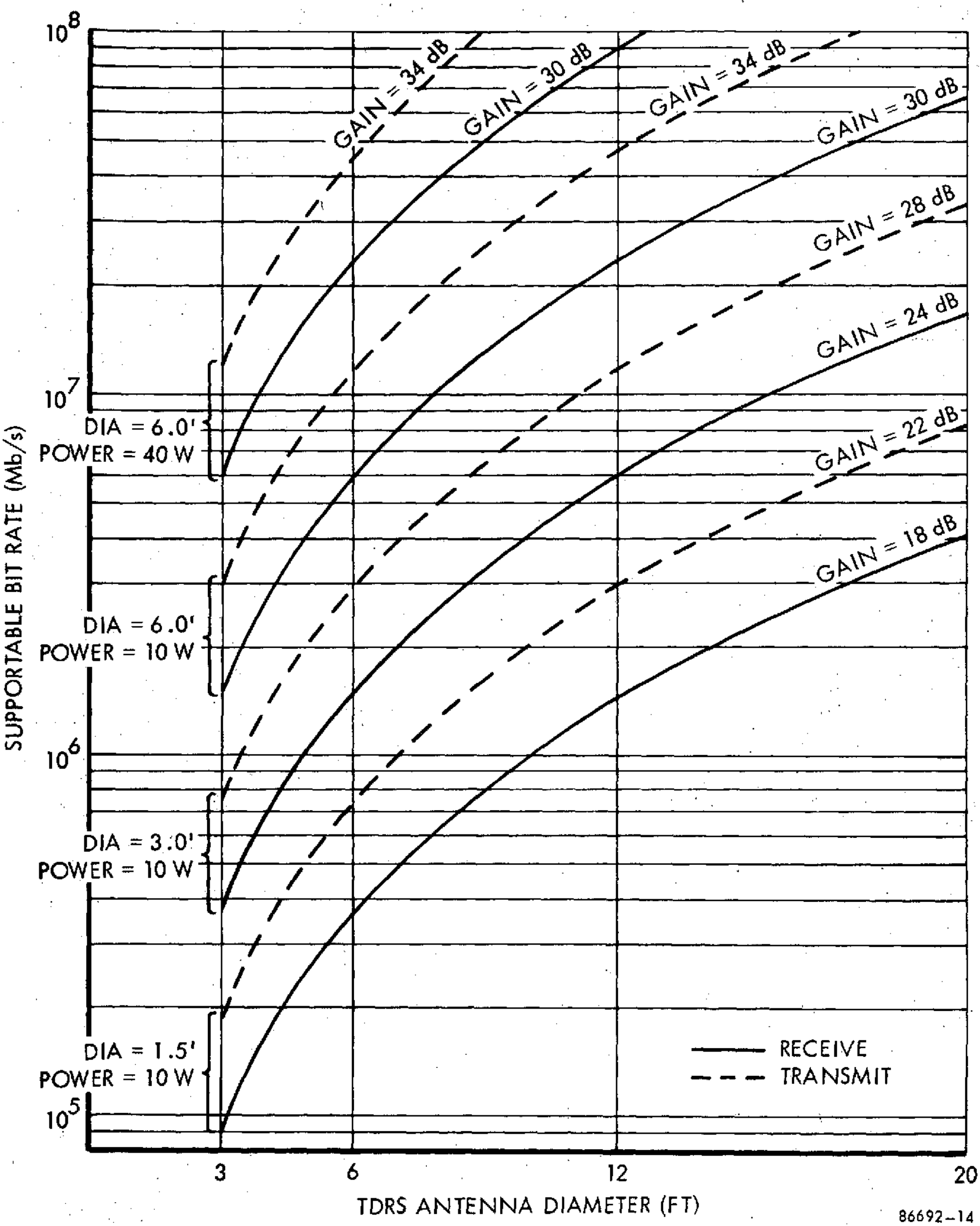


Figure 5.1-2. Supportable Bit Rate at S-Band as Function of Antenna Diameters

5.2 RF Feed Analysis

Two antenna feed concepts have been selected and analyzed which are compatible with the established baseline parameters. Both concepts provide for dual-frequency operation, at Ku- and S-band, and have the following basic characteristics:

- Compatible with 12.5-foot rib-and-mesh reflector
- Single beam direction at a given time determined by reflector steering
- Full duplex operation
- Self-tracking at Ku-band
- Programmed tracking at S-band
- Circular polarization

The analysis was extended to include dual-frequency operation with the cognizance of the NASA Contract Technical Officer. The decision was based on indications that this operation is compatible with and required in the anticipated operation of the TDRS.

The basic characteristics indicated for the selected feed concepts are based on the baseline parameters and other constraints. Although some effort is being expended by NASA to develop feed/reflector concepts which allow multiple frequency, multiple beam and tracking operations simultaneously in a single dish, concepts of this nature were beyond the scope of this program. Hence, only concepts which allow boresight beams and steering by movements of the dish are considered. Full duplex operation, simultaneously receiving and transmitting in the antenna, can be obtained by,

a. Transmitting and receiving in either one of the bands

b. Transmitting in one band and receiving in the other

In most cases, effective use of the latter is obtained only when transmission occurs at S-band frequencies and reception at Ku-band. This allows the narrow Ku-band beam to be utilized for tracking.

The tracking requirement of a 12.5-foot antenna is fundamentally a function of the frequency of operation and the attendant beam width. At S-band frequencies the half-power beam width is relatively large at approximately 2.5°; therefore, a programmed tracking mode is accurate and reliable enough and probably cost-effective for this band. On the other hand, the 3 dB beam width for the Ku-band frequencies is on the order of 0.4° indicating the probable need for self-tracking for the Ku-band. Consequently, concepts having these tracking characteristics have been selected.

Possible applicable self-tracking schemes include analog and digital monopulse implementations and step-track implementations. Both schemes are used in the two concepts presented in this section.

Inasmuch as all requirements for the TDRS system are not fully defined at this time, the two concepts selected for analysis cannot be considered optimum configurations. They are, however, important candidate types meeting the requirements as known and therefore allow meaningful modeling of the system for performance of the overall applications study and in particular, the pointing study task. In addition, the two concepts offer enough contrast to give insight over a relatively broad range of variation in operational requirements of the system. For example, the concepts allow for programmed, monopulse, and step tracking, and right- and left-hand circular polarization are available including like and orthogonal polarization for the receive and transmit signals of a given band. The concepts employ up-to-date, yet proven, techniques for obtaining the required performance for the TDRS antenna.

In the following paragraphs full descriptions of the two selected feed concepts are presented along with analytical projections of gain and efficiency budgets for each.

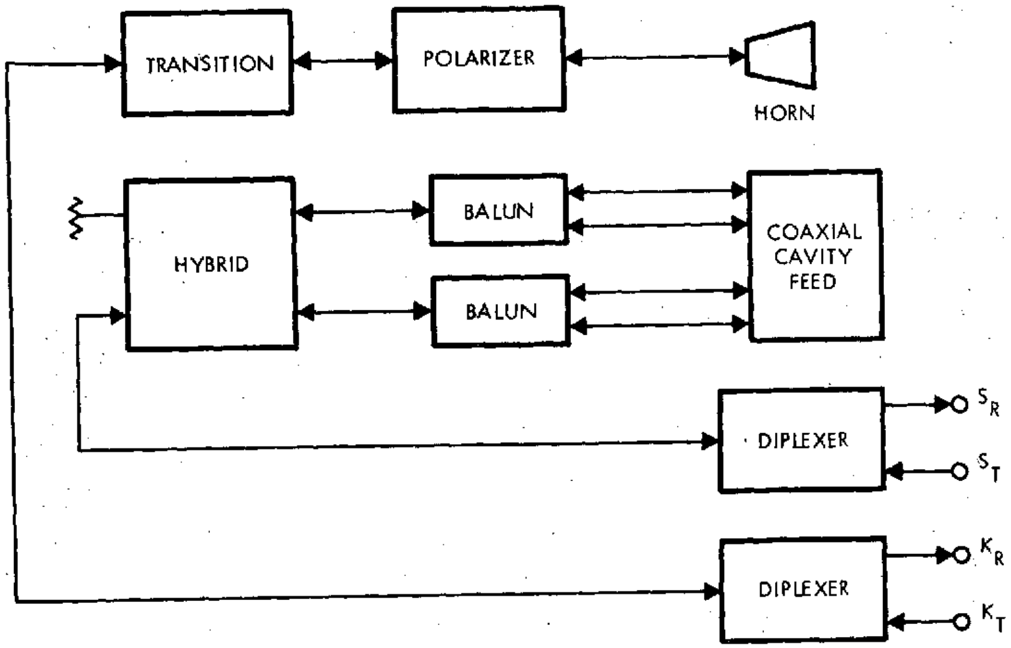
5.2.1 Monopulse Tracking Cassegrain Ku-Band/Programmed Tracking Apex S-Band Feed

A dual frequency feed concept is described in this paragraph employing pseudo-monopulse tracking Cassegrain Ku-band and programmed-tracking apex S-band implementations. A frequency sensitive dichroic lens subreflector is used in the configuration. The feed is configured to mate with a 12.5-foot rib-and-mesh reflector.

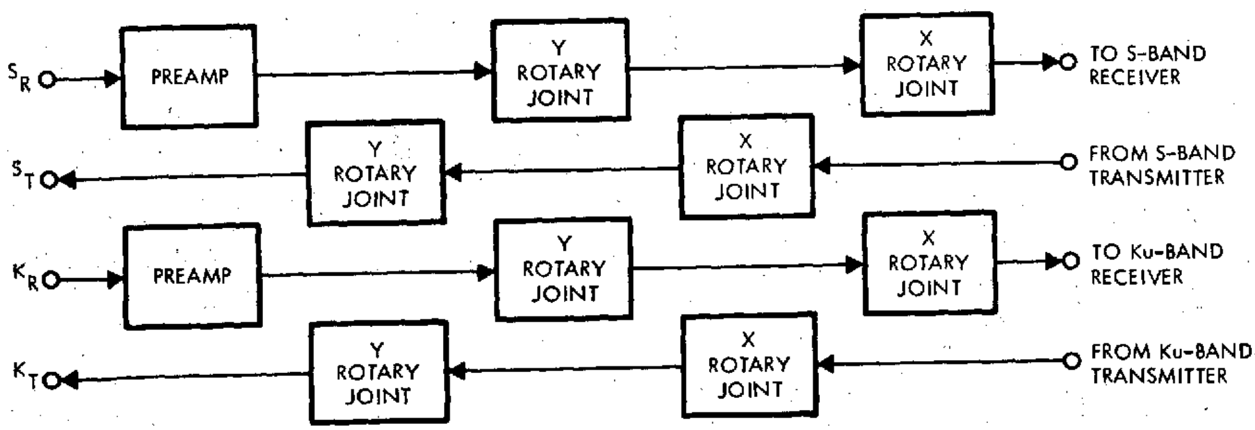
Description

The feed system consists of the components shown in the block diagram, Figure 5.2.1-1, and the sketch of the feed layout, Figure 5.2.1-2. These include an apex-mounted S-band cupped helix antenna which illuminates the 12.5-foot reflector through a frequency-sensitive or dichroic subreflector. The dichroic subreflector operates in the transmissive mode at the S-band frequencies and reflective mode at Ku-band frequencies. The cupped helix provides either right- or left-hand circular polarization for both transmit and receive channels depending on the winding direction of the helix. A low-loss cable interconnects the cupped helix and diplexer required for separating the receive and transmit channels. The received signals are amplified in a preamplifier, probably a tunnel diode or uncooled preamp. Both S-band channels are transmitted through rotary joints on the x-y mount. In the system four identical noncontacting, rotary joints are used, each having a center section of circular waveguide choke-flange coupled through the joint. The S-band channel is concentric to the circular waveguide. The design provides separation of the transmit and receive channels to opposite sides of the gimbal system to maintain good isolation.

The dichroic lens or subreflector is an important component in the concept. This type of subreflector has been developed and demonstrated by test on several programs to exhibit



(A) MICROWAVE SUBSYSTEM BLOCK DIAGRAM



(B) ADDITIONAL COMPONENTS REQUIRED

86748-1

Figure 5.2.1-1. Tracking Cassegrain Ku-Band, Nontracking Apex S-Band Feed

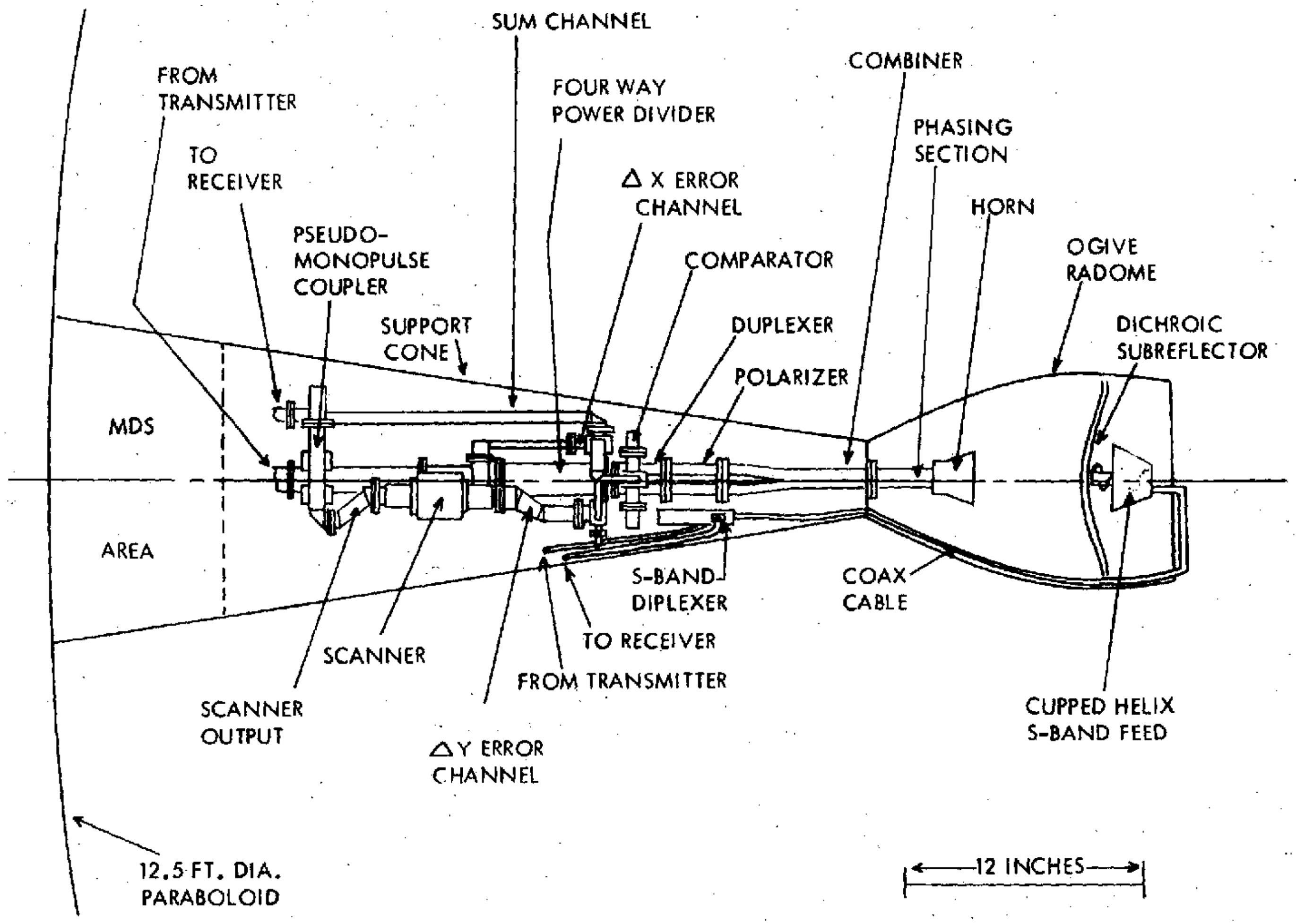


Figure 5.2.1-2. Tracking Cassegrain Ku-Band, Nontracking Apex S-Band Feed Layout

no greater than 0.3 dB loss in the reflective band (Ku-band) and less than 0.1 dB loss in the transmissive band (S-band). The design is amenable to subreflector shaping (as opposed to maintaining a conventional hyperboloid) to achieve greater spillover/amplitude taper ($\eta_{sp}\ \eta_{at}$) efficiency. Spillover/amplitude taper efficiencies in excess of 80 percent have been measured with this technique.

The Ku-band system features the 13-wavelength diameter, dichroic, shaped subreflector mentioned above and a single channel (pseudomonopulse) tracking waveguide circuit in which the received sum channel is modulated sequentially by the x- and y-axis error signals via an electronic scanner. The error signals are subsequently demodulated at the receiver and used for pointing the antenna.

As shown in the block diagram, the transmit signal is coupled through the rotary joints to a power splitter and then to orthomode transducers (duplexers) which serve to maintain about 20 dB isolation between the transmit and receive signals presented to the comparator. This isolation mainly results from the orthogonality of the two polarizations of the receive and transmit signals. An additional 80 to 100 dB of isolation can be provided in the bandstop filter located ahead of the preamplifier. The transmit signals are properly polarized, that is right- or left-hand circular, and then presented to the four-part choked, or corrugated, horn feed.

The received signals present in the four channels are passed through the polarizers and diplexers and presented to the comparator. The comparator develops a sum channel comprised of the sum of the four received signals, and two difference channels corresponding to the difference between the signals in the x and y directions. The scanner sequentially gates the difference channels onto the sum channel via the coupler which consequently modulates the sum channel by the error, or difference, signal. After bandpass filtering the modulated received signal is amplified in a preamplifier, typically a parametric amplifier, and presented at the output connector through the rotary joints.

Several variations on this general concept are possible. For example, the preamplifier may not be necessary in the final configuration, the rotary joints may be replaced by flexible cables especially at S-band frequencies, full monopulse requiring three channels with three receivers may be used instead of the pseudomonopulse, and only two up-down channels (one at S-band and one at Ku-band) may be desired with the result that the duplexers and diplexers may be deleted from the diagram. However, the configuration presented is a likely candidate and will be analyzed in the following section.

<u>Gain and Efficiency Budgets</u>

In Table 5.2.1 budgets for both S-band and Ku-band receive and transmit channel gain and efficiency are presented. The values presented include all elements of the antenna including the rotary joints for the x-y gimbal.

Table 5.2.1

Efficiency Factors	S-Band		Ku-Band	
	Rec	Xmit	Rec	Xmit
Spillover/Amplitude Taper Efficiency	.650	.650	.800	.800
Primary Phase Efficiency	.970	.970	.980	.980
Blockage Efficiency	.957	.957	.981	.981
Primary Cross-Polarization Efficiency	.998	.998	.990	.990
Secondary Cross-Polarization Efficiency	.978	.978	.999	.999
Dichroic Loss Efficiency	.980	.980	.940	.940
A. Illumination Efficiency	.577	.577	.715	.715
Surface Tolerance Efficiency	.999	.999	.870	.870
RF Reflectivity	.995	.995	.980	.980
B. Reflector Efficiency	.994	.994	.853	.853
Horn and Polarizer Loss Efficiency	--	--	.978	.978
Diplexer Loss Efficiency	--	--	.994	.994
Four-Way Power Divider Loss Efficiency	--	--	--	.985
Comparator Loss Efficiency	--	--	.982	--
Coupler Loss Efficiency	--	--	.937	--
Bandpass Filter Loss Efficiency	--	--	.966	--
Rotary Joint Loss Efficiency	--	.978	--	.955
Waveguide Loss Efficiency	--	--	.946	.995
Diplexer Loss Efficiency	.933	.933	--	--
Coaxial Cable Loss Efficiency	.938	.938	--	--
Cupped Helix Feed Loss Efficiency	.995	.995	--	--
Mismatch and Axial Ratio Loss Efficiency	.970	.970	.978	.978
C. Loss Efficiency	.845	.826	.799	.890
Overall Efficiency (A x B x C)	.485	.474	.487	.542
Midband Gain (dB)	35.2	35.8	52.3	52.1
Half-Power Beam Width (Degrees)	2.64	2.42	0.36	0.39

5.2.2 Nested Ku-Band and S-Band Apex Feed

A dual frequency feed concept is described in this section employing apex-mounted Ku-band and S-band nested feeds. Single channels are implemented for both bands. The feed is configured to mate with a 12.5-foot rib- and mesh-reflector.

Description

The feed system consists of the components shown in the block diagram of Figure 5.2.2-1 and the sketch of the feed layout, Figure 5.2.2-2. The Ku-band horn is mounted within the S-band coaxial-cavity feed at the apex. The four ports of the S-band feed are phased and summed in a hybrid and balun network to provide a single channel which may be right- or left-hand circular polarized. A diplexer separates the received signal from the transmitted signal allowing a preamplifier to be placed in the receive channel ahead of the long coaxial cable run and the rotary joints. The transmitted signal is also passed through the rotary joints and low-loss coaxial cable. The rotary joints for this concept are identical to those described for the other feed concept.

The Ku-band system is similarly configured. A choked horn and polarizer is connected to a waveguide diplexer where the transmit and receive signals are separated. Right- or left-hand polarization may be obtained. A preamplifier is provided ahead of the rotary joints and waveguide runs.

It is intended in this concept that self-tracking in the Ku-band be accomplished through the use of a step-tracking technique. Such a technique has been extensively studied at Radiation and utilized in ground antenna systems. The technique consists basically of sensing the change in received signal amplitude which occurs when the antenna is steered in small increments, both in the x and y direction, and developing the necessary tracking signals. Stepping algorithms can be developed for maximizing the tracking capability under the expected operational constraints.

Several variations on this basic configuration are also possible. Orthogonal transmit and receive polarizations may be obtained at Ku-band by providing a waveguide duplexer at the output of the horn and polarizer, and at S-band by simply taking both polarizations from the 3-dB hybrid instead of terminating the unused one. However, this involves doubling the number of cables and waveguide leading to the feed, therefore, increasing the feed blockage losses. The preamplifier may not be necessary in the final configuration and the rotary joints may possibly be replaced by flexible cables. The configuration described above will be considered in the following section where its gain and efficiency budgets are presented.

Gain and Efficiency Budgets

Table 5.2.2 presents a tabulation of the gain efficiency budgets for the nested Ku- and S-band apex feed system described above. The performance of the transmit and receive channels for both frequency bands is detailed.

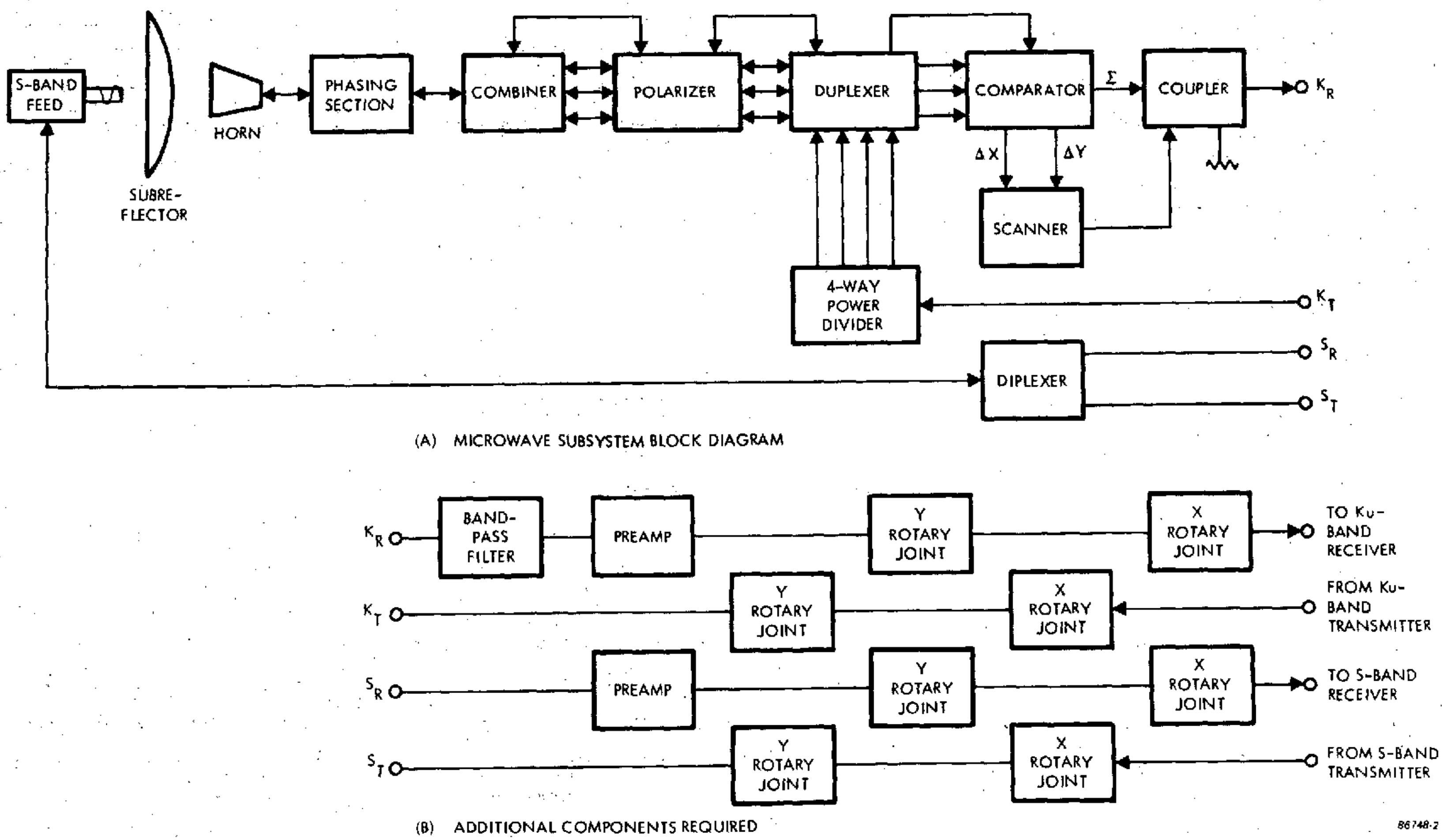


Figure 5.2.2-1. Nested Ku- and S-Band Apex Feed

Table 5.2.2

Efficiency Factor	S-Band		Ku-Band	
	Rec	Xmit	Rec	Xmit
Spillover/Amplitude Taper Efficiency	.680	.680	.620	.620
Primary Phase Efficiency	.970	.970	.970	.970
Blockage Efficiency	.957	.957	.957	.957
Primary Cross-Polarization Efficiency	.998	.998	.998	.998
Secondary Cross-Polarization Efficiency	.978	.978	.978	.978
A. Illumination Efficiency	.616	.616	.562	.562
Surface Tolerance Efficiency	.999	.999	.870	.870
RF Reflectivity	.995	.995	.980	.980
B. Reflector Efficiency	.994	.994	.853	.853
Feed Loss Efficiency	.991	.991	.995	.995
Diplexer Loss Efficiency	.933	.933	.985	.985
Waveguide Loss Efficiency	---	---	.940	.940
Coaxial Cable Loss Efficiency	.938	.938	---	---
Rotary Joint Loss Efficiency	---	.978	---	.955
Phasing Network Loss Efficiency	.912	.912	.990	.990
Mismatch and Axial Ratio Loss Efficiency	.960	.960	.978	.978
C. Loss Efficiency	.759	.743	.892	.852
Overall Efficiency (A x B x C)	.465	.455	.428	.408
Midband Gain (dB)	35.0	35.7	51.7	50.8
Half-Power Beamwidth (degrees)	2.64	2.42	0.37	0.40

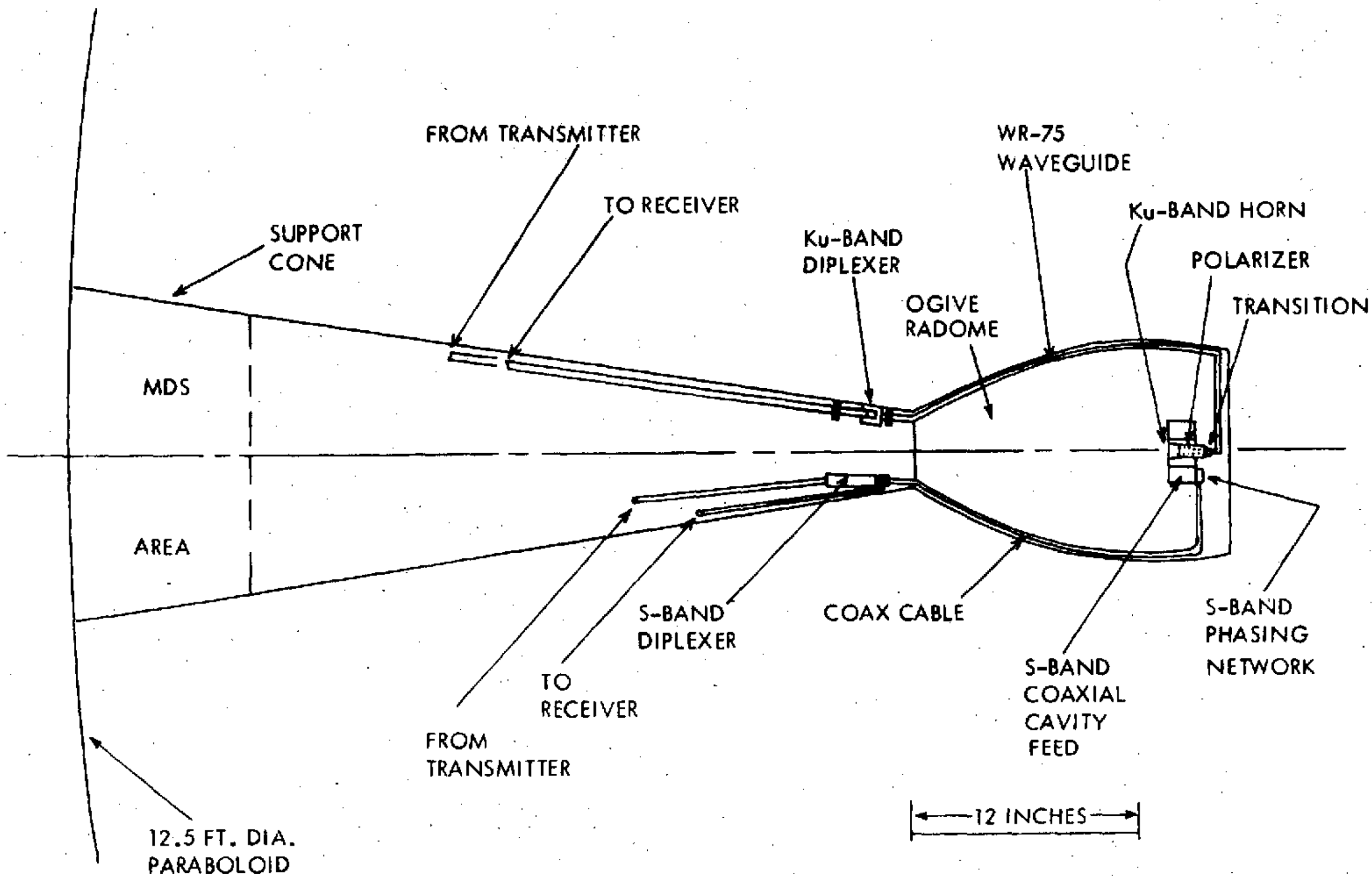


Figure 5.2.2-2. Nested Ku- and S-Band Apex Feed Layout

5.3 Pointing Mechanism Study

This section describes a candidate gimbal design approach for a dual-frequency, dual-tracking, S- and Ku-band antenna system. The dual frequency system utilizes a 12.5-foot diameter antenna with open loop (or program) tracking in S-band and closed loop (pseudomonopulse) tracking in Ku-band. The gimbal design utilizes the TDRS location and ephemeris patterns to minimize the "keyhole" problem and thus simplify the design. The design requirements and the candidate design and its associated control and torquing devices are described in the following paragraphs.

5.3.1 Design Performance Considerations

5.3.1.1 Viewing Angle Requirements

Figure 5.3.1.1 shows the kinematic information relating to the TDRS performance. The maximum viewing angle at 10,000 km (5400 nmi) is 24^{o} from nadir and represents a total field of view cone of 48^{o}. An x-y gimbal configuration, with the axes of rotation at right angles to one another and to the nominal LOS, is preferred for these viewing requirements. Such an x-y mount totally eliminates the "keyhole" problem and does not require unlimited angular freedom. This is an important feature since it eliminates the requirement for slip rings to provide gimbal control signals and power on the outer gimbal on the antenna.

5.3.1.2 Antenna Rates

The basic angular rates linking the TDRS to the user spacecraft are low (on the order of 0.75 radian per hour). Conditions which can increase these rates are slewing and improper choice of the gimbal configuration. Slewing is required when the antenna must sign off one satellite and acquire another. Since the minimum potential communication time to a user satellite is approximately 37 minutes, rapid slewing is not of great importance. A reasonable slew rate is about 0.1 radian per second. This rate allows the entire field of view to be scanned in 10 seconds.

An unknown in the determination of the maximum drive rates is the angular motion of the TDRS spacecraft and the deflections in the antenna support structure. These rates are assumed to be less than the 0.1 radian per second allowed for slewing.

5.3.1.3 Antenna Accelerations

An evaluation of the antenna accelerations and their effects was made based on an antenna inertia of 1.5 feet/pound/second^2 and a peak acceleration during slew of 0.1 radian/second^2. These values yield a peak torque requirement of 0.15 foot/pound or 1.8 inches/pound. Coulomb friction is estimated to add 1.0 inch/pound to this torque requirement. The inertial torque

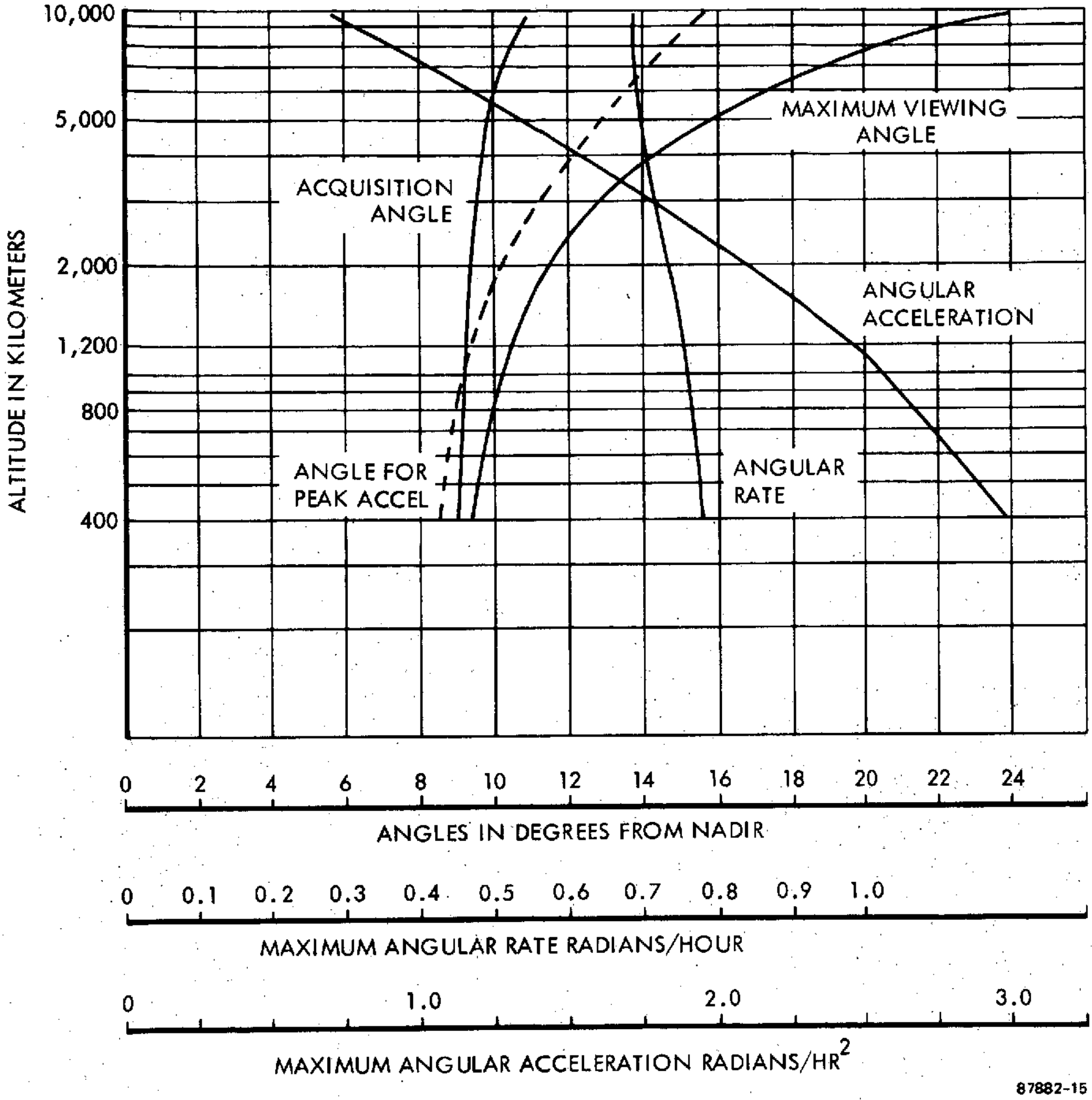


Figure 5.3.1.1. Tracking Data Relay Satellite Kinematic Information

should have negligible effect on support structure bending. This is significant in that support structure bending is therefore almost exclusively a function of the spacecraft motion.

5.3.1.4 Drive Requirements

The gimbal drive requirements were based on the following parameters:

Maximum Torque:	2.5 inches/pound
Maximum Velocity:	0.1 radian/second

The use of a gear train is favored for this combination of torque and speed. The drive may be provided by a dc motor, an ac motor, or a stepper motor. The characteristics of these approaches are shown in Table 5.3.1.4.

Table 5.3.1.4. Candidate Drive System Characteristics (Requirements are Per Axis for Nonredundant System)

Parameter	DC Motor	AC Motor	Stepper	
Power	5	5	10	Watts
Weight				
Motor	2.3			Ounces
Tach	2.3	2.0	3.0	Ounces
Gear Train	4.0	7.0	6.0	Ounces
Total	8.6	9.0	9.0	Ounces
Gear Ratio	40:1	4500:1	1500:1	

The life of the motor brushes in the dc motor and the life of the ac motor and stepper motor gear train are on the order of 5 years in currently available hardware (from firms making space qualified hardware). Since it is entirely likely that a failure may occur in this time span, redundancy should be given some consideration. The prime wear points on the dc motor are the brushes, and any rotation of the motor causes wear, even if the motor is not operating. A method of achieving redundancy in any of these configurations is a differential gear and brake arrangement.

5.3.1.5 Antenna Pointing

The antenna must be pointed prior to acquisition. The transmission 3σ pointing requirements for a 6.5-foot diameter dish are 0.33° at 15 GHz. The acquisition 3σ pointing requirements are somewhat wider at 0.5°. In order to point the antenna within the accuracy requirements, errors such as TDRSS position and attitude uncertainty, user satellite position uncertainty, and support structure deflection must be held under strict control. Providing these errors can be held to less than the pointing requirement, then some form of angular position transducer may be used to point the antenna.

Potentiometers, synchros, shaft encoders, and stepper motors may be used to perform this function. Potentiometers are easily implemented, however, wear characteristics limit their useful life to about two years in this application. Also, the angular accuracy of potentiometer systems is limited to about 0.3° (1σ). Synchros offer good accuracy and wear is limited to low power slip rings. The primary disadvantage of synchro systems is the electronic complexity required for digital-to-synchro conversion.

Optical encoders are currently the most accurate shaft position transducers and have no mechanical wear problem. The primary problem with optical encoders is light source life and, in general, the light source must be turned off when the antenna is not in a pointing mode. In this way, it is possible to achieve a useful life of 5 years. Stepper motors may be used to point antennas in that each step is angularly precise. The design used for the drive requirements portion of this section has a step size of 0.03° while maintaining a slew rate capability of greater than 6° per second. The disadvantages of stepper motors is their poor efficiency and interaction with structural resonance which exist in the zero to 200 pulse per second stepping range.

5.3.1.6 Unaided Acquisition

The normalized receiving and tracking gain curves for candidate antennas are shown in Figure 5.3.1.6. This figure shows that the acquisition beam width is about 30 percent wider than the 3 dB receiving beam width. The pointing requirements for the antenna are shown in Table 5.3.1.6-1. The acquisition half angle is the peak error which may occur. It should be noted that a 2° TDRSS attitude uncertainty will not be adequate for this approach. A TDRSS attitude uncertainty of 0.1° peak will allow the system to be pointed accurately with a budget of 0.182° for a 12-foot dish.

Table 5.3.1.6-1. Dish and Pointing Parameters

	12-Foot Dish	
Gain	53 dB	15 GHz
3 dB Beam Width	0.32°	
Acquisition Half Angle	0.208°	

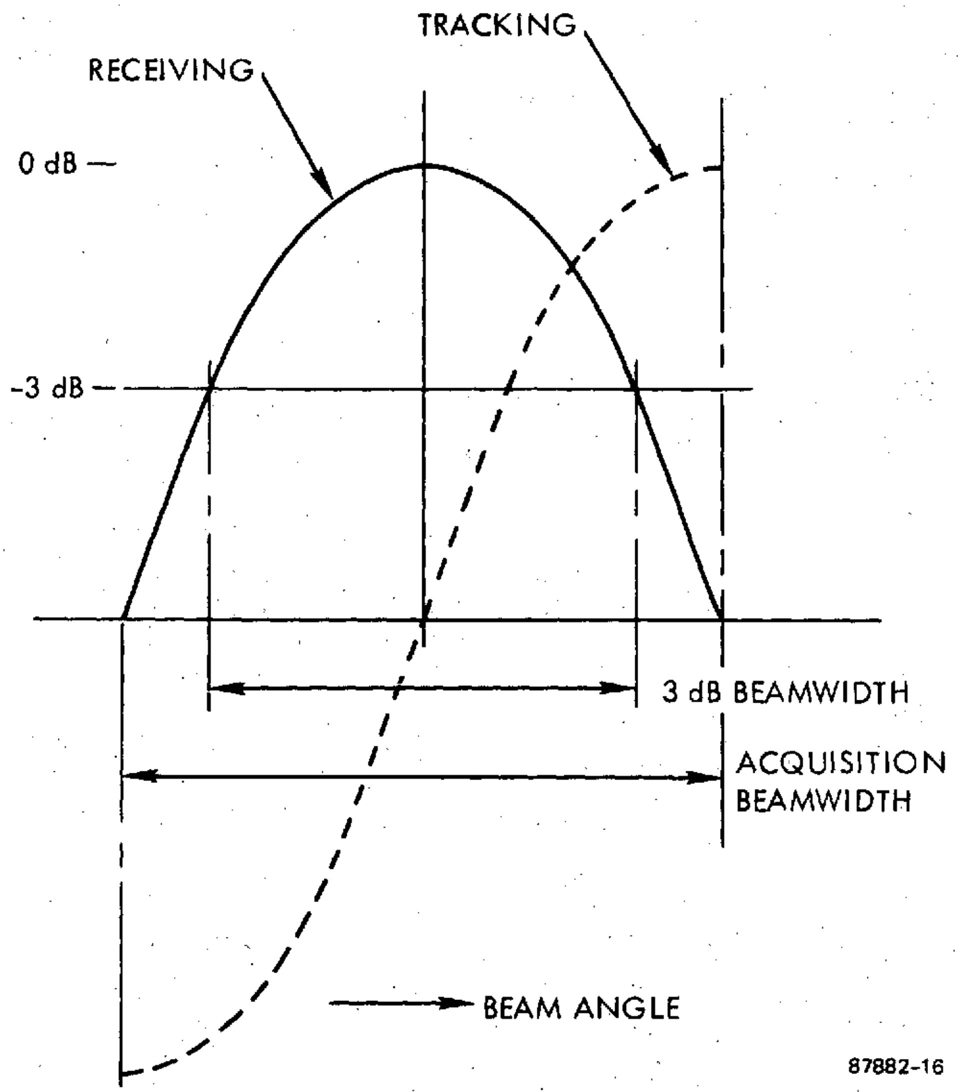


Figure 5.3.1.6. Normalized Receiving and Acquisition Curves

A candidate budget for the 12-foot dish pointing system would be:

User Uncertainty	0.10° (Ephemeris)
TDRSS Position Uncertainty	0.05°
Antenna Deflections and Servo	0.14°
RSS	0.182°

Total servo uncertainties can be held to 0.086° (peak) with a 13-bit encoder or a synchro with 5 minutes (peak) error. Both of these devices are well within the state-of-the-art with the synchro having the edge for long life space use.

A remaining consideration is the control power necessary for the 12-foot dish. True, the inertia of the antenna approximates between the square and the cube of the diameter, however, the inertia loads are insignificant at the angular rates considered for the TDRSS as shown in Tables 5.3.1.6-2 and 5.3.1.6-3. It should also be kept in mind that the frictional loads on the antenna system are on the order of 5 to 10 ounces/inch.

Table 5.3.1.6-2. TDRSS Operation

Orbital Altitude	100 nmi	250 nmi	500 nmi
TDRSS Viewing Angle	17.86°	18.60°	19.90°
TDRSS Acquisition Angle	8.82°	8.93°	9.03°
Single TDRSS Availability	48.5%	54.0%	58.4%
Maximum TDRSS Rate	0.00626°/sec	0.00618°/sec	0.00567°/sec
Approximate Maximum Acceleration	$5.85 \times 10^{-6\circ}/\text{sec}^2$	$5.15 \times 10^{-6\circ}/\text{sec}^2$	$4.64 \times 10^{-6\circ}/\text{sec}^2$

Table 5.3.1.6-3. Antenna Torque Loads

	12-Foot Dish
Inertia	1100 oz/in/sec^2
Acceleration	10^{-7} radians/sec^2
Torque	1100×10^{-7} oz/in

S-Band Aided Acquisition

A second method of acquisition using S-band in place of the Ku-band for acquisition has good overall qualities as shown in Table 5.3.1.6-4.

Table 5.3.1.6-4. S-Band Dish and Pointing Parameters

	12-Foot Dish	
Gain	37.4 dB	
3 dB Beam Width	1.92°	2.5 GHz
Acquisition Half Angle	1.25°	

The 12-foot antenna requires TDRSS uncertainties on the order of 1° and defocusing will be required to broaden the acquisition half angle to greater than 2.25°. This defocusing is easily accomplished at the 37.4 dB gain level.

5.3.2 Description of Candidate Design

One candidate design for the TDRSS antenna is a stepper motor (such as Kearfott or MPC) in a braked differential configuration. This approach offers minimum electronic complexity at the expense of increased power. Figures 5.3.2-1 through 5.3.2-4 show block diagrams for both the servo approach and the stepper motor (open loop) approach. Figure 5.3.2-5 shows the proposed x-y gimbal configuration. If the stepper motor is used redundantly in this configuration, an overall weight for the gimbal structure of 6 pounds is projected.

An accompanying dual redundant electronics package is required to provide the necessary drive and is preferably mounted back on the spacecraft proper. The weight of this unit is approximately 7.5 pounds. The unit controls both the x and y axes.

The power for the stepper motor approach is 8 watts to drive each motor, 4 watts to release the differential brake, and 4 watts dissipation in the electronics. This results in a total power requirement of 24 watts.

The slewing requirements of the antenna introduce a maximum momentum transfer to the spacecraft of 0.15 foot/pound/second for a maximum of 10 seconds (at which time a cancelling momentum impulse occurs). In a passive spacecraft with a moment of inertia of 230 feet/pound/second^2 this represents an angular offset of 0.3°.

The stepper motor approach allows the antenna to be stopped and effectively braked when the power is removed from the drive mechanism.

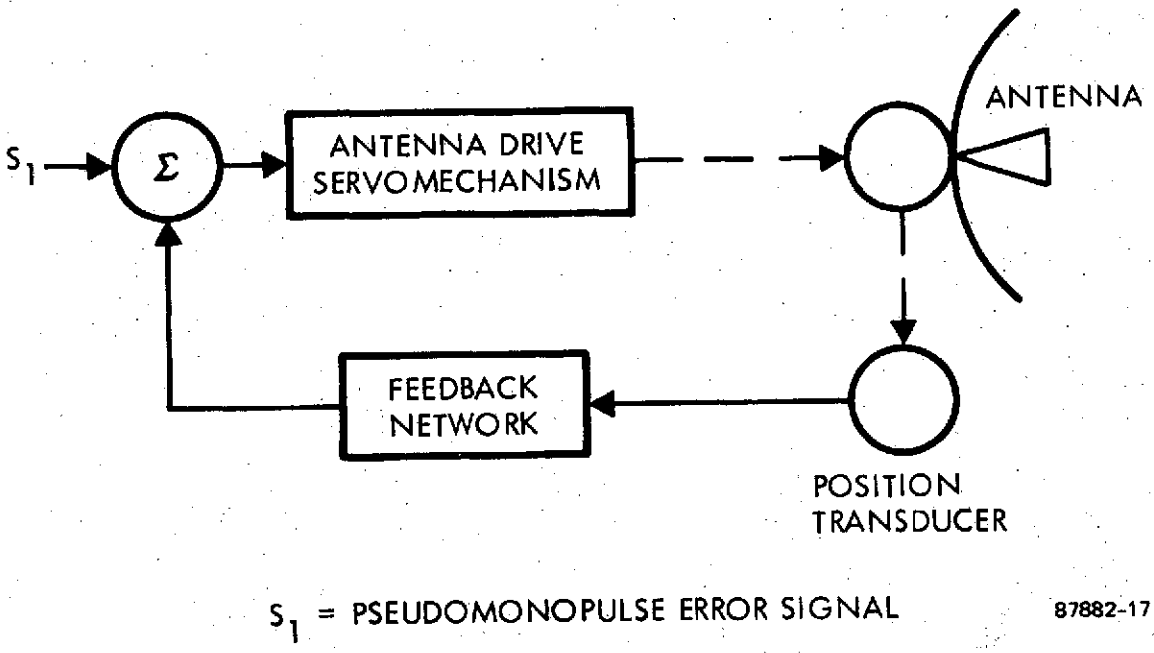


Figure 5.3.2-1. Block Diagram for Antenna Servo in the Tracking Mode

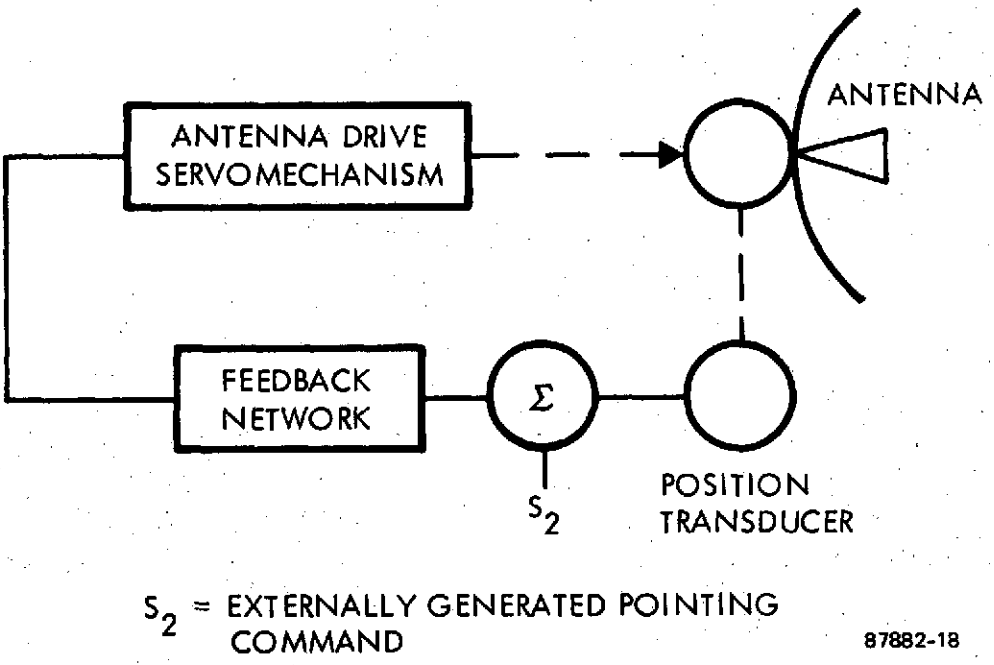


Figure 5.3.2-2. Block Diagram for Antenna Servo in the Pointing Mode

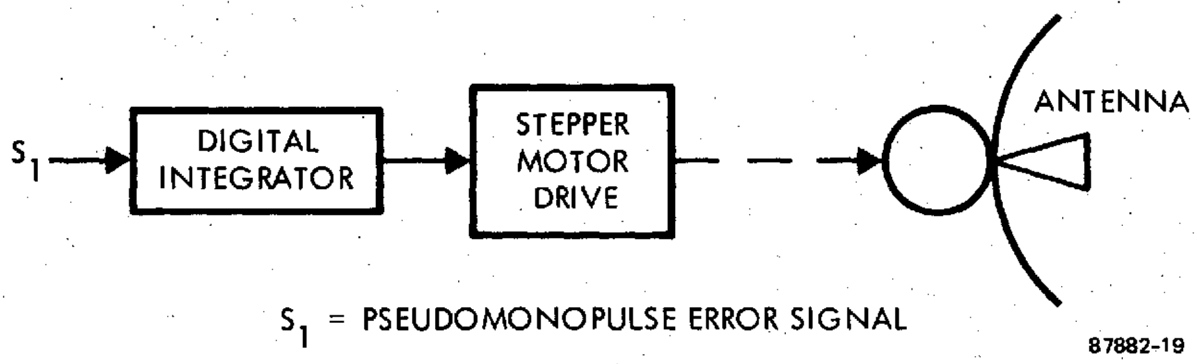


Figure 5.3.2-2. Block Diagram for Stepper Motor in Tracking Mode

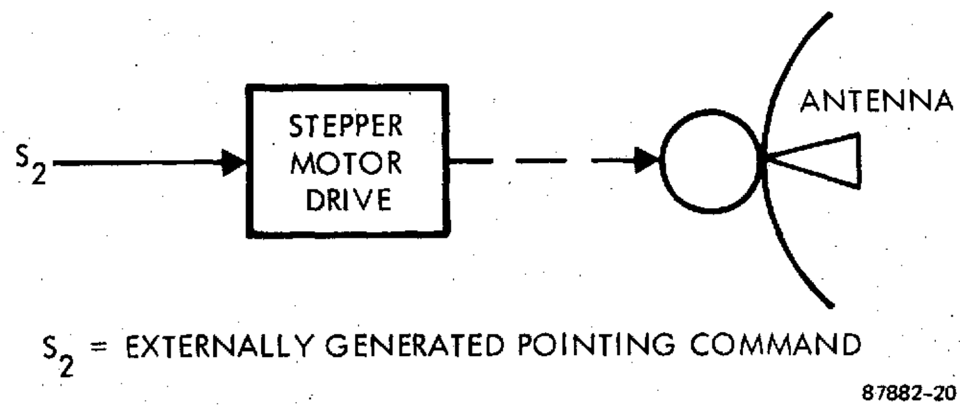


Figure 5.3.2-4. Block Diagram for Stepper Motor in Pointing Mode

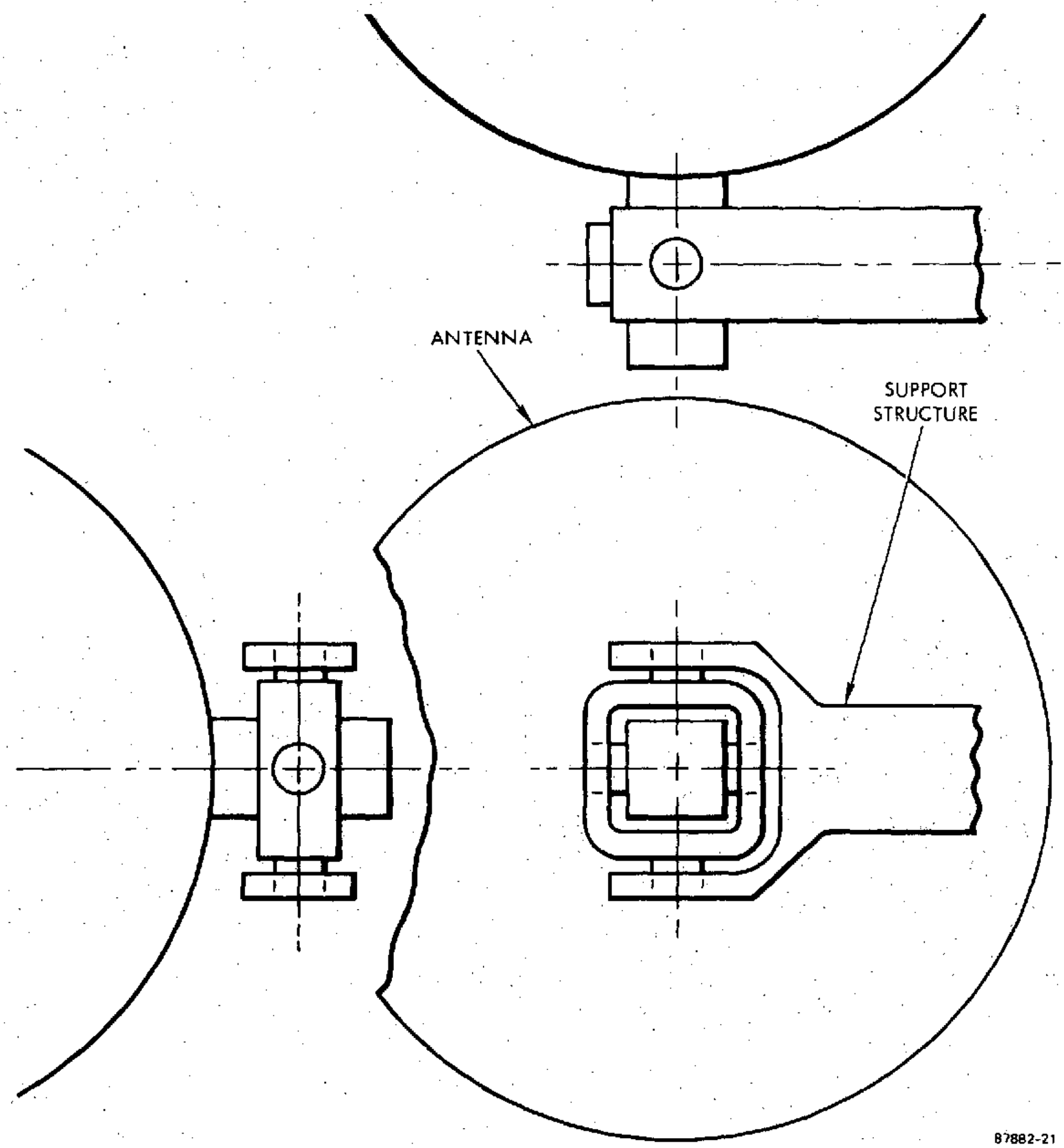


Figure 5.3.2-5. Gimbal Configuration

5.4 Reflector Weight and Surface Accuracy

Based on the measured results achieved on the present program, weight and surface error values were developed for reflectors from six (6) to thirty (30) feet in diameter.

Figure 5.4-1 presents rms surface error as a function of reflector diameter for reflectors up to 30 feet in diameter. The surface error values shown represent the total rms surface error for the orbital condition. These values are based on analyses of the thermal and gravity associated errors and an extrapolation of the manufacturing error based on rib stiffness, mesh stiffness, and number of ribs.

Figure 5.4-2 presents weight as a function of reflector diameter for the double mesh design. The weight values shown represent an extrapolation of the present 12.5-foot diameter design to the larger and smaller diameters.

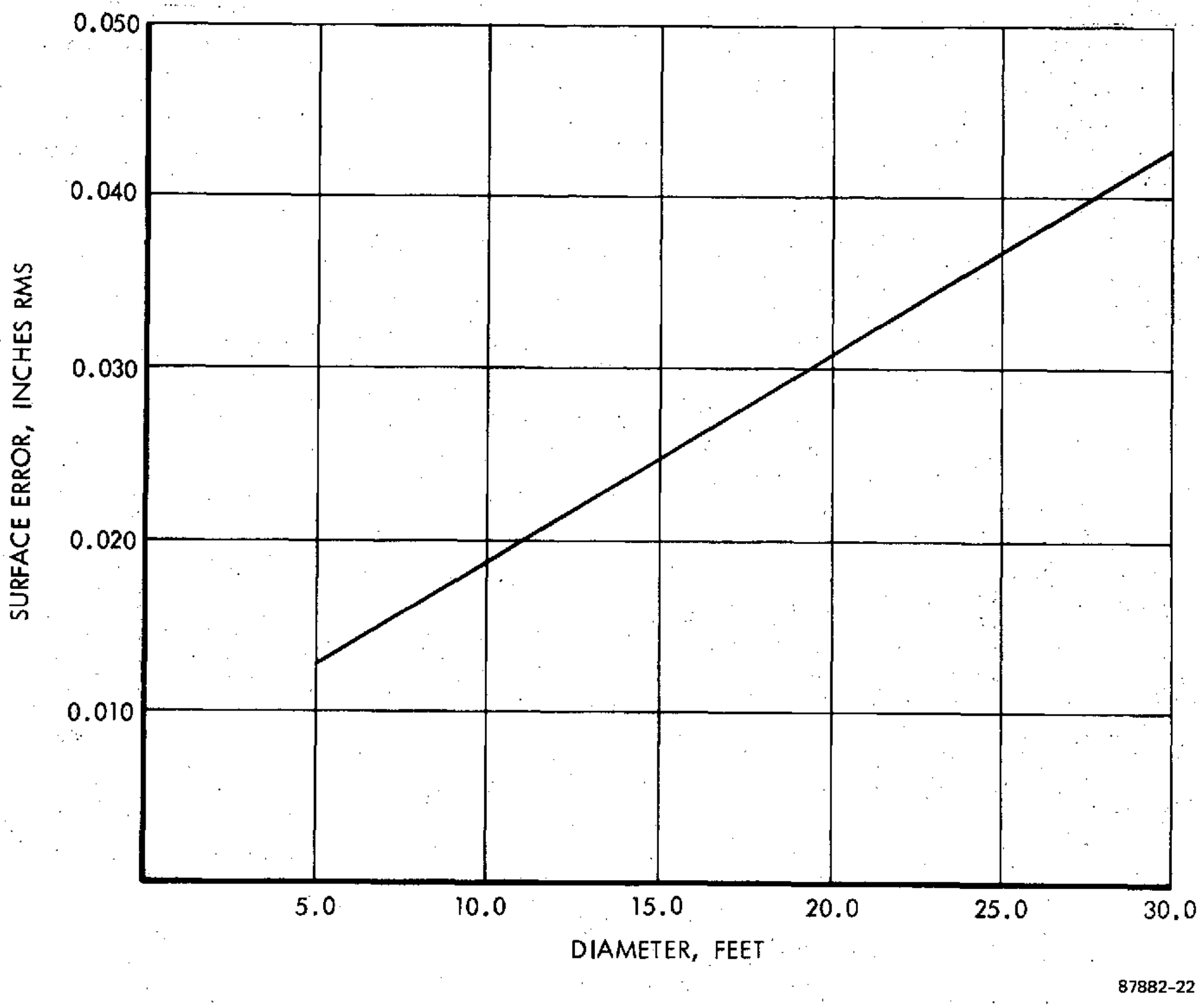


Figure 5.4-1. Orbital RMS Surface Error as a Function of Reflector Diameter

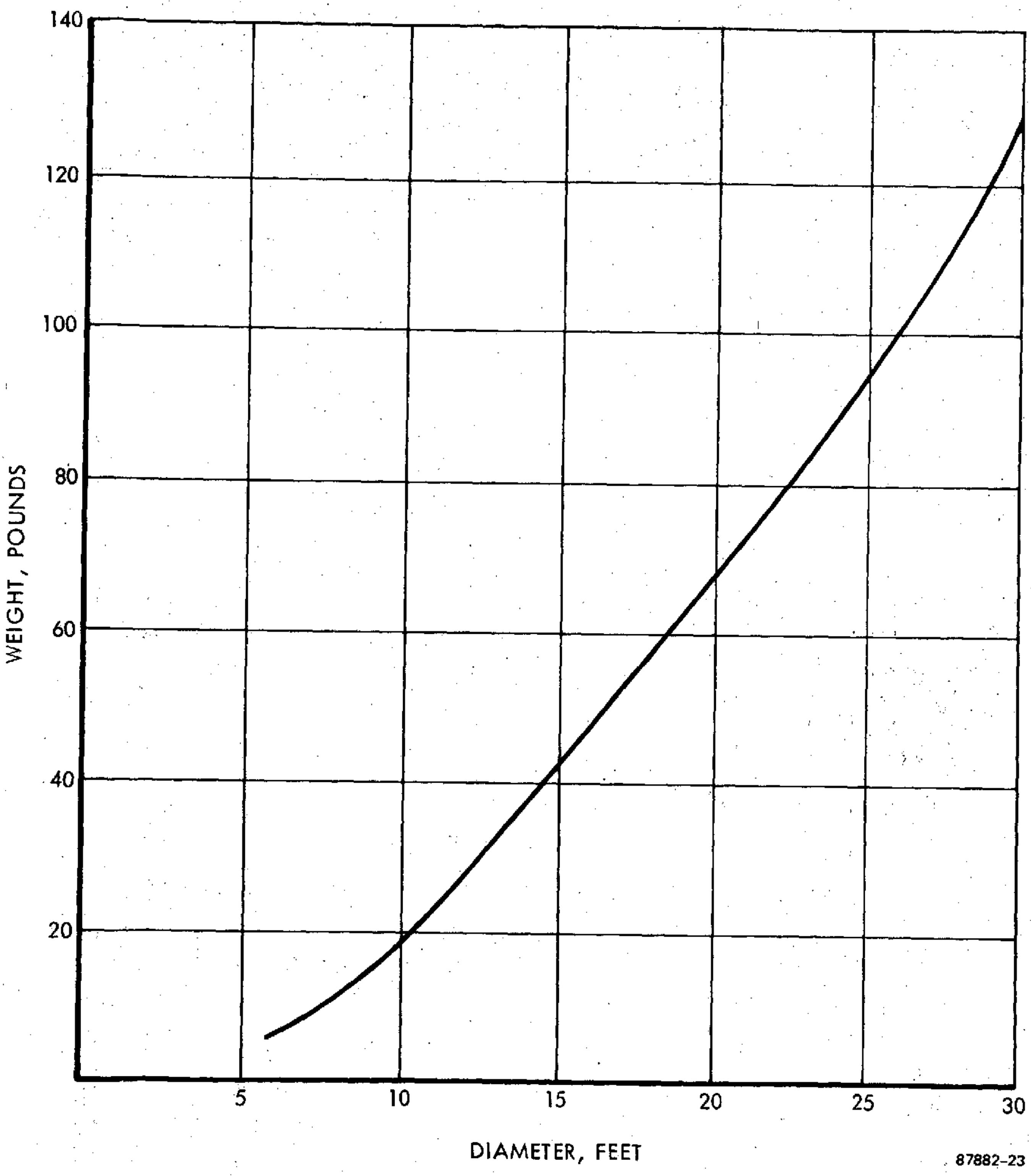


Figure 5.4-2. Antenna Weight (Excluding Feed) as a Function of Reflector Diameter

SECTION 6.0

CONCLUSIONS AND RECOMMENDATIONS

6.0 CONCLUSIONS AND RECOMMENDATIONS

This program has demonstrated that the "rib-dominated" rib-and-mesh deployable reflector design concept is a viable approach for mission applications requiring deployable reflectors. The "double mesh" technique allows the achievement of surface accuracies consistent with Ku-band operation with lightweight (previous technology would have resulted in a reflector weight of no less than twice that achieved).

The test program conducted (RF, deployment, surface accuracy, and vibration) has resulted in a nearly "flight-qualified" design. The solar-thermal-vacuum tests planned by NASA after the reflector delivery will essentially complete the qualification. The high stiffness exhibited by the design in both the stowed and deployed conditions allows users to procure the reflector as a component, thereby reducing both analysis and test costs on applicable programs. The applicability of the design is demonstrated by its selection as the baseline design by both contractors in the recently completed TDRSS Definition Phase Studies (see References 2 and 3) and Figure 6.0.

TDRS BASELINE CONFIGURATION

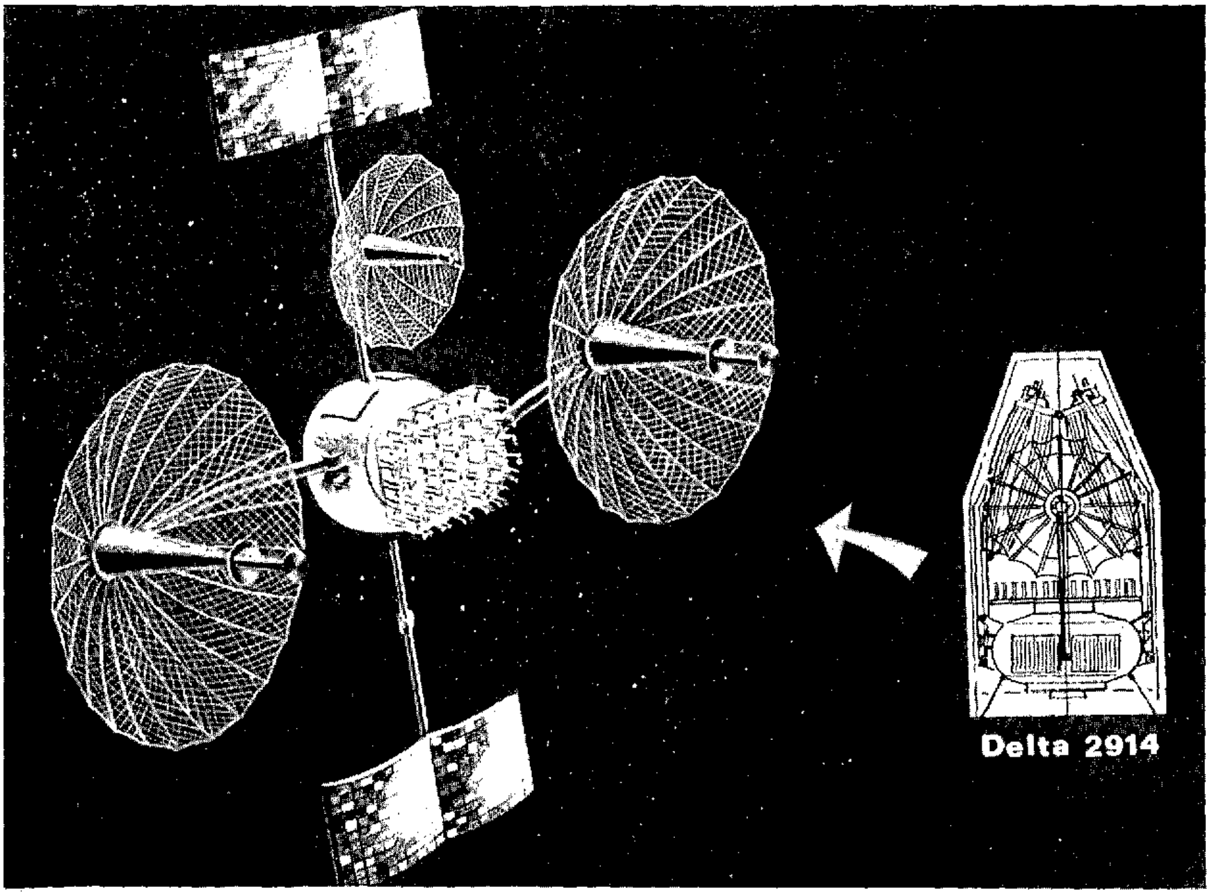


Figure 6.0. TDRS Baseline Configuration

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1. "Delta Launch Vehicle Interface and Environment," December 1970.

2. Tracking and Data Relay Satellite System Configuration and Tradeoff Study - Part II Final Report, Hughes Aircraft Company, Space and Communications Group, 1 April 1973.

3. Tracking and Data Relay Satellite System Configuration and Tradeoff Study, Part II, Final Report, Space Division, Rockwell International, April 1973.

APPENDIX A

DETAIL FABRICATION DRAWINGS

INDEX OF ENGINEERING DRAWINGS

INDEX OF ENGINEERING DRAWINGS (Continued)

INDEX OF ENGINEERING DRAWINGS (Continued)

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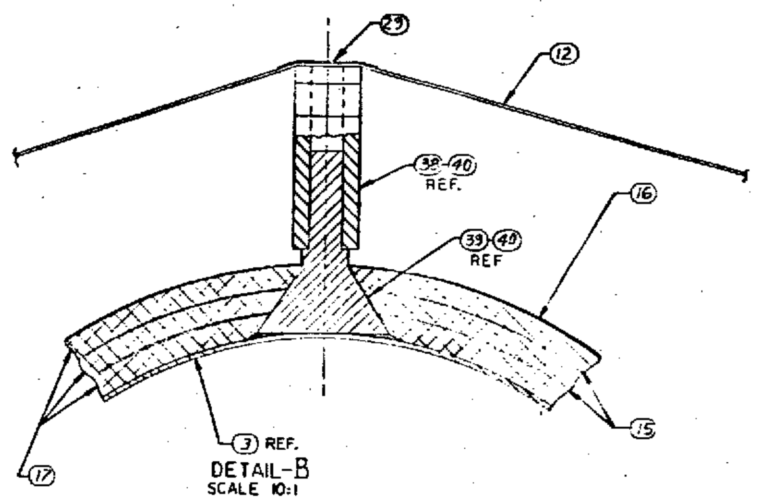
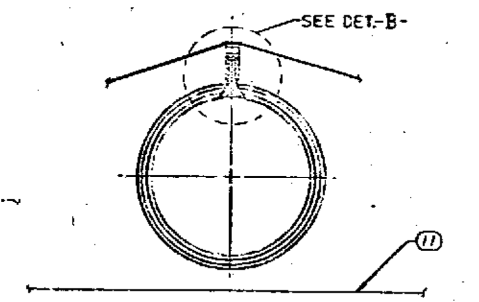
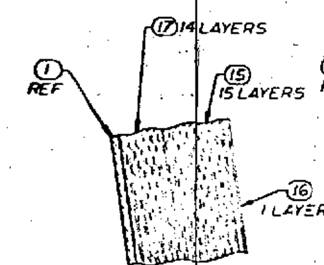
(Place holder)



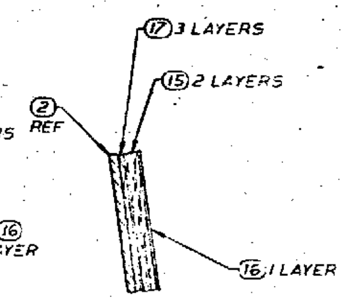
DETAIL-B
SCALE 10:1



SECTION-A-A (ROTATED 90°) SHEET-1
SCALE 2:1



DETAIL-D
SCALE: NONE
SHEET 1



DETAIL-E
SCALE: NONE
SHEET 1

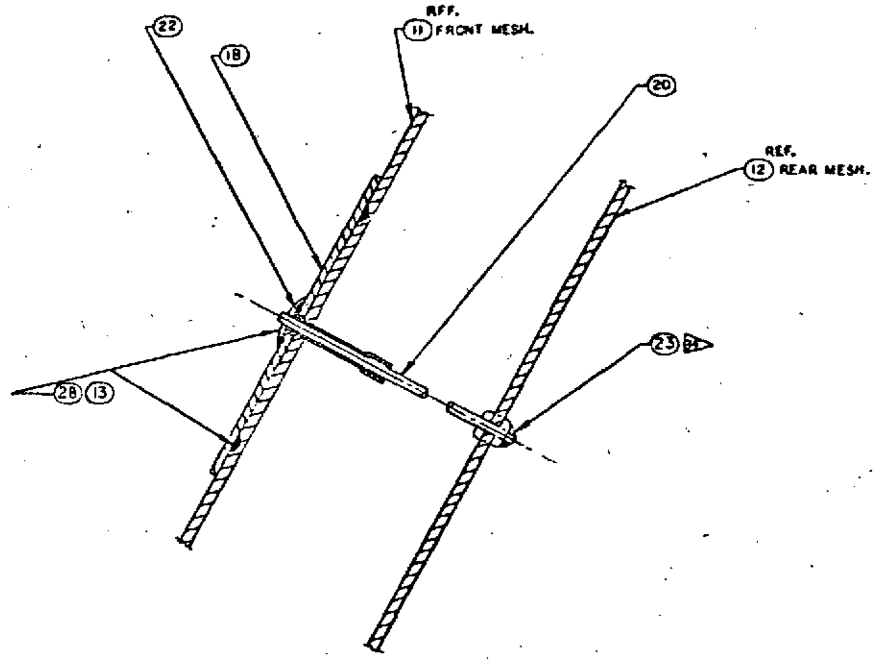
ENGRG DEV

QUANTITY REQUIRED	LIST OF MATERIALS OR PARTS LIST
	RADIATION INCORPORATED
TITLE	AAFE ANTENNA ASSY
SIZE / CODE IDENT NO	E 91417 615283

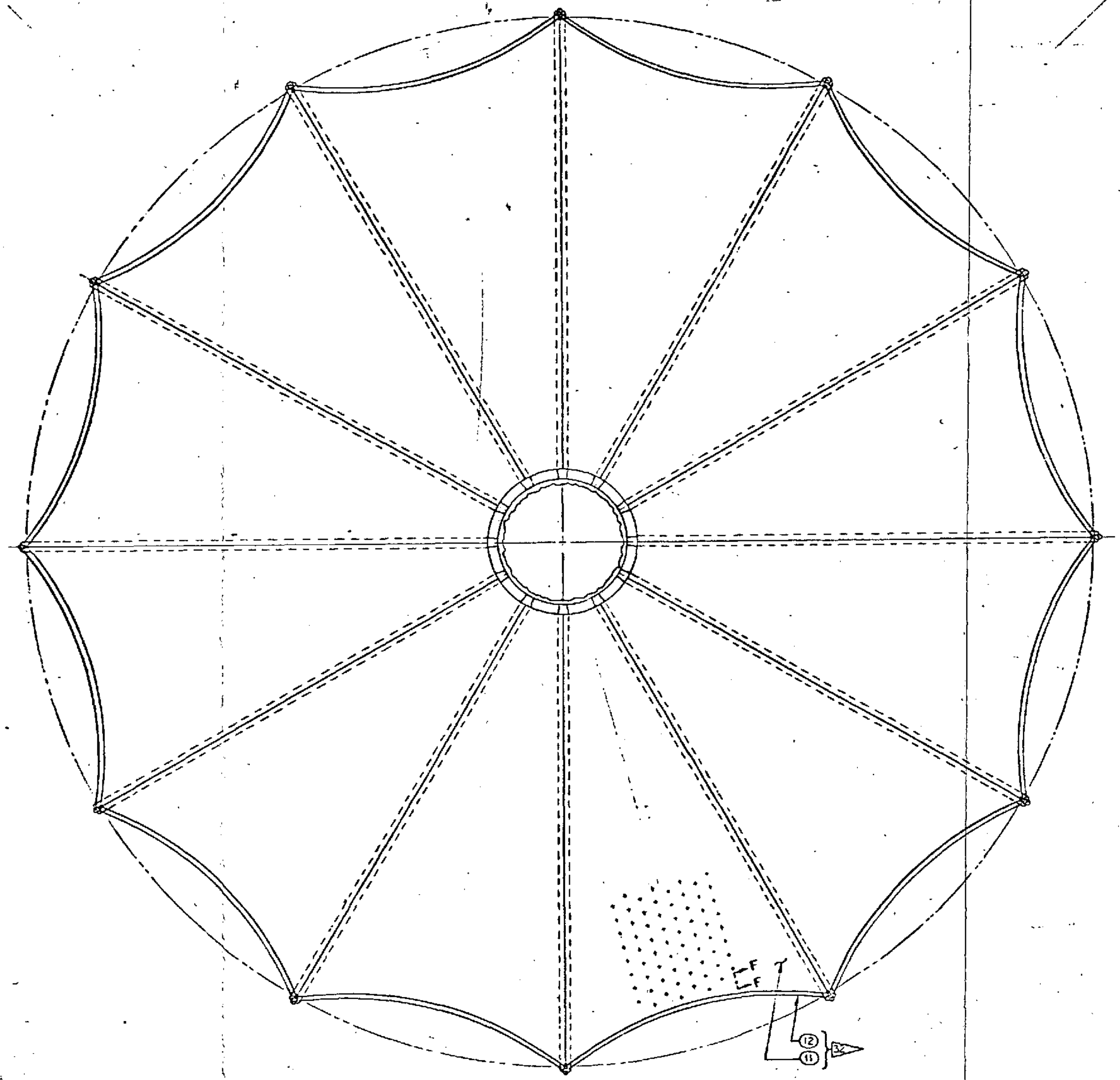
FOLDOUT FRAME 1

FOLDOUT FRAME 2

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



SECTION - F - F
SCALE 20:1



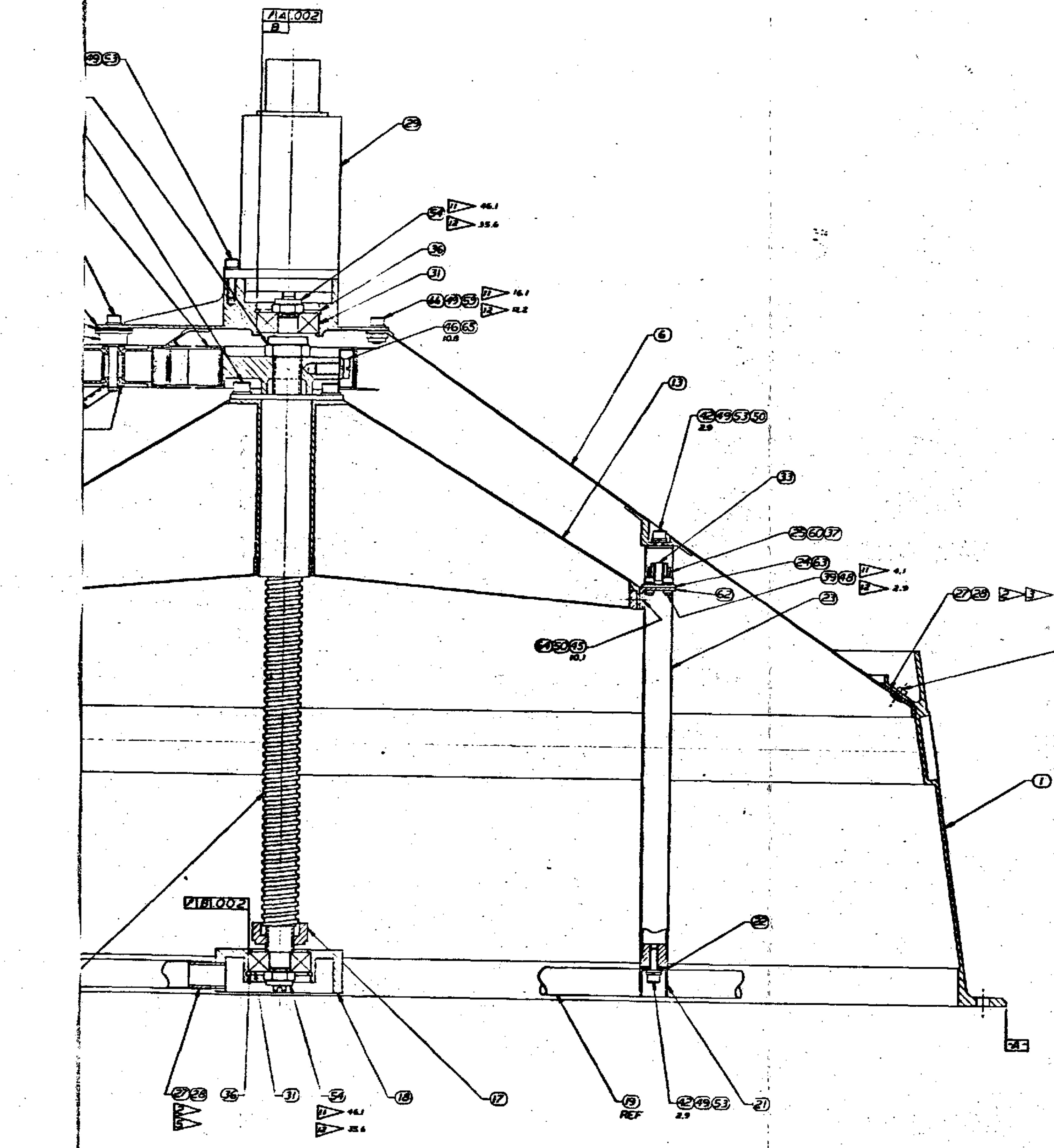
VIEW-C-C. SCALE 1:5
VIEW OF ANTENNA IN A DEPLOYED POSITION.

ENGRG DEV

RADIATION INCORPORATED

AAFE ANTENNA ASSY.

91417 615283



SECTION B-B
SCALE 2-1

NOTE:

1 - MARK 91417-615284G1 PER MIL-STD-130.

2 - BONDING IN ACCORDANCE WITH PROCESS SPEC 5762.

3 - APPLY EPOXY ITEMS 27 & 28 TO JOINTS BEFORE RIVETING.

4 - ALIGN CUTOUTS IN CONE (ITEM 6) WITH PIVOT ARMS (ITEM 2). USING CONE (ITEM 6) AS TEMPLATE DRILL HOLES FOR RIVETS. SEE RAD.-SPEC.7905

5 - ALIGN LOWER BEARING SUPPORT (ITEM 18) WITH TOP BEARING PLATE (ITEM 7) USING BALLSCREW (ITEM 12) BEFORE BONDING LOWER SUPPORT TUBE (ITEM 19) TO LOWER BEARING SUPPORT (ITEM 18) AND LOWER SUPPORT PADS (ITEM 20). SEE RAD.-SPEC.7905

6 - PURCHASED FROM MPC PRODUCTS CORP, CHICAGO, ILL.

7 - PURCHASED FROM HUNTER SPRING CO, HATFIELD, PENN.

8 - PURCHASED FROM BARDEN CORP, DANBURY, CONN.

9 - PURCHASED FROM MICRO SWITCH, FREEPORT, ILL.

11 - FIRST INSTALLATION TORQUE VALUE.

12 - AFTER OBTAINING FIRST INSTALLATION TORQUE, BACK OUT SCREW MINIMUM OF 5 TURNS AND RETORQUE TO NEW VALUE.

13 - ALL TORQUE VALUES TO BE IN IN.-LBS AND TOLERANCE TO BE ±10% OR .50 IN.-LB WHICHEVER IS LESS.

14 - MATERIAL: CORROSION RESISTANT STEEL WITH A TENSILE OF 170,000 PSI.

4	67	MS16995-C	SCREW, SOC. HD. CAP	4-40 x 5/8
8	66	MS16995-9	SCREW, SOC. HD. CAP	4-40 x 1/4
[illegible]	65	GRADE-A	LOCTITE MIL-S-22473, RED	
[illegible]	64	MS35338-136	WASHER, LOCK	NO. 6
1	63	421137-2	CLEVIS ANTI-TORQUE	
1	62	421220G1	BRKT ANTI-TORQUE	
12	61	421221-1	CLEVIS CARRIER	
4	60	308396-2	WASHER	
8	59	MS21083-C04	NUT LOCKING	NO. 4-40
12	58	MS20604AD3T1	RIVET BLIND 3/32 DIA	
8	57	MS21083-C06	NUT LOCKING	6-32
24	56	MS21083-C08		8-32
1	55	MS21083-C6		3/8-24
2	54	MS21083-C3	NUT LOCKING	10-32
57	53	MS35338-135	WASHER-LOCK	NO. 4
6	52	MS35338-134	WASHER-LOCK	NO. 2
[illegible]	51	NAS620-8	WASHER-FLAT	NO. 8
35	50	NAS620-6		NO. 6
57	49	NAS620-4		NO. 4
10	48	NAS620-2	WASHER-FLAT	NO. 2
24	47	MS16995-27	SCREW SOC HD CAP	8-32 x 3/8
1	46	MS35233-43	SCREW PAN HD	8-32 x 3/8
24	45	MS16995-17	SCREW SOC HD CAP	6-32 x 3/8
17	44	MS16995-11		4-40 x 1/2
[illegible]	42	MS16995-10		4-40 x 3/8
2	41	MS16995-4		2-56 x 1/2
4	40	MS16995-3		2-56 x 3/8
4	39	MS16995-1	SCREW SOC HD CAP	2-56 x 1/8
[illegible]	38	MS16633-4009	RETAINER RING	
5	37	MS16624-5012	RETAINER RING	
2	36	MS16625-4086	RETAINER RING	
2	35	JS-5	ACTUATOR	
2	34	M8805-8C	SWITCH	
2	33	SR144SS	BEARING	
2	32	SFR144SS	BEARING	
2	31	3755	BEARING	
1	30	40008	SPRING MOTOR	
1	29	04P400-19	DRIVE MOTOR	
[illegible]	28	117098-001	ADHESIVE	
[illegible]	27	111053-001	CURING AGENT-RESIN	
2	26	421185G1	BRACKET-SWITCH	
2	25	308373-1	SHAFT-ANTI-TORQUE	
1	24	421187-1	CLEVIS-ANTI-TORQUE	
2	23	421186G1	TUBE-ANTI-TORQUE	
2	22	308398-1	SHIM-ANTI-TORQUE TUBE	
2	21	421188-1	LOWER SUPPORT	
12	20	421191G1	PAD-LOWER SUPPORT	
12	19	308386-1	TUBE-LOWER SUPPORT	
1	18	421189G1	LOWER BEARING SUPPORT	
1	17	421236-1	STOP-LOWER	
24	16	308396-3	WASHER	
24	15	308390-1	SHAFT-ROD END	
12	14	534385G1	COMPRESSION ROD ASSY	
1	13	615287G1	CARRIER	
1	12	534066-1	BALLSCREW AND NUT ASSY	
1	11	534091-1	DRUM-OUTPUT	
1	10	534090-1	DRUM-TAKE-UP	
1	9	308383-1	SHAFT-TAKE-UP DRUM	
1	8	308384-1	SHIM-TAKE-UP SHAFT	
1	7	534381-1	TOP BEARING PLATE	
1	6	615217G1	CONE-SUPPORT [illegible] BEARING	
24	5	308396-4	WASHER	
24	4	308392-1	CLAMP-PIVOT SHAFT	
12	3	308359-1	SHAFT-PIVOT	
12	2	615277G1	PIVOT ARM	
1	1	615216G1	HUB	
G1				

QUANTITY REQUIRED

LIST OF MATERIALS OR PARTS LIST

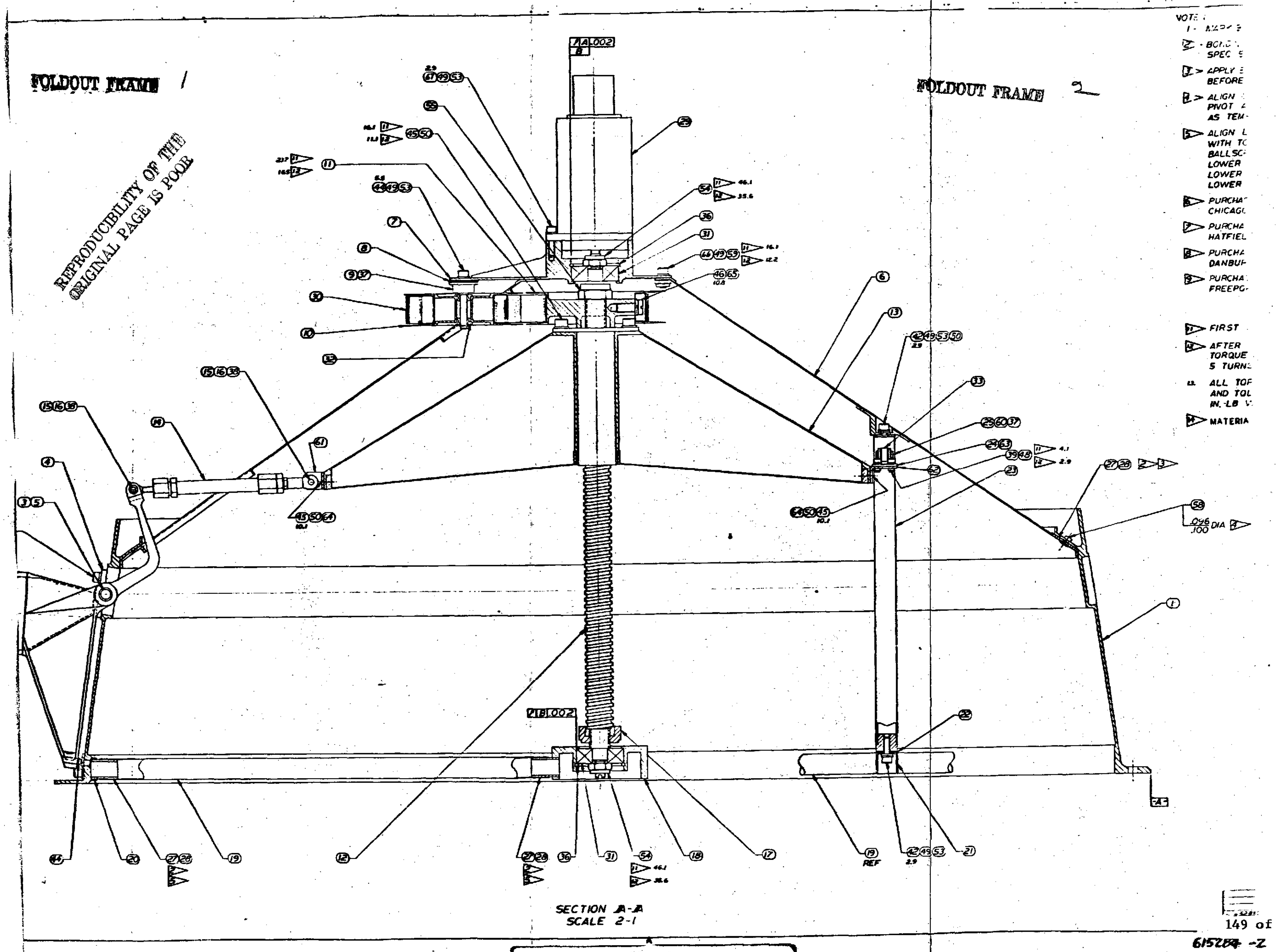
RADIATION INCORPORATED

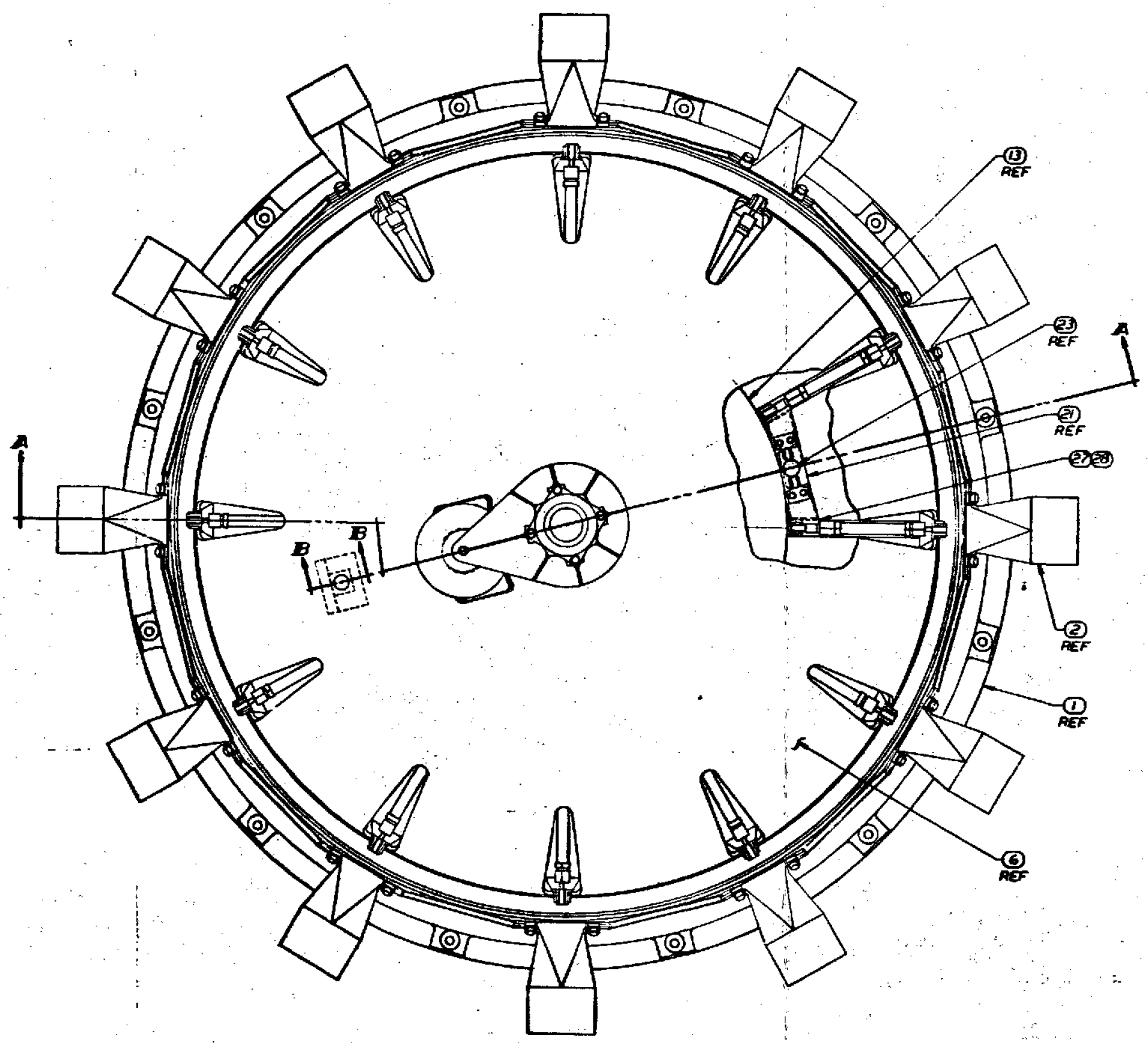
M D S ASSY

J 91417 615284

FOLDOUT FRAME 2

FOLDOUT FRAME 1


FOLDOUT FRAME 1
FOLDOUT FRAME 2
SECTION A-A
SCALE 2-1
PURCHA
FIRST
AFTER
TORQUE
5 TURNS
ALL TOR
MATERIA
615284-2



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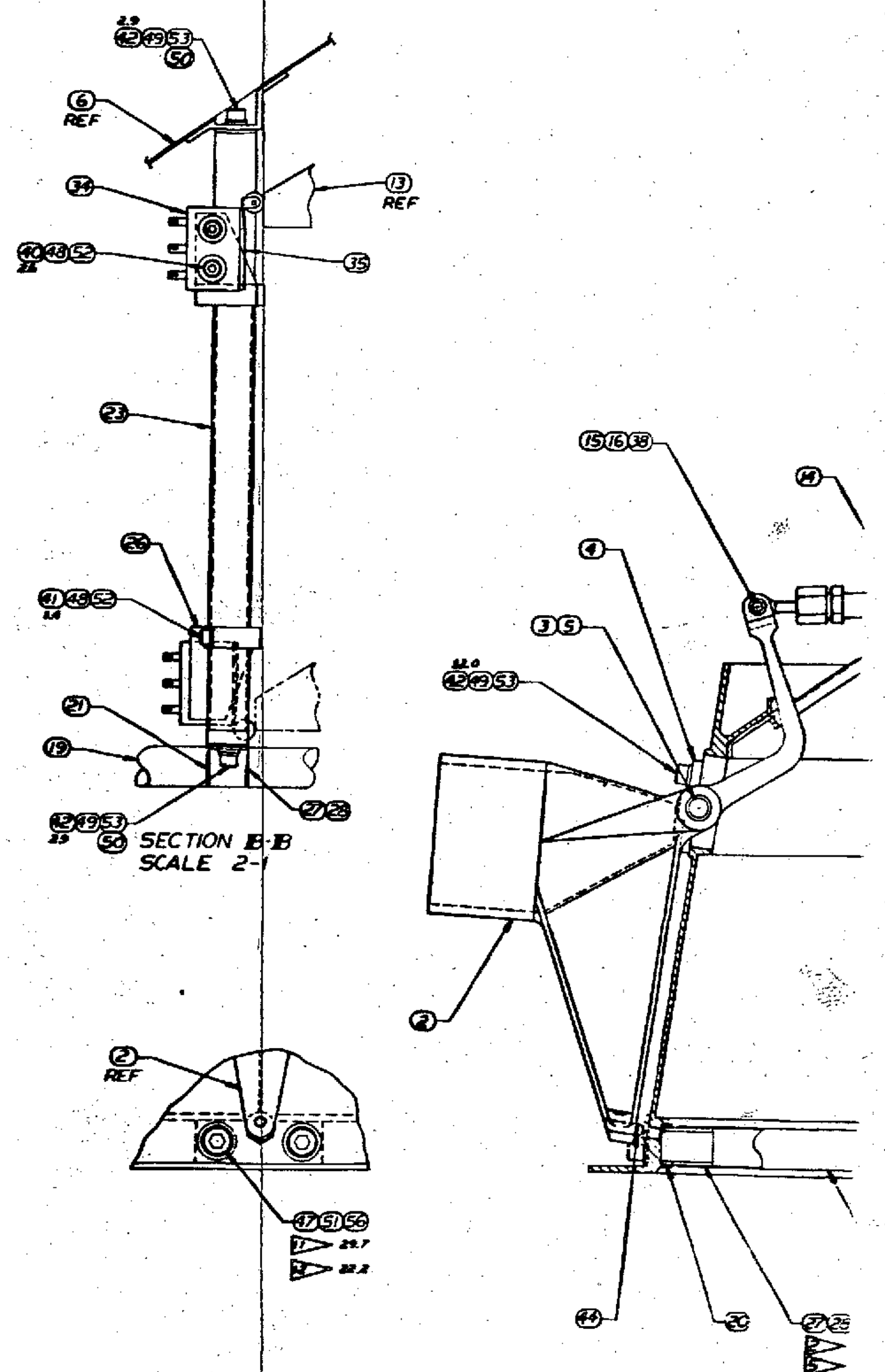

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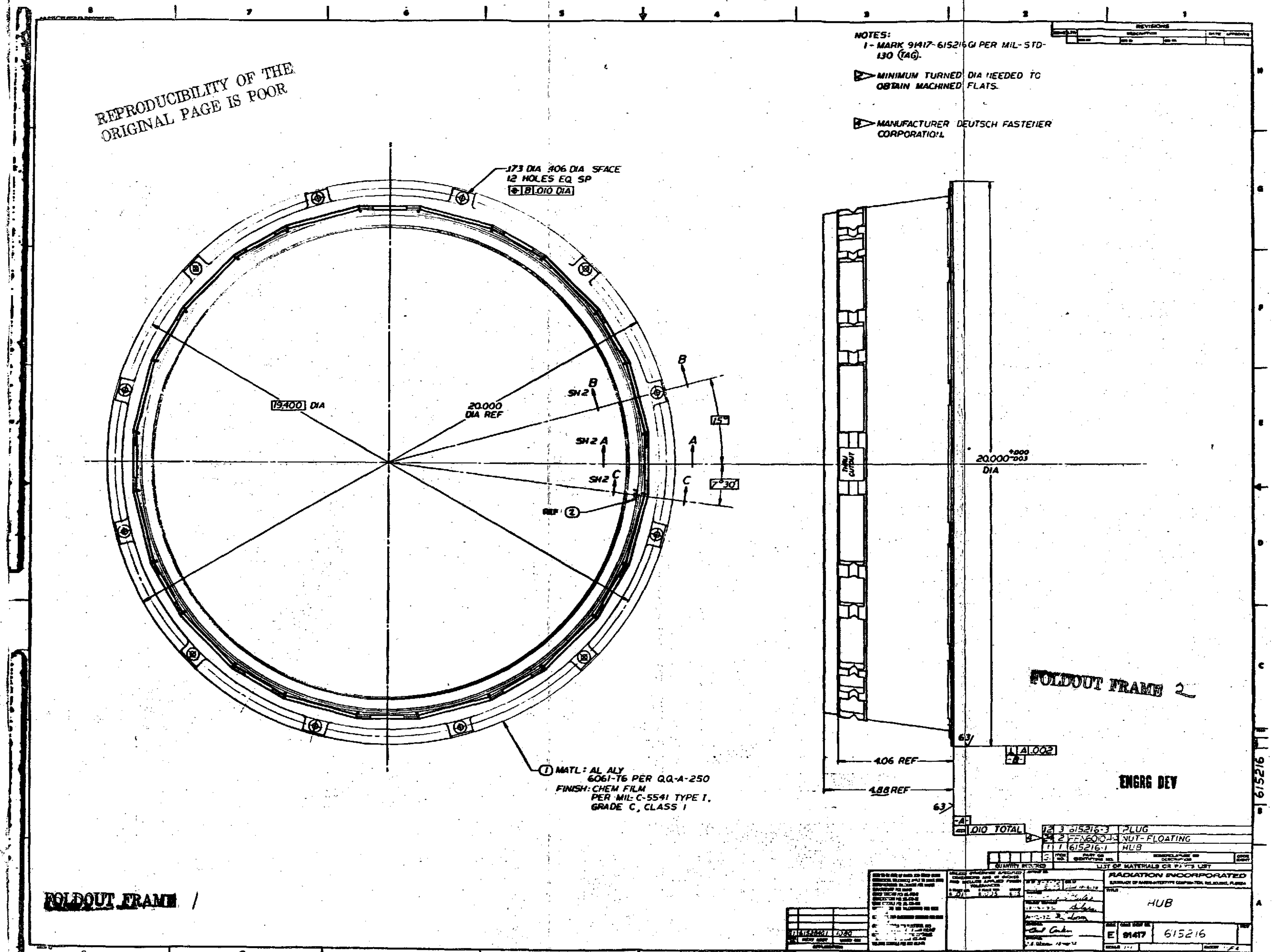
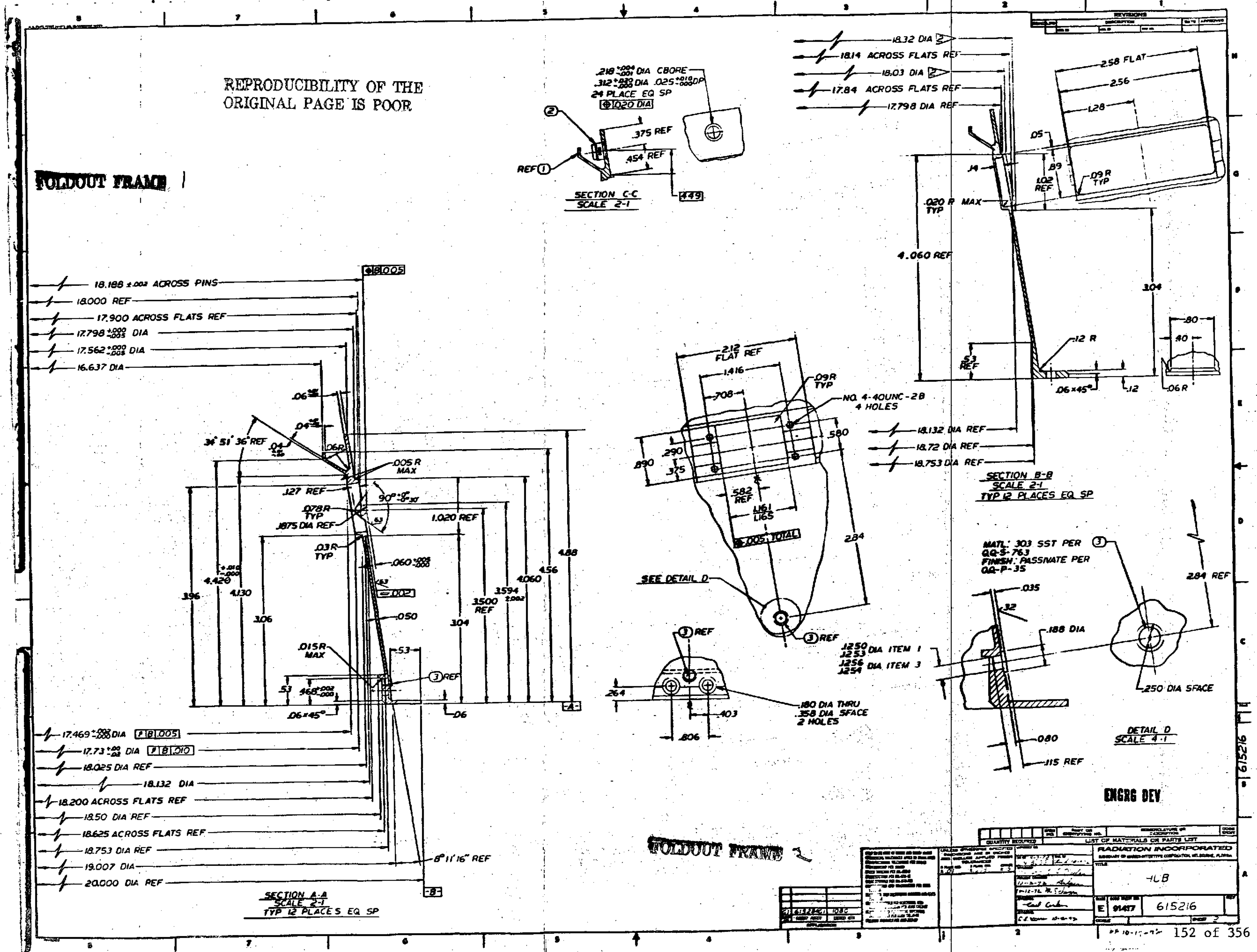
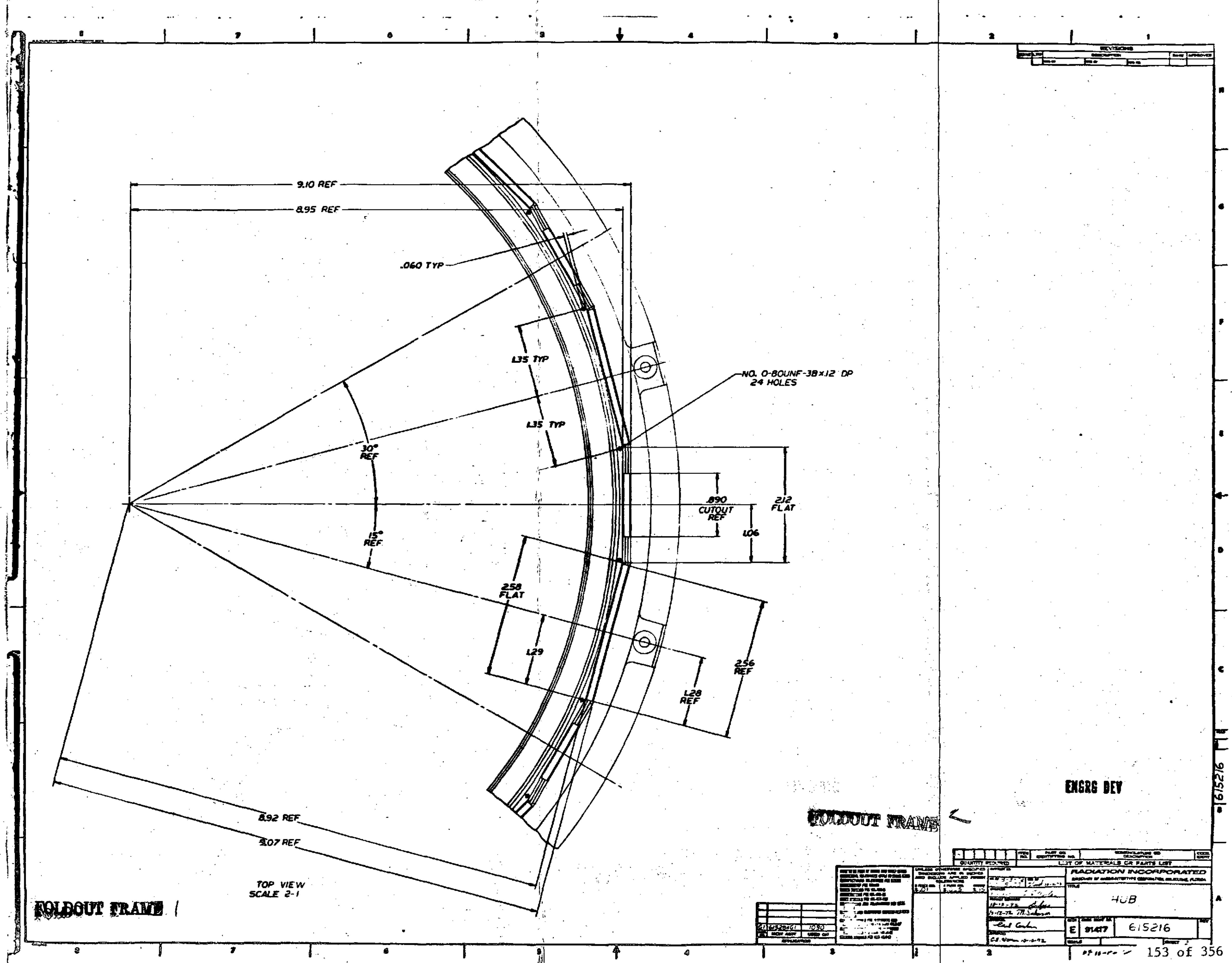
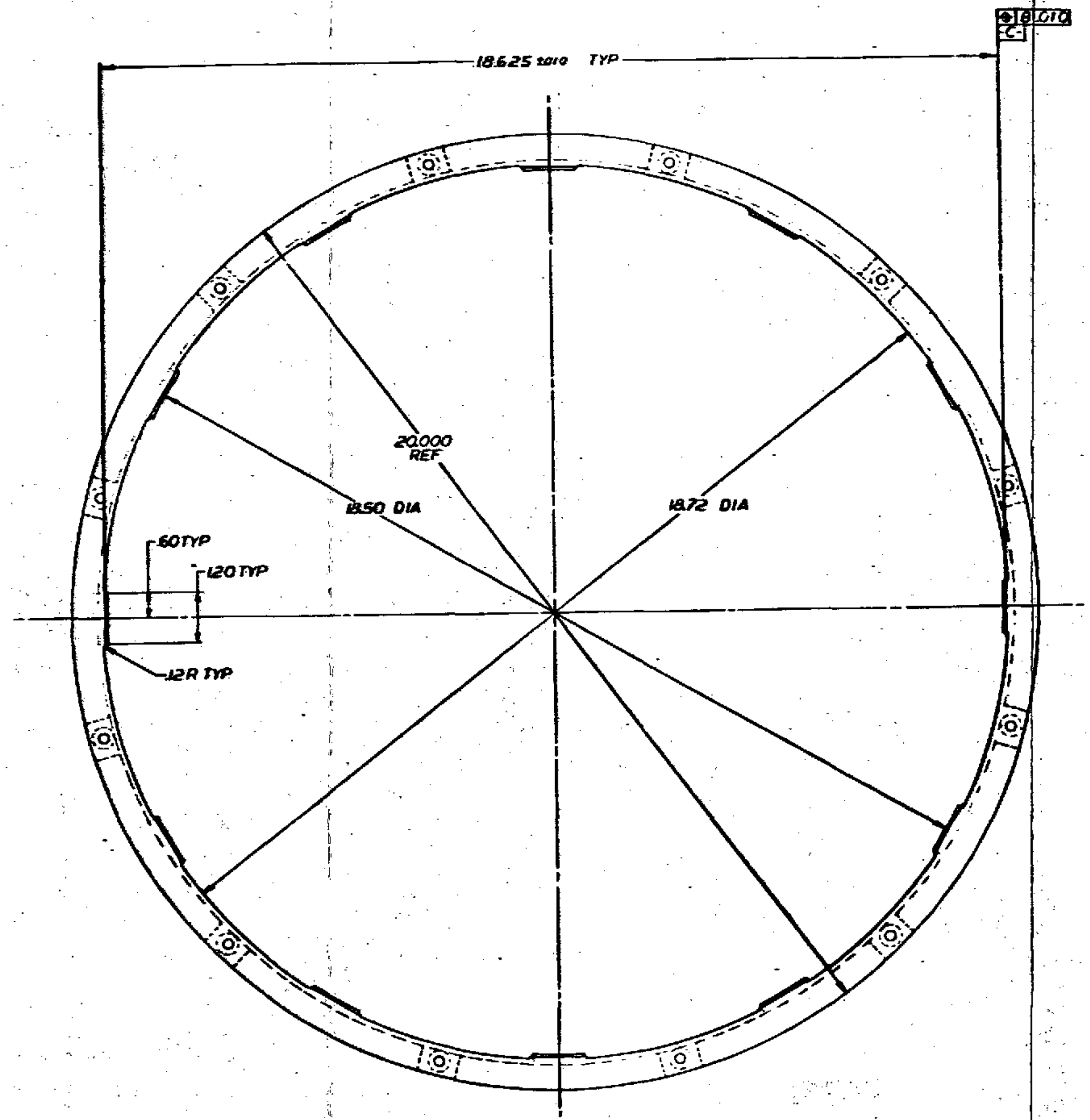

NOTES:
1 - MARK 91417-615216-1 PER MIL-STD-130 (TAG).
MINIMUM TURNED DIA NEEDED TO OBTAIN MACHINED FLATS.
MANUFACTURER DEUTSCH FASTENER CORPORATION.
.173 DIA .406 DIA SFACE
12 HOLES EQ SP
B .010 DIA
19.400 DIA
20.000 DIA REF
SH 2 B
SH 2 A
SH 2 C
15°
7°30'
REF 2
20.000 +.000 -.003 DIA
.406 REF
.488 REF
A .002
.010 TOTAL
1 MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS I
FOLDOUT FRAME 2
ENGRG DEV
3 615216-3 PLUG
2 NUT-FLOATING
1 615216-1 HUB
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
HUB
E 91417 615216
FOLDOUT FRAME 1
615216


REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
FOLDOUT FRAME
SECTION C-C
SCALE 2-1
SECTION B-B
SCALE 2-1
TYP 12 PLACES EQ SP
SECTION A-A
SCALE 2-1
TYP 12 PLACES EQ SP
DETAIL D
SCALE 4-1
SEE DETAIL D
MATL: 303 SST PER QQ-S-763
FINISH: PASSIVATE PER QQ-P-35
NO. 4-40UNC-2B 4 HOLES
.180 DIA THRU .358 DIA SFACE 2 HOLES
.250 DIA SFACE
18.188 ±.002 ACROSS PINS
18.000 REF
17.900 ACROSS FLATS REF
16.637 DIA
17.469 DIA
18.025 DIA REF
18.132 DIA
18.200 ACROSS FLATS REF
18.50 DIA REF
18.625 ACROSS FLATS REF
18.753 DIA REF
19.007 DIA
20.000 DIA REF
18.32 DIA
18.14 ACROSS FLATS REF
18.03 DIA
17.84 ACROSS FLATS REF
17.798 DIA REF
ENGRG DEV
RADIATION INCORPORATED
HUB
615216
FOLDOUT FRAME


9.10 REF
8.95 REF
.060 TYP
1.35 TYP
1.35 TYP
NO. 0-80UNF-3B x .12 DP
24 HOLES
30°
REF
15°
REF
.890
CUTOUT
REF
2.12
FLAT
1.06
2.58
FLAT
1.29
2.56
REF
1.28
REF
8.92 REF
9.07 REF
TOP VIEW
SCALE 2-1
FOLDOUT FRAME
ENGRG DEV
RADIATION INCORPORATED
HUB
E
91417
615216
615216



BOTTOM VIEW

ENGRG DEV

FOLDOUT FRAME

LIST OF MATERIALS OR PARTS LIST

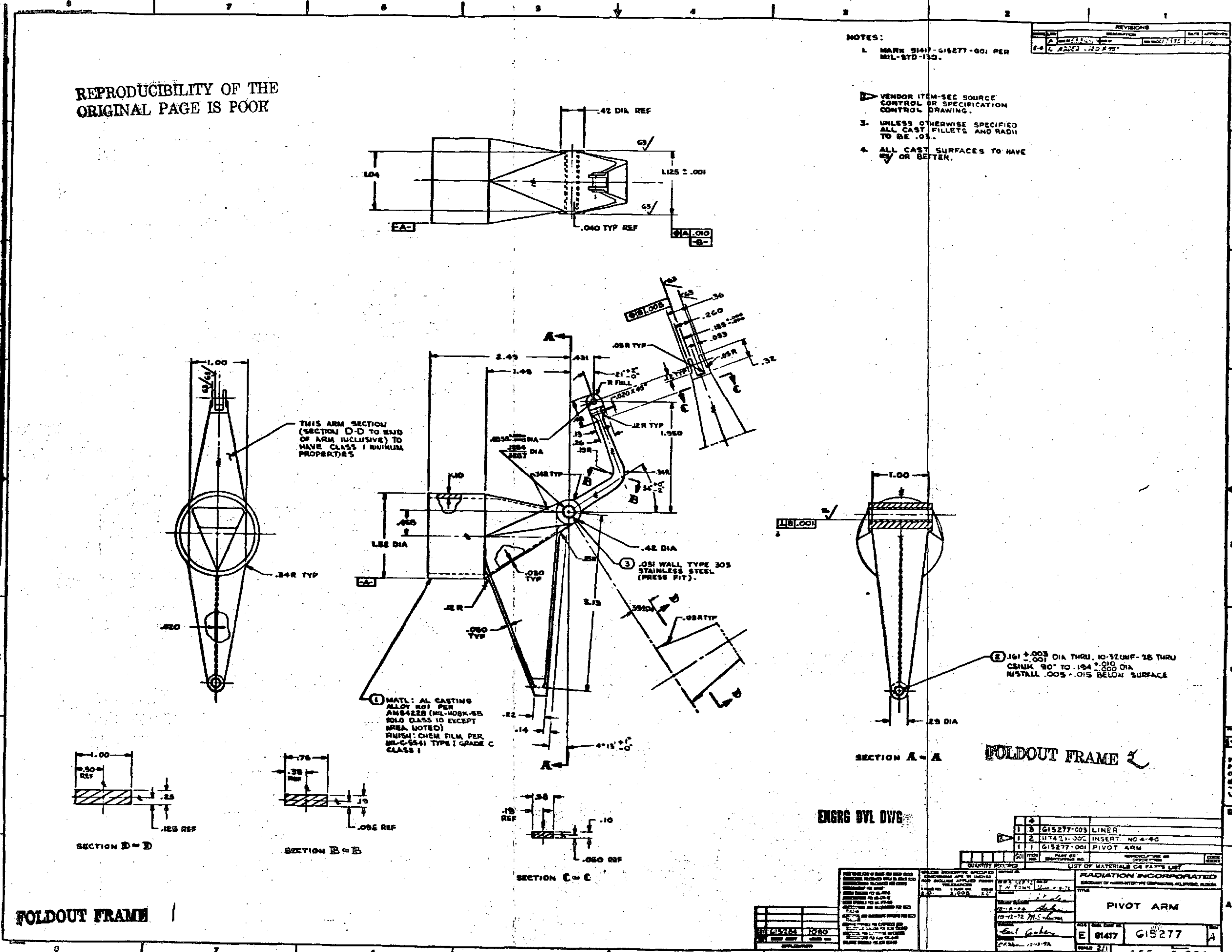
RADIATION INCORPORATED

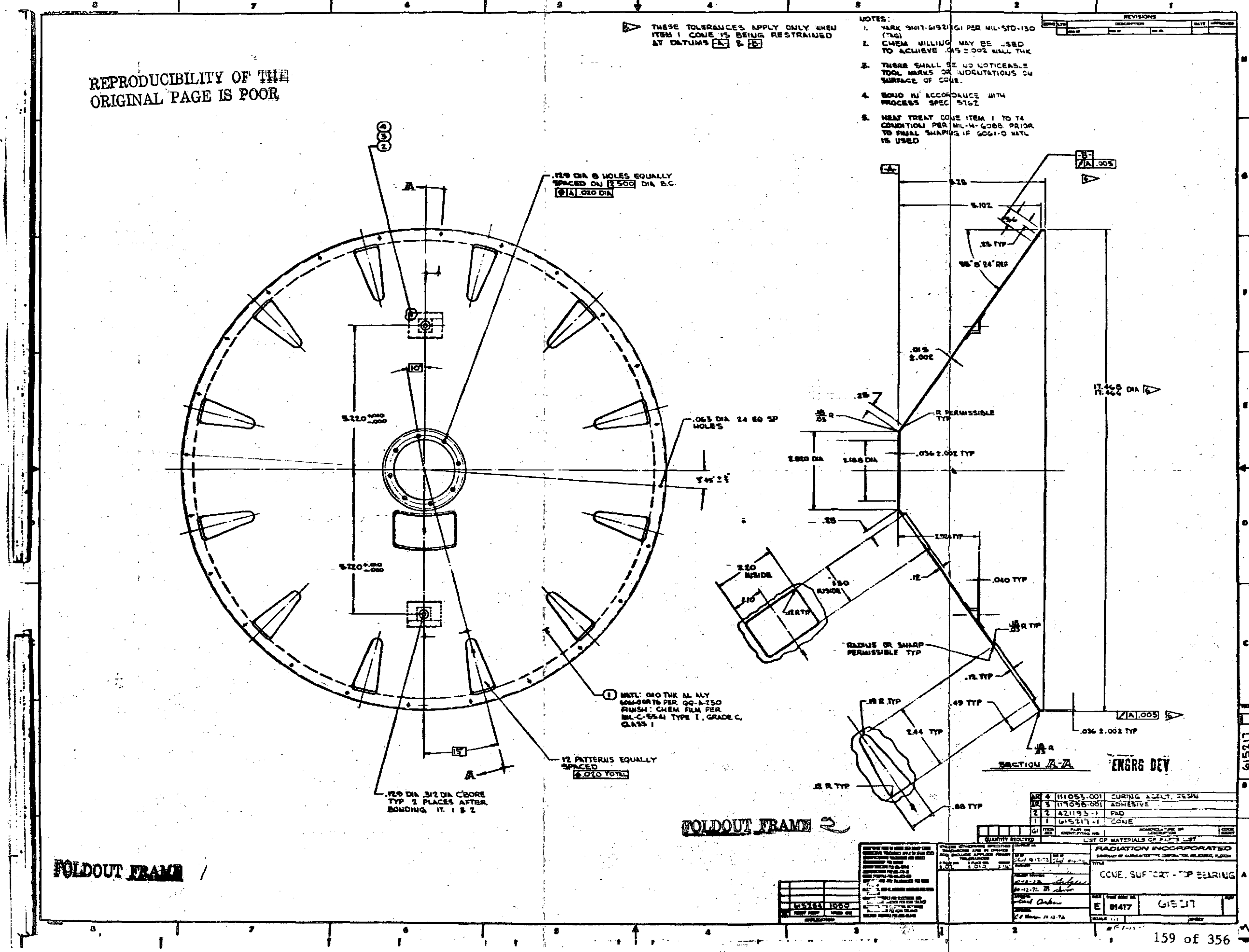
HUB

E 91417 615216

615216

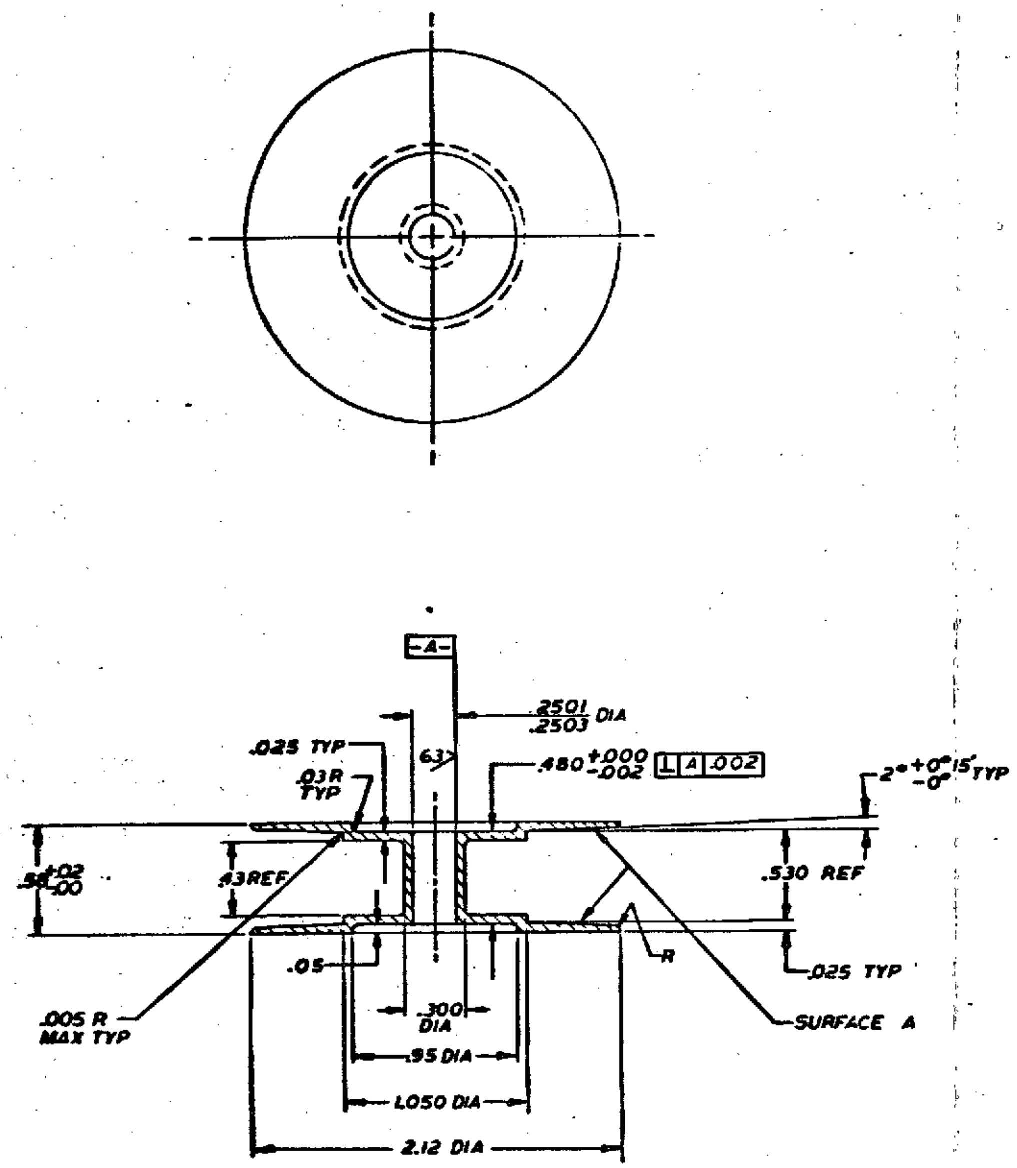
FOLDOUT FRAME


REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
NOTES:
1. MARK 91417-G15277-001 PER MIL-STD-130.
2. VENDOR ITEM-SEE SOURCE CONTROL OR SPECIFICATION CONTROL DRAWING.
3. UNLESS OTHERWISE SPECIFIED ALL CAST FILLETS AND RADII TO BE .03.
4. ALL CAST SURFACES TO HAVE 125 OR BETTER.
THIS ARM SECTION (SECTION D-D TO END OF ARM INCLUSIVE) TO HAVE CLASS I MINIMUM PROPERTIES
MATL: AL CASTING ALLOY A201 PER AMS4228 (MIL-HDBK-5B 2010 CLASS 10 EXCEPT AREA NOTED) FINISH: CHEM FILM PER MIL-C-5541 TYPE I GRADE C CLASS I
.051 WALL TYPE 305 STAINLESS STEEL (PRESS FIT).
.161 +.003 -.001 DIA THRU, 10-32UNF-2B THRU CSINK 90° TO .184 +.010 -.000 DIA INSTALL .005-.015 BELOW SURFACE
SECTION A-A
SECTION D-D
SECTION B-B
SECTION C-C
FOLDOUT FRAME
ENGRG DVL DWG
G15277-003 LINER
HT421-00C INSERT NC 4-40
G15277-001 PIVOT ARM
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
PIVOT ARM
E 91417 G15277 A
FOLDOUT FRAME


THESE TOLERANCES APPLY ONLY WHEN ITEM 1 CONE IS BEING RESTRAINED AT DATUMS -A- & -B-
NOTES:
1. MARK 91417-615217G1 PER MIL-STD-130 (TAG)
2. CHEM MILLING MAY BE USED TO ACHIEVE .015 ±.002 WALL THK
3. THERE SHALL BE NO NOTICEABLE TOOL MARKS OR INDENTATIONS ON SURFACE OF CONE.
4. BOND IN ACCORDANCE WITH PROCESS SPEC 5762
5. HEAT TREAT CONE ITEM 1 TO T4 CONDITION PER MIL-H-6088 PRIOR TO FINAL SHAPING IF 6061-0 MATL IS USED
.129 DIA 8 HOLES EQUALLY SPACED ON 2.500 DIA B.C.
.063 DIA 24 EQ SP HOLES
12 PATTERNS EQUALLY SPACED
.129 DIA .312 DIA C'BORE TYP 2 PLACES AFTER BONDING IT. 1 & 2
MATL: .040 THK AL ALY 6061-0 OR T6 PER QQ-A-250 FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1
RADIUS OR SHARP PERMISSIBLE TYP
R PERMISSIBLE TYP
SECTION A-A
ENGRG DEV
AR | 4 | 111053-001 | CURING AGENT, RESIN
AR | 3 | 117098-001 | ADHESIVE
2 | 2 | 421193-1 | PAD
1 | 1 | 615217-1 | CONE
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
CONE, SUPPORT - TOP BEARING
E 91417 615217
FOLDOUT FRAME

NOTES:

1- 125/ ALL OVER UNLESS OTHERWISE SPECIFIED.
2- MARK 91417-534090-1 PER MIL-STD-130. (TAG)
3- MATL: AL ALLOY 6061-T6.
4- FINISH: SURFACE 'A' ONLY, COAT WITH .003±.001 THK "TUFRAM" BY GENERAL MAGNAPLATE CORP. ALL OTHER AREAS TO BE CHEMICAL FILM PER MIL-C-5541 TYPE-I, GRADE-B, CLASS-I.



FOLDOUT FRAME 2

ENGRG DEV

QUANTITY REQUIRED	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		LIST OF MATERIALS OR PARTS LIST		

1	615284	1030
QTY	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE DEC. ±.01 3 PLACE DEC. ±.005 ANGLES ±

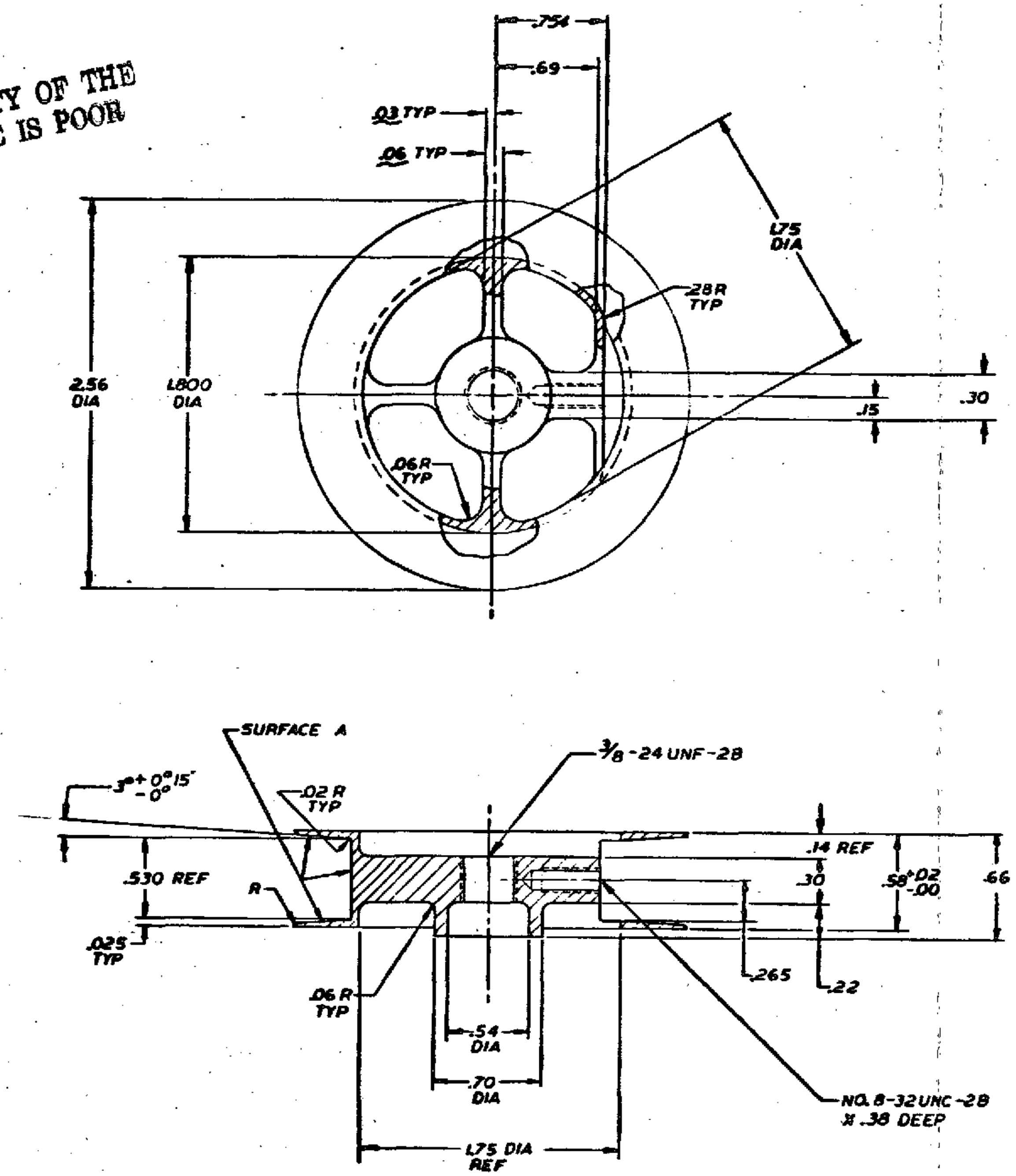
DR 3-26-72 J.N. SUGG
CHK 10-10-72
10-11-72 E.E. Boles
10-12-72
10-12-72 M. Schuman
C.E. 10-13-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE
DRUM TAKE UP SPRING MOTOR

SIZE D CODE IDENT NO. 91417 534090
SCALE 2-1

FOLDOUT FRAME 1



NOTES:

1 - MARK 91417-534091-1 PER MIL-STD-130 (BAG OR TAG).

2 - 125 ALL SURFACES.

3 - MATL: AL ALLOY 6061-T6.

4 - FINISH: SURFACE A ONLY, COAT WITH .003±.001 THK "TUFRAM" BY GENERAL MAGNAPLATE CORP. ALL OTHER AREAS TO BE CHEMICAL FILM PER MIL-C-5541 TYPE-1, GRADE-B, CLASS-1.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	REVISED PER EDC		

FOLDOUT FRAME 2

ENGRG DEV

ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

	NEXT ASSY	USED ON
1	615284	1080

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE DEC ±.01 3 PLACE DEC ±.005 ANGLES ±

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: DRUM-OUTPUT SPRING MOTOR

SIZE D | CODE IDENT NO. 91417 | 534091 | REV A

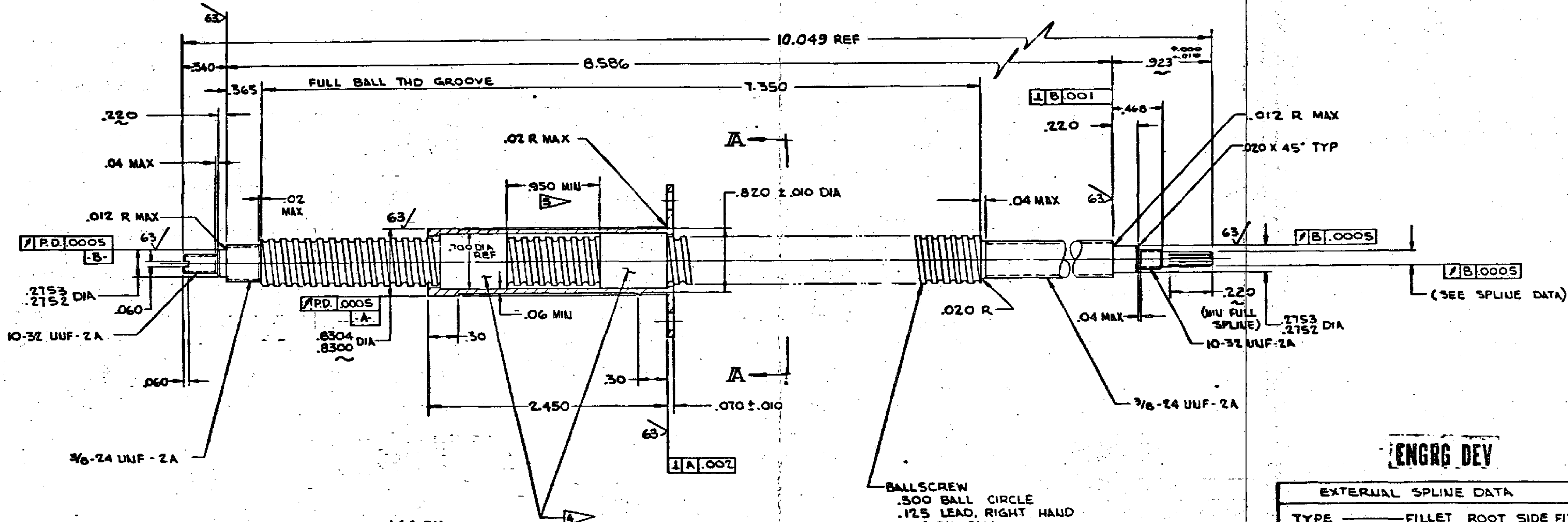
SCALE 2-1 | SHEET

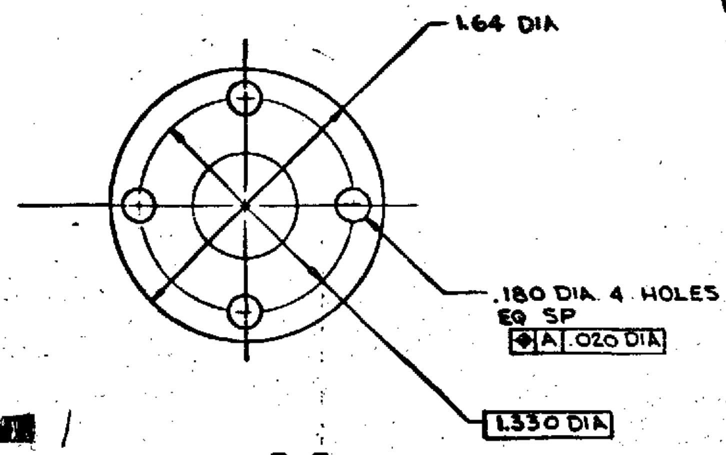
FOOTOUT FRAME 1

NOTES:
1. MARK 91417-534066G1 PER MIL-STD-130 (TAG)
2. BALLSCREW THREADS TO BE CLOSE CONFORMITY GROUND.
3. DOUBLE NUT ASSY TO BE PRE-LOADED TO 15 LB.
4. EACH NUT TO HAVE MINIMUM OF 3.5 CIRCUITS OF BALLS.
5. DISTANCE BETWEEN NUTS.
6. ASSY TO HAVE 58 MIN. ROCKWELL C HARDNESS
7. BALLSCREW THREADS, NUT THREADS, & BALL RETURNS TO BE LUBRICATED IN ACCORDANCE WITH DWG 307611
8. PITCH DIA OF BALLSCREW USED AS REF DIA FOR RUN OUT TOLERANCE CALLOUTS

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A			
B-7		1. NUT DIA WAS .6984-.6980 DIA		
A-7		2. FLANGE DIA WAS 1.58		
A-6		3. B.C. DIA WAS 1.250		
		4. DELETED .310-.319 DIA BORE, PIN & ASSOCIATED DIMS.		
	B	E.S.S. 2-12-73	0217927	
C-2		1. .220 DIM. WAS .250		
C-3		2. .923 DIM. WAS .762		
C-4		3. 10.049 REF. WAS 9.889 REF.		





VIEW A-A

ENGRG DEV

EXTERNAL SPLINE DATA

TYPE	FILLET ROOT SIDE FIT
CLASS	1
PITCH DIA	.1250
NO. TEETH	6
MAJOR DIA	.1458 +.000 -.003
MINOR DIA	.0834 +.000 -.007
FILLET RADIUS	NONE
PRESSURE ANGLE	30°
PITCH	48/96

LIST OF MATERIALS OR PARTS LIST

QUANTITY REQUIRED	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

NEXT ASSY	USED ON
615284	1080

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE DEC. ±.02 3 PLACE DEC. ±.005 ANGLES ±1°

MATL: STAINLESS STEEL TYPE 440 PER QQ-S-763 (6)
FINISH: PASSIVATE PER QQ-P-35

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

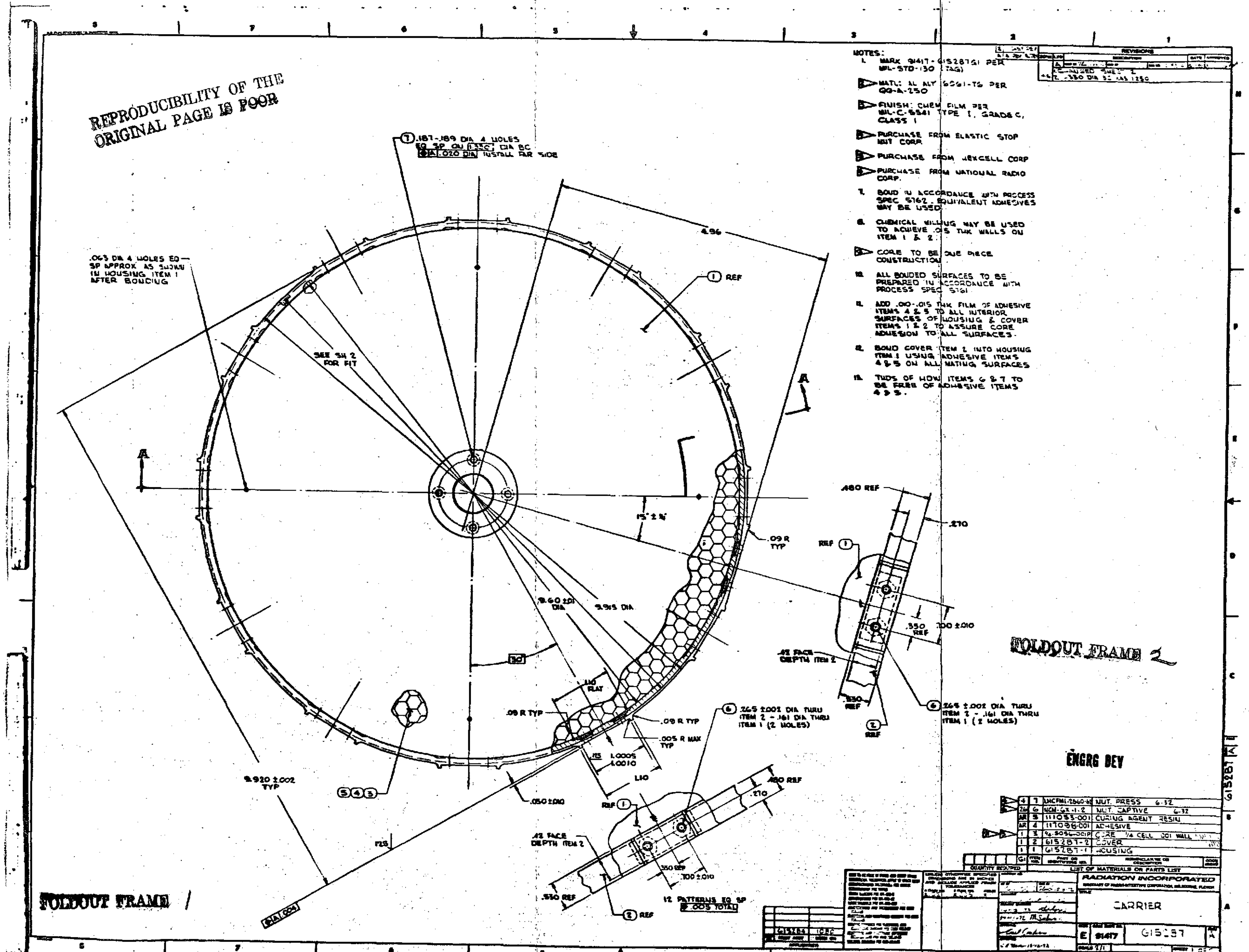
TITLE: BALLSCREW & NUT ASSY

SIZE D | CODE IDENT NO. 91417 | 534066 | REV B

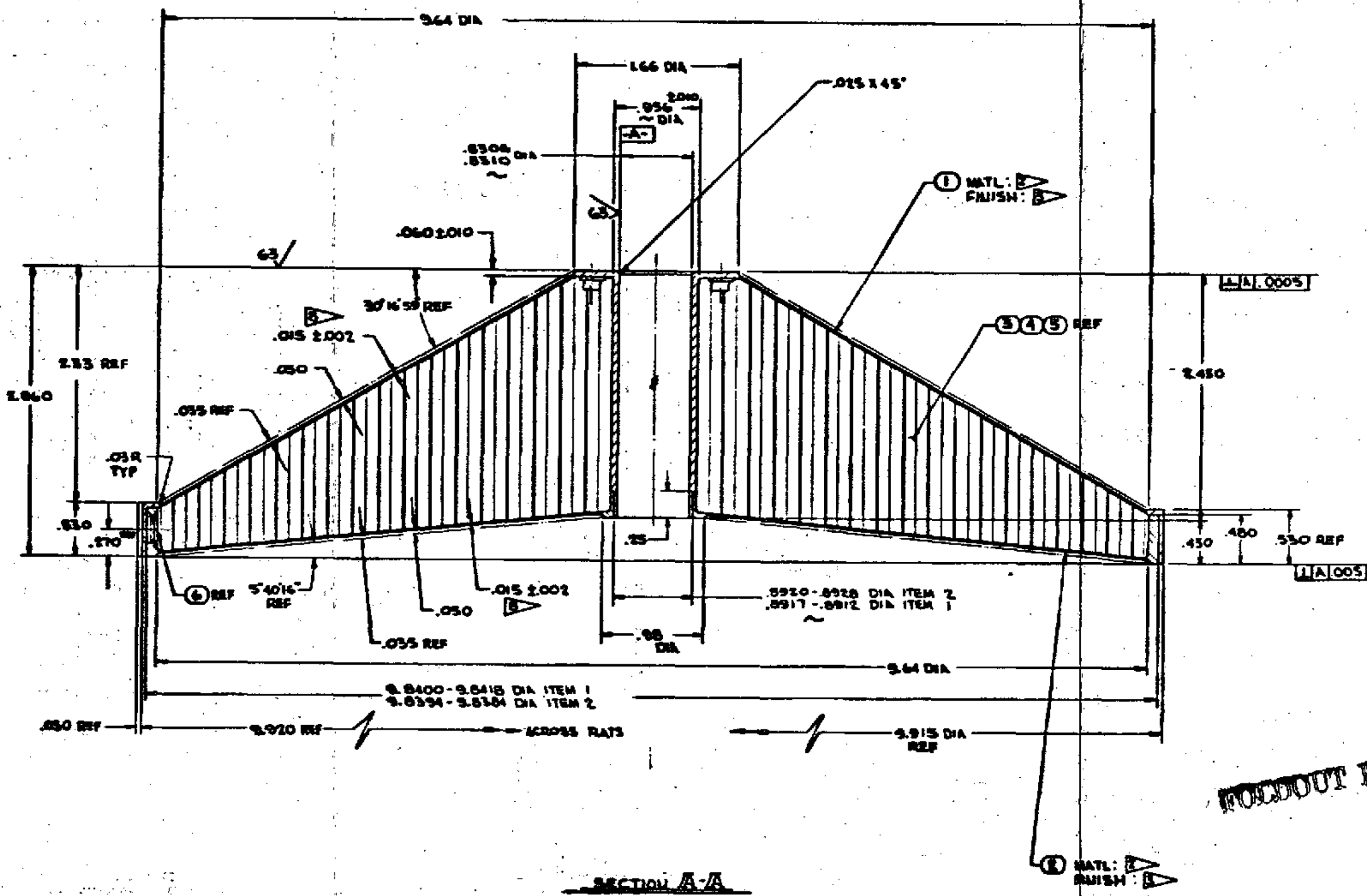
SCALE 2/1

FOLDOUT FRAME 1

FOLDOUT FRAME 2



REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
NOTES:
1. MARK 91417-615287-1 PER MIL-STD-130 (TAG)
2. MATL: AL ALY 6061-T6 PER QQ-A-250
3. FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1
4. PURCHASE FROM ELASTIC STOP NUT CORP.
5. PURCHASE FROM HEXCELL CORP
6. PURCHASE FROM NATIONAL RADIO CORP.
7. BOND IN ACCORDANCE WITH PROCESS SPEC 5162. EQUIVALENT ADHESIVES MAY BE USED.
8. CHEMICAL MILLING MAY BE USED TO ACHIEVE .015 THK WALLS ON ITEM 1 & 2.
9. CORE TO BE ONE PIECE CONSTRUCTION.
10. ALL BONDED SURFACES TO BE PREPARED IN ACCORDANCE WITH PROCESS SPEC 5161
11. ADD .010-.015 THK FILM OF ADHESIVE ITEMS 4 & 5 TO ALL INTERIOR SURFACES OF HOUSING & COVER ITEMS 1 & 2 TO ASSURE CORE ADHESION TO ALL SURFACES.
12. BOND COVER ITEM 2 INTO HOUSING ITEM 1 USING ADHESIVE ITEMS 4 & 5 ON ALL MATING SURFACES
13. THDS OF HOW ITEMS 6 & 7 TO BE FREE OF ADHESIVE ITEMS 4 & 5.
REVISIONS
.187-.189 DIA 4 HOLES EQ SP ON 1.350 DIA BC
.020 DIA INSTALL FAR SIDE
.063 DIA 4 HOLES EQ SP APPROX AS SHOWN IN HOUSING ITEM 1 AFTER BONDING
SEE SH 2 FOR FIT
4.96
1 REF
A
A
15° ± ½°
.09 R TYP
9.60 ±.01 DIA
9.915 DIA
30°
.10 FLAT
.09 R TYP
.09 R TYP
.005 R MAX TYP
1.0005 1.0010
1.10
9.920 ±.002 TYP
5 4 3
.050 ±.010
.480 REF
.270
REF 1
.350 REF
.700 ±.010
.42 FACE DEPTH ITEM 2
.530 REF
2 REF
6 .265 ±.002 DIA THRU ITEM 2 - .161 DIA THRU ITEM 1 (2 HOLES)
.480 REF
.270
REF 1
.42 FACE DEPTH ITEM 2
.350 REF
.700 ±.010
.530 REF
2 REF
12 PATTERNS EQ SP .005 TOTAL
.004
FOLDOUT FRAME 1
FOLDOUT FRAME 2
ENGRG DEV
4 7 NCFM1-2560-6 NUT, PRESS 6-32
26 6 NCM-6X-1-2 NUT, CAPTIVE 6-32
AR 5 111053-001 CURING AGENT RESIN
AR 4 111096-001 ADHESIVE
1 3 1/4-5056-.001P CORE 1/4 CELL .001 WALL
1 2 615287-2 COVER
1 1 615287-1 HOUSING
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
CARRIER
E 91417 615287 A
615287 A



FOLDOUT FRAME 2

ENGRG DEV

LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

CARRIER

E 91417 615287

SCALE 1/1 SHEET 2 OF 2

FOLDOUT FRAME 1

163 65 356

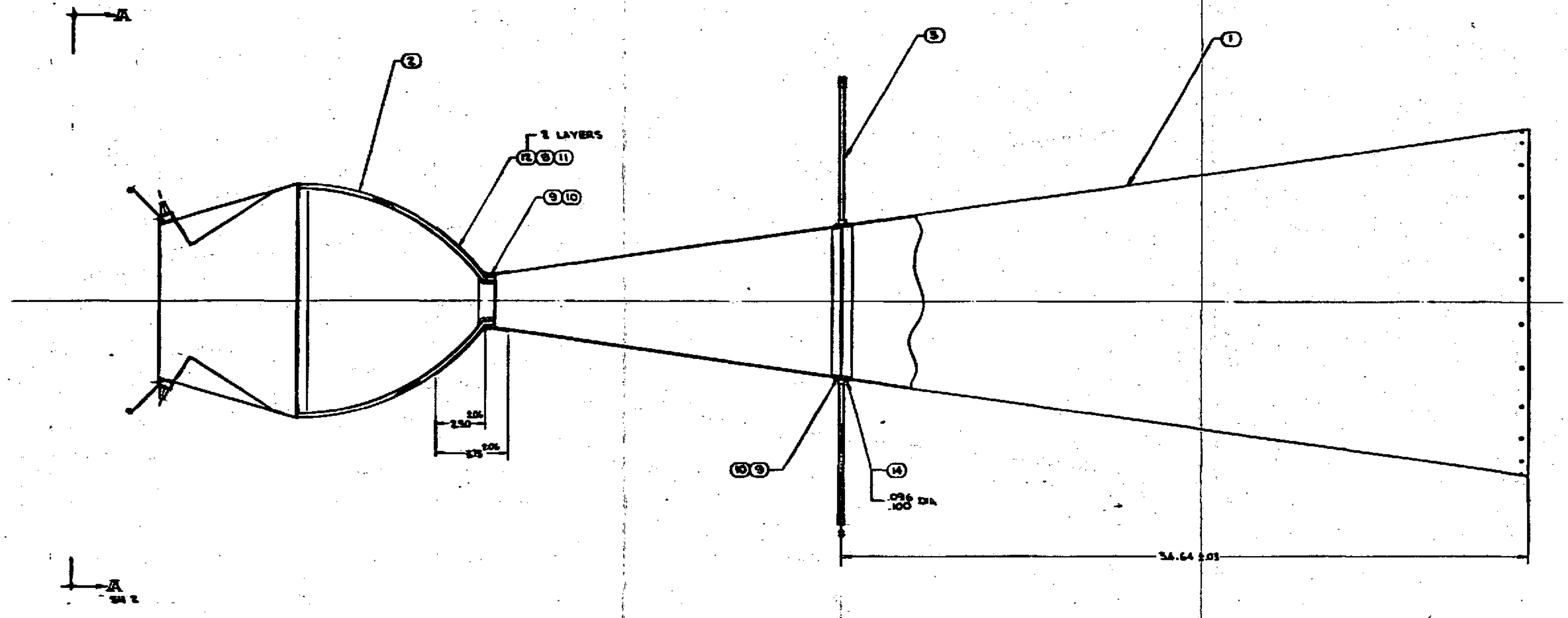
NOTES:

1. MARK 91417-615285G1 PER MIL-STD-130 (TAG)
2. PURCHASE FROM HOLEX INC. HOLLISTER, CALIF
3. BOND IN ACCORDANCE WITH PROCESS SPEC 5762
4. PURCHASE FROM ALLMETAL SCREW PRODUCTS CO. INC.
5. PURCHASE FROM J.P. STEVENS & CO. N.Y. NEW YORK

CONE ITEM 7, CONE OF HOOP SPAR ASSY ITEM 3 & .173 DIA HOLE IN CONE ASSY ITEM 1 TO BE LOCATED TRUE POSITION WITHIN .020 TOTAL

FIRST INSTALLATION TORQUE TO BE 4.1 IN-LB ± .4 IN-LB

AFTER OBTAINING FIRST INSTALLATION TORQUE, BACK OUT SCREW MINIMUM OF 5 TURNS & RETORQUE TO 2.9 IN-LB ± .3 IN-LB



FOLDOUT FRAME 2

ENGRG DEV

QTY	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
3	19	615285-19	BLOCK
32	18	NAS620-2	WASHER, FLAT NO. 2
93	17	50FM-256	NUT, HEX SELF LOCKING 2-56
1	16	MS16995-4	SCREW, SOC HD CAP 2-56 × 1/2
32	15	MS16995-1	SCREW, SOC HD CAP 2-56 × 3/16
96	14	MS20604AD3T1	RIVET, BLIND 3/32 DIA
2	13	5800	GUILLOTINE
AR	12	6116	CLOTH, S-GLASS
AR	11	110700-001	PLASTIC MOLDING MATERIAL
AR	10	111098-001	ADHESIVE
AR	9	111053-001	CURING AGENT, RESIN
1	8	421194G1	SUPPORT, GUILLOTINE
12	7	534379-2	CONE
2	6	308371-1	CLAMP
12	5	308372-1	SPRING
12	4	308387-1	FERRULE
1	3	615215G1	HOOP-SPAR ASSY
1	2	615279G1	OGIVE & TOP RESTRAINT ASSY
1	1	615133G1	CONE ASSY

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

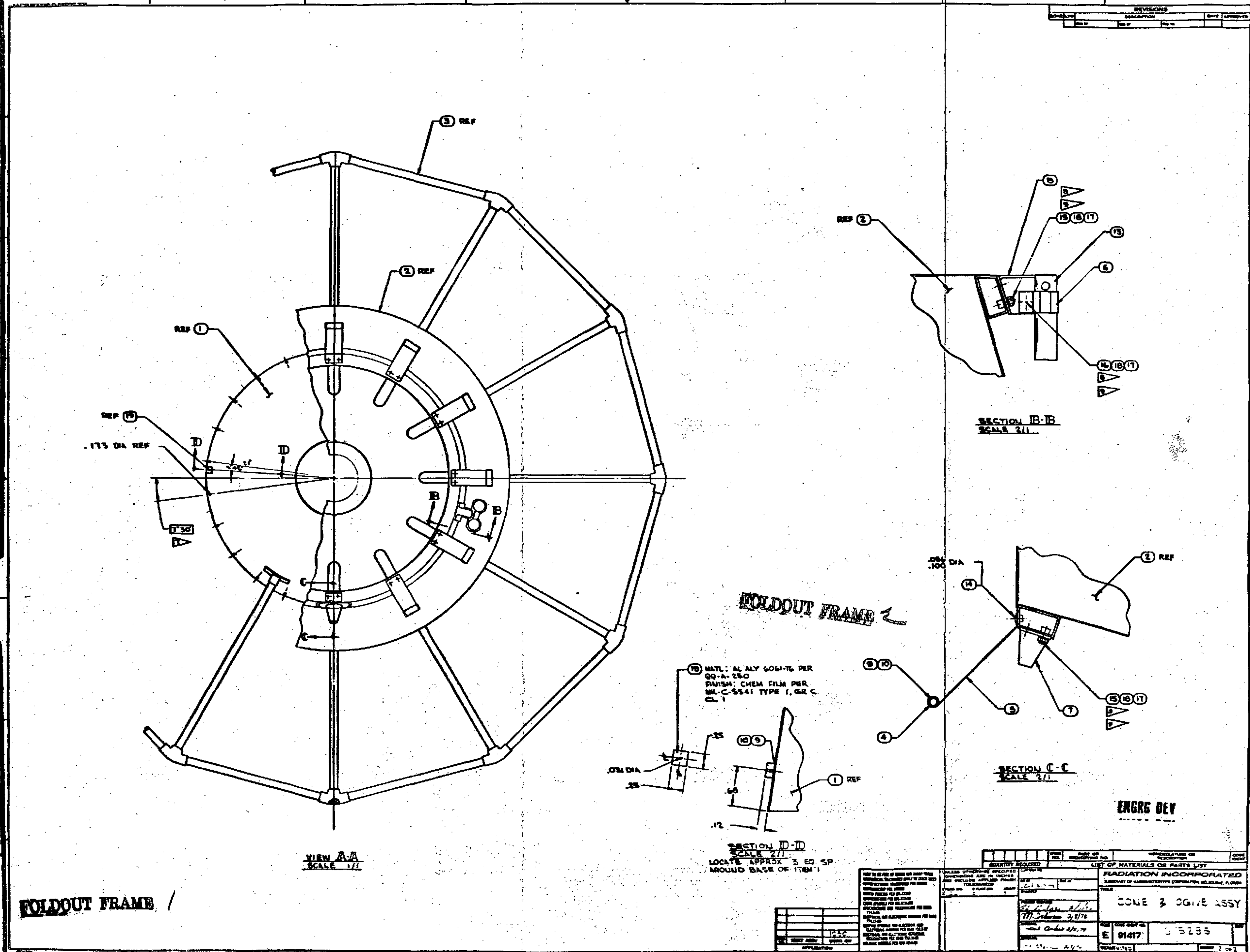
TITLE: CONE & OGIVE ASSY

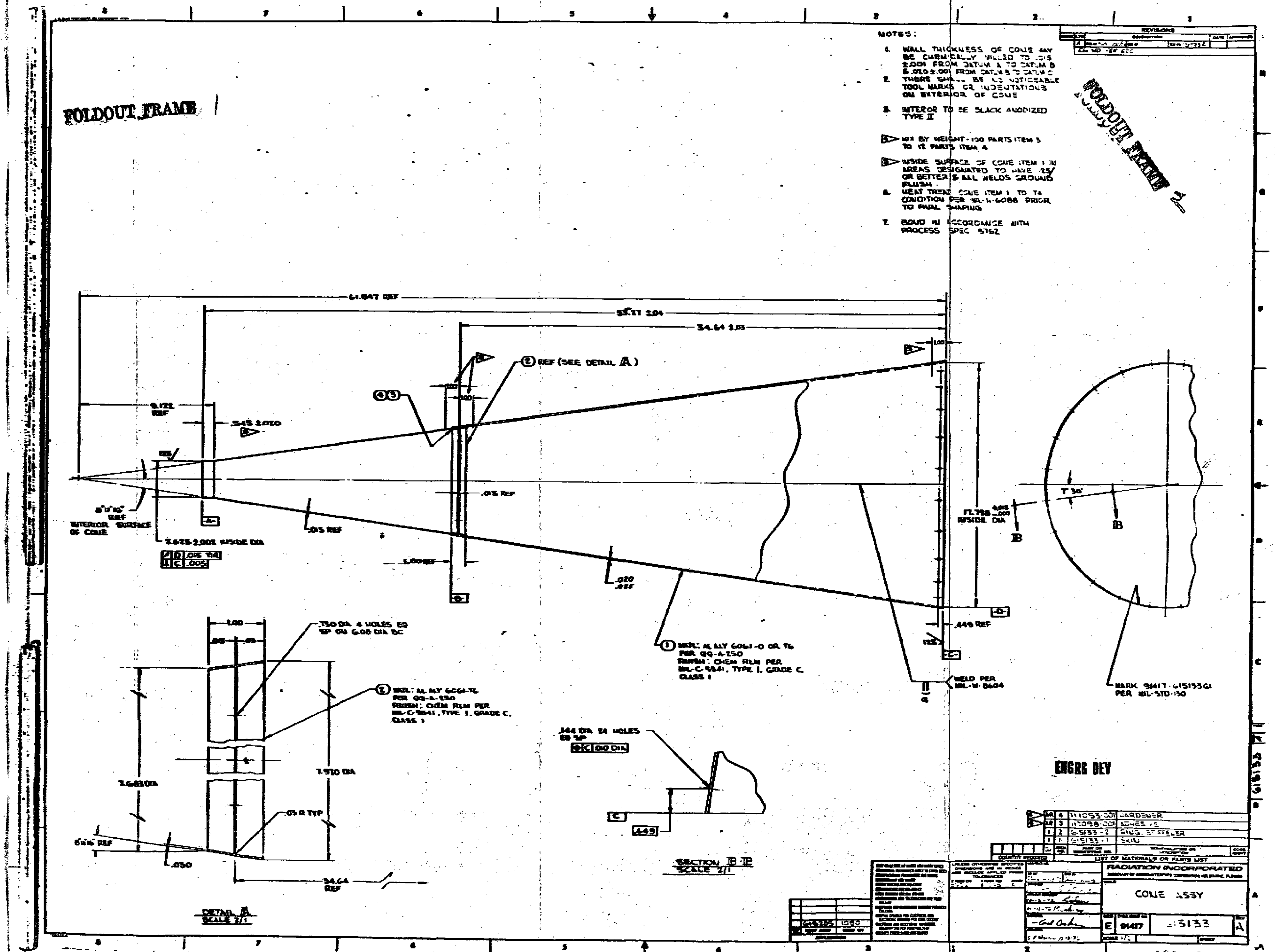
E 91417 615285

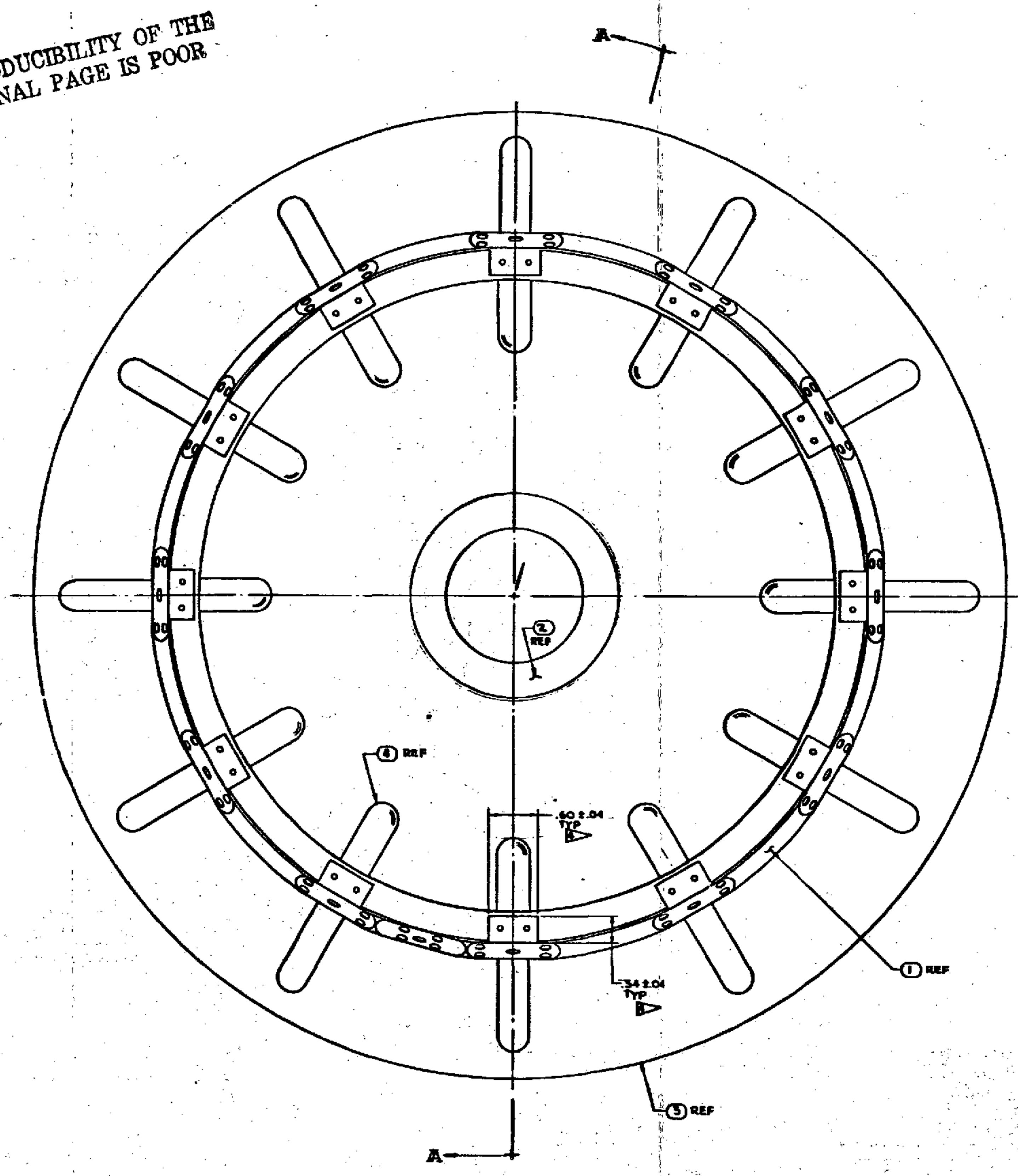
SCALE 1/2 — SHEET 1 OF 2

615285

FOLDOUT FRAME 1


VIEW A-A
SCALE 1/1
SECTION B-B
SCALE 2/1
SECTION C-C
SCALE 2/1
SECTION D-D
SCALE 2/1
LOCATE APPROX 3 EQ SP AROUND BASE OF ITEM 1
MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GR C CL 1
FOLDOUT FRAME
ENGRG DEV
RADIATION INCORPORATED
CONE & OGIVE ASSY
91417
615285


FOLDOUT FRAME
NOTES:
1. WALL THICKNESS OF CONE MAY BE CHEMICALLY MILLED TO .015 ±.001 FROM DATUM A TO DATUM B & .020 ±.001 FROM DATUM B TO DATUM C
2. THERE SHALL BE NO NOTICEABLE TOOL MARKS OR INDENTATIONS ON EXTERIOR OF CONE
3. INTERIOR TO BE BLACK ANODIZED TYPE II
4. MIX BY WEIGHT - 100 PARTS ITEM 3 TO 12 PARTS ITEM 4
5. INSIDE SURFACE OF CONE ITEM 1 IN AREAS DESIGNATED TO HAVE 25/ OR BETTER & ALL WELDS GROUND FLUSH.
6. HEAT TREAT CONE ITEM 1 TO T4 CONDITION PER MIL-H-6088 PRIOR TO FINAL SHAPING
7. BOND IN ACCORDANCE WITH PROCESS SPEC 5762
FOLDOUT FRAME
61.847 REF
35.27 ±.04
34.64 ±.03
2 REF (SEE DETAIL A)
4 3
9.122 REF
.545 ±.020
.015 REF
.015 REF
1.00 REF
.020 .025
7.625 ±.002 INSIDE DIA
8°11'16" REF
INTERIOR SURFACE OF CONE
71.798 INSIDE DIA
.449 REF
7°30'
B
B
1 MATL: AL ALY 6061-0 OR T6 PER QQ-A-250 FINISH: CHEM FILM PER MIL-C-5541, TYPE I, GRADE C, CLASS 1
WELD PER MIL-W-8604
MARK 91417-615133G1 PER MIL-STD-130
.750 DIA 4 HOLES EQ SP ON 6.08 DIA BC
2 MATL: AL ALY 6061-T6 PER QQ-A-250 FINISH: CHEM FILM PER MIL-C-5541, TYPE I, GRADE C, CLASS 1
7.683 DIA
7.910 DIA
.03 R TYP
.030
34.64 REF
DETAIL A SCALE 2/1
.144 DIA 24 HOLES EQ SP
.449
SECTION B-B SCALE 2/1
ENGRG DEV
4 | 111053-001 | HARDENER
3 | 111098-001 | ADHESIVE
2 | 615133-2 | RING, STIFFENER
1 | 615133-1 | SKIN
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
CONE ASSY
E 91417 615133 A
615133



NOTES:

1. MARK 91417-615279G1 PER MIL-STD-130 (TAG)
2. MATL: PRE-IMPREGNATED FABRIC ERS 7551/VOLAN 35 FROM FERRO CORP HUNTINGTON BEACH, CALIF
3. MATL: FIBERGLASS CLOTH NO 1516 FROM J.P. STEVENS CO.
4. NO FIBERGLASS IN THESE AREAS.
5. USE ITEMS 6, 7, & 8 AS FILLER TO ACHIEVE SMOOTH RADIUS AROUND CUTOUT TYP 12 PLACES
6. BOND IN ACCORDANCE WITH PROCESS SPEC 3762
7. ALL LAYUP MATL TO BE REMOVED FROM ACCESS HOLES ON RING ITEM 1

FOLDOUT FRAME 2

ENGRG REV

615279

AR	8	106368-001	PIGMENT, PULVERIZED SILICA
AR	7	111053-001	CURING AGENT, RESIN
AR	6	117095-001	ADHESIVE
1	5	615279-5	ANGLE
12	4	615279-4	COVER
1	3	615279-3	OGIVE
1	2	421190-1	COLLAR
1	1	615278G1	RING, TOP RESTRAINT

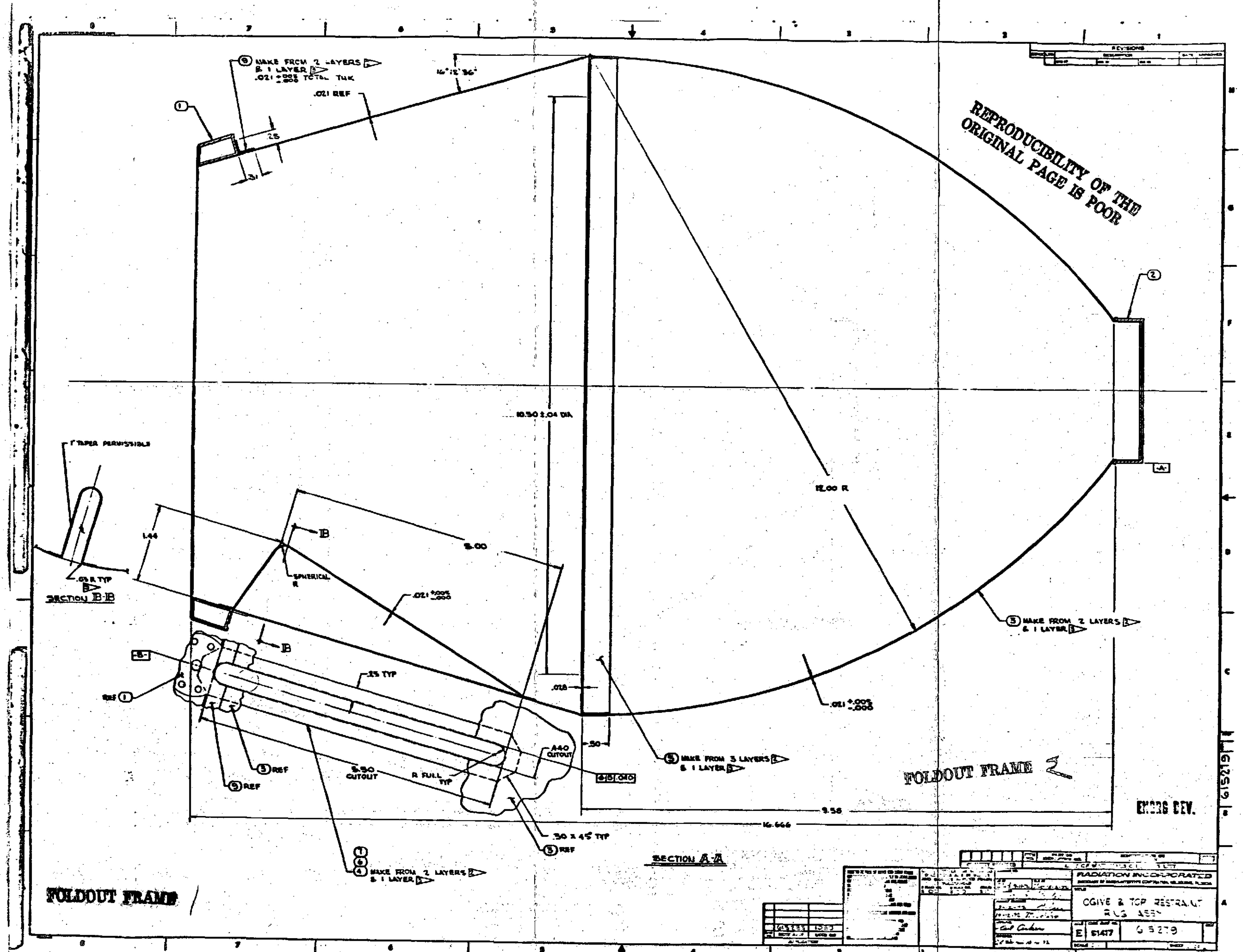
LIST OF MATERIALS OR PARTS LIST

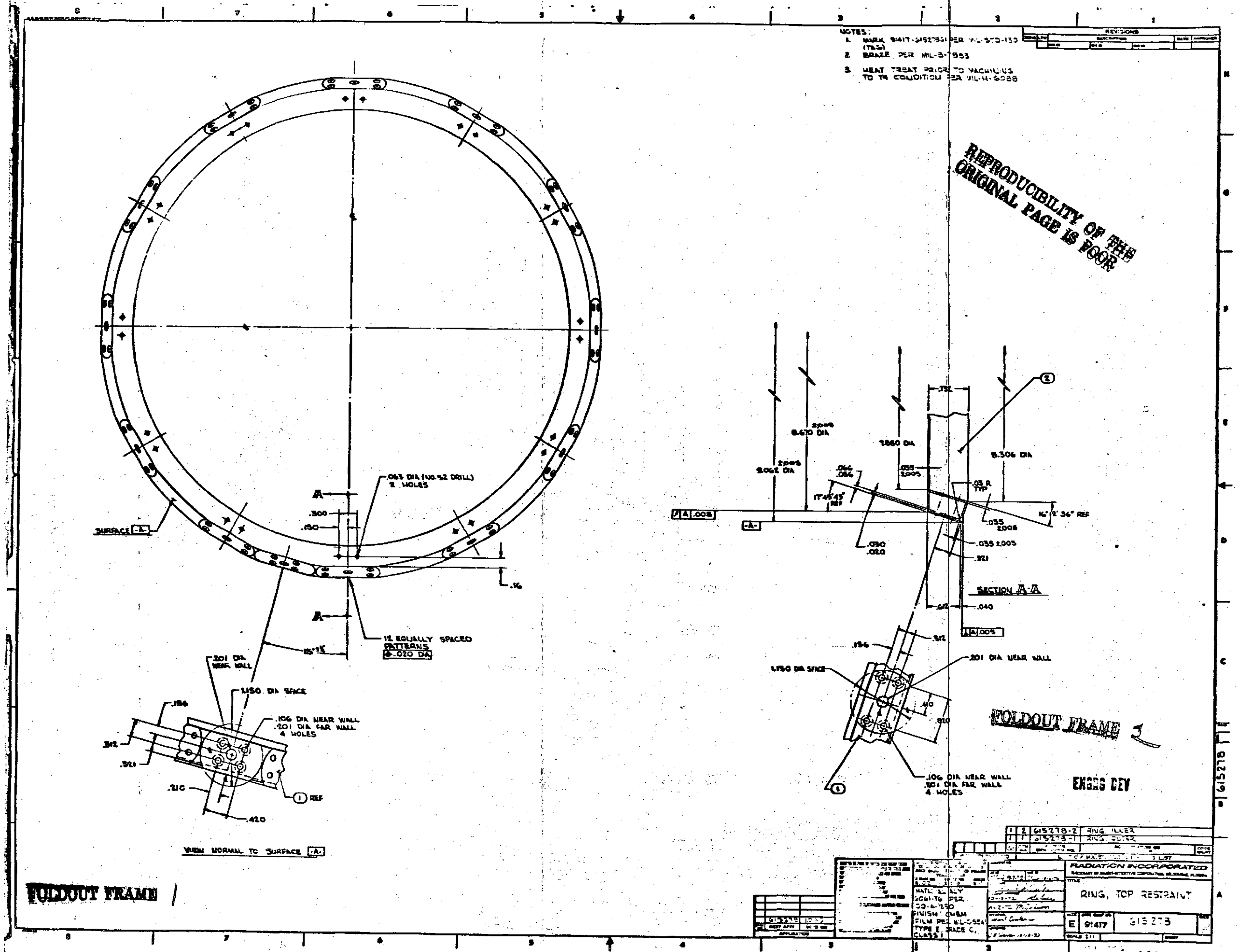
RADIATION INCORPORATED

OGIVE & TOP RESTRAINT RING ASSY

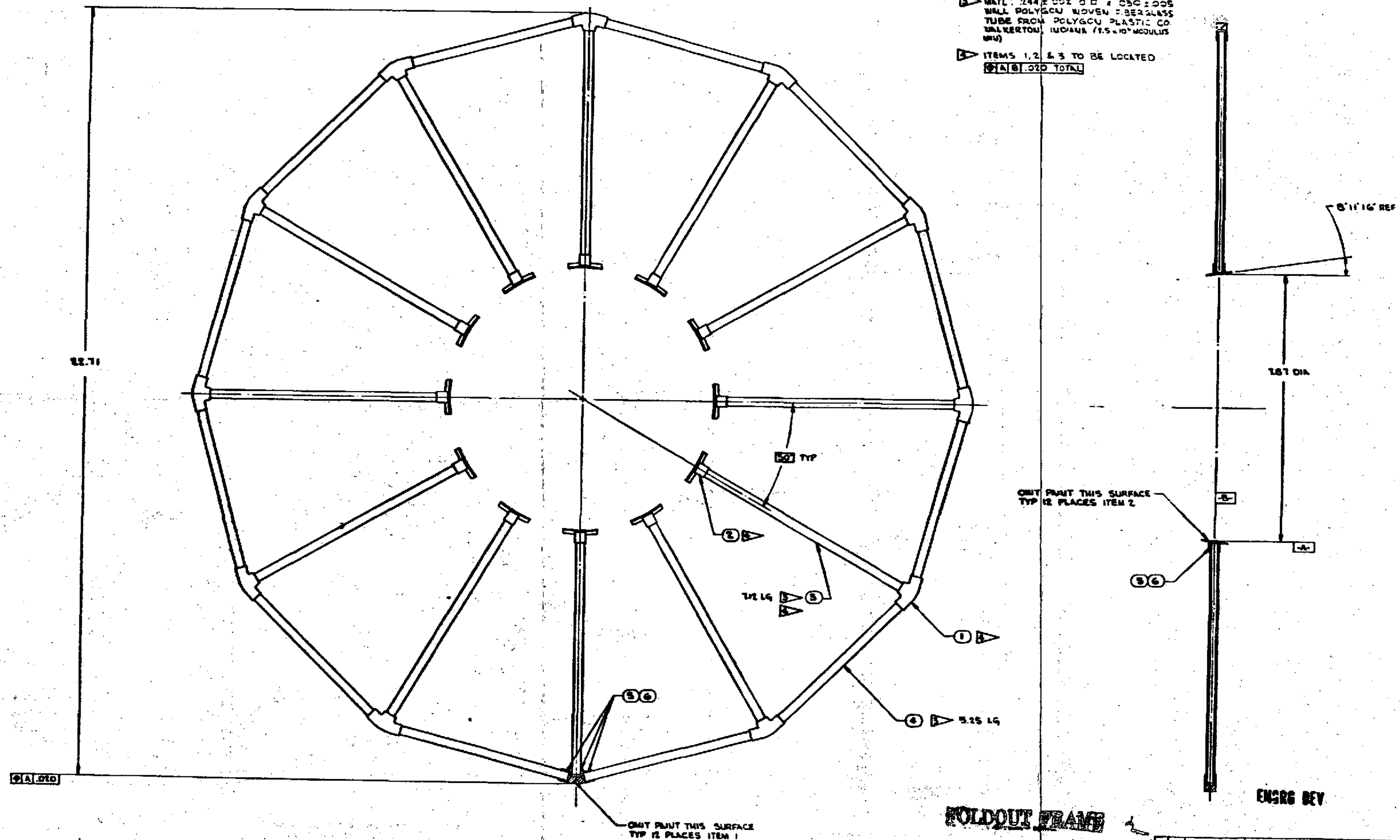
E 91417 615279

FOLDOUT FRAME 1


REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
MAKE FROM 2 LAYERS & 1 LAYER
.021 REF
16°12'36"
.25
.31
10.50 ±.04 DIA
12.00 R
1° TAPER PERMISSIBLE
.03 R TYP
SECTION B-B
1.44
5.00
SPHERICAL R
.021 +.005 -.000
.25 TYP
REF 1
5 REF
5.50 CUTOUT
R FULL TYP
4.40 CUTOUT
.30 X 45° TYP
.018
.50
5 MAKE FROM 3 LAYERS & 1 LAYER
5 MAKE FROM 2 LAYERS & 1 LAYER
.021 +.005 -.000
9.56
16.666
SECTION A-A
4 MAKE FROM 2 LAYERS & 1 LAYER
FOLDOUT FRAME
FOLDOUT FRAME 2
ENGRG DEV.
RADIATION INCORPORATED
OGIVE & TOP RESTRAINT RING ASSY
E 61417 G 5279
615279


NOTES:
1. MARK 91417-615278-1 PER MIL-STD-130 (TAG)
2. BRAZE PER MIL-B-7883
3. HEAT TREAT PRIOR TO MACHINING TO T4 CONDITION PER MIL-H-6088
REVISIONS
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
.063 DIA (NO.52 DRILL) 2 HOLES
SURFACE -A-
12 EQUALLY SPACED PATTERNS
.020 DIA
.201 DIA NEAR WALL
1.150 DIA SPACE
.106 DIA NEAR WALL .201 DIA FAR WALL 4 HOLES
VIEW NORMAL TO SURFACE -A-
SECTION A-A
.201 DIA NEAR WALL
1.150 DIA SPACE
.106 DIA NEAR WALL .201 DIA FAR WALL 4 HOLES
8.670 DIA
7.880 DIA
8.306 DIA
8.062 DIA
FOLDOUT FRAME 1
FOLDOUT FRAME 3
ENGRG DEV
615278-2 RING, INNER
615278-1 RING, OUTER
RADIATION INCORPORATED
RING, TOP RESTRAINT
E 91417 615278
615278

NOTES:
1 MARK 91417-615215G1 PER MIL-STD-130
2 FINISH: COAT WITH S-13 PER RAD SPEC 7741
3 MATL: .244 ± .002 O.D. x .030 ± .005 WALL POLYGON WOVEN FIBERGLASS TUBE FROM POLYGON PLASTIC CO. WALKERTON, INDIANA (1.5 x 10⁶ MODULUS MIN)
4 ITEMS 1, 2, & 3 TO BE LOCATED ⌖ A B .020 TOTAL



ENGRG DEV

FOLDOUT FRAME

QTY	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
AR	6	111053-001	CURING AGENT RESIN
AR	5	111098-001	ADHESIVE
12	4	615215-4	HOOP
12	3	615215-3	SPAR
12	2	420819-1	PAD
12	1	420820-1	SOCKET

LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

TITLE: HOOP-SPAR ASSY

SIZE E | CODE IDENT NO. 91417 | 615215 | REV A

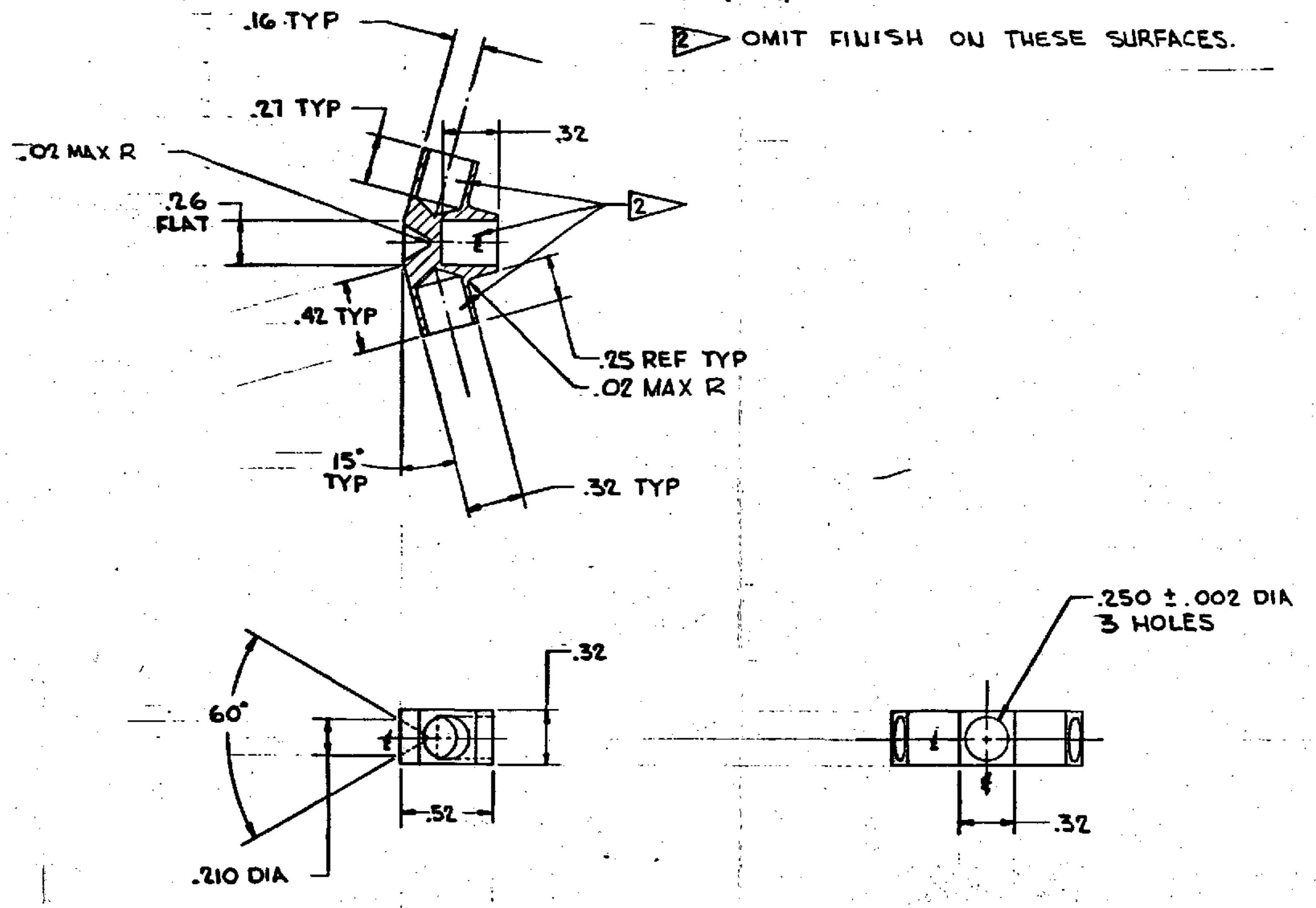
615215 | 1050 (APPLICATION)

FOLDOUT FRAME

A	CHG BY 10/31/73	CHK BY	ECO NO 0217930
	REVISED PER EDC		

NOTES:
1. MARK 91417-420820-1 PER MIL-STD-130 (BAG)

2 OMIT FINISH ON THESE SURFACES.



ENGRG DEV

FOLDOUT FRAME 2

QUANTITY REQUIRED	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

DASH NO.	NEXT ASSY	USED ON
	615215	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65
WELDING SYMBOLS PER AWS A2.0-58

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCES

2 PLACE DEC.	3 PLACE DEC.	ANGLES
±.01	±.005	±1°

MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: ANODIZE PER MIL-A-8625 TYPE III CL 1

CONTRACT NO.

DR BY 7-28-72 | CHK BY 10-10-72

ENGINEER 10-12-72

PROJECT ENGINEER 10-11-72

10-12-72 M Schirm

APPROVAL

APPROVAL C.E. Warren 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE
SOCKET, HOOP-SPAR

SIZE	CODE IDENT NO.		REV
C	91417	420820	A

SCALE 2/1 | SHEET

MF 10-17-72

FOLDOUT FRAME

PARABOLIC COORDINATES

X	Y	X	Y	X	Y	X	Y
0.000 ⊕	0.000	23.000	2.099	41.000	6.639	59.000	13.748
1.000	0.004	23.500	2.181	41.500	6.802	59.500	13.982
2.000	0.016	24.000	2.275	42.000	6.967	60.000	14.218
3.000	0.036	24.500	2.371	42.500	7.134	60.500	14.456
4.000	0.063	25.000	2.468	43.000	7.303	61.000	14.696
5.000	0.099	25.500	2.568	43.500	7.473	61.500	14.938
6.000	0.142	26.000	2.670	44.000	7.646	62.000	15.182
7.000	0.194	26.500	2.773	44.500	7.821	62.500	15.428
8.000	0.253	27.000	2.879	45.000	7.998	63.000	15.675
9.000	0.320	27.500	2.987	45.500	8.176	63.500	15.925
10.000 ⊕	0.395	28.000	3.096	46.000	8.357	64.000	16.177
10.500	0.435	28.500	3.208	46.500	8.540	64.500	16.431
11.000	0.478	29.000	3.321	47.000	8.724	65.000	16.686
11.500	0.522	29.500	3.437	47.500	8.911	65.500	16.944
12.000	0.569	30.000	3.555	48.000	9.100	66.000	17.204
12.500	0.617	30.500	3.674	48.500	9.290	66.500	17.465
13.000	0.667	31.000	3.795	49.000	9.483	67.000	17.729
13.500	0.720	31.500	3.919	49.500	9.677	67.500	17.995
14.000	0.774	32.000	4.044	50.000	9.874	68.000	18.262
14.500	0.830	32.500	4.172	50.500	10.072	68.500	18.532
15.000	0.889	33.000	4.301	51.000	10.273	69.000	18.803
15.500	0.949	33.500	4.432	51.500	10.475	69.500	19.077
16.000	1.011	34.000	4.566	52.000	10.679	70.000	19.352
16.500	1.075	34.500	4.701	52.500	10.886	70.500	19.630
17.000	1.141	35.000	4.838	53.000	11.094	71.000	19.909
17.500	1.210	35.500	4.977	53.500	11.304	71.500	20.191
18.000	1.280	36.000	5.118	54.000	11.517	72.000	20.474
18.500	1.352	36.500	5.262	54.500	11.731	72.500	20.759
19.000	1.426	37.000	5.407	55.000	11.947	73.000	21.047
19.500	1.502	37.500	5.554	55.500	12.165	73.500	21.336
20.000	1.580	38.000	5.703	56.000	12.385	74.000	21.627
20.500	1.660	38.500	5.854	56.500	12.608	74.500	21.920
21.000	1.742	39.000	6.007	57.000	12.832	75.000	22.216
21.500	1.826	39.500	6.162	57.500	13.058		
22.000	1.912	40.000	6.319	58.000	13.286		
22.500	1.999	40.500	6.478	58.500	13.516		

⊕ FOR REFERENCE ONLY

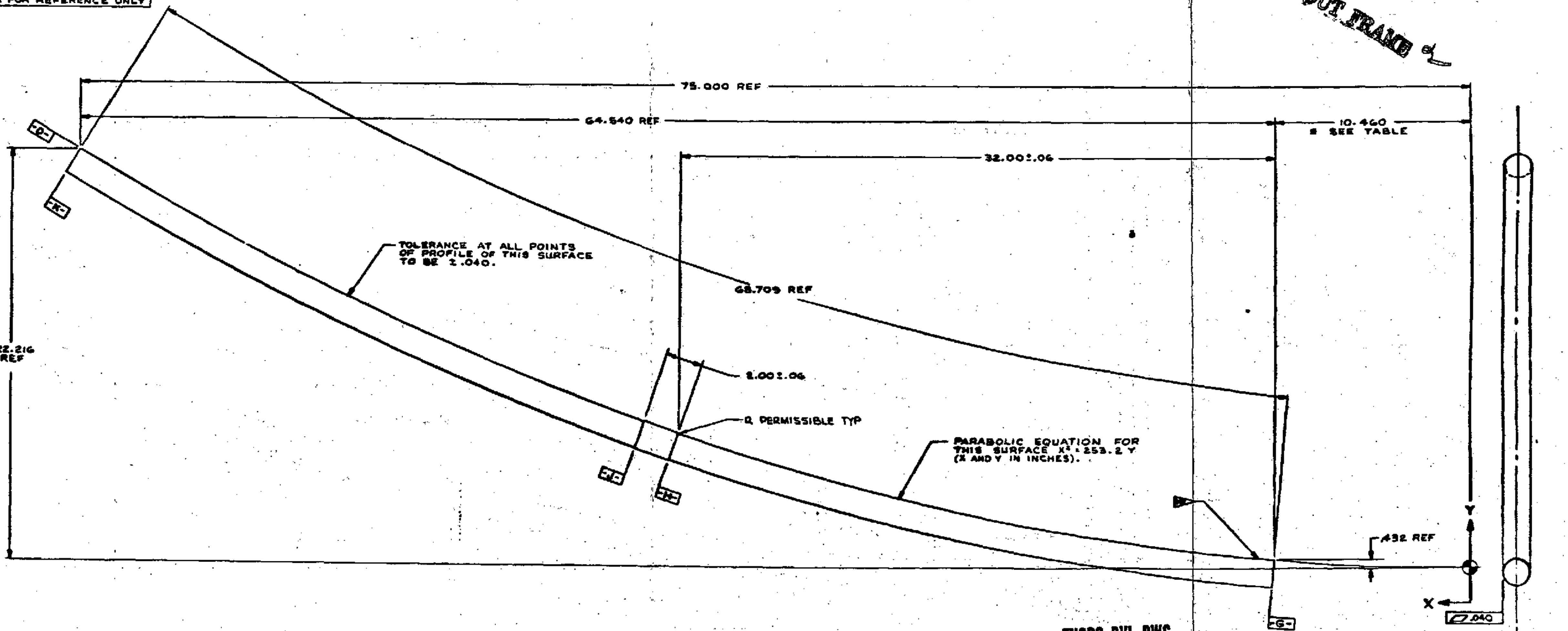
NOTES:

1. DIMENSIONS IN THE TABLE ARE BASIC.
2. TERM "NORMAL TO SURFACE" AS USED ON THIS DRAWING MEANS A THEORETICAL LINE PERPENDICULAR TO SURFACE D (PARABOLIC CURVE) AT ANY GIVEN POINT ON THAT CURVE.
3. FORMED TUBE TO BE ROUND WITHIN .100 TOTAL, FULL LENGTH OF TUBE.
4. SHARP BEND DISCONTINUITIES OR INDENTATIONS NOT PERMITTED.
5. WALL THICKNESS OF TUBE TO BE CHEMICALLY MILLED TO THE FOLLOWING PROFILE: UNIFORMLY TAPERED FROM .009 ±.001 (DATUM G) TO .013±.001 (DATUM H); CONSTANT THICKNESS OF .020±.001 FROM DATUM H TO J; AND UNIFORMLY TAPERED FROM .013±.001 (DATUM J) TO .007±.001 (DATUM K).
6. THERE SHALL BE NO NOTICEABLE TOOL MARKS OR INDENTATIONS ON EXTERIOR SURFACE OF TUBE.

NOTES CONT.

7. ENDS OF TUBE (DATUMS G&K) TO BE CUT OFF NORMAL TO SURFACE D WITHIN .010.
8. MARK 91417-G15274-001 PER MIL-STD-130. (TAG).
9. ELECTRIC ETCH IN AREA SHOWN 1/16 HIGH CHARACTERS SERIALLY ON EACH TUBE (1, 2, 3, --- ETC).

FOLDOUT FRAME



ENGRG DVL DWG

FOLDOUT FRAME

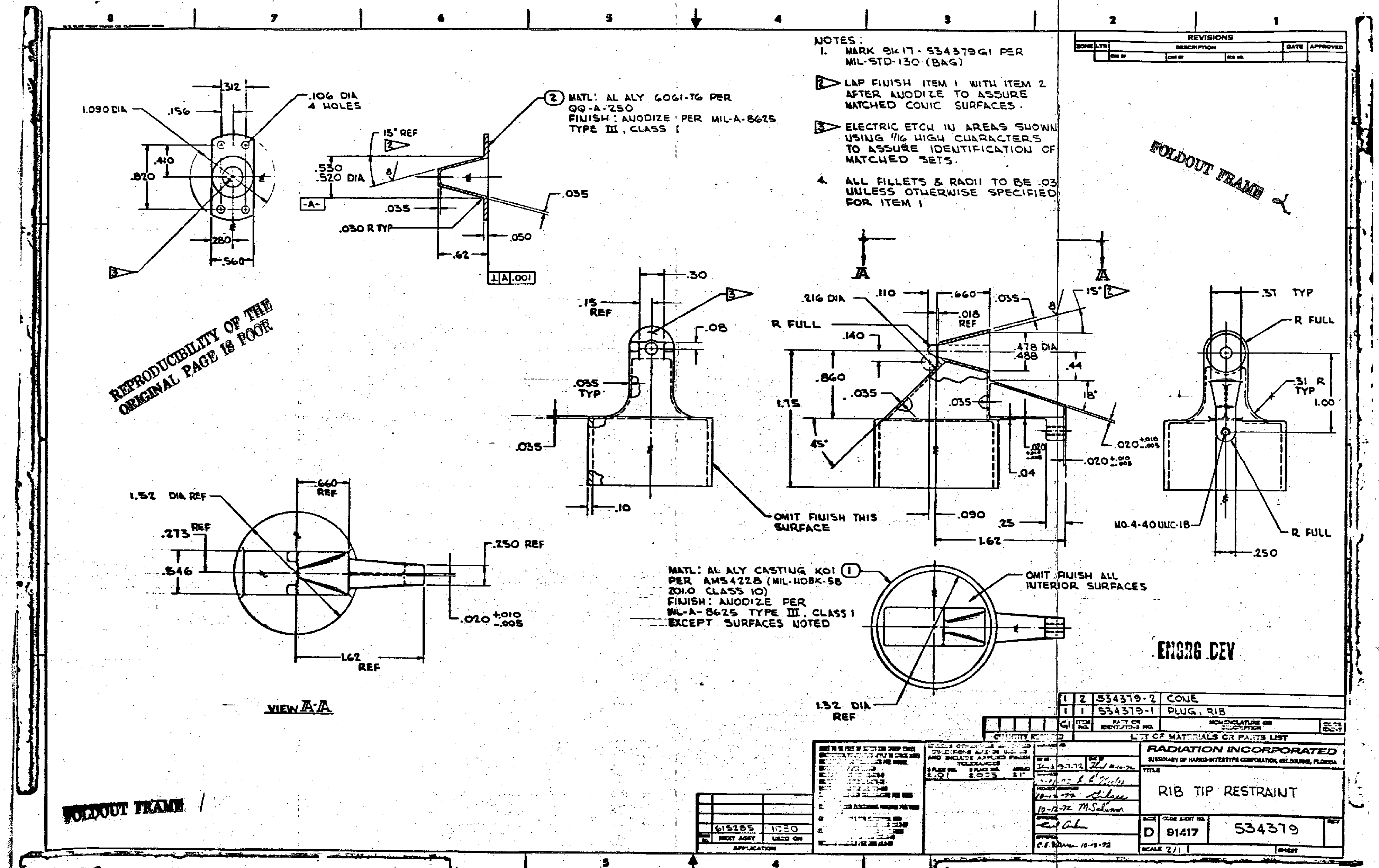
MATL: AL ALLOY TUBE 1.500 O.D. X.022 WALL THK 6061-T6 PER WW-T-700.

LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

RIB

E 91417 G15274 A

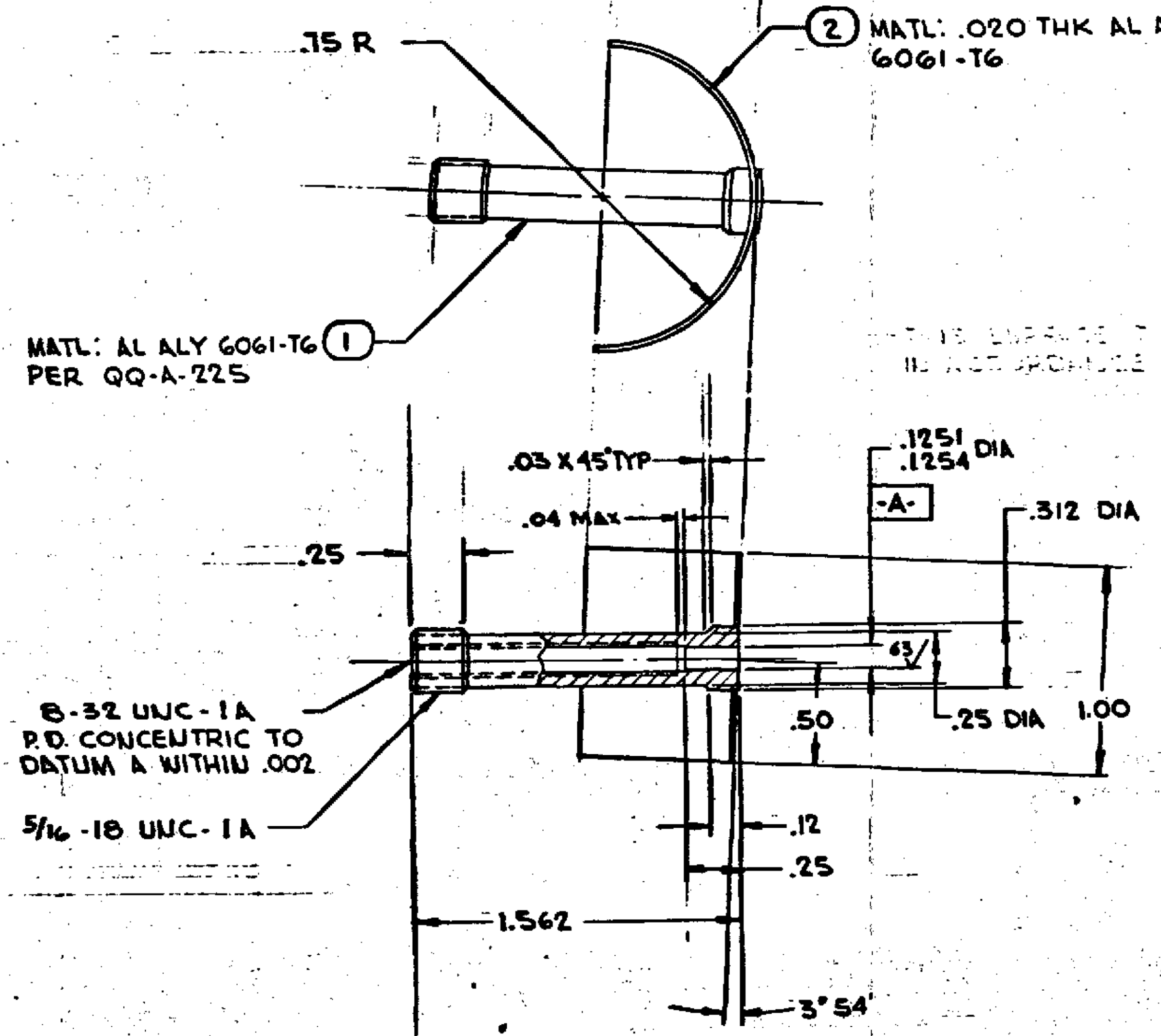

NOTES:
1. MARK 91417-534379G1 PER MIL-STD-130 (BAG)
2 LAP FINISH ITEM 1 WITH ITEM 2 AFTER ANODIZE TO ASSURE MATCHED CONIC SURFACES.
3 ELECTRIC ETCH IN AREAS SHOWN USING 1/16 HIGH CHARACTERS TO ASSURE IDENTIFICATION OF MATCHED SETS.
4. ALL FILLETS & RADII TO BE .03 UNLESS OTHERWISE SPECIFIED FOR ITEM 1
2 MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: ANODIZE PER MIL-A-8625 TYPE III, CLASS I
MATL: AL ALY CASTING K01 PER AMS4228 (MIL-HDBK-5B 201.0 CLASS 10)
FINISH: ANODIZE PER MIL-A-8625 TYPE III, CLASS I EXCEPT SURFACES NOTED
OMIT FINISH ALL INTERIOR SURFACES
OMIT FINISH THIS SURFACE
1.090 DIA
.106 DIA 4 HOLES
.312
.156
.410
.820
.280
.560
15° REF
.530
.520 DIA
-A-
.035
.030 R TYP
.62
.050
⊥ A .001
.30
.15 REF
.08
.035 TYP
.10
.216 DIA
.110
.660
.018 REF
R FULL
.140
.478 DIA
.488
.44
.860
1.75
45°
18°
.020 +.010 -.005
.04
.090
.25
1.62
.31 TYP
.31 R TYP
1.00
NO.4-40 UNC-1B
.250
1.52 DIA REF
.660 REF
.273 REF
.546
.250 REF
1.62 REF
VIEW A-A
1.32 DIA REF
ENGRG DEV
REVISIONS
| 1 | 2 | 534379-2 | CONE |
| 1 | 1 | 534379-1 | PLUG, RIB |
G1 ITEM NO. PART OR IDENTIFYING NO. NOMENCLATURE OR DESCRIPTION
LIST OF MATERIALS OR PARTS LIST
615285 1050 NEXT ASSY USED ON APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
±.01 ±.005 ±1°
9-7-72
10-12-72
10-12-72 M. Schuman
10-12-72
RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA
TITLE RIB TIP RESTRAINT
D 91417 534379
SCALE 2/1

4 3 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	REVISED PER EDC — ECO NO. 6217931		

NOTES:

1. MARK 91417-420847-G1 PER MIL-STD-130 (TAG)
2. BRAZE PER MIL-B-7883
3. HEAT TREAT TO T4 CONDITION PER MIL-H-6088.



FOLDOUT FRAME 2

ENGRG DEV

1	2	420847-2	SUPPORT
1	1	420847-1	TUBE
G1	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION / CODE IDENT
QUANTITY REQUIRED		LIST OF MATERIALS OR PARTS LIST	

APPLICATION	
NEXT ASSY	USED ON
615283	1080

PART TO BE FREE OF BURRS AND SHARP EDGES; COMMERCIAL TOLERANCES APPLY TO STOCK SIZES; MANUFACTURING TOLERANCES PER 900002; WORKMANSHIP PER SC200; SCREW THREADS PER MIL-STD-9; ABBREVIATIONS PER MIL-STD-12; LOGIC SYMBOLS PER MIL-STD-806; DIMENSIONING AND TOLERANCING PER USAS Y14.5-66; ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66; GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAMS PER USAS Y32.2-67; ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65; WELDING SYMBOLS PER AWS A2.0-58

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

TOLERANCES: 2 PLACE DEC. ±.02; 3 PLACE DEC. ±.005; ANGLES ±1°

CONTRACT NO.

DR BY 8-2-72 — CHK BY 10-10-72
ENGINEER 10-12 I. J. Biles
PROJECT ENGINEER 10-11-72 Silger
10-12-72 M. Schwam
APPROVAL Carl Arken
APPROVAL C E Warren 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: SUPPORT, MIDPOINT

SIZE	CODE IDENT NO.		REV
C	91417	420847	A

SCALE 2/1 — SHEET 1

FOLDOUT FRAME 1

4 3 2

308389

NOTES:

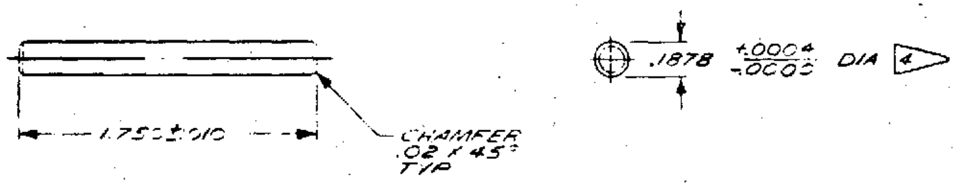
1. MARK 91417-308389-1 PER MIL-STD-130. (BAG)

2. MAKE FROM PIC DESIGN CAT. NO. A5-17, TO BE STRAIGHT WITHIN .0001 PER IN. TO BE .1872±.0002 DIA. AND MADE FROM TYPE 303 CRES, CLEAR PASSIVATED.

3. FIN. O.D. SHALL BE LUBRICATED WITH LUBECO # 905 IN ACCORDANCE WITH RAD DWG. NO. 207610.

4. DIMENSION APPLIES AFTER COATING PER NOTE 3.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		



QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
LIST OF MATERIALS OR PARTS LIST				

DASH NO.	NEXT ASSY	USED ON
	615284	1080
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900082
WORKMANSHIP PER 900060
SCREW THREADS PER MIL STD-9
ABBREVIATIONS PER MIL STD-12
LOGIC SYMBOLS PER MIL STD 806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5 66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15 66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16 65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES: 2 PLACE 3 PLACE ANGLES

MATL: 2
FINISH: 3

CONTRACT NO
DR BY 10-11-72 / CHK BY 10-11-72
10-11-72 L. E. Perlag
PROJECT ENGINEER 10-11-72
10-12-72 M. Schuman
APPROVAL Earl Cacher
APPROVAL C E Warner 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION MELBOURNE, FLORIDA

TITLE
SHAFT, PIVOT

SIZE	CODE IDENT NO.		REV
B	91417	308389	
SCALE 2/1		SHEET	

NF 10-17-72

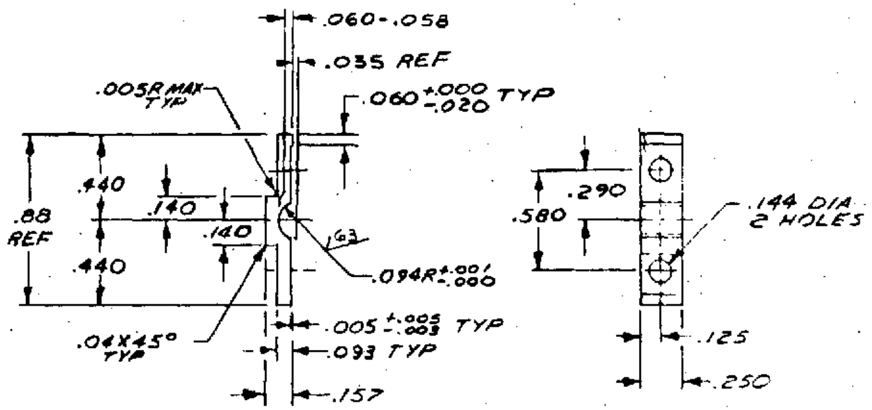
308391

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. MARK 91417-308391-1 PER MIL-STD-130 (BAG)
2. MATL: AL ALY 6061-T6 PER QQ-A-250
3. FINISH: CHEMICAL FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS I
4. 125 ALL OVER UNLESS OTHERWISE SPECIFIED.



ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD	LIST OF MATERIALS OR PARTS LIST		

DASH NO.	NEXT ASSY	USED ON
	615284	1080
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900068
SCREW THREADS PER MIL STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES

MATL: 2
FINISH: 3

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION MELBOURNE, FLORIDA

TITLE: CLAMP, PIVOT SHAFT

SIZE: B | CODE IDENT NO. 91417 | 308391

SCALE 2/1 | SHEET

308396

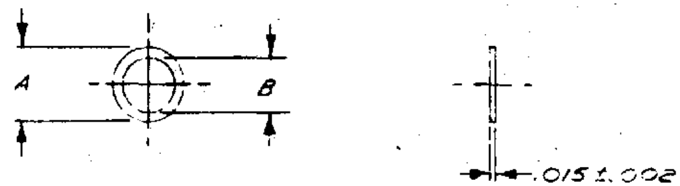
REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHK BY / CHK BY / ECO NO.		

NOTES:

1. MARK 91417-308396 PER MIL-STD-130. (BAG)

2. RT/5813 DUROID-ROGERS CORP, ROGERS, CONN.



PART NO.	DIM A	DIM B
308396-1	.134 DIA	[illegible] DIA
308396-2	.149/.156 DIA	.129 DIA
308396-3	.2[illegible] DIA	.079 DIA
308396-4	.42 DIA	.200 DIA

PART NO.	NEXT ASSY	USED ON
-4	615284	1080
-3	615284	1080
-2	615284	1080
-1	534385	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 980002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL STD 806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT.

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES

MATL: 2

CONTRACT NO

DR BY 9-15-72 CHK BY 10-11-72

ENGINEER 10-11-72 E Hale

PROJECT ENGINEER 10-11-72

10-12-72 McSchwan

APPROVAL

APPROVAL C E Warner 10-12-72

RADIATION INCORPORATED

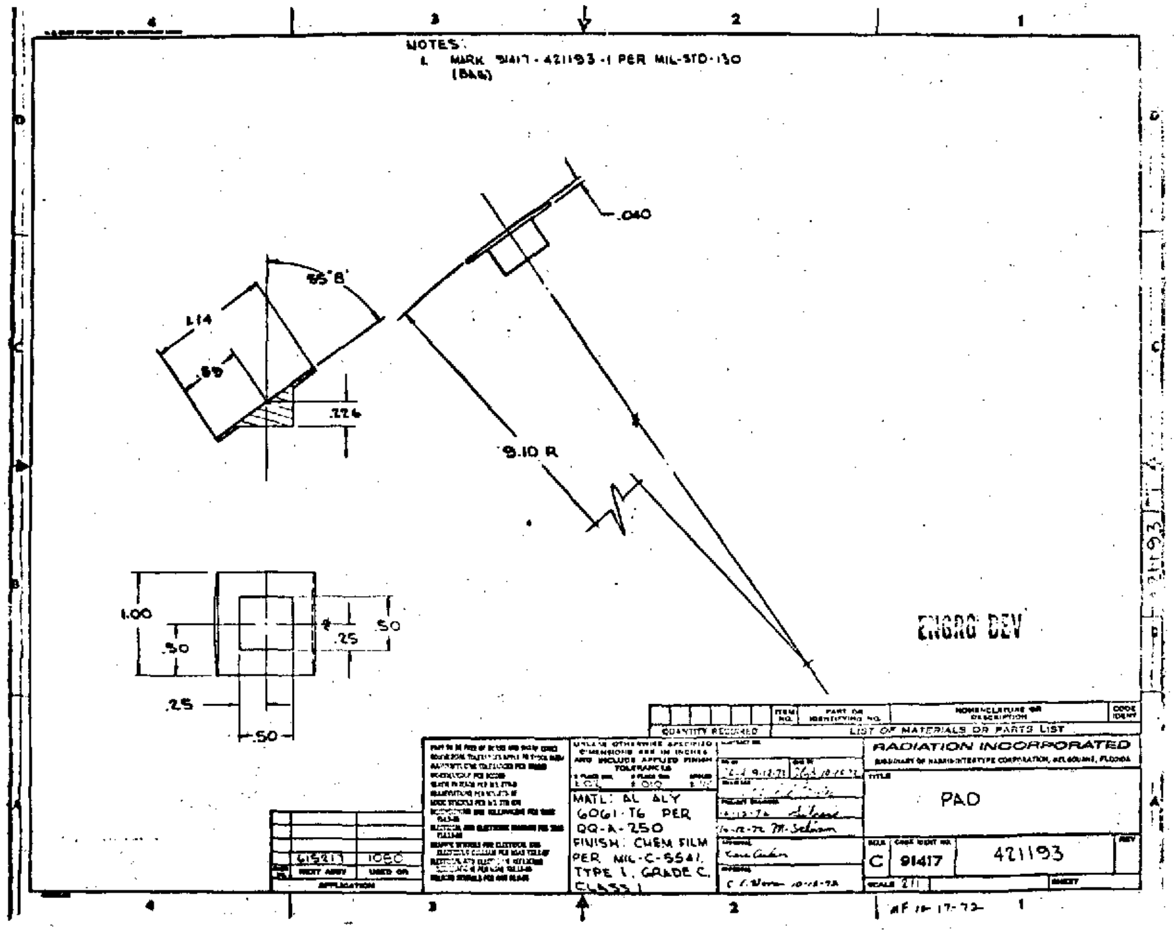
SUBSIDIARY OF HARRIS INTERTYPE CORPORATION, MELBOURNE, FLORIDA

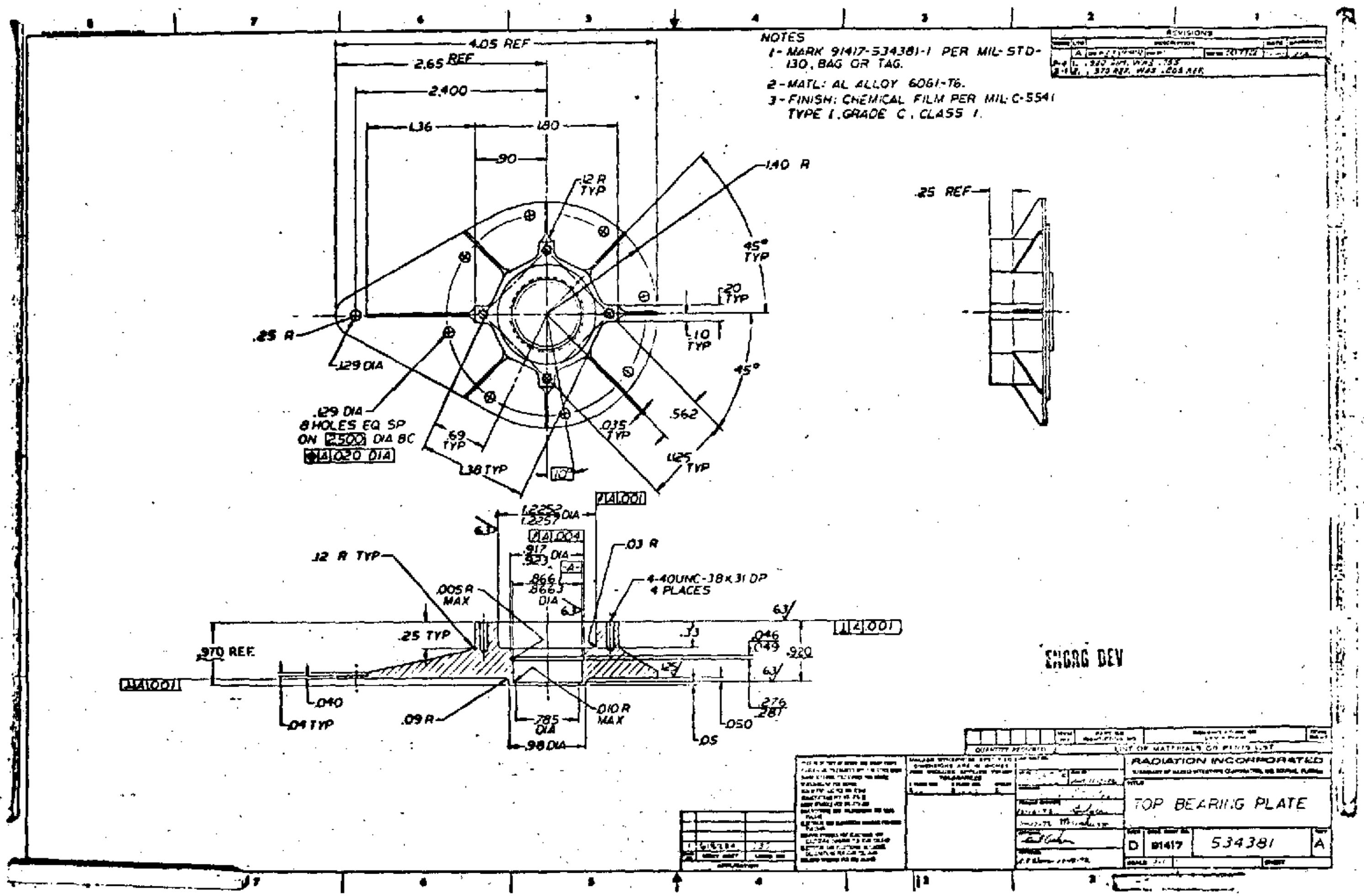
TITLE WASHER

SIZE	CODE IDENT NO.		REV
B	91417	308396	

SCALE 4/1 SHEET

AF 11-17-72-1

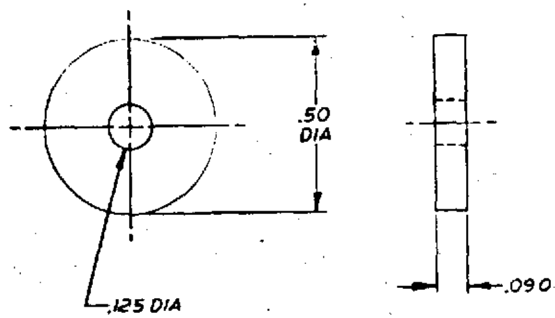

NOTES:
1. MARK 91417-421193-1 PER MIL-STD-130
(BAG)
.040
65°8'
1.14
.86
.226
9.10 R
1.00
.50
.25
.50
.25
.50
ENGRG DEV
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
MATL: AL ALY
6061-T6 PER
QQ-A-250
FINISH: CHEM FILM
PER MIL-C-5541,
TYPE I, GRADE C,
CLASS I
RADIATION INCORPORATED
PAD
C 91417 421193
615211 1060
APPLICATION


NOTES
1- MARK 91417-534381-1 PER MIL-STD-130, BAG OR TAG.
2- MATL: AL ALLOY 6061-T6.
3- FINISH: CHEMICAL FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS I.
4.05 REF
2.65 REF
2.400
1.36
1.80
.90
.12 R TYP
1.40 R
45° TYP
45°
.20 TYP
.10 TYP
.25 R
.129 DIA
.129 DIA
8 HOLES EQ SP ON 2.500 DIA BC
.562
.035 TYP
1.125 TYP
.69 TYP
.38 TYP
.25 REF
.12 R TYP
.005 R MAX
.25 TYP
.970 REF
.040
.04 TYP
.09 R
.785 DIA
.98 DIA
.010 R MAX
.03 R
4-40UNC-3B X .31 DP 4 PLACES
.33
.046
.149
.920
.276
.281
.050
.05
ENGRG DEV
RADIATION INCORPORATED
TOP BEARING PLATE
D 91417 534381 A

308384

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:
1- MARK 91417-308384-1 PER MIL-STD-130. (BAG)
2- MATL: LAMINATED SHIM STOCK PER MIL-S-22499 COMPOSITION-1, TYPE-1, CLASS-1.



ENGRG DEV

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.010 ANGLES ±

CONTRACT NO.
DR BY 8-26-71 CHK BY
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72 M. Schum
APPROVAL
APPROVAL C.F. Warm 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE
SHIM - TAKE-UP SHAFT

SIZE B | CODE IDENT NO. 91417 | 308384 | REV
SCALE 4-1 | SHEET

1	615284	1080
DASH NO.	NEXT ASSY	USED ON
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900050
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-68
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

MF 10-17-72

308383

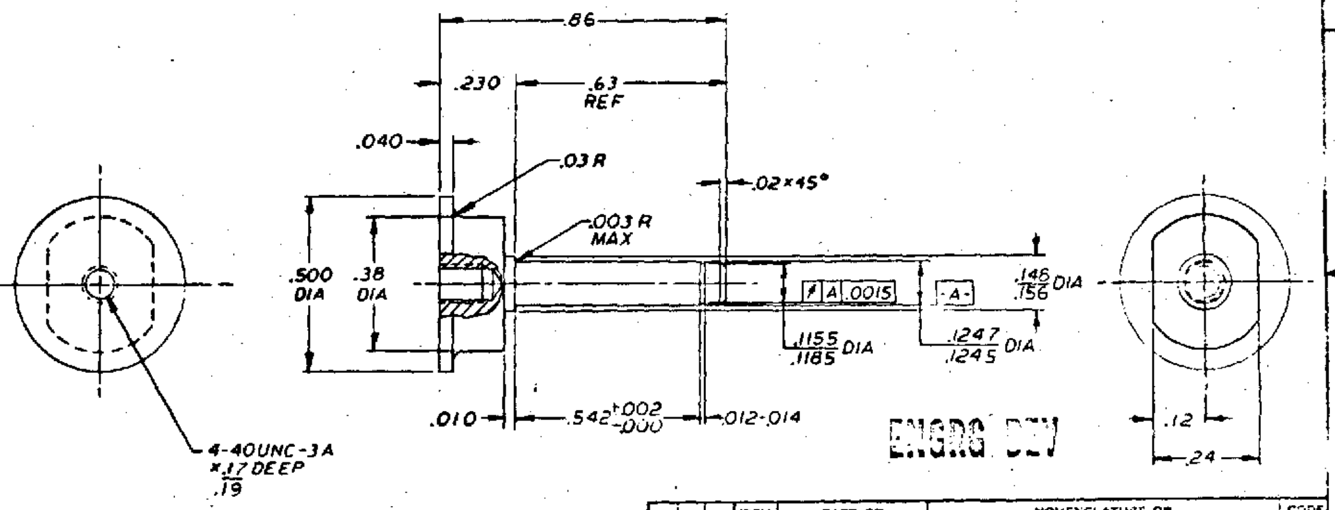
NOTES:

1- MARK 91417-308383-1 PER MIL-STD-130, BAG.

2- MATL: STAINLESS STEEL TYPE 303.

3- FINISH PASSIVATE PER QQ-P-35.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		



ENGRG DEV

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH. TOLERANCES: 2 PLACE ±.01; 3 PLACE ±.005; ANGLES ±

CONTRACT NO.

DR BY 2-24-72 · CHK BY

ENGINEER

PROJECT ENGINEER

12-12-72

APPROVAL

APPROVAL 10-12-72

RADIATION INCORPORATED

SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: SHAFT - TAKE-UP DRUM

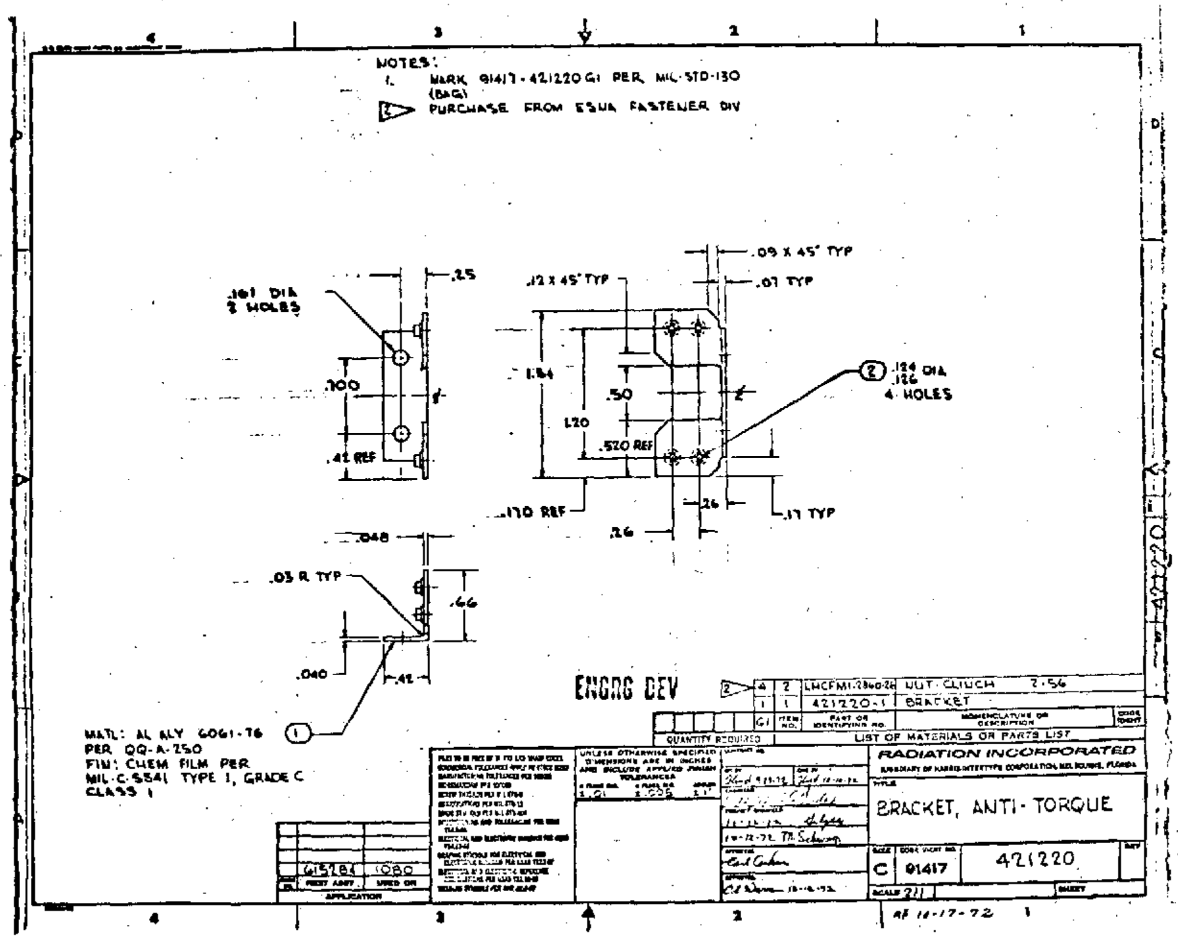
SIZE: B · CODE IDENT NO.: 91417 · 308383 · REV

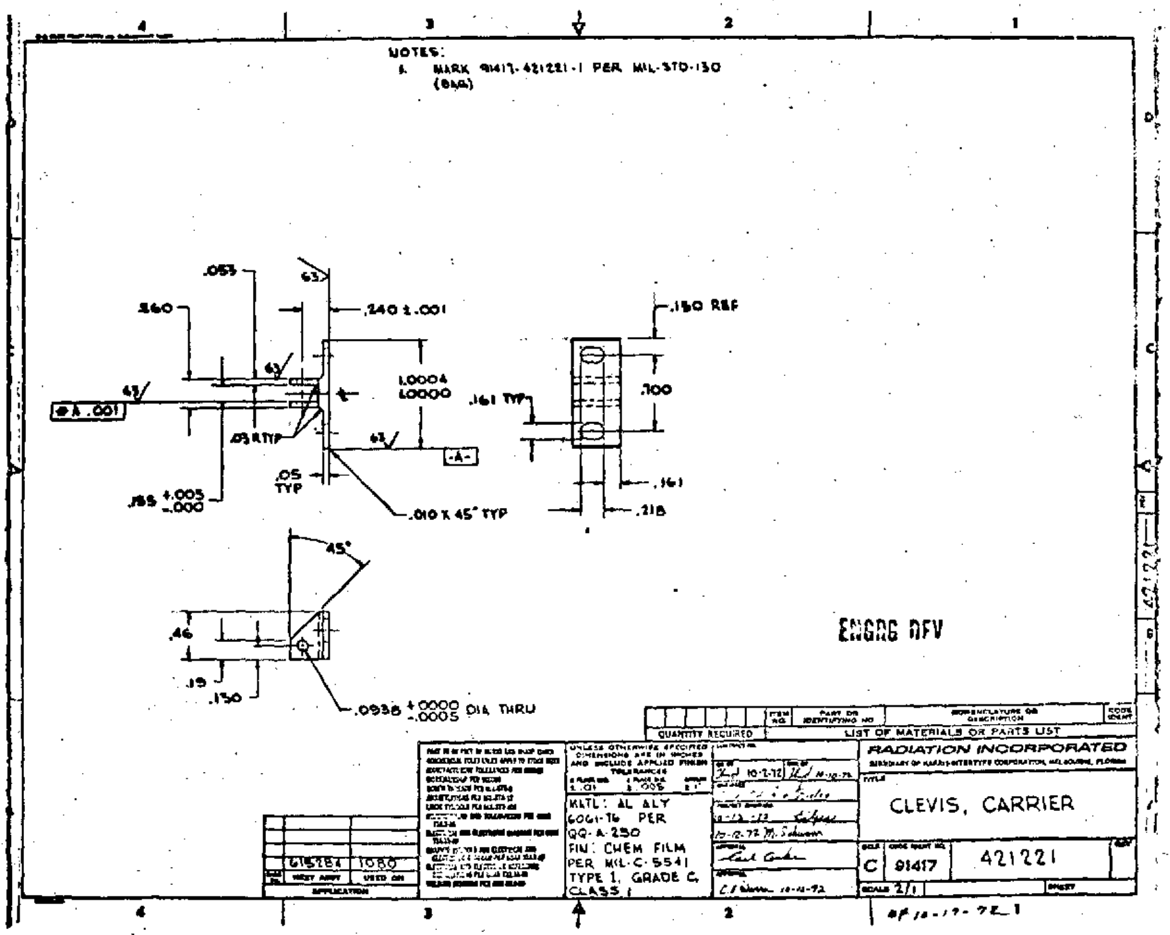
SCALE 4-1 · SHEET

	NEXT ASSY	USED ON
1	615284	1080
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900088
WORKMANSHIP PER 900040
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-68

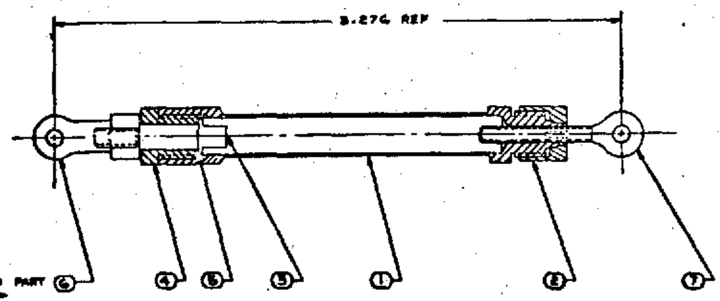
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-68


NOTES:
1. MARK 91417-421220G1 PER MIL-STD-130 (BAG)
2 PURCHASE FROM ESNA FASTENER DIV
.161 DIA 2 HOLES
.25
.100
.41 REF
.12 X 45° TYP
.09 X 45° TYP
.07 TYP
1.84
.50
1.20
.520 REF
.124 DIA .126 4 HOLES
.170 REF
.26
.26
.17 TYP
.048
.03 R TYP
.66
.040
.41
MATL: AL ALY 6061-T6 PER QQ-A-250
FIN: CHEM FILM PER MIL-C-5541 TYPE 1, GRADE C CLASS 1
ENGRG DEV
LHCFM1-2560-24 NUT-CLINCH 2-56
421220-1 BRACKET
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
BRACKET, ANTI-TORQUE
C 91417 421220
615281 1080
NEXT ASSY USED ON
APPLICATION
12-17-72


NOTES:
1. MARK 91417-421221-1 PER MIL-STD-130
.053
.560
.240 ±.001
.150 REF
1.0004
1.0000
.161 TYP
.700
.05
TYP
.010 X 45° TYP
.161
.218
45°
.46
.19
.150
.0938 +.0000 -.0005 DIA THRU
ENGRG DEV
LIST OF MATERIALS OR PARTS LIST
QUANTITY REQUIRED
RADIATION INCORPORATED
MATL: AL ALY 6061-T6 PER QQ-A-250
FIN: CHEM FILM PER MIL-C-5541 TYPE 1, GRADE C, CLASS 1
CLEVIS, CARRIER
C
91417
421221
SCALE 2/1
APPLICATION
615284
1080
NEXT ASSY
USED ON

NOTES:

1. PURCHASE FROM NEW HAMPSHIRE BALLBEARING INC. PETERBOROUGH, NEW HAMPSHIRE.
2. SECURE ITEM 4 TO ITEM 1 AND ITEM 3 TO ITEM 6 USING ITEM 8.
3. SPHERICAL SURFACE OF BALL TO BE LUBRICATED WITH LUBECO #905 IN ACCORDANCE WITH RADIATION DWG 307010.
4. MARK 91417-534385-001 PER MIL-STD-130. (BAG OR TAG).



MATL: MAKE FROM PART NO. F-2
FINISH:

ENGRG DVL DWG

QTY	ITEM	PART NO.	NOMENCLATURE
AR	8	GRADE AA	LOCTITE PER MIL S-22473 (GRADE AA)
1	7	303333-001	ROD END
1	6	534335-004	ROD END, MINIATURE
1	5	303336-001	WASHER
1	4	303335-001	RETAINER
1	3	309337-001	SCREW
1	2	303303-001	NUT, LOCKING
1	1	421136-001	TUBE

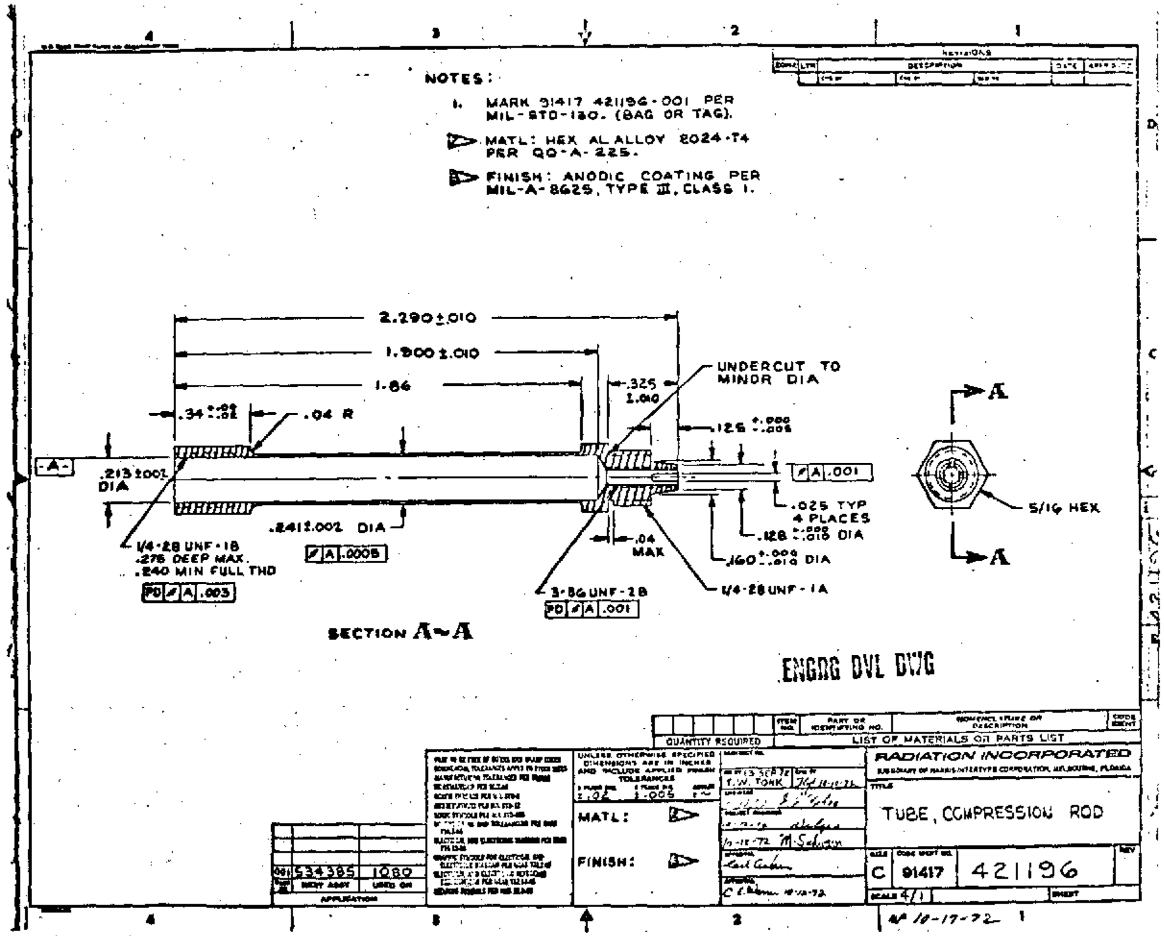
LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

COMPRESSION ROD ASSEMBLY

D | 91417 | 534385

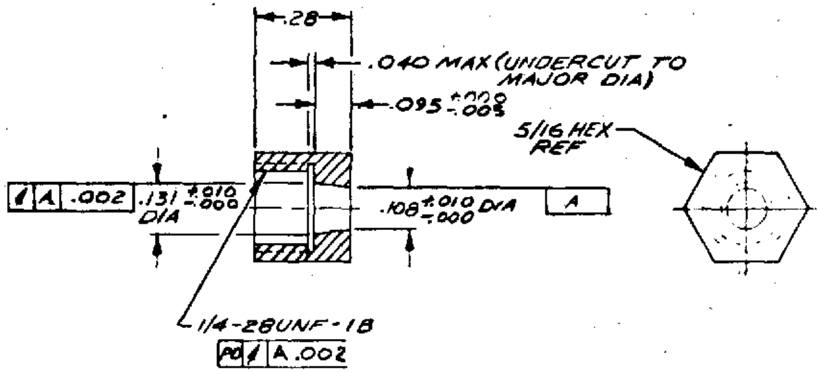
SCALE 4/1


NOTES:
1. MARK 91417 421196-001 PER MIL-STD-130. (BAG OR TAG).
2 MATL: HEX AL ALLOY 2024-T4 PER QQ-A-225.
3 FINISH: ANODIC COATING PER MIL-A-8625, TYPE III, CLASS I.
2.290±.010
1.900±.010
1.86
.325 ±.010
UNDERCUT TO MINOR DIA
.04 R
.125
-A-
.213±.001 DIA
.241±.002 DIA
.025 TYP 4 PLACES
.04 MAX
1/4-28 UNF-1B .275 DEEP MAX. .240 MIN FULL THD
3-56 UNF-2B
1/4-28 UNF-1A
5/16 HEX
A
SECTION A-A
ENGRG DVL DWG
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
534385
1080
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
±.02 ±.005
MATL:
FINISH:
T.W. TONK
RADIATION INCORPORATED
TITLE
TUBE, COMPRESSION ROD
C
91417
421196
SCALE 4/1
SHEET
10-17-72

308393

NOTES:

1. MARK 91417-308393-1 PER MIL-STD-130 (BAG)
2. MATL: HEX AL ALY 2024-T4 PER QQ-A-225.
3. FINISH: ANODIC COATING PER MIL-A-8625, TYPE III, CLASS 1.



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
534385	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER MIL-STD

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES

MATL: 2

FINISH: 3

CONTRACT NO

DR BY 10-12-72 CHK BY 10-12-72

ENGINEER 10-17-72

PROJECT ENGINEER 10-17-72

10-12-72

APPROVAL

APPROVAL 10-2-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: NUT, LOCKING

SIZE B | CODE IDENT NO. 91417 | 308393 | REV

SCALE 4/1 | SHEET

MF 10-17-72

308397

REVISIONS

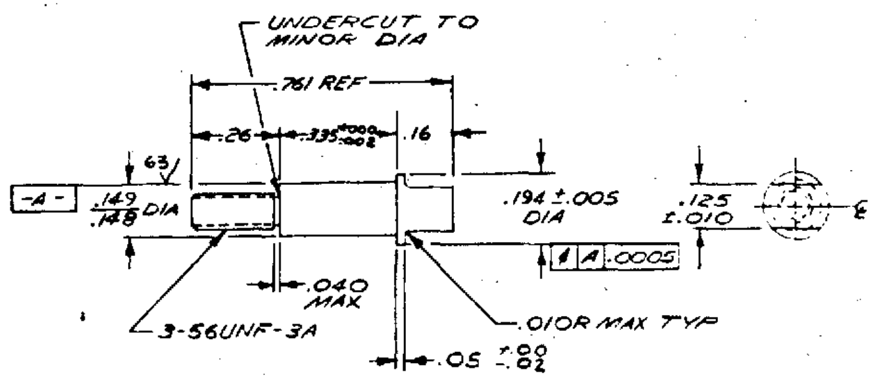
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY. / CHK BY / ECO NO		

NOTES:

1. MARK 91417 · 308397 -1 PER MIL-STD-130. (BAG)

2. MATL: SST TYPE 303 PER QQ-S-763

3. FINISH: PASSIVATE PER QQ-P-35



ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD	LIST OF MATERIALS OR PARTS LIST		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES

MATL: 2

FINISH: 3

	NEXT ASSY	USED ON
	334385	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES. COMMERCIAL TOLERANCES APPLY TO STOCK SIZES. MANUFACTURING TOLERANCES PER 900082. WORKMANSHIP PER 900060. SCREW THREADS PER MIL-STD-9. ABBREVIATIONS PER MIL-STD-12. LOGIC SYMBOLS PER MIL-STD-806. WELDING SYMBOLS PER AWS A2.0-58.

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66. ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66. GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67. ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65.

RADIATION INCORPORATED

SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: SCREW, COMPRESSION ROD

SIZE: B | CODE IDENT NO: 91417 | 308397 | REV

SCALE 4/1 | SHEET

APPROVAL: C.E. Warren 10-12-72

MF 10-19-72

308395

NOTES:

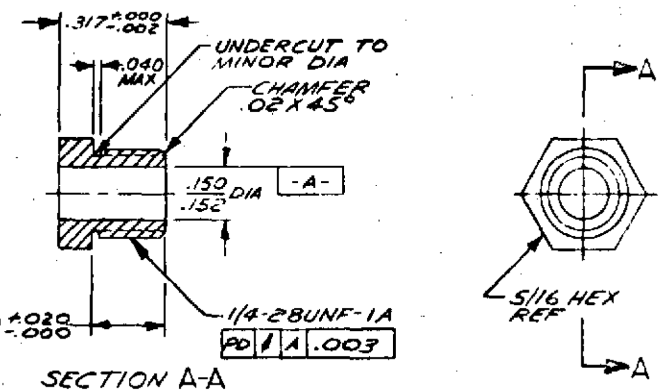
1. MARK 91417-308395-1 PER MIL-STD-130. BAG

2. MATL: 5/16 HEX AL ALY 2024-T4 PER QQ-A-225.

3. FINISH: ANODIC COATING PER MIL-A-8625, TYPE III, CLASS 1.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO		



SECTION A-A

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

	534385	1083
DASH NO.	NEXT ASSY	USED ON
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.005 ANGLES ±1/2°

MATL: 2
FINISH: 3

CONTRACT NO
DR BY 9-18-72 CHK BY
CHK BY 11-72
PROJECT ENGINEER 10-11-72
10-12-72 M. Schwan
APPROVAL
APPROVAL C. E. 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE RETAINER

SIZE B | CODE IDENT NO. 91417 | 308395 | REV

SCALE 4/1 | 001246 C | SHEET

MF 10-17-72

308388

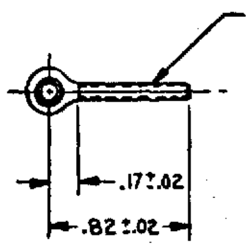
ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		

NOTES:

1. MARK 91417 308388-001 PER MIL-STD-130. (BAG OR TAG).

2. MATL: SIMILAR TO NEW HAMPSHIRE BALL BEARINGS INC., PART NO. M-2.

3. FINISH: SPHERICAL SURFACE OF BALL TO BE LUBRICATED WITH LUBECO # 905 IN ACCORDANCE WITH RADIATION DWG 307610.



ENGRG DVL DWG

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
LIST OF MATERIALS OR PARTS LIST				

DASH NO.	NEXT ASSY	USED ON
001	534385	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900000
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH
TOLERANCES: 2 PLACE ± ~ 3 PLACE ± ~ ANGLES ± ~

MATL: 2
FINISH: 3

CONTRACT NO.
DR BY 13 SEP 72 T.W. Tomkins CHK BY 10-12-72
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72 M. Sebrum
APPROVAL Carl Cuke
APPROVAL C.E. Warner 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: ROD END

SIZE	CODE IDENT NO.		REV
B	91417	308388	

SCALE 2/1 SHEET

MF 10-17-72

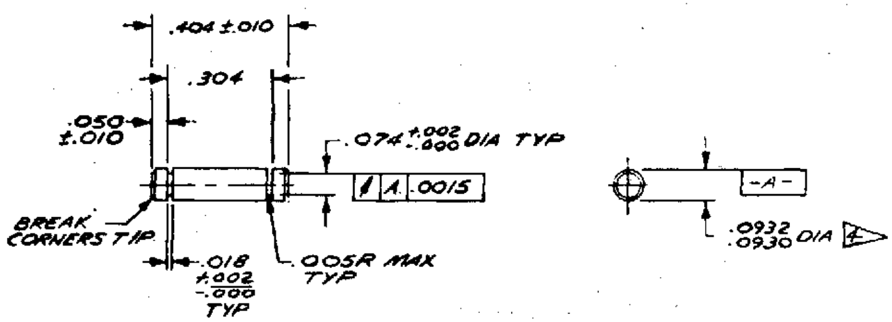
308390

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO		

NOTES:

1. MARK 91417-308390-1 PER MIL-STD-130. (BAG)
2. MATL: .0924 $^{+.0000}_{-.0002}$ STAINLESS STEEL TYPE 416 PER QQ-S-764A
3. PIN O.D. TO BE LUBRICATED WITH LUBECO #905 IN ACCORDANCE WITH RADIATION DWG 307610.
4. DIMENSION APPLIES AFTER COATING PER NOTE 3.



ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD	LIST OF MATERIALS OR PARTS LIST		

NEXT ASSY	USED ON
615284	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH

MATL: 2

FINISH: 3

RADIATION INCORPORATED

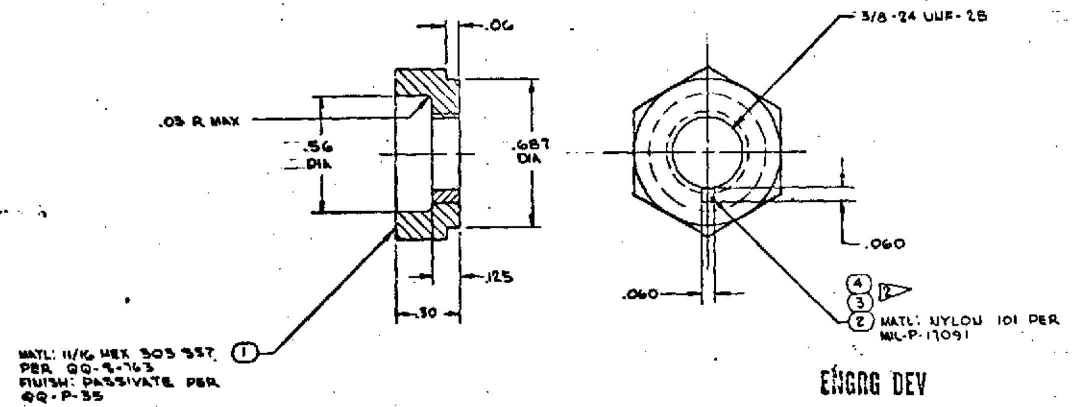
TITLE: SHAFT, ROD END

SIZE B | CODE IDENT NO. 91417 | 308390

SCALE 4/1 | SHEET

APPROVAL: C. E. [illegible] 10-12-72

NOTES:
1. MARK 91417-421236G1 PER MIL-STD-130 (BAG)
2. MIX BY WEIGHT AS FOLLOWS:
   100 PARTS ITEM 3
   12 PARTS ITEM 4



ENGRG DEV

QTY	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
AR	4	111053-001	CURING AGENT, RESIN
AR	3	111098-001	ADHESIVE
1	2	421236-2	PELLET, LOCKING
1	1	421236-1	STOP
G1			

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
615184	1290

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
.02 .005

RADIATION INCORPORATED

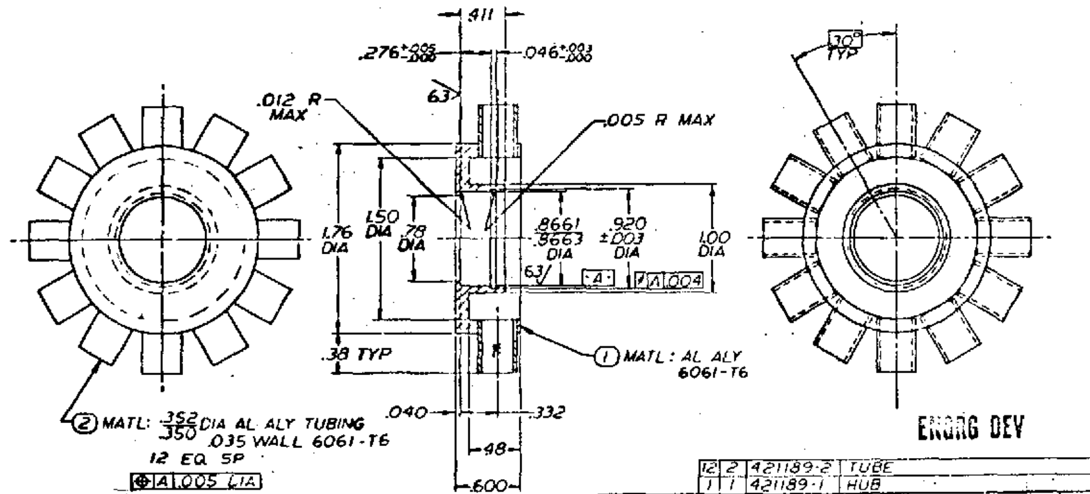
TITLE: STOP, LOWER

SIZE C | CODE IDENT NO. 91417 | 421236

SCALE 4/1

AP 11-17-72 . 1

NOTES:
1- MARK 91417-421189G1 PER MIL-STD-130.
2- BRAZE PER MIL-B-7883.
3- FINISH: CHEM FILM PER MIL-C-5541, TYPE I, GRADE C, CLASS I.
4- HEAT TREAT TO T4 CONDITION PER MIL-H-6088.



ENGRG DEV

12	2	421189-2	TUBE
1	1	421189-1	HUB
G1	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

RADIATION INCORPORATED

TITLE: LOWER BEARING SUPPORT

SIZE C | CODE IDENT NO. 91417 | 421189

SCALE 2-1

DRAWN 9-8-72

308386

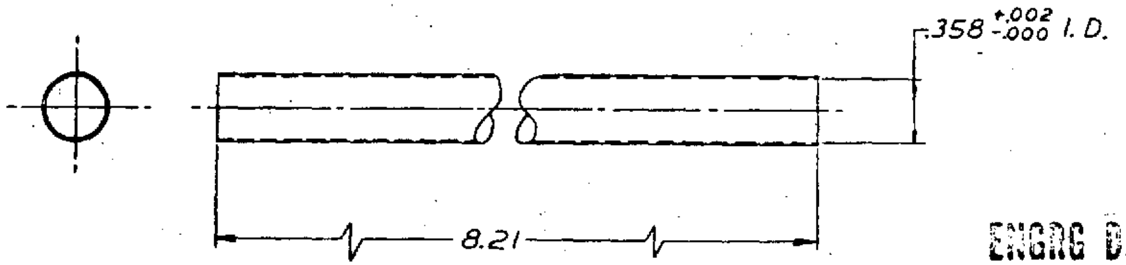
NOTES

1-MARK 91417-308386-1 PER MIL-STD-130.

2-MATL: .010 WALL AL ALY TUBING 6061-T6

3-FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS I.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHK BY / CHK BY / ECO NO.		



ENGRG DEV

QTY. REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH. TOLERANCES: 2 PLACE ±.02, 3 PLACE ±.005, ANGLES ±

CONTRACT NO.

DR BY 10-11-72 CHK BY 10-10-72

ENGINEER

PROJECT ENGINEER 10-11-72, 10-12-72

APPROVAL

APPROVAL 10-18-72 C.E. Ware

RADIATION INCORPORATED

SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: TUBE-LOWER SUPPORT

SIZE	CODE IDENT NO.		REV
B	91417	308386	

SCALE 2-1 SHEET

DASH NO.	NEXT ASSY	USED ON
1	615284	1030

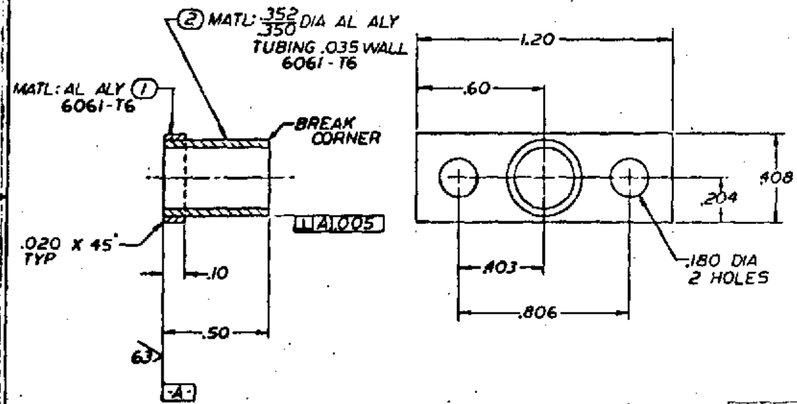
APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES. COMMERCIAL TOLERANCES APPLY TO STOCK SIZES. MANUFACTURING TOLERANCES PER 900002. WORKMANSHIP PER 900060. SCREW THREADS PER MIL-STD-9. ABBREVIATIONS PER MIL-STD-12. LOGIC SYMBOLS PER MIL-STD-806. WELDING SYMBOLS PER AWS A2.0-68.

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66. ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66. GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67. ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-68.

NOTES

1. MARK 91417-421191G1 PER MIL-STD-130.
2. BRAZE PER MIL-B-7883.
3. FINISH: CHEM FILM PER MIL-C-5541, TYPE I, GRADE C, CLASS I.
4. HEAT TREAT TO T4 CONDITION PER MIL-H-6088.
5. PART MAY BE ONE PIECE CONSTRUCTION.



ENGRG DEV

QTY REQD G1	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
1	2	421191-2	TUBE
1	1	421191-1	PAD

LIST OF MATERIALS OR PARTS LIST

G1	NEXT ASSY	USED ON
G1	615284	1080

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
±.02 ±.005

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

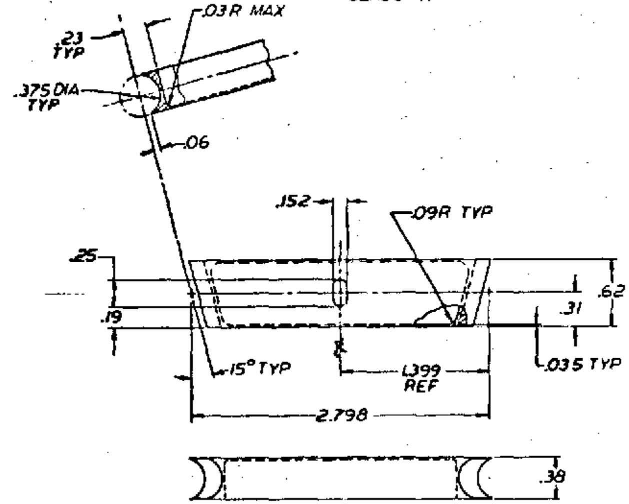
TITLE: PAD - LOWER SUPPORT

SIZE C | CODE IDENT NO. 91417 | 421191

SCALE 4-1

NOTES

1.- MARK 91417-421188-1 PER MIL-STD-130. (TAG)
2.- MATL: AL ALY 6061-T6.
3.- FINISH: CHEM FILM PER MIL-C-5541 TYPE I GRADE C CLASS I.



ENGRG DEV

	RADIATION INCORPORATED
TITLE	LOWER SUPPORT
SIZE	C
CODE IDENT NO.	91417
DWG NO.	421188
SCALE	2-1

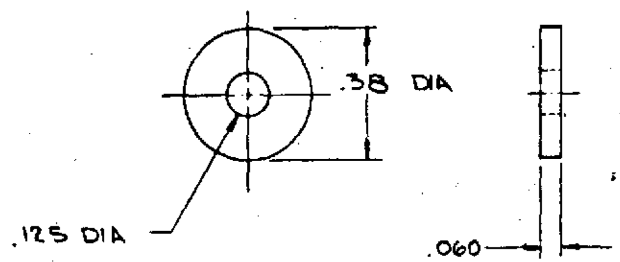
308398

NOTES:

1. MARK 91417-308398-1 PER MIL-STD-130 (BAG).
2. MATL: LAMINATED SHIM STOCK PER MIL-S-22499 COMP. 1, TYPE 1, CLASS 1.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED



ENGRG DEV.

QTY REQD				ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
615284	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES. COMMERCIAL TOLERANCES APPLY TO STOCK SIZES. MANUFACTURING TOLERANCES PER 900002. WORKMANSHIP PER 900068. SCREW THREADS PER MIL-STD-9. ABBREVIATIONS PER MIL-STD-12. LOGIC SYMBOLS PER MIL-STD-806. WELDING SYMBOLS PER AWS A2.0-58.

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66. ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66. GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67. ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH. TOLERANCES: 2 PLACE ±.02, 3 PLACE ±.010, ANGLES ±

CONTRACT NO.

DRAWN 9-29-72 CHK BY 10-10-72

ENGINEER

PROJECT ENGINEER 10-11-72

10-12-72 M. Schwer

APPROVAL Carl Anker

APPROVAL C.E. Warner 10-12-72

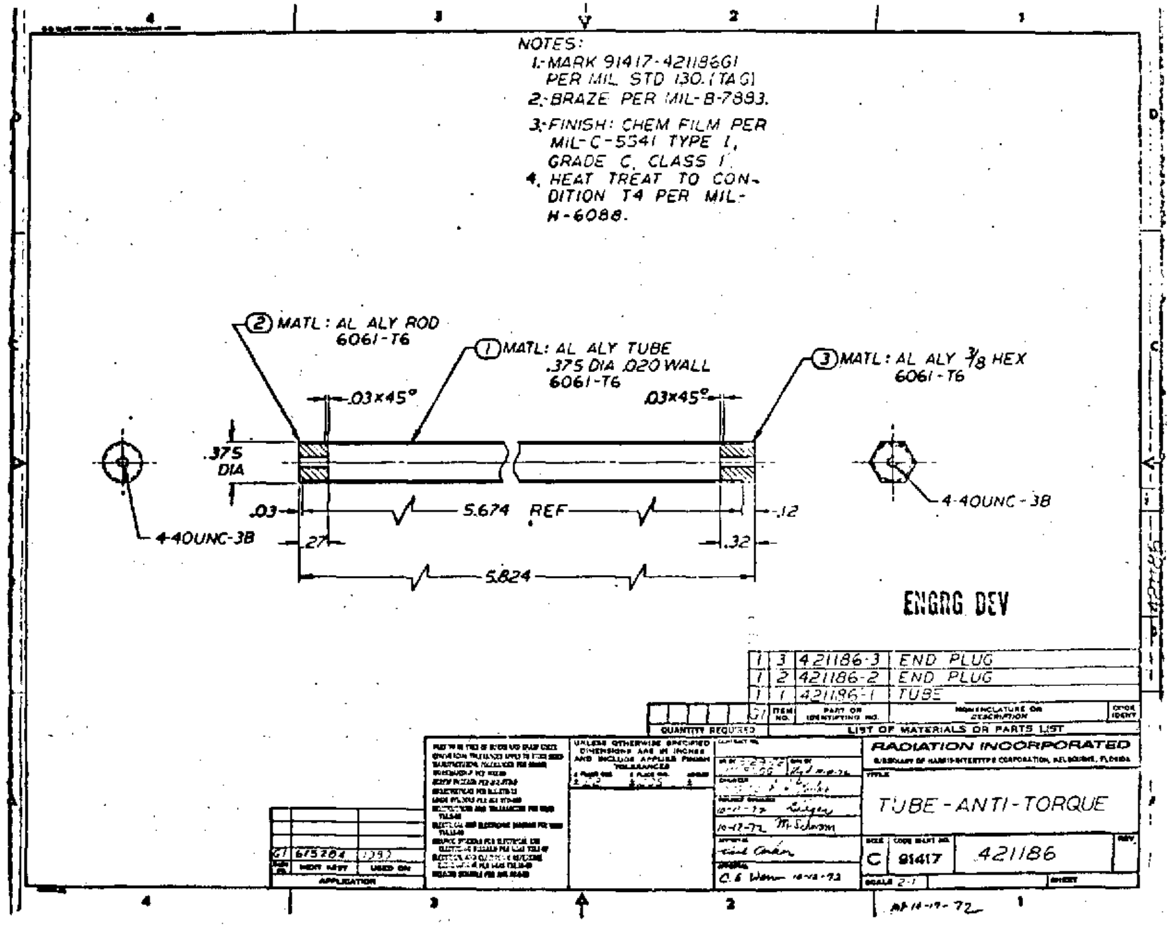
RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: SHIM, ANTI-TORQUE

SIZE	CODE IDENT NO.		REV
B	91417	308398	

SCALE 4/1 SHEET

MP 10-17-72


NOTES:
1. MARK 91417-421186G1 PER MIL STD 130. (TAG)
2. BRAZE PER MIL-B-7883.
3. FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1.
4. HEAT TREAT TO CONDITION T4 PER MIL-H-6088.
(2) MATL: AL ALY ROD 6061-T6
(1) MATL: AL ALY TUBE .375 DIA .020 WALL 6061-T6
(3) MATL: AL ALY 3/8 HEX 6061-T6
.03x45°
.03x45°
.375 DIA
4-40UNC-3B
4-40UNC-3B
.03
5.674 REF
.12
.27
.32
5.824
ENGRG DEV
1 3 421186-3 END PLUG
1 2 421186-2 END PLUG
1 1 421186-1 TUBE
QUANTITY REQUIRED
ITEM NO.
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
TUBE-ANTI-TORQUE
C 91417 421186
SCALE 2:1
G1 675784
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES

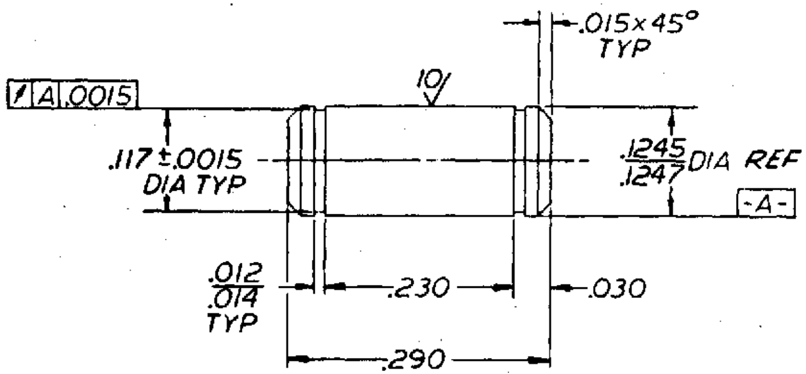
308373

ZONE	LTR	DESCRIPTION	DATE	APPROVED
REVISIONS				
		CHG BY / CHK BY / ECO NO.		

NOTES

1- MARK 91417-308373-1 PER MIL- STD-130. (BAG)

2 MATL: MAKE 2 SHAFTS FROM PIC CATALOG NO. A1-10, PIC DESIGN CORP, RIDGEFIELD CONN.



ENGRG DEV

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

1	615284	1080
DASH NO.	NEXT ASSY	USED ON
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.01 3 PLACE ±.005 ANGLES ±1°

CONTRACT NO.
DR BY 5-9-72
CHK BY 10-10-72
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72
APPROVAL
APPROVAL 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

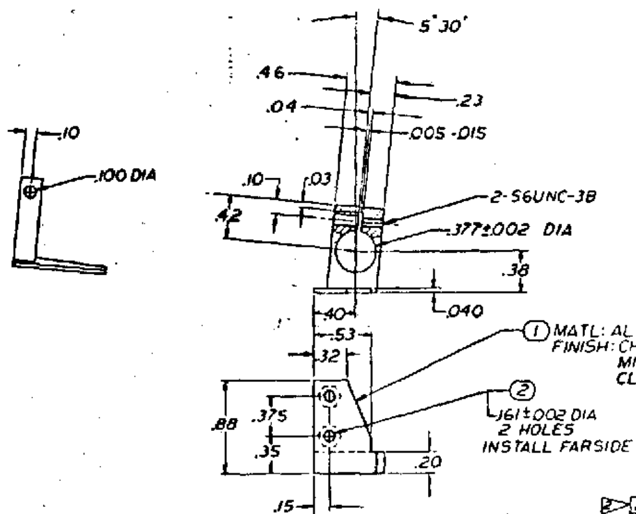
TITLE
SHAFT-ANTI-TORQUE

SIZE	CODE IDENT NO.		REV
B	91417	308373	

SCALE 10-1 SHEET

#E 10-17-72

NOTES:
1 - MARK 91417-421185G1 PER MIL-STD-130. (TAG)
2 PURCHASE FROM NATIONAL RADIO CO INC, MELROSE, MASS.



ENGRG DEV

2	2	2	NCN2-1-040	NUT - CAPTIVE	
	1	1	421185-1	BRACKET	
QUANTITY REQUIRED	G1	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
			LIST OF MATERIALS OR PARTS LIST		

G1	675284	1080
DASH NO.	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES ±.025

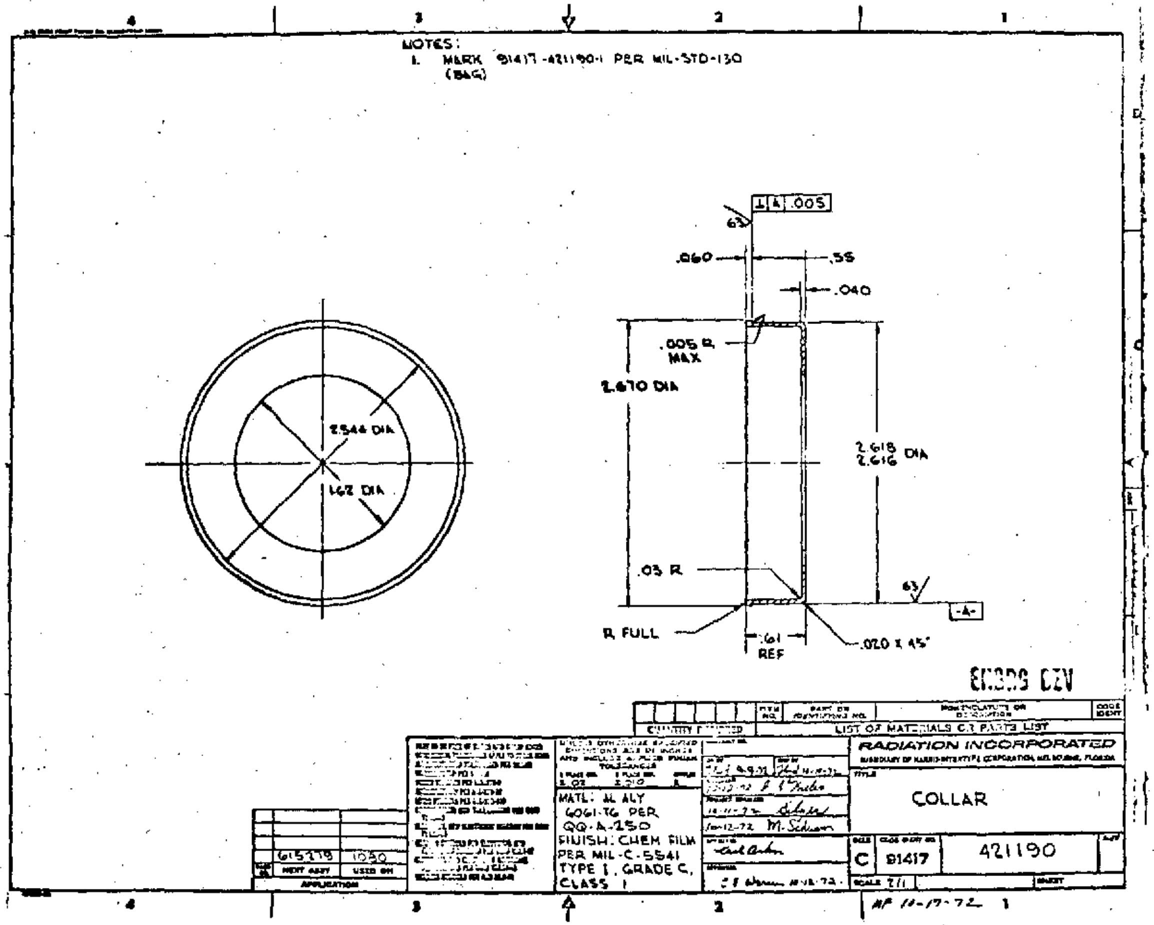
RADIATION INCORPORATED

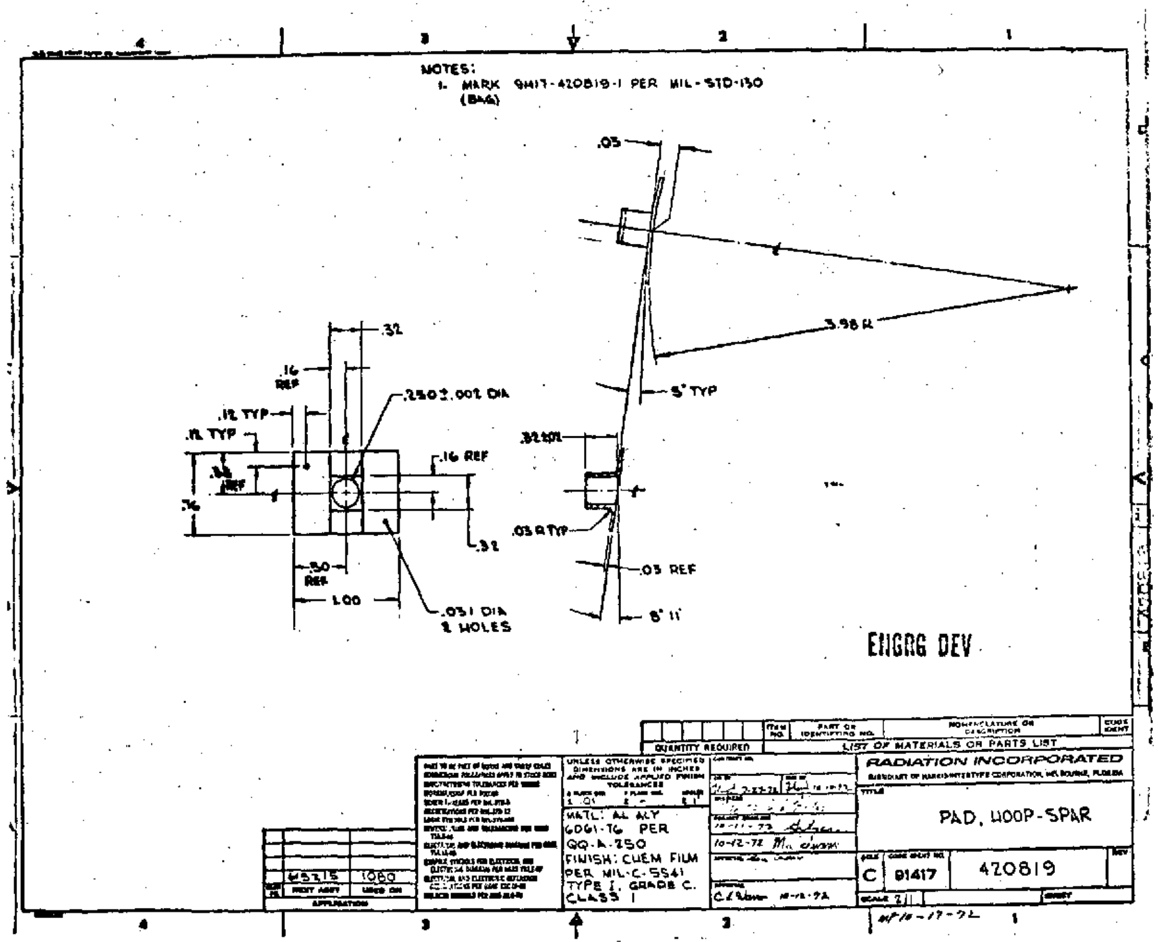
TITLE: BRACKET - SWITCH

SIZE	CODE IDENT NO.	
C	91417	421185

SCALE 2:1

AP 10-17-72-1


NOTES:
1. MARK 91417-421190-1 PER MIL-STD-130 (BAG)
⊥ A .005
63
.060
.55
.040
.005 R MAX
2.670 DIA
2.544 DIA
1.62 DIA
2.618
2.616 DIA
.03 R
R FULL
.61 REF
.020 X 45°
-A-
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
COLLAR
MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1
C
91417
421190
SCALE 2/1
615378
1050
NEXT ASSY
USED ON
APPLICATION
MF 11-17-72



NOTES:
1. MARK 91417-420819-1 PER MIL-STD-130 (BAG)
.05
3.98 R
5° TYP
.32±.01
.03 R TYP
.05 REF
8° 11'
.32
.16 REF
.12 TYP
.12 TYP
.250±.002 DIA
.16 REF
.32
.50 REF
1.00
.031 DIA 2 HOLES
ENGRG DEV
LIST OF MATERIALS OR PARTS LIST
QUANTITY REQUIRED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
MATL: AL ALY 6061-T6 PER QQ-A-250
FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1
RADIATION INCORPORATED
PAD, HOOP-SPAR
C 91417 420819
45215 1060
APPLICATION

308387

REVISIONS

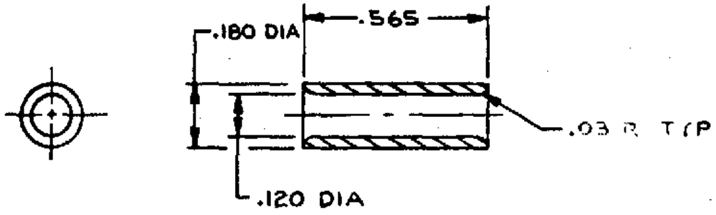
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		

NOTES:

1. MARK 91417 308387-001 PER MIL-STD-130 (BAG)

2. MATL: AL ALLOY ROUND 6061-T6 PER QQ-A-200

3. FINISH: COAT INSIDE SURFACE ONLY WITH "TUFRAM" BY GENERAL MAGNAPLATE CO.



ENGRG DVL DWG

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES.
2 PLACE ±.02 3 PLACE ±.005 ANGLES ± —

CONTRACT NO.
DR BY 13 SEP 72 T. W. TONK CHK BY 10-12-72
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72
APPROVAL
APPROVAL C E. 10-12-72

MATL: 2
FINISH: 3

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE FLORIDA

TITLE FERRULE

SIZE B | CODE IDENT NO. 91417 | 308387 | REV
SCALE 4/1 | SHEET

001	615285	1080
DASH NO.	NEXT ASSY	USED ON
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

AF 10-17-72

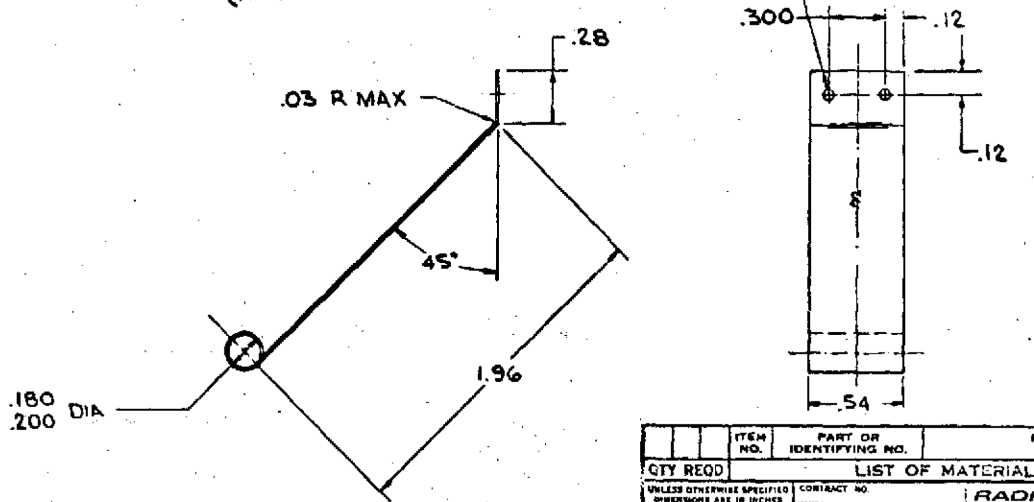
308372 A

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ECO NO. 0217936		
D2		HOLE DIA WAS .063		
D3		REVISED NOTE 1		

NOTES:

1. MATL: SST TYPE 410 PER QQ-S-766 CLASS 3 .008 THK
2. FINISH: PASSIVATE PER QQ-P-35
3. HEAT TREAT TO 180,000 PSI MIN TENSILE ULTIMATE PER MIL-H-6875.
4. MARK 91417-308372-1 PER MIL-STD-130 (TAG)



ENGRG DEV

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.010 ANGLES ±1°

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: SPRING

SIZE: B | CODE IDENT NO. 91417 | 308372 | REV A
SCALE 2/1 | SHEET

NEXT ASSY	USED ON
615285	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900202
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-68

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

DR BY 9-5-72 | CHK BY 10-10-72
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72 M. Schuster
APPROVAL
APPROVAL 10-12-72

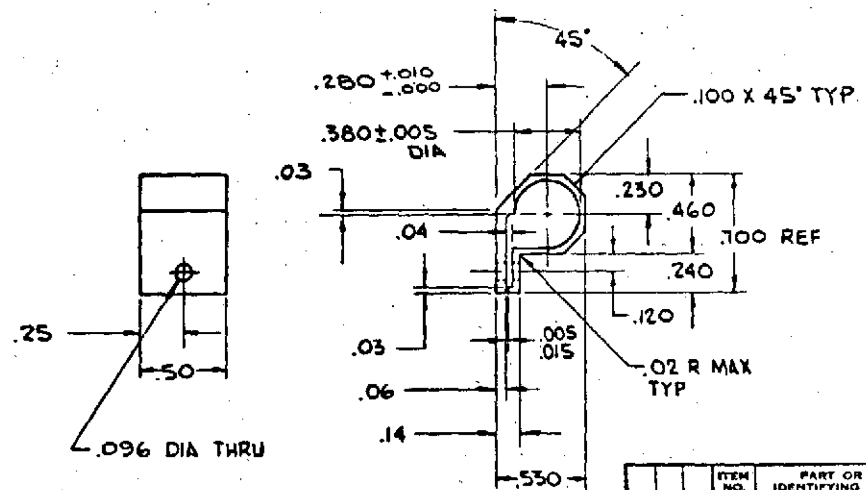
MF 10-17-72-1

1308371

NOTES:

1. MATL: AL ALY 6061-T6 PER QQ-A-250
2. FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS 1.
3. MARK 91417-308371-1 PER MIL-STD-130 (BAG)

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		DWG BY / CHK BY / ECO NO.		



ENGRG DEV

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		LIST OF MATERIALS OR PARTS LIST		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.01 3 PLACE ±.005 ANGLES ±1°

MATL: 1

FINISH: 2

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: CLAMP

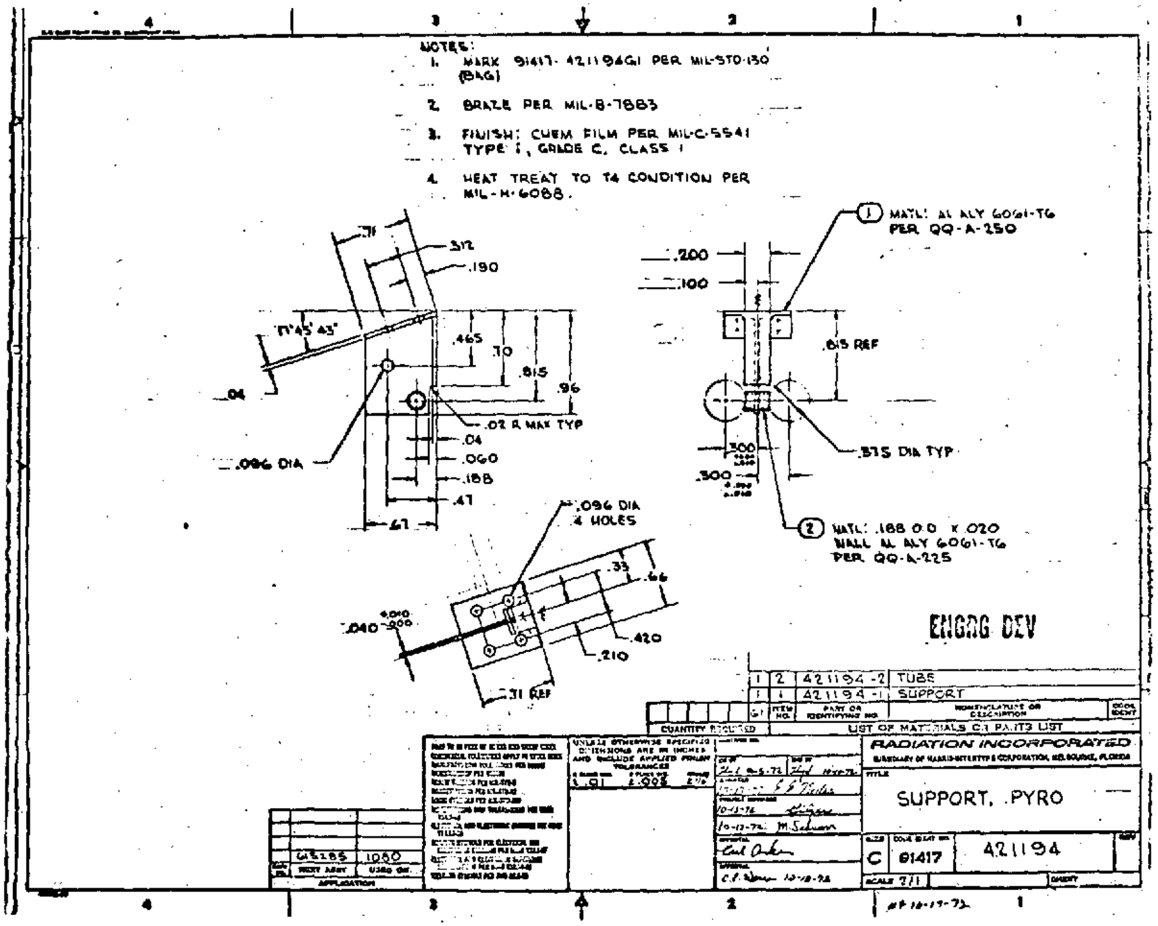
SIZE: B | CODE IDENT NO. 91417 | 308371 | REV

SCALE 2/1 | SHEET

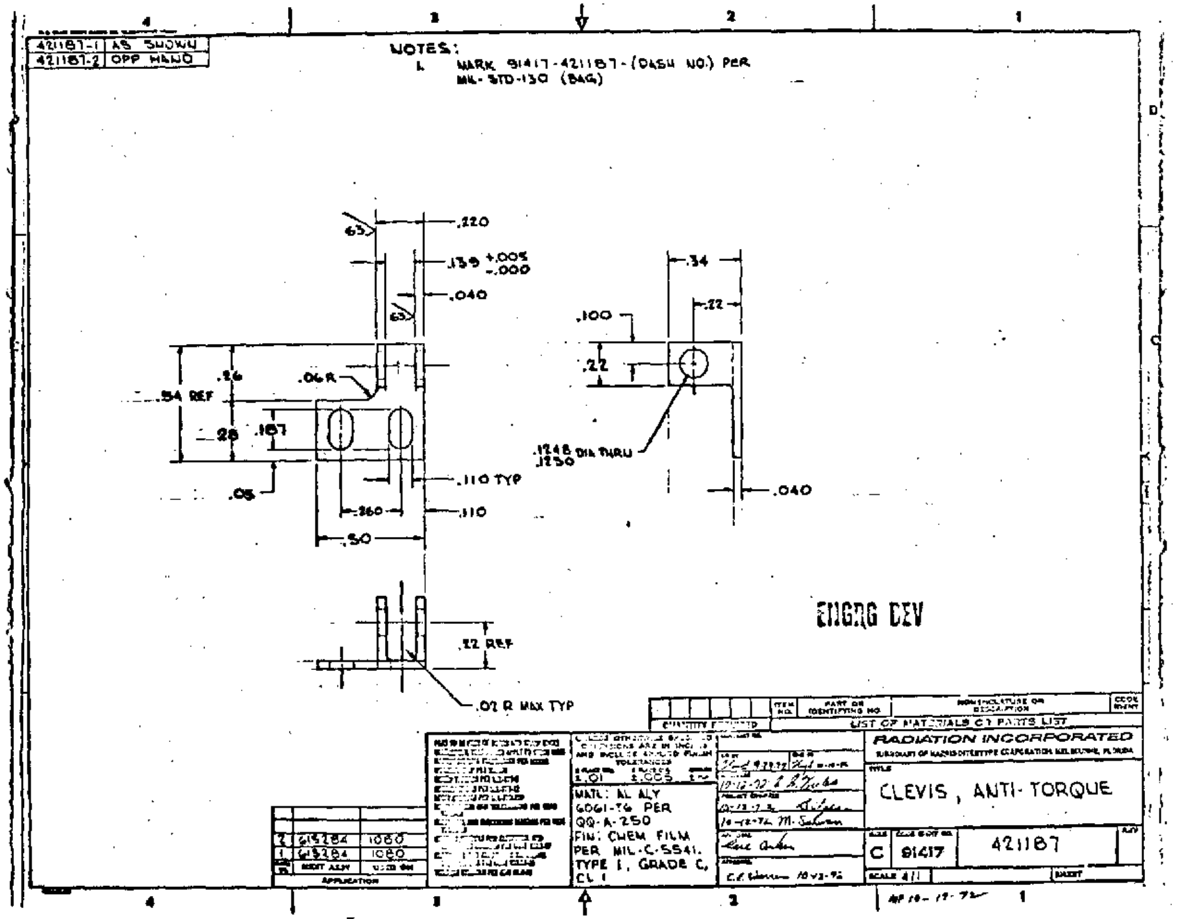
CONTRACT NO.
DR BY 9-5-72 | CHK BY
ENGINEER
PROJECT ENGINEER 10-12-72
APPROVAL
APPROVAL 10-13-72

615285	1080
NEXT ASSY	USED ON
APPLICATION	

PART TO BE FREE OF BURRS AND SHARP EDGES
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65
WELDING SYMBOLS PER MIL-STD-...


NOTES:
1. MARK 91417-421194G1 PER MIL-STD-130 (BAG)
2. BRAZE PER MIL-B-7883
3. FINISH: CHEM FILM PER MIL-C-5541 TYPE I, GRADE C, CLASS I
4. HEAT TREAT TO T4 CONDITION PER MIL-H-6088.
1 MATL: AL ALY 6061-T6 PER QQ-A-250
2 MATL: .188 O.D. X .020 WALL AL ALY 6061-T6 PER QQ-A-225
.096 DIA
.096 DIA 4 HOLES
.02 R MAX TYP
.375 DIA TYP
.815 REF
.31 REF
ENGRG DEV
421194-2 TUBE
421194-1 SUPPORT
QUANTITY REQUIRED
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
SUPPORT, PYRO
C
91417
421194
SCALE 2/1
NEXT ASSY
USED ON
APPLICATION

200 OF 356



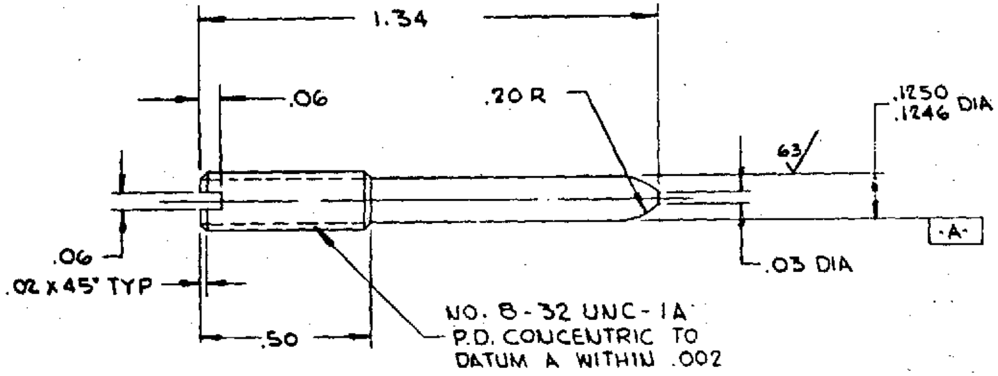
421187-1 AS SHOWN
421187-2 OPP HAND
NOTES:
1. MARK 91417-421187-(DASH NO.) PER MIL-STD-130 (BAG)
.220
.139 +.005 -.000
.040
.54 REF
.26
.28
.187
.06 R
.05
.110 TYP
.260
.110
.50
.22 REF
.02 R MAX TYP
.34
.22
.100
.22
.1248 .1250 DIA THRU
.040
ENGRG DEV
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
CLEVIS, ANTI-TORQUE
MATL: AL ALY 6061-T6 PER QQ-A-250
FIN: CHEM FILM PER MIL-C-5541, TYPE I, GRADE C, CL I
C 91417 421187
615284 1080
APPLICATION

308354

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		

NOTES:

1. MARK 91417-308354-1 PER MIL-STD-130 (BAG)
2. MATL: AL ALY 7075-T6
3. FINISH: ANODIZE PER MIL-A-8625 TYPE II, CLASS I



ENGRG DEV

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

NEXT ASSY	USED ON
615283	1080
APPLICATION	

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900000
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH
TOLERANCES: 2 PLACE ±.02, 3 PLACE ±.005, ANGLES ±1°

CONTRACT NO.
DR BY: 8-2-72 | CHK BY
ENGINEER
PROJECT ENGINEER: 10-11-72
10-12-72
APPROVAL
APPROVAL: C E [signature] 10-18-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: PIN, MIDPOINT

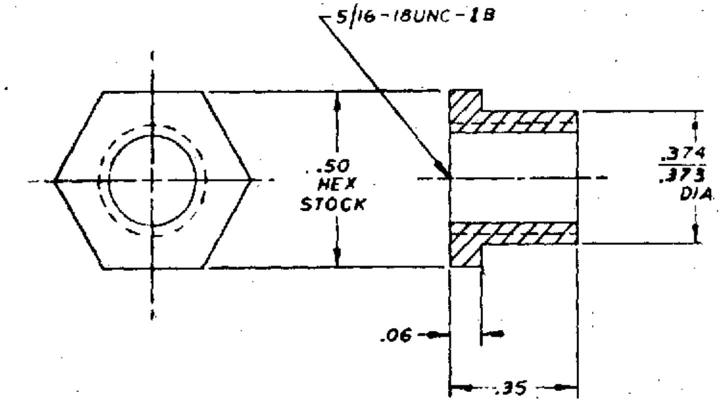
SIZE	CODE IDENT NO.		REV
B	91417	308354	

SCALE 4/1 | SHEET

AF 10-17-72 1

308392

NOTES
1- MARK 91417-308392-1 PER MIL-STD-130.
2- MATL: AL ALLOY 6061-T651.
3- FINISH: ANODIZE PER MIL-A-8625 TYPE II, CLASS I.



ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT.

LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
615283	1080

APPLICATION

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

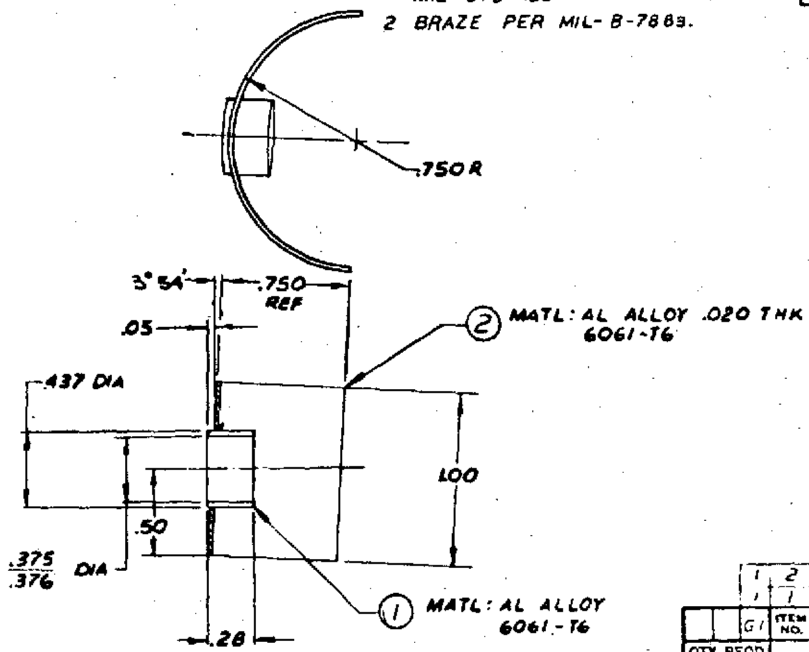
TITLE: NUT - MIDPOINT

SIZE: B | CODE IDENT NO. 91417 | 308392 | REV

SCALE 4-1 | SHEET

308394

NOTES:
1- MARK 91417-308394-G1 PER MIL-STD-130.
2 BRAZE PER MIL-B-7883.



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD		G1	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
		1	2	308394-2	SUPPORT	
		1	1	308394-1	SLEEVE	

LIST OF MATERIALS OR PARTS LIST

615283	1080
NEXT ASSY	USED ON
APPLICATION	

PART TO BE FREE OF BURRS AND SHARP EDGES
CO[illegible] TOLERANCES APPLY TO STOCK SIZES
[illegible]
WELDING SYMBOLS PER [illegible]

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.005 ANGLES ±

CONTRACT NO
DR BY [illegible] 9-18-72
CK BY [illegible] 10-10-72
10-11-72
10-12-72
APPROVAL
10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE
SLEEVE - MIDPOINT

SIZE	CODE IDENT NO.		REV
B	91417	308394	

SCALE 2-1 SHEET

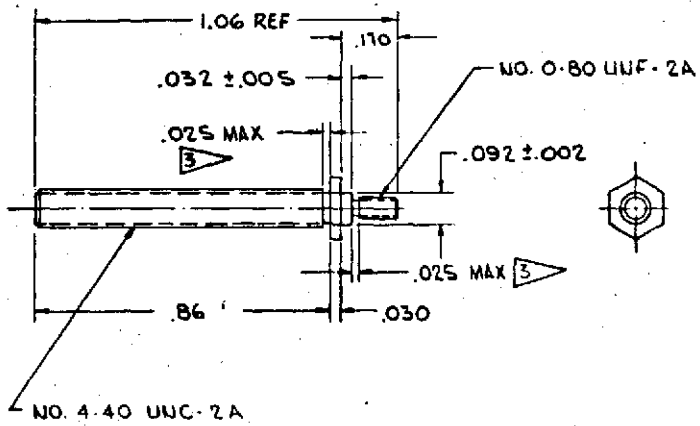
10-19-72

308369

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		

NOTES:

1. MATL: 3/16 HEX SST TYPE 440 PER QQ-S-763.
2. FINISH: PASSIVATE PER QQ-P-35.
3. UNDERCUT TO MINOR DIA OF THD.
4. MARK 91417-308369-1 PER MIL-STD-130(BAG)



ENGRG DEV

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.010 ANGLES ±1°

MATL: 1
FINISH: 2

CONTRACT NO.
DR BY 9-5-72 CHK BY 10-10-72
ENGINEER
PROJECT ENGINEER 10-11-72
10-12-72 M. Schiavo
APPROVAL
APPROVAL 10-12-72

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: STAND-OFF

SIZE	CODE IDENT NO.		REV
B	91417	308369	

SCALE 4/1 SHEET

	NEXT ASSY	USED ON
	615283	1080

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 500082
WORKMANSHIP PER 500060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-68

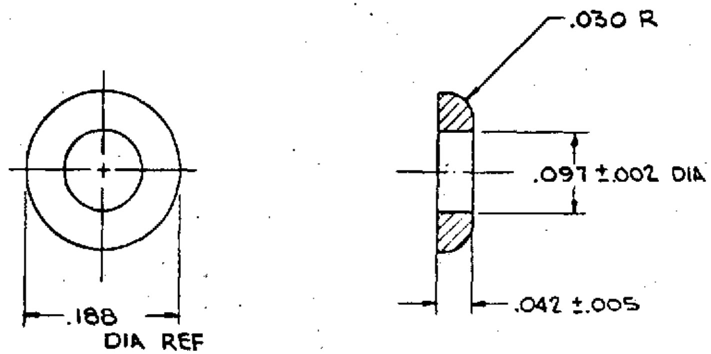
MF 10-17-72-1

308370

NOTES:

1. MATL: 3/16 DIA SST TYPE 303 PER QQ-S-763
2. FINISH: PASSIVATE PER QQ-P-35.
3. MARK 91417-308370-1 PER MIL-STD-130 (BAG)

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



ENGRG DEV

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES: 2 PLACE ±.02, 3 PLACE ±.010, ANGLES ±1°

MATL: 1

FINISH: 2

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: WASHER

SIZE: B | CODE IDENT NO.: 91417 | 308370 | REV

SCALE 10/1 | SHEET

DR BY 9-5-72; CHK BY 10-10-72; ENGINEER; PROJECT ENGINEER 10-11-72; 10-12-72 M. Schwann; APPROVAL; APPROVAL C E ... 10-12-72

	615283	1080
	NEXT ASSY	USED ON
	APPLICATION	

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER
WORKMANSHIP PER
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58
DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

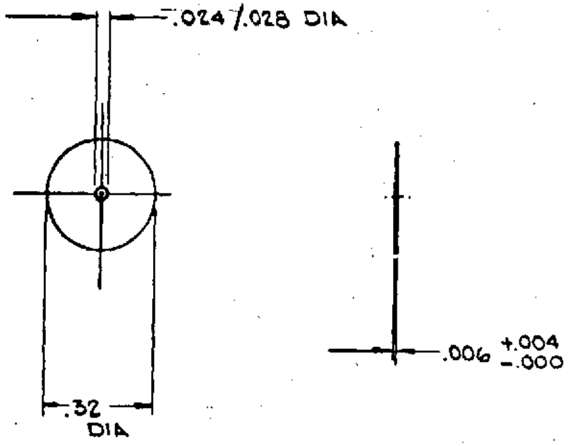
MF10-17-72

308611

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
		CHG BY / CKD BY / ECO NO.		

NOTES:

1. MARK 91417-308611-1 PER MIL-STD-130 (BAG)



ENGRG DEV DWG

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD			LIST OF MATERIALS OR PARTS LIST			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
1 PLACE ±.01 2 PLACE ± ANGLES ±

MATL: AL ALY 6061-T6 PER QQ-A-250 OR EQUIV

CONTRACT NO.
DR BY 7-18-73 CHK BY
ENGINEER
PROJECT ENGINEER
M. Schwam 2/8/74
APPROVAL Carl Anker 2/8/74
APPROVAL CE Warren 2/11/74

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE WASHER, TIE

SIZE	CODE IDENT NO.		REV
B	91417	308611	

SCALE 4/1 SHEET

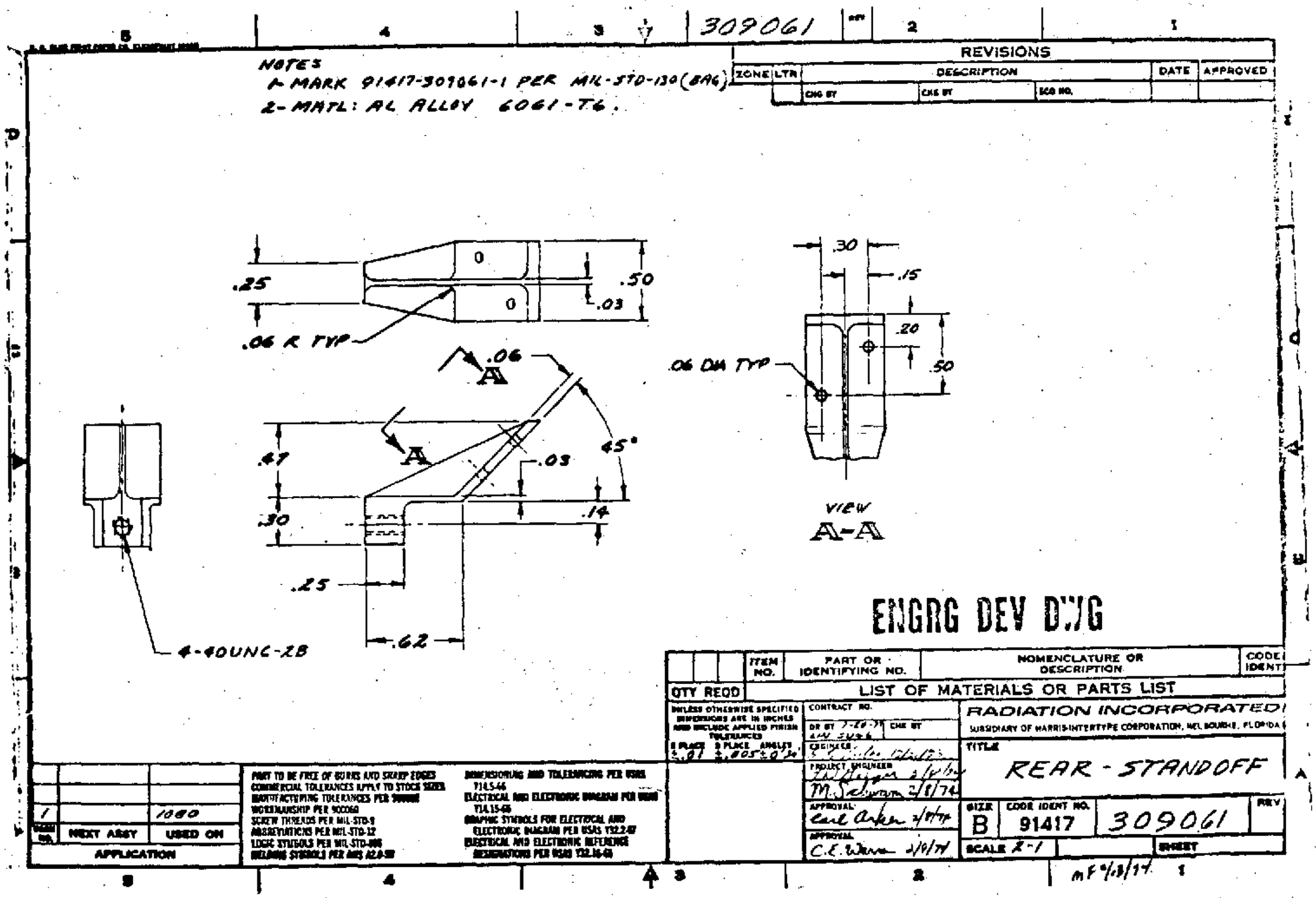
MF 2/13/74

DASH NO.	NEXT ASSY	USED ON
		1750

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

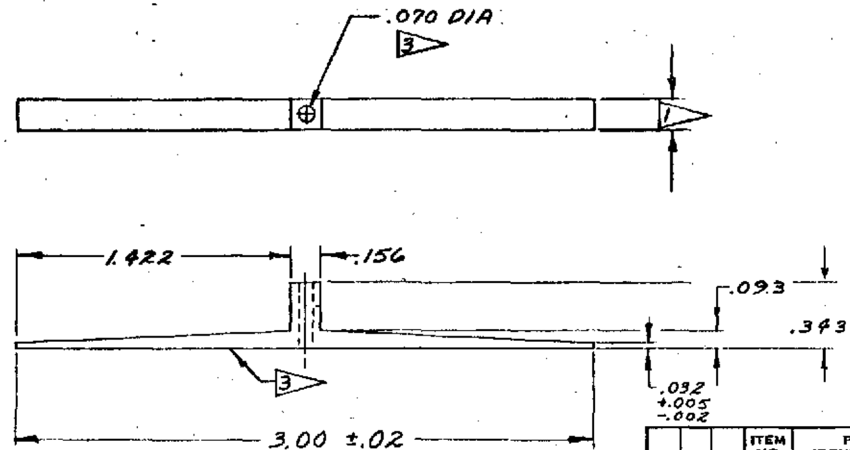

309061
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTES
1- MARK 91417-309061-1 PER MIL-STD-130 (BAG)
2- MATL: AL ALLOY 6061-T6.
.25
.50
.03
.06 R TYP
.06
A
45°
.47
.30
.14
.25
.62
4-40UNC-2B
.30
.15
.20
.50
.06 DIA TYP
VIEW
A-A
ENGRG DEV DWG
ITEM NO.
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
QTY REQD
LIST OF MATERIALS OR PARTS LIST
RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA
TITLE
REAR - STANDOFF
SIZE B
CODE IDENT NO. 91417
309061
SCALE 2-1
SHEET 1
NEXT ASSY
USED ON
APPLICATION
1080

309059

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		CHG BY / CHK BY / ECO NO.		

NOTES:

1. MATL: G10 EPOXY BOARD .117-.132 THICK.
2. PRIME & PAINT PER 7741
3. .070 DIA. HOLE & SURFACE INDICATED TO BE FREE OF PRIMER & PAINT -(NOTE-2).
4. MARK 91417-309059 PER MIL-STD-130. (BAG)



ENGRG DEV DWG

QTY REQD			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE ±.02 3 PLACE ±.005 ANGLES ±

CONTRACT NO.
DR BY 9-6-73 | CHK BY
ENGINEER
PROJECT ENGINEER 2/4/74
M. Sullivan 2/22/74
APPROVAL 2/19/74
APPROVAL C.E. Warren 2/1/74

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE: TEE

SIZE: B | CODE IDENT NO.: 91417 | 309059 | REV
SCALE 2-1 | SHEET

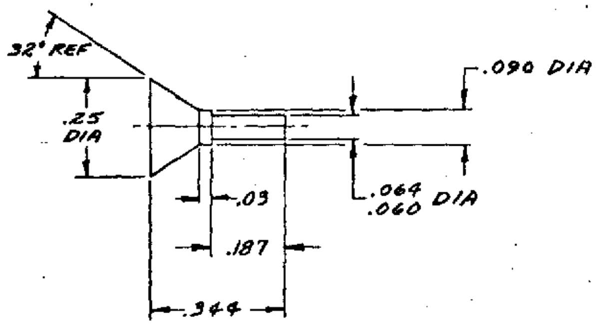
DASH NO.	NEXT ASSY	USED ON
1		1080
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

NOTES:
1-MARK 91417-309062-1 PER MIL-STD-130 (BAG)
2-MATL: AL ALLOY 6061-T6.

REVISIONS					
ZONE	LTR	DESCRIPTION		DATE	APPROVED
	CHG BY	CHK BY	ECO NO.		



ENGRG DEV DWG

			ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QTY REQD				LIST OF MATERIALS OR PARTS LIST		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH
TOLERANCES
2 PLACE ±.02 3 PLACE ±.005 ANGLES ±

CONTRACT NO.
DR BY 7-20-73 LIN 5046 CHK BY
ENGINEER
PROJECT ENGINEER
M. Schlam 2/22/74
APPROVAL 2/20/74
APPROVAL C.E. Warren 2/2/74

RADIATION INCORPORATED
SUBSIDIARY OF HARRIS-INTERTYPE CORPORATION, MELBOURNE, FLORIDA

TITLE STANDOFF

SIZE	CODE IDENT NO.		REV
B	91417	309062	
SCALE 4-1		SHEET	

DASH NO.	NEXT ASSY	USED ON
1		1080
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL-STD-9
ABBREVIATIONS PER MIL-STD-12
LOGIC SYMBOLS PER MIL-STD-806
WELDING SYMBOLS PER AWS A2.0-58

DIMENSIONING AND TOLERANCING PER USAS Y14.5-66
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15-66
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2-67
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16-65

APPENDIX B

TEST PLAN AND PROCEDURES WITH TEST RESULTS

FINAL

TEST PLAN AND PROCEDURES REPORT

FOR

ADVANCED APPLICATIONS FLIGHT EXPERIMENT

NAS1-11444

SEQUENCE NUMBER: 4314-01

PREPARED FOR

LANGLEY RESEARCH CENTER

PREPARED BY

RADIATION
A DIVISION OF HARRIS-INTERTYPE
P.O. BOX 37
MELBOURNE, FLORIDA 32901

9 FEBRUARY 1973

PREPARED BY: ______________________
W. E. Marbry
Test Engineer

APPROVED BY: ______________________
C. E. Warren
Program Manager

APPROVED BY: ______________________
L. A. Baugher
Quality Engineer

RAD 7902

APPENDIX B

TEST PLAN AND PROCEDURES WITH TEST RESULTS

1.0 INTRODUCTION

This Test Plan and Procedure describes the testing program for the 12.5-foot diameter antenna produced during the Advanced Applications Flight Experiment Program.

1.1 Purpose

The purpose of this test plan is to define a meaningful and efficient evaluation and test program for the deployable antenna. The major objectives of this program are:

1. To determine the various physical and operational characteristics of the deployable antenna and

2. To provide test data for correlation with the analyses performed during this program

1.2 Scope

The scope of this document is to detail the overall test program for the 12.5-foot diameter deployable antenna. Included in this plan is a description of parameters to be measured, the test objectives, test methods, required facilities and equipment, and data to be recorded.

2.0 APPLICABLE DOCUMENTS

Applicable documents to the test plan development are:

a. Statement of Work, dated 15 December 1971

b. Program Plan for Advanced Applications Flight Experiment Program, dated 17 May 1972

c. Drawing 615283, Antenna Assembly

3.0 VIBRATION TEST

3.1 Test Objective

The primary purpose of this test is to measure the resonant frequencies and response accelerations of the 12.5-foot diameter model antenna in various stowed and deployed configurations.

3.2 Facilities and Instrumentation

The fixtures shall be designed to restrict the motion of the base of the antenna to the specified input. Crosstalk shall not exceed 50 percent of the input and variation of the input across the antenna base shall not exceed a ratio of 2 to 1. Lowest fundamental frequency for the stowed antenna fixtures shall exceed 500 Hz, and for the deployed antenna the frequency shall exceed 50 Hz. These criteria have been verified by tests with a heavier antenna.

Five Endevco Model 2222B, or equivalent, accelerometers will be attached to the antenna at the locations shown in Figures 3.2-1 through 3.2-3. All accelerometer data shall be recorded on magnetic tape. The test setups are shown in Figures 3.2-4 and 3.2-5.

3.3 Test Procedure

3.3.1 Low-Level Sinusoidal Vibration, Stowed Antenna

3.3.1.1 Lateral Axis

a. Sweep the bandwidth from 10 to 300 Hz in the lateral axis at the rate of one octave per minute using a 0.15 G_{rms} sinusoidal input while recording the output from accelerometers at the locations shown in Figure 3.2-1.

b. Dwell at up to three selected frequencies as determined by analysis and test data from the sinusoidal sweeps. Input level shall be 0.15 G_{rms}. Read accelerations and phase angles from the five accelerometers.

3.3.1.2 Longitudinal Axis

Conduct a low-level sinusoidal vibration as described in Paragraph 3.3.1.1a. on the stowed antenna in the longitudinal axis. Record the output of accelerometers at the locations as shown in Figure 3.2-2.

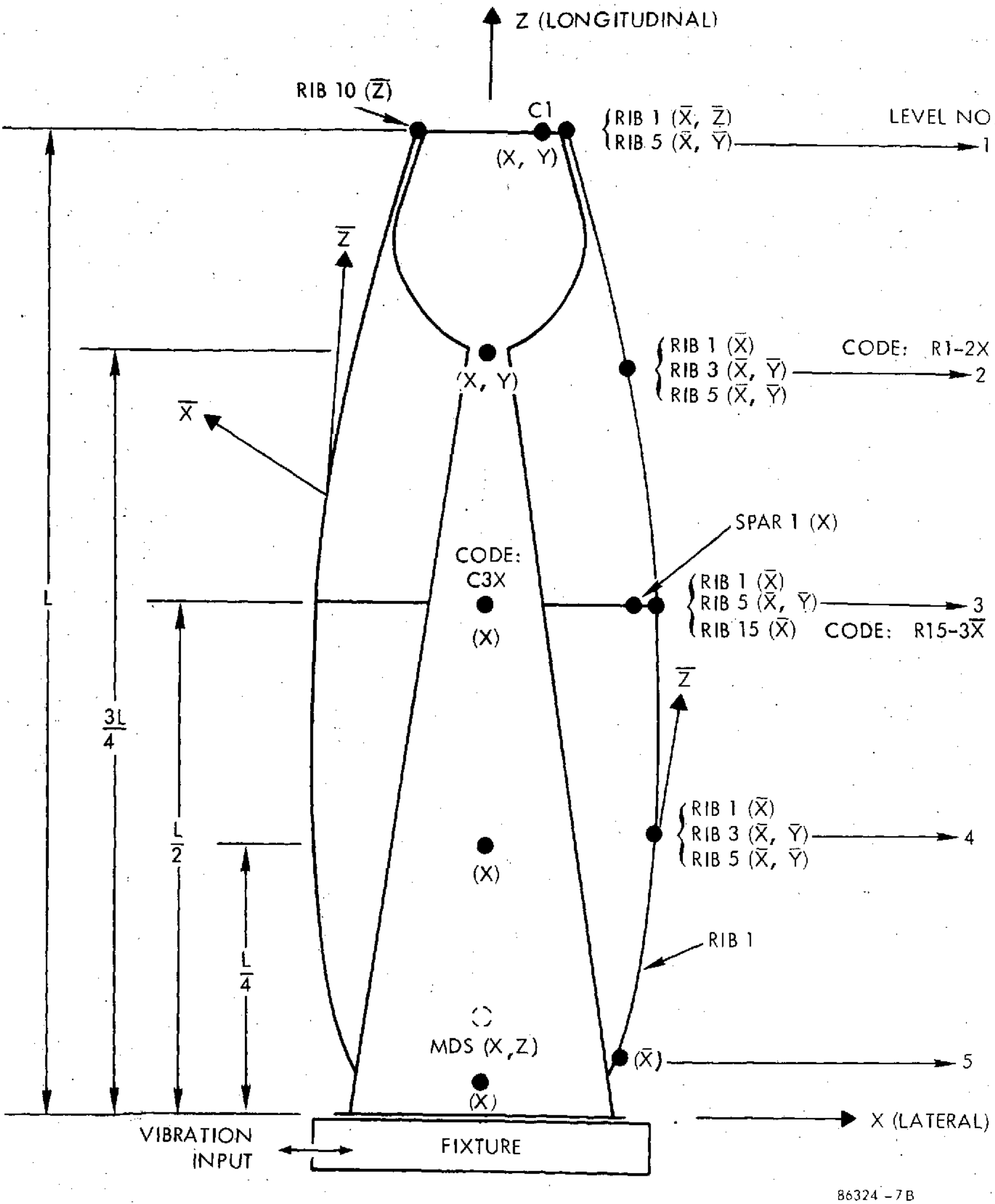


Figure 3.2-1. Accelerometer Locations for the Low-Level Sine Test in the Lateral Axis for the Stowed Antenna

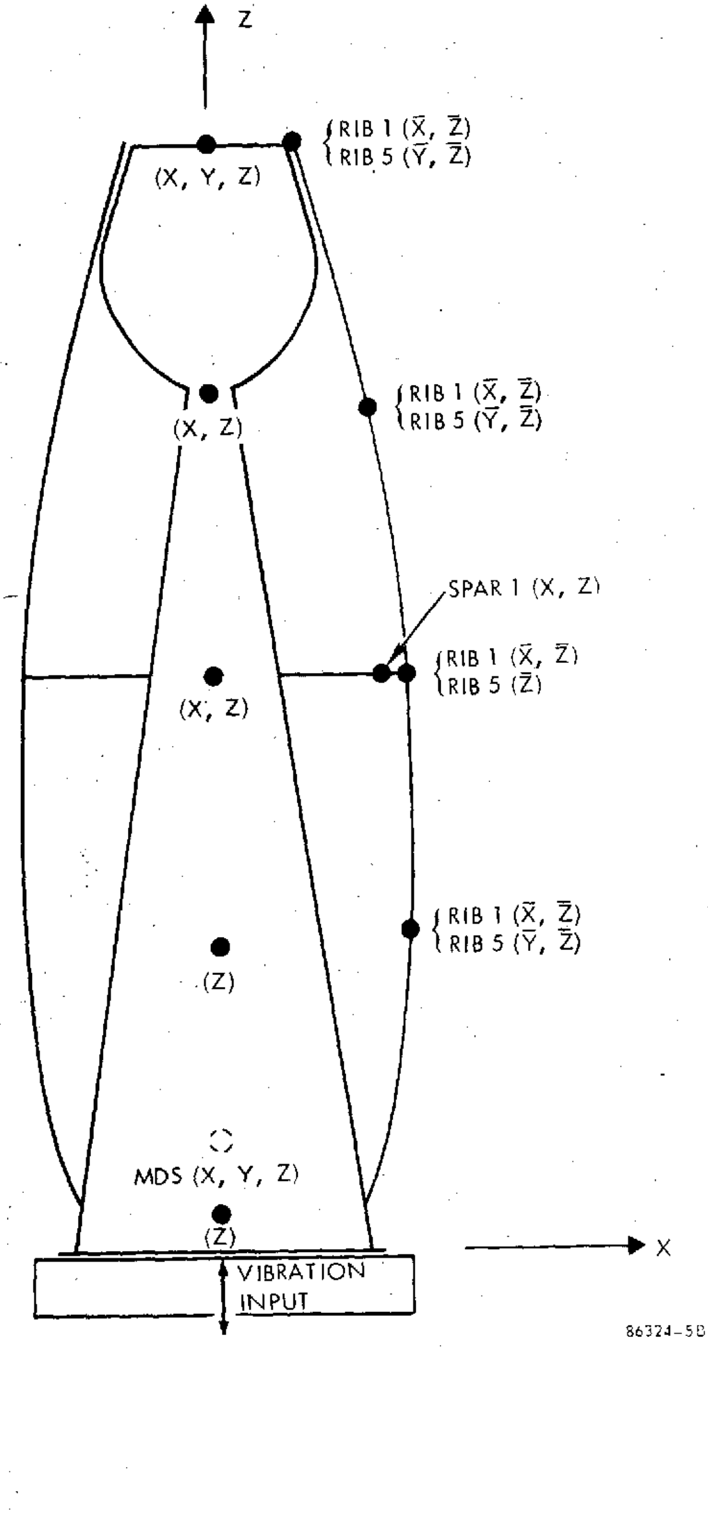


Figure 3.2-2. Accelerometer Locations for the Low-Level Sine Test in the Longitudinal Axis for the Stowed Antenna

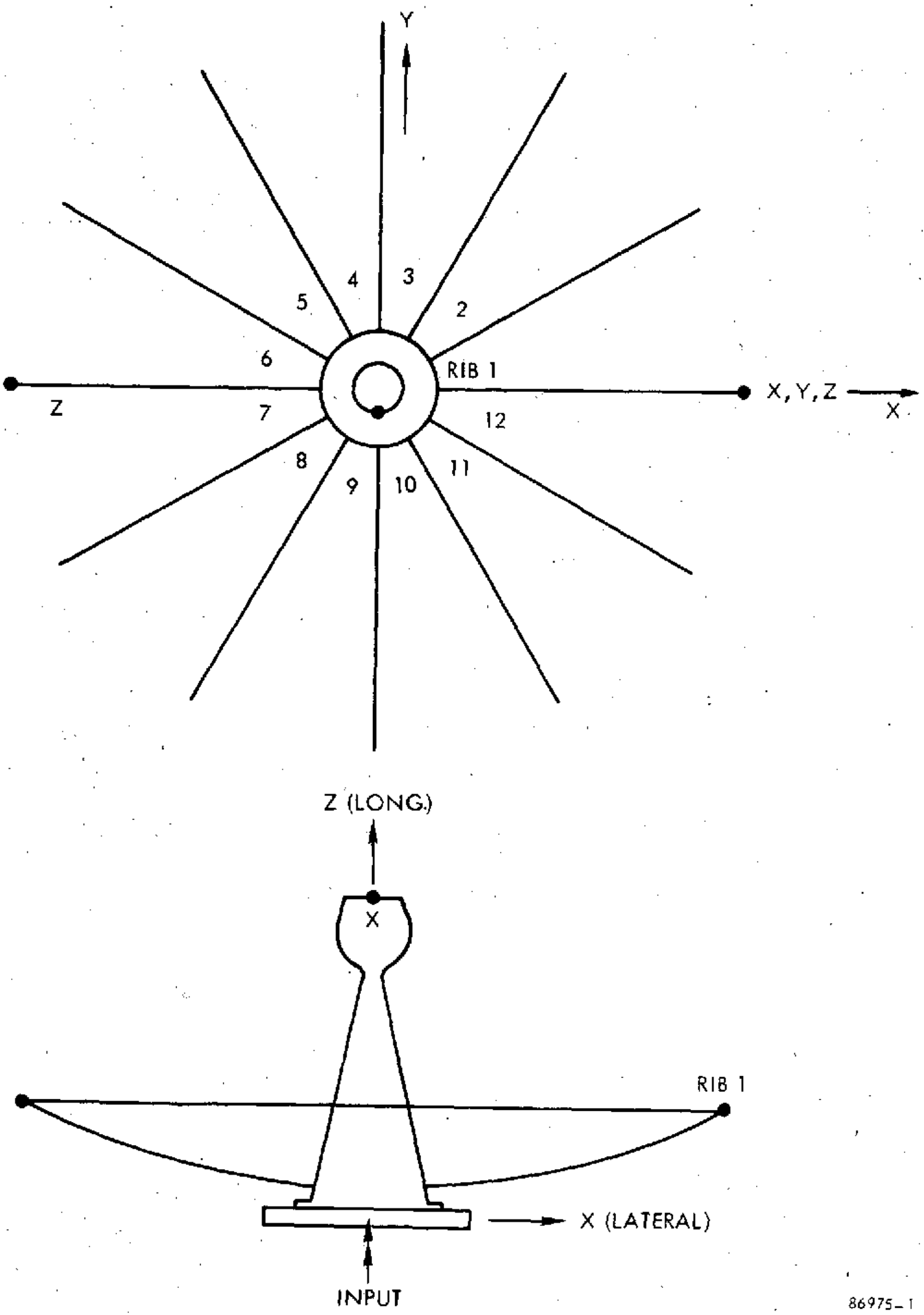


Figure 3.2-3. Accelerometer Locations for the Low-Level Sine Test in the Longitudinal Axis for the Deployable Antenna

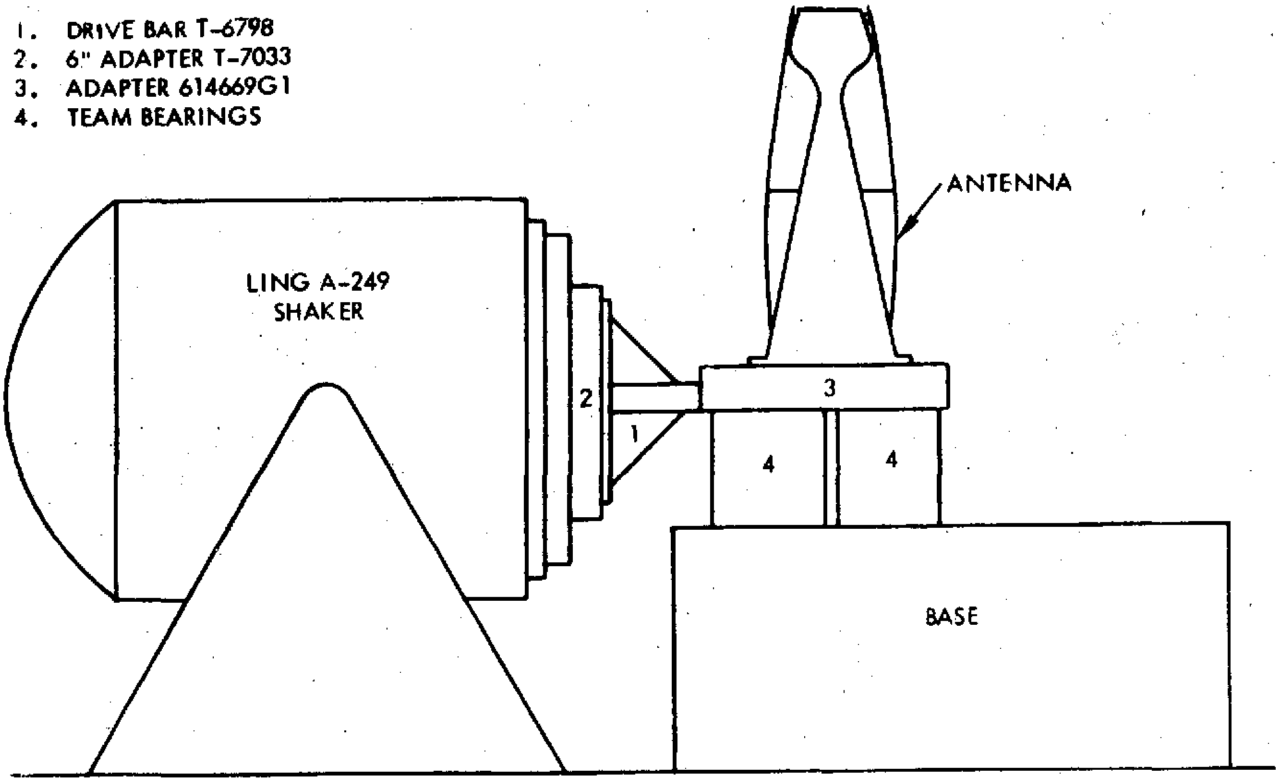


Figure 3.2-4. Setup for Lateral Axis Vibration, Stowed Antenna

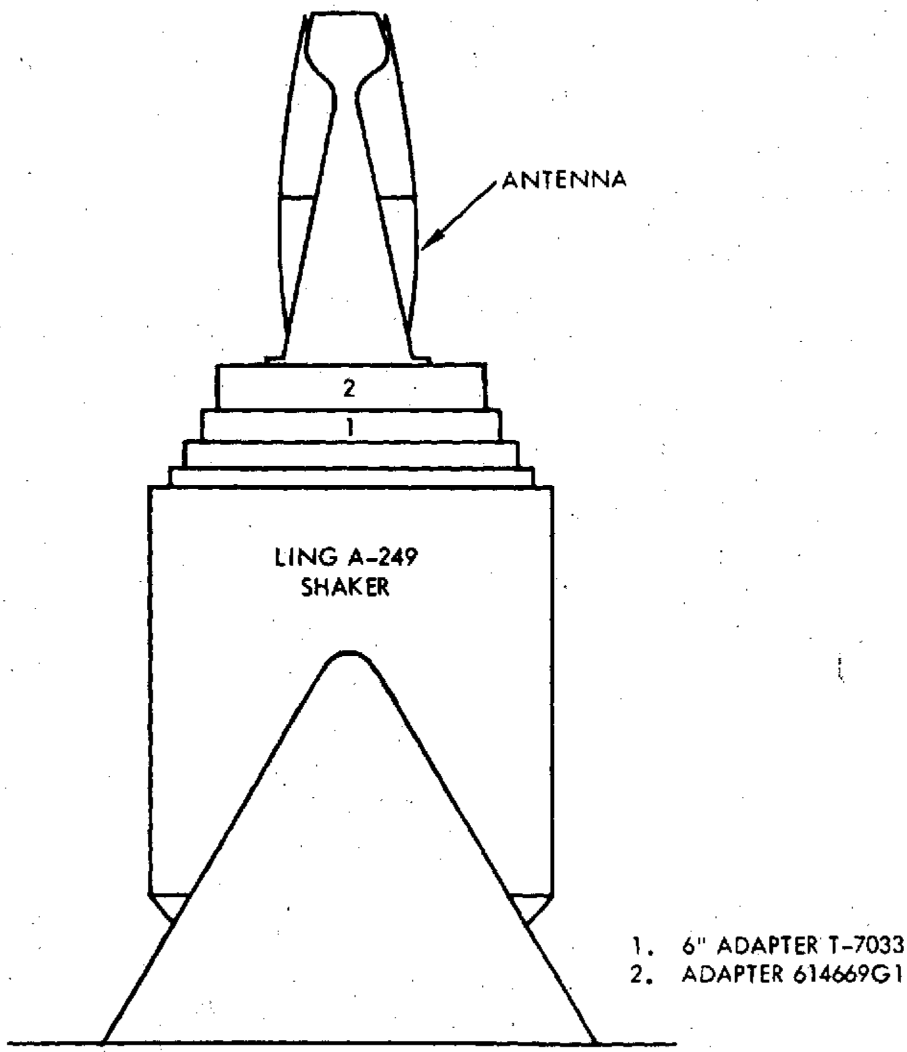


Figure 3.2-5. Setup for Longitudinal Axis Vibration, Stowed or Deployed Antenna

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ENVIRONMENTAL ENGINEERING LABORATORY – TEST EQUIPMENT LIST

ITEM USED	ITEMS	MANUFACTURER	MODEL NUMBER	SERIAL NUMBER	CALIBRATION DUE DATE
✓	ACCELEROMETER	ENDEVCO	2222B	AB10	3-1-74
✓	ACCELEROMETER	ENDEVCO	2222B	AA23	3-1-74
✓	ACCELEROMETER	ENDEVCO	2222B	AC66	3-1-74
✓	ACCELEROMETER	ENDEVCO	2222B	AB49	3-1-74
✓	ACCELEROMETER	ENDEVCO	2222B	XR70	3-1-74
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
NOT USED	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			
	ACCELEROMETER	ENDEVCO			

RADIATION

A DIVISION OF HARRIS-INTERTYPE CORPORATION

ENVIRONMENTAL ENGINEERING LABORATORY — TEST EQUIPMENT LIST

ITEM USED	ITEMS	MANUFACTURER	MODEL NUMBER	SERIAL NUMBER	CALIBRATION DUE DATE
✓	VIBRATION SHAKER	LING ELECTRONICS	A-249-1	69	N/A
✓	VIBRATION POWER AMPLIFIER	LING ELECTRONICS	PP-175/240B	35	N/A
✓	VIBRATION CONSOLE	LING ELECTRONICS	SRC-503L	14	N/A
✓	SWEEP OSCILLATOR SERVO	SPECTRAL DYNAMICS	SD114	94	
✓	CLIPPER-MIXER AMPLIFIER	LING ELECTRONICS	CMA-10	166	N/A
✓	SHAKER CUTOFF	RADIATION	T-4040A	2	N/A
✓	LINE AMPLIFIER	LING ELECTRONICS	LA-100	58	N/A
✓	TEKTRONIX OSCILLOSCOPE	TEKTRONIX	RM 564	001141	1-31-74
✓	TEKTRONIX TIME BASE	TEKTRONIX	2B67	013602	1-31-74
✓	TEKTRONIX AMPLIFIER	TEKTRONIX 3A72	3A72	005740	1-31-74
✓	TRUE RMS VOLTMETER	BALLANTINE	320	8181	3-8-74
✓	TRUE RMS VOLTMETER	BALLANTINE	320	4292	3-8-74
NOT USED	X-Y RECORDER	HEWLETT-PACKARD	135		
✓	X-Y RECORDER	HEWLETT-PACKARD	7034A	1128	12-18-73
✓	LOG CONVERTER	HEWLETT-PACKARD	7560A	648-03339	4-2-74
✓	COUNTER	HEWLETT-PACKARD	5512A	548-00119	2-25-74
NOT USED	COMPUTER CONTROLLER	TIME/DATA	1923	137	
✓	AMPLIFIER POWER SUPPLY	UNHOLTZ-DICKIE	608PS-1	155	N/A
✓	AMPLIFIER POWER SUPPLY	UNHOLTZ-DICKIE	608R	367	N/A
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PCV	2	2-27-74
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PCV	3	2-27-74
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PMCVA	3	2-27-74
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PMCVA	10	2-27-74
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PMCVA	1	3-26-74
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PMCVA	2	12-27-73
✓	ACCELEROMETER AMPLIFIER	UNHOLTZ-DICKIE	8PMCV	172	4-22-74
✓	ACCELEROMETER	ENDEVCO	2224C	NC10	2-1-74
✓	ACCELEROMETER	ENDEVCO	2224C	MC48	2-1-74
✓	TAPE RECORDER	CEC	VR3300	9028	N/A
NOT USED	TIMER	DIMCO-GRAY	171		

3.3.2 Low-Level Sinusoidal Vibration, Deployed Antenna, Longitudinal Axis

Sweep the bandwidth from 40 to 5 Hz at a rate of one octave per minute using a 0.15 G_{rms} input while recording the output of accelerometers at the locations shown in Figure 3.2-3.

3.3.3 Mechanical Inspection

At the completion of each test, the antenna shall be visually inspected for any degradation. After all tests are completed, the antenna shall be visually inspected in more detail. Findings are reported in the test record.

3.4 Measurements and Tolerances

All measurements shall be made with calibrated instruments. The maximum allowable tolerances for test conditions shall be as follows:

a. Vibration amplitude

Sinusoidal: ±10%

b. Vibration Frequency

±2% or 1 Hz, whichever is greater

3.5 Test Record

As a minimum, the data obtained during testing shall be presented in the test report as follows:

1. Plots of response acceleration versus frequency for all accelerometer measurements taken for the 0.15 G_{rms} input test

2. Table showing G_{rms} response and relative phase angle for selected accelerometers for resonant dwell tests using a 0.15 G_{rms} input

AAFE Vibration Test Summary

Lateral Axis, Stowed Antenna

The fundamental frequency of the stowed antenna in the lateral axis was 57.0 Hz. The mode shape was lateral bending of the entire antenna. The second resonant frequency occurred at 93.1 Hz and the mode shape was the first bending mode of the stowed ribs. The third resonant frequency was 245.0 Hz and was the second lateral bending mode of the entire antenna. Figures 3.5-2 through 3.5-6 are acceleration versus frequency plots of the five instrumentation accelerometers.

Longitudinal Axis, Stowed Antenna

There were two primary resonances in the longitudinal axis. The first resonance occurred at 96 Hz and was a rib cage mode combining longitudinal translation (Z-axis) of the rib cage and bending of the ribs. The second resonance was 195 Hz and was the longitudinal mode of the feed support cone-ogive structure. Figures 3.5-7 through 3.5-13 are the acceleration versus frequency slots of the instrumentation accelerometers.

Longitudinal Axis, Deployed Antenna

In the deployed test, there was only one major resonance in the frequency band tested. This was the fundamental bending node of the rib-and-mesh assembly in the longitudinal axis and occurred at a frequency of 8.3 Hz. Figures 3.5-14 through 3.5-19 show the acceleration versus frequency plots of the instrumentation accelerometer.

Post Test Inspection

A complete inspection of the antenna after the completion of all testing showed no signs of any degradations of any parts.

4.0 SURFACE ACCURACY MEASUREMENT TEST

4.1 Test Objectives

The objective of this test is to measure the surface accuracy and deployment repeatability of the deployable antenna using a precise sweep template, and compute the rms surface error. This test is also a demonstration of deployment kinematics of the antenna.

4.2 Test Method

The antenna surface measurement configuration is shown in Figure 4.2. The sweep template consists of an accurately machined track along which a movable micrometer can be positioned. This feature allows any point on the reflector surface to be measured.

Using the sweep template, the surface error of the reflector can be accurately measured. However, some uncertainties exist in predicting the surface error which the reflector would exhibit in a zero-g environment, due to the sag of the mesh between the ribs.

Two techniques for measurement of surface accuracy have been defined for use on the deployable antenna in order to minimize the uncertainty of the gravity error. In both techniques a total of 225 points on the mesh surface are measured, and the surface error is calculated using the paraboloid computer program (Appendix I).

In the first technique, the antenna is placed in a face-side orientation, with the sweep template extending horizontally outward from the antenna axis. The sweep template remains stationary in this position during the entire measurement procedure. Different points on the reflector are measured by rotating the antenna about its central axis until the point to be measured is in the plane of the sweep template. The micrometer is then moved along the template to coincide with the desired point. Using this method, the mesh in the vicinity of the point being measured at any given time is in a vertical plane. In this configuration, the gravity effect on the mesh is reduced, and the surface error calculated from these measurements is an approximation of the actual zero-g error.

In the second technique, the antenna is oriented in a face-side position as in the first technique. However, during the measurement process, the antenna is held stationary while measurements are made by rotating the template about the antenna axis. After all the desired points have been measured in this way, the antenna is then rotated exactly 180° about its central axis. The same points which were measured during the first sweep are then measured a second time, again with the reflector held stationary and the sweep template rotated about its axis. The deviation of each point is averaged for the two readings, and the surface error is computed using the average position of each point.

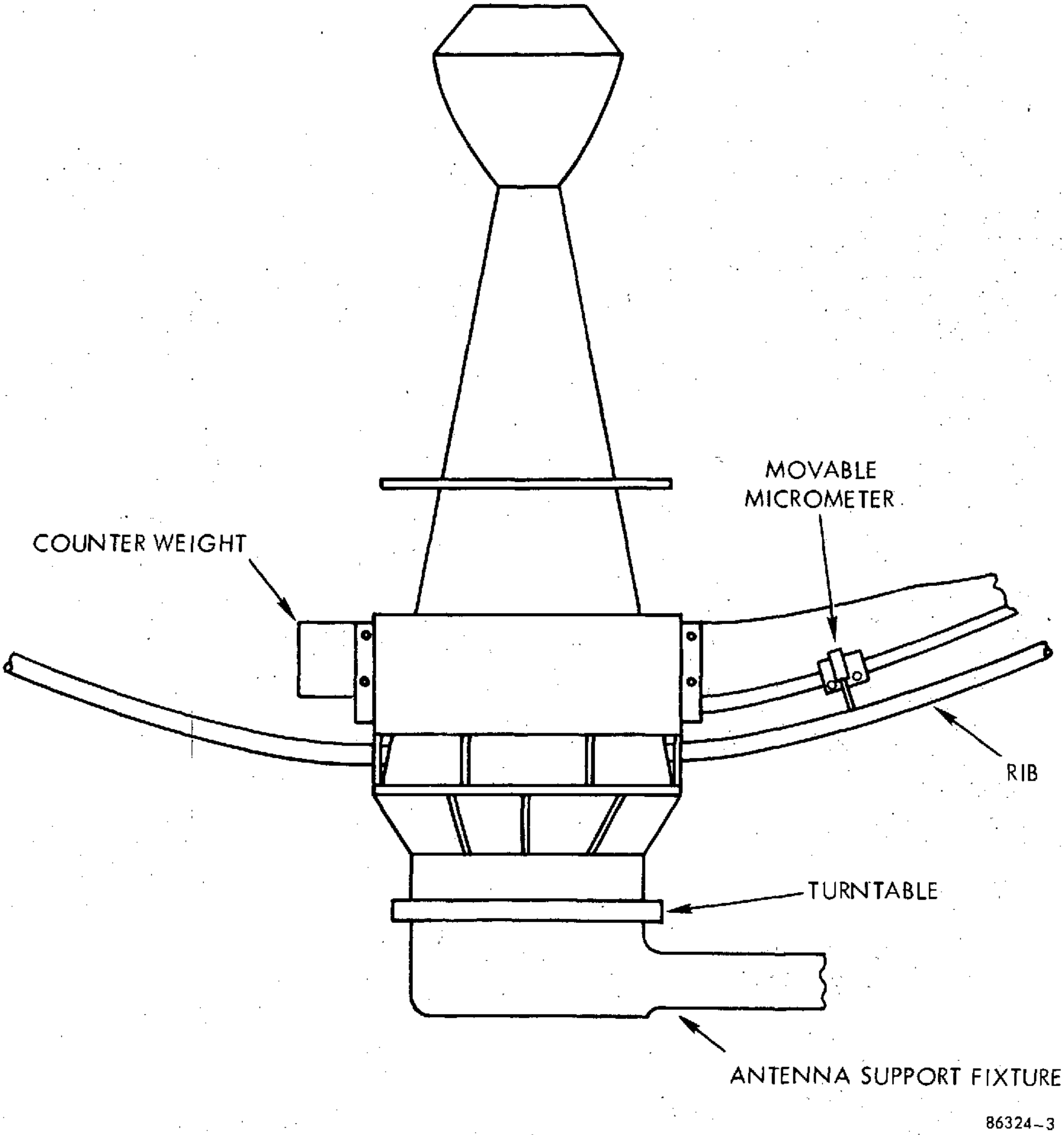

Figure 4.2. Surface Measurement Tooling

The surface error determined by the second technique is expected to provide an upper bound for surface error in a zero-g environment. It contains certain additional errors, such as hysteresis in the ribs and effects of the nonlinearity of the mesh spring rate, which result from measuring the reflector in the two opposite orientations. Past experience has shown these effects to be very small.

As part of the surface accuracy measurement test, the antenna is deployed once by activating the pyrotechnic cable cutter. The antenna is refolded and deployed nine more times using the MDS motor drive. Surface accuracy measurements are performed after the first deployment and then after the nine additional deployments.

4.3 Test Procedure

4.3.1 Test Preparation

Mark the antenna surface at each of the 225 points to be measured. There shall be nine points equally spaced along each of 25 equally spaced radial lines. The marking is accomplished by using either tiny pieces of adhesive-backed tape or by using ink dots.

Install the antenna on the mounting fixture. Deploy the antenna by activating the pyrotechnic cable cutting device.

Attach the sweep template to the antenna in the proper measurement configuration.

4.3.2 Surface Accuracy Test Number 1

Position the antenna in a face-side orientation. Position the sweep template such that it extends horizontally outward from the antenna axis.

Using the sweep template, measure the deviation from the theoretical paraboloid of each of the 225 points marked on the reflector surface. During this test the sweep template remains in a horizontal position. The antenna is rotated about its central axis to bring the desired points into the plane of the sweep template. Record the deviation of each point in the data sheet. Input the data to the paraboloid computer program and record the calculated surface error on the data sheet.

4.3.3 Surface Accuracy Test Number 2

Position the antenna in a face-side orientation. Record the angular position of the support fixture turntable.

With the antenna left stationary in this orientation, rotate the sweep template about the antenna axis and measure each of the 250 points marked on the reflector. Record the data on the data sheet.

Rotate the antenna 180^{o} about its axis. Record the angular position of the support fixture turntable. With the antenna left stationary in this orientation, rotate the sweep template about the antenna axis and measure each of the 225 points again. Record the second readings on the data sheet.

Compute the average of the two readings for each of the 225 points. Record these results on the data sheet. Input these results into the paraboloid computer program and record the calculated surface error on the data sheet.

4.3.4 Surface Accuracy Test Number 3

With the sweep template removed, refold and deploy the antenna nine times ending with the antenna in the deployed configuration.

Attach the sweep template to the antenna in the proper measurement configuration.

Position the antenna in a face-side orientation. Position the sweep template such that it extends horizontally outward from the antenna axis.

Using the sweep template, measure the deviation from the theoretical paraboloid of each of the 225 points marked on the reflector surface. During this test the sweep template remains in a horizontal position. The antenna is rotated about its central axis to bring the desired points into the plane of the sweep template. Record the deviation of each point in the data sheet. Input the data to the paraboloid computer program and record the calculated surface error on the data sheet.

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
INPUT AXIS X
TEST ARTICLE AAFE ANTENNA
INPUT LEVEL [illegible]
RUN NO. 2
ACCEL. LOCATION 1X
TEST DATE 12-8 73
ACCEL. SER. NO. AB1C
OPERATOR [illegible]
ACCEL. SENSITIVE AXIS X

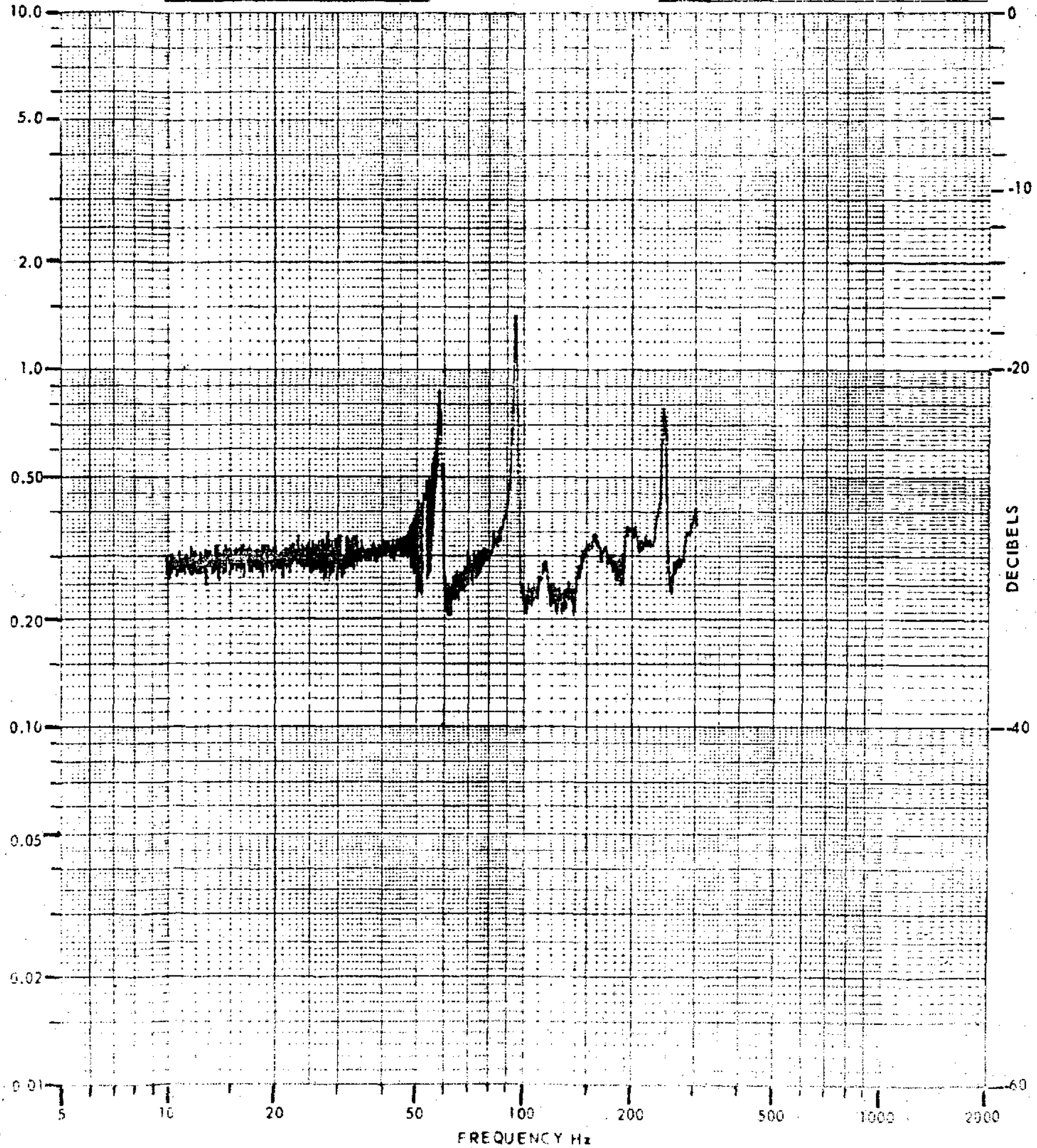

Figure 3.5-2

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFC ANTENNA
RUN NO. 2
TEST DATE 12-8-73
OPERATOR 72C

INPUT AXIS X
INPUT LEVEL .21G
ACCEL. LOCATION 2X
ACCEL. SER. NO. AA23
ACCEL. SENSITIVE AXIS X

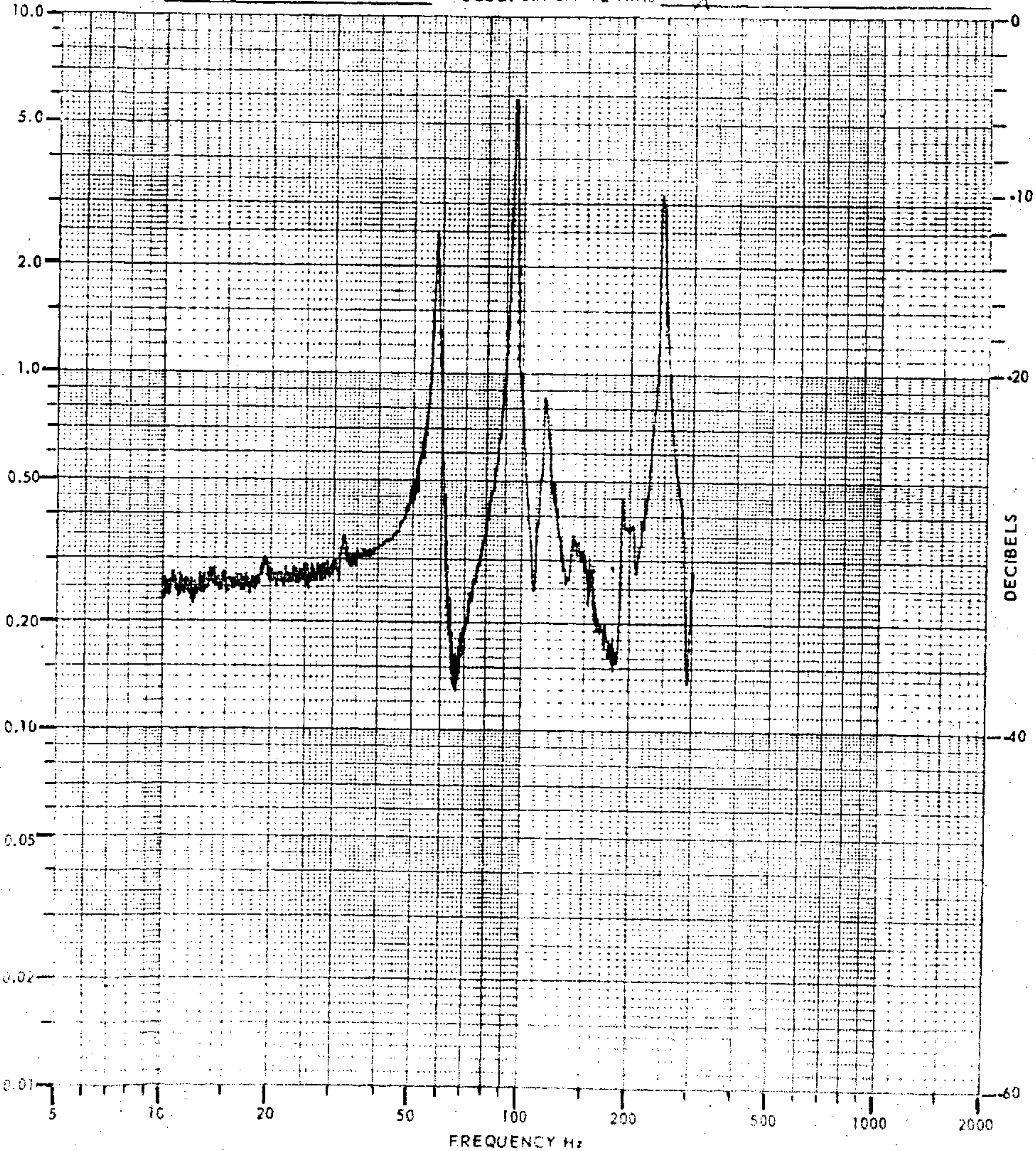

Figure 3.5-3

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT	1080	INPUT AXIS	X
TEST ARTICLE	AAFE ANTENNA	INPUT LEVEL	.21 Gc-pk
RUN NO.	2	ACCEL. LOCATION	3X
TEST DATE	12-8-73	ACCEL. SER. NO.	AC66
OPERATOR	TAC	ACCEL. SENSITIVE AXIS	X

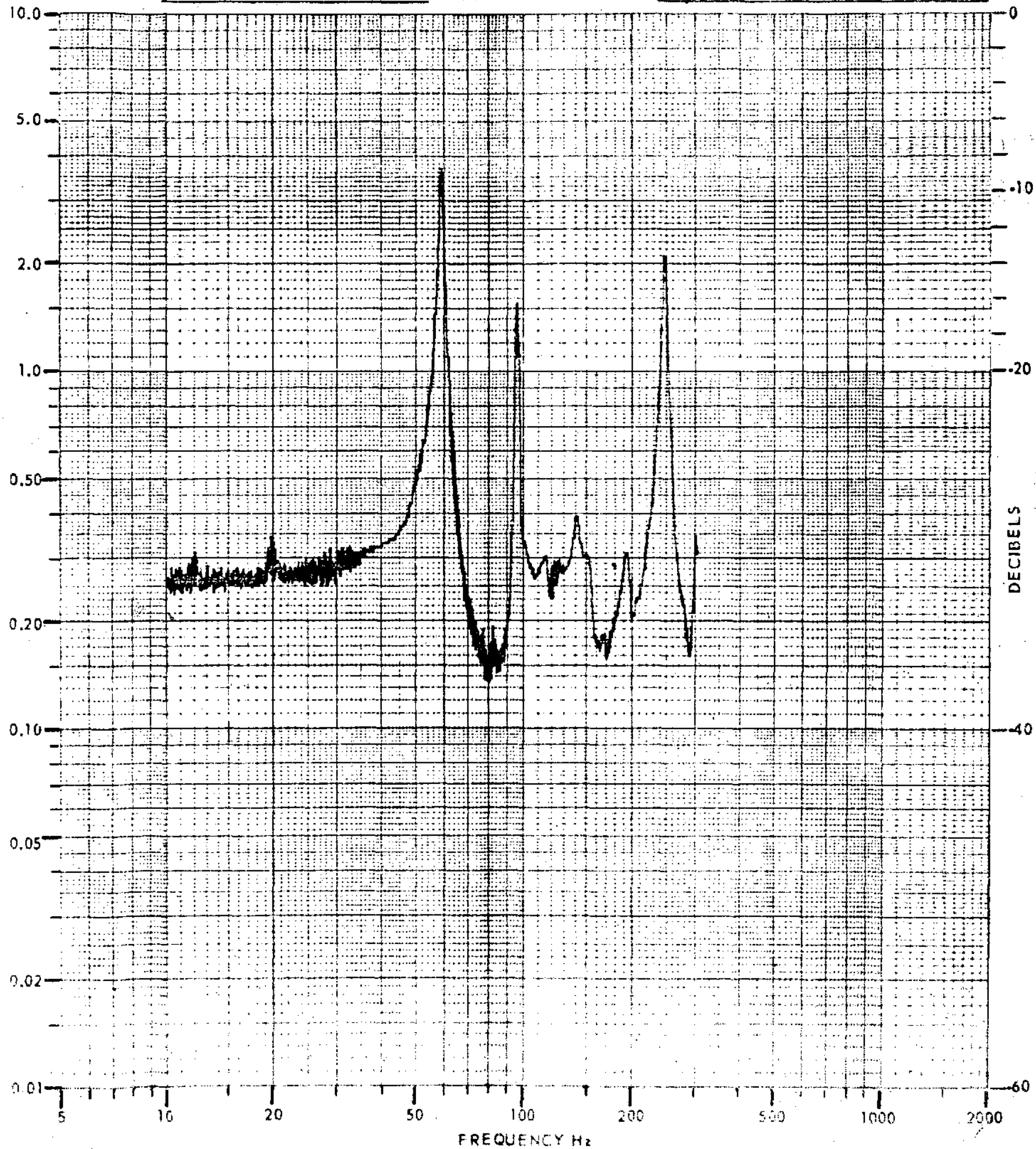

Figure 3.5-4

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT	1080	INPUT AXIS	X
TEST ARTICLE	AAFE ANTENNA	INPUT LEVEL	.5 G pk
RUN NO.	2	ACCEL. LOCATION	4
TEST DATE	12-8-73	ACCEL. SER. NO.	FB 49
OPERATOR	JMC	ACCEL. SENSITIVE AXIS	X

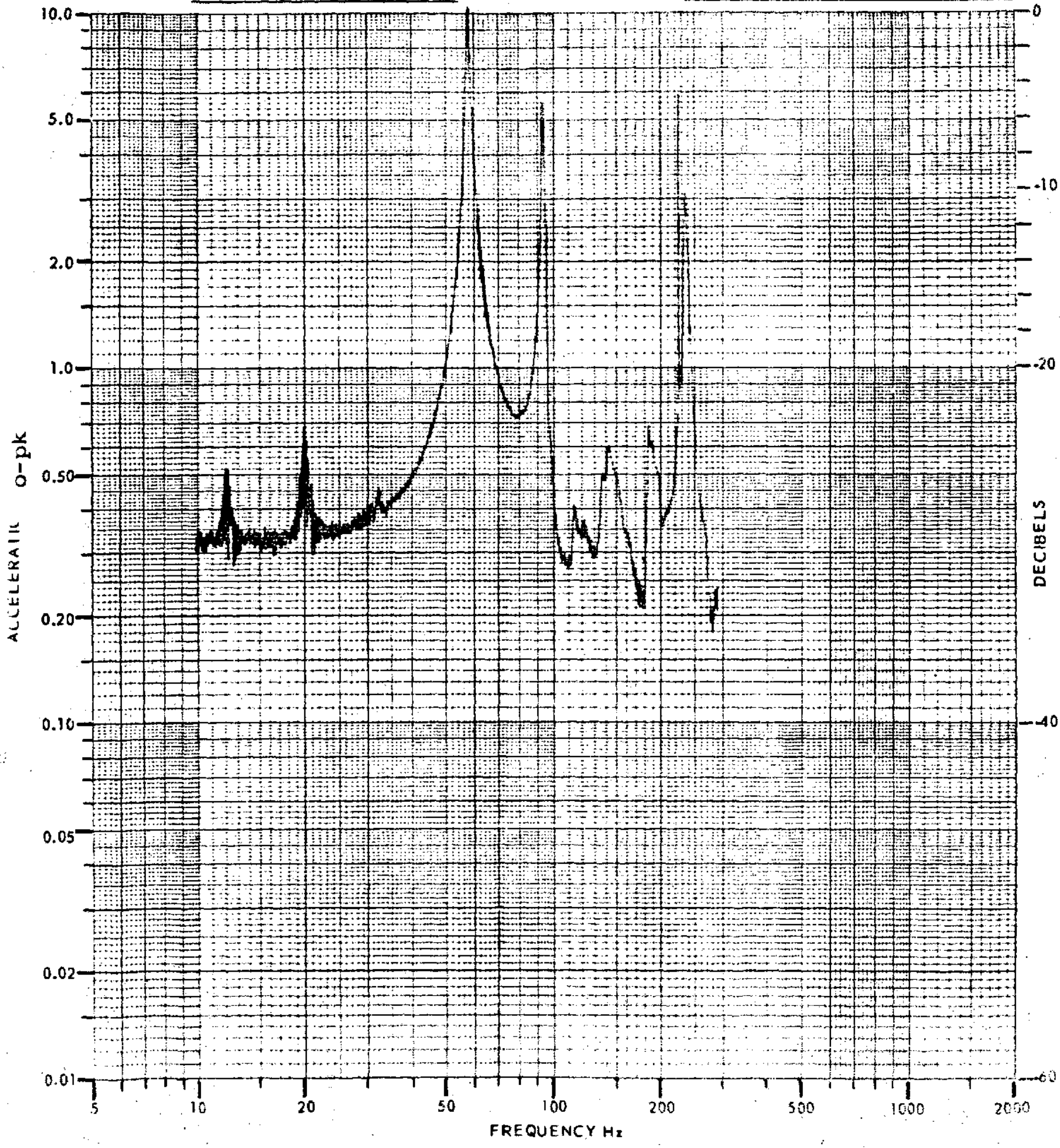

Figure 3.5-5

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080

INPUT AXIS X

TEST ARTICLE AAFE ANTENNA

INPUT LEVEL .21 G

RUN NO. 2

ACCEL. LOCATION 5X

TEST DATE 12-8-73

ACCEL. SER. NO. XR70

OPERATOR TLC

ACCEL. SENSITIVE AXIS X

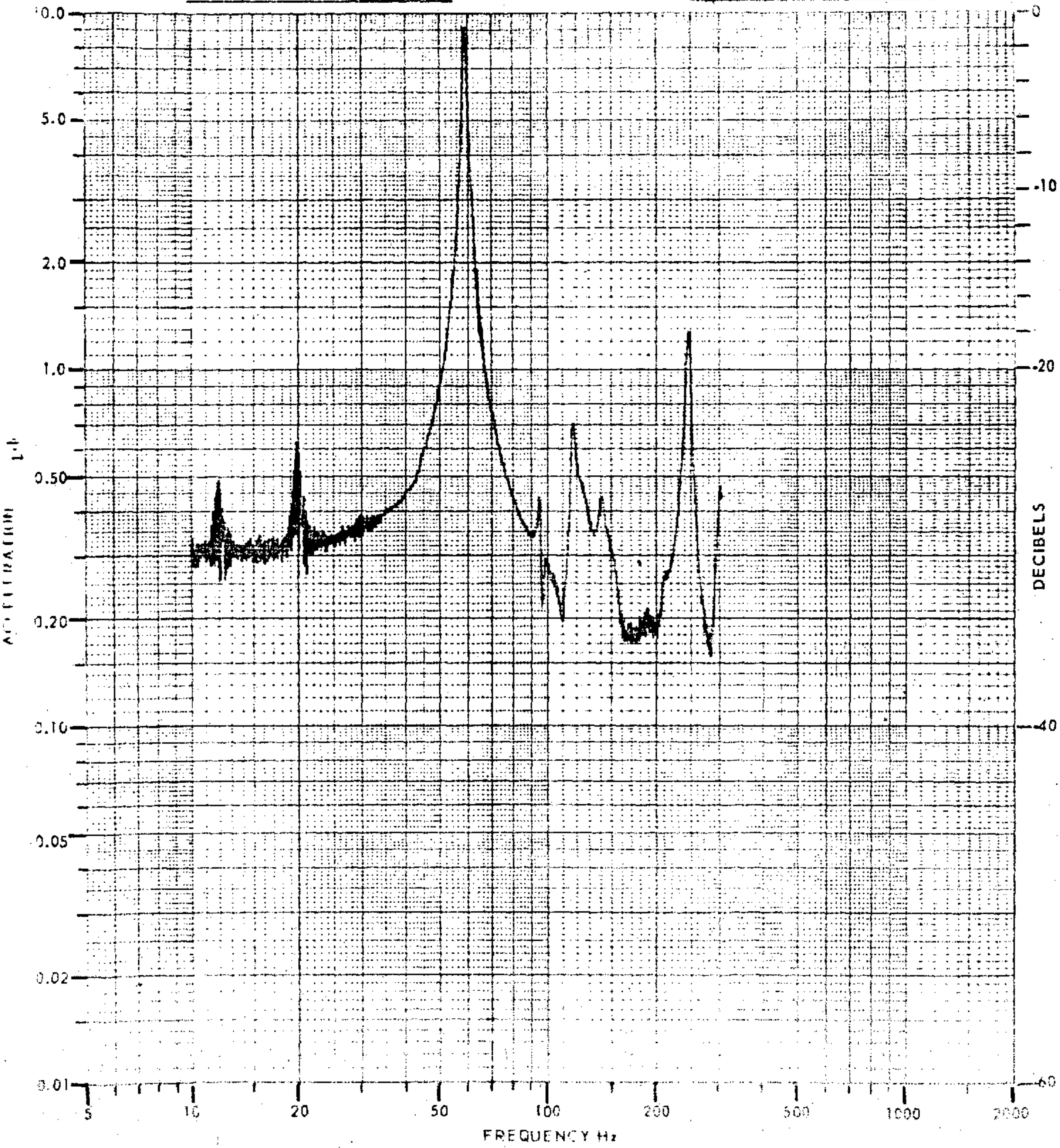

Figure 3.5-6

28

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080

TEST ARTICLE AAFE ANTENNA

RUN NO. 5

TEST DATE 12-8-73

OPERATOR TEC

INPUT AXIS Z

INPUT LEVEL .21 G-pk

ACCEL. LOCATION Control

ACCEL. SER. NO. NL10

ACCEL. SENSITIVE AXIS Z

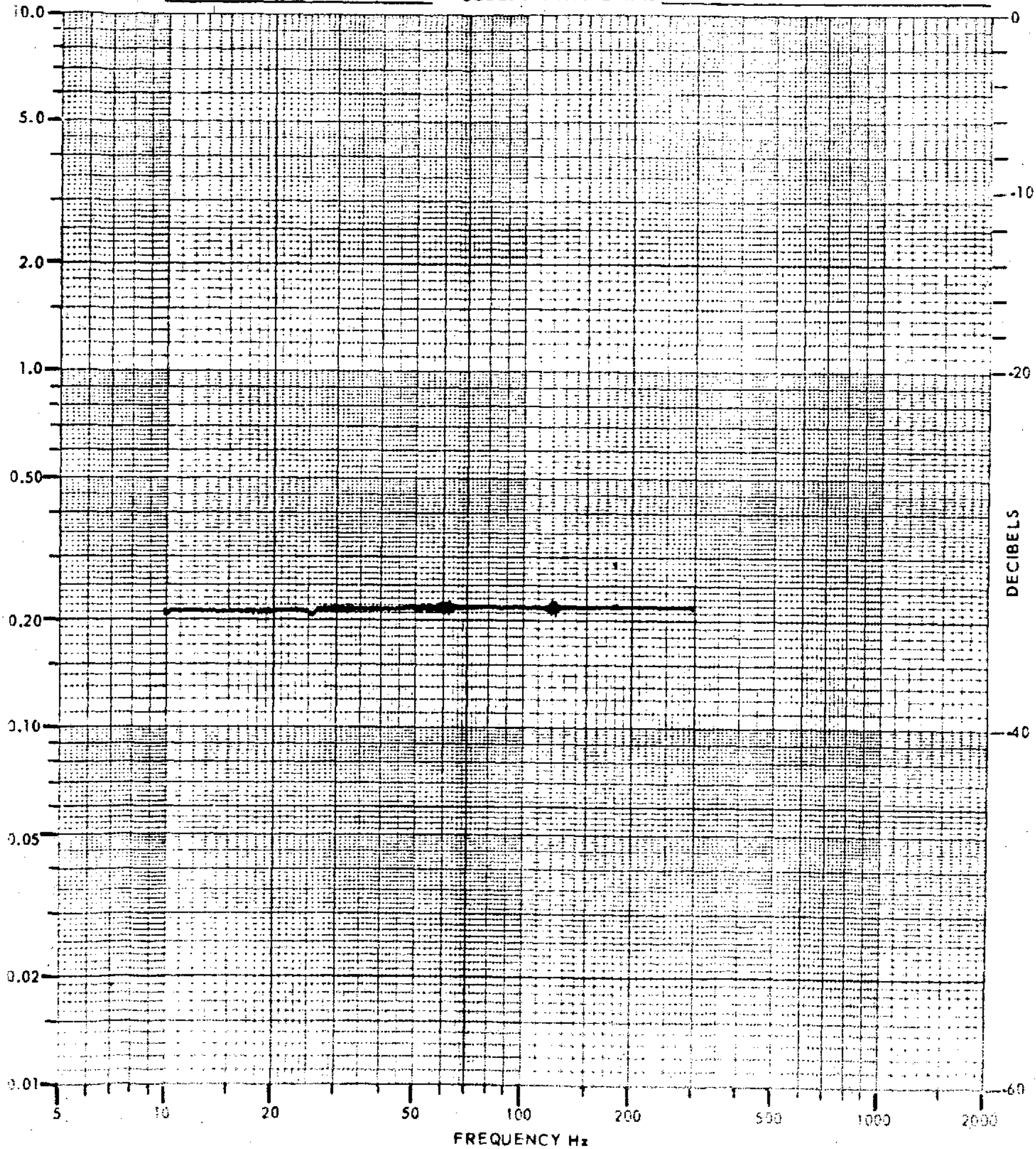

Figure 3.5-7

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 5
TEST DATE 12-8-73
OPERATOR T.L.C

INPUT AXIS Z
INPUT LEVEL .21 G-pk
ACCEL. LOCATION 1 Z
ACCEL. SER. NO. AB49
ACCEL. SENSITIVE AXIS Z

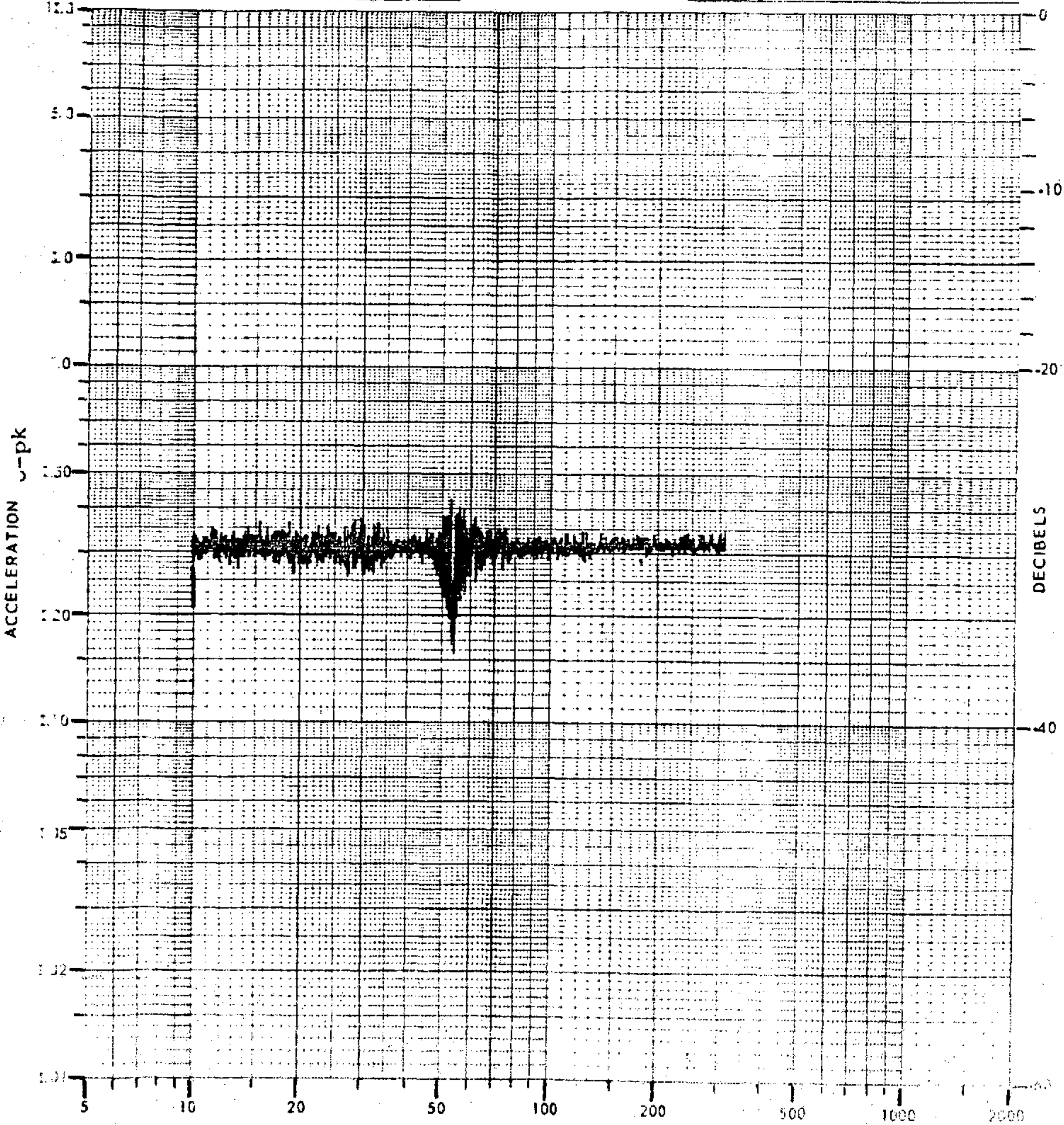

Figure 3.5-8

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 5
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .21 G-pk
ACCEL. LOCATION 2 Z
ACCEL. SER. NO. AC66
ACCEL. SENSITIVE AXIS Z

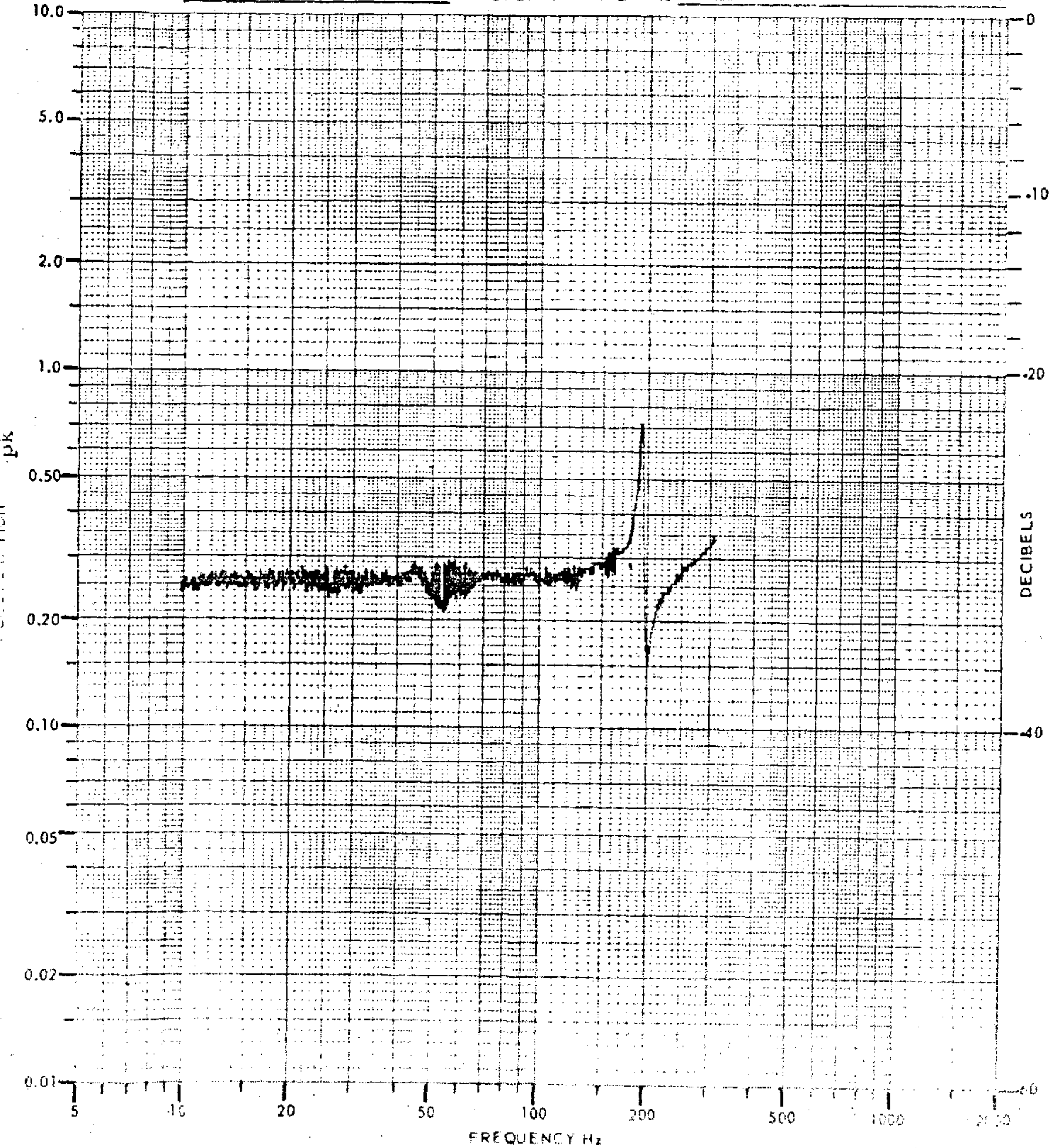

Figure 3.5-9

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE ARFC Antenna
RUN NO. 5
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .21 G-pk
ACCEL. LOCATION 3Z
ACCEL. SER. NO. AB10
ACCEL. SENSITIVE AXIS Z

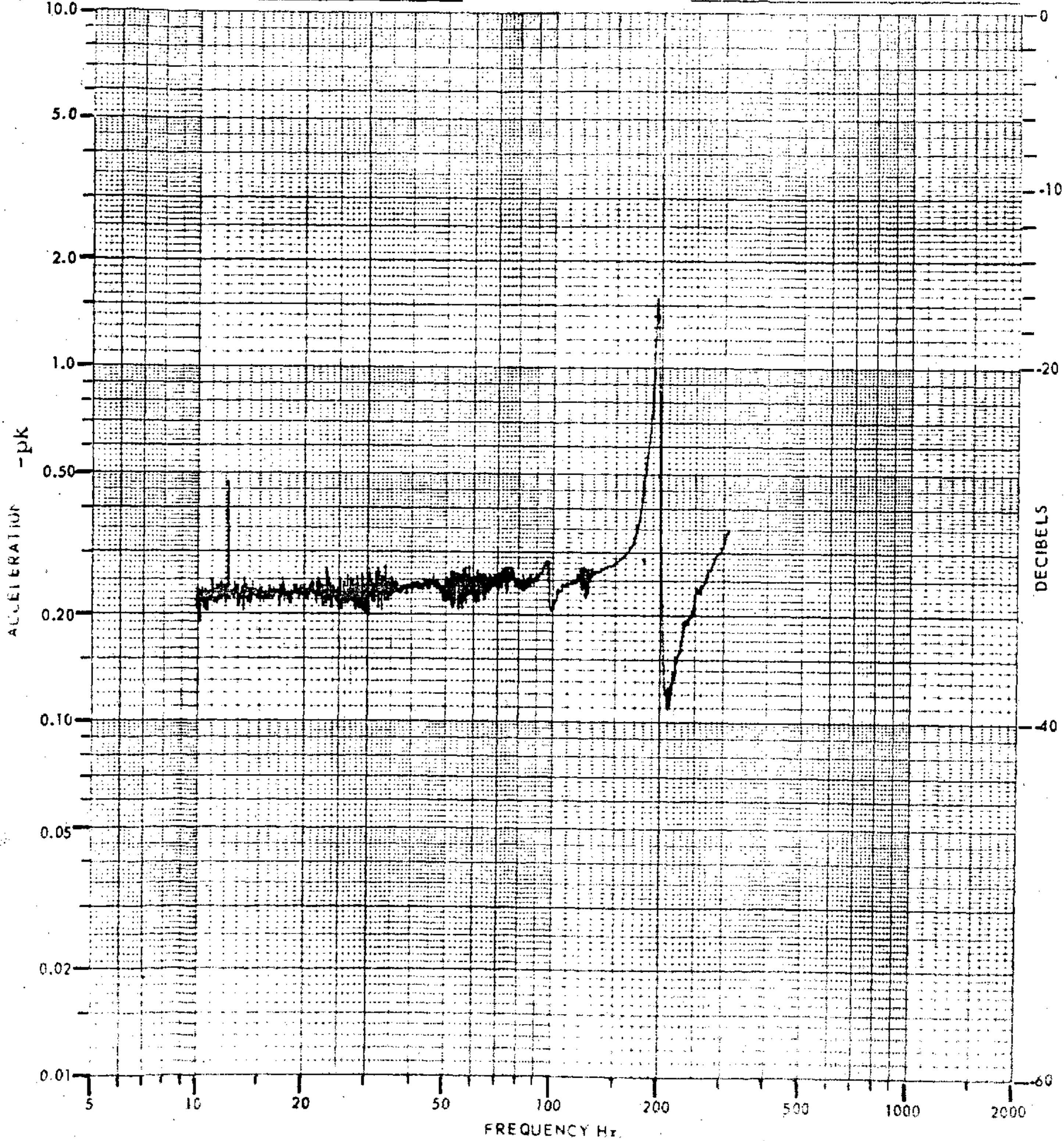

Figure 3.5-10

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 5
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .21 G o-pk
ACCEL. LOCATION 4 Z
ACCEL. SER. NO. XR 70
ACCEL. SENSITIVE AXIS Z

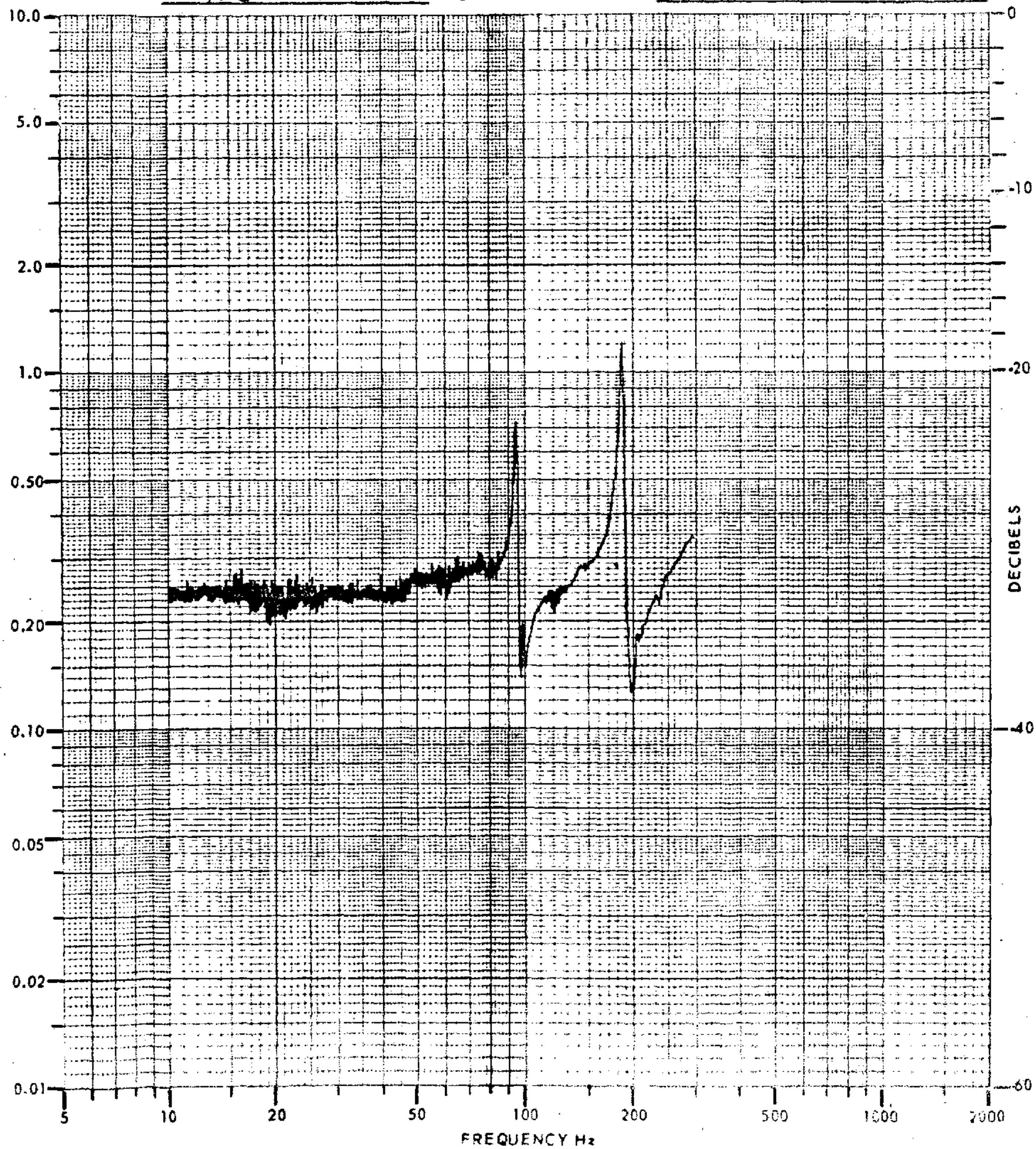

Figure 3.5-11

20

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 5
TEST DATE 12-2-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .21 G-pk
ACCEL. LOCATION 5X
ACCEL. SER. NO. XS34
ACCEL. SENSITIVE AXIS Y

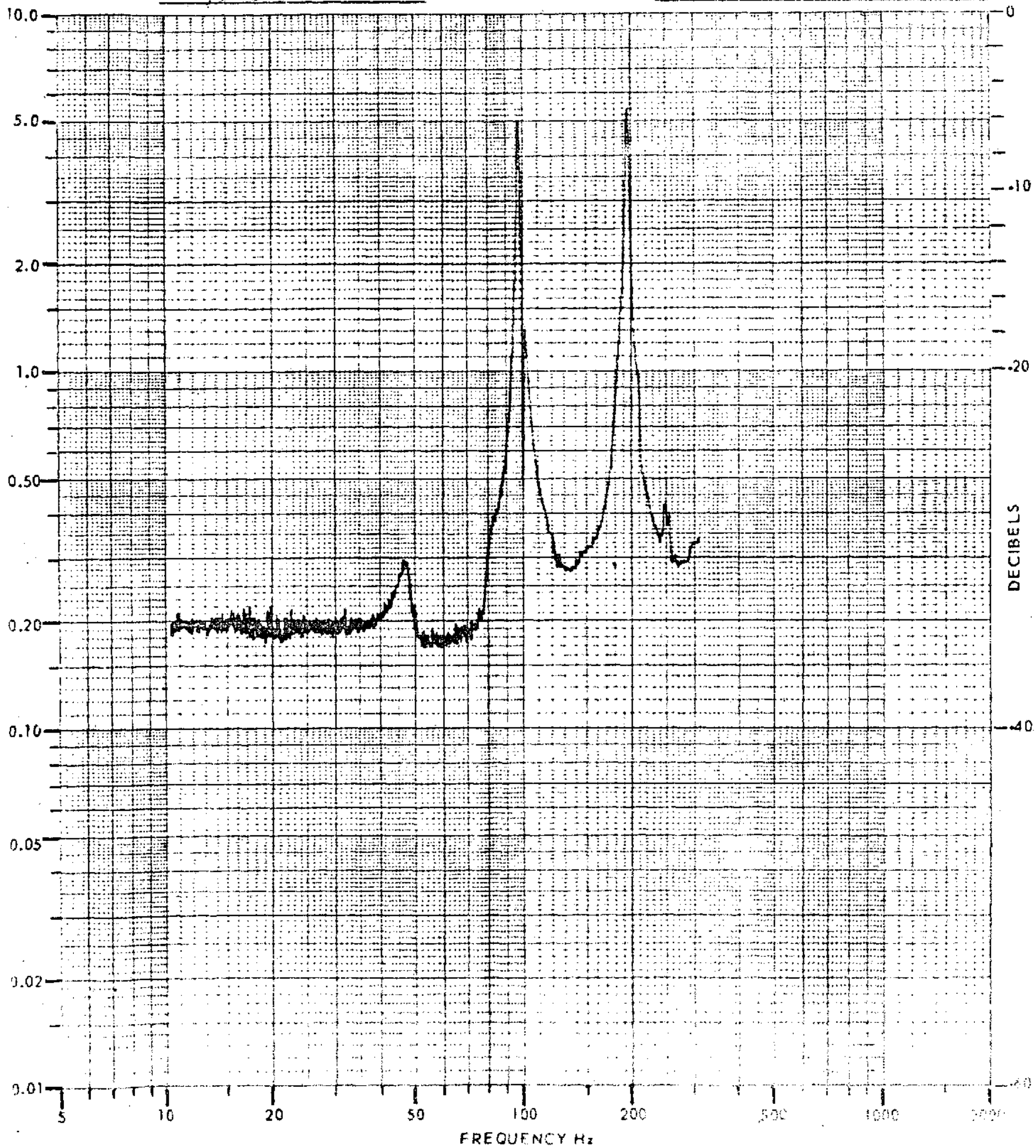

Figure 3.5-12

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
INPUT AXIS Z
TEST ARTICLE AAFE ANTENNA
INPUT LEVEL .21G-pk
RUN NO. 6
ACCEL. LOCATION CONTROL
TEST DATE 12-8-73
ACCEL. SER. NO. N610
OPERATOR TEC
ACCEL. SENSITIVE AXIS Z

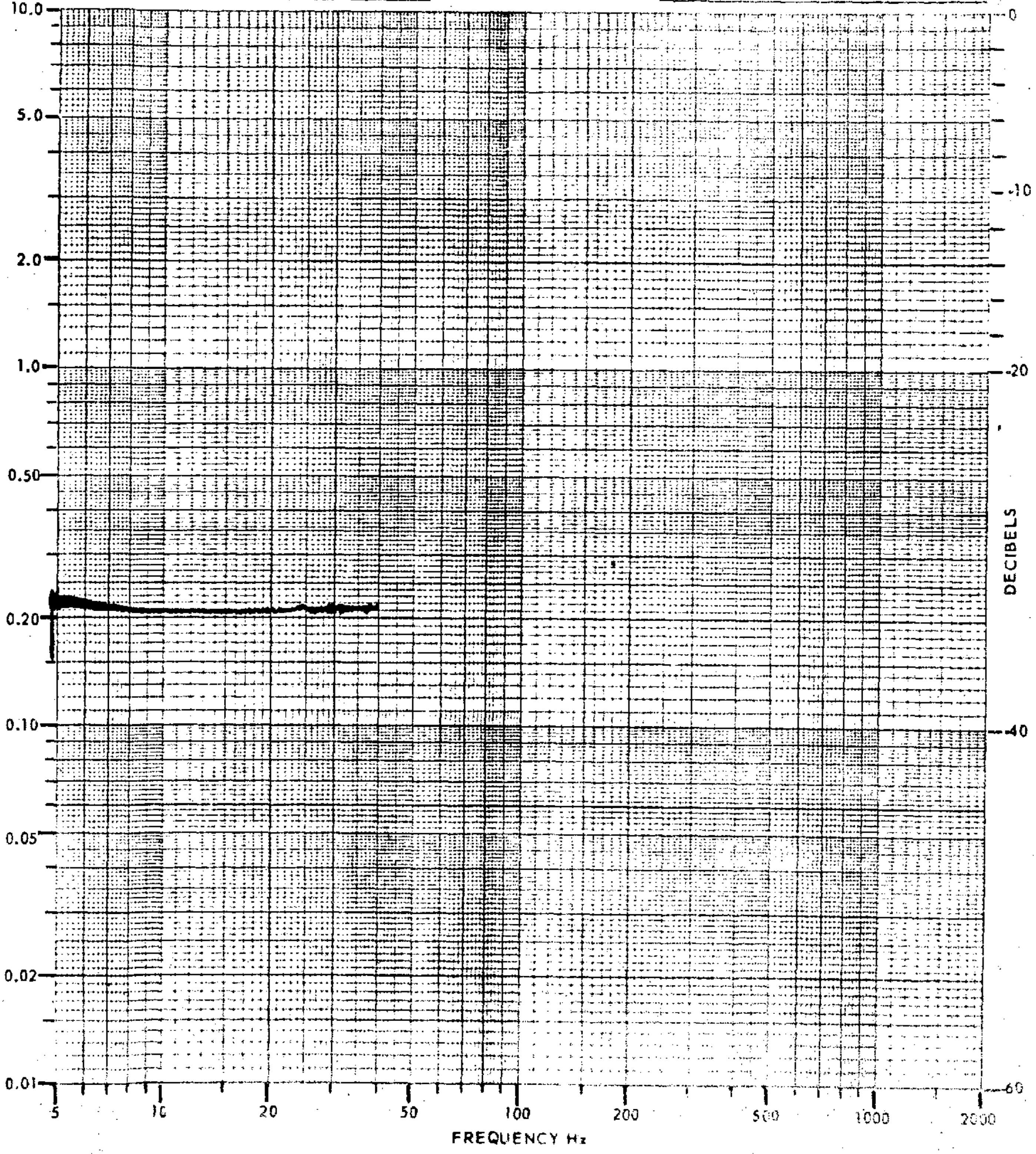

Figure 3.5-13

7 X

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080

TEST ARTICLE AAFE ANTENNA

RUN NO. 5

TEST DATE 12-8-73

OPERATOR TLC

INPUT AXIS Z

INPUT LEVEL .2 g pk

ACCEL. LOCATION 6 Z

ACCEL. SER. NO. AA23

ACCEL. SENSITIVE AXIS Z

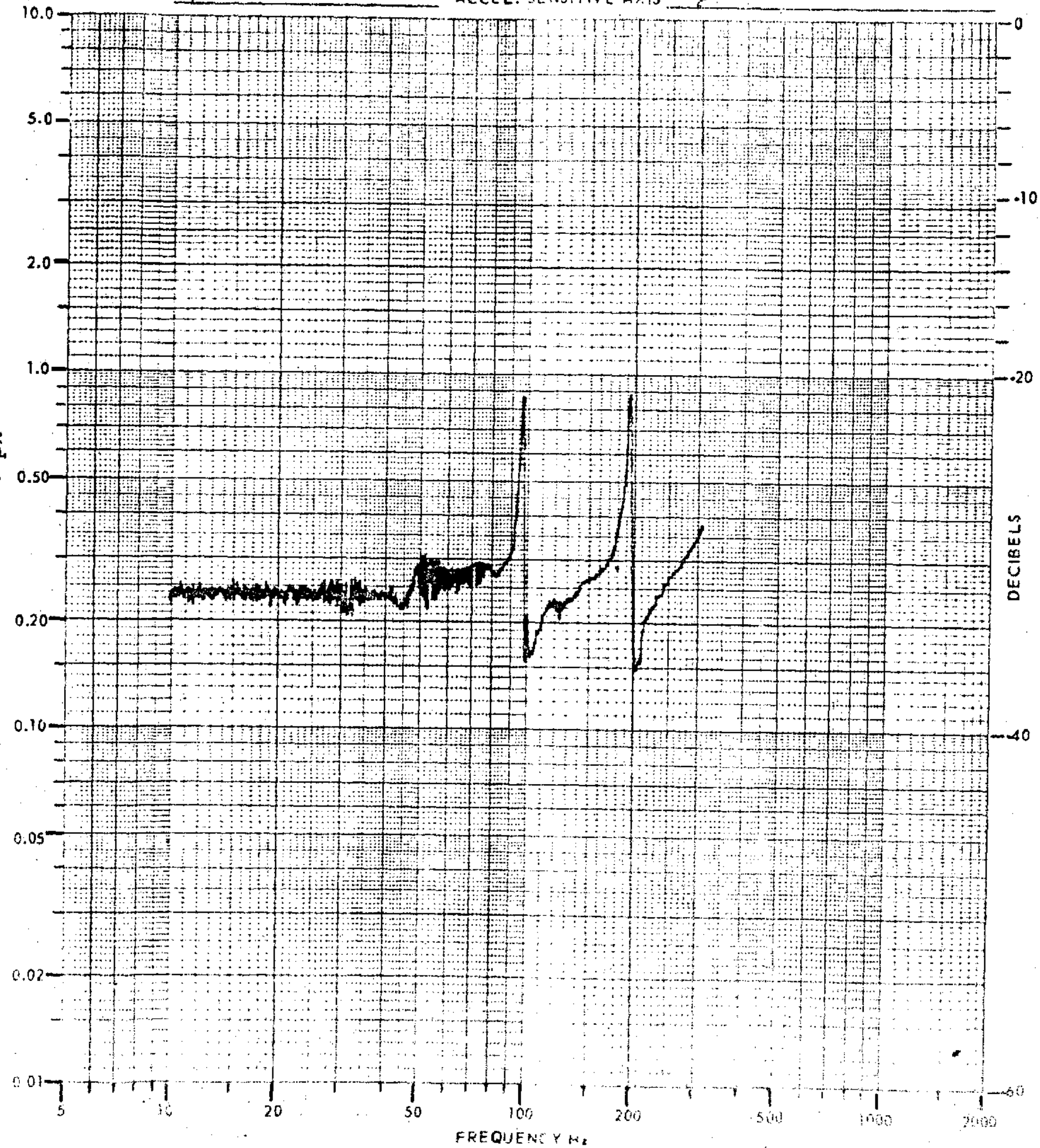

Figure 3.5-14

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE APEL ANTENNA
RUN NO. 6
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .2 G-pk
ACCEL. LOCATION 1 X
ACCEL. SER. NO. AA23
ACCEL. SENSITIVE AXIS X

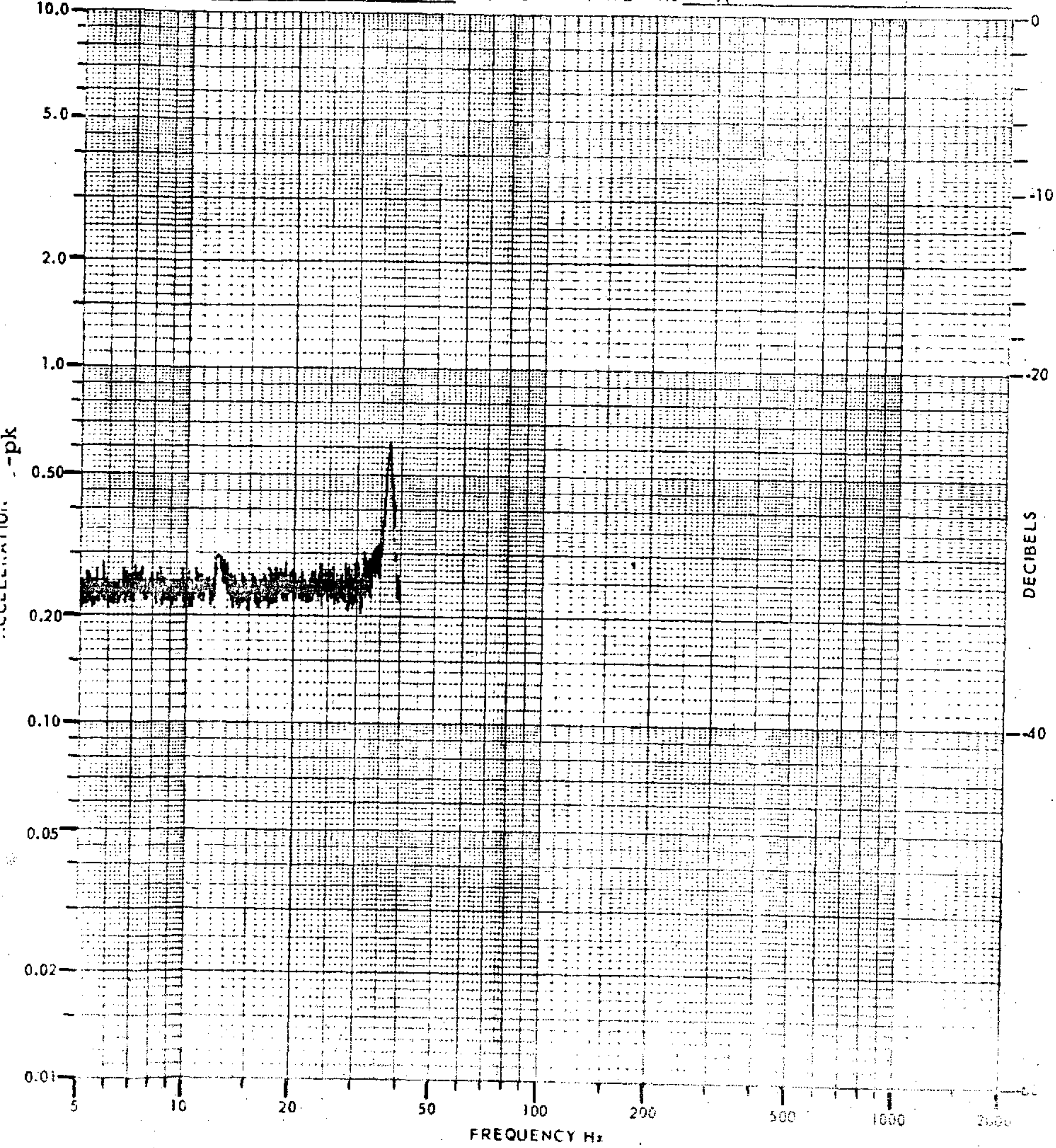

Figure 3.5-15

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VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE BATC ANTENNA
RUN NO. 6
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL .21 G-pk
ACCEL. LOCATION 2X
ACCEL. SER. NO. YH78
ACCEL. SENSITIVE AXIS X

X

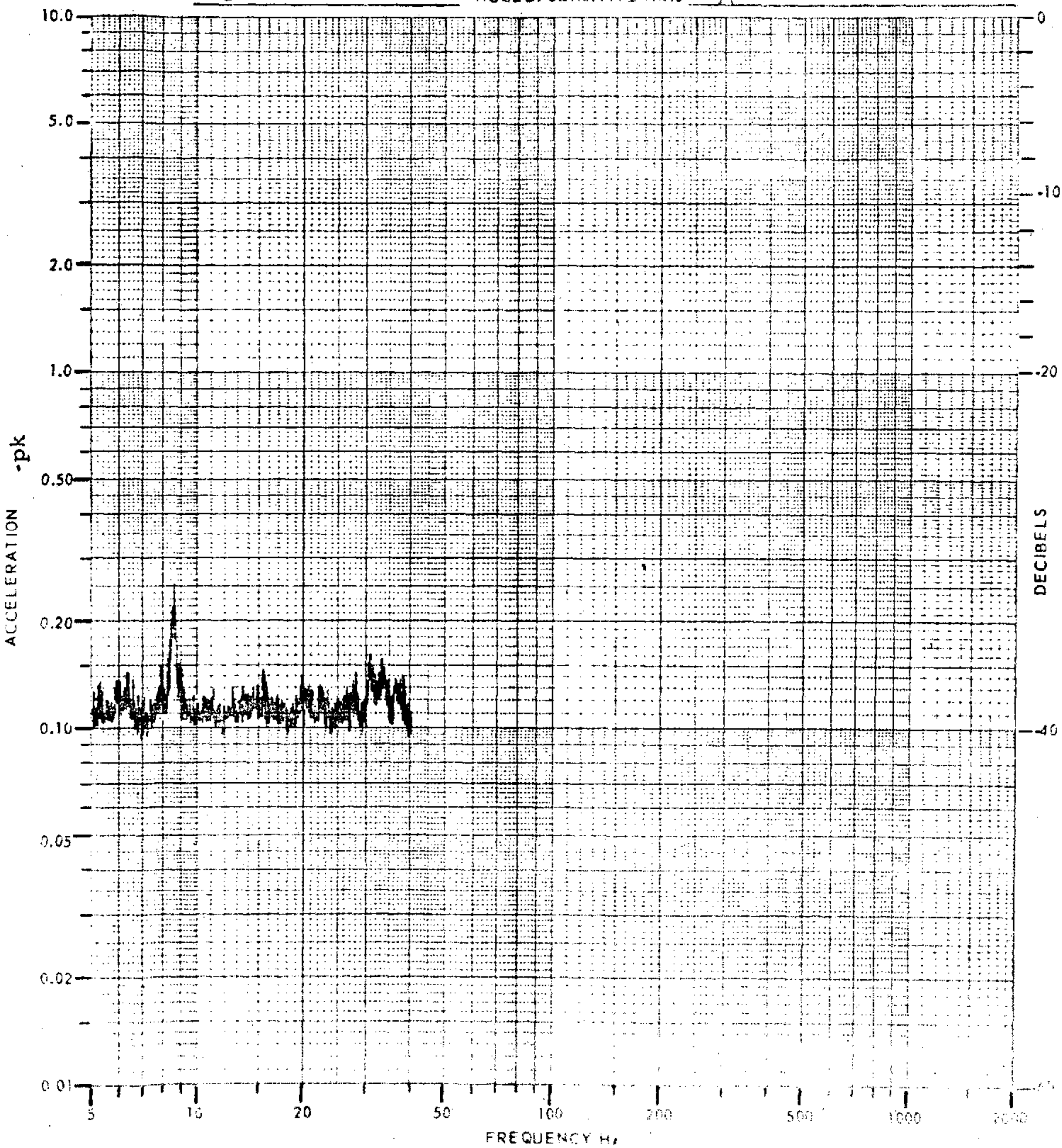

Figure 3.5-16

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE ANTENNA
RUN NO. 6
TEST DATE 12-8-73
OPERATOR TEC
INPUT AXIS Z
INPUT LEVEL
ACCEL. LOCATION 24
ACCEL. SER. NO. TC94
ACCEL. SENSITIVE AXIS

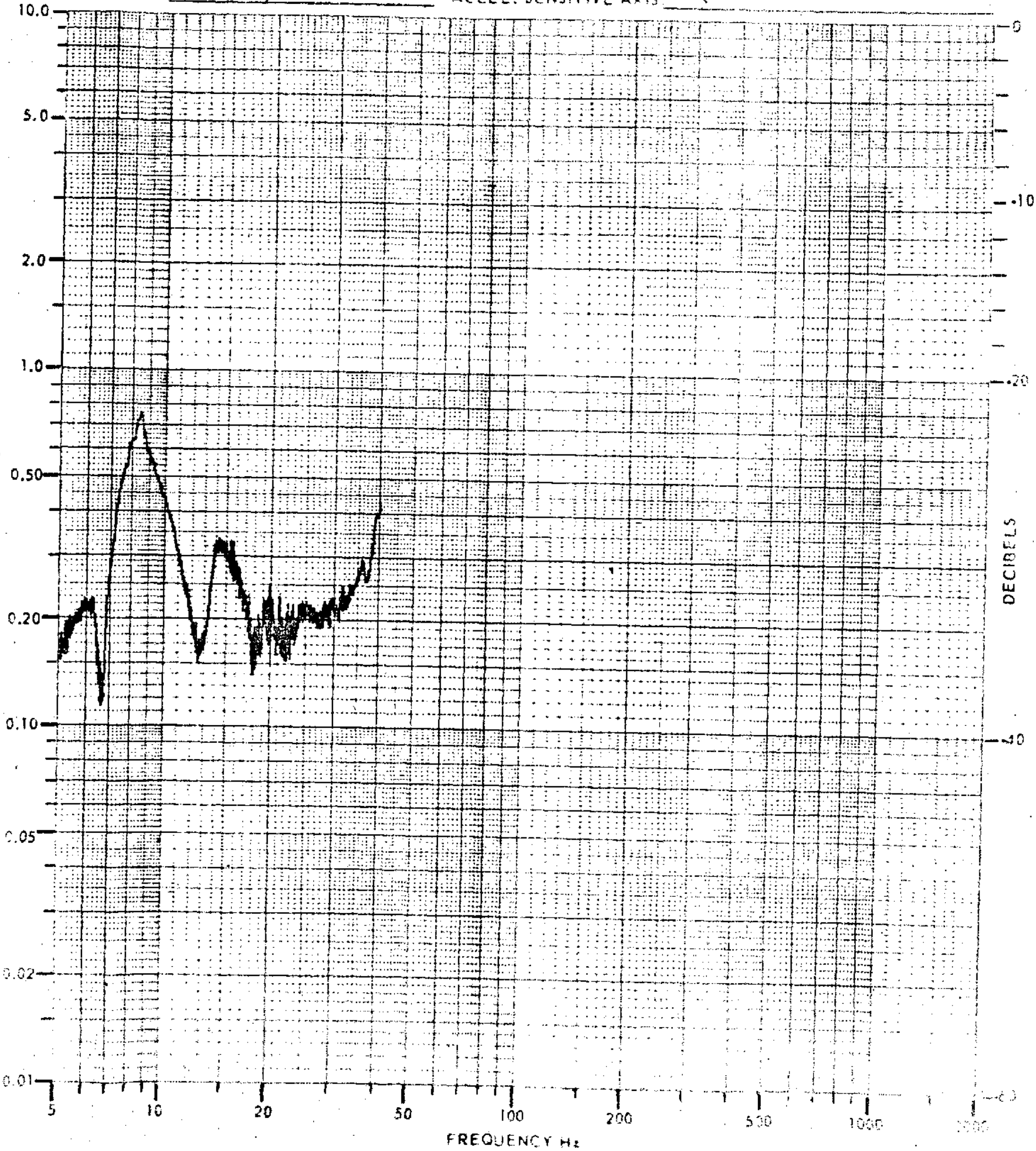

Figure 3.5-17

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 6
TEST DATE 12-8-73
OPERATOR TKC

INPUT AXIS Z
INPUT LEVEL [illegible]
ACCEL. LOCATION 2Z
ACCEL. SER. NO. XX 70
ACCEL. SENSITIVE AXIS Z

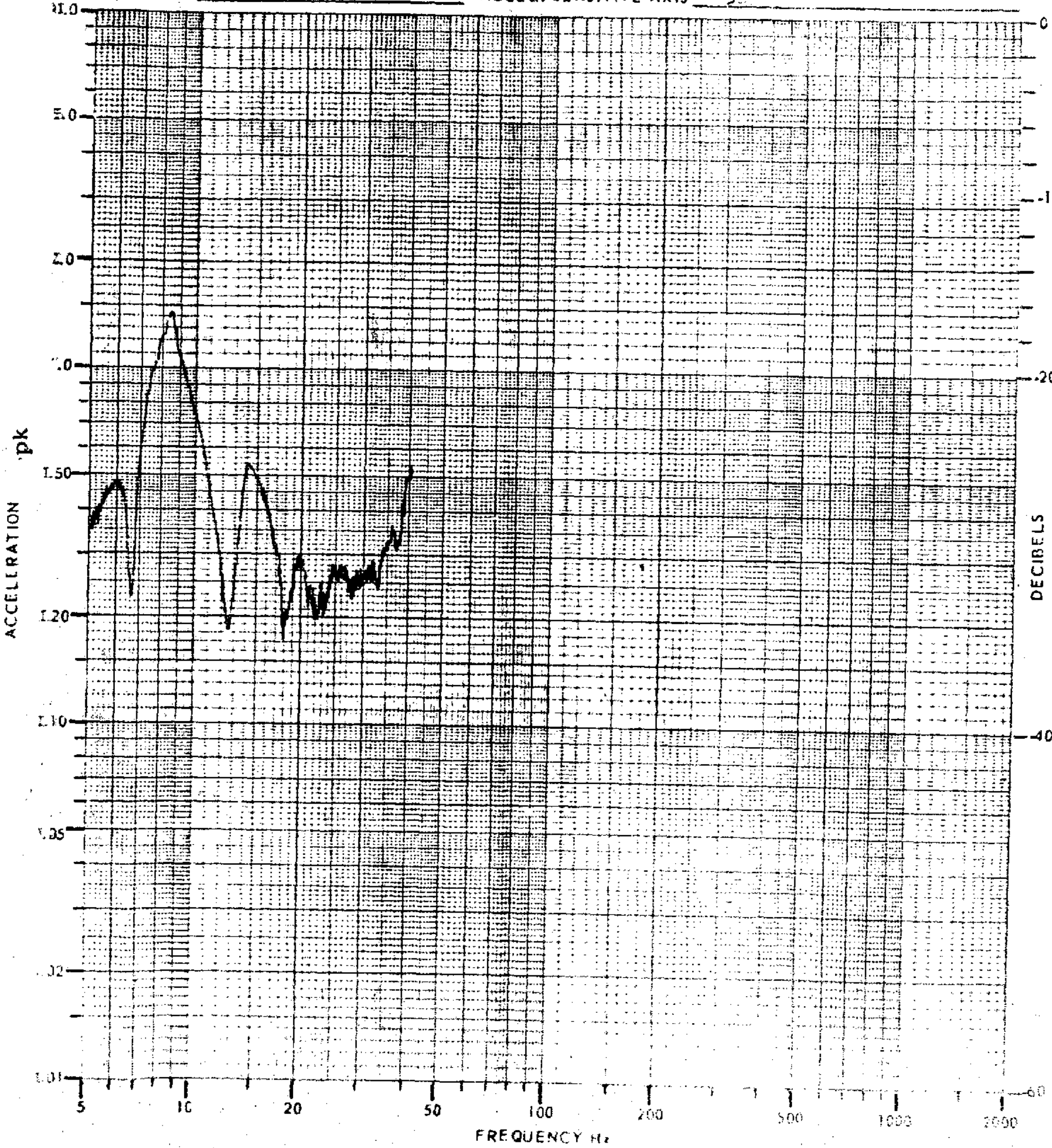

Figure 3.5-18

VIBRATION TEST DATA
ACCELERATION VS. FREQUENCY

PROJECT 1080
TEST ARTICLE AAFE ANTENNA
RUN NO. 6
TEST DATE 12-8-73
OPERATOR TEC

INPUT AXIS Z
INPUT LEVEL 2(G-pk)
ACCEL. LOCATION 3 Z
ACCEL. SER. NO. XK34
ACCEL. SENSITIVE AXIS Z

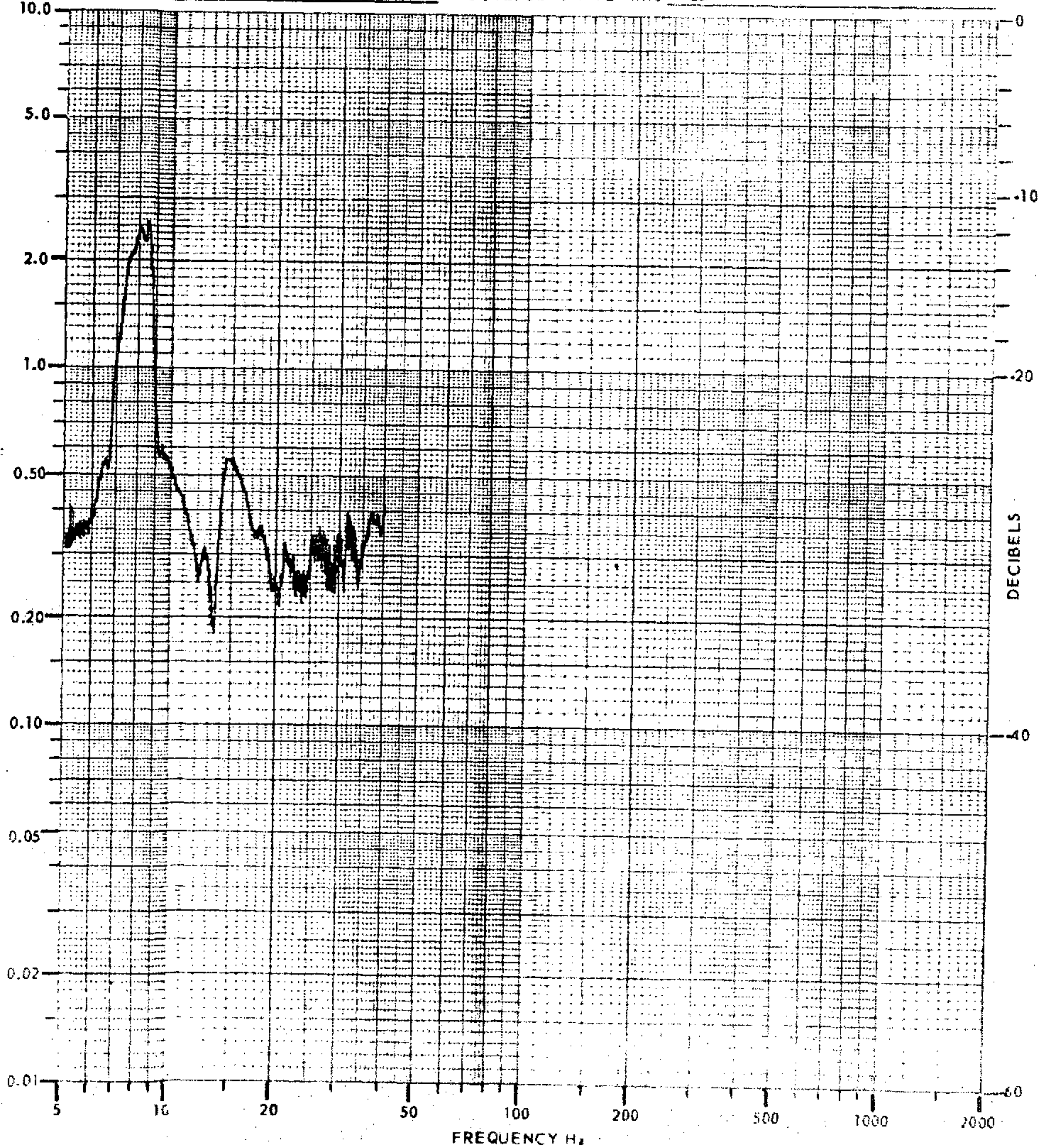

Figure 3.5-19

WITNESS 12-3-73

4.4 Test Record

4.4.1 Surface Accuracy Test No. 1

4.4.1.1 Measurement Data

Surface Deviation (Inches)

Radius (in.) / θ°	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0
14.4		.484	.511	.565	.555	.560	.569	.576	.557	.569
28.8		.507	.513	.545	.520	.525	.553	.554	.563	.567
43.2		.493	.515	.527	.528	.536	.558	.560	.557	.520
57.6		.512	.511	.521	.536	.548	.564	.570	.564	.572
72.0		.514	.532	.544	.564	.566	.561	.599	.617	.583
86.4		.515	.480	.520	.531	.557	.582	.565	.590	.598
100.8		.477	.524	.564	.570	.572	.585	.572	.591	.598
115.2		.513	.507	.552	.533	.584	.590	.583	.569	.596
129.6		.503	.522	.545	.568	.589	.614	.615	.604	.619
144.0		.503	.524	.542	.530	.555	.551	.572	.586	.593
158.4		.518	.535	.550	.523	.590	.608	.628	.595	.610
172.8		.520	.524	.537	.552	.560	.543	.556	.578	.585
187.2		.508	.519	.537	.540	.567	.578	.575	.577	.633
201.6		.520	.503	.515	.511	.523	.543	.550	.568	.596
216.0		.517	.537	.539	.540	.560	.558	.580	.608	.611
230.4		.513	.535	.538	.543	.564	.569	.592	.590	.590
244.8		.500	.533	.550	.555	.566	.579	.582	.587	.605
259.2		.488	.530	.540	.559	.555	.553	.576	.584	.595
273.6		.504	.539	.559	.566	.590	.587	.618	.604	.621
288.0		.514	.535	.545	.549	.570	.605	.602	.599	.615
302.4		.528	.550	.576	.574	.575	.541	.565	.581	.600
316.8		.492	.536	.575	.594	.590	.567	.566	.580	.603
331.2		.504	.512	.532	.546	.536	.567	.570	.574	.591
345.6		.490	.503	.532	.517	.532	.565	.574	.593	.623
360.0		.492	.519	.526	.530	.524	.562	.566	.579	.586

4.4.1.2 Computer Results

Surface Error: 0.0203-inch rms

Monday
Owen

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***************************************************
*                                                 *
*              PARABOLOID PROGRAM                 *
*  THIS PROGRAM COMPUTES THE BEST-FIT PARABOLOID  *
*  FROM A GIVEN SET OF DATA POINTS,               *
*                                                 *
*              STRUCTURES SECTION                 *
*              RADIATION DIVISION                 *
*             HARRIS INTERTYPE INC,               *
*              MELBOURNE, FLORIDA                 *
*                                                 *
*     REVISION DATE OF THIS PROGRAM, AUG-73       *
*                                                 *
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BEST-FIT PARABOLOID FOR 150 INCH ANTENNA

4.4.1.1 MEASUREMENT AND SURFACE DEVIATION

****

JOINT*	JOINT COORDINATES X	Y	Z **	DEFLECTIONS X	Y	Z **	DEFLECTED COORDINATES X	Y	Z *
1	69.00000	-.00000	19.02878	-.03332	.00000	.06042	68.96668	.00000	19.08920
2	66.85224	17.15960	19.02878	-.03134	-.00805	.05867	66.80090	17.15155	19.08744
3	60.46516	33.24100	19.02878	-.00846	-.00465	.01751	60.45670	33.23635	19.04629
4	50.29883	47.23375	19.02878	-.02535	-.02380	.06305	50.27349	47.20995	19.09182
5	36.97205	58.25863	19.02878	-.02148	-.03385	.07268	36.95057	58.22478	19.10145
6	21.32217	65.62290	19.02878	-.01463	-.04501	.08581	21.30755	65.57788	19.11459
7	4.33255	68.86384	19.02878	-.00297	-.04724	.08581	4.32957	68.81661	19.11459
8	-12.92931	67.77782	19.02878	.00869	-.04554	.08406	-12.92062	67.73228	19.11284
9	-29.37877	62.43307	19.02878	.02447	-.05200	.10420	-29.35430	62.38106	19.13298
10	-43.98225	53.16541	19.02878	.02863	-.03461	.08143	-43.95362	53.13081	19.11021
11	-55.82217	40.55718	19.02878	.04298	-.03123	.09632	-55.77919	40.52596	19.12510
12	-64.15458	25.40060	19.02878	.03817	-.01511	.07443	-64.11641	25.38549	19.10321
13	-68.45591	8.64800	19.02878	.06373	-.00805	.11646	-68.39218	8.63995	19.14524
14	-68.45591	-8.64799	19.02878	.04600	.00581	.08406	-68.40992	-8.64218	19.11284
15	-64.15458	-25.40059	19.02878	.04984	.01973	.09720	-64.10474	-25.38085	19.12597
16	-55.82218	-40.55717	19.02878	.03517	.02555	.07881	-55.78701	-40.53162	19.10758
17	-43.98226	-53.16541	19.02878	.03232	.03907	.09194	-43.94990	-53.12633	19.12072
18	-29.37878	-62.43306	19.02878	.01954	.04152	.08319	-29.35925	-62.39155	19.11196
19	-12.92932	-67.77782	19.02878	.01095	.05740	.10595	-12.91837	-67.72041	19.13473
20	4.33253	-68.86384	19.02878	-.00349	.05543	.10070	4.32904	-68.80841	19.12948
21	21.32216	-65.62290	19.02878	-.01492	.04593	.08756	21.30723	-65.57697	19.11634
22	36.97203	-58.25863	19.02878	-.02665	.04200	.09019	36.94538	-58.21663	19.11897
23	50.29882	-47.23376	19.02878	-.03204	.03009	.07968	50.26678	-47.20368	19.10846
24	60.46515	-33.24102	19.02878	-.05206	.02862	.10770	60.41309	-33.21240	19.13648
25	66.83223	-17.15962	19.02878	-.04023	.01033	.07530	66.79200	-17.14929	19.10408
26	63.00000	-.00000	15.86331	-.02654	.00000	.05270	62.97346	.00000	15.91600
27	61.02074	15.66746	15.86331	-.02745	-.00705	.05627	60.99329	15.66042	15.91958
28	55.20732	30.35048	15.86331	-.02247	-.01235	.05091	55.18485	30.33813	15.91422
29	45.92502	43.12647	15.86331	-.02098	-.01971	.05716	45.90404	43.10676	15.92047
30	33.75709	53.19266	15.86331	-.02820	-.04443	.10450	33.72889	53.14823	15.96781
31	19.46807	59.91656	15.86331	-.01251	-.03850	.08038	19.45556	59.87806	15.94369
32	3.95580	62.87568	15.86331	-.00257	-.04085	.08128	3.95323	62.83483	15.94458
33	-11.80502	61.88410	15.86331	.00582	-.03049	.06163	-11.79921	61.85361	15.92494
34	-26.82409	57.00410	15.86331	.01992	-.04233	.09289	-26.80418	56.96178	15.95620
35	-40.15771	48.54233	15.86331	.02466	-.02980	.07681	-40.13305	48.51253	15.94012
36	-50.96807	37.03047	15.86331	.03457	-.02512	.08485	-50.93350	37.00536	15.94816
37	-58.57592	23.19185	15.86331	.03262	-.01291	.06966	-58.54330	23.17894	15.93297
38	-62.50322	7.89600	15.86331	.03436	-.00434	.06877	-62.46886	7.89166	15.93208
39	-62.50323	-7.89599	15.86331	.03034	.00383	.06073	-62.47288	-7.89215	15.92404
40	-58.57592	-23.19184	15.86331	.04517	.01788	.09646	-58.53076	-23.17396	15.95977
41	-50.96807	-37.03046	15.86331	.03275	.02379	.08038	-50.93533	-37.00667	15.94369
42	-40.15772	-48.54233	15.86331	.02494	.03015	.07770	-40.13277	-48.51218	15.94101
43	-26.82410	-57.00410	15.86331	.01609	.03419	.07502	-26.80802	-56.96991	15.93833
44	-11.80503	-61.88409	15.86331	.00877	.04595	.09289	-11.79627	-61.83815	15.95620
45	3.95579	-62.87568	15.86331	-.00280	.04444	.08842	3.95299	-62.83124	15.95173
46	19.46806	-59.91656	15.86331	-.01126	.03465	.07234	19.45680	-59.88191	15.93565
47	33.75708	-53.19267	15.86331	-.02073	.03266	.07681	33.73635	-53.16001	15.94012
48	45.92501	-43.12648	15.86331	-.02426	.02278	.06609	45.90075	-43.10369	15.92940
49	55.20731	-30.35050	15.86331	-.03666	.02015	.08306	55.17066	-30.33034	15.94637
50	61.02073	-15.66748	15.86331	-.03442	.00884	.07056	60.98632	-15.65864	15.93387
51	57.00000	-.00000	12.98561	-.03151	.00000	.06916	56.96849	.00000	13.05477
52	55.20924	14.17532	12.98561	-.02169	-.00557	.04914	55.18755	14.16976	13.03475
53	49.94948	27.45996	12.98561	-.02180	-.01198	.05460	49.92768	27.44797	13.04021
54	41.55121	39.01918	12.98561	-.02116	-.01987	.06370	41.53005	38.99932	13.04931
55	30.54213	48.12669	12.98561	-.02199	-.03466	.09009	30.52013	48.09203	13.07570

56	17.61397	54.21022	12.98561	-.00833	-.02563	.05915	17.60564	54.18459	13.04476
57	3.57906	56.88752	12.98561	-.00187	-.02979	.06552	3.57719	56.85773	13.05113
58	-10.68073	55.99037	12.98561	.00645	-.03380	.07553	-10.67429	55.95657	13.06114
59	-24.26942	51.57514	12.98561	.02030	-.04314	.10465	-24.24912	51.53200	13.09026
60	-36.33317	43.91926	12.98561	.01903	-.02300	.06552	-36.31410	43.89625	13.05113
61	-46.11397	33.50376	12.98561	.04294	-.03119	.11648	-46.07103	33.47257	13.10209
62	-52.99726	20.98310	12.98561	.02159	-.00855	.05096	-52.97567	20.97456	13.03657
63	-56.55058	7.14400	12.98561	.03089	-.00390	.06825	-56.51968	7.14010	13.09386
64	-56.55054	-7.14399	12.98561	.02057	.00260	.04550	-56.52997	-7.14139	13.03111
65	-52.99726	-20.98309	12.98561	.03084	.01221	.07280	-52.96642	-20.97088	13.05881
66	-46.11397	-33.50375	12.98561	.03086	.02242	.08372	-46.08311	-33.48133	13.06933
67	-36.33317	-43.91925	12.98561	.02167	.02620	.07462	-36.31150	-43.89305	13.06023
68	-24.26943	-51.57514	12.98561	.01342	.02851	.06916	-24.25601	-51.54663	13.05477
69	-10.68074	-55.99037	12.98561	.00839	.04399	.09828	-10.67235	-55.94638	13.08389
70	3.57905	-56.88752	12.98561	-.00266	.04221	.09282	3.57639	-56.84532	13.07843
71	17.61396	-54.21022	12.98561	-.00833	.02563	.05915	17.60563	-54.18459	13.04476
72	30.54212	-48.12670	12.98561	-.01466	.02311	.06006	30.52745	-48.10359	13.04567
73	41.55120	-39.01919	12.98561	-.02116	.01987	.06370	41.53004	-38.99933	13.04931
74	49.94947	-27.45997	12.98561	-.02689	.01478	.06734	49.92259	-27.44519	13.05295
75	55.20924	-14.17534	10.39568	-.02410	.00619	.05460	55.18514	-14.16915	13.04021
76	51.00000	-.00000	10.39568	-.02605	.00000	.06389	50.97395	.00000	10.45958
77	49.39774	12.68318	10.39568	-.01938	-.00498	.04908	49.37836	12.67821	10.44476
78	44.69164	24.56944	10.39568	-.01919	-.01055	.05371	44.67245	24.55889	10.44939
79	37.17740	34.91190	10.39568	-.01761	-.01654	.05926	37.15979	34.89536	10.45495
80	27.32717	43.06072	10.39568	-.01234	-.01944	.05649	27.31483	43.04128	10.45217
81	15.75987	48.50388	10.39568	-.00957	-.02944	.07593	15.75030	48.47444	10.47162
82	3.20232	50.89936	10.39568	-.00201	-.03202	.07871	3.20030	50.86734	10.47439
83	-9.55645	50.09665	10.39568	.00637	-.03337	.08334	-9.55008	50.06328	10.47902
84	-21.71474	46.14618	10.39568	.01832	-.03894	.10556	-21.69642	46.10724	10.50129
85	-32.50862	39.29618	10.39568	.01227	-.01483	.04723	-32.49635	39.28134	10.44291
86	-41.25986	29.97705	10.39568	.03298	-.02396	.10001	-41.22688	29.95309	10.49569
87	-47.41860	18.77436	10.39568	.01509	-.00598	.03982	-47.40351	18.76838	10.43550
88	-50.59785	6.39200	10.39568	.02921	-.00369	.07223	-50.56864	6.38831	10.46791
89	-50.59785	-6.39199	10.39568	.01610	.00203	.03982	-50.58174	-6.38996	10.43550
90	-47.41860	-18.77435	10.39568	.02036	.00806	.05371	-47.39824	-18.76629	10.44939
91	-41.25987	-29.97704	10.39568	.02107	.01531	.06389	-41.23880	-29.96173	10.45958
92	-32.50863	-39.29617	10.39568	.01901	.02298	.07315	-32.48962	-39.27319	10.46884
93	-21.71475	-46.14618	10.39568	.00852	.01810	.04908	-21.70623	-46.12807	10.44476
94	-9.55646	-50.09665	10.39568	.00615	.03226	.08056	-9.55030	-50.06439	10.47625
95	3.20231	-50.89936	10.39568	-.00249	.03956	.09723	3.19982	-50.85980	10.49291
96	15.75986	-48.50389	10.39568	-.00478	.01472	.03797	15.75507	-48.48916	10.43365
97	27.32716	-43.06073	10.39568	-.01355	.02136	.06204	27.31360	-43.03937	10.45773
98	37.17739	-34.91191	10.39568	-.01844	.01731	.06204	37.15895	-34.89460	10.45773
99	44.69163	-24.56945	10.39568	-.02150	.01182	.06019	44.67013	-24.55763	10.45587
100	49.39774	-12.68320	8.09353	-.02267	.00582	.05741	49.37507	-12.67738	10.45310
101	45.00000	-.00000	8.09353	-.02031	.00000	.05646	44.97969	.00000	8.14998
102	43.58624	11.19104	8.09353	-.00820	-.00210	.02352	43.57805	11.18894	8.11705
103	39.43380	21.67891	8.09353	-.01068	-.00587	.03388	39.42312	21.67304	8.12740
104	32.80559	30.80462	8.09353	-.01184	-.01112	.04517	32.79174	30.79350	8.13869
105	24.11221	37.99476	8.09353	-.01197	-.01886	.06210	24.10024	37.97589	8.15563
106	13.90577	42.79754	8.09353	-.00596	-.01835	.05364	13.89980	42.77919	8.10716
107	2.82557	44.91120	8.09353	-.00153	-.02432	.06775	2.82404	44.88688	8.16128
108	-8.43216	44.20293	8.09353	.00533	-.02793	.07904	-8.42683	44.17500	8.17257
109	-19.16007	40.71722	8.09353	.01283	-.02726	.08375	-19.14724	40.68996	8.17727
110	-28.68408	34.67310	8.09353	.01187	-.01434	.05175	-28.67221	34.65875	8.14528
111	-36.40576	26.45034	8.09353	.02465	-.01791	.08469	-36.38112	26.43203	8.17821
112	-41.83994	16.56561	8.09353	.01888	-.00748	.05646	-41.82106	16.55813	8.14998
113	-44.64516	5.64000	8.09353	.02250	-.00284	.06105	-44.62266	5.63716	8.15657
114	-44.64516	-5.63999	8.09353	.00772	.00098	.02164	-44.63744	-5.63902	8.11517
115	-41.83994	-16.56560	8.09353	.01888	.00748	.05646	-41.82106	-16.55812	8.14998

116	-36,40577	-26,45033	8,09353	,01753	,01273	,06022	-36,38824	-26,43760	8,1537
117	-28,68408	-34,67309	8,09353	,01424	,01721	,06210	-28,66984	-34,65588	8,15563
118	-19,16007	-40,71721	8,09353	,00793	,01684	,05175	-19,15215	-40,70037	8,14528
119	-8,43217	-44,20292	8,09353	,00571	,02992	,08469	-8,42646	-44,17300	8,17821
120	2,82556	-44,91120	8,09353	-,00149	,02365	,06587	2,82408	-44,88756	8,15939
121	13,90576	-42,79755	8,09353	-,00784	,02414	,07057	13,89791	-42,77340	8,16410
122	24,11220	-37,99476	8,09353	-,01632	,02572	,08469	24,09587	-37,96904	8,17821
123	32,80358	-30,80463	8,09353	-,00888	,00834	,03388	32,79470	-30,79629	8,12740
124	39,43379	-21,67893	8,09353	-,00949	,00522	,03011	39,42430	-21,67371	8,12364
125	43,58624	-11,19106	8,09353	-,00787	,00202	,02258	43,57837	-11,18904	8,11611
126	39,00000	-,00000	6,07914	-,01637	,00000	,05251	38,98363	,00000	6,13164
127	37,77474	9,69891	6,07914	-,00577	-,00148	,01909	37,76898	9,69743	6,09823
128	34,17596	18,78839	6,07914	-,00730	-,00401	,02673	34,16866	18,78438	6,10587
129	28,42978	26,69734	6,07914	-,00781	-,00733	,03437	28,42197	26,69000	6,11351
130	20,89724	32,92879	6,07914	-,01021	-,01608	,06110	20,88704	32,91271	6,14024
131	12,05166	37,09120	6,07914	-,00285	-,00877	,02960	12,04881	37,08243	6,10873
132	2,44883	38,92304	6,07914	-,00131	-,02079	,06683	2,44752	38,90225	6,14596
133	-7,30787	38,30920	6,07914	,00184	-,00965	,03150	-7,30603	38,29956	6,11064
134	-16,60539	35,28825	6,07914	,00862	-,01831	,06492	-16,59677	35,26994	6,14406
135	-24,85953	30,05002	6,07914	,00569	-,00688	,02864	-24,85384	30,04314	6,10778
136	-31,55166	22,92363	6,07914	,01758	-,01277	,06969	-31,53408	22,91086	6,14883
137	-36,26128	14,35686	6,07914	,01439	-,00570	,04964	-36,24689	14,35116	6,12878
138	-38,69247	4,88800	6,07914	,01181	-,00149	,03819	-38,68066	4,88651	6,11732
139	-38,69247	-4,88799	6,07914	,00325	,00041	,01050	-38,68923	-4,88758	6,08964
140	-36,26128	-14,35685	6,07914	,01107	,00438	,03819	-36,25022	-14,35247	6,11732
141	-31,55167	-22,92362	6,07914	,01035	,00752	,04105	-31,54131	-22,91610	6,12019
142	-24,85954	-30,05001	6,07914	,01043	,01261	,05251	-24,84911	-30,03740	6,13164
143	-16,60540	-35,28825	6,07914	,00748	,01589	,05633	-16,59792	-35,27236	6,13546
144	-7,30788	-38,30920	6,07914	,00368	,01930	,06301	-7,30420	-38,28991	6,14215
145	2,44882	-38,92304	6,07914	-,00092	,01455	,04678	2,44791	-38,90849	6,12592
146	12,05165	-37,09121	6,07914	-,00681	,02095	,07065	12,04485	-37,07026	6,14978
147	20,89724	-32,92879	6,07914	-,01499	,02362	,08974	20,88225	-32,90517	6,16888
148	28,42977	-26,69734	6,07914	-,00998	,00937	,04392	28,41979	-26,68797	6,12305
149	34,17596	-18,78840	6,07914	-,00443	,00244	,01623	34,17152	-18,78596	6,09537
150	37,77474	-9,69892	6,07914	-,00865	,00222	,02864	37,76609	-9,69670	6,10778
151	33,00000	-,00000	4,35252	-,01658	,00000	,06285	32,98342	,00000	4,41537
152	31,96324	8,20677	4,35252	-,01112	-,00285	,04351	31,95213	8,20391	4,39603
153	28,91812	15,89787	4,35252	-,00603	-,00332	,02611	28,91209	15,89455	4,37862
154	24,05596	22,59005	4,35252	-,00390	-,00367	,02031	24,05206	22,58639	4,37282
155	17,68228	27,86282	4,35252	-,00601	-,00948	,04254	17,67627	27,85335	4,39506
156	10,19756	31,38487	4,35252	-,00158	-,00485	,01934	10,19598	31,38001	4,37186
157	2,07209	32,93488	4,35252	-,00102	-,01629	,06188	2,07106	32,91859	4,41440
158	-6,18358	32,41548	4,35252	,00249	-,01303	,05028	-6,18110	32,40245	4,40280
159	-14,05072	29,85929	4,35252	,00489	-,01039	,04351	-14,04583	29,84891	4,39603
160	-21,03499	25,42694	4,35252	,00683	-,00825	,04061	-21,02816	25,41868	4,39313
161	-26,69756	19,39691	4,35252	,01032	-,00750	,04835	-26,68724	19,38942	4,40086
162	-30,68262	12,14811	4,35252	,00877	-,00347	,03578	-30,67385	12,14464	4,38829
163	-32,73978	4,13600	4,35252	,00936	-,00118	,03578	-32,73042	4,13482	4,38829
164	-32,73979	-4,13599	4,35252	,00380	,00048	,01450	-32,73599	-4,13551	4,36702
165	-30,68263	-12,14811	4,35252	,00925	,00366	,03771	-30,67338	-12,14444	4,39023
166	-26,69756	-19,39691	4,35252	,00784	,00570	,03674	-26,68972	-19,39121	4,38926
167	-21,03500	-25,42693	4,35252	,00813	,00983	,04835	-21,02687	-25,41711	4,40086
168	-14,05072	-29,85929	4,35252	,00434	,00923	,03868	-14,04638	-29,85006	4,39119
169	-6,18359	-32,41548	4,35252	,00282	,01478	,05705	-6,18077	-32,40070	4,40957
170	2,07208	-32,93488	4,35252	-,00072	,01146	,04351	2,07136	-32,92343	4,39603
171	10,19755	-31,38487	4,35252	-,00599	,01844	,07349	10,19156	-31,36643	4,42600
172	17,68228	-27,86283	4,35252	-,01025	,01615	,07252	17,67203	-27,84667	4,42504
173	24,05596	-22,59006	4,35252	-,00595	,00559	,03094	24,05001	-22,58447	4,38346
174	28,91812	-15,89788	4,35252	-,00715	,00393	,03094	28,91096	-15,89395	4,38346
175	31,96324	-8,20678	4,35252	-,00642	,00165	,02514	31,95682	-8,20513	4,37766

POINT DEVIATION FROM THE BEST FIT PARABOLOID(INCHES)

1	-.02329
2	-.02501
3	-.07912
4	-.02089
5	-.01036
6	.00405
7	.00081
8	-.00503
9	.01744
10	-.01537
11	.00074
12	-.03040
13	.02263
14	-.02067
15	-.00363
16	-.02683
17	-.00803
18	-.01705
19	.01568
20	.01225
21	-.00128
22	.00574
23	-.00465
24	.03481
25	-.00528
26	-.02105
27	-.01604
28	-.02300
29	-.01612
30	.04163
31	.00914
32	.00760
33	-.01998
34	.01623
35	-.00685
36	.00062
37	-.02060
38	-.02330
39	-.03427
40	.01040
41	-.00917
42	-.01121
43	-.01262
44	.01225
45	.00946
46	-.00772
47	.00087
48	-.00979
49	.01392
50	.00012
51	.01017
52	-.01355
53	-.00708
54	.00318
55	.03376

56	-.00543
57	.00011
58	.00982
59	.04253
60	-.00716
61	.05224
62	-.02875
63	-.00920
64	-.03748
65	-.00467
66	.00897
67	-.00100
68	-.00604
69	.03115
70	.02684
71	-.01140
72	-.00784
73	-.00112
74	.00529
75	-.00851
76	.01362
77	-.00323
78	.00211
79	.00804
80	.00377
81	.02505
82	.02655
83	.03002
84	.05394
85	-.01610
86	.04369
87	-.02806
88	.00862
89	-.02988
90	-.01387
91	-.00168
92	.00992
93	-.01694
94	.02139
95	.04269
96	-.02449
97	.00562
98	.00752
99	.00703
100	.00513
101	.01401
102	-.02292
103	-.01112
104	.00125
105	.01959
106	.00890
107	.02348
108	.03469
109	.03839
110	.00065
111	.03639
112	.00325
113	.00974
114	-.03763
115	.00150

116	.00596
117	.00869
118	-.00205
119	.03642
120	.01662
121	.02353
122	.04111
123	-.01478
124	-.01766
125	-.02506
126	.01765
127	-.01868
128	-.01026
129	-.00216
130	.02659
131	-.00886
132	.03094
133	-.00905
134	.02635
135	-.01474
136	.02913
137	.00612
138	-.00724
139	-.03813
140	-.00794
141	-.00467
142	.00835
143	.01327
144	.02158
145	.00492
146	.03238
147	.05463
148	.00556
149	-.02373
150	-.00920
151	.03570
152	.01531
153	-.00326
154	-.00967
155	.01369
156	-.01179
157	.03291
158	.01956
159	.01132
160	.00722
161	.01456
162	.00030
163	-.00033
164	-.02351
165	.00114
166	.00018
167	.01291
168	.00311
169	.02351
170	.00991
171	.04296
172	.04293
173	-.00058
174	.00030
175	-.00518

176	-.01327
177	-.01097
178	-.00886
179	-.01309
180	.00809
181	-.04560
182	-.00119
183	-.01929
184	-.00470
185	-.00341
186	.00712
187	-.00476
188	-.01037
189	-.02708
190	.00754
191	.00553
192	.00371
193	.00104
194	.01080
195	.00737
196	.02346
197	.00990
198	-.01392
199	-.02245
200	-.00551
201	-.03517
202	-.01164
203	-.02578
204	-.00659
205	-.00478
206	-.00411
207	-.04309
208	-.00709
209	-.01778
210	-.01834
211	-.00366
212	-.00210
213	-.01064
214	-.00273
215	-.00591
216	-.00995
217	-.02298
218	-.03487
219	-.01826
220	-.00764
221	.00710
222	-.02885
223	-.01613
224	-.02983
229	-.02738

NUMBER OF ITERATIONS = 12

ANGLE OF ROTATION, ABOUT Z AXIS = .16502433352209+001 RADIANS
OFF AXIS ANGLE, ABOUT ROTATED X AXIS = .77529594809920-003 RADIANS
VALUES DX,DY,DZ LOCATE THE VERTEX OF THE BEST FIT PARABOLOID
IN THE ROTATED COORDINATE SYSTEM

DX = .00521 INCHES

DY = .08564 INCHES

DZ = .01117 INCHES

FOCAL LENGTH OF BEST FIT PARABOLOID = 62.2070 INCHES

RMS WITH RESPECT TO BEST FIT PARABOLOID = .020283 INCHES

12-4-3
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4.4.2 Surface Accuracy Test No. 2

4.4.2.1 First Angular Position of Turntable

0 degrees.

4.4.2.2 Sweep No. 1 Measurement Data

Surface Deviation (Inches)

Radius (in.) / θ°	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0
14.4		.464	.491	.524	.511	.503	.508	.504	.484	.507
28.8		.497	.488	.512	.474	.469	.482	.475	.471	.465
43.2		.476	.476	.477	.467	.461	.453	.459	.429	.396
57.6		.497	.480	.474	.483	.460	.448	.431	.420	.407
72.0		.501	.500	.480	.472	.450	.410	.395	.411	.402
86.4		.474	.459	.469	.453	.449	.445	.405	.424	.423
100.8		.460	.495	.547	.483	.456	.425	.377	.368	.406
115.2		.506	.499	.509	.486	.504	.485	.457	.434	.455
129.6		.495	.493	.512	.509	.501	.495	.480	.438	.473
144.0		.497	.500	.506	.485	.491	.476	.476	.460	.470
158.4		.511	.512	.508	.523	.525	.532	.533	.493	.500
172.8		.510	.499	.503	.517	.517	.495	.497	.512	.513
187.2		.513	.508	.505	.524	.561	.564	.554	.545	.603
201.6		.505	.488	.502	.495	.505	.533	.544	.562	.587
216.0		.510	.532	.545	.550	.578	.583	.617	.648	.646
230.4		.504	.543	.545	.562	.593	.615	.652	.664	.677
244.8		.489	.530	.565	.594	.634	.655	.684	.683	.690
259.2		.487	.524	.568	.590	.605	.635	.685	.700	.702
273.6		.502	.534	.590	.614	.655	.662	.711	.728	.738
288.0		.514	.554	[illegible]	.595	.638	.697	.715	.735	.731
302.4		.523	.561	.597	.616	.634	.620	.660	.687	.689
316.8		.483	.539	.590	.629	.630	.639	.644	.669	.665
331.2		.502	.510	.540	.553	.550	.590	.601	.617	.602
345.6		.482	.483	.524	.527	.537	.560	.580	.607	.622
360.0		.477	.499	.508	.515	.507	.532	.526	.543	.549

4.4.2.3 Computer Results

Surface Error: .0258 inches rms.

QAT 12-4-3

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*                                                *
*              PARABOLOID PROGRAM                *
*  THIS PROGRAM COMPUTES THE BEST-FIT PARABOLOID *
*  FROM A GIVEN SET OF DATA POINTS,              *
*                                                *
*              STRUCTURES SECTION                *
*              RADIATION DIVISION                *
*            HARRIS INTERTYPE INC,               *
*              MELBOURNE, FLORIDA                *
*                                                *
*      REVISION DATE OF THIS PROGRAM, AUG-73     *
*                                                *
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BEST-FIT PARABOLOID FOR 190 INCH ANTENNA

JOINT	JOINT COORDINATES X	Y	Z	DEFLECTIONS X	Y	Z	DEFLECTED COORDINATES X	Y	Z
1	69.00000	-.00000	19.02878	-.00338	.00000	.00613	68.99662	.00000	19.03491
2	66.83224	17.15960	19.02878	.01637	.00420	-.03065	66.84861	17.16381	18.99813
3	60.46516	33.24100	19.02878	.04402	.02420	-.09107	60.50918	33.26520	18.93771
4	50.29883	47.23375	19.02878	.03274	.03075	-.08143	50.33158	47.26450	18.94734
5	36.97205	58.25863	19.02878	.02536	.03996	-.08581	36.99741	58.29859	18.94296
6	21.32217	65.62290	19.02878	.01149	.03537	-.06742	21.33366	65.65827	18.96135
7	4.33255	68.86384	19.02878	.00285	.04531	-.08231	4.33540	68.90915	18.94647
8	-12.92931	67.77782	19.02878	-.00407	.02135	-.03940	-12.93338	67.79917	18.98937
9	-29.37877	62.43307	19.02878	-.00555	.01180	-.02364	-29.38432	62.44487	19.00513
10	-43.98225	53.16541	19.02878	-.00924	.01116	-.02627	-43.99149	53.17658	19.00251
11	-55.82217	40.55718	19.02878	.00000	.00000	.00000	-55.82217	40.55718	19.02878
12	-64.15458	25.40060	19.02878	.00584	-.00231	.01138	-64.14874	25.39829	19.04016
13	-68.45591	8.64800	19.02878	.04935	-.00623	.09019	-68.40656	8.64176	19.11897
14	-68.45591	-8.64799	19.02878	.04169	.00527	.07618	-68.41423	-8.64272	19.10496
15	-64.15458	-25.40059	19.02878	.06556	.02596	.12784	-64.08902	-25.37463	19.15662
16	-55.82218	-40.55717	19.02878	.06916	.05025	.15499	-55.75302	-40.50693	19.18376
17	-43.98226	-53.16541	19.02878	.05849	.07071	.16637	-43.92377	-53.09470	19.19515
18	-29.37878	-62.43306	19.02878	.04154	.08827	.17688	-29.33724	-62.34479	19.20566
19	-12.92932	-67.77782	19.02878	.02154	.11291	.20840	-12.90778	-67.66491	19.23718
20	4.33253	-68.86384	19.02878	-.00701	.11135	.20227	4.32553	-68.75250	19.23105
21	21.32216	-65.62290	19.02878	-.02821	.08681	.16550	21.29395	-65.53609	19.19427
22	36.97205	-58.25865	19.02878	-.04270	.06728	.14448	36.92934	-58.19135	19.17326
23	50.29882	-47.23376	19.02878	-.03591	.03372	.08932	50.26291	-47.20004	19.11809
24	60.46519	-33.24102	19.02878	-.05163	.02839	.10683	60.41352	-33.21263	19.13560
25	66.83223	-17.15962	19.02878	-.02292	.00589	.04291	66.80931	-17.15374	19.07168
26	63.00000	-.00000	15.86331	.00720	.00000	-.01429	63.00720	.00000	15.84902
27	61.02074	15.66746	15.86331	.01263	.00324	-.02590	61.03337	15.67071	15.83741
28	55.20732	30.35048	15.86331	.02798	.01538	-.06341	55.23530	30.36587	15.79990
29	45.92502	43.12647	15.86331	.02623	.02463	-.07145	45.95125	43.15110	15.79186
30	33.75709	53.19266	15.86331	.02145	.03380	-.07949	33.77854	53.22646	15.78382
31	19.46807	59.91656	15.86331	.01056	.03251	-.06788	19.47863	59.94907	15.79543
32	3.95580	62.87568	15.86331	.00373	.05925	-.11789	3.95953	62.93494	15.74541
33	-11.80502	61.88410	15.86331	-.00556	.02916	-.05895	-11.81058	61.91326	15.80436
34	-26.82409	57.00410	15.86331	-.01187	.02523	-.05537	-26.83597	57.02934	15.80793
35	-40.15771	48.54233	15.86331	-.01147	.01386	-.03573	-40.16918	48.55620	15.82758
36	-50.96807	37.03047	15.86331	-.00255	.00185	-.00625	-50.97062	37.03232	15.85706
37	-58.57592	23.19185	15.86331	.00502	-.00199	.01072	-58.57090	23.18986	15.87403
38	-62.50322	7.89600	15.86331	.02008	-.00254	.04019	-62.48314	7.89346	15.90350
39	-62.50323	-7.89599	15.86331	.02767	.00350	.05537	-62.47556	-7.89249	15.91868
40	-58.57592	-23.19184	15.86331	.06189	.02451	.13218	-58.51403	-23.16733	15.99549
41	-50.96807	-37.03046	15.86331	.05968	.04336	.14647	-50.90840	-36.98711	16.00978
42	-40.15772	-48.54233	15.86331	.05247	.06342	.16344	-40.10525	-48.47891	16.02675
43	-26.82410	-57.00410	15.86331	.03830	.08139	.17863	-26.78580	-56.92270	16.04194
44	-11.80503	-61.88409	15.86331	.01922	.10073	.20364	-11.78582	-61.78336	16.06694
45	3.95579	-62.87568	15.86331	-.00664	.10549	.20989	3.94915	-62.77019	16.07320
46	19.46806	-59.91656	15.86331	-.02599	.07999	.16702	19.44207	-59.83657	16.03033
47	33.75708	-53.19267	15.86331	-.04073	.06418	.15094	33.71635	-53.12849	16.01425
48	45.92501	-43.12648	15.86331	-.03836	.03602	.10450	45.88665	-43.09045	15.96781
49	55.20731	-30.35050	15.86331	-.04217	.02319	.09557	55.16514	-30.32731	15.95888
50	61.02073	-15.66748	15.86331	-.01873	.00481	.03840	61.00200	-15.66267	15.90171
51	57.00000	-.00000	12.98561	-.00166	.00000	.00364	56.99834	.00000	12.98925
52	55.20924	14.17532	12.98561	.01004	.00258	-.02275	55.21928	14.17790	12.96286
53	49.94948	27.45996	12.98561	.01490	.00819	-.03731	49.96438	27.46815	12.94830
54	41.55121	39.01918	12.98561	.02086	.01958	-.06279	41.57207	39.03877	12.92282
55	30.54213	48.12669	12.98561	.02333	.03676	-.09559	30.56545	48.16345	12.89006

56	61397	54,21022	12,98561	,01217	,0. [illegible]	-,08645	17,62614	54,24768	12,89916
57	3,57906	56,88752	12,98561	,00320	,05090	-,11193	3,58226	56,93842	12,87368
58	-10,68073	55,99037	12,98561	-,00334	,01751	-,03913	-10,68407	56,00789	12,94648
59	-24,26982	51,57514	12,98561	-,00353	,00750	-,01820	-24,27295	51,58265	12,96741
60	-36,33317	43,91926	12,98561	-,00634	,00767	-,02184	-36,33951	43,92692	12,96377
61	-46,11397	33,50376	12,98561	,01107	-,00804	,03003	-46,10290	33,49572	13,01564
62	-52,99726	20,98310	12,98561	-,00116	,00046	-,00273	-52,99841	20,98356	12,98288
63	-56,55054	7,14400	12,98561	,02221	-,00281	,04914	-56,52832	7,14119	13,03475
64	-56,55054	-7,14399	12,98561	,01810	,00229	,04004	-56,53244	-7,14170	13,02565
65	-52,99726	-20,98309	12,98561	,04510	,01786	,10647	-52,95216	-20,96524	13,09208
66	-46,11397	-33,50375	12,98561	,05099	,03704	,13832	-46,06299	-33,46671	13,12393
67	-36,33317	-43,91925	12,98561	,04863	,05878	,16744	-36,28459	-43,86047	13,15305
68	-24,26983	-51,57514	12,98561	,03266	,06941	,16835	-24,23677	-51,50573	13,15396
69	-10,68074	-55,99037	12,98561	,01619	,08594	,19201	-10,66435	-55,90443	13,17762
70	3,57905	-56,88752	12,98561	-,00560	,08897	,19565	3,57345	-56,79856	13,18126
71	17,61396	-54,21022	12,98561	-,02050	,06309	,14560	17,59346	-54,14713	13,13121
72	30,54212	-48,12670	12,98561	-,03199	,05041	,13104	30,51012	-48,07629	13,11665
73	41,55120	-39,01919	12,98561	-,03053	,02867	,09191	41,52067	-38,99053	13,07752
74	49,94947	-27,45997	12,98561	-,02907	,01598	,07280	49,92041	-27,44399	13,05841
75	55,20924	-14,17534	12,98561	-,01044	,00268	,02366	55,19879	-14,17266	13,00927
76	51,00000	-,00000	10,39568	-,00302	,00000	,00741	50,99698	,00000	10,40309
77	49,39774	12,68318	10,39568	,00658	,00169	-,01667	49,40432	12,68487	10,37902
78	44,69164	24,56944	10,39568	,01555	,00855	-,04352	44,70719	24,57798	10,35216
79	37,17740	34,91190	10,39568	,01431	,01344	-,04815	37,19171	34,92534	10,34753
80	27,32717	43,06072	10,39568	,01821	,02869	-,08334	27,34537	43,08941	10,31230
81	15,75987	48,50388	10,39568	,00642	,01975	-,05093	15,76628	48,52363	10,34475
82	3,20232	50,89936	10,39568	,00178	,02826	-,06945	3,20409	50,92762	10,32623
83	-9,55645	50,09665	10,39568	-,00106	,00556	-,01389	-9,55751	50,10221	10,38179
84	-21,71074	46,14618	10,39568	-,00080	,00171	-,00463	-21,71555	46,14789	10,39105
85	-32,50862	39,29618	10,39568	-,00578	,00698	-,02222	-32,51440	39,30316	10,37346
86	-41,25986	29,97705	10,39568	,00977	-,00710	,02963	-41,25009	29,96995	10,42532
87	-47,41860	18,77436	10,39568	-,00175	,00069	-,00463	-47,42035	18,77505	10,39105
88	-50,59785	6,39200	10,39568	,02584	-,00326	,06389	-50,57201	6,38873	10,45958
89	-50,59785	-6,39199	10,39568	,01236	,00156	,03056	-50,58549	-6,39043	10,42624
90	-47,41860	-18,77435	10,39568	,02913	,01153	,07686	-47,38947	-18,76281	10,47254
91	-41,25987	-29,97704	10,39568	,03512	,02552	,10649	-41,22475	-29,95152	10,50217
92	-32,50863	-39,29617	10,39568	,03730	,04509	,14353	-32,47133	-39,25108	10,53921
93	-21,71075	-46,14618	10,39568	,02170	,04611	,12501	-21,69305	-46,10006	10,52069
94	-9,55646	-50,09665	10,39568	,01287	,06749	,16853	-9,54358	-50,02916	10,56422
95	3,20231	-50,89936	10,39568	-,00467	,07422	,18242	3,19764	-50,82514	10,57811
96	15,75986	-48,50389	10,39568	-,01400	,04308	,11112	15,74586	-48,46080	10,50680
97	27,32716	-43,06073	10,39568	-,02812	,04430	,12871	27,29904	-43,01682	10,52440
98	37,17739	-34,91191	10,39568	-,02477	,02326	,08334	37,15262	-34,88865	10,47902
99	44,69163	-24,56945	10,39568	-,02183	,01200	,06112	44,66980	-24,55705	10,45680
100	49,39774	-12,68320	10,39568	-,01170	,00300	,02963	49,38604	-12,68019	10,42532
101	45,00000	-,00000	8,09353	-,00102	,00000	,00282	44,99898	,00000	8,09635
102	43,58624	11,19104	8,09353	,01016	,00261	-,02917	43,59640	11,19365	8,06435
103	39,43380	21,67891	8,09353	,01157	,00636	-,03670	39,44537	21,68527	8,05683
104	32,80359	30,80462	8,09353	,00987	,00927	-,03764	32,81346	30,81389	8,05569
105	24,11221	37,99476	8,09353	,00907	,01429	-,04705	24,12127	38,00905	8,04648
106	13,90577	42,79754	8,09353	,00533	,01642	-,04799	13,91110	42,81396	8,04554
107	2,82557	44,91120	8,09353	,00094	,01486	-,04140	2,82651	44,92607	8,05212
108	-8,43216	44,20293	8,09353	,00025	-,00133	,00376	-8,43190	44,20160	8,09729
109	-19,16007	40,71722	8,09353	,00014	-,00031	,00094	-19,15992	40,71691	8,09847
110	-28,68408	34,67310	8,09353	-,00194	,00235	-,00847	-28,68602	34,67544	8,08506
111	-36,40576	26,45034	8,09353	,00685	-,00497	,02352	-36,39892	26,44536	8,11705
112	-41,83994	16,56561	8,09353	,00535	-,00212	,01600	-41,83459	16,56349	8,10952
113	-44,64516	5,64000	8,09353	,02048	-,00259	,05740	-44,62468	5,63741	8,15092
114	-44,64516	-5,63999	8,09353	,00168	,00021	,00470	-44,64348	-5,63978	8,09823
115	-41,83994	-16,56560	8,09353	,02455	,00972	,07340	-41,81540	-16,55588	8,16692

116	-,40577	-26,45033	8,09353	,02547	,0 0	,08751	-36,38030	-26,43183	8,18104
117	-28,68408	-34,67309	8,09353	,02891	,03495	,12609	-28,65517	-34,63814	8,21962
118	-19,16007	-40,71721	8,09353	,01513	,03216	,09880	-19,14494	-40,68506	8,19233
119	-8,43217	-44,20292	8,09353	,00983	,05154	,14585	-8,42234	-44,15139	8,23938
120	2,82556	-44,91120	8,09353	-,00293	,04662	,12985	2,82263	-44,86458	8,22338
121	13,90576	-42,79755	8,09353	-,01402	,04314	,12609	13,89174	-42,75441	8,21962
122	24,11220	-37,99476	8,09353	-,02358	,03715	,12233	24,08862	-37,95761	8,21585
123	32,80358	-30,80463	8,09353	-,01234	,01159	,04705	32,79124	-30,79304	8,14057
124	39,43379	-21,67893	8,09353	-,01097	,00603	,03482	39,42282	-21,67289	8,12834
125	43,58624	-11,19106	8,09353	-,00229	,00059	,00659	43,58394	-11,19047	8,10011
126	39,00000	-,00000	6,07914	-,00327	,00000	,01050	38,99673	,00000	6,08964
127	37,77474	9,69891	6,07914	,00750	,00192	-,02482	37,78224	9,70083	6,05431
128	34,17596	18,78839	6,07914	,00861	,00473	-,03150	34,18457	18,79312	6,04763
129	28,42978	26,69734	6,07914	,00369	,00346	-,01623	28,43346	26,70080	6,06291
130	20,89724	32,92879	6,07914	,00447	,00704	-,02673	20,90171	32,93582	6,05241
131	12,05166	37,09120	6,07914	,00432	,01330	-,04487	12,05599	37,10451	6,03427
132	2,44883	38,92304	6,07914	,00032	,00505	-,01623	2,44915	38,92809	6,06291
133	-7,30787	38,30920	6,07914	-,00078	,00409	-,01337	-7,30865	38,31330	6,06577
134	-16,60939	35,28825	6,07914	,00114	-,00242	,00859	-16,60425	35,28583	6,08773
135	-24,85951	30,05002	6,07914	-,00285	,00344	-,01432	-24,86238	30,05346	6,06482
136	-31,55168	22,92363	6,07914	,00554	-,00402	,02196	-31,54612	22,91960	6,10109
137	-36,26128	14,35686	6,07914	,00470	-,00186	,01623	-36,25658	14,35500	6,09537
138	-38,69247	4,88800	6,07914	,00709	-,00090	,02291	-38,68539	4,88710	6,10205
139	-38,69247	-4,88799	6,07914	-,00148	-,00019	-,00477	-38,69395	-4,88818	6,07436
140	-36,26128	-14,35685	6,07914	,01384	,00548	,04773	-36,24745	-14,35138	6,12687
141	-31,55167	-22,92362	6,07914	,01493	,01085	,05919	-31,53674	-22,91277	6,13833
142	-24,85954	-30,05001	6,07914	,01783	,02156	,08974	-24,84171	-30,02846	6,16888
143	-16,60540	-35,28825	6,07914	,01140	,02424	,08592	-16,59399	-35,26402	6,16506
144	-7,30788	-38,30920	6,07914	,00636	,03333	,10883	-7,30152	-38,27587	6,18797
145	2,44882	-38,92304	6,07914	-,00178	,02822	,09069	2,44705	-38,89482	6,16983
146	12,05165	-37,09121	6,07914	-,01067	,03283	,11074	12,04099	-37,05837	6,18988
147	20,89724	-32,92879	6,07914	-,02057	,03242	,12315	20,87666	-32,89638	6,20229
148	28,42977	-26,69734	6,07914	-,01150	,01080	,05060	28,41827	-26,68655	6,12973
149	34,17596	-18,78840	6,07914	-,00704	,00387	,02578	34,16891	-18,78453	6,10491
150	37,77474	-9,69892	6,07914	-,00432	,00111	,01432	37,77042	-9,69781	6,09346
151	33,00000	-,00000	4,35252	-,00612	,00000	,02321	32,99388	,00000	4,37572
152	31,96324	8,20677	4,35252	-,00296	-,00076	,01160	31,96028	8,20600	4,36417
153	28,91812	15,89787	4,35252	,00514	,00283	-,02224	28,92326	15,90070	4,33026
154	24,05596	22,59005	4,35252	,00483	,00454	-,02514	24,06080	22,59459	4,32735
155	17,60228	27,86282	4,35252	,00273	,00431	-,01934	17,68502	27,86713	4,33318
156	10,19756	31,38487	4,35252	,00244	,00752	-,02997	10,20000	31,39238	4,32258
157	2,07209	32,93488	4,35252	-,00075	-,01196	,04545	2,07133	32,92292	4,39796
158	-6,18358	32,41548	4,35252	,00043	-,00225	,00870	-6,18315	32,41322	4,36122
159	-14,05072	29,85929	4,35252	,00130	-,00277	,01160	-14,04941	29,85652	4,36412
160	-21,03499	25,42694	4,35252	,00098	-,00118	,00580	-21,03402	25,42576	4,35832
161	-26,69756	19,39691	4,35252	,00165	-,00120	,00774	-26,69591	19,39572	4,36025
162	-30,68262	12,14811	4,35252	,00071	-,00028	,00290	-30,68191	12,14783	4,35542
163	-32,73978	4,13600	4,35252	,00127	-,00016	,00483	-32,73852	4,13584	4,35735
164	-32,73979	-4,13599	4,35252	,00051	,00006	,00193	-32,73928	-4,13593	4,35445
165	-30,68263	-12,14811	4,35252	,01067	,00423	,04351	-30,67195	-12,14308	4,39603
166	-26,69756	-19,39691	4,35252	,00929	,00675	,04351	-26,68828	-19,39016	4,39603
167	-21,03500	-25,42693	4,35252	,01057	,01277	,06285	-21,02443	-25,41416	4,41537
168	-14,05072	-29,85929	4,35252	,00738	,01569	,06575	-14,04334	-29,84360	4,41827
169	-6,18359	-32,41548	4,35252	,00430	,02255	,08702	-6,17929	-32,39293	4,43954
170	2,07208	-32,93488	4,35252	-,00106	,01680	,06382	2,07102	-32,91808	4,41633
171	10,19755	-31,38487	4,35252	-,00765	,02353	,09379	10,18991	-31,36134	4,44631
172	17,68228	-27,86283	4,35252	-,01230	,01938	,08702	17,66998	-27,80344	4,43954
173	24,05596	-22,59006	4,35252	-,00744	,00698	,03868	24,04852	-22,58308	4,39119
174	28,91812	-15,89788	4,35252	-,00536	,00295	,02321	28,91275	-15,89493	4,37572
175	31,96324	-8,20678	4,35252	-,00198	,00051	,00774	31,96127	-8,20627	4,36025

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176	.00000	-.00000	2.91367	.00190	.0 .0	-.00880	27.00190	.00000	2.90487
177	26.15175	6.71463	2.91367	.00249	.00063	-.01173	26.15420	6.71526	2.90194
178	23.66028	13.00735	2.91367	.00444	.00244	-.02346	23.66472	13.00979	2.89021
179	19.68215	18.48277	2.91367	.00308	.00289	-.01955	19.68523	18.48566	2.89412
180	14.46732	22.79685	2.91367	.00000	.00000	.00000	14.46732	22.79685	2.91367
181	8.34346	25.67853	2.91367	.00267	.00823	-.04008	8.34613	25.68675	2.87359
182	1.69534	26.94672	2.91367	.00007	.00105	-.00489	1.69541	26.94777	2.90878
183	-5.05930	26.52176	2.91367	-.00004	.00021	-.00098	-5.05933	26.52196	2.91269
184	-11.49604	24.43033	2.91367	-.00063	.00134	-.00684	-11.49667	24.43167	2.90683
185	-17.21045	20.80386	2.91367	.00000	.00000	.00000	-17.21045	20.80386	2.91367
186	-21.84346	15.87020	2.91367	.00205	-.00149	.01173	-21.84141	15.86871	2.92540
187	-25.10396	9.93936	2.91367	-.00020	.00008	-.00098	-25.10416	9.93944	2.91269
188	-26.78710	3.38400	2.91367	.00167	-.00021	.00782	-26.78542	3.38379	2.92149
189	-26.78710	-3.38399	2.91367	-.00251	-.00032	-.01173	-26.78961	-3.38431	2.90194
190	-25.10397	-9.93936	2.91367	.00628	.00249	.03128	-25.09769	-9.93687	2.94495
191	-21.84346	-15.87020	2.91367	.00734	.00533	.04203	-21.83612	-15.86487	2.95570
192	-17.21045	-20.80385	2.91367	.00403	.00488	.02932	-17.20642	-20.79898	2.94299
193	-11.49604	-24.43033	2.91367	.00216	.00458	.02346	-11.49389	-24.42575	2.93713
194	-5.05930	-26.52176	2.91367	.00134	.00705	.03323	-5.05796	-26.51471	2.94690
195	1.69534	-26.94672	2.91367	-.00072	.01137	.05278	1.69462	-26.93535	2.96645
196	8.34345	-25.67853	2.91367	-.00398	.01224	.05963	8.33948	-25.66629	2.97330
197	14.46732	-22.79686	2.91367	-.00441	.00695	.03812	14.46291	-22.78991	2.95179
198	19.68215	-18.48278	2.91367	-.00154	.00144	.00977	19.68061	-18.48133	2.92344
199	23.66028	-13.00736	2.91367	.00314	-.00173	-.01662	23.66342	-13.00908	2.89705
200	26.15178	-6.71463	2.91367	.00020	-.00005	-.00098	26.15195	-6.71469	2.91269
201	21.00000	-.00000	1.76259	.00596	.00000	-.03550	21.00596	.00000	1.72709
202	20.34025	5.22249	1.76259	.00048	.00012	-.00296	20.34073	5.22261	1.75963
203	18.40244	10.11683	1.76259	.00348	.00191	-.02367	18.40592	10.11874	1.73892
204	15.30834	14.37549	1.76259	.00036	.00034	-.00296	15.30870	14.37583	1.75963
205	11.25236	17.73089	1.76259	-.00009	-.00014	.00099	11.25227	17.73075	1.76358
206	6.48936	19.97219	1.76259	.00133	.00409	-.02564	6.49069	19.97628	1.73695
207	1.31860	20.95856	1.76259	.00042	.00661	-.03945	1.31902	20.96517	1.72314
208	-3.93501	20.62803	1.76259	.00019	-.00098	.00592	-3.93482	20.62706	1.76851
209	-8.94136	19.00137	1.76259	-.00035	.00075	-.00493	-8.94172	19.00212	1.75766
210	-13.38590	16.18078	1.76259	-.00032	.00038	-.00296	-13.38622	16.18116	1.75963
211	-16.98936	12.34349	1.76259	.00147	-.00107	.01085	-16.98788	12.34242	1.77344
212	-19.52531	7.73062	1.76259	.00154	-.00061	.00986	-19.52377	7.73001	1.77245
213	-20.83441	2.63200	1.76259	.00214	-.00027	.01282	-20.83227	2.63173	1.77541
214	-20.83441	-2.63200	1.76259	.00082	.00010	.00493	-20.83359	-2.63189	1.76752
215	-19.52531	-7.73061	1.76259	.00154	.00061	.00986	-19.52377	-7.73000	1.77245
216	-16.98936	-12.34349	1.76259	.00054	.00039	.00394	-16.98882	-12.34310	1.76653
217	-13.38591	-16.18078	1.76259	-.00116	-.00140	-.01085	-13.38707	-16.18218	1.75174
218	-8.94137	-19.00137	1.76259	-.00092	-.00195	-.01282	-8.94228	-19.00331	1.74977
219	-3.93501	-20.62803	1.76259	.00006	.00033	.00197	-3.93495	-20.62771	1.76456
220	1.31860	-20.95856	1.76259	-.00015	.00231	.01381	1.31845	-20.95625	1.77640
221	6.48935	-19.97219	1.76259	-.00118	.00362	.02268	6.48818	-19.96857	1.78527
222	11.25236	-17.73089	1.76259	.00151	-.00238	-.01677	11.25387	-17.73327	1.74582
223	15.30834	-14.37549	1.76259	-.00024	.00023	.00197	15.30810	-14.37527	1.76456
224	18.40244	-10.11683	1.76259	.00261	-.00184	-.01775	18.40505	-10.11827	1.74484
225	20.34024	-5.22249	1.76259	.00369	-.00095	-.02268	20.34393	-5.22344	1.73991

JOINT	DEVIATION FROM THE BEST FIT PARABOLOID(INCHES)
1	-.01092
2	-.01230
3	-.05076
4	-.00630
5	.00900
6	.04191
7	.01841
8	.05807
9	.05071
10	.00969
11	-.00068
12	-.03476
13	.01798
14	-.04839
15	-.02420
16	-.02439
17	-.03535
18	-.03619
19	.00245
20	.00441
21	-.02180
22	-.01711
23	-.04844
24	.02096
25	-.01269
26	-.03491
27	-.01099
28	-.02465
29	-.00846
30	-.00119
31	.02075
32	-.04545
33	.01517
34	-.00335
35	-.00957
36	-.00936
37	-.02839
38	-.03270
39	-.05331
40	.00731
41	-.00414
42	-.00421
43	.00276
44	.03202
45	.04797
46	.01216
47	.01843
48	-.00632
49	.02087
50	-.00981
51	-.01031
52	-.01078
53	-.00104
54	-.01039
55	-.03587

56	-.01881
57	-.05230
58	.02492
59	.03152
60	.00189
61	.03461
62	-.03793
63	-.00895
64	-.05231
65	-.00122
66	.01321
67	.03085
68	.02210
69	.04891
70	.05989
71	.01408
72	.01802
73	-.00194
74	.00629
75	-.01961
76	-.00365
77	-.00636
78	-.01563
79	-.00365
80	-.03330
81	.00954
82	-.01418
83	.04197
84	.03769
85	-.00322
86	.03314
87	-.03344
88	.01929
89	-.04572
90	-.01524
91	-.00012
92	.02887
93	-.00067
94	.04855
95	.06999
96	-.00132
97	.03648
98	.00560
99	.00495
100	-.00477
101	-.00666
102	-.02258
103	-.01345
104	-.00061
105	-.00204
106	.00084
107	.00671
108	.05084
109	.03563
110	.00879
111	.02567
112	-.00402
113	.02104
114	-.05930
115	-.00053

116	-.00010
117	.03209
118	-.00507
119	.04678
120	.03293
121	.03795
122	.04751
123	-.01991
124	-.01361
125	-.02398
126	.00404
127	-.01883
128	-.01229
129	.01545
130	.01118
131	-.00565
132	.02465
133	.02231
134	.03705
135	-.00084
136	.02388
137	.00095
138	-.00877
139	-.05553
140	-.01271
141	-.01235
142	.01221
143	.00296
144	.02710
145	.01049
146	.03969
147	.06412
148	-.00165
149	-.01307
150	-.00873
151	.01949
152	.01938
153	-.00615
154	-.00080
155	.01105
156	.00209
157	.08205
158	.03843
159	.03431
160	.01832
161	.00872
162	-.00928
163	-.02036
164	-.03612
165	-.00308
166	-.01251
167	.00124
168	.00040
169	.02235
170	.00006
171	.03764
172	.03876
173	-.00231
174	-.00666
175	-.01016

176	-.01277
177	-.00659
178	-.01081
179	-.00035
180	.02441
181	-.01578
182	.02046
183	.02142
184	.00986
185	.00971
186	.01323
187	-.00971
188	-.01040
189	-.04038
190	-.00399
191	.00013
192	-.01836
193	-.02747
194	-.01784
195	.00443
196	.01577
197	-.00045
198	-.02214
199	-.04059
200	-.01442
201	-.03874
202	.00143
203	-.01405
204	.01188
205	.01902
206	-.00705
207	-.02174
208	.02272
209	.00766
210	.00441
211	.01230
212	.00432
213	.00020
214	-.01482
215	-.01598
216	-.02722
217	-.04619
218	-.05039
219	-.03564
220	-.02216
221	-.01002
222	-.04602
223	-.02103
224	-.03068
225	-.03266

NUMBER OF ITERATIONS = 17

ANGLE OF ROTATION, ABOUT Z AXIS = -.2785659453681+000 RADIANS
OFF AXIS ANGLE, ABOUT ROTATED X AXIS = -.1108952159107-001 RADIANS
VALUES DX,DY,DZ LOCATE THE VERTEX OF THE BEST FIT PARABOLOID
IN THE ROTATED COORDINATE SYSTEM

DX = -,00440 INCHES

DY = -1,23237 INCHES

DZ = -,00307 INCHES

FOCAL LENGTH OF BEST FIT PARABOLOID = 62,3226 INCHES

RMS WITH RESPECT TO BEST FIT PARABOLOID = ,025799 INCHES

4-DEC-73
WITNESS

4.4.2.3 Second Angular Position of Turntable

180 Degrees

4.4.2.4 Sweep No. 2 Measurement Data

Surface Deviation (Inches)

Radius (in.) / θ°	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0
14.4		.456	.489	.553	.541	.547	.559	.568	.552	.568
28.8		.486	.492	.535	.524	.541	.577	.577	.583	.588
43.2		.490	.498	.527	.550	.585	.603	.613	.623	.565
57.6		.495	.514	.535	.572	.592	.612	.639	.654	.654
72.0		.501	.545	.574	.620	.646	.672	.727	.757	.696
86.4		.501	.481	.538	.567	.604	.598	.658	.703	.720
100.8		.467	.525	.577	.612	.646	.674	.693	.733	.710
115.2		.505	.505	.566	.557	.626	.649	.650	.651	.690
129.6		.493	.518	.561	.595	.629	.669	.704	.704	.712
144.0		.491	.519	.546	.547	.578	.590	.615	.628	.634
158.4		.513	.520	.555	.577	~~.6~~ .593	.625	.645	.618	.631
172.8		.513	.512	.523	.546	.557	.530	.546	.560	.545
187.2		.506	.500	.498	.512	.538	.538	.524	.523	.575
201.6		.504	.481	.486	.481	.479	.491	.479	.483	.511
216.0		.504	.516	.502	.493	.498	.478	.481	.485	.499
230.4		.497	.517	.502	.492	.496	.479	.478	.460	.464
244.8		.488	.502	.509	.497	.482	.464	.440	.421	.455
259.2		.491	.485	.492	.487	.450	.434	.422	.409	.424
273.6		.495	.496	.512	.484	.476	.452	.423	.411	.438
288.0		.506	.494	.493	.476	.467	.462	.418	.410	.438
302.4		.505	.514	.511	.498	.477	.421	.412	.406	.431
316.8		.472	.495	.512	.519	.489	.442	.426	.431	.451
331.2		.501	.481	.488	.483	.463	.477	.456	.452	.471
345.6		.476	.446	.480	.469	.465	.487	.489	.478	.528
360.0		.478	.493	.501	.508	.502	.525	.523	.536	.538

Surface Error: 0.032-inch rms

12/4/73

BEST-FIT PARABOLOID FOR 150 INCH ANTENNA

AFTERNOON DEFLECTIONS

JOINT	JOINT COORDINATES X	Y	Z	DEFLECTIONS X	Y	Z	DEFLECTED COORDINATES X	Y	Z
1	69.00000	-.00000	19.02878	-.03284	.00000	.05954	68.96716	.00000	19.08832
2	66.83224	17.15960	19.02878	-.04117	-.01057	.07706	66.79107	17.14903	19.10583
3	60.46516	33.24100	19.02878	-.02751	-.01512	.05692	60.43765	33.22588	19.08570
4	50.29883	47.23375	19.02878	-.05422	-.05091	.13485	50.24462	47.18283	19.16363
5	36.97205	58.25863	19.02878	-.05072	-.07993	.17163	36.92133	58.17870	19.20040
6	21.32217	65.62290	19.02878	-.03283	-.10105	.19264	21.28934	65.52185	19.22142
7	4.33255	68.86384	19.02878	-.00637	-.10122	.18388	4.32618	68.76262	19.21266
8	-12.92931	67.77782	19.02878	.01719	-.09014	.16637	-12.91211	67.68768	19.19515
9	-29.37877	62.43307	19.02878	.04360	-.09264	.18564	-29.33517	62.34042	19.21441
10	-43.98225	53.16541	19.02878	.04125	-.04987	.11734	-43.94100	53.11555	19.14611
11	-55.82217	40.55718	19.02878	.05119	-.03719	.11471	-55.77098	40.52000	19.14349
12	-64.15458	25.40060	19.02878	.02021	-.00800	.03940	-64.13437	25.39260	19.06818
13	-68.45591	8.64800	19.02878	.03594	-.00454	.06567	-68.41998	8.64346	19.09445
14	-68.45591	-8.64799	19.02878	.00527	.00067	.00963	-68.45064	-8.64732	19.03841
15	-64.15458	-25.40059	19.02878	-.00045	-.00018	-.00088	-64.15503	-25.40076	19.02790
16	-55.82218	-40.55717	19.02878	-.01407	-.01022	-.03152	-55.83624	-40.56739	18.99725
17	-43.98226	-53.16541	19.02878	-.01385	-.01675	-.03940	-43.99612	-53.18215	18.98937
18	-29.37878	-62.43306	19.02878	-.01563	-.03321	-.06655	-29.39441	-62.46627	18.96223
19	-12.92932	-67.77782	19.02878	-.00561	-.02941	-.05429	-12.93493	-67.80723	18.97449
20	4.33253	-68.86384	19.02878	.00188	-.02988	-.05429	4.33441	-68.89373	18.97449
21	21.32216	-65.62290	19.02878	.01030	-.03169	-.06042	21.33246	-65.65460	18.96836
22	36.97205	-58.25863	19.02878	.01268	-.01998	-.04291	36.98472	-58.27862	18.98587
23	50.29882	-47.23376	19.02878	.01021	-.00959	-.02539	50.30903	-47.24335	19.00338
24	60.46515	-33.24102	19.02878	-.01185	.00651	.02452	60.45330	-33.23450	19.05329
25	66.83223	-17.15962	19.02878	-.01778	.00456	.03327	66.81446	-17.15506	19.06205
26	63.00000	-.00000	15.86331	-.02339	.00000	.04644	62.97661	.00000	15.90975
27	61.02074	15.66746	15.86331	-.03616	-.00928	.07413	60.98458	15.65818	15.93744
28	55.20732	30.35048	15.86331	-.04848	-.02665	.10986	55.15884	30.32383	15.97317
29	45.92502	43.12647	15.86331	-.05049	-.04742	.13754	45.87453	43.07905	16.00085
30	33.75709	53.19266	15.86331	-.06194	-.09760	.22954	33.69515	53.09506	16.09285
31	19.46807	59.91656	15.86331	-.02822	-.08684	.18131	19.43986	59.82972	16.04462
32	3.95580	62.87568	15.86331	-.00658	-.10459	.20810	3.94922	62.77109	16.07141
33	-11.80502	61.88410	15.86331	.01273	-.06671	.13486	-11.79230	61.81738	15.99817
34	-26.82409	57.00410	15.86331	.03907	-.08302	.18220	-26.78503	56.92108	16.04551
35	-40.15771	48.54233	15.86331	.03670	-.04436	.11432	-40.12101	48.49797	15.97763
36	-50.96807	37.03047	15.86331	.04294	-.03120	.10539	-50.92513	36.99928	15.96870
37	-58.57592	23.19185	15.86331	.02509	-.00993	.05359	-58.55082	23.18192	15.91690
38	-62.50322	7.89600	15.86331	.01026	-.00130	.02054	-62.49296	7.89470	15.88385
39	-62.50323	-7.89599	15.86331	-.00759	-.00096	-.01518	-62.51081	-7.89695	15.84813
40	-58.57592	-23.19184	15.86331	-.00627	-.00248	-.01340	-58.58219	-23.19432	15.84991
41	-50.96807	-37.03046	15.86331	-.01456	-.01058	-.03573	-50.98263	-37.04104	15.82758
42	-40.15772	-48.54233	15.86331	-.02265	-.02738	-.07056	-40.18037	-48.56971	15.79275
43	-26.82410	-57.00410	15.86331	-.01743	-.03703	-.08128	-26.84153	-57.04113	15.78203
44	-11.80503	-61.88409	15.86331	-.00750	-.03932	-.07949	-11.81254	-61.92342	15.78382
45	3.95579	-62.87568	15.86331	.00254	-.04040	-.08038	3.95833	-62.91608	15.78293
46	19.46806	-59.91656	15.86331	.01307	-.04021	-.08396	19.48112	-59.95677	15.77935
47	33.75708	-53.19267	15.86331	.01663	-.02620	-.06163	33.77370	-53.21887	15.80168
48	45.92501	-43.12648	15.86331	.01574	-.01478	-.04287	45.94075	-43.14126	15.82044
49	55.20731	-30.35050	15.86331	.00867	-.00477	-.01965	55.21598	-30.35526	15.84366
50	61.02073	-15.66748	15.86331	-.01568	.00403	.03215	61.00505	-15.66345	15.89546
51	57.00000	-.00000	12.98561	-.02819	.00000	.06188	56.97181	.00000	13.04749
52	55.20924	14.17532	12.98561	-.03092	-.00794	.07007	55.17832	14.16738	13.05568
53	49.94948	27.45996	12.98561	-.04106	-.02257	.10283	49.90842	27.43739	13.08844
54	41.55121	39.01918	12.98561	-.04201	-.03945	.12649	41.50920	38.97973	13.11210
55	30.54213	48.12669	12.98561	-.05043	-.07947	.20657	30.49170	48.04722	13.19218

56	61397	54.21022	12.98561	-.02024	-.0. 0	.14378	17.59373	54.14792	13.12939
57	3.57906	56.88752	12.98561	-.00502	-.07986	.17563	3.57404	56.80766	13.16124
58	-10.68073	55.99037	12.98561	.01165	-.06109	.13650	-10.66908	55.92928	13.12211
59	-24.26942	51.57514	12.98561	.03601	-.07653	.18564	-24.23340	51.49861	13.17125
60	-36.33317	43.91926	12.98561	.03039	-.03674	.10465	-36.30277	43.88252	13.09026
61	-46.11397	33.50376	12.98561	.04864	-.03534	.13195	-46.06533	33.46842	13.11756
62	-52.99726	20.98310	12.98561	.01773	-.00702	.04186	-52.97952	20.97608	13.02747
63	-56.55054	7.14400	12.98561	.00987	-.00125	.02184	-56.54066	7.14275	13.00745
64	-56.55054	-7.14399	12.98561	-.00864	-.00109	-.01911	-56.55918	-7.14508	12.96650
65	-52.99726	-20.98309	12.98561	-.00732	-.00290	-.01729	-53.00459	-20.98599	12.96832
66	-46.11397	-33.50375	12.98561	-.00738	-.00536	-.02002	-46.12135	-33.50911	12.96559
67	-36.33317	-43.91925	12.98561	-.01586	-.01917	-.05460	-36.34903	-43.93842	12.93101
68	-24.26943	-51.57514	12.98561	-.01377	-.02926	-.07098	-24.28320	-51.60440	12.91463
69	-10.68074	-55.99037	12.98561	-.00598	-.03136	-.07007	-10.68673	-56.02173	12.91554
70	3.57905	-56.88752	12.98561	.00213	-.03393	-.07462	3.58118	-56.92146	12.91099
71	17.61396	-54.21022	12.98561	.01128	-.03470	-.08008	17.62523	-54.24493	12.90553
72	30.54212	-48.12670	12.98561	.01644	-.02591	-.06734	30.55856	-48.15260	12.91827
73	41.55120	-39.01919	12.98561	.01330	-.01249	-.04004	41.56450	-39.03168	12.94557
74	49.94947	-27.45997	12.98561	.00400	-.00220	-.01081	49.95347	-27.46217	12.97560
75	55.20924	-14.17534	12.98561	-.00924	.00237	.02093	55.20000	-14.17297	13.00654
76	51.00000	-.00000	10.39568	-.02227	.00000	.05463	50.97773	.00000	10.45032
77	49.39774	12.68318	10.39568	-.02815	-.00723	.07130	49.36959	12.67596	10.46699
78	44.69164	24.56944	10.39568	-.03407	-.01873	.09538	44.65757	24.55070	10.49106
79	37.17740	34.91190	10.39568	-.03082	-.02894	.10371	37.14658	34.88296	10.49940
80	27.32717	43.06072	10.39568	-.03479	-.05482	.15927	27.29237	43.00590	10.55496
81	15.75987	48.50388	10.39568	-.01143	-.03519	.09075	15.74843	48.46870	10.48643
82	3.20232	50.89936	10.39568	-.00412	-.06556	.16113	3.19819	50.83381	10.55681
83	-9.55645	50.09665	10.39568	.01054	-.05525	.13797	-9.54591	50.04140	10.53366
84	-21.71474	46.14618	10.39568	.02716	-.05773	.15650	-21.68758	46.08845	10.55218
85	-32.50862	39.29618	10.39568	.02166	-.02618	.08334	-32.48696	39.27000	10.47902
86	-41.25986	29.97705	10.39568	.03818	-.02774	.11575	-41.22169	29.94931	10.51143
87	-47.41860	18.77436	10.39568	.01053	-.00417	.02778	-47.40807	18.77019	10.42346
88	-50.59785	6.39200	10.39568	.01423	-.00180	.03519	-50.58362	6.39020	10.43087
89	-50.59785	-6.39199	10.39568	-.00337	-.00043	-.00833	-50.60122	-6.39242	10.38735
90	-47.41860	-18.77435	10.39568	-.00772	-.00306	-.02037	-47.42632	-18.77740	10.37531
91	-41.25987	-29.97704	10.39568	-.00641	-.00466	-.01945	-41.26628	-29.98170	10.37624
92	-32.50863	-39.29617	10.39568	-.00866	-.01047	-.03334	-32.51729	-39.30664	10.36235
93	-21.71475	-46.14618	10.39568	-.01061	-.02254	-.06112	-21.72536	-46.16872	10.33457
94	-9.55646	-50.09665	10.39568	-.00340	-.01780	-.04445	-9.55985	-50.11445	10.35124
95	3.20231	-50.89936	10.39568	.00090	-.01432	-.03519	3.20321	-50.91368	10.36050
96	15.75986	-48.50389	10.39568	.00922	-.02836	-.07315	15.76907	-48.53225	10.32253
97	27.32716	-43.06073	10.39568	.01173	-.01849	-.05371	27.33889	-43.07922	10.34198
98	37.17739	-34.91191	10.39568	.00633	-.00594	-.02130	37.18372	-34.91785	10.37439
99	44.69163	-24.56945	10.39568	.00430	-.00236	-.01204	44.69593	-24.57181	10.38365
100	49.39774	-12.68320	10.39568	-.00914	.00235	.02315	49.38860	-12.68085	10.41883
101	45.00000	-.00000	8.09353	-.01591	.00000	.04423	44.98409	.00000	8.13775
102	43.58624	11.19104	8.09353	-.01344	-.00345	.03858	43.57280	11.18759	8.13211
103	39.43380	21.67891	8.09353	-.02521	-.01386	.07998	39.40859	21.66505	8.17351
104	32.80359	30.80462	8.09353	-.02270	-.02132	.08657	32.78089	30.78330	8.18009
105	24.11221	37.99476	8.09353	-.02648	-.04173	.13738	24.08573	37.95303	8.23091
106	13.90577	42.79754	8.09353	-.01088	-.03348	.09786	13.89489	42.76406	8.19139
107	2.82557	44.91120	8.09353	-.00310	-.04932	.13738	2.82247	44.86188	8.23091
108	-8.43216	44.20293	8.09353	.00799	-.04189	.11856	-8.42417	44.16103	8.21209
109	-19.16007	40.71722	8.09353	.01859	-.03951	.12139	-19.14148	40.67771	8.21491
110	-28.68408	34.67310	8.09353	.01683	-.02034	.07340	-28.66725	34.65275	8.16692
111	-36.40576	26.45034	8.09353	.02547	-.01850	.08751	-36.38030	26.43184	8.18104
112	-41.83994	16.56561	8.09353	.01794	-.00710	.05364	-41.82200	16.55850	8.14716
113	-44.64516	5.64000	8.09353	.01276	-.00161	.03576	-44.63240	5.63839	8.12928
114	-44.64516	-5.63999	8.09353	-.00705	-.00089	-.01976	-44.65221	-5.64088	8.07376
115	-41.83994	-16.56560	8.09353	-.00063	-.00025	-.00188	-41.84057	-16.56585	8.09164

116	.40577	-26.45033	8.09353	-.00110	-.0[illegible]	-.00376	-38.40686	-26.45113	8.08976
117	-28.68408	-34.67309	8.09353	-.00388	-.00469	-.01694	-28.68797	-34.67779	8.07659
118	-19.16007	-40.71721	8.09353	-.00721	-.01531	-.04705	-19.16728	-40.73253	8.04648
119	-8.43217	-44.20292	8.09353	-.00152	-.00798	-.02258	-8.43369	-44.21090	8.07094
120	2.82556	-44.91120	8.09353	.00070	-.01115	-.03105	2.82627	-44.92235	8.06247
121	13.90576	-42.79755	8.09353	.00241	-.00740	-.02164	13.90816	-42.80495	8.07188
122	24.11220	-37.99476	8.09353	.00200	-.00314	-.01035	24.11419	-37.99791	8.08317
123	32.80358	-30.80463	8.09353	.00913	-.00857	-.03482	32.81271	-30.81320	8.05871
124	39.43379	-21.67893	8.09353	.01038	-.00571	-.03293	39.44418	-21.68463	8.06059
125	43.58624	-11.19106	8.09353	-.00066	.00017	.00188	43.58558	-11.19089	8.09541
126	39.00000	-.00000	6.07914	-.01220	.00000	.03914	38.98780	.00000	6.11828
127	37.77474	9.69891	6.07914	-.00692	-.00178	.02291	37.76782	9.69713	6.10205
128	34.17596	18.78839	6.07914	-.01304	-.00717	.04773	34.16292	18.78122	6.12687
129	28.42978	26.69734	6.07914	-.01562	-.01467	.06874	28.41416	26.68267	6.14787
130	20.89724	32.92879	6.07914	-.01914	-.03015	.11456	20.87811	32.89863	6.19370
131	12.05166	37.09120	6.07914	-.00616	-.01896	.06396	12.04550	37.07224	6.14310
132	2.44883	38.92304	6.07914	-.00209	-.03327	.10692	2.44674	38.88977	6.18606
133	-7.30787	38.30920	6.07914	.00318	-.01666	.05442	-7.30469	38.29254	6.13355
134	-16.60539	35.28825	6.07914	.01204	-.02558	.09069	-16.59335	35.26267	6.16983
135	-24.85953	30.05002	6.07914	.00892	-.01078	.04487	-24.85062	30.03924	6.12401
136	-31.55166	22.92363	6.07914	.01854	-.01347	.07351	-31.53312	22.91016	6.15265
137	-36.26128	14.35686	6.07914	.01273	-.00504	.04392	-36.24855	14.35182	6.12305
138	-38.69247	4.88800	6.07914	.00354	-.00045	.01146	-38.68893	4.88755	6.09059
139	-38.69247	-4.88799	6.07914	-.00561	-.00071	-.01814	-38.69808	-4.88870	6.06100
140	-36.26128	-14.35685	6.07914	-.00194	-.00077	-.00668	-36.26322	-14.35762	6.07245
141	-31.55167	-22.92362	6.07914	-.00193	-.00140	-.00764	-31.55359	-22.92502	6.07150
142	-24.85954	-30.05001	6.07914	-.00057	-.00069	-.00286	-24.86011	-30.05070	6.07627
143	-16.60540	-35.28829	6.07914	-.00165	-.00350	-.01241	-16.60705	-35.29175	6.06673
144	-7.30788	-38.30920	6.07914	-.00089	-.00468	-.01527	-7.30877	-38.31388	6.06386
145	2.44882	-38.92304	6.07914	.00045	-.00713	-.02291	2.44927	-38.93017	6.05622
146	12.05165	-37.09121	6.07914	.00018	-.00057	-.00191	12.05184	-37.09177	6.07723
147	20.89724	-32.92879	6.07914	-.00303	.00477	.01814	20.89421	-32.92402	6.09728
148	28.42977	-26.69734	6.07914	.00369	-.00346	-.01623	28.43346	-26.70081	6.06291
149	34.17596	-18.78840	6.07914	.00809	-.00444	-.02960	34.18404	-18.79285	6.04954
150	37.77474	-9.69892	6.07914	-.00231	.00059	.00764	37.77243	-9.69832	6.08677
151	33.00000	-.00000	4.35252	-.01352	.00000	.05125	32.98648	.00000	4.40376
152	31.96324	8.20677	4.35252	-.00865	-.00222	.03384	31.95460	8.20455	4.38636
153	28.91812	15.89787	4.35252	-.00603	-.00332	.02611	28.91209	15.89455	4.37862
154	24.05596	22.59005	4.35252	-.00651	-.00611	.03384	24.04946	22.58394	4.38636
155	17.68228	27.86282	4.35252	-.01011	-.01594	.07155	17.67217	27.84688	4.42407
156	10.19756	31.38487	4.35252	-.00300	-.00922	.03674	10.19457	31.37565	4.38926
157	2.07209	32.93488	4.35252	-.00123	-.01960	.07445	2.07085	32.91528	4.42697
158	-6.18358	32.41548	4.35252	.00315	-.01654	.06382	-6.18043	32.39894	4.41633
159	-14.05072	29.85929	4.35252	.00662	-.01408	.05898	-14.04409	29.84521	4.41150
160	-21.03499	25.42694	4.35252	.00748	-.00904	.04448	-21.02751	25.41790	4.39700
161	-26.69756	19.39691	4.35252	.01135	-.00825	.05318	-26.68621	19.38867	4.40570
162	-30.68262	12.14811	4.35252	.00545	-.00216	.02224	-30.67717	12.14595	4.37476
163	-32.73978	4.13600	4.35252	-.00051	.00006	-.00193	-32.74029	4.13606	4.35058
164	-32.73979	-4.13599	4.35252	-.00354	-.00045	-.01354	-32.74333	-4.13644	4.33898
165	-30.68263	-12.14811	4.35252	.00047	.00019	.00193	-30.68215	-12.14792	4.35445
166	-26.69756	-19.39691	4.35252	.00041	.00030	.00193	-26.69715	-19.39661	4.35445
167	-21.03500	-25.42693	4.35252	.00146	.00177	.00870	-21.03353	-25.42516	4.36122
168	-14.05072	-29.85929	4.35252	-.00087	-.00185	-.00774	-14.05159	-29.86114	4.34478
169	-6.18359	-32.41548	4.35252	.00057	.00301	.01160	-6.18302	-32.41247	4.36412
170	2.07208	-32.93488	4.35252	.00011	-.00178	-.00677	2.07219	-32.93666	4.34575
171	10.19755	-31.38487	4.35252	-.00087	.00267	.01064	10.19669	-31.38220	4.36315
172	17.68228	-27.86283	4.35252	-.00164	.00258	.01160	17.68064	-27.86024	4.36412
173	24.05596	-22.59006	4.35252	.00223	-.00210	-.01160	24.05819	-22.59216	4.34091
174	28.91812	-15.89788	4.35252	.00447	-.00246	-.01934	28.92259	-15.90034	4.33318
175	31.96324	-8.20678	4.35252	-.00025	.00006	.00097	31.96299	-8.20671	4.35348

176	.00000	-.00000	2.91367	.00232	.00	-.01075	27.00232	.00000	2.9029
177	26.15175	6.71463	2.91367	.00163	.00042	-.00782	26.15338	6.71505	2.90585
178	23.66028	13.00735	2.91367	.00037	.00020	-.00195	23.66065	13.00755	2.91171
179	19.68215	18.48277	2.91367	-.00215	-.00202	.01368	19.68000	18.48075	2.92739
180	14.46732	22.79685	2.91367	-.00509	-.00802	.04399	14.46224	22.78884	2.95766
181	8.34346	25.67853	2.91367	.00124	.00381	-.01857	8.34470	25.68234	2.89510
182	1.69534	26.94672	2.91367	-.00033	-.00526	.02444	1.69501	26.94146	2.93811
183	-5.05930	26.52176	2.91367	.00020	-.00104	.00489	-5.05910	26.52072	2.91856
184	-11.49604	24.43033	2.91367	.00162	-.00344	.01759	-11.49442	24.42689	2.93126
185	-17.21045	20.80386	2.91367	.00256	-.00309	.01857	-17.20789	20.80077	2.93224
186	-21.84346	15.87020	2.91367	.00341	-.00248	.01955	-21.84004	15.86772	2.93322
187	-25.10396	9.93936	2.91367	.00235	-.00093	.01173	-25.10161	9.93843	2.92540
188	-26.78710	3.38400	2.91367	.00000	.00000	.00000	-26.78710	3.38400	2.91367
189	-26.78710	-3.38399	2.91367	-.00398	-.00050	-.01857	-26.79107	-3.38450	2.89510
190	-25.10397	-9.93936	2.91367	.00314	.00124	.01564	-25.10083	-9.93812	2.92931
191	-21.84346	-15.87020	2.91367	.00290	.00211	.01662	-21.84056	-15.86809	2.93029
192	-17.21045	-20.80385	2.91367	.00027	.00033	.00195	-17.21018	-20.80353	2.91562
193	-11.49600	-24.43033	2.91367	-.00135	-.00286	-.01466	-11.49739	-24.43319	2.89901
194	-5.05930	-26.52176	2.91367	-.00016	-.00083	-.00391	-5.05946	-26.52258	2.90976
195	1.69534	-26.94672	2.91367	.00008	-.00126	-.00586	1.69542	-26.94799	2.90780
196	8.34345	-25.67853	2.91367	-.00091	.00281	.01368	8.34254	-25.67572	2.92735
197	14.46732	-22.79686	2.91367	.00057	-.00089	-.00489	14.46788	-22.79775	2.90878
198	19.68215	-18.48278	2.91367	.00292	-.00274	-.01857	19.68507	-18.48552	2.89510
199	23.66028	-13.00736	2.91367	.00998	-.00549	-.05278	23.67026	-13.01284	2.86088
200	26.15174	-6.71463	2.91367	.00143	-.00037	-.00684	26.15317	-6.71500	2.90683
201	21.00000	-.00000	1.76259	.00728	.00000	-.04339	21.00728	.00000	1.71920
202	20.34025	5.22249	1.76259	.00224	.00058	-.01381	20.34249	5.22306	1.74878
203	18.40244	10.11683	1.76259	.00145	.00080	-.00986	18.40389	10.11762	1.75273
204	15.30834	14.37549	1.76259	.00060	.00057	-.00493	15.30894	14.37606	1.75766
205	11.25236	17.73089	1.76259	-.00009	-.00014	.00099	11.25227	17.73075	1.76358
206	6.48936	19.97219	1.76259	-.00005	-.00016	.00099	6.48931	19.97203	1.76358
207	1.31860	20.95856	1.76259	.00034	.00545	-.03254	1.31894	20.96401	1.73005
208	-3.93501	20.62803	1.76259	.00016	-.00081	.00493	-3.93485	20.62722	1.76752
209	-8.94136	19.00137	1.76259	-.00049	.00105	-.00690	-8.94186	19.00242	1.75569
210	-13.38590	16.18078	1.76259	-.00095	.00115	-.00888	-13.38685	16.18193	1.75371
211	-16.98936	12.34349	1.76259	.00174	-.00126	.01282	-16.98761	12.34223	1.77541
212	-19.52531	7.73062	1.76259	.00200	-.00079	.01282	-19.52330	7.72982	1.77541
213	-20.83441	2.63200	1.76259	.00099	-.00012	.00592	-20.83342	2.63188	1.76851
214	-20.83441	-2.63200	1.76259	.00066	.00008	.00394	-20.83375	-2.63191	1.76653
215	-19.52531	-7.73061	1.76259	.00062	.00024	.00394	-19.52469	-7.73037	1.76653
216	-16.98936	-12.34349	1.76259	-.00040	-.00029	-.00296	-16.98976	-12.34378	1.75963
217	-13.38591	-16.18078	1.76259	-.00127	-.00153	-.01183	-13.38717	-16.18231	1.75076
218	-8.94137	-19.00137	1.76259	-.00063	-.00135	-.00888	-8.94200	-19.00271	1.75371
219	-3.93501	-20.62803	1.76259	-.00016	-.00081	-.00493	-3.93517	-20.62884	1.75766
220	1.31860	-20.95856	1.76259	-.00006	.00099	.00592	1.31853	-20.95757	1.76851
221	6.48935	-19.97219	1.76259	-.00026	.00079	.00493	6.48910	-19.97140	1.76752
222	11.25236	-17.73089	1.76259	.00248	-.00391	-.02761	11.25484	-17.73480	1.73498
223	15.30834	-14.37549	1.76259	-.00012	.00011	.00099	15.30822	-14.37538	1.76358
224	18.40244	-10.11683	1.76259	.00348	-.00191	-.02367	18.40592	-10.11875	1.73892
225	20.34024	-5.22249	1.76259	.00353	-.00091	-.02170	20.34377	-5.22340	1.74089

JOINT	DEVIATION FROM THE BEST FIT PARABOLOID(INCHES)
1	-.01607
2	-.02903
3	-.00743
4	-.01214
5	.01685
6	.03384
7	.02119
8	.00640
9	.04844
10	-.01620
11	.01116
12	-.05220
13	.01922
14	-.01718
15	.00333
16	-.00720
17	.00542
18	-.01512
19	.00681
20	.00342
21	-.01709
22	-.01509
23	-.02012
24	.01181
25	-.01310
26	-.01808
27	-.01619
28	-.00105
29	.00903
30	.10636
31	.03549
32	.06711
33	-.01836
34	.05561
35	-.00792
36	.00835
37	-.02510
38	-.03290
39	-.04421
40	-.01048
41	-.01112
42	-.03326
43	-.03232
44	-.02379
45	-.02709
46	-.04208
47	-.03230
48	-.03354
49	-.03417
50	-.00210
51	.01378
52	-.00612
53	.00633
54	.01216
55	.09199

56	.00604
57	.04198
58	-.00023
59	.07163
60	-.00732
61	.05006
62	-.03071
63	-.02465
64	-.04374
65	-.01285
66	.00900
67	-.01277
68	-.01891
69	-.01140
70	-.01812
71	-.03349
72	-.03390
73	-.02276
74	-.01298
75	-.00508
76	.01616
77	.00886
78	.01244
79	.00145
80	.05065
81	-.03889
82	.04037
83	.01730
84	.04948
85	-.01947
86	.03977
87	-.03802
88	-.00244
89	-.02602
90	-.01425
91	.00963
92	.01175
93	-.00793
94	.01782
95	.02812
96	-.02341
97	-.01433
98	.00439
99	-.00814
100	.00674
101	.01391
102	-.01613
103	.00884
104	-.00229
105	.04097
106	-.01257
107	.02908
108	.01082
109	.02287
110	-.01725
111	.01726
112	.00073
113	.00417
114	-.03457
115	.00856

116	.02677
117	.02839
118	.00600
119	.03965
120	.03012
121	.03479
122	.03527
123	-.00810
124	-.02628
125	-.00987
126	.01664
127	-.02172
128	-.01352
129	-.00678
130	.03096
131	-.03261
132	.01158
133	-.04383
134	.00334
135	-.03504
136	.01225
137	-.00155
138	-.01678
139	-.02845
140	.00408
141	.02084
142	.04063
143	.04053
144	.04295
145	.03496
146	.05319
147	.06547
148	.01380
149	-.01826
150	.00287
151	.03658
152	.00051
153	-.02397
154	-.02965
155	-.00014
156	-.04442
157	-.00648
158	-.01659
159	-.01581
160	-.02145
161	.00109
162	-.01633
163	-.02500
164	-.01978
165	.01372
166	.02892
167	.04865
168	.04007
169	.06570
170	.04665
171	.06144
172	.05450
173	.01809
174	-.00479
175	.00034

176	-.02305
177	-.03427
178	-.04146
179	-.03663
180	-.01391
181	-.08533
182	-.04275
183	-.06207
184	-.04406
185	-.03509
186	-.02338
187	-.01880
188	-.01705
189	-.02206
190	.02767
191	.04121
192	.03621
193	.02634
194	.04181
195	.04042
196	.05793
197	.03214
198	.00844
199	-.03917
200	-.00462
201	-.05146
202	-.03217
203	-.03853
204	-.04249
205	-.04350
206	-.04821
207	-.08472
208	-.04538
209	-.05401
210	-.04995
211	-.01939
212	-.00952
213	-.00572
214	.00347
215	.01432
216	.01701
217	.01601
218	.02500
219	.03244
220	.04422
221	.04102
222	.00272
223	.02490
224	-.00957
225	-.01801

NUMBER OF ITERATIONS = 25

ANGLE OF ROTATION, ABOUT Z AXIS = .1560572391695+001 RADIANS
OFF AXIS ANGLE, ABOUT ROTATED X AXIS = -.2279841606625-002 RADIANS
VALUES DX,DY,DZ LOCATE THE VERTEX OF THE BEST FIT PARABOLOID
IN THE ROTATED COORDINATE SYSTEM

DX = -.26576 INCHES

DY = -.28893 INCHES

DZ = -.00066 INCHES

FOCAL LENGTH OF BEST FIT PARABOLOID = 62.3173 INCHES

RMS WITH RESPECT TO BEST FIT PARABOLOID = .031608 INCHES

4.4.2.3 **Average Measurements of Sweep #1 and Sweep #2**

Surface Deviation (Inches)

Radius (in.) / θ°	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0
14.4										
28.8										
43.2										
57.6										
72.0										
86.4										
100.8										
115.2										
129.6										
144.0										
158.4										
172.8										
187.2										
201.6										
216.0										
230.4										
244.8										
259.2										
273.6										
288.0										
302.4										
316.8										
331.2										
345.6										
360.0										

4.4.2 **Computer Results**

Surface Error: ____________ inches rms.

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**********************************************************
*                                                        *
*                 PARABOLOID PROGRAM                     *
*  THIS PROGRAM COMPUTES THE BEST-FIT PARABOLOID         *
*  FROM A GIVEN SET OF DATA POINTS.                      *
*                                                        *
*                 STRUCTURES SECTION                     *
*                 RADIATION DIVISION                     *
*                HARRIS INTERTYPE INC.                   *
*                 MELBOURNE, FLORIDA                     *
*                                                        *
*        REVISION DATE OF THIS PROGRAM, AUG-71           *
*                                                        *
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BEST-FIT PARABOLOID FOR 150 INCH ANTENNA

AVERAGE OF MORNING AND AFTERNOON DEFLECTIONS

JOINT*	JOINT COORDINATES X	Y	Z **	DEFLECTIONS X	Y	Z **	DEFLECTED COORDINATES X	Y	Z *
1	69.00000	-.00000	19.02878	-.01811	.00000	.03284	68.98189	.00000	19.06161
2	66.83220	17.15960	19.02878	-.01240	-.00318	.02320	66.81984	17.15642	19.05198
3	60.46516	33.24100	19.02878	.00825	.00454	-.01707	60.47341	33.24554	19.01170
4	50.29883	47.23375	19.02878	-.01074	-.01008	.02671	50.28810	47.22367	19.05548
5	36.97205	58.25863	19.02878	-.01268	-.01998	.04291	36.95937	58.23864	19.07168
6	21.32217	65.62290	19.02878	-.01067	-.03284	.06261	21.31150	65.59006	19.09139
7	4.33255	68.86384	19.02878	-.00176	-.02796	.05079	4.33079	68.83589	19.07956
8	-12.92931	67.77782	19.02878	.00656	-.03439	.06348	-12.92275	67.74302	19.09226
9	-29.37877	62.43307	19.02878	.01902	-.04042	.08100	-29.35975	62.39264	19.10977
10	-43.98225	53.16541	19.02878	.01601	-.01935	.04553	-43.96624	53.14606	19.07431
11	-55.82217	40.55718	19.02878	.02559	-.01859	.05735	-55.79658	40.53859	19.08613
12	-64.15458	25.40060	19.02878	.01302	-.00516	.02539	-64.14155	25.39544	19.05417
13	-68.45591	8.64800	19.02878	.04265	-.00539	.07793	-68.41327	8.64261	19.10671
14	-68.45591	-8.64799	19.02878	.02348	.00297	.04291	-68.43244	-8.64502	19.07168
15	-64.15458	-25.40059	19.02878	.03256	.01289	.06348	-64.12202	-25.38770	19.09226
16	-55.82218	-40.55717	19.02878	.02755	.02001	.06173	-55.79463	-40.53716	19.09051
17	-43.98226	-53.16541	19.02878	.02232	.02698	.06348	-43.95994	-53.13843	19.09226
18	-29.37878	-62.43306	19.02878	.01296	.02753	.05517	-29.36583	-62.40553	19.08394
19	-12.92932	-67.77782	19.02878	.00796	.04175	.07706	-12.92136	-67.73607	19.10583
20	4.33253	-68.86384	19.02878	-.00256	.04073	.07399	4.32997	-68.82311	19.10277
21	21.32216	-65.62290	19.02878	-.00895	.02756	.05254	21.31320	-65.59534	19.08132
22	36.97203	-58.25863	19.02878	-.01501	.02365	.05079	36.95703	-58.23498	19.07956
23	50.29882	-47.23376	19.02878	-.01285	.01207	.03196	50.28597	-47.22169	19.06074
24	60.46515	-33.24102	19.02878	-.03174	.01745	.06567	60.43341	-33.22357	19.09445
25	66.83223	-17.15962	19.02878	-.02035	.00522	.03809	66.81188	-17.15440	19.06687
26	63.00000	-.00000	15.86331	-.00810	.00000	.01608	62.99190	.00000	15.87939
27	61.02074	15.66746	15.86331	-.01176	-.00302	.02411	61.00898	15.66444	15.88742
28	55.20732	30.35048	15.86331	-.01025	-.00563	.02322	55.19707	30.34485	15.88653
29	45.92502	43.12647	15.86331	-.01213	-.01139	.03305	45.91289	43.11507	15.89636
30	33.75709	53.19266	15.86331	-.02024	-.03190	.07502	33.73684	53.16076	15.93833
31	19.46807	59.91656	15.86331	-.00883	-.02716	.05671	19.45925	59.88940	15.92002
32	3.95580	62.87568	15.86331	-.00143	-.02267	.04510	3.95438	62.85301	15.90841
33	-11.80502	61.88410	15.86331	.00358	-.01878	.03796	-11.80144	61.86532	15.90127
34	-26.82409	57.00410	15.86331	.01360	-.02890	.06341	-26.81050	56.97521	15.92672
35	-40.15771	48.54233	15.86331	.01261	-.01525	.03930	-40.14509	48.52709	15.90261
36	-50.96807	37.03047	15.86331	.02020	-.01467	.04957	-50.94787	37.01580	15.91288
37	-58.57592	23.19185	15.86331	.01506	-.00596	.03215	-58.56086	23.18589	15.89546
38	-62.50322	7.89600	15.86331	.01517	-.00192	.03037	-62.48805	7.89408	15.89368
39	-62.50323	-7.89599	15.86331	.01004	.00127	.02010	-62.49319	-7.89472	15.88340
40	-58.57592	-23.19184	15.86331	.02781	.01101	.05939	-58.54811	-23.18083	15.92270
41	-50.96807	-37.03046	15.86331	.02256	.01639	.05537	-50.94551	-37.01407	15.91868
42	-40.15772	-48.54233	15.86331	.01491	.01802	.04644	-40.14281	-48.52431	15.90975
43	-26.82410	-57.00410	15.86331	.01044	.02218	.04868	-26.81367	-56.98192	15.91199
44	-11.80503	-61.88409	15.86331	.00586	.03071	.06207	-11.79918	-61.85339	15.92538
45	3.95579	-62.87568	15.86331	-.00205	.03254	.06475	3.95374	-62.84314	15.92806
46	19.46806	-59.91656	15.86331	-.00646	.01989	.04153	19.46159	-59.89667	15.90484
47	33.75708	-53.19267	15.86331	-.01205	.01899	.04466	33.74503	-53.17368	15.90797
48	45.92501	-43.12648	15.86331	-.01131	.01062	.03081	45.91370	-43.11586	15.89412
49	55.20731	-30.35050	15.86331	-.01675	.00921	.03796	55.19056	-30.34129	15.90127
50	61.02073	-15.66748	15.86331	-.01721	.00442	.03528	61.00353	-15.66306	15.89859
51	57.00000	-.00000	12.98561	-.01493	.00000	.03276	56.98507	.00000	13.01837
52	55.20924	14.17532	12.98561	-.01044	-.00268	.02366	55.19880	14.17264	13.00927
53	49.94948	27.45996	12.98561	-.01308	-.00719	.03276	49.93640	27.45277	13.01837
54	41.55121	39.01918	12.98561	-.01058	-.00993	.03185	41.54063	39.00925	13.01746
55	30.54213	48.12669	12.98561	-.01355	-.02135	.05551	30.52857	48.10534	13.04112

56	.61397	54.21022	12.98561	-.00404	-.0[illegible]2	.02866	17.60993	54.19780	13.01428
57	3.57906	56.88752	12.98561	-.00091	-.01448	.03185	3.57815	56.87304	13.01746
58	-10.68073	55.99037	12.98561	.00416	-.02179	.04868	-10.67658	55.96858	13.03430
59	-24.26942	51.57514	12.98561	.01624	-.03452	.08372	-24.25318	51.54063	13.06933
60	-36.33317	43.91926	12.98561	.01203	-.01454	.04140	-36.32114	43.90472	13.02702
61	-46.11397	33.50376	12.98561	.02985	-.02169	.08099	-46.08411	33.48207	13.06660
62	-52.99726	20.98310	12.98561	.00829	-.00328	.01956	-52.98897	20.97982	13.00518
63	-56.55054	7.14400	12.98561	.01604	-.00203	.03549	-56.53449	7.14197	13.02110
64	-56.55054	-7.14399	12.98561	.00473	.00060	.01046	-56.54581	-7.14339	12.99608
65	-52.99726	-20.98309	12.98561	.01889	.00748	.04459	-52.97837	-20.97561	13.03020
66	-46.11397	-33.50375	12.98561	.02180	.01584	.05915	-46.09217	-33.48791	13.04476
67	-36.33317	-43.91925	12.98561	.01639	.01981	.05642	-36.31679	-43.89944	13.04203
68	-24.26943	-51.57514	12.98561	.00944	.02007	.04868	-24.25998	-51.55507	13.03430
69	-10.68074	-55.99037	12.98561	.00521	.02729	.06097	-10.67554	-55.96308	13.04658
70	3.57905	-56.88752	12.98561	-.00173	.02752	.06051	3.57732	-56.86001	13.04613
71	17.61396	-54.21022	12.98561	-.00461	.01420	.03276	17.60934	-54.19603	13.01837
72	30.54212	-48.12670	12.98561	-.00778	.01225	.03185	30.53434	-48.11445	13.01746
73	41.55120	-39.01919	12.98561	-.00861	.00809	.02593	41.54259	-39.01111	13.01155
74	49.94947	-27.45997	12.98561	-.01254	.00689	.03139	49.93694	-27.45308	13.01701
75	55.20924	-14.17534	12.98561	-.00984	.00253	.02229	55.19940	-14.17281	13.00791
76	51.00000	-.00000	10.39568	-.01265	.00000	.03102	50.98735	.00000	10.42670
77	49.39774	12.68318	10.39568	-.01079	-.00277	.02732	49.38695	12.68041	10.42300
78	44.69164	24.56944	10.39568	-.00926	-.00509	.02593	44.68238	24.56434	10.42161
79	37.17740	34.91190	10.39568	-.00826	-.00775	.02778	37.16914	34.90415	10.42346
80	27.32717	43.06072	10.39568	-.00829	-.01307	.03797	27.31887	43.04766	10.43365
81	15.75987	48.50388	10.39568	-.00251	-.00772	.01991	15.75736	48.49616	10.41559
82	3.20232	50.89936	10.39568	-.00117	-.01865	.04584	3.20114	50.88071	10.44152
83	-9.55645	50.09665	10.39568	.00474	-.02485	.06204	-9.55171	50.07180	10.45773
84	-21.71474	46.14618	10.39568	.01318	-.02801	.07593	-21.70156	46.11817	10.47162
85	-32.50862	39.29618	10.39568	.00794	-.00960	.03056	-32.50068	39.28658	10.42620
86	-41.25986	29.97705	10.39568	.02397	-.01742	.07269	-41.23589	29.95963	10.46837
87	-47.41860	18.77436	10.39568	.00439	-.00174	.01158	-47.41421	18.77262	10.40726
88	-50.59785	6.39200	10.39568	.02004	-.00253	.04954	-50.57781	6.38947	10.44522
89	-50.59785	-6.39199	10.39568	.00449	.00057	.01111	-50.59336	-6.39142	10.40680
90	-47.41860	-18.77435	10.39568	.01071	.00424	.02824	-47.40790	-18.77011	10.42393
91	-41.25987	-29.97704	10.39568	.01435	.01043	.04352	-41.24552	-29.96661	10.43921
92	-32.50863	-39.29617	10.39568	.01432	.01731	.05510	-32.49431	-39.27886	10.45078
93	-21.71475	-46.14618	10.39568	.00555	.01178	.03195	-21.70921	-46.13439	10.42763
94	-9.55646	-50.09665	10.39568	.00474	.02485	.06204	-9.55172	-50.07180	10.45773
95	3.20231	-50.89936	10.39568	-.00188	.02995	.07362	3.20042	-50.86941	10.46930
96	15.75986	-48.50389	10.39568	-.00239	.00736	.01898	15.75746	-48.49653	10.41467
97	27.32716	-43.06073	10.39568	-.00819	.01291	.03750	27.31896	-43.04782	10.43319
98	37.17739	-34.91191	10.39568	-.00922	.00866	.03102	37.16817	-34.90325	10.42670
99	44.69163	-24.56945	10.39568	-.00877	.00482	.02454	44.68287	-24.56463	10.42022
100	49.39774	-12.68320	10.39568	-.01042	.00268	.02639	49.38732	-12.68052	10.42207
101	45.00000	-.00000	8.09353	-.00846	.00000	.02352	44.99154	.00000	8.11705
102	43.58624	11.19104	8.09353	-.00164	-.00042	.00470	43.58460	11.19062	8.09823
103	39.43380	21.67891	8.09353	-.00682	-.00375	.02164	39.42698	21.67516	8.11517
104	32.80359	30.80462	8.09353	-.00642	-.00602	.02447	32.79717	30.79859	8.11799
105	24.11221	37.99476	8.09353	-.00871	-.01372	.04517	24.10350	37.98104	8.13869
106	13.90577	42.79754	8.09353	-.00277	-.00853	.02494	13.90299	42.78901	8.11846
107	2.82557	44.91120	8.09353	-.00108	-.01723	.04799	2.82449	44.89397	8.14151
108	-8.43216	44.20293	8.09353	.00412	-.02161	.06116	-8.42804	44.18131	8.15469
109	-19.16007	40.71722	8.09353	.00937	-.01991	.06116	-19.15070	40.69731	8.15469
110	-28.68408	34.67310	8.09353	.00744	-.00900	.03246	-28.67663	34.66410	8.12599
111	-36.40576	26.45034	8.09353	.01616	-.01174	.05552	-36.38961	26.43860	8.14904
112	-41.83994	16.56561	8.09353	.01164	-.00461	.03482	-41.82830	16.56100	8.12834
113	-44.64516	5.64000	8.09353	.01662	-.00210	.04658	-44.62854	5.63790	8.14010
114	-44.64516	-5.63999	8.09353	-.00269	-.00034	-.00753	-44.64785	-5.64033	8.08600
115	-41.83994	-16.56560	8.09353	.01196	.00473	.03576	-41.82798	-16.56087	8.12928

116	[illegible].40577	-26.45033	8.09353	.01219	[illegible]	.04187	-36.39358	-26.44148	8.13548
117	-28.68408	-34.67309	8.09353	.01251	.01513	.05458	-28.67157	-34.65796	8.14810
118	-19.16007	-40.71721	8.09353	.00396	.00842	.02588	-19.15611	-40.70879	8.11940
119	-8.43217	-44.20292	8.09353	.00415	.02178	.06163	-8.42801	-44.18115	8.15516
120	2.82556	-44.91120	8.09353	-.00112	.01774	.04940	2.82445	-44.89347	8.14293
121	13.90576	-42.79755	8.09353	-.00581	.01787	.05222	13.89999	-42.77968	8.14575
122	24.11220	-37.99476	8.09353	-.01079	.01700	.05599	24.10141	-37.97776	8.14951
123	32.80358	-30.89463	8.09353	-.00160	.00151	.00612	32.80198	-30.89312	8.09965
124	39.43379	-21.67893	8.09353	-.00030	.00016	.00094	39.43350	-21.67876	8.09447
125	43.58624	-11.19186	8.09353	-.00148	.00038	.00423	43.58476	-11.19148	8.09776
126	39.00000	-.00000	6.07914	-.00774	.00000	.02482	38.99226	.00000	6.10396
127	37.77474	9.69891	6.07914	.00029	.00007	-.00095	37.77503	9.69898	6.07819
128	34.17596	18.78839	6.07914	-.00222	-.00122	.00811	34.17374	18.78717	6.08725
129	28.42978	26.69734	6.07914	-.00597	-.00560	.02625	28.42381	26.69173	6.10539
130	20.89724	32.92879	6.07914	-.00734	-.01156	.04392	20.88991	32.91723	6.12305
131	12.05166	37.09120	6.07914	-.00092	-.00283	.00955	12.05074	37.08837	6.08868
132	2.44883	38.92304	6.07914	-.00089	-.01411	.04535	2.44794	38.90893	6.12448
133	-7.30787	38.30920	6.07914	.00120	-.00629	.02053	-7.30667	38.30292	6.09966
134	-16.60539	35.28825	6.07914	.00659	-.01400	.04964	-16.59880	35.27425	6.12878
135	-24.85953	30.05002	6.07914	.00304	-.00367	.01527	-24.85650	30.04635	6.09441
136	-31.55166	22.92363	6.07914	.01204	-.00875	.04773	-31.53962	22.91488	6.12687
137	-36.26128	14.35686	6.07914	.00872	-.00345	.03007	-36.25256	14.35341	6.10921
138	-38.69247	4.88800	6.07914	.00531	-.00067	.01718	-38.68716	4.88733	6.09632
139	-38.69247	-4.88799	6.07914	-.00354	-.00045	-.01146	-38.69602	-4.88844	6.06768
140	-36.26128	-14.35685	6.07914	.00595	.00236	.02053	-36.25533	-14.35450	6.09966
141	-31.55167	-22.92362	6.07914	.00650	.00472	.02578	-31.54516	-22.91890	6.10491
142	-24.85954	-30.05001	6.07914	.00863	.01043	.04344	-24.85091	-30.03958	6.12257
143	-16.60540	-35.28825	6.07914	.00488	.01037	.03676	-16.60052	-35.27788	6.11589
144	-7.30788	-38.30920	6.07914	.00273	.01433	.04678	-7.30515	-38.29488	6.12592
145	2.44882	-38.92304	6.07914	-.00066	.01054	.03389	2.44816	-38.91250	6.11303
146	12.05165	-37.09121	6.07914	-.00524	.01613	.05442	12.04641	-37.07507	6.13355
147	20.89724	-32.92879	6.07914	-.01180	.01860	.07065	20.88544	-32.91020	6.14978
148	28.42977	-26.69734	6.07914	-.00391	.00367	.01718	28.42586	-26.69368	6.09632
149	34.17596	-18.78840	6.07914	.00052	-.00029	-.00191	34.17648	-18.78869	6.07723
150	37.77474	-9.69892	6.07914	-.00332	.00085	.01098	37.77143	-9.69807	6.09012
151	33.00000	-.00000	4.35252	-.00982	.00000	.03723	32.99018	.00000	4.38975
152	31.96324	8.20677	4.35252	-.00581	-.00149	.02272	31.95744	8.20528	4.37524
153	28.91812	15.89787	4.35252	-.00045	-.00025	.00193	28.91767	15.89763	4.35445
154	24.05598	22.59005	4.35252	-.00084	-.00079	.00435	24.05513	22.58927	4.35687
155	17.68228	27.86282	4.35252	-.00369	-.00581	.02611	17.67859	27.85701	4.37862
156	10.19756	31.38487	4.35252	-.00028	-.00085	.00338	10.19729	31.38402	4.35590
157	2.07209	32.93488	4.35252	-.00099	-.01578	.05995	2.07109	32.91910	4.41247
158	-6.18358	32.41548	4.35252	.00179	-.00940	.03626	-6.18179	32.40608	4.38878
159	-14.05072	29.85929	4.35252	.00396	-.00842	.03529	-14.04675	29.85087	4.38781
160	-21.03497	25.42694	4.35252	.00423	-.00511	.02514	-21.03076	25.42183	4.37766
161	-26.69756	19.39691	4.35252	.00650	-.00472	.03046	-26.69106	19.39219	4.38298
162	-30.68262	12.14811	4.35252	.00308	-.00122	.01257	-30.67954	12.14689	4.36509
163	-32.73978	4.13600	4.35252	.00038	-.00005	.00145	-32.73940	4.13595	4.35397
164	-32.73979	-4.13599	4.35252	-.00152	-.00019	-.00580	-32.74130	-4.13619	4.34672
165	-30.68263	-12.14811	4.35252	.00557	.00221	.02272	-30.67705	-12.14590	4.37524
166	-26.69756	-19.39691	4.35252	.00485	.00352	.02272	-26.69271	-19.39339	4.37524
167	-21.03500	-25.42693	4.35252	.00602	.00727	.03578	-21.02898	-25.41966	4.38829
168	-14.05072	-29.85929	4.35252	.00326	.00692	.02901	-14.04746	-29.85237	4.38153
169	-6.18359	-32.41548	4.35252	.00244	.01278	.04931	-6.18115	-32.40270	4.40183
170	2.07208	-32.93488	4.35252	-.00047	.00751	.02852	2.07161	-32.92737	4.38104
171	10.19755	-31.38487	4.35252	-.00426	.01310	.05221	10.19330	-31.37177	4.40473
172	17.68228	-27.86283	4.35252	-.00697	.01098	.04931	17.67531	-27.85184	4.40183
173	24.05596	-22.59006	4.35252	-.00260	.00244	.01354	24.05336	-22.58762	4.36605
174	28.91812	-15.89788	4.35252	-.00045	.00025	.00193	28.91767	-15.89763	4.35445
175	31.96324	-8.20678	4.35252	-.00111	.00029	.00435	31.96213	-8.20649	4.35687

176	.00000	-.00000	2.91367	.00211	[illegible]	-.00977	27.00211	.00000	2.9038
177	26.15175	6.71463	2.91367	.00204	.00052	-.00977	26.15379	6.71515	2.90384
178	23.66028	13.00735	2.91367	.00240	.00132	-.01271	23.66268	13.00867	2.90096
179	19.68215	18.48277	2.91367	.00046	.00043	-.00293	19.68261	18.48320	2.91074
180	14.46732	22.79685	2.91367	-.00254	-.00401	.02199	14.46478	22.79285	2.93566
181	8.34346	25.67853	2.91367	.00196	.00602	-.02932	8.34541	25.68455	2.88434
182	1.69534	26.94672	2.91367	-.00013	-.00211	.00977	1.69521	26.94462	2.92344
183	-5.05930	26.52176	2.91367	.00008	-.00041	.00195	-5.05922	26.52134	2.91562
184	-11.49604	24.43033	2.91367	.00049	-.00105	.00538	-11.49555	24.42928	2.91905
185	-17.21045	20.80386	2.91367	.00128	-.00154	.00929	-17.20917	20.80231	2.92296
186	-21.84346	15.87020	2.91367	.00273	-.00198	.01564	-21.84073	15.86822	2.92931
187	-25.10396	9.93936	2.91367	.00108	-.00043	.00538	-25.10289	9.93894	2.91905
188	-26.78710	3.38400	2.91367	.00084	-.00011	.00391	-26.78626	3.38389	2.91758
189	-26.78710	-3.38399	2.91367	-.00324	-.00041	-.01515	-26.79034	-3.38440	2.89852
190	-25.10397	-9.93936	2.91367	.00471	.00186	.02346	-25.09926	-9.93750	2.93713
191	-21.84346	-15.87020	2.91367	.00512	.00372	.02932	-21.83834	-15.86648	2.94299
192	-17.21045	-20.80385	2.91367	.00215	.00260	.01564	-17.20830	-20.80125	2.92931
193	-11.49604	-24.43033	2.91367	.00040	.00086	.00440	-11.49564	-24.42947	2.91807
194	-5.05930	-26.52176	2.91367	.00059	.00311	.01466	-5.05871	-26.51865	2.92833
195	1.69534	-26.94672	2.91367	-.00032	.00505	.02346	1.69502	-26.94167	2.93713
196	8.34345	-25.67853	2.91367	-.00244	.00752	.03666	8.34101	-25.67100	2.95033
197	14.46732	-22.79686	2.91367	-.00192	.00303	.01662	14.46540	-22.79383	2.93029
198	19.68215	-18.48278	2.91367	.00069	-.00065	-.00440	19.68284	-18.48343	2.90927
199	23.66028	-13.00736	2.91367	.00656	-.00361	-.03470	23.66684	-13.01096	2.87897
200	26.15174	-6.71463	2.91367	.00082	-.00021	-.00391	26.15256	-6.71484	2.90976
201	21.00000	-.00000	1.76259	.00662	.00000	-.03945	21.00662	.00000	1.72314
202	20.34025	5.22249	1.76259	.00136	.00035	-.00838	20.34161	5.22284	1.75421
203	18.40244	10.11683	1.76259	.00247	.00136	-.01677	18.40491	10.11818	1.74582
204	15.30834	14.37549	1.76259	.00048	.00045	-.00394	15.30882	14.37594	1.75865
205	11.25236	17.73089	1.76259	-.00009	-.00014	.00099	11.25227	17.73075	1.76358
206	6.48936	19.97219	1.76259	.00064	.00197	-.01233	6.49000	19.97415	1.75026
207	1.31860	20.95856	1.76259	.00038	.00603	-.03600	1.31898	20.96459	1.72659
208	-3.93501	20.62803	1.76259	.00017	-.00089	.00542	-3.93484	20.62714	1.76801
209	-8.94136	19.00137	1.76259	-.00042	.00090	-.00592	-8.94179	19.00227	1.75667
210	-13.38590	16.18078	1.76259	-.00063	.00077	-.00592	-13.38654	16.18154	1.75667
211	-16.98936	12.34349	1.76259	.00161	-.00117	.01183	-16.98775	12.34232	1.77442
212	-19.52531	7.73062	1.76259	.00177	-.00070	.01134	-19.52354	7.72992	1.77393
213	-20.83441	2.63200	1.76259	.00156	-.00020	.00937	-20.83285	2.63180	1.77196
214	-20.83441	-2.63200	1.76259	.00074	.00009	.00444	-20.83367	-2.63190	1.76703
215	-19.52531	-7.73061	1.76259	.00108	.00043	.00690	-19.52423	-7.73019	1.76949
216	-16.98936	-12.34349	1.76259	.00007	.00005	.00049	-16.98929	-12.34344	1.76308
217	-13.38591	-16.18078	1.76259	-.00121	-.00147	-.01134	-13.38712	-16.18224	1.75125
218	-8.94137	-19.00137	1.76259	-.00078	-.00165	-.01085	-8.94214	-19.00301	1.75174
219	-3.93501	-20.62803	1.76259	-.00005	-.00024	-.00148	-3.93506	-20.62828	1.76111
220	1.31860	-20.95856	1.76259	-.00010	.00165	.00986	1.31849	-20.95691	1.77245
221	6.48935	-19.97219	1.76259	-.00072	.00220	.01381	6.48864	-19.96998	1.77640
222	11.25236	-17.73089	1.76259	.00200	-.00315	-.02219	11.25435	-17.73403	1.74040
223	15.30834	-14.37549	1.76259	-.00018	.00017	.00148	15.30816	-14.37532	1.76407
224	18.40244	-10.11683	1.76259	.00305	-.00167	-.02071	18.40548	-10.11851	1.74188
225	20.34024	-5.22249	1.76259	.00361	-.00093	-.02219	20.34385	-5.22342	1.74040

JOINT	DEVIATION FROM THE BEST FIT PARABOLOID(INCHES)
1	-.01428
2	-.02636
3	-.07932
4	-.02341
5	-.00428
6	.01877
7	.00020
8	.01335
9	.03272
10	-.01690
11	-.00445
12	-.04859
13	.01826
14	-.02838
15	-.00157
16	-.00303
17	.00089
18	-.00761
19	.02388
20	.02319
21	-.00133
22	-.00018
23	-.02157
24	.02515
25	-.00875
26	-.02656
27	-.01600
28	-.01745
29	-.00624
30	.04459
31	.01920
32	.00177
33	-.01033
34	.01840
35	-.01492
36	-.00478
37	-.02887
38	-.03272
39	-.04647
40	.00276
41	-.00156
42	-.01128
43	-.00634
44	.01313
45	.01952
46	-.00642
47	.00066
48	-.01377
49	-.00230
50	-.00372
51	.00221
52	-.00833
53	.00238
54	.00029
55	.02724

56	-.0[illegible]
57	-.00613
58	.01136
59	.05078
60	-.00314
61	.04219
62	-.03409
63	-.01633
64	-.04737
65	-.00622
66	.01201
67	.01004
68	.00262
69	.01988
70	.02207
71	-.00857
72	-.00679
73	-.01127
74	-.00237
75	-.01158
76	.00712
77	.00322
78	.00136
79	.00265
80	.01307
81	-.00995
82	.01798
83	.03433
84	.04792
85	-.00753
86	.03937
87	-.03380
88	.00916
89	-.03643
90	-.01653
91	.00185
92	.01654
93	-.00875
94	.02852
95	.04448
96	-.01666
97	.00753
98	.00238
99	-.00311
100	.00066
101	.00474
102	-.01614
103	.00281
104	.00523
105	.02734
106	.00276
107	.02675
108	.03938
109	.03706
110	.00241
111	.02645
112	.00140
113	.01349
114	-.04831
115	.00050

116	.00789
117	.02327
118	-.00764
119	.03466
120	.02302
121	.02851
122	.03505
123	-.01916
124	-.02316
125	-.01800
126	.01158
127	-.01636
128	-.00656
129	.01269
130	.03097
131	-.00824
132	.02927
133	.00007
134	.03001
135	-.00965
136	.02422
137	.00339
138	-.01181
139	-.04384
140	-.00883
141	-.00265
142	.01762
143	.01159
144	.02424
145	.01198
146	.03651
147	.05632
148	-.00050
149	-.01984
150	-.00444
151	.02929
152	.01408
153	-.00829
154	-.00625
155	.01609
156	-.00948
157	.04953
158	.02252
159	.01978
160	.00727
161	.01147
162	-.00890
163	-.02170
164	-.02996
165	.00047
166	.00081
167	.01552
168	.00938
169	.03250
170	.01186
171	.03890
172	.03749
173	.00080
174	-.01025
175	-.00659

176	-.01669
177	-.01644
178	-.01961
179	-.00982
180	.01551
181	-.03924
182	.00045
183	-.00909
184	-.00691
185	-.00418
186	.00125
187	-.01051
188	-.01278
189	-.03316
190	.00718
191	.01360
192	-.00012
193	-.01098
194	.00090
195	.01142
196	.02662
197	.00704
198	-.01366
199	-.04425
200	-.01114
201	-.04400
202	-.01186
203	-.02056
204	-.00772
205	-.02324
206	[illegible]
207	-.04303
208	-.00149
209	-.01425
210	-.01531
211	.00199
212	.00069
213	-.00191
214	-.00732
215	-.00084
216	-.01123
217	-.02292
218	-.02172
219	-.01119
220	.00149
221	.00663
222	-.02930
223	-.00395
224	-.02589
225	-.02672

NUMBER OF ITERATIONS = 24

ANGLE OF ROTATION, ABOUT Z AXIS = -.27594703591234000 RADIANS
OFF AXIS ANGLE, ABOUT ROTATED X AXIS = .7484502929341-004 RADIANS
VALUES DX,DY,DZ LOCATE THE VERTEX OF THE BEST FIT PARABOLOID
IN THE ROTATED COORDINATE SYSTEM

DX = .02157 INCHES

DY = .02374 INCHES

DZ = .00116 INCHES

FOCAL LENGTH OF BEST FIT PARABOLOID = 62.3226 INCHES

RMS WITH RESPECT TO BEST FIT PARABOLOID = .021219 INCHES

4.4.3 Surface Accuracy Test No. 3

4.4.3.1 Measurement Data

Surface Deviation (Inches)

Radius (in.) / θ°	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0
14.4		.477	.501	.543	.549	.556	.567	.577	.581	.579
28.8		.482	.497	.532	.507	.516	.545	.556	.573	.589
43.2		.477	.490	.512	.519	.544	.557	.585	.594	.569
57.6		.499	.502	.513	.539	.555	.569	.579	.595	.601
72.0		.499	.516	.528	.561	.575	.585	.615	.642	.604
86.4		.500	.465	.504	.508	.537	.570	.548	.581	.594
100.8		.467	.507	.540	.551	.551	.567	.555	597	~~.597~~ 604
115.2		.501	.496	.529	.520	.561	.577	.572	.561	.595
129.6		488	.500	.532	.553	.573	.600	.604	.590	.615
144.0		.491	.507	.523	.515	.536	.547	.556	.570	.581
158.4		.513	.512	.535	.546	.553	.586	.603	.570	.595
172.8		.501	.507	.513	.533	.532	.527	.548	.556	.561
187.2		.510	.510	.509	.534	.554	.565	.558	.562	.619
201.6		.503	.489	.501	.505	.510	.528	.537	.550	.583
216.0		.507	.519	.529	.528	.546	.537	.565	.528	.597
230.4		.499	.514	.519	.530	.550	.560	.569	.571	.588
244.8		.478	.510	.534	.539	.556	.566	.571	.561	.596
259.2		.500	.502	.525	.539	.539	.540	.555	.575	.580
273.6		.499	.524	.555	.554	.571	.571	.581	.579	.611
288.0		.508	.518	.527	.535	.550	.580	.580	.596	.605
302.4		.519	.536	.559	.564	.559	.518	.541	.558	.589
316.8		.485	.526	.563	.575	.575	.554	.543	.522	.595
331.2		.509	.503	.524	.531	.531	.556	.558	.562	.597
345.6		.487	.495	.529	.506	.524	.551	.560	.587	.619
360.0		.486	.509	.512	.521	.518	.548	.546	.582	.589

4.4.3.2 Computer Results

Surface Error: 0.019-inch rms

12/5/73

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*                                                     *
*              PARABOLOID PROGRAM                     *
*  THIS PROGRAM COMPUTES THE BEST-FIT PARABOLOID      *
*  FROM A GIVEN SET OF DATA POINTS.                   *
*                                                     *
*              STRUCTURES SECTION                     *
*              RADIATION DIVISION                     *
*             HARRIS INTERTYPE INC.                   *
*              MELBOURNE, FLORIDA                     *
*                                                     *
*     REVISION DATE OF THIS PROGRAM, AUG-73           *
*                                                     *
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BEST-FIT PARABOLOID FOR 150 INCH ANTENNA

SURFACE ACCURACY TEST NUMBER 3

JOINT*	JOINT COORDINATES X	Y	Z **	DEFLECTIONS X	Y	Z **	DEFLECTED COORDINATES X	Y	Z *
1	69,00000	-,00000	19,02878	-,03815	,00000	,06918	68,96185	,00000	19,09795
2	66,83224	17,15960	19,02878	-,04163	-,01069	,07793	66,79060	17,14891	19,10671
3	60,46516	33,24100	19,02878	-,02920	-,01605	,06042	60,43596	33,22495	19,08920
4	50,29883	47,23375	19,02878	-,03556	-,03339	,08844	50,26328	47,20036	19,11722
5	36,97205	58,25863	19,02878	-,02691	-,04241	,09107	36,94513	58,21622	19,11984
6	21,32217	65,62290	19,02878	-,01403	-,04318	,08231	21,30814	65,57972	19,11109
7	4,33255	68,86384	19,02878	-,00315	-,05013	,09107	4,32939	68,81371	19,11984
8	-12,92931	67,77782	19,02878	,00860	-,04507	,08319	-12,92071	67,73275	19,11196
9	-29,37877	62,43307	19,02878	,02365	-,04426	,10070	-29,35512	62,38881	19,12948
10	-43,98225	53,16541	19,02878	,02494	-,03014	,07093	-43,95732	53,13527	19,09970
11	-55,82217	40,55718	19,02878	,03712	-,02697	,08319	-55,78505	40,53022	19,11196
12	-64,15458	25,40060	19,02878	,02739	-,01085	,05341	-64,12718	25,38975	19,08219
13	-68,45591	8,64800	19,02878	,05702	-,00720	,10420	-68,39889	8,64080	19,13298
14	-68,45591	-8,64799	19,02878	,03977	,00502	,07268	-68,41614	-8,64296	19,10145
15	-64,15458	-25,40059	19,02878	,04356	,01725	,08494	-64,11102	-25,38334	19,11371
16	-55,82218	-40,55717	19,02878	,03438	,02498	,07706	-55,78779	-40,53219	19,10583
17	-43,98226	-53,16541	19,02878	,02955	,03572	,08406	-43,95271	-53,12968	19,11284
18	-29,37878	-62,43306	19,02878	,01645	,03496	,07005	-29,36233	-62,39810	19,09883
19	-12,92932	-67,77782	19,02878	,01005	,05266	,09720	-12,91928	-67,72516	19,12597
20	4,33253	-68,86384	19,02878	-,00318	,05061	,09194	4,32935	-68,81323	19,12072
21	21,32216	-65,62290	19,02878	-,01328	,04088	,07793	21,30888	-65,58202	19,10671
22	36,97203	-58,25863	19,02878	-,02458	,03874	,08319	36,94745	-58,21990	19,11196
23	50,29882	-47,23376	19,02878	-,03415	,03207	,08494	50,26467	-47,20169	19,11371
24	60,46515	-33,24102	19,02878	-,05036	,02769	,10420	60,41479	-33,21333	19,13298
25	66,83223	-17,15962	19,02878	-,04163	,01069	,07793	66,79060	-17,14893	19,10671
26	63,00000	-,00000	15,86331	-,03643	,00000	,07234	62,96357	,00000	15,93565
27	61,02074	15,66746	15,86331	-,03180	-,00817	,06520	60,98894	15,65930	15,92851
28	55,20732	30,35048	15,86331	-,03705	-,02037	,08396	55,17027	30,33011	15,94726
29	45,92502	43,12647	15,86331	-,03115	-,02925	,08485	45,89387	43,09722	15,94816
30	33,75709	53,19266	15,86331	-,03422	-,05393	,12683	33,72286	53,13873	15,99013
31	19,46807	59,91656	15,86331	-,01126	-,03465	,07234	19,45681	59,88191	15,93565
32	3,95580	62,87568	15,86331	-,00274	-,04354	,08663	3,95306	62,83214	15,94994
33	-11,80502	61,88410	15,86331	,00514	-,02695	,05448	-11,79988	61,85715	15,91779
34	-26,82409	57,00410	15,86331	,01724	-,03663	,08038	-26,80686	56,96748	15,94369
35	-40,15771	48,54233	15,86331	,02007	-,02426	,06252	-40,13764	48,51808	15,92583
36	-50,96807	37,03047	15,86331	,02547	-,01851	,06252	-50,94260	37,01197	15,92583
37	-58,57592	23,19185	15,86331	,02342	-,00927	,05002	-58,55250	23,18258	15,91333
38	-62,50322	7,89600	15,86331	,02767	-,00350	,05537	-62,47556	7,89250	15,91868
39	-62,50323	-7,89599	15,86331	,02231	,00282	,04466	-62,48091	-7,89317	15,90797
40	-58,57592	-23,19184	15,86331	,03262	,01291	,06966	-58,54330	-23,17893	15,93297
41	-50,96807	-37,03046	15,86331	,02584	,01877	,06341	-50,94224	-37,01169	15,92672
42	-40,15772	-48,54233	15,86331	,01749	,02114	,05448	-40,14023	-48,52119	15,91779
43	-26,82410	-57,00410	15,86331	,01436	,03052	,06699	-26,80974	-56,97358	15,93029
44	-11,80503	-61,88409	15,86331	,00666	,03490	,07056	-11,79838	-61,84919	15,93387
45	3,95579	-62,87568	15,86331	-,00271	,04309	,08574	3,95308	-62,83259	15,94905
46	19,46806	-59,91656	15,86331	-,00806	,02481	,05180	19,46000	-59,89175	15,91511
47	33,75708	-53,19267	15,86331	-,01735	,02734	,06431	33,73972	-53,16532	15,92762
48	45,92501	-43,12648	15,86331	-,02033	,01909	,05537	45,90468	-43,10739	15,91868
49	55,20731	-30,35050	15,86331	-,03429	,01885	,07770	55,17302	-30,33164	15,94101
50	61,02073	-15,66748	15,86331	-,03572	,00917	,07324	60,98501	-15,65831	15,93655
51	57,00000	-,00000	12,98561	-,03193	,00000	,07007	56,96807	,00000	13,05568
52	55,20924	14,17532	12,98561	-,02249	-,00577	,05096	55,18675	14,16955	13,03657
53	49,94948	27,45996	12,98561	-,03088	-,01698	,07735	49,91860	27,44298	13,06296
54	41,55121	39,01918	12,98561	-,02388	-,02242	,07189	41,52733	38,99676	13,05750
55	30,54213	48,12669	12,98561	-,02555	-,04026	,10465	30,51658	48,08643	13,09026

56	[illegible]1397	54.21022	12.98561	-.00615	-.01[illegible]	.04360	17.60782	54.19129	[illegible]
57	[illegible]7906	56.88752	12.98561	-.00143	-.02276	.05005	3.57763	56.86476	13.03566
58	-10.68073	55.99037	12.98561	.00559	-.02932	.06652	-10.67514	55.96105	13.05113
59	-24.26942	51.57510	12.98561	.01836	-.03902	.09464	-24.25106	51.55612	13.08025
60	-36.33317	43.91986	12.98561	.01480	-.01789	.05096	-36.31837	43.90137	13.05687
61	-46.11397	33.50376	12.98561	.03455	-.02510	.09373	-46.07942	33.47866	13.07934
62	-52.99726	20.98310	12.98561	.01850	-.00733	.04368	-52.97875	20.97576	13.02929
63	-56.55054	7.14400	12.98561	.02386	-.00301	.05278	-56.52668	7.14098	13.03839
64	-56.55054	-7.14399	12.98561	.01522	.00192	.03367	-56.53532	-7.14207	13.01928
65	-52.99726	-20.98309	12.98561	.02506	.00992	.05915	-52.97220	-20.97317	13.04476
66	-46.11397	-33.50375	12.98561	.02315	.01682	.06279	-46.09083	-33.48694	13.04840
67	-36.33317	-43.91925	12.98561	.01876	.02268	.06461	-36.31441	-43.89687	13.05022
68	-24.26943	-51.57514	12.98561	.00971	.02063	.05009	-24.25972	-51.55450	13.03566
69	-10.68074	-55.99037	12.98561	.00629	.03299	.07371	-10.67445	-55.95738	13.07932
70	3.57905	-56.88752	12.98561	-.00208	.03310	.07280	3.57697	-56.85442	13.05841
71	17.61396	-54.21022	12.98561	-.00525	.01617	.03731	17.60870	-54.19406	13.02292
72	30.54212	-48.12670	12.98561	-.00955	.01505	.03913	30.53256	-48.11165	13.02474
73	41.55120	-39.01919	12.98561	-.01753	.01646	.05278	41.53367	-39.00273	13.03839
74	49.94947	-27.45997	12.98561	-.02180	.01198	.05460	49.92767	-27.44799	13.04021
75	55.20924	-14.17534	12.98561	-.01847	.00474	.04186	55.19076	-14.17060	13.02747
76	51.00000	-.00000	10.39568	-.02529	.00000	.06204	50.97471	.00000	10.45773
77	49.39774	12.68318	10.39568	-.01645	-.00422	.04167	49.38129	12.67896	10.43735
78	44.69164	24.56944	10.39568	-.01886	-.01037	.05278	44.67278	24.55907	10.44847
79	37.17740	34.91190	10.39568	-.01899	-.01783	.06389	37.15841	34.89407	10.45958
80	27.32717	43.06072	10.39568	-.01719	-.02709	.07871	27.30997	43.03363	10.47439
81	15.75987	48.50388	10.39568	-.00817	-.02513	.06482	15.75170	48.47875	10.46050
82	3.20232	50.89936	10.39568	-.00159	-.02524	.06204	3.20073	50.87412	10.45773
83	-9.55645	50.09665	10.39568	.00545	-.02855	.07130	-9.55100	50.06810	10.46699
84	-21.71474	46.14618	10.39568	.01607	-.03416	.09260	-21.69867	46.11202	10.48828
85	-32.50862	39.29618	10.39568	.01131	-.01367	.04352	-32.49731	39.28250	10.43921
86	-41.25986	29.97705	10.39568	.02627	-.01908	.07964	-41.23360	29.95797	10.47532
87	-47.41860	18.77436	10.39568	.00948	-.00375	.02500	-47.40912	18.77060	10.42069
88	-50.59785	6.39200	10.39568	.02434	-.00308	.06019	-50.57350	6.38892	10.45587
89	-50.59785	-6.39199	10.39568	.01049	.00132	.02593	-50.58736	-6.39066	10.42161
90	-47.41860	-18.77435	10.39568	.01299	.00514	.03426	-47.40562	-18.76920	10.42995
91	-41.25987	-29.97704	10.39568	.01832	.01331	.05556	-41.24155	-29.96373	10.45124
92	-32.50863	-39.29617	10.39568	.01588	.01920	.06112	-32.49275	-39.27697	10.45680
93	-21.71475	-46.14618	10.39568	.00643	.01366	.03704	-21.70832	-46.13251	10.43272
94	-9.55646	-50.09665	10.39568	.00502	.02633	.06575	-9.55143	-50.07032	10.46143
95	3.20231	-50.89936	10.39568	-.00190	.03014	.07408	3.20041	-50.86922	10.46976
96	15.75986	-48.50389	10.39568	-.00210	.00646	.01667	15.75776	-48.49742	10.41235
97	27.32716	-43.06073	10.39568	-.01092	.01721	.05000	27.31623	-43.04352	10.44569
98	37.17739	-34.91191	10.39568	-.01541	.01447	.05186	37.16198	-34.89744	10.44754
99	44.69163	-24.56945	10.39568	-.01687	.00928	.04723	44.67476	-24.56017	10.44291
100	49.39774	-12.68320	10.39568	-.01755	.00451	.04445	49.38019	-12.67869	10.44013
101	45.00000	-.00000	8.09353	-.01895	.00000	.05269	44.98105	.00000	8.14622
102	43.58624	11.19104	8.09353	-.00525	-.00135	.01506	43.58100	11.18970	8.10858
103	39.43380	21.67891	8.09353	-.01305	-.00717	.04140	39.42075	21.67174	8.13493
104	32.80359	30.80462	8.09353	-.01357	-.01274	.05175	32.79002	30.79188	8.14528
105	24.11221	37.99476	8.09353	-.01360	-.02143	.07057	24.09860	37.97332	8.16410
106	13.90577	42.79754	8.09353	-.00387	-.01191	.03482	13.90190	42.78563	8.12834
107	2.82557	44.91120	8.09353	-.00108	-.01723	.04799	2.82449	44.89397	8.14151
108	-8.43216	44.20293	8.09353	.00387	-.02028	.05740	-8.42829	44.18264	8.15092
109	-19.16007	40.71722	8.09353	.01052	-.02236	.06869	-19.14955	40.69486	8.16222
110	-28.68408	34.67310	8.09353	.00777	-.00939	.03388	-28.67631	34.66371	8.12740
111	-36.40576	26.45034	8.09353	.01451	-.01054	.04987	-36.39125	26.43979	8.14340
112	-41.83994	16.56561	8.09353	.01007	-.00399	.03011	-41.82987	16.56162	8.12364
113	-44.64516	5.64000	8.09353	.01813	-.00229	.05081	-44.62703	5.63771	8.14434
114	-44.64516	-5.63999	8.09353	.00336	.00042	.00941	-44.64180	-5.63957	8.10293
115	-41.83994	-16.56560	8.09353	.01448	.00573	.04328	-41.82547	-16.55987	8.13681

116	-3[illegible]40577	-26,46033	8,09353	,01369	[illegible]	,04705	-[illegible],39208	-26,44038	8,14057
117	-[illegible]8408	-34,67509	8,09353	,01208	[illegible]	,05869	-[illegible],67200	-34,65849	8,14022
118	-19,16007	-40,71721	8,09353	,00562	,01194	,03670	-19,15445	-40,70527	8,13022
119	-8,43217	-44,20292	8,09353	,00450	,02361	,06681	-8,42766	-44,17932	8,16033
120	2,82556	-44,91120	8,09353	-,00196	[illegible]	,04705	2,82450	-44,89431	8,14057
121	13,90976	-42,79755	8,09353	-,00617	[illegible]	,05592	13,89958	-42,77855	8,14904
122	24,11220	-37,99476	8,09353	-,01360	,02143	,07057	24,09859	-37,97333	8,16410
123	32,80358	-30,80463	8,09353	-,00765	,00718	,02917	32,79593	-30,79744	8,12870
124	39,43379	-21,67893	8,09353	-,00712	,00391	,02298	39,42668	-21,67501	8,11611
125	43,58624	-11,19106	8,09353	-,00590	,00152	,01694	43,58034	-11,18954	8,11046
126	39,00000	-,00000	6,07914	-,01458	,00000	,04678	38,98542	,00000	6,12592
127	37,77474	9,69891	6,07914	-,00202	-,00052	,00668	37,77273	9,69839	6,08582
128	34,17596	18,78839	6,07914	-,00496	-,00022	,01814	34,17100	18,78567	6,09728
129	28,42978	26,69734	6,07914	-,00846	-,00705	,03783	28,42132	26,68959	6,11637
130	20,89724	32,92879	6,07914	-,00973	-,01533	,05824	20,88792	32,91346	6,13737
131	12,05166	37,09120	6,07914	-,00074	-,00226	,00764	12,05093	37,08894	6,08677
132	2,44883	38,92304	6,07914	-,00095	-,01515	,04869	2,44788	38,90789	6,12763
133	-7,30787	38,30920	6,07914	,00112	-,00589	,01909	-7,30676	38,30336	6,09823
134	-16,60539	35,28825	6,07914	,00672	-,01427	,05060	-16,59868	35,27398	6,12973
135	-24,85983	30,05002	6,07914	,00285	-,00344	,01432	-24,85669	30,04658	6,09346
136	-31,55166	22,92363	6,07914	,01108	-,00885	,04392	-31,54059	22,91558	6,12305
137	-36,26128	14,35686	6,07914	,00913	-,00362	,03150	-36,25215	14,35324	6,11064
138	-38,69247	4,88800	6,07914	,01004	-,00127	,03246	-38,68243	4,88673	6,11160
139	-38,69247	-4,88799	6,07914	,00148	,00019	,00477	-38,69100	-4,88781	6,08391
140	-36,26128	-14,35685	6,07914	,00775	,00307	,02673	-36,25554	-14,35579	6,10987
141	-31,55167	-22,92362	6,07914	,00722	,00588	,02864	-31,58444	-22,91837	6,10778
142	-24,85954	-30,05001	6,07914	,00740	,00894	,03723	-24,85214	-30,04107	6,11637
143	-16,60540	-35,28825	6,07914	,00494	,01090	,03723	-16,60046	-35,27775	6,11637
144	-7,30788	-38,30920	6,07914	,00301	,01579	,05155	-7,30487	-38,29341	6,13069
145	2,44882	-38,92304	6,07914	-,00065	,01040	,03341	2,44017	-38,91269	6,11255
146	12,05165	-37,09121	6,07914	-,00589	,01012	,06110	12,04577	-37,07309	6,14024
147	20,89724	-32,92879	6,07914	-,01196	,01085	,07160	20,88528	-32,90995	6,15074
148	28,42977	-26,69734	6,07914	-,00673	,00632	,02960	28,42304	-26,69103	6,10873
149	34,17596	-18,78840	6,07914	-,00156	,00086	,00573	34,17439	-18,78754	6,08486
150	37,77474	-9,69892	6,07914	-,00605	,00155	,02005	37,76869	-9,69736	6,09919
151	33,00000	-,00000	4,35252	-,01097	,00000	,04158	32,98903	,00000	4,39410
152	31,96324	8,20677	4,35252	-,00791	-,00203	,03094	31,95534	8,20474	4,38346
153	28,91812	15,89787	4,35252	-,00268	-,00187	,01160	28,91544	15,89640	4,36412
154	24,05596	22,59005	4,35252	-,00242	-,00227	,01257	24,05355	22,58778	4,36509
155	17,68228	27,86282	4,35252	-,00383	-,00603	,02707	17,67846	27,85679	4,37959
156	10,19756	31,38487	4,35252	-,00032	-,00097	,00387	10,19725	31,38389	4,35639
157	2,07209	32,93488	4,35252	-,00064	-,01014	,03868	2,07145	32,92470	4,39119
158	-6,18358	32,41548	4,35252	,00139	-,00727	,02804	-6,18220	32,40821	4,38056
159	-14,05072	29,85929	4,35252	,00348	-,00739	,03094	-14,04724	29,89191	4,38346
160	-21,03499	25,42694	4,35252	,00374	-,00452	,02224	-21,03125	25,42242	4,37476
161	-26,69756	19,39691	4,35252	,00722	-,00529	,03384	-26,69034	19,39167	4,38636
162	-30,68262	12,14811	4,35252	,00308	-,00122	,01257	-30,67954	12,14689	4,36509
163	-32,73978	4,13600	4,35252	,00228	-,00029	,00870	-32,73751	4,13571	4,36122
164	-32,73979	-4,13599	4,35252	,00025	,00003	,00097	-32,73953	-4,13596	4,35348
165	-30,68263	-12,14811	4,35252	,00688	,00272	,02804	-30,67575	-12,14538	4,38056
166	-26,69756	-19,39691	4,35252	,00392	,00289	,01837	-26,69364	-19,39406	4,37089
167	-21,03500	-25,42693	4,35252	,00553	,00668	,03288	-21,02947	-25,42025	4,38539
168	-14,05072	-29,85929	4,35252	,00272	,00577	,02417	-14,04801	-29,85352	4,37669
169	-6,18359	-32,41548	4,35252	,00263	,01378	,05318	-6,18096	-32,40170	4,40570
170	2,07208	-32,93488	4,35252	-,00043	,00687	,02611	2,07165	-32,92801	4,37862
171	10,19755	-31,38487	4,35252	-,00465	,01431	,05705	10,19290	-31,37055	4,40957
172	17,68228	-27,86283	4,35252	-,00861	,01357	,06092	17,67367	-27,84926	4,41343
173	24,05596	-22,59006	4,35252	-,00446	,00419	,02321	24,05150	-22,58587	4,37572
174	28,91812	-15,89788	4,35252	-,00648	,00356	,02804	28,91163	-15,89432	4,38056
175	31,96324	-8,20678	4,35252	-,00296	,00076	,01160	31,96028	-8,20601	4,36412

176	2[illegible]0000	-,00000	2,91367	-,00021	,00[illegible]	,00000	26,99979	,00000	2,91465
177	[illegible]	6,71463	2,91367	,00061	[illegible]	-,00293	26,15236	6,71878	2,91074
178	23,66028	13,00735	2,91367	,00185	,00102	-,00977	23,66213	13,00837	2,90389
179	19,68215	18,48277	2,91367	-,00031	-,00029	,00195	19,68185	18,48248	2,91562
180	14,46732	22,79685	2,91367	-,00181	-,00285	,01564	14,46551	22,79400	2,92931
181	8,34346	25,67853	2,91367	,00228	,00702	-,03421	8,34574	25,68555	2,87946
182	1,69534	26,94672	2,91367	-,00009	-,00147	,00684	1,69525	26,94525	2,92051
183	-5,05930	26,52176	2,91367	-,00016	,00083	-,00391	-5,05945	26,52258	2,90976
184	-11,49604	24,43033	2,91367	,00000	,00000	,00000	-11,49604	24,43033	2,91367
185	-17,21045	20,80386	2,91367	,00094	-,00114	,00684	-17,20951	20,80272	2,92051
186	-21,84346	15,87020	2,91367	,00205	-,00149	,01173	-21,84141	15,86871	2,92540
187	-25,10396	9,93936	2,91367	,00137	-,00054	,00684	-25,10259	9,93882	2,92051
188	-26,78710	3,38400	2,91367	,00209	-,00026	,00977	-26,78500	3,38374	2,92344
189	-26,78710	-3,38399	2,91367	-,00230	-,00029	-,01075	-26,78940	-3,38429	2,90292
190	-25,10397	-9,93936	2,91367	,00373	,00148	,01857	-25,10024	-9,93788	2,93224
191	-21,84346	-15,87020	2,91367	,00239	,00174	,01368	-21,84107	-15,86846	2,92735
192	-17,21045	-20,80385	2,91367	,00134	,00163	,00977	-17,20911	-20,80223	2,92344
193	-11,49604	-24,43033	2,91367	,00018	,00038	,00195	-11,49587	-24,42995	2,91562
194	-5,05930	-26,52176	2,91367	,00095	,00497	,02346	-5,05835	-26,51678	2,93713
195	1,69534	-26,94672	2,91367	-,00024	,00379	,01759	1,69510	-26,94293	2,93126
196	8,34345	-25,67853	2,91367	-,00235	,00722	,03519	8,34111	-25,67130	2,94886
197	14,46732	-22,79686	2,91367	-,00294	,00463	,02541	14,46438	-22,79223	2,93908
198	19,68215	-18,48278	2,91367	-,00046	,00043	,00293	19,68169	-18,48234	2,91660
199	23,66028	-13,00736	2,91367	,00092	-,00051	-,00489	23,66120	-13,00786	2,90878
200	26,15174	-6,71463	2,91367	-,00184	,00047	,00880	26,14990	-6,71416	2,92247
201	21,00000	-,00000	1,76259	,00381	,00000	-,02268	21,00381	,00000	1,73991
202	20,34025	5,22249	1,76259	,00289	,00074	-,01775	20,34313	5,22323	1,74484
203	18,40244	10,11683	1,76259	,00334	,00183	-,02268	18,40578	10,11866	1,73991
204	15,30834	14,37549	1,76259	,00012	,00011	-,00099	15,30846	14,37560	1,76160
205	11,25236	17,73089	1,76259	,00009	,00014	-,00099	11,25245	17,73103	1,76160
206	6,48936	19,97219	1,76259	,00000	,00000	,00000	6,48936	19,97219	1,76259
207	1,31860	20,95856	1,76259	,00034	,00545	-,03254	1,31894	20,96401	1,73005
208	-3,93501	20,62803	1,76259	,00003	-,00016	,00099	-3,93498	20,62787	1,76358
209	-8,94136	19,00137	1,76259	-,00085	,00180	-,01183	-8,94221	19,00317	1,75076
210	-13,38590	16,18078	1,76259	-,00095	,00115	-,00888	-13,38685	16,18193	1,75371
211	-16,98936	12,34349	1,76259	,00174	-,00126	,01282	-16,98761	12,34223	1,77541
212	-19,52531	7,73062	1,76259	,00015	-,00006	,00099	-19,52515	7,73056	1,76358
213	-20,83441	2,63200	1,76259	,00164	-,00021	,00986	-20,83277	2,63179	1,77245
214	-20,83441	-2,63200	1,76259	,00049	,00006	,00296	-20,83392	-2,63193	1,76555
215	-19,52531	-7,73061	1,76259	,00108	,00043	,00690	-19,52423	-7,73019	1,76949
216	-16,98936	-12,34349	1,76259	-,00013	-,00010	-,00099	-16,98949	-12,34359	1,76160
217	-13,38591	-16,18078	1,76259	-,00232	-,00281	-,02170	-13,38823	-16,18358	1,74089
218	-8,94137	-19,00137	1,76259	,00000	,00000	,00000	-8,94137	-19,00137	1,76259
219	-3,93501	-20,62803	1,76259	-,00003	-,00016	-,00099	-3,93504	-20,62819	1,76160
220	1,31860	-20,95856	1,76259	-,00008	,00132	,00789	1,31851	-20,95724	1,77048
221	6,48935	-19,97219	1,76259	-,00097	,00299	,01874	6,48838	-19,96920	1,78133
222	11,25236	-17,73089	1,76259	,00133	-,00210	-,01479	11,25369	-17,73299	1,74780
223	15,30834	-14,37549	1,76259	-,00109	,00102	,00888	15,30725	-14,37447	1,77147
224	18,40244	-10,11683	1,76259	,00189	-,00104	-,01282	18,40432	-10,11787	1,74977
225	20,34024	-5,22249	1,76259	,00224	-,00058	-,01381	20,34249	-5,22307	1,74878

JOINT	DEVIATION FROM THE BEST FIT PARABOLOID(INCHES)
1	-.02685
2	-.01741
3	-.04173
4	-.00601
5	-.00276
6	-.01369
7	-.00112
8	-.00969
9	.01536
10	-.02097
11	-.00226
12	-.03842
13	.03048
14	-.00846
15	.00934
16	.00023
17	.00993
18	-.00854
19	.02609
20	.01775
21	-.00256
22	.00189
23	.00152
24	.02393
25	-.01303
26	-.00490
27	-.01506
28	.00761
29	.00826
30	.06086
31	-.00708
32	.01162
33	-.02757
34	.00634
35	-.01446
36	-.01275
37	-.02674
38	-.01842
39	-.03051
40	.00196
41	-.00520
42	-.01615
43	-.00061
44	.00328
45	.02135
46	-.02258
47	-.00843
48	-.02134
49	.00496
50	-.00230
51	.00832
52	-.01535
53	.01615
54	.00939
55	.04902

56	-.03034
57	-.01616
58	.00320
59	.03919
60	-.01270
61	.03992
62	-.01968
63	-.00785
64	-.03028
65	.00105
66	.00575
67	.00801
68	-.00977
69	.01844
70	.01674
71	-.02695
72	-.02562
73	-.01004
74	-.00877
75	-.02503
76	.01320
77	-.01068
78	.00226
79	.01527
80	.03269
81	.01670
82	.01373
83	.02484
84	.05002
85	-.00690
86	.03557
87	-.02791
88	.01341
89	-.02643
90	-.01661
91	.00827
92	.01467
93	-.01362
94	.01966
95	.02908
96	-.03830
97	.00027
98	.00208
99	-.00363
100	-.00714
101	.01540
102	-.02690
103	.00308
104	.01498
105	.03642
106	-.00381
107	.01116
108	.02184
109	.03459
110	-.00481
111	.01316
112	-.00932
113	.01390
114	-.03311
115	.00498

117	,01982
118	-,00303
119	,03089
120	,00846
121	,01800
122	,03504
123	-,01169
124	-,01900
125	-,02521
126	,02018
127	-,02339
128	-,01043
129	,01082
130	,03408
131	-,02134
132	,02368
133	-,00892
134	,02541
135	-,01473
136	,01736
137	,00330
138	,00390
139	-,02695
140	-,00323
141	-,00147
142	,00771
143	,00756
144	,02324
145	,00339
146	,03396
147	,04576
148	-,00000
149	-,02579
150	-,00961
151	,02428
152	,01344
153	-,00678
154	-,00540
155	,01032
156	-,01444
157	,02270
158	,01109
159	,01383
160	,00404
161	,01591
162	-,00745
163	-,01219
164	-,02103
165	,00745
166	-,00330
167	,01195
168	,00250
169	,03356
170	,00473
171	,03815
172	,04270
173	,00285
174	,00860
175	-,00838

176	-.01021
177	-.01374
178	-.02043
179	-.00781
180	.00671
181	-.04542
182	-.00258
183	-.01412
184	-.01044
185	-.00380
186	.00071
187	-.00504
188	-.00861
189	-.02470
190	.00590
191	-.00003
192	-.00439
193	-.01270
194	.00987
195	.00392
196	.02269
197	.01292
198	-.01006
199	-.01762
200	-.00265
201	-.02753
202	-.02195
203	-.02659
204	-.00398
205	-.00381
206	-.00278
207	-.03637
208	-.00216
209	-.01574
210	-.01319
211	.00856
212	-.00420
213	.00434
214	-.00330
215	.00029
216	-.00819
217	-.02973
218	-.00751
219	-.00847
220	.00086
221	.01235
222	-.02170
223	.00317
224	-.01856
225	-.01898

NUMBER OF ITERATIONS = 14

ANGLE OF ROTATION, ABOUT Z AXIS = -.53278392091434+000 RADIANS
OFF AXIS ANGLE, ABOUT ROTATED X AXIS = .19344088837911-002 RADIANS
VALUES DX,DY,DZ LOCATE THE VERTEX OF THE BEST FIT PARABOLOID
IN THE ROTATED COORDINATE SYSTEM

DY = .25785 INCHES

DZ = -.00591 INCHES

FOCAL LENGTH OF BEST FIT PARABOLOID = 62.1693 INCHES

RMS WITH RESPECT TO BEST FIT PARABOLOID = .018856 INCHES

TEST EQUIPMENT

Manufacturer	Model No.	Serial No.	Cal. Exp. Date
Starrett	25-441		4-29-74

COMMENTS:

* Approved all except 4.4.3 Test Number 3 (Results not available)

TEST ENGINEER ______________________ DATE ____________

QUALITY CONTROL ______________________ DATE ____________

*CUSTOMER REP. ______________________ DATE ____________

DCAS REP. ______________________ DATE ____________

5.0 RF EVALUATION TEST

5.1 Test Objective

The purpose of this test is to evaluate the RF performance of the 12.5-foot diameter deployable antenna. This is done in three separate procedures. First, the gain of the deployable antenna with a feed installed is compared with the gain of the same feed in a standard solid metal parabola with a known and relatively small surface tolerance and the same diameter and focal length. Second, a feed with a known phase center is placed at the designed focal point of the parabola, and the gain difference is measured between this feed position and the feed position obtained by electrical testing. Third, the far field radiation patterns of the dish are measured and compared with the far field radiation patterns of the standard parabola. These three measurements are performed at 15 GHz.

5.2 Instrumentation

The model deployable antenna and standard antenna are mounted back-to-back 15 feet above ground on a pedestal which may be remotely adjusted in azimuth and elevation.

For a given test frequency, the three types of measurements, gain comparison, focusing, and patterns can be performed with a single set of test equipment. The list of equipment to be used is shown below:

Function	15.0 GHz
Signal Generator	HP-628A
Source Feed	Radiation
Transmit Reflector	Andrews 6 foot
Mixer	SA-13A-12
Receiver	SA-1600
Pattern Recorder	SA-1540
Precision Attenuator	HP-P382A
Frequency Meter	PRD 536
Reference Antenna	(Advanced) Structures/12 feet

5.3 Gain Comparison Test

The objective of this test is: 1) to determine the rms surface error of the model deployable parabola, and 2) to compare the gain of the entire deployable antenna assembly with the predicted gain of the reference antenna. Both measurements are based upon the measured gain difference between the deployable antenna assembly and a reference antenna assembly. The reference antenna has an accurate surface (0.007 inch rms) so that the loss due to surface phase error is small and accurately known. The reference antenna feed is supported in such a way that its primary blockage is zero and its secondary blockage is minimal. This feed support configuration allows the reference antenna gain to be accurately calculated so that it serves as a gain standard for gain measurements on the deployable antenna assembly. The deployable antenna is tested with the complete feed cone, midrib restraint assembly, and feed support in position, hence, fully representing an operational state.

5.3.1 Surface Accuracy Measurement by Relative RF Gain

The secondary gain of a paraboloidal antenna is degraded by surface error in the shape of the reflector. When the errors have a Gaussian distribution and a correlation interval which is large with respect to a wavelength, the loss due to surface error is:

$$\eta_{\phi s} = e^{-\left[\frac{4\pi\epsilon}{\lambda}\right]^2}$$

Solving for ϵ:

$$\epsilon = \frac{\lambda}{4\pi}\left(-\log_e \eta_{\phi s}\right)^{1/2} \quad \text{, or}$$

$$\epsilon = 0.23\,\frac{\lambda}{4\pi}\left(-10\log\eta_{\phi s}\right)^{1/2}$$

The surface phase error $\eta_{\phi s}$ is isolated and measured to compute G. This error is determined by measuring the difference in gain between the deployable antenna and the reference antenna. This difference in gain is modified by measured or predicted values for all other differences between the two antennas other than surface error. This gives an rms surface error (in inches) of:

$$\epsilon = 0.0144\left[|\Delta G| + \sum_{k=1}^{n} (10\log\eta_k)\right]^{1/2}$$

when f = 15 GHz

The factors η_k are given below.

k	Factor	$10 \log \eta_k$
1.	Diameter Difference	+0.35 dB
2.	Ogive Blockage	-0.45
3.	Midrib Restraint Assembly	-0.60 dB
4.	Scalloped Area Loss	-0.45
5.	Mesh Loss	-0.30 dB
6.	Reference Reflector Feed Support Blockage	+0.05
7.	Deployable Reflector Center Blockage	-0.55 dB
8.	Reference Reflector rms	+0.05 dB
	$\sum 10 \log \eta_k$	-1.9 dB

The derivation of the above terms is given in detail below.

1. Diameter Difference

$$= 10 \log \left[\frac{(12.5 \text{ feet})}{(12.0 \text{ feet}}\right]^2 = +0.35 \text{ dB}.$$

2. Ogive Blockage

= -0.45 dB by substitution measurements in the standard reflector.

3. Midrib Restraint Assembly Blockage

= -0.6 dB by substitution measurements in the standard reflector.

4. Scalloped Area Loss

$= 10 \log (1 - 0.10) = -0.45$ by computation from measured geometry of mesh intercostal.

5. Mesh Loss

= -0.3 from measured flat panel tests.

6. Reference Reflector Feed Support Blockage

= +0.05 dB from calculation similar to 7.0 below.

7. Center Blockage of Deployable

$$\text{loss} = 10 \log \left[1 - \frac{(\text{A center})}{(\text{A reflector})} \left\{ \frac{(1)}{(\eta_{at})} \right\}^2 \right]^2$$

loss = -0.55 dB

8. Reference Reflector rms

$\epsilon = 0.007$ in. rms

$$\text{the rms loss} = 10 \log e^{-\left[\frac{4\pi\epsilon}{\lambda}\right]^2}$$

$$= +0.05 \text{ dB}$$

5.3.2 Determination of Relative Gain

The gain of the deployable antenna assembly with representative feed in place is determined by comparison with the reference reflector. The gain of the reference antenna may be predicted accurately because the normal losses due to surface error and primary blockage are small in this case. This makes it a good standard for measurement of absolute gain. Because it is about the same size as the deployable antenna, ground reflections have a negligible effect on a gain comparison measurement between the two antennas.

The following table lists the factors used to compute the gain of the reference reflector.

Factor	$-10 \log \eta$
$\eta_{sp}\ \eta_{at}$	1.5
η_b	0.05

Factor	$-10 \log \eta$
η_{ϕ}	0.1
$\eta_{\phi s}$	0.0
η_{xs}	0.1
η_{T}	1.75

$$G = 10 \log \left[\eta_T \left(\frac{4 \pi A}{\lambda^2} \right)^2 \right]$$

The gain of the deployable by this method is the measured value of ΔG from Paragraph 5.3.5, subtracted from this reference reflector gain.

$$G_{deployable} = G_{standard} - \Delta G$$

$$= 53.4 - 2.5 \text{ dB}$$

$$G_{deployable} = 50.9 \text{ dB}$$

This is the gain by comparison to the computed gain of the reference reflector in 1 G gravity. The on orbit gain is greater because the surface accuracy is a more accurate paraboloid on orbit where the distortions of gravity are not a factor.

5.3.3 Measurement Technique

The antenna feed for both the deployable antenna assembly and the reference antenna is a flared horn designed for equal 10 dB edge tapered illumination over the entire circumference of the reflector. Figures 5.3.3-1 and 5.3.3-2 are E- and H- plane cuts through this pattern. This feed is representative of the feed which would be used in a flight application. The same feed, reflection isolator, and mixer, and mixer-receiver cable are used in both reflector assemblies, so that no variations in these components affect the accuracy of the gain comparison. The reflection isolator absorbs power reflected from the mixer so that it is not reradiated by the feed horn. This eliminates the possibility that feed VSWR due to vertex reflections might interact with the VSWR of the mixer.

Each of the two reflectors has its own three-dimensional focusing adjustment mechanism with a mounting interface for the feed horn-isolator-mixer assembly. The feed is focused in each reflector axially for minimum null depths and radially for equal side lobes. The feed may then be substituted from one reflector to the other in minimum time. This substitution

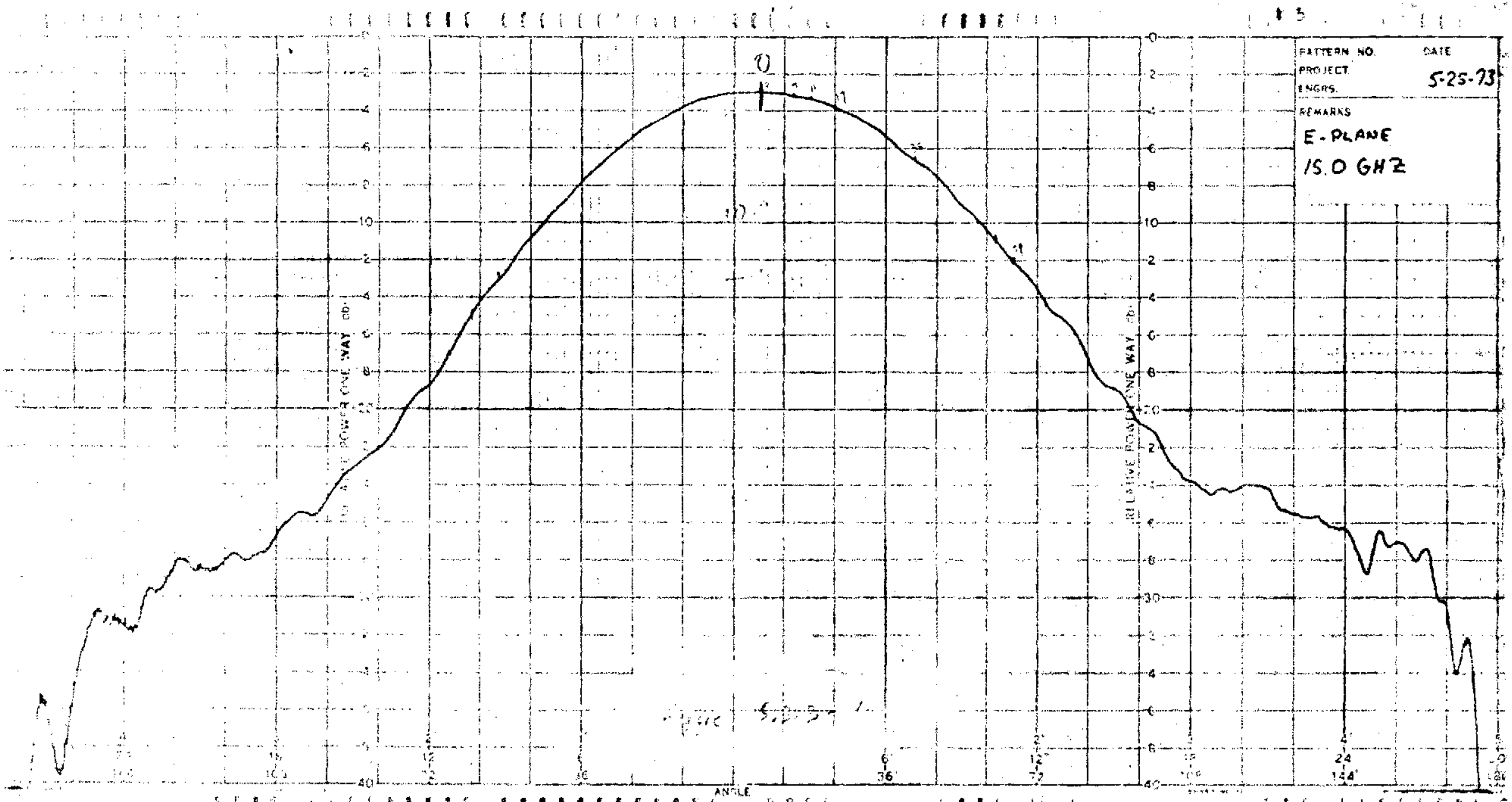

PATTERN NO.
DATE
PROJECT
ENGRS.
5-25-73
REMARKS
E-PLANE
15.0 GHZ
RELATIVE POWER ONE WAY (DB)
ANGLE

Figure 5.3.3-1

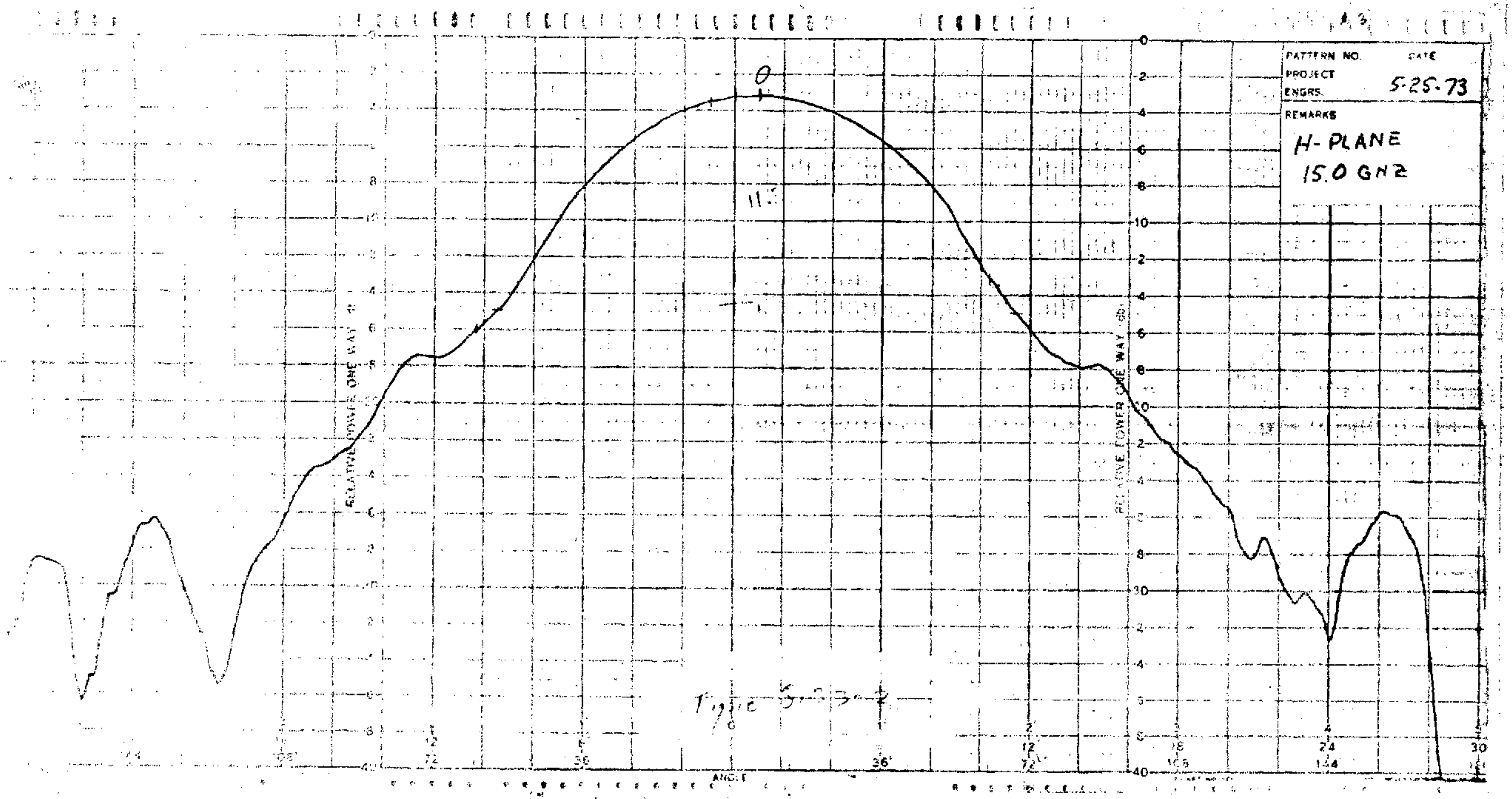

PATTERN NO.
DATE
PROJECT
ENGRS.
5-25-73
REMARKS
H-PLANE
15.0 GHZ
RELATIVE POWER ONE WAY
ANGLE
Figure 5.3.3-2

Figure 5.3.3-2.

is done five times; each time the peak of the antenna beam is pointed at the boresight source. A rotary vane precision attenuator is used as a standard against which to measure the difference in received power levels. The range geometry is shown in Figure 5.3.3-3.

5.3.4 Test Procedures

The following procedure will be used to measure delta gain, ΔG.

1. With the measure configuration shown in Figure 5.3.2, set approximately 3 dB of attenuation in the precision attenuator. Orient the boresight antenna to the vertical polarization position.

2. Set the generator at 15.0 GHz.

3. Focus both antennas for maximum gain.

4. With the waveguide horn feed in the deployable reflector, orient the antenna so that the peak of the main beam is aligned on boresight.

5. Establish a reference level of the antenna output signal on the pattern recorder.

6. Remove the waveguide horn feed and install the feed in the standard reflector.

7. Orient the antenna so that the peak of the main beam is aligned on boresight.

8. Establish a reference level of the antenna output signal on the pattern recorder.

9. Adjust the precision attenuator until the two reference levels are coincident.

10. The amount of attenuation change in the precision attenuator is ΔG.

11. Repeat this procedure until three measurements of ΔG are recorded.

5.3.5 Test Record

Frequency (GHz)	15.0
$+\sum_{k=1}^{N} 10 \log \eta_k$	-1.90
ΔG_1	2.41

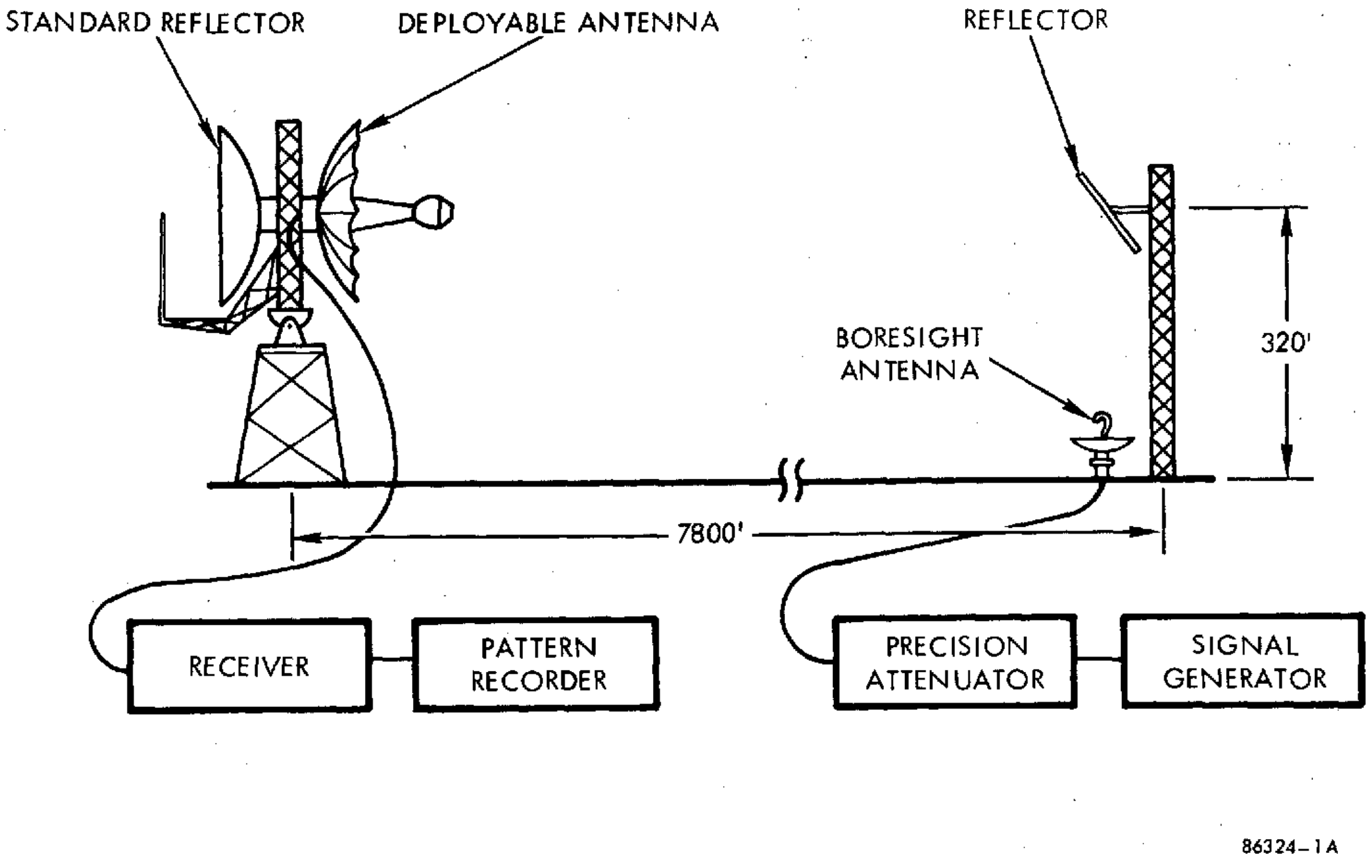


Figure 5.3.3-3. *Measurement Configuration*

Frequency (GHz)	15.0
ΔG_2	2.58
ΔG_3	2.45
ΔG_4	2.53
ΔG_5	2.50
$\Delta G_{average}$	2.49
$-10 \log \eta_{\phi s}$	0.60 dB
ϵ	0.011 inch rms

5.3.6 Error Analysis

The accuracy of the terms $\Sigma 10 \log \eta_k$ and ΔG above determine the accuracy of the measured value of ϵ. The most probable value of $\eta_{\phi s}$ based on estimates of the accuracy of the individual terms η_k and ΔG is as follows:

K	Factor	Accuracy
1.	Diameter Difference	±0.0 dB
2.	Ogive Blockage	±0.15
3.	Midrib Restraint Assembly	±0.20
4.	Scalloped Area Loss	±0.0
5.	Mesh Loss	±0.10
6.	Reference Reflector Feed Support Blockage	±0.05
7.	Deployable Reflector Center Blockage	±0.15
8.	Reference Reflector rms	±0.0
	Measured value of ΔG	±0.15 dB

The square root of the sum of the squares of the above values is 0.35 dB. The most probable value of surface phase loss then lies in the range of 0.60 ±0.35 dB

This corresponds to rms surface accuracies from 0.007 to 0.014 inches based on the use of Ruze's equation for the calculation. It should be noted, however, that it is widely recognized that this equation is typically pessimistic for calculation loss from rms surface accuracy. Comparisons between calculations made using ray tracing pattern computing programs and the use of Ruze's equation often show loss factors of two to three times less with the ray tracing technique. Therefore, if compensations are made in proportion to these factors, then the calculated rms surface error based on RF measurements is more consistent with the 0.025 inch rms measured in the program.

5.4 Focusing Accuracy Test

5.4.1 Test Method

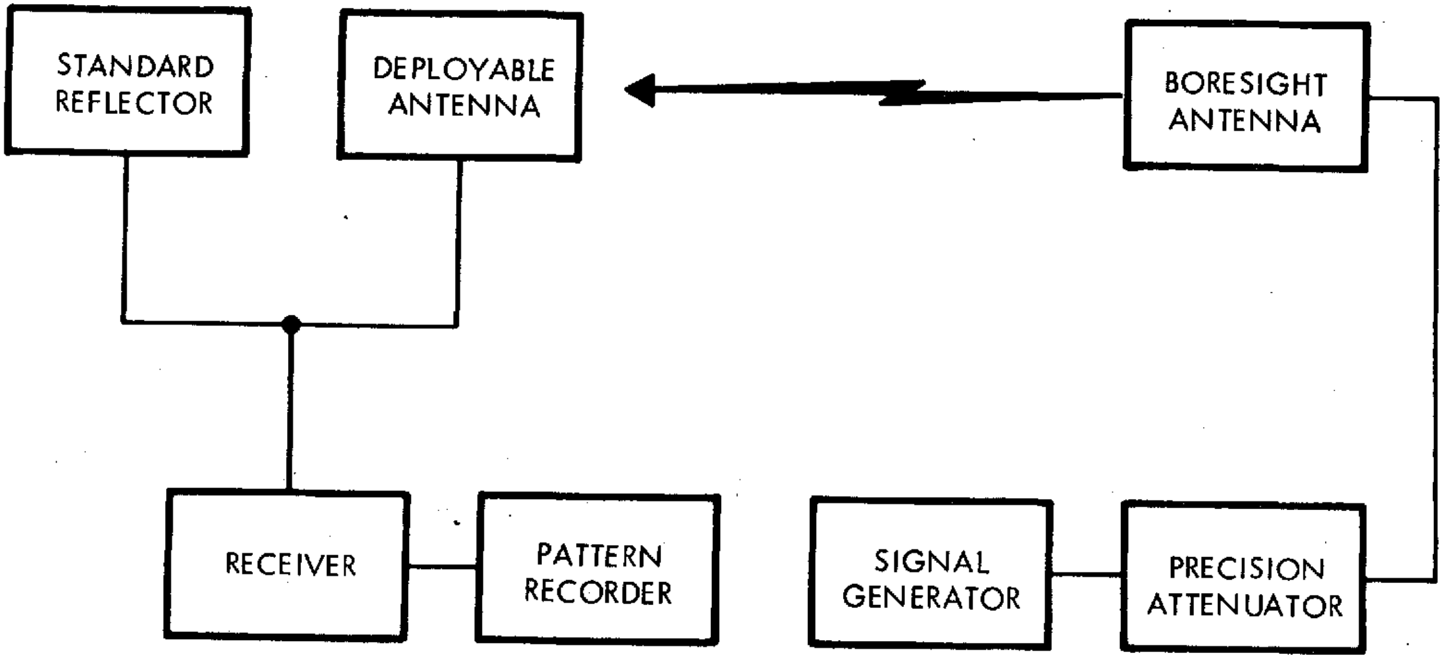
This measurement determines how much gain loss the model deployable antenna suffers due to uncertainty about the location of its focal point. The technique is to locate the feed at the predicted focal point of the deployable antenna and make a gain measurement, using the standard parabola as a reference. Then the feed is focused electrically for deepest nulls and best side-lobe balance. A second gain measurement is made at this point. The gain increase is a measure of the inaccuracy in phase center location and its effect on the antenna's performance. A block diagram of the test configuration is shown in Figure 5.4.1-1. The procedure used to locate the predicted best fit focal point of the parabola is shown in Figure 5.4.1-2. The location of the best electrical focus as determined by running patterns and focusing for best nulls and the location of the best fit paraboloid focal point as computed for best rms surface error are shown in Figure A-7 in the Appendix.

5.4.2 Test Procedure

The following test procedure is used to evaluate the feasibility of positioning the feed at the analytically determined focal point of the deployable antenna.

1. Set up the test equipment as shown in Figure 5.4.1-1.

2. Set approximately 3 dB of attenuation in the precision attenuator.



86324-2

Figure 5.4.1-1. Block Diagram of Antenna Focusing Measurements

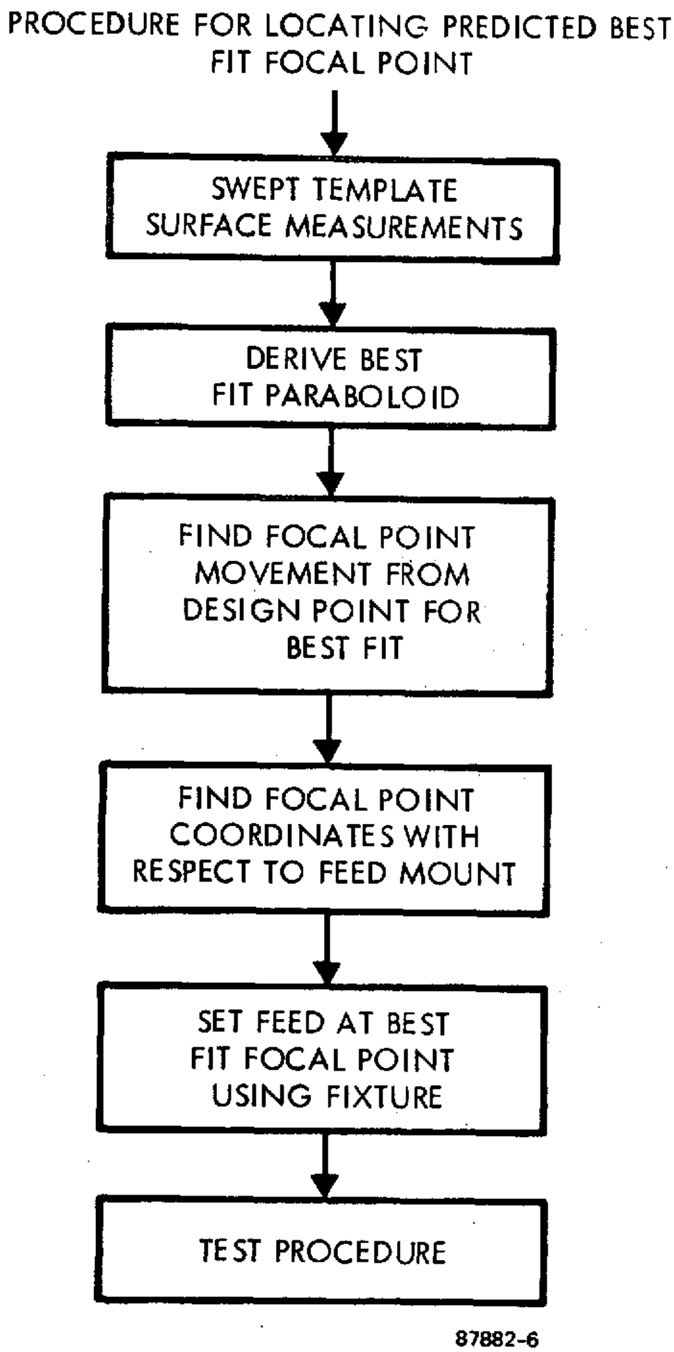


Figure 5.4.1-2. Procedure for Locating Predicted Best Fit Focal Point

3. Set the signal generator to 15.0 GHz.

4. Orient the boresight antenna to the vertical polarization position.

5. Focus the standard reflector by balancing the side-lobe levels and the null depths. Use the standard feed.

6. Focus the deployable antenna model by balancing the side-lobe levels and the null depths. Use the feed with the known phase center.

7. Point the standard reflector on boresight and set a reference level of the received signal power on the recorder.

8. Point the deployable reflector on boresight and set a reference level of the received signal power on the recorder.

9. Adjust the precision attenuator until the two reference levels are coincident. The amount of attenuation change is ΔG_1.

10. Reposition the feed in the deployable reflector until its phase center is coincident with the analytically determined focal point.

11. Position the deployable reflector such that the received signal power is maximized.

12. With the antenna in this position, set a reference level of the received signal power on the recorder.

13. Point the standard reflector on boresight and set a reference level of the received signal power on the recorder.

14. Adjust the precision attenuator until the two reference levels are coincident. The amount of attenuation change is G_2.

15. Subtract G_1 from G_2 to determine the amount of gain difference due to setting the feed at the analytically determined focal point.

5.4.3 Test Record

	Number 1	Number 2	Number 3
$G_{\text{mechanical focus}} - G_{\text{standard}}$	7.5 dB	7.3 dB	7.5 dB
$G_{\text{electrical focus}} - G_{\text{standard}}$	2.5	2.5	2.3

	Number 1	Number 2	Number 3
$G_{\text{electrical focus}} - G_{\text{mechanical focus}}$	5.0	4.8	5.2
Average $G_{\text{electrical focus}} - G_{\text{mechanical focus}}$	5.0 dB		

5.5 Pattern Measurement

5.5.1 Test Method

To expedite this test, the antenna patterns are recorded during the antenna focusing measurement procedure. The test equipment and test facility required for the focusing measurements are also required to record antenna patterns.

The procedures described in Paragraph 5.4.2 of the antenna focusing measurement procedure are followed to the point where the test feed has been focused electrically in the deployable antenna model.

The focused antenna is then pointed on boresight. With the antenna pattern recorder synchronized to the rotation of the turntable, the turntable is rotated approximately ±10° in azimuth around boresight with the pen of the recorder in the down position.

5.5.2 Test Procedures

Follow the procedure described in Paragraph 5.4.2 to the point where the test feed has been focused electrically in the deployable antenna model, then proceed with the following steps:

1. Orient the antenna at -90° in azimuth.
2. Place the pen of the antenna pattern recorder in the down position.
3. Rotate the antenna in azimuth to +90°.
4. The curve plotted by the antenna pattern recorder as the antenna is rotated from -10° to +10° is the antenna pattern.
5. Perform this measurement at 15.0 GHz where the focusing accuracy test is performed.

5.5.3 Test Record

Attach all patterns taken on the deployable antenna and on the standard antenna. (See Appendix Figures A14, A15, A17.)

5.6 Absolute Gain

5.6.1 Test Objective

The object of this test is to measure the gain of the deployable antenna at 15 GHz.

Test Equipment	Type	Serial No.	Calibration Date
Signal Generator	HP-628A	105785	2-14-74
Transmitting Antenna	6-foot reflector illuminating a 5-foot by 7-foot flat passive reflector		NCR
Standard Attenuator	HP-P382A	102932	8-8-74
Mixer	SA-13A-12	218632	NCR
Standard Gain Horn	NRL-18 MM Band		
Receiver	SA-1600	106350	4-2-74
Pattern Recorder	SA-1520	105987	4-2-74

5.6.2 Error Analysis

The gain of the deployable antenna will be determined by a comparison with an NRL design gain standard horn. There are three basic sources of uncertainty in this measurement: 1) the uncertainty in on-axis gain of the gain standard horn, 2) the measurement uncertainty in the comparison of the deployable antenna with the gain standard, and 3) power which reaches the gain standard horn from reflections which are not focused by the larger deployable reflector. The first uncertainty is ±0.3 dB peak as described in the NRL report. The second is one percent of the amplitude difference between the standard and the test antenna, or 0.25 dB. The third source of error, power which enters the standard gain horn by way of ground reflections (see Figure 5.6.2-1). The value for A in this model is a function of the transmitter pattern, the receiver pattern, and the reflectivity of the ground. The value for Ø is a function of the length difference between the direct and reflected ray path. The change in this path length difference between the top and bottom of the reflector is 11.8 inches. This range geometry is shown in Figure 5.6.2-2.

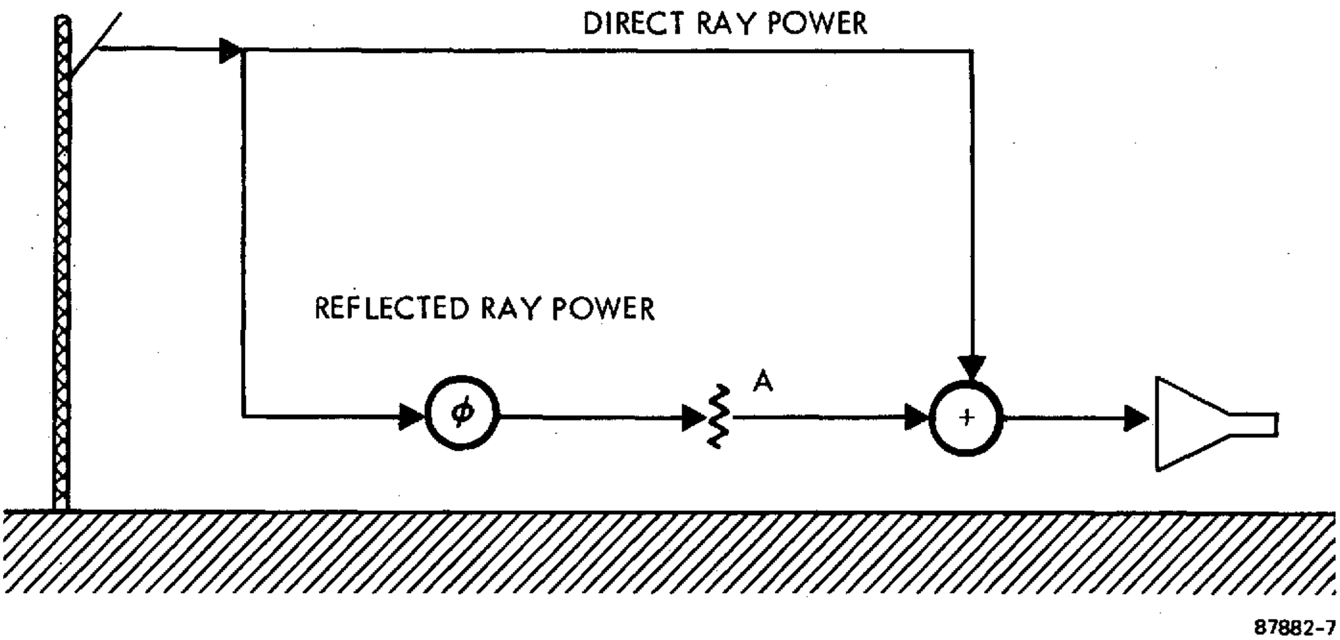


Figure 5.6.2-1. Model for Evaluating Ground Reflection Effects

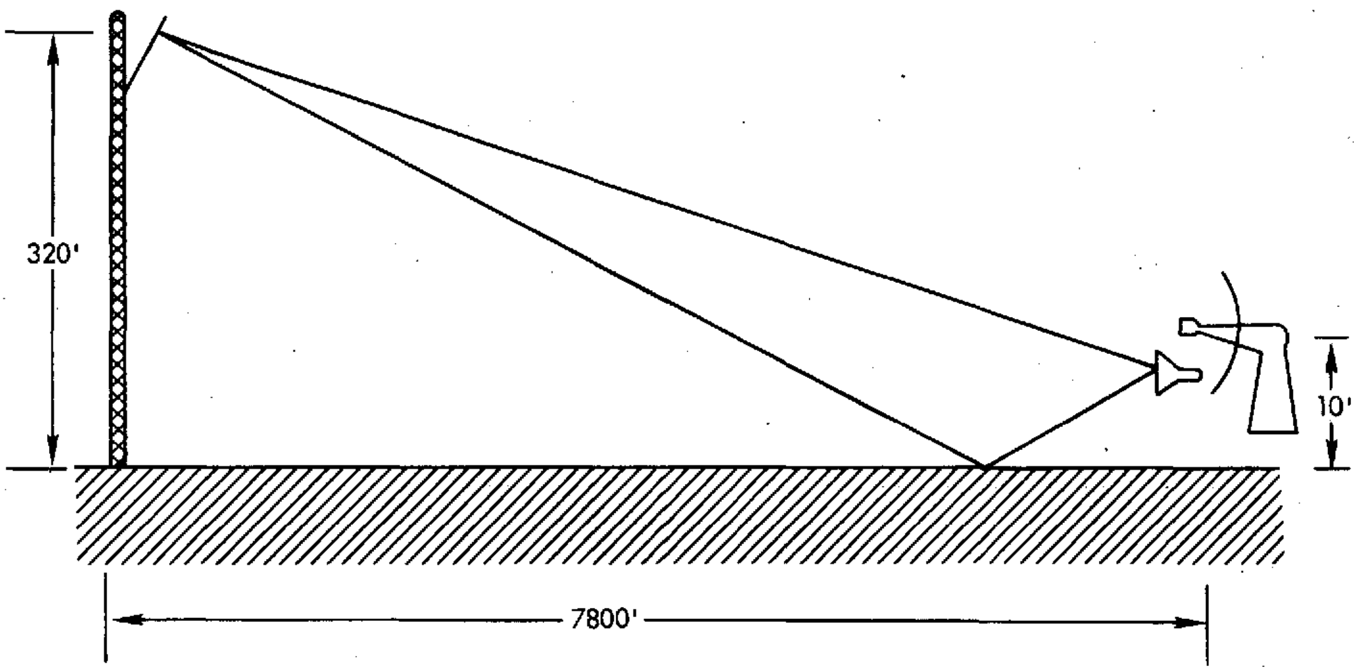


Figure 5.6.2-2. Range Geometry

The ratio $\frac{E \text{ reflected}}{E \text{ direct}} = A$ in the above model.

The peaks of the interference pattern measured as the horn is moved across the field represent successive values of E maximum, and the nulls represent E minimum. At each transition between peak and null the two above equations are solved for E direct and E reflected, so a total of 72 values of E direct are obtained. These are converted back to relative power levels and averaged to obtain the reference power level for the gain measurement.

It is possible to check this value by pointing the large reflector directly at the reflected ray. Measurements of the relative strength of the reflected ray, A in the model, by these two methods, are in close agreement. Deviations in the smoothed signal level of the standard gain horn limit the accuracy to ±0.25 dB error. Together with the two other errors, the peak error of the gain measurement is ±0.8 dB.

5.6.3 Test Procedure

1. Set up the test equipment.
2. Set the generator at 15 GHz.
3. Focus the antenna by balancing side-lobe levels and null depths.
4. Point the antenna toward the boresight.
5. Set the attenuator at 22 dB and record the level on the chart paper. Repeat for 23, 24, 25 and 26 dB settings of the attenuator.
6. Connect the mixer to the standard gain horn. Record vertical field probe using the standard gain horn.
7. Plot the magnitude of the reflected ray and direct ray as computed using the technique described above.
8. Average the direct ray data points and compare this average with the calibration marks made using the precision attenuator.
9. Record the data on the data sheets.

5.6.4 Absolute Gain Measurement Data Sheet

See Figure 5.6.4.

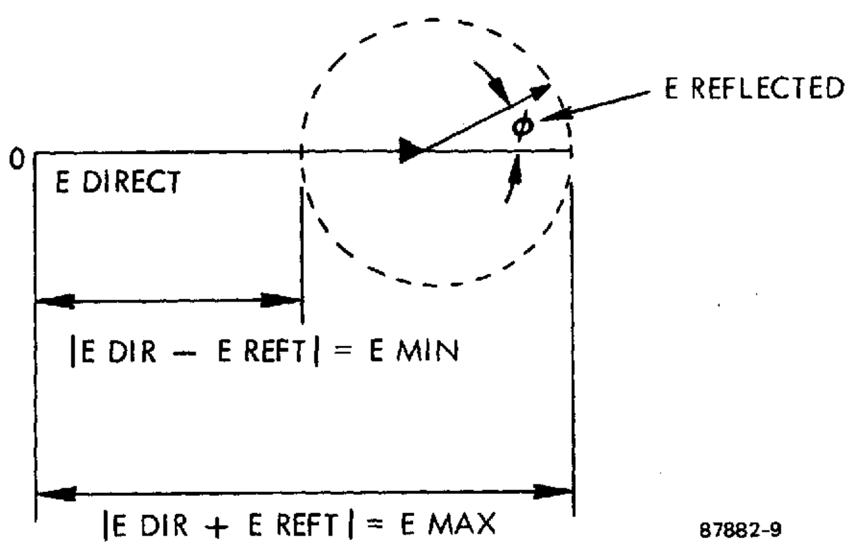
Frequency	15 GHz
Gain of Gain Standard	24.4 dB
Average Direct Ray Gain Standard Reading	26.5 dB
Attenuator Loss at Zero Setting	0.6 dB
Gain of Test Antenna	51.5 dB
Efficiency of Test Antenna	41%*

NOTE

This efficiency is referenced to a circular aperture with the rib-tip diameter. The efficiency with respect to the mean diameter including scallop area loss is 46 percent.

The model based on simple geometrical optics assumes that only a single reflected ray enters the standard gain horn from the point of specular reflection. Because the relative phase Ø between the direct and reflected rays varies directly as the height up and down the aperture of the large reflector, the standard gain horn sees an interference pattern as it is raised and lowered in front of the large reflector. This interference pattern results from the vector addition of the two signals in the standard gain horn.

The locus of received voltage level at the standard horn is shown below:



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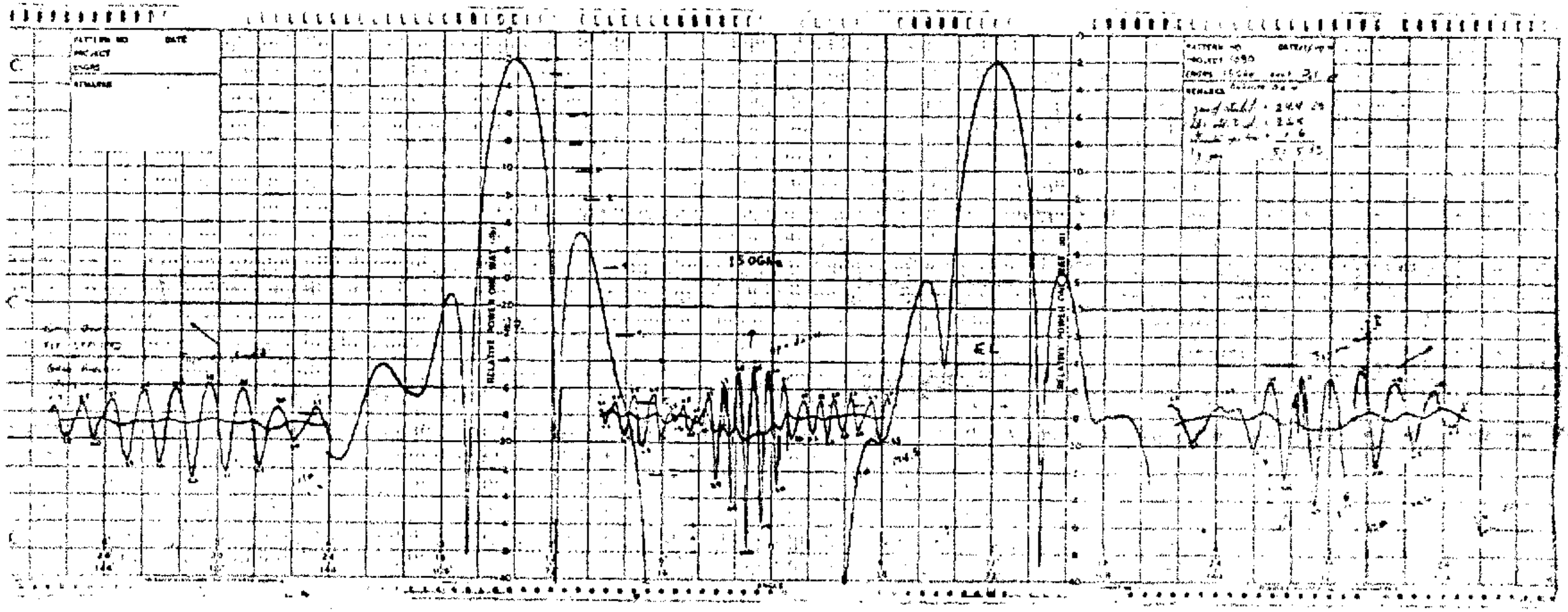


Figure 5.6.4

The desired reference voltage for gain measurements is E direct, but the only directly observable are E maximum and E minimum. By solving the two simultaneous equations,

$$E\ \text{direct} = \frac{E\ \text{maximum} + E\ \text{minimum}}{2}$$

$$E\ \text{reflected} = \frac{E\ \text{maximum} - E\ \text{minimum}}{2}$$

5.7 S-Band Pattern and Relative Gain Measurements

Pattern measurements on the deployable antenna and gain comparison between the deployable antenna and the reference antenna are made. The feed horn used is a flared horn with equal E- and H-plane beam widths and 10-11 dB illumination taper from the center to the edge of the reflector. The measurements were conducted at 2.1 GHz. The pattern measurements follow a procedure similar to that described in detail in Paragraph 5.5. The relative gain measurements follow a procedure similar to that described in Paragraph 5.3.

The elevation (E-plane) pattern from the deployable reflector is shown in Figure 5.7-1. The pattern below -6° is affected by ground reflected energy.

The azimuth (H-plane) pattern of the deployable reflector is shown in Figure 5.7-2. The pattern beyond $\pm 12^{\circ}$ is affected by range reflections.

The azimuth and elevations of the reference reflector are shown in Figure 5.7-3.

The gain comparison measurements between the deployable antenna and the reference reflector are shown in Figure 5.7-4.

6.0 PHYSICAL PROPERTIES MEASUREMENT

In this test, several physical properties of the antenna are measured.

6.1 Test Objectives

The objective of this test is to measure the weight and packaging envelope size of the deployable antenna.

6.2 Test Procedure

The antenna is first placed on a platform scale and its weight is recorded. For this measurement the antenna is completely assembled, including the restraint cable.

The size of the packaging envelope is determined by measuring the overall height and the overall diameter of the antenna in the stowed configuration.

6.3 Test Record

The data specified above are recorded on the data sheets at the time of the test.

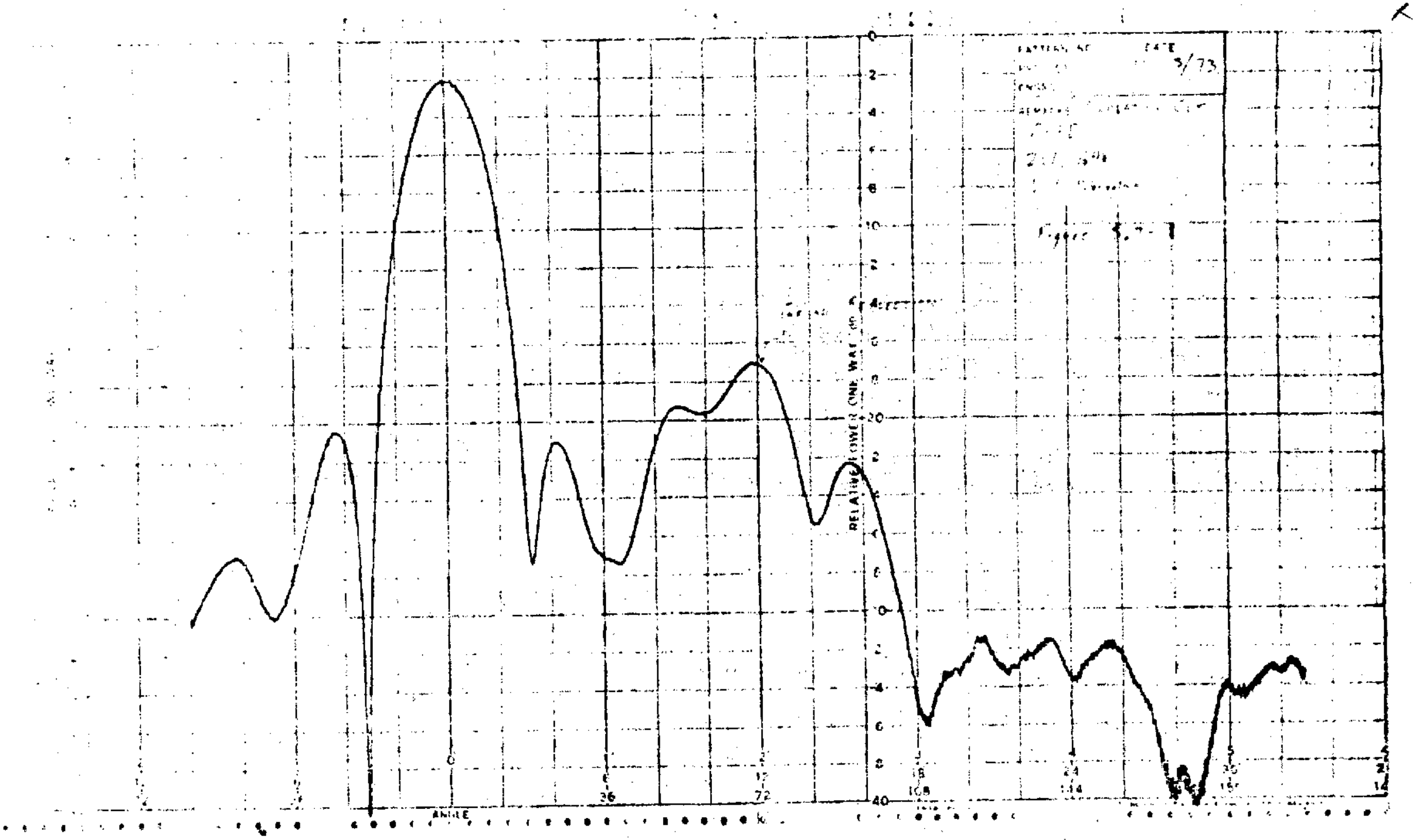


Figure 5.7-1

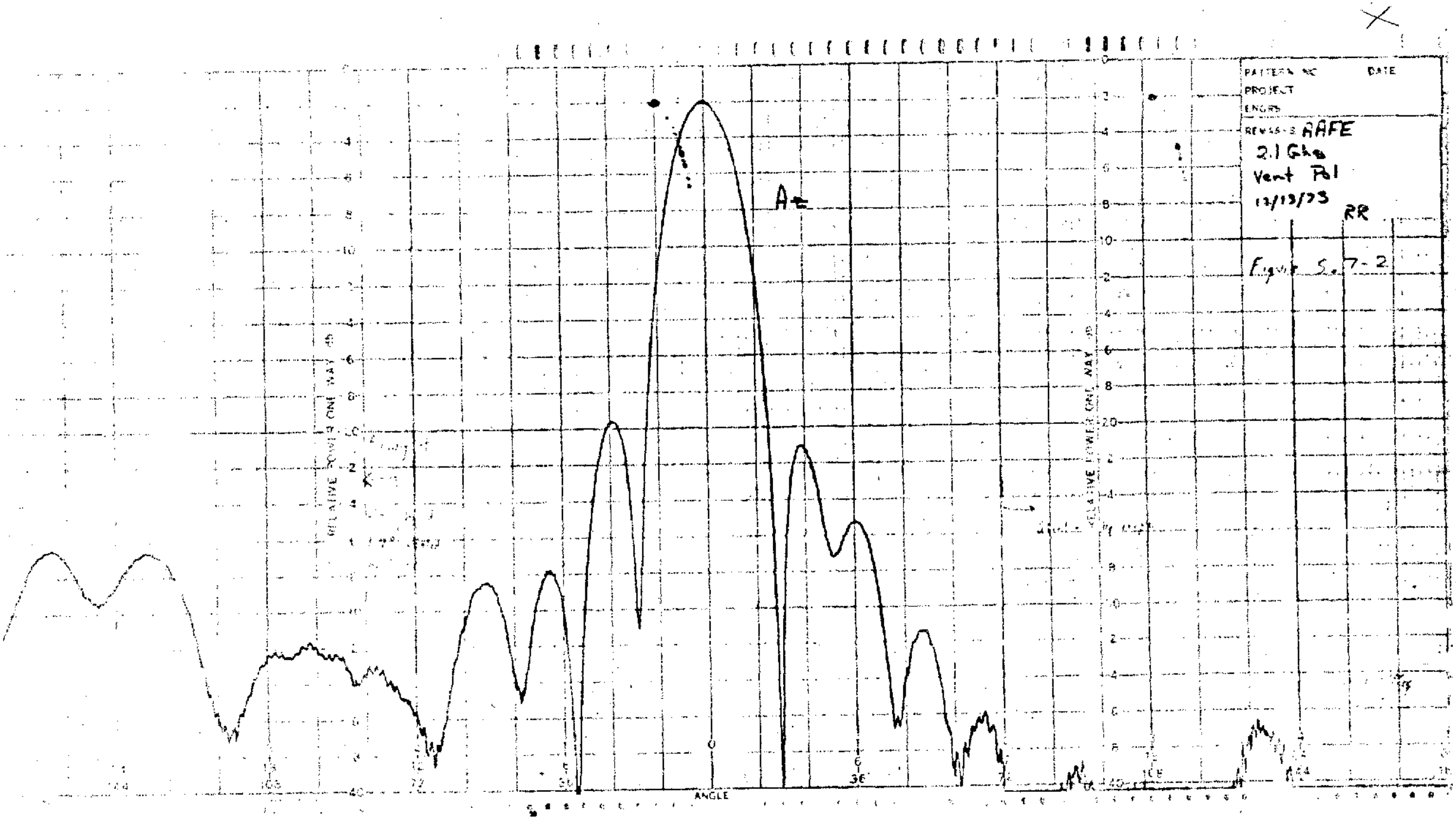

PATTERN NO
DATE
PROJECT
ENGRS
REMARKS AAFE
2.1 Ghz
Vert Pol
12/13/73
RR
Figure 5.7-2
RELATIVE POWER ONE WAY
ANGLE

Figure 5.7-2

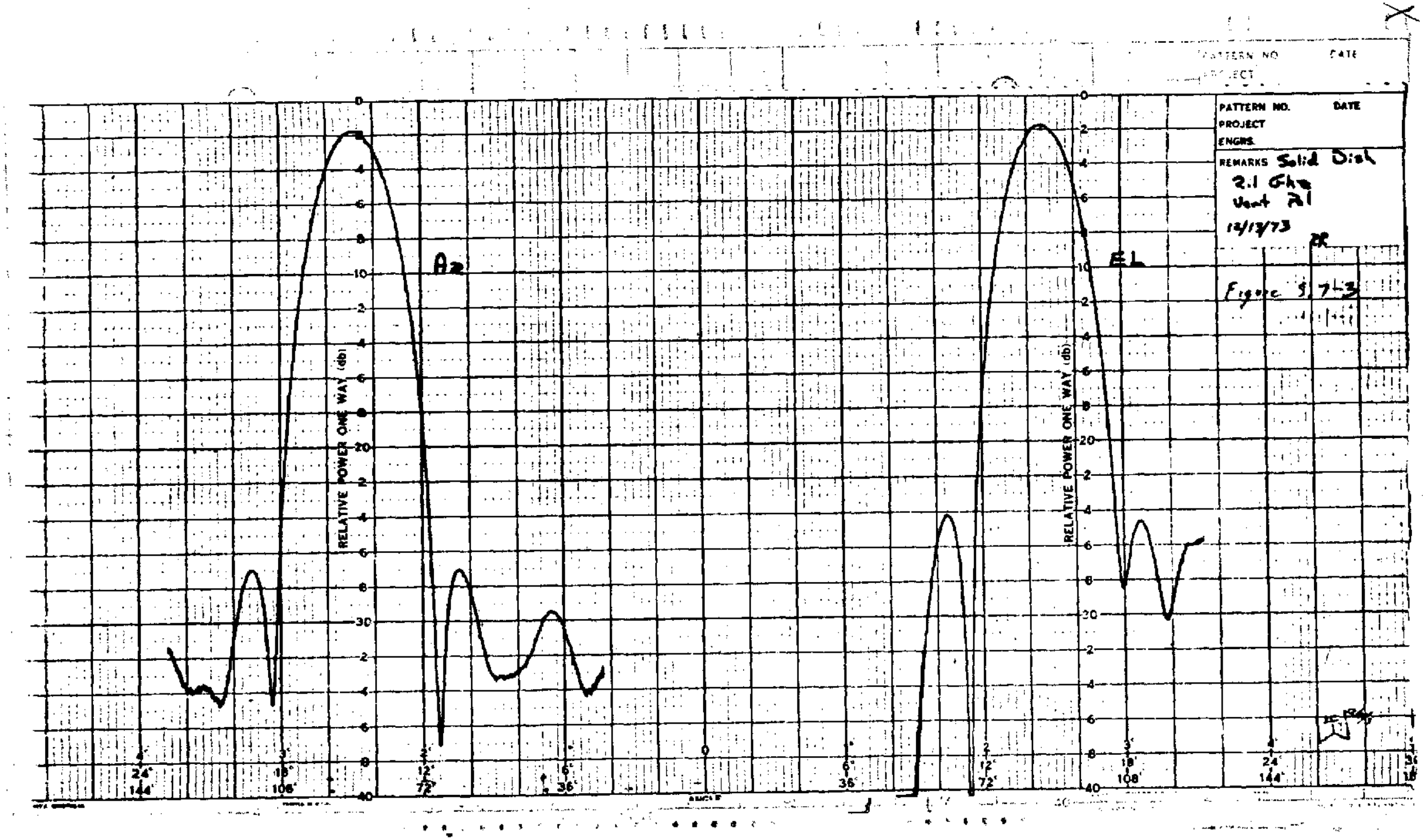

PATTERN NO.
DATE
PROJECT
ENGRS.
REMARKS Solid Disk
2.1 Ghz
Vert Pol
12/13/73
Az
EL
Figure 5.7-3
RELATIVE POWER ONE WAY (db)
ANGLE

Figure 5.7-3

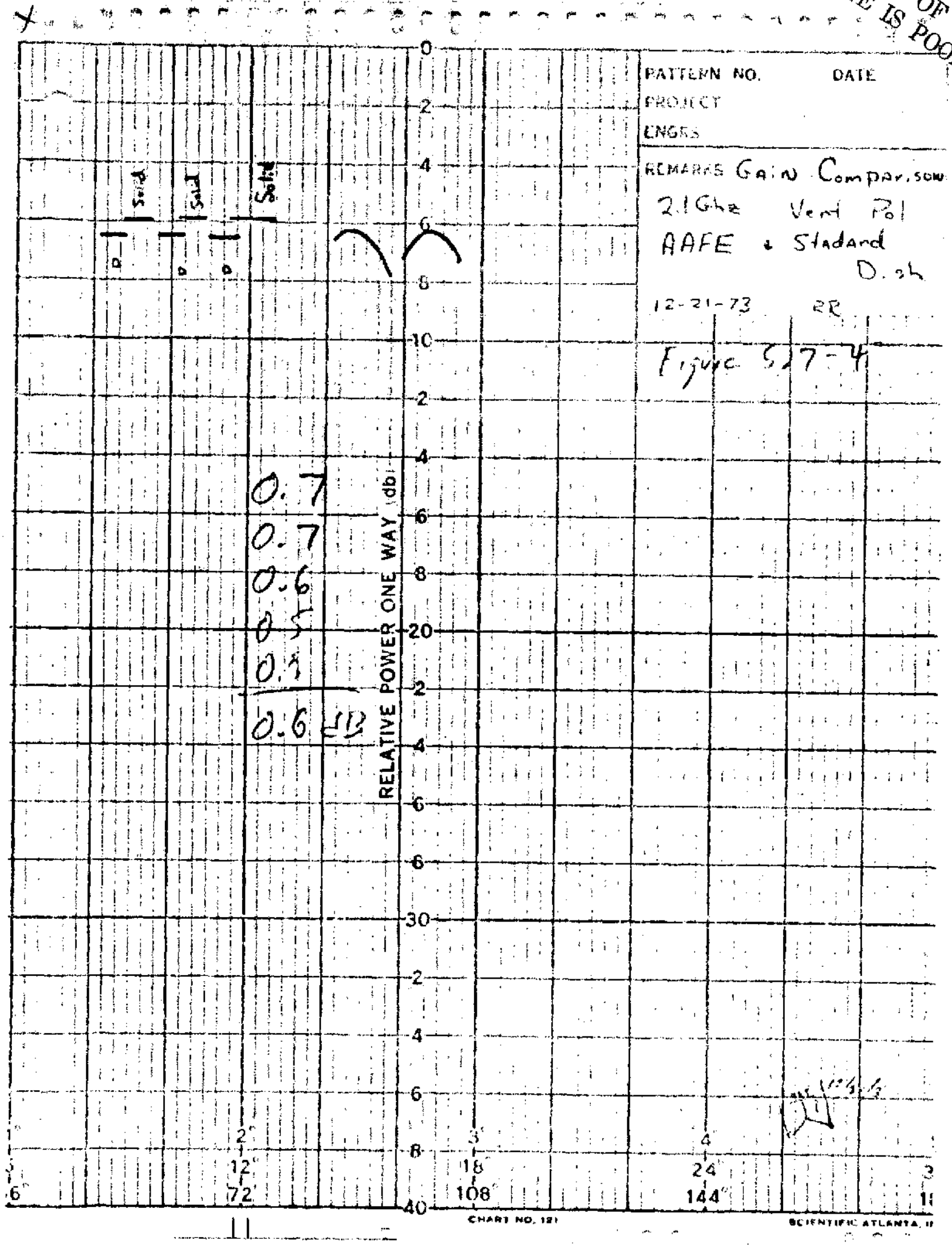

PATTERN NO.
DATE
PROJECT
ENGRS
REMARKS Gain Comparison
2.1Ghz Vert Pol
AAFE + Stadard
Dish
12-21-73 RR
Figure 5.7-4
Solid
Solid
Solid
0.7
0.7
0.6
0.5
0.5
0.6 dB
RELATIVE POWER ONE WAY (db)
0
2
4
6
8
10
20
30
40
12°
72°
18°
108°
24°
144°
CHART NO. 121
SCIENTIFIC ATLANTA, I

Figure 5.7-4

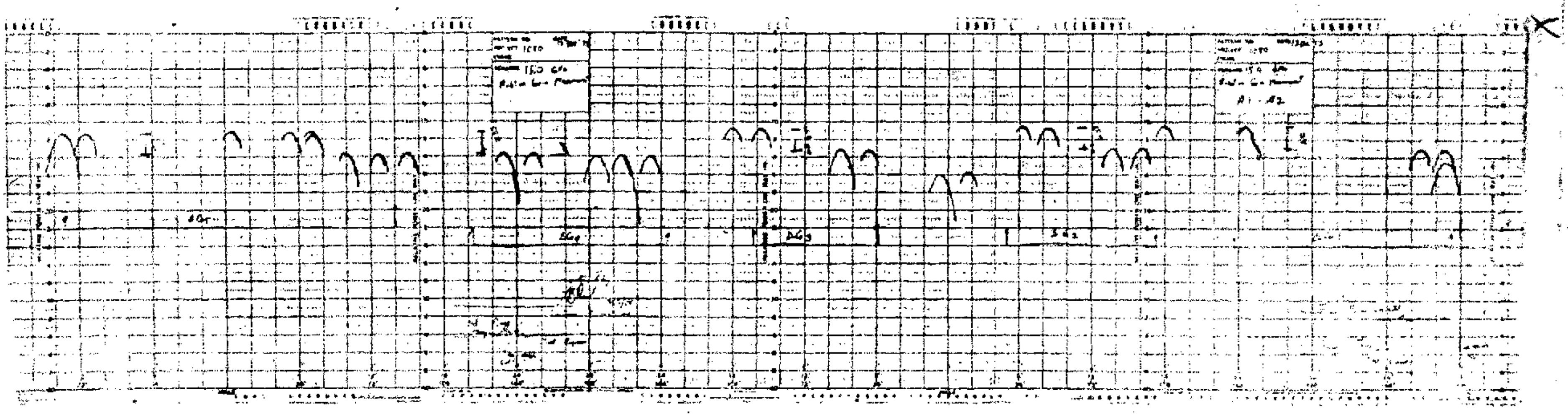


Figure A1-A2

PARABOLOIDAL ANTENNA EFFICIENCY FACTORS

?SIPA?	DPSI	NCUTS	NPTS	NPHASE	NCROSS	IFAP
?5.?00	6,000	4	30	0	0	1

FEED AMPLITUDE PATTERN

.00	.05	.26	.79	1.46	2.36	3.45	4.52
?.05	7.38	8.98	10.51	12.23	14.33	15.83	17.62
1?.37	20.79	21.33	20.98	21.32	22.45	22.72	23.31
24.95	24.00	24.71	27.43	30.23	37.03		

E-PLANE RIGHT SIDE

SPILL., AMP, TAPER, PHASE, CROSS EFFICIENCY	=	73.78431
SPILL., AMP, TAPER, PHASE EFFICIENCY	=	73.78431
SPILL., AMP, TAPER EFFICIENCY	=	73.78431
SPILLOVER EFFICIENCY	=	89.97460
AMPLITUDE TAPER EFFICIENCY	=	82.00570
PHASE EFFICIENCY	=	100.00000
CROSS POLARIZATION EFFICIENCY	=	100.00000
NOISE TEMPERATURE	=	1.99253
MAX (ABSOLUTE)	=	8.10426
MAX (DB)	=	9.08713
PLANE REPETITION NUMBER	=	1

FEED AMPLITUDE PATTERN

.00	.19	.55	.96	1.64	2.60	3.71	5.16
7.25	9.30	11.24	12.98	14.28	14.82	14.84	16.19
1?.33	19.51	20.82	22.49	24.92	26.06	27.11	29.31
24.57	22.85	23.66	30.21	37.41	37.00		

H-PLANE RIGHT SIDE

SPILL., AMP, TAPER, PHASE, CROSS EFFICIENCY	=	68.81827
SPILL., AMP, TAPER, PHASE EFFICIENCY	=	68.81827
SPILL., AMP, TAPER EFFICIENCY	=	68.81827
SPILLOVER EFFICIENCY	=	90.27298
AMPLITUDE TAPER EFFICIENCY	=	76.23353
PHASE EFFICIENCY	=	100.00000
CROSS POLARIZATION EFFICIENCY	=	100.00000
NOISE TEMPERATURE	=	1.87657
MAX (ABSOLUTE)	=	9.26711
MAX (DB)	=	9.66944
PLANE REPETITION NUMBER	=	1

FEED AMPLITUDE PATTERN

.00	.07	.30	.86	1.44	2.51	3.52	4.92
?.25	7.84	9.61	11.32	13.58	15.80	17.21	19.19
2?.13	21.79	22.61	23.73	25.06	25.20	25.48	25.32
2?.62	28.34	27.82	31.26	34.01	37.40		

E-PLANE LEFT SIDE

SPILL., AMP, TAPER, PHASE, CROSS EFFICIENCY = 74.16218

Figure A3

PILL., AMP, TAPER, PHASE EFFICIENCY = 74.16218
PILL., AMP, TAPER EFFICIENCY = 74.16218
PILLOVER EFFICIENCY = 92.26739
MPLITUDE TAPER EFFICIENCY = 80.37796
ASE EFFICIENCY = 100.00000
ROSS POLARIZATION EFFICIENCY = 100.00000
OISE TEMPERATURE = 2.16308
MAX (ABSOLUTE) = 8.65566
MAX (DB) = 9.37300
LANE REPETITION NUMBER = 1
FEED AMPLITUDE PATTERN

.00	.04	.45	.83	1.41	2.34	3.50	4.86
6.67	8.93	10.98	12.55	13.81	14.39	14.54	16.48
18.58	19.92	20.63	23.06	25.22	29.76	30.34	26.77
23.51	24.47	27.79	32.68	25.72	25.51		

H-PLANE LEFT SIDE

PILL., AMP, TAPER, PHASE, CROSS EFFICIENCY = 69.63696
PILL., AMP, TAPER, PHASE EFFICIENCY = 69.63696
PILL., AMP, TAPER EFFICIENCY = 69.63696
PILLOVER EFFICIENCY = 90.49975
MPLITUDE TAPER EFFICIENCY = 76.94712
HASE EFFICIENCY = 100.00000
OSS POLARIZATION EFFICIENCY = 100.00000
OISE TEMPERATURE = 1.91309
MAX (ABSOLUTE) = 8.77788
MAX (DB) = 9.43390
LANE REPETITION NUMBER = 1

DEPLOYABLE ANTENNA RELATI E GAIN MEASUREMENT
REFERENCE REFLECTOR
OTAL SPILL.,AMP, TAPER, PHASE,CROSS EFFICIENCY = .00000
~~OTAL SPILL., AMP, TAPER, PHASE EFFICIENCY = .00000~~
OTAL SPILL., AMP, TAPER EFFICIENCY = 71.58462
OTAL SPILLOVER EFFICIENCY = 90.74923
OTAL AMPLITUDE TAPER EFFICIENCY = 78.88179
~~OTAL PHASE EFFICIENCY = .00000~~
OTAL CROSS POLARIZATION EFFICIENCY = .00000
OTAL NOISE TEMPERATURE = .00000
OTAL GMAX(ABSOLUTE) = 8.68141
OTAL GMAX (DB) = 9.38590
RABOLOID EDGE ANGLE = 65.90000

Figure A4

PARABOLOIDAL ANTENNA EFFICIENCY FACTORS

SIPAT	OPSI	NCUTS	NPTS	NPHASE	NCROSS	IFAP
62,000	6,000	4	30	0	0	1

FEED AMPLITUDE PATTERN

,00	,05	,26	,79	1,46	2,36	3,45	4,52
6,05	7,38	8,98	10,51	12,23	14,33	15,83	17,62
19,37	20,79	21,33	20,98	21,32	22,45	22,72	23,31
24,95	24,00	24,71	27,43	30,23	37,03		

E-PLANE RIGHT SIDE

PILL., AMP, TAPER, PHASE, CROSS EFFICIENCY = 74,47218
PILL., AMP, TAPER, PHASE EFFICIENCY = 74,47218
PILL., AMP, TAPER EFFICIENCY = 74,47218
PILLOVER EFFICIENCY = 87,47132
MPLITUDE TAPER EFFICIENCY = 85,13897
HASE EFFICIENCY = 100,00000
ROSS POLARIZATION EFFICIENCY = 100,00000
OISE TEMPERATURE = 1,86020
MAX (ABSOLUTE) = 8,10426
MAX (DB) = 9,08713
LANE REPETITION NUMBER = 1
FEED AMPLITUDE PATTERN

,00	,19	,55	,96	1,64	2,60	3,71	5,16
7,25	9,30	11,24	12,98	14,28	14,82	14,84	16,19
18,33	19,51	20,82	22,49	24,92	26,06	27,11	29,31
24,57	22,85	23,66	30,21	37,41	37,00		

H-PLANE RIGHT SIDE

ILL., AMP, TAPER, PHASE, CROSS EFFICIENCY = 71,10435
ILL., AMP, TAPER, PHASE EFFICIENCY = 71,10435
PILL., AMP, TAPER EFFICIENCY = 71,10435
PILLOVER EFFICIENCY = 88,61848
MPLITUDE TAPER EFFICIENCY = 80,23649
HASE EFFICIENCY = 100,00000
OSS POLARIZATION EFFICIENCY = 100,00000
OISE TEMPERATURE = 1,83933
MAX (ABSOLUTE) = 9,26711
AX (DB) = 9,66944
LANE REPETITION NUMBER = 1
EED AMPLITUDE PATTERN

,00	,07	,30	,86	1,44	2,51	3,52	4,92
6,25	7,84	9,61	11,32	13,58	15,80	17,21	19,19
20,13	21,79	22,61	23,73	25,06	25,20	25,48	25,32
26,62	28,34	27,82	31,26	34,01	37,40		

E-PLANE LEFT SIDE

ILL., AMP, TAPER, PHASE, CROSS EFFICIENCY = 75,45264

Figure A5

SPILL., AMP. TAPER, PHASE EFFICIENCY = 75.45264
SPILL., AMP. TAPER EFFICIENCY = 75.45264
SPILLOVER EFFICIENCY = 90.01033
AMPLITUDE TAPER EFFICIENCY = 83.82665
PHASE EFFICIENCY = 100.00000
OSS POLARIZATION EFFICIENCY = 100.00000
NOISE TEMPERATURE = 2.03994
GMAX (ABSOLUTE) = 8.65566
GMAX (DB) = 9.37300
PLANE REPETITION NUMBER = 1
FEED AMPLITUDE PATTERN

.00	.04	.45	.83	1.41	2.34	3.50	4.86
6.67	8.93	10.98	12.55	13.81	14.39	14.54	16.48
18.58	19.92	20.63	23.06	25.22	29.76	30.34	26.77
23.51	24.47	27.79	32.68	25.72	25.51		

H-PLANE LEFT SIDE

PILL., AMP. TAPER, PHASE, CROSS EFFICIENCY = 71.86914
SPILL., AMP. TAPER, PHASE EFFICIENCY = 71.86914
PILL., AMP. TAPER EFFICIENCY = 71.86914
PILLOVER EFFICIENCY = 88.79931
MPLITUDE TAPER EFFICIENCY = 80.93434
PHASE EFFICIENCY = 100.00000
CROSS POLARIZATION EFFICIENCY = 100.00000
NOISE TEMPERATURE = 1.86960
GMAX (ABSOLUTE) = 8.77788
GMAX (DB) = 9.43390
PLANE REPETITION NUMBER = 1

DEPLOYABLE ANTENNA RELATI E GAIN MEASUREMENT
DEPLOYABLE REFLECTOR
OTAL SPILL.,AMP. TAPER, PHASE,CROSS EFFICIENCY = .00000
~~OTAL SPILL., AMP. TAPER, PHASE EFFICIENCY = .00000~~
OTAL SPILL., AMP. TAPER EFFICIENCY = 73.20243
OTAL SPILLOVER EFFICIENCY = 88.70497
OTAL AMPLITUDE TAPER EFFICIENCY = 82.52348
~~OTAL PHASE EFFICIENCY = .00000~~
OTAL CROSS POLARIZATION EFFICIENCY = .00000
OTAL NOISE TEMPERATURE = .00000
OTAL GMAX(ABSOLUTE) = 8.68141
OTAL GMAX (DB) = 9.38590
ARABOLOID EDGE ANGLE = 62.00000

Figure A6

FOCAL POINT LOCATION DATA

Location of best electrical focus with respect to design, focal point determined by focusing for best nulls and sidelobe looking balance downrange.

0.49 up

0.14 to right

0.56 in (toward reflector)

Location of focal point predicted by PARABOLOID with respect to design focal point.

0.568 down

0.186 to right

0.230 out (away from reflector)

Location of design focal point with respect to ¼ mounting plate riveted to ogive front surface.

7.96 into ogive (toward reflector)

Figure A7

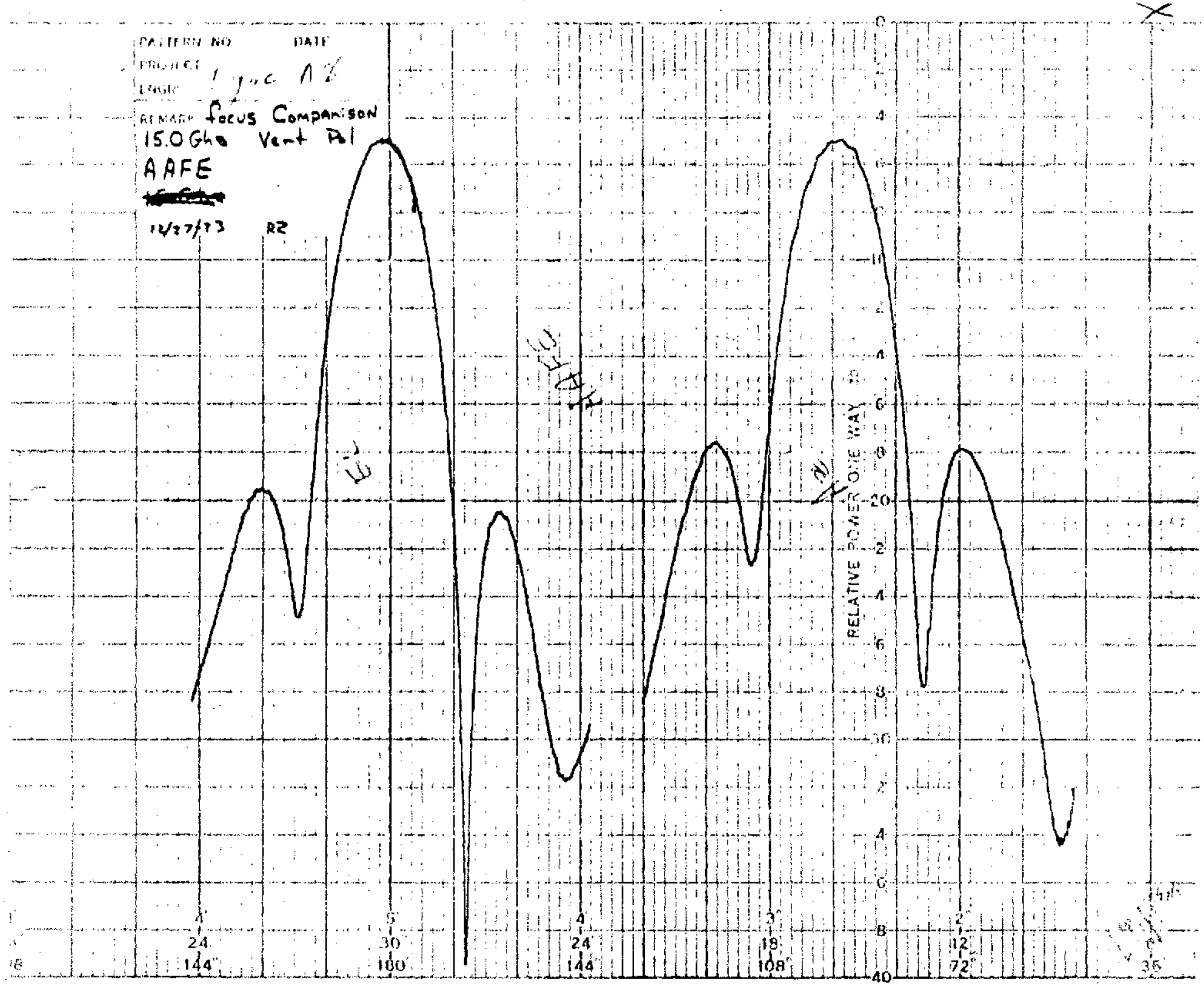

PATTERN NO.
DATE
Figure A8
REMARK Focus Comparison
15.0 Ghz Vert Pol
AAFE
12/27/73
RZ
EL
AZ
RELATIVE POWER ONE WAY

Figure A8

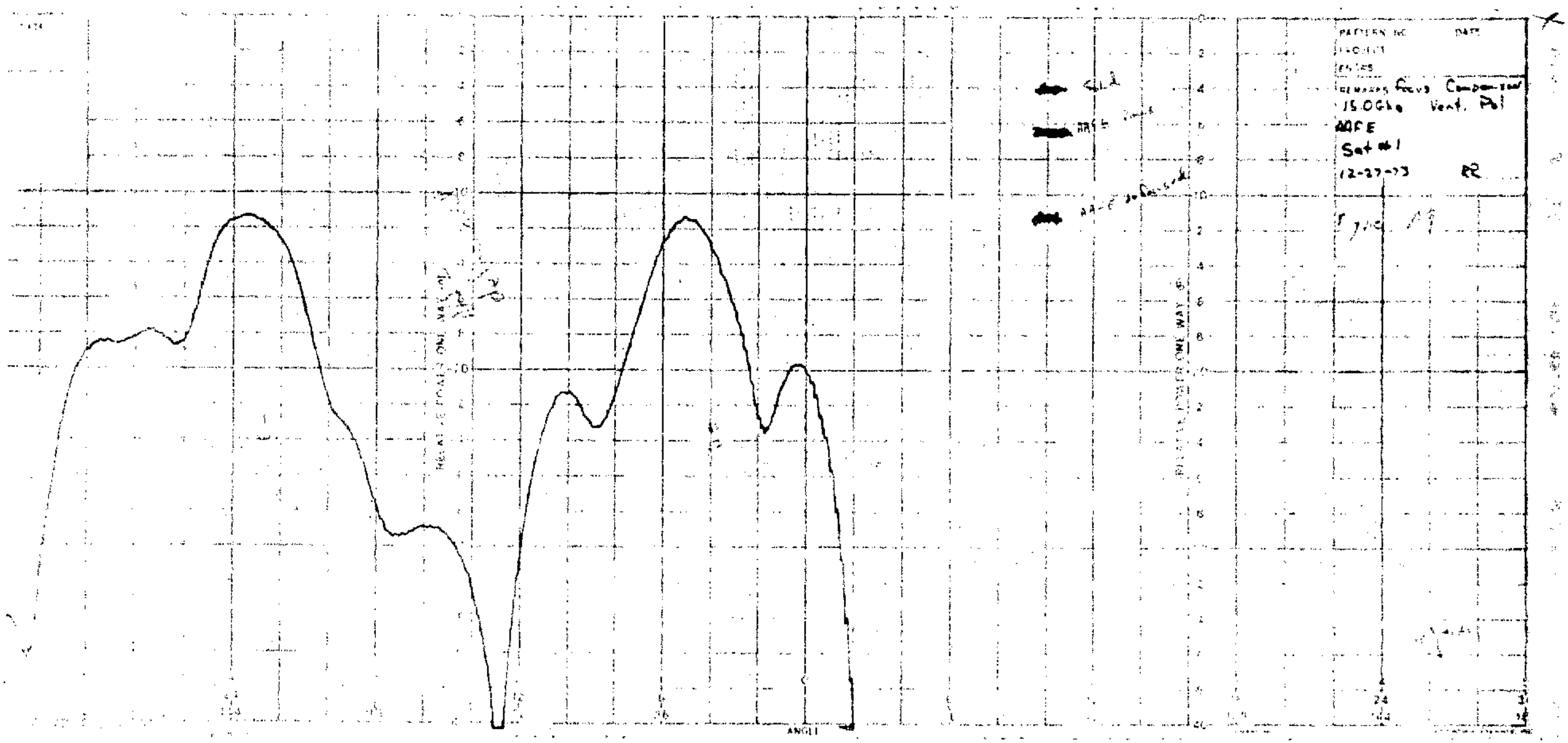


Figure A9

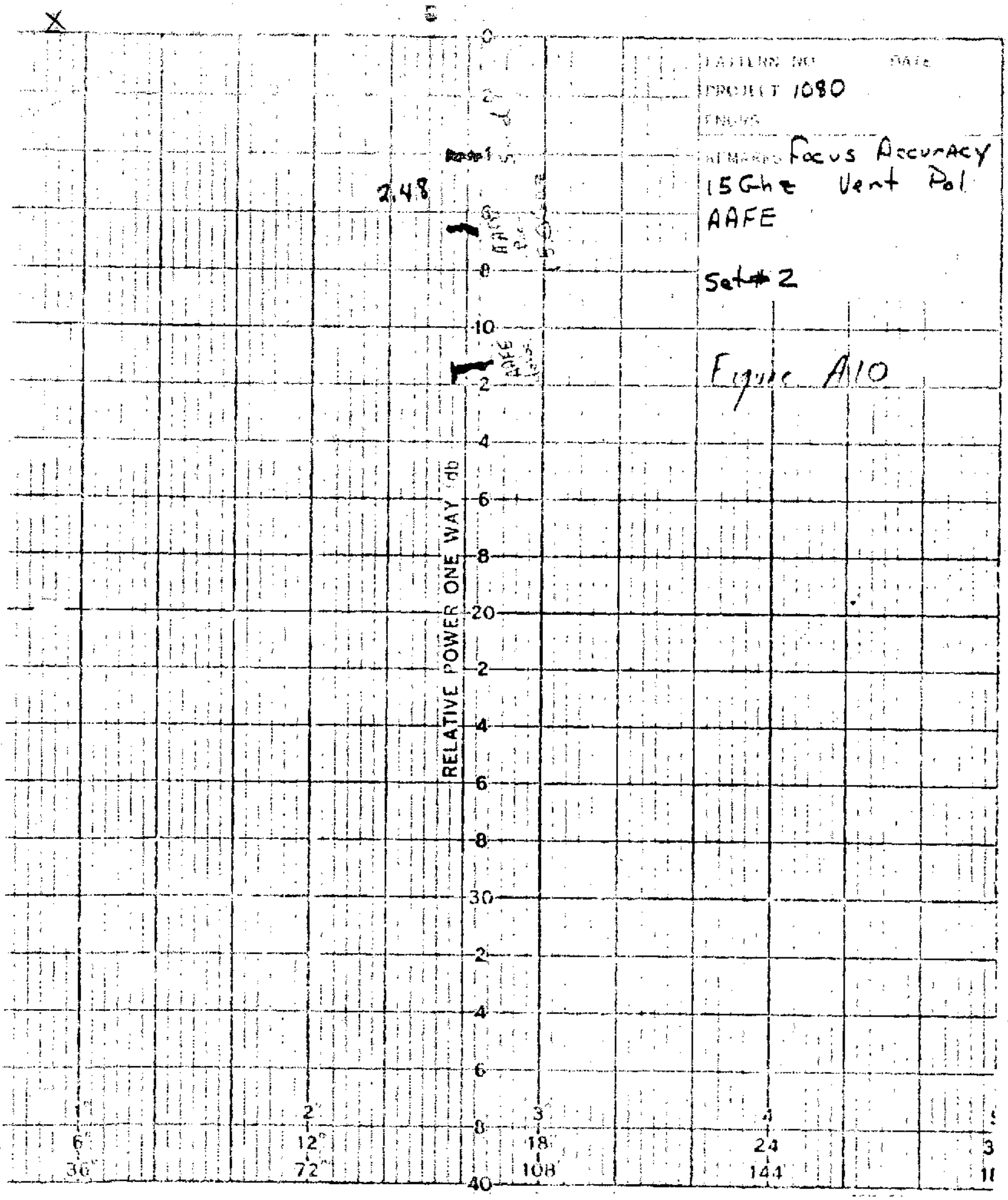
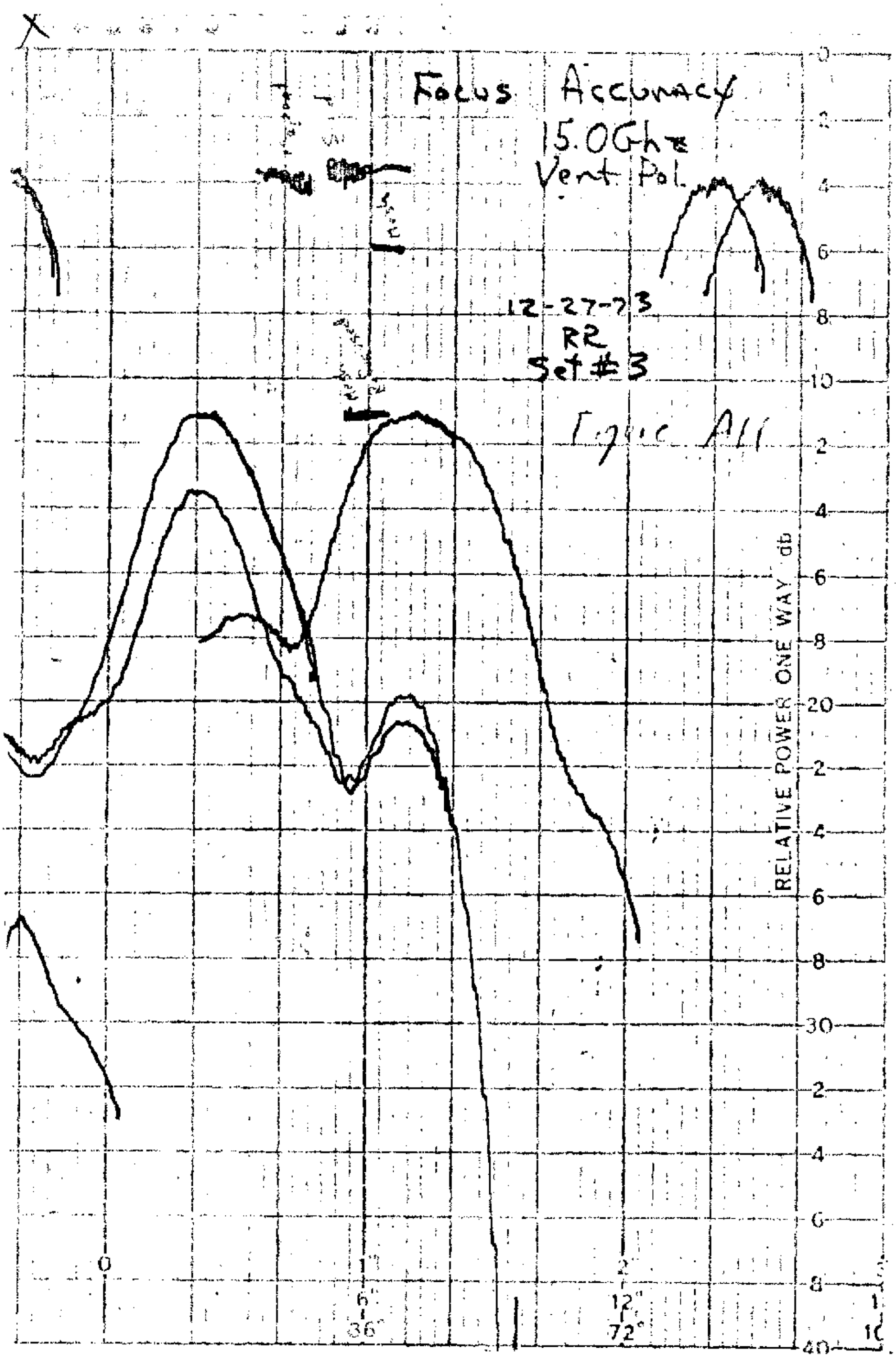

PROJECT 1080
REMARKS Focus Accuracy
15 Ghz Vert Pol
AAFE
Set # 2
Figure A10
2.48
RELATIVE POWER ONE WAY db

Figure A10



Focus Accuracy
15.0 Ghz
Vert. Pol.
12-27-73
R2
Set #3
Figure A11
RELATIVE POWER ONE WAY db
0
1°
6"
36°
2°
12"
72°

Figure A11

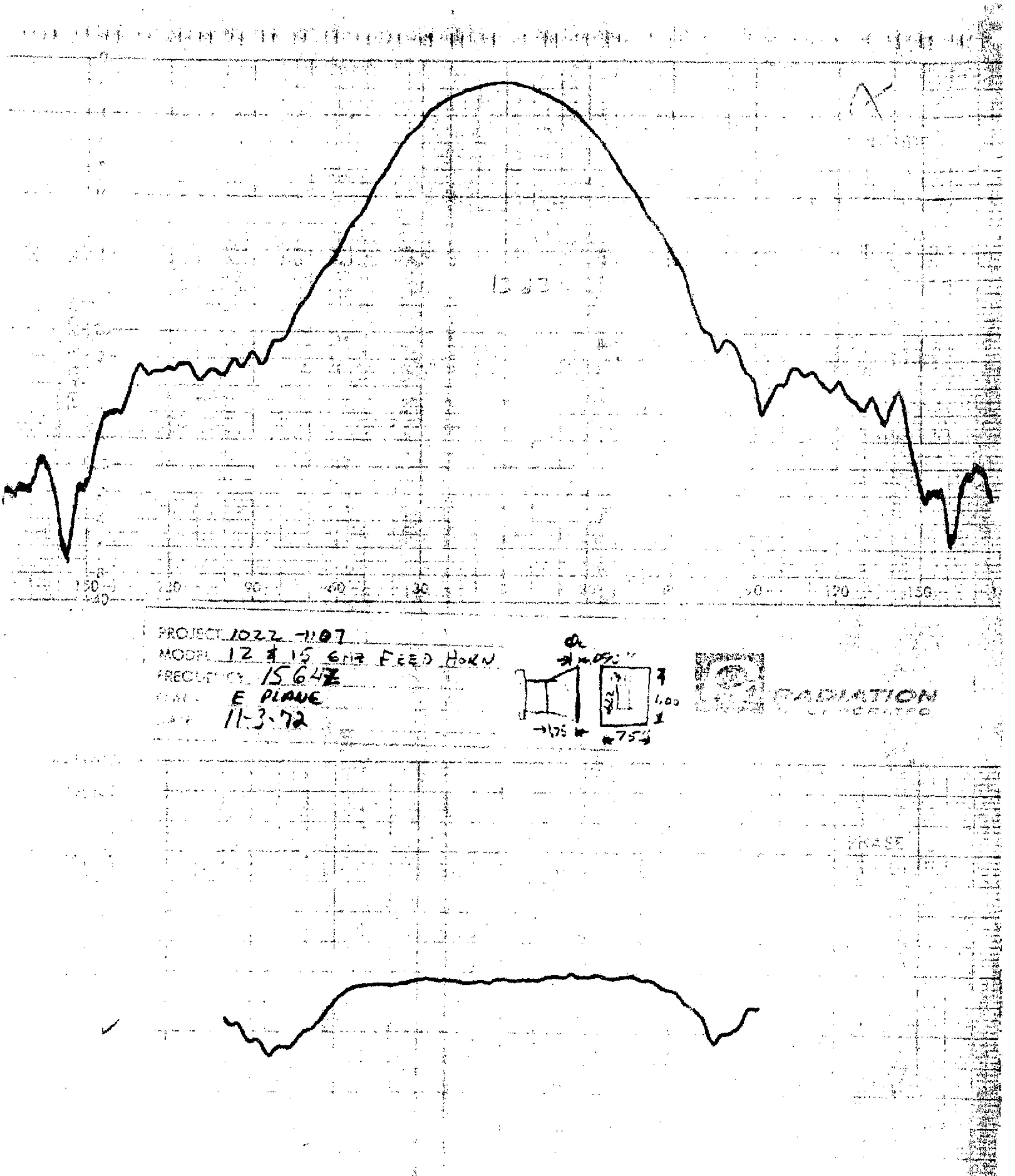

PROJECT 1022-1107
MODEL 12 & 15 GHz FEED HORN
FREQUENCY 15 GHZ
E PLANE
DATE 11-3-72
RADIATION
PHASE
150
120
90
60
30
0
30
60
90
120
150

Figure A12

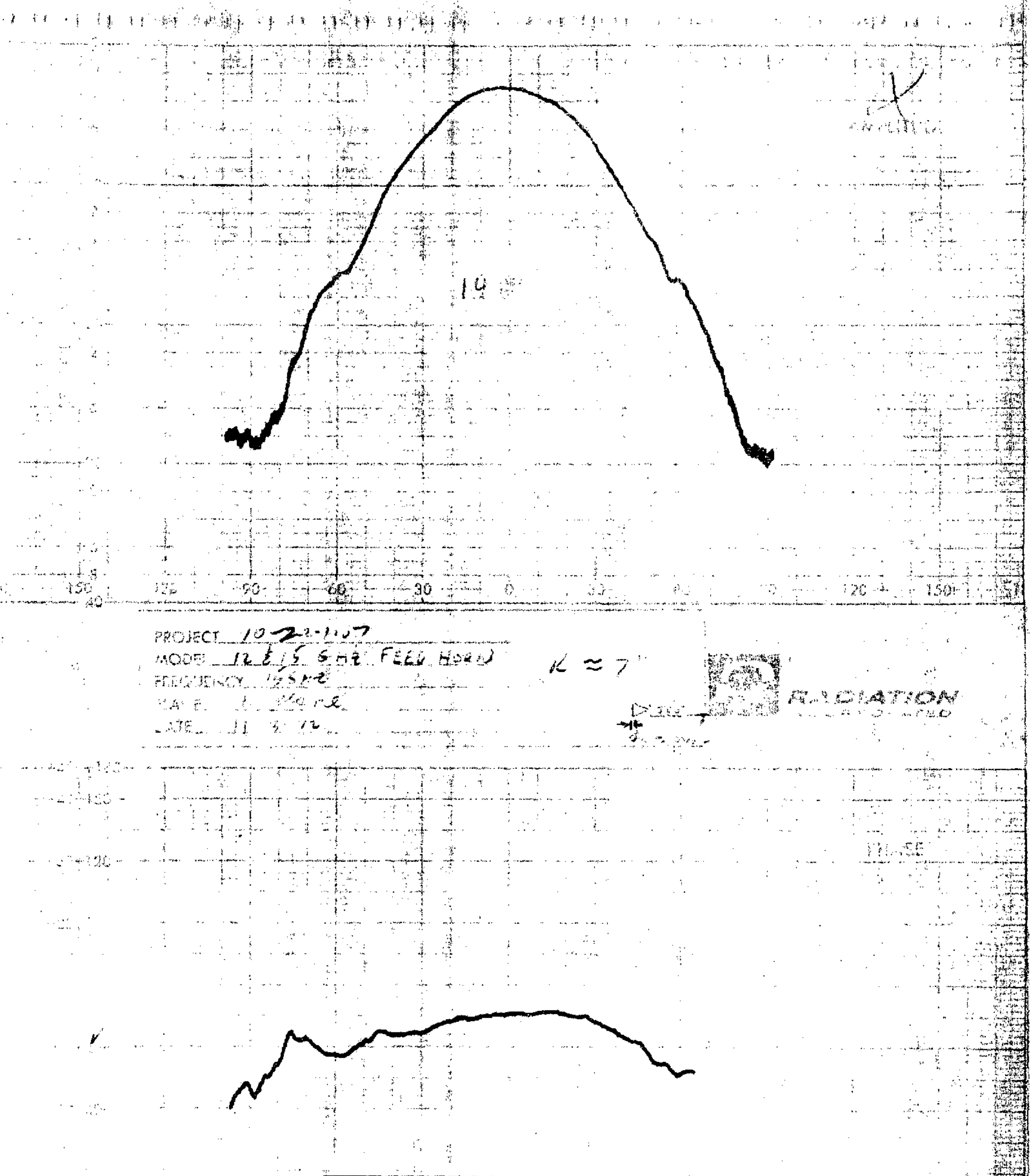

150
120
90
60
30
0
30
120
150
PROJECT 10-22-1107
MODEL 12 & 15 GHz FEED HORN
K ≈ 7"
RADIATION
PHASE

Figure A13

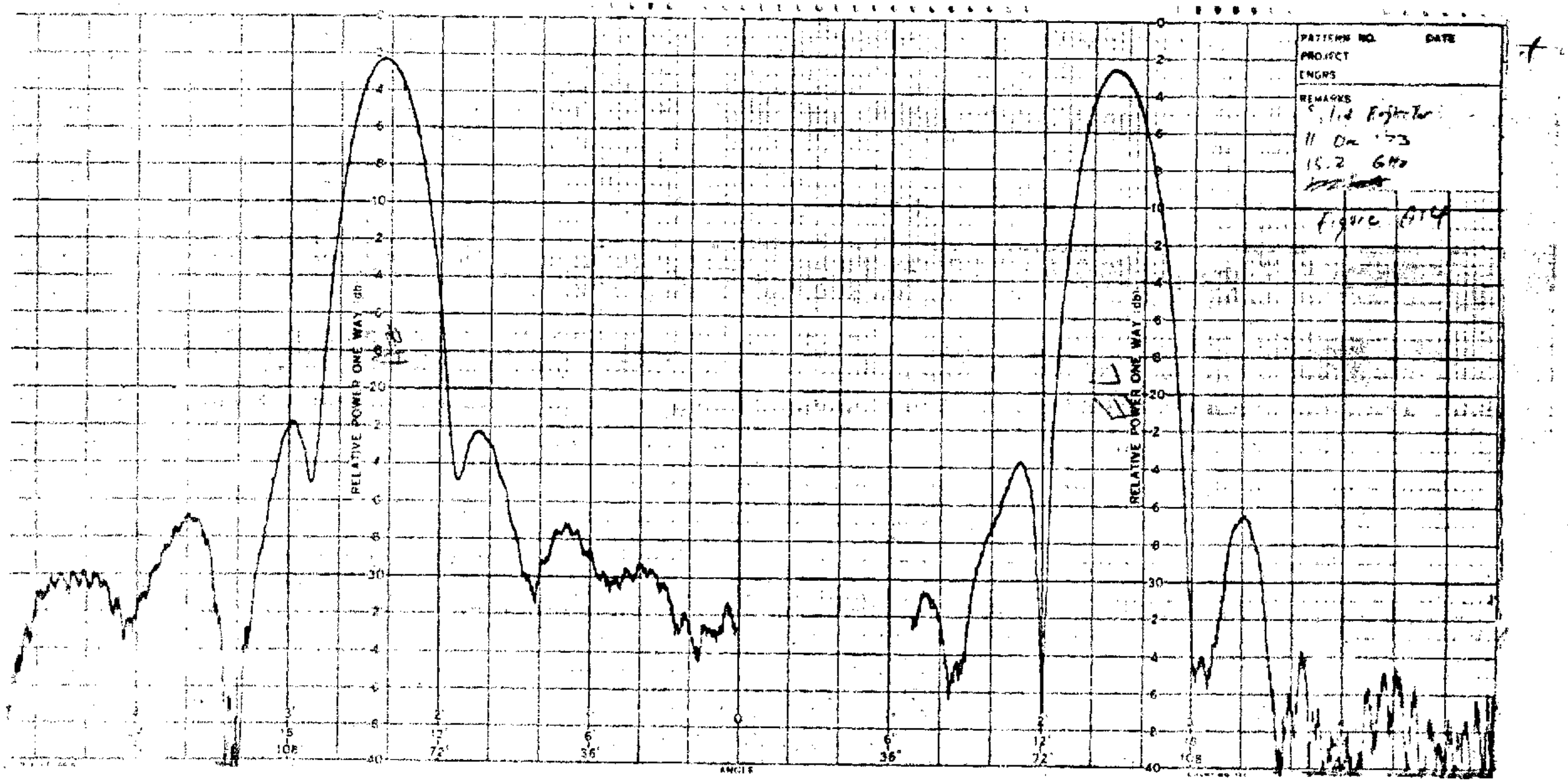

PATTERN NO.
DATE
PROJECT
ENGRS
REMARKS
RELATIVE POWER ONE WAY (db)
ANGLE

Figure A14

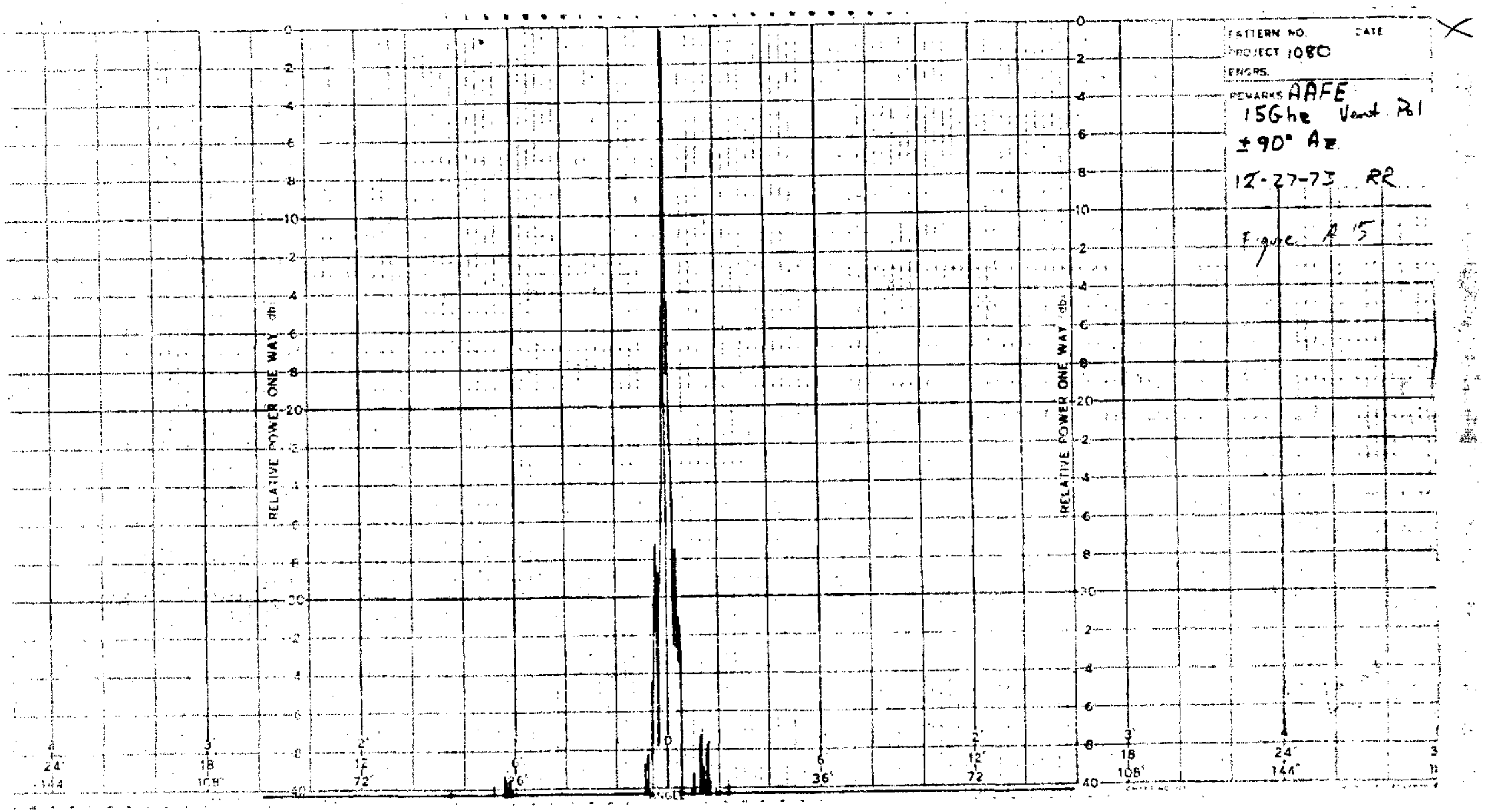

PATTERN NO.
DATE
PROJECT 1080
ENGRS.
REMARKS AAFE
15Ghz Vert Pol
±90° Az
12-27-73 RR
Figure A15
RELATIVE POWER ONE WAY db
RELATIVE POWER ONE WAY db

Figure A15

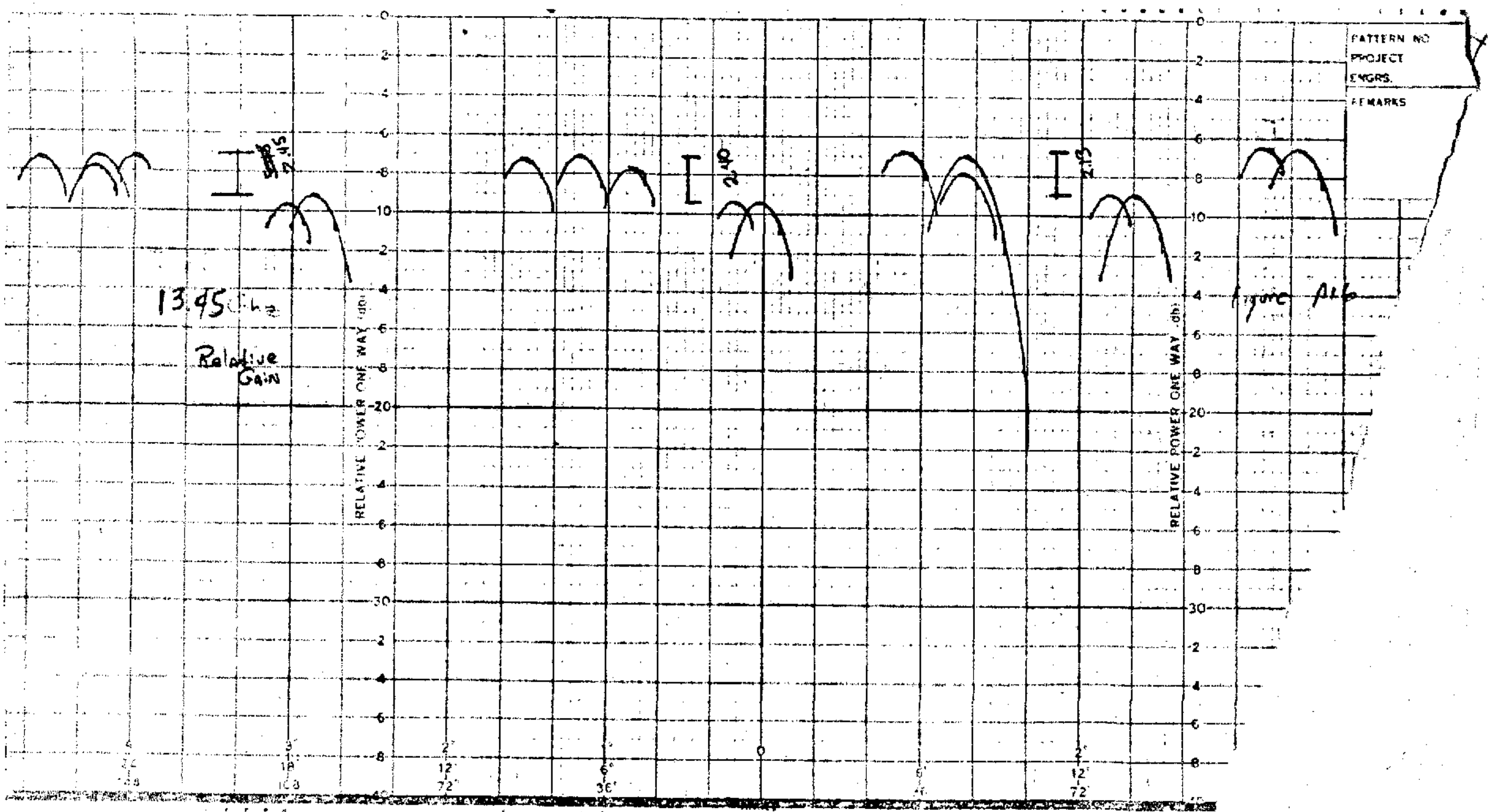

PATTERN NO
PROJECT
ENGRS.
REMARKS
13.45 Ghz
Relative Gain
RELATIVE POWER ONE WAY (db)
figure A16

Figure A16

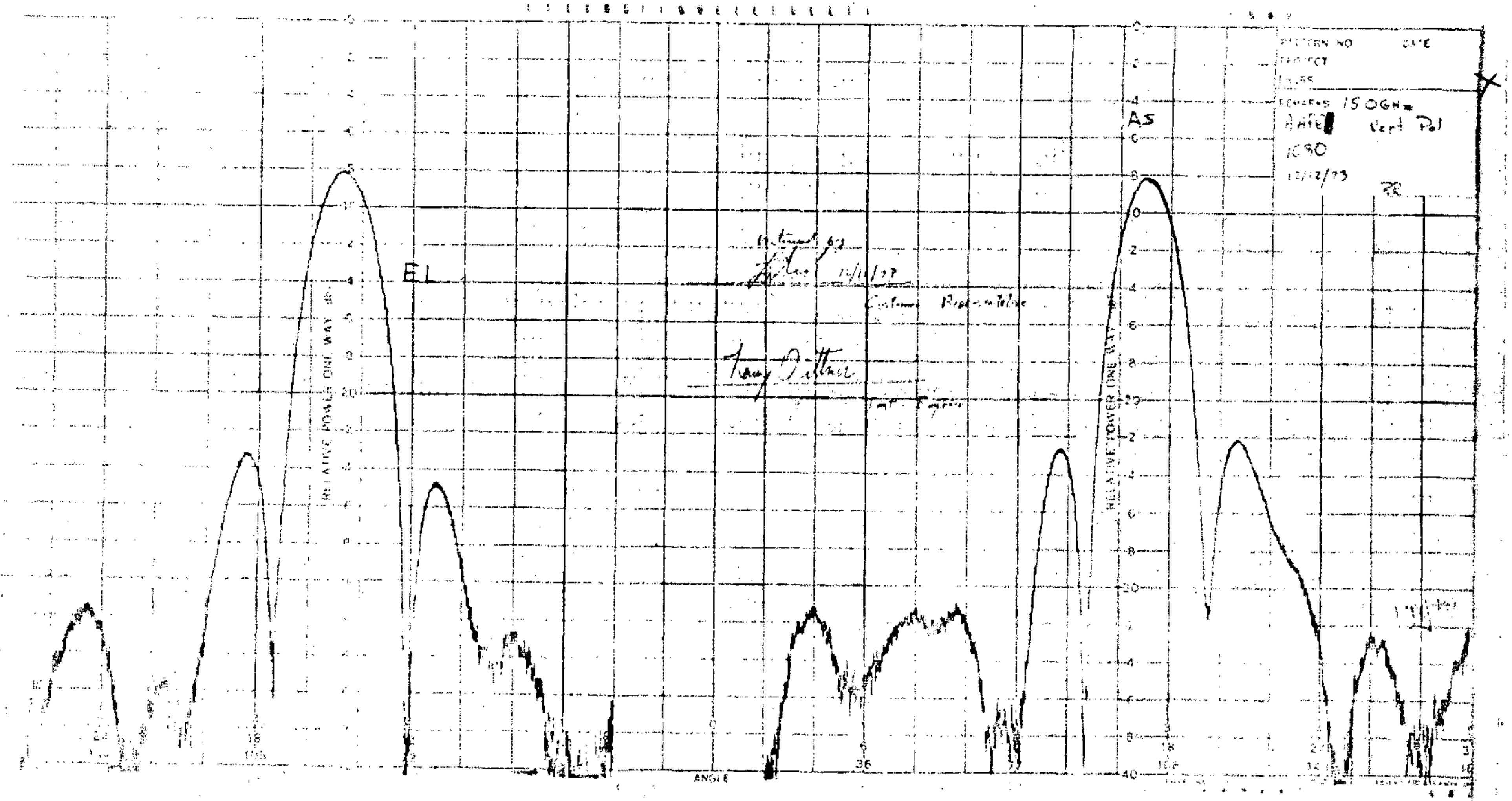

PATTERN NO
DATE
PROJECT
REMARKS 15.0 GHz
Vert Pol
1080
12/12/73
EL
AS
RELATIVE POWER ONE WAY
ANGLE
RELATIVE POWER ONE WAY

Figure A17

Test Equipment

Manufacturer	Model No.	Serial No.	Cal. Exp. Date

Comments:

Test Engineer ______________________ Date ______________________

Quality Control ______________________ Date ______________________

Customer Representative ______________________ Date ______________________

DCAS Representative ______________________ Date ______________________

APPENDIX C

THE PARABOLOID PROGRAM

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APPENDIX C

THE PARABOLOID PROGRAM

The Paraboloid Program was developed to provide a computer technique for the calculation of rms surface accuracy and axis location of parabolic antenna reflectors under arbitrary loadings. A general discussion of the program method is given below.

The input to the program consists basically of the spatial coordinates of points representing the theoretical reflector surface and a set of distortions of these points due to some form of loading. These distortions are obtained directly from STRUDL or SPACE or by measurement, and are used to calculate the spatial location of the deflected or distorted paraboloid. The program then applies statistical techniques to determine a mathematically "best-fit" paraboloid of revolution through the distorted points. This paraboloid is next evaluated to determine the angular location of the axis of revolution, the new location of the paraboloid vertex, and the change in focal length between the theoretical and best-fit paraboloid. Angular values of encoder rotation and feed deflection are inputted to the program and are combined with the above data to yield net values of absolute and encoder corrected azimuth and elevation pointing errors.

Finally, the axial rms deflection of the deflected points is computed with respect to both the best-fit and undistorted parabolic surfaces with and without the area and illumination weighting techniques described below.

The scheme for both area and illumination weighting is to adjust the deviations from the best-fit paraboloid such that the relative difference in area and illumination associated with each joint is taken into account.

Two illumination weighting functions are available in the program. A uniform aperture distribution such as is typical with DIELGUIDE feeds, or the following function:

$$\left[.3 + .7\left(1 - \left(\frac{R}{R_o}\right)^2\right)^P\right]^2$$

where R_o is the radius of the reflector, R is the radius to the point and the exponent P characterizes the illumination provided by the particular feed being used.

The projected area associated with each joint is computed and normalized with respect to the total projected area of the reflector for the area weighting factors.

The coordinates of the data points and deflections can be inputted to the program in several ways. The coordinates of the theoretical paraboloid can be imputted along with deflections in either the x, y and z coordinate directions or in the y (axial) direction only. Also the coordinates of the actual distorted points can be inputted to the program.