FINAL REPORT

FOR

ADVANCED EXTRAVEHICULAR SPACE SUIT (AES)

CONTRACT NAS 9-7555

70-6613 17 August 1970

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Los Angeles California

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17 August 1970

Prepared by Staff

Approved by Karl F. Jackson
K. F. Jackson
Lunar Programs Manager

N71-11177

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1.0 SCOPE

This final report is a summary of achievements of the AES program and includes conclusions and recommendations. A sizing program is defined in this document. Figures 1 through 5 illustrate the AES suit with views of the EX-1A suit.

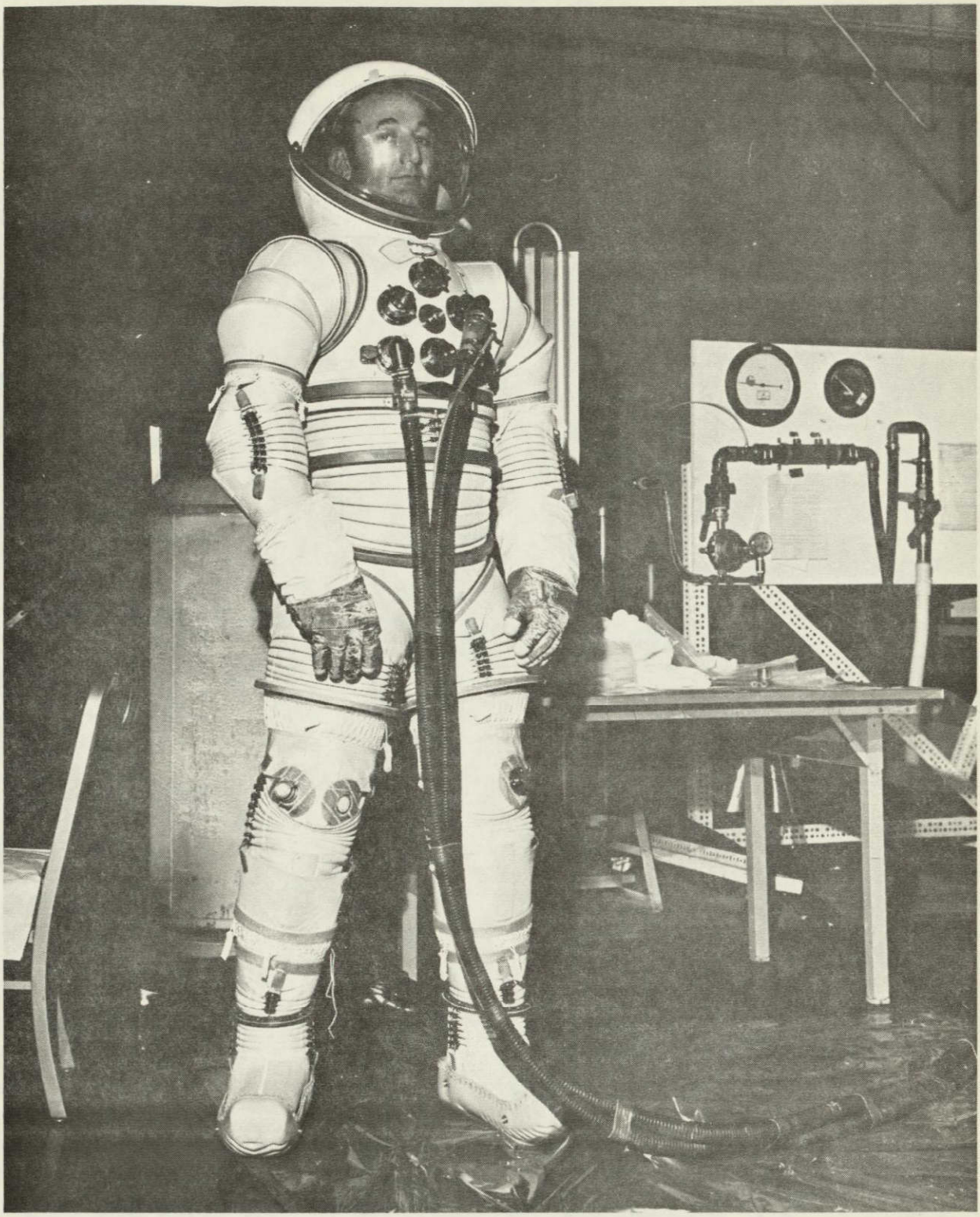
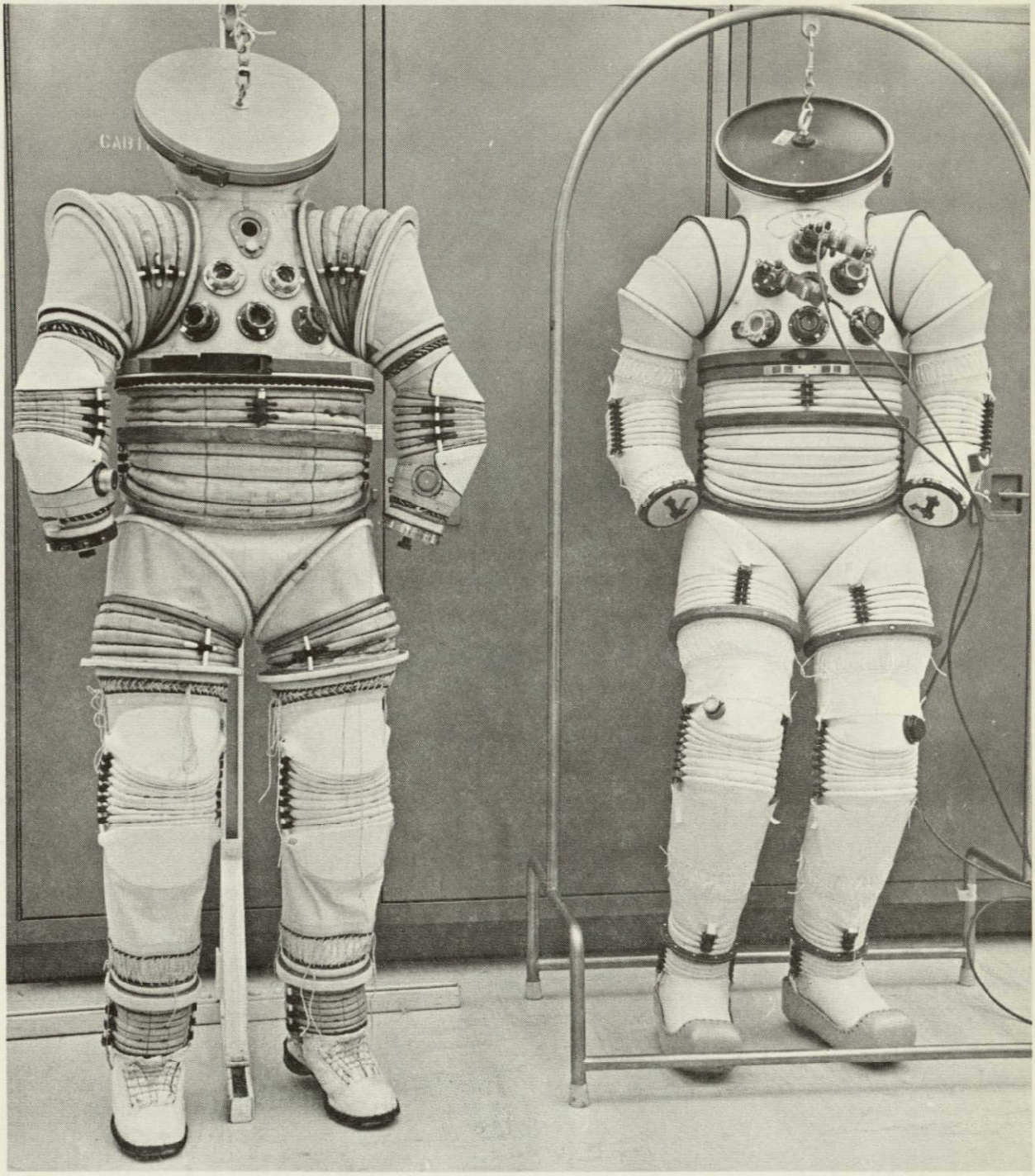


Figure 1. AES Suit - Manned - Visor Raised



EX-1A Suit AES Suit

Figure 3. Front View - EX-1A and AES Suit

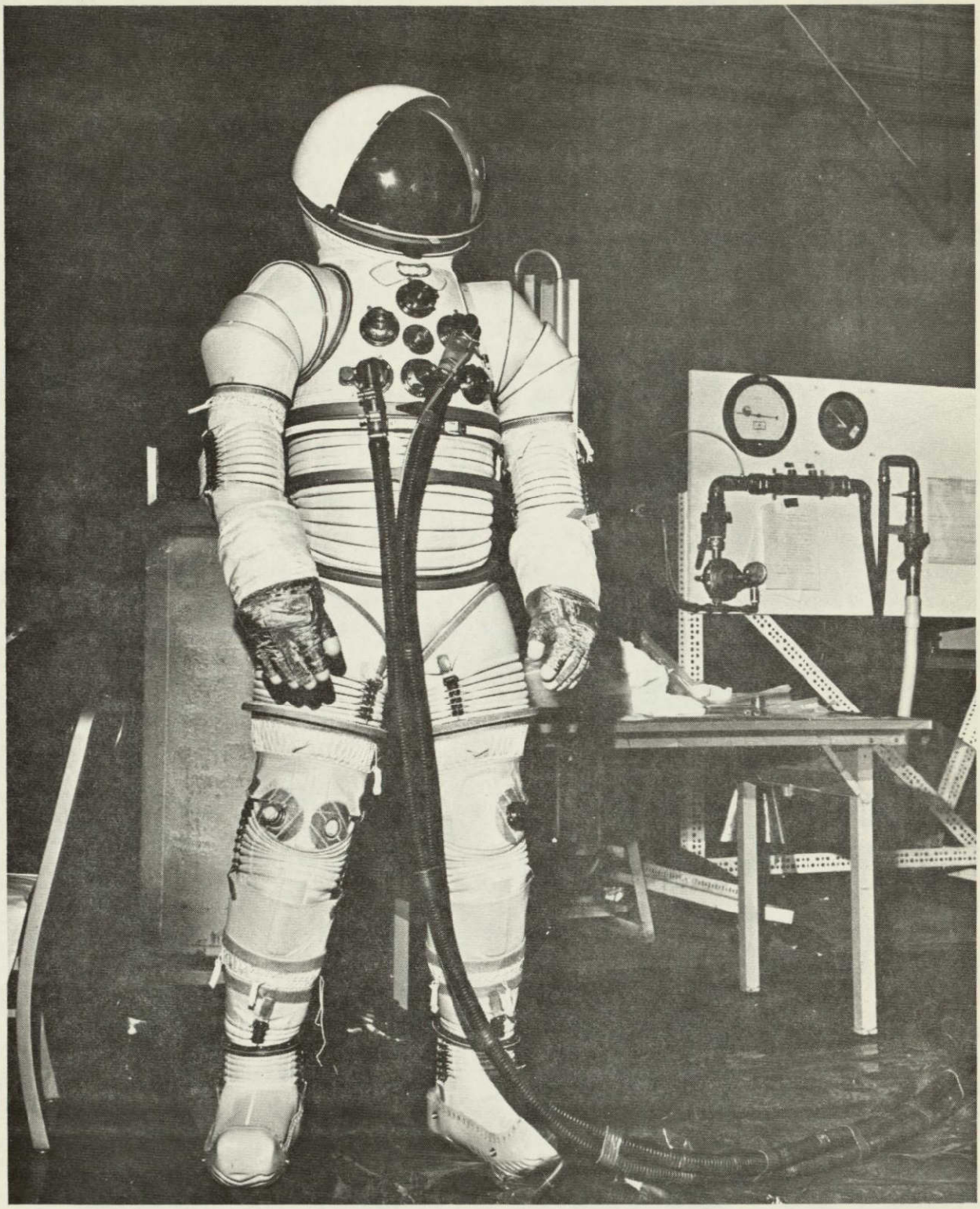
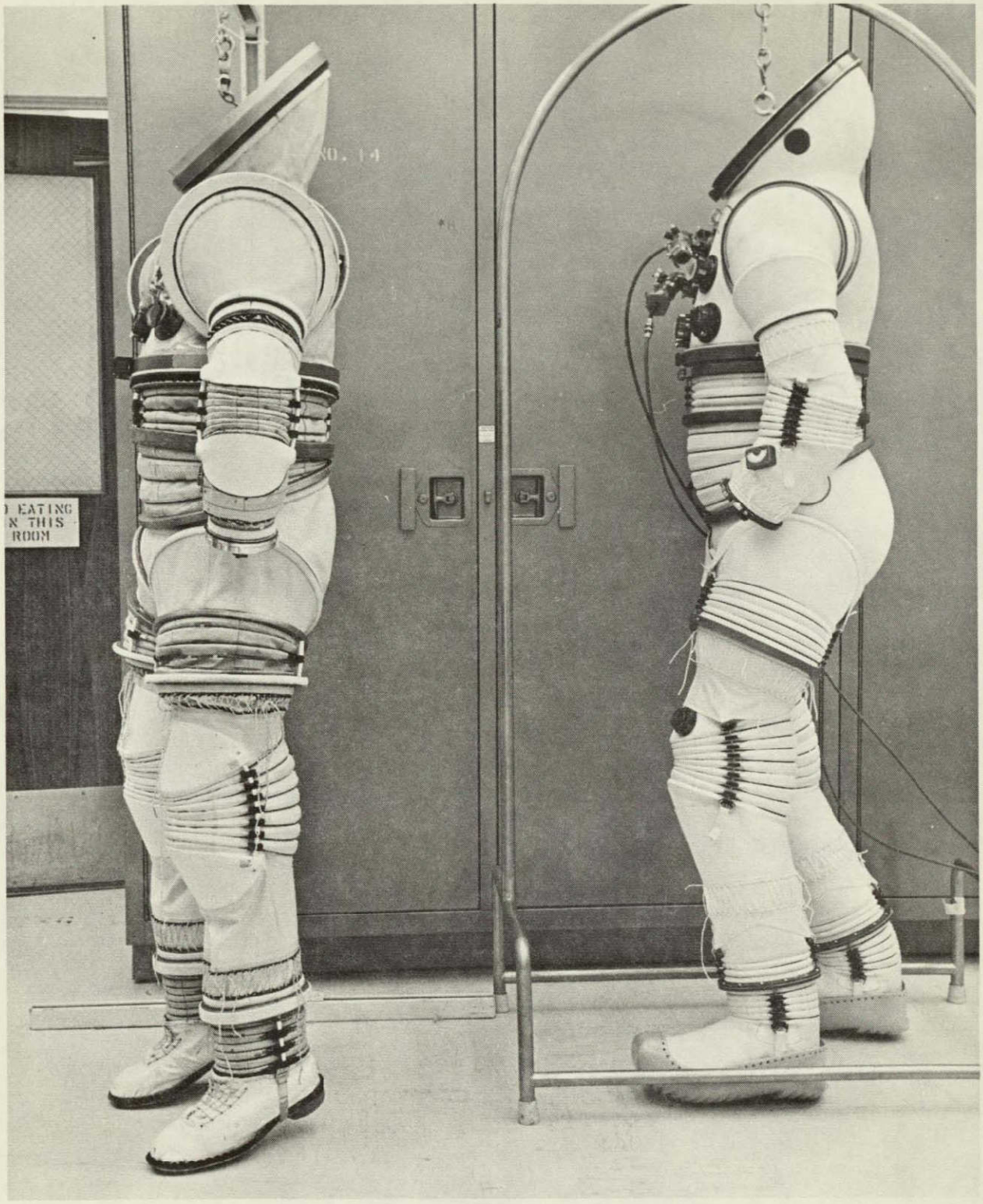
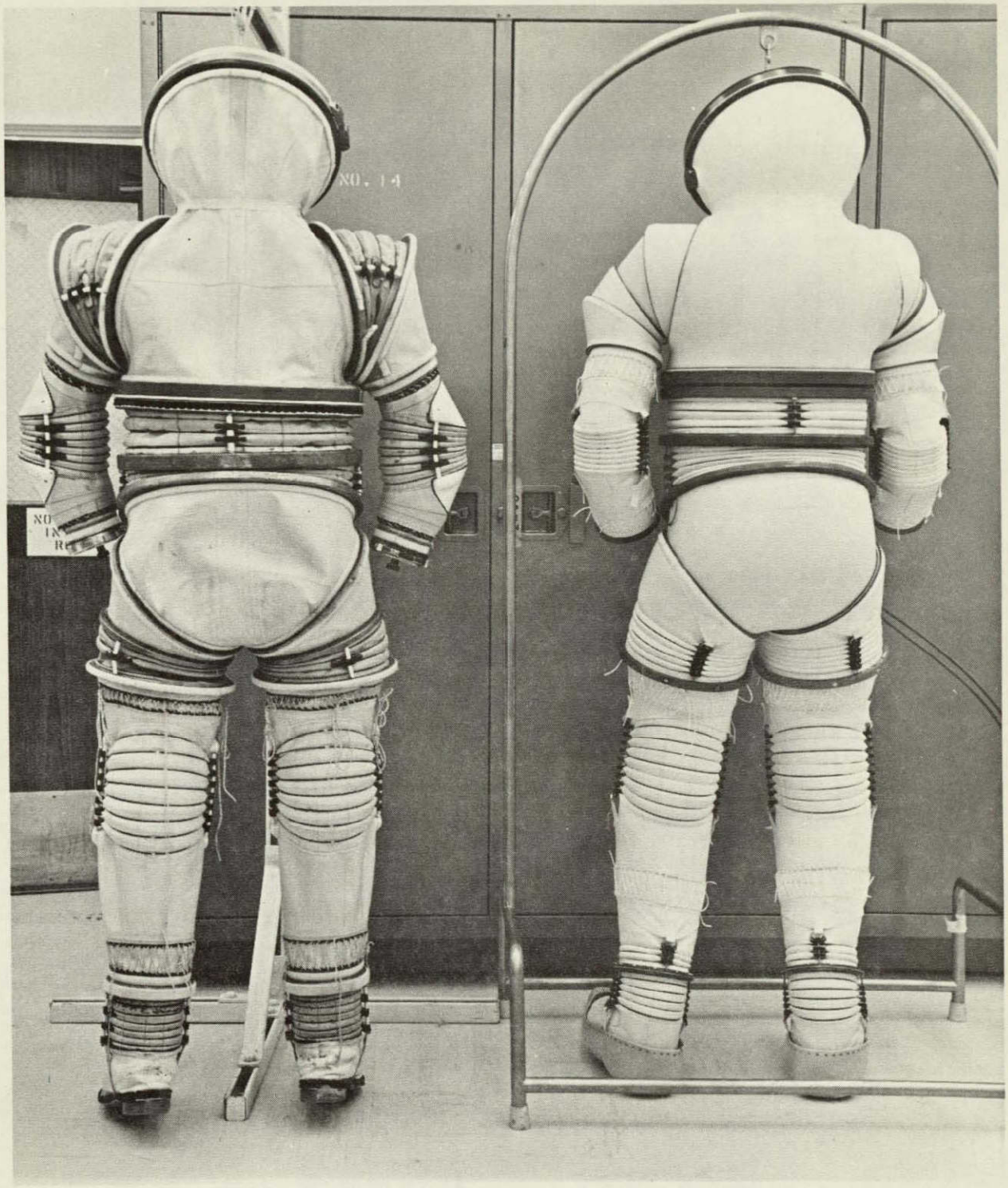


Figure 2. AES Suit - Manned - Visor Lowered



EX-1A Suit AES Suit

Figure 4. Side View - EX-1A and AES Suit



EX-1A Suit AES Suit

Figure 5. Rear View - EX-1A and AES Suit

2.0 PROGRAM MANAGEMENT AND CONTROL

2.1 PROGRAM MANAGEMENT

The AES program was organized in accordance with the program plan originally submitted as a portion of the proposal and subsequently updated/submitted as document 69-5495.

Figure 6 is the work breakdown structure established for the AES program (Ref. Fig. 6 of 69-5495). The program controls were established in general accordance with the WBS integrated into the AiResearch internal systems and procedures.

The organization of the AES is shown in Figure 7 (Ref. Fig. 3 of 69-5495). As can be seen, this program formed a portion of the Lunar Programs Office. The program manager, Karl F. Jackson, had the overall responsibility for successful completion of the program. The directors of quality control, reliability, and configuration management reported directly to him for this effort. In addition, the chief engineer, managers of materiel and manufacturing, and program administrator reported to Mr. Jackson.

Parallel AES programs were awarded to both AiResearch and Litton Industries. At program initiation, it was understood that one of these AES was NASA "baseline for Apollo 16 through 20. In light of this climate, AiResearch chose to undertake relatively major redesigns (shoulder breadth, stowability, etc.) to the prototype EX-1A version suit. This decision was made to ensure product superiori which would lead to flight status. In late October, AiResearch was advised that NASA had decided to baseline the International Latex A7L suit (with possible modifications for increased mobility = A7LB ≈ previously rejected A9L) per a management directive. Apparently the Apollo 11 data and existence of a Rover vehicle about Apollo 17, coupled with the PLSS excess capacity, indicated that metabolic rate reductions for constant volume suits were of little importance.

In December, 1969 it became apparent that a contract overrun was developing. The tooling and two major supplied items (ITMG, Helmet/LEVA) were chief contribut ($107,000) to this situation. A detailed financial analysis in early January, 19 indicated an even greater contract overrun could be expected. By then, a costly ring stress problem had also occurred. In negotiation with NASA on this subject, elected to reduce the scope of the program to arrive at a $100,000 overrun rather than cover the entire projected $300,000 overrun. In this NASA scope reduction,

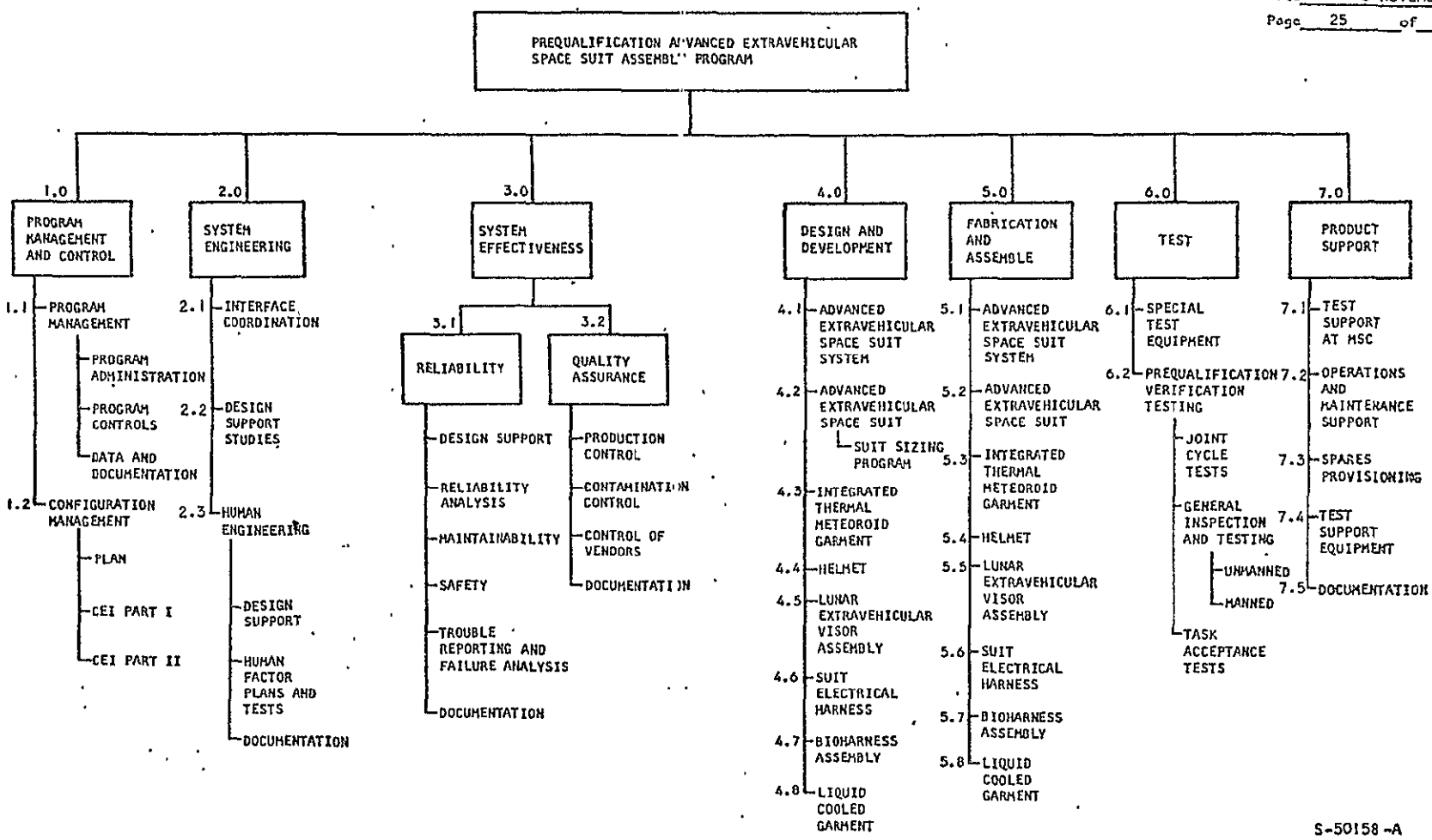


Figure 6. Work Breakdown Structure

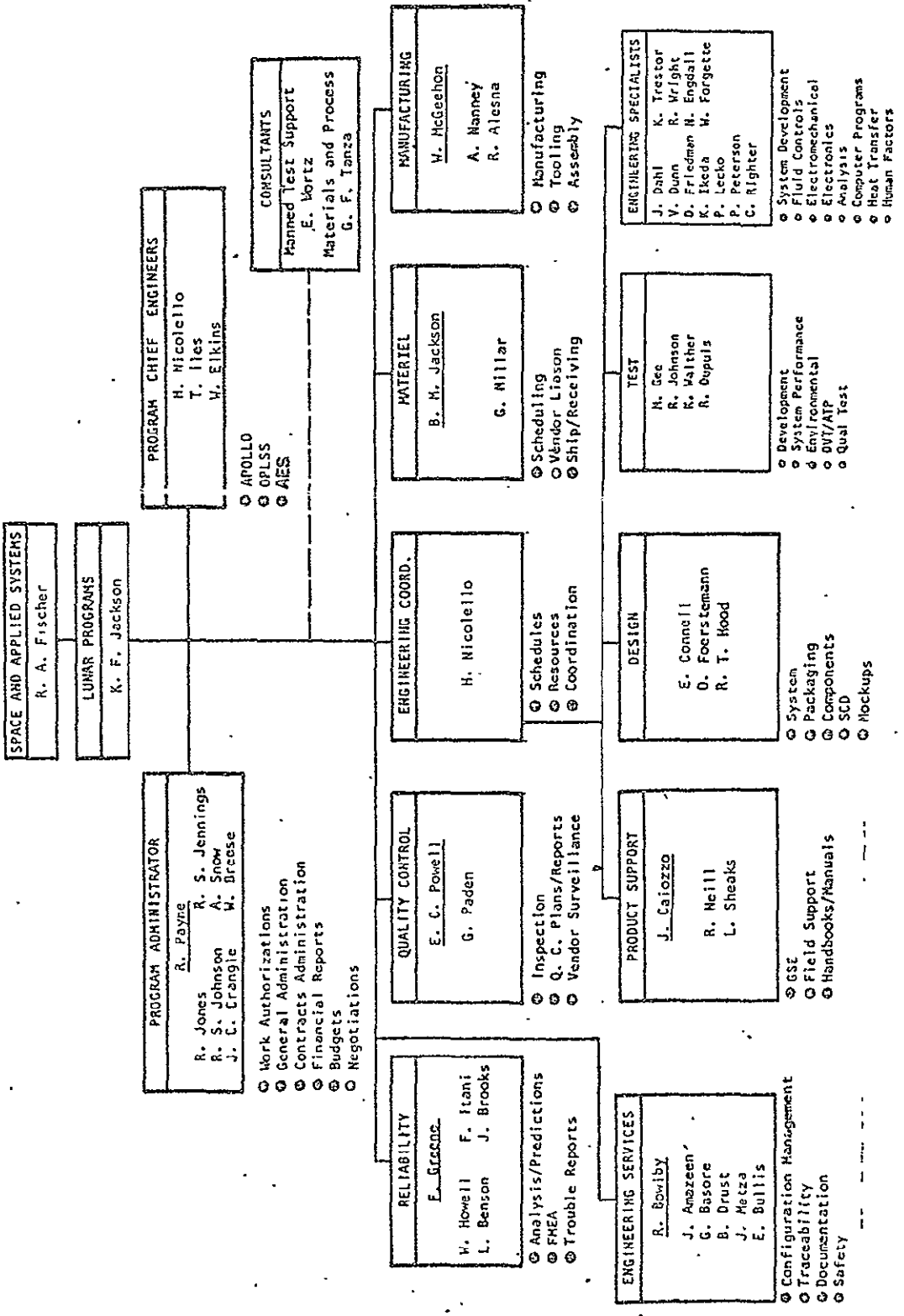


Figure 3. Lunar Programs Organization

Figure 7. Lunar Programs Organization

certain requirements (e.g. product support and suit sizing) were entirely eliminated from the program; the number of deliverable suits was reduced from 2 to 1; the test phase was reduced to life cycle testing of a representative nature; and documentation submittals on a one-time only basis were required.

A second ring failure (after the suit was assembled) at proof pressure caused further schedule delays and cost increases. This ring was subsequently redesigned and the suit accepted by NASA in April, 1970 despite an out-of-spec leakage condition. Tests at AiResearch indicated the pressurized mobility was excellent, the unit stowed in a minimum volume, and generally its overall performance was acceptable.

The development nature of the AES program can be recognized in retrospect at this time. The modular sizing, repair, and replacement program leading to suit reusability has not been completed but could ultimately lead to an interesting cost-effectiveness study for the future. The advancements in manufacturing techniques using break-out plaster mandrels and the single wall laminate construction advantages lead to a reliability improvement. Finally, the technical characteristics of passive stability joint maintenance, mobility, comfort, minimum time self-donning/doffing, and unprogrammed motions provide additional concept proof.

2.2 CONFIGURATION MANAGEMENT

The Configuration Management office prepared and submitted a Configuration Management Plan, Document No. 69-5507. Comments were received from NASA and were incorporated into the plan. The following subparagraphs define the other requirements and achievements of the Configuration Management office.

2.2.1 Documentation

A list of all Type I and Type II documents prepared for the AES program is shown on the Documentation List which forms Appendix A. Part I and II of the MEI/CEI Specifications, the End Item Test and Inspection Procedures (PDA's), and the Cleaning Preservation, Packaging, Handling, Storage and Shipping Procedure were reviewed during the Prequalification Article Review (PQAR). A mutually agreeable list of comments form part of the PQAR minutes.

2.2.2 Specifications

A list of all AiResearch Specifications which have been released for use on the AES hardware is contained in Appendix B.

2.2.3 Drawings

A numeric list of the current drawings which defines the released engineering for fabrication of the Torso Limb Assembly (TLA), Helmet, and Lunar Extravehicular Visor Assembly (LEVA) is shown in Appendix C.

2.2.4 Parts List

Complete indentured parts lists for the TLA, Helmet, and LEVA were prepared. These lists served as the basis for the "As Designed" list prepared by Configuration Management and the "As Built" list prepared by Quality Assurance. The complete "As Designed" and "As Built" lists are found in the Acceptance Data Packages of the above listed three end items. The lists for the LEVA are contained in Appendix D and E respectively to illustrate the format used.

3.0 SYSTEM ENGINEERING

The following subparagraphs define the system engineering accomplishments.

3.1 STRESS ANALYSIS

The stress analysis was an important function in the design of the AES. Appendix F demonstrates the initial stress calculations. Appendix G demonstrates the stress calculations following failure of a ring.

3.2 MATERIAL SELECTION

Material selection was based on information gathered from the following sources: (1) NASA Document MSC-NA-D-68-1, Revision D, "Nonmetallic Materials Design Guidelines and Test Handbook"; (2) Garrett/AiResearch Materials and Process Engineering Group; (3) prior experience; (4) Technical information bulletins; (5) special tests; (6) analytical studies; and (7) various other sources. It must be noted that the materials used for the Liquid Cooled Garment (LCG), Suit Electrical Harness, Biomed Harness, and Integral Thermal Meteoroid Garment (ITMG), are the same materials used in existing Apollo flight hardware and therefore only verification of exact duplication was made. Table I lists the materials applicable to the Torso Limb Assembly (TLA), the Lunar Extravehicular Visor Assembly (LEVA), and the Helmet.

3.3 CONTRACTOR FURNISHED EQUIPMENT (CFE)

The items listed on Table 2, because of their prior use on the Apollo program, were contractor furnished. In some cases, such as in the gas connectors slight modifications were made to the gas plenums to be compatible with the TLA upper torso and vent system. Interface with life support systems was unaffected.

3.4 SYSTEMS INTERFACE

The Portable Life Support System (PLSS) interface is accomplished by use of a specially constructed harness made of nylon webbing attaching to the Torso Limb Assembly (TLA) at the body closure ring and at the neck area of the upper torso. The attachment brackets are permanently affixed at these points. The harness is fully adjustable and would be stowed with the TLA.

TABLE 1

LIST OF MATERIAL

	MATERIAL	SPECIFICATION	USE
1.	Electroformed shapes, nickel	EMS 258	Waist rings, hip rings, body closures
2.	Molded teflon stress relieved Hi density stock	EMS 372	Coating used on all convolut restraint and compression ri
3.	Polytetrafluorethylene felt (Armalon)	EMS 395 Cl. B.	LEVA visor and ITMG visor
4.	Soft, resilient silicone elastomer (Silastic 35)	EMS 93002	Body closure seal and neck s
5.	Polytetrafluorethylene impregnated aluminum (hard anodize)	EMS 93021	Coating used for all bearing races
6.	Suit material, Neoprene coated Nomex	EMS 93022	Fabric used for pressure gar layup
7.	Suit material, Neoprene coated nylon ripstop	EMS 93024	Fabric used for the primary laminant in the convolute ar of the pressure garment and system
8.	Polycarbonate, clear, fire resistant	EMS 93025	LEVA visor assembly
9.	Silicone fluid (SF-1148)	EMS 93026	Primary lubricant for all bearings
10.	Polyester impregnated glass cloth laminate	EMS 93029	Helmet vent duct, knee and e stiffening vent system trans ducts, boot inner liner, LEV shield
11.	Silicone sheet (Silastic 440) self-sealing	EMS 93036	Medical injection patch

TABLE 1 (Cont)

	MATERIAL	SPECIFICATION	USE
12.	Insulation, molded fiberglass, phenolic resin bonded	EMS 93038	Boot insulation
13.	Stainless steel cable, teflon coated	EMS 97293	Convolute restraint system
14.	Adhesive, 140 RTV silastic	ECS 105-021-9001	Bonding agent for medical pat
15.	Adhesive, CN125W Neoprene	ECS 105-078-9001	Coating for Nomex and ripstop fabric
16.	Adhesive, and activator Epon 828	ECS 117-014-9001	Visor bonding-vent duct to wa ring bond
17.	Adhesive, and activator 8615 Urelane, Urethane	ECS 117-047-9001	Bonding agent for fabric to metal and fabric to fabric
18.	Adhesive, and activator N136 Neoprene	ECS 117-048-9001	Fabric to fabric bonding agen
19.	Compound, Loctite, Grade "C"	ECS 219-003-9001	Bonding of screws and bearin ball keepers
20.	Compound, RTV S5370 foam and catalyst	ECS 219-157-9001	Boot inner comfort liner
21.	Compound, RTV 630	ECS 219-214-9001	Boot outer sole
22.	Grease, Krytox 240AC	ECS 369-042-9002	Lubricant for waist and neck seals
23.	Ink, stamp pad, white and black	ECS 429-501-9004	Marking of fabric parts
24.	Primer, Chemloc 218	ECS 588-001-9001	Metal primer for use with Uralane 8615
25.	Primer, Locquic "N"	ECS 588-005-9001	Primer for use with Loctite compound

TABLE I (Cont)

MATERIAL	SPECIFICATION	USE
26. Primer, Chemloc 205	ECS 588-027-9001	Primer for use with N136 adhesive
27. Sealant, Silastic 732 RTV clear	ECS 687-025-9001	Bonding agent for Silastic 3 torso and neck seals
28. Tape, closure, nylon, hook section	S 9388	Affix comfort pads inside su
29. Tape, closure, nylon loop section	S 9389	Affix comfort pads inside su
30. Primer, A 4094	ECS 588-007-9001	Used for priming boot sleeve (fabric) prior to bonding
31. Compound, 93-072	ECS 219-236-9001	Used for bonding boot inner comfort liner to boot sleeve
32 Cord, dacron, polyester	MIL-C-43256A	Used as convolute restraint
33. Webbing, nylon	MIL-T-5038 Type IV	Joint attachment (skirt to convolute restraint)
34. Tape, nylon, loop	MIL-T-26089	Attachment for arm/leg sizin lacing
35. Cord, lacing, nylon	MIL-C-5040 Type 1A	Sizing of arm and leg assemb
36. Pad, comfort, Ensolite, Type AL	MIL-P-24333	Comfort pad inside suit

TABLE 2

CONTRACTOR FURNISHED ITEMS

ITEM	PART NAME	MFG PART NO	PROCUREMENT NO	VENDOR
1	LCG Connector	9203	SCD958606-02	Airlock
2	PGA Recepticle Assembly	9202	SCD958606-01	Airlock
3	LCG Plug	2407	SCD958606-03	Airlock
4	LCG Flange	2553	SCD958606-04	Airlock
5	Electrical Connector - 61 pin	——— Part of Item 27 ———		———
6	Housing	A9046	Supplied with Item 27	Airlock
7	Screw on Housing	9125	Supplied with Item 27	Airlock
8	Right Wrist Disconnect	9314-01	SCD958519-02	Airlock
9	Right Vent Channel	1608R	SCD958519-04	Airlock
10	Left Wrist Disconnect	9315-01	SCD958519-01	Airlock
11	Left Vent Channel	16088	SCD958519-03	Airlock
12	Pressure Relief Valve	9334	SCD958526-01	Airlock
13	Pressure Relief Clamping Band	2371	SCD958526-03	Airlock
14	Pressure Relief Mounting Ring	2372	SCD958526-02	Airlock
15	Pressure Relief "O" Ring	6061-1	SCD958596-05	Airlock
16	Pressure Relief Plug	2370	SCD958546-04	Airlock
17	Inlet, Lower Gas Connector	9321-01	SCD958605	Airlock
18	Inlet, Upper Gas Connector	9321-02	SCD958604	Airlock
19	Exhaust, Lower Gas Connector	9324-01	SCD958602	Airlock
20	Exhaust, Upper Gas Connector	9324-02	SCD958603	Airlock
21	Feed and Water Port	9401-01	SCD958609	Airlock
22	Feed Port Cover	9184	SCD958610	Airlock
23	UCTA Leg Mounted Disconnect	Z-1202-F3	Part of Item 25	Seaton Wilsor
24	UCTA Disconnect Press. Cap	Z-1229-3	Part of Item 25	Seaton Wilsor
25	UCTA Disconnect Assembly	Z-1201-3	SCD958587	Seaton Wilsor
26	Bio-Harness	770A100-4D	SCD958019	Cicoil
27	Suit Electrical Harness	769A100-4E	SCD958021	Cicoil
28	Inner Electrical Flange	958542	Same	AiResearch
29	Outer Electrical Flange	958543	Same	AiResearch
30	Liquid Cooling Garment	BW-1029-001	CEI958573A	B. Welson
31	ITMG	BW-1092-001	CEI958568A	B. Welson
32	Pressure Gage (6 psid)	D572-C-100	SCD958522	Dyna Magnetic
33	Ring, Back	958524	Same	AiResearch
34	Mount, Gage	958523	Same	AiResearch
35	Nut, Mounting	958525	Same	AiResearch

The Remote Control Unit (RCU) interface is provided by a permanently attached pouch located on the Integral Thermal Meteoroid Garment (ITMG) bib. Two inside straps pickup the PLSS bracket on the TLA and support the load of the RCU. The RCU can be removed from this pouch by opening the loop tape closure.

Lunar module restraint is provided by two Velcro patches attached to each boot. Both the patch on the heel and the sole are attached to the boot using Dot fasteners. These restraints are easily removable and will normally be stowed with the TLA.

One of the command module interfaces with the TLA is accomplished by a locking device located in the heel of the boot which mates with the foot restraint assembly of the couch. This locking device is a fiberglass laminated form which is molded in place during boot fabrication and provides a rigid controlled dimension at each heel. The heel is inserted in the restraint clip in a rolling motion and is thus held in place until that motion is reversed.

Gas connectors of the TLA are the same as presently used on existing Apollo flight suits and will mate with the command module and lunar module environmental control systems and the PLSS. No special adapters are required.

Electrical connections on the TLA and subsequently to the communications carrier and bio-medical instrumentation are compatible with existing Apollo interface requirements for command module, lunar module and PLSS operation. No special adapters are required.

The Integral Thermal Meteoroid Garment (ITMG) is attached to the TLA using Velcro fasteners, loop tape and lacing cord. Anti-rub pads are provided to minimize abrasion from the PLSS. The ITMG bib allows for gas, cooling, and electrical connection to the TLA from the PLSS without sacrificing thermal protection.

Interface for liquid cooling is provided by use of an Apollo type liquid cooling receptacle mounted on the TLA. Cooling fluid is passed through this receptacle to the Liquid Cooled Garment (LCG) from the PLSS. Connections are compatible with present Apollo flight hardware and adapters are not necessary.

3.5 WEIGHT CONTROL AND MONITORING

A system of weight control and monitoring was established with monthly reporting a part of the progress report.

Weight goals were established early in the program and for the most part were tracked without too much difficulty. The ITMG, the LCG, the Bio-medical Harness and the Electrical Harness all were within target weights and in most cases were below.

The Helmet weight was very close to the calculated weight but slight variations in forming (free blown) resulted in approximately a 5 percent weight increase over the target.

The LEVA, because of redesign in the latching mechanism and material selection for the outer shield, was 1.26 lbs heavier than the calculated weight.

The TLA was by far the greatest reason for being overweight from a system standpoint. The maximum allowable weight of the TLA was 35.70 lbs with the addition of one extra LCG connector. The actual weight was 46.13 lbs, an increase of 10.43 lbs over the allowable. The boots, electroformed rings, and portions of the vent system represent the majority of the excess in this case. Optimization of design and fabrication techniques could reduce this figure significantly on future programs.

Table 3 is a tabulated breakdown of the target and actual weights for the seven CEI's (contract end items) and their associated equipment.

3.6 SIZING

An important portion of the analysis phase of the program was the development of a modular sizing system. The basic attempt of this system was to use interchangeable hardware; that is, bearings, connectors, chemcast or electroform rings and common interfaces between all suit modules. The sizing system is based upon an analysis of an Apollo astronaut population. Anthropometrics yielded a system in which three upper torso widths, three lower torso lengths, two arm lengths, two leg lengths and three boot sizes, would be provided. In addition to the boot sizes, custom fabricated inner comfort liners would be made for each individual astronaut. Based on the modular system and the fact that any module of any suit system would be capable of three lunar missions, an analysis of suit requirements for Apollo flights 7 through 14 was made. In one case, it was assumed that no suit which had been on

TABLE 3

WEIGHTS

	Target	Actual
TLA	*35.70 lbs	46.13 lbs
LEVA	3.57	4.83
ITMG	18.00	16.507
Electrical Harness	.451	.405
Bio-Med Harness	.210	.198
Helmet	2.120	2.250
LCG	4.40	**3.423
Gloves	2.400	2.380
Communication-Carrier	1.600	1.710
UCTA	.520	.450
Fecal Containment System	.340	.320

* Includes one extra LCG connector

** Dry weight

the lunar surface would be used again for flight and in this case, the equivalent of 43 suits would be required for flights 7 through 14. In the second analysis, it was assumed that suits could be reused for lunar flight but limited to three lunar landings which is the performance requirement of the C-1-A suit as established by CEI specification. In this case, the total number of suits and spares required was approximately 32. Further, a statistical analysis looked at minimum and maximum number of suits which would be required and it yielded a range from 24 to 48. Refer to Appendix H for the sizing system concept.

4.0 SYSTEM EFFECTIVENESS

4.1 RELIABILITY

4.1.1 Program Planning and Control

The Reliability Program Plan Report No. 69-5449 was completed and submitted to NASA/MSC via letter No. ARSJ:9312:0919, dated 19 September 1969. NASA comments and corrections to the plan (letter No. EC62-69-0118, dated 3 October 1969) were subsequently incorporated in the plan and tentative approval (except for the Operational Log Section as explained below) was obtained during Baseline Review.

Reliability program reviews were conducted with NASA/MSC at the Guideline and Baseline Review meetings and documented in the minutes and action items. Reliability requirements for subcontractors were established in AiResearch Report No. 69-5635 and summarized for NASA in the progress report for October 1969.

4.1.2 Design Specifications

Part I and Part II MEI/CEI Specifications were reviewed by Reliability.

4.1.3 Failure Modes, Effects and Criticality Analyses

A preliminary FMEA was completed and submitted to NASA for comments. Those comments were received via letter No. EC62-70-0321 and attached to the final FMEA report.

4.1.4 Design Reviews

The Design Review Program Report No. 69-5556 was submitted to and approved by NASA. Supporting checklists were issued in Report No. 69-5555 entitled "AES Design Checklists." Design reviews were initiated and attended by reliability.

4.1.5 Failure Reporting and Correction

In-house trouble reports initiated during the program are on file at AiResearch. FIAR No. C-AR-0001 was written during initial acceptance test of the AES and was completed and subsequently approved by NASA on 28 April 1970.

4.1.6 Materials Program

The nonmetallics materials list (Approved Materials List, Report No. 69-5881) was prepared in close coordination with NASA personnel and submitted via letter No. ARSJ:0003:0106 dated 6 January 1970. A sample of suit material was prepared and submitted to NASA the week of 19 December 1969 in accordance with NASA letter No. EC62-69-0234, for preliminary outgassing tests; these tests were completed successfully.

4.1.7 Operational Logs

Formats for the operational logs were developed to satisfy the new requirements contained in NASA letter No. EC62-69-0082 dated 16 September 1969. It was necessary to carefully develop these logs to ensure that all modes of usage could be covered while providing for the accumulation of all mandatory cyclic and time oriented data. For this reason the log formats were not finalized until late in the program. However, the logs were successfully implemented for the AES as confirmed at PQAR the week of 18 May 1970.

4.2 QUALITY ASSURANCE

Summarized below are the different types of documentation and program effort areas of the AES Quality Program. Comments one through five represent documentation generated by or under the responsibility of program quality.

1. Seven monthly quality status reports
2. AES Quality Program Plan, 69-5397
3. Cleaning, Preservation, Packaging, Handling, Storage, and Shipping Procedure, 70-6003
4. Seven end item test and inspection procedures
   a. Helmet, AT958007-01
   b. LEVA, AT958009-01
   c. LCG, AT948017-01
   d. TLA, AT958013-01
   e. Suit Elec. Harness, AT958021-01
   f. Bio-Harness, AT958019-01
   g. ITMG, AT958015-01

5. Two hundred-twenty six in-process test and inspection procedures covering all aspects of fabrication and testing of the program.

Program quality reviewed and gave final approval to all production drawings, which totaled one hundred and eighty-three; reviewed and approved all manufacturing process documents, which totaled two hundred and twenty-six; and inspected fifty-two tools with a 92.3% acceptance rating.

In fabrication and test inspection we had a total of 1024 inspection points with an overall acceptance rating of 94.5%. However, it should be noted that some of these rejections were major and had serious impact on the AES Program, i.e., waist ring failure (see 958013-01 data package) stopped the program progress for more than five weeks.

In procurement inspection 293 units were inspected with an overall acceptance rating of 98.73%. Quality control and DCASO approved 321 purchase orders with an 100% acceptance and approval.

The material review board for the AES Program was presented to NASA-MSC and approved in the month of December 1969.

All AES subcontractors were surveyed by AiResearch and found to be acceptable to produce space flight type hardware.

5.0 DESIGN AND DEVELOPMENT

5.1 ADVANCED EXTRAVEHICULAR SPACE SUIT SYSTEM

The entire AES system consisted of seven Contract End Items (CEI's) and three items which were Government Furnished Equipment (GFE). The CEI's consisted of the Torso Limb Assembly (TLA), the Integral Thermal Meteoroid Garment (ITMG), the Lunar Extravehicular Visor Assembly (LEVA), the Suit Electrical Harness, the Bioharness Assembly, and the Liquid Cooled Garment (LCG). The three GFE items consisted of the Extravehicular Pressure Gloves, the Communications Carrier and the Waste Management System. The Waste Management System consists of the Urine Containment Device (UCD) and the Fecal Containment System (FCS).

5.2 TORSO LIMB ASSEMBLY (TLA)

Although the TLA is based on the X1A suit configuration, a number of major changes were made in the design. See Figure 3, 4 and 5 for comparison. These design changes were made to achieve the design goal of the suit, that is, to assure flight compatibility of the system on the lunar surface, in the lunar module, and in the command module. This meant that the TLA would have to stow within the volumes available under the couch in the command module and in the existing A7L bags in the Lunar module. The X1A was virtually unstowable under these conditions because of the techniques used in achieving proper convolute spacing and in the techniques used in the arms and legs for picking up cable loads from the convoluted portions of these sections. The TLA uses a completely collapsible joint system and a newly developed five-bearing shoulder joint. The new joint reduced the overall shoulder width of the suit from 26-1/2 inches to approximately 23 inches. In addition, the new shoulder joint is completely stowable and the entire suit, with ITMG, will stow in a volume of 14-3/4 inches high by 28 inches long by 26 inches wide. See Figures 8 and 9 for a pictorial representation. These dimensions are compatible with the stowage volumes available for the suit. The suit is designed to meet the medium-long size of the Air Force sizing system and, in addition, vernier sizing is provided at all extremity segments.

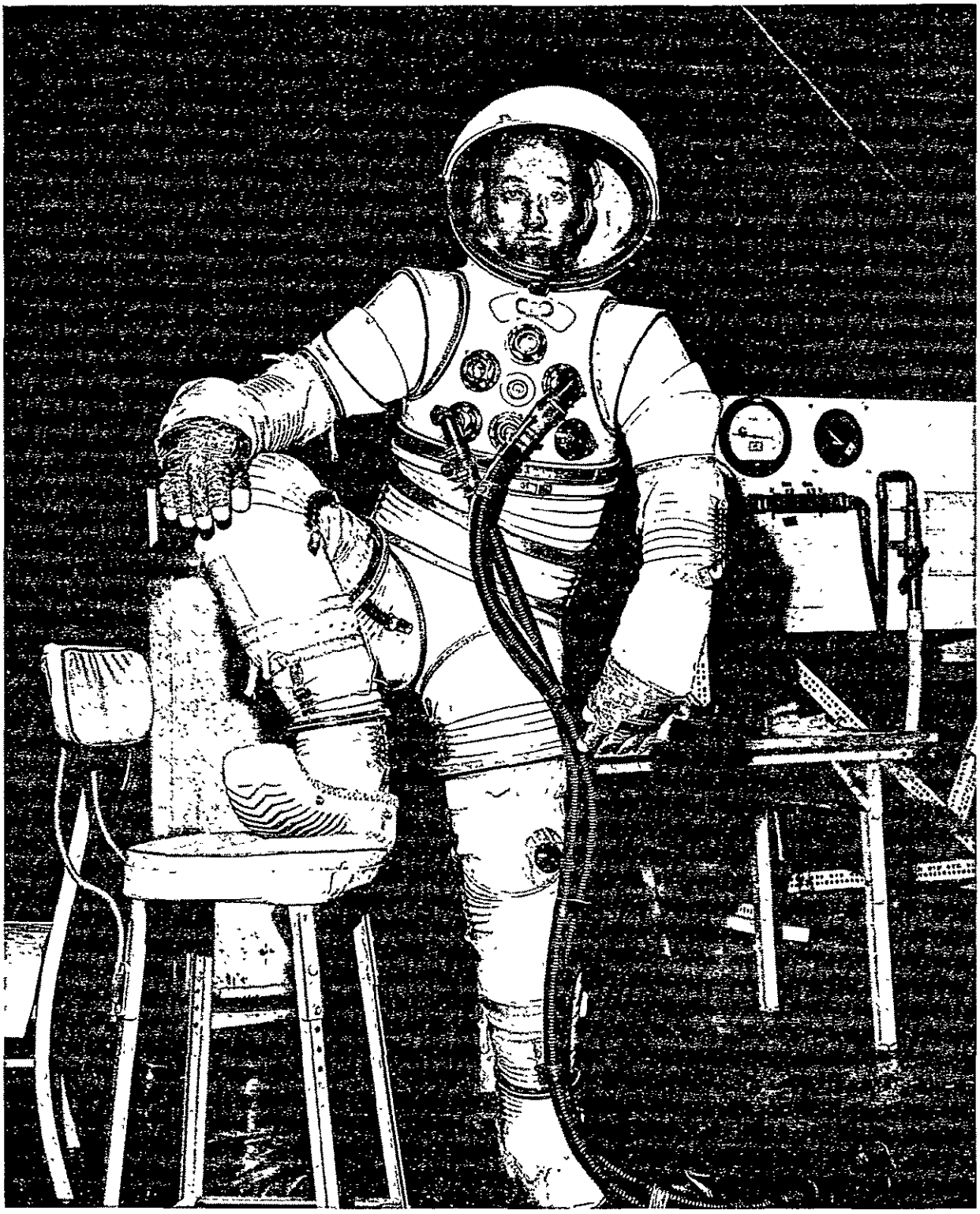


Figure 10. AES Suit Mobility



Figure 11. AES Suit Mobility



Figure 12. AES Suit Mobility



Figure 13. AES Suit Mobility

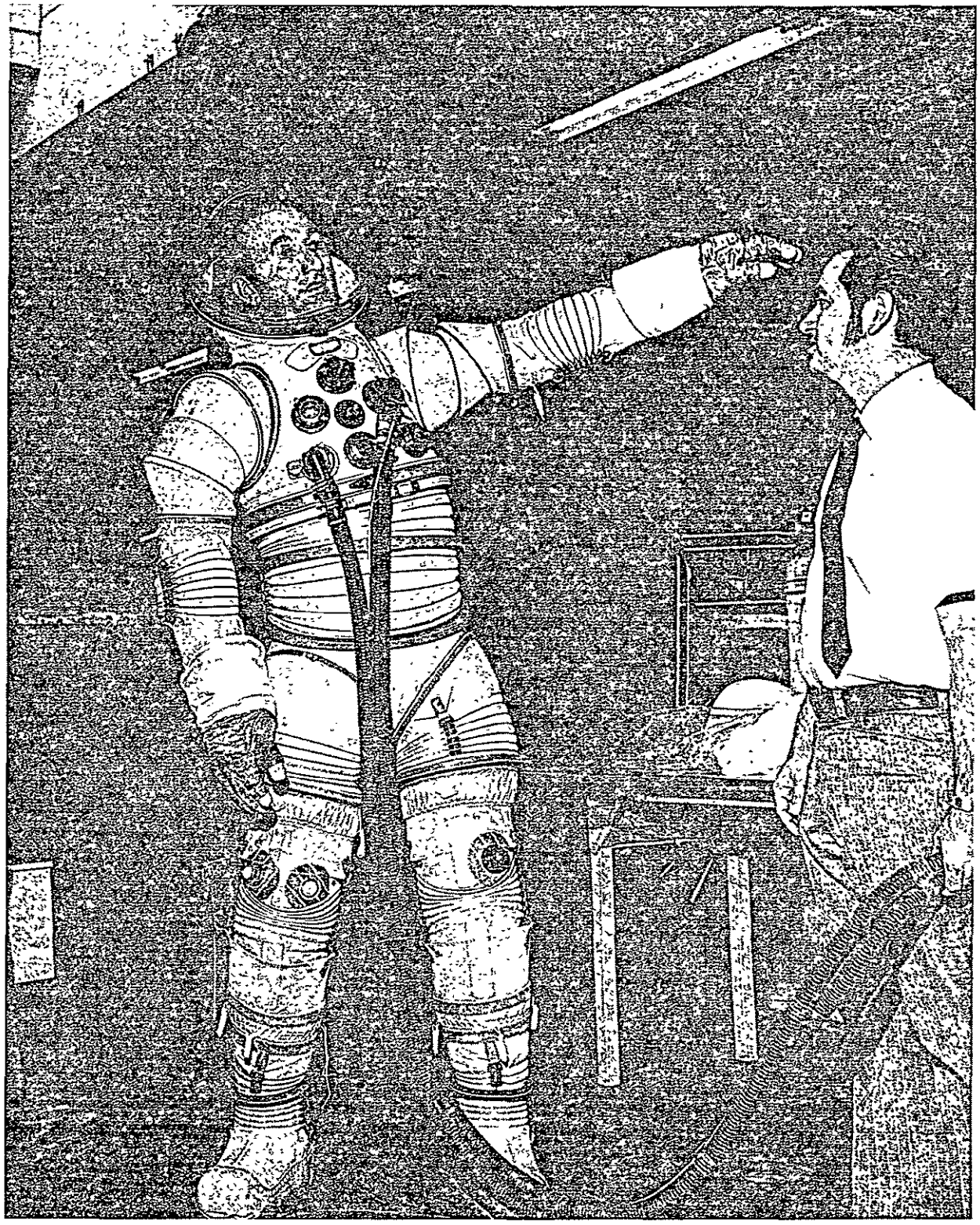


Figure 14. AES Suit Mobility

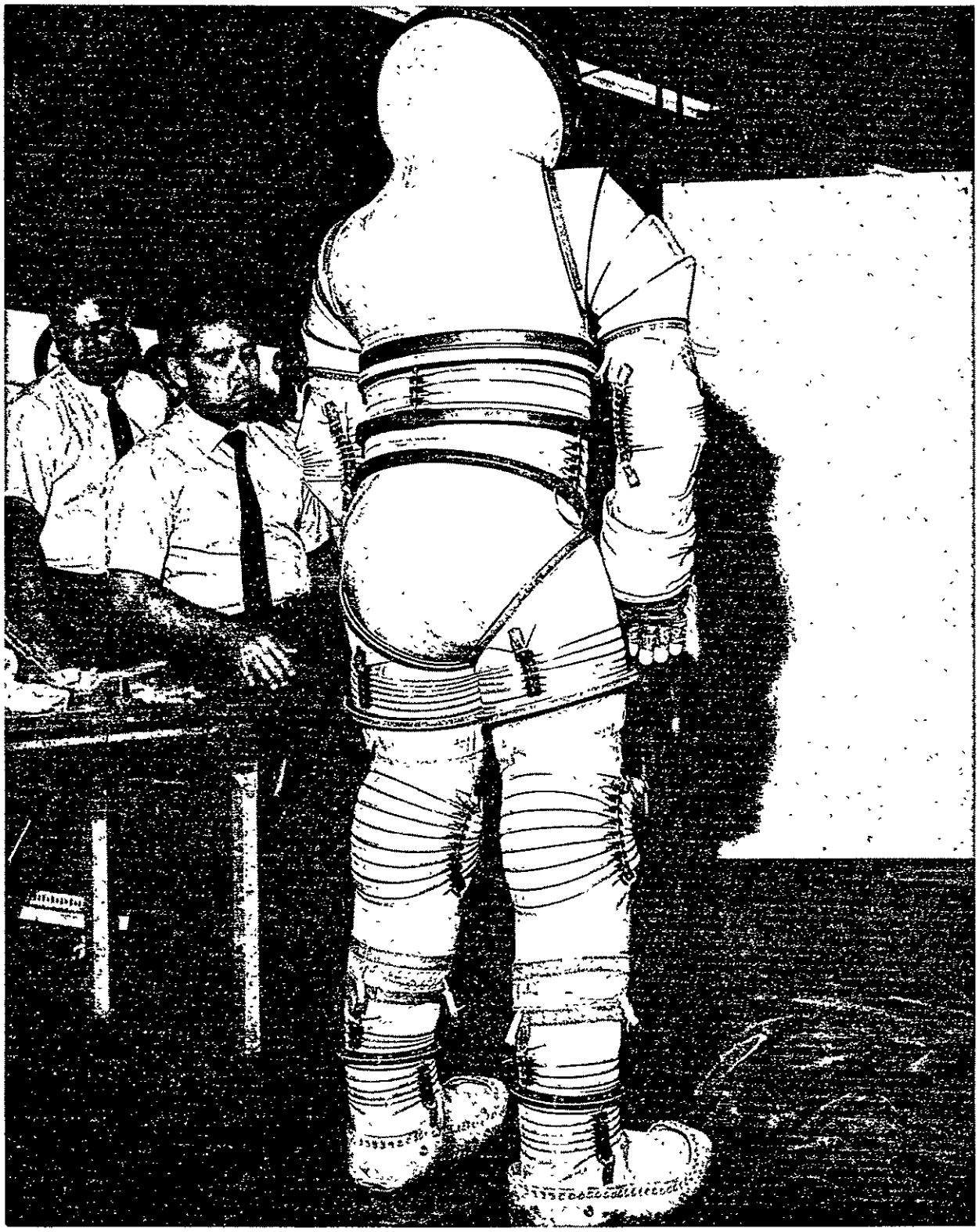


Figure 15. AES Suit Mobility

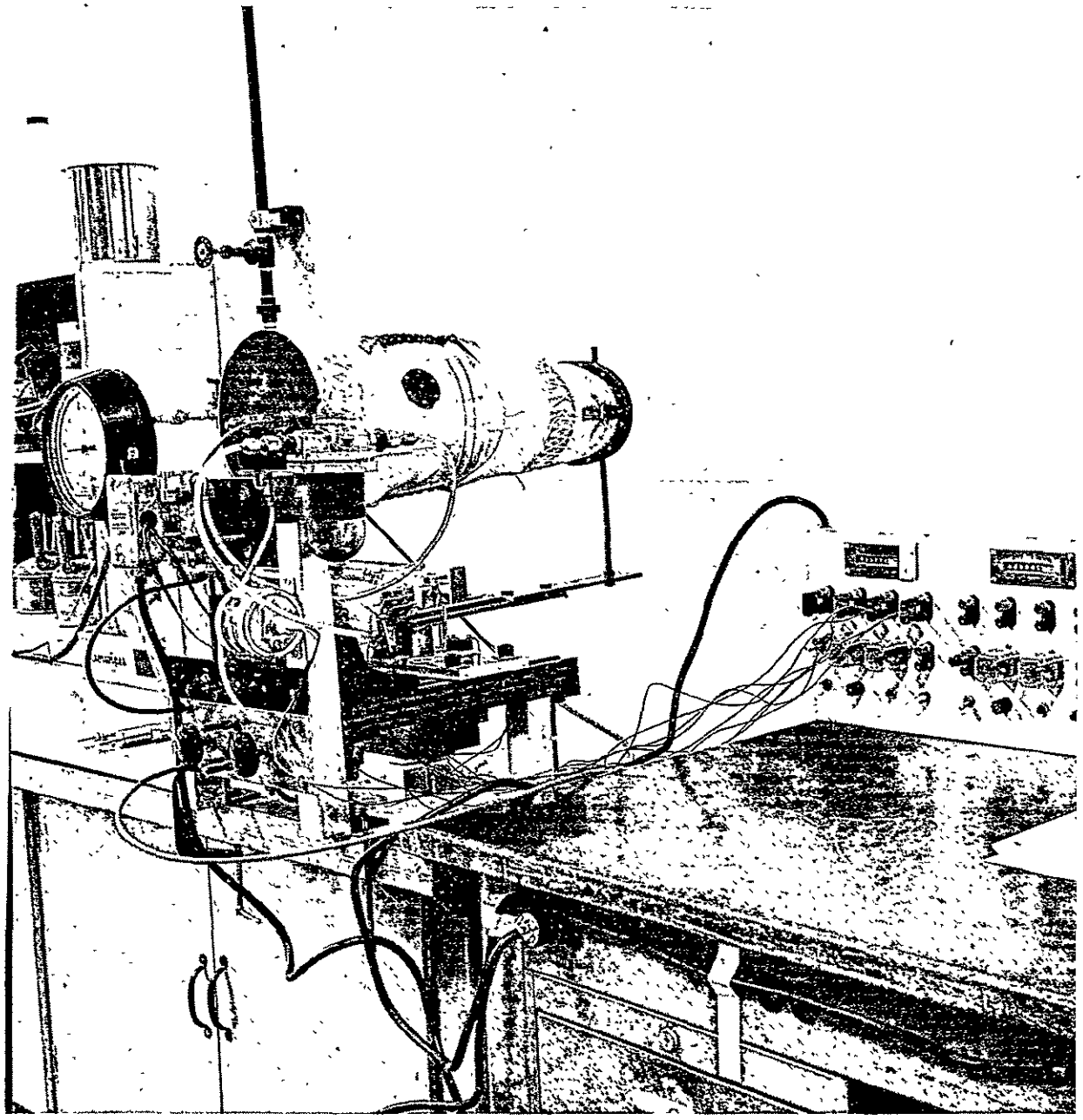


Figure 16. Typical Cycling Setup

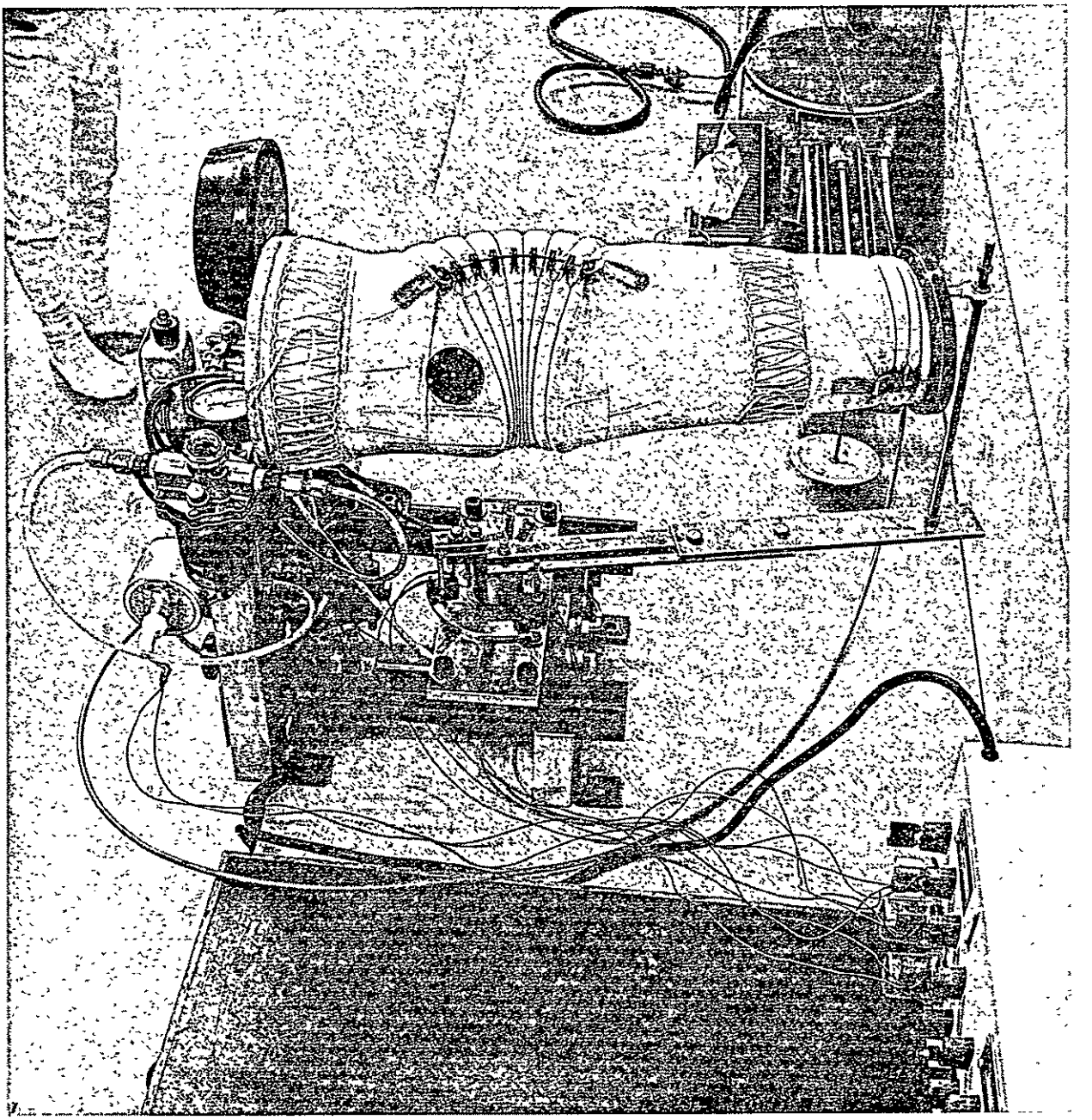


Figure 17. Typical Cycling Setup

range as compared to 48° range in the XIA. A major problem area existed due to the failures in test of the electroformed rings which form a part of the waist joint and torso closure. These failures, in part, accounted for schedule slippages and cost overruns in the program. New concepts were being utilized in the design and fabrication of these rings and it must be so stated that the failures were due to design detail rather than to material or fabrication techniques and manufacturing processes.

5.2.4 Hip Joint

The hip joint consists of two opposed bearings and an interposed wedge and convoluted section. Again, the hip joint utilizes a collapsible convoluted system so that minimum storage volume can be used.

5.2.5 Knee Joint

The knee joint consists of a stowable single axis convoluted section of eliptical cross-section. Both the knee and elbow use a secondary sleeve to pick up single-point loads from the cable and distribute the load circumferentially into the primary pressure barrier of the suit. This system eliminates the high unit loading of the pressure barrier and reduces the distortion of the convoluted section itself.

5.2.6 Ankle Joint

The ankle joint consists of two single axis joint sets so configured that their planes of flexure are 90° apart.

5.2.7 Vent System

The vent system of the TLA utilizes a unique race track section wire reinforced tubing. This system produces considerably less impedance to gas flow then the conventional multiple coil spring reinforcement tubing. Measured flow delta P at 3.7 psig and 7 acfm was only 1.3 inches of water. The vent system is similar to that used in the Apollo suit in that positive inlet flow is directed to the Helmet and, in the IVA mode, to the waist while return flow occurs from the extremeties. Automatic interconnect between the upper and lower torso vent lines is accomplished during the torso closing. Not only is the vent system far more efficient than the conventional systems but it weighs approximately 30 to 40 percent less than a comparable system.

5.2.8 Boots

A multiple laminated EVA boot is integral with the TLA. The boot consists of an outer Silastic 630 sole laminated to a molded glass felt intersole which in turn is bonded to a contoured fiberglas innersole. This multiple laminate thermal sole is then bonded directly to the pressure barrier. The boot is contoured so that normal walking and balance can be maintained while pressurized. A unique custom molded silastic foam comfort liner is provided. These comfort liners are made from master molds taken directly from the subject's feet. They provide maximum contact area for load distribution on both the lower and upper portions of the foot. The foot-toe angle is set at approximately 20^0 and this is in compliance with the contour of the boot itself. The vent lines are bonded directly into the foamed comfort liner.

5.2.9 Torso and Helmet Closures

The torso closure and helmet closure utilize a safety-latched clamping band technique. To open, the pins in the clamping band are driven up ramps to a larger clearance diameter. The safety latching mechanism consists of a safety lock button which must be depressed before the latch can be rotated 90^0 which then unlocks the clamp bond. Translation of approximately 3/4 of an inch then moves the clamp band to the clearance diameter allowing the separation of the upper torso or helmet. The bands are so designed that a pneumatic lock occurs whenever the suit is pressurized. If misalignment occurs during closure, the safety latch cannot be rotated into a locked position which is a positive indication of a safely made closure. The locked latching system provides a three-movement requirement for opening; that is, (1) the safety button is depressed; (2) the latch is rotated; and (3) the band is translated.

5.2.10 Comfort Liners

Individual quilted dacron and nylon comfort pads are provided at each knee, at each elbow, at the front and back of the waist joint, across the shoulders, and at the front area of the torso. These pads are easily removable and can be used at the option of the wearer of the suit. A padded segment similar to a bicycle seat is provided for the lower torso. This provides a means of maintaining a proper eye reference point when the subject is seated.

5.2.11 Mission Interfaces

The TLA provides interfacing with system requirements in that it has a cable loop available for the Lunar Module restraint system. The boots are so designed that they will interlock with the Command Module couch. The UCTA transfer valve is incorporated into the right leg as is an injection patch. PLSS attachment brackets are provided at the torso closure and just below the helmet latching mechanism. A feed port is provided at the helmet area.

5.2.12 Problem Areas

As a result of redesign of the waist ring joints, considerable additional weight was added to the TLA and this along with the unexpectedly high weight of the EVA boots resulted in an overall overweight condition of 9.29 pounds.

The distortion of the number one bearing in the suit led to excessive leak rates so that at 3.7 psig the leakage rate was slightly over one liter per minute. Modifications of the mounting technique of this bearing would eliminate this problem and would also reduce the torques.

Obviously, a follow-on development program for the boot, ring and bearing mounting would be in order. In spite of the problem area mentioned, the production of a markedly improved system compatible EVA suit in a period of ten months indicates the basic engineering soundness of the approaches taken in the TLA development.

5.3 INTEGRAL THERMAL METEOROID GARMENT (ITMG)

5.3.1 ITMG

The ITMG was fabricated for AiResearch by B. Welson and Company. The ITMG design is based on the design of a similar garment for the X1A. The basic layup is similar to that used in the Apollo suit program in that it is a multi-layer system using Super-Beta cloth, aluminized Kapton and Beta cloth marquiesette, aluminized mylar and dacron scrim and coated ripstop interliners. Additional overcovers of teflon cloth is used wherever rubbing would occur between the multiple segments of the ITMG. The segments which form the complete ITMG comprise the LEVA cover, upper torso, lower torso, left and right upper arms, left and right lower arms, left and right hips, left and right legs, left and right boots and the bib.

5.3.2 LEVA Segment

The ITMG for the LEVA covers the rear quadrant of the hemisphere of the helmet or LEVA segments. It contains a unique overvisor thermal segment which can be raised or lowered by the astronaut as required. This, in combination with other LEVA segments, provides a variable field of vision from a full spherical quadrant to something less than 1/16 of a spherical section.

5.3.3 Upper Torso Segment

The upper torso segment is a shirt-like covering which overlaps the shoulder portion of the upper arm segments so that the shoulder portion is tucked beneath the upper torso segment. The interliner at the overlap of the shoulder is a layer of teflon fabric. The upper torso segment contains a flap for access to the feed port and a flap for access to the helmet latching device. Four large flap segments completely cover the torso closure after clo-closure is made. These lower flaps are designed so that they can be velcroed to the upper shirt section to aid in donning the suit. The upper torso segment is loop-tape laced in the vicinity of the upper torso of the TLA and in the vicinity of the neck closure.

5.3.4 Lower Torso Segment

The lower torso segment covers the area from the torso closure to the crotch of the suit. This includes the dual axis waist joint and lower section of the lower torso. Sufficient fabric is gathered and maintained in the gathered position with elastic strapping to allow complete unencumbered range of the waist joint. The lower torso segment overlaps the hip joint segments and, in the area of the overlap, an interlining of teflon fabric is provided. The lower torso segment is loop-tape laced to the corresponding portion of the TLA at the upper and lower rings of the waist joint.

5.3.5 Left and Right Upper Arm Segments

The upper arm segments cover the shoulder joint areas immediately adjacent to the upper torso down to an area just above the elbow joint. The upper arm sleeve is loop-tape laced to the first wedge section of the shoulder joint immediately adjacent to the upper torso and underlaps the corresponding section of the upper torso segment. In the area of the underlap, an overcover of

teflon cloth is provided. The corresponding portion of the upper torso segment has an interliner of teflon so that teflon on teflon rubbing occurs when the shoulder is moved. Similarly, the overlapping section of the upper arm segment has an interliner of teflon cloth where it overlaps the lower arm segment.

5.3.6 Left and Right Lower Arm Segments

The lower arm segments are velcroed to the corresponding parts of the TLA and can easily be moved to provide access to the sizing adjustment areas of the upper and lower arms. The left lower arm segment contains a flap which covers the pressure gage and is secured by use of a glass velcro attachment.

5.3.7 Left and Right Hip Segments

The hip segments are secured to the TLA hip joints by use of velcro. The hip segments underlap the crotch area of the lower torso segment and overlap the leg segments. Because of the close proximity of both hips in the crotch area, almost the entire outer surface of the hip joint segments are teflon covered.

5.3.8 Left and Right Leg Segments

The right leg segment contains two flaps so that the UCTA valve and the injection patch can be reached. Both legs are velcroed to the corresponding upper and lower leg sections and can easily be moved to provide access to the sizing adjustment areas of the legs. The right leg segment contains a flap for access to the pressure relief valve. The leg segments overlap the boots just above the ankle area and in the overlap areas, teflon cloth is fixed to both surfaces.

5.3.9 Left and Right Boot Segments

Each boot segment is laced through a series of grommets to the EVA sole on the boot. It is tucked under a flap provided in the outer sole of the EVA boot. Sufficient material is present to allow complete motion of the two-axis ankle joint and the entire boot is covered with an outer cover of teflon cloth.

5.3.10 Bib Segment

The bib segment is an overcover for the upper torso segment and is donned after hookup to all PLSS connections. The bib segment is velcroed and snapped

to the upper torso. The bib segment also contains a thermal layup envelope which the remote control unit for the PLSS fits into. This unit is loop-tape laced to the bib segment. Immediately beneath the mounting of the RCU to the bib segment are two strap and clip assemblies which attach the bib segment to the PLSS bracket of the upper torso. This offloads any of the weight from the RCU directly to the suit and minimizes the stress on the bib segment itself.

5.4 HELMET

The helmet construction is a free-blown polycarbonate hemisphere bonded to a machined and anodized aluminum ring. The ring mates with the corresponding torso helmet closure portion of the upper torso. Since the vent line is an integral part of the TLA and is not a portion of the helmet, the helmet can be rotated about the mating plane to any number of positions while being latched. This allows the clearest optical segment of the helmet to be positioned in a critical vision area should any optical damage occur to the helmet itself. The helmet ring which is bonded to the hemisphere, contains a flange and groove arrangement for accepting the LEVA.

5.5 LUNAR EXTRAVEHICULAR VISOR ASSEMBLY (LEVA)

The LEVA is made up of three basic parts; (1) the LEVA frame and protective cover; (2) the low emission visor/left glare shield; and (3) the sun visor. The LEVA frame and protective cover consists of an aluminum machined frame to which is attached a clamp band and toggle latch assembly and a protective cover quadrant of fiberglas construction which protects the rear half of the LEVA. The low emission visor/left glare shield is a free blown polycarbonate hemisphere which is bonded to an aluminum ring. The rear 180^0 of the hemisphere is painted white on the exterior and black on the interior. The protective cover is also painted the same way. The black interior paint is to minimize interior reflections of the helmet and LEVA. The low emission visor is mounted in a 360^0 track. The mounting ring has an extension which can be rotated 90^0. This allows a 90^0 portion of the left glare shield to be moved to whatever position the wearer desires for minimizing glare to the left side of the helmet. The LEVA can be rotated about the attachment plane so that the protective cover acts as the right glare shield. The sun visor is pivoted at two points on the protective

cover assembly and it can be deployed in any increment desired. A light shield between visors is provided by teflon felt (Armalon) tape. The glare shield portion of the helmet segment of the ITMG can also be deployed over the top portion of the LEVA.

5.6 SUIT ELECTRICAL HARNESS

The Suit Electrical Harness was identical to the one used in the Apollo suit and no development effort was incurred in procurement from Cicoil, Incorporated.

5.7 BIOHARNESS ASSEMBLY

The Bioharness Assembly was identical to the one used in the Apollo suit and no development effort was incurred in procurement from Cicoil, Incorporated.

5.8 LIQUID COOLED GARMENT (LCG)

The LCG was identical to the units currently being used in the Apollo suit program. No development effort was incurred procuring these items. The only difference between this and units used in the A7L suit is the length of the inlet and outlet lines to the Airlock LCG connector.

5.9 CONCLUSIONS AND RECOMMENDATIONS

The AES suit system at the conclusion of the AES program represents the state-of-the-art in pressurized suit mobility. There are a number of developmental efforts which should be accomplished as soon as is practical to modify the current AES. These efforts are recommended as the result of several factors:

(1) Reduction in scope of the original program

(2) Overweight condition in several components

(3) Design improvements which are recommended as the result of the Acceptance Test and Design Verification test.

The recommended efforts are:

(1) Sizing Program - Although the analysis for modular sizing was completed under the AES program, the results of the analysis must be applied to: a detailed design effort; the fabrication of a complete set of modules; and the verification of the sizing system through tests at MSC utilizing

the complete astronaut population. The modular sizing concept is critical to the ultimate economy of using the AES system, for advanced missions.

(2) Weight Reduction - The overall system weight for the 7 CEI's was 73.74 lbs. This figure is 9.29 lbs. over specified weight. The majority of this weight condition can be attributed to the excessive weight in the chemcast rings which form a part of the waist joint/closure and are utilized in the hip joint and in the EVA boots. The chemcast rings went through two redesigns as a result of failures in tests. These redesigns were accomplished in minimum time with maximum emphasis on insuring that a subsequent failure did not occur. Little effort was spent on minimizing the weight. It would appear that now would be the time to re-examine these rings by instrumenting a complete ring set and running a series of pull tests to determine where wall thickness can be reduced, where lightening holes can be introduced and what would be the optimized form for inserts utilized to pick up cable loads. Weight reductions of 4-5 lbs. in these ring sets is probably achievable. The EVA boots weigh approximately 4-1/2 lbs. each, this is double the targeted weight for these items. Reasons for the overweight condition can be attributed to late delivery of tooling and subsequent problems in tooling interface and to the weight of the fiberglas felt inner liner. The boot outer sole of RTV-630 which now exceed 0.20 inch in many areas and the inner fiberglas contoured shell is approximately 1/8 inch thick. Weight reductions can be achieved in all these items. In the fiberglas shell the microballons can be introduced into the structure to reduce its weight by approximately 50 percent. Lightening holes filled with aluminized Milar chaff can reduce the weight of the fiberglas by approximately the same amount and the RTV-630 outer liner can be reduced to approximately 0.060 thousands wall thickness. All these items would bring the weight of the boot down into the targeted area so that another 4-5 lbs. can be reduced from the suit weight in this area.

(3) Because of the overall weight of the suit and the flexibility of all the joints, the suit tends to slip down onto the shoulders of the suited subject. During DVT testing at AiResearch, suspenders were introduced

in the suit to maintain suit/subject relative position. This, however, loads the shoulder area of the subject and would be uncomfortable over prolonged periods. A more efficient way of achieving the same goal, that is, suit/subject alignment, would be to introduce a waist belt attached to the middle ring of the waist joint so that the suit could be attached through webbing to the subject's waist. This will leave the shoulders free to assume optimum relationships with the wedge sections of the shoulder joint and still maintain suit position while distributing a load in a more comfortable manner.

(4) The LEVA assembly was 1.26 lbs. over targeted weight (3.57 lbs.). Substitution in materials from aluminum to poly-carbonate would alleviate this problem and at the same time investigations should be made so that all parts are interchangeable. Ths current AES has matched parts for the LEVA latching and retaining band system and the corresponding/mating part on the helmet ring. Redesign should be initiated to assure interchangeability of LEVA and helmet assemblies.

(5) Problems in development of the helmet and LEVA optical segments, especially in the hemispherical visors, developed during the AES program. The primary problem was overblow of the spherical section which resulted in these parts being somewhat out of tolerance, and therefore requiring matched fit of helmet and LEVA hemispheres. Further control of free blowing of this material as well as investigation of injection molding of optically correct visors should be pursued.

(6) The current helmet latching system operates very satisfactorily, however, it was the intent that the helmet and LEVA could be donned to the suit while mated, unfortunately the latch housing interferes with the LEVA frame when it is rotated, making simultaneous donning impossible. An increase of approximately .030-.060 in. in the height of the latch button spacer would alleviate this problem and certainly would be worthwhile accomplishing.

(7) All the joints in the suit reflect the neutral stability or passive stability desired in this type of constant volume suit with the exception of the elbow joint, which is not quite passively stable and tends to return to its neutral position. A slight modification to the cable clamps/guides would alleviate this problem and should be accomplished.

6.0 FABRICATION AND ASSEMBLY

Fabrication and assembly of all fabric detail parts and the assembly and test of all suit subassemblies was performed in an area especially prepared and equipped for this particular task.

Positive pressure ventilation was required using special intake filters for cleanliness, and additional air-conditioning capacity as needed for temperature stability. Due to the toxicity of fumes from the required solvents all work stations were equipped with an exhaust system.

Fabric subassemblies were built-up in layers on evacuated, expendable plaster mandrels and then oven cured. Primary fabrication consideration in this area of activity is the age-consciousness of the adhesives and the calendered-uncured fabric material. Handling techniques and cleanliness are also important in that uneven lamination of fabric panels and improper bonding can result.

Final assembly, preceded by proper cleaning per specification, was performed in the AiResearch Space Lab clean room facility. Cleaning of this irregular material surface did present some unusual considerations in handling, but was satisfactorily accomplished. Final assembly operations were completed without tooling except for outer seal insertion.

Manufacturing fabrication and assembly of this spacesuit presented many unique considerations in procedures, methods and support equipment; but all were accomplished in a timely manner within the scope of the specifications and drawings.

7.0 TEST

Testing of the TLA assembly was performed in the AiResearch Torrance Space Lab clean room, a 100,000 level laminar flow facility encompassing 3,000 square feet.

PDA testing was begun on 7 May 1970 and completed on 15 May 1970. The TLA assembly was tested concurrently with the other six CEI items.

Test requirements were satisfactorily completed on all items except TLA leakage and TLA weight was high, and LEVA sunshade torque was high.

Design verification testing was satisfactorily completed following review of PDA data. DVT was performed in the Douglas Street facility's white room. All test were completed satisfactorily with no deviations recorded.

8.0 PRODUCT SUPPORT

A preliminary copy of the Field Support Plan was submitted to NASA for approval. While waiting approval, the field support task was cancelled. NASA comments on the Field Support Plan were never received.

A quantity of reusable shipping and packaging containers sets was reduced from two to one. One set was designed and built and was used to ship the TLA and Helmet-LEVA assemblies to Houston. Set consisted of one container for TLA and one container for Helmet-LEVA.

APPENDIX A

DOCUMENTATION LIST

A● PROGRAM

DATE 5-15-70

DOCUMENTATION LIST

	Title	Document Identification
1	PROGRAM PLAN	69-5495
2	CONFIGURATION MANAGEMENT PLAN	69-5507
3	FIELD SUPPORT PLAN	69-5575
4	QUALITY CONTROL PROGRAM PLAN	69-5397
5	RELIABILITY PROGRAM PLAN	69-5449
6	MONTHLY PROGRESS REPORT	69-5522, Vol I thru 5
7	MEI/CEI SPECIFICATION - TORSO LIMB ASSEMBLY (TLA)	CP 958567
8	MEI/CEI SPECIFICATION - INTEGRAL THERMAL METEOROID GARMENT (ITMG)	CP 958568
9	MEI/CEI SPECIFICATION - HELMET	CP 958569
10	MEI/CEI SPECIFICATION - LUNAR EXTRAVEHICULAR VISOR ASSEMBLY (LEVA)	CP 958570
11	MEI/CEI SPECIFICATION - SUIT ELECTRICAL HARNESS	CP 958571
12	MEI/CEI SPECIFICATION - BIO HARNESS ASSEMBLY	CP 958572
13	MEI/CEI SPECIFICATION - LIQUID COOLED GARMENT (LCG)	CP 958573
14	CLEANING, PRESERVATION, PACKAGING, HANDLING, STORAGE AND SHIPPING PROCEDURES	70-6003
15	APPROVED MATERIALS LIST	69-5881
16	END ITEM TEST AND INSPECTION PROCEDURE (PDA) HELMET	AT 958007-01
17	END ITEM TEST AND INSPECTION PROCEDURE (PDA) (LEVA)	AT 958009-01
	END ITEM TEST AND INSPECTION PROCEDURE (PDA) (TLA)	AT 958013-01
	END ITEM TEST AND INSPECTION PROCEDURE (PDA) (ITMG)	AT 958015-01

DATE 5-15-70

DOCUMENTATION LIST

	Title	Document Identification
20	END ITEM TEST AND INSPECTION PROCEDURE (PDA) (LCG)	AT 958017-01
21	END ITEM TEST AND INSPECTION PROCEDURE (PDA) BIO HARNESS ASSY.	AT 958019-01
22	END ITEM TEST AND INSPECTION PROCEDURE (PDA) SUIT ELECTRICAL HARNESS	AT 958021-01
23		
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APPENDIX B

SPECIFICATION LIST

AES SPECIFICATION LIST

Rev. 4 Date 5-12-70

LINE NO.	SPECIFICATION NUMBER	TITLE	CHG. LTR.	RELEASE DATE
1	AF440	SPACE SUIT FABRICATION AND ASSEMBLY OF	--	10-3-69
2				
3	C-38	CONTAMINATION CONTROL	P	9-9-69
4	C-90	CLEANING, PREPARATION OF MATERIALS FOR BONDING	--	12-12-69
5				
6	EMS 240	ULTRASONIC INSPECTION	G	9-9-69
7	EMS 251	ELECTROPOLISHING	C	9-10-69
8	EMS 258	ELECTROFORMED SHAPES - NICKEL	B	10-3-69
9	EMS 372	MOLDED TEFLON STRESS-RELIEVED HI DENSITY STOCK	a	10-3-69
10	EMS 395	POLYTETRAFLUORETHYLENE FELT (ARMALON)	C	9-18-69
11	EMS 93002	SOFT, RESILIENT SILICONE ELASTOMER	--	9-10-69
12	EMS 93021	POLYTETRAFLUORETHYLENE IMPREGNATED ALUM. (HARD ANODIZE)	--	9-9-69
13	EMS 93022	SUIT MATERIAL, NEOPRENE COATED NOMEX	--	10-3-69
14	EMS 93024	SUIT MATERIAL-NEOPRENE COATED NYLON RIPSTOP	--	10-23-69
15	EMS 93025	POLYCARBONATE, CLEAR, FIRE RESISTANT	--	9-15-69
16	EMS 93026	SILICONE FLUIDS	--	2-11-70
17	EMS 93029	POLYESTER IMPREGNATED GLASS CLOTH LAMINATE	A	9-18-69
18	EMS 93036	SILICONE SHEET FOR SELF SEALING PATCH	--	11-13-69
19	EMS 93038	INSULATION, MOLDED FIBERGLASS, PHENOLIC RESIN BONDED	--	10-30-69
20	EMS 93039	ELECTRIC BLUE TAFFETY NYLON QUILTED		2-17-70
21	EMS 97293	STAINLESS STEEL CABLE, TEFLON COATED	--	11-18-69
22				
23	FP36	APPLICATION OF EPOXY ESTER COATING FOR CORROSION PROTECTION & SEALING	H	10-2-69
24	FP44	APPLICATION OF FLUOROCARBON DISPERSION COATING	L	9-18-69
25	FP79	APPLICATION OF POLYESTER COATING	--	9-18-69

AES SPECIFICATION LIST

Rev. 4 Date 5-12-70

LINE NO.	SPECIFICATION NUMBER	TITLE	CHG. LTR.	RELEASE DATE
1	HT29	STABILIZATION OF SPRINGS	C	9-10-69
2	HT38	HEAT TREATMENT OF THE HEAT AND CORROSION RESISTANT ALLOYS	g	9-10-69
3	HT85	HEAT TREATMENT AND TEST REQUIREMENTS FOR 7075-T73	A	9-9-69
4				
5	MC9	APPLICATION OF METAL FOIL IDENTIFICATION PLATES AND NONMETALLIC DECALS	K	9-23-69
6	MC16	MARKING REQUIREMENTS - LOS ANGELES	E	9-9-69
7				
8	P1B5	INTERPRETATION OF ENGINEERING DRAWINGS	A	9-9-69
9				
10	RS4	RUBBER SEALANTS AND CEMENTS FOR FAYING SURFACES	F	12-18-69
11	RS13	APPLICATION OF EPOXY-BASED ADHESIVES	V	9-9-69
12	RS42	APPLICATION OF LOCTITE SEALANTS	C	11-18-69
13	RS45	APPLICATION OF ROOM TEMPERATURE VULCANIZING (RTV) RUBBER	J	
14	RS149	APPLICATION OF POLYURETHANE ADHESIVES	E	9-18-69
15				
16	S8500-2	RIVET INSTALLATION - FLUSH TYPE 100°	--	9-18-69
17	S9389	TAPE, CLOSURE, NYLON, LOOP SECTION	--	2-11-70
18	S9456	TAPE, CLOSURE, BETA GLASS BASE, LOOP SECTION	--	2-17-70
19				
20	SC653	CONTROL OF BURRS AND SHARP EDGES OF AIRESEARCH PARTS	--	9-9-69
21	SC958566	HELMET AND VISORS OPTICAL REQUIREMENTS SPECIFICATION	--	9-15-69
22				
23	WBS-18	WELDING, BRASING, SOLDERING	K	10-10-69
24				
25				

AES SPECIFICATION LIST

Rev. 4 Date 5-12-70

LINE NO.	SPECIFICATION NUMBER	TITLE	CHG. LTR.	RELEASE DATE
1	CP958567	MEI/CEI SPECIFICATION - TORSO-LIME ASSEMBLY (TLA)		
2	CP958568	MEI/CEI SPECIFICATION - INTEGRAL HERMAL METEOROID GARMENT (ITMG)		
3	CP958569	MEI/CEI SPECIFICATION - HELMET		
4	CP958570	MEI/CEI SPECIFICATION - LUNAR EXTRAVEHICULAR VISOR ASSEMBLY (LEVA)		
5	CP958571	MEI/CEI SPECIFICATION - SUIT ELECTRICAL HARNESS		
6	CP958572	MEI/CEI SPECIFICATION - BIO-HARNESS ASSEMBLY		
7	CP958573	MEI/CEI SPECIFICATION - LIQUID COOLED GARMENT (LCG)		
8				
9				
10				
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12				
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23				
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APPENDIX C

DRAWING LIST

DATA LIST	1. AGENCY: AIRESEARCH MFG CO. A DIVISION OF THE GARRETT CORP. LOS ANGELES, CALIFORNIA	1A. CONTRACT NUMBER: NAS 9-7555	2 CODE IDENT: 70210	3. DL AES PROGRAM
4. REVISION LTR. — DATE 5-13-70	5. LIST TITLE: DRAWING LIST TLA, HELMET AND LEVA	6 AUTHENTICATION	7. REV. AUTH NO.	8 SHEET 1 OF 4

9 IDENT. NO	10 DWG SIZE	11 DOCUMENT NUMBER	12. SHT. NO.	13 REV LTR	14. DOCUMENT NOMENCLATURE
	A	CI958007-01		-	CONFIG INDEX
	A	CI958009-02		-	CONFIG INDEX
	A	CI958013-01		-	CONFIG INDEX
	D	958007		B	HELMET
	E	958009		C	VISOR ASSY
	E	958013		H	TORSO-LIMB ASSY
	C	958208		E	RING
	C	958228		D	RING
	C	958229		E	RING
	C	958237		D	RING
	D	958333		C	RING
	C	958400		B	PLATE FACE
	D	958401		-	RING HELMET
	D	958402		A	HOUSING ASSY
	D	958403		-	HOUSING VISOR
	E	958404		B	RING VISOR MTG
	C	958405		-	PAD
	B	958406		-	PIN GUIDE
	B	958409		A	PLATE IDENT
	D	958411		A	VISOR ASSY
	D	958412		C	VISOR
	D	958413		-	RING ASSY
	D	958414		A	VISOR
	D	958415		B	VISOR
	E	958416		B	FRAME VISOR
	C	958419		-	SEAL LIGHT
	C	958420		A	PIN PIVOT
	B	958421		-	PLATE IDENT
	C	958423		-	LINK LATCH
	C	958424		-	HANDLE LATCH
	C	958425		-	PIN BEARING
	D	958426		A	RING NECK CLOS
	D	958427		A	SEAL HELMET
	E	958428		-	RING ASSY
	E	958429		A	BAND ASSY
	D	958430		A	PLATE ASSY
	D	958431		A	PLATE ASSY
	D	958432		B	TONGUE
	C	958433		-	KNOB ASSY
	D	958434		D	BUTTON ASSY
	E	958435		A	SLEEVE HIP
	C	958436		-	BASE KNOB
	B	958437		A	SPRING CPRSN
	C	958438		A	PLATE KNOB
	E	958440		D	HIP ASSY
	B	958443		-	DOUBLER INTMD
	C	958444		-	DOUBLER END
	C	958445		-	STIFFENER
	J	958446		B	SLEEVE ARM
	B	958448		A	PATCH

FORM 1002 B (REV. SEPT. 60)

DATA LIST	1. AGENCY: AIRESEARCH MFG. CO, A DIVISION OF THE GARRETT CORP, LOS ANGELES CALIFORNIA	1A. CONTRACT NUMBER: NAS 9-7555	2. CODE IDENT.: 70210	3: DL AES PROGRAM
4. REVISION LTR. DATE 5-13-70	5. LIST TITLE: DRAWING LIST TLA, HELMET AND LEVA	6 AUTHENTICATION	7. REV. AUTH. NO.	8. SHEET OF 2 4

9. IDENT. NO.	10 DWG. SIZE	11. DOCUMENT NUMBER	12. SHT. NO	13. REV. LTR	14. DOCUMENT NOMENCLATURE
	B	958449		B	BALL BEARING
	E	958451		C	ARM ASSY
	B	958452		B	RING GUIDE
	C	958454		-	PLATE IDENT
	B	958455		A	KEEPER BALL
	B	958456		A	BALL
	A	958457		-	HOSE ASSY
	J	958458		D	TORSO ASSY
	J	958459		A	FABRIC TORSO
	D	958460		-	RACE OUTER
	D	958461		A	RACE INNER
	D	958462		-	RETAINER BRG
	C	958463		-	SEAL DUST
	D	958464		-	RACE OUTER
	D	958465		A	RACE INNER
	D	958466		A	RETAINER BRG
	C	958467		A	SEAL DUST
	D	958468		-	RACE OUTER
	D	958469		A	RACE INNER
	D	958470		A	RETAINER BRG
	C	958471		A	SEAL DUST
	D	958472		-	RACE OUTER
	D	958473		A	RACE INNER
	D	958474		-	RETAINER BRG
	C	958475		-	SEAL DUST
	D	958476		D	SHLDR SUBASSY
	D	958477		A	SHLDR SUBASSY
	D	958478		A	SHLDR SUBASSY
	D	958479		A	SHLDR SUBASSY
	D	958481		-	RACE OUTER
	D	958482		A	RACE INNER
	D	958483		-	RETAINER BRG
	C	958484		-	SEAL DUST
	D	958485		-	RACE OUTER
	D	958486		A	RACE INNER
	D	958487		-	RETAINER BRG
	C	958488		-	SEAL DUST
	E	958489		C	BOOT ASSY
	J	958491		G	LEG ASSY
	J	958493		E	TORSO ASSY
	J	958494		A	LOWER TORSO
	C	958495		-	SHIM SUPPORT
	D	958496		A	RING RESTRAINT
	C	958499		-	PIN RETAINING
	B	958500		-	KEEPER BALL
	D	958502		E	GUIDE CABLE
	C	958503		A	BRACKET
	D	958504		C	GUIDE ASSY
	C	958505		C	GUIDE CABLE
	D	958506		B	GUIDE ASSY
	D	958507		D	GUIDE CABLE
	E	958511		A	PAD COMFORT

ASPM 1632 B (REV SEPT 68)

DATA LIST	1. AGENCY: AIRESEARCH MFG. CO. A DIVISION OF THE GARRETT CORP LOS ANGELES CALIFORNIA	1A. CONTRACT NUMBER: NAS 9-7555	2. CODE IDENT.: 70210	3.: DL AES PROGRAM

4. REVISION LTR	DATE	5. LIST TITLE	6. AUTHENTICATION	7. REV. AUTH NO.	8. SHEET OF
	5-13-70	DRAWING LIST TLA, HELMET AND LEVA			3 4

9. IDENT. NO	10 DWG SIZE	11. DOCUMENT NUMBER	12 SHT NO	13. REV. LTR.	14. DOCUMENT NOMENCLATURE
	D	958513		C	VENT ARM
	E	958514		-	PAD COMFORT
	C	958516		-	ADAPTER
	D	958517		-	PAD COMFORT
	A	958519		A	DISCONNECT
	E	958520		-	PAD COMFORT
	C	958521		A	TAB
	A	958522		A	GAGE PRESSURE
	B	958523		A	MOUNT GAGE
	B	958524		-	RING BACKING
	B	958525		-	NUT GAGE PRESS
	A	958526		A	VALVE PRESS RLF
	D	958529		A	RING CPRSN
	D	958530		B	RING
	D	958531		-	VENT LWR TORSO
	E	958532		B	RING TORSO
	E	958533		C	RING CLAMPING
	E	958534		B	RING ASSY
	D	958536		B	SEAL TORSO CLOS
	C	958537		A	NUT CABLE
	B	958539		A	SEAL XFR DUCT
	D	958540		A	DUCT TRANSFER
	D	958541		A	DUCT
	C	958542		-	FLANGE OUTER
	D	958543		-	FLANGE INNER
	D	958544		-	DIFFUSER
	D	958545		B	RING
	C	958548		B	FLANGE ASSY
	E	958549		B	SUPPORT-VENT
	J	958553		B	SLEEVE BOOT
	J	958554		C	SOLE BOOT
	C	958560		-	VENT OUTFLOW
	C	958579		-	STIFFENER
	C	958580		-	STIFFENER
	C	958581		B	FLANGE
	C	958583		-	SPRING
	J	958584		D	PANEL LEG
	C	958585		-	VENT FLEXIBLE
	A	958587		A	DISCONNECT
	C	958588		-	RING CPRSN
	C	958589		A	RING RESTRAINT
	E	958590		B	PANEL SHOULDER
	E	958591		A	PANEL SHOULDER
	E	958592		A	PANEL SHOULDER
	E	958593		A	PANEL SHOULDER
	C	958596		-	BRACKET
	D	958597		A	VENT LINE INLET
	D	958598		A	VENT LINE INLET
	D	958599		-	VENT LINE EXH
	C	958600		B	VENT LINE EXH
	E	958601		-	PAD COMFORT
	A	958602		A	CONNECTOR GAS

FORM 1002 B (REV. SEPT. 68)

DATA LIST	1 AGENCY: AIRESEARCH MFG CO. A DIVISION OF THE GARRETT CORP LOS ANGELES CALIFORNIA	1A CONTRACT NUMBER: NAS 9-7555	2. CODE IDENT.: 70210	3.: DL AES PROGRAM
4. REVISION LTR. DATE: 5-13-70	5. LIST TITLE: DRAWING LIST TLA, HELMET AND LEVA	6. AUTHENTICATION	7. REV. AUTH. NO.	8. SHEET OF 4 4

9. CODE IDENT. NO.	10. DWG SIZE	11 DOCUMENT NUMBER	12. SHT NO	13. REV. LTR	14. DOCUMENT NOMENCLATURE
	A	958603		A	CONNECTOR GAS
	A	958604		A	CONNECTOR GAS
	A	958605		A	CONNECTOR GAS
	A	958606		A	PLUG
	A	958609		A	PORT
	E	958611		A	PAD COMFORT
	B	958614		A	PLATE IDENT
	D	958615		-	DUCT LWR TORSO
	C	958616		-	DUCT TRANSITION
	D	958619		A	GUIDE
	E	958620		B	RING WAIST JT
	E	958621		A	RING FAB ATCH
	E	958622		B	RING TORSO CLOS
	D	958623		-	RING RESTRAINT
	D	958624		-	RING ASSY
	C	958625		-	BRACKET
	D	958626		-	BAND
	C	958627		-	SPACER
	B	958628		-	RETAINER
	C	958633		-	DOUBLER REINF
	D	958634		-	DOUBLER REINF
	B	958635		A	WASHER LATCH

ORM 1602 B (REV. SEPT. 68)

APPENDIX D

"AS DESIGNED" LIST

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER 958009-02
PART NAME VISOR ASSY

"AS DESIGNED" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE 5-13-70 REV
SHEET 1 OF 3
APPROVED A. P. Bradley 5-15-

IND.	PART NUMBER	DWG CH.	TITLE	S/N EFFECT	1 - REMARKS	LIN NO
1	958009-02	C	VISOR ASSY	001 & SUB.		1
2	958402-01	A	HOUSING ASSY			2
3	958403-01	NC	HOUSING VISOR			3
3	958404-01	B	RING VISOR MTG			4
3	958619-01	A	GUIDE			5
3	958626-01	NC	BAND			6
3	958627-01	NC	SPACER			7
3	117-014-9001		ACHESIVE			8
3	243-011-9001		CATALYST			9
3	588-005-9001		PRIMER			10
3	219-003-9001		STAKING CMPD			11
3	429-501-9004		INK STAMP PAD			12
3	NAS662C2R4		SCREW MACHINE			13
2	958405-01	NC	PAD			14
2	958411-02	A	VISOR ASSY			15
3	958412-02	C	VISOR			16
4	958412-03	C	VISOR			17
3	958413-01	NC	RING ASSY			18

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER
PART NAME

"AS DESIGNED" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE 5-13-70 REV
SHEET 2 OF 3

APPROVED

IND.	PART NUMBER	DWG CH.	TITLE	S/N EFFECT	2 - REMARKS	LINE NO.
4	958413-03	NC	RING	001 & SUB.		1
4	423-507-9021		INSERT SCR THD			2
3	117-038-9001		ADHESIVE			3
3	588-001-9001		PRIMER ADHESIVE			4
2	958414-02	A	VISOR			5
3	958415-02	B	VISOR			6
3	958416-01	B	FRAME VISOR			7
4	958416-03	B	FRAME			8
4	958416-05	B	CORNER			9
4	958416-07	B	TAB			10
4	958416-09	B	WIRE			11
3	958419-01	NC	SEAL LIGHT			12
3	117-014-9001		ADHESIVE			13
3	243-011-9001		CATALYST			14
3	S8157CH301-015		WASHER			15
2	958420-01	A	PIN PIVOT			16
2	958421-02	NC	PLATE IDENT			17
3	S9454M1H1		PLATE IDENT			18

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER
PART NAME

"AS DESIGNED" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE 5-13-70 REV
SHEET 3 OF 3

APPROVED

IND.	PART NUMBER	DWG CH.	TITLE	S/N EFFECT	3 - REMARKS	LINE NO.
2	958423-01	NC	LINK LATCH	001 & SUB.		1
2	958424-01	NC	HANDLE LATCH			2
2	958425-01	NC	PIN BEARING			3
2	958425-02	NC	PIN BEARING			4
2	958499-01	NC-	PIN RETAINING			5
3	AN565AC2L5		SETSCREW			6
2	117-014-9001		ADHESIVE			7
2	243-011-9001		CATALYST			8
2	S8154-339C010		WASHER FLAT			9
2	S8154-339C002		WASHER FLAT			10
2	S8157CH301-015		WASHER			11
2	S8157N27-032		WASHER			12
2	S8809C18		WASHER SPR TNSN			13
2	NAS561C2-10		PIN SPRING			14
2	MS51923-168		PIN SPRING			15
2	S9456-1-230		TAPE CLOSURE			16
2	S9456-1-012		TAPE CLOSURE			17
						18

APPENDIX E

"AS BUILT" LIST

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER
PART NAME
SERIAL NO.

"AS BUILT" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE REV
SHEET OF
APPROVED

IND.	PART NUMBER	DWG CH.	TITLE	TRACEABILITY CODE	TRACEABILITY S/N	TRACEABILITY LOT OR BATCH NUMBER	1 - INSPECTION	LINE NO.
1	958009-01	C	VISOR ASSY	1	1	81195		1
2	958402-01	A	HOUSING ASSY	2	-	81194		2
3	958403-01	N/C	HOUSING VISOR	2	-	71808		3
3	958404-01	B	RING VISOR MTG	2	-	55939		4
3	958619-01	A	GUIDE	2	-	55942		5
3	958626-01	N/C	BAND	2	-	276450		6
3	958627-01	N/C	SPACER	2	-	276451		7
3	117-014-9001		ADHESIVE		-	276451		8
3	243-011-9001		CATALYST		-	276451		9
3	588-005-9001		PRIMER		-	276451		10
3	219-003-9001		STAKING CMPD		-	276451		11
3	420-501-9004		INK STAMP PAD		-	276451		12
3	NAS662C2R4		SCREW MACHINE		-	276451		13
2	958405-01	N/C	PAD	2	-	55940		14
2	958411-01	A	VISOR ASSY	2	-	81193		15
3	958412-02	C	VISOR	2	-	71927		16
3	958412-03	C	VISOR	2	-	71927		17
3	958413-01	N/C	RING ASSY	2	-	50042		18

Traceability Code: 1 = S/N, 2 = Lot or Batch, 3 = None

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER
PART NAME
SERIAL NO.

"AS BUILT" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE REV
SHEET OF
APPROVED

IND.	PART NUMBER	DWG CH.	TITLE	TRACEABILITY CODE	TRACEABILITY S/N	TRACEABILITY LOT OR BATCH NUMBER	2 - INSPECTION	LINE NO.
4	958413-03	N/C	RING	2	-	50042		1
4	423-507-9021		INSERT SCR THD	2	-	50042		2
3	117-038-9001		ADHESIVE	2	-	50042		3
3	588-001-9001		PRIMER ADHESIVE	2	-	50042		4
2	958414-01	A	VISOR	2	-	81192		5
3	958415-01	B	VISOR	2	-	71928		6
3	958416-01	B	FRAME VISOR	2	-	71929		7
4	958416-03	B	FRAME	2	-	71929		8
4	958416-05	B	CORNER	2	-	71929		9
4	958416-07	B	TAB	2	-	71929		10
4	958416-09	B	WIRE	2	-	71929		11
3	958419-01	N/C	SEAL LIGHT	2	-	55942		12
3	117-014-9001		ADHESIVE	2	-	55942		13
3	243-011-9001		CATALYST	2	-	55942		14
3	S815ACH301-015		WASHER	2	-	55942		15
2	958420-01	A	PIN PIVOT	2	-	55943		16
2	958421-01	N/C	PLATE IDENT	2	-	55943		17
3	S9454N1H1		PLATE IDENT	2	-	55943		18

Traceability Code: 1 = S/N, 2 = Lot or Batch, 3 = None

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

PART NUMBER _____
PART NAME _____
SERIAL NO. _____

"AS BUILT" PARTS LIST
AES PROGRAM
NAS 9-7555

DATE _____ REV ____
SHEET ____ OF ____
APPROVED

IND.	PART NUMBER	DWG CH.	TITLE	TRACEABILITY CODE	TRACEABILITY S/N	TRACEABILITY LOT OR BATCH NUMBER	3 - INSPECTION	LINE NO.
2	958423-01	N/C	LINK LATCH	2	-	50047		1
2	958424-01	N/C	HANDLE LATCH	2	-	50043		2
2	958425-01	N/C	PIN BEARING	2	-	55944		3
2	958425-02	N/C	PIN BEARING	2	-	55945		4
2	958499-01	N/C	PIN RETAINING	2	-	55947		5
3	AN565AC2L5		SETSCREW	2	-	55947		6
2	117-014-9001		ADHESIVE	2	-	55947		7
2	243-011-9001		CATALYST	2	-	55947		8
2	S8154-339C010		WASHER FLAT	2	-	55947		9
2	S8154-339C002		WASHER FLAT	2	-	55947		10
2	S8157CH301-015		WASHER	2	-	55947		11
2	S8157M27-032		WASHER	2	-	55947		12
2	S8809C18		WASHER SPR TNSN	2	-	55947		13
2	MS561C2-10		PIN SPRING	2	-	55947		14
2	MS51923-168		PIN SPRING	2	-	55947		15
2	S9456-1-230		TAPE CLOSURE	2	-	42003		16
2	S9456-1-012		TAPE CLOSURE	2	-	42003		17
								18

Traceability Code: 1 = S/N 2 = Lot or Batch 3 = None

APPENDIX F

STRESS CALCULATIONS FOR THE AES SUIT

Form 2427

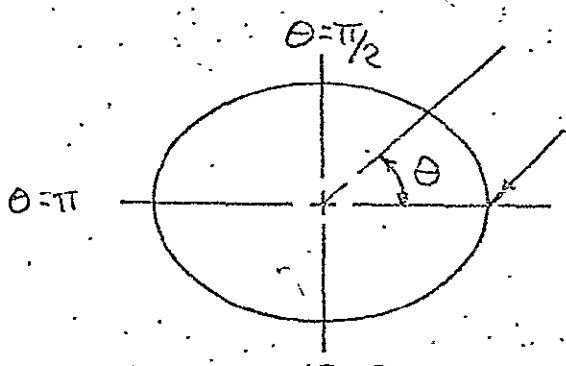
AiRESEARCH MFG. CO.

DATE 9-16-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

DEFLECTION SUMMARY

RING DESCRIPTION	LOAD	MAXIMUM VALUES		
		TWIST	Normal Disp	IN PLANE DISP
Middle Waist ring	Proof load (10 psi)	.1257 rad @ $\theta=0°$	.3702 @ $\theta=90°$	.3721 @ $\theta=90°$
Upper Waist ring (no help from suit ring)	Proof load (10 psi)	.00859 rad @ $\theta=0°$	.020 @ $\theta=90°$	.53 @ $\theta=90°$
Lower Torso Elliptic ring (DWG 958509)	Operating load (5 psi)	—	.3526 @ $\theta=90°$	—
LOWER HIP BEARING & Support ring	Operating load (5 psi)	.0105 rad @ $\theta=0°$	.0348 @ $\theta=90°$	—
UPPER HIP BEARING	OPERATING LOAD (5 PSI)	$.6614\times10^{-3}$ rad @ $\theta=91°$	.00169 @ $\theta=94°$	.0376 radial .0263 tangential
Shoulder Bearing	Operating load (5 psi)	7.14° (contact angle changes from 30° To 37.14°)	—	—



O reference point for displacements

Note: all displacements in inches.

REPORT
PAGE OF

Form 2427

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DATE_____ CALC. NO._____

PREPARED BY_____ MODEL _____

CHECKED BY_____ PART NO._____

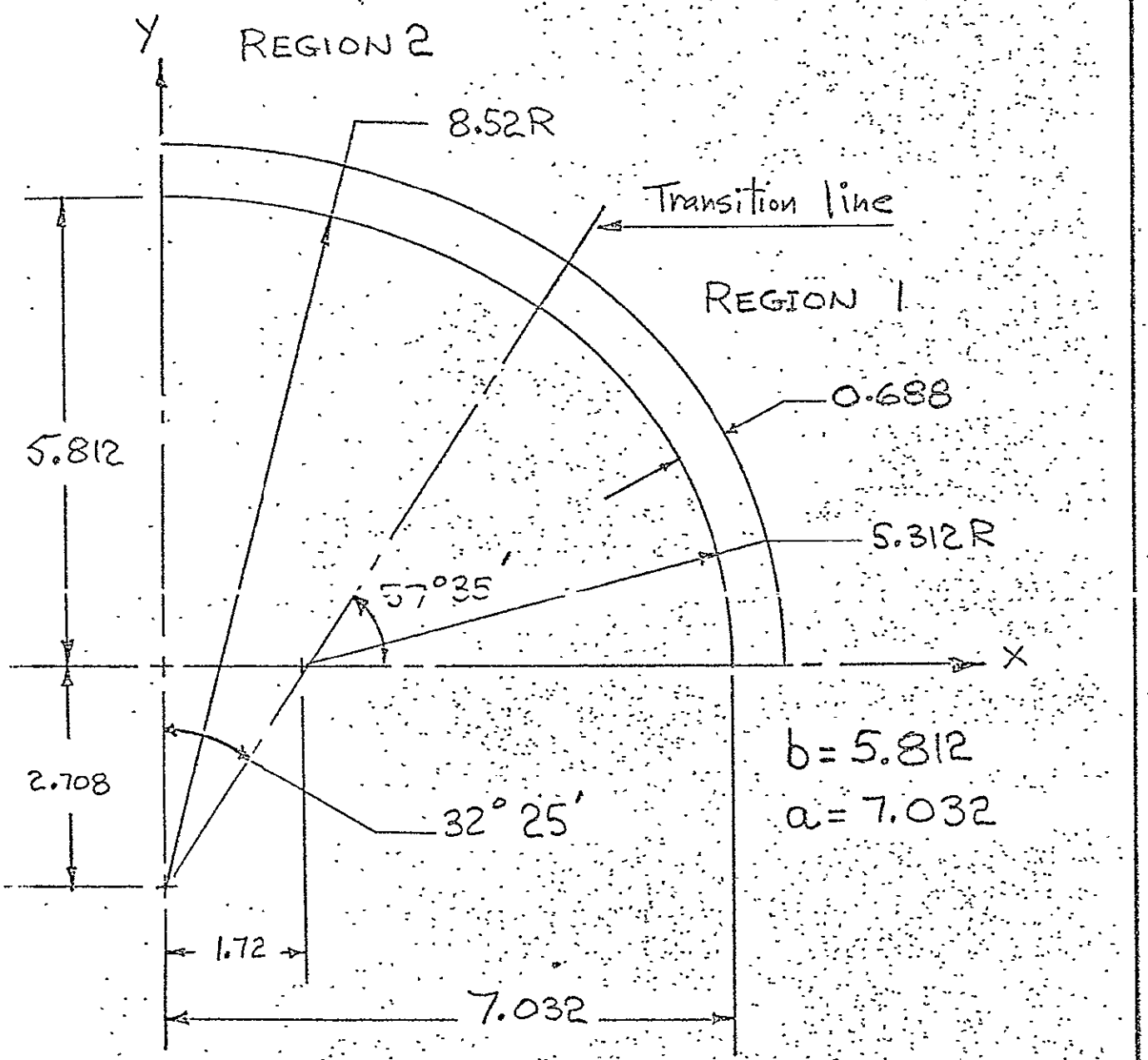
IN & OUT OF PLANE BENDING EQUATIONS FOR ELLIPTIC RING

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The ellipse can be analyzed as two circular rings. Slope and deflection boundary conditions will have to be matched at the transition line, where the radius and circle center change. Call the two circular regions; region 1 and region 2.

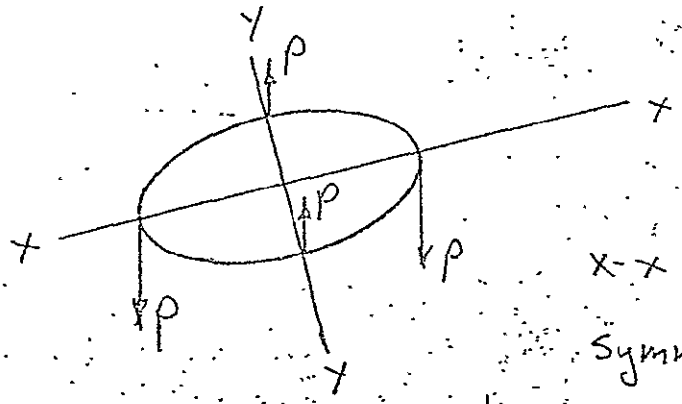
Form 2427

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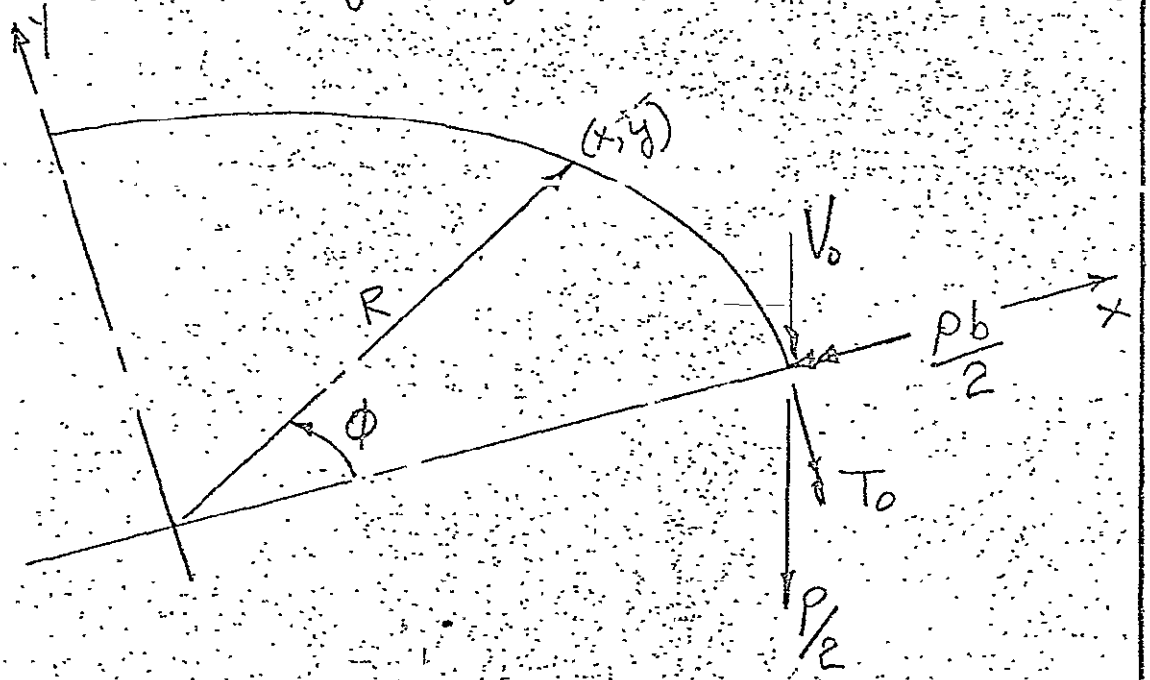
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LOADING NORMAL TO THE PLANE OF THE RING



x-x and y-y are axes of symmetry. Because of this fact, only one quadrant need be considered



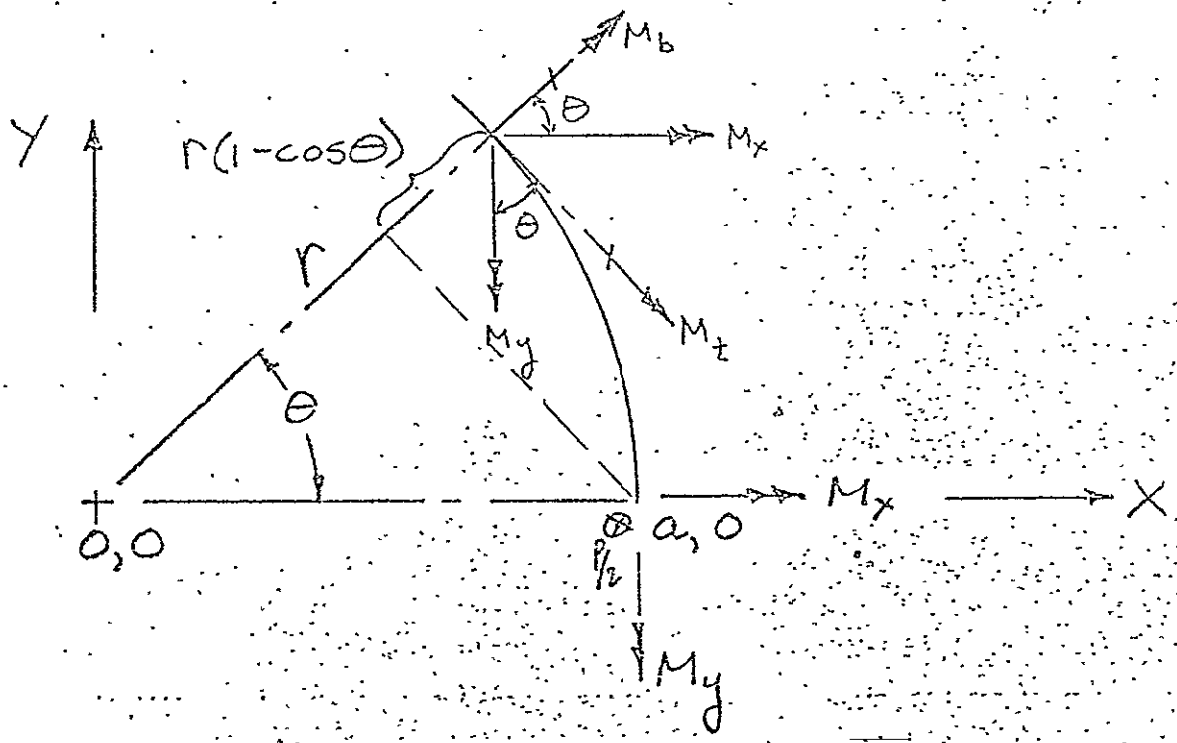
$T_o = 0$ By Symmetry

$V_o = 0$ By Symmetry

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$\theta < \gamma$

$$M_b = -\frac{Pb}{2}\cos\theta + \frac{Pr}{2}\sin\theta - T_o \sin\theta$$

$$M_t = T_o \cos\theta - \frac{Pb}{2}\sin\theta + \frac{Pr}{2}(1-\cos\theta)$$

$\theta > \gamma$

$$M_b = \tilde{M}_b\cos(\theta-\gamma) - \tilde{M}_t\sin(\theta-\gamma) + 0.5Pr\sin(\theta-\gamma)$$

$$M_t = \tilde{M}_b\sin(\theta-\gamma) + \tilde{M}_t\cos(\theta-\gamma) + 0.5Pr\{1-\cos(\theta-\gamma)\}$$

$$\tilde{M}_b = -0.5Pb\cos\gamma + 0.5Pr\sin\gamma$$

$$\tilde{M}_t = -0.5Pb\sin\gamma + 0.5Pr(1-\cos\gamma)$$

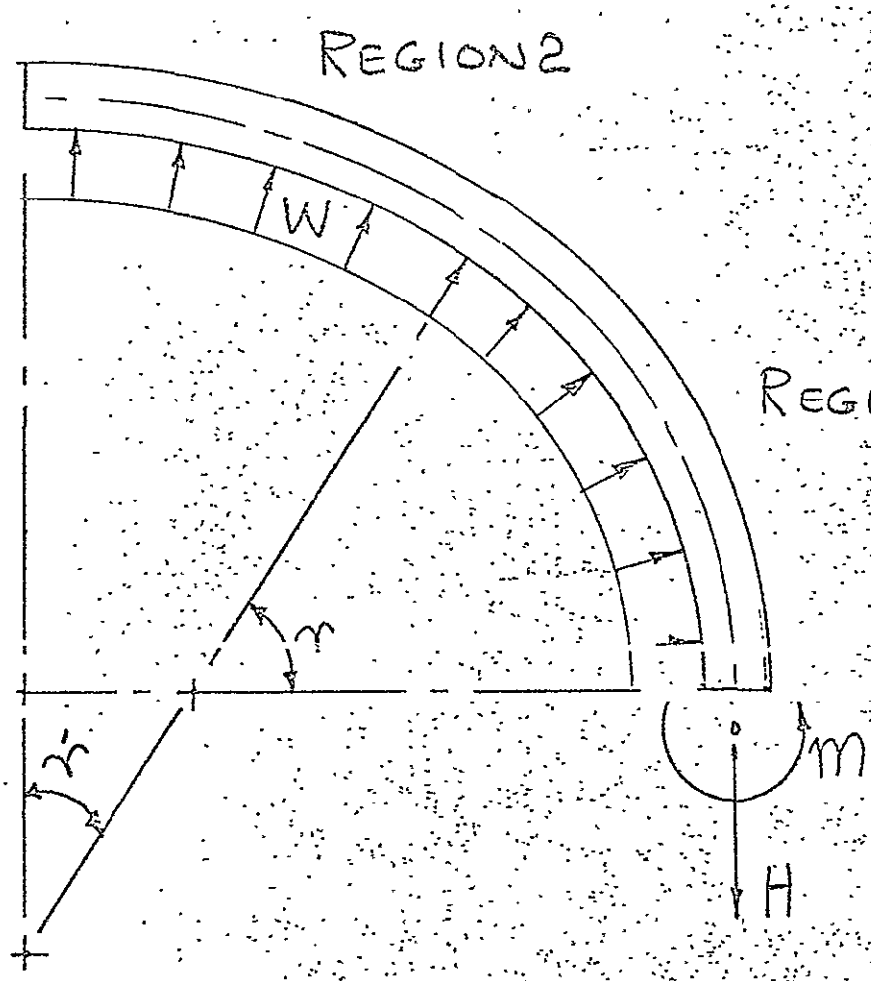
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LOADING IN THE PLANE OF THE RING



AXIAL FORCE = $H\cos\theta$

$$M_z = m - HR(1-\cos\theta) + WR^2\int_0^\theta \sin(\theta-\beta)\,d\beta$$

$$M_z = m + (-HR+WR)^2(1-\cos\theta)$$

R will change to R' and r to r' when going from region 1 to region 2.

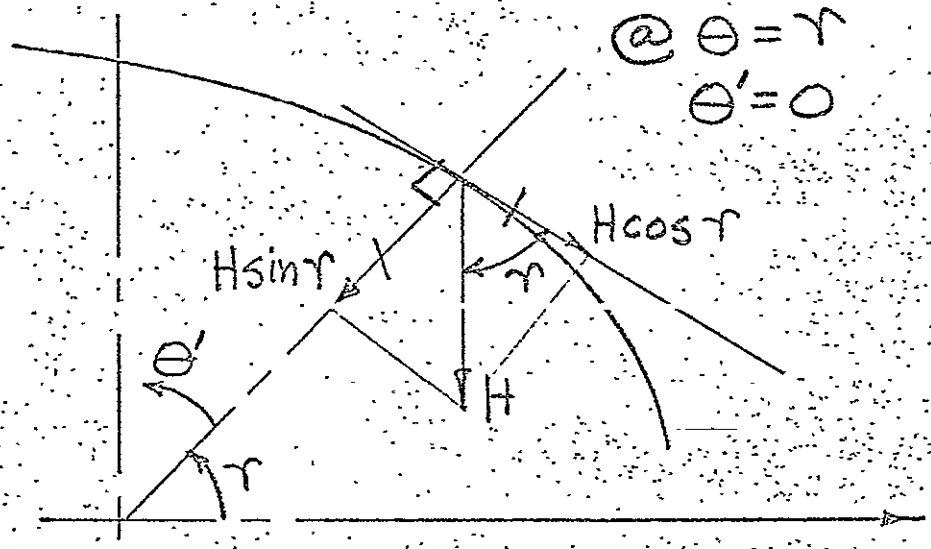
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The two redundants are m & H

$$\left.\begin{aligned}\frac{\partial M_z}{\partial m} &= 1 \\ \frac{\partial M_z}{\partial H} &= -R(1-\cos\theta)\end{aligned}\right\} \text{ for Region 1}$$



$$M_z = m + (WR^2 - HR)(1-\cos\gamma) + W(R')^2(1-\cos\theta') - HR'\cos\gamma(1-\cos\theta') - HR'\sin\gamma\sin\theta'$$

Axial Force $= H\cos(\theta'+\gamma)$

$$\frac{\partial M_z}{\partial m} = 1$$

$$\frac{\partial M_z}{\partial H} = -R(1-\hat{C}) - R'\hat{C}(1-\cos\theta') - R'\hat{S}\sin\theta'$$

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Ignore shear component (insignificant)

$$U = \int_0^r \frac{M_z^2}{2EI} R\,d\theta + \int_0^r \frac{P^2 R\,d\theta}{2AE}$$

(using Castigliano's Theorem)

$$\frac{\partial U}{\partial m} = \int_0^r \frac{M_z}{EI}\frac{\partial M_z}{\partial m} R\,d\theta = 0$$

$$\frac{\partial U}{\partial H} = \int_0^r \frac{M_z}{EI}\frac{\partial M_z}{\partial H} R\,d\theta + \int_0^r \frac{P}{AE}\frac{\partial P}{\partial H} R\,d\theta = 0$$

small, ignore

$$\frac{\partial U}{\partial m} = 0 = \int_0^r \left\{ m + (wR^2 - HR)(1-\cos\theta) \right\} R\,d\theta$$

$$+ R' \int_0^{r'} \left\{ m + (wR^2 - HR)(1-\hat{c}) + w(R')^2(1-\cos\theta') - HR'\hat{c}(1-\cos\theta') - HR'\hat{s}\sin\theta' \right\} d\theta'$$

$$m\left\{r + r'\frac{R'}{R}\right\} + H\left\{-R(r-\hat{s}) - R'r'(1-\hat{c}) - R'\hat{c}(r'-\hat{c}) - R'\hat{s}(1-\hat{s})\right\} + w\left\{R^2(r-\hat{s}) + \frac{1}{R}(R')^3(r'-\hat{c}) + RR'(1-\hat{c})r'\right\} = 0$$

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$$\frac{\partial U}{\partial H} = 0 = \int_0^{\gamma} R(\cos\theta - 1)\left\{m + (WR^2 - HR)(1-\cos\theta)\right\} R\,d\theta$$

$$+ R' \int_0^{\gamma'} \left\{ -R(1-\hat{c}) - R'\hat{c} + R'\hat{c}\cos\theta' - R'\hat{s}\sin\theta' \right\} \left\{ m \right.$$

$$\left. + (WR^2 - HR)(1-\hat{c}) + W(R')^2(1-\cos\theta') - HR'\hat{c}(1-\cos\theta') - HR'\hat{s}\sin\theta' \right\} d\theta'$$

$$m\left[R^2(\hat{s}-\gamma) - \gamma' R'\left\{R(1-\hat{c}) + R'\hat{c}\right\} + (\hat{c}R')^2 - \hat{s}(1-\hat{s})(R')^2\right]$$

$$+ H\left[R^3\left(\tfrac{3}{2}\gamma + \tfrac{1}{4}\sin 2\gamma - 2\hat{s}\right) + R'\left\{R(1-\hat{c}) + R'\hat{c}\right\}\left\{R'\hat{c}(\gamma' - \hat{c})\right.\right.$$

$$\left. + R'\hat{s}(1-\hat{s}) - R\gamma'(1-\hat{c})\right\} - \hat{c}(R')^2\left\{R\hat{c}(1-\hat{c}) + R'\hat{c}\left(\hat{c}\right.\right.$$

$$\left.\left. - \frac{\gamma'}{2} - \frac{1}{4}\sin 2\gamma'\right) + \frac{1}{2}R'\hat{s}(\hat{c})^2\right\} + \hat{s}(R')^2\left\{R(1-\hat{c})(1-\hat{s})\right.$$

$$\left. + R'\hat{c}\left(1 - \hat{s} - \tfrac{1}{2}\hat{c}\hat{c}\right) + R'\hat{s}\left(\frac{\gamma'}{2} - \frac{1}{4}\sin 2\gamma'\right)\right\}\Bigg]$$

$$+ W\left[R^3\left(2\hat{s} - \tfrac{3}{2}\gamma - \tfrac{1}{4}\sin 2\gamma\right) - R'\left\{R(1-\hat{c}) + R'\hat{c}\right\}\left\{R^2\gamma'(1-\hat{c})\right.\right.$$

$$\left.\left. + (R')^2(\gamma' - \hat{c})\right\} + \hat{c}(R')^4\left\{\frac{R^2}{(R')^2}\hat{c}(1-\hat{c}) + \hat{c} - \frac{\gamma'}{2} - \frac{1}{4}\sin 2\gamma'\right\}\right.$$

$$\left. - \hat{s}(R')^4\left\{\frac{R^2}{(R')^2}(1-\hat{c})(1-\hat{s}) + 1 - \hat{s} - \tfrac{1}{2}(\hat{c})^2\right\}\right] = 0$$

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Solution for m & H by Cramer's Rule.

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{Bmatrix} m \\ H \end{Bmatrix} = \begin{Bmatrix} W1 \\ W2 \end{Bmatrix}$$

$$DET = a11 * a22 - a21 * a12$$

$$m = (W1 * a22 - W2 * a12)/DET$$

$$H = (a11 * W2 - a21 * W1)/DET$$

The computer program on page 56 calculates the in and out of plane moments for a unit cable load and an unit loading in the plane of the ring.

```
PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0002        0002         0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
      DIMENSION BMB(91),BMT(91),BMZ(91),AXIAL(91)
C
C     THIS PROGRAM CALCULATES MOMENTS AND DEFLECTIONS OF ELLIPTIC RINGS.
C
C      Q IS THE IN PLANE LOAD PER INCH
C      P IS THE CONCENTRATED NORMAL LOAD
C      BIX IS THE MOMENT OF INERTIA ABOUT X-X AXIS
C      BIY IS THE MOMENT OF INERTIA ABOUT Z-Z AXIS
C      BIP IS THE POLAR MOMENT OF INERTIA
C      AREA IS THE CROSS-SECTION AREA
C      R1 IS THE CURVATURE IN REGION 1
C      R2 IS THE CURVATURE IN REGION 2
C      GOMMA IS THE ANGLE AT WHICH REGION 2 BEGINS
C      POISS IS POISSONS RATIO
C      E IS YOUNGS MODULUS
C
      READ(2,8)Q,P,BIX,BIY,BIP,AREA,BB
      READ(2,8)R1,R2,GOMMA,POISS,E,C ZZ,DEL
    8 FORMAT(7E10.5)
      GAMMA=GOMMA/57.295779
      C=COS(GAMMA)
      S=SIN(GAMMA)
      PO=1.+POISS
      CON=BIX/BIP
      CON1=BIY/AREA
      S2=SIN(2.*GAMMA)
      GAM1=1.570796-GAMMA
      AID1=GAMMA-0.5*S2
      AID2=GAMMA+0.5*S2
      S3=SIN(2.*GAM1)
      AID3=GAM1+0.5*S3
      AID4=GAM1-0.5*S3
C     OUT OF PLANE PROBLEM
C
C     TO EQUALS ZERO BY SYMMETRY.
C     SHEAR IS ZERO BY SYMMETRY.
C
      TO=0.0
C     IN PLANE PROBLEM
      CAP1=R2/R1
      CAP2=R1/R2
      CAP3=1.5*GAMMA+0.25*S2-2.*S
      CAP4=C*(C-0.5*AID3)
      CAP5=R1*(1.-C)+R2*C
      CAP6=R1*R1*R1
      CAP7=R2*R2*R2
      A11=GAMMA+GAM1*CAP1
      A12=-R 2*(CAP2*(GAMMA-S)+GAM1*(1.-C)+C*(GAM1-C)+S*(1.-S))
      A21=-R1*R1*(GAMMA-S+R2*C*R1*CAP1*(GAM1-C)+CAP1*(1.-C)*(A11)
```

```
      A21=R2*R2*(CAP2*CAP2*(S-GAMMA)-GAM1*(CAP2*(1.-C)+C)+C*C -S*(1.-C)
      A22=CAP6*CAP3+R2*R2*CAP5*(C*(GAM1-C)+S*(1.-S)-CAP2*GAM1*(1.-C))-(
     1*CAP7*(CAP2*C*(1.-C)+CAP4+0.5*S*C*C)+S*CAP7*(CAP2*(1.-C)*(1.-S) -
     2C*(1.-S-0.5*C*C)+0.5*S*AID4)
      W2=-CAP7*(-CAP6/CAP7*CAP3-CAP5*(CAP2*CAP2*GAM1*(1.-C)+GAM1-C)+C*(
     1*(CAP2*CAP2*C*(1.-C)+CAP4/C)-S*R2*(CAP2*CAP2*(1.-C)*(1.-S)+1.-S
     2 -0.5*C*C))
      DET=A11*A22-A21*A12
      BM=(W1*A22-W2*A12)/DET
      H=(A11*W2-A21*W1)/DET
      AXE1=-.5*P*BB*C+0.5*P*R1*S
      AXE2=-.5*P*BB*S+0.5*P*R1*(1.-C)
      WRITE(3,90)BM,H,AXE1,AXE2
   90 FORMAT(1H ,12HBENDING MOM=F12.4,10X,17HHORIZONTAL SHEAR=F12.4/
     112HBM AT GAMMA=F12.4,10X,12HTM AT GAMMA=F12.4/)
      DO 30 J=1,91
      THETA=FLOAT(J-1)*0.0175
      IF(THETA-GAMMA)35,35,37
   35 TIG1=SIN(THETA)
      TIG2=COS(THETA)
      BMB(J)=-.5*P*BB*TIG2+TIG1*(0.5*P*R1-TO)
      BMT(J)=TO*TIG2-0.5*P*BB*TIG1+0.5*P*R1*(1.-TIG2)
      BMZ(J)=BM+(1.-TIG2)*(Q*R1-H)*R1
      AXIAL(J)=H*TIG2
      GO TO 30
   37 TIG3=COS(THETA-GAMMA)
      TIG4=SIN(THETA-GAMMA)
      BMB(J)=AXE1*TIG3-AXE2*TIG4+0.5*P*R2*TIG4
      BMT(J)=AXE1*TIG4+AXE2*TIG3+0.5*P*R2*(1.-TIG3)
      BMZ(J)=BM+R1*(Q*R1-H)*(1.-C)+R2*(Q*R2-H*C)*(1.-TIG3)-H*R2*S*TIG4
      AXIAL(J)=H*COS(THETA+GAMMA)
   30 CONTINUE
      WRITE(3,60)
   60 FORMAT(1H1,12X,7HDEGREES,15X,14HOUT PLANE BEND.14X,
     17HTORSION,14X,13HIN PLANE BEND,11X,11HAXIAL FORCE//)
      DO 40 J=1,91
      THETA=FLOAT(J-1)
   40 WRITE(3,50)THETA,BMB(J),BMT(J),BMZ(J),AXIAL(J)
   50 FORMAT(1H ,     5(10X,E14.7))
      WRITE(3,200)Q,P,BIX,BIY,BIP,AREA,BB
      WRITE(3,200)R1,R2,GOMMA,POISS,E,CZZ
  200 FORMAT  (1H ,7E14.7///)
      STOP
      END
VARIABLE ALLOCATIONS
   BMB(R )=0084-0000    BMT(R )=016A-00B6    BMZ(R )=0220-016C AXIAL(R )=
   BIX(R )=02DC         BIY(R )=02DE         BIP(R )=02E0       AREA(R )=
    R2(R )=02E8       GOMMA(R )=02EA       POISS(R )=02EC          E(R )=
 GAMMA(R )=02F4          C(R )=02F6           S(R )=02F8         PO(R )=
    S2(R )=0300       GAM1(R )=0302        AID1(R )=0304       AID2(R )=
  AID4(R )=030C         TO(R )=030E        CAP1(R )=0310       CAP2(R )=
  CAP5(R )=0318       CAP6(R )=031A        CAP7(R )=031C        A11(R )=
   A21(R )=0324        A22(R )=0326          W2(R )=0328        DET(R )=
  AXE1(R )=0330       AXE2(R )=0332       THETA(R )=0334       TIG1(R )=
  TIG4(R )=033C          J(I )=035C

STATEMENT ALLOCATIONS
```

MOMENTS DUE TO UNIT LOADS INPUT

DEGREES	OUT PLANE BEND	TORSION
0.0000000E 00	-0.3077999E 01	0.3166198E-06
0.1000000E 01	-0.3031050E 01	-0.5345536E-01
0.2000000E 01	-0.2983173E 01	-0.1060811E 00
0.3000000E 01	-0.2934382E 01	-0.1578609E 00
0.4000000E 01	-0.2884692E 01	-0.2087790E 00
0.5000000E 01	-0.2834120E 01	-0.2588201E 00
0.6000000E 01	-0.2782679E 01	-0.3079681E 00
0.7000000E 01	-0.2730386E 01	-0.3562088E 00
0.8000001E 01	-0.2677257E 01	-0.4035266E 00
0.9000001E 01	-0.2623309E 01	-0.4499080E 00
0.1000000E 02	-0.2568556E 01	-0.4953379E 00
0.1100000E 02	-0.2513017E 01	-0.5398027E 00
0.1200000E 02	-0.2456709E 01	-0.5832891E 00
0.1300000E 02	-0.2399648E 01	-0.6257835E 00
0.1400000E 02	-0.2341852E 01	-0.6672723E 00
0.1500000E 02	-0.2283339E 01	-0.7077436E 00
0.1600000E 02	-0.2224127E 01	-0.7471852E 00
0.1700000E 02	-0.2164234E 01	-0.7855843E 00
0.1800000E 02	-0.2103678E 01	-0.8229298E 00
0.1900000E 02	-0.2042478E 01	-0.8592094E 00
0.2000000E 02	-0.1980651E 01	-0.8944125E 00
0.2100000E 02	-0.1918219E 01	-0.9285286E 00
0.2200000E 02	-0.1855200E 01	-0.9615467E 00
0.2300000E 02	-0.1791612E 01	-0.9934569E 00
0.2400000E 02	-0.1727476E 01	-0.1024250E 01
0.2500000E 02	-0.1662810E 01	-0.1053915E 01
0.2600000E 02	-0.1597635E 01	-0.1082445E 01
0.2700000E 02	-0.1531971E 01	-0.1109830E 01
0.2800000E 02	-0.1465837E 01	-0.1136062E 01
0.2900000E 02	-0.1399255E 01	-0.1161132E 01
0.3000000E 02	-0.1332245E 01	-0.1185032E 01
0.3100000E 02	-0.1264826E 01	-0.1207758E 01
0.3200000E 02	-0.1197020E 01	-0.1229299E 01
0.3300000E 02	-0.1128847E 01	-0.1249651E 01
0.3400000E 02	-0.1060330E 01	-0.1268807E 01
0.3500000E 02	-0.9914869E 00	-0.1286761E 01
0.3600000E 02	-0.9223405E 00	-0.1303507E 01
0.3700000E 02	-0.8529108E 00	-0.1319041E 01
0.3800000E 02	-0.7832214E 00	-0.1333358E 01
0.3900000E 02	-0.7132908E 00	-0.1346452E 01
0.4000000E 02	-0.6431423E 00	-0.1358322E 01
0.4100000E 02	-0.5727968E 00	-0.1368961E 01
0.4200000E 02	-0.5022761E 00	-0.1378368E 01
0.4300000E 02	-0.4316014E 00	-0.1386540E 01
0.4400000E 02	-0.3607938E 00	-0.1393473E 01
0.4500000E 02	-0.2898762E 00	-0.1399167E 01
0.4600000E 02	-0.2188710E 00	-0.1403619E 01
0.4700000E 02	-0.1477976E 00	-0.1406827E 01
0.4800000E 02	-0.7667888E-01	-0.1408791E 01
0.4900000E 02	-0.5537030E-02	-0.1409511E 01
0.5000000E 02	0.6560634E-01	-0.1408985E 01
0.5100000E 02	0.1367295E 00	-0.1407215E 01
0.5200000E 02	0.2078121E 00	-0.1404200E 01
0.5300000E 02	0.2788298E 00	-0.1399941E 01
0.5400000E 02	0.3497624E 00	-0.1394441E 01
0.5500000E 02	0.4205882E 00	-0.1387700E 01

T PLANE BEND | TORSION | IN PLANE BEND | AXIAL FORCE

18[illegible]E 00	-0.1370507E 01	-0.5725053E 01	0.1539237E 01
81[illegible]E 00	-0.1359977E 01	-0.5841670E 01	-0.1232433E 01
64129E 00	-0.1347776E 01	-0.6179286E 01	-0.1276976E 01
44292E 00	-0.1333855E 01	-0.6498461E 01	-0.1321127E 01
21382E 00	-0.1318222E 01	-0.6799127E 01	-0.1364874E 01
39657E 01	-0.1300880E 01	-0.7081166E 01	-0.1408203E 01
36808E 01	-0.1281835E 01	-0.7344500E 01	-0.1451101E 01
35612E 01	-0.1261093E 01	-0.7589062E 01	-0.1493556E 01
30037E 01	-0.1238661E 01	-0.7814761E 01	-0.1535552E 01
26054E 01	-0.1214545E 01	-0.8021545E 01	-0.1577077E 01
21635E 01	-0.1188752E 01	-0.8209323E 01	-0.1618120E 01
16751E 01	-0.1161290E 01	-0.8378061E 01	-0.1658667E 01
11371E 01	-0.1132168E 01	-0.8527694E 01	-0.1698706E 01
05467E 01	-0.1101395E 01	-0.8658187E 01	-0.1738225E 01
99011E 01	-0.1068980E 01	-0.8769500E 01	-0.1777213E 01
91972E 01	-0.1034933E 01	-0.8861579E 01	-0.1815656E 01
84323E 01	-0.9992655E 00	-0.8934427E 01	-0.1853542E 01
.76037E 01	-0.9619859E 00	-0.8987995E 01	-0.1890861E 01
67084E 01	-0.9231082E 00	-0.9022287E 01	-0.1927601E 01
57436E 01	-0.8826427E 00	-0.9037277E 01	-0.1963750E 01
47068E 01	-0.8406015E 00	-0.9032960E 01	-0.1999299E 01
35948E 01	-0.7969994E 00	-0.9009351E 01	-0.2034235E 01
24053E 01	-0.7518484E 00	-0.8966445E 01	-0.2068548E 01
11355E 01	-0.7051618E 00	-0.8904258E 01	-0.2102227E 01
97825E 01	-0.6569554E 00	-0.8822814E 01	-0.2135263E 01
83489E 01	-0.6072436E 00	-0.8722139E 01	-0.2167644E 01
68[illegible]9E 01	-0.5560407E 00	-0.8602254E 01	-0.2199362E 01
51992E 01	-0.5033628E 00	-0.8463205E 01	-0.2230408E 01
34878E 01	-0.4492260E 00	-0.8305021E 01	-0.2260768E 01
16805E 01	-0.3936479E 00	-0.8127773E 01	-0.2290438E 01
97748E 01	-0.3366436E 00	-0.7931493E 01	-0.2319405E 01
77679E 01	-0.2782316E 00	-0.7716244E 01	-0.2347662E 01
56578E 01	-0.2184316E 00	-0.7482126E 01	-0.2375201E 01
34418E 01	-0.1572582E 00	-0.7229159E 01	-0.2402012E 01

E-02 0.8390000E-02 0.1517000E-01 0.1090000E 00 0.6156000E 01

I_{zz} I_p AREA B

E 02 0.3200000E 00 0.1700000E 08 0.0000000E 00

Y E BLANK

DEGREES OUT PLANE BEND TORSION

0.5700000E 02	0.5618309E 00	-0.1370507E (
0.5800000E 02	0.6481678E 00	-0.1359977E (
0.5900000E 02	0.7464129E 00	-0.1347776E (
0.6000000E 02	0.8444292E 00	-0.1333855E (
0.6100000E 02	0.9421882E 00	-0.1318222E (
0.6200000E 02	0.1039657E 01	-0.1300880E (
0.6300000E 02	0.1136808E 01	-0.1281835E (
0.6400001E 02	0.1233612E 01	-0.1261093E (
0.6500001E 02	0.1330037E 01	-0.1238561E (
0.6600001E 02	0.1426054E 01	-0.1214545E (
0.6700001E 02	0.1521635E 01	-0.1188752E (
0.6800001E 02	0.1616751E 01	-0.1161290E (
0.6900001E 02	0.1711371E 01	-0.1132168E (
0.7000001E 02	0.1805467E 01	-0.1101395E (
0.7100001E 02	0.1899011E 01	-0.1068980E (
0.7200001E 02	0.1991972E 01	-0.1034933E (
0.7300001E 02	0.2084323E 01	-0.9992655E (
0.7400001E 02	0.2176037E 01	-0.9619859E (
0.7500001E 02	0.2267084E 01	-0.9231082E (
0.7600001E 02	0.2357436E 01	-0.8826427E (
0.7700001E 02	0.2447068E 01	-0.8406015E (
0.7800001E 02	0.2535948E 01	-0.7969994E
0.7900001E 02	0.2624053E 01	-0.7518484E
0.8000001E 02	0.2711355E 01	-0.7051618E
0.8100001E 02	0.2797825E 01	-0.6569554E
0.8200001E 02	0.2883439E 01	-0.6072436E
0.8300001E 02	0.2968169E 01	-0.5560407E
0.8400001E 02	0.3051992E 01	-0.5033628E
0.8500001E 02	0.3134878E 01	-0.4492260E
0.8600001E 02	0.3216805E 01	-0.3936479E
0.8700001E 02	0.3297748E 01	-0.3366436E
0.8800001E 02	0.3377679E 01	-0.2782316E
0.8900001E 02	0.3456578E 01	-0.2184316E
0.9000001E 02	0.3534418E 01	-0.1572582E

Q	P	Ixx	Izz	Ip
0.1000000E 01	0.1000000E 01	0.9760001E-02	0.8390000E-02	0.1517000E-01

R1	R2	ν	γ	E
0.5312000E 01	0.8520000E 01	0.5758500E 02	0.3200000E 00	0.1700000E 08

"select 1-station mode-F1" to the spacecraft, the two ground stations are also commanded to transmit sequentially, both operating on 8.15 GHz. Alternatively, if the "select 1-station mode-F2" is sent, both stations are commanded to transmit on 8.155 GHz. The format generator commands the digital converter input data switch to connect to the appropriate IF/detector channel.

The ratio of the length of the coarse baseline to that of the vernier baseline has been made 1:16 so that a 4-bit word could be used for the coarse data. If a change in this ratio should occur due to extreme temperature cycling, it is desirable to be able to have a 9-bit coarse data available. Therefore, a command "convert to 9-bit data" has been incorporated. Upon receipt of this command the format generator stops the automatic sequencing of the RF switches from vernier to coarse baselines. The 9-bit coarse phase readings are thus substituted for the vernier readings.

To provide design assurance for the antenna array thermal/mechanical design, and provide baseline calibration capability in the 1-station mode, a set of transducers has been incorporated into the array. Both temperature gauges and strain gauges have been included. In this manner, information about the array dimensions and temperature can be transmitted to the ground by using the "array transducers on" command.

10.2.5 IN-ORBIT TESTING AND OPERATION

The in-orbit testing of the Interferometer Subsystem can be functionally grouped into three identifiable test periods or phases:

- Phase I Tests — which provide the relatively gross (qualitative) checkout and verification of all operating modes to ascertain launch survival as soon as possible after attitude stabilization in synchronous orbit.
- Phase II Tests — which provide a thorough, in-depth evaluation of all interferometer characteristics, including in-flight calibration, as necessary to mission performance.
- Phase III Tests — which are the post-verification functional and operational tasks required of the Interferometer Subsystem.

Table 10.2-2 defines a set of anticipated tests, identifies the test phase, and defines the test requirement in terms of anticipated test usefulness. See subsection 2.5 of the Technical Proposal for more details.

10.2.6 LINK CALCULATION

The calculations which determine the necessary ground station effective radiated power are given in Table 10.2-3.

necessary to calibrate at both frequencies since the two IF amplifiers have different center frequencies. The phase readings obtained are formatted in the same way as in the 2-station mode and are sent to the Telemetry Subsystem for transmission to the ground station.

The baseline calibration mode enables changes in the baseline length, baseline orthogonality, and various phase bias errors to be calibrated out. The system is put into this mode with the "select diagonal baseline mode" command. The format generator in the digital converter then commands the switch drive to connect the RF switches (in the coupler switch module) so that phase readings are made on two diagonal baselines. Thus, the reference channel is connected to the pitch reference antenna element (P_r) while the signal channel is connected to the roll vernier element (R_v). Then the switches sequence so that the two phase-measuring channels are connected to the R_r and P_v elements. This sequence is performed repetitively, and the phase readings so obtained are formatted into the interferometer output word in the locations where the vernier word appears in the 2-station mode. The output word containing the diagonal baseline readings is sent to the ground station, where it is stored. The phase readings on the two diagonal baselines from illumination from two ground stations are redundant to the readings taken with the orthogonal baselines since only three phase readings are necessary to sense three attitude angles. Therefore, the eight phase readings (four from orthogonal baselines and four from diagonal baselines) can be used to calibrate changes in the orthogonal baseline length, the baseline orthogonality, and the pre-switch phase bias error. The calibration of the baseline parameters is efficient since the attitude angles and the baseline parameters are not strongly correlated. The calibration of the pre-switch phase errors is weaker since this type of error is strongly correlated with attitude angle. The calibration process involves filtering the phase data using a least-squares formulation of a Kalman recursive filter. This is more fully described in Appendix A of the technical proposal.

10.2.4.3 Backup Modes

The backup modes have been provided to enable interferometer system operation to continue reliably should certain failures occur.

The two ac-dc converters in the power regulator module have been connected to redundant prime electrical power buses. Should one converter fail, the "standby converter on" command will switch the system load over to the other converter and bus.

The 2-channel receiver, which is made up of the mixer/amplifier module, the IF detector module, the first local oscillator module, the double local oscillator module, and digital converter module, has been provided with a standby redundant powered-down 2-channel receiver. When the "standby channel on" command is sent, dc power is applied to the standby mixer/amplifiers, first LO, DLO, and digital converter. A pair of RF electromechanical latching switches in the mixer/amplifier is also energized to switch the input channels to the redundant channels. The prime channels are "powered down." The gate module switches inputs to the standby digital converter.

As mentioned previously, the two IF amplifiers in the IF detector module are tuned to frequencies spaced 5 MHz apart, viz., 27.5 MHz and 32.5 MHz. To improve system reliability it has been arranged to make these two IF amplifiers operationally redundant. This is accomplished by enabling the 2-station mode to be implemented with transmission or only one RF frequency. Upon transmission of the command

The converter feeds this 60-bit word to the buffer module, where it goes to the Data Acquisition Control Unit (DACU) in the Telemetry Subsystem. While the buffer accumulates a new word every 34 msec, the DACU reads this word once every three seconds.

The interferometer is directly connected to the attitude control system in the single-station mode. The digital output of the interferometer is fed into the digital operational controller (DOC). Since the illumination from only one ground station is used, the interferometer can only measure pitch and roll angles. If yaw angle data is available from another sensor (the Polaris sensor, for example), 3-axis attitude control can be achieved.

There are two ways to use the single station mode: (1) In the boresight-mode the interferometer is used to point the spacecraft exactly at the ground station. To accomplish this, the angle errors are fed to the ACS until the spacecraft is slewed to exactly boresight, at which time the angle error goes to zero. (2) In the boresight offset mode, a desired offset angle ϕ_1, θ_1 from the LOS line to the ground station is fed into the DOC in the form of counts $N\phi_1$, $N\theta_1$. These offset counts are subtracted from the interferometer output counts $N\phi$, $N\theta$. The count differences $\Delta N\phi$, $\Delta N\theta$ are then used as attitude error signals. This effectively offsets the angle null positions. In this boresight offset mode, the scale factor F, which relates the angle error to the output count, is a function of the yaw angle.

$$\epsilon_\phi = F_\phi N_\phi, \qquad \epsilon_\theta = F_\theta N_\theta$$

$$F_\phi = f_1(\psi), \qquad F_\theta = f_2(\psi)$$

There are two possible ways to implement the yaw axis control in this mode: either maintain the yaw angle at zero ($\psi = 0$) or measure the yaw angle and compensate both F_ϕ and F_θ.

In the single-station mode, the interferometer supplies the DOC in the Attitude Control System with a 26-bit word from either the f_1 (ground station 1 readings) or the f_2 (ground station 2) half of the buffer output register. The 26-bit words are clocked out serially by the DOC strobe. An interrogate pulse from the DOC determines which of the two 26-bit words is required by the DOC.

10.2.4.2 Calibration Modes

The injection calibrate mode functions to phase calibrate the receiver front end subassembly and the receiver/converter assembly. A calibration signal is injected into each transmission line from the antenna elements at the point where the line enters the switch. This injection is accomplished via directional couplers built into the coupler/switch module. The equi-phased signals for calibration are generated by dividing the output of the calibration oscillator with a 6-way power divider.

To accomplish the injection calibration, the "calibration system on" command is sent. The two ground stations are also commanded off. The receiver command receptor circuit generates a signal to disable the automatic sequential switching of the input gate to the digital converter. The format generator then switches the calibrate oscillator frequency between 8.15 and 8.155 GHz. At the same time the digital converter is automatically sequenced between the two IF amplifier detectors. It is

Table 10.2-1. Error Sources

	Electrical Degrees Short Term	Electrical Degrees Long Term
1. SPACECRAFT SYSTEM	(3σ)	(3σ)
1.1 Pre-switch Errors	(degrees)	(degrees)
1.1.1 Antenna Distortion		
Phase Center Ripple (1)		0.7
Reflector Interaction		1.0
1.1.2 Other		
Baseline Tilt		1.5
Injection Calibrator Phase Drift		2.5
Component Mismatch		1.0
Transmission Line Tracking		0.5
1.2 Post-switch Errors		
Front-End Phase Tracking (2)		---
Data Filter Drift (2)		---
Gating	0.18	
Quantization	0.60	
L.O. Phase Jitter	negligible	
2. EVM DISTORTIONS		
Mechanical Distortions ($\pm 0.01^{o}$)		1.6
Thermal Distortions ($\pm 0.01^{o}$)		1.6
3. PROPAGATION ERRORS		
Refraction errors	negligible	negligible
4. SCALE FACTOR ERRORS		
Baseline Length		
Baseline Orthogonality		
Ambiguity Resolution		negligible
5. GROUND STATION ERRORS		
Ground Station Location	negligible	negligible
Satellite Location	negligible	negligible
	0.74^{o} (RSS)	3.9^{o} (RSS)

(1) Includes Mutual Coupling
(2) Those are removed by injection calibration

Baseline Length 38.53 in. $\Delta\phi$ (electr. deg) = $\frac{2\pi D}{\lambda} \sin\theta\Delta\theta$ (attitude angle)

$\Delta\phi = (159.5)\Delta\theta$
$\Delta\phi$ = phase error = 4.6^{o}
$\Delta\theta$ = attitude error = 0.03^{o}

10.2.3 PERFORMANCE ANALYSIS SUMMARY

The performance of the Interferometer Subsystem is determined by the magnitude of the various error sources and how these errors interact. Performance was determined by a combination of analysis and breadboard measurements. The analysis was done by synthesizing a mathematical model of the entire system (spacecraft equipment and ground equipment) embodying all significant error sources. Estimates of the magnitude of the error sources were made, and computer runs of the attitude angle sensing accuracy of the model were made using Monte Carlo techniques for simulating random errors. The magnitudes of the error sources were then varied to determine their individual effect on system accuracy. Various in-orbit calibration schemes were also explored to increase the accuracy achievable.

The results of the model analysis, which are too extensive to present here (see appendixes A and B of the technical proposal), indicated that the attitude accuracy of 0.03° (3σ) can be achieved. It was also found that by using phase readings from diagonal baselines, changes in the baseline length and orthogonality can be calibrated out. This calibration process involves using only two ground stations with an associated computer.

A tabulation of the estimated magnitudes of the error sources is given in Table 10.2-1. Where breadboard measurements have been made, the measured errors are equal or lower than the estimations.

This table applies to 3-axis attitude sensing where the scale factor error due to baseline length changes has been calibrated out. For 2-axis sensing, baseline length changes can be evaluated with the array transducers.

For a complete description of the error sources, see section 2.3.3 of the Technical proposal.

10.2.4 OPERATIONAL MODES

There are three classes of commandable operational modes for the interferometer: the primary modes, the calibration modes, and the backup modes. The two primary modes are 3-axis attitude angle sensing and 2-axis sensing. The two calibration modes, injection calibrate and baseline calibrate, are used for in-orbit system calibration. The backup modes allow the system operation to be modified or the system to be reconfigured to compensate for certain system failure modes.

10.2.4.1 Primary Modes

The interferometer is capable of sensing all three attitude angles (pitch, roll, and yaw) and can be used for 3-axis or 2-axis sensing. For 3-axis sensing, the interferometer is sent a "select 2-station mode" command. The interferometer sequentially makes vernier and coarse phase readings on the pitch and roll baselines while it is being illuminated simultaneously from two ground stations. The readings from the two ground stations are distinguished by the fact that the RF transmitting frequencies from the two stations are separated by 5 MHz. The diplexer therefore feeds the two down-converted signals into the two separate IF amplifier/detector/filter channels. The digital converter repetitively sequences between the two filter outputs by means of its input data switch. The converter also formats the four phase readings and adds a mode code bit signifying that the system is operating in the 2-station mode.

An IF detector extracts a 2 kHz different frequency from reference and comparison signals. The 2 kHz data signal is filtered and amplified to adequate level by an operational amplifier and then shaped to digital form by a zero crossing detector. The output is fed in parallel to the prime and standby digital converters. These signal operations apply equally to the f_1 and f_2 channels.

The digital converter consists of an input data switch, a digital phase comparator, a phase count gate, an averaging counter, gating logic, discontinuity detector logic, voting logic, a receiver clock, a clock divider, and a format generator. A receiver clock acts as a stable time reference for a converter's circuits, while a format generator acts as the master control for the converter's operations. A receiver clock also serves as the source of phase counting pulses for the averaging counter. A format generator contains digital and logic circuits to generate and shape timing waveforms which are used to achieve converter synchronous operation.

The 1.024 MHz output of the receiver clock in the converter is transformed by the clock divider (a 512 divider) to 2 kHz. This signal serves as the reference for the format generator, digital phase comparator, and DLO module.

The f_1 and f_2 data signals from the detector module are alternately sampled in sequence and are timed by the format generator. The 2 kHz digital data signals are compared in the digital phase comparator with the 2 kHz reference (from the clock divider). The resultant 2 kHz signal containing the phase information is used in the phase count gate to stop counter action previously initiated by the 2 kHz reference signal from the format generator. The number of pulses supplied by the receiver clock and allowed to exist in the phase count gate is in proportion to the phase difference between the data signal and the reference, and in proportion to the interferometer attitude angle.

To reduce the phase jitter caused by random noise during the counter turn-on and turn-off, many successive counts are averaged together. The random phase variance is thereby reduced by the inverse of the number of readings averaged.

The pulses from the phase count gate are counted in the averaging counter which at first accepts only three samples for the purpose of detecting potential discontinuity errors. The discontinuity logic examines these samples for an indication of measurement in the area of discontinuity, where the line-of-sight angle is near a full count of a vernier cycle and a zero count of the adjacent cycle, and a decision is made based on the three samples made by the voting logic. The voting logic, upon two positive samples of the discontinuous condition, compels complementing adjustment to the clock divider and averaging counter. The remaining data samples are then received by the averaging counter and proceed to the gating logic for output to the buffer module. The voting logic, upon detection of two negative samples, allows the remaining data samples to proceed to the gating logic without any adjustments to the clock divider and averaging buffer. Gating of the data to the buffer module is under the direction of the format generator.

In addition to controlling the digital data extracting process, the format generator also serves as the central timing unit for the RF switch driver (in the coupler/switch module), the calibrate oscillator, and the gates and buffers in the buffer module. Accordingly, the format generator develops the waveforms that direct their operation.

Power for all components of the receiver front end, with exception of the front end command therminator, is supplied by the Interface Circuits Module. It contains necessary regulating and signal conditioning networks. It receives its power from the power regulator in the receiver/converter assembly.

Upon command for interferometer power on, power from the regulator (in the receiver/converter) is fed to the Interface Circuits Module which applies required biasing voltage to the transducer conditioner and to the RF switch driver. Power is also applied to prime mixer/amplifiers, first LO, and DLO. At the same time, logic functions will ensure that no power is applied to the standby circuits. In response to the standby command, power is applied to the latching coaxial switches for standby operation and to standby mixer/amplifiers, first LO, and DLO, and is simultaneously removed from the prime circuits through the logic. An indication of which mode (prime or standby) is operating is transmitted to the telemetry system. A calibration command enables the calibrate oscillator. Command signals from the Command Decoder Distributors (A232 and A236) are interpreted by a decoding matrix in the command receptor module. The command receptor derives its power from the power regulator in the receiver/converter.

The receiver/converter is comprised of seven modules: (1) IF detector module, (2) prime digital converter, (3) standby digital converter, (4) buffer module, (5) gate module, (6) power regulator, and (7) receiver command receptor.

The requirement that signals be received simultaneously from the two ground stations is implemented by providing a diplexer and two separate IF amplifiers in the IF/detector module. The diplexer output ports are tuned to 27.5 MHz and 32.5 MHz, and the two IF amplifiers are similarly tuned. By spacing the transmitting frequencies by 5 MHz, the requisite simultaneous reception is accomplished. Should one IF amplifier fail, the other IF amplifier would be operationally redundant since the ground stations could then be operated sequentially. The tradeoffs involved in selecting this method of simultaneous operation are described in subsection 6.3 of the technical proposal.

Signals from the receiver front end are detected in the IF detector module after filtering and amplification. If the two carrier frequencies for dual frequency operation are f_1 (8.150 GHz) and f_2 (8.155 GHz), the output of the first mixer/amplifiers in both comparison and reference channels of the front end would be 150 MHz and 155 MHz, respectively, with a first LO of 8.000 GHz. If the lower DLO frequency to the reference channel, i.e., 122.500 MHz and 122.502 MHz is the corresponding comparison channel member, the "reference" mixer outputs would be 27.500 MHz and 32.500 MHz, respectively, for the 8.150 and 8.155 GHz carriers. The four signal frequencies (two reference and two comparison signals) are combined into a common signal (in the combiner module) and are fed to the diplexer in the IF detector module. The diplexer separates the f_1 reference and comparison signal and the f_2 reference and comparison signal into their respective channels.

Each channel in the IF detector module contains a main IF amplifier, an IF detector, a baseband filter, a low frequency amplifier, and a zero crossing detector. The main IF amplifier performs the conventional amplifying function with Automatic Gain Control (AGC). AGC affords the system a sufficient dynamic range to handle the expected levels of the received signal. The AGC voltage is sent via telemetry to ground stations as an indicator of received signal strength and receiver sensitivity.

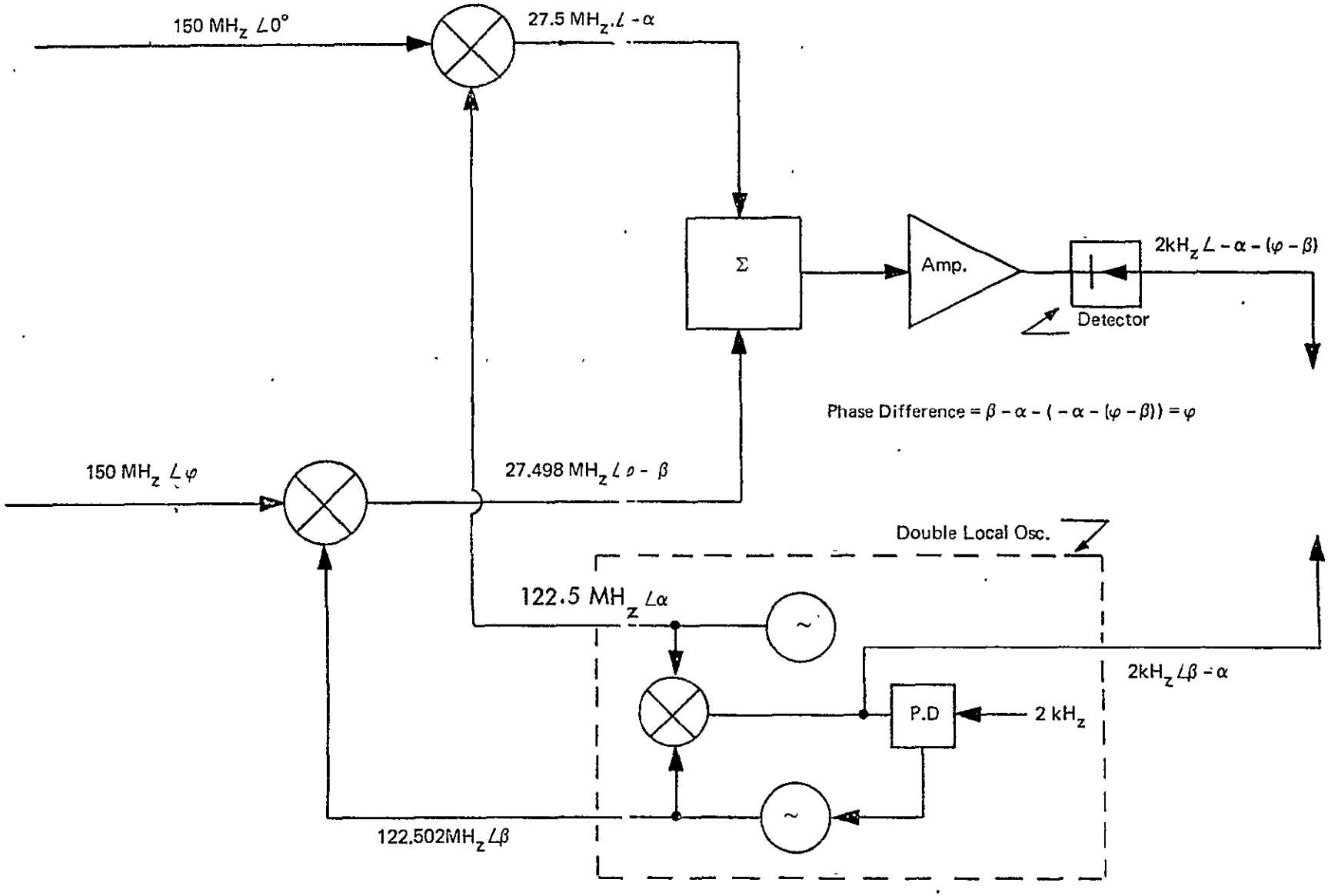


Figure 10.2-4. Phase Coherent Down-Conversion

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(nominally 150 MHz). The resultant signals at this frequency are amplified and in turn down-converted in the second mixing action to a lower intermediate frequency (30 MHz nominally) where they are further amplified.

To perform the first conversion, the mixer/amplifier module uses the first LO module that contains local oscillator for both the prime first mixer/amplifier and the standby first mixer/amplifiers. The particular oscillator is selected by command. To obtain the first IF frequency of 150 MHz from the RF input at 8.15 GHz, the first LO operates at a frequency of 8.0 GHz.

The DLO is used for the second conversion process. The module contains the local oscillator for the prime second mixer/amplifiers and the local oscillator for the standby second mixer/amplifiers. Oscillator selection is by command. The DLO operates at 120 MHz to provide a 30 MHz second IF frequency from the 150 MHz first IF. The DLO also provides two outputs differing in frequency by the low frequency reference (2 kHz) from the digital converter used in derivation of the outputs. Additionally, the phase of the low frequency that results from DLO's two outputs is coherently related to its reference from the digital converter and forms a firm basis for correct data extraction. A phase-locked loop constitutes an important part of the DLO for coherent operation. Finally, a DLO transmits lockup condition to the telemetry system to indicate when data may be regarded as valid.

The method by which the double local oscillator down-converts an RF phase difference to a low frequency phase difference is illustrated in Figure 10.2-4. Two 8-GHz RF signals from two antenna elements with a phase difference ϕ are fed into the first mixer (and shown), where they are down-converted to 150 MHz while preserving the difference. These two signals are again down-converted by using the double local oscillator. This introduces a frequency offset of 2 kHz to the second mixer output signals. These signals are then summed, amplified, and detected. The 2 kHz difference frequency is then phase-compared to the 2 kHz reference signal which was used to phase-lock the DLO. Because the two outputs of the DLO are phase coherent, the phase difference ϕ of the IF inputs are preserved in the down-conversion and detection process. This can be appreciated by tracing the signal phases as is done in Figure 10.2-4. The tradeoffs involved in selecting this type of phase-measuring receiver are discussed in subsection 6.1.1 of the technical proposal.

The combiner is the final stage in the receiver front end. The outputs of the two second mixers are summed in the final combiner before they are fed into the high-gain IF amplifier. The comparison and reference combiners feed signals from either the prime or the standby circuits, whichever is operational.

The calibration oscillator constitutes a source of radio frequency signals to be injected into the interferometer system for calibration purposes. The oscillator applies signals of the same frequency, amplitude, and phase upon command at each of the three directional couplers of the coupler/switch module. Calibration is executed sequentially and in synchronism with the digital converter at the two interferometer operational frequencies.

The Interface Circuits Module is associated with the measurement of system performance and contains all the accessory electronics that are necessary to operate the measuring transducers in the array subassembly. This includes the excitation, amplification, bridge and signal conditioning circuits required for satisfactory transducer performance. Thermal and strain gauge transducers are sampled periodically by the telemetry subsystem.

all electrical components of the array assembly. The baseline structure also maintains the antenna array and transmission line positional stabilities that are vital to system performance, and effectively distributes accumulated thermal energy. The transducer module incorporates thermistors and strain gauges. These measuring transducers verify the integrity of the mechanical entities. Properly placed thermistors verify the baseline lengths by the relationship between length and thermal gradient. Verification of baseline planarity is provided by strain gauges. The structural design tradeoffs for the baseline and transmission lines are discussed in subsection 6.7 (technical proposal).

From the cable subassembly, the RF signals enter the front end which selects, down converts, and amplifies the signals. To accomplish these processes the front end contains: (1) coupler/switch module, (2) mixer/amplifier module (including filter and summing networks), (3) first LO module, (4) double local oscillator (DLO) module, (5) calibration oscillator, and (6) interface circuit module (transducer conditioner, power conditioner and front end command receptor). The type of receiver and receiver configuration tradeoffs is discussed in subsection 6.1 (technical proposal).

The receiver is a switched dual-channel, triple down-conversion system using direct counting. The signal and reference channels of the mixer/amplifier module are sequenced between the various antenna baselines by the coupler/switch module. The rationale for choosing a dual-channel switched system instead of a 6-channel unswitched system are discussed in subsection 6.1.2 of the technical proposal. The reference antenna elements are switched by one switch while the other elements are switched by another, as shown schematically inside the coupler switch module.

The coupler/switch module provides for signal selection and injection of calibration signals. Diode RF switches, a switch driver, and six directional couplers provide the selection and calibration functions. The sampling operation allows only those signals that correspond to pitch or roll axis data to be processed at the appropriate time. Thus, only a comparison of vernier and coarse data signals with their correct reference takes place. The proper sequence, duration and periodicity of the comparative measurements is under control of the digital converter, where the actual comparison is also made.

Signals that leave the coupler/switch module enter the filter module and its bandpass filter, circulator, and coaxial switch components. The components are interconnected in the above order along two channels. One channel contains a reference signal and the other channel contains the signal to be compared against the reference. Only signals of the correct frequency are passed through the bandpass filter. The circulator stabilizes circuit operation by isolating the input and output networks. The coaxial switch connects the signal from the filter module to one of the two complementary circuits in the mixer/amplifier module. Thus, the coaxial switch directs the signal in each of its channels to the appropriate prime or standby (redundant) circuits of the mixer/amplifier module, and is operated by remote commands.

To accomplish conversion and amplification, the mixer/amplifier module contains two mixer/amplifiers in series in each of the prime and standby circuits and two in each of the reference channel prime and standby circuits; i.e., double conversion is performed in each comparison and reference channel prime and standby circuits, thus requiring eight mixer/amplifiers. Radio frequency signals at the module input are down-converted in the first mixing action to an intermediate frequency



Figure 8. AES Suit - Collapsed Position for Stowage - End View

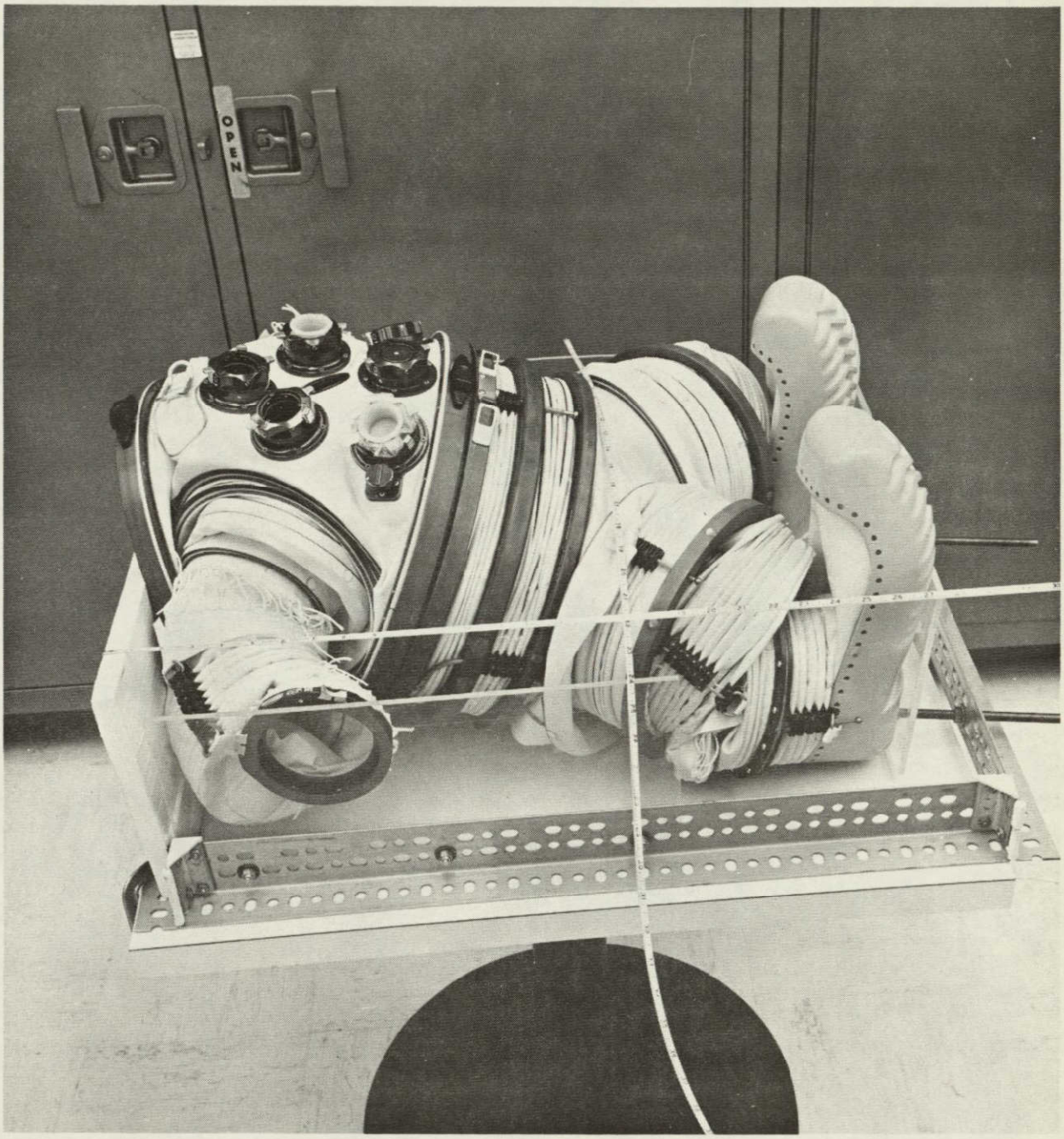


Figure 9. AES Suit - Collapsed Position for Stowage - Side View

The TLA uses a combination of multiple bearing and constant volume convoluted joints comprising the total mobility subsystem. See Figure 10 through 15 for a pictorial presentation of suit mobility. The suit is separable into individual removable and interchangeable modules; boot, leg, hip, lower torso, upper torso, shoulder wedges and arm segments.

5.2.1 Shoulder Joint

The shoulder joint consists of four wedge sections and five rotary seal bearings. Wedge angles are determined in such a manner that the arm may be moved in any plane without restriction or programming. The shoulder joint subsystem is based on the multi-bearing shoulder joint developed at Ames Research Center, Bio-Technology Branch. A problem area does exist in the current shoulder configuration because of distortion in the bearing immediately adjacent to the shoulder. This distortion has increased the torque of this bearing with a resultant higher torque in certain arm motions. In the critical area, that is in the typical work areas of the suit, the shoulder joint works exceedingly well with little, or no programming evident. The bearings are truly compact and provide not only pneumatic sealing but also contain environmental seals both exterior and interior to the ball bearing race/seal itself. Similar bearings are used in the hip.

A shoulder joint incorporating the bearing has been cycled 450,000 times through a 120 degree arc (one cycle moves the joint 240 degrees) at 5 psig without an appreciable increase in torque or a discernable increasing leakage trend. This demonstrated improvement affords greater suit life and indicates the feasibility of suit reuse. Figures 16 and 17 show a typical cycling setup.

5.2.2 Elbow Joint

The elbow joint uses a single axis constant volume convoluted joint. The cable is free to slide so that the joint can be completely collapsed during stowage.

5.2.3 Waist Joint

The waist joint consists of two elliptical, convoluted section, single axis joints so constructed that planes of flexure are 90^{0} to each other. Waist abduction is provided with approximately $\pm 20^{0}$ range. Waist flexion has 65^{0}

Form 2427

AiRESEARCH MFG. CO.

DATE 7-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

CABLE LOADS

975 #
650 #
325 #

SUIT PRESS (PSI)

15 BURST
10 PROOF
5 OPER.

BENDING MOMENTS & AXIAL FORCES FOR UNIT LOADS

$M_{r-r} = -3.07$
$T = 0$
$M_{z-z} = -11.73$
$F_{axial} = 2.83$
} @ $\Theta = 0°$

$M_{r-r} = 0$
$T = -1.41$
$M_{z-z} = -7.19$
$F_{axial} = 1.85$
} @ $\Theta = 49°$

$M_{r-r} = 3.53$
$T = 0$
$M_{z-z} = -7.23$
$F_{axial} = -2.40$
} @ $\Theta = 90°$

PRESS ACTS ON 2.7" OF MATERIAL ATTACHED TO RING

Form 2427

AiRESEARCH MFG. CO.

DATE 7-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

BURST CONDITIONS (15 PSI)

$\theta = 0°$

$M_{r\text{-}r} = -3.07(975) = -2993.$ #in

$M_{z\text{-}z} = -11.73(1.7)(15) = -299$ #in

$F_{AXAL} = 2.83(1.7)(15) = 72.2$ #

$T = 0$

$\theta = 49°$

$M_{r\text{-}r} = 0$

$T = -1.41(975) = -1374.$ #in

$M_{z\text{-}z} = -7.19(1.7)(15) = -183$ #in

$F_{axial} = 1.85(1.7)(15) = 47.2$ #

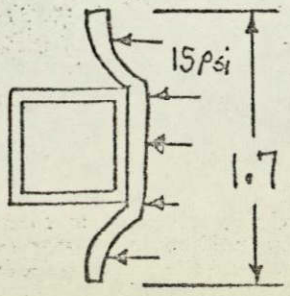
$\theta = 90°$

$M_{r\text{-}r} = 3.53(975) = 3441.$ #in

$T = 0$

$M_{z\text{-}z} = -7.23(1.7)(15) = -184.3$ #in

$F_{axial} = -2.4(1.7)(15) = -61.2$ #



REPORT
PAGE 62 OF

Form 2427

AiRESEARCH MFG. CO.

DATE 7-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

PROOF CONDITIONS (10 PSI)

$\theta = 0°$

$M_{r-r} = -3.07(650) = -1995$ #in

$M_{z-z} = -11.73(1.7)(10) = -199.$ #in

$F_{axial} = 2.83(1.7)(10) = -48$ #

$T = 0$

$\theta = 49°$

$M_{r-r} = 0$

$T = -1.41(650) = -916.5$ #in

$M_{z-z} = -7.19(1.7)(10) = -122$ #in

$F_{axial} = 1.85(1.7)(10) = 31.4$ #

$\theta = 90°$

$M_{r-r} = 3.53(650) = 2294$ #in

$T = 0$

$M_{z-z} = -7.23(1.7)(10) = -122.9$ #in

$F_{axial} = -2.4(1.7)(10) = -40.8$ #

AiRESEARCH MFG. CO.

DATE 7-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

OPERATING CONDITIONS (SPSI)

$\Theta = 0$

$M_{r-r} = -997.$

$M_{z-z} = -100$

$F_{axial} = 24.$

$T = 0$

$\Theta = 49°$

$M_{r-r} = 0$

$T = -458$

$M_{zz} = -61.$

$F_{axial} = 15.$

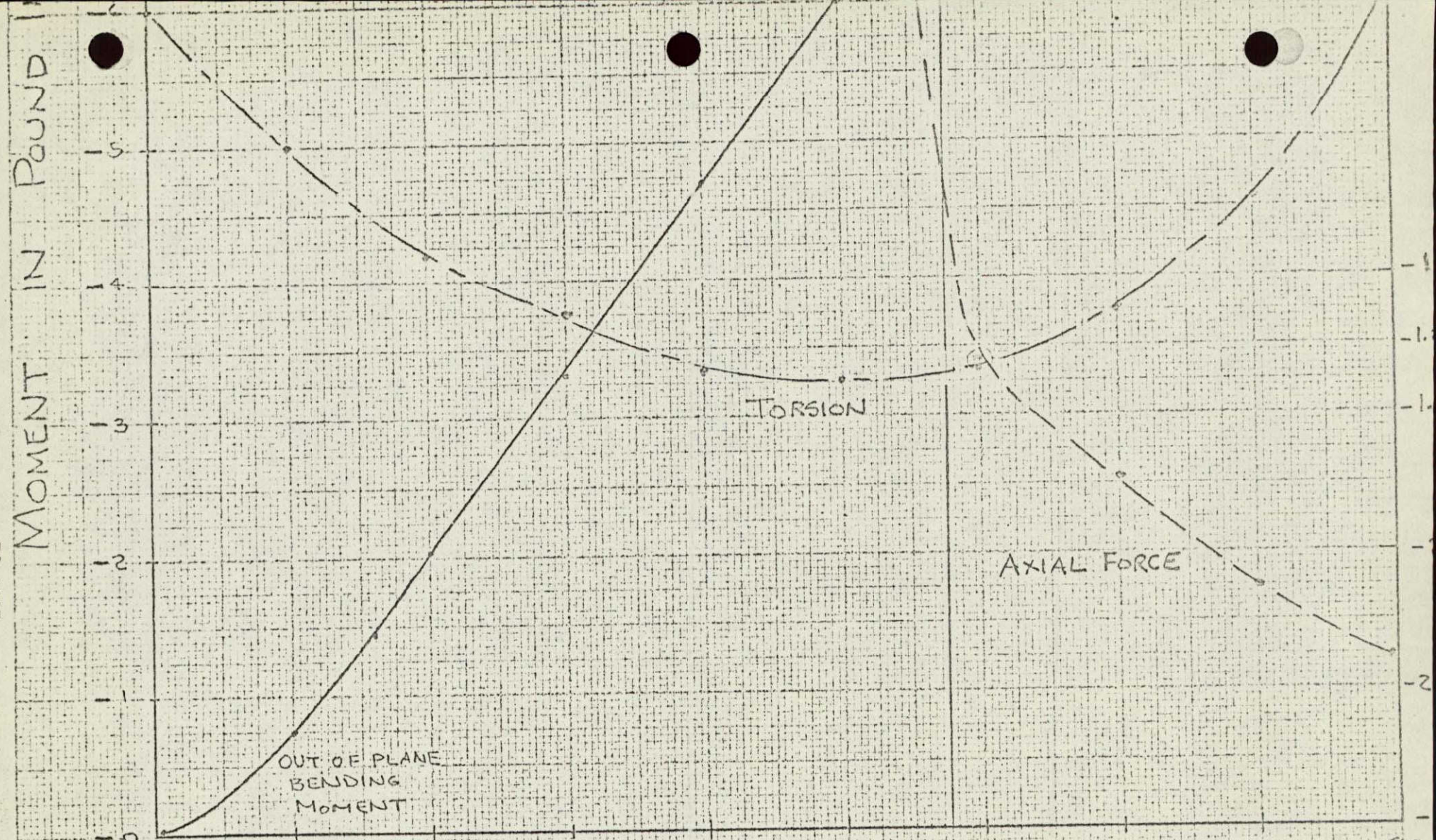
$\Theta = 90°$

$M_{r-r} = 1147.$

$T = 0$

$M_{z-z} = -61.$

$F_{axial} = -20.4$



CALCULATED BY	M.W.	7-16	UNIT BENDING MOMENTS FOR ELASTIC RUNS	MATERIAL
CHECKED BY				
APPROVED BY			THE GARRETT CORPORATION Airesearch Manufacturing Division LOS ANGELES CALIFORNIA	
UNIT NO.				

PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO.
KEUFFEL & ESSER CO. NO. 218. 20 DIVISIONS PER INCH BOTH WAYS. 300 BY 200 DIVISIONS

FOLDOUT FRAME 2

```
// JOB T
LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
      DIMENSION BMB(91),BMT(91),BMZ(91),AXIAL(91) ,V(91)
      DIMENSION  BETA(91),AN(15),BN(15)
      DIMENSION  TITLE(20)
      DIMENSION U(91)
      READ(2,2)(TITLE(ITLE),ITLE=1,20)
    2 FORMAT(20A4)
C
C     THIS PROGRAM CALCULATES MOMENTS AND DEFLECTIONS OF ELLIPTIC RINGS.
C     PROGRAMMER  MARTIN WOLFSON 93-33  EXT. 2364
C
C      Q IS THE IN PLANE LOAD PER INCH
C      P IS THE CONCENTRATED NORMAL LOAD
C      BIX IS THE MOMENT OF INERTIA ABOUT X-X AXIS
C      BIY IS THE MOMENT OF INERTIA ABOUT Z-Z AXIS
C      BIP IS THE POLAR MOMENT OF INERTIA
C      AREA IS THE CROSS-SECTION AREA
C      R1 IS THE CURVATURE IN REGION 1
C      R2 IS THE CURVATURE IN REGION 2
C      GOMMA IS THE ANGLE AT WHICH REGION 2 BEGINS(IN DEGREES)
C      POISS IS POISSONS RATIO
C      E IS YOUNGS MODULUS
C
      READ(2,8)Q,P,BIX,BIY,BIP,AREA,BB
      READ(2,8)R1,R2,GOMMA,POISS,E,C ZZ,DEL
    8 FORMAT(7E10.5)
      GAMMA=GOMMA/57.295779
      C=COS(GAMMA)
      S=SIN(GAMMA)
      PO=1.+POISS
      CON=BIX/BIP
      CON1=BIY/AREA
      S2=SIN(2.*GAMMA)
      GAM1=1.570796-GAMMA
      AID1=GAMMA-0.5*S2
      AID2=GAMMA+0.5*S2
      S3=SIN(2.*GAM1)
      AID3=GAM1+0.5*S3
      AID4=GAM1-0.5*S3
C     OUT OF PLANE PROBLEM
C
C     TO EQUALS ZERO BY SYMMETRY.
C     SHEAR IS ZERO BY SYMMETRY.
C
      TO=0.0
C     IN PLANE PROBLEM
      CAP1=R2/R1
      CAP2=R1/R2
      CAP3=1.5*GAMMA+0.25*S2-2.*S
      CAP4=C*(C-0.5*AID3)
```

```
      CAP5=R1*(1.-C)+R2*C
      CAP6=R1*R1*R1
      CAP7=R2*R2*R2
      A11=GAMMA+GAM1*CAP1
      A12=-R 2*(CAP2*(GAMMA-S)+GAM1*(1.-C)+C*(GAM1-C)+S*(1.-S))
      W1=-R1*R1*(GAMMA-S+R2*CAP1*CAP1*(GAM1-C)+CAP1*(1.-C)*GAM1)
      A21=R2*R2*(CAP2*CAP2*(S-GAMMA)-GAM1*(CAP2*(1.-C)+C)+C*C -S*(1.-C))
      A22=CAP6*CAP3+R2*R2*CAP5*(C*(GAM1-C)+S*(1.-S)-CAP2*GAM1*(1.-C))-C
     1*CAP7*(CAP2*C*(1.-C)+CAP4+0.5*S*C*C)+S*CAP7*(CAP2*(1.-C)*(1.-S) +
     2C*(1.-S-0.5*C*C)+0.5*S*AID4)
      W2=-CAP7*(-CAP6/CAP7*CAP3-CAP5*(CAP2*CAP2*GAM1*(1.-C)+GAM1-C)+C*R2
     1*(CAP2*CAP2*C*(1.-C)+CAP4/C)-S*R2*(CAP2*CAP2*(1.-C)*(1.-S)+1.-S
     2-0.5*C*C))
      DET=A11*A22-A21*A12
      BM=(W1*A22-W2*A12)/DET
      H=(A11*W2-A21*W1)/DET
      AXE1=-.5*P*BB*C+0.5*P*R1*S
      AXE2=-.5*P*BB*S+0.5*P*R1*(1.-C)
      WRITE(3,200)Q,P,BIX,BIY,BIP,AREA,BB
      WRITE(3,200)R1,R2,GOMMA,POISS,E,CZZ
  200 FORMAT  (1H ,7E14.7///)
      WRITE(3,90)BM,H,AXE1,AXE2
   90 FORMAT(1H ,12HBENDING MOM=F12.4,10X,17HHORIZONTAL SHEAR=F12.4/
     112HBM AT GAMMA=F12.4,10X,12HTM AT GAMMA=F12.4/)
      DO 30 J=1,91
      THETA=FLOAT(J-1)*0.0175
      TIG1=SIN(THETA)
      TIG2=COS(THETA)
      IF(THETA-GAMMA)35,35,37
   35 BMB(J)=-.5*P*BB*TIG2+TIG1*(0.5*P*R1-TO)
      BMT(J)=TO*TIG2-0.5*P*BB*TIG1+0.5*P*R1*(1.-TIG2)
      BMZ(J)=BM+(1.-TIG2)*(Q*R1-H)*R1
      AXIAL(J)=H*TIG2
      GO TO 30
   37 TIG3=COS(THETA-GAMMA)
      TIG4=SIN(THETA-GAMMA)
      BMB(J)=AXE1*TIG3-AXE2*TIG4+0.5*P*R2*TIG4
      BMT(J)=AXE1*TIG4+AXE2*TIG3+0.5*P*R2*(1.-TIG3)
      BMZ(J)=BM+R1*(Q*R1-H)*(1.-C)+R2*(Q*R2-H*C)*(1.-TIG3)-H*R2*S*TIG4
      AXIAL(J)=H*COS(THETA+GAMMA)
   30 CONTINUE
      WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      WRITE(3,60)
    4 FORMAT(1H1,10X,20A4//)
   60 FORMAT(1H ,12X,7HDEGREES,15X,14HOUT PLANE BEND,14X,
     117HTORSION,14X,13HIN PLANE BEND,11X,11HAXIAL FORCE//)
      DO 40 J=1,91
      THETA=FLOAT(J-1)
   40 WRITE(3,50)THETA,BMB(J),BMT(J),BMZ(J),AXIAL(J)
   50 FORMAT(1H ,    5(10X,E14.7))
C
```

```
C
C      CALCULATES DEFLECTIONS IN THE PLANE OF THE RING.
C
       CAP9=1.0/(E*BIY)
       ZAP1=R1*R1
       ZAP2=R2*R2
       W=Q
       ZAP3=W*R1-H
       A2=-R1*ZAP2*(W*R1-C*H)*(C+1.5707*S)-H*CAP7*(S-C)
       W1=CAP9*(-BM*ZAP1-CAP6*ZAP3*(1.0-0.5*S*GAMMA)+0.5*C*A2+BM*ZAP2+R1*
      1ZAP2*ZAP3*(1.0-C)+CAP7*(W*R2-H*C)+0.5*H*CAP7*S*GAMMA)
       W2=0.5*CAP9*(CAP6*(S+C*GAMMA)-S*A2-R1*ZAP2*(W*R1-C*H)*GAMMA
      1-H*S*CAP7)
       A1=C*W1-S*W2
       B2=-W2*C-W1*S
       DO 300 KK=1,91
       THETA=FLOAT(KK-1)*.0175
       TRIG1=SIN(THETA)
       TRIG2=COS(THETA)
       IF(THETA-GAMMA)301,301,302
  301  U(KK)=A1*TRIG2+ZAP1*CAP9*(BM+R1*ZAP3*(1.0-.5*THETA*TRIG1))
       GO TO 300
  302  SII=THETA-GAMMA
       TRIG3=SIN(SII)
       TRIG4=COS(SII)
       U(KK)=0.5*A2*CAP9*TRIG2+B2*TRIG1+ZAP2*CAP9*(BM+R1*ZAP3*(1.0-C)+
      1R2*(W*R2-H*C)*(1.0-0.5*THETA*TRIG3)+0.5*H*R2*S*THETA*TRIG4)
  300  CONTINUE
       WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
       WRITE(3,95)
   95  FORMAT(1H ,12X,7HDEGREES,15X,12HY DEFLECTION,15X,5HTWIST,
      115X,12HX DEFLECTION//)

      DO 120 K=1,91
      THETA=FLOAT(K-1)
      WRITE(3,92)THETA,V(K),BETA(K),U(K)
   92 FORMAT(1H ,4(10X,E14.7))
  120  CONTINUE
      STOP
      END
```

RING LOADED NORMAL TO PLANE OF RING.

PLANE BEND	TORSION	IN PLANE BEND	AXIAL FORCE
2000699E 04	0.2058029E-03	-0.1173913E 02	0.2837804E 01
1970182E 04	-0.3474599E 02	-0.1166802E 02	0.2837370E 01
1939062E 04	-0.6895275E 02	-0.1145461E 02	0.2836066E 01
1907348E 04	-0.1026095E 03	-0.1109897E 02	0.2833894E 01
1875050E 04	-0.1357063E 03	-0.1060126E 02	0.2830854E 01
1842178E 04	-0.1682330E 03	-0.9961658E 01	0.2826948E 01
1808741E 04	-0.2001793E 03	-0.9180257E 01	0.2822175E 01
1774751E 04	-0.2315357E 03	-0.8257398E 01	0.2816538E 01
1740217E 04	-0.2622923E 03	-0.7193246E 01	0.2810039E 01
1705150E 04	-0.2924401E 03	-0.5988302E 01	0.2802679E 01
1669561E 04	-0.3219696E 03	-0.4642784E 01	0.2794461E 01
1633461E 04	-0.3508718E 03	-0.3157136E 01	0.2785387E 01
1596861E 04	-0.3791378E 03	-0.1531858E 01	0.2775460E 01
1559771E 04	-0.4067593E 03	0.2325512E 00	0.2764684E 01
1522203E 04	-0.4337269E 03	0.2135705E 01	0.2753059E 01
1484170E 04	-0.4600333E 03	0.4176774E 01	0.2740593E 01
1445682E 04	-0.4856702E 03	0.6355314E 01	0.2727287E 01
1406752E 04	-0.5106297E 03	0.8670549E 01	0.2713146E 01
1367391E 04	-0.5349044E 03	0.1112181E 02	0.2698174E 01
1327611E 04	-0.5584862E 03	0.1370838E 02	0.2682376E 01
1287423E 04	-0.5813681E 03	0.1642955E 02	0.2665756E 01
1246843E 04	-0.6035437E 03	0.1928425E 02	0.2648320E 01
1205880E 04	-0.6250054E 03	0.2227178E 02	0.2630073E 01
1164548E 04	-0.6457471E 03	0.2539110E 02	0.2611020E 01
1122859E 04	-0.6657626E 03	0.2864146E 02	0.2591168E 01
1080826E 04	-0.6850454E 03	0.3202168E 02	0.2570522E 01
1038463E 04	-0.7035896E 03	0.3553083E 02	0.2549089E 01
9957812E 03	-0.7213896E 03	0.3916777E 02	0.2526875E 01
9527946E 03	-0.7384404E 03	0.4293138E 02	0.2503888E 01
9095162E 03	-0.7547358E 03	0.4682054E 02	0.2480134E 01
8659597E 03	-0.7702713E 03	0.5083406E 02	0.2455620E 01
8221374E 03	-0.7850429E 03	0.5497069E 02	0.2430354E 01
7780634E 03	-0.7990448E 03	0.5922924E 02	0.2404344E 01
7337512E 03	-0.8122734E 03	0.6360830E 02	0.2377598E 01
6892146E 03	-0.8247248E 03	0.6810652E 02	0.2350123E 01
6444664E 03	-0.8363946E 03	0.7272264E 02	0.2321929E 01
5995213E 03	-0.8472802E 03	0.7745513E 02	0.2293024E 01
5543922E 03	-0.8573770E 03	0.8230265E 02	0.2263416E 01
5090939E 03	-0.8666827E 03	0.8726356E 02	0.2233116E 01
4636389E 03	-0.8751943E 03	0.9233657E 02	0.2202131E 01
4180426E 03	-0.8829094E 03	0.9751992E 02	0.2170473E 01
3723178E 03	-0.8898251E 03	0.1028121E 03	0.2138149E 01
3264795E 03	-0.8959399E 03	0.1082114E 03	0.2105171E 01
2805410E 03	-0.9012515E 03	0.1137163E 03	0.2071548E 01
2345161E 03	-0.9057581E 03	0.1193252E 03	0.2037290E 01
1884197E 03	-0.9094592E 03	0.1250362E 03	0.2002408E 01
1422662E 03	-0.9123522E 03	0.1308475E 03	0.1966914E 01
960[illegible]840E 02	-0.9144382E 03	0.1367575E 03	0.1930817E 01
49[illegible]33E 02	-0.9157146E 03	0.1427643E 03	0.1894129E 01
3599052E 01	-0.9161824E 03	0.1488660E 03	0.1856861E 01
4264402E 02	-0.9158405E 03	0.1550609E 03	0.1819024E 01
8887428E 02	-0.9146899E 03	0.1613469E 03	0.1780630E 01
1350779E 03	-0.9127304E 03	0.1677223E 03	0.1741690E 01

PROOF LOADS FOR ELLIPTIC RING LOADED NORMAL TO PLANE OF RING.

DEGREES	OUT PLANE BEND	TORSION
0.0000000E 00	-0.2000699E 04	0.2058029E-03
0.1000000E 01	-0.1970182E 04	-0.3474599E 02
0.2000000E 01	-0.1939062E 04	-0.6895275E 02
0.3000000E 01	-0.1907348E 04	-0.1026095E 03
0.4000000E 01	-0.1875050E 04	-0.1357063E 03
0.5000000E 01	-0.1842178E 04	-0.1682330E 03
0.6000000E 01	-0.1808741E 04	-0.2001793E 03
0.7000000E 01	-0.1774751E 04	-0.2315357E 03
0.8000001E 01	-0.1740217E 04	-0.2622923E 03
0.9000001E 01	-0.1705150E 04	-0.2924401E 03
0.1000000E 02	-0.1669561E 04	-0.3219696E 03
0.1100000E 02	-0.1633461E 04	-0.3508718E 03
0.1200000E 02	-0.1596861E 04	-0.3791378E 03
0.1300000E 02	-0.1559771E 04	-0.4067593E 03
0.1400000E 02	-0.1522203E 04	-0.4337269E 03
0.1500000E 02	-0.1484170E 04	-0.4600333E 03
0.1600000E 02	-0.1445682E 04	-0.4856702E 03
0.1700000E 02	-0.1406752E 04	-0.5106297E 03
0.1800000E 02	-0.1367391E 04	-0.5349044E 03
0.1900000E 02	-0.1327611E 04	-0.5584862E 03
0.2000000E 02	-0.1287423E 04	-0.5813681E 03
0.2100000E 02	-0.1246843E 04	-0.6035437E 03
0.2200000E 02	-0.1205880E 04	-0.6250054E 03
0.2300000E 02	-0.1164548E 04	-0.6457471E 03
0.2400000E 02	-0.1122859E 04	-0.6657626E 03
0.2500000E 02	-0.1080826E 04	-0.6850454E 03
0.2600000E 02	-0.1038463E 04	-0.7035896E 03
0.2700000E 02	-0.9957812E 03	-0.7213896E 03
0.2800000E 02	-0.9527946E 03	-0.7384404E 03
0.2900000E 02	-0.9095162E 03	-0.7547358E 03
0.3000000E 02	-0.8659597E 03	-0.7702713E 03
0.3100000E 02	-0.8221374E 03	-0.7850429E 03
0.3200000E 02	-0.7780634E 03	-0.7990448E 03
0.3300000E 02	-0.7337512E 03	-0.8122734E 03
0.3400000E 02	-0.6892146E 03	-0.8247248E 03
0.3500000E 02	-0.6444664E 03	-0.8363946E 03
0.3600000E 02	-0.5995213E 03	-0.8472802E 03
0.3700000E 02	-0.5543922E 03	-0.8573770E 03
0.3800000E 02	-0.5090939E 03	-0.8666827E 03
0.3900000E 02	-0.4636389E 03	-0.8751943E 03
0.4000000E 02	-0.4180426E 03	-0.8829094E 03
0.4100000E 02	-0.3723178E 03	-0.8898251E 03
0.4200000E 02	-0.3264795E 03	-0.8959399E 03
0.4300000E 02	-0.2805410E 03	-0.9012515E 03
0.4400000E 02	-0.2345161E 03	-0.9057581E 03
0.4500000E 02	-0.1884197E 03	-0.9094592E 03
0.4600000E 02	-0.1422662E 03	-0.9123522E 03
0.4700000E 02	-0.9606840E 02	-0.9144382E 03
0.4800000E 02	-0.4984133E 02	-0.9157146E 03
0.4900000E 02	-0.3599052E 01	-0.9161824E 03
0.5000000E 02	0.4264402E 02	-0.9158405E 03
0.5100000E 02	0.8887428E 02	-0.9146899E 03
0.5200000E 02	0.1350779E 03	-0.9127304E 03

UT PLANE BEND	TORSION	IN PLANE BEND	AXIAL FORCE
1812394E 03	-0.9099624E 03	0.1741850E 03	0.1702218E 01
2273455E 03	-0.9063870E 03	0.1807330E 03	0.1642224E 01
2733823E 03	-0.9020058E 03	0.1873644E 03	0.1621721E 01
31[illegible]355E 03	-0.8968194E 03	0.1940771E 03	0.1580721E 01
36[illegible]901E 03	-0.8908297E 03	0.2008690E 03	0.1539237E 01
4213090E 03	-0.8839858E 03	0.2036799E 03	-0.1232433E 01
4851682E 03	-0.8760545E 03	0.2037222E 03	-0.1276976E 01
5488789E 03	-0.8670059E 03	0.2041388E 03	-0.1321127E 01
6124223E 03	-0.8568446E 03	0.2049290E 03	-0.1364874E 01
6757773E 03	-0.8455723E 03	0.2060930E 03	-0.1408203E 01
7389252E 03	-0.8331931E 03	0.2076303E 03	-0.1451101E 01
8018479E 03	-0.8197110E 03	0.2095402E 03	-0.1493556E 01
8645240E 03	-0.8051298E 03	0.2118223E 03	-0.1535552E 01
9269354E 03	-0.7894549E 03	0.2144758E 03	-0.1577077E 01
9890631E 03	-0.7726893E 03	0.2175002E 03	-0.1618120E 01
1050888E 04	-0.7548389E 03	0.2208943E 03	-0.1658667E 01
1112391E 04	-0.7359097E 03	0.2246571E 03	-0.1698706E 01
1173553E 04	-0.7159073E 03	0.2287874E 03	-0.1738225E 01
1234357E 04	-0.6948376E 03	0.2332840E 03	-0.1777213E 01
1294781E 04	-0.6727066E 03	0.2381457E 03	-0.1815656E 01
1354810E 04	-0.6495227E 03	0.2433706E 03	-0.1853542E 01
1414424E 04	-0.6252908E 03	0.2489576E 03	-0.1890861E 01
1473604E 04	-0.6000205E 03	0.2549044E 03	-0.1927601E 01
1532333E 04	-0.5737180E 03	0.2612096E 03	-0.1963750E 01
1590594E 04	-0.5463911E 03	0.2678714E 03	-0.1999299E 01
1648366E 04	-0.5180498E 03	0.2748873E 03	-0.2034235E 01
1705634E 04	-0.4887015E 03	0.2822554E 03	-0.2068548E 01
1762380E 04	-0.4583552E 03	0.2899736E 03	-0.2102227E 01
1818[illegible]586E 04	-0.4270211E 03	0.2980392E 03	-0.2135263E 01
18[illegible]235E 04	-0.3947084E 03	0.3064498E 03	-0.2167644E 01
1929310E 04	-0.3614266E 03	0.3152031E 03	-0.2199362E 01
1983794E 04	-0.3271859E 03	0.3242962E 03	-0.2230408E 01
2037671E 04	-0.2919968E 03	0.3337265E 03	-0.2260768E 01
2090923E 04	-0.2558712E 03	0.3434906E 03	-0.2290438E 01
2143536E 04	-0.2188183E 03	0.3535861E 03	-0.2319405E 01
2195491E 04	-0.1808506E 03	0.3640098E 03	-0.2347662E 01
2246775E 04	-0.1419807E 03	0.3747579E 03	-0.2375201E 01
2297371E 04	-0.1022179E 03	0.3858281E 03	-0.2402012E 01

DEGREES	OUT PLANE BEND	TORSION
0.5300000E 02	0.1812394E 03	-0.9099624E 03
0.5400000E 02	0.2273455E 03	-0.9063870E 03
0.5500000E 02	0.2733823E 03	-0.9020058E 03
0.5600000E 02	0.3193355E 03	-0.8968194E 03
0.5700000E 02	0.3651901E 03	-0.8908297E 03
0.5800000E 02	0.4213090E 03	-0.8839858E 03
0.5900000E 02	0.4851682E 03	-0.8760545E 03
0.6000000E 02	0.5488789E 03	-0.8670059E 03
0.6100000E 02	0.6124223E 03	-0.8568446E 03
0.6200000E 02	0.6757773E 03	-0.8455723E 03
0.6300000E 02	0.7389252E 03	-0.8331931E 03
0.6400001E 02	0.8018479E 03	-0.8197110E 03
0.6500001E 02	0.8645240E 03	-0.8051298E 03
0.6600001E 02	0.9269354E 03	-0.7894549E 03
0.6700001E 02	0.9890631E 03	-0.7726893E 03
0.6800001E 02	0.1050888E 04	-0.7548389E 03
0.6900001E 02	0.1112391E 04	-0.7359097E 03
0.7000001E 02	0.1173553E 04	-0.7159073E 03
0.7100001E 02	0.1234357E 04	-0.6948376E 03
0.7200001E 02	0.1294781E 04	-0.6727066E 03
0.7300001E 02	0.1354810E 04	-0.6495227E 03
0.7400001E 02	0.1414424E 04	-0.6252908E 03
0.7500001E 02	0.1473604E 04	-0.6000205E 03
0.7600001E 02	0.1532333E 04	-0.5737180E 03
0.7700001E 02	0.1590594E 04	-0.5463911E 03
0.7800001E 02	0.1648366E 04	-0.5180498E 03
0.7900001E 02	0.1705634E 04	-0.4887015E 03
0.8000001E 02	0.1762380E 04	-0.4583552E 03
0.8100001E 02	0.1818586E 04	-0.4270211E 03
0.8200001E 02	0.1874235E 04	-0.3947084E 03
0.8300001E 02	0.1929310E 04	-0.3614266E 03
0.8400001E 02	0.1983794E 04	-0.3271859E 03
0.8500001E 02	0.2037671E 04	-0.2919968E 03
0.8600001E 02	0.2090923E 04	-0.2558712E 03
0.8700001E 02	0.2143536E 04	-0.2188183E 03
0.8800001E 02	0.2195491E 04	-0.1808506E 03
0.8900001E 02	0.2246775E 04	-0.1419807E 03
0.9000001E 02	0.2297371E 04	-0.1022179E 03

Form 2427

AiRESEARCH MFG. CO.

DATE_____
PREPARED BY_____
CHECKED BY_____

CALC. NO_____
MODEL _____
PART NO_____

RING DEFLECTIONS

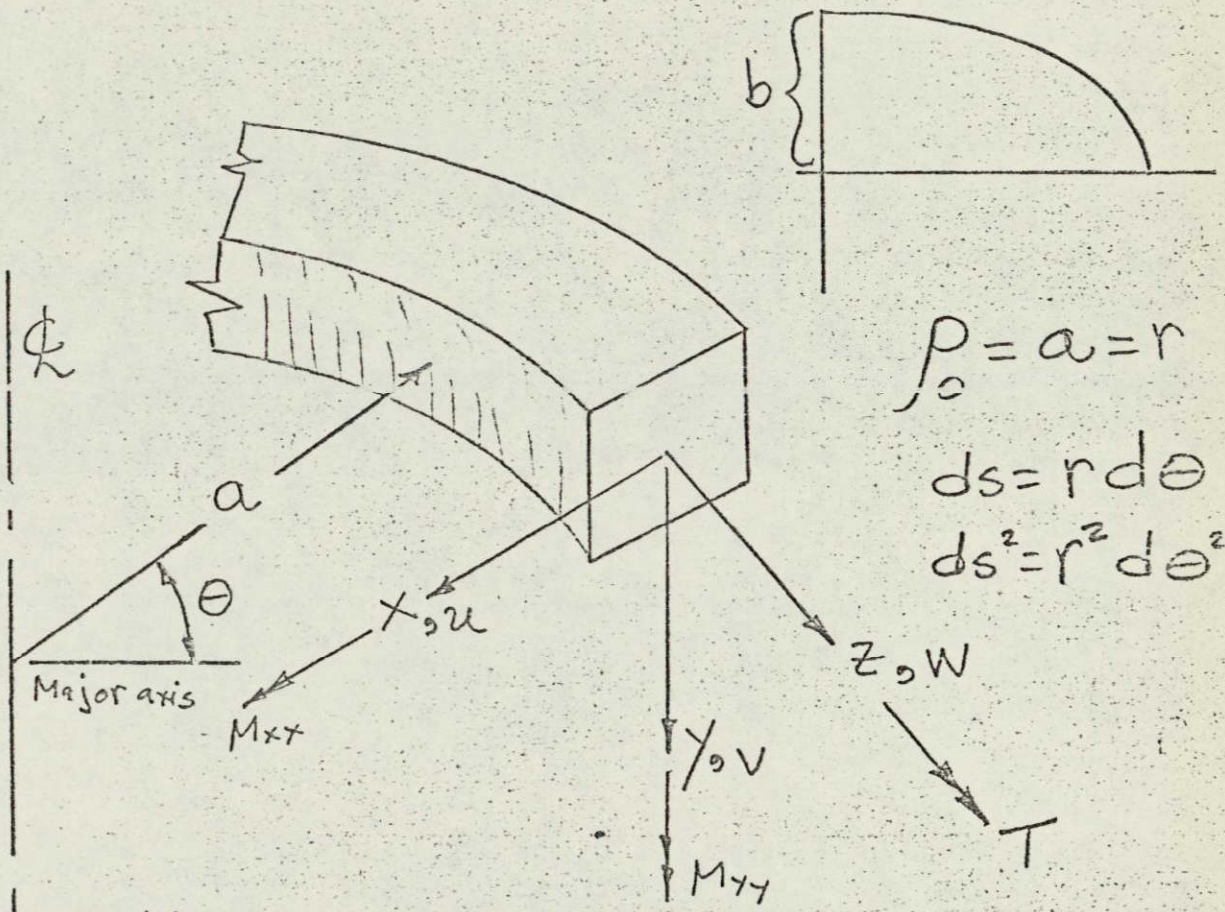
REPORT
PAGE 72 OF

DATE 7-9-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

RING DEFLECTIONS

Reference: Love, A.E.H., A Treatise on the Mathematical Theory of Elasticity, 4th Edit., Dover Publications pgs. 381-398, 445-447



$\rho_o = a = r$

$ds = r\,d\theta$

$ds^2 = r^2\,d\theta^2$

$$-\frac{M_{xx}}{EI_{xx}} = -\frac{\beta}{\rho_o} + \frac{d^2V}{ds^2}$$

$$\frac{M_{yy}}{EI_{yy}} = \frac{d^2u}{ds^2} + \frac{1}{\rho_o}\frac{dw}{ds}$$

$$\frac{T}{GJ} = \frac{d\beta}{ds} + \frac{1}{\rho_o}\frac{dV}{ds}$$

for inextensional bending: $\frac{dw}{d\theta} = u$

These equations can be combined to get:

$$\frac{d^3V}{d\theta^3} + \frac{dV}{d\theta} = -\frac{T r^2}{GJ} - \frac{r^2}{EI_{xx}} \frac{dM_{xx}}{d\theta}$$

$$\beta = -\frac{M_{xx} r}{EI_{xx}} + \frac{1}{r} \frac{d^2V}{d\theta^2}$$

The general solution for the V equation is:

$$V = C_{1i} + C_{2i}\cos\theta + C_{3i}\sin\theta + \bar{C}_i\theta - \tfrac{1}{2}A_i\theta\sin\theta - \tfrac{1}{2}B_i\theta\cos\theta$$

There will be one solution for $\theta < \gamma$ and another solution for $\theta > \gamma$

$\therefore$ $C_{11}, C_{21}, C_{31}, \bar{C}_1, A_1, B_1$

$C_{12}, C_{22}, C_{32}, \bar{C}_2, A_2, B_2$

$$A_1 = -\frac{P}{2} R_1^2 (b)\left(\frac{1}{EI} - \frac{1}{GJ}\right)$$

$$B_1 = -\frac{P}{2} R_2^2 R_1 \left(\frac{1}{EI} - \frac{1}{GJ}\right)$$

$$\bar{C}_1 = -\frac{P}{2GJ} R_1^3$$

$$A_2 = R_2^2\left(\frac{1}{EI}-\frac{1}{GJ}\right)\left[\sin\gamma\left(\tilde{T}-.5PR_2\right)+\tilde{M}\cos\gamma\right]$$

$$B_2 = R_2^2\left(\frac{1}{EI}-\frac{1}{GJ}\right)\left[\cos\gamma\left(\tilde{T}-.5PR_2\right)-\tilde{M}\sin\gamma\right]$$

$$\bar{C}_2 = -\frac{PR_2^3}{2GJ}$$

$$C_{31} = .5B_1 - \bar{C}_1$$

$$C_{22} = \bar{C}_2 - .5A_2 - \frac{\pi}{4}B_2$$

$$C_{21} = -W_2\sin\gamma - W_3\cos\gamma$$

$$C_{32} = W_3\sin\gamma - W_2\cos\gamma$$

$$C_{11} = W_1 + W_3$$

$$C_{12} = 0$$

Where:

$$W_1 = C_{22}\cos\gamma - C_{31}\sin\gamma + \dot{(}\bar{C}_2-\bar{C}_1)\gamma + \frac{\gamma}{2}\left[\sin\gamma(A_1-A_2)+\cos\gamma(B_1-B_2)\right]$$

$$W_2 = -C_{31}\cos\gamma - C_{22}\sin\gamma + \bar{C}_2-\bar{C}_1+\tfrac{1}{2}(A_1-A_2)\left[\sin\gamma+\gamma\cos\gamma\right]+\tfrac{1}{2}(B_1-B_2)\left[\cos\gamma-\gamma\sin\gamma\right]$$

$$W_3 = C_{31}\sin\gamma - C_{22}\cos\gamma + \tfrac{1}{2}(A_1-A_2)\left[2\cos\gamma-\gamma\sin\gamma\right]+\tfrac{1}{2}(B_2-B_1)\left[2\sin\gamma+\gamma\cos\gamma\right]$$

Form 2427

AiRESEARCH MFG. CO.

DATE 7-22-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

IN PLANE DEFLECTIONS

$$\frac{d^2 u_1}{d\theta^2} + u_1 = \frac{R_1^2}{EI}\left\{ m + R_1(WR_1 - H)(1-\cos\theta) \right\}$$

$$\frac{d^2 u_2}{d\theta^2} + u_2 = \frac{R_2^2}{EI}\left\{ m + R_1(WR_1 - H)(1-\cos\gamma) \right.$$

$$\left. + R_2(WR_2 - H\cos\gamma)(1-\cos\overline{\theta-\gamma}) - HR_2\sin\gamma\sin(\theta-\gamma) \right.$$

Boundary Conditions

$@\ \theta = 0 \quad u_1' = 0$

$@\ \theta = \pi/2 \quad u_2' = 0$

$@\ \theta = \gamma \quad u_1 = u_2$

$u_1' = u_2'$

$$u_1 = A_1\cos\theta + \cancel{B_1\sin\theta} + R_1^2\frac{m}{EI}$$

$$+ \frac{R_1^3}{EI}(WR_1 - H)\left(1 - \frac{1}{2}\theta\sin\theta\right)$$

$$u_2 = A_2\cos\theta + B_2\sin\theta + \frac{mR_2^2}{EI} + \frac{R_1R_2^2}{EI}(WR_1 - H)(1-\cos\gamma)$$

$$\frac{R_2^3}{EI}(WR_2 - H\cos\gamma)\left(1 - \tfrac{1}{2}\theta\sin\overline{\theta-\gamma}\right)$$

$$+ \frac{HR_2^3}{2EI}\theta\sin\gamma\cos(\theta-\gamma)$$

$$\frac{du_1}{d\theta} = -A_1\sin\theta + B_1\cos\theta - \frac{R_1^3}{2EI}(\sin\theta + \theta\cos\theta)$$

$$\frac{du_2}{d\theta} = -A_2\sin\theta + B_2\cos\theta - \frac{R_1R_2^2}{2EI}\overset{(WR_1 - H\cos\gamma)}{\wedge}\left(\sin\overline{\theta-\gamma} + \theta\cos\overline{\theta-\gamma}\right)$$

$$- \frac{HR_2^3}{2EI}\sin\gamma\left(\cos\overline{\theta-\gamma} - \theta\sin\overline{\theta-\gamma}\right)$$

$\theta = 0$

$$0 = B_1 - \frac{R_1^3}{2EI}(0+0)$$

$$B_1 = 0$$

$\theta = \pi/2$

$$A_2 = -\frac{R_1R_2^2}{2EI}(WR_1 - H\cos\gamma)(\cos\gamma + \pi/2\sin\gamma) - \frac{HR_2^3}{2EI}\sin\gamma(\sin\gamma - \cos\gamma)$$

@ $\theta = \gamma$ $\quad u_1 = u_2$

$$A_1 \cos\gamma + \frac{R_1^2 m}{EI} + \frac{R_1^3}{EI}(WR_1 - H)\left(1 - \frac{\gamma}{2}\sin\gamma\right) = A_2 \cos\gamma$$

$$+ B_2 \sin\gamma + \frac{mR_2^2}{EI} + \frac{R_1 R_2^2}{EI}(WR_1 - H)(1 - \cos\gamma) + \frac{R_2^3}{EI}(WR_2 - H\cos\gamma)$$

$$+ \frac{HR_2^3}{2EI}\gamma\sin\gamma$$

$u_1' = u_2'$

$$-A_1 \sin\gamma - \frac{R_1^3}{2EI}(\sin\gamma + \gamma\cos\gamma) = -A_2 \sin\gamma + B_2 \cos\gamma$$

$$-\frac{R_1 R_2^2}{2EI}(WR_1 - H\cos\gamma)\gamma - \frac{HR_2^3}{2EI}\sin\gamma$$

The above equations define the constants A_1, A_2, B_1, B_2

IN PLANE DEFLECTIONS (CONTINUED)

$$A_2 = -R_1 R_2^2 (WR_1 - HC)\left(C + \frac{\Pi}{2} S\right) - HR_2^3 S(S - C)$$

$$W_1 = \frac{1}{EI}\left\{-mR_1^2 - R_1^3 (WR_1 - H)(1 - 0.5\gamma S) + 0.5 A_2 C + mR_2^2 \right.$$

$$\left. + R_1 R_2^2 (WR_1 - H)(1 - C) + R_2^3 (WR_2 - HC) + 0.5 HR_2^3 \gamma S \right\}$$

$$W_2 = \frac{1}{2EI}\left\{R_1^3 (S + \gamma C) - A_2 S - R_1 R_2^2 (WR_1 - HC)\gamma - HR_2^3 S\right\}$$

$$A_1 = W_1 * C - W_2 * S$$

$$B_2 = -W_2 C - W_1 S$$

$$u_1 = A_1 \cos\theta + \frac{R_1^2}{EI}\left\{m + R_1 (WR_1 - H)\left(1 - \frac{\theta}{2}\sin\theta\right)\right\}$$

$$u_2 = \frac{A_2}{2EI}\cos\theta + B_2 \sin\theta + \frac{R_2^2}{EI}\left\{m + R_1 (WR_1 - H)(1 - C)\right.$$

$$+ R_2 (WR_2 - HC)\left(1 - \frac{\theta}{2}\sin\overline{\theta - \gamma}\right)$$

$$\left. + \frac{H}{2} R_2 \theta S \cos\overline{\theta - \gamma}\right\}$$

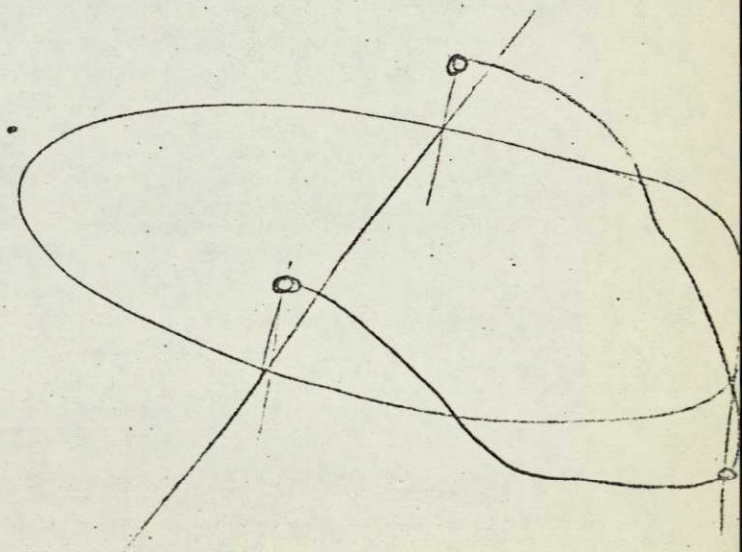
NOTE: INWARD IS POSITIVE FOR u.

MIDDLE WAIST RING
PROOF LOAD

DEGREES	NORMAL DISP.	TWIST	X DEFLECTION
0.[illegible]00000E 00	-0.1081575E 01	-0.1257199E 00	0.3342413E 00
0.[illegible]0000E 01	-0.1081500E 01	-0.1245636E 00	0.3341898E 00
0.2000000E 01	-0.1081276E 01	-0.1233693E 00	0.3340353E 00
0.3000000E 01	-0.1080904E 01	-0.1221375E 00	0.3337777E 00
0.4000000E 01	-0.1080385E 01	-0.1208685E 00	0.3334172E 00
0.5000000E 01	-0.1079721E 01	-0.1195627E 00	0.3329540E 00
0.6000000E 01	-0.1078912E 01	-0.1182205E 00	0.3323882E 00
0.7000000E 01	-0.1077960E 01	-0.1168423E 00	0.3317201E 00
0.8000001E 01	-0.1076867E 01	-0.1154286E 00	0.3309499E 00
0.9000001E 01	-0.1075633E 01	-0.1139797E 00	0.3300779E 00
0.1000000E 02	-0.1074260E 01	-0.1124960E 00	0.3291044E 00
0.1100000E 02	-0.1072750E 01	-0.1109782E 00	0.3280299E 00
0.1200000E 02	-0.1071103E 01	-0.1094265E 00	0.3268548E 00
0.1300000E 02	-0.1069322E 01	-0.1078415E 00	0.3255795E 00
0.1400000E 02	-0.1067408E 01	-0.1062237E 00	0.3242044E 00
0.1500000E 02	-0.1065364E 01	-0.1045736E 00	0.3227302E 00
0.1600000E 02	-0.1063189E 01	-0.1028916E 00	0.3211574E 00
0.1700000E 02	-0.1060886E 01	-0.1011783E 00	0.3194867E 00
0.1800000E 02	-0.1058457E 01	-0.9943425E-01	0.3177187E 00
0.1900000E 02	-0.1055904E 01	-0.9765988E-01	0.3158540E 00
0.2000000E 02	-0.1053228E 01	-0.9585575E-01	0.3138934E 00
0.2100000E 02	-0.1050432E 01	-0.9402246E-01	0.3118377E 00
0.2200000E 02	-0.1047516E 01	-0.9216052E-01	0.3096877E 00
0.2300000E 02	-0.1044484E 01	-0.9027051E-01	0.3074442E 00
0.2400000E 02	-0.1041337E 01	-0.8835306E-01	0.3051080E 00
0.2500000E 02	-0.1038076E 01	-0.8640868E-01	0.3026802E 00
0.[illegible]0000E 02	-0.1034705E 01	-0.8443801E-01	0.3001616E 00
0.2700000E 02	-0.1031225E 01	-0.8244161E-01	0.2975533E 00
0.2800000E 02	-0.1027638E 01	-0.8042012E-01	0.2948561E 00
0.2900000E 02	-0.1023947E 01	-0.7837413E-01	0.2920714E 00
0.3000000E 02	-0.1020153E 01	-0.7630431E-01	0.2891999E 00
0.3100000E 02	-0.1016259E 01	-0.7421125E-01	0.2862430E 00
0.3200000E 02	-0.1012267E 01	-0.7209554E-01	0.2832018E 00
0.3300000E 02	-0.1008178E 01	-0.6995794E-01	0.2800774E 00
0.3400000E 02	-0.1003997E 01	-0.6779901E-01	0.2768712E 00
0.3500000E 02	-0.9997246E 00	-0.6561945E-01	0.2735842E 00
0.3600000E 02	-0.9953629E 00	-0.6341992E-01	0.2702179E 00
0.3700000E 02	-0.9909149E 00	-0.6120108E-01	0.2667735E 00
0.3800000E 02	-0.9863823E 00	-0.5896356E-01	0.2632524E 00
0.3900000E 02	-0.9817686E 00	-0.5670814E-01	0.2596560E 00
0.4000000E 02	-0.9770752E 00	-0.5443543E-01	0.2559857E 00
0.4100000E 02	-0.9723050E 00	-0.5214616E-01	0.2522429E 00
0.4200000E 02	-0.9674608E 00	-0.4984100E-01	0.2484290E 00
0.4300000E 02	-0.9625446E 00	-0.4752065E-01	0.2445457E 00
0.4400000E 02	-0.9575592E 00	-0.4518587E-01	0.2405943E 00
0.4500000E 02	-0.9525072E 00	-0.4283731E-01	0.2365764E 00
0.4600000E 02	-0.9473911E 00	-0.4047574E-01	0.2324938E 00
0.4700000E 02	-0.9422134E 00	-0.3810181E-01	0.2283478E 00
0.4800000E 02	-0.9369766E 00	-0.3571626E-01	0.2241402E 00
0.4900000E 02	-0.9316837E 00	-0.3331986E-01	0.2198726E 00
0.5000000E 02	-0.9263372E 00	-0.3091331E-01	0.2155467E 00
0.[illegible]00000E 02	-0.9209398E 00	-0.2849735E-01	0.2111642E 00
0.[illegible]200000E 02	-0.9154940E 00	-0.2607272E-01	0.2067267E 00
0.5300000E 02	-0.9100028E 00	-0.2364015E-01	0.2022362E 00
0.5400000E 02	-0.9044685E 00	-0.2120036E-01	0.1976942E 00
0.5500000E 02	-0.8988940E 00	-0.1875411E-01	0.1931027E 00
0.5600000E 02	-0.8932822E 00	-0.1630217E-01	0.1884633E 00
0.5700000E 02	-0.8876358E 00	-0.1384526E-01	0.1837781E 00

DEGREES	NORMAL DISP	TWIST	X DEFLECTION
0.5800000E 02	-0.8819583E 00	-0.9492941E-04	0.1778731E 00
0.5900000E 02	-0.8762516E 00	0.3409876E-02	0.1710494E 00
0.[illegible]00000E 02	-0.8705216E 00	0.6914718E-02	0.1642050E 00
0.[illegible]00000E 02	-0.8647725E 00	0.1041878E-01	0.1573420E 00
0.6200000E 02	-0.8590093E 00	0.1392104E-01	0.1504630E 00
0.6300000E 02	-0.8532366E 00	0.1742070E-01	0.1435700E 00
0.6400001E 02	-0.8474593E 00	0.2091681E-01	0.1366652E 00
0.6500001E 02	-0.8416823E 00	0.2440836E-01	0.1297513E 00
0.6600001E 02	-0.8359102E 00	0.2789456E-01	0.1228307E 00
0.6700001E 02	-0.8301481E 00	0.3137436E-01	0.1159060E 00
0.6800001E 02	-0.8244001E 00	0.3484699E-01	0.1089797E 00
0.6900001E 02	-0.8186717E 00	0.3831145E-01	0.1020545E 00
0.7000001E 02	-0.8129670E 00	0.4176689E-01	0.9513296E-01
0.7100001E 02	-0.8072916E 00	0.4521237E-01	0.8821792E-01
0.7200001E 02	-0.8016498E 00	0.4864694E-01	0.8131219E-01
0.7300001E 02	-0.7960462E 00	0.5206981E-01	0.7441881E-01
0.7400001E 02	-0.7904860E 00	0.5547992E-01	0.6754046E-01
0.7500001E 02	-0.7849739E 00	0.5887654E-01	0.6068031E-01
0.7600001E 02	-0.7795144E 00	0.6225871E-01	0.5384131E-01
0.7700001E 02	-0.7741124E 00	0.6562548E-01	0.4702638E-01
0.7800001E 02	-0.7687727E 00	0.6897607E-01	0.4023909E-01
0.7900001E 02	-0.7635002E 00	0.7230949E-01	0.3348225E-01
0.8000001E 02	-0.7582992E 00	0.7562495E-01	0.2675905E-01
0.8100001E 02	-0.7531747E 00	0.7892154E-01	0.2007295E-01
0.8200001E 02	-0.7481316E 00	0.8219836E-01	0.1342714E-01
0.8300001E 02	-0.7431741E 00	0.8545459E-01	0.6824963E-02
0.8400001E 02	-0.7383074E 00	0.8868934E-01	0.2696719E-03
0.8500001E 02	-0.7335358E 00	0.9190176E-01	-0.6234895E-02
0.[illegible]0001E 02	-0.7288639E 00	0.9509105E-01	-0.1268564E-01
0.8700001E 02	-0.7242968E 00	0.9825626E-01	-0.1907898E-01
0.8800001E 02	-0.7198386E 00	0.1013966E 00	-0.2541125E-01
0.8900001E 02	-0.7154941E 00	0.1045113E 00	-0.3167928E-01
0.9000001E 02	-0.7112680E 00	0.1075995E 00	-0.3787900E-01

IP	BB	R1	R2	GAMMA	POISSONS	E
00E-01	0.61560E 01	0.53120E 01	0.85200E 01	0.57585E 02	0.36000E 00	0.30000E 08



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MISCELLANEOUS CALCULATIONS

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STRESSES AND STABILITY AT PROOF CONDITIONS

@ $\theta = 10°$ WITH UNIT LOADS

$M_{r-r} = -2.62$

$T = -0.5$

@ PROOF CONDITIONS

$T = -0.5 \times 650 = 325$ #IN

$M_{r-r} = -2.62 \times 650 = 1703$ #IN

$$\tau = \frac{325}{\pi(.059)(.456)} = 6040 \text{ psi}$$

$$\sigma = \frac{1703 \times .375}{.0107} = 59318$$

Combined Stresses

$$\sigma_{max} = \frac{1}{2}(59318) + \left\{\frac{1}{4}(59318)^2 + (6040)^2\right\}^{1/2}$$

$$= 29659 + 30267$$

$$\sigma_{max} = 59926 \text{ psi}$$

@ $\theta = 34°$

$T = -1.2$

$M_{r\text{-}r} = -1.2$

@ Proof conditions

$T = -1.2(650) = 780$ #IN

$M_{r\text{-}r} = 1.2(650) = 780$ #IN

$$\tau = \frac{780}{2(.059)(.456)} = 14496 \text{ PSI}$$

$$\sigma = \frac{780 \cdot 0.373}{0.0107} = 27168 \text{ PSI}$$

Combined stresses

$$\sigma_{max} = \frac{1}{2}(27168) + \left\{\frac{1}{4}(27168)^2 + (14496)^2\right\}^{1/2}$$

$$= 13584 + 19866$$

$$\sigma_{max} = 33450 \text{ PSI}$$

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ELASTIC STABILITY

REF: ROARK, FORMULAS FOR STRESS & STRAIN
3rd Edit p. 312 case 3

for $a/b = \infty$
$K = 5.73$
} fixed edges

$$\sigma_{crit} = K \frac{E}{1-\nu^2}\left(\frac{t}{b}\right)^2$$

$E = 30 \times 10^6$
$\nu = 0.36$
} for nickel

$$\sigma_{crit} = \frac{5.73 \times 30 \times 10^6}{1-.36^2}\left(\frac{.059}{.688}\right)^2 = 1.45 \times 10^6 \text{ psi}$$

all edges simply supported

$$\sigma = \frac{3.29}{5.73} \times 1.45 \times 10^6 = .83 \times 10^6 \text{ psi}$$

The above results are for compression buckling of the cap.

FOR SHEAR BUCKLING OF CAP

$$\tau_{crit} = \frac{4.40}{5.73} \times 1.45 \times 10^6 = 1.115 \times 10^6 \text{ psi}$$

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BUCKLING OF CAP UNDER COMBINED STRESSES

Ref: MIL HDBK-5

$$\left(\frac{\sigma}{\sigma_{crit}}\right)^2+\left(\frac{\tau}{\tau_{crit}}\right)^2=1 \quad , \quad R_b=\frac{\sigma}{\sigma_{crit}} \quad , R_s=\frac{\tau}{\tau_{crit}}$$

$$M.S.=\frac{1}{\sqrt{R_b^2+R_s^2}}-1$$

$$R_b=\frac{59926}{.833\times10^6}=.07186 \quad , R_s=\frac{6040}{1.1152\times10^6}=.00541$$

$$\sqrt{R_b^2+R_s^2}=0.10282$$

$$M.S.=\frac{1}{0.10282}-1=8.72$$

SHEAR BUCKLING OF WEBS

$a/b=\infty$, $K=4.40$

$$\tau_{crit}=\frac{4.4\times30\times10^6}{1-0.36^2}\left(\frac{0.025}{0.75}\right)^2=168{,}000\ psi$$

$$\tau=\frac{325}{2(.025)(.456)}=14300\ psi$$

$$M.S.=\frac{168}{14.3}-1>10$$

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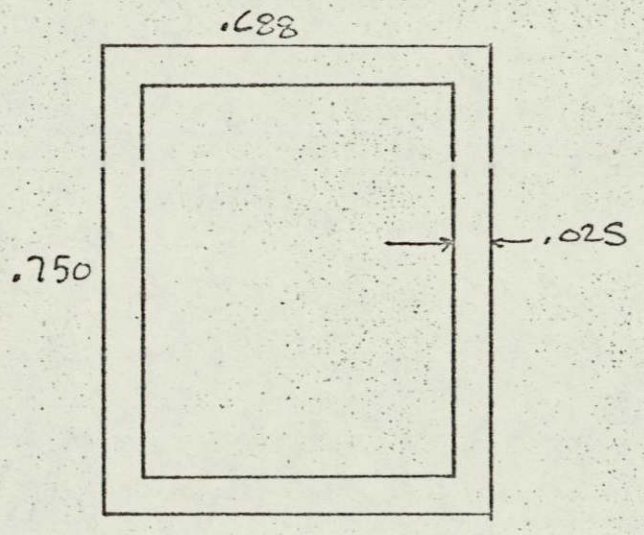
INVESTIGATION OF TAPERED SECTION

Maximum torsion and minimum bending occur @ $\theta = 49°$

$M_{r-r} = -3.59$ #in

$T = -916$ #in

reduce caps to 0.025 in



.060
−.025
.035 ← material saved.

$A_m = (.688-.025)(.750-.025) = 0.480675\ in^2$

$T = 916.$

$\tau = \frac{T}{2tA_m} = \frac{916}{2(.025)\times .480675} = 38113.\ psi$

$M.S. = \frac{96200}{38113} - 1 = 0.18$

REPORT
PAGE 87 OF

Form 2427

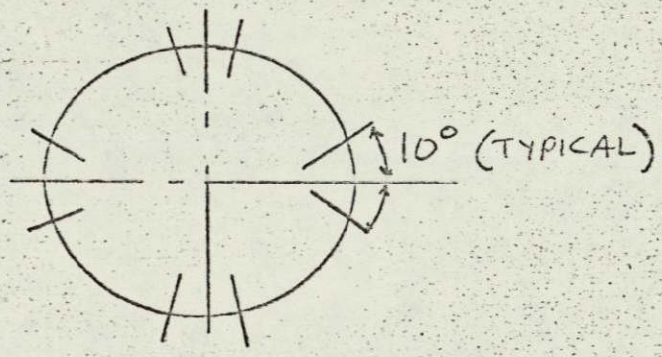
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LOCATION OF CLEAN OUT HOLES & HOLE DIAMETER

The holes should be located in the .750 side. The best location is where the torsional moment is smallest (at the major and minor axes of the ellipse). Since this is where the cables come in, consider a location 10° off the axis.



@ $\Theta = 10°$

$T = 0.5$ #in/#

@ $\Theta = 80°$

$T = 0.70$ #in/#

CABLE LOAD @ Proof = 650#

$T = 0.7 \times 650 = 455$ #IN

$A_m = .456$ in^2

$t = .025$ in

REPORT
PAGE 93 OF

$$\tau = \frac{T}{2tA} = \frac{455}{2(.025)(.456)} = 20{,}000 \text{ psi}$$

STRESS CONCENTRATIONS

Ref: Timoshenko, STRENGTH OF MATERIALS
VOL. 2 3rd Edit p. 305

for a hole ≤ 0.01

$k = 4$

$\therefore \tau = 4 \times 20{,}000 = 80{,}000$ psi

$F_{sy} = 46200$ psi

holes @ $\theta = 80°$ are not good

@ $\theta = 10°$

$$\tau = 20{,}000 \times \frac{.5}{.7} \times 4 = 57200 \text{ psi}$$

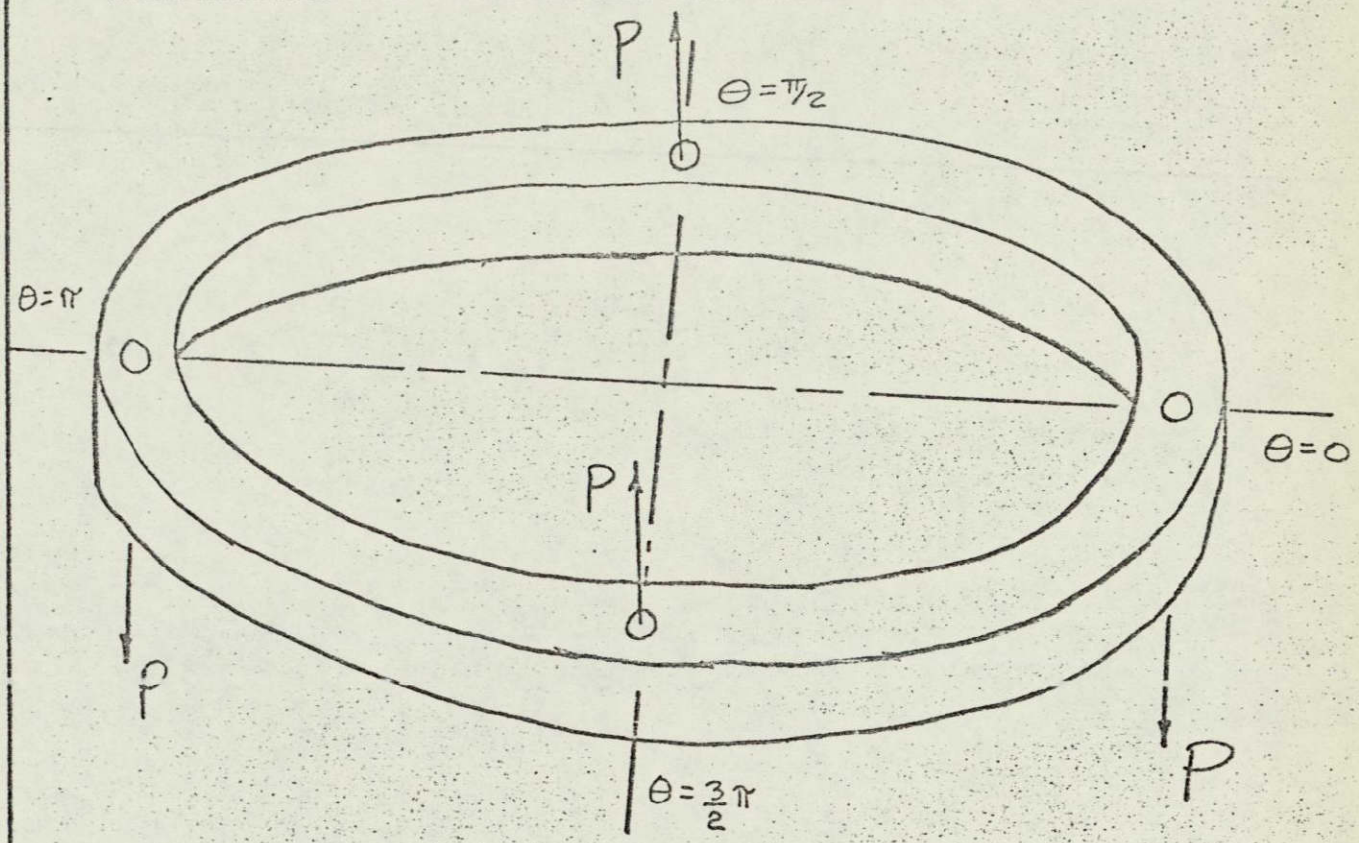
Some slight yielding will take place at proof.

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ULTIMATE FAILURE OF RING



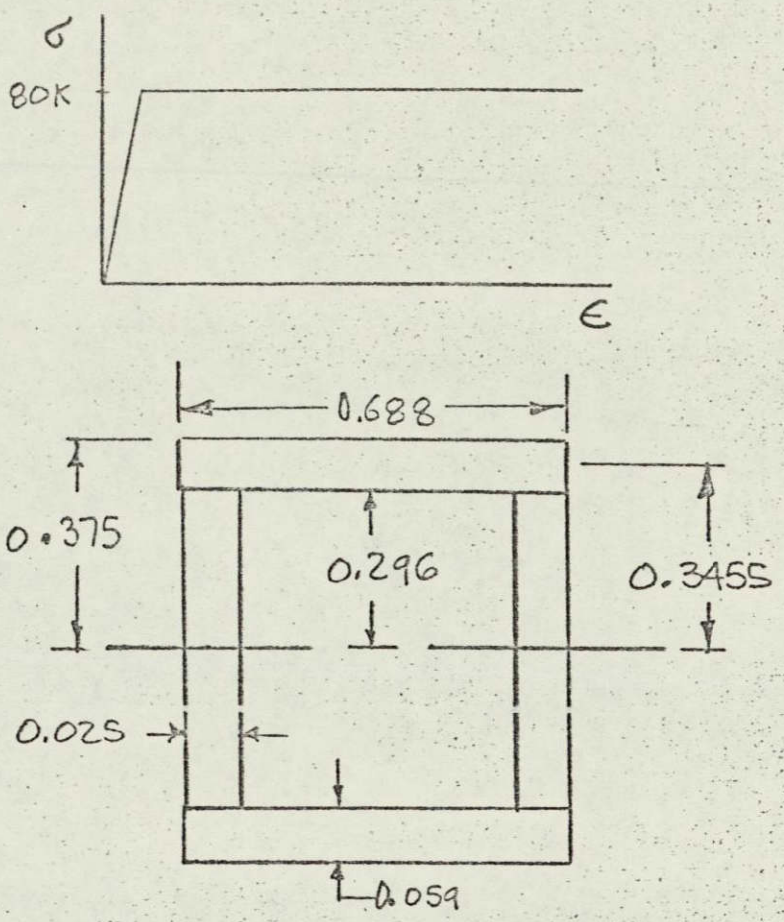
Ultimate failure will come by plastic bending. Hinges will form at $\theta = 0, \pi/2, \pi, 3/2\pi$. The last hinges to form will be at $\theta = 0, \pi$, since the bending moment is less than at $\theta = \pi/2, 3/2\pi$.

If the material is assumed to be perfectly plastic with a yield of 80,000 psi, a lower bound to P will result.

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$$M_p = \left(0.688 \times 0.059 \times 0.3455 + .050 \times .296 \times .296 \times .5\right) 80{,}000 \times 2$$

$$M_p = 16.19 \times 1.6 \times 10^2 = 2590 \ \#\text{in}$$

from page 65 @ $\theta = 0$

$$M = -3P$$

$$\therefore P > \frac{2590}{3} = 863 \ \#$$

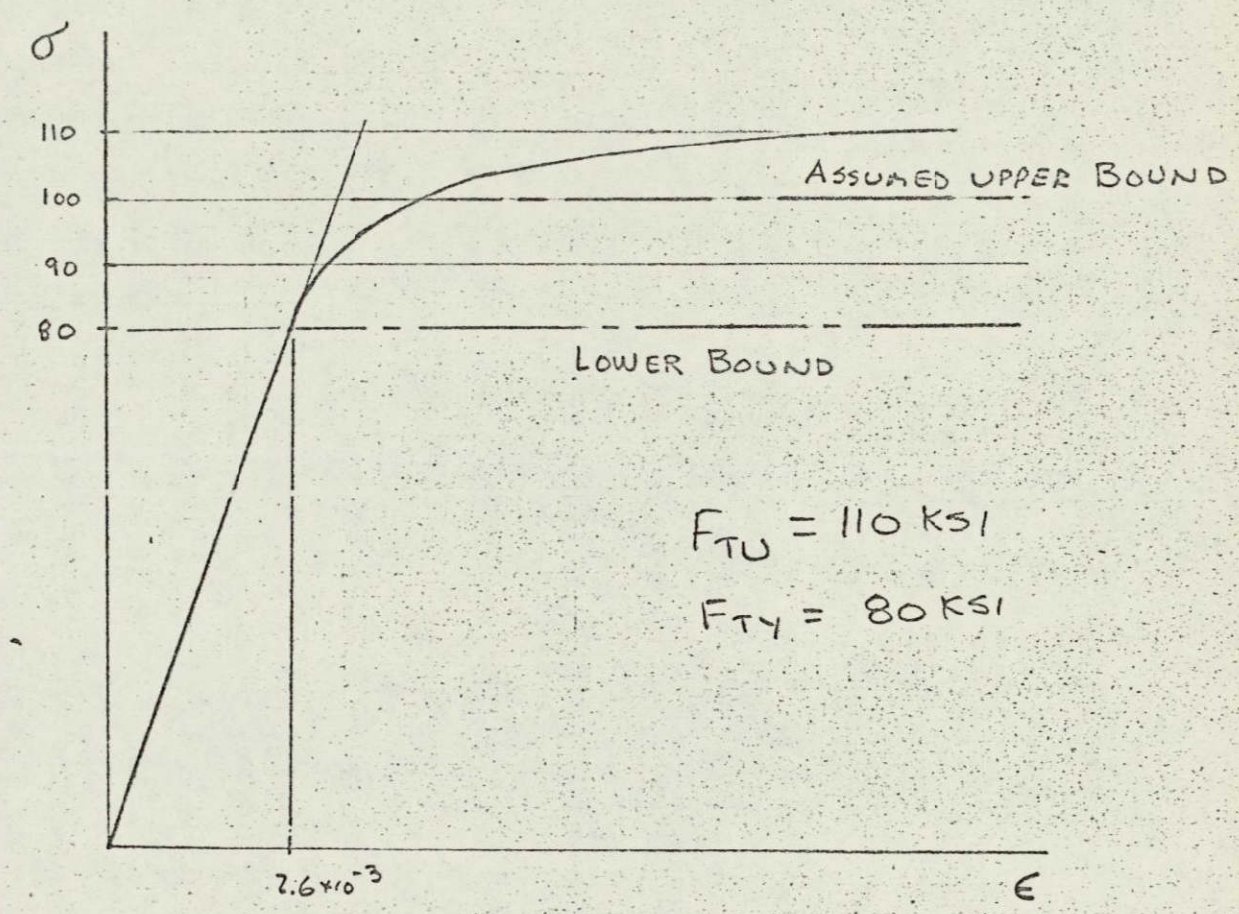
This is a lower bound on P.

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To get some idea of the upper bound, construct a stress strain diagram.



$$M_p = 2590 \times \frac{100}{80} = 3240 \text{ \# IN}$$

$$P < \frac{3240}{3} = 1080 \text{ \#}$$

$$\therefore \quad 863.^{\#} < P < 1080.^{\#}$$

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The cable load at burst is 975 lbs. This value lies between the assumed upperbound and the lower bound. The exact failure moment will have to be determined by test.

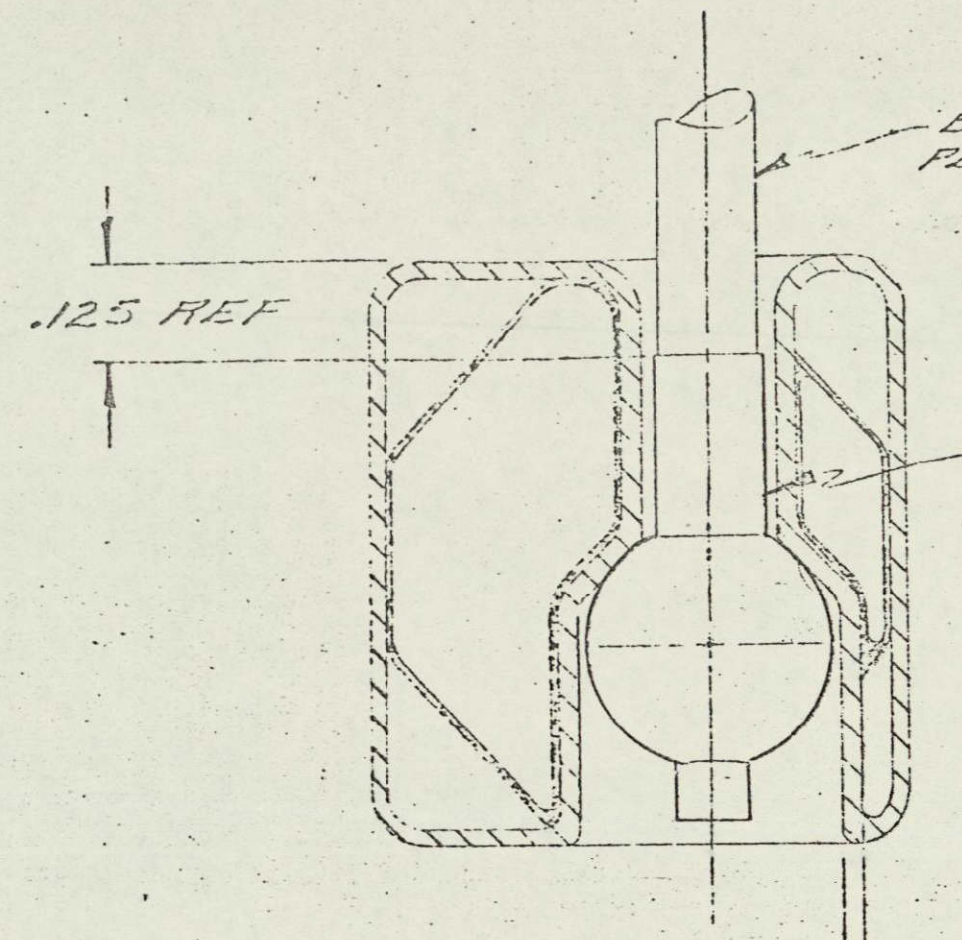
$$M.S. < \frac{1080}{975} - 1 = 0.1$$

$$M.S. > \frac{863}{975} - 1 = -0.115$$

$$-0.115 < M.S. < 0.10$$

@ burst.

CABLE SEAT



SECTION B-B
TYP 4 PLCS (2 ON MAJOR AXIS AS SHOWN & 2 ON MINOR AXIS BUT OPPOSITE)
SCALE - 4/1

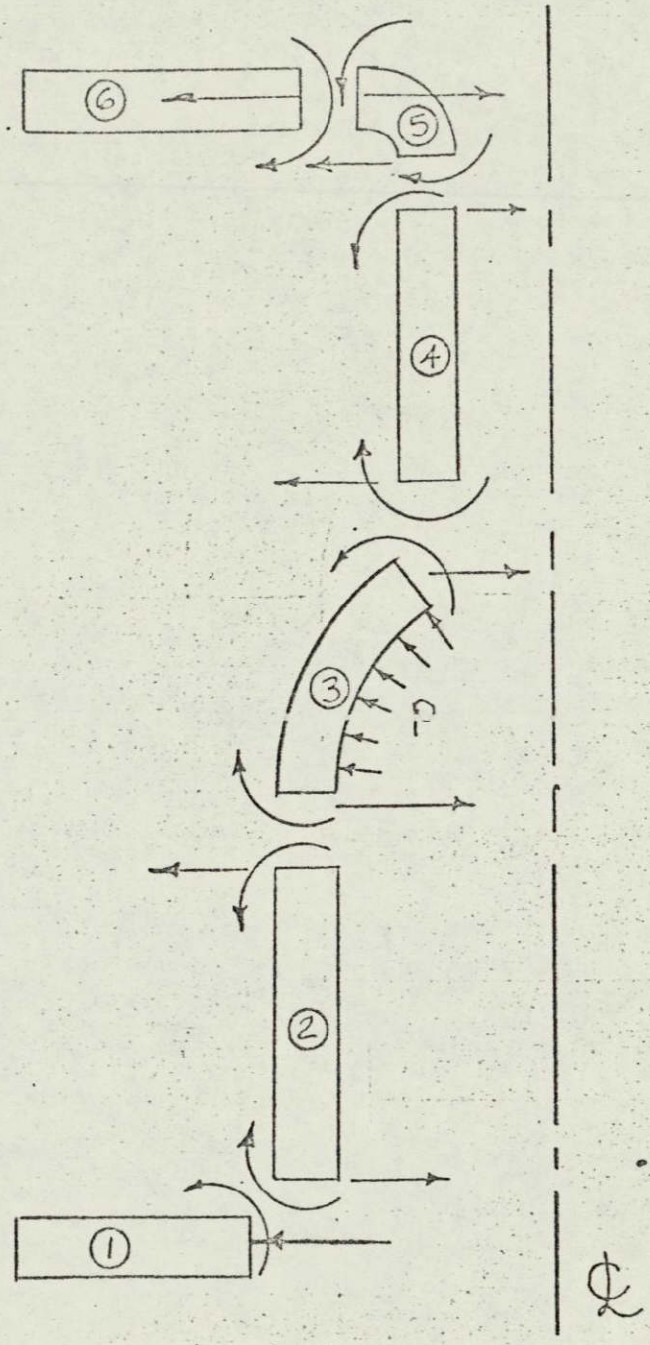
FIGURE 3

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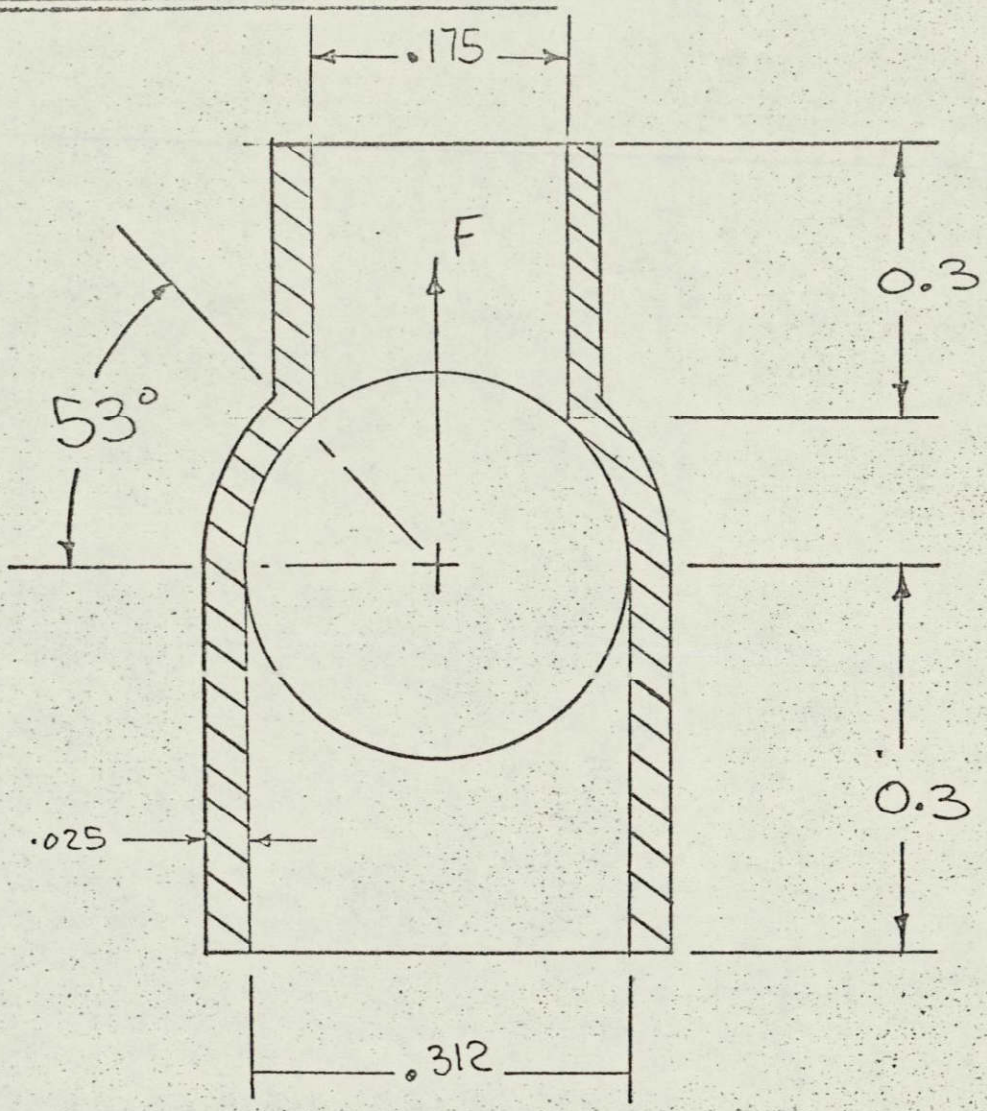
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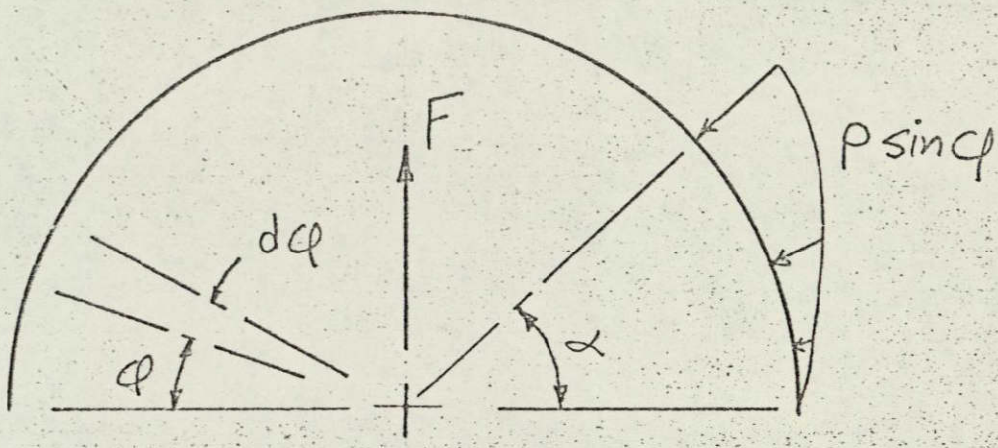
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CABLE SEAT



F = 325.# operating
650.# proof
975.# burst

PRESSURE ON BALL



$$dA = 2\pi r \cos\varphi \; r\,d\varphi = 2\pi r^2 \cos\varphi \, d\varphi$$

$$df = p \sin\varphi \, dA = 2\pi r^2 p \sin\varphi \cos\varphi \, d\varphi$$

vertical component $= f \sin\varphi$

$$\therefore F = 2\pi r^2 p \int_0^{\alpha} \sin^2\varphi \cos\varphi \, d\varphi$$

$$F = \frac{2\pi r^2 p}{2}\left\{\int_0^{\alpha} \cos\varphi \, d\varphi - \int_0^{\alpha} \cos\varphi \cos 2\varphi \, d\varphi\right\}$$

$$F = \frac{\pi r^2 p}{2}\left\{3\sin\alpha + \frac{1}{3}\sin 3\alpha\right\}$$

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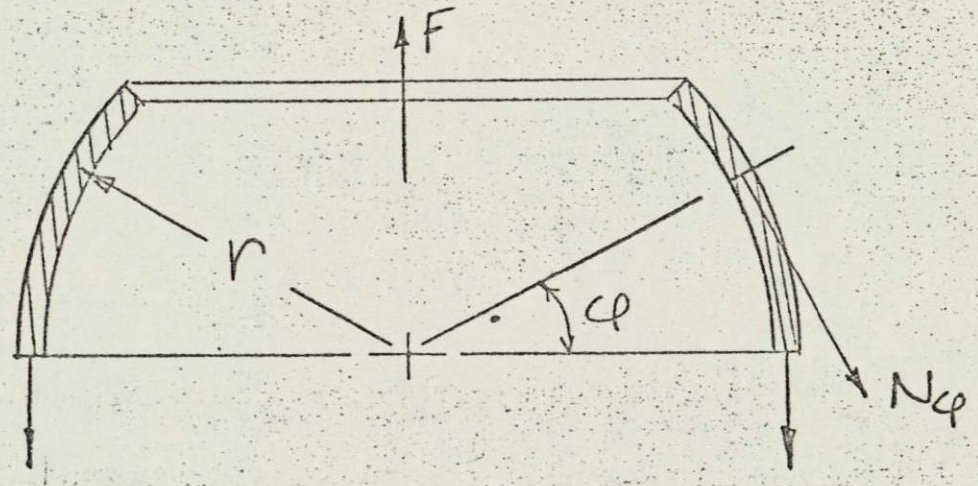
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$$p = \frac{2F}{\pi r^2 \left\{ 3\sin\alpha + \frac{1}{3}\sin 3\alpha \right\}}$$

$$\therefore \text{ pressure} = \frac{2F\sin\varphi}{\pi r^2 \left[3\sin\alpha + \frac{1}{3}\sin 3\alpha \right]}$$

Membrane Analysis of Spherical dome

Ref: Timoshenko, Plates & Shells p. 358 - 360



$$F = 2\pi r \cos\varphi \, N_\varphi \cos\varphi .$$

$$N_\varphi = \frac{F}{2\pi r \cos^2\varphi}$$ (this is only approximate)

$$\frac{N_\varphi}{r} + \frac{N_\theta}{r} = \rho$$

$$N_\theta = \rho r - N_\varphi$$

$$N_\theta = \rho r - \frac{F}{2\pi r \cos^2\varphi}$$

$$N_\theta = \frac{2Fr\sin\varphi}{\pi r^2\left[3\sin\alpha + \frac{1}{3}\sin 3\alpha\right]} - \frac{F}{2\pi r\cos^2\varphi}$$

$$N_\varphi = \frac{F}{2\pi r\cos^2\varphi}$$

$$\epsilon_\theta = \frac{1}{Et}\left\{N_\theta - \nu N_\varphi\right\}$$

$$\epsilon_\theta = \frac{F}{Et}\left\{\frac{2\sin\varphi}{\pi r\left[3\sin\alpha + \frac{1}{3}\sin 3\alpha\right]} - \frac{(1+\nu)}{2\pi r\cos^2\varphi}\right\}$$

$$\epsilon_\theta = \frac{F}{Et\pi r}\left\{\frac{2\sin\varphi}{3\sin\alpha + \frac{1}{3}\sin 3\alpha} - \frac{(1+\nu)}{2\cos^2\varphi}\right\}$$

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$$\epsilon_\varphi = \frac{1}{Et}\left\{N_\varphi - \nu N_\theta\right\}$$

$$\epsilon_\varphi = \frac{F}{Et\pi r}\left\{\frac{(1+\nu)}{2\cos^2\varphi} - \frac{2\nu\sin\varphi}{3\sin\alpha + \frac{1}{3}\sin 3\alpha}\right\}$$

$$\epsilon_\theta \approx \frac{\Delta r}{r}$$

$$\Delta r = \frac{\Gamma}{\pi Et}\left\{\frac{2\sin\varphi}{3\sin\alpha + \frac{1}{3}\sin 3\alpha} - \frac{(1+\nu)}{2\cos^2\varphi}\right\}$$

@ $\varphi = 0$

$$\Delta r = -\frac{F(1+\nu)}{2\pi Et}$$

@ $\varphi = \alpha$

$$\Delta r = \frac{F}{\pi Et}\left\{\frac{2}{3 + \frac{1}{3}\frac{\sin 3\alpha}{\sin\alpha}} - \frac{(1+\nu)}{2\cos^2\alpha}\right\}$$

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Membrane Stresses in Spherical Segment

$r = 0.16$

$t = 0.025$

$\alpha = 53°$

$\sin\alpha = 0.7986$

$\cos\alpha = 0.6018$

$\sin 3\alpha = 0.515$

@ $\varphi = 53°$

$$N_\varphi = \frac{F}{2\pi(0.16)(.6018)^2} = 2.7466F$$

$$N_\theta = \frac{F\ 0.7986}{\frac{\pi}{2}(0.16)\left[3\times.7986+\frac{1}{3}\times 0.515\right]} - N_\varphi = -1.5089F$$

$\sigma_\varphi = 109.86F$

$\sigma_\theta = -60.356F$

	σ_θ	σ_φ
operating F = 325	-19600	35600
Proof F = 650	-39200	71100
Burst F = 975	-59000	Plastic region

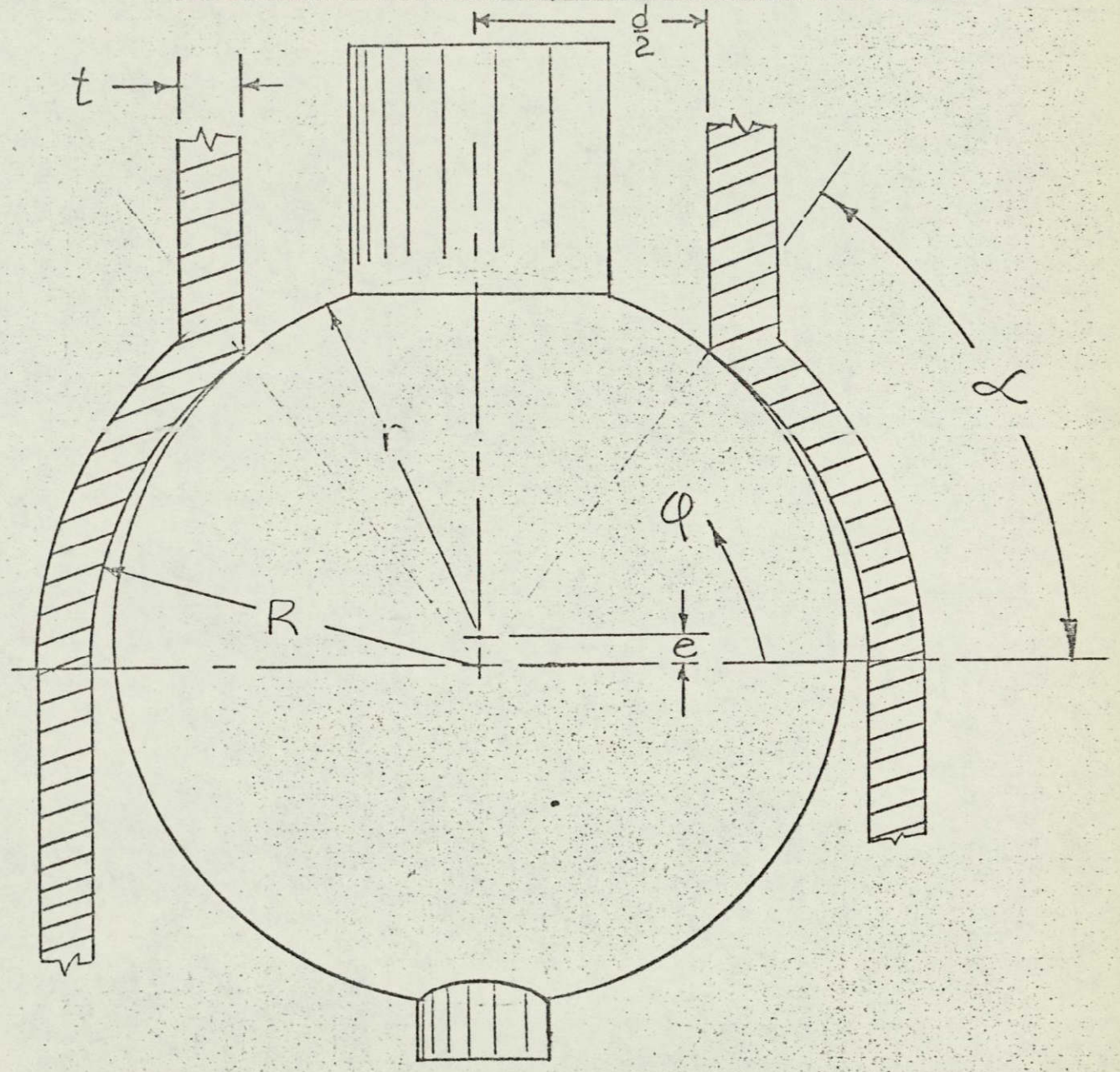
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ANALYSIS OF INCOMPLETE BALL CONTACT WITH SPHERICAL SEAT



MATERIALS:

BALL ~ STEEL

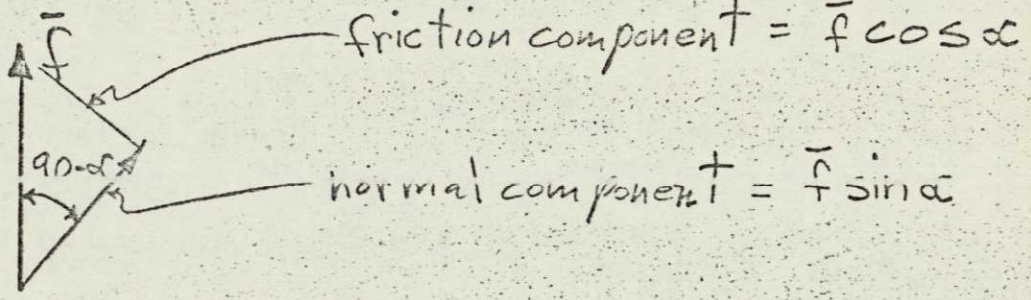
SPHERICAL SECTOR ~ NICKEL

@ $\varphi = \alpha$ there will be line contact between the ball and the spherical sector.

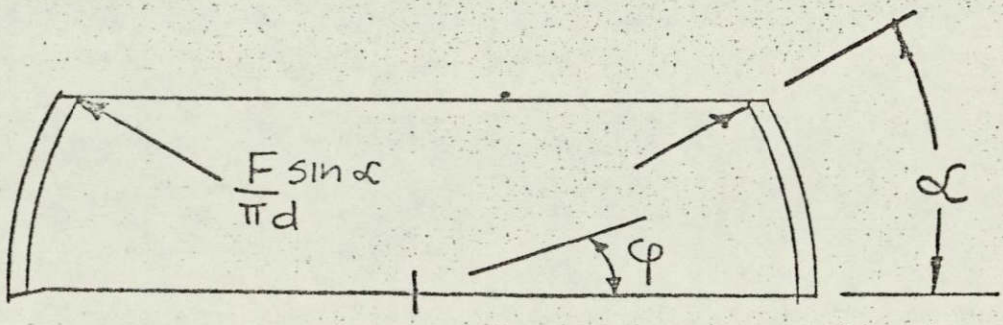
$\frac{d}{2} = R\cos\alpha$

let F = cable load

$\therefore$ load/inch $= \frac{F}{\pi d} = \bar{f}$



Membrane Analysis of Spherical Sector



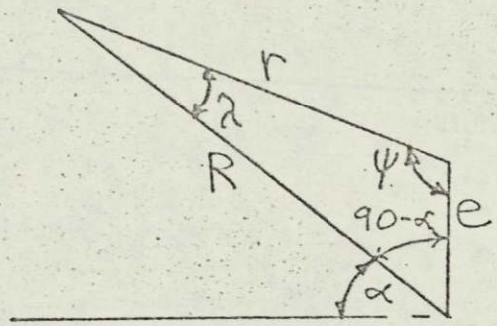
$$N_\varphi = \frac{F}{2\pi R\cos^2\varphi}$$

$$N_\theta = -N_\varphi = \frac{-F}{2\pi R\cos^2\varphi}$$

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$$\frac{\sin(90-\alpha)}{r} = \frac{\sin\lambda}{e} = \frac{\sin\psi}{R}$$

$$\sin\lambda = \frac{e}{r}\cos\alpha$$

$$\lambda + \psi + (90-\alpha) = 180$$

$$\psi = 90 + \alpha - \lambda$$

$$\therefore R = \frac{r}{\cos\alpha}\sin(90+\alpha-\lambda)$$

$$\lambda = \sin^{-1}\left[\frac{e}{r}\cos\alpha\right]$$

$\alpha = 53°$

$r = 0.1562$

$e \approx 0.005$ (guess)

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$$\frac{e}{r} = \frac{.005}{0.1562}$$

$$\cos\alpha = 0.6018$$

$$\frac{e}{r}\cos\alpha = \frac{.005 \times 0.6018}{0.1562} = 0.0193$$

$$\lambda = 0.0193$$

$$90 + \alpha - \lambda = 1.5707 + 0.925 - 0.0193 = 2.4764$$

$$\sin(90+\alpha-\lambda) = 0.618$$

$$R = \frac{0.1562 \times 0.618}{0.6018} = 0.1605$$

$$\epsilon_\theta = \frac{1}{Et}\left\{N_\theta - \nu N_\varphi\right\} = \frac{1}{Et}\left\{\frac{F}{2\pi R\cos^2\varphi}\right\}(-1-\nu)$$

$$\epsilon_\theta \approx \frac{\Delta R}{R}$$

$$\therefore \Delta R = \frac{-F(1+\nu)}{2\pi Et\cos^2\varphi}$$

$$\varphi = \alpha = 53^\circ$$

$$\cos 53 = 0.6018$$

$$\nu = 0.36$$

$$\Delta R_{\varphi=53} = \frac{-650(1.36)}{2\pi\, 30\times10^6 \times (.6018)^2(.025)} = 520\times10^{-6}$$

$$\Delta R_{\varphi=0} = 188.\times10^{-6}$$

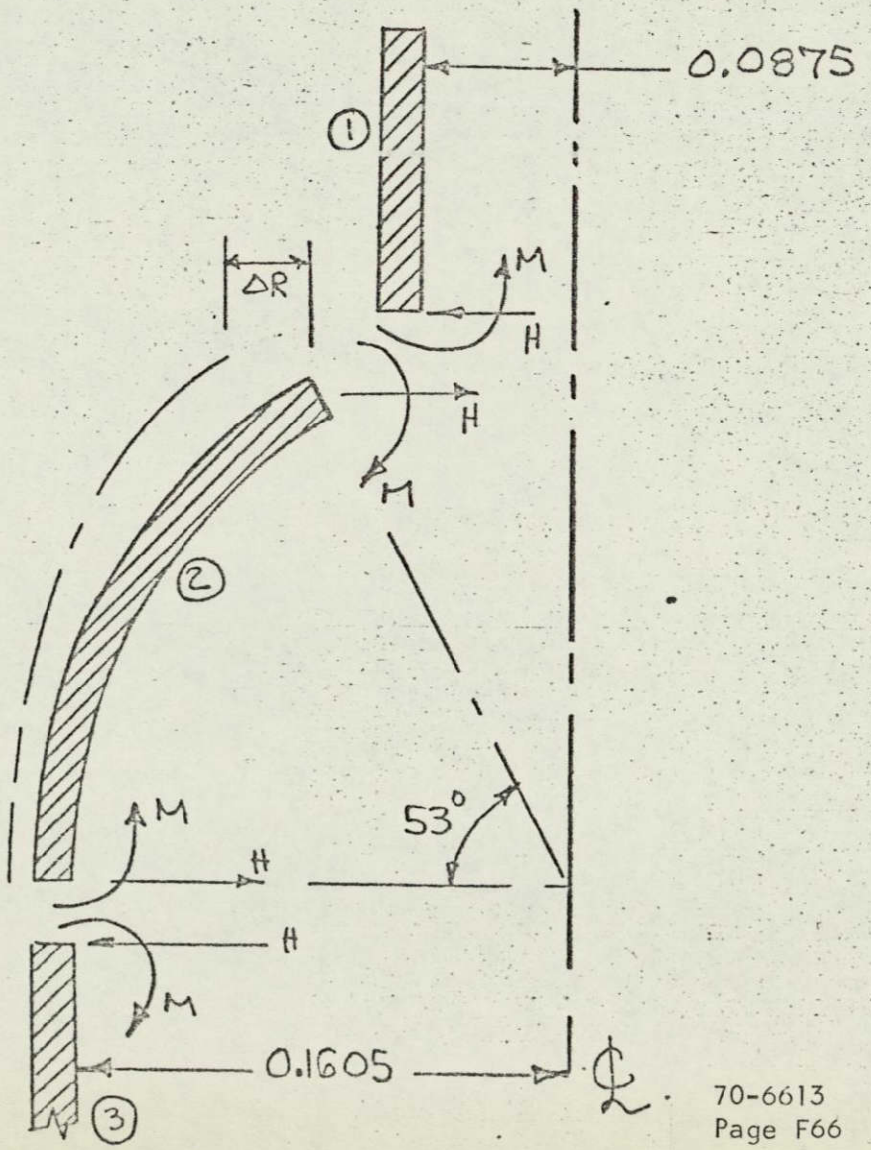
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$$\sigma_\theta = -\sigma_\varphi = \frac{650}{2\pi(.1605)(.6018)^2(.025)} = 7200 \text{ PSI}$$

@ $\varphi = 53°$

To this number must be added the discontinuity stress @ the intersection between the sphere and the cylinder

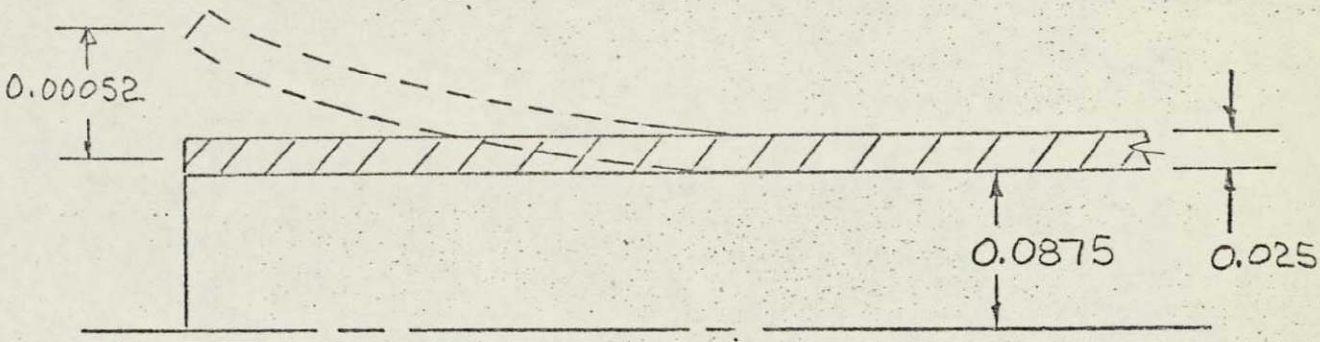


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APPROXIMATE DISCONTINUITY ANALYSIS



$$W = \frac{1}{2\beta^3 D}\left[\beta M\ \psi(\beta x) + H\ \theta(\beta x)\right]$$

$$\frac{dw}{dx} = \frac{1}{2\beta^2 D}\left[2\beta M\ \theta(\beta x) + H\ \phi(\beta x)\right]$$

$$\beta^4 = \frac{3(1-\nu^2)}{R^2 t^2}$$

$$D = \frac{E t^3}{12(1-\nu^2)}$$

$\nu = 0.36$

$E = 30 \times 10^6$

$\beta = 23.1$

$D = 44.878$

$$\frac{dW}{dx} \approx -\frac{.00052 + .000188}{0.35} = -0.00095$$

$$-520(1.1) = 23.1M + H$$

$$-95(.478) = 46.2M + H$$

$$M = 22.8 \ \#in/in$$

$$H = -1105.5 \ \#/in$$

This assumes that no moment is shared with the spherical segment.

$$\sigma = \frac{6M}{t^2} = \frac{6(22.8)}{(.025)^2} = 220{,}000 \text{ Psi}$$

Even if the moment was shared equally with the sphere, the stresses would still be above the yield for nickel.

Form 2427

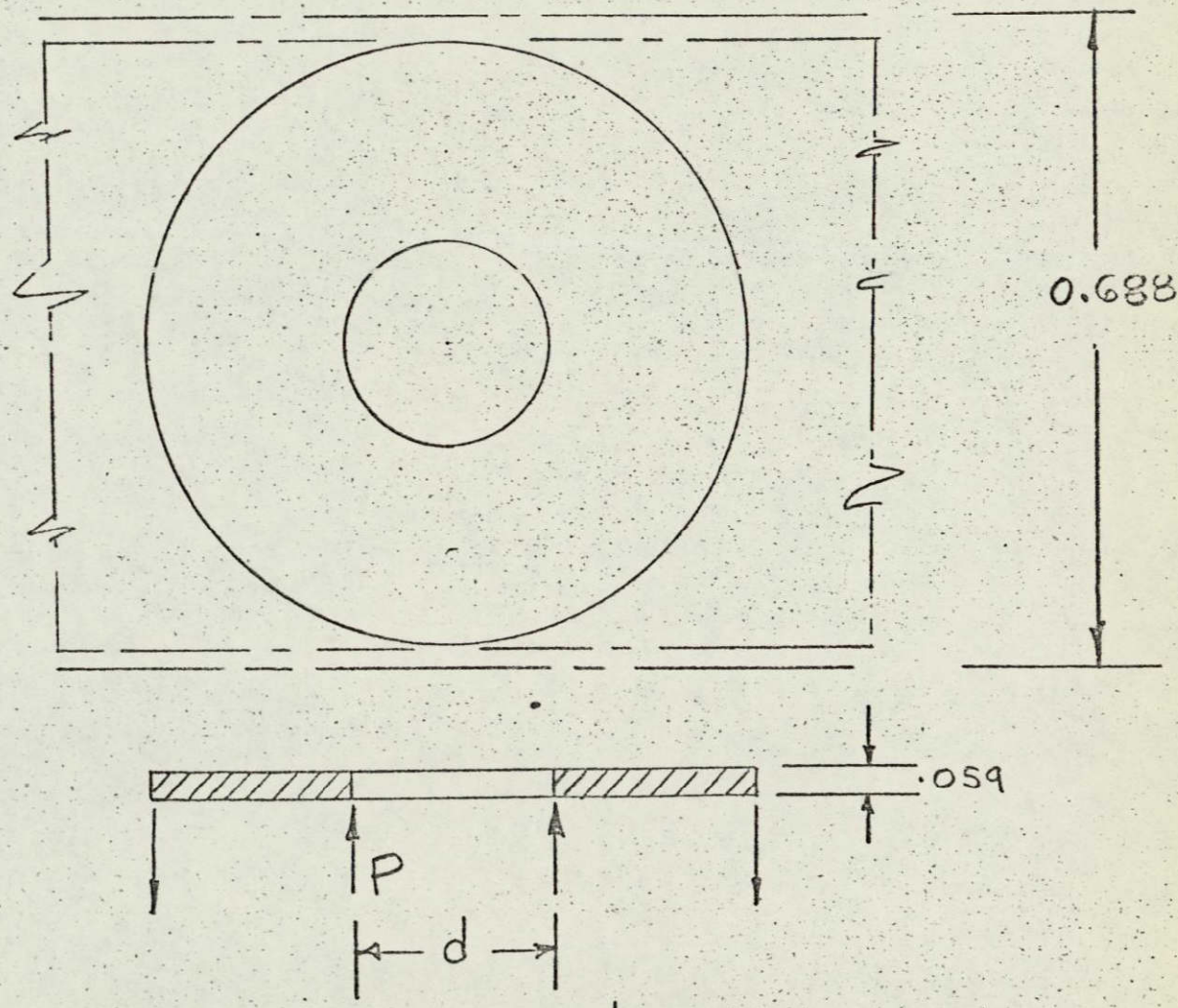
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DATE 7-24-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

INTERSECTION OF CABLE SEAT WITH TOP & BOTTOM CAPS

For calculation purposes, assume a circular plate with a central hole.



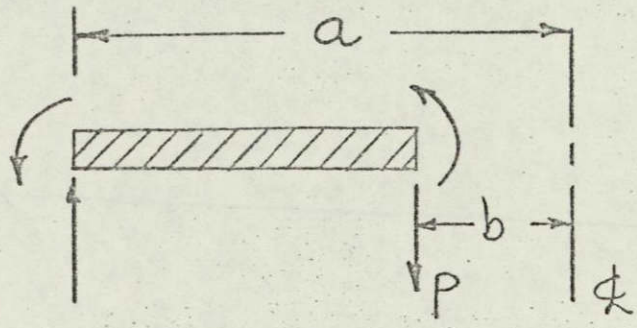
	Load	d
TOP PLATE	To be determined	.17
BOTTOM PLATE	To be determined	.34

Form 2427

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PART NO



Ref: Roark, Formulas for stress & Strain 3rd edit.

p. 200 Case 20

@ inner edge

$$\sigma_{rad} = \frac{3W}{2\pi t^2}\left[1 - \frac{2a^2}{a^2-b^2}\left(\log \frac{a}{b}\right)\right]$$

$$y = \frac{3W(m^2-1)}{4\pi m^2 E t^3}\left[a^2-b^2 - \frac{4a^2b^2}{a^2-b^2}\left(\log \frac{a}{b}\right)^2\right]$$

$$m = \frac{1}{\gamma}$$

ITEM	a	b	a/b	log a/b	a^2	b^2	a^2-b^2
TOP R	.319	.085	3.75	1.32176	0.102	0.0072	0.0948
BOTTOM R	.319	.17	1.87	0.62594	0.102	0.0288	0.0732

$t = 0.059$

$t^2 = 0.00347$

$t^3 = 0.000205$

$m = 1./0.36 = 2.78$

$y_{TOP} = y_{bottom}$ (compatibility of deformations)

$$W_T\left[.0948 - \frac{4(.102)(.0072)(1.32176)^2}{.0948}\right] = W_B\left[.0732 - \frac{4(.102)(.0288)(.62594)^2}{.0732}\right]$$

$$W_T(.0408) = W_B(.0104)$$

$$W_T + W_B = W_{TOTAL}$$

$$W_T = W_B \frac{.0104}{.0408} = W_B(0.254)$$

$$\therefore \quad .254\,W_B + W_B = W_{TOTAL}$$

$$W_B = \frac{W_{TOTAL}}{1.254} = 0.8\,W_{TOTAL}$$

$$W_T = 0.2\,W_{TOTAL}$$

$W_{TOTAL} = 650^{\#}$ (proof)

$W_B = 520^{\#}$

$W_T = 130^{\#}$

$$\sigma_{r_{top}} = \frac{-3(130)10^3}{2\pi(3.97)}\left[1 - \frac{2(.102)}{0.0948}\times 1.32176\right] = +33100 \text{ psi}$$

$$\sigma_{r_{bottom}} = \frac{-3(520)10^3}{2\pi(3.97)}\left[1 - \frac{2(.102)}{0.0732}\times .62594\right] = +53200 \text{ psi}$$

Stresses in Plate due to bending of ring

$\theta = 0$

$$\sigma = \frac{Mc}{I} = \frac{1995 \times .375}{.0107} = -70{,}000 \text{ psi (top)}$$

$\theta = 90°$

$$\sigma = \frac{2294 \times .375}{.0107} = +80{,}000 \text{ psi (top)}$$

Because of the hole there will be a stress concentration.

Ref: Roark p. 344 case 5

$$k = \frac{3(.688)}{d + .688} = \frac{1.264}{0.688 + d}$$

Form 2427

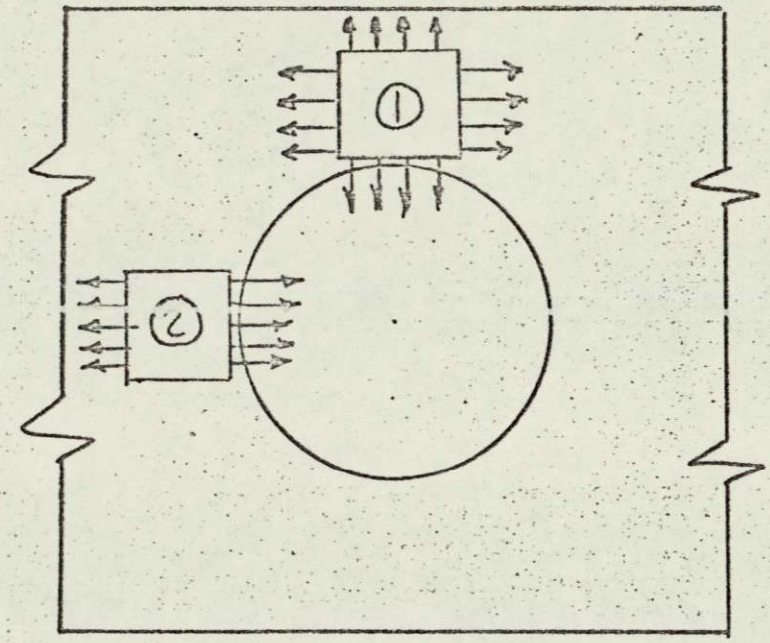
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DATE 7-24-69
PREPARED BY M. WOLFSON
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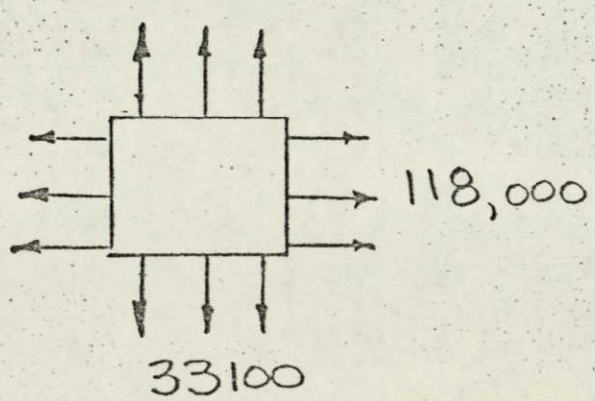
CALC. NO.
MODEL
PART NO.

BENDING STRESSES

	d	k	$\sigma_{\theta=0}$	$\sigma_{\theta=90°}$
TOP R	0.17	1.47	−103000	+118000
BOTTOM R	0.34	1.23	86000	− 98200



@ Location 1, a state of biaxial stress exists



Max shear = $\frac{1}{2}(118 - 33.1) = 84900$ psi

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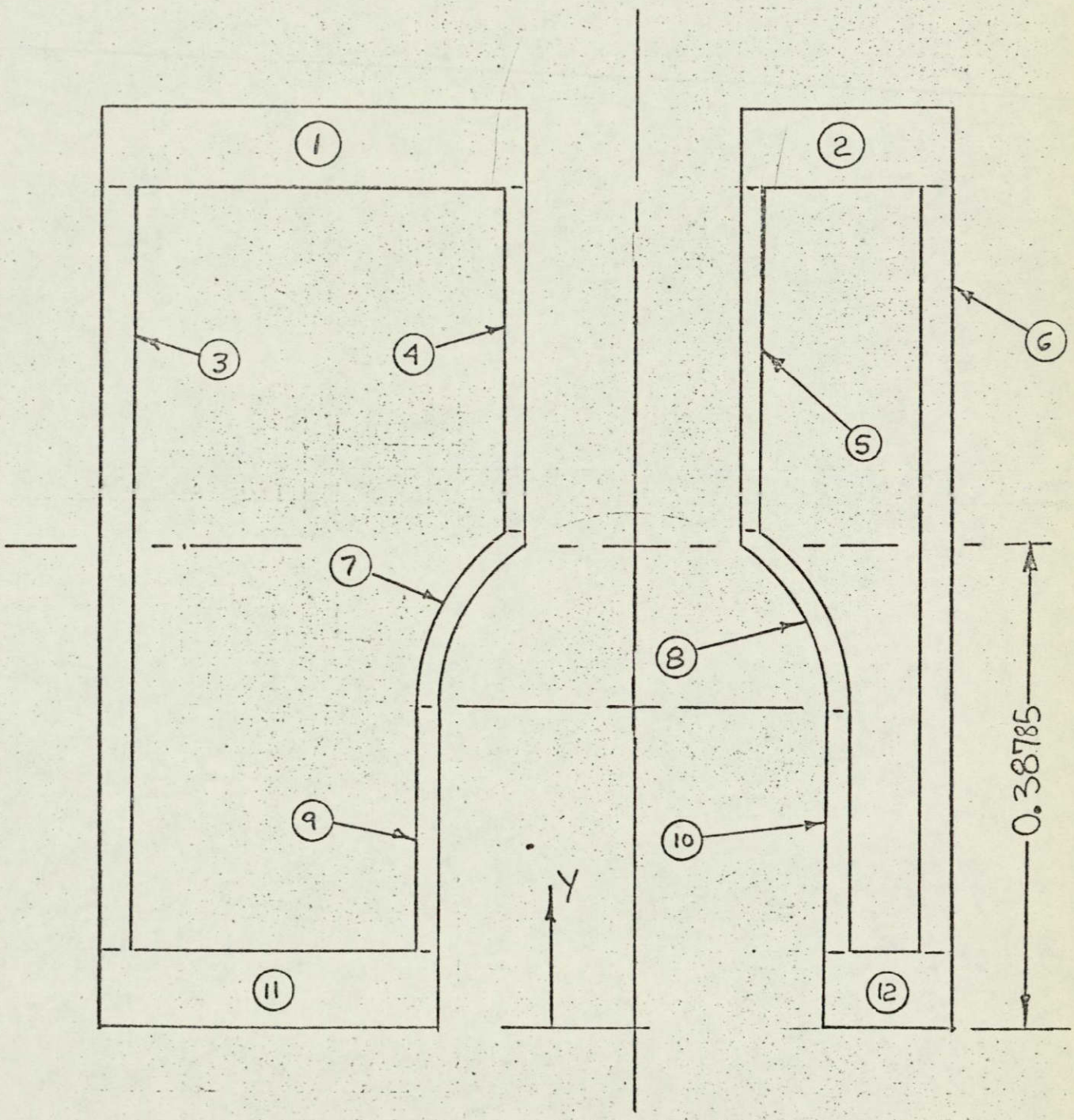
Form 2427

AiRESEARCH MFG. CO.

DATE 7-25-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

LOWER BOUND FOR STRESS AT HOLE



SCALE 8X

Form 2427

AiRESEARCH MFG. CO.

DATE 7-25-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

ITEM	AREA	Y	Y^2	AY	AY^2	I_{oxx}
1	0.0206	0.71	.5041	.01462	0.01038	—
2	0.0101	0.71	.5041	.007171	.00509	—
3	0.01546	0.375	.1406	.005797	.002174	.000496
4	0.0084	0.54	.2916	.004536	.002449	—
5	0.0084	0.54	.2916	.004536	.002449	—
6	0.01546	0.375	.1406	.005797	.002174	.000496
7	0.00975	0.33	.1089	.003217	.0010618	—
8	0.00975	0.33	.1089	.003217	.0010618	—
9	0.006	0.15	.0225	.0009	.000135	—
10	0.006	0.15	.0225	.0009	.000135	—
11	0.0165	0.03	.0009	.000495	.00001485	—
12	0.006	0.03	.0009	.00018	.00000054	—
	0.13242			.05136	.027129	.000992

$$\bar{Y} = \frac{.05136}{.13242} = 0.38785 \text{ in}$$

$$I = .027129 + .000992 - .13242(.38785)^2 = 0.008201 \text{ IN}^4$$

$$C_1 = 0.75 - 0.3878 = 0.3622$$

$$C_2 = 0.3878$$

@ $\theta = 0$ (top)

$$\sigma = \frac{Mc_1}{I} = \frac{-1995 \times 0.3622}{0.008201} = -88110.\ \text{psi}$$

@ $\theta = 90°$ (top)

$$\sigma = \frac{+2294 \times 0.3622}{0.008201} = +101{,}315.\ \text{psi}$$

@ $\theta = 0$ (bottom)

$$\sigma = \frac{1995 \times 0.3878}{0.008201} = +94337.\ \text{psi}$$

@ $\theta = 90°$ (bottom)

$$\sigma = \frac{-2294 \times 0.3878}{0.008201} = -108476.\ \text{psi}$$

Form 2427

AIRESEARCH MFG. CO.

DATE 7-28-69
PREPARED BY M. U/CLEFSON
CHECKED BY

CALC. NO
MODEL
PART NO

LOCATION	LOAD	θ	σ	τ	u	V	β
Top of Ring	Proof	0°	-88110	0	.3342	.036	0
Bottom of Ring	Proof	0°	+94337	0	.3342	.036	0
Top of Ring	Proof	90°	101315.	0	-0.0378	-.033	0
Bottom of Ring	Proof	90°	-108476	0	-0.0378	-.033	0
TOP & BOTTOM	Proof	44°	∓8800	16500	.2405	∓0	∓.00247
SIDE	Proof	44°	0	39600	.2405	0	-.00247

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STRESS SUMMARY FOR ELLIPTIC RING

TOP & BOTTOM CAP THICK = 0.060
WEB THICK. = 0.025

WIDTH = 0.688
DEPTH = 0.750

REPORT
PAGE 117 OF

DATE 7-29-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

HERTZ STRESS ANALYSIS OF CONTACT BETWEEN BALL & SPHERE

Because of the hole in the sphere, the situation approximates a cylinder in a circular groove

Ref: Roark, Formulas for Stress & Strain 3rd Edit.
p. 282 case 6

$D_1 = 0.3124$

$D_2 = 0.321$

$D_1 - D_2 = 0.0086$

$D_1 D_2 = 0.10028$

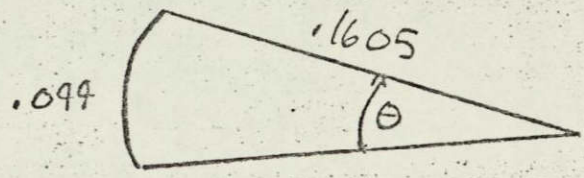
$$p = \frac{650}{\pi(.321)\cos 53} = 1070.68$$

$$S_c = 0.591 \sqrt{P E \frac{D_1 - D_2}{D_1 D_2}}$$

$$b = 2.15 \sqrt{\frac{P}{E} \frac{D_1 D_2}{D_1 - D_2}}$$

$$b = 2.15\sqrt{\frac{1070.68 \times 0.10028}{30\times10^6 \times 0.0086}} = 0.044 \text{ in}$$

$$S_c = 0.591\sqrt{\frac{1070.68 \times 1.0086 \times 30\times10^6}{0.10028}} = 31{,}000 \text{ psi}$$



$$\theta = \frac{.094}{.1605} = 0.274_{rad} = 15.7°$$

The actual load is 650/sin 34

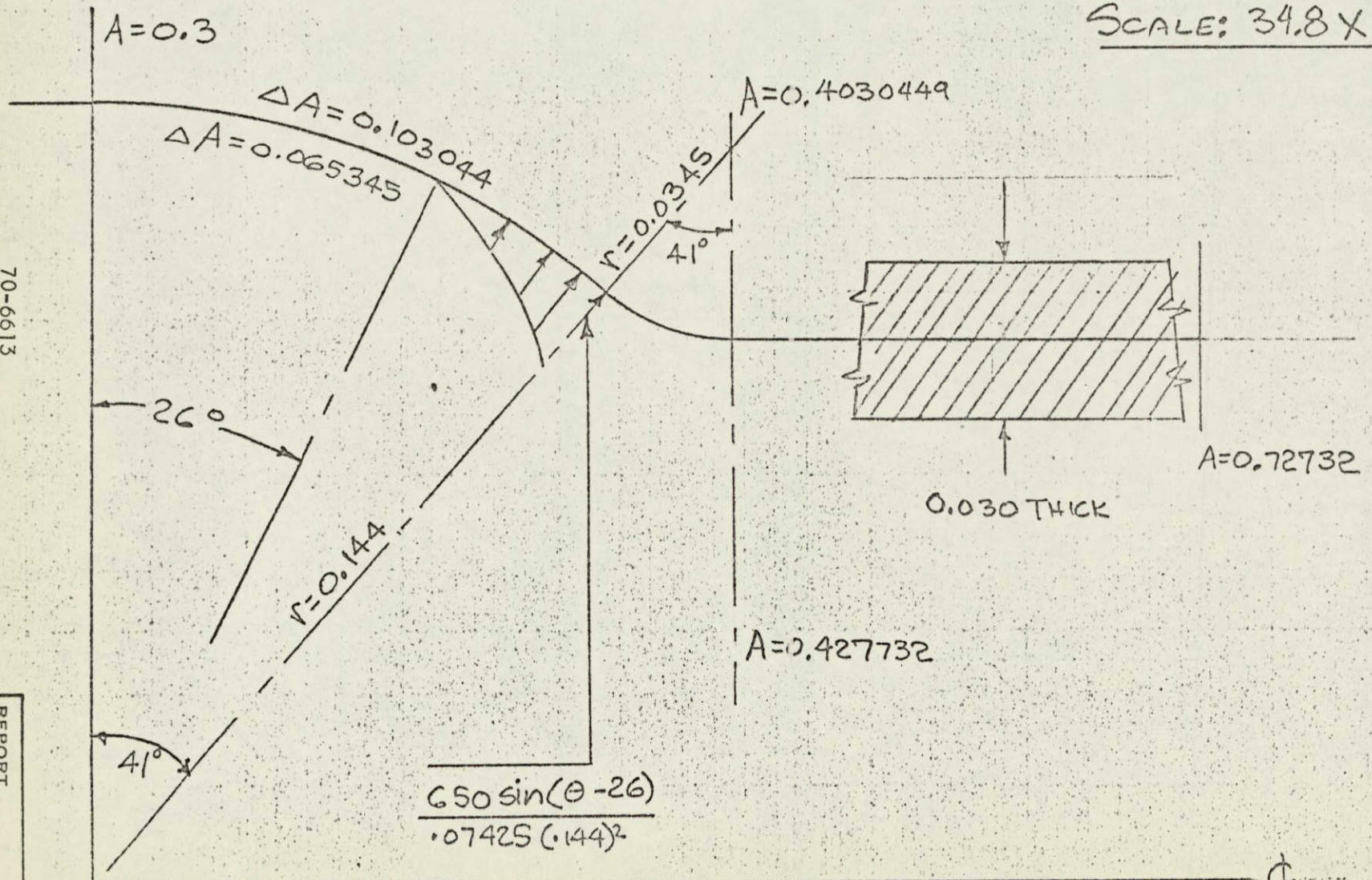
$$\therefore\ p = \frac{1070.68}{\sin 34} = 1820 \text{ psi}$$

$$\therefore\ S_c = 31000\sqrt{\frac{1820}{1070}} = 40400 \text{ psi}$$

This is the best approximation that can be arrived at using Hertz theory. The actual stress distribution does not lend itself to Hertz theory calculations

COMPUTER ANALYSIS OF SPHERICAL SEAT USING X0300A

SCALE: 34.8 X



DATE 8-4-69
PREPARED BY M. W. OLSON
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AIRESEARCH MFG. CO.

CALC. NO
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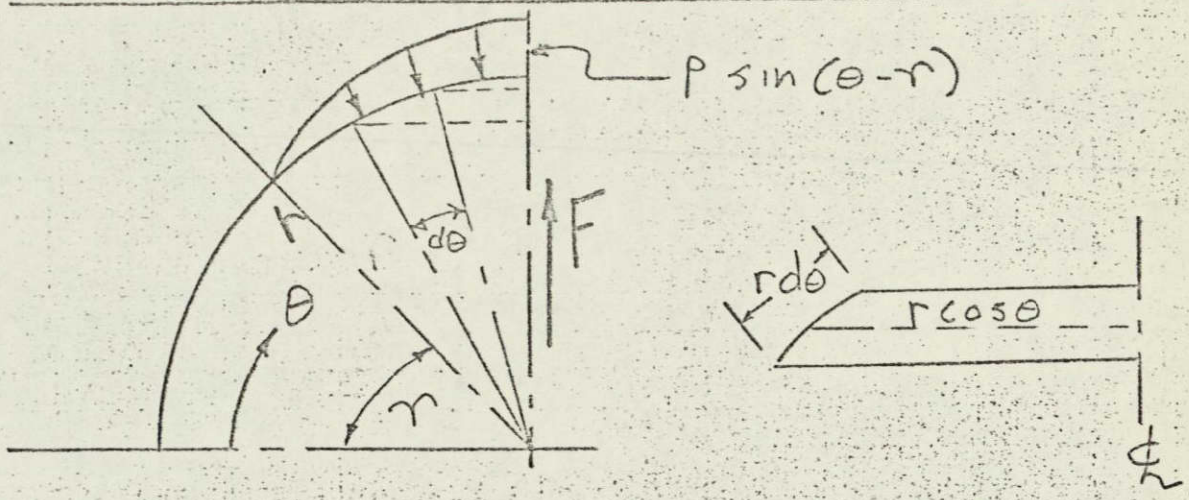
Form 2427

AiRESEARCH MFG. CO.

DATE 8-4-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

PRESSURE ON SPHERICAL BALL



$$P = P\sin(\theta-\gamma)$$

$$dA = r\,d\theta\, 2\pi r\cos\theta$$

$$F = \int_{\gamma}^{41} P\sin(\theta-\gamma)\,2\pi r^2\cos\theta\sin\theta\,d\theta$$

$$F = \pi r^2 P \int_{\gamma}^{41} \sin(\theta-\gamma)\sin 2\theta\,d\theta$$

$$\gamma = 26^\circ$$

$$F = \frac{\pi r^2}{2} P\left[\cos 26\left(\sin\theta - \frac{\sin 3\theta}{3}\right) + \sin 26\left(\cos\theta + \frac{\cos 3\theta}{3}\right)\right]_{26}^{41}$$

$$F = -0.07425\, r^2 P$$

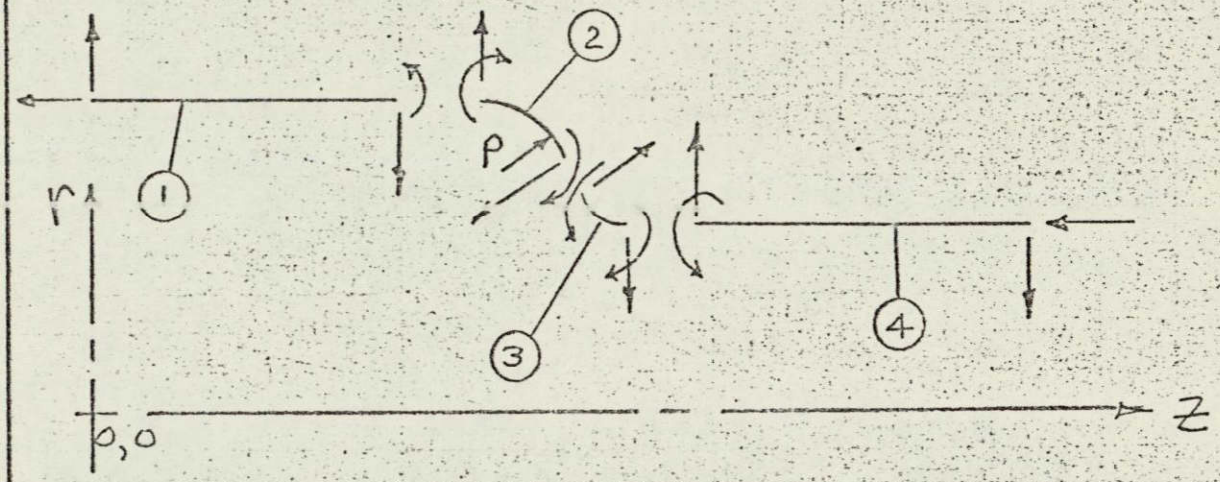
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CALC. NO.
MODEL
PART NO.

$$\rho = \frac{650}{0.07425(0.144)^2} = 422174 \text{ psi}$$

$$N_\varphi = N_\theta = \frac{PR}{2} = \frac{422174(0.144)}{2} = 30396.528 \text{ \#/IN}$$

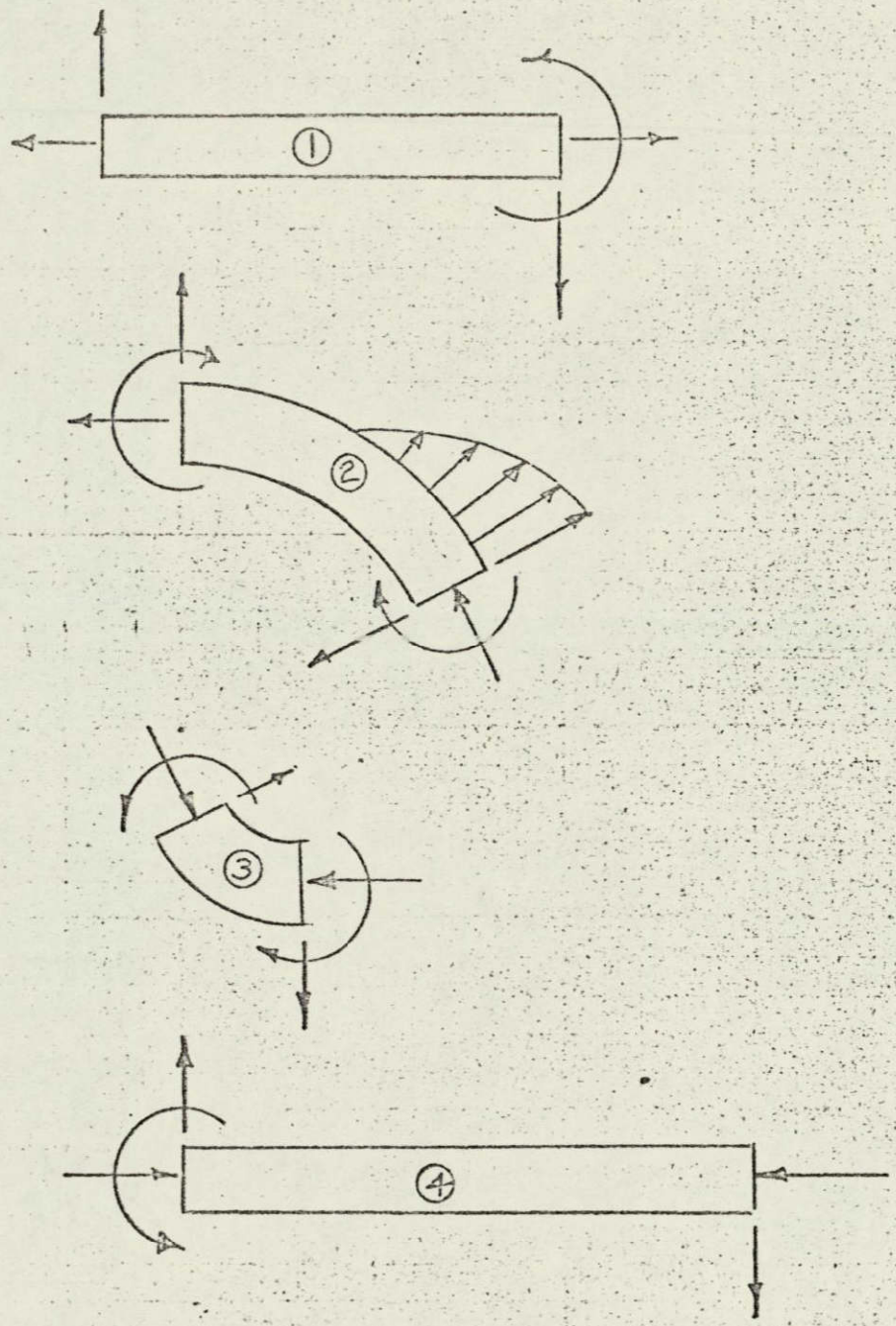


Form 2427

AiRESEARCH MFG. CO.

DATE 8-4-69
PREPARED BY M. WOLFSON
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CALC. NO
MODEL
PART NO



Form 2477

AiRESEARCH MFG. CO.

DATE_____
PREPARED BY_____
CHECKED BY_____

CALC. NO_____
MODEL _____
PART NO_____

X0300A RUN ON SPHERICAL SEAT

```
FORTRAN IV G LEVEL 1, MOD 2          R                    DATE = 69225          13

0001                FUNCTION R(A)
0002                IF(A-.3)5,5,6
0003              5 R=0.144
0004                RETURN
0005              6 IF(A-.403044)7,7,8
0006              7 DIS=(A-.3)/0.144
0007                R=0.144*COS(DIS)
0008                RETURN
0009              8 IF(A-.427732)9,9,10
0010              9 DIS=(A-.4030449)/.0345
0011                R=0.1335-.0345*COS(.7155897-DIS)
0012                RETURN
0013             10 R=0.099
0014                RETURN
0015                END
```

```
FORTRAN IV G LEVEL 1, MOD 2          Z                    DATE = 69225          1

0001                FUNCTION  Z(A)
0002                IF(A-.3)5,5,6
0003              5 Z=A
0004                RETURN
0005              6 IF(A-.403044)7,7,8
0006              7 DIS=(A-.3)/0.144
0007                Z=0.144*SIN(DIS) +0.3
0008                RETURN
0009              8 IF(A-.427732)9,9,10
0010              9 DIS=(A-.4030499)/0.0345
0011                Z=0.417113-0.0345*SIN(.7155897-DIS)
0012                RETURN
0013             10 Z= A-.010619
0014                RETURN
0015                END
```

```
0001              FUNCTION V(A)
0002              IF(A-.3653)5,5,7
0003            5 IF(A-.3)6,6,9
0004            6 V= 574.72
0005              RETURN
0006            9 DIS=(A-.3)/0.144
0007              R=0.144*COS(DIS)
0008              V= 82.8/R
0009              RETURN
0010            7 IF(A-.403044)8,8,10
0011            8 DIS=(A-.3)/0.144
0012              PRES= 30396.528
0013              V=PRES*SIN(DIS-.454)*SIN(DIS)
0014              RETURN
0015           10 IF(A-.427732)11,11,12
0016           11 DIS=(A-.403044)/0.0345
0017              R=0.099+0.0345*(1.-COS(.716-DIS))
0018              V=-20.75/R
0019              RETURN
0020           12 V=-208.99
0021              RETURN
0022              END
```

```
0001              FUNCTION T(A)
0002              T=0.055
0003              RETURN
0004              END
```

```
0001              FUNCTION AT(A)
0002              AT(A)=0.0
0003              RETURN
0004              END
```

```
0001              FUNCTION PR(A)
0002              IF(A-.3653)5,5,7
0003            5 PR=0.0
0004              RETURN
0005            7 IF(A-.403044)8,8,5
0006            8 DIS=(A-0.3)/0.144
0007              PRES= 30396.528
0008              PR= PRES*SIN(DIS- .453788)*COS(DIS)
0009              RETURN
0010              END
```

RING. T=0.055

	AXIAL MOMENT	HOOP MOMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	ANGULAR ROTATION
			0.0	0.0	0.0
01	-1.0567E 00	-1.0567E 00	0.0	9.7688E-07	-4.5353E-06
01	-7.0696E-01	-2.5450E-01	-1.2506E-05	1.9539E-06	-8.6425E-06
01	-6.3879E-01	-2.2997E-01	-1.2526E-05	2.9312E-06	-1.2345E-05
01	-5.7439E-01	-2.0678E-01	-1.2556E-05	3.9087E-06	-1.5664E-05
01	-5.1371E-01	-1.8494E-01	-1.2597E-05	4.8866E-06	-1.8625E-05
01	-4.5675E-01	-1.6443E-01	-1.2647E-05	5.8650E-06	-2.1248E-05
01	-4.0345E-01	-1.4524E-01	-1.2706E-05	6.8438E-06	-2.3557E-05
01	-3.5379E-01	-1.2736E-01	-1.2771E-05	7.8231E-06	-2.5573E-05
01	-3.0772E-01	-1.1078E-01	-1.2843E-05	8.8030E-06	-2.7319E-05
01	-2.6518E-01	-9.5465E-02	-1.2920E-05	9.7835E-06	-2.8815E-05
01	-2.2613E-01	-8.1407E-02	-1.3002E-05	1.0765E-05	-3.0083E-05
01	-1.9051E-01	-6.8584E-02	-1.3088E-05	1.1746E-05	-3.1144E-05
01	-1.5827E-01	-5.6977E-02	-1.3178E-05	1.2729E-05	-3.2018E-05
01	-1.2934E-01	-4.6561E-02	-1.3270E-05	1.3712E-05	-3.2725E-05
01	-1.0365E-01	-3.7314E-02	-1.3365E-05	1.4696E-05	-3.3285E-05
01	-8.1152E-02	-2.9215E-02	-1.3461E-05	1.5681E-05	-3.3717E-05
01	-6.1774E-02	-2.2239E-02	-1.3559E-05	1.6666E-05	-3.4040E-05
01	-4.5449E-02	-1.6361E-02	-1.3658E-05	1.7652E-05	-3.4273E-05
01	-3.2111E-02	-1.1560E-02	-1.3758E-05	1.8639E-05	-3.4433E-05
01	-2.1689E-02	-7.8081E-03	-1.3858E-05	1.9626E-05	-3.4538E-05
01	-1.4119E-02	-5.0827E-03	-1.3959E-05	2.0614E-05	-3.4605E-05
01	-9.3311E-03	-3.3592E-03	-1.4060E-05	2.1603E-05	-3.4652E-05
01	-7.2540E-03	-2.6114E-03	-1.4162E-05	2.2593E-05	-3.4694E-05
01	-7.8229E-03	2.8163E-03	-1.4263E-05	2.3583E-05	-3.4748E-05
01	-1.0969E-02	-3.9488E-03	-1.4365E-05	2.4575E-05	-3.4828E-05
01	-1.6618E-02	-5.9826E-03	-1.4467E-05	2.5566E-05	-3.4951E-05
01	-2.4703E-02	-8.8932E-03	-1.4569E-05	2.6559E-05	-3.5130E-05
01	-3.5156E-02	-1.2656E-02	-1.4672E-05	2.7553E-05	-3.5381E-05
01	-4.7905E-02	-1.7246E-02	-1.4776E-05	2.8547E-05	-3.5716E-05
01	-6.2885E-02	-2.2638E-02	-1.4880E-05	2.9542E-05	-3.6149E-05
01	-8.0023E-02	-2.3808E-02	-1.4985E-05	3.0538E-05	-3.6694E-05
01	-9.9246E-02	-3.5729E-02	-1.5092E-05	3.1534E-05	-3.7363E-05
01	-1.2048E-01	-4.3373E-02	-1.5200E-05	3.2531E-05	-3.8167E-05
01	-1.4365E-01	-5.1714E-02	-1.5311E-05	3.3530E-05	-3.9119E-05
01	-1.6868E-01	-6.0727E-02	-1.5424E-05	3.4529E-05	-4.0229E-05
01	-1.9551E-01	-7.0382E-02	-1.5541E-05	3.5529E-05	-4.1509E-05
01	-2.2404E-01	-8.0654E-02	-1.5660E-05	3.6529E-05	-4.2968E-05
01	-2.5420E-01	-9.1511E-02	-1.5784E-05	3.7531E-05	-4.4616E-05
01	-2.8590E-01	-1.0292E-01	-1.5912E-05	3.8534E-05	-4.6463E-05
01	-3.1906E-01	-1.1486E-01	-1.6046E-05	3.9538E-05	-4.8517E-05
01	-3.5358E-01	-1.2729E-01	-1.6185E-05	4.0542E-05	-5.0786E-05
01	-3.8933E-01	-1.4018E-01	-1.6330E-05	4.1548E-05	-5.3277E-05
01	-4.2634E-01	-1.5348E-01	-1.6482E-05	4.2555E-05	-5.5998E-05
01	-4.6438E-01	-1.6718E-01	-1.6642E-05	4.3564E-05	-5.8954E-05
01	-5.0336E-01	-1.8121E-01	-1.6811E-05	4.4573E-05	-6.2151E-05
01	-5.4319E-01	-1.9555E-01	-1.6988E-05	4.5584E-05	-6.5594E-05
01	-5.8375E-01	-2.1015E-01	-1.7175E-05	4.6597E-05	-6.9288E-05
01	-6.2491E-01	-2.2497E-01	-1.7372E-05	4.7611E-05	-7.3234E-05
01	-6.6654E-01	-2.3995E-01	-1.7581E-05	4.8626E-05	-7.7436E-05
01	-7.0849E-01	-2.5506E-01	-1.7801E-05		

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	VERTICAL FORCE	HORIZONTAL FORCE	HOOP FORCE	AXIAL MOMENT	HOOP MOMENT
0.0	5.7472E 02	-2.5271E C1	6.3749E 01	-1.0567E 00	-1.0567E 0
2.9210E-03	5.7472E 02	-2.3980E 01	6.3598E 01	-7.0696E-01	-2.5450E-0
5.8419E-03	5.7472E 02	-2.2691E 01	6.3377E 01	-6.3879E-01	-2.2997E-0
8.7629E-03	5.7472E 02	-2.1409E 01	6.3025E 01	-5.7439E-01	-2.0678E-0
1.1684E-02	5.7472E 02	-2.0134E C1	6.2556E 01	-5.1371E-01	-1.8494E-0
1.4605E-02	5.7472E 02	-1.8871E 01	6.1981E 01	-4.5675E-01	-1.6443E-0
1.7526E-02	5.7472E 02	-1.7620E 01	6.1314E 01	-4.0345E-01	-1.4524E-0
2.0447E-02	5.7472E 02	-1.6333E 01	6.0564E 01	-3.5379E-01	-1.2736E-0
2.3368E-02	5.7472E 02	-1.5163E 01	5.9741E 01	-3.0772E-01	-1.1078E-0
2.6289E-02	5.7472E 02	-1.3960E C1	5.8857E 01	-2.6518E-01	-9.5465E-0
2.9210E-02	5.7472E 02	-1.2775E 01	5.7917E 01	-2.2613E-01	-8.1407E-0
3.2131E-02	5.7472E 02	-1.1610E 01	5.6929E 01	-1.9051E-01	-6.8584E-0
3.5052E-02	5.7472E 02	-1.0465E 01	5.5902E 01	-1.5827E-01	-5.6977E-0
3.7973E-02	5.7472E 02	-9.3421E 00	5.4845E 01	-1.2934E-01	-4.6561E-0
4.0893E-02	5.7472E 02	-8.2405E 00	5.3762E 01	-1.0365E-01	-3.7314E-0
4.3814E-02	5.7472E 02	-7.1611E 00	5.2655E 01	-8.1152E-02	-2.9215E-0
4.6735E-02	5.7472E 02	-6.1043E 00	5.1531E 01	-6.1774E-02	-2.2239E-0
4.9656E-02	5.7472E 02	-5.0705E 00	5.0398E 01	-4.5449E-02	-1.6361E-0
5.2577E-02	5.7472E 02	-4.0597E 00	4.9254E 01	-3.2111E-02	-1.1560E-0
5.5498E-02	5.7472E 02	-3.0723E C0	4.8105E 01	-2.1689E-02	-7.8081E-0
5.8419E-02	5.7472E 02	-2.1082E 00	4.6950E 01	-1.4119E-02	-5.0827E-0
6.1340E-02	5.7472E 02	-1.1676E C0	4.5791E 01	-9.3311E-03	-3.3592E-0
6.4261E-02	5.7472E 02	-2.5050E-01	4.4628E 01	-7.2540E-03	-2.6114E-0
6.7182E-02	5.7472E 02	6.4295E-01	4.3463E 01	-7.8229E-03	-2.8163E-0
7.0103E-02	5.7472E 02	1.5128E C0	4.2297E 01	-1.0969E-02	-3.9480E-0
7.3024E-02	5.7472E 02	2.3539E 00	4.1128E 01	-1.6618E-02	-5.9826E-0
7.5945E-02	5.7472E 02	3.1813E 00	3.9956E 01	-2.4703E-02	-8.8932E-0
7.8866E-02	5.7472E 02	3.9799E C0	3.8779E 01	-3.5156E-02	-1.2656E-0
8.1787E-02	5.7472E 02	4.7545E 00	3.7595E 01	-4.7905E-02	-1.7246E-0
8.4708E-02	5.7472E 02	5.5051E C0	3.6401E C1	-6.2385E-02	-2.2638E-0
8.7629E-02	5.7472E 02	6.2313E 00	3.5194E 01	-8.0023E-02	-2.8808E-0
9.0550E-02	5.7472E 02	6.9329E 00	3.3971E 01	-9.9246E-02	-3.5729E-0
9.3471E-02	5.7472E 02	7.6095E 00	3.2728E 01	-1.2048E-01	-4.3373E-0
9.6392E-02	5.7472E 02	8.2606E 00	3.1460E 01	-1.4365E-01	-5.1714E-0
9.9313E-02	5.7472E 02	8.8857E 00	3.0162E 01	-1.6868E-01	-6.0727E-0
1.0223E-01	5.7472E 02	9.4842E C0	2.8829E 01	-1.9551E-01	-7.0382E-0
1.0515E-01	5.7472E 02	1.0055E 01	2.7458E 01	-2.2404E-01	-8.0654E-0
1.0808E-01	5.7472E 02	1.0598E 01	2.6040E 01	-2.5420E-01	-9.1511E-0
1.1100E-01	5.7472E 02	1.1112E 01	2.4570E 01	-2.8590E-01	-1.0292E-0
1.1392E-01	5.7472E 02	1.1595E 01	2.3042E 01	-3.1906E-01	-1.1486E-0
1.1684E-01	5.7472E 02	1.2047E 01	2.1448E 01	-3.5358E-01	-1.2729E-0
1.1976E-01	5.7472E 02	1.2465E 01	1.9782E 01	-3.8933E-01	-1.4018E-0
1.2268E-01	5.7472E 02	1.2849E 01	1.8037E 01	-4.2634E-01	-1.5348E-0
1.2560E-01	5.7472E 02	1.3197E 01	1.6204E 01	-4.6438E-01	-1.6718E-0
1.2852E-01	5.7472E 02	1.3506E 01	1.4276E 01	-5.0336E-01	-1.8121E-0
1.3144E-01	5.7472E 02	1.3776E 01	1.2245E 01	-5.4319E-01	-1.9555E-0
1.3436E-01	5.7472E 02	1.4003E 01	1.0103E 01	-5.8375E-01	-2.1015E-0
1.3729E-01	5.7472E 02	1.4186E 01	7.8417E 00	-6.2491E-01	-2.2497E-0
1.4021E-01	5.7472E 02	1.4321E 01	5.4529E 00	-6.6654E-01	-2.3995E-0
1.4313E-01	5.7472E 02	1.4407E 01	2.9273E 00	-7.0849E-01	-2.5506E-0

	AXIAL MOMENT	HOOP MOMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	ANGULAR ROTATION
01	-7.5061E-01	-2.7022E-01	-1.8034E-05	4.9643E-05	-8.1895E-05
00	-7.9275E-01	-2.3539E-01	-1.8281E-05	5.0662E-05	-8.6612E-05
00	-8.3474E-01	-3.0051E-01	-1.8541E-05	5.1683E-05	-9.1587E-05
00	-8.7639E-01	-3.1550E-01	-1.8817E-05	5.2706E-05	-9.6817E-05
C1	-9.1754E-01	-3.3031E-01	-1.9108E-05	5.3731E-05	-1.0230E-04
01	-9.5796E-01	-3.4487E-01	-1.9416E-05	5.4759E-05	-1.0803E-04
01	-9.9746E-01	-3.5909E-01	-1.9740E-05	5.5788E-05	-1.1401E-04
01	-1.0358E 00	-3.7289E-01	-2.0083E-05	5.6821E-05	-1.2023E-04
01	-1.0728E 00	-3.8620E-01	-2.0444E-05	5.7855E-05	-1.2667E-04
01	-1.1081E 00	-3.9893E-01	-2.0824E-05	5.8893E-05	-1.3334E-04
01	-1.1416E 00	-4.1098E-01	-2.1224E-05	5.9934E-05	-1.4022E-04
01	-1.1729E 00	-4.2226E-01	-2.1644E-05	6.0977E-05	-1.4730E-04
01	-1.2018E 00	-4.3266E-01	-2.2085E-05	6.2024E-05	-1.5456E-04
01	-1.2280E 00	-4.4207E-01	-2.2548E-05	6.3074E-05	-1.6199E-04
C1	-1.2511E C0	-4.5039E-01	-2.3032E-05	6.4128E-05	-1.6957E-04
01	-1.2708E C0	-4.5749E-01	-2.3539E-05	6.5185E-05	-1.7729E-04
01	-1.2868E 00	-4.6326E-01	-2.4069E-05	6.6247E-05	-1.8511E-04
01	-1.2987E 00	-4.6755E-01	-2.4622E-05	6.7312E-05	-1.9302E-04
C1	-1.3062E 00	-4.7023E-01	-2.5197E-05	6.8382E-05	-2.0099E-04
01	-1.3088E 00	-4.7117E-01	-2.5797E-05	6.9455E-05	-2.0899E-04
01	-1.3061E 00	-4.7021E-01	-2.6419E-05	7.0534E-05	-2.1699E-04
02	-1.2978E 00	-4.6722E-01	-2.7065E-05	7.1617E-05	-2.2495E-04
02	-1.2834E 00	-4.6202E-01	-2.7734E-05	7.2705E-05	-2.3285E-04
02	-1.2624E 00	-4.5445E-01	-2.8426E-05	7.3798E-05	-2.4064E-04
02	-1.2343E C0	-4.4436E-01	-2.9140E-05	7.4897E-05	-2.4828E-04
02	-1.1988E 00	-4.3155E-01	-2.9877E-05	7.6000E-05	-2.5573E-04
C2	-1.1552E C0	-4.1586E-01	-3.0634E-05	7.7110E-05	-2.6294E-04
02	-1.1030E 00	-3.9709E-01	-3.1413E-05	7.8225E-05	-2.6985E-04
02	-1.0418E 00	-3.7506E-01	-3.2211E-05	7.9345E-05	-2.7642E-04
02	-9.7100E-01	-3.4956E-01	-3.3028E-05	8.0472E-05	-2.8259E-04
02	-8.9000E-01	-3.2040E-01	-3.3862E-05	8.1605E-05	-2.8829E-04
02	-7.9825E-01	-2.8737E-01	-3.4712E-05	8.2744E-05	-2.9347E-04
02	-6.9522E-01	-2.5028E-01	-3.5577E-05	8.3889E-05	-2.9805E-04
02	-5.8028E-01	-2.0890E-01	-3.6453E-05	8.5041E-05	-3.0197E-04
02	-4.5285E-C1	-1.6302E-01	-3.7340E-05	8.6199E-05	-3.0515E-04
02	-3.1235E-01	-1.1244E-01	-3.8236E-05	8.7364E-05	-3.0751E-04
02	-1.5815E-01	-5.6935E-02	-3.9136E-05	8.8535E-05	-3.0896E-04
02	1.0361E-02	3.7299E-03	-4.0040E-05	8.9713E-05	-3.0944E-04
02	1.9383E-01	6.9777E-02	-4.0943E-05	9.0898E-05	-3.0884E-04
02	3.9281E-01	1.4141E-01	-4.1843E-05	9.2089E-05	-3.0707E-04
C2	6.0791E-01	2.1885E-01	-4.2736E-05	9.3286E-05	-3.0404E-04
02	8.3977E-01	3.0232E-01	-4.3618E-05	9.4491E-05	-2.9964E-04
02	1.0890E 00	3.9204E-01	-4.4485E-05	9.5701E-05	-2.9377E-04
02	1.3562E 00	4.8823E-01	-4.5333E-05	9.6917E-05	-2.8632E-04
02	1.6419E 00	5.9108E-01	-4.6156E-05	9.8140E-05	-2.7719E-04
02	1.9466E 00	7.0078E-01	-4.6950E-05	9.9368E-05	-2.6625E-04
02	2.2710E 00	8.1756E-01	-4.7709E-05	1.0060E-04	-2.5339E-04
02	2.6155E 00	9.4159E-01	-4.8428E-05	1.0184E-04	-2.3849E-04
02	2.9807E C0	1.0730E 00	-4.9101E-05	1.0309E-04	-2.2142E-04
C	3.3669E 00	1.2121E 00	-4.9719E-05	1.0433E-04	-2.0205E-04

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	VERTICAL FORCE	HORIZONTAL FORCE	HOOP FORCE	AXIAL MOMENT	HOOP MOMENT
1.4605E-01	5.7472E 02	1.4440E 01	2.5662E-01	-7.5061E-01	-2.7022E-01
1.4897E-01	5.7472E 02	1.4417E 01	-2.5674E 00	-7.9275E-01	-2.8539E-01
1.5189E-01	5.7472E 02	1.4336E 01	-5.5536E 00	-8.3474E-01	-3.0051E-01
1.5481E-01	5.7472E 02	1.4192E 01	-8.7107E 00	-8.7639E-01	-3.1550E-01
1.5773E-01	5.7472E 02	1.3983E 01	-1.2047E 01	-9.1754E-01	-3.3031E-01
1.6065E-01	5.7472E 02	1.3703E 01	-1.5571E 01	-9.5796E-01	-3.4487E-01
1.6357E-01	5.7472E 02	1.3351E 01	-1.9291E 01	-9.9746E-01	-3.5909E-01
1.6649E-01	5.7472E 02	1.2921E 01	-2.3215E 01	-1.0358E 00	-3.7289E-01
1.6942E-01	5.7472E 02	1.2409E 01	-2.7351E 01	-1.0728E 00	-3.8620E-01
1.7234E-01	5.7472E 02	1.1811E 01	-3.1707E 01	-1.1081E 00	-3.9893E-01
1.7526E-01	5.7472E 02	1.1123E 01	-3.6289E 01	-1.1416E 00	-4.1098E-01
1.7818E-01	5.7472E 02	1.0339E 01	-4.1105E 01	-1.1729E 00	-4.2226E-01
1.8110E-01	5.7472E 02	9.4551E 00	-4.6160E 01	-1.2018E 00	-4.3266E-01
1.8402E-01	5.7472E 02	8.4663E 00	-5.1462E 01	-1.2280E 00	-4.4207E-01
1.8694E-01	5.7472E 02	7.3674E 00	-5.7015E 01	-1.2511E 00	-4.5039E-01
1.8986E-01	5.7472E 02	6.1532E 00	-6.2823E 01	-1.2708E 00	-4.5749E-01
1.9278E-01	5.7472E 02	4.8187E 00	-6.8892E 01	-1.2868E 00	-4.6326E-01
1.9570E-01	5.7472E 02	3.3534E 00	-7.5224E 01	-1.2987E 00	-4.6755E-01
1.9863E-01	5.7472E 02	1.7669E 00	-8.1822E 01	-1.3062E 00	-4.7023E-01
2.0155E-01	5.7472E 02	3.8964E-02	-8.8686E 01	-1.3088E 00	-4.7117E-01
2.0447E-01	5.7472E 02	-1.8310E 00	-9.5819E 01	-1.3061E 00	-4.7021E-01
2.0739E-01	5.7472E 02	-3.8483E 00	-1.0322E 02	-1.2978E 00	-4.6722E-01
2.1031E-01	5.7472E 02	-6.0185E 00	-1.1088E 02	-1.2834E 00	-4.6202E-01
2.1323E-01	5.7472E 02	-8.3468E 00	-1.1881E 02	-1.2624E 00	-4.5445E-01
2.1615E-01	5.7472E 02	-1.0839E 01	-1.2700E 02	-1.2343E 00	-4.4436E-01
2.1907E-01	5.7472E 02	-1.3499E 01	-1.3544E 02	-1.1988E 00	-4.3155E-01
2.2199E-01	5.7472E 02	-1.6333E 01	-1.4412E 02	-1.1552E 00	-4.1586E-01
2.2491E-01	5.7472E 02	-1.9346E 01	-1.5304E 02	-1.1030E 00	-3.9709E-01
2.2784E-01	5.7472E 02	-2.2542E 01	-1.6219E 02	-1.0418E 00	-3.7506E-01
2.3076E-01	5.7472E 02	-2.5926E 01	-1.7155E 02	-9.7100E-01	-3.4956E-01
2.3368E-01	5.7472E 02	-2.9501E 01	-1.8111E 02	-8.9000E-01	-3.2040E-01
2.3660E-01	5.7472E 02	-3.3273E 01	-1.9085E 02	-7.9825E-01	-2.8737E-01
2.3952E-01	5.7472E 02	-3.7244E 01	-2.0075E 02	-6.9522E-01	-2.5028E-01
2.4244E-01	5.7472E 02	-4.1417E 01	-2.1079E 02	-5.8028E-01	-2.0890E-01
2.4536E-01	5.7472E 02	-4.5796E 01	-2.2096E 02	-4.5285E-01	-1.6302E-01
2.4828E-01	5.7472E 02	-5.0381E 01	-2.3122E 02	-3.1235E-01	-1.1244E-01
2.5120E-01	5.7472E 02	-5.5176E 01	-2.4154E 02	-1.5815E-01	-5.6935E-02
2.5412E-01	5.7472E 02	-6.0180E 01	-2.5189E 02	1.0361E-02	3.7299E-03
2.5704E-01	5.7472E 02	-6.5395E 01	-2.6224E 02	1.9383E-01	6.9777E-02
2.5997E-01	5.7472E 02	-7.0819E 01	-2.7255E 02	3.9281E-01	1.4141E-01
2.6289E-01	5.7472E 02	-7.6452E 01	-2.8278E 02	6.0791E-01	2.1885E-01
2.6581E-01	5.7472E 02	-8.2291E 01	-2.9289E 02	8.3977E-01	3.0232E-01
2.6873E-01	5.7472E 02	-8.8334E 01	-3.0283E 02	1.0890E 00	3.9204E-01
2.7165E-01	5.7472E 02	-9.4577E 01	-3.1254E 02	1.3562E 00	4.8823E-01
2.7457E-01	5.7472E 02	-1.0101E 02	-3.2198E 02	1.6419E 00	5.9108E-01
2.7749E-01	5.7472E 02	-1.0764E 02	-3.3107E 02	1.9466E 00	7.0078E-01
2.8041E-01	5.7472E 02	-1.1444E 02	-3.3977E 02	2.2710E 00	8.1756E-01
2.8333E-01	5.7472E 02	-1.2142E 02	-3.4801E 02	2.6155E 00	9.4159E-01
2.8625E-01	5.7472E 02	-1.2856E 02	-3.5571E 02	2.9807E 00	1.0730E 00
2.8918E-01	5.7472E 02	-1.3585E 02	-3.6280E 02	3.3669E 00	1.2121E 00

	AXIAL MOMENT	HOOP MOMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	ANGULAR ROTATION	
02	3.7746E 00	1.3588E 00	-5.0278E-05	1.0559E-04	-1.8026E-04	
02	4.2041E 00	1.5135E 00	-5.0770E-05	1.0684E-04	-1.5591E-04	
02	4.6556E 00	1.6762E 00	-5.1184E-05	1.0810E-04	-1.2886E-04	
02	5.1227E 00	1.8466E 00	-5.1529E-05	1.0936E-04	-9.8993E-05	end of large cyl
02	5.5918E 00	2.0181E 00	-5.1792E-05	1.1063E-04	-6.6249E-05	start of spherical
02	6.0531E 00	2.1832E 00	-5.1980E-05	1.1190E-04	-3.0660E-05	
02	6.5051E 00	2.3403E 00	-5.2086E-05	1.1319E-04	7.7288E-06	
02	6.9478E 00	2.4889E 00	-5.2103E-05	1.1449E-04	4.8872E-05	
02	7.3815E 00	2.6285E 00	-5.2024E-05	1.1581E-04	9.2728E-05	
02	7.8061E 00	2.7586E 00	-5.1841E-05	1.1716E-04	1.3926E-04	
02	8.2216E 00	2.8787E 00	-5.1548E-05	1.1855E-04	1.8842E-04	
02	8.6278E 00	2.9882E 00	-5.1138E-05	1.1997E-04	2.4018E-04	
02	9.0245E 00	3.0865E 00	-5.0607E-05	1.2144E-04	2.9449E-04	
02	9.4113E 00	3.1730E 00	-4.9946E-05	1.2296E-04	3.5132E-04	
02	9.7878E 00	3.2470E 00	-4.9151E-05	1.2454E-04	4.1063E-04	
02	1.0153E 01	3.3077E 00	-4.8219E-05	1.2619E-04	4.7237E-04	
02	1.0507E 01	3.3543E 00	-4.7143E-05	1.2792E-04	5.3651E-04	
02	1.0849E 01	3.3859E 00	-4.5919E-05	1.2972E-04	6.0299E-04	
02	1.1177E 01	3.4017E 00	-4.4544E-05	1.3162E-04	6.7176E-04	
02	1.1491E 01	3.4006E 00	-4.3016E-05	1.3362E-04	7.4277E-04	
02	1.1789E 01	3.3816E 00	-4.1329E-05	1.3573E-04	8.1596E-04	
02	1.2070E 01	3.3436E 00	-3.9481E-05	1.3795E-04	8.9125E-04	
02	1.2333E 01	3.2854E 00	-3.7470E-05	1.4029E-04	9.6858E-04	
02	1.2575E 01	3.2058E 00	-3.5297E-05	1.4277E-04	1.0479E-03	
02	1.2796E 01	3.1033E 00	-3.2958E-05	1.4540E-04	1.1290E-03	
02	1.2992E 01	2.9767E 00	-3.4237E-05	1.4820E-04	1.2119E-03	start of load
02	1.3425E 01	2.9192E 00	-2.3488E-05	1.5062E-04	1.2964E-03	
01	1.3904E 01	2.8565E 00	-2.4499E-05	1.5362E-04	1.3857E-03	
01	1.3945E 01	2.6163E 00	-2.1534E-05	1.5717E-04	1.4773E-03	
02	1.3477E 01	2.1772E 00	-1.8619E-05	1.6128E-04	1.5683E-03	
02	1.2426E 01	1.5178E 00	-1.5788E-05	1.6598E-04	1.6555E-03	
02	1.0716E 01	6.1777E-01	-1.3087E-05	1.7124E-04	1.7352E-03	
02	8.2671E 00	-5.4236E-01	-1.0565E-05	1.7705E-04	1.8029E-03	
02	4.9957E 00	-1.9802E 00	-8.2838E-06	1.8339E-04	1.8540E-03	
02	8.1646E-01	-3.7117E 00	-6.3120E-06	1.9022E-04	1.8831E-03	
03	-4.3592E 00	-5.7502E 00	-4.7310E-06	1.9747E-04	1.8843E-03	
03	-1.0622E 01	-8.1062E 00	-3.6314E-06	2.0506E-04	1.8510E-03	
03	-1.9506E 01	-1.2695E 01	-1.7580E-05	2.1419E-04	1.7761E-03	
02	-2.4411E 01	-1.4147E 01	8.4610E-06	2.1834E-04	1.6412E-03	start of reverse curve
01	-2.3402E 01	-1.1910E 01	-1.1270E-07	2.2099E-04	1.5047E-03	
01	-2.2381E 01	-1.0899E 01	3.3550E-06	2.2306E-04	1.3727E-03	
02	-2.1321E 01	-9.9156E 00	6.7223E-06	2.2459E-04	1.2455E-03	
02	-2.0234E 01	-8.9721E 00	9.9344E-06	2.2562E-04	1.1234E-03	
02	-1.9132E 01	-8.0816E 00	1.2944E-05	2.2619E-04	1.0067E-03	
02	-1.8032E 01	-7.2552E 00	1.5711E-05	2.2637E-04	8.9554E-04	
02	-1.6946E 01	-6.5016E 00	1.8201E-05	2.2621E-04	7.9011E-04	
02	-1.5890E 01	-5.8467E 00	2.0398E-05	2.2578E-04	6.9040E-04	end of reverse curve
02	-1.4871E 01	-5.3635E 00	2.2290E-05	2.2523E-04	5.9649E-04	start of small cylinder
02	-1.3881E 01	-4.9971E 00	2.3910E-05	2.2466E-04	5.0866E-04	
02	-1.2919E 01	-4.6510E 00	2.5276E-05	2.2407E-04	4.2680E-04	

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	VERTICAL FORCE	HORIZONTAL FORCE	HOOP FORCE	AXIAL MOMENT	HOOP MOMENT
2.9210E-01	5.7472E 02	-1.4328E 02	-3.6921E 02	3.7746E 00	1.3588E
2.9502E-01	5.7472E 02	-1.5083E 02	-3.7484E 02	4.2041E 00	1.5135E
2.9794E-01	5.7472E 02	-1.5849E 02	-3.7956E 02	4.6556E 00	1.6762E
3.0086E-01	5.7501E 02	-1.6623E 02	-3.8296E 02	5.1227E 00	1.8466E
3.0378E-01	5.7520E 02	-1.7408E 02	-3.8502E 02	5.5918E 00	2.0181E
3.0670E-01	5.7562E 02	-1.8205E 02	-3.8622E 02	6.0531E 00	2.1832E
3.0962E-01	5.7629E 02	-1.9012E 02	-3.8660E 02	6.5051E 00	2.3403E
3.1254E-01	5.7719E 02	-1.9829E 02	-3.8609E 02	6.9478E 00	2.4889E
3.1546E-01	5.7833E 02	-2.0655E 02	-3.8461E 02	7.3815E 00	2.6285E
3.1839E-01	5.7972E 02	-2.1439E 02	-3.8205E 02	7.8061E 00	2.7586E
3.2131E-01	5.8135E 02	-2.2330E 02	-3.7835E 02	8.2216E 00	2.8787E
3.2423E-01	5.8323E 02	-2.3176E 02	-3.7340E 02	8.6278E 00	2.9882E
3.2715E-01	5.8537E 02	-2.4026E 02	-3.6713E 02	9.0245E 00	3.0865E
3.3007E-01	5.8777E 02	-2.4879E 02	-3.5946E 02	9.4113E 00	3.1730E
3.3299E-01	5.9043E 02	-2.5731E 02	-3.5028E 02	9.7878E 00	3.2470E
3.3591E-01	5.9336E 02	-2.6581E 02	-3.3954E 02	1.0153E 01	3.3077E
3.3883E-01	5.9656E 02	-2.7427E 02	-3.2714E 02	1.0507E 01	3.3543E
3.4175E-01	6.0005E 02	-2.8266E 02	-3.1300E 02	1.0849E 01	3.3859E
3.4467E-01	6.0383E 02	-2.9095E 02	-2.9703E 02	1.1177E 01	3.4017E
3.4759E-01	6.0790E 02	-2.9910E 02	-2.7916E 02	1.1491E 01	3.4006E
3.5052E-01	6.1229E 02	-3.0709E 02	-2.5929E 02	1.1789E 01	3.3816E
3.5344E-01	6.1700E 02	-3.1486E 02	-2.3733E 02	1.2070E 01	3.3436E
3.5636E-01	6.2203E 02	-3.2239E 02	-2.1322E 02	1.2333E 01	3.2854E
3.5928E-01	6.2741E 02	-3.2962E 02	-1.8685E 02	1.2575E 01	3.2058E
3.6220E-01	6.3315E 02	-3.3650E 02	-1.5815E 02	1.2796E 01	3.1033E
3.6512E-01	6.3926E 02	-3.4298E 02	-1.7520E 02	1.2992E 01	2.9767E
3.6804E-01	2.5606E 02	-3.5118E 02	-1.6265E 02	1.3425E 01	2.9192E
3.7096E-01	5.5773E 02	-3.6064E 02	-8.0333E 01	1.3904E 01	2.8565E
3.7388E-01	8.8097E 02	-3.6883E 02	5.8260E 01	1.3945E 01	2.6163E
3.7680E-01	1.2252E 03	-3.7552E 02	2.0077E 02	1.3477E 01	2.1772E
3.7973E-01	1.5900E 03	-3.8050E 02	3.4619E 02	1.2426E 01	1.5178E
3.8265E-01	1.9746E 03	-3.8358E 02	4.9331E 02	1.0716E 01	6.1777E-
3.8557E-01	2.3784E 03	-3.8457E 02	6.4080E 02	8.2671E 00	-5.4236E-
3.8849E-01	2.8007E 03	-3.8331E 02	7.8715E 02	4.9957E 00	-1.9802E
3.9141E-01	3.2410E 03	-3.7965E 02	9.3062E 02	8.1646E-01	-3.7117E
3.9433E-01	3.6984E 03	-3.7346E 02	1.0693E 03	-4.3592E 00	-5.7502E
3.9725E-01	4.1722E 03	-3.6469E 02	1.2009E 03	-1.0622E 01	-8.1062E
4.0017E-01	4.6616E 03	-3.5330E 02	1.1343E 03	-1.9506E 01	-1.2695E
4.0309E-01	-1.9313E 02	-3.5344E 02	1.8359E 02	-2.4411E 01	-1.4147E
4.0601E-01	-1.9646E 02	-3.5963E 02	1.7281E 01	-2.3402E 01	-1.1910E
4.0893E-01	-1.9951E 02	-3.6414E 02	5.9748E 01	-2.2381E 01	-1.0899E
4.1186E-01	-2.0225E 02	-3.6683E 02	1.0155E 02	-2.1321E 01	-9.9156E
4.1478E-01	-2.0462E 02	-3.6760E 02	1.4168E 02	-2.0234E 01	-8.9721E
4.1770E-01	-2.0656E 02	-3.6640E 02	1.7926E 02	-1.9132E 01	-8.0816E
4.2062E-01	-2.0805E 02	-3.6326E 02	2.1345E 02	-1.8032E 01	-7.2552E
4.2354E-01	-2.0906E 02	-3.5825E 02	2.4358E 02	-1.6946E 01	-6.5016E
4.2646E-01	-2.0955E 02	-3.5149E 02	2.7002E 02	-1.5890E 01	-5.8467E
4.2938E-01	-2.0899E 02	-3.4324E 02	2.9669E 02	-1.4871E 01	-5.3635E
4.3230E-01	-2.0899E 02	-3.3406E 02	3.2326E 02	-1.3881E 01	-4.9971E
4.3522E-01	-2.0899E 02	-3.2416E 02	3.4603E 02	-1.2919E 01	-4.6510E

P E	AXIAL MOMENT	HOOP MOMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	ANGULAR ROTATION
02	-1.1988E 01	-4.3157E 00	2.6411E-05	2.2346E-04	3.5072E-04
02	-1.1088E 01	-3.9917E 00	2.7333E-05	2.2285E-04	2.8025E-04
02	-1.0221E 01	-3.6795E 00	2.8057E-05	2.2223E-04	2.1517E-04
02	-9.3873E 00	-3.3794E 00	2.8593E-05	2.2161E-04	1.5530E-04
02	-8.5885E 00	-3.0918E 00	2.8971E-05	2.2098E-04	1.0041E-04
02	-7.8247E 00	-2.8169E 00	2.9192E-05	2.2034E-04	5.0304E-05
02	-7.0964E 00	-2.5547E 00	2.9273E-05	2.1971E-04	4.7556E-06
02	-6.4037E 00	-2.3053E 00	2.9227E-05	2.1908E-04	-3.6450E-05
02	-5.7465E 00	-2.0687E 00	2.9066E-05	2.1845E-04	-7.3530E-05
02	-5.1245E 00	-1.8448E 00	2.8803E-05	2.1782E-04	-1.0670E-04
02	-4.5374E 00	-1.6335E 00	2.8449E-05	2.1720E-04	-1.3618E-04
02	-3.9847E 00	-1.4345E 00	2.8013E-05	2.1658E-04	-1.6217E-04
02	-3.4657E 00	-1.2477E 00	2.7506E-05	2.1596E-04	-1.8489E-04
02	-2.9798E 00	-1.0727E 00	2.6937E-05	2.1535E-04	-2.0454E-04
02	-2.5260E 00	-9.0937E-01	2.6315E-05	2.1475E-04	-2.2132E-04
02	-2.1036E 00	-7.5730E-01	2.5648E-05	2.1416E-04	-2.3542E-04
02	-1.7116E 00	-6.1616E-01	2.4943E-05	2.1357E-04	-2.4703E-04
02	-1.3488E 00	-4.8558E-01	2.4208E-05	2.1299E-04	-2.5634E-04
02	-1.0144E 00	-3.6518E-01	2.3449E-05	2.1242E-04	-2.6352E-04
02	-7.0712E-01	-2.5456E-01	2.2672E-05	2.1186E-04	-2.6874E-04
02	-4.2593E-01	-1.5334E-01	2.1882E-05	2.1130E-04	-2.7217E-04
02	-1.6970E-01	-6.1090E-02	2.1084E-05	2.1076E-04	-2.7395E-04
02	6.2717E-02	2.2578E-02	2.0284E-05	2.1022E-04	-2.7424E-04
02	2.7248E-01	9.8094E-02	1.9484E-05	2.0969E-04	-2.7318E-04
02	4.6077E-01	1.6588E-01	1.8690E-05	2.0917E-04	-2.7091E-04
02	6.2867E-01	2.2632E-01	1.7903E-05	2.0866E-04	-2.6755E-04
02	7.7738E-01	2.7986E-01	1.7128E-05	2.0815E-04	-2.6323E-04
02	9.0796E-01	3.2686E-01	1.6367E-05	2.0766E-04	-2.5805E-04
02	1.0215E 00	3.6774E-01	1.5622E-05	2.0717E-04	-2.5213E-04
02	1.1191E 00	4.0287E-01	1.4895E-05	2.0669E-04	-2.4556E-04
02	1.2017E 00	4.3263E-01	1.4189E-05	2.0622E-04	-2.3844E-04
02	1.2705E 00	4.5739E-01	1.3504E-05	2.0575E-04	-2.3087E-04
02	1.3264E 00	4.7750E-01	1.2841E-05	2.0529E-04	-2.2291E-04
02	1.3703E 00	4.9330E-01	1.2202E-05	2.0484E-04	-2.1465E-04
02	1.4031E 00	5.0512E-01	1.1587E-05	2.0440E-04	-2.0616E-04
02	1.4258E 00	5.1329E-01	1.0998E-05	2.0396E-04	-1.9750E-04
01	1.4392E 00	5.1811E-01	1.0434E-05	2.0353E-04	-1.8873E-04
01	1.4441E 00	5.1986E-01	9.8962E-06	2.0310E-04	-1.7991E-04
01	1.4412E 00	5.1883E-01	9.3844E-06	2.0268E-04	-1.7108E-04
01	1.4313E 00	5.1528E-01	8.8975E-06	2.0226E-04	-1.6229E-04
01	1.4152E 00	5.0947E-01	8.4369E-06	2.0185E-04	-1.5358E-04
01	1.3934E 00	5.0162E-01	8.0016E-06	2.0144E-04	-1.4499E-04
01	1.3666E 00	4.9198E-01	7.5904E-06	2.0104E-04	-1.3654E-04
01	1.3354E 00	4.8074E-01	7.2037E-06	2.0064E-04	-1.2828E-04
01	1.3003E 00	4.6811E-01	6.8407E-06	2.0025E-04	-1.2022E-04
01	1.2619E 00	4.5427E-01	6.5010E-06	1.9985E-04	-1.1238E-04
01	1.2206E 00	4.3941E-01	6.1838E-06	1.9947E-04	-1.0479E-04
01	1.1769E 00	4.2369E-01	5.8892E-06	1.9908E-04	-9.7463E-05
0	1.1312E 00	4.0725E-01	5.6155E-06	1.9870E-04	-9.0406E-05
0	1.0840E 00	3.9024E-01	5.3613E-06	1.9832E-04	-8.3633E-05

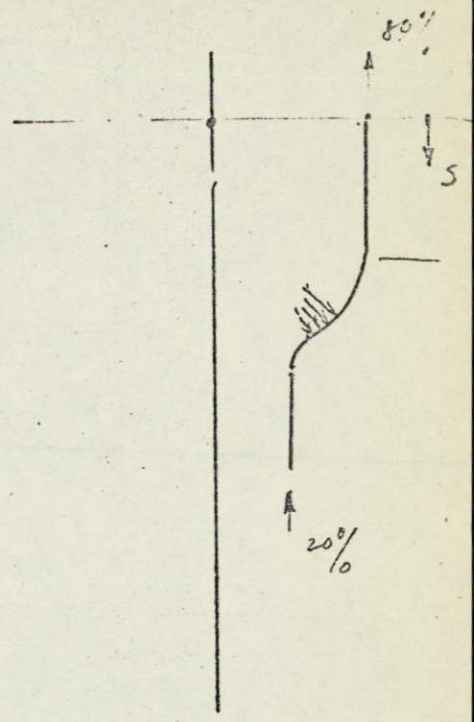
ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	VERTICAL FORCE	HORIZONTAL FORCE	HOOP FORCE	AXIAL MOMENT	M MO
4.3814E-01	-2.0899E 02	-3.1365E 02	3.6495E 02	-1.1988E 01	-4.31
4.4107E-01	-2.0899E 02	-3.0263E 02	3.8032E 02	-1.1088E 01	-3.9
4.4399E-01	-2.0899E 02	-2.9120E 02	3.9238E 02	-1.0221E 01	-3.6
4.4691E-01	-2.0899E 02	-2.7947E 02	4.0140E 02	-9.3873E 00	-3.3
4.4983E-01	-2.0899E 02	-2.6752E 02	4.0762E 02	-8.5885E 00	-3.0
4.5275E-01	-2.0899E 02	-2.5542E 02	4.1129E 02	-7.8247E 00	-2.8
4.5567E-01	-2.0899E 02	-2.4325E 02	4.1265E 02	-7.0964E 00	-2.5
4.5859E-01	-2.0899E 02	-2.3107E 02	4.1188E 02	-6.4037E 00	-2.3
4.6151E-01	-2.0899E 02	-2.1894E 02	4.0920E 02	-5.7465E 00	-2.0
4.6443E-01	-2.0899E 02	-2.0692E 02	4.0482E 02	-5.1245E 00	-1.8
4.6735E-01	-2.0899E 02	-1.9505E 02	3.9891E 02	-4.5374E 00	-1.6
4.7028E-01	-2.0899E 02	-1.8338E 02	3.9165E 02	-3.9847E 00	-1.4
4.7320E-01	-2.0899E 02	-1.7194E 02	3.8320E 02	-3.4657E 00	-1.2
4.7612E-01	-2.0899E 02	-1.6077E 02	3.7371E 02	-2.9798E 00	-1.0
4.7904E-01	-2.0899E 02	-1.4989E 02	3.6335E 02	-2.5260E 00	-9.0
4.8196E-01	-2.0899E 02	-1.3933E 02	3.5223E 02	-2.1036E 00	-7.5
4.8488E-01	-2.0899E 02	-1.2911E 02	3.4049E 02	-1.7116E 00	-6.1
4.8780E-01	-2.0899E 02	-1.1924E 02	3.2823E 02	-1.3488E 00	-4.8
4.9072E-01	-2.0899E 02	-1.0974E 02	3.1558E 02	-1.0144E 00	-3.6
4.9364E-01	-2.0899E 02	-1.0061E 02	3.0263E 02	-7.0712E-01	-2.5
4.9656E-01	-2.0899E 02	-9.1879E 01	2.8946E 02	-4.2593E-01	-1.5
4.9948E-01	-2.0899E 02	-8.3534E 01	2.7617E 02	-1.6970E-01	-6.1
5.0241E-01	-2.0899E 02	-7.5582E 01	2.6283E 02	6.2717E-02	2.2
5.0533E-01	-2.0899E 02	-6.8025E 01	2.4950E 02	2.7248E-01	9.8
5.0825E-01	-2.0899E 02	-6.0859E 01	2.3626E 02	4.6077E-01	1.6
5.1117E-01	-2.0899E 02	-5.4083E 01	2.2315E 02	6.2867E-01	2.2
5.1409E-01	-2.0899E 02	-4.7691E 01	2.1023E 02	7.7738E-01	2.7
5.1701E-01	-2.0899E 02	-4.1677E 01	1.9754E 02	9.0796E-01	3.2
5.1993E-01	-2.0899E 02	-3.6034E 01	1.8512E 02	1.0215E 00	3.6
5.2285E-01	-2.0899E 02	-3.0753E 01	1.7301E 02	1.1191E 00	4.0
5.2577E-01	-2.0899E 02	-2.5825E 01	1.6124E 02	1.2017E 00	4.3
5.2869E-01	-2.0899E 02	-2.1239E 01	1.4983E 02	1.2705E 00	4.5
5.3162E-01	-2.0899E 02	-1.6984E 01	1.3878E 02	1.3264E 00	4.7
5.3454E-01	-2.0899E 02	-1.3049E 01	1.2813E 02	1.3703E 00	4.9
5.3746E-01	-2.0899E 02	-9.4231E 00	1.1789E 02	1.4031E 00	5.0
5.4038E-01	-2.0899E 02	-6.0929E 00	1.0806E 02	1.4258E 00	5.1
5.4330E-01	-2.0899E 02	-3.0464E 00	9.8662E 01	1.4392E 00	5.1
5.4622E-01	-2.0899E 02	-2.7093E-01	8.9701E 01	1.4441E 00	5.1
5.4914E-01	-2.0899E 02	2.2468E 00	8.1170E 01	1.4412E 00	5.1
5.5206E-01	-2.0899E 02	4.5188E 00	7.3055E 01	1.4313E 00	5.1
5.5498E-01	-2.0899E 02	6.5578E 00	6.5379E 01	1.4152E 00	5.0
5.5790E-01	-2.0899E 02	8.3768E 00	5.8124E 01	1.3934E 00	5.0
5.6082E-01	-2.0899E 02	9.9876E 00	5.1271E 01	1.3666E 00	4.9
5.6375E-01	-2.0899E 02	1.1402E 01	4.4825E 01	1.3354E 00	4.8
5.6667E-01	-2.0899E 02	1.2633E 01	3.8776E 01	1.3003E 00	4.6
5.6959E-01	-2.0899E 02	1.3690E 01	3.3114E 01	1.2619E 00	4.5
5.7251E-01	-2.0899E 02	1.4587E 01	2.7828E 01	1.2206E 00	4.3
5.7543E-01	-2.0899E 02	1.5333E 01	2.2917E 01	1.1769E 00	4.2
5.7835E-01	-2.0899E 02	1.5939E 01	1.8356E 01	1.1312E 00	4.0
5.8127E-01	-2.0899E 02	1.6416E 01	1.4120E 01	1.0840E 00	3.9

	AXIAL MOMENT	HOOP MOMENT	HORIZONTAL DISPLACEMENT	VERTICAL DISPLACEMENT	ANGULAR ROTATION
01	1.0356E 00	3.7280E-01	5.1265E-06	1.9794E-04	-7.7154E-05
00	9.8622E-01	3.5504E-01	4.9102E-06	1.9757E-04	-7.0974E-05
00	9.3631E-01	3.3707E-01	4.7115E-06	1.9720E-04	-6.5097E-05
01	8.8612E-01	3.1900E-01	4.5295E-06	1.9683E-04	-5.9527E-05
00	8.3590E-01	3.0093E-01	4.3633E-06	1.9646E-04	-5.4265E-05
00	7.8590E-01	2.8292E-01	4.2120E-06	1.9609E-04	-4.9309E-05
00	7.3633E-01	2.6508E-01	4.0748E-06	1.9573E-04	-4.4657E-05
00	6.8740E-01	2.4746E-01	3.9514E-06	1.9536E-04	-4.0307E-05
01	6.3927E-01	2.3014E-01	3.8404E-06	1.9500E-04	-3.6254E-05
01	5.9211E-01	2.1316E-01	3.7400E-06	1.9464E-04	-3.2492E-05
01	5.4606E-01	1.9658E-01	3.6501E-06	1.9428E-04	-2.9015E-05
01	5.0125E-01	1.8045E-01	3.5701E-06	1.9392E-04	-2.5816E-05
01	4.5780E-01	1.6481E-01	3.4989E-06	1.9356E-04	-2.2887E-05
01	4.1580E-01	1.4969E-01	3.4360E-06	1.9320E-04	-2.0220E-05
01	3.7536E-01	1.3513E-01	3.3812E-06	1.9284E-04	-1.7804E-05
01	3.3654E-01	1.2115E-01	3.3331E-06	1.9249E-04	-1.5631E-05
01	2.9942E-01	1.0779E-01	3.2903E-06	1.9213E-04	-1.3690E-05
01	2.6405E-01	9.5059E-02	3.2528E-06	1.9177E-04	-1.1971E-05
01	2.3050E-01	8.2979E-02	3.2201E-06	1.9142E-04	-1.0462E-05
01	1.9880E-01	7.1568E-02	3.1914E-06	1.9106E-04	-9.1528E-06
01	1.6900E-01	6.0842E-02	3.1663E-06	1.9070E-04	-8.0317E-06
01	1.4114E-01	5.0812E-02	3.1442E-06	1.9035E-04	-7.0868E-06
01	1.1525E-01	4.1490E-02	3.1247E-06	1.8999E-04	-6.3062E-06
01	9.1352E-02	3.2887E-02	3.1072E-06	1.8964E-04	-5.6778E-06
01	6.9476E-02	2.5011E-02	3.0920E-06	1.8928E-04	-5.1894E-06
01	4.9642E-02	1.7871E-02	3.0782E-06	1.8893E-04	-4.8285E-06
01	3.1871E-02	1.1474E-02	3.0644E-06	1.8857E-04	-4.5825E-06
01	1.6182E-02	5.8255E-03	3.0512E-06	1.8822E-04	-4.4339E-06
01	2.5944E-03	9.3397E-04	3.0384E-06	1.8787E-04	-4.3847E-06
01	-8.8734E-03	-3.1944E-03	3.0255E-06	1.8751E-04	-4.4072E-06
01	-1.8203E-02	-6.5530E-03	3.0125E-06	1.8716E-04	-4.4932E-06
01	-2.5375E-02	-9.1351E-03	2.9999E-06	1.8680E-04	-4.6297E-06
01	-3.0373E-02	-1.0934E-02	2.9869E-06	1.8645E-04	-4.8034E-06
01	-3.3176E-02	-1.1944E-02	2.9726E-06	1.8610E-04	-5.0010E-06
01	-3.3766E-02	-1.2156E-02	2.9584E-06	1.8574E-04	-5.2090E-06
01	-3.2120E-02	-1.1563E-02	2.9436E-06	1.8539E-04	-5.4138E-06
01	-2.8219E-02	-1.0159E-02	2.9275E-06	1.8504E-04	-5.6016E-06
01	-2.2039E-02	-7.9339E-03	2.9109E-06	1.8469E-04	-5.7587E-06
01	-1.3555E-02	-4.8799E-03	2.8940E-06	1.8433E-04	-5.8711E-06
01	-2.7449E-03	-9.8815E-04	2.8767E-06	1.8398E-04	-5.9245E-06
01	1.0417E-02	3.7503E-03	2.8595E-06	1.8363E-04	-5.9046E-06
01	2.5957E-02	9.3443E-03	2.8431E-06	1.8327E-04	-5.7971E-06
01	4.3896E-02	1.5303E-02	2.8272E-06	1.8292E-04	-5.5873E-06
01	6.4258E-02	2.3133E-02	2.8114E-06	1.8257E-04	-5.2605E-06
01	8.7066E-02	3.1344E-02	2.7967E-06	1.8222E-04	-4.8018E-06
01	1.1234E-01	4.0443E-02	2.7835E-06	1.8187E-04	-4.1961E-06
01	1.4010E-01	5.0436E-02	2.7724E-06	1.8151E-04	-3.4284E-06
01	1.7036E-01	6.1331E-02	2.7638E-06	1.8116E-04	-2.4834E-06
01	2.0314E-01	7.3130E-02	2.7582E-06	1.8081E-04	-1.3457E-06
01	3.2256E-01	3.2256E-01	0.0	1.8046E-04	0.0

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	VERTICAL FORCE	HORIZONTAL FORCE	HOOP FORCE	AXIAL MOMENT	HOOP MOMENT
5.8419E-01	-2.0899E 02	1.6772E 01	1.0206E 01	1.0356E 00	3.7280E-
5.8711E-01	-2.0899E 02	1.7018E 01	6.6007E 00	9.8622E-01	3.5504E-
5.9003E-01	-2.0899E 02	1.7162E 01	3.2884E 00	9.3631E-01	3.3707E-
5.9296E-01	-2.0899E 02	1.7212E 01	2.5515E-01	8.8612E-01	3.1900E-
5.9588E-01	-2.0899E 02	1.7177E 01	-2.5145E 00	8.3590E-01	3.0093E-
5.9880E-01	-2.0899E 02	1.7064E 01	-5.0357E 00	7.8590E-01	2.8292E-
6.0172E-01	-2.0899E 02	1.6880E 01	-7.3231E 00	7.3633E-01	2.6508E-
6.0464E-01	-2.0899E 02	1.6632E 01	-9.3787E 00	6.8740E-01	2.4746E-
6.0756E-01	-2.0899E 02	1.6326E 01	-1.1230E 01	6.3927E-01	2.3014E-
6.1048E-01	-2.0899E 02	1.5969E 01	-1.2903E 01	5.9211E-01	2.1316E-
6.1340E-01	-2.0899E 02	1.5565E 01	-1.4400E 01	5.4606E-01	1.9658E-
6.1632E-01	-2.0899E 02	1.5119E 01	-1.5735E 01	5.0125E-01	1.8045E-
6.1924E-01	-2.0899E 02	1.4636E 01	-1.6921E 01	4.5780E-01	1.6481E-
6.2217E-01	-2.0899E 02	1.4121E 01	-1.7970E 01	4.1580E-01	1.4969E-
6.2509E-01	-2.0899E 02	1.3576E 01	-1.8883E 01	3.7536E-01	1.3513E-
6.2801E-01	-2.0899E 02	1.3006E 01	-1.9684E 01	3.3654E-01	1.2115E-
6.3093E-01	-2.0899E 02	1.2414E 01	-2.0398E 01	2.9942E-01	1.0779E-
6.3385E-01	-2.0899E 02	1.1803E 01	-2.1022E 01	2.6405E-01	9.5059E-
6.3677E-01	-2.0899E 02	1.1174E 01	-2.1568E 01	2.3050E-01	8.2979E-
6.3969E-01	-2.0899E 02	1.0530E 01	-2.2046E 01	1.9880E-01	7.1568E-
6.4261E-01	-2.0899E 02	9.8730E 00	-2.2464E 01	1.6900E-01	6.0842E-
6.4553E-01	-2.0899E 02	9.2044E 00	-2.2832E 01	1.4114E-01	5.0812E-
6.4845E-01	-2.0899E 02	8.5257E 00	-2.3158E 01	1.1525E-01	4.1490E-
6.5137E-01	-2.0899E 02	7.8379E 00	-2.3450E 01	9.1352E-02	3.2887E-
6.5430E-01	-2.0899E 02	7.1419E 00	-2.3702E 01	6.9476E-02	2.5011E-
6.5722E-01	-2.0899E 02	6.4392E 00	-2.3934E 01	4.9642E-02	1.7871E-
6.6014E-01	-2.0899E 02	5.7296E 00	-2.4163E 01	3.1871E-02	1.1474E-
6.6306E-01	-2.0899E 02	5.0134E 00	-2.4382E 01	1.6182E-02	5.8255E-
6.6598E-01	-2.0899E 02	4.2908E 00	-2.4597E 01	2.5944E-03	9.3397E-
6.6890E-01	-2.0899E 02	3.5619E 00	-2.4811E 01	-8.8734E-03	-3.1944E-
6.7182E-01	-2.0899E 02	2.8267E 00	-2.5028E 01	-1.8203E-02	-6.5530E-
6.7474E-01	-2.0899E 02	2.0851E 00	-2.5237E 01	-2.5375E-02	-9.1351E-
6.7766E-01	-2.0899E 02	1.3375E 00	-2.5455E 01	-3.0373E-02	-1.0934E-
6.8058E-01	-2.0899E 02	5.8302E-01	-2.5693E 01	-3.3176E-02	-1.1944E-
6.8351E-01	-2.0899E 02	-1.7865E-01	-2.5930E 01	-3.3766E-02	-1.2156E-
6.8643E-01	-2.0899E 02	-9.4707E-01	-2.6176E 01	-3.2120E-02	-1.1563E-
6.8935E-01	-2.0899E 02	-1.7233E 00	-2.6444E 01	-2.8219E-02	-1.0159E-
6.9227E-01	-2.0899E 02	-2.5075E 00	-2.6720E 01	-2.2039E-02	-7.9339E-
6.9519E-01	-2.0899E 02	-3.3000E 00	-2.7004E 01	-1.3555E-02	-4.8799E-
6.9811E-01	-2.0899E 02	-4.1010E 00	-2.7291E 01	-2.7449E-03	-9.8815E-
7.0103E-01	-2.0899E 02	-4.9104E 00	-2.7579E 01	1.0417E-02	3.7503E-
7.0395E-01	-2.0899E 02	-5.7284E 00	-2.7851E 01	2.5957E-02	9.3443E-
7.0687E-01	-2.0899E 02	-6.5539E 00	-2.8116E 01	4.3896E-02	1.5803E-
7.0979E-01	-2.0899E 02	-7.3875E 00	-2.8380E 01	6.4258E-02	2.3133E-
7.1272E-01	-2.0899E 02	-8.2286E 00	-2.8625E 01	8.7066E-02	3.1344E-
7.1564E-01	-2.0899E 02	-9.0766E 00	-2.8844E 01	1.1234E-01	4.0443E-
7.1856E-01	-2.0899E 02	-9.9306E 00	-2.9029E 01	1.4010E-01	5.0436E-
7.2148E-01	-2.0899E 02	-1.0790E 01	-2.9173E 01	1.7036E-01	6.1331E-
7.2440E-01	-2.0899E 02	-1.1652E 01	-2.9266E 01	2.0314E-01	7.3130E-
7.2732E-01	-2.0899E 02	-1.2517E 01	-2.9331E 01	3.2256E-01	3.2256E-



OOP S	OUTER HOOP STRESS	SHEAR STRESS	EQUIVALENT INNER STRESS	EQUIVALENT OUTER STRESS
02	3.2551E 03	2.0141E 00	8.8591E 03	1.1276E 04
02	1.6611E 03	6.5399E 02	8.7397E 03	1.1115E 04
02	1.6084E 03	6.1885E 02	8.8549E 03	1.1001E 04
02	1.5560E 03	5.8387E 02	8.9650E 03	1.0894E 04
02	1.5042E 03	5.4912E 02	9.0698E 03	1.0795E 04
02	1.4531E 03	5.1466E 02	9.1694E 03	1.0703E 04
02	1.4029E 03	4.8054E 02	9.2636E 03	1.0618E 04
02	1.3538E 03	4.4682E 02	9.3524E 03	1.0540E 04
02	1.3059E 03	4.1353E 02	9.4358E 03	1.0468E 04
02	1.2595E 03	3.8072E 02	9.5137E 03	1.0403E 04
02	1.2145E 03	3.4841E 02	9.5863E 03	1.0344E 04
02	1.1711E 03	3.1664E 02	9.6535E 03	1.0292E 04
02	1.1294E 03	2.8542E 02	9.7154E 03	1.0245E 04
02	1.0895E 03	2.5479E 02	9.7720E 03	1.0205E 04
02	1.0515E 03	2.2474E 02	9.8233E 03	1.0170E 04
02	1.0153E 03	1.9530E 02	9.8696E 03	1.0141E 04
02	9.81C4E 02	1.6648E 02	9.9107E 03	1.0117E 04
02	9.4877E C2	1.3829E 02	9.9469E 03	1.0099E 04
02	9.1846E 02	1.1072E 02	9.9781E 03	1.0085E 04
02	8.9012E 02	8.3790E 01	1.0005E 04	1.0077E 04
02	8.6372E 02	5.7496E 01	1.0026E 04	1.0073E 04
02	8.3923E C2	3.1842E 01	1.0043E 04	1.0074E 04
02	8.1660E 02	6.8317E 00	1.0056E 04	1.0080E 04
02	7.9583E C2	-1.7535E 01	1.0065E 04	1.0091E 04
02	7.7687E 02	-4.1257E 01	1.0069E 04	1.0105E 04
02	7.5965E 02	-6.4333E 01	1.0069E 04	1.0124E 04
02	7.4412E 02	-8.6762E 01	1.0065E 04	1.0147E 04
02	7.3018E 02	-1.0854E 02	1.0057E 04	1.0174E 04
02	7.1776E 02	-1.2967E 02	1.0045E 04	1.0205E 04
02	7.0674E C2	-1.5014E 02	1.0030E 04	1.0239E 04
02	6.97C4E 02	-1.6994E 02	1.0012E 04	1.0277E 04
02	6.8852E C2	-1.8908E 02	9.9904E 03	1.0319E 04
02	6.8108E 02	-2.0753E 02	9.9657E 03	1.0365E 04
02	6.7457E C2	-2.2529E 02	9.9381E 03	1.0413E 04
02	6.6884E C2	-2.4234E 02	9.9078E 03	1.0466E 04
02	6.6377E C2	-2.5866E 02	9.8750E C3	1.0521E 04
02	6.5920E 02	-2.7424E 02	9.8398E 03	1.0580E 04
02	6.5496E 02	-2.8904E 02	9.8025E 03	1.0641E 04
02	6.5087E 02	-3.0305E 02	9.7633E 03	1.0706E 04
02	6.4676E C2	-3.1622E 02	9.7224E 03	1.0773E 04
02	6.4244E 02	-3.2854E 02	9.6801E 03	1.0844E 04
01	6.3771E 02	-3.3996E 02	9.6365E 03	1.0917E 04
01	6.3237E 02	-3.5043E 02	9.5921E 03	1.0993E 04
01	6.2620E 02	-3.5991E 02	9.5469E 03	1.1071E 04
01	6.1898E 02	-3.6836E 02	9.5013E 03	1.1151E 04
02	6.1050E C2	-3.7571E 02	9.4557E 03	1.1234E 04
02	6.0052E 02	-3.8190E 02	9.4103E 03	1.1319E 04
02	5.8879E C2	-3.8688E 02	9.3654E 03	1.1406E 04
02	5.7509E 02	-3.9058E 02	9.3215E 03	1.1495E 04
02	5.5912E 02	-3.9292E 02	9.2788E 03	1.1585E 04

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

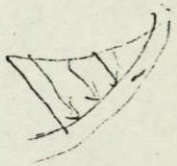
ARC DISTANCE	INNER AXIAL STRESS	OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHE STR
0.0	8.3535E 03	1.2545E 04	-9.3689E 02	3.2551E 03	2.014
2.9210E-03	9.0472E 03	1.1852E 04	6.5153E 02	1.6611E 03	6.539
5.8419E-03	9.1824E 03	1.1716E 04	6.9618E 02	1.6084E 03	6.188
8.7629E-03	9.3102E 03	1.1589E 04	7.3577E 02	1.5560E 03	5.838
1.1684E-02	9.4305E 03	1.1468E 04	7.7056E 02	1.5042E 03	5.491
1.4605E-02	9.5435E 03	1.1355E 04	8.0080E 02	1.4531E 03	5.146
1.7526E-02	9.6492E 03	1.1250E 04	8.2672E 02	1.4029E 03	4.805
2.0447E-02	9.7477E 03	1.1151E 04	8.4854E 02	1.3538E 03	4.468
2.3368E-02	9.8391E 03	1.1060E 04	8.6648E 02	1.3059E 03	4.135
2.6289E-02	9.9235E 03	1.0975E 04	8.8077E 02	1.2595E 03	3.807
2.9210E-02	1.0001E 04	1.0898E 04	8.9157E 02	1.2145E 03	3.484
3.2131E-02	1.0072E 04	1.0827E 04	8.9904E 02	1.1711E 03	3.166
3.5052E-02	1.0136E 04	1.0763E 04	9.0339E 02	1.1294E 03	2.854
3.7973E-02	1.0193E 04	1.0706E 04	9.0483E 02	1.0895E 03	2.547
4.0893E-02	1.0244E 04	1.0655E 04	9.0348E 02	1.0515E 03	2.247
4.3814E-02	1.0288E 04	1.0610E 04	8.9941E 02	1.0153E 03	1.953
4.6735E-02	1.0327E 04	1.0572E 04	8.9282E 02	9.81C4E 02	1.664
4.9656E-02	1.0359E 04	1.0540E 04	8.8387E 02	9.4877E 02	1.382
5.2577E-02	1.0386E 04	1.0513E 04	8.7261E 02	9.1846E 02	1.107
5.5498E-02	1.0406E 04	1.0492E 04	8.5914E 02	8.9012E 02	8.379
5.8419E-02	1.0421E 04	1.0477E 04	8.4356E 02	8.6372E 02	5.749
6.1340E-02	1.0431E 04	1.0468E 04	8.2590E 02	8.3923E 02	3.184
6.4261E-02	1.0435E 04	1.0464E 04	8.0624E 02	8.1660E 02	6.831
6.7182E-02	1.0434E 04	1.0465E 04	7.8465E 02	7.9583E 02	-1.753
7.0103E-02	1.0428E 04	1.0471E 04	7.6120E 02	7.7687E 02	-4.125
7.3024E-02	1.0416E 04	1.0482E 04	7.3592E 02	7.5965E 02	-6.433
7.5945E-02	1.0400E 04	1.0498E 04	7.0884E 02	7.4412E 02	-8.670
7.8866E-02	1.0380E 04	1.0519E 04	6.7998E 02	7.3018E 02	-1.085
8.1787E-02	1.0354E 04	1.0544E 04	6.4934E 02	7.1776E 02	-1.296
8.4708E-02	1.0325E 04	1.0574E 04	6.1694E 02	7.0674E 02	-1.501
8.7629E-02	1.0291E 04	1.0608E 04	5.8276E 02	6.97C4E 02	-1.699
9.0550E-02	1.0253E 04	1.0646E 04	5.4679E 02	6.8852E 02	-1.890
9.3471E-02	1.0210E 04	1.0688E 04	5.0902E 02	6.8108E 02	-2.075
9.6392E-02	1.0164E 04	1.0734E 04	4.6942E 02	6.7457E 02	-2.252
9.9313E-02	1.0115E 04	1.0784E 04	4.2795E 02	6.6884E 02	-2.423
1.0223E-01	1.0062E 04	1.0837E 04	3.8457E 02	6.6377E 02	-2.586
1.0515E-01	1.0005E 04	1.0894E 04	3.3925E 02	6.5920E 02	-2.742
1.0808E-01	9.9452E 03	1.0954E 04	2.9194E 02	6.5496E 02	-2.890
1.1100E-01	9.8823E 03	1.1016E 04	2.4258E 02	6.5087E 02	-3.030
1.1392E-01	9.8166E 03	1.1082E 04	1.9112E 02	6.4676E 02	-3.162
1.1684E-01	9.7481E 03	1.1151E 04	1.3749E 02	6.4244E 02	-3.285
1.1976E-01	9.6771E 03	1.1222E 04	8.1643E 01	6.3771E 02	-3.399
1.2268E-01	9.6038E 03	1.1295E 04	2.3508E 01	6.3237E 02	-3.504
1.2560E-01	9.5283E 03	1.1371E 04	-3.6973E 01	6.2620E 02	-3.599
1.2852E-01	9.4510E 03	1.1448E 04	-9.9867E 01	6.1898E 02	-3.683
1.3144E-01	9.3720E 03	1.1527E 04	-1.6524E 02	6.1050E 02	-3.757
1.3436E-01	9.2916E 03	1.1607E 04	-2.3314E 02	6.0052E 02	-3.819
1.3729E-01	9.2099E 03	1.1689E 04	-3.0364E 02	5.8879E 02	-3.868
1.4021E-01	9.1274E 03	1.1771E 04	-3.7680E 02	5.7509E 02	-3.905
1.4313E-01	9.0442E 03	1.1855E 04	-4.5267E 02	5.5912E 02	-3.929

CC S	OUTER HOOP STRESS	SHEAR STRESS	EQUIVALENT INNER STRESS	EQUIVALENT OUTER STRESS
02	5.4064E 02	-3.9382E 02	9.2377E 03	1.1677E 04
C2	5.1939E C2	-3.9320E 02	9.1987E 03	1.1771E 04
02	4.9507E 02	-3.9098E 02	9.1622E 03	1.1865E 04
02	4.6741E 02	-3.8706E 02	9.1285E 03	1.1961E 04
02	4.3613E 02	-3.8134E 02	9.0982E 03	1.2057E 04
02	4.0092E 02	-3.7373E 02	9.0716E 03	1.2154E 04
03	3.6149E 02	-3.6411E 02	9.0494E 03	1.2251E 04
03	3.1752E 02	-3.5238E 02	9.0320E 03	1.2348E 04
03	2.6873E C2	-3.3843E 02	9.0198E 03	1.2445E 04
03	2.1478E C2	-3.2212E 02	9.0135E 03	1.2541E 04
03	1.5537E C2	-3.0335E 02	9.0135E 03	1.2637E 04
03	9.0179E C1	-2.8197E 02	9.0204E 03	1.2731E 04
03	1.8885E 01	-2.5787E 02	9.0347E 03	1.2824E 04
03	-5.8835E 01	-2.3090E 02	9.0571E 03	1.2915E 04
03	-1.4329E 02	-2.0093E 02	9.0879E 03	1.3003E 04
03	-2.3481E C2	-1.6782E 02	9.1279E 03	1.3089E 04
03	-3.3372E 02	-1.3142E 02	9.1775E C3	1.3172E 04
03	-4.4034E 02	-9.1592E 01	9.2373E 03	1.3251E 04
03	-5.5497E 02	-4.8189E 01	9.3079E 03	1.3326E 04
03	-6.7793E 02	-1.0627E 00	9.3897E 03	1.3397E 04
03	-8.0951E 02	4.9936E 01	9.4834E 03	1.3463E 04
03	-9.5000E C2	1.0495E 02	9.5894E 03	1.3524E 04
03	-1.0997E 03	1.6414E 02	9.7082E 03	1.3578E 04
03	-1.2588E 03	2.2764E 02	9.8403E 03	1.3626E 04
03	-1.4277E C3	2.9560E 02	9.9862E 03	1.3668E 04
03	-1.6065E 03	3.6815E 02	1.0146E 04	1.3701E 04
C3	-1.7955E C3	4.4545E 02	1.0321E C4	1.3727E 04
03	-1.9950E 03	5.2761E 02	1.0512E 04	1.3744E 04
03	-2.2050E 03	6.1478E 02	1.0718E 04	1.3752E 04
03	-2.4257E 03	7.0706E 02	1.0940E C4	1.3750E 04
03	-2.6573E 03	8.0458E 02	1.1179E 04	1.3737E 04
03	-2.8999E C3	9.0744E 02	1.1434E 04	1.3715E 04
03	-3.1536E C3	1.0157E 03	1.1708E 04	1.3681E 04
03	-3.4183E 03	1.1296E 03	1.2000E 04	1.3635E 04
03	-3.6941E 03	1.2490E 03	1.2310E 04	1.3577E 04
03	-3.9809E C3	1.3740E 03	1.2639E 04	1.3507E 04
C3	-4.2787E 03	1.5048E 03	1.2988E 04	1.3424E 04
03	-4.5872E 03	1.6413E 03	1.3357E C4	1.3328E 04
03	-4.9064E 03	1.7835E 03	1.3746E 04	1.3220E 04
03	-5.2360E 03	1.9314E 03	1.4157E C4	1.3098E 04
C3	-5.5756E 03	2.0850E 03	1.4590E 04	1.2964E 04
03	-5.9249E 03	2.2443E 03	1.5045E 04	1.2818E 04
03	-6.2836E 03	2.4091E 03	1.5523E 04	1.2660E 04
03	-6.6510E 03	2.5794E 03	1.6025E 04	1.2492E 04
03	-7.0265E 03	2.7549E 03	1.6551E 04	1.2315E 04
03	-7.4095E 03	2.9356E 03	1.7102E 04	1.2129E 04
03	-7.7993E 03	3.1212E 03	1.7678E 04	1.1939E 04
03	-8.1951E 03	3.3115E 03	1.8280E 04	1.1746E 04
03	-8.5959E C3	3.5063E 03	1.8908E 04	1.1553E 04
C	-9.0006E 03	3.7051E 03	1.9564E 04	1.1366E 04

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	INNER AXIAL STRESS	OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS
1.4605E-01	8.9606E 03	1.1938E 04	-5.3131E 02	5.4064E 02	-3.9382E 02
1.4897E-01	8.8770E 03	1.2022E 04	-6.1274E 02	5.1939E 02	-3.9320E 02
1.5189E-01	8.7937E 03	1.2105E 04	-6.9702E 02	4.9507E 02	-3.9098E 02
1.5481E-01	8.7111E 03	1.2188E 04	-7.8416E 02	4.6741E 02	-3.8706E 02
1.5773E-01	8.6295E 03	1.2269E 04	-8.7420E 02	4.3613E 02	-3.8134E 02
1.6065E-01	8.5493E 03	1.2350E 04	-9.6714E 02	4.0092E 02	-3.7373E 02
1.6357E-01	8.4710E 03	1.2428E 04	-1.0630E 03	3.6149E 02	-3.6411E 02
1.6649E-01	8.3949E 03	1.2504E 04	-1.1617E 03	3.1752E 02	-3.5238E 02
1.6942E-01	8.3216E 03	1.2577E 04	-1.2633E 03	2.6873E 02	-3.3843E 02
1.7234E-01	8.2515E 03	1.2647E 04	-1.3678E 03	2.1478E 02	-3.2212E 02
1.7526E-01	8.1851E 03	1.2714E 04	-1.4750E 03	1.5537E 02	-3.0335E 02
1.7818E-01	8.1229E 03	1.2776E 04	-1.5849E 03	9.0179E 01	-2.8197E 02
1.8110E-01	8.0656E 03	1.2833E 04	-1.6974E 03	1.8885E 01	-2.5787E 02
1.8402E-01	8.0138E 03	1.2885E 04	-1.8125E 03	-5.8835E 01	-2.3090E 02
1.8694E-01	7.9679E 03	1.2931E 04	-1.9300E 03	-1.4329E 02	-2.0093E 02
1.8986E-01	7.9288E 03	1.2970E 04	-2.0497E 03	-2.3481E 02	-1.6782E 02
1.9278E-01	7.8970E 03	1.3002E 04	-2.1714E 03	-3.3372E 02	-1.3142E 02
1.9570E-01	7.8734E 03	1.3025E 04	-2.2951E 03	-4.4034E 02	-9.1592E 01
1.9863E-01	7.8586E 03	1.3040E 04	-2.4204E 03	-5.5497E 02	-4.8189E 01
2.0155E-01	7.8534E 03	1.3045E 04	-2.5470E 03	-6.7793E 02	-1.0627E 00
2.0447E-01	7.8587E 03	1.3040E 04	-2.6748E 03	-8.0951E 02	4.9936E 01
2.0739E-01	7.8752E 03	1.3024E 04	-2.8034E 03	-9.5000E 02	1.0495E 02
2.1031E-01	7.9039E 03	1.2995E 04	-2.9325E 03	-1.0997E 03	1.6414E 02
2.1323E-01	7.9455E 03	1.2953E 04	-3.0616E 03	-1.2588E 03	2.2764E 02
2.1615E-01	8.0012E 03	1.2898E 04	-3.1904E 03	-1.4277E 03	2.9560E 02
2.1907E-01	8.0717E 03	1.2827E 04	-3.3185E 03	-1.6065E 03	3.6815E 02
2.2199E-01	8.1582E 03	1.2741E 04	-3.4452E 03	-1.7955E 03	4.4545E 02
2.2491E-01	8.2616E 03	1.2637E 04	-3.5702E 03	-1.9950E 03	5.2761E 02
2.2784E-01	8.3830E 03	1.2516E 04	-3.6928E 03	-2.2050E 03	6.1478E 02
2.3076E-01	8.5235E 03	1.2375E 04	-3.8124E 03	-2.4257E 03	7.0706E 02
2.3368E-01	8.6841E 03	1.2215E 04	-3.9283E 03	-2.6573E 03	8.0458E 02
2.3660E-01	8.8661E 03	1.2033E 04	-4.0399E 03	-2.8999E 03	9.0744E 02
2.3952E-01	9.0705E 03	1.1828E 04	-4.1464E 03	-3.1536E 03	1.0157E 01
2.4244E-01	9.2985E 03	1.1600E 04	-4.2470E 03	-3.4183E 03	1.1296E 01
2.4536E-01	9.5512E 03	1.1348E 04	-4.3408E 03	-3.6941E 03	1.2490E 01
2.4828E-01	9.8299E 03	1.1069E 04	-4.4270E 03	-3.9809E 03	1.3740E 01
2.5120E-01	1.0136E 04	1.0763E 04	-4.5045E 03	-4.2787E 03	1.5048E 01
2.5412E-01	1.0470E 04	1.0429E 04	-4.5724E 03	-4.5872E 03	1.6413E 01
2.5704E-01	1.0834E 04	1.0065E 04	-4.6296E 03	-4.9064E 03	1.7835E 01
2.5997E-01	1.1229E 04	9.6703E 03	-4.6750E 03	-5.2360E 03	1.9314E 01
2.6289E-01	1.1655E 04	9.2436E 03	-4.7074E 03	-5.5756E 03	2.0850E 01
2.6581E-01	1.2115E 04	8.7838E 03	-4.7257E 03	-5.9249E 03	2.2443E 01
2.6873E-01	1.2609E 04	8.2894E 03	-4.7284E 03	-6.2836E 03	2.4091E 01
2.7165E-01	1.3139E 04	7.7595E 03	-4.7142E 03	-6.6510E 03	2.5794E 01
2.7457E-01	1.3706E 04	7.1928E 03	-4.6817E 03	-7.0265E 03	2.7549E 01
2.7749E-01	1.4310E 04	6.5884E 03	-4.6295E 03	-7.4095E 03	2.9356E 01
2.8041E-01	1.4954E 04	5.9449E 03	-4.5561E 03	-7.7993E 03	3.1212E 01
2.8333E-01	1.5637E 04	5.2616E 03	-4.4598E 03	-8.1951E 03	3.3115E 01
2.8625E-01	1.6362E 04	4.5373E 03	-4.3391E 03	-8.5959E 03	3.5063E 01
2.8918E-01	1.7128E 04	3.7713E 03	-4.1923E 03	-9.0006E 03	3.7051E 01

OOP	OUTER HOOP STRESS	SHEAR STRESS	EQUIVALENT INNER STRESS	EQUIVALENT OUTER STRESS	
03	-9.4081E 03	3.9077E 03	2.0246E 04	1.1188E 04	
03	-9.8172E 03	4.1136E 03	2.0957E 04	1.1025E 04	
03	-1.0226E 04	4.3155E 03	2.1695E 04	1.0885E 04	end of large cylinder
03	-1.0626E 04	4.4000E 03	2.2473E 04	1.0788E 04	start of spherical cap
03	-1.1003E 04	4.3340E 03	2.3272E 04	1.0737E 04	
03	-1.1352E 04	4.2290E 03	2.4073E 04	1.0722E 04	
03	-1.1671E 04	4.1237E 03	2.4867E 04	1.0735E 04	
03	-1.1957E 04	4.0176E 03	2.5653E 04	1.0771E 04	
03	-1.2206E 04	3.9099E 03	2.6432E 04	1.0822E 04	
03	-1.2418E 04	3.7996E 03	2.7202E 04	1.0884E 04	
03	-1.2589E 04	3.6857E 03	2.7962E 04	1.0952E 04	
02	-1.2716E 04	3.5676E 03	2.8713E 04	1.1020E 04	
02	-1.2797E 04	3.4443E 03	2.9453E 04	1.1085E 04	
02	-1.2829E 04	3.3144E 03	3.0180E 04	1.1144E 04	
01	-1.2809E 04	3.1772E 03	3.0894E 04	1.1193E 04	
02	-1.2734E 04	3.0311E 03	3.1594E 04	1.1231E 04	
02	-1.2601E 04	2.8751E 03	3.2276E 04	1.1256E 04	
03	-1.2407E 04	2.7081E 03	3.2941E 04	1.1267E 04	
03	-1.2148E 04	2.5286E 03	3.3585E 04	1.1265E 04	
03	-1.1821E 04	2.3351E 03	3.4206E 04	1.1249E 04	
03	-1.1422E 04	2.1264E 03	3.4802E 04	1.1222E 04	
03	-1.0947E 04	1.9006E 03	3.5369E 04	1.1186E 04	
03	-1.0393E 04	1.6561E 03	3.5904E 04	1.1147E 04	
03	-9.7558E 03	1.3919E 03	3.6404E 04	1.1109E 04	
03	-9.0307E 03	1.1054E 03	3.6864E 04	1.1081E 04	
03	-9.0897E 03	7.9519E 02	3.7662E 04	1.1256E 04	start of load
03	-8.7474E 03	5.3496E 03	3.2356E 04	1.6987E 04	
03	-7.1263E 03	1.4692E 03	3.7688E 04	1.3477E 04	
03	-4.1301E 03	-3.0299E 03	4.2130E 04	9.0828E 03	
03	-6.6803E 02	-8.1700E 03	4.5921E 04	3.7889E 03	
03	3.2833E 03	-1.3972E 04	4.8889E 04	3.4405E 03	
04	7.7439E 03	-2.0451E 04	5.0863E 04	1.1068E 04	
04	1.2727E 04	-2.7623E 04	5.1671E 04	2.0245E 04	
04	1.8239E 04	-3.5496E 04	5.1136E 04	3.0931E 04	
03	2.4282E 04	-4.4076E 04	4.9081E 04	4.3236E 04	
03	3.0847E 04	-5.3367E 04	4.5330E 04	5.7289E 04	
03	3.7914E 04	-6.3368E 04	3.9713E 04	7.3232E 04	
03	4.5803E 04	-1.0051E 05	3.4356E 04	9.5006E 04	
04	3.1399E 04	1.1885E 04	3.9630E 04	4.4661E 04	start of reverse curve
04	2.3936E 04	1.1068E 04	3.9370E 04	4.1032E 04	
04	2.2705E 04	1.1299E 04	3.8189E 04	3.8731E 04	
04	2.1514E 04	1.1399E 04	3.7076E 04	3.6340E 04	
04	2.0372E 04	1.1359E 04	3.6029E 04	3.3892E 04	
04	1.9289E 04	1.1175E 04	3.5040E 04	3.1426E 04	
04	1.8271E 04	1.0846E 04	3.4095E 04	2.8983E 04	
03	1.7324E 04	1.0377E 04	3.3179E 04	2.6605E 04	
03	1.6506E 04	9.8274E 03	3.2227E 04	2.4369E 04	end of reverse curve
03	1.6033E 04	9.3926E 03	3.0986E 04	2.2497E 04	start of small cylinder
03	1.5789E 04	9.1108E 03	2.9522E 04	2.0924E 04	
03	1.5516E 04	8.8407E 03	2.8073E 04	1.9454E 04	



ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	INNER AXIAL STRESS	OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS
2.9210E-01	1.7936E 04	2.9627E 03	-4.0177E 03	-9.4081E 03	3.9077E
2.9502E-01	1.8788E 04	2.1106E 03	-3.8133E 03	-9.8172E 03	4.1136E
2.9794E-01	1.9685E 04	1.2164E 03	-3.5765E 03	-1.0226E 04	4.3155E
3.0086E-01	2.0640E 04	3.1875E 02	-3.3001E 03	-1.0626E 04	4.4000E
3.0378E-01	2.1628E 04	-5.5414E 02	-2.9976E 03	-1.1003E 04	4.3340E
3.0670E-01	2.2614E 04	-1.3934E 03	-2.6917E 03	-1.1352E 04	4.2290E
3.0962E-01	2.3587E 04	-2.2181E 03	-2.3872E 03	-1.1671E 04	4.1237E
3.1254E-01	2.4548E 04	-3.0134E 03	-2.0833E 03	-1.1957E 04	4.0176E
3.1546E-01	2.5497E 04	-3.7847E 03	-1.7794E 03	-1.2206E 04	3.9099E
3.1839E-01	2.6434E 04	-4.5320E 03	-1.4749E 03	-1.2418E 04	3.7996E
3.2131E-01	2.7359E 04	-5.2550E 03	-1.1693E 03	-1.2589E 04	3.6857E
3.2423E-01	2.8272E 04	-5.9536E 03	-8.6211E 02	-1.2716E 04	3.5676E
3.2715E-01	2.9172E 04	-6.6273E 03	-5.5309E 02	-1.2797E 04	3.4443E
3.3007E-01	3.0058E 04	-7.2756E 03	-2.4192E 02	-1.2829E 04	3.3144E
3.3299E-01	3.0930E 04	-7.8976E 03	7.1625E 01	-1.2809E 04	3.1772E
3.3591E-01	3.1785E 04	-8.4923E 03	3.8729E 02	-1.2734E 04	3.0311E
3.3883E-01	3.2623E 04	-9.0586E 03	7.0509E 02	-1.2601E 04	2.8751E
3.4175E-01	3.3441E 04	-9.5952E 03	1.0251E 03	-1.2407E 04	2.7081E
3.4467E-01	3.4238E 04	-1.0101E 04	1.3466E 03	-1.2148E 04	2.5286E
3.4759E-01	3.5010E 04	-1.0573E 04	1.6693E 03	-1.1821E 04	2.3351E
3.5052E-01	3.5756E 04	-1.1011E 04	1.9930E 03	-1.1422E 04	2.1264E
3.5344E-01	3.6471E 04	-1.1411E 04	2.3169E 03	-1.0947E 04	1.9006E
3.5636E-01	3.7151E 04	-1.1772E 04	2.6399E 03	-1.0393E 04	1.6561E
3.5928E-01	3.7794E 04	-1.2091E 04	2.9613E 03	-9.7558E 03	1.3919E
3.6220E-01	3.8395E 04	-1.2365E 04	3.2800E 03	-9.0307E 03	1.1054E
3.6512E-01	3.8948E 04	-1.2591E 04	2.7187E 03	-9.0897E 03	7.9519E
3.6804E-01	3.9679E 04	-1.9577E 04	2.8329E 03	-8.7474E 03	5.3496E
3.7096E-01	3.9614E 04	-1.5544E 04	4.2051E 03	-7.1263E 03	1.4692E
3.7388E-01	4.4905E 04	-1.0414E 04	6.2486E 03	-4.1301E 03	-3.0299E
3.7680E-01	4.9384E 04	-4.0784E 03	7.9687E 03	-6.6803E 02	-8.1700E
3.7973E-01	5.2873E 04	3.5782E 03	9.3048E 03	3.2838E 03	-1.3972E
3.8265E-01	5.5188E 04	1.2677E 04	1.0195E 04	7.7439E 03	-2.0451E
3.8557E-01	5.6140E 04	2.3345E 04	1.0575E 04	1.2727E 04	-2.7623E
3.8849E-01	5.5531E 04	3.5713E 04	1.0384E 04	1.8239E 04	-3.5496E
3.9141E-01	5.3157E 04	4.9918E 04	9.5585E 03	2.4282E 04	-4.4076E
3.9433E-01	4.8810E 04	6.6103E 04	8.0362E 03	3.0847E 04	-5.3367E
3.9725E-01	4.2277E 04	8.4415E 04	5.7570E 03	3.7914E 04	-6.3368E
4.0017E-01	3.1851E 04	1.0923E 05	-4.5562E 03	4.5803E 04	-1.0051E
4.0309E-01	-4.5710E 04	5.1128E 04	-2.4723E 04	3.1399E 04	1.1885E
4.0601E-01	-4.5455E 04	4.7379E 04	-2.3308E 04	2.3936E 04	1.1068E
4.0893E-01	-4.4063E 04	4.4721E 04	-2.0532E 04	2.2705E 04	1.1299E
4.1186E-01	-4.2621E 04	4.1957E 04	-1.7821E 04	2.1514E 04	1.1399E
4.1478E-01	-4.1141E 04	3.9124E 04	-1.5220E 04	2.0372E 04	1.1359E
4.1770E-01	-3.9634E 04	3.6263E 04	-1.2770E 04	1.9289E 04	1.1175E
4.2062E-01	-3.8113E 04	3.3418E 04	-1.0510E 04	1.8271E 04	1.0846E
4.2354E-01	-3.6592E 04	3.0633E 04	-8.4670E 03	1.7324E 04	1.0377E
4.2646E-01	-3.5046E 04	2.7939E 04	-6.6873E 03	1.6506E 04	9.8274E
4.2938E-01	-3.3274E 04	2.5717E 04	-5.2440E 03	1.6033E 04	9.3926E
4.3230E-01	-3.1332E 04	2.3732E 04	-4.0340E 03	1.5789E 04	9.1108E
4.3522E-01	-2.9425E 04	2.1825E 04	-2.9337E 03	1.5516E 04	8.8407E

OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS	EQUIVALENT INNER STRESS	EQUIVALENT OUTER STRESS
.9978E 04	-1.9246E 03	1.5195E 04	8.5539E 03	2.6667E 04	1.8068E 04
1.8193E 04	-1.0025E 03	1.4832E 04	8.2534E 03	2.5306E 04	1.6767E 04
1.6473E 04	-1.6395E 02	1.4432E 04	7.9419E 03	2.3991E 04	1.5553E 04
1.4820E 04	5.9511E 02	1.4001E 04	7.6219E 03	2.2723E 04	1.4428E 04
1.3235E 04	1.2787E 03	1.3544E 04	7.2959E 03	2.1503E 04	1.3392E 04
1.1720E 04	1.8908E 03	1.3065E 04	6.9659E 03	2.0331E 04	1.2447E 04
1.0276E 04	2.4354E 03	1.2570E 04	6.6340E 03	1.9209E 04	1.1594E 04
8.9018E 03	2.9161E 03	1.2061E 04	6.3018E 03	1.8136E 04	1.0833E 04
7.5932E 03	3.3368E 03	1.1543E 04	5.9711E 03	1.7112E 04	1.0162E 04
6.3645E 03	3.7012E 03	1.1019E 04	5.6433E 03	1.6136E 04	9.5813E 03
5.2000E 03	4.0129E 03	1.0493E 04	5.3196E 03	1.5208E 04	9.0871E 03
4.1037E 03	4.2756E 03	9.9661E 03	5.0013E 03	1.4328E 04	8.6756E 03
3.0744E 03	4.4925E 03	9.4419E 03	4.6893E 03	1.3493E 04	8.3411E 03
2.1105E 03	4.6671E 03	8.9225E 03	4.3846E 03	1.2704E 04	8.0768E 03
1.2105E 03	4.8026E 03	8.4101E 03	4.0879E 03	1.1958E 04	7.8749E 03
3.7264E 02	4.9021E 03	7.9063E 03	3.7999E 03	1.1255E 04	7.7267E 03
-4.0499E 02	4.9685E 03	7.4128E 03	3.5211E 03	1.0592E 04	7.6234E 03
-1.1245E 03	5.0048E 03	6.9310E 03	3.2519E 03	9.9690E 03	7.5562E 03
-1.7878E 03	5.0135E 03	6.4621E 03	2.9928E 03	9.3835E 03	7.5172E 03
-2.3973E 03	4.9974E 03	6.0072E 03	2.7440E 03	8.8338E 03	7.4989E 03
-2.9550E 03	4.9588E 03	5.5671E 03	2.5058E 03	8.3183E 03	7.4950E 03
-3.4632E 03	4.9001E 03	5.1424E 03	2.2782E 03	7.8351E 03	7.4999E 03
-3.9242E 03	4.8234E 03	4.7339E 03	2.0613E 03	7.3826E 03	7.5090E 03
-4.3403E 03	4.7310E 03	4.3418E 03	1.8552E 03	6.9588E 03	7.5189E 03
-4.[illegible]37E 03	4.6246E 03	3.9666E 03	1.6598E 03	6.5621E 03	7.5267E 03
-5.0468E 03	4.5062E 03	3.6084E 03	1.4750E 03	6.1909E 03	7.5300E 03
-5.3417E 03	4.3775E 03	3.2673E 03	1.3007E 03	5.8433E 03	7.5274E 03
-5.6007E 03	4.2400E 03	2.9434E 03	1.1367E 03	5.5180E 03	7.5177E 03
-5.8259E 03	4.0953E 03	2.6365E 03	9.8275E 02	5.2135E 03	7.5002E 03
-6.0195E 03	3.9447E 03	2.3465E 03	8.3873E 02	4.9286E 03	7.4743E 03
-6.1834E 03	3.7897E 03	2.0735E 03	7.0432E 02	4.6620E 03	7.4401E 03
-6.3199E 03	3.6314E 03	1.8169E 03	5.7924E 02	4.4127E 03	7.3976E 03
-6.4306E 03	3.4704E 03	1.5762E 03	4.6320E 02	4.1794E 03	7.3467E 03
-6.5177E 03	3.3081E 03	1.3512E 03	3.5589E 02	3.9615E 03	7.2879E 03
-6.5829E 03	3.1453E 03	1.1415E 03	2.5699E 02	3.7583E 03	7.2216E 03
-6.6279E 03	2.9829E 03	9.4668E 02	1.6617E 02	3.5694E 03	7.1484E 03
-6.6544E 03	2.8215E 03	7.6619E 02	8.3083E 01	3.3943E 03	7.0687E 03
-6.6640E 03	2.6620E 03	5.9980E 02	7.3890E 00	3.2330E 03	6.9833E 03
-6.6584E 03	2.5049E 03	4.4673E 02	-6.1277E 01	3.0852E 03	6.8926E 03
-6.6388E 03	2.3503E 03	3.0624E 02	-1.2324E 02	2.9505E 03	6.7971E 03
-6.6063E 03	2.1992E 03	1.7820E 02	-1.7385E 02	2.8294E 03	6.6977E 03
-6.5636E 03	2.0518E 03	6.1842E 01	-2.2846E 02	2.7219E 03	6.5947E 03
-6.5104E 03	1.9080E 03	-4.3627E 01	-2.7239E 02	2.6277E 03	6.4887E 03
-6.4485E 03	1.7685E 03	-1.3854E 02	-3.1097E 02	2.5473E 03	6.3804E 03
-6.3789E 03	1.6335E 03	-2.2345E 02	-3.4453E 02	2.4804E 03	6.2702E 03
-6.3027E 03	1.5031E 03	-2.9895E 02	-3.7338E 02	2.4271E 03	6.1586E 03
-6.2208E 03	1.3775E 03	-3.6560E 02	-3.9782E 02	2.3871E 03	6.0463E 03
-6.1342E 03	1.2570E 03	-4.2370E 02	-4.1816E 02	2.3600E 03	5.9337E 03
-6.0436E 03	1.1415E 03	-4.7402E 02	-4.3470E 02	2.3453E 03	5.8211E 03
-5.[illegible]499E 03	1.0308E 03	-5.1732E 02	-4.4770E 02	2.3419E 03	5.7089E 03

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	INNER AXIAL STRESS	OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS
4.3814E-01	-2.7578E 04	1.9978E 04	-1.9246E 03	1.5195E 04	8.5539E 03
4.4107E-01	-2.5792E 04	1.8193E 04	-1.0025E 03	1.4832E 04	8.2534E 03
4.4399E-01	-2.4072E 04	1.6473E 04	-1.6395E 02	1.4432E 04	7.9419E 03
4.4691E-01	-2.2419E 04	1.4820E 04	5.9511E 02	1.4001E 04	7.6219E 03
4.4983E-01	-2.0835E 04	1.3235E 04	1.2787E 03	1.3544E 04	7.2959E 03
4.5275E-01	-1.9320E 04	1.1720E 04	1.8908E 03	1.3065E 04	6.9659E 03
4.5567E-01	-1.7875E 04	1.0276E 04	2.4354E 03	1.2570E 04	6.6340E 03
4.5859E-01	-1.6501E 04	8.9018E 03	2.9161E 03	1.2061E 04	6.3018E 03
4.6151E-01	-1.5198E 04	7.5932E 03	3.3368E 03	1.1543E 04	5.9711E 03
4.6443E-01	-1.3964E 04	6.3645E 03	3.7012E 03	1.1019E 04	5.6433E 03
4.6735E-01	-1.2800E 04	5.2000E 03	4.0129E 03	1.0493E 04	5.3196E 03
4.7028E-01	-1.1703E 04	4.1037E 03	4.2756E 03	9.9661E 03	5.0013E 03
4.7320E-01	-1.0674E 04	3.0744E 03	4.4925E 03	9.4419E 03	4.6893E 03
4.7612E-01	-9.7101E 03	2.1105E 03	4.6671E 03	8.9225E 03	4.3846E 03
4.7904E-01	-8.8101E 03	1.2105E 03	4.8026E 03	8.4101E 03	4.0879E 03
4.8196E-01	-7.9722E 03	3.7264E 02	4.9021E 03	7.9063E 03	3.7999E 03
4.8488E-01	-7.1946E 03	-4.0499E 02	4.9685E 03	7.4128E 03	3.5211E 03
4.8780E-01	-6.4752E 03	-1.1245E 03	5.0048E 03	6.9310E 03	3.2519E 03
4.9072E-01	-5.8118E 03	-1.7878E 03	5.0135E 03	6.4621E 03	2.9928E 03
4.9364E-01	-5.2024E 03	-2.3973E 03	4.9974E 03	6.0072E 03	2.7440E 03
4.9656E-01	-4.6446E 03	-2.9550E 03	4.9588E 03	5.5671E 03	2.5058E 03
4.9948E-01	-4.1364E 03	-3.4632E 03	4.9001E 03	5.1424E 03	2.2782E 03
5.0241E-01	-3.6754E 03	-3.9242E 03	4.8234E 03	4.7339E 03	2.0613E 03
5.0533E-01	-3.2593E 03	-4.3403E 03	4.7310E 03	4.3418E 03	1.8552E 03
5.0825E-01	-2.8859E 03	-4.7137E 03	4.6246E 03	3.9666E 03	1.6598E 03
5.1117E-01	-2.5529E 03	-5.0468E 03	4.5062E 03	3.6084E 03	1.4750E 03
5.1409E-01	-2.2579E 03	-5.3417E 03	4.3775E 03	3.2673E 03	1.3007E 03
5.1701E-01	-1.9989E 03	-5.6007E 03	4.2400E 03	2.9434E 03	1.1367E 03
5.1993E-01	-1.7737E 03	-5.8259E 03	4.0953E 03	2.6365E 03	9.8275E 02
5.2285E-01	-1.5802E 03	-6.0195E 03	3.9447E 03	2.3465E 03	8.3873E 02
5.2577E-01	-1.4162E 03	-6.1834E 03	3.7897E 03	2.0735E 03	7.0432E 02
5.2869E-01	-1.2798E 03	-6.3199E 03	3.6314E 03	1.8169E 03	5.7924E 02
5.3162E-01	-1.1690E 03	-6.4306E 03	3.4704E 03	1.5762E 03	4.6320E 02
5.3454E-01	-1.0819E 03	-6.5177E 03	3.3081E 03	1.3512E 03	3.5589E 02
5.3746E-01	-1.0168E 03	-6.5829E 03	3.1453E 03	1.1415E 03	2.5699E 02
5.4038E-01	-9.7175E 02	-6.6279E 03	2.9829E 03	9.4668E 02	1.6617E 02
5.4330E-01	-9.4521E 02	-6.6544E 03	2.8215E 03	7.6619E 02	8.3083E 01
5.4622E-01	-9.3557E 02	-6.6640E 03	2.6620E 03	5.9980E 02	7.3890E 00
5.4914E-01	-9.4126E 02	-6.6584E 03	2.5049E 03	4.4673E 02	-6.1277E 01
5.5206E-01	-9.6080E 02	-6.6388E 03	2.3503E 03	3.0624E 02	-1.2324E 02
5.5498E-01	-9.9283E 02	-6.6068E 03	2.1992E 03	1.7820E 02	-1.7385E 02
5.5790E-01	-1.0360E 03	-6.5636E 03	2.0518E 03	6.1842E 01	-2.2846E 02
5.6082E-01	-1.0892E 03	-6.5104E 03	1.9080E 03	-4.3627E 01	-2.7239E 02
5.6375E-01	-1.1511E 03	-6.4485E 03	1.7685E 03	-1.3854E 02	-3.1097E 02
5.6667E-01	-1.2207E 03	-6.3789E 03	1.6335E 03	-2.2345E 02	-3.4453E 02
5.6959E-01	-1.2969E 03	-6.3027E 03	1.5031E 03	-2.9895E 02	-3.7338E 02
5.7251E-01	-1.3788E 03	-6.2208E 03	1.3775E 03	-3.6560E 02	-3.9782E 02
5.7543E-01	-1.4654E 03	-6.1342E 03	1.2570E 03	-4.2370E 02	-4.1816E 02
5.7835E-01	-1.5560E 03	-6.0436E 03	1.1415E 03	-4.7402E 02	-4.3470E 02
5.8127E-01	-1.6497E 03	-5.9499E 03	1.0308E 03	-5.1732E 02	-4.4770E 02

OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS	EQUIVALENT INNER STRESS	EQUIVALENT OUTER STRESS
-5.8538E 03	9.2500E 02	-5.5387E 02	-4.5742E 02	2.3491E 03	5.5974E 03
-5.7559E 03	8.2422E 02	-5.8419E 02	-4.6413E 02	2.3660E 03	5.4872E 03
-5.6570E 03	7.2836E 02	-6.0878E 02	-4.6805E 02	2.3915E 03	5.3785E 03
-5.5574E 03	6.3737E 02	-6.2810E 02	-4.6942E 02	2.4246E 03	5.2715E 03
-5.4578E 03	5.5116E 02	-6.4259E 02	-4.6846E 02	2.4641E 03	5.1666E 03
-5.3586E 03	4.6961E 02	-6.5273E 02	-4.6537E 02	2.5090E 03	5.0639E 03
-5.2603E 03	3.9263E 02	-6.5892E 02	-4.6035E 02	2.5583E 03	4.9637E 03
-5.1632E 03	3.2031E 02	-6.6136E 02	-4.5359E 02	2.6113E 03	4.8664E 03
-5.0678E 03	2.5229E 02	-6.6065E 02	-4.4526E 02	2.6669E 03	4.7719E 03
-4.9742E 03	1.8819E 02	-6.5740E 02	-4.3551E 02	2.7243E 03	4.6803E 03
-4.8829E 03	1.2809E 02	-6.5174E 02	-4.2449E 02	2.7830E 03	4.5918E 03
-4.7940E 03	7.1826E 01	-6.4401E 02	-4.1234E 02	2.8422E 03	4.5067E 03
-4.7078E 03	1.9245E 01	-6.3454E 02	-3.9917E 02	2.9014E 03	4.4248E 03
-4.6245E 03	-2.9817E 01	-6.2363E 02	-3.8511E 02	2.9603E 03	4.3464E 03
-4.5443E 03	-7.5298E 01	-6.1135E 02	-3.7025E 02	3.0184E 03	4.2716E 03
-4.4673E 03	-1.1759E 02	-5.9820E 02	-3.5472E 02	3.0752E 03	4.2003E 03
-4.3937E 03	-1.5707E 02	-5.8467E 02	-3.3857E 02	3.1303E 03	4.1325E 03
-4.3235E 03	-1.9368E 02	-5.7077E 02	-3.2189E 02	3.1836E 03	4.0683E 03
-4.2570E 03	-2.2757E 02	-5.5674E 02	-3.0474E 02	3.2348E 03	4.0077E 03
-4.1941E 03	-2.5888E 02	-5.4279E 02	-2.8718E 02	3.2837E 03	3.9508E 03
-4.1350E 03	-2.8776E 02	-5.2911E 02	-2.6926E 02	3.3301E 03	3.8975E 03
-4.0798E 03	-3.1434E 02	-5.1591E 02	-2.5103E 02	3.3737E 03	3.8478E 03
-4.0284E 03	-3.3876E 02	-5.0335E 02	-2.3252E 02	3.4145E 03	3.8018E 03
-3.9810E 03	-3.6113E 02	-4.9159E 02	-2.1376E 02	3.4522E 03	3.7594E 03
-3.9376E 03	-3.8134E 02	-4.8056E 02	-1.9478E 02	3.4870E 03	3.7207E 03
-3.8983E 03	-3.9971E 02	-4.7060E 02	-1.7561E 02	3.5186E 03	3.6855E 03
-3.8630E 03	-4.1656E 02	-4.6208E 02	-1.5626E 02	3.5467E 03	3.6540E 03
-3.8319E 03	-4.3176E 02	-4.5487E 02	-1.3673E 02	3.5715E 03	3.6259E 03
-3.8050E 03	-4.4536E 02	-4.4907E 02	-1.1702E 02	3.5927E 03	3.6015E 03
-3.7822E 03	-4.5744E 02	-4.4477E 02	-9.7144E 01	3.6105E 03	3.5806E 03
-3.7637E 03	-4.6804E 02	-4.4205E 02	-7.7093E 01	3.6246E 03	3.5633E 03
-3.7495E 03	-4.7698E 02	-4.4074E 02	-5.6866E 01	3.6352E 03	3.5497E 03
-3.7396E 03	-4.8450E 02	-4.4112E 02	-3.6477E 01	3.6421E 03	3.5397E 03
-3.7340E 03	-4.9084E 02	-4.4346E 02	-1.5900E 01	3.6451E 03	3.5332E 03
-3.7328E 03	-4.9556E 02	-4.4734E 02	4.8721E 00	3.6444E 03	3.5305E 03
-3.7361E 03	-4.9886E 02	-4.5299E 02	2.5829E 01	3.6398E 03	3.5315E 03
-3.7438E 03	-5.0095E 02	-4.6065E 02	4.6998E 01	3.6313E 03	3.5361E 03
-3.7561E 03	-5.0156E 02	-4.7009E 02	6.8386E 01	3.6189E 03	3.5445E 03
-3.7729E 03	-5.0065E 02	-4.8129E 02	9.0000E 01	3.6026E 03	3.5568E 03
-3.7944E 03	-4.9815E 02	-4.9423E 02	1.1184E 02	3.5822E 03	3.5730E 03
-3.8205E 03	-4.9399E 02	-5.0887E 02	1.3392E 02	3.5580E 03	3.5932E 03
-3.8513E 03	-4.8785E 02	-5.2492E 02	1.5623E 02	3.5298E 03	3.6175E 03
-3.8869E 03	-4.7985E 02	-5.4254E 02	1.7874E 02	3.4976E 03	3.6460E 03
-3.9273E 03	-4.7011E 02	-5.6188E 02	2.0148E 02	3.4613E 03	3.6786E 03
-3.9725E 03	-4.5828E 02	-5.8262E 02	2.2441E 02	3.4211E 03	3.7156E 03
-4.0226E 03	-4.4421E 02	-6.0465E 02	2.4754E 02	3.3769E 03	3.7570E 03
-4.0777E 03	-4.2776E 02	-6.2784E 02	2.7083E 02	3.3287E 03	3.8028E 03
-4.1377E 03	-4.0877E 02	-6.5207E 02	2.9426E 02	3.2767E 03	3.8533E 03
-4.2027E 03	-3.8706E 02	-6.7716E 02	3.1778E 02	3.2208E 03	3.9084E 03
-4.4396E 03	1.0648E 02	-1.1731E 03	9.9709E-01	3.2146E 03	3.9847E 03

ING DUE TO ERROR COUNT FOR ERROR NUMBER 217

A SET ON UNIT 5

NE ISN REG. 14 REG. 15 REG. 0 REG. 1

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PAGE    3


FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FCOS     FSIN     FSUB     FMPY     FDIV     FLD      FSTO     FSTOX    FSBR     FLOAT
 SFIO     SIOFX    SIOF     SUBSC    STOP     SNR

REAL CONSTANTS
  .572957E 02=0360     .100000E 01=0362     .200000E 01=0364     .157079E 01=0366
  .150000E 01=036C     .250000E 00=036E     .175000E-01=0370

INTEGER CONSTANTS
     2=0372       3=0373       1=0374      91=0375       0=0376

CORE REQUIREMENTS FOR RING
 COMMON       0  VARIABLES     864  PROGRAM    1278

 END OF COMPILATION

// XEQ
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BENDING MOM=     -11.7391          HORIZONTAL SHEAR=       2.8378
M AT GAMMA=        0.5922          TM AT GAMMA=       -1.3661
```

UNIT LOADS INPUT

LANE BEND	TORSION	IN PLANE BEND	AXIAL FORCE
77999E 01	0.3166198E-06	-0.1173919E 02	0.2837804E 01
31050E 01	-0.5345536E-01	-0.1173718E 02	0.2837370E 01
83173E 01	-0.1060811E 00	-0.1173114E 02	0.2836066E 01
34382E 01	-0.1578609E 00	-0.1172108E 02	0.2833894E 01
84692E 01	-0.2087790E 00	-0.1170700E 02	0.2830854E 01
34120E 01	-0.2588201E 00	-0.1168891E 02	0.2826948E 01
82679E 01	-0.3079681E 00	-0.1166681E 02	0.2822175E 01
30386E 01	-0.3562088E 00	-0.1164070E 02	0.2816538E 01
77257E 01	-0.4035266E 00	-0.1161060E 02	0.2810039E 01
23309E 01	-0.4499080E 00	-0.1157651E 02	0.2802679E 01
68556E 01	-0.4953379E 00	-0.1153845E 02	0.2794461E 01
13017E 01	-0.5398027E 00	-0.1149643E 02	0.2785387E 01
56709E 01	-0.5832891E 00	-0.1145045E 02	0.2775460E 01
99648E 01	-0.6257835E 00	-0.1140054E 02	0.2764684E 01
41852E 01	-0.6672723E 00	-0.1134671E 02	0.2753059E 01
83339E 01	-0.7077436E 00	-0.1128897E 02	0.2740593E 01
24127E 01	-0.7471852E 00	-0.1122734E 02	0.2727287E 01
64234E 01	-0.7855843E 00	-0.1116185E 02	0.2713146E 01
03678E 01	-0.8229298E 00	-0.1109251E 02	0.2698174E 01
42478E 01	-0.8592094E 00	-0.1101934E 02	0.2682376E 01
80651E 01	-0.8944125E 00	-0.1094237E 02	0.2665756E 01
18219E 01	-0.9285286E 00	-0.1086162E 02	0.2648320E 01
55200E 01	-0.9615467E 00	-0.1077711E 02	0.2630073E 01
91612E 01	-0.9934569E 00	-0.1068887E 02	0.2611020E 01
727[illegible]6E 01	-0.1024290E 01	-0.1059692E 02	0.2591168E 01
62810E 01	-0.1053915E 01	-0.1050131E 02	0.2570522E 01
97635E 01	-0.1082445E 01	-0.1040204E 02	0.2549089E 01
31971E 01	-0.1109830E 01	-0.1029916E 02	0.2526875E 01
65837E 01	-0.1136062E 01	-0.1019270E 02	0.2503888E 01
99255E 01	-0.1161132E 01	-0.1008269E 02	0.2480134E 01
32245E 01	-0.1185032E 01	-0.9969158E 01	0.2455620E 01
64826E 01	-0.1207758E 01	-0.9852144E 01	0.2430354E 01
97020E 01	-0.1229299E 01	-0.9731679E 01	0.2404344E 01
29847E 01	-0.1249651E 01	-0.9607807E 01	0.2377598E 01
06033E 01	-0.1268807E 01	-0.9480566E 01	0.2350123E 01
91486[illegible]E 00	-0.1286761E 01	-0.9349987E 01	0.2321929E 01
23405E 00	-0.1303507E 01	-0.9216115E 01	0.2293024E 01
29108E 00	-0.1319041E 01	-0.9078992E 01	0.2263416E 01
32214E 00	-0.1333358E 01	-0.8938661E 01	0.2233116E 01
32908E 00	-0.1346452E 01	-0.8795158E 01	0.2202131E 01
31423E 00	-0.1358322E 01	-0.8648534E 01	0.2170473E 01
27968E 00	-0.1368961E 01	-0.8498832E 01	0.2138149E 01
22761E 00	-0.1378368E 01	-0.8346099E 01	0.2105171E 01
16014E 00	-0.1386540E 01	-0.8190378E 01	0.2071548E 01
07938E 00	-0.1393473E 01	-0.8031717E 01	0.2037290E 01
98762E 00	-0.1399167E 01	-0.7870169E 01	0.2002408E 01
88710E 00	-0.1403619E 01	-0.7705781E 01	0.1966914E 01
77976E 00	-0.1406827E 01	-0.7538603E 01	0.1930817E 01
667[illegible]8E-01	-0.1408791E 01	-0.7368685E 01	0.1894129E 01
53[illegible]0E-02	-0.1409511E 01	-0.7196084E 01	0.1856861E 01
56[illegible]34E-01	-0.1408985E 01	-0.7020847E 01	0.1819024E 01
67295E 00	-0.1407215E 01	-0.6843030E 01	0.1780630E 01
78121E 00	-0.1404200E 01	-0.6662687E 01	0.1741690E 01
88298E 00	-0.1399941E 01	-0.6479875E 01	0.1702218E 01
97624E 00	-0.1394441E 01	-0.6294648E 01	0.1662224E 01
05882E 00	-0.1387700E 01	-0.6107063E 01	0.1621721E 01
12852E 00	-0.1379722E 01	-0.5917178E 01	0.[illegible]

ANALYSIS OF SPHERICAL SEAT IN SPACE SUIT WAIST RING. T=0.055

ARC DISTANCE	INNER AXIAL STRESS	OUTER AXIAL STRESS	INNER HOOP STRESS	OUTER HOOP STRESS	SHEAR STRESS
5.8419E-01	-1.7458E 03	-5.8538E 03	9.2500E 02	-5.5387E 02	-4.5742E 02
5.8711E-01	-1.8437E 03	-5.7559E 03	8.2422E 02	-5.8419E 02	-4.6413E 02
5.9003E-01	-1.9427E 03	-5.6570E 03	7.2836E 02	-6.0878E 02	-4.6805E 02
5.9296E-01	-2.0422E 03	-5.5574E 03	6.3737E 02	-6.2810E 02	-4.6942E 02
5.9588E-01	-2.1418E 03	-5.4578E 03	5.5116E 02	-6.4259E 02	-4.6846E 02
5.9880E-01	-2.2410E 03	-5.3586E 03	4.6961E 02	-6.5273E 02	-4.6537E 02
6.0172E-01	-2.3393E 03	-5.2603E 03	3.9263E 02	-6.5892E 02	-4.6035E 02
6.0464E-01	-2.4364E 03	-5.1632E 03	3.2031E 02	-6.6136E 02	-4.5359E 02
6.0756E-01	-2.5318E 03	-5.0678E 03	2.5229E 02	-6.6065E 02	-4.4526E 02
6.1048E-01	-2.6254E 03	-4.9742E 03	1.8819E 02	-6.5740E 02	-4.3551E 02
6.1340E-01	-2.7167E 03	-4.8829E 03	1.2809E 02	-6.5174E 02	-4.2449E 02
6.1632E-01	-2.8056E 03	-4.7940E 03	7.1826E 01	-6.4401E 02	-4.1234E 02
6.1924E-01	-2.8918E 03	-4.7078E 03	1.9245E 01	-6.3454E 02	-3.9917E 02
6.2217E-01	-2.9751E 03	-4.6245E 03	-2.9817E 01	-6.2363E 02	-3.8511E 02
6.2509E-01	-3.0553E 03	-4.5443E 03	-7.5298E 01	-6.1135E 02	-3.7025E 02
6.2801E-01	-3.1323E 03	-4.4673E 03	-1.1759E 02	-5.9820E 02	-3.5472E 02
6.3093E-01	-3.2059E 03	-4.3937E 03	-1.5707E 02	-5.8467E 02	-3.3857E 02
6.3385E-01	-3.2761E 03	-4.3235E 03	-1.9368E 02	-5.7077E 02	-3.2189E 02
6.3677E-01	-3.3426E 03	-4.2570E 03	-2.2757E 02	-5.5674E 02	-3.0474E 02
6.3969E-01	-3.4055E 03	-4.1941E 03	-2.5888E 02	-5.4279E 02	-2.8718E 02
6.4261E-01	-3.4646E 03	-4.1350E 03	-2.8776E 02	-5.2911E 02	-2.6926E 02
6.4553E-01	-3.5199E 03	-4.0798E 03	-3.1434E 02	-5.1591E 02	-2.5103E 02
6.4845E-01	-3.5712E 03	-4.0284E 03	-3.3876E 02	-5.0335E 02	-2.3252E 02
6.5137E-01	-3.6186E 03	-3.9810E 03	-3.6113E 02	-4.9159E 02	-2.1376E 02
6.5430E-01	-3.6620E 03	-3.9376E 03	-3.8154E 02	-4.8056E 02	-1.9478E 02
6.5722E-01	-3.7013E 03	-3.8983E 03	-3.9971E 02	-4.7060E 02	-1.7561E 02
6.6014E-01	-3.7366E 03	-3.8630E 03	-4.1656E 02	-4.6208E 02	-1.5626E 02
6.6306E-01	-3.7677E 03	-3.8319E 03	-4.3176E 02	-4.5487E 02	-1.3673E 02
6.6598E-01	-3.7947E 03	-3.8050E 03	-4.4536E 02	-4.4907E 02	-1.1702E 02
6.6890E-01	-3.8174E 03	-3.7822E 03	-4.5744E 02	-4.4477E 02	-9.7144E 01
6.7182E-01	-3.8359E 03	-3.7637E 03	-4.6804E 02	-4.4205E 02	-7.7093E 01
6.7474E-01	-3.8501E 03	-3.7495E 03	-4.7698E 02	-4.4074E 02	-5.6866E 01
6.7766E-01	-3.8601E 03	-3.7396E 03	-4.8450E 02	-4.4112E 02	-3.6477E 01
6.8058E-01	-3.8656E 03	-3.7340E 03	-4.9084E 02	-4.4346E 02	-1.5900E 01
6.8351E-01	-3.8668E 03	-3.7328E 03	-4.9556E 02	-4.4734E 02	4.8721E 00
6.8643E-01	-3.8635E 03	-3.7361E 03	-4.9886E 02	-4.5299E 02	2.5829E 01
6.8935E-01	-3.8558E 03	-3.7438E 03	-5.0095E 02	-4.6065E 02	4.6998E 01
6.9227E-01	-3.8435E 03	-3.7561E 03	-5.0156E 02	-4.7009E 02	6.8386E 01
6.9519E-01	-3.8267E 03	-3.7729E 03	-5.0065E 02	-4.8129E 02	9.0000E 01
6.9811E-01	-3.8053E 03	-3.7944E 03	-4.9815E 02	-4.9423E 02	1.1184E 02
7.0103E-01	-3.7791E 03	-3.8205E 03	-4.9399E 02	-5.0887E 02	1.3392E 02
7.0395E-01	-3.7483E 03	-3.8513E 03	-4.8785E 02	-5.2492E 02	1.5623E 02
7.0687E-01	-3.7127E 03	-3.8869E 03	-4.7985E 02	-5.4254E 02	1.7874E 02
7.0979E-01	-3.6724E 03	-3.9273E 03	-4.7011E 02	-5.6188E 02	2.0148E 02
7.1272E-01	-3.6271E 03	-3.9725E 03	-4.5828E 02	-5.8262E 02	2.2441E 02
7.1564E-01	-3.5770E 03	-4.0226E 03	-4.4421E 02	-6.0465E 02	2.4754E 02
7.1856E-01	-3.5219E 03	-4.0777E 03	-4.2776E 02	-6.2784E 02	2.7083E 02
7.2148E-01	-3.4619E 03	-4.1377E 03	-4.0877E 02	-6.5207E 02	2.9426E 02
7.2440E-01	-3.3969E 03	-4.2027E 03	-3.8706E 02	-6.7716E 02	3.1778E 02
7.2732E-01	-3.1600E 03	-4.4396E 03	1.0648E 02	-1.1731E 03	9.9709E-02

IHC900I EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

IHC217I FIOCS - END OF DATA SET ON UNIT 5

TRACEBACK FOLLOWS- ROUTINE ISN REG. 14 REG. 15 REG. 0 REG.

Form 2427

AiRESEARCH MFG. CO.

DATE_____
PREPARED BY_____
CHECKED BY_____

CALC. NO_____
MODEL _____
PART NO_____

UPPER WAIST RING

ANALYSIS

Form 2427

AiRESEARCH MFG. CO.

DATE_____

PREPARED BY_____

CHECKED BY_____

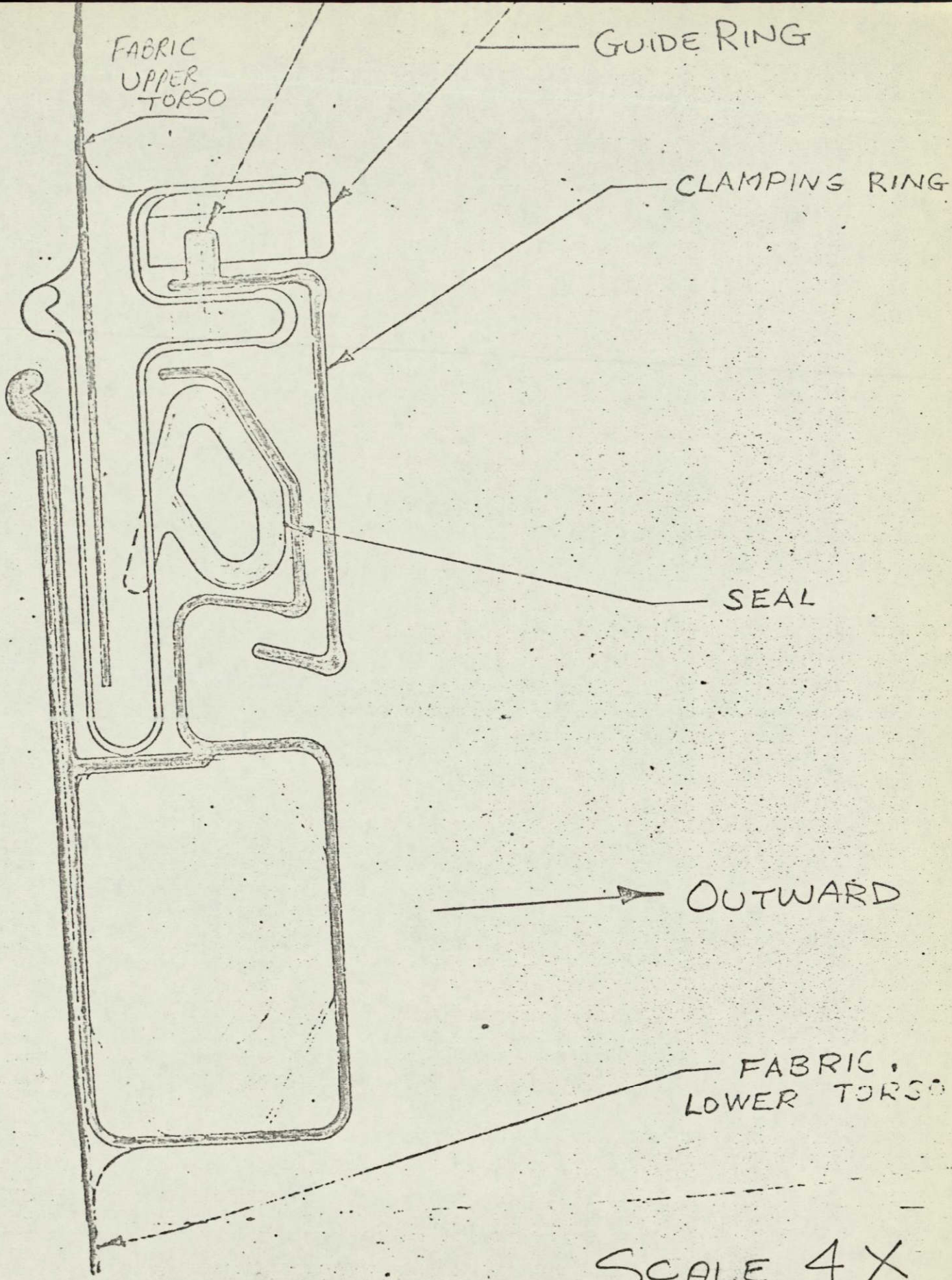
CALC. NO_____

MODEL _____

PART NO_____

REPORT

PAGE 138 OF



SCALE 4X

DETAIL B

(SECTION AT CENTERLINE)

Form 2427

AiRESEARCH MFG. CO.

DATE_____

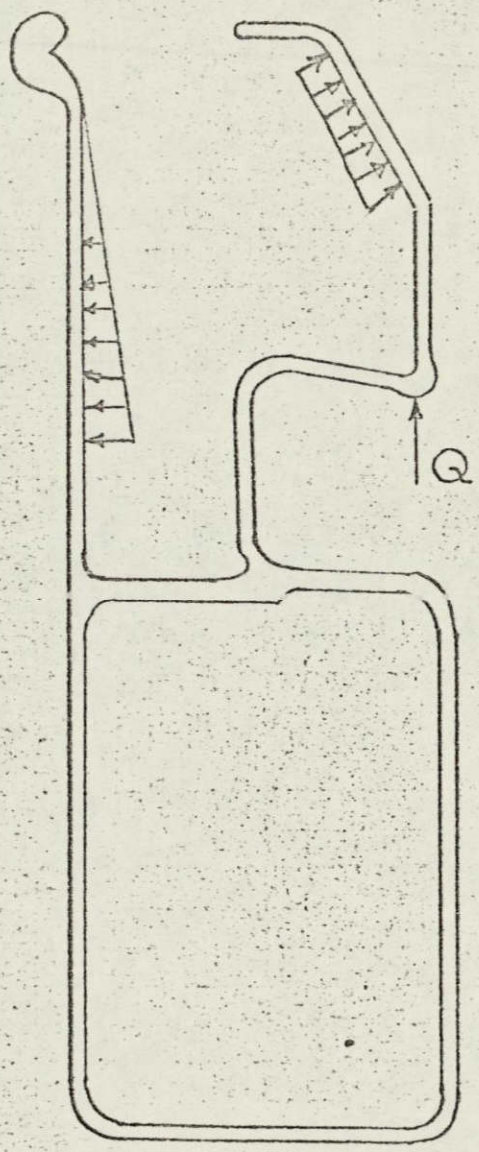
PREPARED BY_____

CHECKED BY_____

CALC. NO_____

MODEL _____

PART NO_____

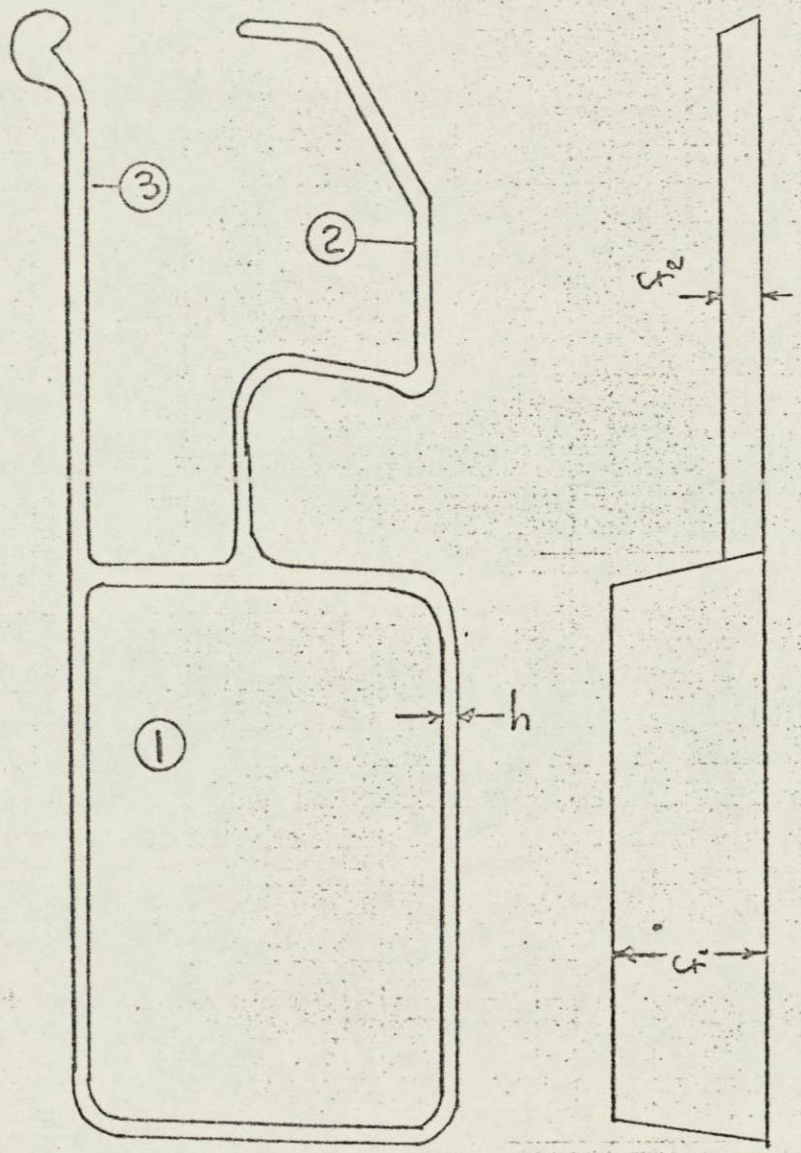


AiRESEARCH MFG. CO.

DATE 8-7-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

SECTION TORSIONAL STIFFNESS AND MOMENTS OF INERTIA



$$\tau_i = \frac{f_i}{h_i}$$

$$M_t = 2\Sigma A_i f_i$$

$$2A_j\theta = \Sigma \tau_i \frac{\Delta S}{G}$$

$$K = \frac{M_t}{G\theta}$$

for $h = 0.025$

$A_1 = 0.35162$

$A_2 = 0.026$

$A_3 = 0.0178$

$$M_t = 2\{0.35162 f_1 + 0.026 f_2 + 0.0178 f_3\}$$

$$2G\theta(0.35162)(.025) = 2.47 f_1 + .025(f_1 - f_2) + .025(f_1 - f_3)$$

$$2G\theta(0.026)(0.025) = 1.125 f_2 + .025(f_2 - f_1)$$

$$2G\theta(0.0178)(0.025) = 0.65 f_3 + .025(f_3 - f_1)$$

$f_1 = 0.007004\, G\theta$

$f_2 = 0.00128\, G\theta$

$f_3 = 0.00157\, G\theta$

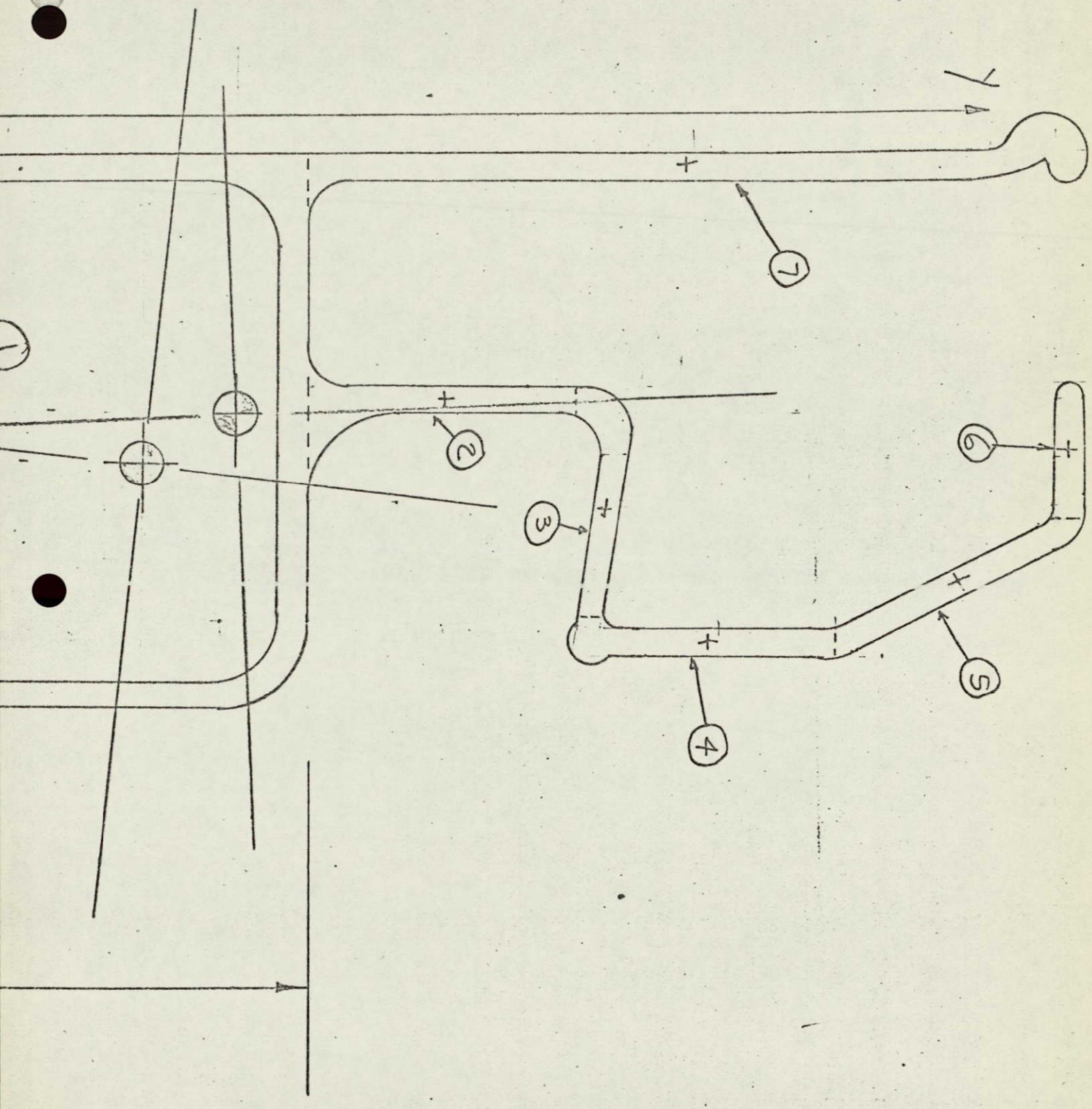
$$K = \frac{G\theta}{G\theta}(2)\{.35162(.007004) + .026(.00128) + .0178(.00157)\}$$

$K = 0.00504 \text{ in}^4$ (assumes all material is effective)

If only the closed section is working:

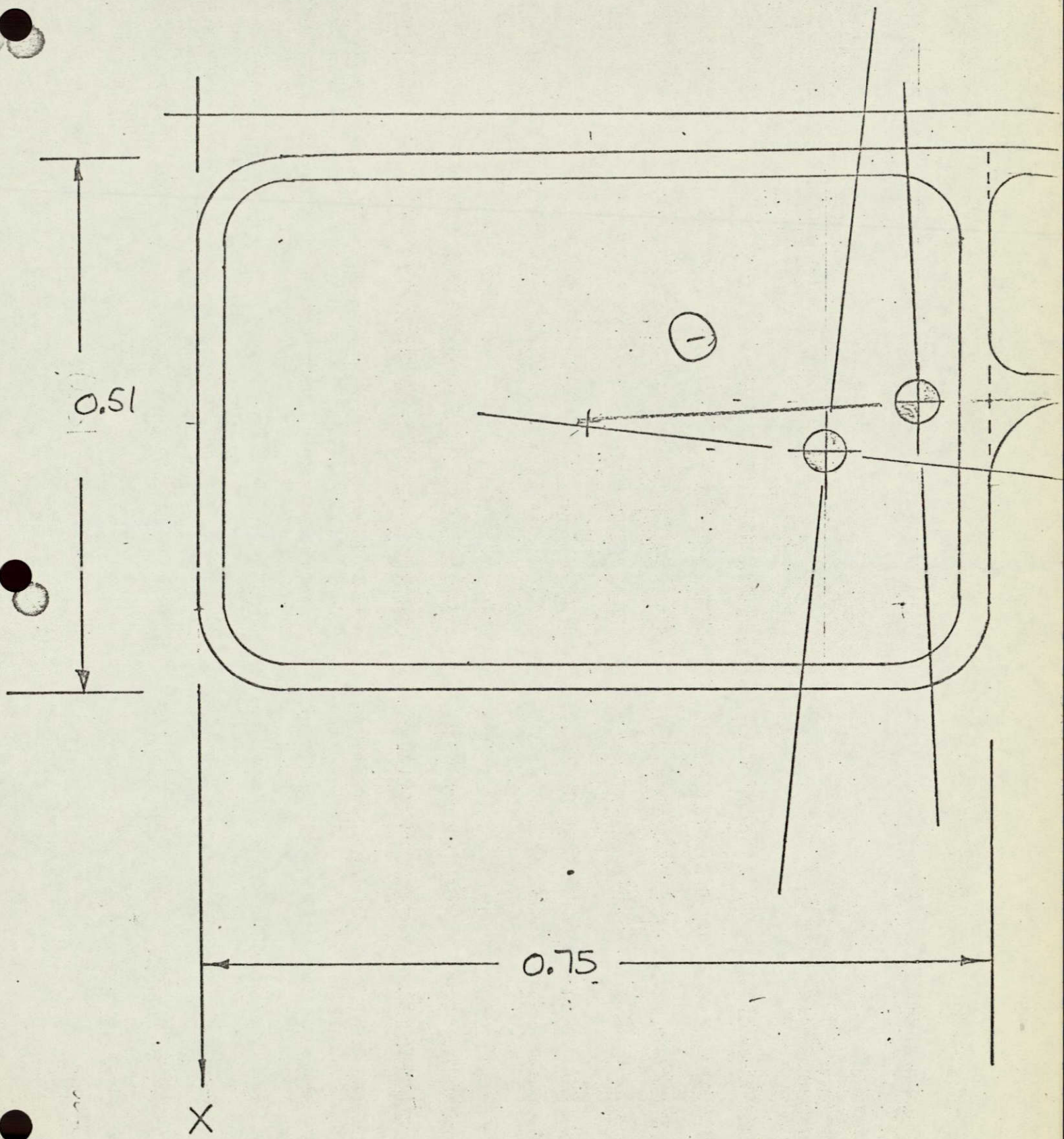
$$K = \frac{4A^2h}{U} = \frac{4(0.35162)(0.025)}{2.52}$$

$K = 0.004906 \text{ in}^4$



SCALE 8X

WALL THICKNESS = 0.025


0.51
0.75
X

AIRESEARCH MFG. CO.

DATE 8-11-69 CALC. NO.
PREPARED BY M.W. MODEL
CHECKED BY PART NO.

SECTION PROPERTIES

ITEM	AREA	X	Y	XY	X^2	Y^2	Ax^2	Ay^2	AXY	Ax	AY
1	.0605	.2927	.375	.10976	.0856	.1406	.00517	.0085	.00664	.0177	.02268
2	.006	.262	.875	.2292	.0686	.7656	.00041	.00459	.00137	.00157	.00525
3	.005	.362	1.02	.3692	.131	1.04	.00065	.0052	.00184	.00181	.0051
4	.006	.4875	1.125	.5984	.2376	1.256	.0014	.00759	.00329	.00292	.00675
5	.006	.43	1.356	.5831	.1849	1.8387	.0011	.01103	.00349	.00258	.00813
6	.003	.312	1.45	.4524	.0973	2.1025	.00028	.0063	.00135	.00093	.00435
*7	.0178	.045	1.1	.0495	.002	1.21	.00003	.02153	.000881	.000801	.01958
	.0865						.00901	.04321	.01798	.02751	.0522
	.1043	← may not be effective →					.00904	.06474	.01886	.02831	.07184

$A_1 = 0.75 \times 0.51 - 0.70 \times 0.46 = 0.06055\ in^2$

$I_{xx_1} = \frac{1}{12}\{0.51(0.75)^3 - 0.46(0.7)^3\} = 0.00478\ in^4$

$I_{yy} = \frac{1}{12}\{0.75(0.51)^3 - 0.7(0.46)^3\} = 0.002612\ in^4$

$X_1 = 0.2927\ in$

$Y_1 = 0.375\ in$

Form 2427

AiRESEARCH MFG. CO.

DATE 8-11-69
PREPARED BY M.W.
CHECKED BY

CALC. NO
MODEL
PART NO

Effective

$\bar{x} = \frac{.02751}{.0865} = 0.31803$

$\bar{y} = \frac{.0522}{.0865} = 0.6034$

$I_{xx} = .00478 + .04321 - .0522(.6034) = 0.01649$

$I_{yy} = .002612 + .00901 - .02751(.31803) = 0.00287$

$A_{xy} = .01792 - .0865(.318)(.304) = 0.00138$

$\theta = \frac{1}{2}\tan^{-1}\frac{2(.00138)}{.00287 - .01649}$

$\theta = -5.75°$

Max

$\bar{x} = \frac{.02831}{.1043} = 0.2714$

$\bar{y} = \frac{.07184}{.1043} = 0.6887$

$I_{xx} = .00478 + .06474 - .07184(.6887) = 0.02004$

$I_{yy} = .002612 + .00904 - .02831(.2714) = 0.003968$

$A_{xy} = .01886 - .1043(.2714)(.6887) = -0.000635$

$\theta = \frac{1}{2}\tan^{-1}\frac{2(-.000635)}{.003968 - .02004}$

$\theta = 2.25°$

The maximum section may not be effective do to local buckling of the unsupported edge.

Form 2427

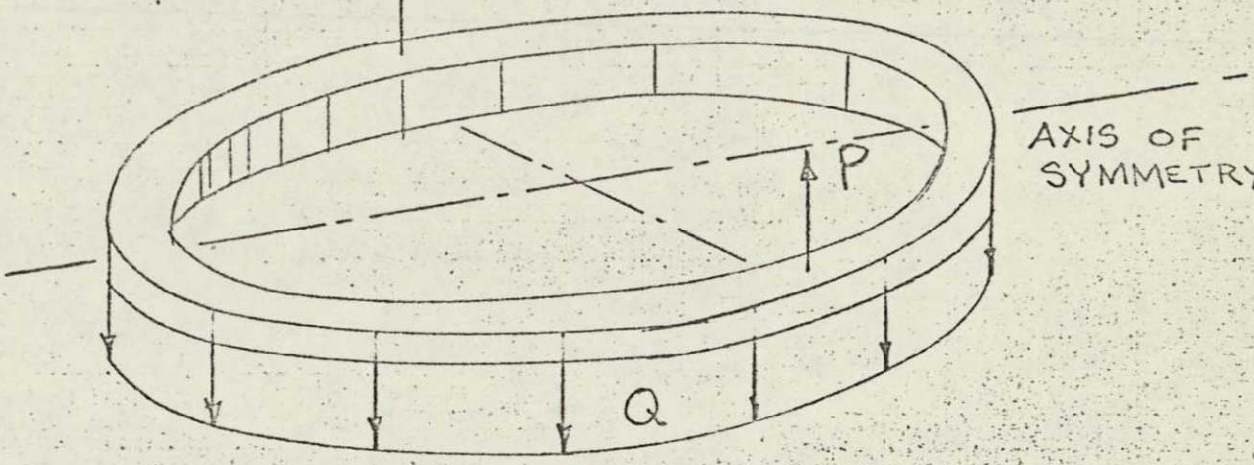
AiRESEARCH MFG. CO.

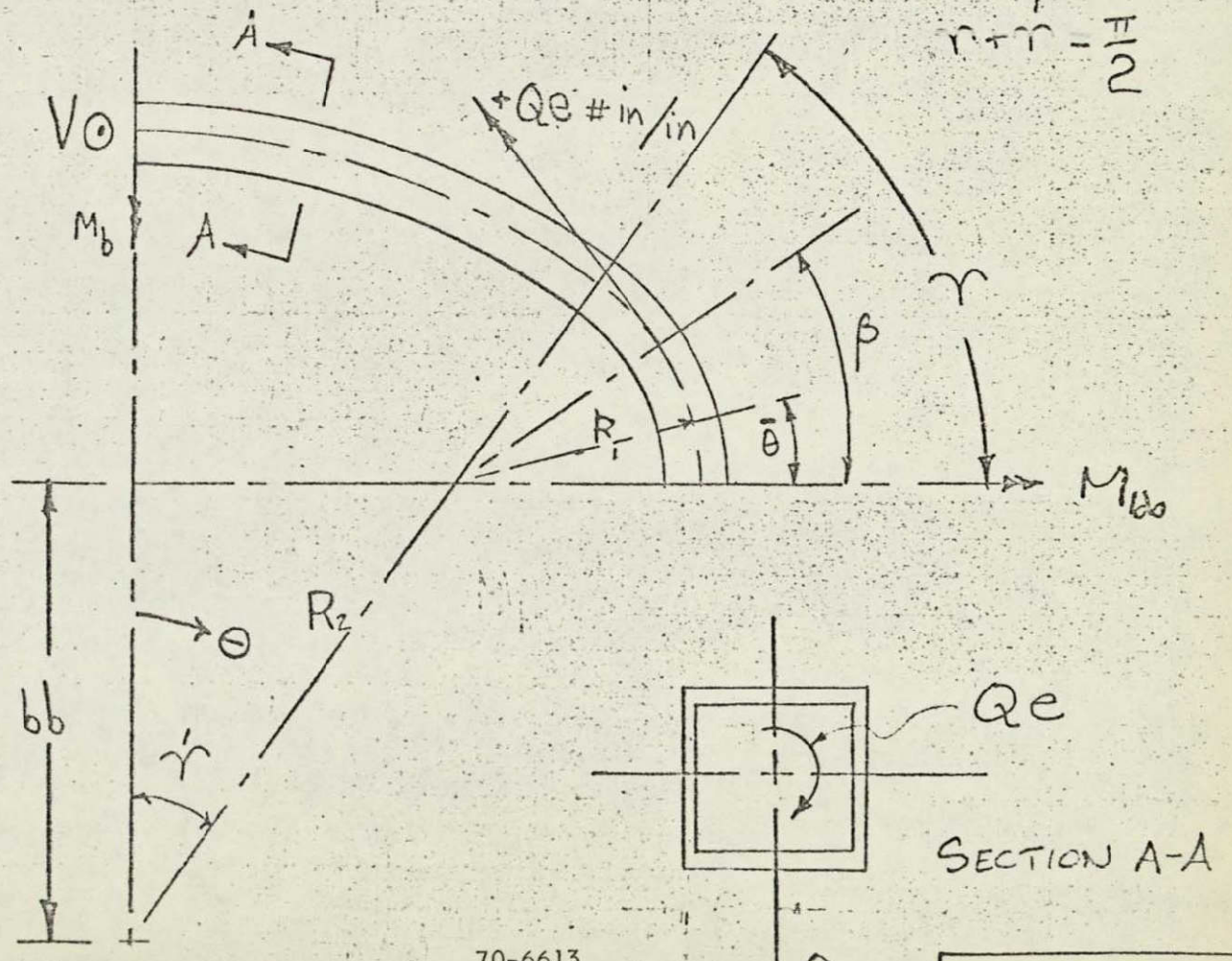
DATE 8-5-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

UPPER WAIST RING ANALYSIS

$$\frac{1}{2}\int Q\,ds = P = 2Q(\gamma' R + \gamma r)$$





AiRESEARCH MFG. CO.

DATE 8-25-69
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CALC. NO
MODEL
PART NO

$$M_{bb} - QR_1^2 \int_0^{\gamma} \sin\theta\, d\theta - QeR_1 \int_0^{\gamma} \sin\theta\, d\theta + V(R_2 - bb)$$

$$- QR_2 \int_{\gamma}^{\pi/2} \{R_2 \sin\theta - bb\}\, d\theta - QeR_2 \int_{\gamma}^{\pi/2} \sin\theta\, d\theta = 0$$

$$M_{bb} = +(1-\cos\gamma)QR_1(R_1+e) - V(R_2-bb)$$

$$+ QR_2(R_2+e)\cos\gamma - QR_2\, bb(\pi/2-\gamma)$$

for $\theta < \gamma$

$$M = M_{bb}\cos\theta + QR_1^2 \int_0^{\theta} \sin(\theta-\beta)\, d\beta + QeR_1 \int_0^{\theta} \sin(\theta-\beta)\, d\beta$$

$$T = M_{bb}\sin\theta + QR_1^2 \int_0^{\theta} \{1-\cos(\theta-\beta)\}\, d\beta - QeR_1 \int_0^{\theta} \cos(\theta-\beta)\, d\beta$$

$$M = \left[M_{bb} - QR_1(R_1+e)\right]\cos\theta + QR_1^2$$

$$T = \left[M_{bb} - QR_1(R_1+e)\right]\sin\theta + QR_1^2\theta$$

} only good for $\theta \le \gamma$

$$V = Q(R_2\gamma' + R_1\gamma)$$

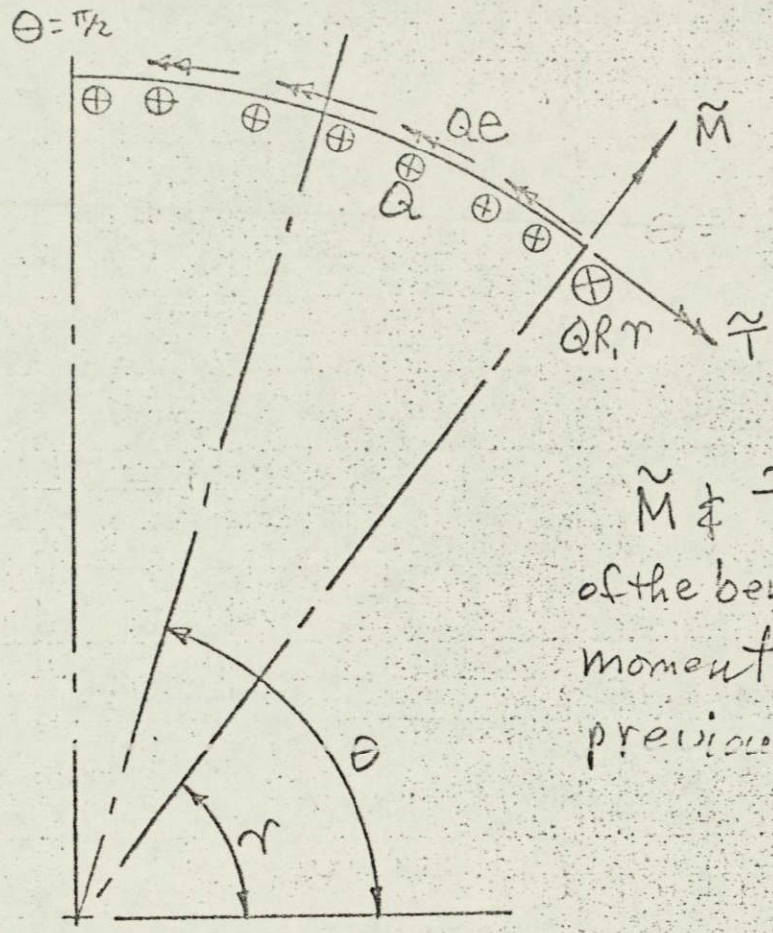
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AiRESEARCH MFG. CO.

DATE 8-25-69
PREPARED BY M. WOLFSON
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CALC. NO
MODEL
PART NO

$\theta \geq \gamma$



$\tilde{M}$ & $\tilde{T}$ are the values of the bending and torsional moment @ $\theta=\gamma$ from the previous equations.

$$M = \tilde{M}\cos(\theta-\gamma) - \tilde{T}\sin(\theta-\gamma) + QR_2^2\int_{\gamma}^{\theta}\sin(\theta-\beta)\,d\beta + QeR_2\int_{\gamma}^{\theta}\sin(\theta-\beta)\,d\beta + QR_1\gamma\left[R_2\sin(\theta-\gamma)\right]$$

$$T = \tilde{M}\sin(\theta-\gamma) + \tilde{T}\cos(\theta-\gamma) + QR_2^2\int_{\gamma}^{\theta}\{1-\cos(\theta-\beta)\}\,d\beta - QeR_2\int_{\gamma}^{\theta}\cos(\theta-\beta)\,d\beta + QR_1\gamma\,R_2\{1-\cos(\theta-\gamma)\}$$

AiRESEARCH MFG. CO.

DATE 8-25-69
PREPARED BY M. WOLFSON
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CALC. NO.
MODEL
PART NO.

$$M = \tilde{M}\cos(\theta-\gamma) + \left[QR_1R_2\gamma - \tilde{T}\right]\sin(\theta-\gamma)$$
$$+\left[1-\cos(\theta-\gamma)\right]QR_2(R_2+e)$$

$$T = \left[\tilde{M} - QR_2(R_2+e)\right]\sin(\theta-\gamma) - \left[QR_1R_2\gamma - \tilde{T}\right]\cos(\theta-\gamma)$$
$$+QR_1R_2\gamma + QR_2^2(\theta-\gamma)$$

$\theta \geq \gamma$

$$M = \left[\tilde{M} - QR_2(R_2+e)\right]\cos(\theta-\gamma) + \left[QR_1R_2\gamma - \tilde{T}\right]\sin(\theta-\gamma)$$
$$+QR_2(R_2+e)$$

$$T = \left[\tilde{M} - QR_2(R_2+e)\right]\sin(\theta-\gamma) - \left[QR_1R_2\gamma - \tilde{T}\right]\cos(\theta-\gamma)$$
$$+QR_2\gamma(R_1-R_2) + QR_2^2\theta$$

DEFLECTIONS

$$\frac{d^3V}{d\theta^3} + \frac{dU}{d\theta} = -R^2(\theta)\left\{\frac{T}{GJ} + \frac{1}{EI}\frac{dM}{d\theta}\right\}$$

$$\beta = \frac{-MR(\theta)}{EI} + \frac{1}{R(\theta)}\frac{d^2U}{d\theta^2}$$

for $\theta < \gamma$

$$T = \left[M_{bb} - QR_1(R_1+e)\right]\sin\theta + QR_1^2\theta$$

$$\frac{dM}{d\theta} = -\left[M_{bb} - QR_1(R_1+e)\right]\sin\theta$$

for $\theta \geq \gamma$

$$T = \left[\tilde{M} - QR_2(R_2+e)\right]\sin(\theta-\gamma) - \left[QR_1R_2\gamma - \tilde{T}\right]\cos(\theta-\gamma) + QR_2\gamma(R_1-R_2) + QR_2^2\theta$$

$$\frac{dM}{d\theta} = -\left[\tilde{M} - QR_2(R_2+e)\right]\sin(\theta-\gamma) + \left[QR_1R_2\gamma - \tilde{T}\right]\cos(\theta-\gamma)$$

$$V = C_{1i} + C_{2i}\cos\theta + C_{3i}\sin\theta + \tilde{C}_i\theta + \frac{1}{2}\bar{C}_i\theta^2 - \frac{A_i}{2}\theta\sin\theta - \frac{B_i}{2}\theta\cos\theta$$

$$\dot{V} = -C_{2i}\sin\theta + C_{3i}\cos\theta + \tilde{C}_i + \bar{C}_i\theta - \frac{A_i}{2}\left[\sin\theta + \theta\cos\theta\right] - \frac{B_i}{2}\left[\cos\theta - \theta\sin\theta\right]$$

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DATE 8-25-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

$$V'' = -C_{2i}\cos\theta - C_{3i}\sin\theta + \bar{C}_i - \frac{A}{2}\left[2\cos\theta - \theta\sin\theta\right] + \frac{B}{2}\left[2\sin\theta + \theta\cos\theta\right]$$

$$V''' = C_{2i}\sin\theta - C_{3i}\cos\theta + \frac{A_i}{2}\left[3\sin\theta + \theta\cos\theta\right] + \frac{B_i}{2}\left[3\cos\theta - \theta\sin\theta\right]$$

$$\boxed{V''' + V' = \tilde{C}_i + \bar{C}_i\theta + A_i\sin\theta + B_i\cos\theta}$$

where:

$$\tilde{C}_1 = 0$$

$$\bar{C}_1 = -\frac{QR_1^4}{GJ}$$

$$B_1 = 0$$

$$A_1 = -R_1^2\left(\frac{1}{GJ} - \frac{1}{EI}\right)\left[M_{bb} - QR_1(R_1 + e)\right]$$

$$\tilde{C}_2 = -\frac{QR_2^3\gamma(R_1 - R_2)}{GJ}$$

$$\bar{C}_2 = -\frac{QR_2^4}{GJ}$$

$$A_2 = \left(\frac{1}{EI} - \frac{1}{GJ}\right) R_2^2 \left\{ \cos\gamma \left[\tilde{M} - QR_2(R_2+e)\right] - \sin\gamma \left[QR_1R_2\gamma - \tilde{T}\right] \right\}$$

$$B_2 = R_2^2 \left(\frac{1}{GJ} - \frac{1}{EI}\right) \left\{ \cos\gamma \left[QR_1R_2\gamma - \tilde{T}\right] + \sin\gamma \left[\tilde{M} - QR_2(R_2+e)\right] \right\}$$

$$\begin{bmatrix} C_{21} & C_{31} & C_{12} & C_{22} & C_{32} \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ \cos\gamma & \sin\gamma & -1 & -\cos\gamma & -\sin\gamma \\ -\sin\gamma & \cos\gamma & 0 & \sin\gamma & -\cos\gamma \\ -\cos\gamma & -\sin\gamma & 0 & \cos\gamma & \sin\gamma \end{bmatrix} \begin{Bmatrix} C_{21} \\ C_{31} \\ C_{12} \\ C_{22} \\ C_{32} \end{Bmatrix} = \begin{Bmatrix} 0 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \end{Bmatrix}$$

$$W_2 = \tilde{C}_2 + \frac{\pi}{2}\bar{C}_2 - \frac{1}{2}A_2 + \frac{\pi}{4}B_2$$

$$W_3 = \tilde{C}_2\gamma + \frac{\gamma^2}{2}(\bar{C}_2 - \bar{C}_1) + \frac{1}{2}(A_1 - A_2)\gamma\sin\gamma - \frac{B_2}{2}\gamma\cos\gamma$$

$$W_4 = \tilde{C}_2 + \gamma(\bar{C}_2 - \bar{C}_1) + \frac{1}{2}(A_1 - A_2)\left[\sin\gamma + \gamma\cos\gamma\right] - \frac{B_2}{2}\left[\cos\gamma - \gamma\sin\gamma\right]$$

$$W_5 = \bar{C}_2 - \bar{C}_1 + \frac{1}{2}(A - A_2)\left[2\cos\gamma - \gamma\sin\gamma\right] + \frac{B_2}{2}\left[2\sin\gamma + \gamma\cos\gamma\right]$$

$C_{11} = 0$ (arbitrary constant, will only affect the reference point value.)

$C_{31} = 0$, $C_{22} = W_2$

$$\begin{bmatrix} \cos\gamma & -1 & -\sin\gamma \\ -\sin\gamma & 0 & -\cos\gamma \\ -\cos\gamma & 0 & \sin\gamma \end{bmatrix} \begin{Bmatrix} C_{21} \\ C_{12} \\ C_{32} \end{Bmatrix} = \begin{Bmatrix} W_3 + W_2\cos\gamma \\ W_4 - W_2\sin\gamma \\ W_5 - W_2\cos\gamma \end{Bmatrix}$$

$$DET = -1.$$

$$C_{21} = -\{W_4\sin\gamma + W_5\cos\gamma - W_2\}$$

$$C_{12} = -\{W_3 + W_5\}$$

$$C_{32} = -\{W_4\cos\gamma - W_5\sin\gamma\}$$

$$C_{22} = W_2$$

$$C_{31} = 0.0$$

$$C_{11} = 0.0$$

```
// JOB T

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
      DIMENSION BMB(91),BMT(91),BMZ(91),AXIAL(91)
      DIMENSION  TITLE(20)
      DIMENSION U(91)
      READ(2,2)(TITLE(ITLE),ITLE=1,20)
    2 FORMAT(20A4)
C
C     THIS PROGRAM CALCULATES MOMENTS AND DEFLECTIONS OF ELLIPTIC RINGS.
C     PROGRAMMER  MARTIN WOLFSON 93-33  EXT. 2364
C
C     IRING EQUALS DEL IN THE INPUT
C     IRING =0, 4CABLE LOADS
C     IRING .GT.0  2 CABLE LOADS AND DISTRIBUTED FABRIC LOAD.
C      Q IS THE IN PLANE LOAD PER INCH
C     IF  IRING =0 ,P IS A CONCENTRATED NORMAL LOAD
C     IF  IRING .GT.0 , P IS A DISTRIBUTED NORMAL LOAD
C      BIX IS THE MOMENT OF INERTIA ABOUT X-X AXIS
C      BIY IS THE MOMENT OF INERTIA ABOUT Z-Z AXIS
C      BIP IS THE POLAR MOMENT OF INERTIA
C      AREA IS THE CROSS-SECTION AREA
C      R1 IS THE CURVATURE IN REGION 1
C      R2 IS THE CURVATURE IN REGION 2
C      GOMMA IS THE ANGLE AT WHICH REGION 2 BEGINS(IN DEGREES)
C      POISS IS POISSONS RATIO
C      E IS YOUNGS MODULUS
C
      READ(2,8)Q,P,BIX,BIY,BIP,AREA,BB ,CZZ
      READ(2,8)R1,R2,GOMMA,POISS,E,EXC,DEL      ,DUMM
    8 FORMAT(8E10.5)
      IRING= IFIX(DEL)
      GAMMA=GOMMA/57.295779
      C=COS(GAMMA)
      S=SIN(GAMMA)
      PO=1.+POISS
      CON=BIX/BIP
      CON1=BIY/AREA
      S2=SIN(2.*GAMMA)
      GAM1=1.570796-GAMMA
      AID1=GAMMA-0.5*S2
      AID2=GAMMA+0.5*S2
      S3=SIN(2.*GAM1)
      AID3=GAM1+0.5*S3
      AID4=GAM1-0.5*S3
C     OUT OF PLANE PROBLEM
C
C     TO EQUALS ZERO BY SYMMETRY.
C     SHEAR IS ZERO BY SYMMETRY.
C
      SEE1=R2*GAM1+2.*R1*GAMMA
      VOM = P*(GAM1*R2+GAMMA*R1)
```

```
      DMO=(1.-C)*P*R1*(R1+EXC)-VOM*BB+P*R2*(R2+EXC)*C-P*R2*GAM1*(R2-BB)
      BEM1=DMO-P*R1*(R1+EXC)
      BEM2=BEM1*C+P*R1*R1
      BEM3=BEM1*S +P*R1*R1*GAMMA
      BEM4= BEM2 -P*R2*(R2+EXC)
      BEM5= P*R1*R2*GAMMA-BEM3
      TO=0.0
      WRITE(3,200)DMO,BEM1,BEM2,VOM,BEM3,BEM4,SEE1
C     IN PLANE PROBLEM
      CAP1=R2/R1
      CAP2=R1/R2
      CAP3=1.5*GAMMA+0.25*S2-2.*S
      CAP4=C*(C-0.5*AID3)
      CAP5=R1*(1.-C)+R2*C
      CAP6=R1*R1*R1
      CAP7=R2*R2*R2
      A11=GAMMA+GAM1*CAP1
      A12=-R 2*(CAP2*(GAMMA-S)+GAM1*(1.-C)+C*(GAM1-C)+S*(1.-S))
      W1=-R1*R1*(GAMMA-S+R2*CAP1*CAP1*(GAM1-C)+CAP1*(1.-C)*GAM1)
      A21=R2*R2*(CAP2*CAP2*(S-GAMMA)-GAM1*(CAP2*(1.-C)+C)+C*C -S*(1.-C))
      A22=CAP6*CAP3+R2*R2*CAP5*(C*(GAM1-C)+S*(1.-S)-CAP2*GAM1*(1.-C))-C
     1*CAP7*(CAP2*C*(1.-C)+CAP4+0.5*S*C*C)+S*CAP7*(CAP2*(1.-C)*(1.-S) +
     2C*(1.-S-0.5*C*C)+0.5*S*AID4)
      W2=-CAP7*(-CAP6/CAP7*CAP3-CAP5*(CAP2*CAP2*GAM1*(1.-C)+GAM1-C)+C*R2
     1*(CAP2*CAP2*C*(1.-C)+CAP4/C)-S*R2*(CAP2*CAP2*(1.-C)*(1.-S)+1.-S
     2 -0.5*C*C))
      DET=A11*A22-A21*A12
      BM=(W1*A22-W2*A12)/DET
      H=(A11*W2-A21*W1)/DET
      AXE1=-.5*P*BB*C+0.5*P*R1*S
      AXE2=-.5*P*BB*S+0.5*P*R1*(1.-C)
      DO 30 J=1,91
      THETA=FLOAT(J-1)*0.0175
      TIG1=SIN(THETA)
      TIG2=COS(THETA)
      IF(IRING)210,210 ,212
  210 IF(THETA-GAMMA)35,35,37
   35 BMB(J)=-.5*P*BB*TIG2+TIG1*(0.5*P*R1-TO)
      BMT(J)=TO*TIG2-0.5*P*BB*TIG1+0.5*P*R1*(1.-TIG2)
      BMZ(J)=BM+(1.-TIG2)*(Q*R1-H)*R1
      AXIAL(J)=H*TIG2
      GO TO 30
   37 TIG3=COS(THETA-GAMMA)
      TIG4=SIN(THETA-GAMMA)
      BMB(J)=AXE1*TIG3-AXE2*TIG4+0.5*P*R2*TIG4
      BMT(J)=AXE1*TIG4+AXE2*TIG3+0.5*P*R2*(1.-TIG3)
      BMZ(J)=BM+R1*(Q*R1-H)*(1.-C)+R2*(Q*R2-H*C)*(1.-TIG3)-H*R2*S*TIG4
      AXIAL(J)=H*COS(THETA+GAMMA)
      GO TO 30
  212 IF(THETA-GAMMA)213,213,214
  213 BMB(J)= BEM1*TIG2 +P*R1*R1
      BMT(J)= BEM1*TIG1+P*R1*R1*THETA
      BMZ(J)=BM+(1.-TIG2)*(Q*R1-H)*R1
      AXIAL(J)=H*TIG2
      GO TO 30
  214 TIG3=COS(THETA-GAMMA)
      TIG4=SIN(THETA-GAMMA)
      BMB(J)=BEM4*TIG3 +BEM5*TIG4 +P*R2*(R2+EXC)
```

```
      BMT(J)= BEM4*TIG4-BEM5*TIG3 +P*R2*GAMMA*(R1-R2)+P*R2*R2*THETA
      BMZ(J)=BM+R1*(Q*R1-H)*(1.-C)+R2*(Q*R2-H*C)*(1.-TIG3)-H*R2*S*TIG4
      AXIAL(J)=H*COS(THETA+GAMMA)
   30 CONTINUE
      IPAGE=0
      WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      WRITE(3,60)
      DO 41 J=1,91
      IPAGE=IPAGE +1
      IF(IPAGE-52)40,40,52
   52 WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      IPAGE=0
      WRITE(3,60)
    4 FORMAT(1H1,10X,20A4//)
   60 FORMAT(1H ,12X,7HDEGREES,15X,14HOUT PLANE BEND,14X,
     17HTORSION,14X,13HIN PLANE BEND,11X,11HAXIAL FORCE//)
   40 THETA=FLOAT(J-1)
   41 WRITE(3,50)THETA,BMB(J),BMT(J),BMZ(J),AXIAL(J)
   50 FORMAT(1H ,    5(10X,E14.7))
C
C       CALCULATES DEFLECTIONS IN THE PLANE OF THE RING.
C
      CAP9=1./(E*BIY)
      ZAP1=R1*R1
      ZAP2=R2*R2
      W=Q
      ZAP3=W*R1-H
      A2=-R1*ZAP2*(W*R1-C*H)*(C+1.5707*S)-H*CAP7*(S-C)
      W1=CAP9*(-BM*ZAP1-CAP6*ZAP3*(1.-0.5*S*GAMMA)+0.5*C*A2+BM*ZAP2+R1*
     1ZAP2*ZAP3*(1.-C)+CAP7*(W*R2-H*C)+0.5*H*CAP7*S*GAMMA)
      W2=0.5*CAP9*(CAP6*(S+C*GAMMA)-S*A2-R1*ZAP2*(W*R1-C*H)*GAMMA
     1-H*S*CAP7)
      A1=C*W1-S*W2
      B2=-W2*C-W1*S
      DO 300 KK=1,91
      THETA=FLOAT(KK-1)*.0175
      TRIG1=SIN(THETA)
      TRIG2=COS(THETA)
      IF(THETA-GAMMA)301,301,302
  301 U(KK)=A1*TRIG2+ZAP1*CAP9*(BM+R1*ZAP3*(1.-.5*THETA*TRIG1))
      GO TO 300
  302 SII=THETA-GAMMA
      TRIG3=SIN(SII)
      TRIG4=COS(SII)
      U(KK)=0.5*A2*CAP9*TRIG2+B2*TRIG1+ZAP2*CAP9*(BM+R1*ZAP3*(1.-C)+
     1R2*(W*R2-H*C)*(1.-0.5*THETA*TRIG3)+0.5*H*R2*S*THETA*TRIG4)
  300 CONTINUE
      IPAGE=0
      WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      WRITE(3,95)
      DO 120 K=1,91
      IPAGE=IPAGE +1
      IF(IPAGE-52)96,96,97
   97 WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      IPAGE=0
      WRITE(3,95)
   95 FORMAT(1H ,12X,7HDEGREES,15X,12HX DEFLECTION//)
```

```
      BMT(J)= BEM4*TIG4-BEM5*TIG3 +P*R2*GAMMA*(R1-R2)+P*R2*R2*THETA
      BMZ(J)=BM+R1*(Q*R1-H)*(1.-C)+R2*(Q*R2-H*C)*(1.-TIG3)-H*R2*S*TIG4
      AXIAL(J)=H*COS(THETA+GAMMA)
   30 CONTINUE
      IPAGE=0
      WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      WRITE(3,60)
      DO 41 J=1,91
      IPAGE=IPAGE +1
      IF(IPAGE-52)40,40,52
   52 WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      IPAGE=0
      WRITE(3,60)
    4 FORMAT(1H1,10X,20A4//)
   60 FORMAT(1H ,12X,7HDEGREES,15X,14HOUT PLANE BEND,14X,
     17HTORSION,14X,13HIN PLANE BEND,11X,11HAXIAL FORCE//)
   40 THETA=FLOAT(J-1)
   41 WRITE(3,50)THETA,BMB(J),BMT(J),BMZ(J),AXIAL(J)
   50 FORMAT(1H ,     5(10X,E14.7))
C
C       CALCULATES DEFLECTIONS IN THE PLANE OF THE RING.
C
      CAP9=1./(E*BIY)
      ZAP1=R1*R1
      ZAP2=R2*R2
      W=Q
      ZAP3=W*R1-H
      A2=-R1*ZAP2*(W*R1-C*H)*(C+1.5707*S)-H*CAP7*(S-C)
      W1=CAP9*(-BM*ZAP1-CAP6*ZAP3*(1.-0.5*S*GAMMA)+0.5*C*A2+BM*ZAP2+R1*
     1ZAP2*ZAP3*(1.-C)+CAP7*(W*R2-H*C)+0.5*H*CAP7*S*GAMMA)
      W2=0.5*CAP9*(CAP6*(S+C*GAMMA)-S*A2-R1*ZAP2*(W*R1-C*H)*GAMMA
     1-H*S*CAP7)
      A1=C*W1-S*W2
      B2=-W2*C-W1*S
      DO 300 KK=1,91
      THETA=FLOAT(KK-1)*.0175
      TRIG1=SIN(THETA)
      TRIG2=COS(THETA)
      IF(THETA-GAMMA)301,301,302
  301 U(KK)=A1*TRIG2+ZAP1*CAP9*(BM+R1*ZAP3*(1.-.5*THETA*TRIG1))
      GO TO 300
  302 SII=THETA-GAMMA
      TRIG3=SIN(SII)
      TRIG4=COS(SII)
      U(KK)=0.5*A2*CAP9*TRIG2+B2*TRIG1+ZAP2*CAP9*(BM+R1*ZAP3*(1.-C)+
     1R2*(W*R2-H*C)*(1.-0.5*THETA*TRIG3)+0.5*H*R2*S*THETA*TRIG4)
  300 CONTINUE
      IPAGE=0
      WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      WRITE(3,95)
      DO 120 K=1,91
      IPAGE=IPAGE +1
      IF(IPAGE-52)96,96,97
   97 WRITE(3,4)(TITLE(ITLE),ITLE=1,20)
      IPAGE=0
      WRITE(3,95)
   95 FORMAT(1H ,12X,7HDEGREES,15X,12HX DEFLECTION//)
```

```
  BMZ(R )=0220-016C AXIAL(R )=02D6-0222 TITLE(R )=02FE-02D8     U(R )=03B4-0300
  BIX(R )=03BA       BIY(R )=03BC       BIP(R )=03BE       AREA(R )=03C0
   R1(R )=03C6        R2(R )=03C8      GOMMA(R )=03CA      POISS(R )=03CC
  DEL(R )=03D2      DUMM(R )=03D4      GAMMA(R )=03D6        C(R )=03D8
  CON(R )=03DE      CON1(R )=03E0         S2(R )=03E2     GAM1(R )=03E4
   S3(R )=03EA      AID3(R )=03EC      AID4(R )=03EE     SEE1(R )=03F0
 BEM1(R )=03F6      BEM2(R )=03F8      BEM3(R )=03FA     BEM4(R )=03FC
 CAP1(R )=0402      CAP2(R )=0404      CAP3(R )=0406     CAP4(R )=0408
 CAP7(R )=040E       A11(R )=0410       A12(R )=0412       W1(R )=0414
   W2(R )=041A       DET(R )=041C        BM(R )=041E        H(R )=0420
THETA(R )=0426      TIG1(R )=0428      TIG2(R )=042A     TIG3(R )=042C
 ZAP1(R )=0432      ZAP2(R )=0434         W(R )=0436     ZAP3(R )=0438
   B2(R )=043E     TRIG1(R )=0440     TRIG2(R )=0442      SII(R )=0444
 ITLE(I )=0468     IRING(I )=046A        J(I )=046C     IPAGE(I )=046E


=04A8  50   =04D3  95   =04DA  92   =04ED  200  =04F4  210  =08E3  35   =08EA
=0A42  30   =0AF4  52   =0B2C  40   =0B4B  41   =0B56  301  =0CA1  302  =0CCC
=0DAA

FLD     FSTO    FSTOX   FSBR    FDVR    IFIX    FLOAT   CARDZ   PRNTZ   SRED
SUBSC   STOP    SNR

 .200000E 01=047A    .157079E 01=047C    .500000E 00=047E    .000000E 00=0480
 .175000E-01=0486    .157070E 01=0488

3=048D     91=048E     0=048F     52=0490     0=0491

M   2402

   UOM          BEM3          BEM4          SEE1
02 .1620716E 03-0.2074447E 03-0.1176728E 04 0.1661085E 02
```

```
   96 THETA=FLOAT(K-1)
      WRITE(3,92)THETA,U(K)
   92 FORMAT(1H ,4(10X,E14.7))
  120  CONTINUE
      WRITE(3,200)Q,P,BIX,BIY,BIP,AREA,BB
      WRITE(3,200)R1,R2,GOMMA,POISS,E,CZZ
  200 FORMAT  (1H ,7E14.7///)
      STOP
      END
```

VARIABLE ALLOCATIONS

BMB(R)=00B4-0000	BMT(R)=016A-00B6	BMZ(R)=0220-016C	AXIAL(R)=02		
Q(R)=03B6	P(R)=03B8	BIX(R)=03BA	BIY(R)=03		
BB(R)=03C2	CZZ(R)=03C4	R1(R)=03C6	R2(R)=03		
E(R)=03CE	EXC(R)=03D0	DEL(R)=03D2	DUMM(R)=03		
S(R)=03DA	PO(R)=03DC	CON(R)=03DE	CON1(R)=03		
AID1(R)=03E6	AID2(R)=03E8	S3(R)=03EA	AID3(R)=03		
VOM(R)=03F2	DMO(R)=03F4	BEM1(R)=03F6	BEM2(R)=03		
BEM5(R)=03FE	TO(R)=0400	CAP1(R)=0402	CAP2(R)=04		
CAP5(R)=040A	CAP6(R)=040C	CAP7(R)=040E	A11(R)=04		
A21(R)=0416	A22(R)=0418	W2(R)=041A	DET(R)=04		
AXE1(R)=0422	AXE2(R)=0424	THETA(R)=0426	TIG1(R)=04		
TIG4(R)=042E	CAP9(R)=0430	ZAP1(R)=0432	ZAP2(R)=04		
A2(R)=043A	A1(R)=043C	B2(R)=043E	TRIG1(R)=04		
TRIG3(R)=0446	TRIG4(R)=0448	ITLE(I)=0468	IRING(I)=04		
KK(I)=0470	K(I)=0472				

STATEMENT ALLOCATIONS

2	=049A	8	=049D	4	=04A0	60	=04A8	50	=04D3	95	=04DA
37	=094E	212	=09F2	213	=09F9	214	=0A42	30	=0AF4	52	=0B2C
300	=0D3B	97	=0D73	96	=0D92	120	=0DAA				

FEATURES SUPPORTED
IOCS

CALLED SUBPROGRAMS

FCOS	FSIN	FSUB	FMPY	FDIV	FLD	FSTO	FSTOX	FSBR
SWRT	SCOMP	SFIO	SIOFX	SIOF	SUBSC	STOP	SNR	

REAL CONSTANTS

.572957E 02=0476	.100000E 01=0478	.200000E 01=047A	.157079E 01
.150000E 01=0482	.250000E 00=0484	.175000E-01=0486	.157070E 01

INTEGER CONSTANTS

2=048A	1=048B	20=048C	3=048D	91=048E	0=048F

CORE REQUIREMENTS FOR RING
COMMON 0 VARIABLES 1142 PROGRAM 2402

END OF COMPILATION

// XEQ

DMO	BEM1	BEM2	VOM	BEM3
-0.3221687E 03	-0.8340058E 03	0.5180755E 02	0.1620716E 03	-0.2074447E 03

RING. P=10 PSI.FULL SECTION.

E BEND	TORSION	IN PLANE BEND	AXIAL FORCE
24E 03	0.0000000E 00	-0.1341682E 02	.0.3073369E 01
47E 03	-0.5953494E 01	-0.1333387E 02	0.3072898E 01
16E 03	-0.1190252E 02	-0.1308497E 02	0.3071486E 01
32E 03	-0.1784260E 02	-0.1267019E 02	0.3069134E 01
98E 03	-0.2376929E 02	-0.1208970E 02	0.3065842E 01
17E 03	-0.2967810E 02	-0.1134372E 02	0.3061611E 01
91E 03	-0.3556461E 02	-0.1043236E 02	0.3056442E 01
25E 03	-0.4142435E 02	-0.9356025E 01	0.3050337E 01
23E 03	-0.4725289E 02	-0.8114894E 01	0.3043298E 01
94E 03	-0.5304575E 02	-0.6709552E 01	0.3035328E 01
42E 03	-0.5879856E 02	-0.5140259E 01	0.3026427E 01
75E 03	-0.6450694E 02	-0.3407533E 01	0.3016600E 01
00E 03	-0.7016642E 02	-0.1511953E 01	0.3005849E 01
29E 03	-0.7577270E 02	0.5458979E 00	0.2994178E 01
66E 03	-0.8132133E 02	0.2765568E 01	0.2981589E 01
28E 03	-0.8680796E 02	0.5146089E 01	0.2968088E 01
23E 03	-0.9222843E 02	0.7686944E 01	0.2953677E 01
64E 03	-0.9757824E 02	0.1038722E 02	0.2938363E 01
64E 03	-0.1028532E 03	0.1324616E 02	0.2922148E 01
33E 03	-0.1080489E 03	0.1626292E 02	0.2905038E 01
88E 03	-0.1131615E 03	0.1943664E 02	0.2887038E 01
[illegible] 03	-0.1181863E 03	0.2276612E 02	0.2868155E 01
918E 03	-0.1231195E 03	0.2625049E 02	0.2848393E 01
925E 03	-0.1279566E 03	0.2988869E 02	0.2827759E 01
581E 03	-0.1326938E 03	0.3367952E 02	0.2806259E 01
905E 03	-0.1373269E 03	0.3762191E 02	0.2783899E 01
915E 03	-0.1418517E 03	0.4171468E 02	0.2760687E 01
631E 03	-0.1462643E 03	0.4595648E 02	0.2736629E 01
073E 03	-0.1505606E 03	0.5034601E 02	0.2711734E 01
261E 03	-0.1547367E 03	0.5488199E 02	0.2686008E 01
218E 03	-0.1587886E 03	0.5956300E 02	0.2659460E 01
964E 03	-0.1627127E 03	0.6438761E 02	0.2632096E 01
522E 03	-0.1665047E 03	0.6935440E 02	0.2603927E 01
916E 03	-0.1701612E 03	0.7446176E 02	0.2574960E 01
173E 03	-0.1736782E 03	0.7970805E 02	0.2545206E 01
311E 03	-0.1770521E 03	0.8509190E 02	0.2514671E 01
363E 03	-0.1802791E 03	0.9061145E 02	0.2483366E 01
349E 03	-0.1833556E 03	0.9626518E 02	0.2451301E 01
298E 03	-0.1862781E 03	0.1020511E 03	0.2418486E 01
236E 03	-0.1890430E 03	0.1079678E 03	0.2384929E 01
194E 03	-0.1916467E 03	0.1140132E 03	0.2350642E 01
198E 03	-0.1940860E 03	0.1201855E 03	0.2315635E 01
279E 03	-0.1963573E 03	0.1264828E 03	0.2279920E 01
463E 03	-0.1984574E 03	0.1329033E 03	0.2243506E 01
783E 03	-0.2003829E 03	0.1394450E 03	0.2206404E 01
700E 02	-0.2021307E 03	0.1461058E 03	0.2168627E 01
95[illegible] 02	-0.2036972E 03	0.1528836E 03	0.2130187E 01
869[illegible] 02	-0.2050798E 03	0.1597764E 03	0.2091094E 01
0443E 02	-0.2062753E 03	0.1667823E 03	0.2051359E 01
5172E 02	-0.2072806E 03	0.1738988E 03	0.2010998E 01
3185E 02	-0.2080926E 03	0.1811239E 03	0.1970020E 01
4816E 02	-0.2087087E 03	0.1884554E 03	0.1928439E 01

PROOF LOAD FOR UPPER WAIST RING. P=10 PSI, FULL SECTION.

DEGREES	OUT PLANE BEND	TORSION
0.0000000E 00	-0.3402424E 03	0.0000000E 00
0.1000000E 01	-0.3401147E 03	-0.5953494E 01
0.2000000E 01	-0.3397316E 03	-0.1190252E 02
0.3000000E 01	-0.3390932E 03	-0.1784260E 02
0.4000000E 01	-0.3381998E 03	-0.2376929E 02
0.5000000E 01	-0.3370517E 03	-0.2967810E 02
0.6000000E 01	-0.3356491E 03	-0.3556461E 02
0.7000000E 01	-0.3339925E 03	-0.4142435E 02
0.8000001E 01	-0.3320823E 03	-0.4725289E 02
0.9000001E 01	-0.3299194E 03	-0.5304575E 02
0.1000000E 02	-0.3275042E 03	-0.5879856E 02
0.1100000E 02	-0.3248375E 03	-0.6450694E 02
0.1200000E 02	-0.3219200E 03	-0.7016642E 02
0.1300000E 02	-0.3187529E 03	-0.7577270E 02
0.1400000E 02	-0.3153366E 03	-0.8132133E 02
0.1500000E 02	-0.3116728E 03	-0.8680796E 02
0.1600000E 02	-0.3077623E 03	-0.9222843E 02
0.1700000E 02	-0.3036064E 03	-0.9757824E 02
0.1800000E 02	-0.2992064E 03	-0.1028532E 03
0.1900000E 02	-0.2945633E 03	-0.1080489E 03
0.2000000E 02	-0.2896788E 03	-0.1131615E 03
0.2100000E 02	-0.2845545E 03	-0.1181863E 03
0.2200000E 02	-0.2791918E 03	-0.1231195E 03
0.2300000E 02	-0.2735925E 03	-0.1279566E 03
0.2400000E 02	-0.2677581E 03	-0.1326938E 03
0.2500000E 02	-0.2616905E 03	-0.1373269E 03
0.2600000E 02	-0.2553915E 03	-0.1418517E 03
0.2700000E 02	-0.2488631E 03	-0.1462643E 03
0.2800000E 02	-0.2421073E 03	-0.1505606E 03
0.2900000E 02	-0.2351261E 03	-0.1547367E 03
0.3000000E 02	-0.2279218E 03	-0.1587886E 03
0.3100000E 02	-0.2204964E 03	-0.1627127E 03
0.3200000E 02	-0.2128522E 03	-0.1665047E 03
0.3300000E 02	-0.2049916E 03	-0.1701612E 03
0.3400000E 02	-0.1969173E 03	-0.1736782E 03
0.3500000E 02	-0.1886311E 03	-0.1770521E 03
0.3600000E 02	-0.1801363E 03	-0.1802791E 03
0.3700000E 02	-0.1714349E 03	-0.1833556E 03
0.3800000E 02	-0.1625298E 03	-0.1862781E 03
0.3900000E 02	-0.1534236E 03	-0.1890430E 03
0.4000000E 02	-0.1441194E 03	-0.1916467E 03
0.4100000E 02	-0.1346198E 03	-0.1940860E 03
0.4200000E 02	-0.1249279E 03	-0.1963573E 03
0.4300000E 02	-0.1150463E 03	-0.1984574E 03
0.4400000E 02	-0.1049783E 03	-0.2003829E 03
0.4500000E 02	-0.9472700E 02	-0.2021307E 03
0.4600000E 02	-0.8429548E 02	-0.2036972E 03
0.4700000E 02	-0.7368696E 02	-0.2050793E 03
0.4800000E 02	-0.6290443E 02	-0.2062753E 03
0.4900000E 02	-0.5195172E 02	-0.2072806E 03
0.5000000E 02	-0.4083185E 02	-0.2080926E 03
0.5100000E 02	-0.2954816E	-0.2087087E 03

RING. P=10 PSI,FULL SECTION.

ND	TORSION	IN PLANE BEND	AXIAL FORCE
25E 02	-0.2091259E 03	0.1958911E 03	0.1886267E 01
07E 01	-0.2093414E 03	0.2034286E 03	0.1843518E 01
00E 01	-0.2093527E 03	0.2110656E 03	0.1800204E 01
80E 02	-0.2091567E 03	0.2187998E 03	0.1756339E 01
24E 02	-0.2087514E 03	0.2266289E 03	0.1711936E 01
89E 02	-0.2081338E 03	0.2345504E 03	0.1667009E 01
39E 02	-0.2073766E 03	0.2412579E 03	-0.1354753E 01
32E 02	-0.2067638E 03	0.2411198E 03	-0.1402820E 01
50E 02	-0.2058412E 03	0.2413937E 03	-0.1450457E 01
18E 03	-0.2046033E 03	0.2420799E 03	-0.1497650E 01
08E 03	-0.2030437E 03	0.2431779E 03	-0.1544384E 01
73E 03	-0.2011565E 03	0.2446874E 03	-0.1590645E 01
58E 03	-0.1989360E 03	0.2466079E 03	-0.1636420E 01
98E 03	-0.1963762E 03	0.2489390E 03	-0.1681693E 01
35E 03	-0.1934718E 03	0.2516796E 03	-0.1726451E 01
10E 03	-0.1902169E 03	0.2548293E 03	-0.1770680E 01
61E 03	-0.1866063E 03	0.2583870E 03	-0.1814367E 01
26E 03	-0.1826343E 03	0.2623516E 03	-0.1857498E 01
39E 03	-0.1782962E 03	0.2667218E 03	-0.1900061E 01
38E 03	-0.1735864E 03	0.2714963E 03	-0.1942043E 01
55E 03	-0.1685002E 03	0.2766737E 03	-0.1983428E 01
22E 03	-0.1630329E 03	0.2822521E 03	-0.2024207E 01
79[illegible]03	-0.1571793E 03	0.2882303E 03	-0.2064366E 01
45[illegible]03	-0.1509352E 03	0.2946063E 03	-0.2103892E 01
70E 03	-0.1442955E 03	0.3013781E 03	-0.2142774E 01
72E 03	-0.1372564E 03	0.3085434E 03	-0.2181001E 01
83E 03	-0.1298132E 03	0.3161004E 03	-0.2218559E 01
29E 03	-0.1219621E 03	0.3240465E 03	-0.2255437E 01
47E 03	-0.1136989E 03	0.3323793E 03	-0.2291625E 01
53E 03	-0.1050196E 03	0.3410964E 03	-0.2327111E 01
77E 03	-0.9592079E 02	0.3501949E 03	-0.2361885E 01
52E 03	-0.8639855E 02	0.3596721E 03	-0.2395935E 01
01E 03	-0.7644903E 02	0.3695255E 03	-0.2429252E 01
44E 03	-0.6606913E 02	0.3797515E 03	-0.2461824E 01
11E 03	-0.5525587E 02	0.3903473E 03	-0.2493643E 01
25E 03	-0.4400580E 02	0.4013095E 03	-0.2524698E 01
01E 03	-0.3231609E 02	0.4126348E 03	-0.2554979E 01
72E 03	-0.2018398E 02	0.4243195E 03	-0.2584479E 01
60E 03	-0.7606530E 01	0.4363606E 03	-0.2613187E 01

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PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMEMAIN
*IOCS (CARD,1132 PRINTER)
*LISTALL
      EQUIVALENCE (TIG1,TRIG1),(TIG2,TRIG2)
      READ(2,5)P,BIX,BIP,BB,R1
      READ(2,5)R2,GOMMA,POISS,E,RING,EXC
    5 FORMAT(6E10.5)
      GAMMA=GOMMA/57.295779
      C=COS(GAMMA)
      S=SIN(GAMMA)
      PO=1.+POISS
      G=E*0.5/PO
      D= E*BIX
      CC=G*BIP
      GAM1=1.570796-GAMMA
      BMB=0.5*P*(R1*S-BB*C)
      BMT=0.5*P*(-BB*S+R1*(1.-C))
      WRITE(3,14)
   14 FORMAT(1H1,33X,7HDEGREES,14X,12HNORMAL DISP.,15X,5HTWIST/)
      CAN=1./D -1./CC
      IRING= IFIX(RING)
      IF(IRING)20,25,20
   25 A2=R2*R2*CAN*(S*(BMT-0.5*P*R2)+BMB*C)
      B2=R2*R2*CAN*(C*(BMT-0.5*P*R2)-BMB*S)
      CO2=-0.5*P*R2**3/CC
      CO1=-0.5*P*R1*R1*R1/CC
      A1=-0.5*R1*R1*BB*CAN
      B1=-0.5*R1*R1*R1*CAN
      C31= 0.5*B1-CO1
      C22= CO2-0.5*A2-0.7854*B2
      W1=C22*C-C31*S+GAMMA*(CO2-CO1)+0.5*(A1-A2)*GAMMA*S+.5*GAMMA*C*(
     1B1-B2)
      W2=-C31*C-C22*S+CO2-CO1+.5*(A1-A2)*(S+C*GAMMA)+.5*(B1-B2)*(C-S*
     1GAMMA)
      W3= C31*S -C22*C+.5*(A1-A2)*(2.*C-S*GAMMA)+.5*(B2-B1)*(2.*S + C*
     1GAMMA)
      C21= -S*W2-C*W3
      C32= S*W3-C*W2
      C11= W1+W3
      GO TO 33
   20 CONTINUE
      VOM = P*(GAM1*R2+GAMMA*R1)
      DMO=(1.-C)*P*R1*(R1+EXC)-VOM*BB+P*R2*(R2+EXC)*C-P*R2*GAM1*(R2-BB)
      BEM1=DMO-P*R1*(R1+EXC)
      BEM2=BEM1*C+P*R1*R1
      BEM3=BEM1*S +P*R1*R1*GAMMA
      BEM4= BEM2 -P*R2*(R2+EXC)
      BEM5= P*R1*R2*GAMMA-BEM3
      CO1=-P*R1**4/CC
      A1 = R1*R1*CAN*BEM1
      CE2=-P*R2**3*GAMMA*(R1-R2)/CC
```

PROOF LOAD FOR UPPER WAIST RING. P=10 PSI, FULL SECTION.

DEGREES	OUT PLANE BEND	TORSION
0.5200000E 02	-0.1810425E 02	-0.2091259E 03
0.5300000E 02	-0.6503607E 01	-0.2093414E 03
0.5400000E 02	0.5250300E 01	-0.2093527E 03
0.5500000E 02	0.1715380E 02	-0.2091567E 03
0.5600000E 02	0.2920324E 02	-0.2087514E 03
0.5700000E 02	0.4139489E 02	-0.2081338E 03
0.5800000E 02	0.5448539E 02	-0.2073766E 03
0.5900000E 02	0.7198832E 02	-0.2067638E 03
0.6000000E 02	0.8984550E 02	-0.2058412E 03
0.6100000E 02	0.1080518E 03	-0.2046033E 03
0.6200000E 02	0.1266008E 03	-0.2030437E 03
0.6300000E 02	0.1454873E 03	-0.2011565E 03
0.6400001E 02	0.1647058E 03	-0.1989360E 03
0.6500001E 02	0.1842498E 03	-0.1963762E 03
0.6600001E 02	0.2041135E 03	-0.1934718E 03
0.6700001E 02	0.2242910E 03	-0.1902169E 03
0.6800001E 02	0.2447761E 03	-0.1866063E 03
0.6900001E 02	0.2655626E 03	-0.1826343E 03
0.7000001E 02	0.2866439E 03	-0.1782962E 03
0.7100001E 02	0.3080138E 03	-0.1735864E 03
0.7200001E 02	0.3296655E 03	-0.1685002E 03
0.7300001E 02	0.3515922E 03	-0.1630329E 03
0.7400001E 02	0.3737879E 03	-0.1571793E 03
0.7500001E 02	0.3962450E 03	-0.1509352E 03
0.7600001E 02	0.4189570E 03	-0.1442955E 03
0.7700001E 02	0.4419172E 03	-0.1372564E 03
0.7800001E 02	0.4651183E 03	-0.1298132E 03
0.7900001E 02	0.4885529E 03	-0.1219621E 03
0.8000001E 02	0.5122147E 03	-0.1136989E 03
0.8100001E 02	0.5360953E 03	-0.1050196E 03
0.8200001E 02	0.5601877E 03	-0.9592079E 02
0.8300001E 02	0.5844852E 03	-0.8639855E 02
0.8400001E 02	0.6089801E 03	-0.7644903E 02
0.8500001E 02	0.6336644E 03	-0.6606913E 02
0.8600001E 02	0.6585311E 03	-0.5525587E 02
0.8700001E 02	0.6835725E 03	-0.4400580E 02
0.8800001E 02	0.7087801E 03	-0.3231609E 02
0.8900001E 02	0.7341472E 03	-0.2018398E 02
0.9000001E 02	0.7596660E 03	-0.7606530E 01

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      CO2 = -P*R2**4/CC
      A2=R2*R2*CAN*(C*BEM4-S*BEM5)
      B2=-R2*R2*CAN*(C*BEM5+S*BEM4)
      W2=CE2+1.5707*CO2-.5*A2 +.7854*B2
      W3=CE2*GAMMA+0.5*(CO2-CO1)*GAMMA**2+.5*(A1-A2)*S*GAMMA-.5*B2*C*
     1GAMMA
      W4=CE2+(CO2-CO1)*GAMMA+.5*(A1-A2)*(S+C*GAMMA)-.5*B2*(C-S*GAMMA)
      W5=CO2-CO1+.5*(A1-A2)*(2.*C-S*GAMMA)+B2*(S+.5*C*GAMMA)
      C22=W2
      C21=W2-S*W4-C*W5
      C12=-W3-W5
      C32=W5*S-W4*C
   33 DO 30 I=1,91
      THETA=FLOAT(I-1)*.01745
      TRIG1= SIN(THETA)
      TRIG2= COS(THETA)
      IF(IRING)40,45,40
   45 IF(THETA-GAMMA)10,10,15
   10 V= C11+C21*TRIG2+C31*TRIG1+CO1*THETA-.5*THETA*(A1*TRIG1+B1*TRIG2)
      BETA=.5*P*R1/D*(R1*TRIG1-BB*TRIG2)+1./R1*(C21*TRIG2+C31*TRIG1
     1+0.5*A1*(2.*TRIG2-THETA*TRIG1)-.5*B1*(2.*TRIG1+THETA*TRIG2))
        GO TO 31
   15 V=C22*TRIG2+C32*TRIG1+CO2*THETA-.5*THETA*(A2*TRIG1+B2*TRIG2)
      BETA=R2/D*((.5*P*R2-BMT)*(C*TRIG1-S*TRIG2)+BMB*(C*TRIG2+S*TRIG1))
     1+1./R2*(C22*TRIG2+C32*TRIG1+.5*A2*(2.*TRIC2-THETA*TRIG1)
     2-.5*B2*(2.*TRIG1+THETA*TRIG2))
      GO TO 31
   40 IF(THETA-GAMMA)48,48,50
   48 V=C21*TRIG2 +.5*CO1*THETA*THETA-.5*A1*THETA*TRIG1
      VO2=-C21*TRIG2+CO1-A1*(TRIG2-.5*THETA*TRIG1)
      BETA=(-BEM1*TRIG2-P*R1*R1)*R1/D +VO2/R1
   50 TIG3=COS(THETA-GAMMA)
      TIG4=SIN(THETA-GAMMA)
      V=C12+C22*TRIG2+C32*TRIG1+CE2*THETA+.5*CO2*THETA**2 -.5*THETA*
     1(A2*TRIG1+B2*TRIG2)
      VO2=-C22*TRIG2-C32*TRIG1+CO2-A2*(TRIG2-.5*THETA*TRIG1)
     1+B2*(TRIG1+THETA*TRIG2*.5)
      BETA=(-BEM4*TIG3-BEM5*TIG4-P*R2*(R2+EXC))*R2/D +VO2/R2
   31 ANG = FLOAT(I-1)
   30 WRITE(3, 35) ANG, V,BETA
   35 FORMAT(1H ,20X,3(10X,E14.7))
      WRITE(3,3)
    3 FORMAT(1H0,4X,1HP,12X,3HIXX,10X,2HIP,8X,2HBB,10X,2HR1,10X,2HR2,
     1 8X,5HGAMMA,8X,8HPOISSONS,5X,1HE/)
      WRITE(3,12)P,BIX,BIP,BB,R1,R2,GOMMA,POISS,E
   12 FORMAT(1H ,9E12.5)
      STOP
      END
VARIABLE ALLOCATIONS
  TIG1(R )=0000      TRIG1(R )=0000      TIG2(R )=0002      TRIG2(R )=0002
   BIP(R )=0008        BB(R )=000A        R1(R )=000C        R2(R )=000E
     E(R )=0014      RING(R )=0016      EXC(R )=0018     GAMMA(R )=001A
    PO(R )=0020         G(R )=0022         D(R )=0024        CC(R )=0026
   BMT(R )=002C       CAN(R )=002E        A2(R )=0030        B2(R )=0032
    A1(R )=0038        B1(R )=003A       C31(R )=003C       C22(R )=003E
    W5(R )=0044       C21(R )=0046       C32(R )=0048       C11(R )=004A
  BEM5(R )=0050      BEM2(R )=0052      BEM3(R )=0054      BEM4(R )=0056
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PROOF LOAD FOR UPPER WAIST RING. P=10 PSI, FULL SECTION.

DEGREES	NORMAL DISP.	TWIST	X DEFLECTION
0.0000000E 00	-0.6920772E 00	-0.8592721E-02	0.4894554E 00
0.1000000E 01	-0.6914789E 00	-0.8523315E-02	0.4893799E 00
0.2000000E 01	-0.6909137E 00	-0.8450420E-02	0.4891534E 00
0.3000000E 01	-0.6903810E 00	-0.8373653E-02	0.4887760E 00
0.4000000E 01	-0.6898823E 00	-0.8292762E-02	0.4882478E 00
0.5000000E 01	-0.6894167E 00	-0.8207459E-02	0.4875691E 00
0.6000000E 01	-0.6889839E 00	-0.8117547E-02	0.4867401E 00
0.7000000E 01	-0.6885843E 00	-0.8022747E-02	0.4857612E 00
0.8000001E 01	-0.6882184E 00	-0.7922794E-02	0.4846327E 00
0.9000001E 01	-0.6878850E 00	-0.7817640E-02	0.4833551E 00
0.1000000E 02	-0.6875845E 00	-0.7707032E-02	0.4819290E 00
0.1100000E 02	-0.6873166E 00	-0.7590856E-02	0.4803547E 00
0.1200000E 02	-0.6870824E 00	-0.7468938E-02	0.4786331E 00
0.1300000E 02	-0.6868798E 00	-0.7341206E-02	0.4767649E 00
0.1400000E 02	-0.6867096E 00	-0.7207649E-02	0.4747505E 00
0.1500000E 02	-0.6865717E 00	-0.7068071E-02	0.4725912E 00
0.1600000E 02	-0.6864647E 00	-0.6922612E-02	0.4702875E 00
0.1700000E 02	-0.6863895E 00	-0.6771124E-02	0.4678404E 00
0.1800000E 02	-0.6863449E 00	-0.6613708E-02	0.4652510E 00
0.1900000E 02	-0.6863310E 00	-0.6450341E-02	0.4625202E 00
0.2000000E 02	-0.6863468E 00	-0.6281186E-02	0.4596490E 00
0.2100000E 02	-0.6863927E 00	-0.6106170E-02	0.4566389E 00
0.2200000E 02	-0.6864669E 00	-0.5925537E-02	0.4534908E 00
0.2300000E 02	-0.6865694E 00	-0.5739356E-02	0.4502060E 00
0.2400000E 02	-0.6867008E 00	-0.5547768E-02	0.4467859E 00
0.2500000E 02	-0.6868585E 00	-0.5350958E-02	0.4432319E 00
0.2600000E 02	-0.6870430E 00	-0.5149122E-02	0.4395452E 00
0.2700000E 02	-0.6872538E 00	-0.4942391E-02	0.4357275E 00
0.2800000E 02	-0.6874892E 00	-0.4731165E-02	0.4317802E 00
0.2900000E 02	-0.6877491E 00	-0.4515619E-02	0.4277051E 00
0.3000000E 02	-0.6880326E 00	-0.4296079E-02	0.4235035E 00
0.3100000E 02	-0.6883391E 00	-0.4072776E-02	0.4191774E 00
0.3200000E 02	-0.6886672E 00	-0.3846063E-02	0.4147282E 00
0.3300000E 02	-0.6890167E 00	-0.3616265E-02	0.4101579E 00
0.3400000E 02	-0.6893860E 00	-0.3383803E-02	0.4054685E 00
0.3500000E 02	-0.6897749E 00	-0.3149052E-02	0.4006615E 00
0.3600000E 02	-0.6901820E 00	-0.2912390E-02	0.3957390E 00
0.3700000E 02	-0.6906067E 00	-0.2674316E-02	0.3907030E 00
0.3800000E 02	-0.6910470E 00	-0.2435165E-02	0.3855556E 00
0.3900000E 02	-0.6915035E 00	-0.2195554E-02	0.3802986E 00
0.4000000E 02	-0.6919739E 00	-0.1955812E-02	0.3749344E 00
0.4100000E 02	-0.6924576E 00	-0.1716544E-02	0.3694650E 00
0.4200000E 02	-0.6929532E 00	-0.1478350E-02	0.3638927E 00
0.4300000E 02	-0.6934603E 00	-0.1241615E-02	0.3582196E 00
0.4400000E 02	-0.6939774E 00	-0.1006948E-02	0.3524481E 00
0.4500000E 02	-0.6945034E 00	-0.7750160E-03	0.3465803E 00
0.4600000E 02	-0.6950371E 00	-0.5463737E-03	0.3406189E 00
0.4700000E 02	-0.6955775E 00	-0.3216236E-03	0.3345661E 00
0.4800000E 02	-0.6961231E 00	-0.1014300E-03	0.3284244E 00
0.4900000E 02	-0.6966735E 00	0.1135741E-03	0.3221962E 00
0.5000000E 02	-0.6972270E 00	0.3227799E-03	0.3158841E 00
0.5100000E 02	-0.6977827E 00	0.5253752E-03	0.3094906E 00
0.5200000E 02	-0.6983393E 00	0.7207200E-03	0.3030182E 00
0.5300000E 02	-0.6988958E 00	0.9080899E-03	0.2964696E 00
0.5400000E 02	-0.6994515E 00	0.1086814E-02	0.2898475E 00
0.5500000E 02	-0.7000039E 00	0.1256018E-02	0.2831545E 00
0.5600000E 02	-0.7005531E 00	0.1415051E-02	0.2763933E 00

DEGREES	NORMAL DISP.	TWIST	X DEFLECTION
0.5700000E 02	-0.7010984E 00	0.1563128E-02	0.2695667E 0
0.5800000E 02	-0.7016375E 00	0.1699427E-02	0.2622652E 0
0.5900000E 02	-0.7021698E 00	0.1823142E-02	0.2526692E 0
0.6000000E 02	-0.7026944E 00	0.1933477E-02	0.2430456E 0
0.6100000E 02	-0.7032105E 00	0.2029647E-02	0.2333971E 0
0.6200000E 02	-0.7037165E 00	0.2110753E-02	0.2237271E 0
0.6300000E 02	-0.7042123E 00	0.2176017E-02	0.2140386E 0
0.6400001E 02	-0.7046958E 00	0.2224548E-02	0.2043347E 0
0.6500001E 02	-0.7051669E 00	0.2255468E-02	0.1946193E 0
0.6600001E 02	-0.7056245E 00	0.2267932E-02	0.1848954E 0
0.6700001E 02	-0.7060678E 00	0.2261036E-02	0.1751669E 0
0.6800001E 02	-0.7064962E 00	0.2233904E-02	0.1654369E 0
0.6900001E 02	-0.7069089E 00	0.2185666E-02	0.1557095E 0
0.7000001E 02	-0.7073048E 00	0.2115346E-02	0.1459887E 0
0.7100001E 02	-0.7076835E 00	0.2022113E-02	0.1362777E 0
0.7200001E 02	-0.7080444E 00	0.1904989E-02	0.1265811E 0
0.7300001E 02	-0.7083868E 00	0.1763085E-02	0.1169026E 0
0.7400001E 02	-0.7087103E 00	0.1595430E-02	0.1072463E 0
0.7500001E 02	-0.7090147E 00	0.1401165E-02	0.9761683E-01
0.7600001E 02	-0.7092990E 00	0.1179288E-02	0.8801807E-01
0.7700001E 02	-0.7095643E 00	0.9289390E-03	0.7845410E-01
0.7800001E 02	-0.7098090E 00	0.6491260E-03	0.6892985E-01
0.7900001E 02	-0.7100330E 00	0.3388950E-03	0.5944953E-01
0.8000001E 02	-0.7102365E 00	-0.2669956E-05	0.5001742E-01
0.8100001E 02	-0.7104197E 00	-0.3765321E-03	0.4063890E-01
0.8200001E 02	-0.7105822E 00	-0.7835683E-03	0.3131806E-01
0.8300001E 02	-0.7107242E 00	-0.1224829E-02	0.2205949E-01
0.8400001E 02	-0.7108463E 00	-0.1701151E-02	0.1286814E-01
0.8500001E 02	-0.7109491E 00	-0.2213553E-02	0.3749246E-02
0.8600001E 02	-0.7110321E 00	-0.2762926E-02	-0.5292826E-02
0.8700001E 02	-0.7110958E 00	-0.3350210E-02	-0.1429308E-01
0.8800001E 02	-0.7111417E 00	-0.3976356E-02	-0.2312595E-01
0.8900001E 02	-0.7111698E 00	-0.4642267E-02	-0.3190705E-01
0.9000001E 02	-0.7111817E 00	-0.5348848E-02	-0.4059091E-01

IP	BB	R1	R2	GAMMA	POISSONS	E
0.50400E-02	0.62370E 01	0.57370E 01	0.89450E 01	0.58000E 02	0.36000E 00	0.30000E 08

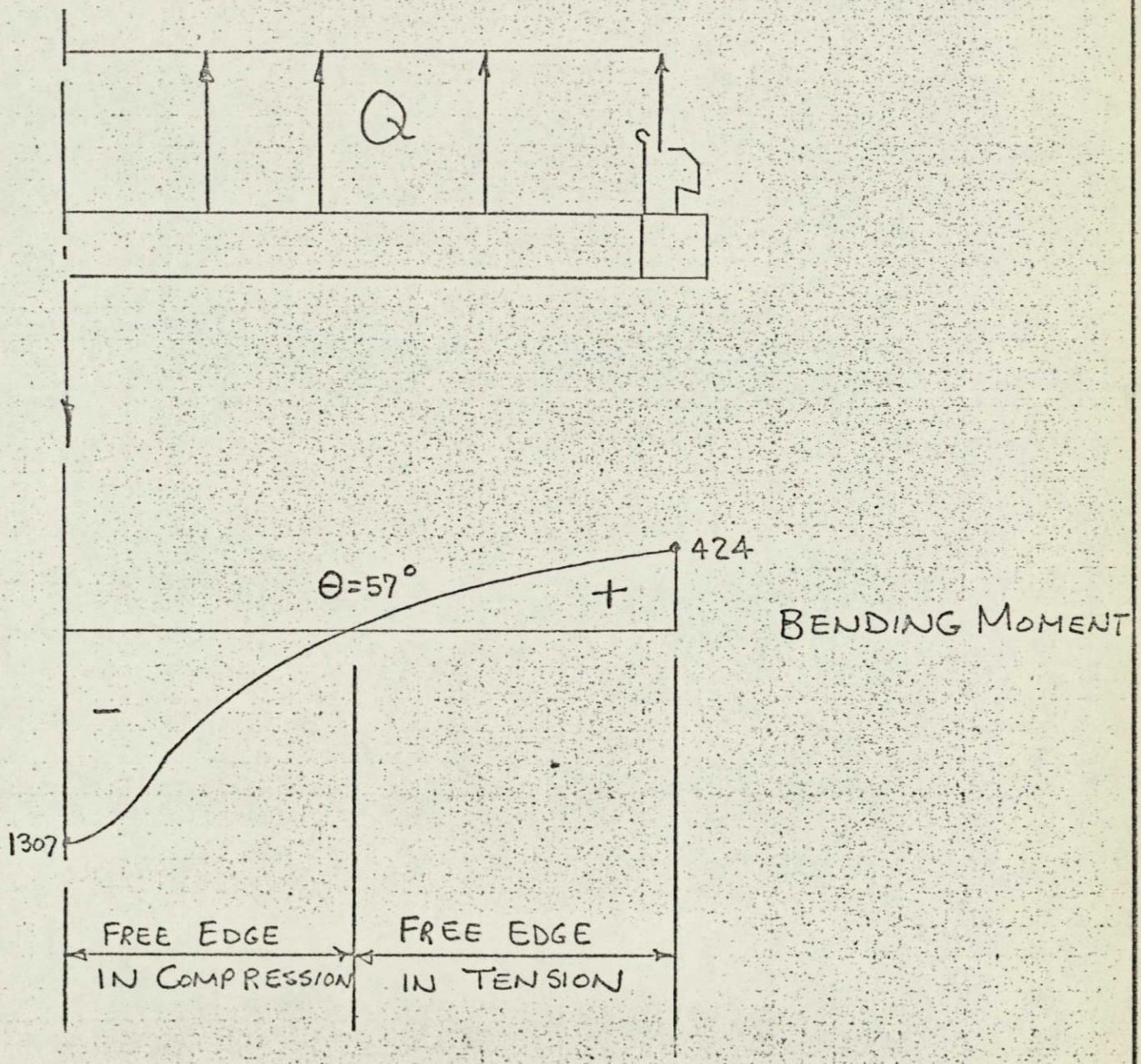
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CALC. NO
MODEL
PART NO

INSTABILITY OF TOP EDGE OF UPPER WAIST RING

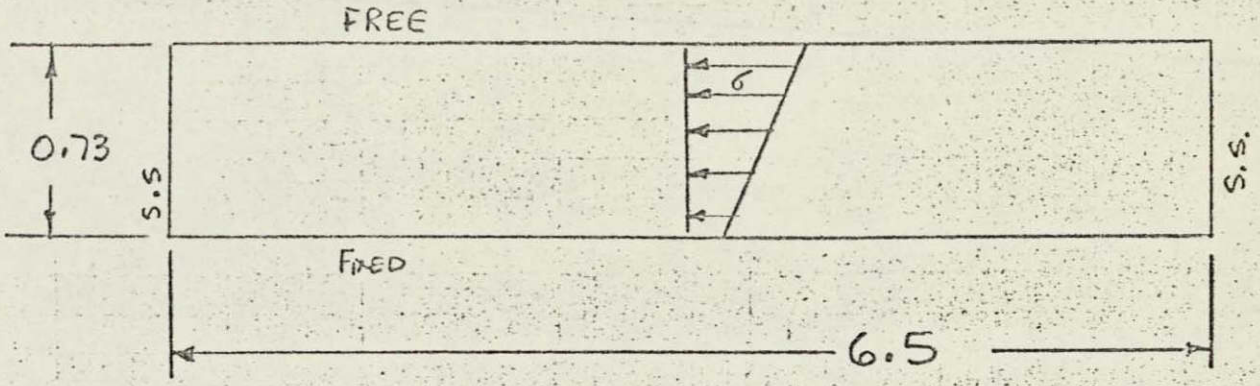


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$t = 0.025$

$I = 0.02004 \text{ in}^4$

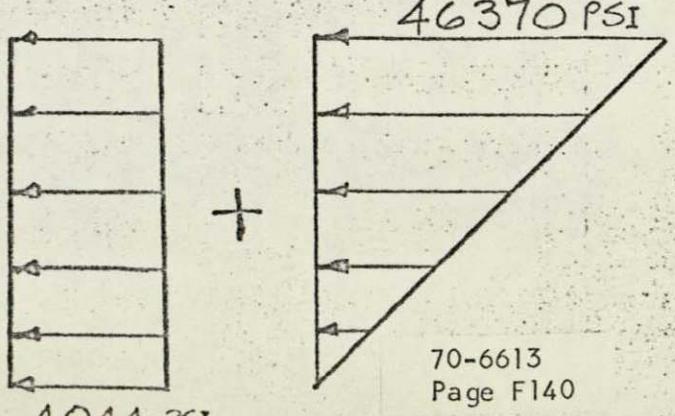
$c_t = 0.773$

$c_b = 0.062$

$M_{center} = 1307$

$$\sigma_{max} = \frac{-1307(0.773)}{0.02004} = -50414 \text{ psi}$$

$$\sigma_{min} = \frac{-1307(0.062)}{0.02004} = -4044. \text{ psi}$$



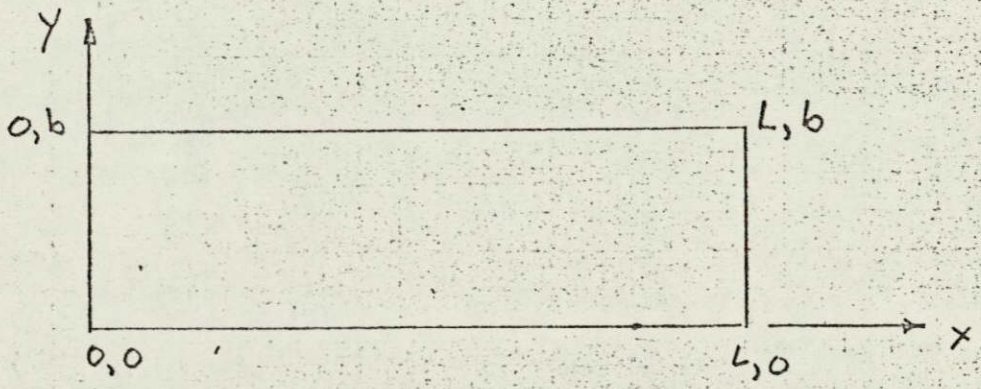
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To approximate the free edge, assume that the plate width is $2(0.73) = 1.46$ in and use case 9 p. 313 in Roark.

$$\alpha = \frac{\sigma_{min}}{\sigma_{max} - \sigma_{min}} = \frac{4044}{50414 - 4044} = \frac{4044}{46370} = 0.087$$

$$\frac{a}{b} = \frac{6.5}{1.46} = 4.45$$

Outside of Roark's formula. For an approximate solution, do the following:



$$\nabla^4 W = -\frac{N_x}{D} \frac{\partial^2 W}{\partial x^2}$$

Assume a form for W & N_x that satisfies the boundary conditions:

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LET:

$$N_x = N_{x\max}\, y \sin\frac{\pi x}{L}$$

$$W = \bar{W} y^2 \sin\frac{n\pi x}{L}$$

substitute into the differential equation:

$$+\bar{W} y^2\left(\frac{n\pi}{L}\right)^4 + 4\bar{W}\left(\frac{n\pi}{L}\right)^2 = -\frac{N_{x\max}}{D}\bar{W} y^3\left(\frac{n\pi}{L}\right)^2 \sin\frac{\pi x}{L}$$

$$-y^2\left(\frac{n\pi}{L}\right)^2 + 4 = \frac{N_{x\max}}{D} y^3 \sin\frac{\pi x}{L}$$

$N_{x\max}$ will be a maximum at $y = b$, $x = \frac{L}{2}$
$n = 1$

$$\therefore N_{x\max} = -\frac{D}{b^3}\left\{4 - \left(\frac{b\pi}{L}\right)^2\right\}$$

This solution approaches the true value from above.

$$\therefore N_{x\max} < -\frac{D}{b^3}\left\{4 - \left(\frac{b\pi}{L}\right)^2\right\}$$

$$\sigma_{max} < \frac{N_{x\max}}{h}$$

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$$\sigma_{max} < \frac{-E h^2}{12(1-\nu^2)b^3}\left\{4-\left(\frac{b\pi}{L}\right)^2\right\}$$

$E = 30\times10^6$
$\nu = 0.36$
$b = 0.73$
$L = 6.5$
$h = 0.025$

$$\therefore \sigma < \frac{-30\times10^6(.025)^2}{12(1-.36^2)(.73)^3}\left\{4-\left(\frac{\pi\times.73}{6.5}\right)^2\right\}$$

$$\sigma < -4614 \text{ psi}$$

Stress at free edge is -5041 4.

Therefore this edge will buckle and not be effective.

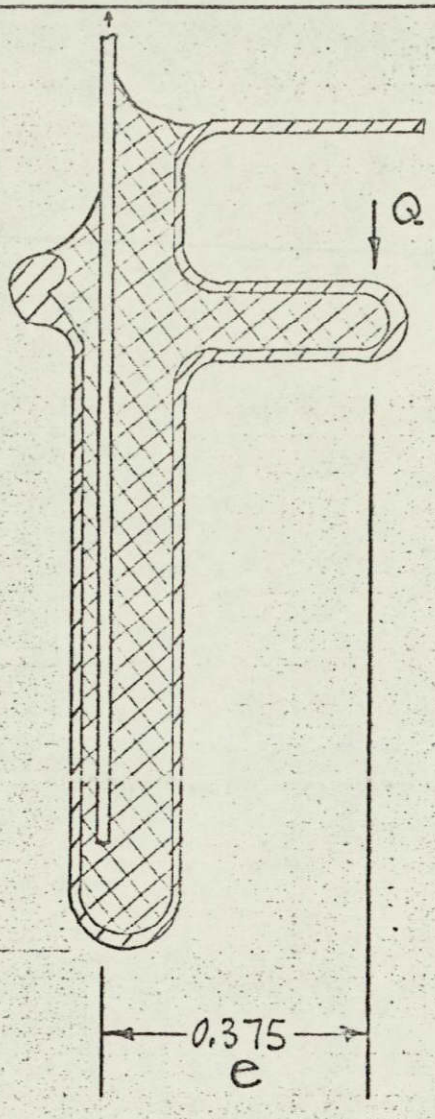
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UPPER SUIT EDGE RING



$Q = 15$ #/in

$Qe = 0.375(15) = 5.62$ # in/in (at proof press)

$$M_b = -Q[Re(1-\sin\gamma) + re\sin\gamma]$$

$$M_{bb} = -Q[re(1-\cos\gamma) + Re\cos\gamma]$$

$R = 8.94$
$r = 5.73$
$\gamma = 58°$

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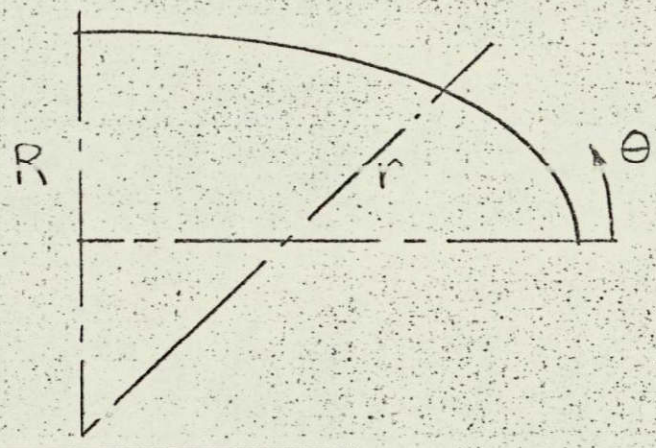
CALC. NO
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$\theta < \gamma$

$$M = M_{bb}\cos\theta - Qer(1-\cos\theta)$$
$$T = M_{bb}\sin\theta + Qer\sin\theta$$

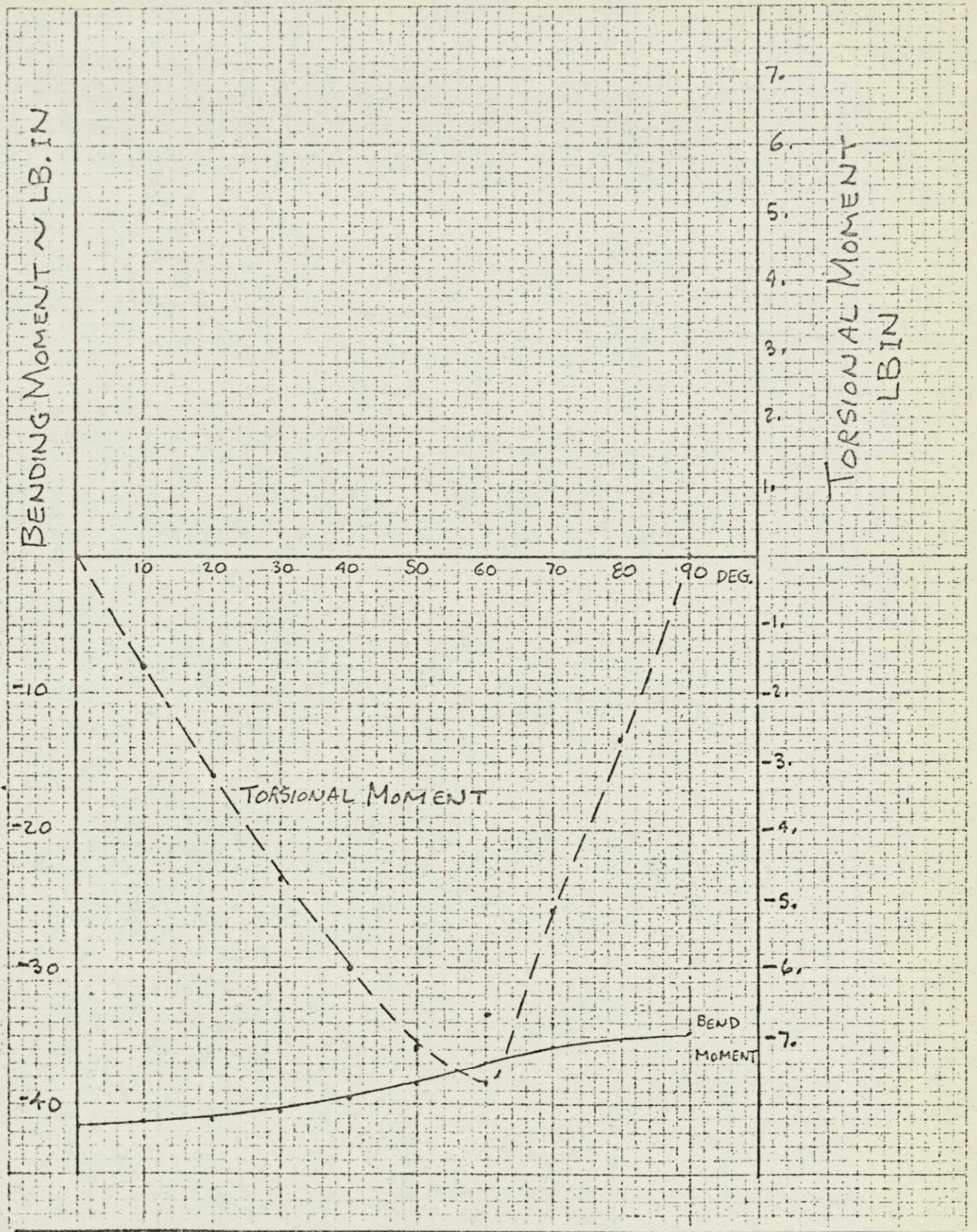
$\theta > \gamma$

$$M = -M_b\sin\theta - QeR(1-\sin\theta)$$
$$T = +M_b\cos\theta - QeR\cos\theta$$

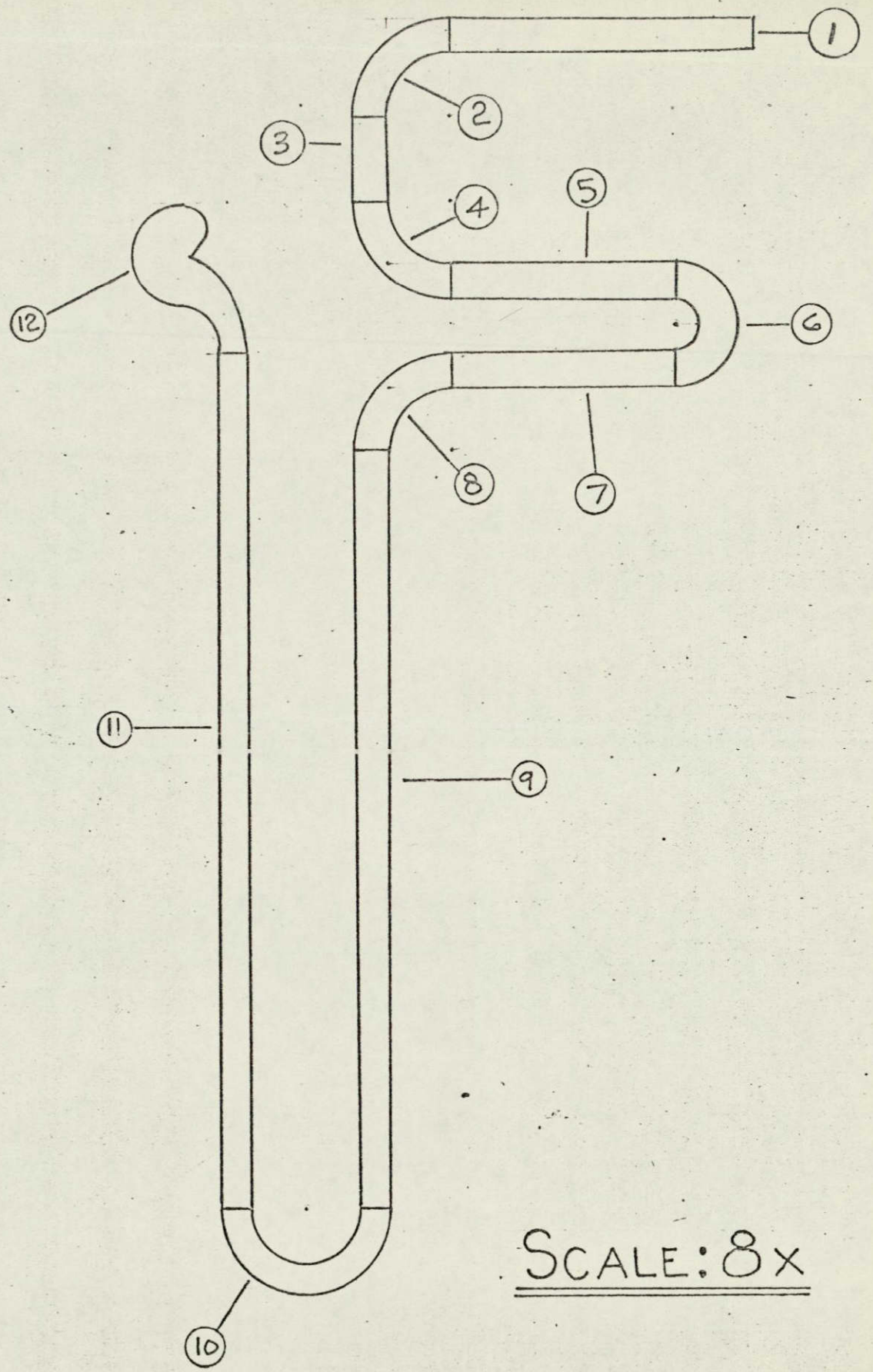


θ	M	T
0	-41.7	0
10	-41.6	-1.6
20	-41.2	-3.2
30	-40.5	-4.7
40	-39.6	-6.
50	-38.4	-7.2
60	-37.0	-7.7
70	-35.9	-5.2
80	-35.2	-2.7
90	-34.9	0

(Moments are in LB IN.)



CALCULATED BY	M.UJ.		UPPER SUIT EDGE RING
TRACED BY			
CHECKED BY			
APPROVED BY			AIRESEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION LOS ANGELES, CALIFORNIA
UNIT NO.			



SCALE: 8X

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ITEM	Y	AY	AY^2	I_{oxx}	A
1	1.05	0.00672	0.00672	—	0.0064
2	1.03	0.00257	0.00265	—	0.0025
3	0.95	0.00171	0.00162	—	0.0018
4	0.869	0.00217	0.00188	—	0.0025
5	0.845	0.00397	0.00335	—	0.0047
6	0.805	0.00201	0.00162	—	0.0025
7	0.771	0.00362	0.00279	—	0.0047
8	0.755	0.00188	0.00142	—	0.0025
9	0.39	0.00608	0.00237	0.0005	0.0156
10	0.047	0.00021	—	—	0.0046
11	0.432	0.0076	0.00328	0.00075	0.0178
12	0.855	0.00342	0.00292	—	0.004
		0.04196	0.03062	0.00125	0.0696

$$\bar{Y} = \frac{0.04196}{0.0696} = 0.60287 \text{ in}$$

$$I_{xx} = 0.00125 + 0.03062 - 0.60287(0.04196)$$

$$= 0.00657 \text{ in}^4$$

$M_{max} = 34.9$ #in

$C = 0.6$ in

$I = 0.00657$ in^4

$$\sigma_b = \frac{Mc}{I} = \frac{34.9 \times 0.6}{6.57 \times 10^{-3}}$$

$$\sigma_b = \underline{3200 \text{ psi}}$$

TORSIONAL STRESSES

$T = 7.7$ #in

$U \approx 2.4$

$$K = \frac{1}{3} U t^3$$

$t = 0.025$

$$K = \frac{1}{3}(2.4)(2.5 \times 10^{-2})^3 = 13 \times 10^{-6} \text{ in}^4$$

$C \approx 0.025$

$$\tau = \frac{Tc}{K}$$

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$$\tau = \frac{7.7 \times 0.025}{13 \times 10^{-6}}$$

$$\tau = 0.0148 \times 10^{6}$$

$$\tau = \underline{14800. \text{ PSI}}$$

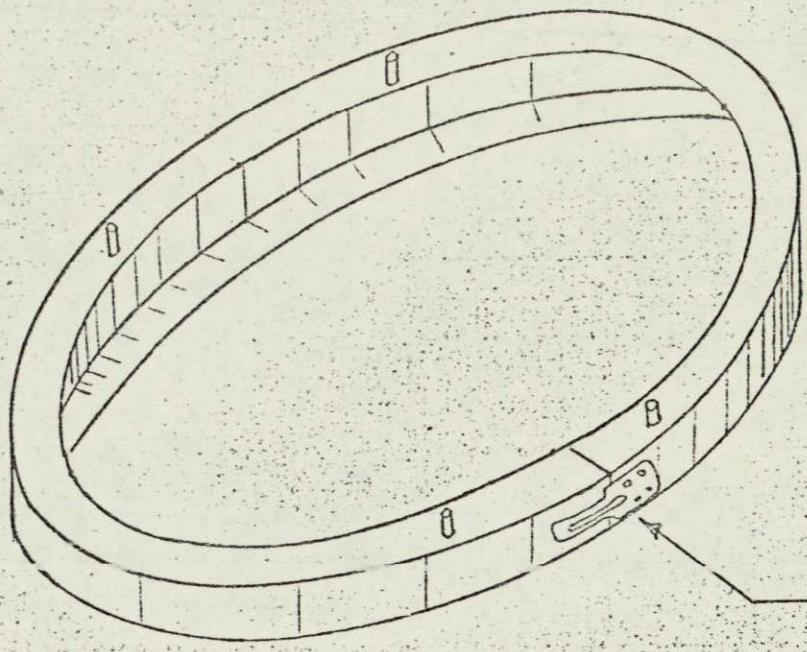
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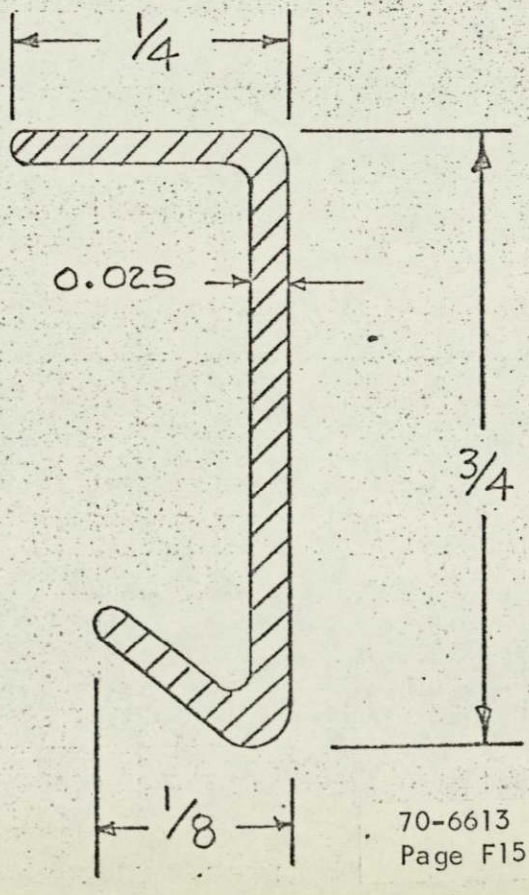
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DATE 8-15-69
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CALC. NO
MODEL
PART NO

SUIT LOCK RING





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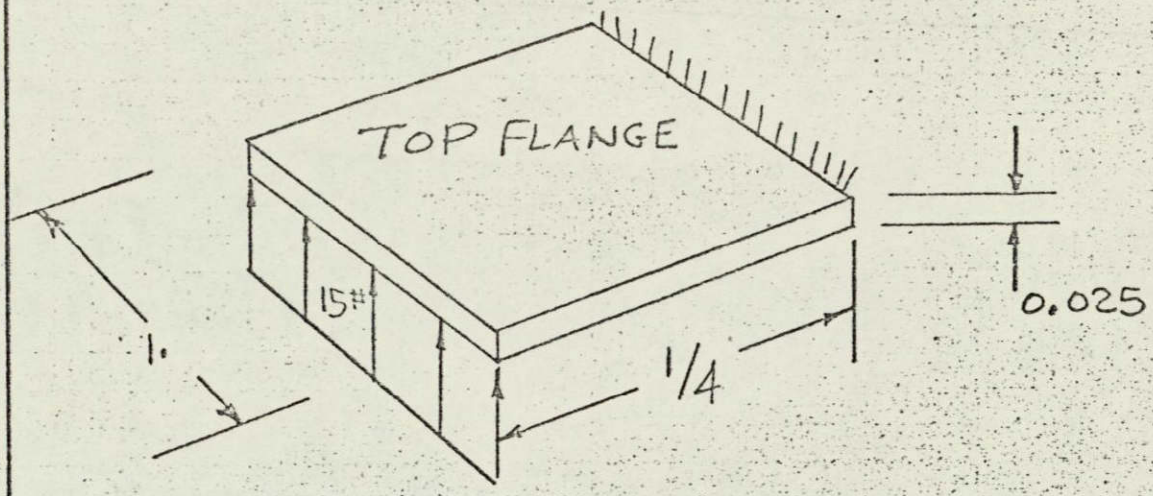
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DATE 8-15-69
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MODEL
PART NO.

LOAD PER INCH ON LOCK RING = 15 #/IN
(OPERATING LOAD)



assume a 1 inch length of flange and treat it as a cantilever beam.

$$M = 15 \times 1 \times 1/4 = 3.75 \text{ \# in}$$

$$\sigma = \frac{6M}{t^2} = \frac{6(3.75)}{(0.025)^2} = 36{,}000 \text{ psi}$$

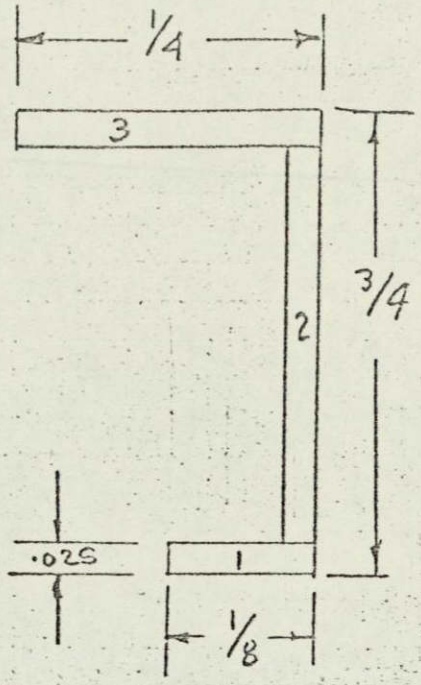
TORSION DUE TO LOAD NOT BEING APPLIED AT SHEAR CENTER

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CHECKED BY

CALC. NO
MODEL
PART NO

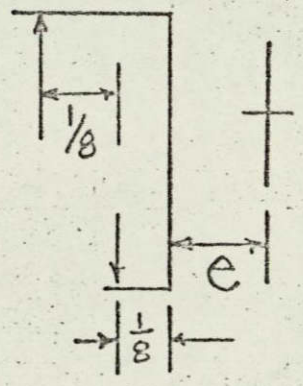


ITEM	y	A	Ay	Ay^2	I_{oxx}
1	.0125	.0031	.0000387	—	—
2	.375	.0175	.00656	.00246	.0007
3	.737	.0062	.00456	.00336	—
		.0268	.0111587	.00582	.0007

$\bar{y} = .4163$

$I_{xx} = .00652 - .0111587(.416369) = .00187$

$$e = \frac{b^2 h^2 L}{4 I_{xx}} = \frac{(0.25)^2 (.125)^2 (.025)}{4(.00187)} = 0.109 \text{ in}$$



$$T = 15\left(\frac{1}{4} + e - \frac{1}{8} - e\right) = \frac{15}{8} = 1.875 \text{ \#in}$$

$$K \approx \frac{1}{3} U t^3 = \frac{1}{3}(1.125)(.025)^3 = 0.0000058594 \text{ in}^4$$

$$\tau = \frac{Tc}{K} = \frac{1.875 \times .025}{.58594 \times 10^{-5}} = 8000 \text{ psi}$$

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ACTUALLY, MOST OF THIS TORQUE

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CALC. NO
MODEL
PART NO

WILL SHOW UP AS RING BENDING.
Since this ring is similar to the Upper suit edge ring, the following should apply:

* $T_{torsion} \approx 0.5\,T$

$\therefore\ T = 0.5(8000) = \underline{4000\ psi}$

* $M_b = 1.875 \times \frac{40}{15} = 5\ ^{\#}_{in}$

$$\sigma_b = \frac{5. \times 0.4163}{.187 \times 10^{-2}} = \underline{\underline{100\ psi}}$$

* $\frac{40}{15}$ is the ratio of M_b to ring couple
0.5 is the ratio of $T_{torsion}$ to ring couple for the Upper suit edge ring.

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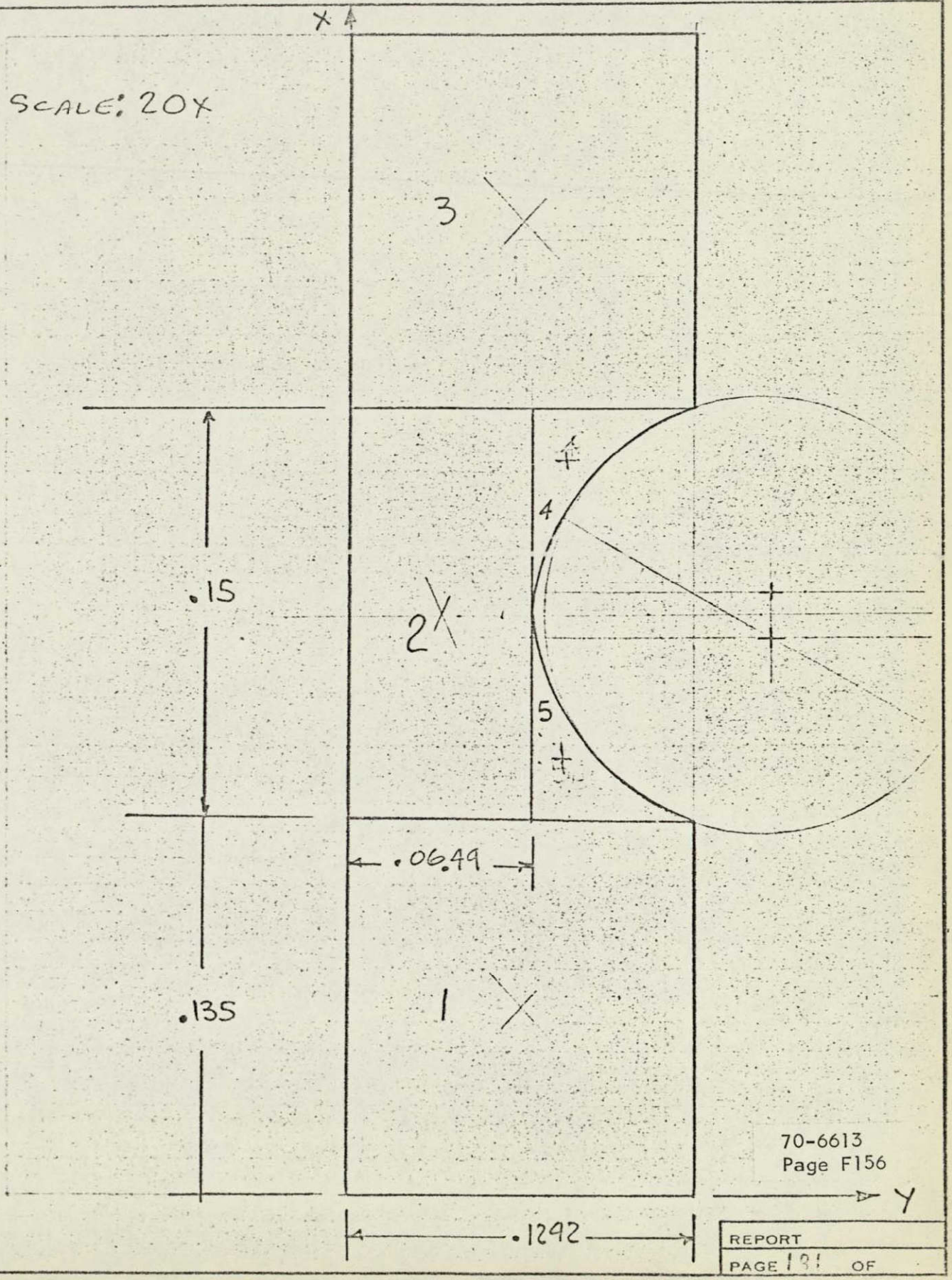
SHOULDER BEARING ANALYSIS

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ITEM	AREA	x	y	Ay	Ay²	Ax²	I_{oxx}	I_{oyy}
1	.0168	.0675	.0621	.00104	.0000645	.0000765	.0000216	.0000254
2	.00971	.21	.034	.00033	.0001122	.000428	—	.0000182
3	.0168	.35	.0621	.00104	.0000645	.002058	.0000216	.0000254
4	.0013	.265	.0775	.0001	.0000775	.00009129	—	—
5	.0013	.1575	.0775	.0001	.0000775	.000032	—	—
	.04591			.00261	.000155	.002686	.0000431	.000069

$$\bar{y} = \frac{.00261}{.04591} = 0.05685$$

$$\bar{x} = .210 \qquad F = \sum_{u=.42} t_i^3 u_i = (.1242)^3(2)(.135) + .15(.0644)^3 = .00055828$$

$$I_x = .0000431 + .000155 - .00261(.05685) = 0.0000 4972$$

$$I_y = .000069 + .002686 - .04591(.21)^2 = 0.0007303$$

$$K = \frac{\frac{1}{3}F}{1 + \frac{4}{3}\frac{F}{Au^2}} = 0.0001704 \text{ in}^4 \quad \text{Ref: Roark p. 176 case 16}$$

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PREPARED BY_____ MODEL_____

CHECKED BY_____ PART NO_____

HERTZ STRESS BETWEEN BALLS & RACE

$R_{1\,race} = 0.0875$

$R'_{1\,race} = 4.6286$

$R_{2\,ball} = R'_{2\,ball} = 0.07835$

$$\#balls = \frac{\pi(9.0985)}{0.1875} - 1 = 151.$$

$$\text{total load} \approx 305.5 / \sin 30^\circ = 611^{\#}$$

$$\text{load/ball} = \frac{611}{151} = 4.05^{\#}$$

Ref: Roark 3rd edit p. 289 case 8

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$$\delta = \frac{4}{\frac{1}{.0875} + \frac{2}{.07835} + \frac{1}{4.6286}} = 0.1076104$$

$$\phi = \pi/2$$

$$\cos 2\phi = -1.$$

$$\theta = \cos^{-1}\frac{\delta}{4}\left[\left(\frac{1}{.0375} - \frac{1}{4.6286}\right)^2\right]^{1/2} = \cos^{-1} 0.30164$$

$$K = \frac{8}{3}\frac{10^7}{2(1-.3^2)} = \frac{1.3333}{0.91}\times 10^7 = 1.4652 \times 10^7$$

$$\Theta = 72.5^\circ$$

$$\alpha = 1.243$$
$$\beta = 0.824$$
$$\lambda = 1.9555$$

$$C = 1.243\left[\frac{4.050 \times .10761}{1.4652 \times 10^7}\right]^{1/3} = 1.293\left(29.908\times 10^{-9}\right)^{1/3} = .00386$$

$$d = 0.824\left[\frac{4.050 \times .10761}{1.4652 \times 10^7}\right]^{1/3} = 0.824\left(29.906\times 10^{-9}\right)^{1/3} = .00256$$

$$y = 1.9555\left[\frac{4.050^2 \times 10^{-14}}{1.4652^2 \times .1076104}\right]^{1/3} = 1.95555\left(.71000\times 10^{-12}\right)^{1/3} = .000175$$

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$$S_{comp} = \frac{1.5P}{\pi cd} = \frac{1.5(4.05)\times10^6}{\pi(3.86)(2.56)} = 196000. \text{ psi}$$

From Mark Hdbk 5th Edit p. 983

$$S_{mem} = \frac{S_{max}}{1.5}$$

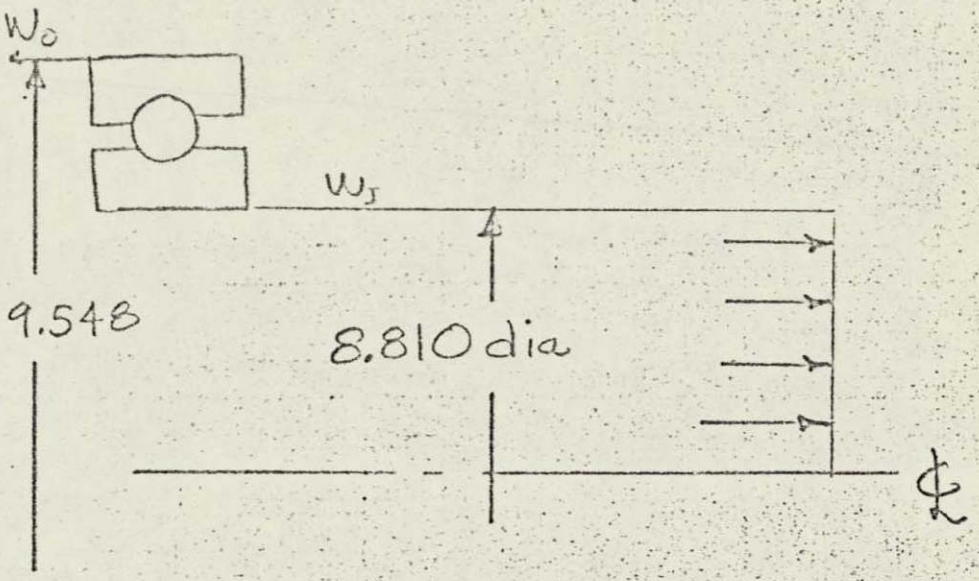
$$S_m = \frac{196{,}000}{1.5} = 131{,}000 \text{ psi}$$

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$$A = \frac{\pi}{4} d^2 = \frac{\pi}{4}(8.81)^2 = 61.1 \text{ in}^2$$

$$W_I = \frac{5(61.1)}{\pi(8.81)} = 11.05 \text{ \#/IN}$$

$$W_o = \frac{5(61.1)}{\pi(9.548)} = 10.15 \text{ \#/IN}$$

Form 2427

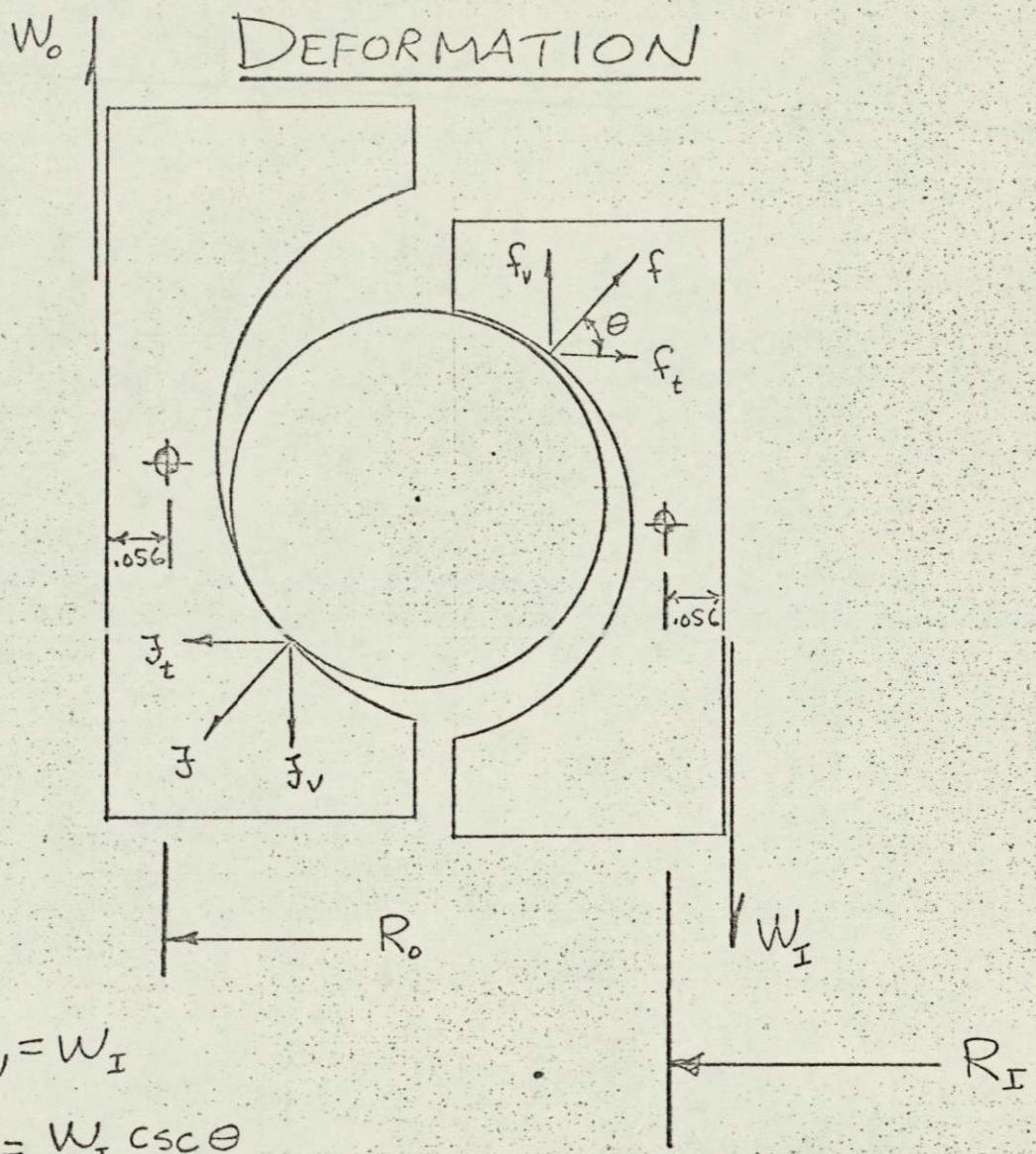
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BALL MOUEMENT IN RACE DUE TO RACE

DEFORMATION



$f_v = W_I$

$f = W_I \csc\theta$

$f_t = W_I \cot\theta$

$\mathcal{F}_v = W_o$

$\mathcal{F} = W_o \csc\theta$

$\mathcal{F}_t = W_o \cot\theta$

$R_I \approx 4.461$

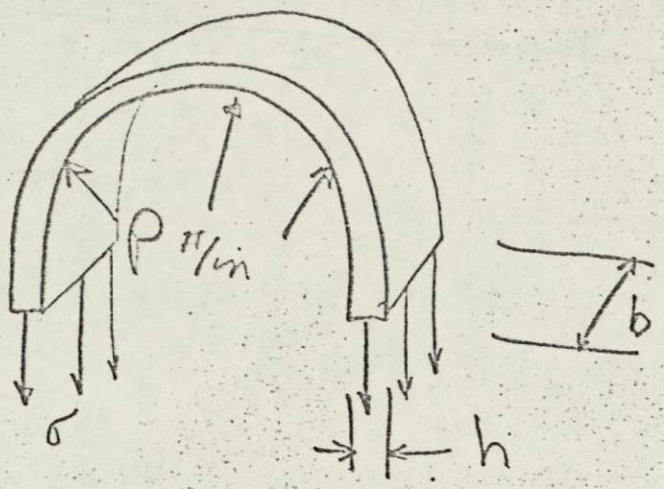
$R_o \approx 4.637$

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$$2RP = 2bh\sigma$$

$$\sigma = \frac{PR}{bh}$$

$$\epsilon = \frac{\Delta R}{R} = \frac{\sigma}{E} = \frac{PR}{Ebh}$$

$$\therefore \Delta R = \frac{PR^2}{Ebh}$$

$b = 0.42$

$h \approx \frac{1}{2}(.0649 + .1242) = 0.095$

$bh = 0.04$

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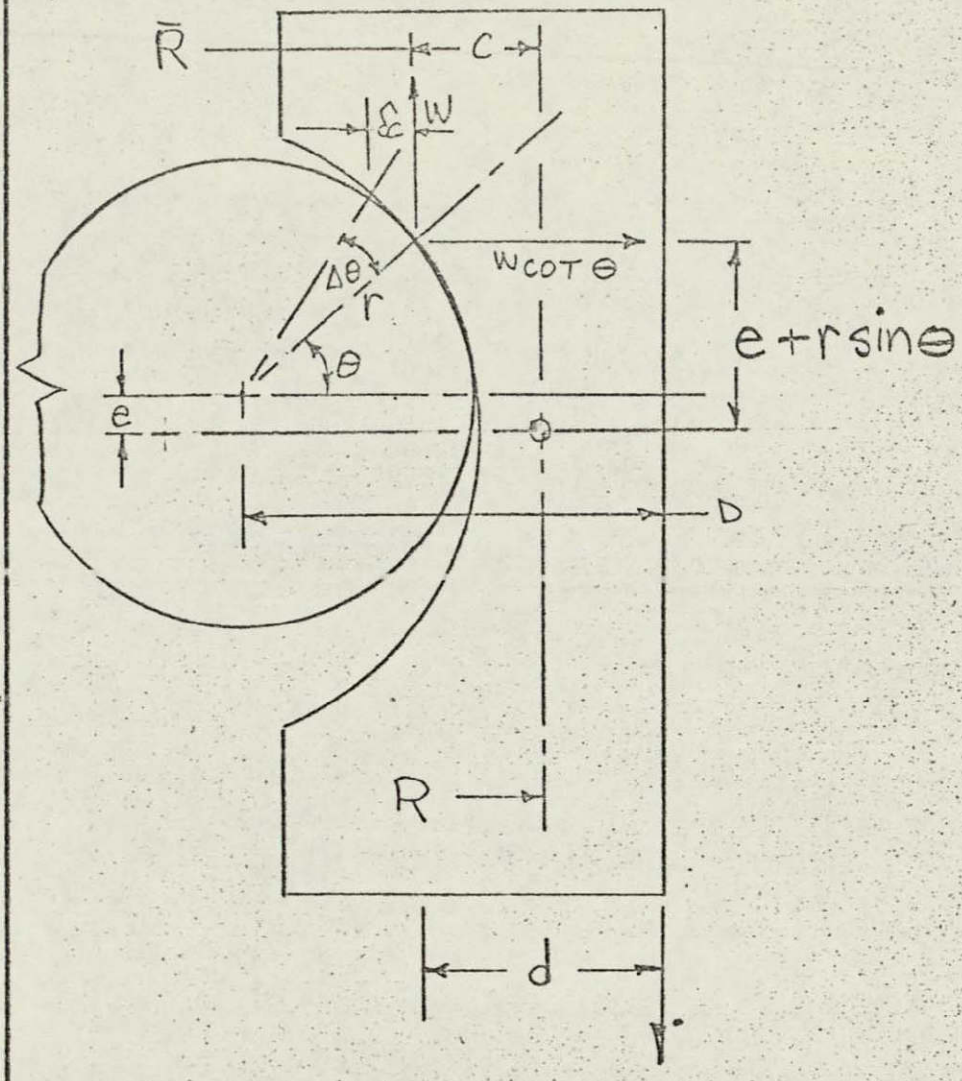
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RACE ROTATION BY ITERATION



$$d = D - r\cos\theta$$

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$$\Delta R = \frac{P \bar{R}^2}{Ebh}$$

$$\Delta\theta = \frac{m R^2}{EI}$$

$$m = W\cot\theta\left[e + r\sin\theta\right] + \left[D - r\cos\theta\right]W$$

$$\cot\theta = \frac{\cos\theta}{\sin\theta}$$

$$m = eW\cot\theta + DW$$

let $\theta + \Delta\theta = \theta$

$$m = W\left\{e\cot(\theta+\Delta\theta) + D\right\}$$

$$P = W\cot(\theta+\Delta\theta)$$

Total angle change = $\theta_{TWIST} + \theta_{ring\ disp}$

$$\bar{R} = R - C - \delta c$$

$$\delta c = r\cos\theta - r\cos(\theta+\Delta\theta) = \Delta R$$

$$\bar{R} = R - C - r\left\{\cos\theta - \cos(\theta+\Delta\theta)\right\}$$

$$\therefore \Delta R = \frac{P}{Ebh}\left\{R - C - r\left[\cos\theta - \cos(\theta+\Delta\theta)\right]\right\}^2$$

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$$r\cos\theta - r\cos(\theta+\Delta\theta_{ring\,disp}) = \frac{W}{Ebh}\cot(\theta+\Delta\theta_T)\left\{R-c - r\left[\cos\theta-\cos(\theta+\Delta\theta_T)\right]\right\}^2$$

$$\Delta\theta_T = \Delta\theta_{TWIST} + \Delta\theta_{ring\,disp}$$

$$\Delta\theta_{TWIST} = \frac{R^2}{EI}W\left[e\cot(\theta+\Delta\theta_T) + D\right]$$

let θ = initial contact angle

Proceedure

PICK a $\Delta\theta_{T_{GUESS}}$
sdue for $\Delta\theta_{ring\,disp}$ & $\Delta\theta_{TWIST}$

$$\Delta\theta_{T_{GUESS}} - \Delta\theta_{ring\,disp} - \Delta\theta_{TWIST} = TEST$$

IF TEST
- <0 decrease $\Delta\theta_{T_{G+1}}$
- $=0$ problem solved
- >0 increase $\Delta\theta_{T_{G+1}}$

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$$\Delta\theta_{TWIST} = \frac{R^2 W}{EI}\left[e\cot(\theta+\Delta\theta_T)+D\right]$$

$$\cos(\theta+\Delta\theta_{RING\ DISP}) = \cos\theta - \left[\frac{W}{Ebhr}\right]\cot(\theta+\Delta\theta_T)\left\{[R-C] - r[\cos\theta - \cos(\theta+\Delta\theta_T)]\right\}^2$$

$$\Delta\theta_T - \Delta\theta_{ring\ disp} - \Delta\theta_{TWIST} = TEST$$

$$TAN(\theta+\Delta\theta_{ring\ disp}) = \frac{1.}{\cos^2(\theta+\Delta\theta_{ring\ disp})} - 1.$$

```
PAGE    1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0002        0002        0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
      READ(2,5)RR,RB,RI,AREA,E,D,EXC,W
      READ(2,5)C
    5 FORMAT(8E10.5)
      THE TA=0.
      CON1=W/(E*AREA*RB)
      CON2= RR*RR*W/(E*RI)
    7 ANG3=0.523598+THETA
      COT=COS(ANG3)/SIN(ANG3)
      AID1=0.866-CON1*COT*(RR-C-RB*(.866-COS(ANG3)))**2
      AID2=CON2*(EXC*COT+D)
      TAN1= 1./(AID1*AID1)-1.
      AID3 =ATAN(TAN1)
      AID4=AID3-0.523598
      TEST= THETA-AID4-AID2
      WRITE(3,10)THETA,AID4,AID2,TEST
   10 FORMAT(1H ,4E14.7)
      IF(TEST)40,30,20
   20   THETA=THETA-.001
      GO TO 7
   30 GO TO 100
   40 THETA=THETA +.001
      GO TO 7
  100 STOP
      END

VARIABLE ALLOCATIONS
    RR(R )=0000        RB(R )=0002        RI(R )=0004      AREA(R )=0006
   EXC(R )=000C         W(R )=000E         C(R )=0010     THETA(R )=0012
  ANG3(R )=0018       COT(R )=001A      AID1(R )=001C      AID2(R )=001E
  AID4(R )=0024      TEST(R )=0026

STATEMENT ALLOCATIONS
 5    =003C  10   =003F  7    =0091  20   =00FA  30   =0102  40   =0104  100

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FCOS    FSIN    FATAN   FSUB    FMPY    FLD     FSTO    FSBR    FDVR    FAXI
 SFIO    SIOF    STOP

REAL CONSTANTS
  .000000E 00=002C    .523598E 00=002E    .866000E 00=0030    .100000E 01=0032

INTEGER CONSTANTS
     2=0036      3=0037      0=0038

CORE REQUIREMENTS FOR RING
 COMMON      0  VARIABLES     44  PROGRAM     226
```

```
PAGE   1

// JOB T

LOG DRIVE    CART SPEC    CART AVAIL   PHY DRIVE
  0000         0002         0002         0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)

FEATURES SUPPORTED
 IOCS

CORE REQUIREMENTS FOR RING
 COMMON       0  VARIABLES      44  PROGRAM     226

 END OF COMPILATION

// XEQ
```

① ② ③ ②+③ - 1

$\Delta\Theta_T$	$\Delta\Theta_{ring\ disp}$	$\Delta\Theta_{TWIST}$	
0.0000000E 00	0.1311339E 00	0.8066512E-01	-0.2117990E 00
0.1000000E-02	0.1303519E 00	0.8060666E-01	-0.2099585E 00
0.2000000E-02	0.1295724E 00	0.8054840E-01	-0.2081207E 00
0.3000000E-02	0.1287954E 00	0.8049035E-01	-0.2062857E 00
0.3999999E-02	0.1280211E 00	0.8043250E-01	-0.2044536E 00
0.4999998E-02	0.1272491E 00	0.8037483E-01	-0.2026239E 00
0.5999998E-02	0.1264801E 00	0.8031737E-01	-0.2007974E 00
0.6999997E-02	0.1257131E 00	0.8026009E-01	-0.1989732E 00
0.7999997E-02	0.1249488E 00	0.8020304E-01	-0.1971518E 00
0.8999995E-02	0.1241871E 00	0.8014614E-01	-0.1953332E 00
0.9999994E-02	0.1234277E 00	0.8008946E-01	-0.1935172E 00
0.1099999E-01	0.1226707E 00	0.8003297E-01	-0.1917037E 00
0.1199999E-01	0.1219165E 00	0.7997667E-01	-0.1898932E 00
0.1299998E-01	0.1211645E 00	0.7992056E-01	-0.1880851E 00
0.1399998E-01	0.1204147E 00	0.7986463E-01	-0.1862793E 00
0.1499998E-01	0.1196677E 00	0.7980890E-01	-0.1844767E 00
0.1599998E-01	0.1189230E 00	0.7975335E-01	-0.1826764E 00
0.1699998E-01	0.1181805E 00	0.7969798E-01	-0.1808785E 00
0.1799998E-01	0.1174410E 00	0.7964280E-01	-0.1790838E 00
0.1899997E-01	0.1167031E 00	0.7958778E-01	-0.1772909E 00
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0.2399997E-01	0.1130505E 00	0.7931551E-01	-0.1683661E 00
0.2499996E-01	0.1123271E 00	0.7926160E-01	-0.1665887E 00
0.2599996E-01	0.1116056E 00	0.7920785E-01	-0.1648135E 00
0.2699996E-01	0.1108864E 00	0.7915426E-01	-0.1630407E 00
0.2799996E-01	0.1101697E 00	0.7910087E-01	-0.1612706E 00

```
0.2899996E-01 0.1094554E 00 0.7904765E-01-0.1595031E 00
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0.3199996E-01 0.1073249E 00 0.7888901E-01-0.1542140E 00
0.3299995E-01 0.1066197E 00 0.7883647E-01-0.1524562E 00
0.3399994E-01 0.1059160E 00 0.7878410E-01-0.1507001E 00
0.3499994E-01 0.1052148E 00 0.7873189E-01-0.1489467E 00
0.3599993E-01 0.1045161E 00 0.7867987E-01-0.1471960E 00
0.3699993E-01 0.1038190E 00 0.7862800E-01-0.1454471E 00
0.3799992E-01 0.1031242E 00 0.7857628E-01-0.1437006E 00
0.3899992E-01 0.1024315E 00 0.7852475E-01-0.1419563E 00
0.3999991E-01 0.1017409E 00 0.7847337E-01-0.1402144E 00
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0.9499938E-01 0.6677009E-01 0.7587555E-01-0.4764624E-01
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0.9799934E-01 0.6501711E-01 0.7574549E-01-0.4276325E-01
0.9899933E-01 0.6443609E-01 0.7570238E-01-0.4113913E-01
0.9999932E-01 0.6385661E-01 0.7565937E-01-0.3951666E-01
0.1009993E 00 0.6327869E-01 0.7561650E-01-0.3789588E-01
0.1019992E 00 0.6270219E-01 0.7557375E-01-0.3627664E-01
0.1029992E 00 0.6212771E-01 0.7553112E-01-0.3465955E-01
0.1039992E 00 0.6155467E-01 0.7548861E-01-0.3304401E-01
0.1049992E 00 0.6098330E-01 0.7544620E-01-0.3143025E-01
0.1059992E 00 0.6041324E-01 0.7540391E-01-0.2981791E-01
0.1069992E 00 0.5984473E-01 0.7536175E-01-0.2820726E-01
0.1079992E 00 0.5927801E-01 0.7531970E-01-0.2659850E-01
0.1089992E 00 0.5871237E-01 0.7527776E-01-0.2499092E-01
0.1099991E 00 0.5814863E-01 0.7523593E-01-0.2338536E-01
0.1109991E 00 0.5758643E-01 0.7519422E-01-0.2178147E-01
0.1119991E 00 0.5702544E-01 0.7515263E-01-0.2017890E-01
0.1129991E 00 0.5646646E-01 0.7511115E-01-0.1857845E-01
0.1139991E 00 0.5590890E-01 0.7506978E-01-0.1697944E-01
0.1149991E 00 0.5535257E-01 0.7502852E-01-0.1538196E-01
0.1159991E 00 0.5479753E-01 0.7498736E-01-0.1378578E-01
0.1169991E 00 0.5424452E-01 0.7494632E-01-0.1219174E-01
0.1179990E 00 0.5369282E-01 0.7490539E-01-0.1059912E-01
0.1189990E 00 0.5314219E-01 0.7486458E-01-0.9007694E-02
0.1199990E 00 0.5259347E-01 0.7482387E-01-0.7418275E-02
0.1209990E 00 0.5204594E-01 0.7478326E-01-0.5830154E-02
0.1219990E 00 0.5150032E-01 0.7474276E-01-0.4244045E-02
0.1229990E 00 0.5095577E-01 0.7470238E-01-0.2659127E-02
0.1239990E 00 0.5041254E-01 0.7466210E-01-0.1075625E-02
0.1249990E 00 0.4987133E-01 0.7462193E-01 0.5057455E-03
0.1259989E 00 0.5041254E-01 0.7466210E-01-0.1075640E-02

① $\Delta\Theta_T$	② $\Delta\Theta_{ring\ disp}$	③ $\Delta\Theta_{TWIST}$	②+③-1
0.1249989E 00	0.4987133E-01	0.7462193E-01	0.5057306E-03
0.1239989E 00	0.5041254E-01	0.7466210E-01	-0.1075655E-02
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0.1239989E 00	0.5041254E-01	0.7466210E-01	-0.1075670E-02
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0.1249989E 00	0.4987133E-01	0.7462194E-01	0.5056412E-03
0.1239989E 00	0.5041254E-01	0.7466210E-01	-0.1075729E-02
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0.1239986E 00	0.5041302E-01	0.7466211E-01	-0.1076475E-02
0.1249986E 00	0.4987133E-01	0.7462194E-01	0.5053729E-03
0.1239986E 00	0.5041302E-01	0.7466211E-01	-0.1076489E-02

.00050537
-.00107

.1249

.1246

.1245

.1240

.1239

$(.12456) = \Delta\theta_T$

$= 7.1367$ degrees

CONTACT ANGLE

$= 30 + 7.14°$

$= 37.14$ deg

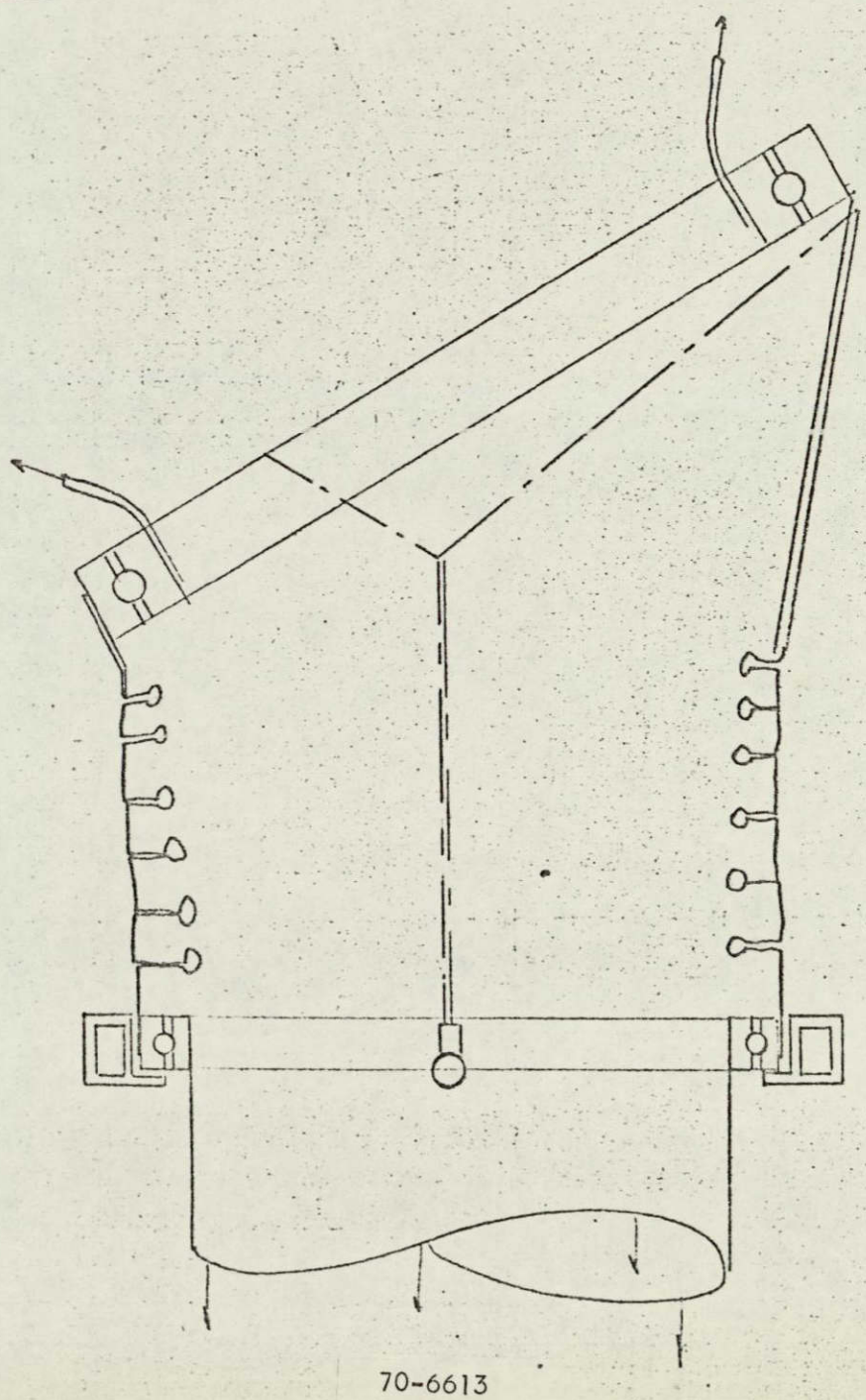
Form 2427

AiRESEARCH MFG. CO.

DATE_____
PREPARED BY_____
CHECKED BY_____

CALC. NO._____
MODEL _____
PART NO._____

HIP BEARING ASSEMBLY



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PAGE 199 OF

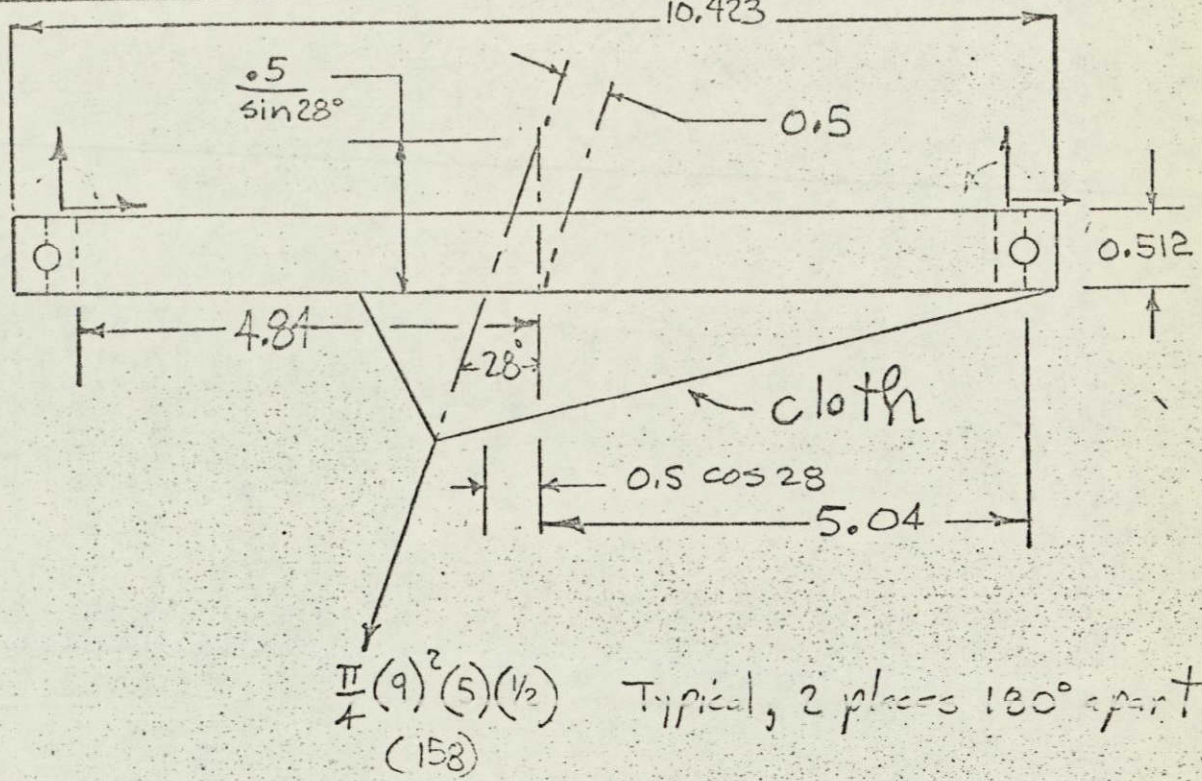
Form 2477

AiRESEARCH MFG. CO.

DATE 8-27-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

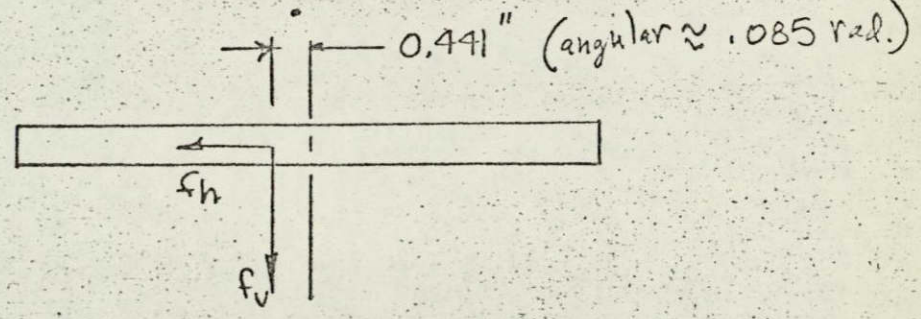
UPPER BEARING



$\frac{\pi}{4}(9)^2(5)(\frac{1}{2})$ (158) Typical, 2 places 180° apart

Most of the cloth will buckle and only a local band in the vicinity of the load line of action will be effective.

Therefore



$f_h = 158 \sin 28 = 74.$

$f_v = 158 \cos 28 = 139.$

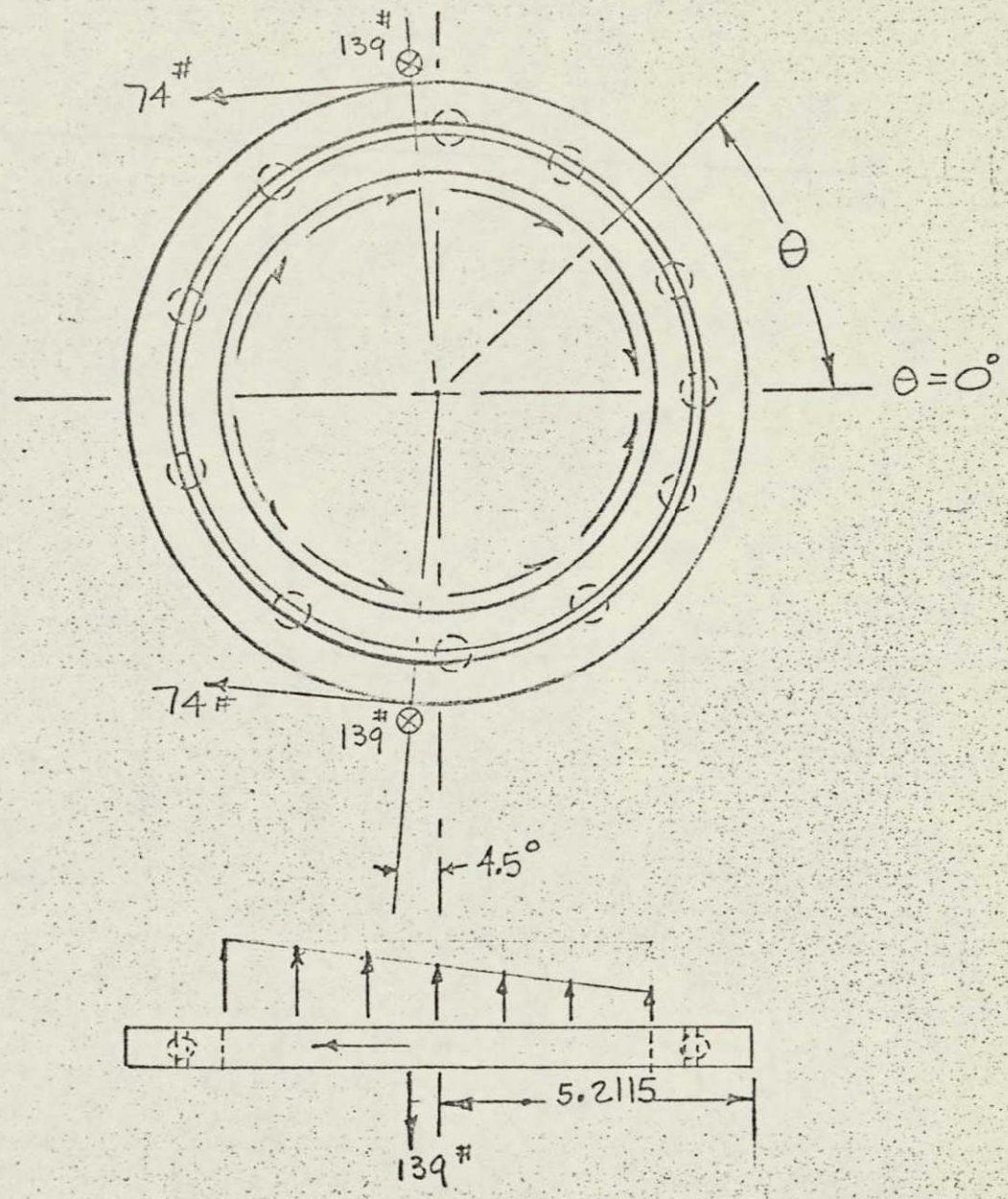
$\#\text{Balls} \approx \frac{2\pi(5.04)}{0.187} - 1 = 168$

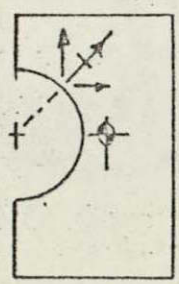
Form 2427

AiRESEARCH MFG. CO.

DATE_____
PREPARED BY_____
CHECKED BY_____

CALC. NO_____
MODEL _____
PART NO_____





moment arm = 5.2115 sin 4.5°
= 0.409"

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AiRESEARCH MFG. CO.

DATE_____ CALC. NO._____

PREPARED BY Wolfson MODEL_____

CHECKED BY_____ PART NO._____

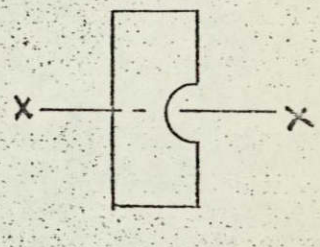
UPPER HIP BEARING INNER RACE PROPERTIES

Area	r	r^2	Ar	Ar^2	I_{o-o}
17.35	1.4	1.96	24.29	34.006	11.368
19.0	4.233	17.918	80.42	340.445	11.368
23.5	7.066	49.928	166.05	1173.31	15.726
19.2	9.899	97.9902	190.06	1881.411	12.315
13.8	12.732	162.1038	175.7	2237.032	8.905
13.7	15.565	242.269	213.24	3319.	8.905
19.1	18.398	338.986	351.401	6465.08	12.694
23.6	21.231	450.755	504.05	10637.8	15.726
10.4	24.06	578.88	250.224	6020.38	5.684
159.65			1955.4	32108.4	102.691

ALL VALUES BASED ON A 50x PRINT

$$\bar{r} = \frac{1955.4}{159.65} = \frac{12.248}{50} = 0.2449 \text{ in}$$

$$I = 32108.4 + 102.691 - 1955.4(12.248)$$



$$I = \frac{8260.99}{6.25 \times 10^6} = 0.001321 \text{ in}^4$$

$$A = \frac{159.65}{2500} = 0.06386 \text{ in}^2$$

BASED ON DWG. L145595

REPORT
PAGE 202 OF

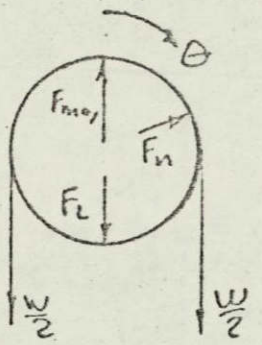
Form 2427

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DATE
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CALC. NO
MODEL
PART NO

BALL LOAD BASED ON A RIGID RACE (no clearance)



$$W = 2\sum_{n=1}^{L} F_n \cos\theta_n$$

$$\delta = \delta_{max}\cos\theta_n$$

$$F = K\delta$$

$$W = 2K\delta_{max}\sum_{n=1}^{L}\cos^2\theta_n$$

$$F_{max} = K\delta_{max}$$

$$W = 2F_{max}\sum_{n=1}^{L}\cos^2\theta_n$$

$$F_{max} = \frac{W}{2\sum_{n=1}^{L}\cos^2\theta_n}$$

($L - \frac{1}{2}$ number of balls)

$$\#\text{balls} = \frac{2\pi(5.09)}{.187} - 1. = 168.$$

$$.5W = 74\ \#$$

$$F_{max} = \frac{.5W}{1 + \sum_{n=1}^{84}\cos^2\frac{\pi n}{84}}$$

$F_{max} = 1.7209$ LBS. (due to in plane load)

```
PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0002        0002         0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
      SUM=0.0
      DO 20 N=1,84
      X=FLOAT(N)*.0373999
      C=COS(X)
   84 SUM=SUM +C*C
   20 CONTINUE
      SUM =SUM+ 1.
      FMAX= 74./SUM
      WRITE(3,10) FMAX
   10 FORMAT(1H ,5HFMAX=E14.7)
      STOP
      END
VARIABLE ALLOCATIONS
   SUM(R )=0000          X(R )=0002          C(R )=0004          FM

STATEMENT ALLOCATIONS
 10   =001A  84   =004D  20   =0055

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FCOS    FMPY    FDIV    FLD     FSTO    FLOAT   CARDZ   PRNTZ

REAL CONSTANTS
  .000000E 00=000A    .373999E-01=000C    .100000E 01=000E    .

INTEGER CONSTANTS
     1=0012     84=0013     3=0014     0=0015

CORE REQUIREMENTS FOR RING
 COMMON      0  VARIABLES.    10  PROGRAM    104

 END OF COMPILATION

// XEQ

FMAX= 0.1720938E 01
```

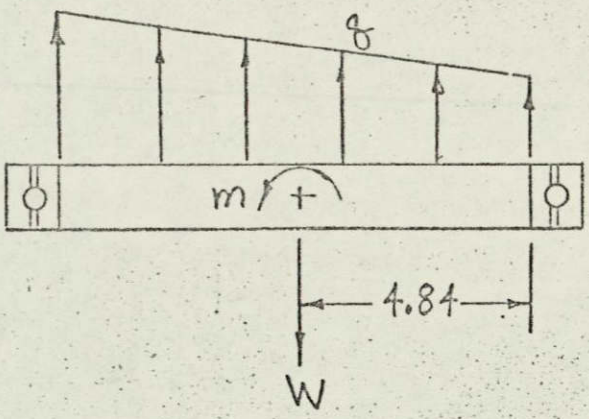
Form 2427

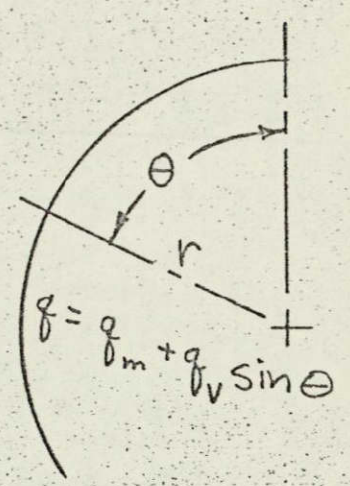
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DATE 9-4-69
PREPARED BY M. WOLFSON
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CALC. NO.
MODEL
PART NO.

UPPER HIP JOINT BEARING ASSEMBLY





$m = 55.6$ #in

$W = 139.$ #

$2\pi r \cdot q_m = 139$

$$q_m = \frac{139}{2\pi(4.84)} = 4.57 \text{ \#/in}$$

$$m = 2\int_0^{\pi/2} q_v \sin\theta \sin\theta r^2 d\theta = q_v r^2 \frac{\pi}{2}$$

$$q_v = \frac{2m}{\pi r^2} = \frac{2(55.6)}{\pi(4.84)^2} = 1.511 \text{ \#/in}$$

$$q = 4.57 + 1.511 \sin\theta$$

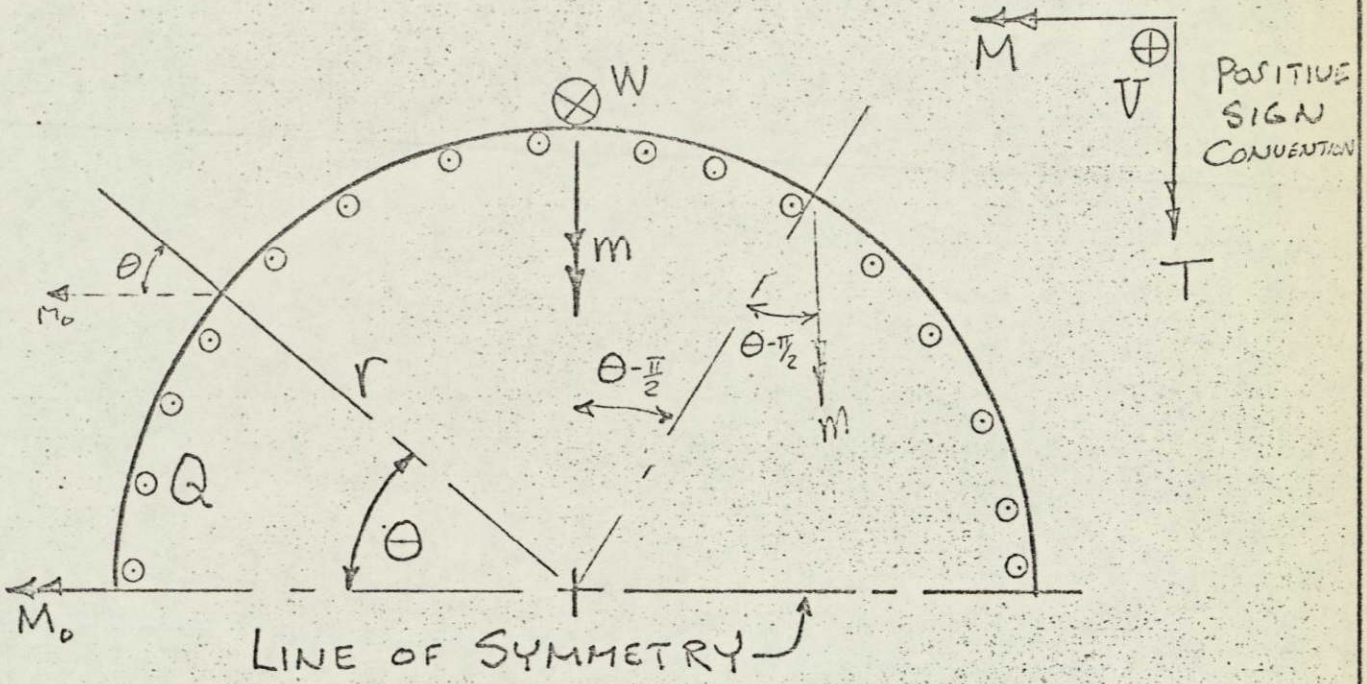
let $A = \dfrac{139}{2\pi(4.84)}$

$$B = \frac{55.6}{\pi(4.84)^3}$$

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CALC. NO.
MODEL
PART NO.



$$Q = A + B\cos\theta$$

@ $\theta = 0$ $\quad V = T = 0$ (by symmetry)

$$M = M_0\cos\theta + \int_0^\theta Q r^2 \sin(\theta-\beta)\,d\beta - Wr\sin(\theta-\pi/2)$$

$$- m\cos(\theta-\pi/2)$$

$$T = M_0\sin\theta + Qr^2\int_0^\theta \{1-\cos(\theta-\beta)\}\,d\beta$$

$$- Wr\{1-\cos(\theta-\pi/2)\} - m\sin(\theta-\pi/2)$$

$$U = \int \frac{M^2}{2EI} r\,d\theta + \int \frac{T^2}{2GK} r\,d\theta$$

$$\frac{\partial U}{\partial M_o} = \int_0^{\pi} \frac{Mr}{EI} \frac{\partial M}{\partial M_o} d\theta + \int_0^{\pi} \frac{Tr}{GK} \frac{\partial T}{\partial M_o} d\theta = 0$$

$$\frac{\partial M}{\partial M_o} = \cos\theta \quad , \quad \frac{\partial T}{\partial M_o} = \sin\theta$$

$$M = M_o\cos\theta - Ar^2(1-\cos\theta) + \frac{Br^2}{2}\theta\sin\theta$$
$$- Wr\sin(\theta - \pi/2) - m\cos(\theta - \pi/2)$$

$$T = M_o\sin\theta + Ar^2\theta + r^2\left(\frac{B}{2} - A\right)\sin\theta - \frac{Br^2}{2}\theta\cos\theta$$
$$- Wr\{1 - \cos(\theta - \pi/2)\} - m\sin(\theta - \pi/2)$$

---

let $\lambda = \frac{EI}{GK}$

$$\int_0^{\pi} M_o\cos^2\theta\,d\theta - Ar^2\int_0^{\pi}(\cos\theta - \cos^2\theta)\,d\theta + \frac{Br^2}{4}\int_0^{\pi}\theta\sin 2\theta\,d\theta$$
$$- \frac{Wr}{2}\int_0^{\pi/2}\sin 2\theta\,d\theta - m\int_0^{\pi/2}\cos^2\theta\,d\theta$$
$$+ \lambda\left[\int_0^{\pi} M_o\sin^2\theta\,d\theta + Ar^2\int_0^{\pi}\theta\sin\theta\,d\theta + r^2\left(\frac{B}{2} - A\right)\int_0^{\pi}\sin^2\theta\,d\theta\right.$$

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DATE 9-5-69
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PART NO

$$-\frac{Br^2}{4}\int_0^{\pi}\theta\sin 2\theta\,d\theta - Wr\int_0^{\pi/2}\left\{\sin\theta-\frac{1}{2}\sin 2\theta\right\}d\theta$$

$$-m\int_0^{\pi/2}\sin^2\theta\,d\theta\Bigg] = 0$$

$$M_o\frac{\pi}{2} + Ar^2\frac{\pi}{2} - \frac{\pi}{8}Br^2 - \frac{Wr}{4} - \frac{\pi}{4}m$$

$$+\lambda\left[M_o\frac{\pi}{2} + Ar^2\pi + \frac{\pi}{2}r^2\left(\frac{B}{2}-A\right) + \frac{\pi}{8}Br^2 - \frac{Wr}{2}\right.$$

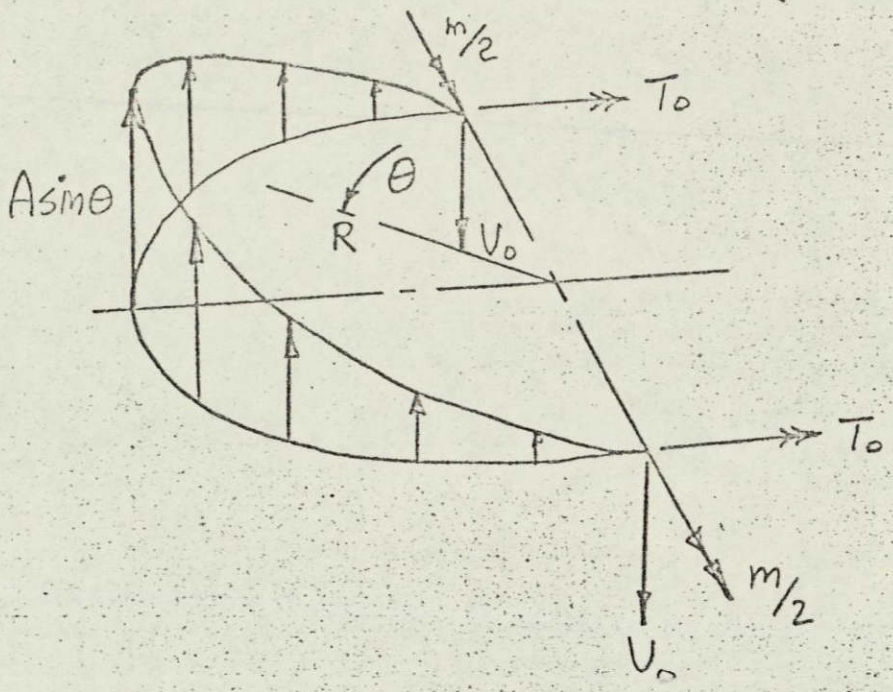
$$\left.-m\frac{\pi r}{4}\right] = 0$$

$$M_o = \frac{2r}{(1+\lambda)}\left\{-\frac{Ar}{2}(1+\lambda) + \frac{Br}{8}(1-3\lambda) + \frac{W}{4\pi}(1+2\lambda)\right.$$

$$\left.+\frac{m}{4}(1+\lambda)\right\}$$

$$M_o = -Ar^2 + \frac{Br^2}{4}\left(\frac{1-3\lambda}{1+\lambda}\right) + \frac{Wr}{2\pi}\left(\frac{1+2\lambda}{1+\lambda}\right) + \frac{mr}{2}$$

SINUSOIDAL LOADING (UPPER HIP RING)



$$V_o = \int_0^{\pi/2} A\sin\theta\, R\, d\theta = AR$$

$$M_{bend} = -T_o \sin\theta - \frac{m}{2}\cos\theta + Ar^2\sin\theta - \int_0^{\theta} Ar^2 \sin\beta \sin(\theta-\beta)\, d\beta$$

$$M_{TORS} = T_o\cos\theta - \frac{m}{2}\sin\theta + Ar^2(1-\cos\theta) - Ar^2\int_0^{\theta} \sin\beta\,[1-\cos(\theta-\beta)]\, d\beta$$

$$M_b = -T_o\sin\theta - \frac{m}{2}\cos\theta + \frac{Ar^2}{2}\sin\theta + \frac{Ar^2}{2}\theta\cos\theta$$

$$M_t = T_o\cos\theta - \frac{m}{2}\sin\theta + \frac{Ar^2}{2}\theta\sin\theta$$

$$\frac{\partial U}{\partial T_o} = \int_0^{\pi/2} M_b \frac{\partial M_b}{\partial T_o}\, d\theta + \lambda\int M_t \frac{\partial M_t}{\partial T_o}\, d\theta = 0 \qquad \lambda = \frac{EI}{GK}$$

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DATE 9-11-69
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CHECKED BY

CALC. NO
MODEL
PART NO

$$T_o = \frac{m}{\pi}\left(\frac{\lambda-1}{\lambda+1}\right) + \frac{A\Omega^2}{4}\left(\frac{5-\lambda}{1+\lambda}\right)$$

Where $A = \frac{m}{\pi R^3}$

$$V''' + V' = -\frac{R^2}{EI}\left\{T\lambda + \frac{dM}{d\theta}\right\}$$

$$\beta = -\frac{MR}{EI} + \frac{V''}{R}$$

$$V''' + V' = -\frac{R}{EI}\left\{\left[T_o(\lambda-1) + AR^2\right]\cos\theta + \left[\frac{m}{2}(1-\lambda)\right]\sin\theta + \frac{AR^2}{2}(\lambda-1)\theta\sin\theta\right\}$$

$$V = C_1 + C_2\sin\theta + C_3\cos\theta - \left\{\frac{K_1}{2} + \frac{3}{4}K_3\right\}\theta\cos\theta - \frac{K_2}{2}\theta\sin\theta - \frac{K_3}{4}\theta^2\sin\theta$$

$$K_1 = -\frac{R}{EI}\left[T_o(\lambda-1) + AR^2\right]$$

$$K_2 = +\frac{Rm(\lambda-1)}{2EI}$$

$$K_3 = \frac{AR^3}{2EI}(1-\lambda)$$

REPORT
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Boundary Conditions:

@ $\theta = 0$ @ $\theta = \pi/2$

$V = 0$ $V' = 0$

substituting into solution:

$$C_1 = -C_3 = \frac{\pi}{4} K_1 - \frac{1}{2} K_2 + \frac{\pi}{8} K_3$$

$C_2 = 0$ arbitrary

$$\therefore V = C_3(\cos\theta - 1) - \frac{1}{2}\left(K_1 + \frac{3}{2}K_3\right)\theta\cos\theta - \frac{K_2}{2}\theta\sin\theta - \frac{K_3}{4}\theta^2\sin\theta$$

$$V'' = -C_3\cos\theta + \frac{1}{2}\left(K_1 + \frac{3}{2}K_3\right)(2\sin\theta + \theta\cos\theta) - \frac{K_2}{2}(2\cos\theta - \theta\sin\theta) - \frac{K_3}{4}(2\sin\theta + 4\theta\cos\theta - \theta^2\sin\theta)$$

$$-\frac{M_b R}{EI} = \frac{T_o R}{EI}\sin\theta + \frac{mR}{2EI}\cos\theta - \frac{AR^3}{2EI}\sin\theta - \frac{AR^3}{2EI}\theta\cos\theta$$

```
T SPEC    CART AVAIL   PHY DRIVE
001          0001         0000



2 PRINTER)

L LOADING OF CIRCULAR RING,REACTED BY TWO MOMENTS
BLAM,BI,E,R,BM
10.5)


E*BI)
96
R3)
*(BLAM-1.)/(BLAM+1.)+.25*A*R2*(5.-BLAM)/(BLAM+1.)
TIF*(TO*(BLAM-1.)+A*R2)
*BM*STIF*(BLAM-1.)
STIF*R3*(1.-BLAM)
PI*BK1-.5*BK2 +.125*PI*BK3
,91
-1)
 X


S-.5*BM*C+.5*A*R2*(S+T*C)
C-.5*S +.5*A*R2*T*S
-1.)-.5*(BK1+1.5*BK3)*T*C-.5*BK2*T*S-.25*BK3*T*T*S
+.5*(BK1+1.5*BK3)*(2.*S+T*C)-.5*BK2*(2.*C-T*S)
(2.*S+4.*T*C-T*T*S)
D*R*STIF+VV/R
0)X,V,BETA,BEND,TT
 ,5(5X,E14.7))


TIONS
        BI(R )=0002          E(R )=0004          R(R )=0006          BM(R )=0008
      STIF(R )=000E         PI(R )=0010          A(R )=0012         TO(R )=0014
       BK3(R )=001A        CON(R )=001C          X(R )=001E          T(R )=0020
      BEND(R )=0026         TT(R )=0028          V(R )=002A         VV(R )=002C


ATIONS
   =0067  10    =023B

TED


AMS
  FSUB     FMPY     FDIV     FLD      FSTO     FSBR     FDVR     FLOAT    CARDZ    PRNTZ    SR
  SNP      SNR


046     .314159E 01=0048     .250000E 00=004A     .500000E 01=004C     .500000E 00=004E
052     .150000E 01=0054     .200000E 01=0056     .400000E 01=0058
```

```
// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMERING
*IOCS (CARD,1132 PRINTER)
*LISTALL
C      SINUSOIDAL LOADING OF CIRCULAR RING,REACTED BY TWO MOMENTS
       READ(2,5)BLAM,BI,E,R,BM
     5 FORMAT(5E10.5)
       R2=R*R
       R3=R2*R
       STIF=1./(E*BI)
       PI=3.141596
       A=BM/(PI*R3)
       TO= BM/PI*(BLAM-1.)/(BLAM+1.)+.25*A*R2*(5.-BLAM)/(BLAM+1.)
       BK1= -R*STIF*(TO*(BLAM-1.)+A*R2)
       BK2=+.5*R*BM*STIF*(BLAM-1.)
       BK3=.5*A*STIF*R3*(1.-BLAM)
       CON =.25*PI*BK1-.5*BK2 +.125*PI*BK3
       DO 10 I=1,91
       X=FLOAT(I-1)
       T=.01745* X
       S= SIN(T)
       C= COS(T)
       BEND=-TO*S-.5*BM*C+.5*A*R2*(S+T*C)
       TT  = TO*C-.5*S +.5*A*R2*T*S
       V= CON*(C-1.)-.5*(BK1+1.5*BK3)*T*C-.5*BK2*T*S-.25*BK3*T*T*S
       VV=-CON*C+.5*(BK1+1.5*BK3)*(2.*S+T*C)-.5*BK2*(2.*C-T*S)
      1-.25*BK3*(2.*S+4.*T*C-T*T*S)
       BETA=-BEND*R*STIF+VV/R
    10 WRITE(3,20)X,V,BETA,BEND,TT
    20 FORMAT(1H ,5(5X,E14.7))
       STOP
       END
VARIABLE ALLOCATIONS
  BLAM(R )=0000        BI(R )=0002         E(R )=0004         R(R )=0006
    R3(R )=000C       STIF(R )=000E        PI(R )=0010         A(R )=0012
   BK2(R )=0018        BK3(R )=001A       CON(R )=001C         X(R )=001E
     C(R )=0024       BEND(R )=0026        TT(R )=0028         V(R )=002A
     I(I )=0044

STATEMENT ALLOCATIONS
 5    =0064  20   =0067  10   =023B

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FSIN    FCOS    FSUB    FMPY    FDIV    FLD     FSTO    FSBR    FDVR    FLOA
 SFIO    SIOF    STOP    SNR

REAL CONSTANTS
  .100000E 01=0046    .314159E 01=0048    .250000E 00=004A    .500000E 01=004
  .174500E-01=0052    .150000E 01=0054    .200000E 01=0056    .400000E 01=005
```

INTEGER CONSTANTS
2=005A 1=005B 91=005C 3=005D 0=005E

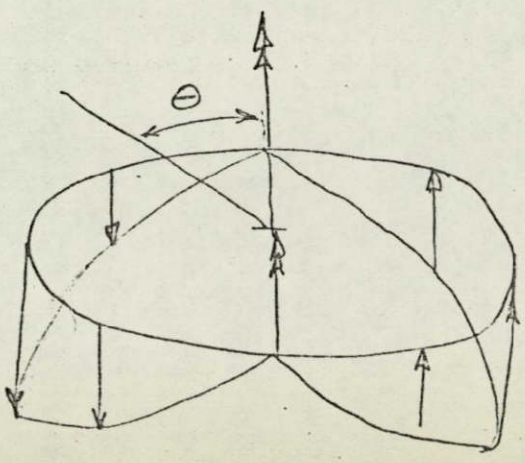
CORE REQUIREMENTS FOR RING
COMMON 0 VARIABLES 70 PROGRAM 526

END OF COMPILATION

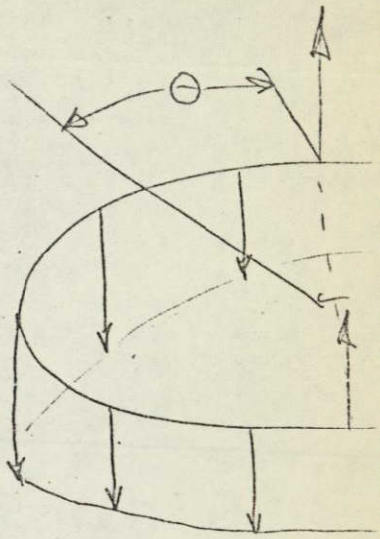
// XEQ

DEGREES	DISP	TWIST	BEND MOM
0.0000000E 00	0.5410639E-09	0.3489435E-02	-0.2779999E 02
0.1000000E 01	0.2259434E-04	0.3488401E-02	-0.2787837E 02
0.2000000E 01	0.4487056E-04	0.3486640E-02	-0.2794828E 02
0.3000000E 01	0.6681267E-04	0.3484154E-02	-0.2800971E 02
0.4000000E 01	0.8840257E-04	0.3480948E-02	-0.2806268E 02
0.5000000E 01	0.1096253E-03	0.3477027E-02	-0.2810717E 02
0.6000000E 01	0.1304658E-03	0.3472396E-02	-0.2814320E 02
0.7000000E 01	0.1509098E-03	0.3467058E-02	-0.2817077E 02
0.8000001E 01	0.1709422E-03	0.3461020E-02	-0.2818989E 02
0.9000001E 01	0.1905506E-03	0.3454284E-02	-0.2820057E 02
0.1000000E 02	0.2097226E-03	0.3446858E-02	-0.2820282E 02
0.1100000E 02	0.2284456E-03	0.3438746E-02	-0.2819668E 02
0.1200000E 02	0.2467075E-03	0.3429953E-02	-0.2818215E 02
0.1300000E 02	0.2644995E-03	0.3420486E-02	-0.2815926E 02
0.1400000E 02	0.2818100E-03	0.3410348E-02	-0.2812803E 02
0.1500000E 02	0.2986301E-03	0.3399547E-02	-0.2808850E 02
0.1600000E 02	0.3149521E-03	0.3388085E-02	-0.2804068E 02
0.1700000E 02	0.3307667E-03	0.3375972E-02	-0.2798461E 02
0.1800000E 02	0.3460674E-03	0.3363212E-02	-0.2792034E 02
0.1900000E 02	0.3608471E-03	0.3349810E-02	-0.2784789E 02
0.2000000E 02	0.3751006E-03	0.3335773E-02	-0.2776731E 02
0.2100000E 02	0.3888218E-03	0.3321107E-02	-0.2767863E 02
0.2200000E 02	0.4020072E-03	0.3305819E-02	-0.2758190E 02
0.2300000E 02	0.4146528E-03	0.3289913E-02	-0.2747716E 02
0.2400000E 02	0.4267538E-03	0.3273397E-02	-0.2736448E 02
0.2500000E 02	0.4383097E-03	0.3256278E-02	-0.2724389E 02
0.2600000E 02	0.4493182E-03	0.3238560E-02	-0.2711545E 02
0.2700000E 02	0.4597773E-03	0.3220252E-02	-0.2697922E 02
0.2800000E 02	0.4696878E-03	0.3201359E-02	-0.2683526E 02
0.2900000E 02	0.4790493E-03	0.3181888E-02	-0.2668362E 02
0.3000000E 02	0.4878630E-03	0.3161846E-02	-0.2652436E 02
0.3100000E 02	0.4961304E-03	0.3141241E-02	-0.2635756E 02
0.3200000E 02	0.5038541E-03	0.3120075E-02	-0.2618327E 02
0.3300000E 02	0.5110368E-03	0.3098361E-02	-0.2600158E 02
0.3400000E 02	0.5176824E-03	0.3076102E-02	-0.2581253E 02
0.3500000E 02	0.5237947E-03	0.3053307E-02	-0.2561623E 02
0.3600000E 02	0.5293791E-03	0.3029982E-02	-0.2541273E 02
0.3700000E 02	0.5344410E-03	0.3006134E-02	-0.2520211E 02
0.3800000E 02	0.5389875E-03	0.2981770E-02	-0.2498445E 02
0.3900000E 02	0.5430240E-03	0.2956898E-02	-0.2475983E 02
0.4000000E 02	0.5465598E-03	0.2931525E-02	-0.2452835E 02
0.4100000E 02	0.5496016E-03	0.2905657E-02	-0.2429006E 02
0.4200000E 02	0.5521597E-03	0.2879303E-02	-0.2404508E 02
0.4300000E 02	0.5542425E-03	0.2852469E-02	-0.2379349E 02
0.4400000E 02	0.5558601E-03	0.2825164E-02	-0.2353537E 02
0.4500000E 02	0.5570236E-03	0.2797393E-02	-0.2327081E 02

0.4600000E 02	0.5577444E-03	0.2769165E-02	-0.2299992E 02
0.4700000E 02	0.5580340E-03	0.2740487E-02	-0.2272279E 02
0.4800000E 02	0.5579056E-03	0.2711366E-02	-0.2243950E 02
0.4900000E 02	0.5573711E-03	0.2681812E-02	-0.2215018E 02
0.5000000E 02	0.5564453E-03	0.2651828E-02	-0.2185490E 02
0.5100000E 02	0.5551407E-03	0.2621425E-02	-0.2155377E 02
0.5200000E 02	0.5534740E-03	0.2590611E-02	-0.2124691E 02
0.5300000E 02	0.5514594E-03	0.2559390E-02	-0.2093441E 02
0.5400000E 02	0.5491130E-03	0.2527773E-02	-0.2061638E 02
0.5500000E 02	0.5464511E-03	0.2495765E-02	-0.2029292E 02
0.5600000E 02	0.5434906E-03	0.2463377E-02	-0.1996416E 02
0.5700000E 02	0.5402487E-03	0.2430613E-02	-0.1963018E 02
0.5800000E 02	0.5367427E-03	0.2397482E-02	-0.1929112E 02
0.5900000E 02	0.5329921E-03	0.2363992E-02	-0.1894708E 02
0.6000000E 02	0.5290145E-03	0.2330151E-02	-0.1859817E 02
0.6100000E 02	0.5248293E-03	0.2295966E-02	-0.1824452E 02
0.6200000E 02	0.5204571E-03	0.2261444E-02	-0.1788624E 02
0.6300000E 02	0.5159168E-03	0.2226595E-02	-0.1752344E 02
0.6400001E 02	0.5112298E-03	0.2191423E-02	-0.1715625E 02
0.6500001E 02	0.5064172E-03	0.2155939E-02	-0.1678479E 02
0.6600001E 02	0.5014989E-03	0.2120149E-02	-0.1640916E 02
0.6700001E 02	0.4964984E-03	0.2084062E-02	-0.1602952E 02
0.6800001E 02	0.4914369E-03	0.2047683E-02	-0.1564595E 02
0.6900001E 02	0.4863354E-03	0.2011023E-02	-0.1525862E 02
0.7000001E 02	0.4812189E-03	0.1974086E-02	-0.1486761E 02
0.7100001E 02	0.4761097E-03	0.1936882E-02	-0.1447307E 02
0.7200001E 02	0.4710311E-03	0.1899420E-02	-0.1407513E 02
0.7300001E 02	0.4660065E-03	0.1861704E-02	-0.1367390E 02
0.7400001E 02	0.4610605E-03	0.1823744E-02	-0.1326952E 02
0.7500001E 02	0.4562167E-03	0.1785547E-02	-0.1286211E 02
0.7600001E 02	0.4515000E-03	0.1747121E-02	-0.1245181E 02
0.7700001E 02	0.4469341E-03	0.1708473E-02	-0.1203875E 02
0.7800001E 02	0.4425460E-03	0.1669610E-02	-0.1162304E 02
0.7900001E 02	0.4383592E-03	0.1630541E-02	-0.1120483E 02
0.8000001E 02	0.4343998E-03	0.1591272E-02	-0.1078425E 02
0.8100001E 02	0.4306936E-03	0.1551812E-02	-0.1036142E 02
0.8200001E 02	0.4272644E-03	0.1512168E-02	-0.9936491E 01
0.8300001E 02	0.4241397E-03	0.1472346E-02	-0.9509571E 01
0.8400001E 02	0.4213454E-03	0.1432356E-02	-0.9080810E 01
0.8500001E 02	0.4189087E-03	0.1392203E-02	-0.8650329E 01
0.8600001E 02	0.4168531E-03	0.1351896E-02	-0.8218265E 01
0.8700001E 02	0.4152061E-03	0.1311442E-02	-0.7784760E 01
0.8800001E 02	0.4139957E-03	0.1270848E-02	-0.7349935E 01
0.8900001E 02	0.4132463E-03	0.1230122E-02	-0.6913931E 01
0.9000001E 02	0.4129846E-03	0.1189270E-02	-0.6476874E 01



UPPER HIP JOINT BEARING




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PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000

// FOR
*NAMEBEAR
*IOCS (CARD,1132 PRINTER)

FEATURES SUPPORTED
 IOCS

CORE REQUIREMENTS FOR BEAR
 COMMON      0  VARIABLES     70  PROGRAM     454

 END OF COMPILATION

// XEQ
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DEGREES	DISP	TWIST	BEND MOM
0.0000000E 00	0.4202399E-07	0.1669451E-01	-0.1160853E 03
0.1000000E 01	0.2437596E-04	0.1661628E-01	-0.1126969E 03
0.2000000E 01	0.9685326E-04	0.1651726E-01	-0.1093096E 03
0.3000000E 01	0.2166944E-03	0.1639796E-01	-0.1059243E 03
0.4000000E 01	0.3829003E-03	0.1625891E-01	-0.1025421E 03
0.5000000E 01	0.5946571E-03	0.1610058E-01	-0.9916413E 02
0.6000000E 01	0.8510753E-03	0.1592352E-01	-0.9579124E 02
0.7000000E 01	0.1151176E-02	0.1572825E-01	-0.9242453E 02
0.8000001E 01	0.1493941E-02	0.1551531E-01	-0.8906501E 02
0.9000001E 01	0.1878442E-02	0.1528520E-01	-0.8571374E 02
0.1000000E 02	0.2303648E-02	0.1503848E-01	-0.8237171E 02
0.1100000E 02	0.2768478E-02	0.1477569E-01	-0.7903994E 02
0.1200000E 02	0.3271797E-02	0.1449737E-01	-0.7571946E 02
0.1300000E 02	0.3812628E-02	0.1420408E-01	-0.7241127E 02
0.1400000E 02	0.4389773E-02	0.1389636E-01	-0.6911636E 02
0.1500000E 02	0.5002133E-02	0.1357477E-01	-0.6583578E 02
0.1600000E 02	0.5648571E-02	0.1323986E-01	-0.6257045E 02
0.1700000E 02	0.6327893E-02	0.1289219E-01	-0.5932147E 02
0.1800000E 02	0.7038894E-02	0.1253231E-01	-0.5608975E 02
0.1900000E 02	0.7780405E-02	0.1216079E-01	-0.5287630E 02
0.2000000E 02	0.8551210E-02	0.1177820E-01	-0.4968209E 02
0.2100000E 02	0.9350040E-02	0.1138509E-01	-0.4650812E 02
0.2200000E 02	0.1017573E-01	0.1098203E-01	-0.4335532E 02
0.2300000E 02	0.1102701E-01	0.1056956E-01	-0.4022468E 02
0.2400000E 02	0.1190250E-01	0.1014827E-01	-0.3711712E 02
0.2500000E 02	0.1280109E-01	0.9718719E-02	-0.3403363E 02
0.2600000E 02	0.1372140E-01	0.9281460E-02	-0.3097510E 02
0.2700000E 02	0.1466215E-01	0.8837051E-02	-0.2794249E 02
0.2800000E 02	0.1562212E-01	0.8386051E-02	-0.2493672E 02
0.2900000E 02	0.1659997E-01	0.7929017E-02	-0.2195872E 02
0.3000000E 02	0.1759435E-01	0.7466509E-02	-0.1900937E 02
0.3100000E 02	0.1860407E-01	0.6999077E-02	-0.1608959E 02
0.3200000E 02	0.1962772E-01	0.6527257E-02	-0.1320022E 02
0.3300000E 02	0.2066399E-01	0.6051627E-02	-0.1034219E 02
0.3400000E 02	0.2171174E-01	0.5572697E-02	-0.7516387E 01
0.3500000E 02	0.2276948E-01	0.5091032E-02	-0.4723639E 01
0.3600000E 02	0.2383597E-01	0.4607149E-02	-0.1964780E 01
0.3700000E 02	0.2490996E [illegible]	4121605E-02	0.7593102E 00

0.3800000E 02	0.2599016E-01	0.3634893E-02	0.3447843E 01
0.3900000E 02	0.2707519E-01	0.3147562E-02	0.6099964E 01
0.4000000E 02	0.2816383E-01	0.2660136E-02	0.8714885E 01
0.4100000E 02	0.2925471E-01	0.2173108E-02	0.1129181E 02
0.4200000E 02	0.3034683E-01	0.1686993E-02	0.1382993E 02
0.4300000E 02	0.3143870E-01	0.1202293E-02	0.1632853E 02
0.4400000E 02	0.3252907E-01	0.7195032E-03	0.1878678E 02
0.4500000E 02	0.3361681E-01	0.2391231E-03	0.2120396E 02
0.4600000E 02	0.3470070E-01	-0.2383741E-03	0.2357932E 02
0.4700000E 02	0.3577943E-01	-0.7125085E-03	0.2591217E 02
0.4800000E 02	0.3685192E-01	-0.1182810E-02	0.2820181E 02
0.4900000E 02	0.3791686E-01	-0.1648808E-02	0.3044750E 02
0.5000000E 02	0.3897319E-01	-0.2110074E-02	0.3264855E 02
0.5100000E 02	0.4001963E-01	-0.2566121E-02	0.3480435E 02
0.5200000E 02	0.4105528E-01	-0.3016548E-02	0.3691416E 02
0.5300000E 02	0.4207883E-01	-0.3460892E-02	0.3897740E 02
0.5400000E 02	0.4308918E-01	-0.3898746E-02	0.4099346E 02
0.5500000E 02	0.4408534E-01	-0.4329704E-02	0.4296166E 02
0.5600000E 02	0.4506628E-01	-0.4753341E-02	0.4488143E 02
0.5700000E 02	0.4603082E-01	-0.5169264E-02	0.4675218E 02
0.5800000E 02	0.4697809E-01	-0.5577091E-02	0.4857336E 02
0.5900000E 02	0.4790711E-01	-0.5976448E-02	0.5034439E 02
0.6000000E 02	0.4881677E-01	-0.6366965E-02	0.5206474E 02
0.6100000E 02	0.4970616E-01	-0.6748272E-02	0.5373392E 02
0.6200000E 02	0.5057446E-01	-0.7120028E-02	0.5535134E 02
0.6300000E 02	0.5142068E-01	-0.7481886E-02	0.5691661E 02
0.6400000E 02	0.5224391E-01	-0.7833527E-02	0.5842921E 02
0.6500001E 02	0.5304350E-01	-0.8174633E-02	0.5988862E 02
0.6600001E 02	0.5381847E-01	-0.8504891E-02	0.6129448E 02
0.6700001E 02	0.5456809E-01	-0.8824015E-02	0.6264630E 02
0.6800001E 02	0.5529160E-01	-0.9131710E-02	0.6394371E 02
0.6900001E 02	0.5598817E-01	-0.9427692E-02	0.6518632E 02
0.7000001E 02	0.5665723E-01	-0.9711721E-02	0.6637373E 02
0.7100001E 02	0.5729803E-01	-0.9983526E-02	0.6750558E 02
0.7200001E 02	0.5790998E-01	-0.1024287E-01	0.6858151E 02
0.7300001E 02	0.5849242E-01	-0.1048952E-01	0.6960122E 02
0.7400001E 02	0.5904480E-01	-0.1072327E-01	0.7056437E 02
0.7500001E 02	0.5956658E-01	-0.1094392E-01	0.7147071E 02
0.7600001E 02	0.6005723E-01	-0.1115127E-01	0.7231993E 02
0.7700001E 02	0.6051597E-01	-0.1134511E-01	0.7311180E 02
0.7800001E 02	0.6094235E-01	-0.1152531E-01	0.7384605E 02
0.7900001E 02	0.6133714E-01	-0.1169169E-01	0.7452246E 02
0.8000001E 02	0.6169855E-01	-0.1184412E-01	0.7514085E 02
0.8100001E 02	0.6202673E-01	-0.1198246E-01	0.7570097E 02
0.8200001E 02	0.6232117E-01	-0.1210658E-01	0.7620274E 02
0.8300001E 02	0.6258156E-01	-0.1221639E-01	0.7664593E 02
0.8400001E 02	0.6280834E-01	-0.1231177E-01	0.7703045E 02
0.8500001E 02	0.6300039E-01	-0.1239268E-01	0.7735615E 02
0.8600001E 02	0.6315797E-01	-0.1245900E-01	0.7762297E 02
0.8700001E 02	0.6328077E-01	-0.1251071E-01	0.7783079E 02
0.8800001E 02	0.6336884E-01	-0.1254775E-01	0.7797956E 02
0.8900001E 02	0.6342192E-01	-0.1257008E-01	0.7806924E 02
0.9000001E 02	0.6343999E-01	-0.1257769E-01	0.7809982E 02

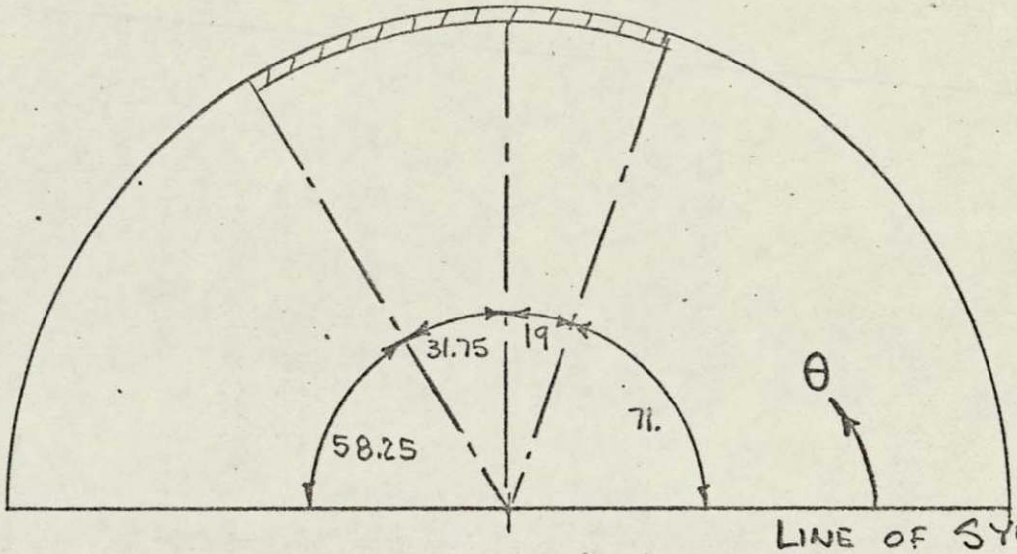
Form 2427

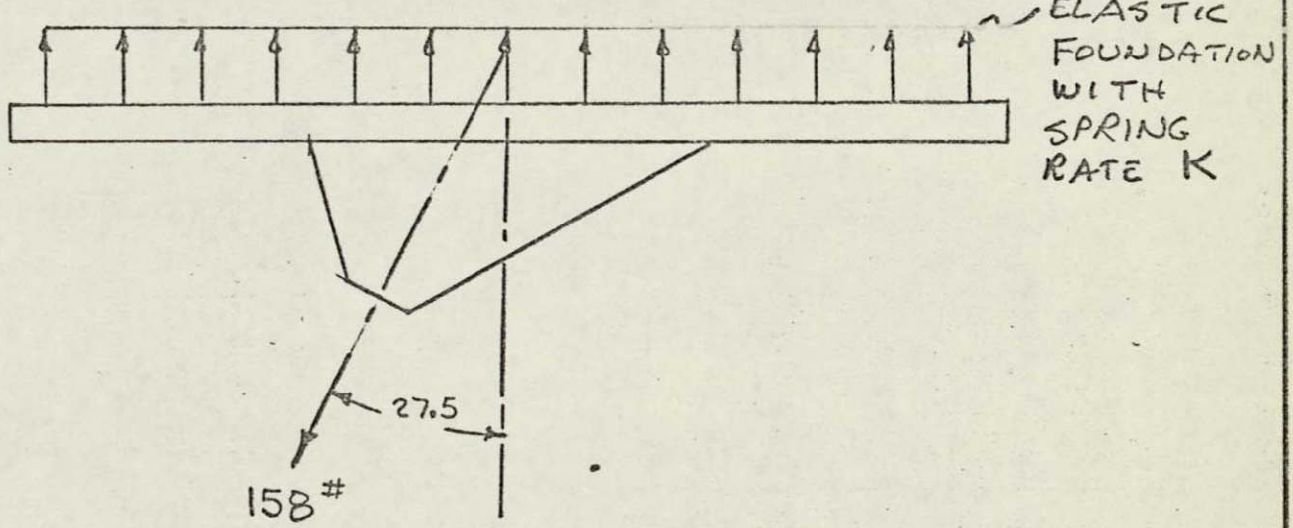
AiRESEARCH MFG. CO.

DATE 9-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

UPPER HIP BEARING ANALYIS





ASSUME UNIFORM LOAD OUER 50.75° ARC OF MAGNITUDE P.

BOUNDARY CONDITIONS:

@ $\theta = 0, \pi$

$y' = y''' = 0$

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Form 2427

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CHECKED BY

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MODEL
PART NO

USING VOLTERRA'S APPROACH (J. A. M. JUNE 1953)

$$y(\theta) = \frac{1}{2\pi K R^2} \int_0^{2\pi} P(\xi)\,d\xi + \frac{R}{a\mu\pi} \sum_{n=1}^{\infty} Y_n \left[\cos n\theta \int_0^{2\pi} P(\xi) \cos n\xi\, d\xi \right.$$

$$\left. + \sin n\theta \int_0^{2\pi} P(\xi) \sin n\xi\, d\xi \right]$$

$$P(\xi) = \begin{cases} 0 & ; \ 0 < \xi < 58.25 \\ P & ; \ 58.25 \le \xi \le 119 \\ 0 & ; \ 119 < \xi < 261 \\ P & ; \ 261 \le \xi \le 301.75 \\ 0 & ; \ 360 \ge \xi > 301.75 \end{cases}$$

Performing the necessary integration

$$y(\theta) = \frac{0.885754\,P}{\pi k R^2} + \frac{RP}{a\mu\pi} \sum_{n=1}^{\infty} \frac{Y_n}{n} \left[\cos n\theta \{ \sin 2.0769n + \right.$$

$$\left. \sin 5.2665n - \sin 1.0166n - \sin 4.5553n \} - \sin n\theta \{ \cos 2.0769n \right.$$

$$\left. + \cos 5.2665n - \cos 1.0166n - \cos 4.5553n \} \right]$$

$$\beta(\theta) = \frac{RP}{a\mu\pi} \sum_{n=1}^{\infty} \frac{B_n}{n} [\quad]$$

$$M(\theta) = \frac{RP}{\mu\pi} \sum_{n=1} \frac{M_{xn}}{n} [\quad]$$

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$$Y_n = \frac{\mu n^2 - 1}{n^6 - 2n^4 + n^2(1+\lambda) + \lambda/\mu}$$

$$B_n = \frac{(1+\mu)n^2}{1+\mu n^2} Y_n$$

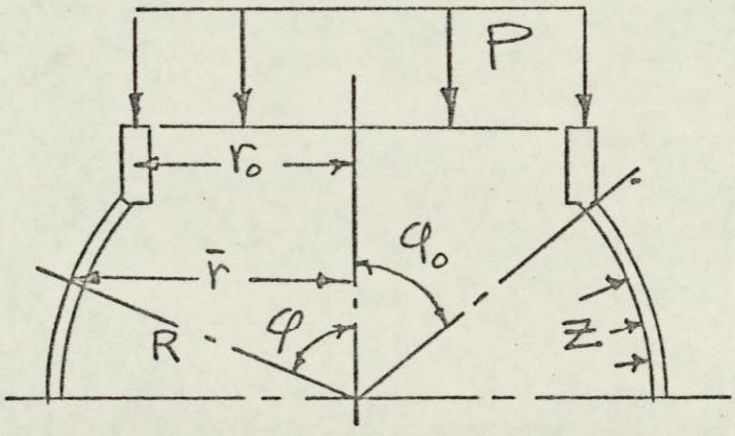
$$M_{xn} = B_n + n^2 Y_n$$

$$\lambda = kR^4/EI$$

$$\mu = GJ/EI$$

$$a = EI/R$$

SPRING RATE OF FOUNDATION



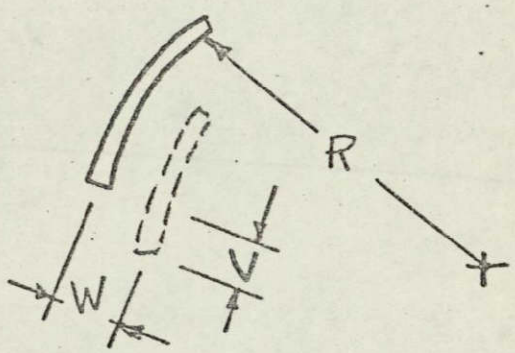
$$N_\varphi + N_\theta = -ZR$$

$$N_\varphi = \frac{-r_o P}{R \sin^2 \varphi}$$

$$N_\theta = \frac{r_o P}{R \sin^2 \varphi} - ZR$$

$$\epsilon_\varphi = \frac{1}{Eh}\{N_\varphi - \nu N_\theta\}$$

$$\epsilon_\theta = \frac{1}{Eh}\{N_\theta - \nu N_\varphi\}$$



$$\frac{dV}{d\varphi} - V\cot\varphi = \frac{R(1+\nu)}{Eh}\left[N_\varphi - N_\theta\right] = f(\varphi)$$

$$\frac{1}{Eh}(N_\theta - \nu N_\varphi) = \frac{V}{R}\cot\varphi - \frac{W}{R}$$

$$V = \sin\varphi\left\{\int \frac{f(\varphi)\,d\varphi}{\sin\varphi} + C\right\}$$

$$\int \frac{f(\varphi)\,d\varphi}{\sin\varphi} = \frac{(1+\nu)}{Eh}\left\{-2r_0 P\int \frac{d\varphi}{\sin^3\varphi} + 2R^2\int \frac{d\varphi}{\sin\varphi}\right\}$$

$$= \frac{(1+\nu)}{Eh}\left[-r_0 P\frac{\cos\varphi}{\sin^2\varphi} + (2R^2 - r_0 P)\log\tan\frac{\varphi}{2}\right]$$

$$V = C\sin\varphi + \frac{(1+\nu)}{Eh}\left[-r_0 P\cot\varphi + (2R^2 - r_0 P)\sin\varphi\log\tan\frac{\varphi}{2}\right]$$

Boundary Condition

@ $\varphi = \pi/2$

$V = 0$

$\therefore C = 0$

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$$V = \frac{(1+\nu)}{Eh}\left[-r_0 P\cot\varphi + (2R^2 - r_0 P)\sin\varphi \log\tan\frac{\varphi}{2}\right]$$

$$W = \frac{(1+\nu)P}{Eh}\left[-r_0\cot^2\varphi + \left(\frac{z}{p}R^2 - r_0\right)\cos\varphi \log\tan\frac{\varphi}{2}\right]$$

$$K = \frac{P}{W}$$

$$K = \frac{Eh}{(1+\nu)\left[-r_0(2\csc^2\varphi - 1) + \left\{\left(\frac{z}{p}\right)R^2 - r_0\right\}\cos\varphi \log\tan\frac{\varphi}{2}\right] + \left(\frac{z}{p}\right)R^2}$$

$r_0 = 5.21$
$R \approx 9$
$P = 34.5$
$z = -5$

$$K = \frac{Eh}{(1+\nu)\,10.7 + 10.8}$$

for Nylon

$E = 4.5 \times 10^5$
$\nu \approx 0.5$
$h \approx .015$

$K = 252$ #/in/in

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```
// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMECHECK
*IOCS (CARD,1132 PRINTER)
*LISTALL
C       RING ON ELASTIC FOUNDATION                                              0002
        DIMENSION A(20),B(20),C(20),D(20),BY(20),BB(20),BMM(20),DISP(181)        0004
        DIMENSION BETA(181),BMOM(181)                                           0006
        DIMENSION TMOM(181)
        READ(2,5)E,R,BI,BJ,BK,POIS,P,NU                                         0008
      5 FORMAT(7E10.5,I5)                                                       0010
        WRITE(3,62)E,R,BI,BJ,BK,POIS,P
     62 FORMAT(1H ,8E14.7)
        STIF=E*BI                                                               0012
        STIF1=.5*E*BJ/(1.+POIS)                                                 0014
        BMU= STIF1/STIF                                                         0016
        AA = STIF/R                                                             0018
        BLA= BK*R**4/STIF                                                       0020
        PI = 3.1415926                                                          0022
        DO 10 I=1,NU                                                            0024
        X=FLOAT(I)                                                              0026
        CON1=BMU*X*X -1.0                                                       0028
        CON2=X*X*(X**4-2.*X*X +1.0+BLA) +BLA/BMU                                0030
        BY(I)=CON1/CON2                                                         0032
        BB(I)=X*X*(1.+BMU)*BY(I)/(1.+BMU*X*X)                                   0034
        BMM(I)= BB(I)+ X*X*BY(I)                                                0036
        A(I)= SIN(2.07694*X) +SIN(5.26653*X)                                    0038
        B(I)= SIN(1.01665*X) +SIN(4.5553*X)                                     0040
        C(I)= COS(2.07694*X) +COS(5.26653*X)                                    0042
     10 D(I)= COS(1.01665*X) +COS(4.5553*X)                                     0044
        CON3=.885754*P/(PI*BK*R*R)                                              0046
        CON4= P*R/(AA*BMU*PI)                                                   0048
        CON5=P*R/(PI*BMU)                                                       0050
        DO 30 J=1,181                                                           0052
        X=FLOAT(J-1)                                                            0054
        T =.01745*X                                                             0056
        SUM1=0.0                                                                0058
        SUM2=0.0                                                                0060
        SUM3=0.0                                                                0062
        SUM4=0.0
        DO 20 I=1,NU                                                            0064
        Y=FLOAT(I)                                                              0066
        TR1= COS(Y*T)                                                           0068
        TR2= SIN(Y*T)                                                           0070
        CON6=(TR1*(A(I)-B(I))-TR2*(C(I)-D(I)))/Y                                0072
        CON7=(TR2*(A(I)-B(I))-TR1*(C(I)-D(I)))/Y
        SUM1=SUM1 +BY(I)*CON6                                                   0074
        SUM2=SUM2 +BB(I)*CON6                                                   0076
        SUM4=SUM4+BMM(I)*CON7/Y
     20 SUM3=SUM3 +BMM(I)*CON6                                                  0078
        DISP(J)= CON3 +CON4*SUM1                                                0080
        BETA(J)= CON4*SUM2                                                      0082
        TMOM(J)=CON5*SUM4
```

```
   30 BMOM(J)= CON5*SUM3                                                    0084
      WRITE(3,35)                                                           0085
   35 FORMAT(1H1,10X,35HCIRCULAR RING ON ELASTIC FOUNDATION//14X,7HDEGRE    0086
     1ES,10X,8HBEND MOM,15X,4HDISP,11X,5HTWIST11X,13HTORSIONAL MOM//)
      DO 50  I=1,181                                                        0092
      J=I-1                                                                 0093
   50 WRITE(3,60) J,BMOM(I),DISP(I),BETA(I),TMOM(I)                         0094
   60 FORMAT(1H ,15X,I3,5X,4(5X,E14.7))
      STOP
      END
VARIABLE ALLOCATIONS
     A(R )=0026-0000     B(R )=004E-0028     C(R )=0076-0050     D(R )=009E-007
   BMM(R )=0116-00F0   DISP(R )=0280-0118   BETA(R )=03EA-0282   BMOM(R )=0554-03E
     R(R )=06C2          BI(R )=06C4         BJ(R )=06C6         BK(R )=06C8
  STIF(R )=06CE       STIF1(R )=06D0       BMU(R )=06D2        AA(R )=06D4
     X(R )=06DA        CON1(R )=06DC       CON2(R )=06DE       CON3(R )=06E0
     T(R )=06E6        SUM1(R )=06E8       SUM2(R )=06EA       SUM3(R )=06EC
   TR1(R )=06F2         TR2(R )=06F4       CON6(R )=06F6       CON7(R )=06F8
     J(I )=0704

STATEMENT ALLOCATIONS
 5    =072A  62   =072E  35   =0733  60   =076C  10   =089C  20   =0982  30   =

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FSIN    FCOS    FADDX   FSUB    FSUBX   FMPY    FMPYX   FDIV    FLD     FLDX
 FLOAT   CARDZ   PRNTZ   SRED    SWRT    SCOMP   SFIO    SIOFX   SIOF    SIOI

REAL CONSTANTS
  .500000E 00=0708    .100000E 01=070A    .314159E 01=070C    .200000E 01=070E
  .101665E 01=0714    .455530E 01=0716    .885754E 00=0718    .174500E-01=071A

INTEGER CONSTANTS
     2=071E      3=071F      4=0720      1=0721    181=0722      0=0723

CORE REQUIREMENTS FOR CHECK
 COMMON       0  VARIABLES   1800  PROGRAM    744

 END OF COMPILATION

// XEQ

 0.1000000E 08 0.5100000E 01 0.3000000E-02 0.3600000E-02 0.2520000E 03 0.300000
```

CIRCULAR RING ON ELASTIC FOUNDATION {K= 252 #/in OPERATING LOADS}

DEGREES	BEND MOM	DISP	TWIST
0	-0.1322488E 02	0.1015062E-02	-0.8540832E-03
1	-0.1333256E 02	0.1009594E-02	-0.8616744E-03
2	-0.1343223E 02	0.1004554E-02	-0.8684799E-03
3	-0.1352392E 02	0.9999452E-03	-0.8744932E-03
4	-0.1360770E 02	0.9957696E-03	-0.8797100E-03
5	-0.1368359E 02	0.9920306E-03	-0.8841247E-03
6	-0.1375164E 02	0.9887309E-03	-0.8877323E-03
7	-0.1381182E 02	0.9858727E-03	-0.8905277E-03
8	-0.1386401E 02	0.9834580E-03	-0.8925042E-03
9	-0.1390802E 02	0.9814894E-03	-0.8936583E-03
10	-0.1394357E 02	0.9799685E-03	-0.8939843E-03
11	-0.1397028E 02	0.9788973E-03	-0.8934759E-03
12	-0.1398771E 02	0.9782773E-03	-0.8921284E-03
13	-0.1399541E 02	0.9781096E-03	-0.8899370E-03
14	-0.1399292E 02	0.9783953E-03	-0.8868967E-03
15	-0.1397983E 02	0.9791355E-03	-0.8830028E-03
16	-0.1395577E 02	0.9803301E-03	-0.8782511E-03
17	-0.1392046E 02	0.9819800E-03	-0.8726390E-03
18	-0.1387373E 02	0.9840845E-03	-0.8661617E-03
19	-0.1381548E 02	0.9866433E-03	-0.8588162E-03
20	-0.1374566E 02	0.9896559E-03	-0.8506018E-03
21	-0.1366424E 02	0.9931211E-03	-0.8415151E-03
22	-0.1357117E 02	0.9970371E-03	-0.8315558E-03
23	-0.1346632E 02	0.1001402E-02	-0.8207215E-03
24	-0.1334947E 02	0.1006215E-02	-0.8090130E-03
25	-0.1322024E 02	0.1011472E-02	-0.7964299E-03
26	-0.1307811E 02	0.1017171E-02	-0.7829733E-03
27	-0.1292242E 02	0.1023309E-02	-0.7686448E-03
28	-0.1275236E 02	0.1029881E-02	-0.7534456E-03
29	-0.1256700E 02	0.1036885E-02	-0.7373802E-03
30	-0.1236563E 02	0.1044314E-02	-0.7204525E-03
31	-0.1214723E 02	0.1052163E-02	-0.7026677E-03
32	-0.1191111E 02	0.1060428E-02	-0.6840331E-03
33	-0.1165672E 02	0.1069101E-02	-0.6645568E-03
34	-0.1138366E 02	0.1078174E-02	-0.6442499E-03
35	-0.1109179E 02	0.1087641E-02	-0.6231229E-03
36	-0.1078114E 02	0.1097492E-02	-0.6011896E-03
37	-0.1045191E 02	0.1107719E-02	-0.5784654E-03
38	-0.1010436E 02	0.1118310E-02	-0.5549675E-03
39	-0.9738771E 01	0.1129255E-02	-0.5307148E-03
40	-0.9355285E 01	0.1140542E-02	-0.5057273E-03
41	-0.8953859E 01	0.1152160E-02	-0.4800284E-03
42	-0.8534179E 01	0.1164095E-02	-0.4536408E-03
43	-0.8095575E 01	0.1176333E-02	-0.4265915E-03
44	-0.7637053E 01	0.1188861E-02	-0.3989080E-03
45	-0.7157311E 01	0.1201662E-02	-0.3706206E-03
46	-0.6654783E 01	0.1214721E-02	-0.3417623E-03
47	-0.6127825E 01	0.1228021E-02	-0.3123686E-03
48	-0.5574831E 01	0.1241542E-02	-0.2824774E-03
49	-0.4994447E 01	0.1255266E-02	-0.2521317E-03
50	-0.4385753E 01	0.1269171E-02	-0.2213770E-03
51	-0.3748456E 01	0.1283236E-02	-0.1902634E-03
52	-0.3083038E 01	0.1297437E-02	-0.1588447E-03
53	-0.2390906E	.311749E-02	-0.1271788E-03

54	-0.1674422E 01	0.1326146E-02	-0.9532773E-04	-0.
55	-0.9269274E 00	0.1340601E-02	-0.6335740E-04	-0.
56	-0.1826480E 00	0.1355085E-02	-0.3133660E-04	-0.
57	0.5834300E 00	0.1369568E-02	0.6631373E-06	-0.
58	0.1355752E 01	0.1384021E-02	0.3256813E-04	-0.
59	0.2128448E 01	0.1398415E-02	0.6430399E-04	-0.
60	0.2895[illegible]E 01	0.1412717E-02	0.9579495E-04	-0.
61	0.3651337E 01	0.1426900E-02	0.1269674E-03	-0.
62	0.4390469E 01	0.1440931E-02	0.1577473E-03	-0.
63	0.5108310E 01	0.1454784E-02	0.1880642E-03	-0.
64	0.5801020E 01	0.1468429E-02	0.2178496E-03	-0.
65	0.6465661E 01	0.1481841E-02	0.2470379E-03	-0.
66	0.7100265E 01	0.1494993E-02	0.2755678E-03	-0.
67	0.7703742E 01	0.1507862E-02	0.3033817E-03	-0.
68	0.8275867E 01	0.1520424E-02	0.3304256E-03	-0.
69	0.8817031E 01	0.1532659E-02	0.3566498E-03	-0.
70	0.9328186E 01	0.1544546E-02	0.3820086E-03	-0.
71	0.9810556E 01	0.1556067E-02	0.4064588E-03	-0.
72	0.1026551E 02	0.1567203E-02	0.4299610E-03	-0.
73	0.1069440E 02	0.1577940E-02	0.4524791E-03	-0.
74	0.1109838E 02	0.1588260E-02	0.4739791E-03	-0.
75	0.1147837E 02	0.1598151E-02	0.4944299E-03	-0.
76	0.1183496E 02	0.1607597E-02	0.5139021E-03	-0.
77	0.1216842E 02	0.1616588E-02	0.5320690E-03	-0.
78	0.1247873E 02	0.1625111E-02	0.5492052E-03	-0.
79	0.1276564E 02	0.1633155E-02	0.5651877E-03	-0.
80	0.1302877E 02	0.1640711E-02	0.5799961E-03	-0.
81	0.1326760E 02	0.1647769E-02	0.5936111E-03	-0.
82	0.1348168E 02	0.1654321E-02	0.6060149E-03	-0.
83	0.1367060E 02	0.1660359E-02	0.6171932E-03	-0.
84	0.1383408E 02	0.1665878E-02	0.6271332E-03	-0.
85	0.1397196E 02	0.1670872E-02	0.6358241E-03	-0.
86	0.1408425E 02	0.1675336E-02	0.6432572E-03	-0.
87	0.1417105E 02	0.1679267E-02	0.6494260E-03	0.
88	0.1423258E 02	0.1682663E-02	0.6543273E-03	0.
89	0.1426909E 02	0.1685521E-02	0.6579583E-03	0.
90	0.1428087E 02	0.1687841E-02	0.6603186E-03	0.
91	0.1426814E 02	0.1689622E-02	0.6614109E-03	0.
92	0.1423114E 02	0.1690867E-02	0.6612389E-03	0.
93	0.1417000E 02	0.1691576E-02	0.6598075E-03	0.
94	0.1408483E 02	0.1691753E-02	0.6571251E-03	0.
95	0.1397570E 02	0.1691401E-02	0.6532013E-03	0.
96	0.1384263E 02	0.1690524E-02	0.6480477E-03	0.
97	0.1368566E 02	0.1689128E-02	0.6416777E-03	0.
98	0.1350479E 02	0.1687219E-02	0.6341064E-03	0.
99	0.1330004E 02	0.1684804E-02	0.6253510E-03	0.
100	0.1307141E 02	0.1681892E-02	0.6154314E-03	0.
101	0.1281885E 02	0.1678490E-02	0.6043686E-03	0.
102	0.1254225E 02	0.1674608E-02	0.5921860E-03	0.
103	0.1224139E 02	0.1670256E-02	0.5789095E-03	0.
104	0.1191589E 02	0.1665451E-02	0.5645666E-03	0.
105	0.1156526E 02	0.1660198E-02	0.5491876E-03	0.
106	0.1118891E 02	0.1654515E-02	0.5328051E-03	0.
107	0.1078576E 02	0.1648414E-02	0.5154535E-03	0.
108	0.1035525E 02	0.1641912E-02	0.4971715E-03	0.
109	0.9896480E 01	0.1635026E-02	0.4779996E-03	0.
110	0.9408773E 01	0.1627773E-02	0.4579819E-03	0.
111	0.8891773E 01	0.1620172E-02	0.4371660E-03	0.

112	0.8345560E 01	0.1612244E-02	0.4156027E-03
113	0.7770827E 01	0.1604011E-02	0.3933468E-03
114	0.7169001E 01	0.1595496E-02	0.3704564E-03
115	0.6542269E 01	0.1586722E-02	0.3469921E-03
116	0.5893742E 01	0.1577716E-02	0.3230198E-03
117	0.5227333E 01	0.1568503E-02	0.2986061E-03
118	0.4547698E 01	0.1559110E-02	0.2738199E-03
119	0.3860186E 01	0.1549565E-02	0.2487335E-03
120	0.3170500E 01	0.1539896E-02	0.2234184E-03
121	0.2484552E 01	0.1530131E-02	0.1979462E-03
122	0.1808168E 01	0.1520298E-02	0.1723875E-03
123	0.1146872E 01	0.1510423E-02	0.1468129E-03
124	0.5055494E 00	0.1500534E-02	0.1212883E-03
125	-0.1117253E 00	0.1490655E-02	0.9587685E-04
126	-0.7017830E 00	0.1480811E-02	0.7063987E-04
127	-0.1262563E 01	0.1471026E-02	0.4563207E-04
128	-0.1793056E 01	0.1461318E-02	0.2090445E-04
129	-0.2293217E 01	0.1451711E-02	-0.3495123E-05
130	-0.2763906E 01	0.1442220E-02	-0.2752470E-04
131	-0.3206659E 01	0.1432865E-02	-0.5114627E-04
132	-0.3623471E 01	0.1423659E-02	-0.7432629E-04
133	-0.4016531E 01	0.1414618E-02	-0.9703247E-04
134	-0.4388050E 01	0.1405756E-02	-0.1192382E-03
135	-0.4740023E 01	0.1397085E-02	-0.1409190E-03
136	-0.5074034E 01	0.1388616E-02	-0.1620512E-03
137	-0.5391231E 01	0.1380360E-02	-0.1826150E-03
138	-0.5692216E 01	0.1372327E-02	-0.2025919E-03
139	-0.5977122E 01	0.1364528E-02	-0.2219653E-03
140	-0.6245651E 01	0.1356970E-02	-0.2407190E-03
141	-0.6497221E 01	0.1349662E-02	-0.2588400E-03
142	-0.6731131E 01	0.1342612E-02	-0.2763168E-03
143	-0.6946678E 01	0.1335826E-02	-0.2931389E-03
144	-0.7143337E 01	0.1329310E-02	-0.3092985E-03
145	-0.7320887E 01	0.1323069E-02	-0.3247895E-03
146	-0.7479456E 01	0.1317109E-02	-0.3396082E-03
147	-0.7619591E 01	0.1311433E-02	-0.3537522E-03
148	-0.7742218E 01	0.1306043E-02	-0.3672222E-03
149	-0.7848611E 01	0.1300941E-02	-0.3800199E-03
150	-0.7940223E 01	0.1296131E-02	-0.3921475E-03
151	-0.8018653E 01	0.1291612E-02	-0.4036109E-03
152	-0.8085451E 01	0.1287385E-02	-0.4144156E-03
153	-0.8142004E 01	0.1283451E-02	-0.4245674E-03
154	-0.8189466E 01	0.1279808E-02	-0.4340744E-03
155	-0.8228660E 01	0.1276458E-02	-0.4429441E-03
156	-0.8260046E 01	0.1273398E-02	-0.4511842E-03
157	-0.8283763E 01	0.1270629E-02	-0.4588027E-03
158	-0.8299669E 01	0.1268149E-02	-0.4658087E-03
159	-0.8307439E 01	0.1265956E-02	-0.4722106E-03
160	-0.8306648E 01	0.1264050E-02	-0.4780177E-03
161	-0.8296932E 01	0.1262428E-02	-0.4832393E-03
162	-0.8278026E 01	0.1261088E-02	-0.4878860E-03
163	-0.8249914E 01	0.1260029E-02	-0.4919680E-03
164	-0.8212854E 01	0.1259247E-02	-0.4954964E-03
165.	-0.8167419E 01	0.1258739E-02	-0.4984834E-03
166	-0.8114442E 01	0.1258502E-02	-0.5009414E-03
167	-0.8054979E 01	0.1258532E-02	-0.5028825E-03
168	-0.7990231E 01	0.1258826E-02	-0.5043200E-03
169	-0.7921440E 01	0.1259380E-02	-0.5052667E-03

170	-0.7849754E 01	0.1260191E-02	-0.5057352E-03	0.
171	-0.7776201E 01	0.1261254E-02	-0.5057384E-03	0.
172	-0.7701509E 01	0.1262565E-02	-0.5052883E-03	0.
173	-0.7626152E 01	0.1264121E-02	-0.5043963E-03	0.
174	-0.7550285E 01	0.1265918E-02	-0.5030734E-03	0.
175	-0.7473767E 01	0.1267953E-02	-0.5013293E-03	0.
176	-0.7396245E 01	0.1270223E-02	-0.4991742E-03	0.
177	-0.7317226E 01	0.1272723E-02	-0.4966178E-03	0.
178	-0.7236153E 01	0.1275451E-02	-0.4936682E-03	0.
179	-0.7152544E 01	0.1278402E-02	-0.4903340E-03	0.
180	-0.7066043E 01	0.1281576E-02	-0.4866236E-03	0.

Form 2427

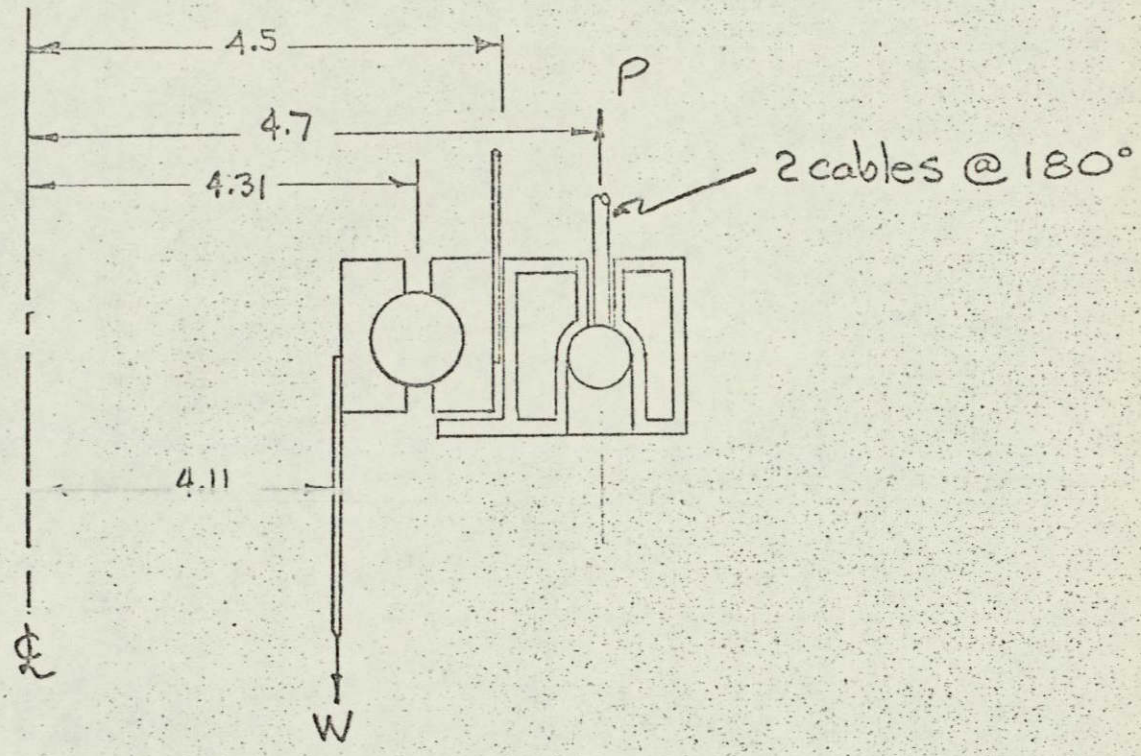
AiRESEARCH MFG. CO.

DATE 9-8-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

LOWER HIP BEARING & SUPPORT RING

5 PSI OPERATING LOAD



$$\text{Load} = \frac{\pi}{4}(9)^2 5 = 317^{\#}$$

$$W = P\frac{r}{2} = \frac{5}{2}(4.11) = 10.3\ \#/\text{in}$$

$$\text{CABLE LOAD} = \tfrac{1}{2}(317) = 158.5^{\#} = P$$

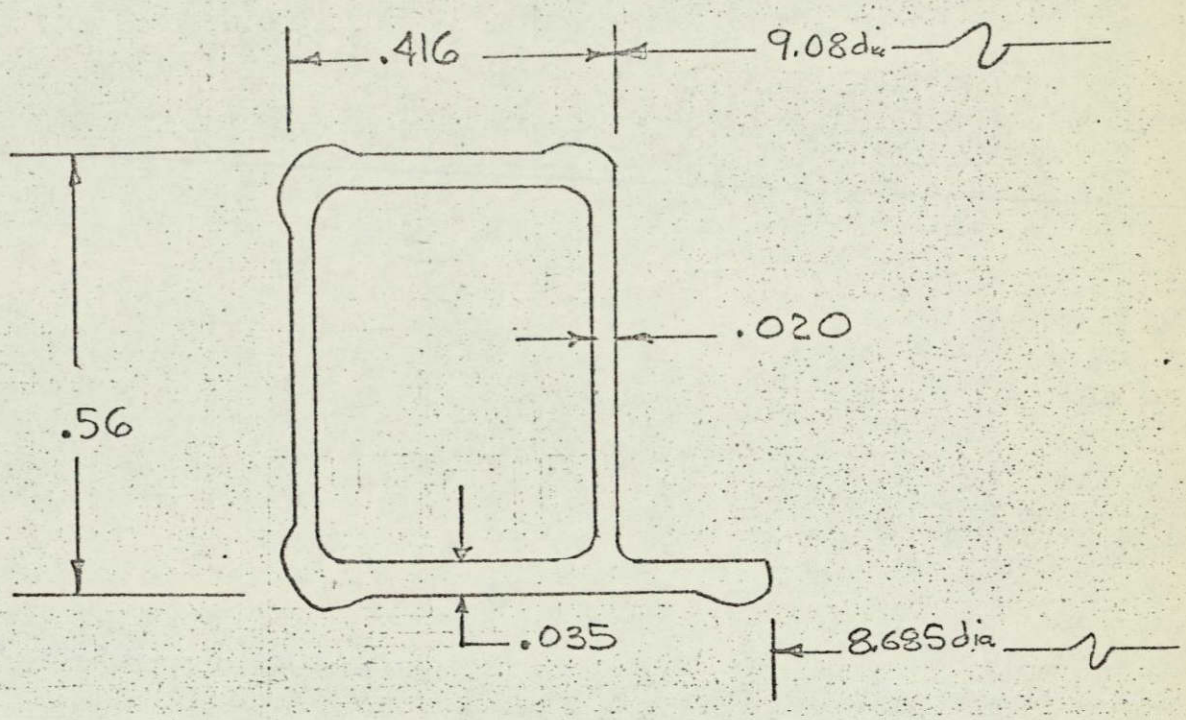
FOR OUT OF PLANE LOADS, BOTH PARTS OF THE BEARING SHOULD WORK TOGETHER.

$$2\pi r W = 8.22\pi(10.3) = 266.^{\#}$$

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$$I = \frac{1}{12}\left\{.416(.56)^3 - .376(.49)^3\right\} = 0.002401 \text{ in}^4$$

$$A = .416(.56) - .376(.49) = 0.04872 \text{ in}^2$$

$$A_m = .525(.396) = 0.2079 \text{ in}^2$$

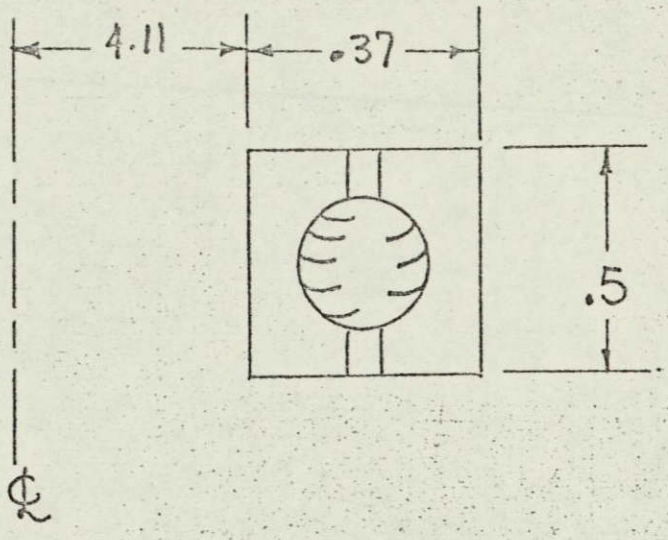
$$K = \frac{4A^2}{\sum \frac{u}{t}} = \frac{4(0.2079)^2}{\frac{.832}{.035} + \frac{.98}{.02}} = 0.002375 \text{ in}^4$$

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$2b = 0.37$
$2a = 0.5$

FIGURE THE INERTIA FOR A SOLID RECTANGLE AND TAKE A PERCENTAGE OF THAT AS BEING EFFECTIVE

$$I = \frac{bh^3}{12} = \frac{0.37(.5)^3}{12} = 0.00385 \text{ in}^4$$

assume 80% effective.

$$I = 0.8(.00385) = 0.00308 \text{ in}^4$$

$$K = ab^3\left[\frac{16}{3} - 3.36\frac{b}{a}\right] = 0.25(0.185)^3\left[\frac{16}{3} - 3.36\times\frac{0.185}{0.25}\right]$$

$$K = 0.0045 \text{ in}^4$$

$$K = 0.8(.0045) = 0.0036 \text{ in}^4$$

$$A = .37\times.5 = 0.185 \text{ in}^2$$

$$A = 0.8(.185) = 0.148 \text{ in}^2$$

REPORT
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Form 2427

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PART NO

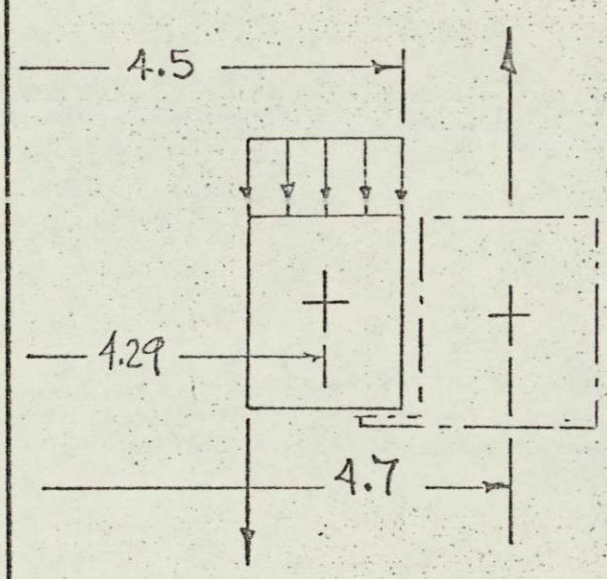
$$EI = 10\times10^{6}\times 3.08\times10^{-3} + 30\times10^{6}\times 2.4\times10^{-3}$$

$$EI \approx 102.8\times10^{3}$$

$$GK = 3.8\times10^{6}\times 3.6\times10^{-3} + 11.5\times10^{6}\times 2.375\times10^{-3}$$

$$GK \approx 41.1\times10^{3}$$

$$\lambda = \frac{EI}{GK} = \frac{102.8}{41.1} = 2.5$$



Centroid of combined section $= \dfrac{4.29\times.148 + 4.7\times.048}{.148 + .048}$

$= \dfrac{.864}{.196} = 4.41$

DISTRIBUTED LOAD $= \dfrac{317}{8.82\pi} = 11.4$ #/in

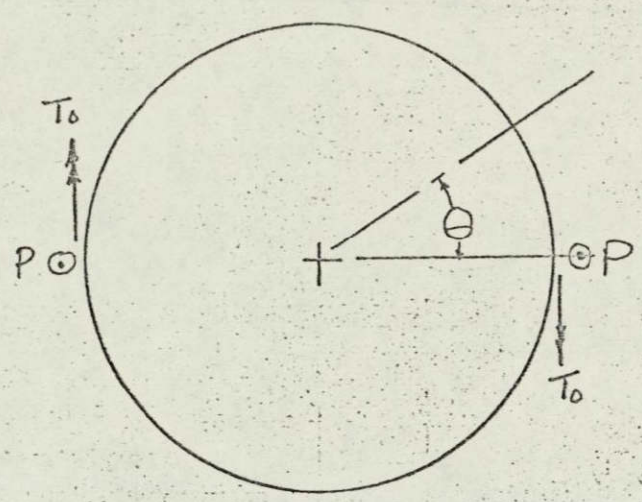
TWISTING COUPLE (@ $\theta = {}^{0}_{180}$) $= \dfrac{317}{2}(4.7 - 4.41)$

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$T_o = 46$ #in



$$y = \frac{r^2 T_o}{8EI}(1+\lambda)(2\theta\cos\theta - \pi\cos\theta + \pi - 2\sin\theta) + \frac{Wr^4}{8EI}\left\{2\pi(\theta\cos\theta - \sin\theta) + \pi^2(1-\cos\theta) + \lambda\left[2\pi(\theta\cos\theta - 3\sin\theta) + \pi^2(1-\cos\theta) + 4\theta(\pi-\theta)\right]\right\}$$

$$\beta = \frac{r T_o}{8EI}\left[2(1-\lambda)\sin\theta + (1+\lambda)(\pi - 2\theta)\cos\theta\right] + \frac{\pi W r^3}{8EI}(1+\lambda)\left[2\sin\theta + (\pi - 2\theta)\cos\theta - \frac{8}{\pi}\right]$$

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$$\text{BEND MOM} = \frac{T_o}{2}\sin\theta - Wr^2(1 - 1.5708\sin\theta)$$

$$\text{TORSIONAL MOMENT} = \frac{T_o}{2}\cos\theta + Wr^2\left[\theta + 1.5708(\cos\theta - 1)\right]$$

θ	BEND MOM	TORSIONAL MOM
0	-160	23
10		
20		
30	-22.9	137
40		188.6
50		
60	77.3	46.
70		
80		
90	114	0

TORSIONAL MOMENT IS A MAXIMUM AT $\theta = 36$

$$\sin\theta = \frac{2Wr^2}{T_o + \pi Wr^2} = \frac{320}{546} = 0.588$$

```
PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000

// FOR
*NAMEBEAR
*IOCS (CARD,1132 PRINTER)
*LISTALL
      READ(2,3)TO,W,R,E,BI,BLAM
    3 FORMAT(6E10.5)
      CON1=R*TO*.125/(E*BI)
      CON2=R*R*R*W*.125/(E*BI)
      PI=3.141596
      BLA=BLAM
      DO 10 I=1,181
      X= FLOAT(I-1)
      ANG=.01745*X
      S=SIN(ANG)
      C=COS(ANG)
      Y= R*CON1*(1.+BLAM)*(2.*ANG*C-PI*C+PI-2.*S)+R*CON2*(2.*PI*(C*ANG
     1-S)+PI*PI*(1.-C)+BLA*(2.*PI*(ANG*C-3.*S)+PI*PI*(1.-C)+4.*ANG*(PI-
     2ANG)))
      BETA=CON1*(2.*(1.-BLAM)*S+(1.+BLAM)*C*(PI-2.*ANG))+PI*CON2*(1.+BLA
     1M)*(2.*S+(PI-2.*ANG)*C- 8./PI)
   10 WRITE(3,5)X,Y,BETA
    5 FORMAT(1H ,   3(5X,E14.7))
      STOP
      END
VARIABLE ALLOCATIONS
    TO(R )=0000          W(R )=0002          R(R )=0004          E(R )=0006
  CON1(R )=000C       CON2(R )=000E        PI(R )=0010        BLA(R )=0012
     S(R )=0018          C(R )=001A          Y(R )=001C       BETA(R )=001E

STATEMENT ALLOCATIONS
 3    =005C  5    =005F  10   =01B1

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 FSIN    FCOS    FSUB    FMPY    FDIV    FLD     FSTO    FSBR    FDVR    FLOAT
 SFIO    SIOF    STOP

REAL CONSTANTS
  .125000E 00=0042    .314159E 01=0044    .174500E-01=0046    .100000E 01=0048
  .400000E 01=004E    .800000E 01=0050

INTEGER CONSTANTS
     2=0052      1=0053    181=0054      3=0055      0=0056

CORE REQUIREMENTS FOR BEAR
 COMMON      0  VARIABLES     66  PROGRAM    388

 END OF COMPILATION

// XEQ
```

DEGREES	DISP	TWIST
0.0000000E 00	0.2303681E-07	0.1049190E-01
0.1000000E 01	0.1337798E-04	0.1044224E-01
0.2000000E 01	0.5315473E-04	0.1037956E-01
0.3000000E 01	0.1189251E-03	0.1030418E-01
0.4000000E 01	0.2101405E-03	0.1021641E-01
0.5000000E 01	0.3263539E-03	0.1011658E-01
0.6000000E 01	0.4670771E-03	0.1000501E-01
0.7000000E 01	0.6317727E-03	0.9882038E-02
0.8000001E 01	0.8198813E-03	0.9747993E-02
0.9000001E 01	0.1030892E-02	0.9603194E-02
0.1000000E 02	0.1264241E-02	0.9447988E-02
0.1100000E 02	0.1519334E-02	0.9282719E-02
0.1200000E 02	0.1795548E-02	0.9107723E-02
0.1300000E 02	0.2092347E-02	0.8923349E-02
0.1400000E 02	0.2409072E-02	0.8729940E-02
0.1500000E 02	0.2745121E-02	0.8527843E-02
0.1600000E 02	0.3099869E-02	0.8317399E-02
0.1700000E 02	0.3472662E-02	0.8098971E-02
0.1800000E 02	0.3862837E-02	0.7872894E-02
0.1900000E 02	0.4269754E-02	0.7639531E-02
0.2000000E 02	0.4692744E-02	0.7399233E-02
0.2100000E 02	0.5131111E-02	0.7152352E-02
0.2200000E 02	0.5584219E-02	0.6899233E-02
0.2300000E 02	0.6051366E-02	0.6640232E-02
0.2400000E 02	0.6531797E-02	0.6375708E-02
0.2500000E 02	0.7024900E-02	0.6106008E-02
0.2600000E 02	0.7529917E-02	0.5831488E-02
0.2700000E 02	0.8046155E-02	0.5552493E-02
0.2800000E 02	0.8572934E-02	0.5269374E-02
0.2900000E 02	0.9109525E-02	0.4982481E-02
0.3000000E 02	0.9655186E-02	0.4692164E-02
0.3100000E 02	0.1020926E-01	0.4398766E-02
0.3200000E 02	0.1077097E-01	0.4102627E-02
0.3300000E 02	0.1133961E-01	0.3804107E-02
0.3400000E 02	0.1191455E-01	0.3503524E-02
0.3500000E 02	0.1249497E-01	0.3201235E-02
0.3600000E 02	0.1308019E-01	0.2897563E-02
0.3700000E 02	0.1366952E-01	0.2592857E-02
0.3800000E 02	0.1426226E-01	0.2287426E-02
0.3900000E 02	0.1485764E-01	0.1981614E-02
0.4000000E 02	0.1545501E-01	0.1675749E-02
0.4100000E 02	0.1605360E-01	0.1370141E-02
0.4200000E 02	0.1665287E-01	0.1065113E-02
0.4300000E 02	0.1725200E-01	0.7609784E-03
0.4400000E 02	0.1785032E-01	0.4580482E-03
0.4500000E 02	0.1844718E-01	0.1566356E-03
0.4600000E 02	0.1904193E-01	-0.1429629E-03
0.4700000E 02	0.1963385E-01	-0.4404466E-03
0.4800000E 02	0.2022233E-01	-0.7355209E-03
0.4900000E 02	0.2080669E-01	-0.1027890E-02
0.5000000E 02	0.2138631E-01	-0.1317287E-02
0.5100000E 02	0.2196050E-01	-0.1603405E-02
0.5200000E 02	0.2252877E-01	-0.1885994E-02
0.5300000E 02	0.2309040E-01	-0.2164763E-02
0.5400000E 02	0.2364480E-01	-0.2439457E-02
0.5500000E 02	0.2419140E-01	-0.2709821E-02
0.5600000E 02	0.2472965E-01	-0.2975590E-02
0.5700000E 02	0.2525890E-01	-0.3236517E-02

DEGREES	DISP	TWIST
0.5800000E 02	0.2577867E-01	-0.3492362E-02
0.5900000E 02	0.2628842E-01	-0.3742892E-02
0.6000000E 02	0.2678756E-01	-0.3987873E-02
0.6100000E 02	0.2727557E-01	-0.4227075E-02
0.6200000E 02	0.2775201E-01	-0.4460284E-02
0.6300000E 02	0.2821633E-01	-0.4687282E-02
0.6400001E 02	0.2866804E-01	-0.4907868E-02
0.6500001E 02	0.2910677E-01	-0.5121845E-02
0.6600001E 02	0.2953200E-01	-0.5329016E-02
0.6700001E 02	0.2994331E-01	-0.5529199E-02
0.6800001E 02	0.3034031E-01	-0.5722214E-02
0.6900001E 02	0.3072251E-01	-0.5907880E-02
0.7000001E 02	0.3108962E-01	-0.6086046E-02
0.7100001E 02	0.3144122E-01	-0.6256544E-02
0.7200001E 02	0.3177700E-01	-0.6419227E-02
0.7300001E 02	0.3209658E-01	-0.6573947E-02
0.7400001E 02	0.3239967E-01	-0.6720572E-02
0.7500001E 02	0.3268597E-01	-0.6858979E-02
0.7600001E 02	0.3295518E-01	-0.6989039E-02
0.7700001E 02	0.3320690E-01	-0.7110630E-02
0.7800001E 02	0.3344112E-01	-0.7223666E-02
0.7900001E 02	0.3365746E-01	-0.7328027E-02
0.8000001E 02	0.3385577E-01	-0.7423638E-02
0.8100001E 02	0.3403584E-01	-0.7510414E-02
0.8200001E 02	0.3419739E-01	-0.7588269E-02
0.8300001E 02	0.3434043E-01	-0.7657147E-02
0.8400001E 02	0.3446470E-01	-0.7716979E-02
0.8500001E 02	0.3457008E-01	-0.7767725E-02
0.8600001E 02	0.3465654E-01	-0.7809330E-02
0.8700001E 02	0.3472391E-01	-0.7841762E-02
0.8800001E 02	0.3477223E-01	-0.7864994E-02
0.8900001E 02	0.3480136E-01	-0.7879005E-02
0.9000001E 02	0.3481128E-01	-0.7883779E-02
0.9100001E 02	0.3480196E-01	-0.7879316E-02
0.9200001E 02	0.3477357E-01	-0.7865624E-02
0.9300001E 02	0.3472590E-01	-0.7842708E-02
0.9400001E 02	0.3465919E-01	-0.7810588E-02
0.9500001E 02	0.3457341E-01	-0.7769295E-02
0.9600001E 02	0.3446864E-01	-0.7718866E-02
0.9700001E 02	0.3434503E-01	-0.7659339E-02
0.9800001E 02	0.3420268E-01	-0.7590772E-02
0.9900001E 02	0.3404171E-01	-0.7513221E-02
0.1000000E 03	0.3386229E-01	-0.7426749E-02
0.1010000E 03	0.3366466E-01	-0.7331443E-02
0.1020000E 03	0.3344889E-01	-0.7227373E-02
0.1030000E 03	0.3321533E-01	-0.7114640E-02
0.1040000E 03	0.3296412E-01	-0.6993333E-02
0.1050000E 03	0.3269559E-01	-0.6863564E-02
0.1060000E 03	0.3240992E-01	-0.6725447E-02
0.1070000E 03	0.3210740E-01	-0.6579099E-02
0.1080000E 03	0.3178837E-01	-0.6424644E-02
0.1090000E 03	0.3145321E-01	-0.6262237E-02
0.1100000E 03	0.3110212E-01	-0.6092003E-02
0.1110000E 03	0.3073555E-01	-0.5914099E-02
0.1120000E 03	0.3035386E-01	-0.5728683E-02
0.1130000E 03	0.2995733E-01	-0.5535918E-02
0.1140000E 03	0.2954656E-01	-0.5335983E-02

DEGREES	DISP	TWIST
0.1150000E 03	0.2912178E-01	-0.5129043E-02
0.1160000E 03	0.2868355E-01	-0.4915300E-02
0.1170000E 03	0.2823226E-01	-0.4694936E-02
0.1180000E 03	0.2776834E-01	-0.4468142E-02
0.1190000E 03	0.2729234E-01	-0.4235148E-02
0.1200000E 03	0.2680475E-01	-0.3996148E-02
0.1210000E 03	0.2630595E-01	-0.3751368E-02
0.1220000E 03	0.2579658E-01	-0.3501019E-02
0.1230000E 03	0.2527718E-01	-0.3245355E-02
0.1240000E 03	0.2474824E-01	-0.2984596E-02
0.1250000E 03	0.2421027E-01	-0.2718980E-02
0.1260000E 03	0.2366396E-01	-0.2448783E-02
0.1270000E 03	0.2310985E-01	-0.2174236E-02
0.1280000E 03	0.2254846E-01	-0.1895593E-02
0.1290000E 03	0.2198043E-01	-0.1613131E-02
0.1300000E 03	0.2140640E-01	-0.1327126E-02
0.1310000E 03	0.2082696E-01	-0.1037848E-02
0.1320000E 03	0.2024276E-01	-0.7455704E-03
0.1330000E 03	0.1965442E-01	-0.4505823E-03
0.1340000E 03	0.1906261E-01	-0.1531834E-03
0.1350000E 03	0.1846805E-01	0.1463514E-03
0.1360000E 03	0.1787120E-01	0.4477056E-03
0.1370000E 03	0.1727291E-01	0.7505852E-03
0.1380000E 03	0.1667381E-01	0.1054681E-02
0.1390000E 03	0.1607459E-01	0.1359687E-02
0.1400000E 03	0.1547594E-01	0.1665278E-02
0.1410000E 03	0.1487854E-01	0.1971133E-02
0.1420000E 03	0.1428306E-01	0.2276963E-02
0.1430000E 03	0.1369030E-01	0.2582398E-02
0.1440000E 03	0.1310087E-01	0.2887142E-02
0.1450000E 03	0.1251546E-01	0.3190853E-02
0.1460000E 03	0.1193483E-01	0.3493194E-02
0.1470000E 03	0.1135980E-01	0.3793836E-02
0.1480000E 03	0.1079086E-01	0.4092434E-02
0.1490000E 03	0.1022891E-01	0.4388662E-02
0.1500000E 03	0.9674606E-02	0.4682152E-02
0.1510000E 03	0.9128622E-02	0.4972582E-02
0.1520000E 03	0.8591765E-02	0.5259597E-02
0.1530000E 03	0.8064644E-02	0.5542850E-02
0.1540000E 03	0.7548023E-02	0.5821992E-02
0.1550000E 03	0.7042587E-02	0.6096675E-02
0.1560000E 03	0.6549106E-02	0.6366543E-02
0.1570000E 03	0.6068220E-02	0.6631243E-02
0.1580000E 03	0.5600673E-02	0.6890434E-02
0.1590000E 03	0.5147054E-02	0.7143762E-02
0.1600000E 03	0.4708198E-02	0.7390859E-02
0.1610000E 03	0.4284707E-02	0.7631389E-02
0.1620000E 03	0.3877243E-02	0.7864996E-02
0.1630000E 03	0.3486406E-02	0.8091324E-02
0.1640000E 03	0.3113109E-02	0.8310019E-02
0.1650000E 03	0.2757728E-02	0.8520733E-02
0.1660000E 03	0.2420973E-02	0.8723124E-02
0.1670000E 03	0.2103640E-02	0.8916834E-02
0.1680000E 03	0.1806170E-02	0.9101521E-02
0.1690000E 03	0.1529237E-02	0.9276837E-02
0.1700000E 03	0.1273374E-02	0.9442446E-02
0.1710000E 03	0.1039358E-02	0.9597994E-02
0.1720000E 03	0.8275957E-03	0.9743148E-02

DEGREES	DISP	TWIST
0.1730000E 03	0.6387054E-03	0.9877575E-02
0.1740000E 03	0.4731534E-03	0.1000093E-01
0.1750000E 03	0.3316627E-03	0.1011289E-01
0.1760000E 03	0.2145295E-03	0.1021313E-01
0.1770000E 03	0.1224822E-03	0.1030131E-01
0.1780000E 03	0.5587073E-04	0.1037712E-01
0.1790000E 03	0.1524315E-04	0.1044023E-01
0.1800000E 03	0.9899911E-06	0.1049034E-01

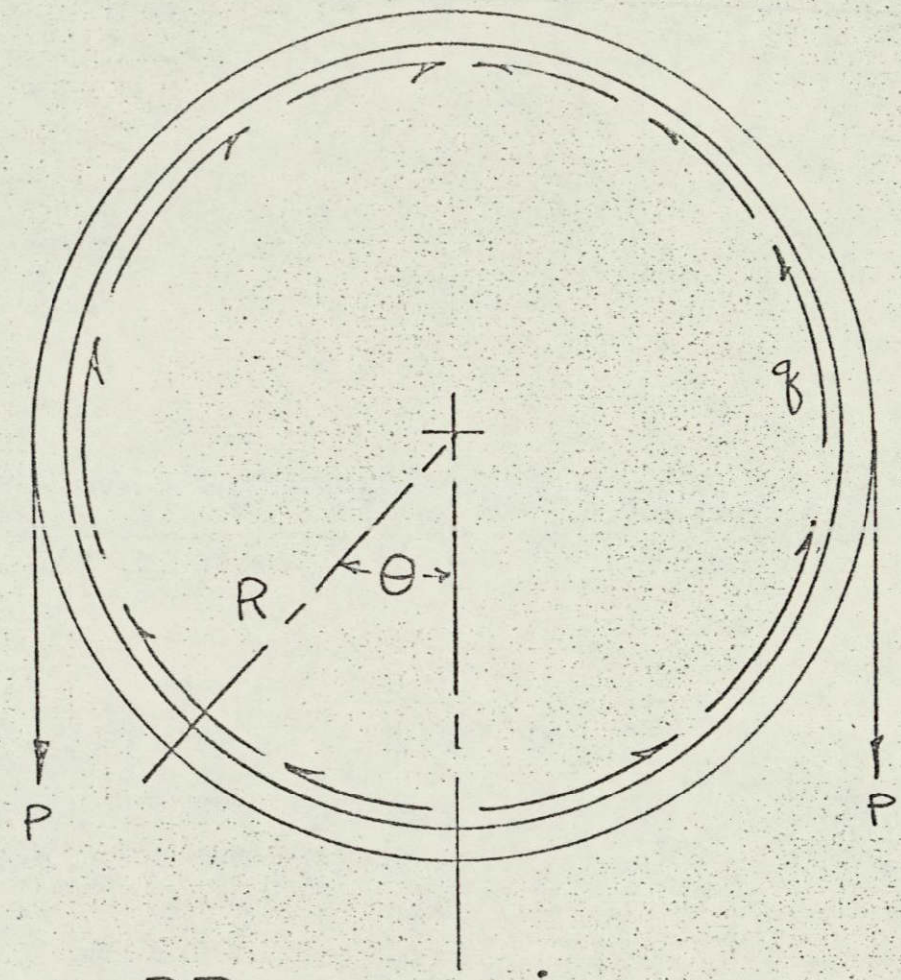
Form 2427

AiRESEARCH MFG. CO.

DATE 9-10-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

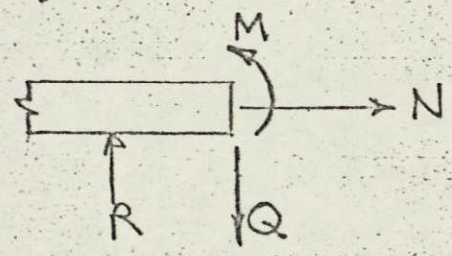
UPPER HIP BEARING IN PLANE LOADS



$M = K_m PR$

$N = K_n P$

$Q = K_Q P$



@ $\theta = 5/8\pi$

$K_m = .02917$

$K_n = .2855$

@ $\theta = \pi/2$

$K_Q = .15916$

REPORT
PAGE 239 OF

Form 2427

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DATE 9-10-69
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CALC. NO
MODEL
PART NO

P=74

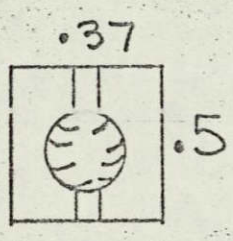
R=5.1

PR=376

M=376 x .02917 = 11 #in

N = 74 x .2855 = 21.1 #

Q = 74 x .1592 = 11.75 #



If both inner & outer races work together.
(assume about 80% effective)

$A = .8(.5 \times .37) = 0.148 in^2$

$I = \frac{.8}{12}(.5)(.37)^3 = 0.003 in^4$

$\sigma = \frac{Mc}{I} + \frac{N}{A} = \frac{11 \times .18}{.003} + \frac{21.1}{.198} \approx 1000 psi$

@ $\theta = 5/8\,\pi = 112°$

REPORT
PAGE 240 OF

Form 2427

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DATE 9-10-69
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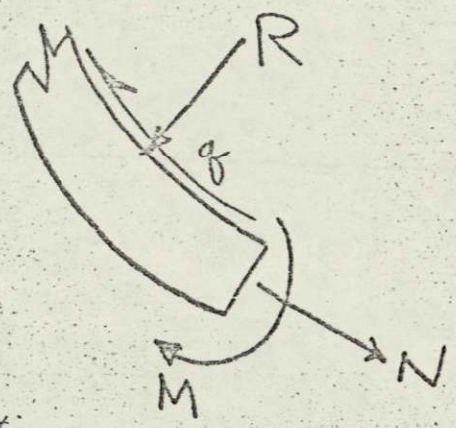
CALC. NO.
MODEL
PART NO.

@ $\theta = 0$

$K_m = .02254$

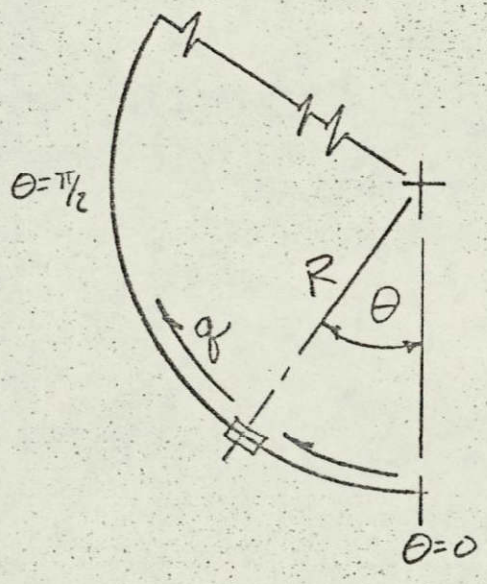
$K_n = .15916$

$K_Q = 0.0$



$M = .02254(376) = 8.45\ ^{\#}/_{in}$

$N = .15916(74) = 11.8\ \#$



$$I = \pi R^3 t$$

$$Q = 2\int_0^{\theta} tR^2(\cos\beta - \cos\theta)\,d\beta$$

$$Q = 2tR^2(\sin\theta - \theta\cos\theta)$$

$$q = \frac{VQ}{I} = 2P\,\frac{2tR^2(\sin\theta - \theta\cos\theta)}{\pi R^3 t}$$

$$q = \frac{4P}{\pi R}(\sin\theta - \theta\cos\theta)$$

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MODEL
PART NO

$$\mathcal{M} = M - NR(1-\cos\theta) + \int_0^\theta qR^2\{1-\cos(\theta-\beta)\}d\beta$$

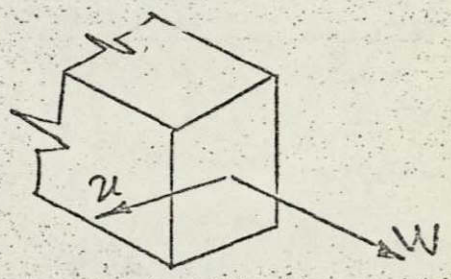
$$- PR\{1-\cos(\theta-\pi/2)\}$$

$$\mathcal{M} = M + \left\{\frac{8}{\pi}PR - NR\right\}(1-\cos\theta) - \frac{5}{\pi}PR\theta\sin\theta$$

$$+ \frac{PR}{\pi}\theta^2\cos\theta - PR\{1-\cos(\theta-\pi/2)\}$$

$$\frac{d^2v}{d\theta^2} + v = \mathcal{M}\frac{R^2}{EI}$$

$$\frac{dw}{d\theta} = v$$



$$M = .02254\,PR$$

$$N = .15916\,P$$

$$\frac{\mathcal{M}R^2}{EI} = \frac{PR^3}{EI}\{.02254 + 2.38731(1-\cos\theta)$$

$$-1.591547\,\theta\sin\theta$$

$$+.318309\,\theta^2\cos\theta - [1-\cos(\theta-\pi/2)]\}$$

θ	$\frac{du}{d\theta}$	u	W
0.4187995E 00	0.2392690E-02	0.5741356E-03	0.8424068E-04
0.4711494E 00	0.2485326E-02	0.7021016E-03	0.1176247E-03
0.5234992E 00	0.2507411E-02	0.8330984E-03	0.1578030E-03
0.5758488E 00	0.2452605E-02	0.9632646E-03	0.2048348E-03
0.6281983E 00	0.2315108E-02	0.1088418E-02	0.2585682E-03
0.6805479E 00	0.2089748E-02	0.1204095E-02	0.3186253E-03
0.7328975E 00	0.1772060E-02	0.1305575E-02	0.3843874E-03
0.7852470E 00	0.1358378E-02	0.1387924E-02	0.4549833E-03
0.8375966E 00	0.8459357E-03	0.1446043E-02	0.5292781E-03
0.8899462E 00	0.2329609E-03	0.1474710E-02	0.6058670E-03
0.9422957E 00	-0.4812044E-03	0.1468638E-02	0.6830705E-03
0.9946453E 00	-0.1296002E-02	0.1422540E-02	0.7589315E-03
0.1046994E 01	-0.2209523E-02	0.1331193E-02	0.8312172E-03
0.1099344E 01	-0.3218393E-02	0.1189510E-02	0.8974253E-03
0.1151694E 01	-0.4317638E-02	0.9926210E-03	0.9547920E-03
0.1204043E 01	-0.5500550E-02	0.7359656E-03	0.1000306E-02
0.1256393E 01	-0.6758559E-02	0.4153791E-03	0.1030726E-02
0.1308742E 01	-0.8081076E-02	0.2719834E-04	0.1042610E-02
0.1361092E 01	-0.9455358E-02	-0.4316291E-03	0.1032336E-02
0.1413441E 01	-0.1086640E-01	-0.9634308E-03	0.9961403E-03
0.1465791E 01	-0.1229675E-01	-0.1569684E-02	0.9301611E-03
0.1518141E 01	-0.1372639E-01	-0.2250886E-02	0.8304832E-03
0.1570490E 01	-0.1513260E-01	-0.3006417E-02	0.6931937E-03
0.1622840E 01	-0.1649573E-01	-0.3834470E-02	0.5144438E-03
0.1675189E 01	-0.1782416E-01	-0.4732899E-02	0.2904962E-03
0.1727539E 01	-0.1913302E-01	-0.5700298E-02	0.1770686E-04
0.1779888E 01	-0.2043373E-01	-0.6735962E-02	-0.3075138E-03
0.1832238E 01	-0.2170370E-01	-0.7839683E-02	-0.6887322E-03
0.1884588E 01	-0.2303603E-01	-0.9011507E-02	-0.1129511E-02
0.1936937E 01	-0.2433914E-01	-0.1025154E-01	-0.1633419E-02
0.1989287E 01	-0.2563651E-01	-0.1155968E-01	-0.2204026E-02
0.2041635E 01	-0.2691641E-01	-0.1293534E-01	-0.2844884E-02
0.2093984E 01	-0.2816163E-01	-0.1437718E-01	-0.3559498E-02
0.2146332E 01	-0.2934932E-01	-0.1588281E-01	-0.4351274E-02
0.2198680E 01	-0.3045077E-01	-0.1744847E-01	-0.5223455E-02
0.2251028E 01	-0.3143125E-01	-0.1906878E-01	-0.6179057E-02
0.2303376E 01	-0.3224992E-01	-0.2073635E-01	-0.7220753E-02
0.2355724E 01	-0.3285983E-01	-0.2244155E-01	-0.8350778E-02
0.2408072E 01	-0.3320772E-01	-0.2417206E-01	-0.9570788E-02
0.2460421E 01	-0.3323417E-01	-0.2591262E-01	-0.1088172E-01
0.2512769E 01	-0.3287357E-01	-0.2764473E-01	-0.1228364E-01
0.2565117E 01	-0.3205434E-01	-0.2934628E-01	-0.1377553E-01
0.2617465E 01	-0.3069896E-01	-0.3099124E-01	-0.1535515E-01
0.2669813E 01	-0.2872417E-01	-0.3254938E-01	-0.1701873E-01
0.2722161E 01	-0.2604125E-01	-0.3398598E-01	-0.1876086E-01
0.2774509E 01	-0.2255629E-01	-0.3526154E-01	-0.2057416E-01
0.2826858E 01	-0.1817058E-01	-0.3633153E-01	-0.2244907E-01
0.2879206E 01	-0.1278098E-01	-0.3714608E-01	-0.2437352E-01
0.2931554E 01	-0.6280339E-02	-0.3764989E-01	-0.2633274E-01
0.2983902E 01	0.1441994E-02	-0.3778189E-01	-0.2830887E-01
0.3036250E 01	0.1049962E-01	-0.3747513E-01	-0.3028075E-01
0.3088598E 01	0.2100851E-01	-0.3665670E-01	-0.3222347E-01
0.3140946E 01	0.3308637E-01	-0.3524757E-01	-0.3410821E-01

$\theta = 2.95 \times 57.295 = 169^\circ$

IN PLANE LOADING UPPER HIP BEARING

XEQ

P	K	E	I	H
0.7400001E 02	0.5100000E 01	0.1000000E 08	0.3000000E-02	0.8725000E-02

0.5234999E-01	0.3849696E-03	0.1009204E-04	0.1762124E-06
0.1046999E 00	0.7620448E-03	0.4016669E-04	0.1405586E-05
0.1570498E 00	0.1122749E-02	0.8958853E-04	0.4719508E-05
0.2093997E 00	0.1458693E-02	0.1572804E-03	0.1110451E-04
0.2617497E 00	0.1761618E-02	0.2417294E-03	0.2147932E-04
0.3140996E 00	0.2023444E-02	0.3409942E-03	0.3667218E-04
0.3664495E 00	0.2236322E-02	0.4527170E-03	0.5739877E-04

θ	$\frac{du}{d\theta}$	u	W
0.4187995E 00	0.2392690E-02	0.5741356E-03	0.8424068E-04
0.4711494E 00	0.2485326E-02	0.7021016E-03	0.1176247E-03
0.5234992E 00	0.2507411E-02	0.8330984E-03	0.1578030E-03
0.5758488E 00	0.2452605E-02	0.9632646E-03	0.2048348E-03
0.6281983E 00	0.2315108E-02	0.1088418E-02	0.2585682E-03
0.6805479E 00	0.2089748E-02	0.1204095E-02	0.3186253E-03
0.7328975E 00	0.1772060E-02	0.1305575E-02	0.3843874E-03
0.7852470E 00	0.1358378E-02	0.1387924E-02	0.4549833E-03
0.8375966E 00	0.8459357E-03	0.1446043E-02	0.5292781E-03
0.8899462E 00	0.2329609E-03	0.1474710E-02	0.6058670E-03
0.9422957E 00	-0.4812044E-03	0.1468638E-02	0.6830705E-03
0.9946453E 00	-0.1296002E-02	0.1422540E-02	0.7589315E-03
0.1046994E 01	-0.2209523E-02	0.1331193E-02	0.8312172E-03
0.1099344E 01	-0.3218393E-02	0.1189510E-02	0.8974253E-03
0.1151694E 01	-0.4317638E-02	0.9926210E-03	0.9547920E-03
0.1204043E 01	-0.5500550E-02	0.7359656E-03	0.1000306E-02
0.1256393E 01	-0.6758559E-02	0.4153791E-03	0.1030726E-02
0.1308742E 01	-0.8081076E-02	0.2719834E-04	0.1042610E-02
0.1361092E 01	-0.9455358E-02	-0.4316291E-03	0.1032336E-02
0.1413441E 01	-0.1086640E-01	-0.9634308E-03	0.9961403E-03
0.1465791E 01	-0.1229675E-01	-0.1569684E-02	0.9301611E-03
0.1518141E 01	-0.1372639E-01	-0.2250886E-02	0.8304832E-03
0.1570490E 01	-0.1513260E-01	-0.3006417E-02	0.6931937E-03
0.1622840E 01	-0.1649573E-01	-0.3834470E-02	0.5144438E-03
0.1675189E 01	-0.1782416E-01	-0.4732899E-02	0.2904962E-03
0.1727539E 01	-0.1913302E-01	-0.5700298E-02	0.1770686E-04
0.1779888E 01	-0.2043373E-01	-0.6735962E-02	-0.3075138E-03
0.1832238E 01	-0.2173370E-01	-0.7839683E-02	-0.6887322E-03
0.1884588E 01	-0.2303603E-01	-0.9011507E-02	-0.1129511E-02
0.1936937E 01	-0.2433914E-01	-0.1025154E-01	-0.1633419E-02
0.1989287E 01	-0.2563651E-01	-0.1155968E-01	-0.2204026E-02
0.2041635E 01	-0.2691641E-01	-0.1293534E-01	-0.2844884E-02
0.2093984E 01	-0.2816163E-01	-0.1437718E-01	-0.3559498E-02
0.2146332E 01	-0.2934932E-01	-0.1588281E-01	-0.4351274E-02
0.2198680E 01	-0.3045077E-01	-0.1744847E-01	-0.5223455E-02
0.2251028E 01	-0.3143125E-01	-0.1906878E-01	-0.6179057E-02
0.2303376E 01	-0.3224992E-01	-0.2073635E-01	-0.7220753E-02
0.2355724E 01	-0.3285983E-01	-0.2244155E-01	-0.8350778E-02
0.2408072E 01	-0.3320772E-01	-0.2417206E-01	-0.9570788E-02
0.2460421E 01	-0.3323417E-01	-0.2591262E-01	-0.1088172E-01
0.2512769E 01	-0.3287357E-01	-0.2764473E-01	-0.1228364E-01
0.2565117E 01	-0.3205434E-01	-0.2934628E-01	-0.1377553E-01

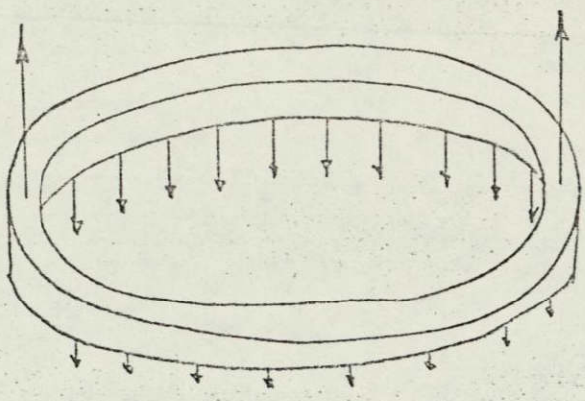
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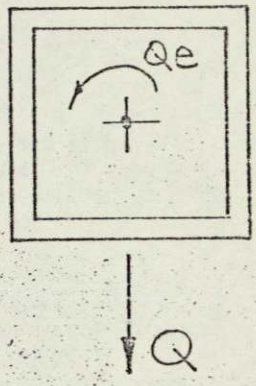
DATE 9-12-69
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CHECKED BY

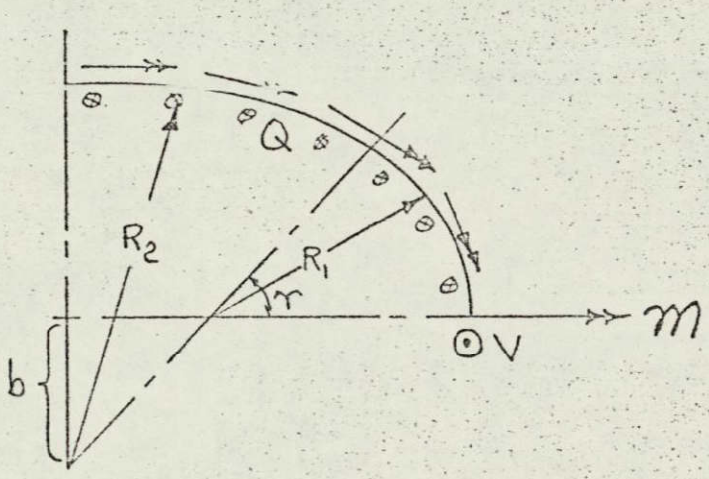
CALC. NO
MODEL
PART NO

DWG 958509

LOWER TORSO ELLIPTIC RING







$$V = R_1 r Q + R_2 Q (\pi/2 - r)$$

$$m - \int_0^r Q R_1^2 \sin\theta \, d\theta - \int_r^{\pi/2} Q R_2 [R_2 \sin\theta - b] \, d\theta$$

$$+ Qe R_1 \int_0^r \sin\theta \, d\theta + Qe R_2 \int_r^{\pi/2} \sin\theta \, d\theta = 0$$

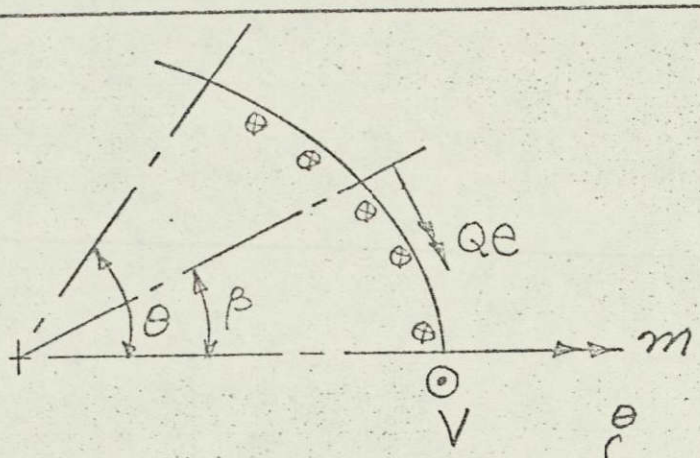
$$m = Q\left[R_1^2 - eR_1 + R_2 b(r - \pi/2) + (R_2^2 - R_1^2 + e(R_1 - R_2))\cos r\right]$$

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CALC. NO
MODEL
PART NO

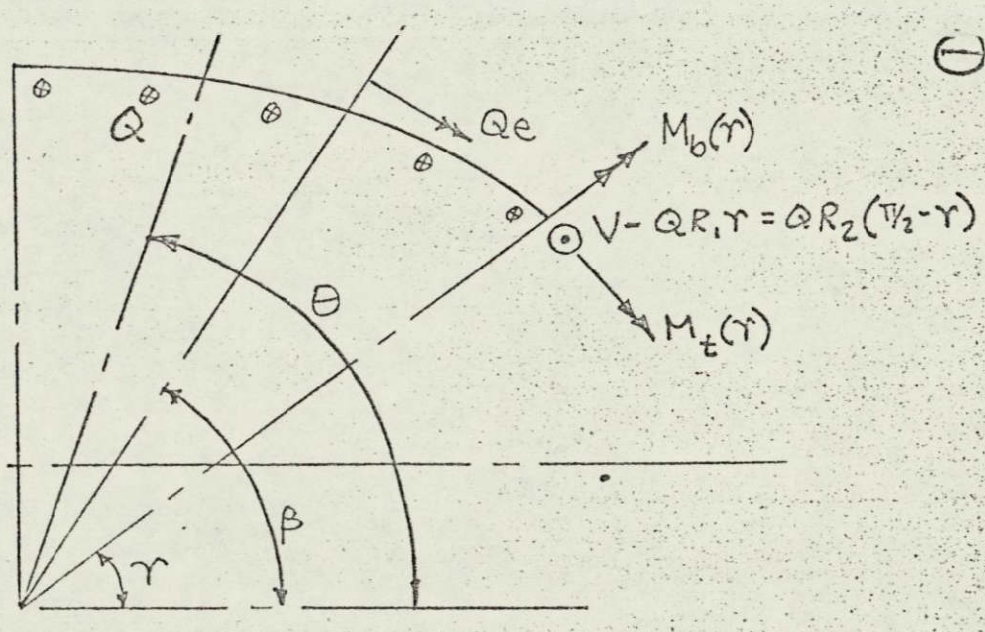
$\theta \leq \gamma$



$$M_b = m\cos\theta - VR_1\sin\theta + QR_1\int_0^\theta R_1\sin(\theta-\beta)d\beta - Qe\int_0^\theta R_1\sin(\theta-\beta)\,d\beta$$

$$M_t = m\sin\theta - VR_1(1-\cos\theta) + QeR_1\int_0^\theta \cos(\theta-\beta)d\beta + QR_1^2\int_0^\theta [1-\cos(\theta-\beta)]d\beta$$

$\theta > \gamma$



Where:

$$M_t(\gamma) = (m + QR_1(e-R_1))\sin\gamma - VR_1(1-\cos\gamma) + QR_1^2\gamma$$

$$M_b(\gamma) = m\cos\gamma - VR_1\sin\gamma + [QR_1^2 - QeR_1](1-\cos\gamma)$$

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MODEL
PART NO.

$$M_b = M_b(\gamma)\cos(\theta-\gamma) - QR_2^2(\pi/2-\gamma)\sin(\theta-\gamma) - M_t(\gamma)\sin(\theta-\gamma)$$
$$+ QR_2(R_2-e)\int_\gamma^\theta \sin(\theta-\beta)\,d\beta$$

$$M_t = M_b(\gamma)\sin(\theta-\gamma) + M_t(\gamma)\cos(\theta-\gamma) - QR_2^2(\pi/2-\gamma)[1-\cos(\theta-\gamma)]$$
$$+ QR_2^2\int_\gamma^\theta [1-\cos(\theta-\beta)]\,d\beta + QeR_2\int_\gamma^\theta \cos(\theta-\beta)\,d\beta$$

Moment Equations

$\theta < \gamma$

$$M_t = m\sin\theta - VR_1(1-\cos\theta) + QeR_1\sin\theta + QR_1^2(\theta-\sin\theta)$$
$$M_b = m\cos\theta - VR_1\sin\theta - QeR_1(1-\cos\theta) + QR_1^2(1-\cos\theta)$$

$\gamma < \theta \le \pi/2$

$$M_b = M_b(\gamma)\cos(\theta-\gamma) - M_t(\gamma)\sin(\theta-\gamma) - QR_2^2(\pi/2-\gamma)\sin(\theta-\gamma)$$
$$+ QR_2(R_2-e)[1-\cos(\theta-\gamma)]$$

$$M_t = M_b(\gamma)\sin(\theta-\gamma) + M_t(\gamma)\cos(\theta-\gamma) - QR_2^2(\pi/2-\gamma)[1-\cos(\theta-\gamma)]$$
$$+ QR_2^2(\theta-\gamma) + QR_2(e-R_2)\sin(\theta-\gamma)$$

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PART NO

RING DEFLECTIONS

$$\frac{d^3U}{d\theta^3} + \frac{dU}{d\theta} = -\frac{R_i^2}{EI}\left\{M_t\lambda + \frac{dM_b}{d\theta}\right\}$$

This can be solved numerically using the Runge Kutta technique.

let $p = \frac{dU}{d\theta}$

$$q = \frac{dp}{d\theta} = \frac{d^2U}{d\theta^2}$$

$$\frac{dq}{d\theta} = \frac{d^2p}{d\theta^2} = \frac{d^3U}{d\theta^3}$$

$$\frac{dq}{d\theta} = -p - \frac{R_i^2}{EI}\left\{T\lambda + \frac{dM_b}{d\theta}\right\}$$

$$\frac{dp}{d\theta} = q$$

$$\frac{dV}{d\theta} = p$$

$$\frac{dM_b}{d\theta} = -m\sin\theta - VR_1\cos\theta + QR_1(R_1 - e)\sin\theta \qquad \theta < \gamma$$

$$\frac{dM_b}{d\theta} = \left(QR_2(R_2 - e) - M_b(\gamma)\right)\sin(\theta - \gamma) \qquad \gamma < \theta \leq \pi/2$$

$$- \left(M_t(\gamma) + QR_2^2(\pi/2 - \gamma)\right)\cos(\theta - \gamma)$$

Form 2427

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MODEL
PART NO

Boundary Conditions

@ $\theta = 0$

$V' = 0$

$V'' = \frac{M_b(0)}{EI}$

$V = 0$ (arbitrary)

Properties of ELLIPSE

Circumference $= 4\left\{\frac{5.912 \times 32.416 + 8.62 \times 57.584}{57.295}\right\} = 46.90178$

area $= \pi ab = \pi(7.132)(5.912) = 132.46346$

@ operating pressure = 5 psi

$Q = 5 \times \frac{132.463}{46.902} = 14.121$ #/in

RING,FABRIC ATTACH,LOWER TORSO,(OPER PRES= 5PSI)

θ	V	$dV/d\theta$	$d^2V/d\theta^2$
0.1745000E-01	0.3338722E-02	0.7403169E-04	0.4242950E-02
0.3490000E-01	0.6634051E-02	0.1480858E-03	0.4244884E-02
0.5234999E-01	0.9886384E-02	0.2221849E-03	0.4248109E-02
0.6979998E-01	0.1309611E-01	0.2963515E-03	0.4252628E-02
0.8724996E-01	0.1626366E-01	0.3706082E-03	0.4258443E-02
0.1046999E 00	0.1938940E-01	0.4449777E-03	0.4265556E-02
0.1221499E 00	0.2247374E-01	0.5194827E-03	0.4273966E-02
0.1395998E 00	0.2551711E-01	0.5941456E-03	0.4283678E-02
0.1570498E 00	0.2851989E-01	0.6689892E-03	0.4294695E-02
0.1744998E 00	0.3148249E-01	0.7440366E-03	0.4307018E-02
0.1919498E 00	0.3440529E-01	0.8193105E-03	0.4320654E-02
0.2093997E 00	0.3728871E-01	0.8948339E-03	0.4335603E-02
0.2268497E 00	0.4013315E-01	0.9706296E-03	0.4351872E-02
0.2442997E 00	0.4293901E-01	0.1046720E-02	0.4369469E-02
0.2617497E 00	0.4570671E-01	0.1123129E-02	0.4388396E-02
0.2791997E 00	0.4843663E-01	0.1199880E-02	0.4408658E-02
0.2966496E 00	0.5112918E-01	0.1276997E-02	0.4430263E-02
0.3140996E 00	0.5378476E-01	0.1354502E-02	0.4453217E-02
0.3315496E 00	0.5640377E-01	0.1432419E-02	0.4477527E-02
0.3489996E 00	0.5898660E-01	0.1510773E-02	0.4503200E-02
0.3664495E 00	0.6153365E-01	0.1589586E-02	0.4530246E-02
0.3838995E 00	0.6404531E-01	0.1668884E-02	0.4558671E-02
0.4013495E 00	0.6652197E-01	0.1748689E-02	0.4588483E-02
0.4187995E 00	0.6896401E-01	0.1829027E-02	0.4619695E-02
0.4362494E 00	0.7137186E-01	0.1909922E-02	0.4652312E-02
0.4536994E 00	0.7374589E-01	0.1991398E-02	0.4686345E-02
0.4711494E 00	0.7608644E-01	0.2073479E-02	0.4721806E-02
0.4885994E 00	0.7839395E-01	0.2156192E-02	0.4758704E-02
0.5060493E 00	0.8066879E-01	0.2239562E-02	0.4797051E-02
0.5234992E 00	0.8291134E-01	0.2323613E-02	0.4836860E-02
0.5409491E 00	0.8512198E-01	0.2408372E-02	0.4878140E-02
0.5583989E 00	0.8730107E-01	0.2493863E-02	0.4920907E-02
0.5758488E 00	0.9298457E-01	0.2580115E-02	0.4965172E-02
0.5932986E 00	0.1020596E 00	0.2667151E-02	0.5010948E-02
0.6107485E 00	0.1109542E 00	0.2755000E-02	0.5058250E-02
0.6281983E 00	0.1196697E 00	0.2843688E-02	0.5107092E-02
0.6456482E 00	0.1282074E 00	0.2933242E-02	0.5157491E-02
0.6630980E 00	0.1365686E 00	0.3023689E-02	0.5209459E-02
0.6805479E 00	0.1447546E 00	0.3115057E-02	0.5263014E-02
0.6979978E 00	0.1527667E 00	0.3207373E-02	0.5318171E-02
0.7154476E 00	0.1606062E 00	0.3300665E-02	0.5374946E-02
0.7328975E 00	0.1682743E 00	0.3394963E-02	0.5433359E-02
0.7503473E 00	0.1757722E 00	0.3490294E-02	0.5493427E-02
0.7677972E 00	0.1831011E 00	0.3586688E-02	0.5555168E-02
0.7852470E 00	0.1902622E 00	0.3684175E-02	0.5618600E-02
0.8026969E 00	0.1972566E 00	0.3782783E-02	0.5683743E-02
0.8201468E 00	0.2040854E 00	0.3882543E-02	0.5750617E-02
0.8375966E 00	0.2107498E 00	0.3983483E-02	0.5819241E-02
0.8550465E 00	0.2172508E 00	0.4085636E-02	0.5889638E-02
0.8724963E 00	0.2235895E 00	0.4189033E-02	0.5961827E-02
0.8899462E 00	0.2297669E 00	0.4293705E-02	0.6035833E-02
0.9073960E 00	0.2357839E 00	0.4399685E-02	0.6111676E-02
0.9248459E 00	0.2416416E 00	0.4507005E-02	0.6189380E-02
0.9422957E 00	0.2473409E 00	0.4615697E-02	0.6268969E-02

RING, FABRIC ATTACH, LOWER TORSO, (OPER PRES = 5PSI)

θ	V	$dV/d\theta$	$d^2V/d\theta^2$
0.9597456E 00	0.2528826E 00	0.4725794E-02	0.6350466E-02
0.9771955E 00	0.2582677E 00	0.4837230E-02	0.6433898E-02
0.9946453E 00	0.2634971E 00	0.4950338E-02	0.6519289E-02
0.1012095E 01	0.2685714E 00	0.5064855E-02	0.6606665E-02
0.1029545E 01	0.2734918E 00	0.5180913E-02	0.6696052E-02
0.1046994E 01	0.2782589E 00	0.5298550E-02	0.6787479E-02
0.1064444E 01	0.2828735E 00	0.5417799E-02	0.6880972E-02
0.1081894E 01	0.2873361E 00	0.5538698E-02	0.6976561E-02
0.1099344E 01	0.2916477E 00	0.5661284E-02	0.7074275E-02
0.1116794E 01	0.2958088E 00	0.5785593E-02	0.7174141E-02
0.1134244E 01	0.2998201E 00	0.5911665E-02	0.7276192E-02
0.1151694E 01	0.3036822E 00	0.6039537E-02	0.7380459E-02
0.1169143E 01	0.3073957E 00	0.6169247E-02	0.7486973E-02
0.1186593E 01	0.3109610E 00	0.6300834E-02	0.7595768E-02
0.1204043E 01	0.3143789E 00	0.6434341E-02	0.7706874E-02
0.1221493E 01	0.3176496E 00	0.6569808E-02	0.7820326E-02
0.1238943E 01	0.3207737E 00	0.6707274E-02	0.7936157E-02
0.1256393E 01	0.3237517E 00	0.6846784E-02	0.8054403E-02
0.1273843E 01	0.3265839E 00	0.6988378E-02	0.8175103E-02
0.1291292E 01	0.3292707E 00	0.7132099E-02	0.8298290E-02
0.1308742E 01	0.3318125E 00	0.7277991E-02	0.8424008E-02
0.1326192E 01	0.3342094E 00	0.7426101E-02	0.8552286E-02
0.1343642E 01	0.3364619E 00	0.7576472E-02	0.8683173E-02
0.1361092E 01	0.3385701E 00	0.7729148E-02	0.8816698E-02
0.1378542E 01	0.3405343E 00	0.7884178E-02	0.8952913E-02
0.1395992E 01	0.3423547E 00	0.8041607E-02	0.9091852E-02
0.1413441E 01	0.3440314E 00	0.8201483E-02	0.9233560E-02
0.1430891E 01	0.3455646E 00	0.8363856E-02	0.9378079E-02
0.1448341E 01	0.3469542E 00	0.8528776E-02	0.9525453E-02
0.1465791E 01	0.3482004E 00	0.8696293E-02	0.9675730E-02
0.1483241E 01	0.3493033E 00	0.8866459E-02	0.9828951E-02
0.1500691E 01	0.3502627E 00	0.9039325E-02	0.9985165E-02
0.1518141E 01	0.3510787E 00	0.9214943E-02	0.1014441E-01
0.1535590E 01	0.3517512E 00	0.9393366E-02	0.1030676E-01
0.1553040E 01	0.3522801E 00	0.9574648E-02	0.1047224E-01
0.1570490E 01	0.3526653E 00	0.9758844E-02	0.1064091E-01

```
PAGE   1

// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMECHECK
*IOCS (CARD,1132 PRINTER)
*LISTALL
C      LOWER TORSO ELLIPTIC RING MOMENTS.
       READ(2,5)R1,R2,GOMA,B,EXC,Q
     5 FORMAT(8E10.5)
       GAMMA=GOMA*.01745
       GAM1=1.5707-GAMMA
       V=Q*(R1*GAMMA+R2*GAM1)
       BM=Q*(R1*R1-EXC*R1-R2*B*GAM1+(R2*R2-R1*R1+EXC*(R1-R2))*COS(GAMMA))
       BM1=(BM+Q*R1*(EXC-R1))*SIN(GAMMA)-V*R1*(1.-COS(GAMMA))+Q*R1*R1*
      1GAMMA
       BM2=BM*COS(GAMMA)-V*R1*SIN(GAMMA)+Q*R1*(R1-EXC)*(1.-COS(GAMMA))
       DO 15 J=1,91
       X=FLOAT(J-1)
       Z=X*.01745
       IF(Z-GAMMA)10,10,12
    10 S=SIN(Z)
       C=COS(Z)
       BMB=BM*S-V*R1*(1.-C)+Q*EXC*R1*S+Q*R1*R1*(Z-S)
       BMT=BM*C-V*R1*S+Q*R1*(R1-EXC)*(1.-C)
       GO TO 15
    12 S=SIN(Z-GAMMA)
       C=COS(Z-GAMMA)
       BMB=BM1*C-BM2*S-Q*R2*R2*GAM1*S+Q*R2*(R2-EXC)*(1.-C)
       BMT=BM1*S+BM2*C-Q*R2*(R2*GAM1*(1.-C)+R2*(Z-GAMMA)+(EXC-R2)*S)
    15 WRITE(3,25)X,BMB,BMT
    25 FORMAT(1H ,3(5X,E14.7))
       STOP
       END
VARIABLE ALLOCATIONS
    R1(R )=0000        R2(R )=0002       GOMA(R )=0004         B(R )=0006
 GAMMA(R )=000C     GAM1(R )=000E          V(R )=0010        BM(R )=0012
     X(R )=0018        Z(R )=001A          S(R )=001C         C(R )=001E
     J(I )=0030

INVALID STATEMENTS
 C 36 ERROR AT STATEMENT NUMBER 5     +005

OUTPUT HAS BEEN SUPPRESSED

COMPILATION DISCONTINUED

// XEQ
M 12  EXECUTION SUPPRESSED
```

PAGE 1

```
// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

// FOR
*NAMECHECK
*IOCS (CARD,1132 PRINTER)

FEATURES SUPPORTED
 IOCS

CORE REQUIREMENTS FOR CHECK
 COMMON      0  VARIABLES     50  PROGRAM     536

 END OF COMPILATION

// XEQ
```

DEGREES	BEND MOM	TORSIONAL MOM
0.0000000E 00	-0.9402394E-04	0.5329626E 03
0.1000000E 01	0.9646656E 01	0.5191776E 03
0.2000000E 01	0.1905249E 02	0.5053524E 03
0.3000000E 01	0.2821664E 02	0.4914912E 03
0.4000000E 01	0.3713878E 02	0.4775980E 03
0.5000000E 01	0.4581826E 02	0.4636773E 03
0.6000000E 01	0.5425456E 02	0.4497333E 03
0.7000000E 01	0.6244731E 02	0.4357698E 03
0.8000001E 01	0.7039637E 02	0.4217917E 03
0.9000001E 01	0.7810136E 02	0.4078036E 03
0.1000000E 02	0.8556208E 02	0.3938077E 03
0.1100000E 02	0.9277861E 02	0.3798104E 03
0.1200000E 02	0.9975103E 02	0.3658153E 03
0.1300000E 02	0.1064791E 03	0.3518265E 03
0.1400000E 02	0.1129633E 03	0.3378484E 03
0.1500000E 02	0.1192036E 03	0.3238852E 03
0.1600000E 02	0.1252004E 03	0.3099412E 03
0.1700000E 02	0.1309542E 03	0.2960206E 03
0.1800000E 02	0.1364653E 03	0.2821277E 03
0.1900000E 02	0.1417342E 03	0.2682667E 03
0.2000000E 02	0.1467614E 03	0.2544417E 03
0.2100000E 02	0.1515479E 03	0.2406571E 03
0.2200000E 02	0.1560942E 03	0.2269170E 03
0.2300000E 02	0.1604010E 03	0.2132256E 03
0.2400000E 02	0.1644696E 03	0.1995871E 03
0.2500000E 02	0.1683005E 03	0.1860056E 03
0.2600000E 02	0.1718950E 03	0.1724852E 03
0.2700000E 02	0.1752542E 03	0.1590301E 03
0.2800000E 02	0.1783791E 03	0.1456444E 03
0.2900000E 02	0.1812710E 03	0.1323321E 03
0.3000000E 02	0.1839314E 03	0.1190974E 03
0.3100000E 02	0.1863616E 03	0.1059442E 03
0.3200000E 02	0.1885629E 03	0.9287643E 02
0.3300000E 02	0.1905370E 03	0.7989523E 02
0.3400000E 02	0.1922853E 03	0.6701359E 02
0.3500000E 02	0.1938098E 03	0.5422630E 02
0.3600000E 02	0.1951119E 03	0.4154019E 02
0.3700000E 02	0.1961937E 03	0.2895936E 02

DEGREES	BEND MOM	TORSIONAL MOM
0.3800000E 02	0.1970568E 03	0.1648736E 02
0.3900000E 02	0.1977032E 03	0.4128256E 01
0.4000000E 02	0.1981350E 03	-0.8114381E 01
0.4100000E 02	0.1983542E 03	-0.2023681E 02
0.4200000E 02	0.1983630E 03	-0.3223507E 02
0.4300000E 02	0.1981635E 03	-0.4410593E 02
0.4400000E 02	0.1977579E 03	-0.5584549E 02
0.4500000E 02	0.1971488E 03	-0.6745022E 02
0.4600000E 02	0.1963383E 03	-0.7891651E 02
0.4700000E 02	0.1953290E 03	-0.9024113E 02
0.4800000E 02	0.1941232E 03	-0.1014205E 03
0.4900000E 02	0.1927237E 03	-0.1124512E 03
0.5000000E 02	0.1911331E 03	-0.1233297E 03
0.5100000E 02	0.1893540E 03	-0.1340531E 03
0.5200000E 02	0.1873891E 03	-0.1446177E 03
0.5300000E 02	0.1852412E 03	-0.1550204E 03
0.5400000E 02	0.1829133E 03	-0.1652584E 03
0.5500000E 02	0.1804082E 03	-0.1753281E 03
0.5600000E 02	0.1777288E 03	-0.1852266E 03
0.5700000E 02	0.1748783E 03	-0.1949509E 03
0.5800000E 02	0.1699708E 03	-0.1986210E 03
0.5900000E 02	0.1633238E 03	-0.1964626E 03
0.6000000E 02	0.1569336E 03	-0.1944340E 03
0.6100000E 02	0.1508022E 03	-0.1925414E 03
0.6200000E 02	0.1449313E 03	-0.1907909E 03
0.6300000E 02	0.1393229E 03	-0.1891887E 03
0.6400001E 02	0.1339785E 03	-0.1877407E 03
0.6500001E 02	0.1288999E 03	-0.1864531E 03
0.6600001E 02	0.1240885E 03	-0.1853319E 03
0.6700001E 02	0.1195459E 03	-0.1843827E 03
0.6800001E 02	0.1152733E 03	-0.1836118E 03
0.6900001E 02	0.1112722E 03	-0.1830246E 03
0.7000001E 02	0.1075437E 03	-0.1826271E 03
0.7100001E 02	0.1040891E 03	-0.1824250E 03
0.7200001E 02	0.1009092E 03	-0.1824238E 03
0.7300001E 02	0.9800521E 02	-0.1826293E 03
0.7400001E 02	0.9537780E 02	-0.1830467E 03
0.7500001E 02	0.9302793E 02	-0.1836816E 03
0.7600001E 02	0.9095622E 02	-0.1845395E 03
0.7700001E 02	0.8916326E 02	-0.1856259E 03
0.7800001E 02	0.8764976E 02	-0.1869449E 03
0.7900001E 02	0.8641601E 02	-0.1885031E 03
0.8000001E 02	0.8546260E 02	-0.1903049E 03
0.8100001E 02	0.8478947E 02	-0.1923554E 03
0.8200001E 02	0.8439727E 02	-0.1946597E 03
0.8300001E 02	0.8428575E 02	-0.1972226E 03
0.8400001E 02	0.8445512E 02	-0.2000488E 03
0.8500001E 02	0.8490527E 02	-0.2031431E 03
0.8600001E 02	0.8563620E 02	-0.2065101E 03
0.8700001E 02	0.8664749E 02	-0.2101543E 03
0.8800001E 02	0.8793881E 02	-0.2140804E 03
0.8900001E 02	0.8951011E 02	-0.2182926E 03
0.9000001E 02	0.9136038E 02	-0.2227950E 03

Form 2427

AiRESEARCH MFG. CO.

DATE 9-16-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

$I = .004557$

$C = .26$

$K = 0.00862$

$M_{b\,max} = 198.3$

$M_{t\,max} = 532.9$

$$\sigma_b = \frac{Mc}{I} = \frac{198.3(0.26)}{.004557} = 11314.\ psi$$

$$\tau = \frac{Tc}{K} \approx \frac{532.9(.26)}{.00862} = 16073.\ psi$$

REPORT
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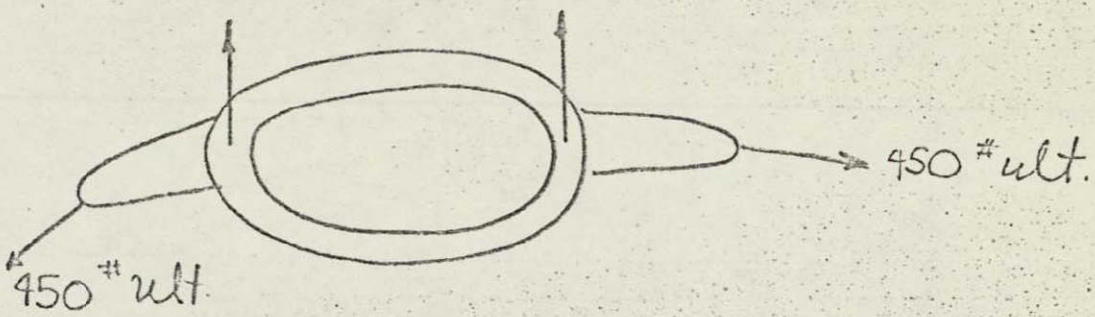
Form 2427

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DATE 9-15-69
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CALC. NO.
MODEL
PART NO.

SUSPENSION LOADS IN MODULE

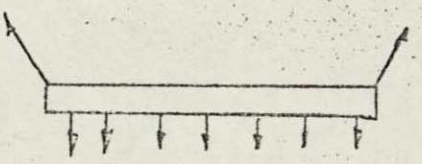


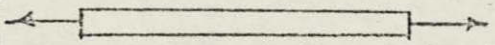
Load can be in any direction

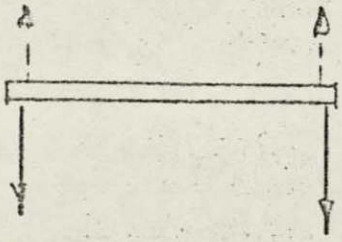
Limit load = $450/1.5 = 300^{\#}$

Possible Loads

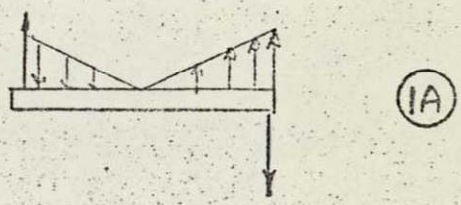
Symmetric loads

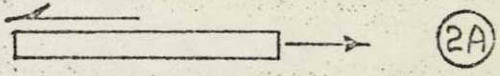


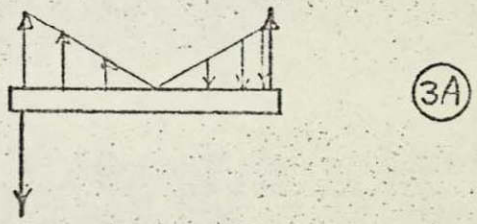




Assymmetric loads





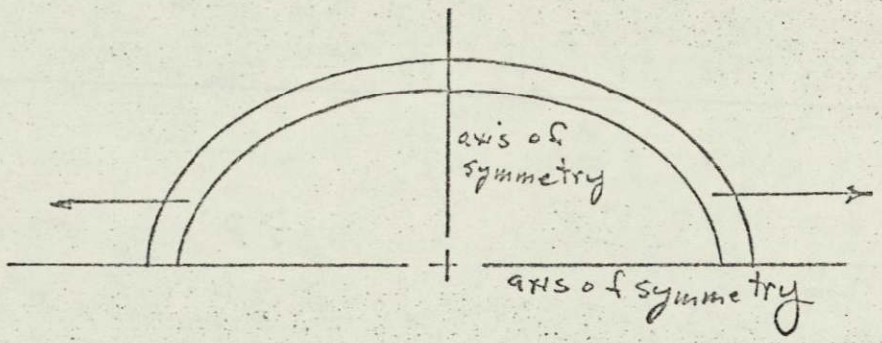


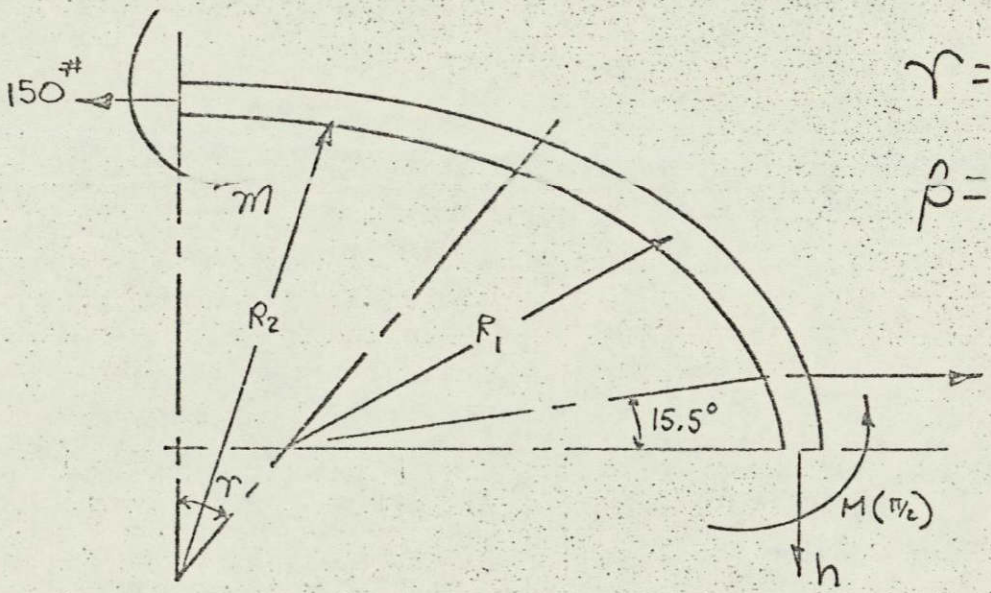
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CALC. NO
MODEL
PART NO

By inspection, the worst load condition is 2S





$\gamma = 32.5°$

$\beta = 70 - 15.5 = 71.5°$

$M = m + 150 R_2 (1 - \cos\theta) \qquad \theta \leq \gamma$

@ $\theta = \gamma$

$M(\gamma) = m + 150 R_2 (1 - \cos\gamma)$

$M = M(\gamma) + 150\{R_2 \cos\gamma - R_1 \cos\theta\} - 150 \cos 15.5\, R_1 \sin(\theta - \beta)$

$- 150 R_1 \sin 15.5 \left\{1 - \cos(\theta - \beta)\right\} \qquad \theta > \gamma$

Form 2427

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CALC. NO.
MODEL
PART NO.

$$\frac{\partial U}{\partial m} = R\int_0^{\pi/2} M \frac{\partial M}{\partial m} d\theta = 0$$

$$\frac{\partial M}{\partial m} = 1$$

$$0 = \int_0^{\pi} \{m + 150R_2(1-\cos\theta)\} d\theta$$

$$+ \frac{R_1}{R_2}\int_{\pi}^{\pi/2} \{m + 150R_2(1-\cos\pi) + 150[R_2\cos\pi - R_1\cos\theta]\} d\theta$$

$$- \frac{R_1}{R_2}\int_{74.5}^{\pi/2} 150R_1\cos 15.5 \sin(\theta - 74.5)\, d\theta$$

$$- \frac{R_1}{R_2}\int_{74.5}^{\pi/2} 150R_1 \sin 15.5 \{1 - \cos(\theta - 74.5)\} d\theta$$

$R_1 = 5.762$

$R_2 = 8.97$

$\frac{R_1}{R_2} = 0.641$

$c = 0.35$ in

$A = 0.10034$ in^2

$I = \frac{1}{12}\{.52(.68)^3 - .402(.63)^3\} = .00524$ in^4

REPORT
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Form 2427

AiRESEARCH MFG. CO.

DATE 9-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO
MODEL
PART NO

$$m\gamma + 150R_2(\gamma - \sin\gamma) + \frac{R_1}{R_2}\left[m\frac{57.5}{57.295} + 150R_2\left(\frac{57.5}{57.295}\right)(1-\cos\gamma)\right.$$

$$\left. + 150\left\{\frac{57.5}{57.295}R_2\cos\gamma - R_1(1-\sin\gamma)\right\} + 150R_1\left\{\cos^2 15.5 - \cos 15.5\right\}\right.$$

$$- 150R_1\sin 15.5\left\{\frac{15.5}{57.295} - \sin 15.5\right\} = 0$$

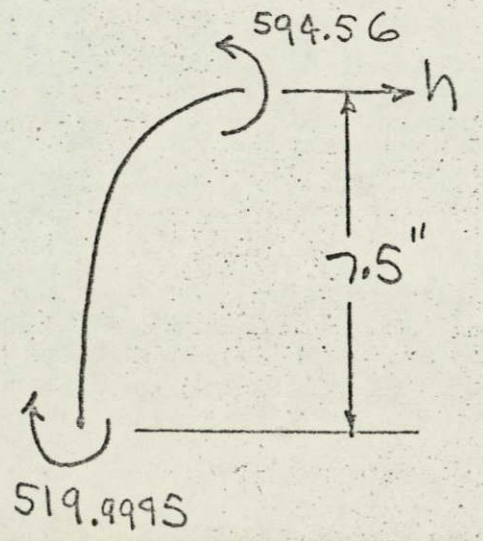
$$1.210488m + 40.23045 + 589.2167 = 0$$

$$m = -519.9945 \text{ \#in}$$

$$M(\gamma) = -519.9945 + 150(8.97)(1-.8434) = -309.29$$

$$M(\pi/2) = -309.29 + 150(8.97)(.8434) - 150(5.762)(.9639)(.2672)$$

$$-150(5.762)(.2672)(1-.9639) = +594.56 \text{ \#in}$$



$$519.9945 + 7.5h - 594.56 = 0$$

$$h = 9.942\#$$

REPORT
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Form 2427

AiRESEARCH MFG. CO.

DATE 9-15-69
PREPARED BY M. WOLFSON
CHECKED BY

CALC. NO.
MODEL
PART NO.

@ $\theta = 0$

$$\sigma = \frac{P}{A} + \frac{Mc}{I} = \frac{150}{.1} + \frac{519.99(.35)}{.00524} = 36232.\ psi$$

@ $\theta = \pi/2$

$$\sigma = \frac{9.942}{.1} + \frac{594.56(.35)}{.00524} = 39812.\ psi$$

APPENDIX G

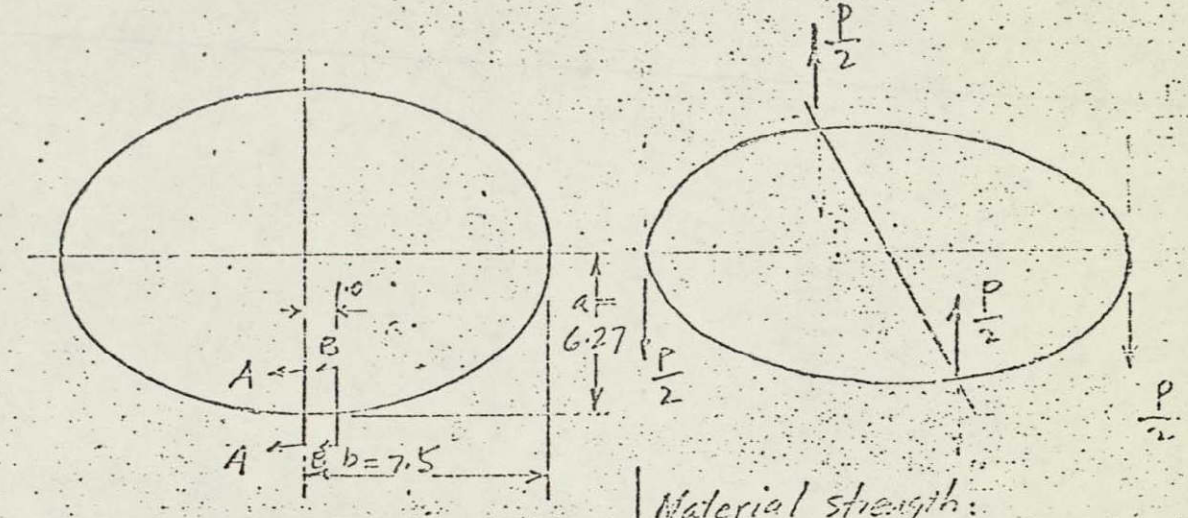
STRESS CALCULATIONS
FOLLOWING RING FAILURE

DATE 11-15-69
PREPARED BY [illegible]
CHECKED BY

CALC. NO
MODEL
PART NO

Structural Review of Lower Torso Ring – 958508

Design Loading



Operating Load $P_o = 686$ #

Proof Load $P_t = 1373$ #

Ultimate load $P_u = 2060$ #

Material strength:

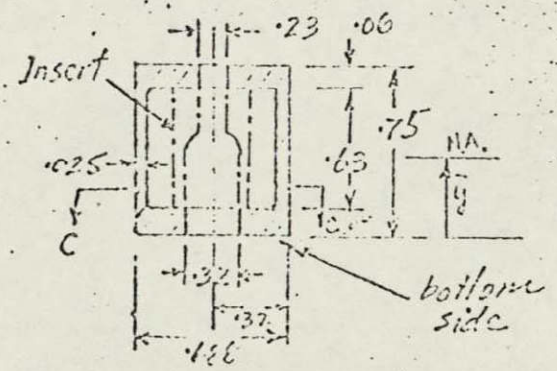
$F_{tu} = 160$ KSI

$F_{ty} = 100$ KSI

$E = 29 \times 10^6$

$F_{su} \approx .6 \times F_{ty} = 60$ KSI

Section A-A



$$\bar{y} = \frac{(.66)(.41)+(.06)(.315)+(.05)(.63)}{.02745 + .02251 + .0315} = \frac{.03226}{.08106}$$

$$\bar{y} = \frac{.02745 \times .72 + .02205 \times .03 + .0315 \times .375}{.02745 + .02205 + .0315} = \frac{.03226}{.08106} = .398"$$

$$I = .02745 \times .322^2 + .02205 \times .345^2 + \frac{.05}{12}(.63)^3 + .0315(.023)^2 = .006898 \text{ in}^4$$

$$Z_c = \frac{.006898}{.398} = .01733 \text{ in}^3 \qquad Z_t = \frac{.006898}{.352} = .0196 \text{ in}^3$$

REPORT
PAGE 1 OF

ATTACH I

Bending moment at section A-A (operating load)

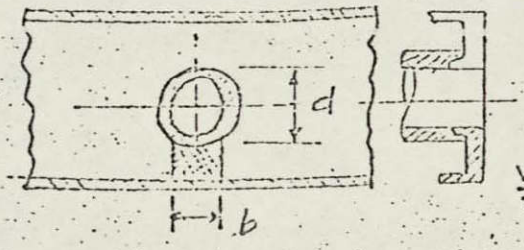
$$M_A = \frac{1}{2} \cdot \frac{P_o}{2} b = \frac{1}{2} \cdot \frac{686}{2} \times 7.5 = 1286 \text{ in-lb}$$

$$\sigma_c = \frac{M_A}{Z_c} = \frac{-1286}{.01733} = \underline{-74,300 \text{ psi}}$$

Transverse load from insert.

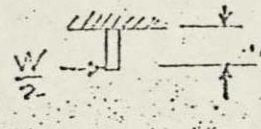
Assuming the bottom side takes 60% of the load, because of the larger hole or shorter edge distance than the top edge.

$$W = (60\%) \frac{P_o}{2} = .6 \times \frac{686}{2} = 206 \#$$



View C-C

consider the plate portion as a cantilever beam



$$b = \frac{2}{\pi} \cdot d = .286"$$

$$d = .45$$

$$M = \frac{W}{2} \times .143 = 14.71.$$

$$\sigma_r = \frac{6M}{b t^2} = \frac{6 \times 14.71}{.286 \times (.060)^2} = \frac{88.3}{.00103} = \underline{85900 \text{ psi}}$$

There may be stress concentration factor of 2.0 or greater at the root of the cylinder joining the bottom plate.

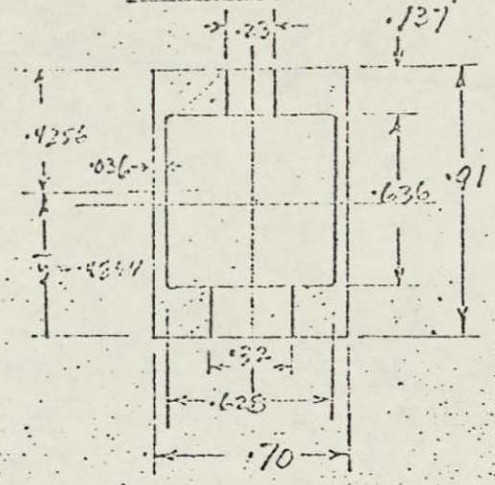
$$\sigma_{max} = 85,900 \times 2.5 = 215,000 \text{ psi} !$$

DATE
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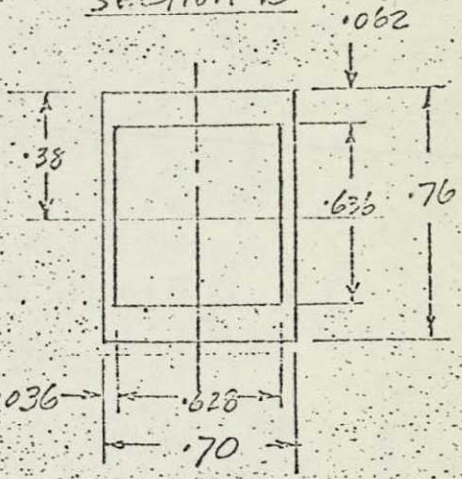
CALC. NO
MODEL
PART NO

Revised Sections (Dwg # 958620)

Section A



Section B



Section A

$$\bar{y}_A = \frac{.05206 \times .6625 + .16432 \times .8415 + .04579 \times .455}{.137 \times .38 + .137 \times .47 + 2 \times .036 \times .636} = \frac{.07859}{.1622} = .4844''$$

$$I_A = .05206(.416)^2 + .06432(.3571)^2 + \frac{.072}{12}(.636)^3 + .04579(.0174)^2$$

$$= .009009 + .008211 + .001544 + .000014 = 0.018778 \text{ in.}^4$$

$$Z_{Ac} = \frac{.018778}{.4844} = .03877 \text{ in.}^3$$

$$Z_{At} = \frac{.018778}{.4256} = .04412 \text{ in.}^3$$

Area $A = .1622$ in.

Section B

$$I_B = \frac{1}{12}\left[.70(.76)^3 - .628(.636)^3\right] = \frac{1}{12}\left[.307283 - .161558\right] = .012144 \text{ in.}^4$$

$$Z_B = \frac{.012144}{.38} = .03196 \text{ in.}^3$$

Area $A = .76 \times .70 - .636 \times .628 = .1326$ in.^{2}

ATTACH I

REPORT
PAGE OF

Beam Bending at section A (operating Load)

$$\sigma_c = \frac{1286}{Z_{Ac}} = \frac{1286}{.03877} = -33{,}200 \text{ psi}$$

$$\sigma_t = \frac{1286}{Z_{At}} = \frac{1286}{.04412} = 29{,}100 \text{ psi}$$

Local bending at section A

$$\sigma_r = \frac{6 \times 14.7}{.286(.137)^2} = \frac{88.3}{.00536} = 16{,}500 \text{ psi}$$

$K = 2.5$

$$\sigma_{r,max} = 16{,}500 \times 2.5 = 41{,}100 \text{ psi}$$

At proof Load $P_f = 1372$ #

$$\sigma_{r,max} = 41{,}100 \times 2 = 82{,}200 \text{ psi}$$

$$M.S. = \frac{100{,}000}{82{,}200} - 1 = +.21$$

At section B.

$$M_B = 1286 \frac{7.5 - 1.0}{7.5} = 1115 \text{ in.-lb}$$

$$\sigma = \frac{M_B}{Z} = \frac{1115}{.03196} = 34{,}900 \text{ psi} \quad \text{at operating}$$

$$= 69{,}800 \text{ psi} \quad \text{at proof.}$$

Side wall shear due to torsion

$$\tau_T = \frac{T}{2At} = \frac{T}{2 \times .628 \times .636 \times .036} = \frac{T}{.0288}$$

t = wall thickness

Due to vertical shear

$$\tau_V = \frac{V}{I_B(2t)} Q$$

$$Q = .70 \times .38 \times \frac{.38}{2} - .628 \times .318 \times \frac{.318}{2} = .05054 - .03175 = .01879$$

$$\tau_V = \frac{172 \times .01879}{.01214 \times .036 \times 2} = \frac{3.232}{.0008741} = 3700 \text{ psi}$$

$$T = .4\left(\frac{P}{4} a\right) = .4 \times 172 \times 7.5 = 516 \text{ in-lb}$$

$$\tau = \tau_T + \tau_V = \frac{516}{.0288} + 3700 = 18000 + 3700 = 21{,}700 \text{ psi}$$

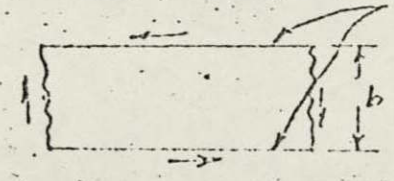
At Proof load.

$$\tau_p = 21{,}700 \times 2.0 = 43{,}400 \text{ psi}$$

Assume $F_{sy} = .6 \times F_{tu} = .6 \times 100{,}000 = 60{,}000$ psi

$$M.S. = \frac{60000}{43{,}400} - 1 = +.38$$

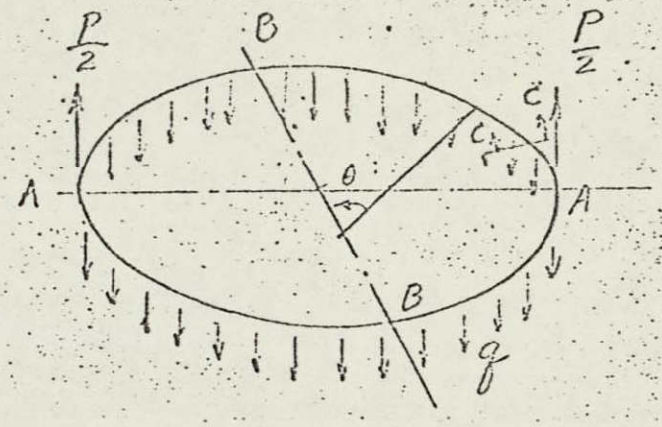
Shear Buckling of Side wall



$$\tau_{cr} = 4.5 E \left(\frac{t}{b}\right)^2 = 4.5 \times 29 \times 10^6 \left(\frac{.036}{.636}\right)^2 = 139.1 \times 3025 = 420{,}000 \text{ psi}$$

Inelastic buckling may occur above proof load. - No buckling below proof load.

Lower Torso Fabric Attachment Ring – 758509



$a = 7.5$

$b = 6.27$

Perimeter $S = \pi \frac{a+b}{4}\left[3(1+\lambda) + \frac{1}{1-\lambda}\right]$

$\lambda = \left[\frac{a-b}{2(a+b)}\right]^2 = \left[\frac{7.5-6.27}{2(7.5+6.27)}\right]^2 = \left(\frac{1.23}{27.54}\right)^2 = (.0446)^2 = .001972$

$S = \pi \frac{7.5+6.27}{4}\left[3(1.002) + \frac{1}{.998}\right] = \frac{13.77\pi}{4}\left[3.006 + 1.001\right] = 43.3''$

$q = \frac{P}{43.3}$ #/in.

Let $P_o = 686$ # operating load

From computer output

$M_A = 671$ in-lb

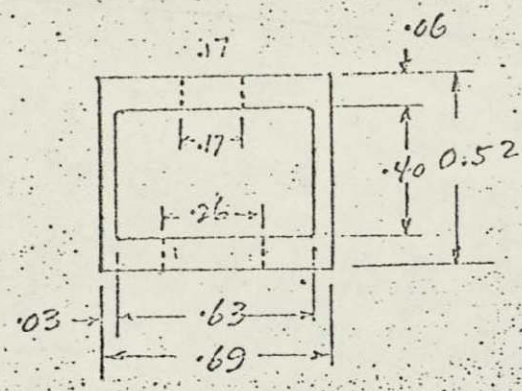
$M_C = 518$ in-lb

$M_C = 408$ in-lb $(\theta = 15.0°)$

Joint moment $T = 247.4$ in-lb

Revised sections

Section B (Nominal beam section)



Section C with holes

$I_c = .004725 - .43(.06)(.23)^2$

$= .004725 - .001365 = .00336$

$I_c = .01243 \text{ in.}^3$

$\sigma_c = \frac{408}{.01243} = 32{,}800 \text{ PSI}$

$I_B = \frac{1}{12}\left[.69(.52)^3 - .63(.40)^3\right] = \frac{1}{12}\left[.09702 - .04032\right] = .004725 \text{ in.}^4$

$Z_B = \frac{.004725}{.26} = .01817 \text{ in.}^3$

Torsion area $A_m = .63 \times .40 = .252$ in.

$\sigma_B = \frac{M_B}{Z_B} = \frac{518}{.01817} = 28{,}510 \text{ PSI}$

Shear Stress

$\tau = \frac{T}{2 \times .252 \times .03} + \frac{V}{I(2 \times .03)} Q$

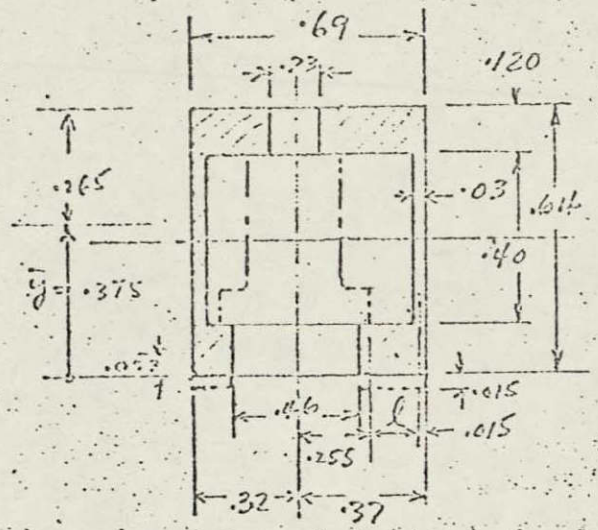
$Q = .69 \times .26 \times .13 - .63 \times .20 \times .10 = .02332 - .0126 = .01072$

$V \simeq 172 - 30 = 142$

$T = 247.4$

$\tau = \frac{247.4}{.01512} + \frac{142 \times .0107}{.004725 \times .06} = 16360 + \frac{1.5194}{.0002835} = 21{,}720 \text{ PSI}$

Section A



$$\bar{y} = \frac{.03105 \times .053 + .0552 \times .580 + .024 \times .318}{.23 \times .155 + .46 \times .120 + .06 \times .4} = \frac{.04134}{.1103} = .375''$$

$$I = .03105(.322)^2 + .0552 \times (.205)^2 + .024(.055)^2 + \frac{.06}{12}(.40)^3$$

$$= .003219 + .00232 + .0000726 + .00032 = .005932 \text{ in.}^4$$

$$Z_c = \frac{.005932}{.375} = .01582 \text{ in}^3$$

$$Z_t = \frac{.00532}{.265} = .02238$$

$$\sigma_c = \frac{671}{.01582} = \underline{42,400 \text{ psi}}$$

Transverse Loading,

$$V = \frac{W}{2} = \frac{1}{2}(.6 \times 343) = 103$$

$$M = VL = 103 \times (.355 - .255) = 10.3 \text{ in-lb}$$

$$\sigma = K_t \frac{6M}{bt^2} = 2.5 \times \frac{6 \times 10.3}{.394(.12)^2} = \frac{2.5 \times 61.9}{.00747} = 2.5 \times 13,240 = \underline{33,100 \text{ psi}}$$

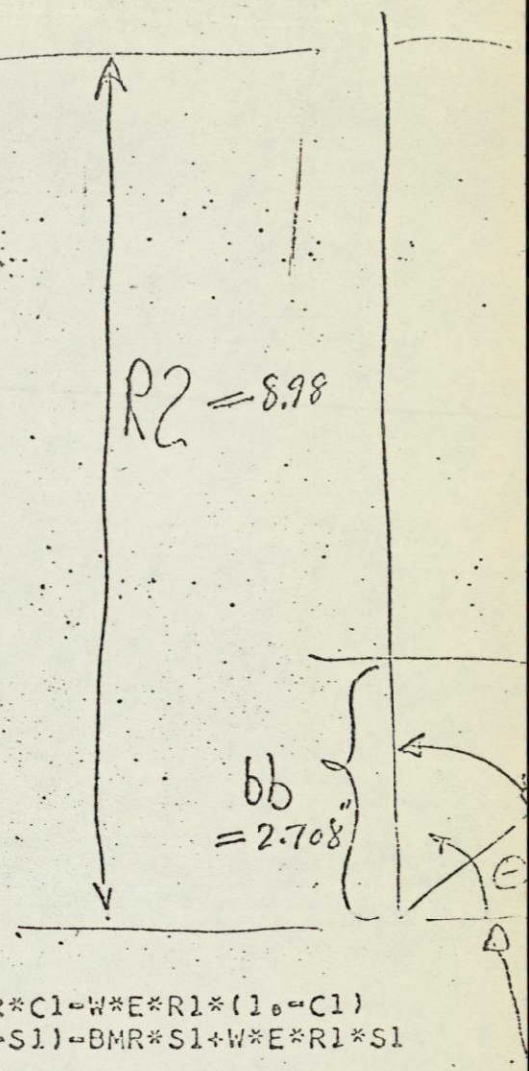
```
// JOB T

LOG DRIVE   CART SPEC   CART AVAIL   PHY DRIVE
  0000        0001        0001         0000

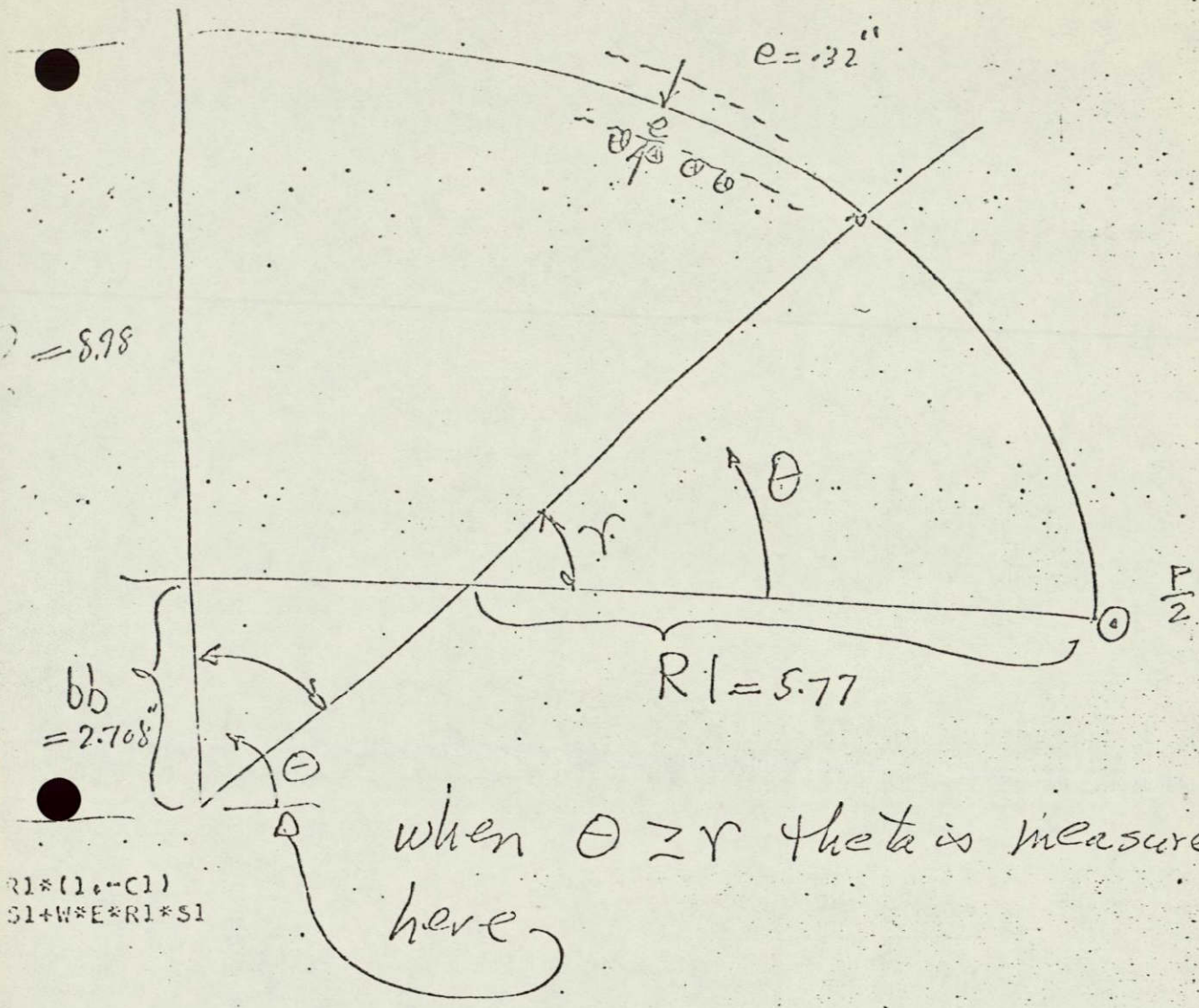
// FOR
*NAMEMOMT
*IOCS (CARD,1132 PRINTER)
*LISTALL
      READ(2,3)P,R1,R2,E,GAMMA,BB
    3 FORMAT(8E10.5)
      GAMMA =GAMMA/57.2957795
      S= SIN(GAMMA)
      C= COS(GAMMA)
      GAM1=1.5707 - GAMMA
      CC=1.-C
      W = 0.5*P /(R1*GAMMA +R2*GAM1)
      BM= W*(R1*R1*CC+R2*R2*C -R2*BB*GAM1)
      BMR= W*E*(R1*CC +R2*C)
      BMB= BM*C -.5*P*R1*S +W*R1*R1*CC
      TB = BM*S -.5*P*R1*CC+W*R1*R1*(GAMMA-S)
      VB = .5*P -W *R1*GAMMA
      BMBR = -BMR*C -W*E*R1*CC
      TBR = -BMR*S +W*E*R1*S
      DO 30 J= 1,91
      Z=FLOAT(J-1)
      ANG=.01745*Z
      S1 = SIN(ANG)
      C1 = COS(ANG)
      ANG1= ANG -GAMMA
      IF(ANG1)10,10,20
   10 BMOMT=BM*C1-.5*P*R1*S1+W*R1*R1*(1.-C1)-BMR*C1-W*E*R1*(1.-C1)
      TWIST= BM*S1-.5*P*R1*(1.-C1)+W*R1*R1*(ANG-S1)-BMR*S1+W*E*R1*S1
      GO TO 29
   20 CO = COS(ANG1)
      SO = SIN(ANG1)
      BMOMT =BMB*CO-TB*SO-VB*R2*SO+W*R2*R2*(1.-CO)+BMBR*CO -TBR*SO
     1 -W*E*R2*(1.-CO)
      TWIST=BMB*SO+TB*CO-VB*R2*(1.-CO)+W*R2*R2*(ANG1-SO)+BMBR*SO
     1+TBR*CO +W*E*R2*SO
   29 THETA = 57.2957795*ANG
   30 WRITE(3,50) THETA, BMOMT,TWIST
   50 FORMAT(1H , F8.2,2(5X,E14.7))
      STOP
      END
VARIABLE ALLOCATIONS
     P(R )=0000        R1(R )=0002        R2(R )=0004         E(R )=000
     S(R )=000C         C(R )=000E    GAM1(R )=0010        CC(R )=001
   BMR(R )=0018       BMB(R )=001A        TB(R )=001C        VB(R )=001
     Z(R )=0024       ANG(R )=0026        S1(R )=0028        C1(R )=002
 TWIST(R )=0030        CO(R )=0032        SO(R )=0034     THETA(R )=003

STATEMENT ALLOCATIONS
  3    =005E  50   =0061  10   =0197  20   =0215  29   =02B7  30   =02BD

FEATURES SUPPORTED
 IOCS
```



ATTACH I



R1*(1.-C1)
S1+W*E*R1*S1

CO -TBR*SO

+BMBR*SO

E(R)=0006	GAMMA(R)=0008	BB(R)=000A
CC(R)=0012	W(R)=0014	BM(R)=0016
VB(R)=001E	BMBR(R)=0020	TBR(R)=0022
C1(R)=002A	ANG1(R)=002C	BMOMT(R)=002E
THETA(R)=0036	J(I)=0048	

30 =0280

PAGE 2

CALLED SUBPROGRAMS
FSIN FCOS FSUB FMPY FDIV FLD FSTO FSBR FDVR FLOAT
SFIO SIOF STOP SNR

REAL CONSTANTS
.572957E 02=004A .157070E 01=004C .100000E 01=004E .500000E 00=0050

INTEGER CONSTANTS
2=0054 1=0055 91=0056 3=0057 0=0058

CORE REQUIREMENTS FOR MOMT
COMMON 0 VARIABLES 74 PROGRAM 648

END OF COMPILATION

// XEQ

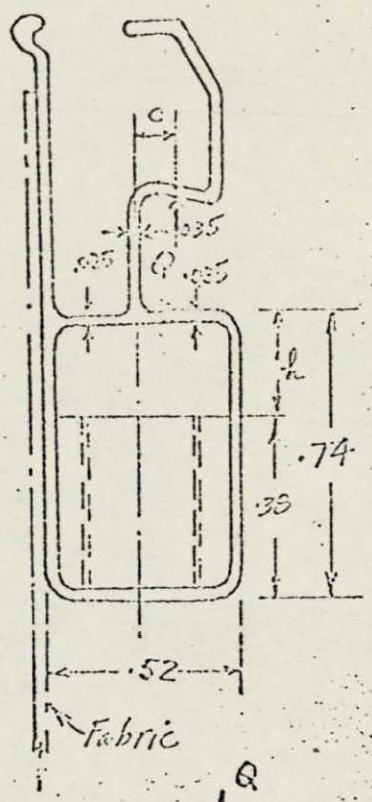
Θ	BENDING MoM	TWISTING MoM
0.00	0.6703348E 03	-0.1179641E-03
0.99	0.6530413E 03	0.1205435E 02
1.99	0.6356999E 03	0.2380662E 02
2.99	0.6183161E 03	0.3525576E 02
3.99	0.6008948E 03	0.4640142E 02
4.99	0.5834415E 03	0.5724279E 02
5.99	0.5659615E 03	0.6777929E 02
6.99	0.5484603E 03	0.7801054E 02
7.99	0.5309428E 03	0.8793637E 02
8.99	0.5134146E 03	0.9755633E 02
9.99	0.4958809E 03	0.1068702E 03
10.99	0.4783475E 03	0.1158782E 03
11.99	0.4608192E 03	0.1245805E 03
12.99	0.4433015E 03	0.1329760E 03
13.99	0.4257998E 03	0.1410676E 03
14.99	0.4083197E 03	0.1488532E 03
15.99	0.3908657E 03	0.1563339E 03
16.99	0.3734440E 03	0.1635104E 03
17.99	0.3560593E 03	0.1703832E 03
18.99	0.3387172E 03	0.1769531E 03
19.99	0.3214230E 03	0.1832206E 03
20.99	0.3041820E 03	0.1891869E 03
21.99	0.2869990E 03	0.1948528E 03
22.99	0.2698798E 03	0.2002192E 03
23.99	0.2528292E 03	0.2052879E 03
24.99	0.2358527E 03	0.2100594E 03
25.99	0.2189553E 03	0.2145354E 03
26.99	0.2021422E 03	0.2187173E 03
27.99	0.1854184E 03	0.2226055E 03
28.99	0.1687892E 03	0.2262048E 03
29.99	0.1522596E 03	0.2295137E 03
30.99	0.1358345E 03	0.2325352E 03
31.99	0.1195189E 03	0.2352709E 03
32.99	0.1033179E 03	0.2377229E 03
33.99	0.8723651E 02	0.2398932E 03
34.99	0.7127948E 02	0.2417840E 03
35.99	0.5545164E 02	0.2433974E 03
36.99	0.3975793E 02	0.2447359E 03
37.99	0.2420293E 02	0.2458016E 03
38.99	0.8791582E 01	0.2465973E 03
39.99	-0.6471471E 01	0.2471253E 03

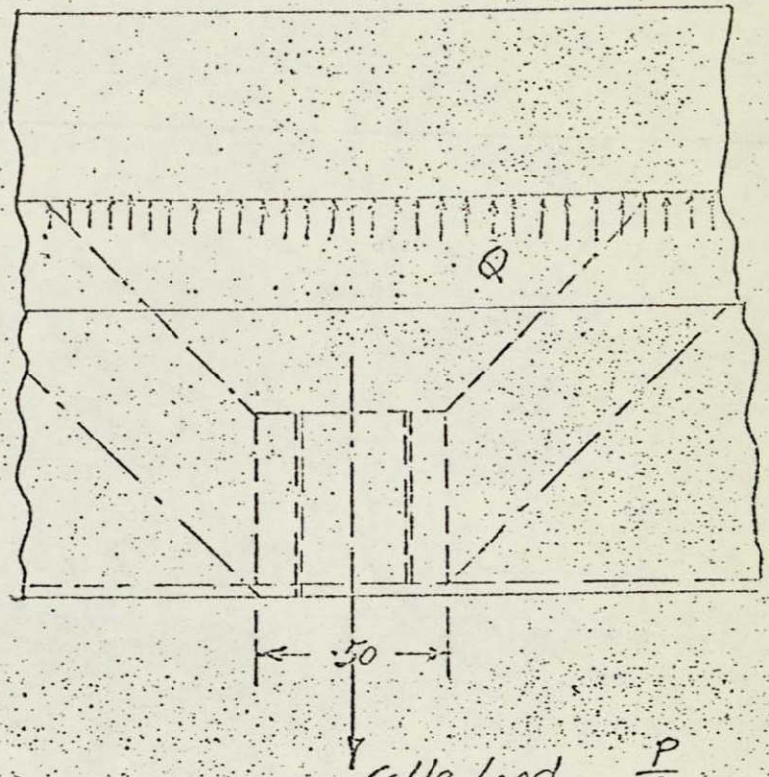
ATTACH I

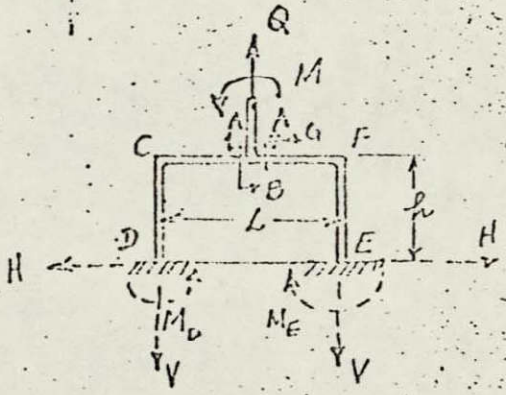
	BENDING MOM	TWISTING MOM
40.99	-0.2158166E 02	0.2473882E 03
41.99	-0.3653421E 02	0.2473888E 03
42.99	-0.5132479E 02	0.2471299E 03
43.99	-0.6594876E 02	0.2466144E 03
44.99	-0.8040167E 02	0.2458452E 03
45.99	-0.9467903E 02	0.2448253E 03
46.99	-0.1087767E 03	0.2435578E 03
47.99	-0.1226905E 03	0.2420458E 03
48.99	-0.1364159E 03	0.2402928E 03
49.99	-0.1499487E 03	0.2383019E 03
50.99	-0.1632849E 03	0.2360767E 03
51.99	-0.1764204E 03	0.2336203E 03
52.99	-0.1893513E 03	0.2309367E 03
53.99	-0.2020738E 03	0.2280291E 03
54.99	-0.2145836E 03	0.2249013E 03
55.99	-0.2268771E 03	0.2215571E 03
56.99	-0.2389506E 03	0.2180004E 03
57.99	-0.2526080E 03	0.2143432E 03
58.99	-0.2685142E 03	0.2105863E 03
59.99	-0.2839651E 03	0.2065558E 03
60.99	-0.2989562E 03	0.2022596E 03
61.99	-0.3134831E 03	0.1977059E 03
62.99	-0.3275414E 03	0.1929028E 03
63.99	-0.3411264E 03	0.1878584E 03
64.99	-0.3542343E 03	0.1825812E 03
65.99	-0.3668612E 03	0.1770794E 03
66.99	-0.3790029E 03	0.1713616E 03
67.99	-0.3906561E 03	0.1654362E 03
68.99	-0.4018168E 03	0.1593117E 03
69.99	-0.4124819E 03	0.1529966E 03
70.99	-0.4226484E 03	0.1465000E 03
71.99	-0.4323126E 03	0.1398302E 03
72.99	-0.4414719E 03	0.1329961E 03
73.99	-0.4501236E 03	0.1260068E 03
74.99	-0.4582650E 03	0.1188708E 03
75.99	-0.4658933E 03	0.1115973E 03
76.99	-0.4730065E 03	0.1041952E 03
77.99	-0.4796026E 03	0.9667350E 02
78.99	-0.4856791E 03	0.8904116E 02
79.99	-0.4912346E 03	0.8130725E 02
80.99	-0.4962672E 03	0.7348094E 02
81.99	-0.5007752E 03	0.6557165E 02
82.99	-0.5047576E 03	0.5758798E 02
83.99	-0.5082129E 03	0.4953956E 02
84.99	-0.5111405E 03	0.4143551E 02
85.99	-0.5135388E 03	0.3328486E 02
86.99	-0.5154075E 03	0.2509724E 02
87.99	-0.5167459E 03	0.1688136E 02
88.99	-0.5175540E 03	0.8646873E 01
89.99	-0.5178308E 03	0.4027705E 00

ATTACH I

Structural Review of Torso Closure Ring -958535







Assume distributed load acts in an effective length of 2.5 in.

$$Q = \frac{P}{2} \div 2.5 = \frac{P}{5} = 137.2\ \#/in.$$

$$M = Qe = \frac{686}{5} \times .15$$

From frame analysis,

$$M_D = \frac{QL}{8\left[\left(\frac{.035}{.035}\right)^3 \frac{h}{L} + 2\right]} - \frac{M}{2} = \frac{686 \times .5}{8\left[.365 \times \frac{.26}{.50} + 2\right]5} - \frac{686 \times .15}{5 \times 2}$$

$$= \frac{34.3}{8[2.25]5} - 10.28 = 3.3 - 10.28 = -6.98\ in.\text{-}lb$$

$$H = \frac{3QL}{8[2.256]h} = \frac{3 \times 686 \times .5}{8 \times 2.256 \times .335} = \frac{1028}{32.4} = 31.7\ \#/in.$$

$$V = \frac{1}{2}Q = \frac{P}{10} = 68.6\ \#/in.$$

$M_C = Hh - M_D = 31.7 \times .36 + 6.48 = 11.41 + 6.48 = 17.89$ in-lb/in.

$M_B = Hh - M_D - \frac{Vl}{2} = 17.89 - \frac{68.6 \times .5}{2} = 17.89 - 17.15 = .74$ in-lb/in.

Since there is considerable thickening at corner C. The moment away from the corner is M_C'

$M_C' = M_C - (.05)V = 17.89 - .05 \times 68.6 = 17.89 - 3.43 = 14.46$ in-lb/in.

$\sigma_C = \frac{6M_C'}{t^2} = \frac{6 \times 14.46}{(.025)^2} = \frac{86.8}{.000625} = 139{,}000$ psi !!

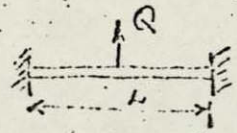
$M_E = 3.8 + \frac{M}{2} = 3.8 + 10.26 = 14.08$ in-lb/in.

$M_F = M_E - Hh = 14.08 - 31.1 \times .26 = 2.65$ in-lb/in.

$M_G = M_F + .23V = 2.65 + 15.8 = 18.45$ in-lb

$\sigma_G = \frac{6 \times 18.45}{(.035)^2} = \frac{110.8}{.001225} = 89{,}800$ psi

Deflection at B and G.



$\delta = \frac{QL^3}{192EI} = \frac{12 \times 137.2 \times .5^3}{192 \times 29 \times 10^6 \times 1 \times (.03)^3} = \frac{206}{150100} = .00137"$

Since the local deflection is small in comparison with ring deflection ($\frac{489}{2} = .245"$ @ 5 psi pressure, page 162 Ref.) the local load intensification is possible. For uniform load $q \approx 68C/43.3 = 15.84$ #/in.

$$\sigma_E = \frac{P}{2t} + \frac{6M_E}{t^2} = \frac{137.2}{.03\times 2} + \frac{6\times 14.08}{(.03)^2} = 2290 + 94000 = 96290 \text{ psi}$$

Try .035" min. wall and .1" long nut

$$P' = P \times \frac{2.5}{3.0} = 137.2 \times .833 = 114.5$$

$$M_E' = 14.08 \times .833 = 11.75$$

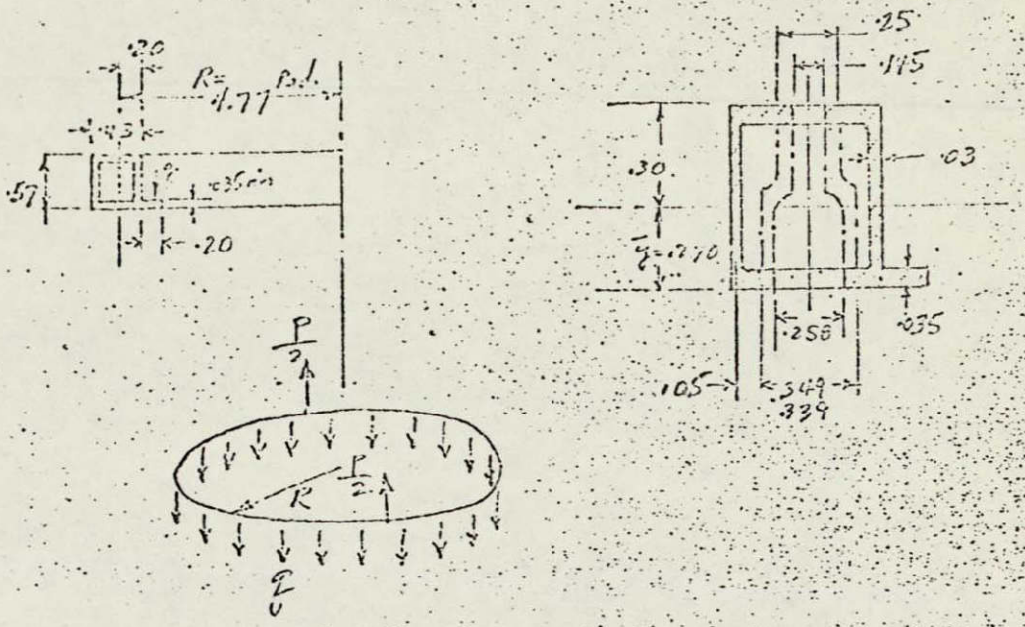
$$\sigma_{E'} = \frac{114.5}{2\times .035} + \frac{6\times 11.75}{(.035)^2} = 1640 + 57500 = 59{,}400 \text{ psi}$$

Increase min. thickness to .045 and .05 respectively,

$$\sigma_c = \frac{6\times 14.46}{.045^2} = \frac{6\times 14.46}{.002025} = 42{,}900 \text{ psi} \qquad \text{Allowable } F = 50{,}000 \text{ psi}$$

$$\sigma_c = \frac{6\times 18.45}{.05^2} = \frac{6\times 18.45}{.0025} = 44{,}300 \text{ psi}$$

Structural Review of Lower Hip Ring – 958441



$P_o = \frac{\pi}{4}(9.1)^2(5.0) = 325$ #

$q = P_o/\pi(8.9) = 325/28 = 11.61$ #/in.

Full section properties - from Page 229.

$I = .002401$ in.^{4}, $Z = \frac{.002401}{.285} = .00842$ in.^{3}

$A = .0487$ in.^{2}

$A_m = .2079$ in.^{2}

Insert section

$$\bar{y} = \frac{.00775\times.552 + .01302\times.0175 + .03\times.285}{.035\times.285 + .035\times.372 + 2\times.02\times.5} = \frac{.005506 + .000228 + .00855}{.053} = \frac{.014284}{.053} = .27$$

$$I = .00775\times.282^2 + .01302\times.252^2 + .03\times(.015)^2 + \frac{.06}{12}(.5)^3$$

$$= .00\ldots + .00\ldots + .00\ldots + .00625 = .00\ldots \text{ in.}^4$$

$$Z_x = \frac{.00\ldots}{.30} = .0054 \text{ in.}^3$$

$$Z_c = \frac{.00\ldots}{.27} = .0060 \text{ in.}^3$$

$M_A = QR^2$

$Q = \frac{P_o}{2\pi R}$

$M_A = \frac{P_o}{2\pi} R = \frac{325}{2\pi} 4.77 = 247$ in.-lb

$\sigma_A = \frac{M_A}{Z_t} = \frac{247}{.0542} = 45{,}500$ PSI OK

Local bending on bottom plate at insert.

$M = .05 \times \left(.6 \times \frac{P_o}{2} \times \frac{1}{2}\right) = .05 \left(.6 \times \frac{325}{2} \times \frac{1}{2}\right) = .05 \times 48.8 = 2.44$ in.-lb

Effective width, $b = \frac{2}{\pi} d = \frac{2}{\pi} \times .34 = .216$

$\sigma = \frac{6M}{bt^2} = \frac{6 \times 2.44}{.216 \times (.035)^2} = \frac{14.64}{.000265} = 55200$ PSI

If $t = .055$ min. Top and bottom plates, 1" on each side of insert.

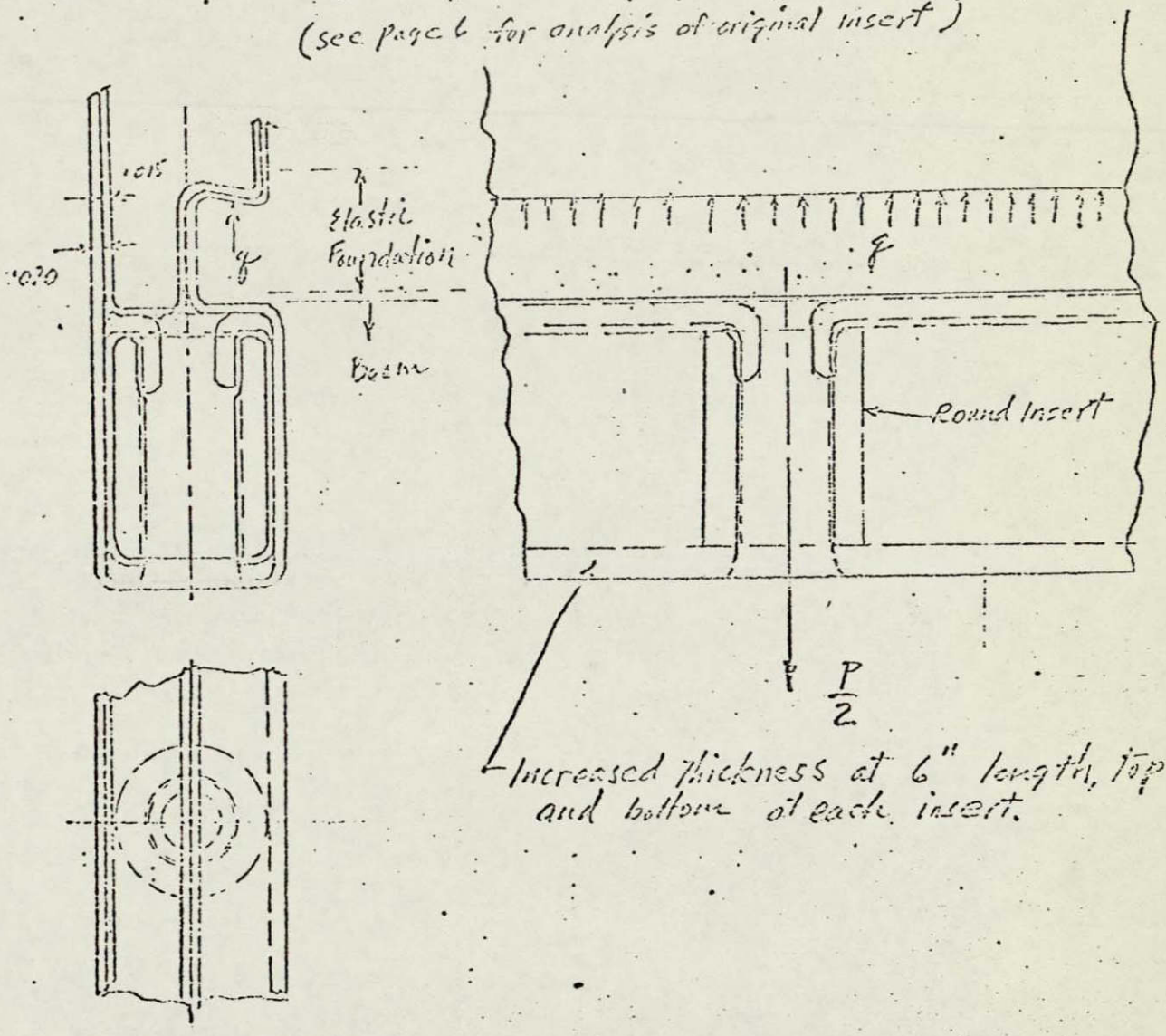
$\sigma = 55200 \times \left(\frac{.035}{.055}\right)^2 = 22{,}300$ PSI OK.

DATE 1-9-70
PREPARED BY E. Corbin
CHECKED BY

CALC. NO.
MODEL
PART NO.

Torso Closure Ring with Round Insert Design - 9585-35

(see page 6 for analysis of original insert)

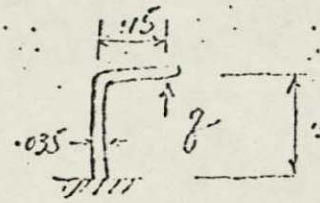


Since the insert is connected to the top and bottom flange the cable load represents a concentrated load on a rectangular cross-section beam. The upper vertical web is to transfer the concentrated load to a more uniformly distributed load. The upper vertical web serves as an elastic foundation for the lower beam.

DATE 1-70
PREPARED BY J.C. Lin
CHECKED BY

CALC. NO.
MODEL
PART NO.

Foundation Modulus



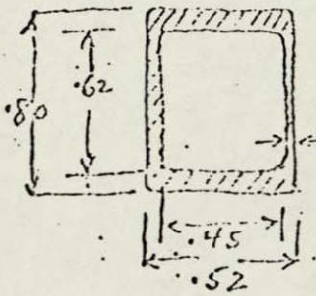
$$I = \frac{1}{12}(.035)^3 = \frac{10^{-3}}{12}(.0429) = .357\times10^{-5}$$

$$\delta_f = \frac{q(.35)(.15)^2}{EI} + \frac{q(.15)^3}{3EI}$$

$$= \frac{q}{EI}\left[.00787 + \frac{.00337}{3}\right] = \frac{.0099}{EI} = \frac{.009\times q}{29\times.375\times10}$$

$$k = \frac{q}{\delta_f} = \frac{108.8}{.009} = \underline{12{,}000\ \#/in/in.}$$

Beam section moment of inertia. I



$$\frac{t}{} .09 = .015 + .055 + .020$$

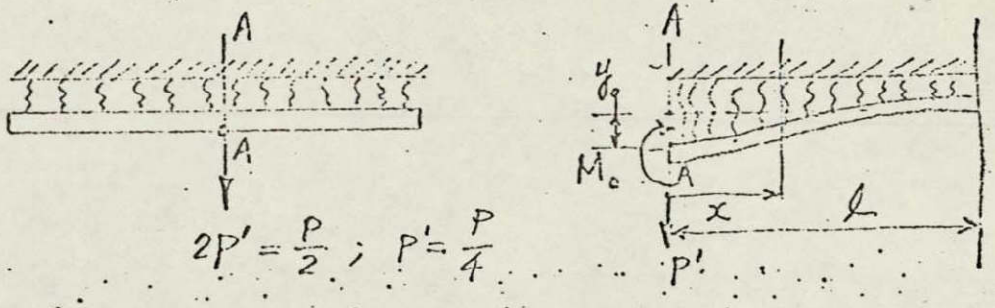
$$I = \frac{1}{12}\left[.52\times.80^3 - .45\times.62^3\right]$$

$$= \frac{1}{12}\left[.21992 - .10725\right] = \frac{.10574}{12} = .00881\ in^4$$

$$EI = 29\times10^6 \times .00881 = 25.5\times10^4$$

$$\beta = \sqrt[4]{\frac{k}{4EI}} = \sqrt[4]{\frac{12000}{4\times25.5\times10^4}} = \frac{1}{10}\times3.3 = .33$$

Beam on Elastic Foundation



$$2P' = \frac{P}{2} \; ; \; P' = \frac{P}{4}$$

For symmetry at section A-A

$$P' - 2\beta M_o = 0$$

$$M_o = \frac{P'}{2\beta}$$

The deflection,

$$y = \frac{e^{-\beta x}}{2\beta^3 EI}\left[P'\cos\beta x - \beta M_o(\cos\beta x - \sin\beta x)\right]$$

$$= \frac{e^{-\beta x}}{2\beta^3 EI}\left[P'\cos\beta x - \frac{P'}{2}(\cos\beta x - \sin\beta x)\right] = \frac{e^{-\beta x}P'}{4\beta^3 EI}(\cos\beta x + \sin\beta x)$$

Let $\beta x = 1.6$ or $x = 1.6/.33 = 4.85$ in.

Distributed load $q = ky$

$$y_o = \frac{P'}{4(.33)^3 \times 25.5 \times 10^4} = \frac{P'}{.144 \times 25.5 \times 10^4} = \frac{P'}{3.67 \times 10^4}$$

$$Q = q_{max} = ky_o = 12000 \times \frac{P'}{3.67 \times 10^4} = \frac{12000 \times 17.2}{3.67 \times 10^4} = \underline{56.3 \text{ \#/in.}}$$

$$M = Qc = 56.3 \times .15 = 8.5 \text{ in.-lb}$$

Stress at vertical web $t = .035$"

$$\sigma = \frac{56.3}{.035} + \frac{6 \times 8.5}{.035^2} = 1610 + 41700 = \underline{43{,}300 \text{ psi}}$$

use .035" min.

Form 2427

AiRESEARCH MFG. CO.

DATE 1-70
PREPARED BY
CHECKED BY

CALC. NO
MODEL
PART NO

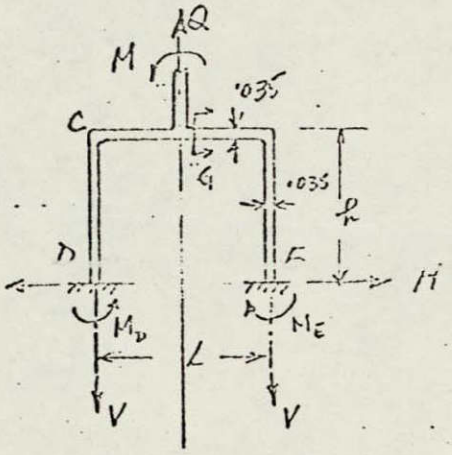
At $\beta x = 1.0$; $x = 3.0$"

$$y = \frac{.368P'}{3.67\times10^6}(\cos 57.3 + \sin 57.3) = \frac{.368P'}{3.67\times10^6}(.5402 + .8415) = \frac{.51P'}{3.67\times10^6}$$

The load reduces to 51% at $x = 3.0$".

$Q = 56.3 \times .51 = 28.7$ #/in.

$M = 8.5 \times .51 = 4.4$ in-#/in



$h = .72$

$L = .5$

$$M_{E,D} = \frac{QL}{8\left[\frac{R}{L}+2\right]} \pm \frac{M}{2} = \frac{28.7\times.5}{8[1.44+2]} \pm 2.2 = .53 \pm 2.2 = 2.72, -1.67$$

$$H = \frac{3QL}{8\left(\frac{R}{L}+2\right)R} = \frac{3\times28.7}{8\times3.44\times.72} = 4.35\ \#/in.$$

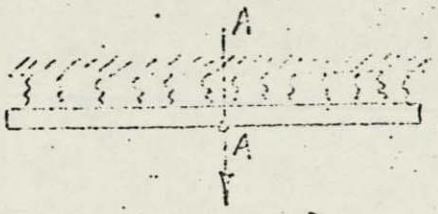
$$V = \frac{Q}{2} = \frac{28.7}{2} = 14.35$$

$M_C = HR - M_D = 4.35\times.72 + 1.67 = 3.13 + 1.67 = 4.8$ in-lb/in.

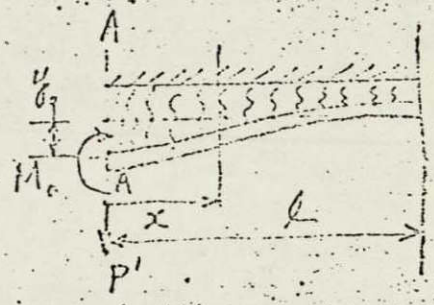
$M_G = V\frac{L}{2} + M_E - Hx = 14.35\times.25 + 2.72 - 3.13 = 3.2$ in-lb/in.

$$\sigma_c = \frac{6\times4.8}{(.035)^2} + \frac{14.35}{.035} = 23500 + 410 = \underline{24{,}000\ psi} \quad OK.$$

Beam on Elastic Foundation



$$2P' = \frac{P}{2} \; ; \; P' = \frac{P}{4}$$



For symmetry at section A-A

$$P' - 2\beta M_0 = 0$$

$$M_0 = \frac{P'}{2\beta}$$

The deflection,

$$y = \frac{e^{-\beta x}}{2\beta^3 EI}\left[P'\cos\beta x - \beta M_0(\cos\beta x - \sin\beta x)\right]$$

$$= \frac{e^{-\beta x}}{2\beta^3 EI}\left[P'\cos\beta x - \frac{P'}{2}(\cos\beta x - \sin\beta x)\right] = \frac{e^{-\beta x}P'}{4\beta^3 EI}(\cos\beta x + \sin\beta x)$$

Let $\beta x = 1.6$ or $x = 1.6/.33 = 4.85$ in.

Distributed load $p = ky$

$$y_0 = \frac{P'}{4\times(.33)^3\times 25.5\times 10^4} = \frac{P'}{.144\times 25.5\times 10^4} = \frac{P'}{3.67\times 10^4}$$

$$Q = Q_{max} = ky_0 = 12000\times\frac{P'}{3.67\times 10^4} = \frac{12000\times 17.2}{3.67\times 10^4} = 56.3 \text{ #/in.}$$

$$M = Qe = 56.3\times .15 = 8.5 \text{ in-lb}$$

Use .035" with $t = .035$.

$$f = \frac{56.3}{.035} + \frac{6\times 8.5}{.035^2} = 1610 + 41700 = 43{,}300 \text{ psi}$$

use .035" min.

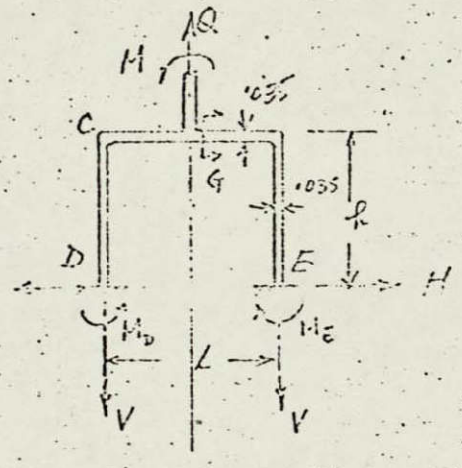
At $\beta x = 1.0$; $\therefore x = 3.0$

$$y = \frac{.365 P'}{3.67 \times 10^4}\left(\cos 57.3 + \sin 57.3\right) = \frac{.358\ P'}{3.67 \times 10^4}\left(.5402 + .8415\right) = \frac{.51 P'}{3.67 \times 10^4}$$

the load reduces to 51% at $x = 3.0$"

$Q = 56.3 \times .51 = 28.7$ #/in

$M = 8.5 \times .51 = 4.3$ in-#/in



$h = .72$

$L = .5$

$$M_{E,F} = \frac{QL}{8\left[\frac{2}{L} + 2\right]} \pm \frac{M}{2} = \frac{28.7 \times .5}{8\left[1.44 + 2\right]} \pm 2.2 = .53 \pm 2.2 = 2.72, -1.67$$

$$H = \frac{3QL}{8\left(\frac{2}{L} + 2\right)h} = \frac{3 \times 28.7}{8 \times 3.44 \times .72} = 4.35\ \#/in$$

$$V = \frac{Q}{2} = \frac{28.7}{2} = 14.35$$

$$M_C = Hh - M_D = 4.35 \times .72 + 1.67 = 3.13 + 1.67 = 4.8\ in\text{-}lb/in.$$

$$M_G = V\frac{L}{2} + M_E - Hh = 14.35 \times .25 + 2.72 - 3.13 = 3.2\ in\text{-}lb/in.$$

$$\sigma_c = \frac{6 \times 4.8}{(.035)^2} + \frac{14.35}{.035} = 23500 + 410 = \underline{24{,}000\ psi} \quad ok.$$

ATTACH II

AIRESEARCH MFG. CO.

LOG SHEET

Test No. WAIST RING LOAD TEST S/N 620-1 Date 1/8/69 70

Assy No. 958620-01 Assy Page _____ Data Sheet No. _____ Page No. 1 of 7

RUN TIME	
	The test procedure attached was used to conduct the test on the waist ring.
	The specimen's cable pick up points are considerably bulged up compared to the original designs. The ring was placed on parallel plate (at Douglas 1st) and found to be warped approximately .023 to -.001 from a baseline point. See FIG. 1 & 2 for DIMENSIONAL data.
	The specimen was placed in the test fixture and onto an Instron tensile test machine. The load was applied to the ring and held for 15 min then the load was increased to 940. The ring was again placed on parallel plate (at main plant) and dimensional data taken again.
	The proof test was then performed on the unit. At approximately 940 lbs load there was a cracking sound and the load/deflection curve plot on the Instron machine was marked.

Page Time: _____

Page Starts: _____

ATTACH III

FORM #2890A
AIRESEARCH MFG. CO.

LOG SHEET

Test No. WAIST RING LOAD TESTS S/N 620-1 Date 1/8/69

Assy No. 958620-01 Assy Page _____ Data Sheet No. _____ Page No. 2 of 4

RUN TIME	
	The test was continued. The same creaking sound was heard again at approximately 1050 lbs load. The load/deflection curve plot was marked. At approximately 1170 lbs there emanated from the specimen a clear bell like ring. The test was continued to 1350 lbs and held for two minutes. Then the load was brought to zero. The unit was returned to Douglas St and dimensional data recorded. See 7-3 for load deflection curves.
	Looking at the dimensional data there seems to be a error in the data after the 5 psig test and the initial and after 10 psig test. The initial and after 10 psig test were done at Douglas St using the same equipment. The 5 psig test measurements were done at the main plant inspection booth using different equipment.

Page Time: _____

Page Starts: _____

ATTACH. III

FORM #2890A
AIRESEARCH MFG. CO.

LOG SHEET

Test No. WAIST RING, LOAD TESTS S/N 620-1 Date 1/8/69

Assy No. 958620-01 Assy Page _____ Data Sheet No. _____ Page No. 3017

RUN TIME	
	Disregarding the after 5 psig data the following observation can be made from FIG 1 and FIG 2.
	1) Pick up holes along the major axis changed ±.061 maximum from base line readings.
	2) Pickup holes along the minor axis indicated a change of +.009 to +.015 maximum from original base line readings
	3) Midpoints changed from +.001 to +.002 from baseline readings
	The waist ring shows a change of +.009 to +.015 from the original dimensions using the same measurement equipment. No other non-destructive tests were performed on the unit but should be done to check for surface cracks not visible by visual observation

Page Time: _____

Page Starts: _____

ATTACH III

DATE 12/17/69
PREPARED BY A. K. Walther
CHECKED BY

CALC. NO
MODEL
PART NO 958620

Conduct Waist Ring Load Tests as Follows:

1) Measure the plane height of the ring using a surface plate and parallel bars. Measure at each boss and midway between bosses. Record dimensions on a marked print and on data sheet.

2) Install the test ring in a set up by attaching the ring to the fixture with 1/8" diameter teflon coated wire rope at its four mounting points.

3) Load the ring to 675 lbs (5 psi) at a rate of 0.050" inches/minute. Hold this load for 15 minutes.

4) Reduce the load to 0 lbs at a rate of 0.050 inches/minute.

5) Remove the ring and measure at mounting holes, etc to record evidence of permanent set on marked print and on data sheet.

6) Reinstall the ring in the test set up and load the ring to 1350 lbs (10 psi) at a rate of 0.050" inches/minute. Hold this load for 2 minutes.

7) Reduce the load to 0 lbs at a rate of 0.050 inches/minute.

8) Remove the ring and measure at some points as Step 1. Record on marked print and make up data sheets.

DATE 1-9-69
PREPARED BY (AE)
CHECKED BY

CALC. NO.
MODEL
PART NO.

P/N 958620-01
S/N 620-1

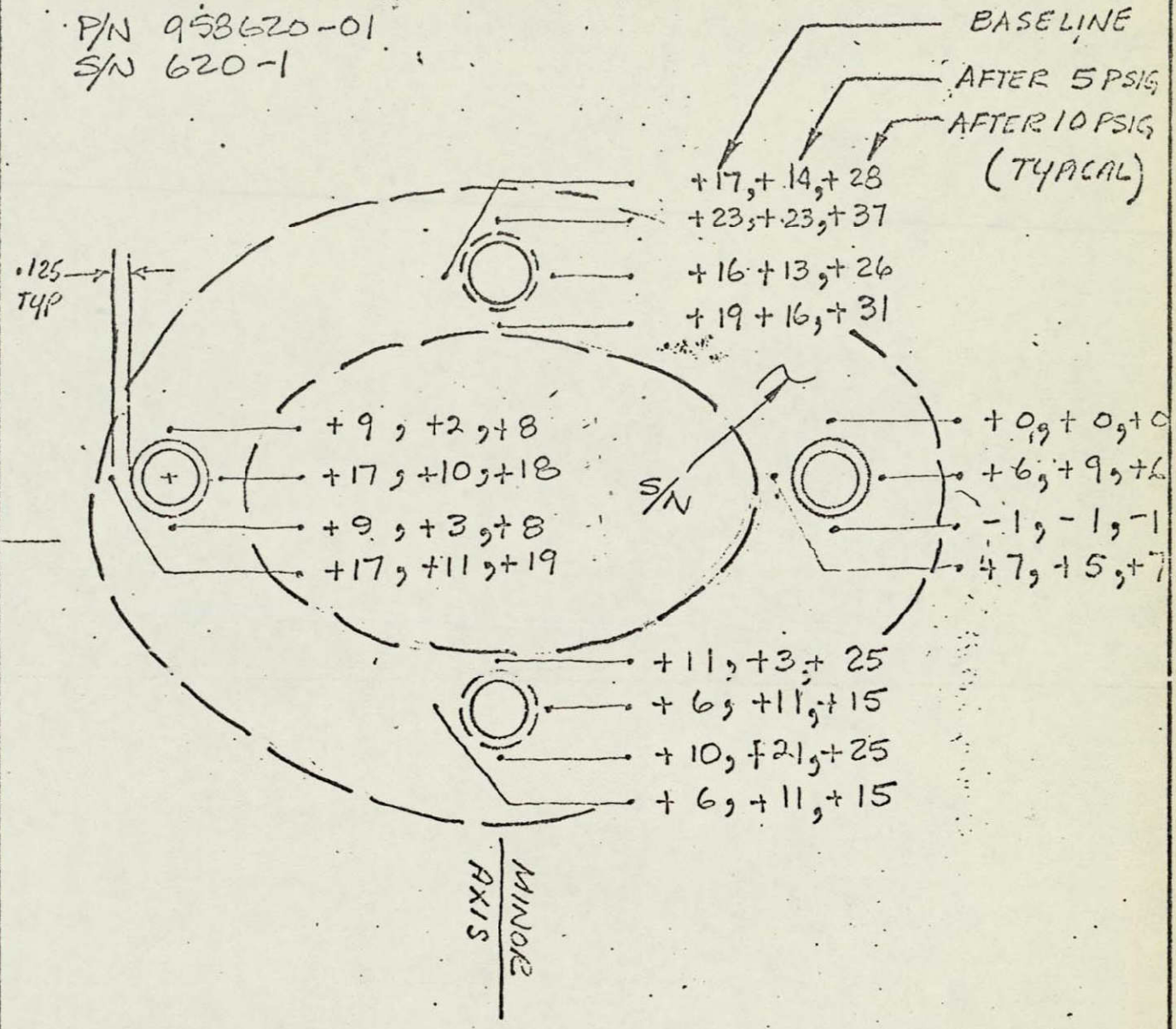


FIG. 1

PICKUP HOLES INITIAL, AFTER 5 PSIG, AFTER 10 PSIG DIMENSIONS. ALL MEASUREMENTS IN THOUSANDS OF AND INCH.

DATE 4-9-69
PREPARED BY AC
CHECKED BY

CALC. NO
MODEL
PART NO

P/N 958620-01
S/N 620-1

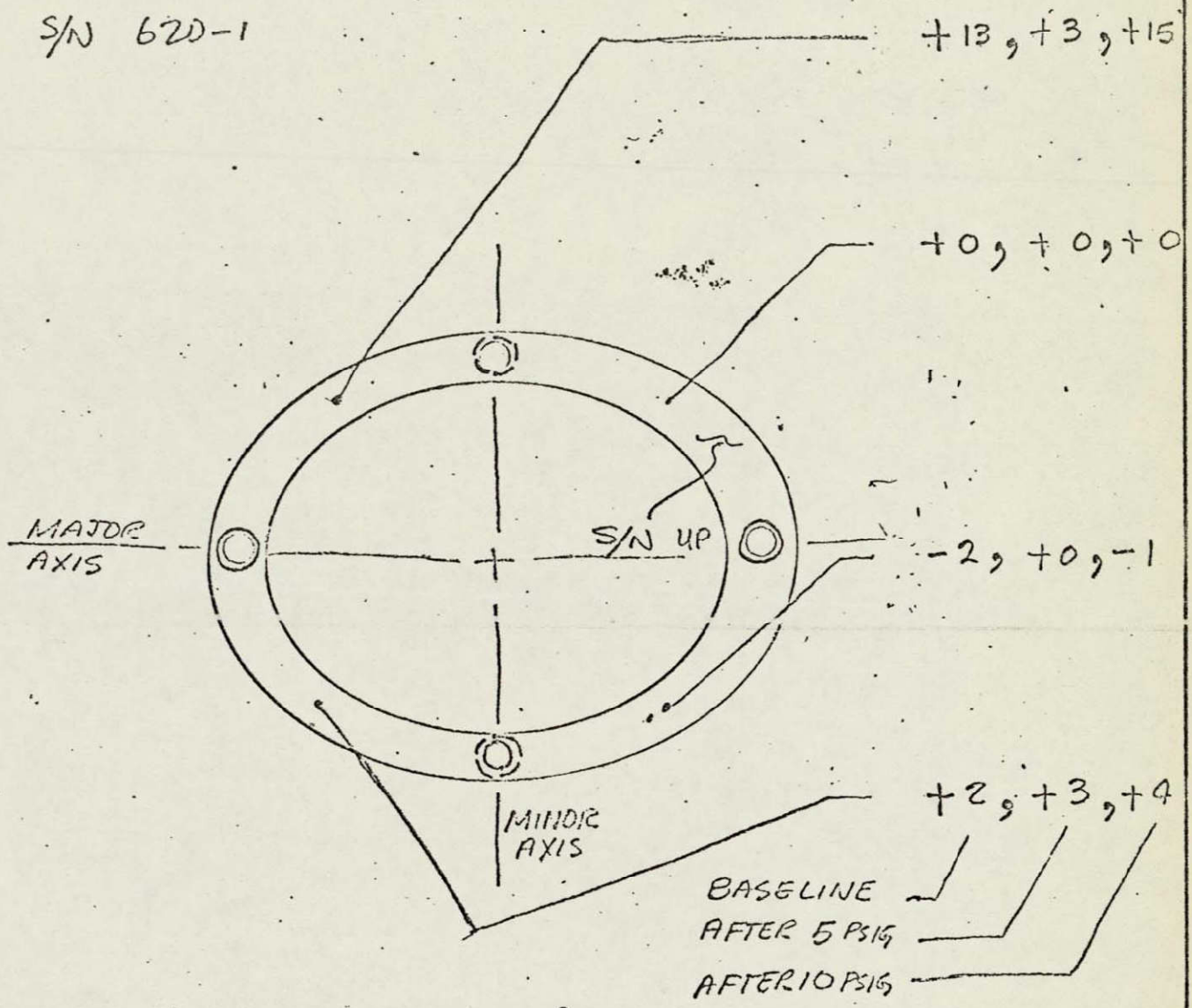
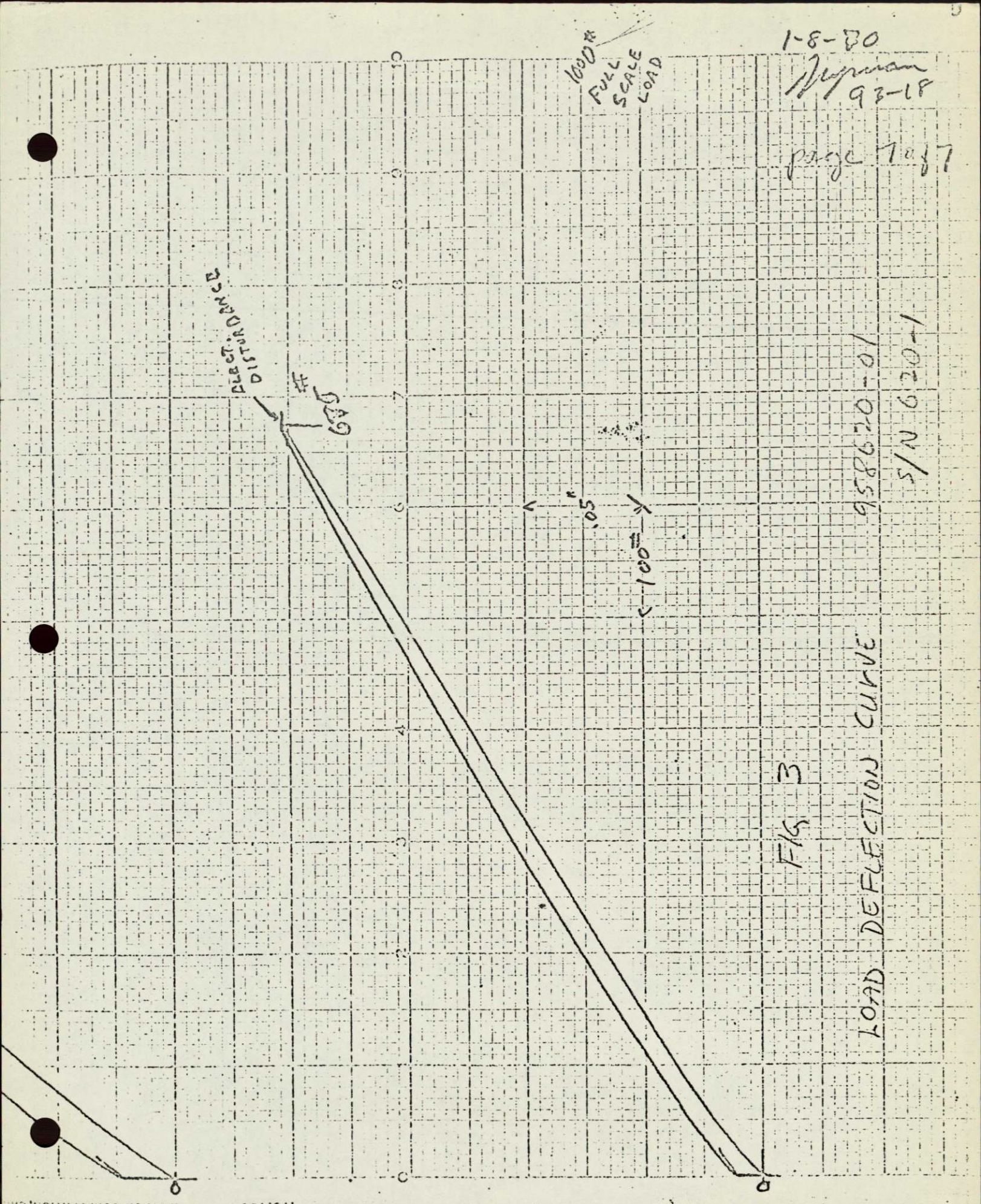
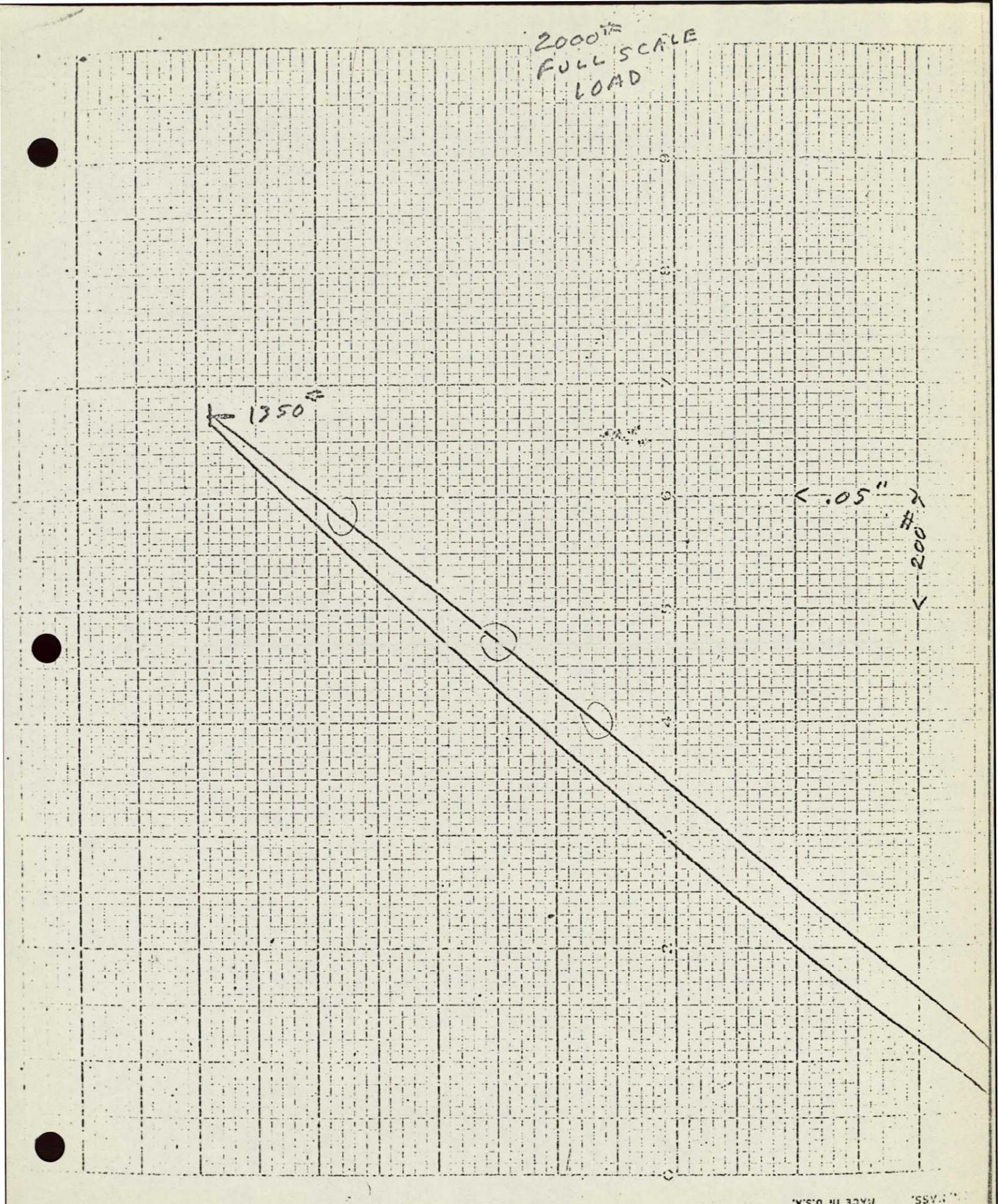


FIG 2.

MID POINTS INTIAL, AFTER 5 PSIG, AFTER 10 PSIG DIMENSIONS. ALL MEASUREMENTS IN THOUSANDS OF AN INCH.


1-8-80
Wyman
93-18
page 1 of 1
1000 # FULL SCALE LOAD
ELECT. DISTURBANCE
6000 #
.05"
1000 #
9586-20-01
S/N 6120-1
FIG 3
LOAD DEFLECTION CURVE


2000# FULL SCALE LOAD
1350#
.05"
200#

APPENDIX H

SUIT SIZING

LEGEND

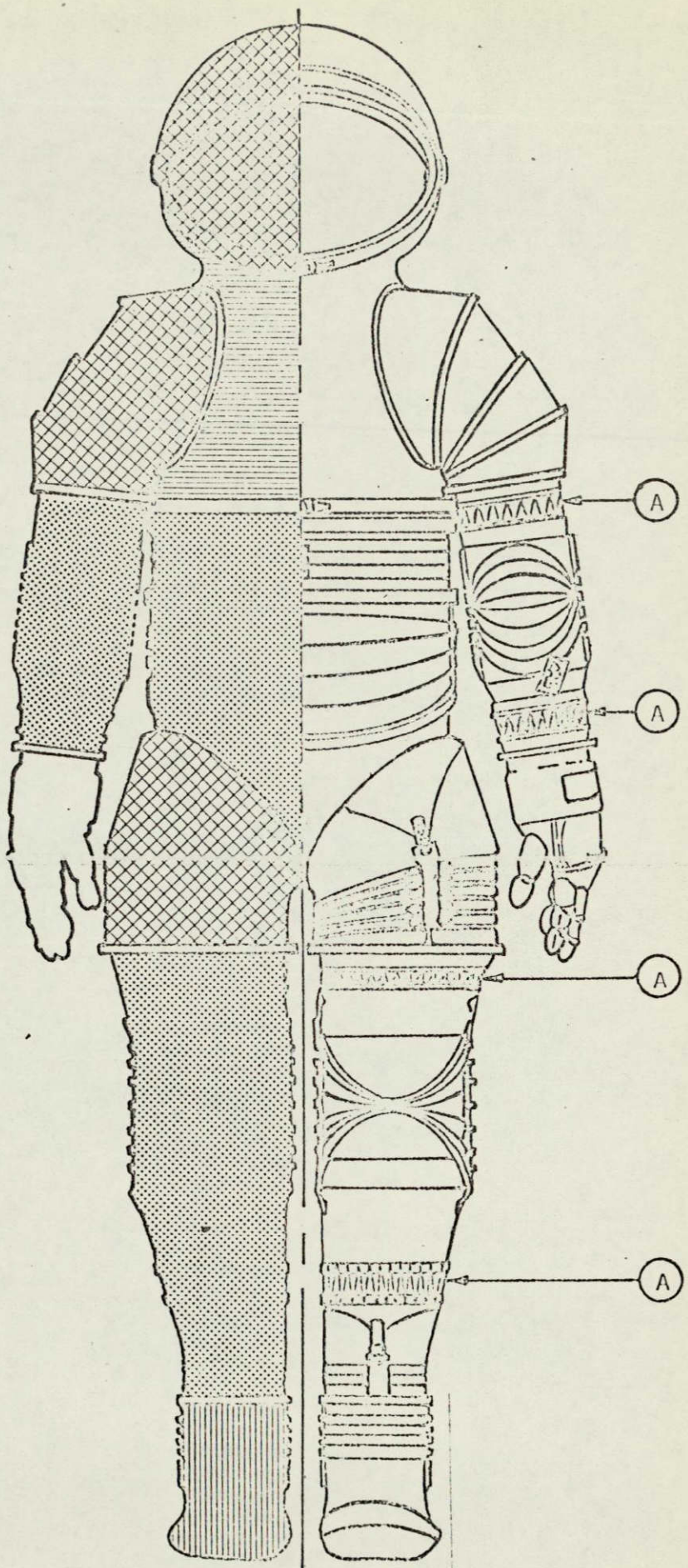
WIDTH SIZING

COMMON & INTERCHANGEABLE

HEIGHT SIZING

VERNIER SIZING ADJUSTMENT (A)

FOOT LENGTH SIZING WITH CUSTOM INNER SOLES



SIZING CONSIDERATIONS

- 42 SAMPLES USED TO ESTABLISH SIZES

	SMALL	% DIST	MEDIUM	% DIST	LARGE	% DIST	SAMPLE RANGE
UPPER TORSO (CHEST BREADTH)	11.3 TO 12.5	44.8	12.5 TO 13.8	48.4	13.8 TO 15.0	6.8	11.3 TO 15.0
LOWER TORSO (CROTCH TO SHOULDER)	22.3 TO 23.6	31.0	23.6 TO 24.8	27.6	24.8 TO 26.1	41.4	22.3 TO 26.1
ARM (SHOULDER TO ELBOW AND ELBOW TO WRIST)	22.0 TO 24.0	44.8	*		24.0 TO 26.1	55.2	22.0 TO 26.1
LEG (CROTCH HEIGHT)	30.5 TO 32.8	51.6	**		32.8 TO 35.0	48.4	30.5 TO 35.0
BOOT (FOOT LENGTH)	8.5 TO 9.8	48.4	9.8 TO 11.2	37.9	11.2 TO 12.5	13.7	8.5 TO 12.5

* ONLY TWO SIZES NECESSARY DUE TO ADJUSTMENT VERNIERS; 1.5 INCH IN UPPER ARM & 1.25 INCH IN LOWER ARM.

** ONLY TWO SIZES NECESSARY DUE TO ADJUSTMENT VERNIERS; 2.0 INCH IN UPPER LEG & 2.0 INCH IN LOWER LEG.

FORM 3

ANTHROPOMETRIC MEASUREMENTS OF ASTRONAUTS (APOLLO 7 THRU 14)

CODE	ASTRONAUT	UPPER TORSO	LOWER TORSO	ARM	LEG	BOOT
1	SHIRRA	L	L	S	S	M
2	EISELE	S	L	L	S	S
3	CUNNINGHAM	M	S	S	S	S
4	STAFFORD	M	L	L	L	M
5	YOUNG	S	L	S	S	S
6	CERNAN	M	L	S	L	M
7	BORMAN	S	S	L	L	S
8	LOVELL	S	L	S	L	M
9	ANDERS	S	S	S	S	S
10	ARMSTRONG	L	M	L	L	S
11	ALDRIN	M	M	S	S	M
12	HAISE	S	S	S	L	S
13	McDIVITT	M	M	S	S	L
14	SCOTT	M	M	L	L	L
15	SCHWEICKART	S	S	S	L	M
16	CONRAD	S	S	S	S	S
17	GORDON	S	S	S	S	M
18	BEAN	S	M	L	S	S
19	COOPER	M	M	L	S	S
20	MITCHELL	S	L	L	S	L
21	COLLINS	M	L	L	S	L
22	WORDEN	M	M	L	L	M
23	IRWIN	L	S	S	S	M
24	MATTINGLY	S	M	S	S	S
25	SWIGERT	M	L	L	L	L
26	DUKE	S	L	L	L	S
27	SHEPARD	M	M	L	L	M
28	ROOSA	M	S	L	L	M
29	EVANS	S	L	L	L	M
30	ENGLE	S	L	L	L	S

CONFIDENTIAL

APOLLO 7 THRU 14 FLIGHT SCHEDULE

FLIGHT	DATE	PRIME CREW	BACK UP CREW
7	10-11-68	1, 2, 3	4, 5, 6
8	12-21-68	7, 8, 9	10, 11, 12
9	3-3-69	13, 14, 15	16, 17, 18
10	5-18-69	4, 5, 6	19, 2, 20
11	7-16-69	10, 21, 11	8, 9, 12
12	11-14-69	16, 17, 18	14, 22, 23
13	3-9-70	8, 24, 12	5, 25, 26
14	7-70	27, 28, 20	6, 29, 30

X INDICATES LUNAR EVA PERSONNEL

RESIZING RATIONALE (APOLLO 7 THRU 14)

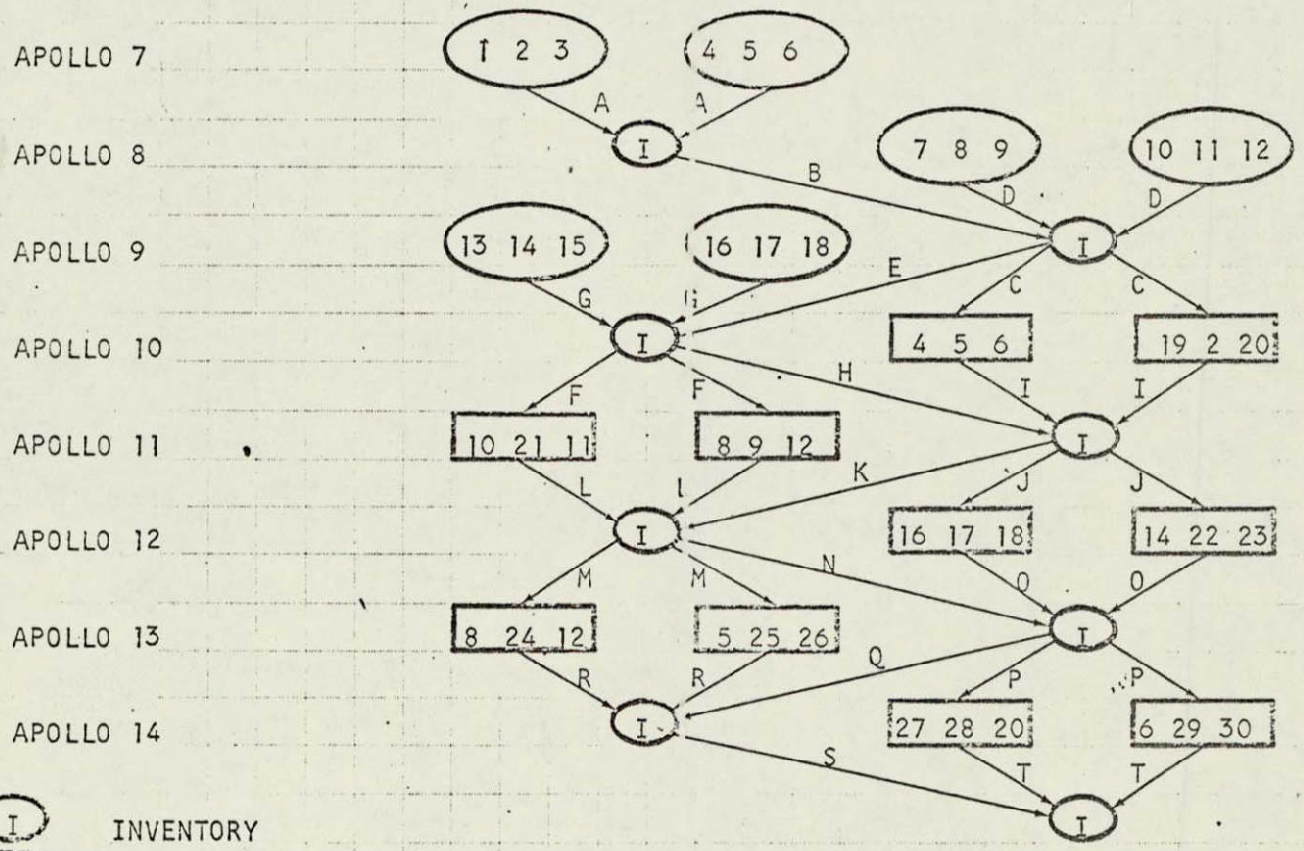
- FLIGHT SUITS REQUIRED 4 MONTHS (120 DAYS) PRIOR TO FLIGHT
- TRAINING SUITS REQUIRED 6 MONTHS (180 DAYS) PRIOR TO FLIGHT
- TRAINING SUITS CANNOT BE INTERCHANGED WITH FLIGHT OR CONTINGENCY SUITS
- CONTINGENCY SUITS REQUIRED AT TIME OF FLIGHT
- NO LUNAR LANDING UNTIL APOLLO 11
- ONE WEEK REQUIRED FOR SIZING
- SUITS USED FOR LUNAR EVA WILL NOT BE REUSED

FLIGHT NO.	7	8	9	10	11	12	13	14
7								
8	72							
9	143	73						
10	219	149	96					
11	A	208	135	59				
12	A	A	257	181	122			
13	A	A	A	297	238	116		
14	A	A	A	A	A	230	114	

DAYS BETWEEN FLIGHTS

FLIGHT NO.

SIZING TECHNIQUE (GENERAL CASE - TRAINING SUITS)



I INVENTORY

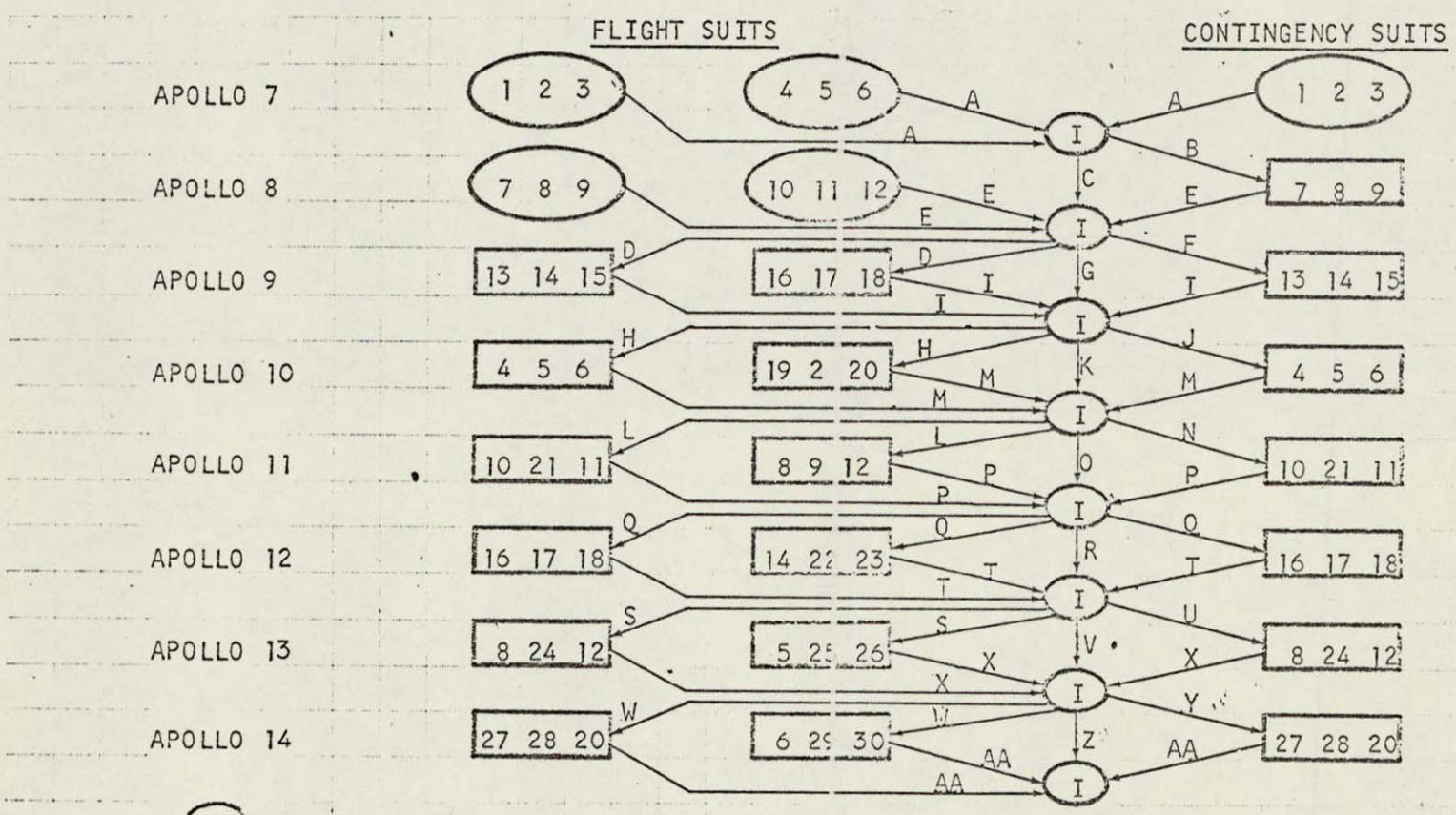
NEW SUITS REQUIRED

RESIZED SUITS

N LETTER INDICATES ORDER OF OPERATION

FORM

SIZING TECHNIQUE (GENERAL CASE) FLIGHT AND CONTINGENCY SUITS)



I — INVENTORY

NEW SUITS REQUIRED

RESIZED SUITS

N — LETTER INDICATES ORDER OF OPERATION

APOLLO 7 THRU 14 SPECIFIC SIZING STUDY RESULTS

	FLIGHT AND CONTINGENCY	TRAINING	TOTAL
○ NEW SUITS REQUIRED	15	18	33

○ SIZING REQUIREMENTS	FLIGHT AND CONTINGENCY S	M	L	TRAINING S	M	L	TOTAL
UPPER TORSOS	6	2	0	1	1	0	10
LOWER TORSOS	3	5	2	0	1	2	13
ARM PAIRS	0	-	5	0	-	2	7
LEG PAIRS	1	-	6	1	-	1	9
BOOT PAIRS	1	2	5	0	0	2	10

○ REMAINING INVENTORY AFTER COMPLETION OF APOLLO 14 FLIGHT

	FLIGHT AND CONTINGENCY S	M	L	T	LUNAR EVA S	M	L	T	TRAINING S	M	L	T	TOTAL
UPPER TORSO	8	5	2	15	5	2	1	8	11	7	2	20	43
LOWER TORSO	6	3	8	17	2	4	2	8	7	6	8	21	46
ARM PAIRS	6	-	6	12	4	-	4	8	12	-	8	20	40
LEG PAIRS	6	-	8	14	4	-	4	8	11	-	9	20	42
BOOT PAIRS	6	5	4	15	4	3	1	8	9	7	4	20	43

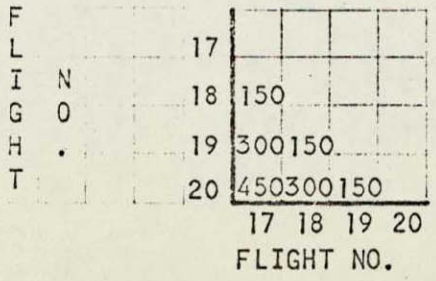
ANTHROPOMETRIC MEASUREMENTS OF ASTRONAUTS (APOLLO 17 THRU 20)

CODE	ASTRONAUT	UPPER TORSO	LOWER TORSO	ARM	LEG	BOOT
1	BEAN	S	M	L	S	S
2	BRAND	M	S	L	L	S
3	CARR	M	S	S	S	S
4	CERNAN	M	L	S	L	M
5	COOPER	M	M	L	S	S
6	CONRAD	S	S	S	S	S
7	DUKE	S	L	L	L	S
8	EISELE	S	L	L	S	S
9	ENGLE	S	L	L	L	S
10	EVANS	S	L	L	L	M
11	GORDON	S	S	S	S	M
12	HAISE	S	S	S	L	S
13	IRWIN	L	S	S	S	M
14	LIND	M	L	L	S	M
15	LOUSMA	L	L	L	L	M
16	MATTINGLY	S	M	S	S	S
17	McCANDLE	M	M	S	S	S
18	ROOSA	M	S	L	L	M
19	STAFFORD	M	L	L	L	M
20	SCOTT	M	M	L	L	L
21	SWIGERT	M	L	L	L	L
22	SCHMITT	M	S	S	S	S
23	WEITZ	M	M	L	S	L
24	WORDEN	M	M	L	L	M
25	YOUNG	S	L	S	S	S
26	SCHWEICKART	S	S	S	L	M
27	POGUE	M	M	S	S	S
28	LOVELL	S	L	S	L	M
29	MITCHELL	S	L	L	S	L

STUDY CONDUCTED USING ABOVE ORDER FOR FLIGHT PERSONNEL WITH FIRST TWO ODD NUMBERS OF EACH SET OF SIX BEING ASSIGNED LUNAR EVA RESPONSIBILITIES.

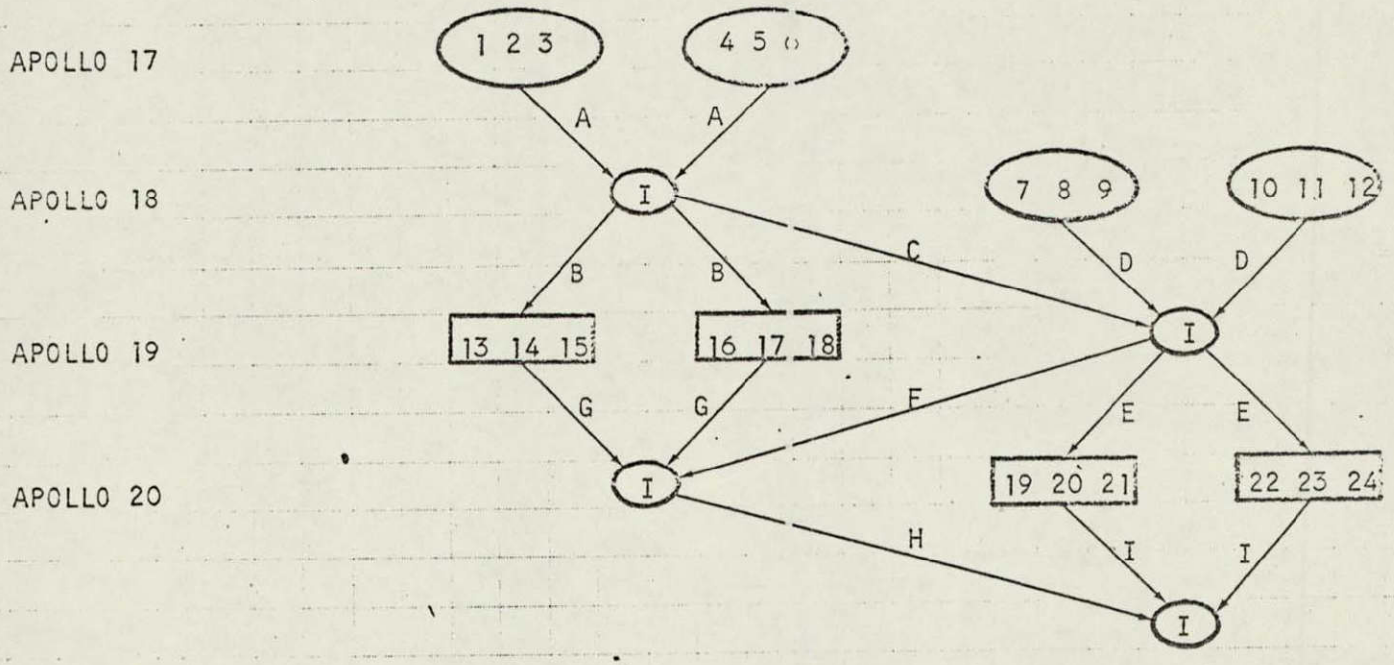
RESIZING RATIONALE (APOLLO 17 THRU 20)

- FLIGHTS SCHEDULED ON FIVE MONTH INTERVALS
- FLIGHT SUITS REQUIRED 4 MONTHS (120 DAYS) PRIOR TO FLIGHT
- TRAINING SUITS REQUIRED 6 MONTHS (180 DAYS) PRIOR TO FLIGHT
- CONTINGENCY SUITS REQUIRED AT TIME OF FLIGHT
- TRAINING SUITS CANNOT BE INTERCHANGED WITH FLIGHT OR CONTINGENCY SUITS
- ALL FLIGHTS WILL INCLUDE LUNAR EVA
- ALL SUITS ARE REUSABLE
- SUITS LIMITED TO THREE LUNAR LANDINGS



DAYS BETWEEN FLIGHTS

SIZING TECHNIQUE (GENERAL CASE - TRAINING SUITS)



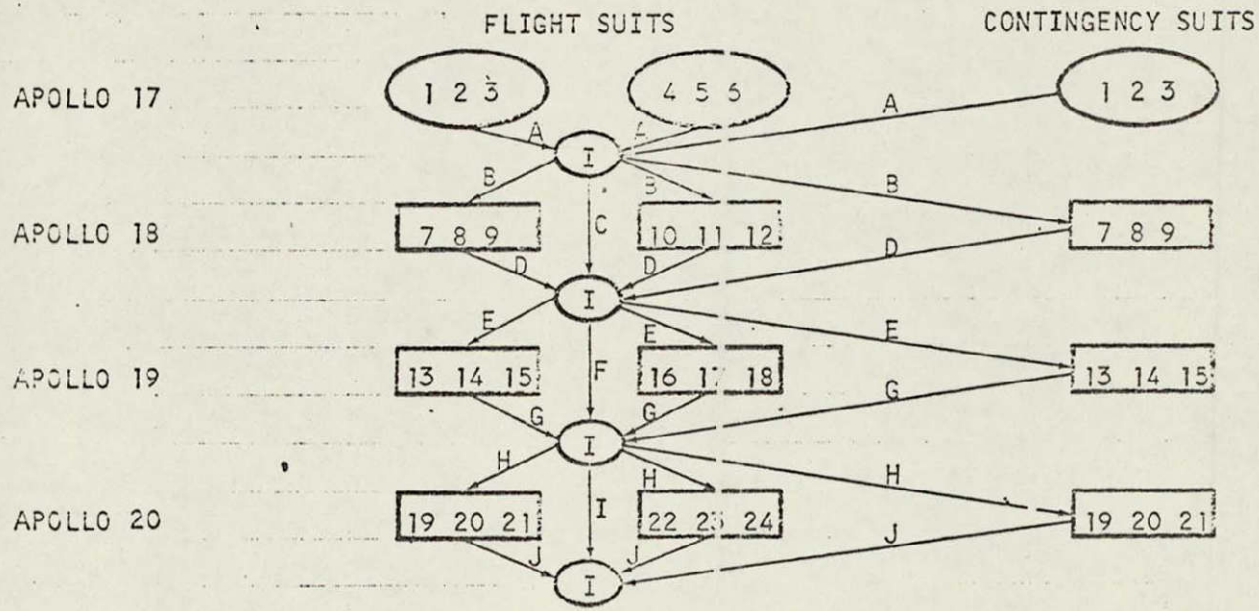
I — INVENTORY

NEW SUITS REQUIRED

RESIZED SUITS

N — LETTER INDICATES ORDER OF OPERATION

SIZING TECHNIQUE (GENERAL CASE - FLIGHT AND CONTINGENCY SUITS)



I — INVENTORY

NEW SUITS REQUIRED

RESIZED SUITS

N — LETTER INDICATES ORDER OF OPERATION

VIII

APOLLO 17 THRU 20 SPECIFIC SIZING STUDY RESULTS

	FLIGHT AND CONTINGENCY	TRAINING	TOTAL
○ NEW SUITS REQUIRED	9	12	21

○ SIZING REQUIREMENTS	S	M	L	S	M	L	
UPPER TORSO	6	3	4	0	5	2	20
LOWER TORSO	0	1	6	0	3	1	11
ARM PAIRS	0	-	3	0	-	1	4
LEG PAIRS	0	-	4	0	-	0	4
BOOT PAIRS	0	6	5	0	3	3	17

○ REMAINING INVENTORY AFTER COMPLETION OF APOLLO 20 FLIGHT

	FLIGHT AND CONTINGENCY				TRAINING				TOTAL
	S	M	L	T	S	M	L	T	
UPPER TORSO	9	9	4	22	8	9	2	19	41
LOWER TORSO	5	4	7	16	5	5	6	16	32
ARM PAIRS	4	-	8	12	5	-	8	13	25
LEG PAIRS	6	-	7	13	6	-	6	12	25
BOOT PAIRS	8	7	5	20	9	6	3	18	38

APOLLO 17 THRU 20 SIZING STUDY RESULTS (MINIMUM SUITS REQUIRED)

- CREW ASSIGNMENTS

17 - 6, 7, 8	2, 5, 4
18 - 11, 9, 25	18, 17, 14
19 - 12, 29, 28	3, 27, 21
20 - 26, 10, 1	22, 23, 9

NOTE: OPTIMIZATION ON COST BASIS

	FLIGHT AND CONTINGENCY				TRAINING				TOTAL
- NEW SUITS REQUIRED	9				12				21
- SIZING REQUIREMENTS	S	M	L	T	S	M	L	T	
UPPER TORSO	0	0	0	0	0	0	0	0	0
LOWER TORSO	0	2	0	2	0	1	0	1	3
ARM PAIRS	3	-	0	3	2	-	0	2	5
LEG PAIRS	1	-	1	2	0	-	1	1	3
BOOT PAIRS	0	5	3	8	0	1	1	2	10
- REMAINING INVENTORY	S	M	L	T	S	M	L	T	
UPPER TORSO	6	3	0	9	6	6	0	12	21
LOWER TORSO	3	3	5	11	4	3	6	13	24
ARM PAIRS	6	-	6	12	7	-	7	14	26
LEG PAIRS	6	-	5	11	7	-	6	13	24
BOOT PAIRS	8	6	3	17	8	5	1	14	31

APOLLO 17 THRU 20 SIZING STUDY RESULTS (MAXIMUM SUITS REQUIRED)

- MAXIMUM NUMBER OF SUITS REQUIRED RESULTS FROM PROVIDING ADEQUATE INVENTORY FOR ALL POSSIBLE CREWMEN ON LIST

- REQUIRED INVENTORY

	FLIGHT AND CONTINGENCY				TRAINING				TOTAL
	S	M	L	T	S	M	L	T	
UPPER TORSO	9	9	4	22	12	12	2	26	48
LOWER TORSO	9	9	9	27	9	8	12	29	56
ARM PAIRS	9	-	9	18	12	-	12	24	42
LEG PAIRS	9	-	9	18	12	-	12	24	42
BOOT PAIRS	9	9	7	25	12	11	4	27	52

FORM

APOLLO 17 THRU 20 SIZING STUDY RESULTS - COMPARISON MATRIX

	FLIGHT AND CONTINGENCY			TRAINING		
	RANDOM STUDY	MINIMUM STUDY	MAXIMUM STUDY	RANDOM STUDY	MINIMUM STUDY	MAXIMUM STUDY
UPPER TORSO	22	9	22	19	12	26
LOWER TORSO	16	11	27	16	13	29
ARM PAIRS	12	12	18	13	14	24
LEG PAIRS	13	11	18	12	13	24
BOOT PAIRS	20	17	25	18	14	27