PART I

MANUFACTURING METHODS FOR AIRCRAFT TIRES BY FILAMENT-WINDING TECHNIQUES

Merle J. Sanger
Robert E. Landes
Darrel M. Warner
Howard W. Waldo

FOREWORD

This report was prepared by the Structural Composites Department, Mechanical Systems Operations, Electronics Division, Aerojet-General Corporation, Azusa, California, under USAF Contract F33615-67-C-1726, Project 360-7. The work was administered by the Air Force Materials Laboratory, Manufacturing Technology Division, Fabrication Branch, and under the technical direction of Charles Tanis, Senior Project Manager.

This report covers work conducted from 1 May 1967 through 30 June 1969 and is submitted in partial fulfillment of the contract. The manuscript was released by the author in July 1969 for publication as a technical report.

The program was conducted under the direction of the Structural Composites Department, Electronics Division, Aerojet-General Corporation, and by the Advanced Tire Development Department, the General Tire and Rubber Company. Personnel of the General Tire and Rubber Company who participated in this program include W. S. McCormick, Manager Advanced Tire Development; W. Bezbatchenko, Manager Advanced Domestic Products; and R. A. Almond, Project Engineer. Others who cooperated in the program and in the preparation of this report were M. J. Sanger, Program Manager; R. E. Landes, Stress Analyst; D. M. Warner, Machine Design Engineer; D. Bentman, Stress Engineer; H. W. Waldo, Process Engineer; and Frank Salcedo, Consultant. This technical report is catalogued by Aerojet-General as Report No. 3720.

This project has been accomplished as a part of the Air Force Manufacturing Methods Program, the primary objective of which is to develop, on a timely basis, manufacturing processes, techniques and equipment for use in economical production of USAF materials and components.

Your comments are solicited on the potential utilization of the information contained herein as applied to your present and/or future production programs. Suggestions concerning additional manufacturing methods development required on this or other subjects will be appreciated.

This technical report has been reviewed and is approved.

GAIL E. EICHELMAN, Acting Chief
Fabrication Branch
Manufacturing Technology Division

ABSTRACT

This work on the development of new and improved manufacturing methods, controls, equipment and processes was directed toward the fabrication of filament-wound, continuous-cross-section, aircraft tires. Nylon, glass and wire reinforcements in bias, geodesic, and radial types of filament-wound configurations were investigated in the fabrication of subscale, 30 x 8.8, 22-ply-rated tires. Acceptable designs, materials and processes were developed for the fabrication of subscale tires. The findings on work with subscale tires were applied to the fabrication of 49 x 17, 26-ply-rated, prototype tires, which were made with nylon reinforcement in a bias-type configuration. A carcass-winding machine was designed and fabricated for the fabrication of prototype tires. In addition to its capability of producing the nylon reinforcement and bias configuration used for the prototype tires, the winding-machine is capable of utilizing glass and wire reinforcements in geodesic and radial configurations. Operating procedures and control techniques were developed for the production of 49 x 17 tires. Two tires were fabricated which exceeded the burst pressure requirements of USAF Drawing No. 60D2561J, the document which outlines the requirements for tires of this size. The dynamic test requirements of USAF Drawing No. 60D2561J were not achieved by the 49 x 17 prototype tires. The results of the dynamic tests indicated that major design modifications are required to produce satisfactory dynamic performance in the large 49 x 17 tires used on the C-5A and similar aircraft. Part I of this report and appendices I through VI report the design, process development, tooling, fabrication and testing of both subscale and full scale tire sizes, supported by detailed stress analysis for the rim-locking assembly, manufacturing instructions and equipment checkout. Part II presents the computer program for the winding-machine cam design.

Distribution of this Abstract is unlimited.

TABLE OF CONTENTS

PART I. MANUFACTURING METHODS FOR AIRCRAFT TIRES BY FILAMENT-WINDING TECHNIQUES

TABLE OF CONTENTS

PART II. COMPUTER PROGRAM FOR DESIGN OF CAMS TO FILAMENT-WOUND TIRES

APPENDICES

LIST OF ILLUSTRATIONS

PART I

PART II

LIST OF TABLES

DEFINITION OF TERMS AND ABBREVIATIONS

Some of the more commonly used terms in this report are defined below.

Along the ID: The face along the inner surface of the tire between the carcass heels.

Bead-to-bead: The surface from one heel over the crown to the opposite bead.

BR: Polybutadiene rubber.

Carcass ply: One layer of cord and one layer of insulation rubber.

Cord insulation: A layer of rubber compound over a layer of cords.

Ends per inch: The number of cords per inch measured at 90° to the direction of the cord path.

Starter layer: The initial layer of ply elastomer applied to the cured inner liner.

Neop.: Neoprene.

NR: Natural rubber.

Tire carcass: The filament-wound assembly of inner liner, cords, and insulation before application of the tread and sidewalls.

RLA: Rim-locking assembly.

Total end count: The total number of cords per layer.

Winding assembly: The mandrel and RLA covered with the cured inner liner.

PART I

SECTION I

INTRODUCTION

The feasibility of the basic concept of filament-wound continuous-cross-section tires was demonstrated by Aerojet in work under Contract AF33(615)-2315, which is covered in Technical Report AFML-TR-66-154. The filament winding concept was optimized in additional work performed under Contract AF33(615)-5024, which is covered in Technical Report AFML-TR-67-154. In the current 20-month Air Force program, Aerojet-General Corporation and its major subcontractor, The General Tire and Rubber Company, conducted studies on the development of new and improved manufacturing methods, controls, and equipment for the fabrication of filament-wound aircraft tires. The tires produced by these studies were expected to surpass the performance of conventional tires in each of the following areas: They were expected to be lighter in weight and safer in service, to run cooler, to possess a higher flotation, to maintain a more uniform pressure profile, and to be more adaptable to automated processing. The objectives:

- To develop advanced manufacturing methods for fabricating tires by filament-winding techniques
- To define and/or establish, by the fabrication of 30 x 8.8 subscale tires, the limitations on applying the process under development to various reinforcements and configurations
- To design, fabricate, purchase, furnish, operate and modify (as required) pilot or prototype equipment
- To develop and establish optimum operating procedures and control techniques
- To generate engineering data, design criteria, and operating experience necessary for the efficient design and operation of production equipment employing the developed techniques
- To demonstrate achievement of the desired manufacturing method by the fabrication and testing of filament-wound aircraft tires that are physically interchangeable with the Aircraft Pneumatic Tire, Tubeless, Type VII, size 49 x 17, 26-ply-rated (26 PR). The 30 x 8.8 size tire was used as a subscale of the 49 x 17 size tire.

The program consisted of the following tasks:

Task	Title
A	Design and Evaluation
B	Tool and Equipment Design and Fabrication
C	Process Development
D	Full-Scale Process and Equipment Demonstration
E	Fabrication of Test Tires

This final report presents a detailed summary of all work performed during the program. In addition, conclusions and recommendations related to program results are presented for guidance in future work on filament-wound aircraft tires.

SECTION II

SUMMARY

The primary objective of this program was to develop manufacturing methods for filament-wound aircraft tires by applying results obtained during process development of subscale 30 x 8.8[1] 22 PR[2] tires to the fabrication of prototype 49 x 17 26 PR tires.

Designs were prepared for subscale 30 x 8.8 22 PR tires to evaluate various filament reinforcements and cord angle configurations that included nylon bias-ply, nylon modified geodesic-ply, nylon radial-ply, glass radial-ply, and wire radial-ply constructions.

A water-soluble mandrel material was developed and tested to verify the design allowances used in the mandrel design for subscale and prototype tires. After analyzing the merits of steel and aluminum for use in the rim-locking assembly, a glass, filament-reinforced epoxy composite was selected.

An analysis to determine the feasibility of using tape-winding rather than single-cord winding showed that a high buildup of reinforcement at the tire's heel area and inside diameter prevented adoption of the tape winding technique for the tires under design.

A toroidal filament-winding machine capable of winding aircraft tires that fit 16 to 20-in.-dia wheels and have a carcass outside-diameter (OD) range from 38 to 50 in. was designed and fabricated. Tooling- and handling-equipment for production of subscale 30 x 8.8 and prototype 49 x 17 tires were designed and fabricated. The filament-winding machine, and all tooling and handling equipment performed satisfactorily during tire fabrication.

Process development studies in subscale tire fabrication showed that nylon, glass, and wire reinforcements could be filament-wound in bias, modified geodesic, and radial-ply configurations. The critical elements in the winding process were found to be cord tension and cord spacing.

The performance of the new toroidal filament-winding machine was demonstrated in the fabrication of 49 x 17 prototype tires. Complete application of cord and insulation was accomplished without removing the tire from the machine. This application confirmed the predicted time-saving feature of this machine.

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[1] The first number of the tire designation refers to the outside diameter, and the second number refers to the width of the cross section at its maximum dimension when inflated.

[2] "PR" is the abbreviation for ply rated, a term used by tire manufacturers to indicate relative strength values of tires.

Optimum operating procedures and controls were established for the fabrication of prototype tires.

Fifteen 49 x 17 26 PR tubeless, Type VII, tires were fabricated. Of these, two were lost during cure because of equipment malfunction and two blistered during cure. The remaining eleven cured satisfactorily.

Two 49 x 17 prototype tires exceeded the burst pressure requirements for this size conventional tire (USAF Drawing No. 60D2561J) by 12.6% and 5.0%.

The air retention requirements of MIL-T-5041D were passed by all four 49 x 17 tires tested to this specification.

The inflated dimensions of the tires tested were within specification except for a width approximately 0.50 in. over the maximum.

Dynamic test requirements of USAF Drawing No. 60D2561J were not achieved by any of the six prototype tires tested. The test results indicated that major design modifications are required to produce satisfactory dynamic performance in a tire of this size.

SECTION III

DESIGN AND EVALUATION (TASK A)

The objectives of the design and evaluation studies were (1) to develop and evaluate designs for subscale aircraft tires of various cord paths utilizing conventional and experimental reinforcements; (2) to evaluate construction materials for the component parts of filament-wound tires, and (3) to investigate manufacturing methods for these tires. For this purpose, subscale tires (of the 30 x 8.8 22 PR (ply rated) tubeless, Type VII, aircraft type) were designed, fabricated and tested.

Conventional tubeless bias-type pneumatic tires are built on a collapsible contoured drum by the application of the components in successive layers. The inner liner is laid down first, followed by layers of bias-cut rubber-coated woven cord fabric. After a predetermined number of cord plies have been applied to the drum, the beads are anchored in place by turning up the cord plies over a bundle of bead wires on each side of the drum. The carcass is completed by addition of more plies, reinforced cord breakers, tread, and sidewall. Large tire fabrication deviates from this procedure by building up cord plies in the form of a sleeve on a flat drum before the cord plies are placed on the final building drum. The finished carcass, in the form of a short cylindrical tube, is expanded into the tire's approximate final shape by insertion of an air bag into the inside of the cylinder, or by the use of a forming diaphragm inside the curing press. The change in carcass shape resulting from expansion during shaping and curing in a female mold produces realignment or "pantographing" of the cords.

Radial and modified bias-type tires are fabricated according to a somewhat different procedure varying with the manufacturer. More breakers under the tread are used with the radial and belted-bias tires to provide the circumferential strength required by these tires.

The continuous cross-section filament-wound tubeless tire is a completely enclosed toroidal configuration in which the cord reinforcement is wound around an inner-liner-covered rigid mandrel. It differs from the conventional tire by lacking beads and completely enclosing the inflating medium. The filament-wound tires' inside rigidity is provided by a rim-locking assembly (RLA), a stiff flat-like ring that is incorporated inside of the tire during carcass fabrication. The fabrication procedure consists of molding a soluble mandrel, mating the mandrel with the rim-locking assembly previously wound on a contoured mandrel form, applying the inner liner from calendered rubber tape over the mandrel, and continuously winding cord-reinforcement in the desired pattern over the liner. Rubber insulation is placed between the plies of cord by application of calendered tape. The wound carcass is then completed by application of chafer strips (heel reinforcement), breaker strips, tread, and sidewall. The soluble mandrel is removed after application of the tread, and curing is accomplished in a tire mold with inflation by steam or water.

1. DESIGN STUDIES

a. Carcass

(1) 30 x 8.8 22 PR Subscale Tire

The bias cord path is the type used in a conventional tire. The cord angle at the crown is established on the basis of dynamic test results, and the sidewall angle is that which the calendered cord takes when expanded from the flat building-drum to the tire mold. The modified geodesic path approaches the natural angle that the cord follows along the sidewall when the crown angle is established at other than 90°. The radial path is perpendicular (90°) to the circumferential center line of the tire.

Nylon cord was selected for the reinforcement in the prototype 49 x 17 tire. To provide for versatility in design and equipment, however, work was also done on design, fabrication, and testing of 30 x 8.8 tires using glass and wire cords.

The following considerations were used in the design approach for the subscale tires:

- Strength Level - All constructions of the 30 x 8.8 22 PR tires were designed to have equivalent burst strengths.

- Reinforcements - To ensure test results of value on a comparative basis, the reinforcement was limited to a single kind for each type of tire design (bias, geodesic, or radial).

- Elastomers - The same elastomer compounds were used for the component parts of all designs except for the wire-reinforced tires.

- Tread Design - Inasmuch as the 30 x 8.8 22 PR tire used in 250 mph service requires a special tread-retention design of the type used on the 49 x 17 tire, this tire (30 x 8.8) can be considered a subscale for the larger prototype tire.

Preliminary design studies were made of the structural requirements of the candidate carcass, and the rim-locking assembly. The investigations covered nine candidate nylon 6-6 cords, two ECG 75 glass cords, two wire cords, and two rayon cords for each application in the carcass, reinforcement and breakers. Tables I through V present the results. These studies covered design parameters, structural requirements to meet minimum burst conditions, allowable maximum end counts, resulting end counts, plies, gages, and angles as applied to the cured and fabricating states.

TABLE I

CARCASS DESIGNS - 30 x 8.8 22PR BIAS NYLON TIRES (CONVENTIONAL AND FILAMENT-WOUND)[a]

Cord style	840/2	1260/2	1680/2	1260/3	1680/3	3360/2	2520/3	4200/2	3360/3
Tensile strength, lb/cord	30	45	60	67	90	120	135	150	180
Cord gage, in.	0.021	0.026	0.029	0.031	0.036	0.041	0.043	0.045	0.048
Cured cords, total	512	342	256	229	171	128	114	103	85.2
Cords on core, total	479	320	239	214	160	120	107	96	80
Cords on ply, total	485	324	242	207	162	121	109	97	81
Ends per inch (EPI), maximum									
For 65.5% cured cords	31.3	25.2	22.6	21.2	18.2	16	15.3	14.6	13.7
Core	29.2	23.5	21.1	19.8	17	14.95	14.3	13.6	12.8
Ply	29.7	23.9	21.4	20.1	17.2	15.2	14.5	12.9	13
No. of plies, calculated	16.35	13.57	11.3	10.8	9.4	8.0	7.45	7.06	6.22
No. of plies, actual	18	14	12	12	10	8	8	8	8
EPI calculated for actual number of plies									
Cured cords	28.5	24.4	21.4	19.1	17.1	16	14.3	12.9	10.7
Core	26.6	22.8	20	17.8	16	14.95	13.4	12.1	10
Ply	27	23.2	20.3	18.1	16.2	15.15	13.6	12.2	10.2
Growth potential, %, through EPI increase	10	3	6	11	6.2	0	7.2	13	28
Cured-cord insulation, mils	14	15	17	21	23	22	27	32	45
Cured-ply gage, in. (estimated)(9 to 13-mil insulation)	0.030	0.036	0.039	0.042	0.047	0.053	0.055	0.058	0.061
Ply insulation, mils	9	10	10	11	11	12	12	13	13
Cured-carcass thickness, in.	0.540	0.504	0.468	0.504	0.470	0.424	0.440	0.464	0.488

[a] Nylon 6-6 cords. Design station: crown center line. Crown angles: cured angle 35.5° (molded), core angle 50° (filament-wound), and ply angle 38° (conventional construction). Principal stresses (cured-carcass requirement for burst): ply strength (F_p) 15,350 lb/in., transverse strength 4,660 lb/in., and circumferential strength 10,700 lb/in. End-count (EPI) ratios: cured cords to ply = 1.053, and cured cords to core = 1.070.

TABLE II

CARCASS AND REINFORCEMENT DESIGNS - 30 x 8.8 22PR GEODESIC NYLON FILAMENT-WOUND TIRES [a]

	Carcass (Nylon 6-6 Cords)								
Cord style	840/2	1260/2	1680/2	1260/3	1680/3	3360/2	2520/3	4200/2	3360/3
Tensile strength, lb/cord	30	45	60	67	90	120	135	150	180
Cord gage, in.	0.021	0.026	0.029	0.031	0.036	0.041	0.043	0.045	0.048
Cured cords required, total	198	131	99	88	66	49.3	43.8	39.4	32.8
Ends per inch (EPI), maximum at 15-in. diameter									
For 80% cord	38	30.8	27.6	25.8	22.2	19.5	18.6	17.8	16.7
At crown center line									
Cured cords	12.7	10.3	9.25	8.65	7.44	6.55	6.22	5.96	5.60
Core	14.45	11.7	10.5	9.8	8.45	7.40	7.07	6.77	6.35
No. of plies, calculated	15.6	12.7	11.8	10.2	8.9	7.53	7.04	6.6	5.86
No. of plies, actual	16	14	12	12	10	8	8	8	6
Cured cords	12.4	9.35	8.25	7.35	6.6	6.15	5.48	4.93	5.46
Core	14.1	10.6	9.35	8.35	7.5	7.0	6.22	5.6	6.20
Growth potential, %, through EPI increase	2.8	10	1.5	17.5	12	6.1	14	21	2.1
Cured-cord insulation, mils	60	81	92	105	116	121	140	158	135
Cured-ply gage, in. (estimated)	0.030	0.035	0.038	0.040	0.045	0.051	0.053	0.055	0.058
Ply insulation, mils (9 or 10 mils, due to high cord insulation)	9	9	9	9	9	10	10	10	10
Cured-carcass thickness, in.	0.480	0.490	0.456	0.480	0.450	0.408	0.424	0.440	0.348
Carcass circumferential strength, lb/in.	1250	1250	1250	1250	1250	1250	1250	1250	1250

Reinforcement (Circumferential Strength: 10,700 - 1,250 = 9,550 lb/in.)

	Nylon 6-6	Rayon		Glass (ECG 75)		Wire			
Cord style	3360/2	1650/3	2200/3	5/3	5/5	S/033	S/033	S/004	S/004
Cured-ply EPI	16	24	22	16	14	12	18	7	13
Tensile strength, lb/cord	120	50	70	125	185	196	196	355	355
No. of plies	6	10	8	6	4	6	4	4	4
Cured angle, degrees	24	27	28	27	17	34	34	11	44
Ply gage, in.	0.053	0.055	0.060	0.070	0.070	0.070	0.070	0.090	0.090
Total reinforcement, in.	0.318	0.550	0.480	0.420	0.280	0.420	0.280	0.360	0.360

[a] Strength design station: crown center line. Crown angles: cured angle 62.75° (molded), and core angle 26° (filament-wound). Principal stresses (cured-carcass requirement for burst): transverse strength (F_t) 4,660 lb/in., and circumferential strength (F_c) 10,700 lb/in. Cured-ply strength (F_p) to satisfy F_t at cured angle: 5,910 lb/in. End-count (EPI) ratios (crown to bead): cured cords 0.335, and core 0.380. EPI design station: maximum EPI at bead, 15-in. diameter.

TABLE III

CARCASS DESIGNS - 30 x 8.8 22PR RADIAL NYLON TIRES[a]

Cord style	840/2	1260/2	1680/2	1260/3	1680/3	3360/2	2520/3	4200/2	3360/3
Tensile strength, lb/cord	30	45	60	67	90	120	135	150	180
Cord gage, in.	0.021	0.026	0.029	0.031	0.036	0.041	0.043	0.045	0.048
Cured cords required, total	155	104	78	69	52	38.9	34.5	31	25.9
Ends per inch (EPI), maximum at 15-in. diameter									
For 80% cord	38	30.8	27.6	25.8	22.2	19.5	18.6	17.8	16.7
At crown center line									
Cured cords	20.9	17.0	15.2	14.2	12.2	10.7	10.2	9.8	9.2
Core	21.9	17.8	15.9	14.9	12.8	11.25	10.7	10.25	9.6
No. of plies, calculated	7.42	6.12	5.13	4.90	4.26	3.63	3.38	3.16	2.82
No. of plies, actual	8	7	6	5	5	4	4	4	3
EPI calculated for actual number of plies									
Cured cords	19.4	14.9	13	13.9	10.4	9.95	8.6	7.75	8.62
Core	20.4	15.7	13.7	14.6	10.9	10.5	9.05	8.15	9.1
Growth potential, %, through EPI increase	8	14	17	2	17	10	18	26	6
Cured-cord insulation, mils	30	41	48	41	60	59	73	84	68
Cured-ply gage, in. (estimated)	0.031	0.036	0.039	0.041	0.046	0.052	0.054	0.056	0.059
Ply insulation, mils	10	10	10	10	10	11	11	11	11
Cured-carcass thickness, in.	0.248	0.252	0.234	0.246	0.230	0.208	0.216	0.224	0.117

[a] Nylon 6-6 cords. Strength design station: crown center line. Crown angle (carcass) for cured cords and core: 90°. Principal transverse stress: 4,660 lb/in. End-count (EPI) ratios (crown to bead): cured cords 0.550, and core 0.577. EPI design station: maximum EPI at bead, 15-in. diameter.

TABLE IV

CARCASS DESIGNS - 30 x 8.8 22PR RADIAL GLASS AND WIRE TIRES[a]

	ECG 75 Glass		Wire	
Cord style	5/3	5/5	S/033	S/004
Tensile strength, lb/cord	125	185	196	355
Cord gage, in.	0.035	0.047	0.036	0.048
Cured ends required, total	37.3	25.2	23.95	13.15
Ends per inch (EPI), maximum at 15-in. diameter				
For 80% cord	22.9	17	22.2	16.65
At crown center line				
Cured cords	12.8	9.5	12.4	9.3
Core	13.45	9.96	13.0	9.76
No. of plies, calculated	2.92	2.65	1.85	1.41
No. of plies, actual	3	3	2	2
EPI calculated for actual number of plies				
Cured cords	12.4	8.4	12	6.6
Core	13	8.8	12.6	6.95
Growth potential, %, through EPI increase	2.5	13	8	42
Cured-ply gage, in. (estimated)	0.054	0.066	0.054	0.076
Ply insulation, mils	19	19	18	18
Cured-carcass thickness, in.	0.162	0.198	0.108	0.152

[a] Strength design station: crown center line. Crown angle (carcass) for cured cords and core: 90°. Principal transverse stress: 4,660 lb/in. End-count (EPI) ratios (crown to bead): cured cords 0.550, and core 0.577. EPI design station: maximum EPI at bead, 15-in. diameter.

TABLE V

BREAKERS FOR 30 x 8.8 22PR FILAMENT-WOUND RADIAL NYLON, GLASS, AND WIRE TIRES[a]

	Rayon Breakers		ECG 75 Glass Breakers		Wire Breakers	
Cord style	1650/3	2200/3	5/3	5/5	S/033	S/004
Tensile strength, lb/cord	50	70	125	185	196	355
Cord gage, in.	0.034	0.039	0.035	0.047	0.036	0.048
Ends per inch, maximum	24	22	16	14	18	13
Cured cords required (total) for 12° cured angle	223	160	89.5	60.5	50.7	31.5
No. of plies calculated for 12° cured angle	9.3	7.26	5.6	4.22	3.1	2.42
No. of plies, actual	10	8	6	6	4	4
Cured angle, degrees, for actual number of plies	19	17.5	15	32	27	39
Ply gage, in.	0.055	0.060	0.070	0.070	0.070	0.090
Total belt thickness, in.	0.550	0.480	0.420	0.420	0.280	0.360

[a] Principal circumferential stress (F_c) = 10,700 lb/in.

Style 3360/2 cord was selected for the nylon-reinforced tires on the basis of high strength and proven performance. The bias design required eight plies. The modified-geodesic design required 4 plies. The radials required 4 plies for nylon, 3 plies for glass, and 2 plies for wire. Although the wire and glass cords have approximately the same strengths, the larger diameter of the glass cord restricts the amount that can be placed in each ply; therefore, an extra ply is required.

Glass-reinforced breaker strips were employed in the nylon and glass radial tires. A wire-reinforced breaker strip was used in the wire radial tire. Breaker strips are low-angle calendered cord fabrics used between the plies and tread to provide circumferential strength.

The construction features adopted for the 30 x 8.8 22 PR subscale tires are shown in Table VI. The green-carcass (uncured) profiles of the five 30 x 8.8 subscale tire constructions are shown in Figures1 through 5. These profiles were used to design the mandrel molds and the cams for the winding machine. A tire mold profile was made utilizing these basic parameters and considering the required cured-tire dimensions, most of which are controlled by Air Force specifications.

During the development of the winding machine cam profile for the geodesic design, it was found that the cord path which had been developed by analysis would not fit the limitations of winding a continuous cross-section torus. For the cord to go through the inside diameter of the torus, it has to make a drastic angle change at the bead area, i.e., the geodesic cord angle at the bead was $\approx 58^\circ$ and it had to change to 20° to go through the center. This would cause a distortion of the cord path over most of the sidewall. As a result, a new cord path was determined. This path has a shallower angle (45°) at the bead and allows for a smooth angle transition through the inside diameter of the torus. A new green carcass profile was determined and is shown in Figure 6.

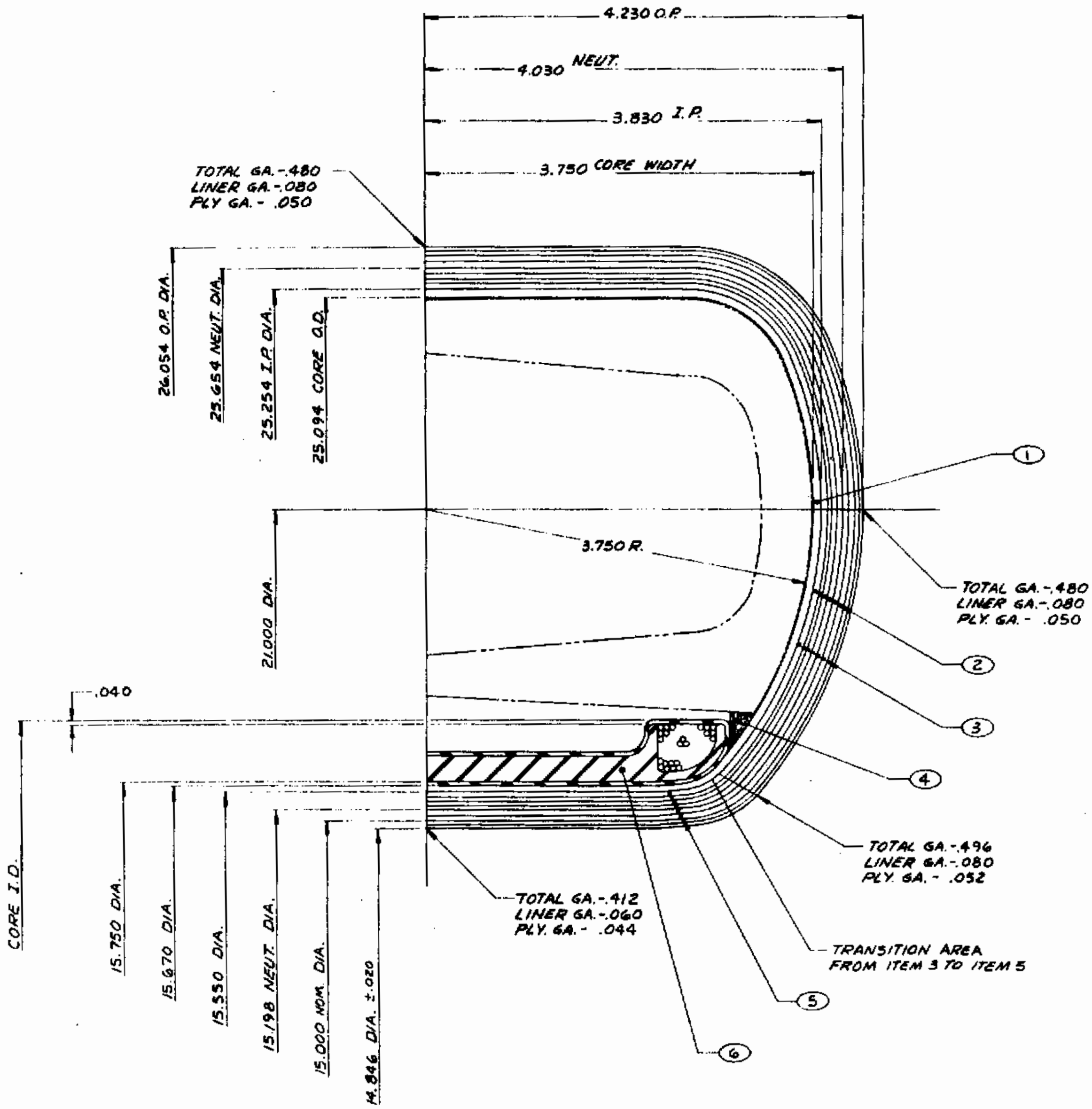
TABLE VI

CONSTRUCTIONS FOR 30 x 8.8 22PR TIRES

			Cured Cords		Core		Cured-Carcass Thickness, in.	
Type	Cord	Plies	Ends per Inch	Angle degrees	Ends per Inch	Angle degrees	Sidewall[a]	Crown
Bias	3360/2 nylon	8	16	33.5	16	50	0.488	0.408
Modified geodesic								
Carcass	3360/2 nylon	8	6.2	62.8	7	26	0.488	0.908[b]
Breaker	ECG 75 5/3	6	16	15	---	---	---	0.420
Radial, nylon								
Carcass	3360/2 nylon	4	10	90	10.5	0	0.288	0.708[b]
Breaker	ECG 75 5/3	6	16	15	---	---	---	0.420
Radial, glass								
Carcass	ECG 75 5/3	3	12.4	90	13	0	0.242	0.662[b]
Breaker	ECG 75 5/3	6	16	15	---	---	---	0.420
Radial, wire								
Carcass	S-033	2	12	90	12.6	0	0.188	0.468[b]
Breaker	S-033	4	18	20	---	---	---	0.280

[a] Includes liner thickness of 0.080 in.

[b] Carcass and breaker thicknesses.



REQ'D	SYM	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	UNIT WT.	ZONE	ITEM NO.
1			1269154-1	RIM LOCK ASSY.					6
AR			XGP-122 A	INSULATION					5
AR			XEF-221	FILLER					4
AR			XGP-121 A	INSULATION					3
AR			V-2222	NYLON					2
AR			XGP-120 A	INNER LINER					1

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

AEROJET-GENERAL CORPORATION

Figure 1

TITLE: BIAS NYLON ASSY. GREEN CARCASS PROFILE

SIZE E 70143 DWG NO. 1269159

Figure 1. Bias Nylon Assembly, Green-Carcass Profile

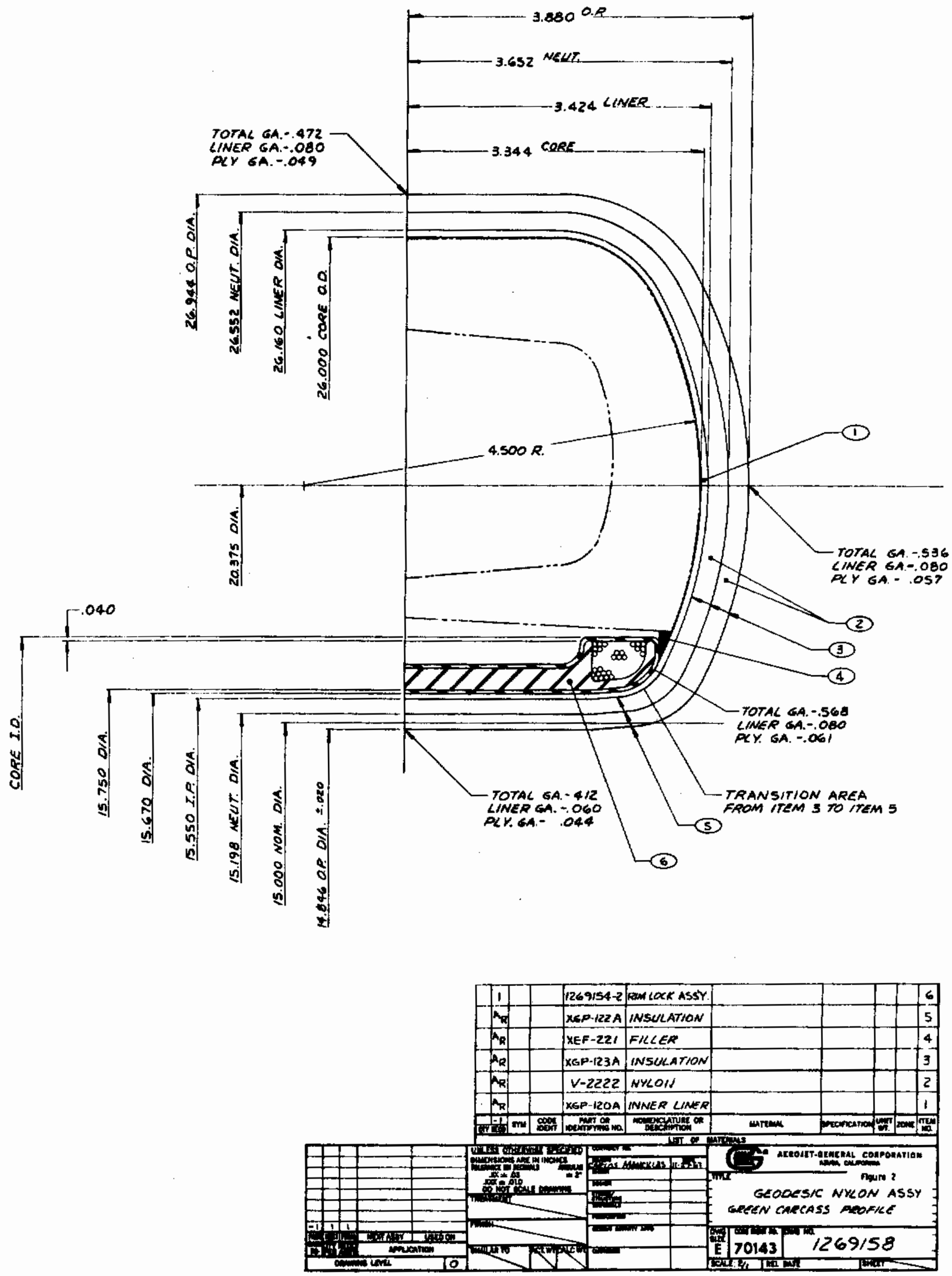


Figure 2. Geodesic Nylon Assembly, Green-Carcass Profile

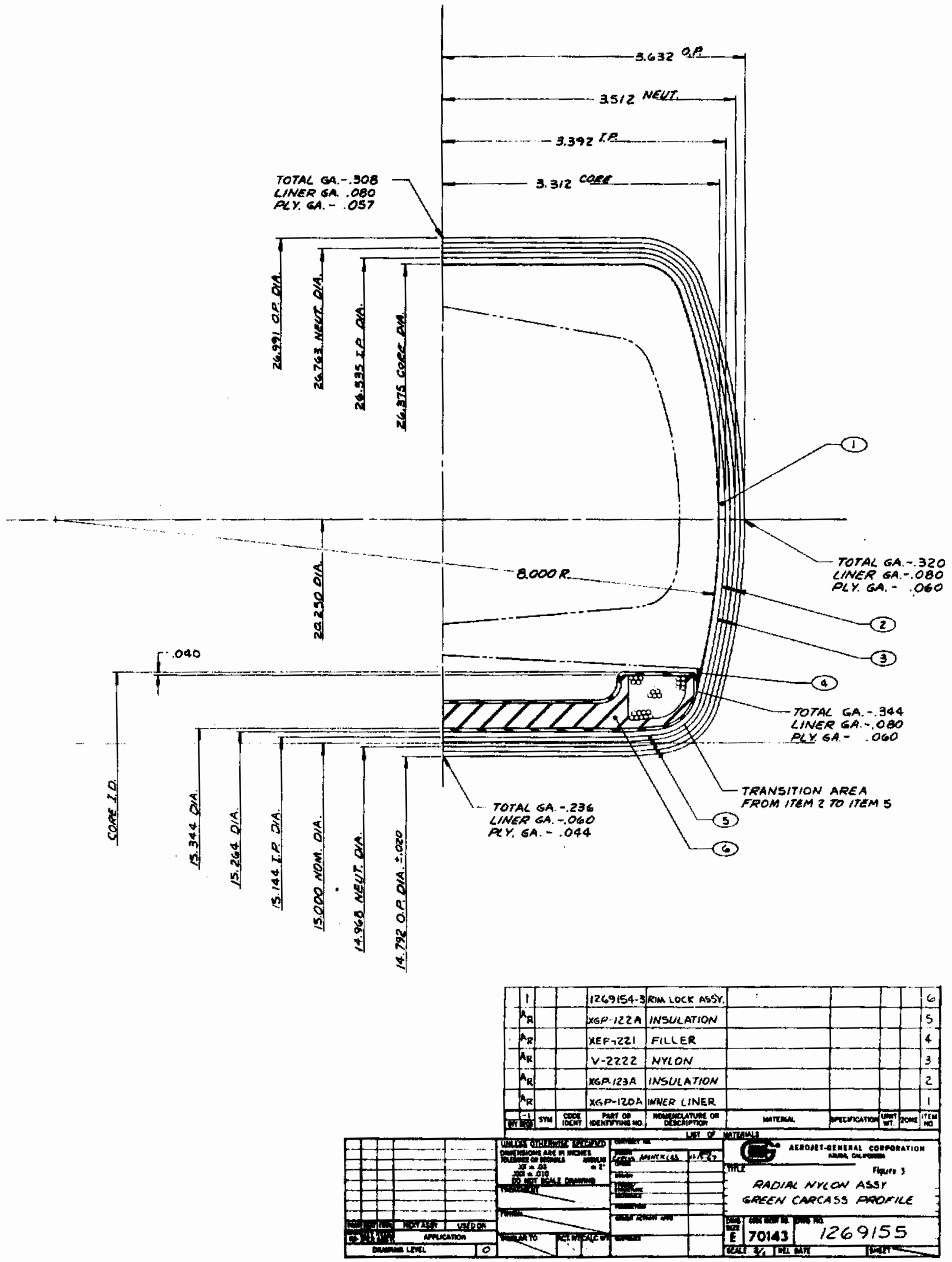


Figure 3. Radial Nylon Assembly, Green-Carcass Profile

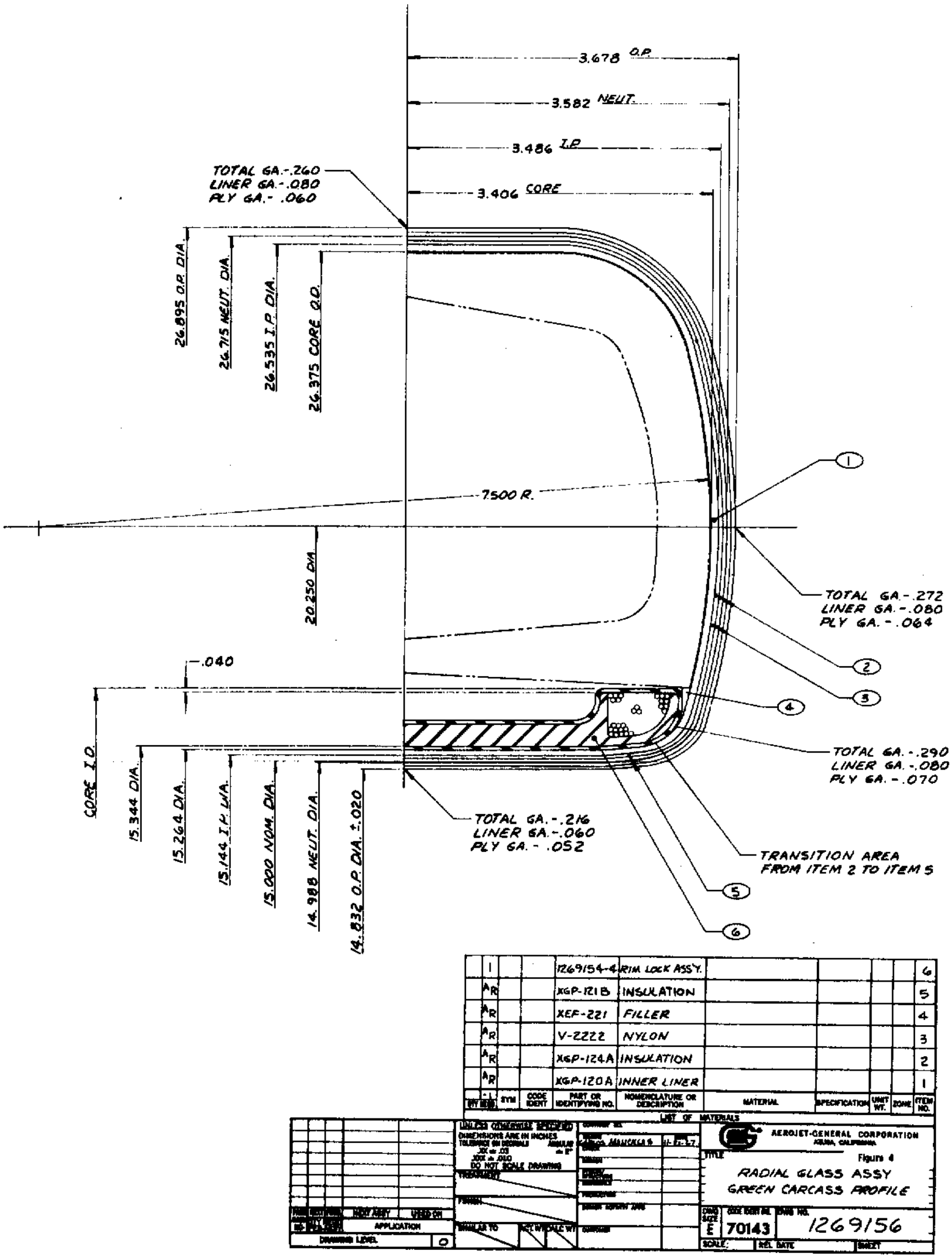


Figure 4. Radial Glass Assembly, Green-Carcass Profile

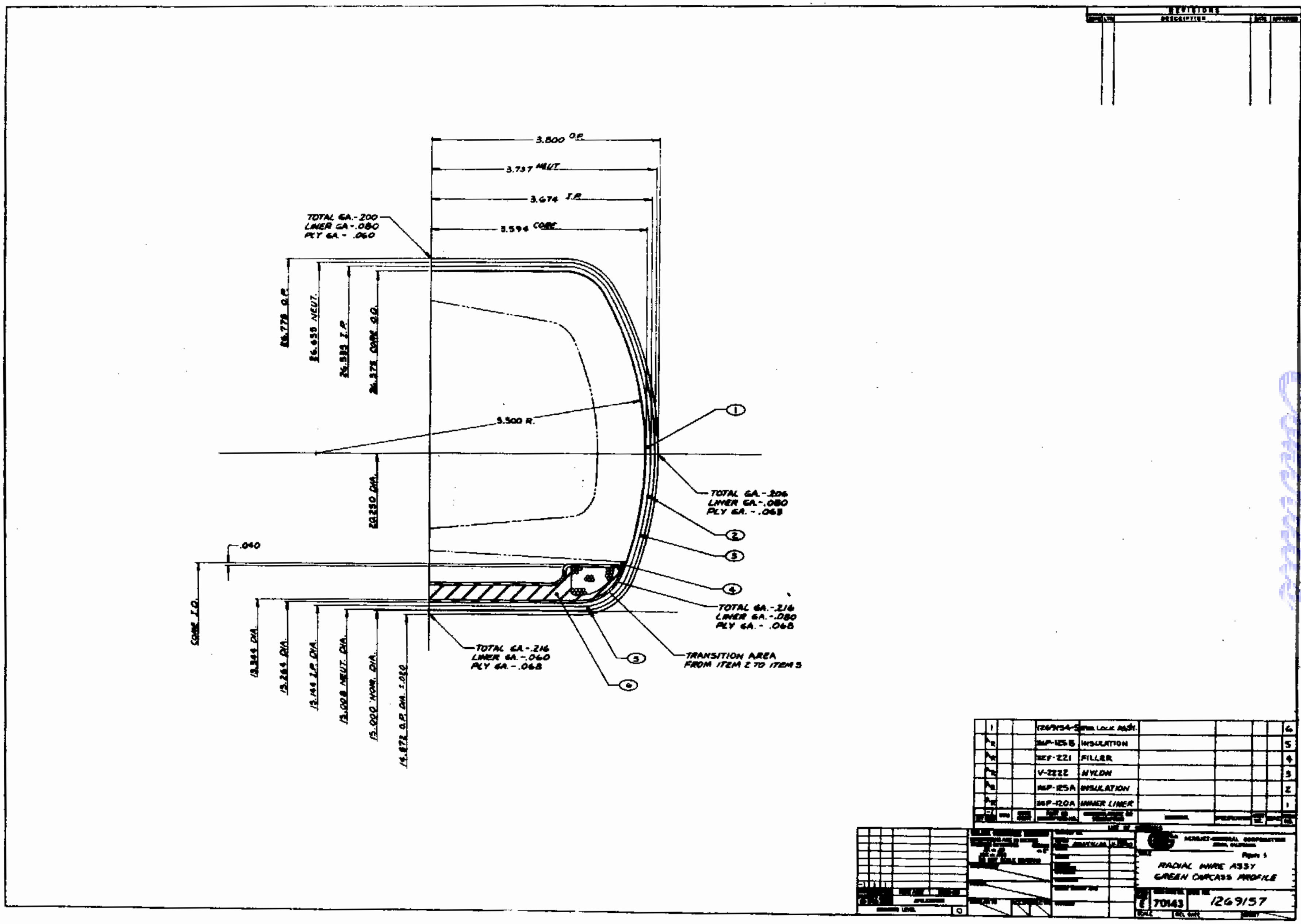


Figure 5. Radial Wire Assembly, Green-Carcass Profile

Figure 5

18

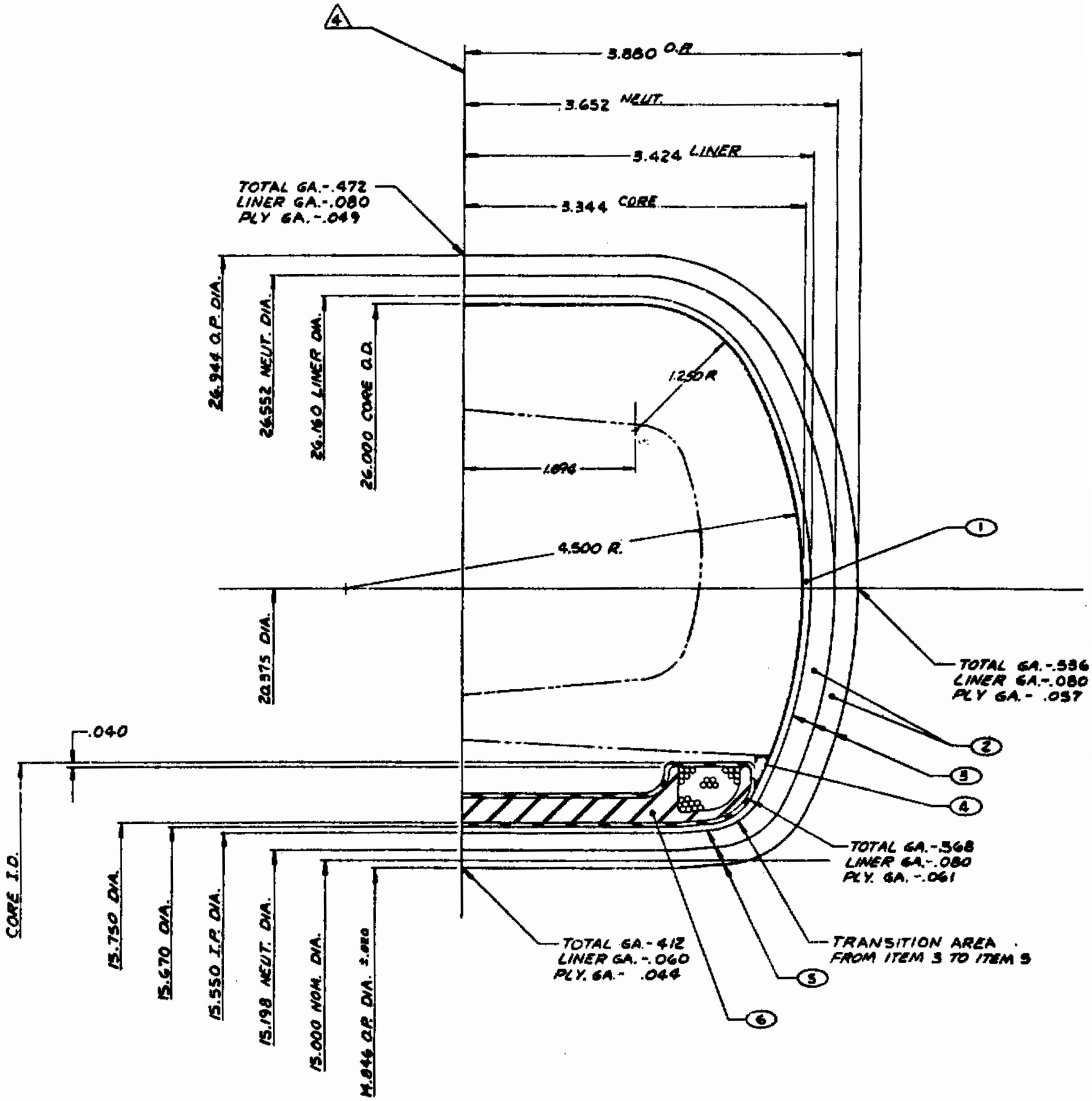


Figure 6. Revised Geodesic Nylon Assembly, Green-Carcass Profile

Because of the shallower angle, it was possible to increase the cord end count in each ply. In addition, the angle change allows the radial strength requirement to be satisfied with fewer cords. The combination of these two changes permitted the design of a 4-ply tire. A summary of the design differences between the original and revised modified-geodesic tire is given below:

TABLE VII

COMPARISON OF GEODESIC DESIGNS

	Designs	
	Original, Geodesic Cured	Revised, Geodesic Wound
Carcass		
Cord	3360/2 nylon 6.6	3360/2 nylon 6.6
Plies	8	4
Cured Ply		
Ends per inch	6.15	7
Cured Angle, °	62.75	65.66
Core		
Crown, ends per inch	7	7.32
Crown wind angle, °	26	23.7
Total cords per ply	520	555
Reinforcement (Breakers)		
Cord	ECG 75 5/3	ECG 75 5/3
Plies	6	6
Ends per inch	16	16
Cured angle, °	27	23.25
Estimated Weight, Lb	60.6	52.5

(2) 49 x 17 26 PR Prototype Tire

A bias construction utilizing the originally selected nylon reinforcements was used for the prototype 49 x 17 tire (see Figure 7). Design details are as follows:

Construction	bias ply
Reinforcement	nylon 6-6
Cord type	3360/2
Number of plies	8
Cord ends per inch, cured crown	14.5
Total ends per ply, neutral axis	1200
Cured-crown angle	35°
Wrapped-crown angle	39.4°
Liner thickness	0.075 in.
Insulation thickness per ply	0.025 in.
Carcass thickness (side)	0.452 in.

Tabulated below are weight comparisons based on calculations by tire design engineers and the recent K revision of USAF Drawing 60D2561J in which the Air Force increased the nonskid depth of the 49 x 17 tire from 0.30 in. to 0.40 in.

	Weight (lb)	
	J Revision (Nonskid Depth = 0.30 in.)	K Revision (Nonskid Depth = 0.40 in.)
Specified maximum	215	Not yet established
Presently qualified General Tire & Rubber tire, conventional configuration	187	---
Conventional configuration, under development by General Tire & Rubber	---	206, estimated
Filament-wound tire, under development in this program	---	182, estimated

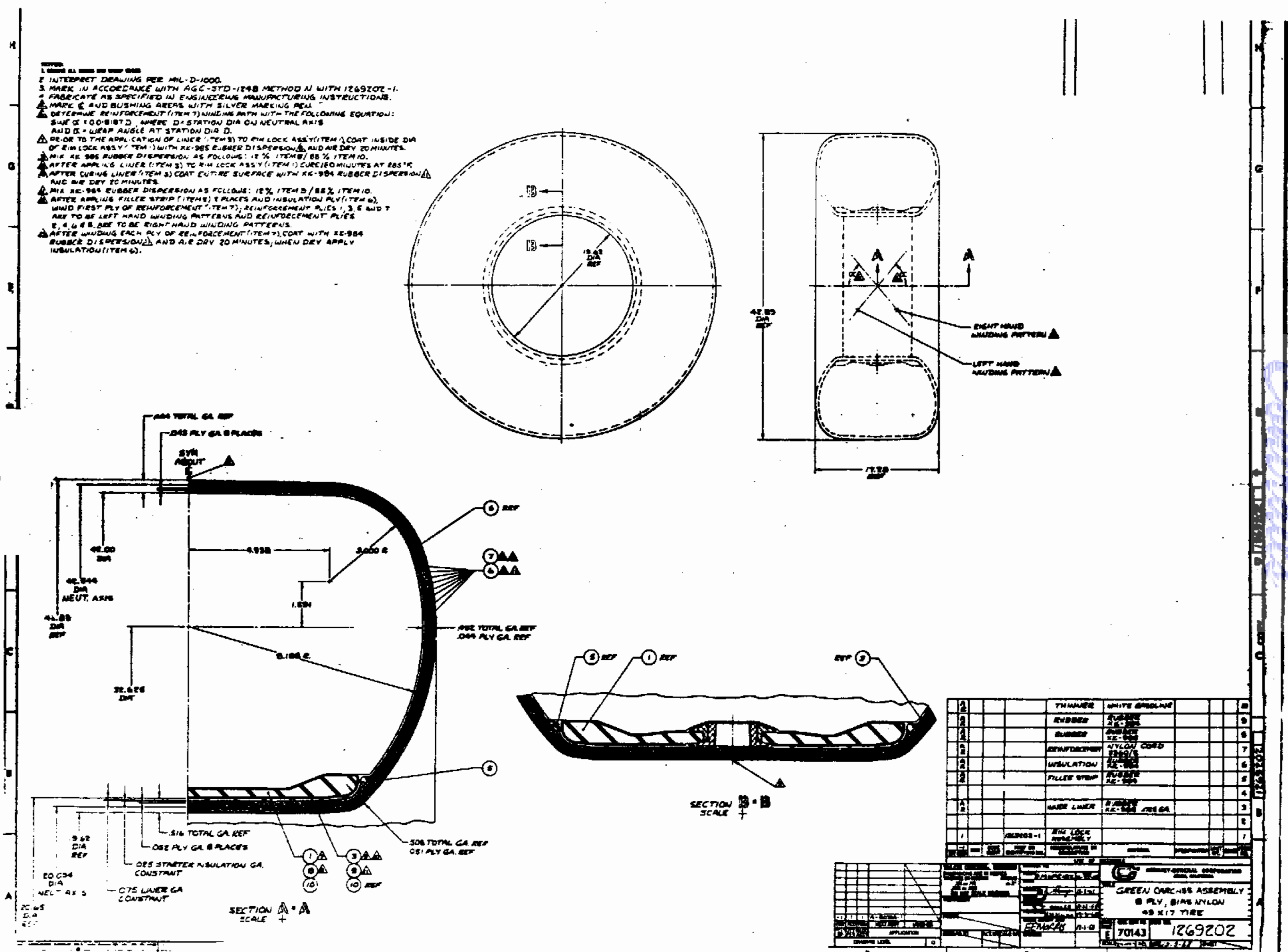


Fig. 7 Green-Carcass Assembly 8-Ply Bias Nylon 49 x 17 Tire

Figure 7

The estimate of 182 lb, which represents a weight advantage of 11.6% as compared with 206 lb for the conventional tire, was arrived at as follows:

Component	Quality	Weight (lb)
Inner-liner compound	497.6 cu in.	22.10
Ply-insulation compound	1153 cu in.	45.10
Nylon cord	17,000 yards	27.20
Chafer plies	0.97 square yards	2.50
Heel filler	16.5 cu in.	0.95
Tread and sidewall	1448 cu in.	59.17
	Total - rubber, cord, and fabric	157.02
	Rim-locking assembly	25.00
	Total estimated weight	182.02

The original target for the cured crown angle of the 49 x 17 26 PR prototype tire was 35 degrees ± 1 degree. This angle was considered necessary to retain, during dynamic operation, the higher tread mass resulting from an increase in nonskid depth from 0.30 to 0.40 inch. It was determined by test of conventional tires that retention of the thicker tread was maintained with a cured crown angle of 36.5 degrees ± 1 degree. To provide this in the cured tire, a 39° to 41° wrapped crown angle was selected for fabrication of the prototype tires.

The original target for cord ends per ply was 1200. One tire with an average end count of 1295, when subjected to a burst test yielded a burst factor (burst strength/operating pressure) of 3.94. This was higher than the 3.5 factor required by the conventional tire specification USAF Dwg. 60D2561J. Another tire with an average end count of 1244 yielded a burst factor of 3.70. On the basis of these tests, a 1230 ± 30 end count was selected as standard. This provides a satisfactory margin of safety above the required 3.50 minimum burst factor.

During the cure of a 49 x 17 prototype tire in the process development effort, a high buildup of cord and insulation on the inside of the carcass interferred with closing of the curing mold. It was, therefore, determined that a reduction in insulation thickness was required. The thickness of insulation was reduced from 0.025 to 0.020 in. This reduction provided a weight reduction of 2.41 lb in the tire carcass. An additional 1.6 lb saving in weight resulted from a reduction from two layers to one layer of rubber covering the rim locking assembly.

Following are the final design details for the 49 x 17 26 PR prototype tire:

Construction	bias ply
Reinforcement	nylon 6-6
Cord Type	3360/2
Number of plies	8
Cord ends per inch, cured crown	14.5
Total ends per ply	1230 ± 30
Cured-crown angle	36.6°
Wrapped-crown angle	39-41°
Liner thickness	0.075 in.
Insulation thickness per ply	0.020 in.
Carcass thickness (side)	0.420

b. Rim-Locking Assembly

(1) Design

The importance of the rim-locking assembly (RLA) to the performance of a filament-wound tire required that careful attention be given to the design, materials, and fabrication of this part. The RLA must have high lateral compressive strength to tolerate the clamping pressure during mounting and the loads that are imposed on the tire during use. High hoop strength is also required to maintain tire integrity during high-speed operation, high-pressure inflation and applied loads.

Table VIII gives the basic parameters used in the design of the rim-locking assemblies for the 30 x 8.8 subscale and the 49 x 17 prototype tires:

TABLE VIII

RLA DESIGN PARAMETERS

Tire Size and Cord Path	Inflation Pressure (psi)	Casing Load at Rim[a] (lb/in.)	Maximum Allowable Hoop Tension (lb.)	Maximum Allowable Hoop Strain (in./in.)	Maximum Allowable Lateral Deflection (in.)
30 x 8.8 bias	295 (rated)	1300	17,300	0.0065	0.031
	1035 (burst)	4550	60,500	0.0120	0.094
30 x 8.8 geodesic	295 (rated)	1140	15,500	0.0065	0.031
	1035 (burst)	4000	54,200	0.0120	0.094
30 x 8.8 radial	295 (rated)	1770	24,200	0.0065	0.031
	1035 (burst)	6200	84,500	0.0120	0.094
49 x 17 bias	170 (rated)	1290	29,100	0.0090	0.031
	595 (burst)	4520	102,000	0.0170	0.094

[a] The casing load at the rim is the load exerted at each edge of the RLA. It is derived from the internal pressure and is assumed to be applied at a 45° angle to the edge of the RLA.

An analysis was made to determine the dimensions required to accommodate the stresses and strains exerted on the RLA. Several design concepts for the RLA were considered together with various materials and methods of fabrication. Three materials were considered: 6061-T6 aluminum, 4130 steel, and a glass-fabric and roving/epoxy composite. Tradeoff studies were made of the concepts to arrive at a strong, lightweight, low-cost component. Two design approaches were followed. One assumed that the RLA was composed of two parts: a bead strong enough to carry all the hoop stresses and a spacer that would restrict the lateral compressive forces. The other assumed that the RLA was a unit and the entire ring contributed to the hoop as well as the lateral strength. The RLA is considered as a right circular cylinder subjected to shear loading on its ends, external pressure, and lateral compression. The analysis showed that, using weight as the criterion, the glass fabric and roving/epoxy composite was the most desirable material.

Another consideration used in the RIA design was the chafing of cord reinforcements that resulted in early dynamic test failures of 30 x 7.7 tires on an earlier program. The failures occurred in approximately the same location, at the lower radius of the edge of the RIA, a point of maximum stress concentration. An increase in the radius of the RIA in this area was selected as a first step in the improvement of dynamic performance.

(2) Manufacturing Methods

On the basis of the design studies, an S-901 glass/epoxy composite was selected for the RIA. A hand layup process was chosen in preference to a molding process because of the high tooling costs required for the latter method. The initial fabrication process consisted of wrapping alternate layers of resin-impregnated Type 181 glass cloth, resin-impregnated 2-oz. Rovmat, and glass roving over the mandrel until the desired thickness was obtained. Compacting rings were placed over the entire mass and spaced equidistant from the RIA edges. Resin-impregnated glass roving was wound in the cavity between the compacting rings and the edge of the RIA to form the hoop reinforcement. After curing, the RIA was sandblasted, covered with liner rubber, and fitted with air-vent bushings. Figure 8 shows the 30 x 8.8 RIA in various stages of fabrication.

Tests on sections of 30 x 8.8 RIA fabricated according to the above procedure showed a compressive yield strength of 8400 lb/in. at a deflection of 0.0246 in. A maximum casing load of 6200 lb/in. at burst and a maximum dflection of 0.031 at rated inflation pressure were the design criteria for the 30 x 8.8 tires; this construction appeared to have adequate strength and stiffness.

During the test program on the 30 x 8.8 tires, however, a weakness in the lateral compressive strength of the RIA became evident. A stress analysis of the RIA indicated the need for more lateral reinforcement to provide an adequate margin of safety. A configuration consisting of laminated layers of Style 341 glass fabric, which has a warp count of 30 and a fill count of 49, appeared to meet this requirement. Tests of laminates prepared in this manner showed the following values:

Specimen Width (in.)	Thickness (in.)	Ultimate Compressive Strength (lb/in.)	(psi)	Flexural Strength (psi)
1.031	0.268	10,580	39,342	---
1.962	0.278	10,560	37,866	---
1.025	0.267	---	---	70,765

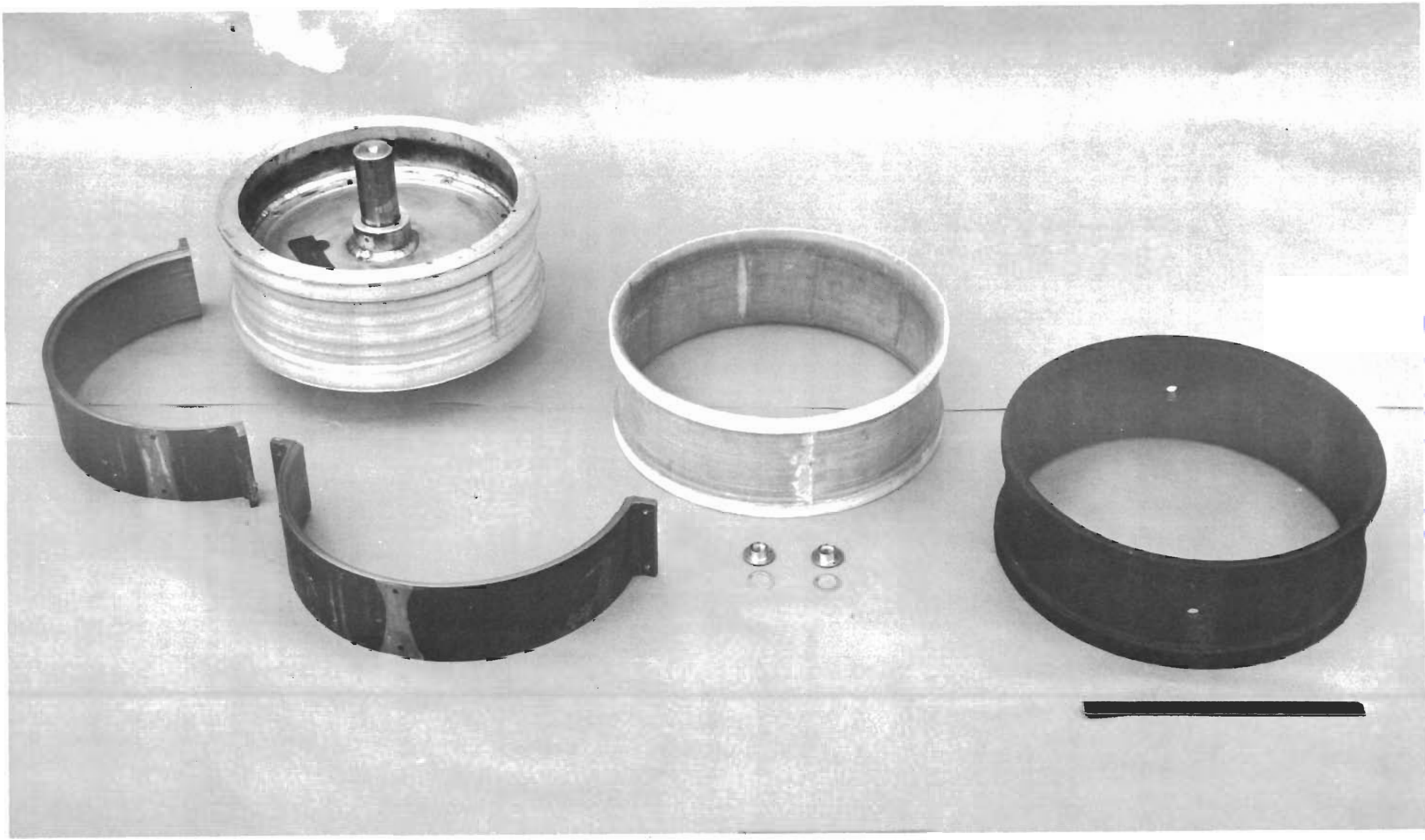


Figure 8. Rim-Locking Assembly Fabrication Sequence

These data indicate that the use of Style 341 glass fabric provides additional compressive and flexural strength for the RLA. The construction incorporating this glass fabric was, therefore, used in the fabrication of the RLA's for the 30 x 8.8 subscale and 49 x 17 prototype tires.

The final RLA fabrication process consisted of wrapping a layer of preimpregnated Style 341 glass fabric around the mandrel to form the desired contour. Layers of preimpregnated Style 341 glass fabric and glass roving were wrapped over the first layer of prepreg until the desired thickness was obtained. The width of the glass fabric was reduced stepwise to provide a cavity on each edge for the hoop winding. Prepreg glass roving was wound at each edge of the RLA, the full thickness and over the glass fabric to provide adequate hoop strength. A stress analysis for the rim locking assembly, 49 x 17 tire, is presented in Appendix I.

The design for the rim lock assembly of the 30 x 8.8 tire is shown in Figure 9 Drawing No. 1269154. The design for the rim lock assembly of the 49 x 17 tire is shown in Figure 10 as Drawing No. 1269203.

c. Winding Mandrel

(1) Material Studies

Studies of various types of mandrel materials and moldfilling methods were made to determine optimum compositions and handling techniques. The two prime candidates were a sand/acrylic-resin mixture and a sand/sodium silicate mixture. These were compared for mold shrinkage, moldability, solubility, and strength. The effects of short cures and unique curing techniques on the mechanical and chemical properties of promising mandrel materials were also investigated.

The most significant forces acting on the winding mandrel during processing are:

- Vacuum pressure cure of inner liner over the mandrel.
- Lifting of mandrel into and out of filament-winding machine.
- Pressure of 30 lb on crown roller during application of the tread and sidewall.

The mandrel must be simply fabricated, relatively inexpensive, and easily removable from the carcass after application of the tread and sidewall. A stress analysis that took into account the above forces was made on a sand/resin mandrel material with a compressive strength of 4150 psi, a shear strength of 800 psi, and a modulus of elasticity of 0.6×10^5 psi. The results of this analysis showed that a mandrel material with these properties and 0.375 in. thickness would withstand the forces applied during processing.

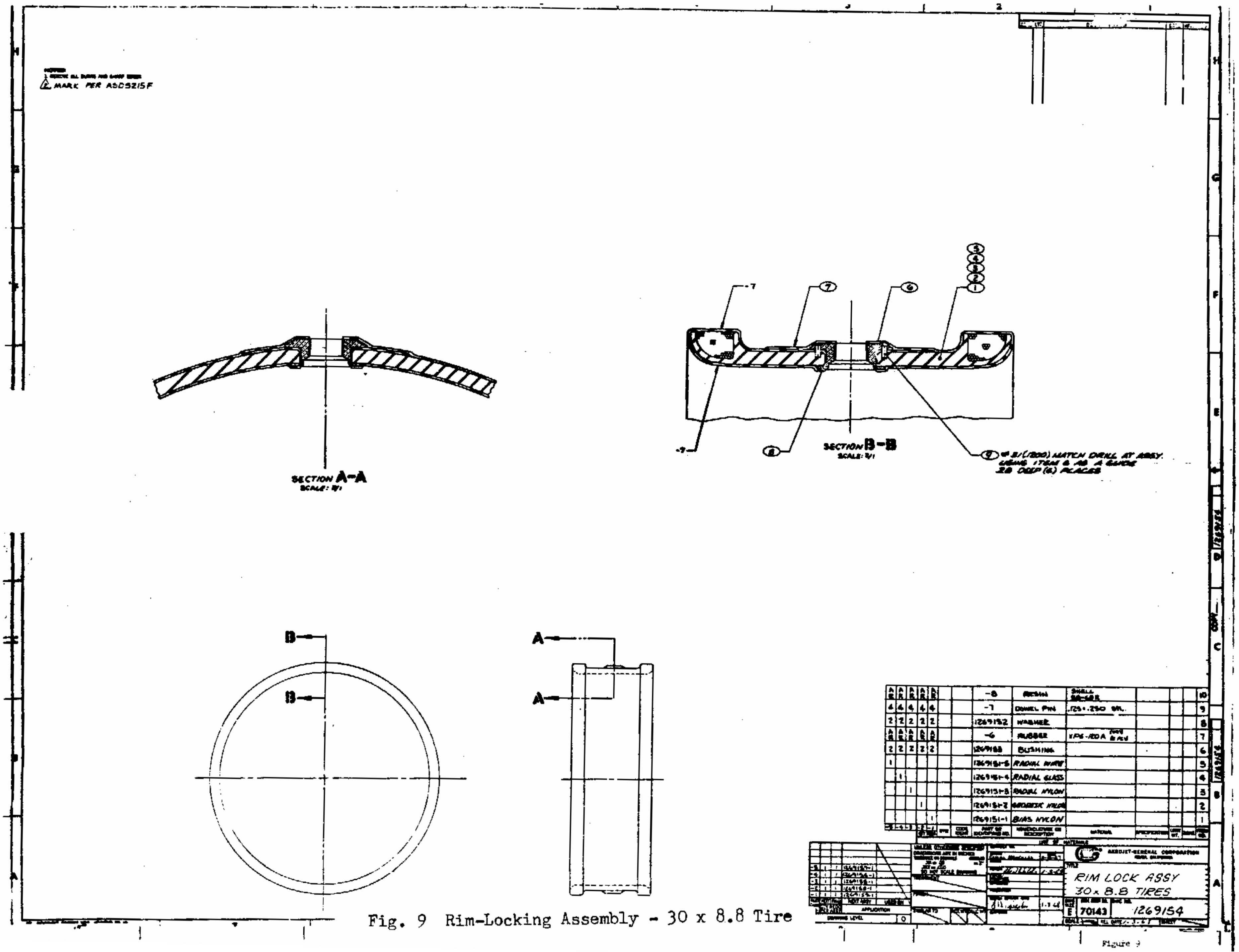


Fig. 9 Rim-Locking Assembly - 30 x 8.8 Tire

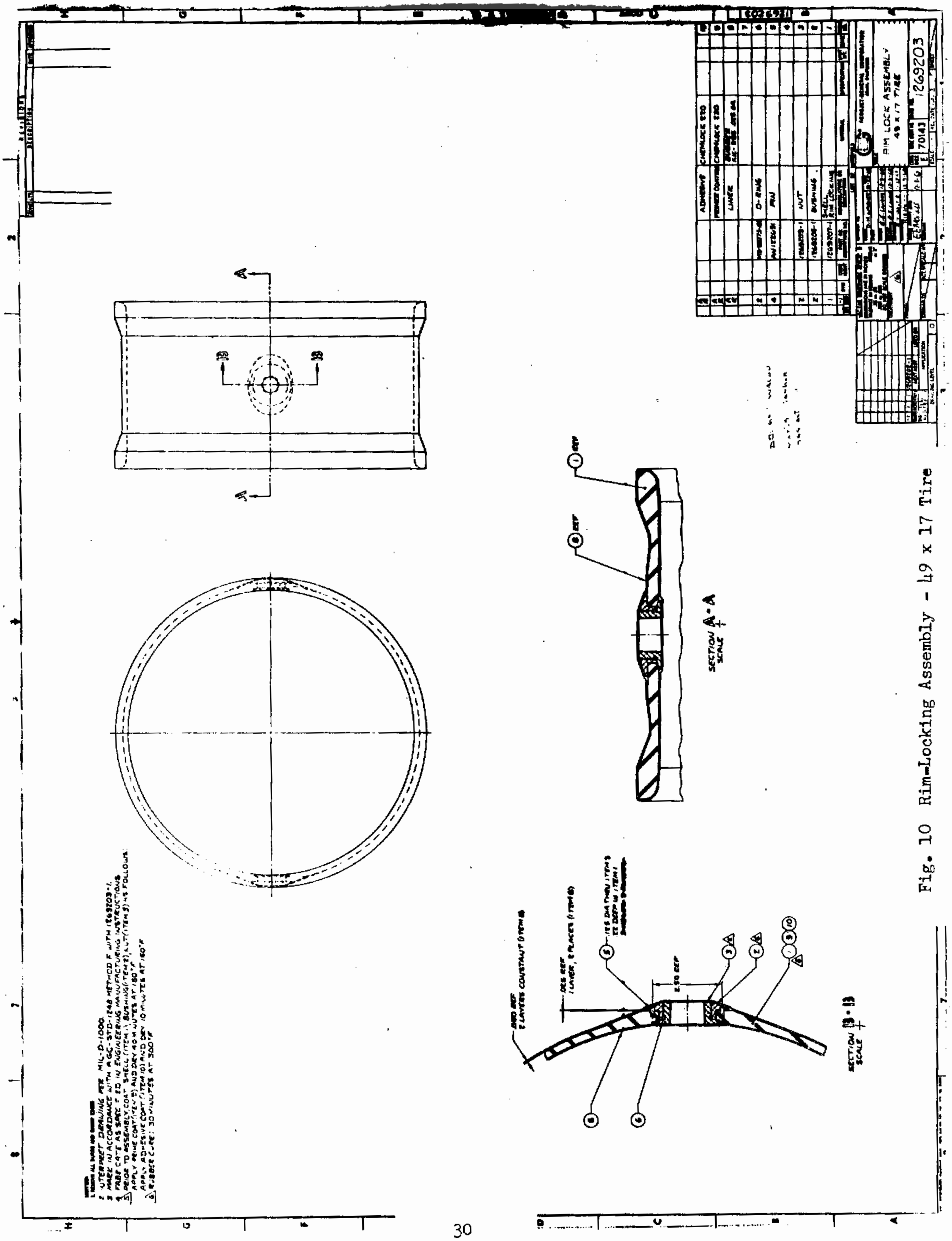


Fig. 10 Rim-Locking Assembly - 49 x 17 Tire

(2) Candidate Materials

Two combinations of binder and filler were compared with the standard Kerr DMM[3] plaster mandrel material for tensile, compressive, flexural, and shear strength properties. The following compositions were tested:

- PL-1, consisting of Kerr DMM plaster (69.50 wt%) and water (30.50 wt%).

- SA-1, consisting of 40-30 Wedron[4] sand (85.00 wt%), silica flour (8.50 wt%), and A-73X acrylic resin[5] (6.50 wt%).

- SS-6, consisting of 76 mesh Ottawa bonding sand[6] (89.00 wt%) and Steinex C[7] (sodium silicate) (11.00 wt%).

Following are the results of the mechanical-strength tests on these materials. All values are averages of three determinations except the tensile strength of PL-1 which represents only one test.

Property	PL-1 (Plaster)		SA-1 (Acrylic)		SS-6 (Sodium Silicate)	
	70°F	250°F	70°F	250°F	70°F	250°F
Tensile Strength (psi)	26	---	248	---	285	---
Compressive Strength (psi)	198	309	2338	2699	3095	1740
Compressive Modulus (10^5 psi)	0.573	---	2.167	---	2.016	---
Flexural Strength (psi)	65	107	1041	918	822	597
Shear Strength (psi)	49	100	725	703	660	443

These results indicate that the sand-based materials are substantially stronger than the standard plaster mandrel material. Although the sand/acrylic mixture shows higher strength properties than the sand/sodium silicate material at 250°F, both candidates were considered adequate for the vacuum bag curing pressure.

---

3. Kerr Manufacturing Co., Detroit, Michigan.

4. Wedron Silica Sand Co., Wedron, Illinois.

5. B. F. Goodrich Chemical Co., Cleveland, Ohio.

6. Ottawa Sand Co., Ottawa, Illinois.

7. Carver Foundry Co., Muscatine, Iowa.

The solubilities of SA-1 and SS-6 were compared by immersing equal volumes in 150°F water and mechanically agitating for five minutes. Any undissolved remainder was dried and weighed: 63% of the SA-1 specimen dissolved in five minutes, and 100% of the SS-6 dissolved in 35 seconds, indicating the higher solubility of the material with a sodium silicate binder.

In the development of a mandrel material, it was found that the addition of a fine-particle silica filler improved the molding characteristics and surface finish. It was found, however, that higher amounts of the silica filler decreased the solubility of the compound. The effect of filler content on washout characteristics was studied. The results follow:

Compound Identification	Type of Binder	Silica Filler (wt%)	Immersion Time in 150° water (min)	Washout (wt%)
SA-1	A-73-X	8.5	5.0	50.5
SS-12	Steinex C	0.0	1.5	100.0
SR-5	Steinex C	3.0	3.0	100.0
SR-6	Steinex C	6.0	5.0	97.3
SR-8	Steinex C	14.0	5.0	28.0

This test indicated that washout characteristics are profoundly influenced by the silica-filler content - i.e., the higher the content, the slower the disintegration of the cured part in water. This effect is believed to be due to the filling of voids between the coarser sand particles by the fine filler, creating a dense structure not easily attacked by water. The result is slow penetration by water and retarded disintegration.

A formulation containing no silica filler (e.g., SS-12) would provide the fastest washout time. A certain amount of fine-particle filler is required, however, for satisfactory moldability and good surface finish. SR-6 was therefore selected as the standard formulation on the basis of a trade-off of processing, surface-finish and washout properties.

The effect of cure time on the compressive strength of SR-6 mandrel material was studied in order to select the optimum curing cycle. Following are the results of this study:

Specimen Identification	Hours of Cure at 250°F	Compressive Strength (psi) (Ave. of Two Specimens)
SR-6-1	1	7460
SR-6-2	2	5360
SR-6-4	4	7180
SR-6-6	6	5780
SR-6-16	16	3920

The results of this study indicate that cures of one hour to six hours at 250°F produce satisfactory compressive strength. A recheck of the two-hour cure produced 7642 psi compressive strength. On the basis of these tests, a two-hour cure at 250°F was selected for the SR-6 mandrel material. Following is the composition of SR-6, the compound used in the fabrication of all 30 x 8.8 and 49 x 17 mandrels:

Material	% by wt.	Source
70-30 Wedron sand	81.0	Wedron Silica Sand Co., Wedron, Ill.
Silica flour	6.0	Any local foundry supply company
Steinex C resin	13.0	Carver Foundry Co., Muscatine, Ia.
	100.0	

The compound is mixed by blending all ingredients in batches of 200 lb in a Carver Muller Blender (Carver Foundry Co.) for eight minutes.

(3) Manufacturing Methods

The fabrication procedures considered for the mandrel were compression molding, and mechanical vibration in conjunction with hand tamping. The compression molding method would require a substantial tooling investment which could only be justified by a large-production operation. In the second method, the mandrel halves are formed by vibration in a mold into which an insert is forced to produce the annular cavity. Hand tamping was also used to provide maximum compaction of the material. The mandrel half was given a preliminary set cure while still in the mold. It was then inverted and given a final cure. Two halves of the mandrel were bonded together with an adhesive consisting of SR-6 diluted with a small amount of Steinex C. The bonded mandrel was then given an additional cure of one hour at 250°F.

The use of CO_2 for curing the mandrel was investigated by subjecting small specimens to solid CO_2 (dry ice) and to gaseous CO_2. It was found that the mandrel material in immediate contact with the CO_2 cured quite rapidly. However, penetration through the material was slow and it was concluded that this process was not suitable for a formulation containing silica filler. Also, long contact with the CO_2 produced a high degree of insolubility in the material. In a controlled production operation, the CO_2 treatment may be useful in surface hardening of the mandrel material to provide rapid turnover of the molds.

2. MATERIALS EVALUATION

a. Cord-Rubber Adhesion

Static adhesion tests were performed according to ASTM D2138-62T on the cords of nylon, fiber glass, and wire used in the fabrication of subscale and prototype tires. This test, commonly referred to as the H test, measures the shearing force necessary to separate a single cord in the direction of its axis from a strip of rubber in which the cords are imbedded. The following data, representing 464 individual tests, were obtained:

TABLE IX

H-ADHESION VALUES FOR TIRE CORDS

Material	Cord	Temp (°F)	H-Adhesion, lb for Various Elastomers[d] A	B	C
Nylon	840/2[a]	RT	26.7	27.6	---
		200	19.9	21.2	---
Nylon	1680/2[a]	RT	51.9	47.1	---
		200	39.5	41.6	---
Nylon	3360/2[a]	RT	52.9	52.3	---
		200	42.3	43.6	---
		300	28.1	32.5	---
Fiber glass	5/3[b]	RT	60.2	56.1	---
		200	43.2	41.8	---
		300	29.2	32.3	---
Fiber glass	5/5[b]	RT	59.1	60.8	---
Brass-plated wire	S-033[c]	RT	---	---	65.4
		200	---	---	62.9
		300	---	---	53.6
Brass-plated wire	S-004[c]	RT	---	---	63.1
		200	---	---	53.6

(a) Monsanto Chemical Co. St. Louis, Mo.
(b) Owens-Corning Fiberglas Corp., Ashton, Rhode Island.
(c) Bekaert Steel Wire Corp., Zweregen, Belgium
(d) A = carcass-ply elastomer (nylon/glass); B = breaker elastomer (nylon/glass); C = carcass and breaker elastomer (wire).

The results indicate that a high degree of adhesion can be obtained between the elastomer compound and the cords used for reinforcement in the filament-wound tires. These was a substantial drop in adhesion at 300°F but reasonably good shear strength still remained.

b. RLA-Elastomer Adhesion

A good bond is required between the glass-reinforced, resin-impregnated RLA and the rubber covering to prevent separation during cure and shearing off during dynamic testing. Various combinations of primers and adhesives were evaluated to determine the best to use in the fabrication of filament-wound tires. T-peel test specimens were prepared and tested to Federal Test Methods Standard No. 601, Method 8031. The following results (averages for three tests) were obtained:

TABLE X

RLA TO ELASTOMER ADHESION-TEST RESULTS

Specimen	Bonding Agents	T-Peel Adhesion lb/in. of width	Type of Failure
RLB-1	Chemlok 205 and 231	58	Plastic to primer
RLB-2	Chemlok 305-1 and 305-2	101	Plastic to adhesive
RLB-3	Ty-Ply T, Ty-Ply W[a]	101	In rubber
RLB-4	Chemlok 205 and 220	122	In rubber
RLB-5	Chemlok 205 and 217	22	Primer to rubber
RLB-6	Chemlok 205, 220 and 233	110	In rubber
RLB-7	Chemlok 205, EXB-576-6	29	Primer to rubber

(a) Product of R. T. Vanderbilt Co., Norwalk, Conn. All others made by Hughson Chemical Co., Erie, Pa.

The test results indicate that several combinations of bonding agents provide adequate adhesion between the resin-impregnated glass mat and the rubber compound used as a coating for the RLA. The failure of the more promising adhesive combinations occurred in the rubber, which shows that maximum bond strength was obtained. On the basis of this test, a combination of Chemlok 205 primer and Chemlok 220 adhesive was selected for the bonding of the rubber covering to the RLA.

c. Load versus Elongation of Tire Cords at Various Temperatures

Load-elongation tests were conducted on two of the tire cords (nylon 6-6 and wire) to determine their probable behavior under dynamic conditions. Figure 11 shows the plotted data for nylon 6-6 cord at temperatures of 75, 200 and 300°F. Similar data for the wire cord are presented in Figure 12.

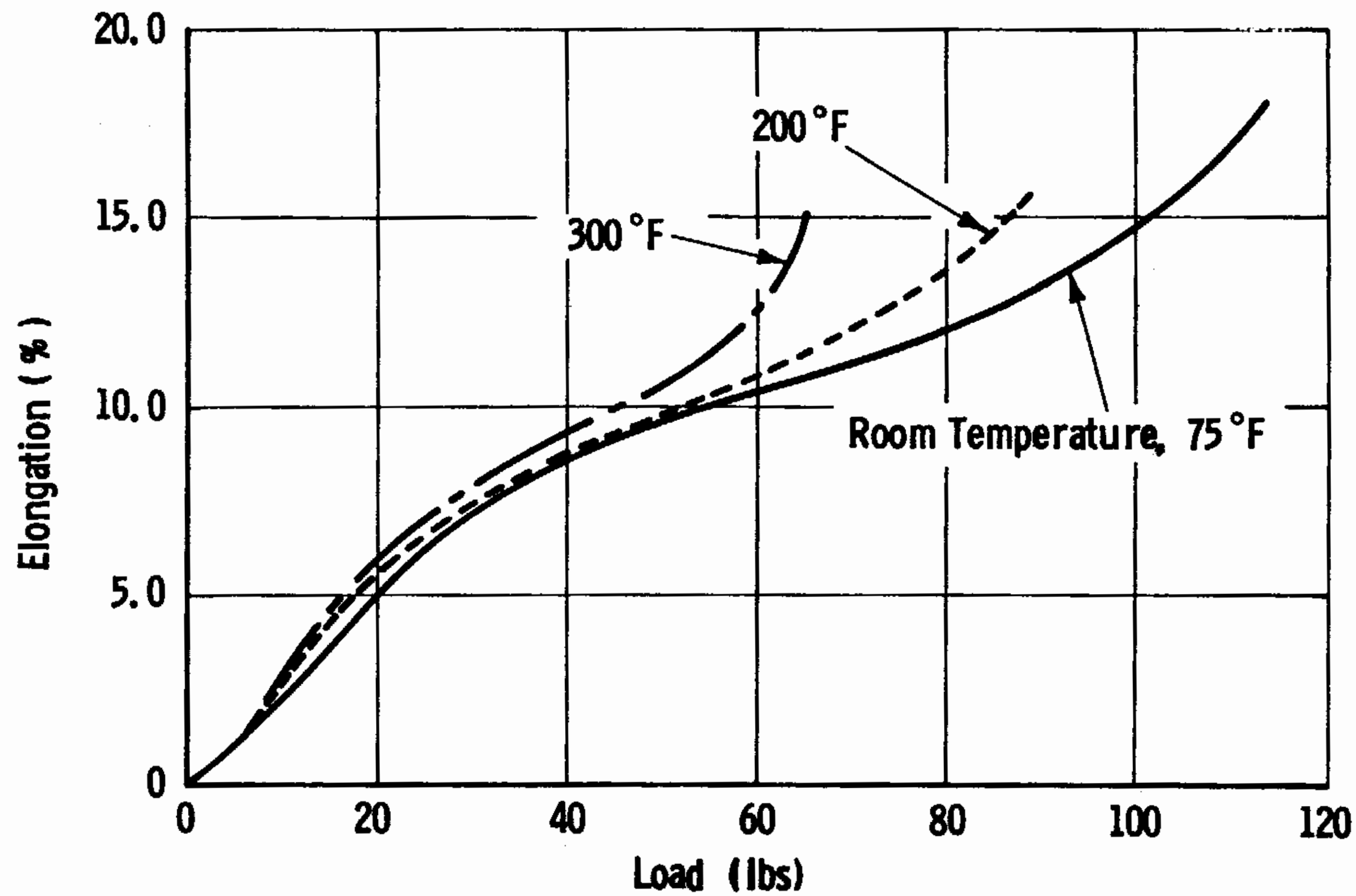


Fig. 11 Load vs Elongation of Nylon 6-6 at Various Temperatures

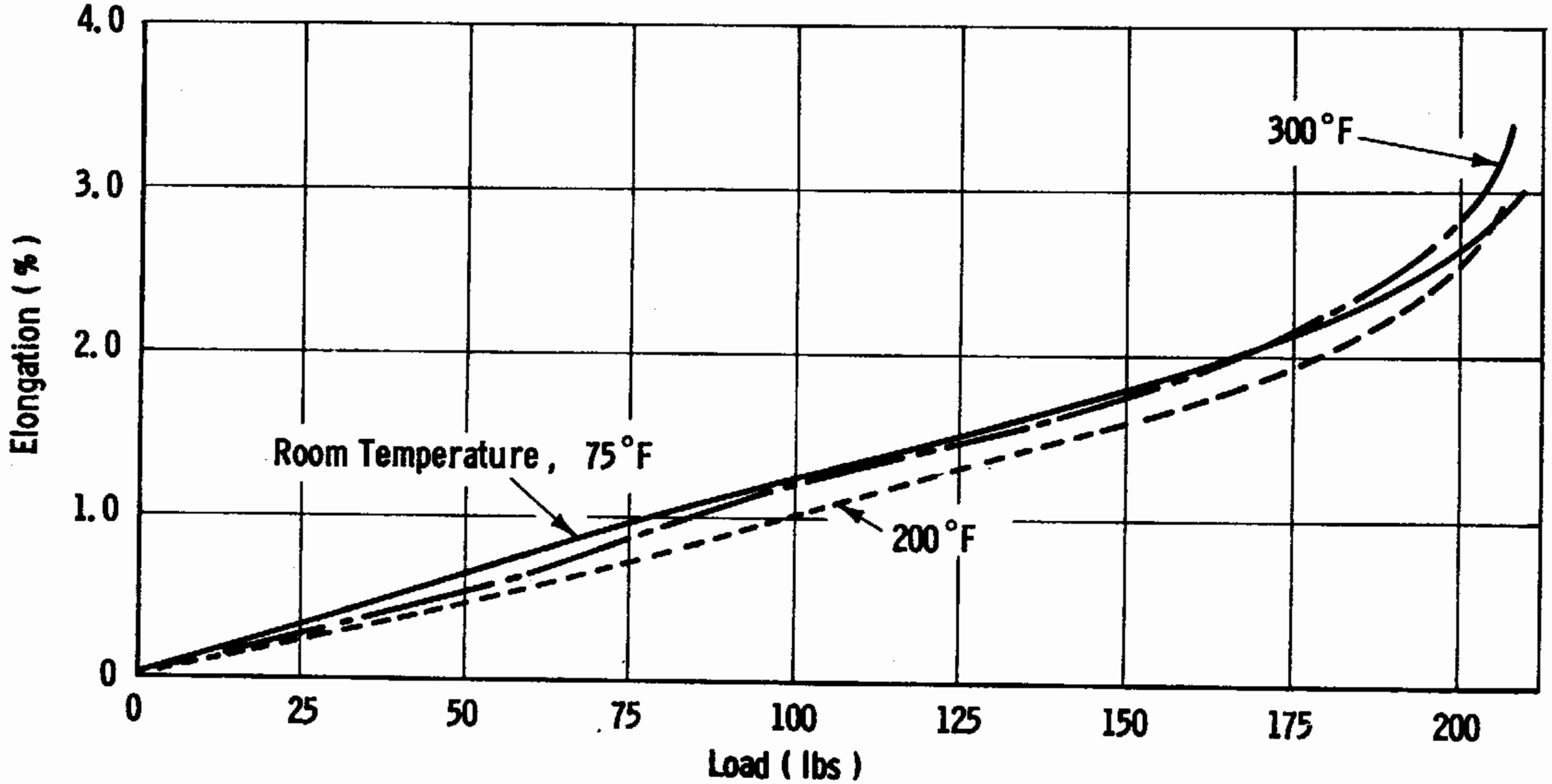


Fig. 12 Load vs Elongation of Steel Wire at Various Temperatures

The test results indicate the much greater stability of the wire cord as compared with the nylon 6-6 cord over the temperature range of the test. The nylon cord is reasonably stable as the temperature is raised to 200°F, but starts to soften at 300°F and elongates to quite an extent. For service conditions at high temperatures, the wire cord is preferred. However, all organic elastomers are degraded at temperatures of 300°F and above, and limit the usefulness of a tire at high temperatures.

d. Cord Creep Properties

Creep tests were conducted on the reinforcement materials used in the fabrication of the filament-wound tires. The applied load was 25% of the ultimate strength of the materials. Tests were conducted at 75,200 and 300°F. These data are presented in Tables XI through XIII for nylon 6-6, ECG fiber glass.

TABLE XI

CORD CREEP DATA - NYLON 6.6

	Creep (%)				
Type Cord	840/2[a]	1680/2[a]	3360/2[a]		
Test Temp (°F)	75	75	75	200	300
Applied Load (lb)	7.0	15.5	29.5	29.5	29.5
Time (min)					
0	0.000	0.000	0.000	0.000	0.000
1	0.290	0.285	0.280	0.310	0.350
2	0.410	0.365	0.350	0.385	0.425
3	0.450	0.395	0.400	0.420	0.465
4	0.455	0.420	0.430	0.445	0.485
5	0.475	0.440	0.465	0.465	0.520
10	0.515	0.500	0.510	0.530	0.600
15	0.555	0.525	0.535	0.565	0.650
30	0.575	0.550	0.585	0.605	0.705
45	0.645	0.605	0.620	0.630	0.740
60	0.675	0.625	0.650	0.675	0.775
120	0.780	0.675	0.700	0.720	0.920
180	0.800	0.695	0.735	0.755	0.985
240	0.810	0.710	0.745	0.765	1.035
300	0.810	0.735	0.765	0.765	1.060
360	0.810	0.735	0.765	0.765	1.090

(a) Product of Monsanto Chemical Co., St. Louis, Mo.

TABLE XII

CORD CREEP DATA - ECG FIBERGLAS[a]

	Creep (%)	
Type Cord	5/3	5/5
Test Temp (°F)	75	75
Applied Load (lb)	47.0	62.0
Time (min)		
0	0.000	0.000
1	0.050	0.080
2	0.065	0.085
3	0.070	0.095
4	0.080	0.105
5	0.080	0.125
10	0.095	0.135
15	0.105	0.135
30	0.125	0.145
45	0.130	0.160
60	0.135	0.180
120	0.135	0.180
180	0.135	0.180
240	0.135	0.180

(a) Product of Owens Corning Fiberglas Corp., Ashton, Rhode Island

TABLE XIII

CORD CREEP DATA - BRASS-PLATED STEEL WIRE

	Creep (%)			
Type Cord	S-004	S-033[a]		
Test Temp (°F)	75	75	200	300
Applied Load (lb)	90.0	57.0	57.0	57.0
Time (min)				
0	0.000	0.000	0.000	0.000
1			0.010	0.025
2			0.015	0.025
3			0.020	0.025
4			0.025	0.025
5			0.025	0.025
10			0.025	0.025
15			0.025	0.040
30			0.025	0.040
45			0.030	0.050
60			0.030	0.065
120			0.030	0.075
180			0.030	0.075
240	0.000	0.000	0.030	0.075
300	---	---	---	0.075

(a) Product of Bekaert Steel Wire Corp, Zweregem, Belgium

The data show that at 75 and 200°F, the nylon has stabilized after four hours. Since nylon is a thermoplastic material, stability in creep is never achieved at any time period at 300°F. The fiber glass cord stabilized after two hours at 75°F. The steel wire showed no increase in creep after 30 minutes at 200°F, or after two hours at 300°F.

e. Tape Versus Cord Reinforcements

The use of reinforcements in tape form was considered for filament-wound tires because of the saving in fabrication time that could be realized. That is, winding time is an inverse function of the number of reinforcements either as tapes or cords in each wrap. In the winding of a torus, however, the tapes overlap and cross each other on the inside of the torus. The overlapping produces excessive buildup which introduces interference in curing of the tire, and the crossing of cords produces lower dynamic life.

The extent of overlap and thickness increase is a function of the difference in diameters between the inside and the outside of the torus. The greater this difference, the greater the overlap. A detailed theoretical analysis, presented as Appendix II, shows the extent of the overlap and the area where it occurs on a 30 x 7.7 aircraft tire. In this analysis, a tape width of 0.25 inch and thickness of 0.047 inch is assumed. For a tire of 26.894-in. OD and 15.127-in. ID, the overlapping starts at 19.25-in. diameter, which is approximately one-third of the distance from the heel area to the crown of the tire. This is a rather critical area from the standpoint of dynamic flexing. The crossing of cords at this point introduces chafing and lowers dynamic life. The buildup of cords on the inside of the tire by the use of tape winding is approximately twice that of the carcass thickness at the upper sidewall. An increase in RLA diameter would be necessary to accommodate this buildup. It also represents a substantial weight penalty. It was concluded that the undesirable features of tape winding more than overbalanced the time economy that might be produced by its use. It should be emphasied, however, that this analysis of tape winding effects was directed for a specific theoretical situation. It may not apply to all tape winding concepts.

SECTION IV

TOOL AND EQUIPMENT DESIGN AND FABRICATION (TASK B)

The objectives of this effort were (1) to design and fabricate tooling and equipment for the fabrication of 30 x 8.8 22 PR subscale tires, and (2) to utilize performance data from this equipment in the design of tooling and equipment for the 49 x 17 26 PR prototype tires.

1. SUBSCALE TOOLING AND EQUIPMENT

a. Carcass-Winding Machine

The carcass-winding machine for the 30 x 8.8 tires was available from earlier programs for 30 x 7.7 tires. It was adaptable to winding the 30 x 8.8 tire, although interference was encountered in the winding of the bias nylon and modified geodesic nylon tires. This required modification of the payoff mechanism and redesign of the winding cams. No interference problems were encountered in the winding of the radial tires. During the subscale tire program, an improvement in winding tension uniformity was accomplished by the addition of hysteresis brake tension controls to this machine. The cams for the winding machine were designed from formulas developed in a computer study presented in Part II. Drawings for the cams used for the 30 x 8.8 bias and geodesic tires are shown in Appendix III.

b. Handling and Curing Equipment

Molds for the sand mandrels were designed in accordance with the requirements outlined in Task A - Design and Evaluation. The cavities were made of glass-reinforced polyester, and the plug for forming the inside diameter of the mold was made of aluminum. The insert for forming the annular cavity was cast from Ultracal-30[8], a high-strength plaster material.

The aluminum mandrels for fabrication of the rim locking assembly were made in two parts to permit easy removal of the RLA.

The machine used for the application of treads on both subscale and prototype tires was a series 200 American Machine and Foundry "Orbitread" machine. This machine was operated by punch card control to automatically apply the strips of extruded rubber to the carcass for the tread and sidewall.

The mold used for curing the 30 x 8.8 filament-wound tire contained a segmented curing ring to facilitate mounting in the mold. This is shown in Appendix III.

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[8] Product of U.S. Gypsum Company supplied by George Throop Company, Pasadena, California

Other tooling for fabrication, mandrel washout, handling and curing of the 30 x 8.8 tires is documented in the following drawings, which are on file.

Tool Number	Description
T-1286078 (Aerojet)	Mold, Sand Mandrel, 30 x 8.8 Bias
T-120848 (Aerojet)	Mandrel, RLA, 30 x 8.8 Bias
T-120852-001 (Aerojet)	Mold, Sand Mandrel, 30 x 8.8 Bias
T-120855 (Aerojet)	Mold, Sand Mandrel, 30 x 8.8 Geodesic
T-120849 (Aerojet)	Mandrel, RLA, 30 x 8.8 Geodesic
T-120851 (Aerojet)	Mold, Sand Mandrel, 30 x 8.8 Radial
DK-4811 (General Tire)	Tire Mold, 30 x 8.8 F/W
CK-8555 (General Tire)	Bead Rings, 30 x 8.8 F/W
CK-4135-2 (General Tire)	Mold Stamping, 30 x 8.8 F/W
CK-8600 (General Tire)	Curing Assembly, 30 x 8.8 F/W
D221A-39 (General Tire)	Test Rim, 30 x 8.8
D221A-40 (General Tire)	Test Rim Side Plates, 30 x 8.8
D-17716 (General Tire)	Building Mach. and Access., 30 x 8.8 F/W

2. 49 x 17 TIRE TOOLING AND EQUIPMENT

a. Carcass-Winding Machine (T-120850)

The factors considered in the design of the 49 x 17 prototype tire carcass-winding machine were (1) mechanical complexity as defined by the operations, requiring (2) machine versatility for various sizes and for operation modifications, (3) adaptability to various types of filament reinforcements, and (4) simplicity of operation to minimize maintenance. The machine size, as finally agreed upon, will wind any size of tire for wheel sizes of 16 to 20 in. It will not wind the 56 x 16 Type VII tire, which has a rim diameter of 28 in. To include this size in the range would eliminate some of the smaller sizes that have greater utility. The machine can be modified however, if necessary to also wind the 56 x 16 tire. Drawings of the carcass winding machine are presented in Appendix III (T-120850).

The experience gained in the operation of the subscale tire-winding machine was applied to the design of the prototype tire winding machine. The new winding machine was designed to have the following improvements and advantages over the subscale tire winding machine: (1) six dual payoff assemblies to minimize winding time, (2) ability to wind tape as well as cord, (3) a hysteresis-type brake cord-tensioning device to improve tension control, (4) a mechanical device for the application of insulation without requiring carcass removal, (5) a capability for changing from helical to radial winding by a simple exchange of gears, (6) a feedback system (electro-mechanical) to correct machine-drive ratios as the diameter increases, and (7) an adjustable winding head to cover a broad range of tire sizes. Figure 13

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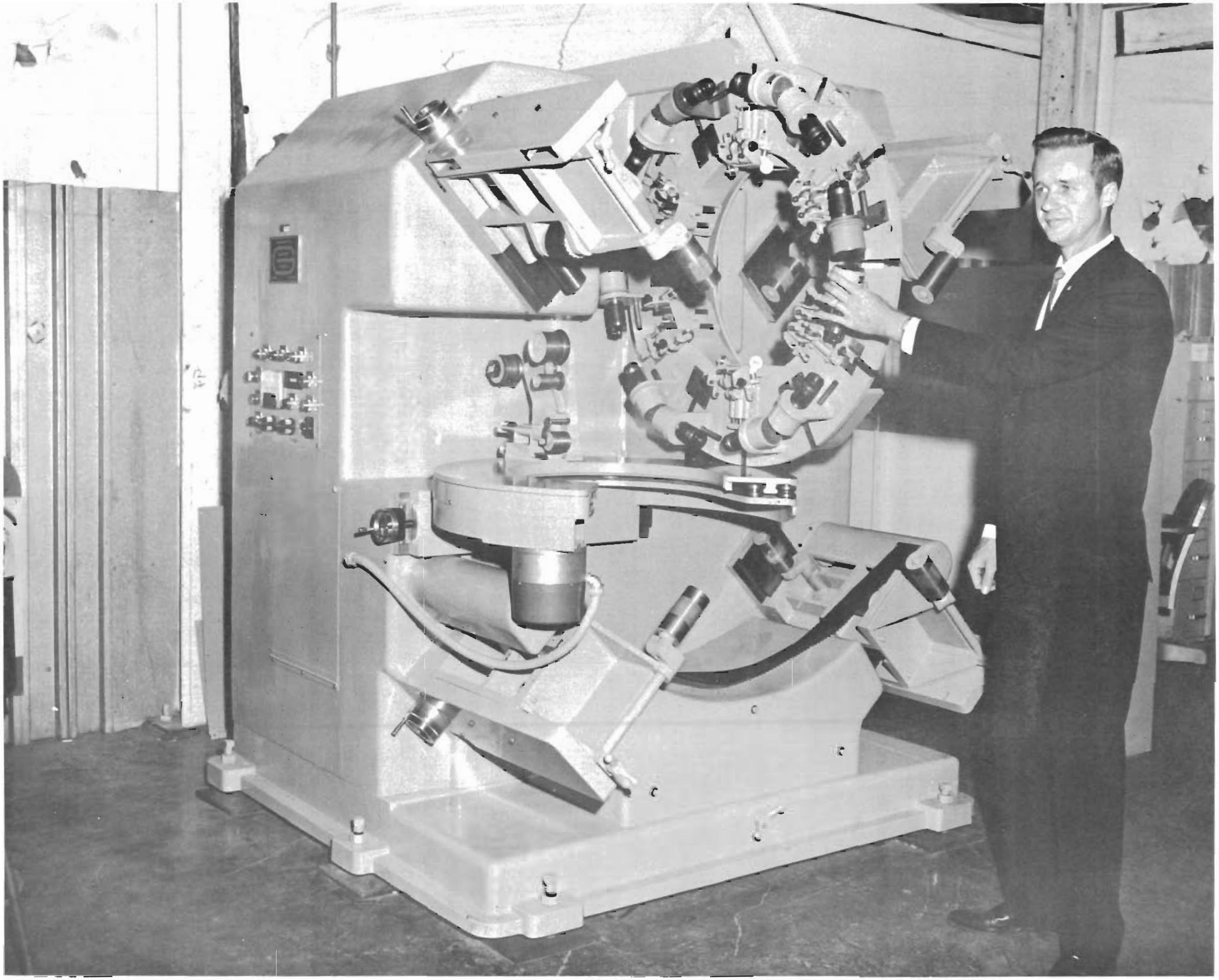

Figure 13. Prototype 49 x 17 Tire-Winding Machine

shows the 49 x 17 prototype tire winding machine. The cams for this winding machine were designed from formulas derived in a computer study program presented in Part II. Drawings for the cams used on the prototype tire-winding machine are shown in Appendix III.

The carcass-winding machine contains a ratio-adjust control that regulates the speed of the winding head relative to the mandrel speed. This control can be operated either manually or automatically. The automatic feedback control is a combination electromechanical system in which a sensor device automatically adjusts the rotation of the winding head to return the end count to the specified value when variation develops because of mandrel slippage.

Modifications were made to the automatic feedback control system to improve uniformity of cord spacing and end count. The first modification consisted of a zero-null device to synchronize the mandrel with the master position control disk. The second was an error-amplitude-detection system which provides automatic measuring of the mandrel position error amplitude with respect to true position. Each of these modifications accomplished its intended purpose.

Examination of the winding machine during operation indicated that a very small but significant change in the mandrel speed occurs as covering of the rubber ply insulation by cord takes place. Traction improves as cord covers the tacky rubber surface. The cord spacing is reduced and the winding head speed must be increased when this occurs. Control of cord spacing, and ultimately the ply end count, requires constant observation of the cord lay down. Immediate application of corrective measures is necessary to maintain uniformity of cord spacing. The automatic feedback control system is designed to provide cord spacing control by varying the speed of the winding head relative to the mandrel speed. Corrections can be made only twice during each mandrel revolution because only two sensing points are available. The addition of more pickup points such as metallic spots on the edge or inside of the RLA would improve the reaction rate of the automatic feedback control system. Perfection of this technique would require considerable study and additional cost. By use of manual control, the operator is able to make corrections rapidly when variable cord spacing appears.

Various techniques were considered for reducing the slippage between the drive belt and the tire carcass. The application of a rough surface on the belt would require a special mold and custom curing. This surface was, however, provided by application of 1 x 4 in. panels of molded, adhesive-coated antislip rubber material to the surface of, and perpendicular to, the movement of the belt. These panels, shown in Figure 14, provide the required nonslip surface and increase the coefficient of friction between the tire carcass and the drive belt.

b. Handling and Curing Equipment

Figure 15 shows the mandrel fabrication equipment for the 49 x 17 prototype tire. The mold cavity was fabricated from a glass-fabric/polyester resin laminate reinforced with steel rings to support the sand-mandrel half-section which weighed up to 175 lb. The insert was fabricated from Ultracal-30 plaster. The mandrel turnover device is designed for inverting the mandrel half after the initial cure. The sling shown here is used to support the mandrel half after removal from the mold and during bonding. The mandrel locating device, or "spider," is designed to support the top-half of the mandrel during bonding. Special adjusting screws locate the top-half with respect to the bottom-half to provide exact mandrel-width control.

Figure 16 shows the RLA building mandrel disassembled. The mandrel is made of aluminum and has two removable inserts used in forming the chamfer areas in the RLA. A drawing of the RLA building mandrel is shown in Appendix III.

The carcass handling truck is shown in Figure 17. This truck is used for transporting sand mandrels and the rubber-covered mandrel into and out of the curing oven.

A special washout device was designed to remove the mandrel from the 49 x 17 tire. This equipment consists of a syphon tube that fits inside the air inlet tube, a sand trap, and a vacuum source for pulling sand and water out of the tire. This equipment is shown schematically in Figure 18.

Other tooling used in the fabrication of 49 x 17 prototype tires is shown in the following documented drawings on file:

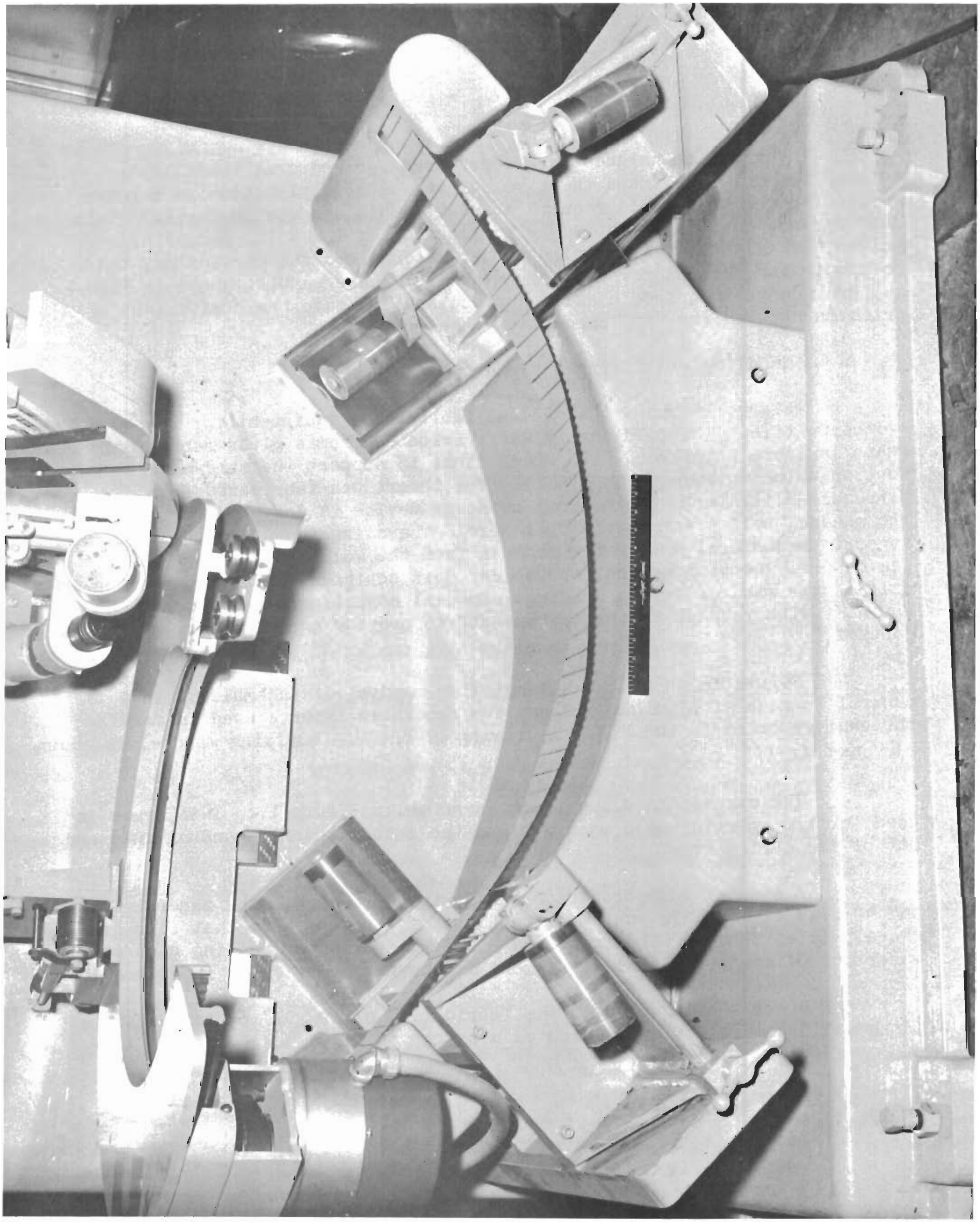

Figure 14. Non-Slip Panels on Drive Belt

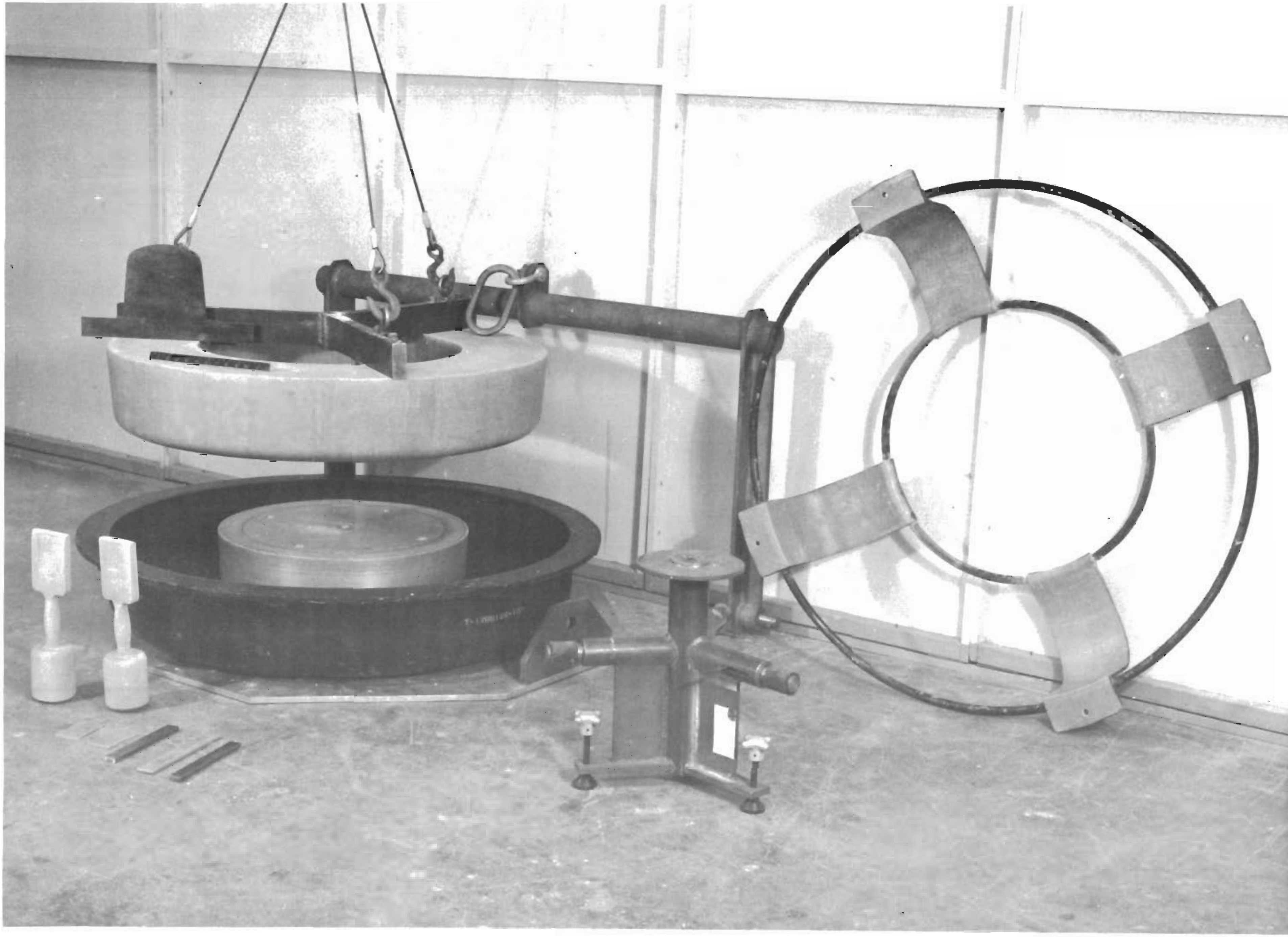

Figure 15. Mandrel Fabrication Equipment

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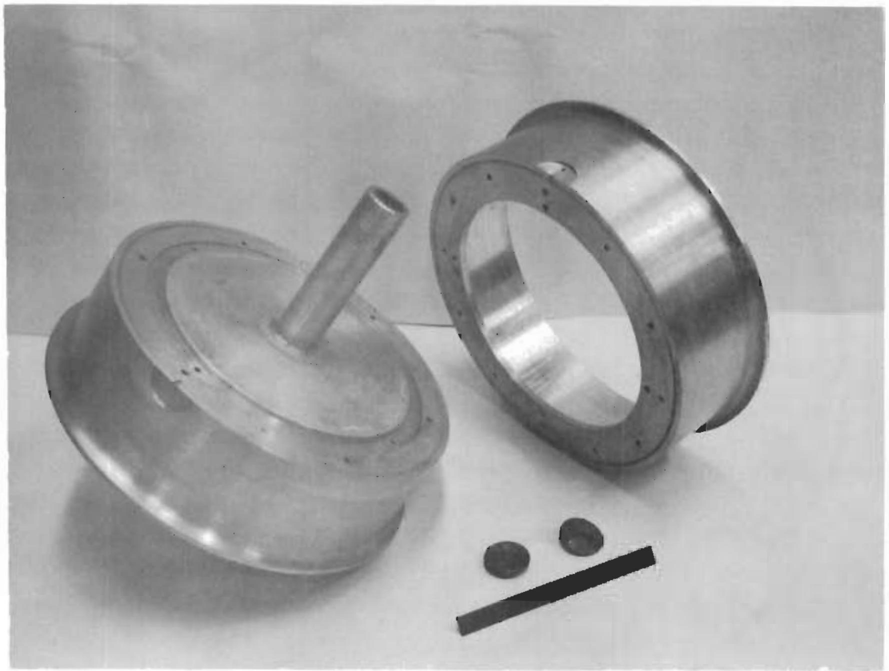

Figure 16. RLA Building-Mandrel, Disassembled

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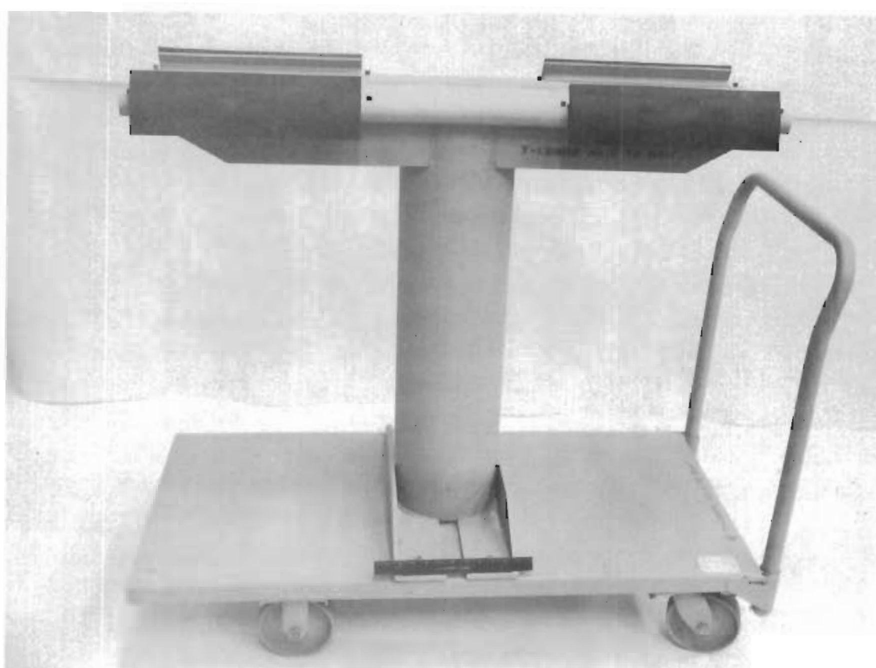
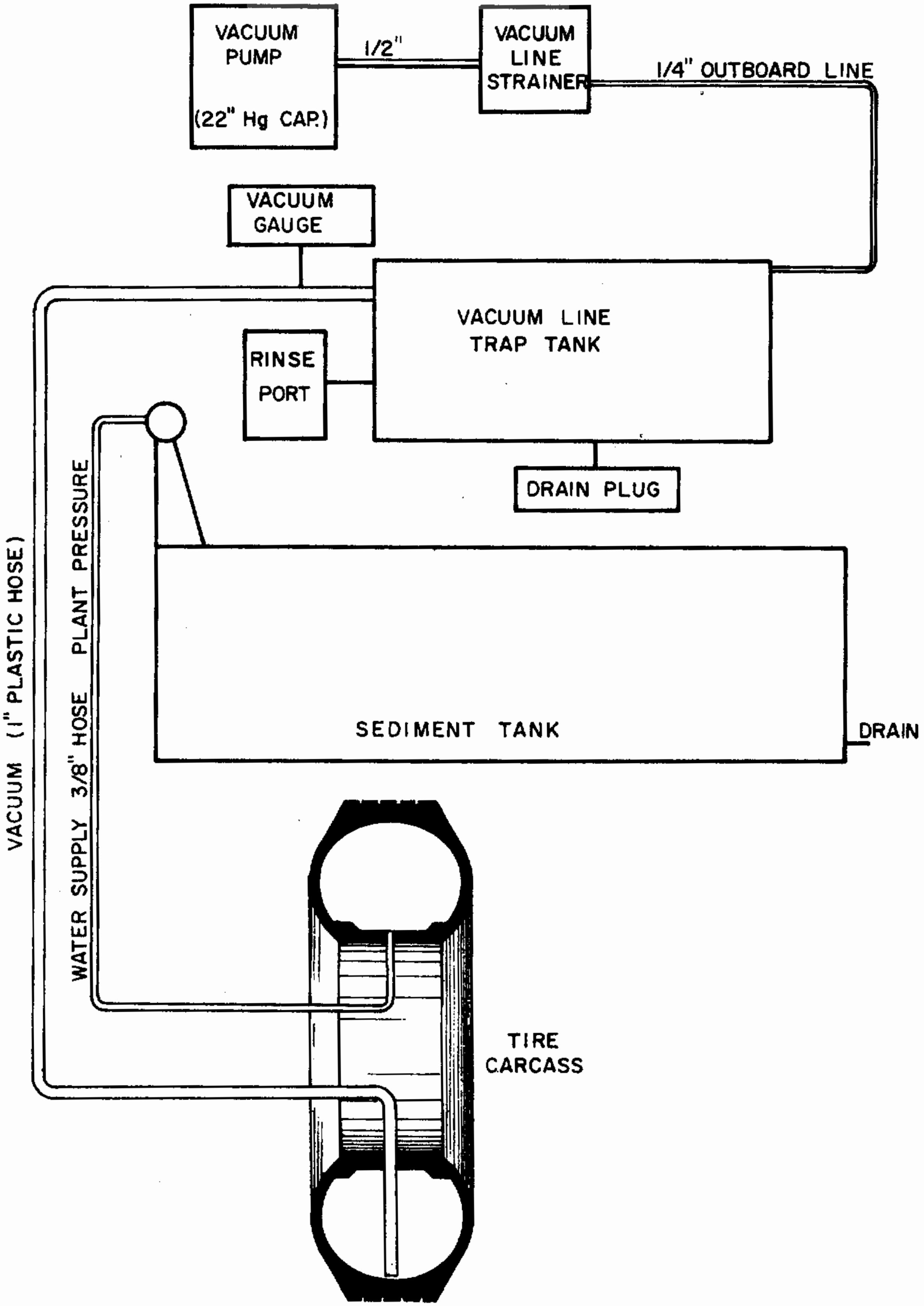


Figure 17. Carcass Handling Truck



MANDREL WASHOUT EQUIPMENT

Figure 18

Tool Number	Description
T-1286126 (Aerojet)	Mold, Sand Mandrel - 49 x 17 Tire
T-1286127 (Aerojet)	Handling Tongs - 49 x 17 Tire
T-1286128 (Aerojet)	Inverting Fixture - 49 x 17 Tire
T-1286129 (Aerojet)	Handling Harness - 49 x 17 Tire
T-120802 (Aerojet)	Handling Cart - 49 x 17 Tire
T-120854 (Aerojet)	Handling Fixture - 49 x 17 Tire
T-1286141 (Aerojet)	Test Mandrel
DK-5646 (General Tire)	Bottom Half Stamping Arrangement - 49 x 17 Tire
DK-5647 (General Tir)	Top Half Stamping Arrangement - 49 x 17 Tire
BK-4251 (General Tire)	Interchangeable Plate - 49 x 17 Tire
BK-4255 (General Tire)	Spacing Arrangement - 49 x 17 Tire
221A215 (General Tire)	Tire Test Rim - 49 x 17 Tire
221A216 (General Tire)	Tire Test Rim Side Plates - 49 x 17 Tire

SECTION V

PROCESS DEVELOPMENT (TASK C)

The objective of this program phase was to isolate and solve those manufacturing and processing problems that might arise in the fabrication of various types of filament-wound constructions and reinforcements by the fabrication and testing of subscale tires. Three constructions were evaluated: bias cord path, radial cord path, and modified-geodesic cord path. The bias and modified-geodesic tires were reinforced with nylon cords; the radials were reinforced with glass and steel wire cords in addition to nylon.

1. FABRICATION OF SUBSCALE TIRES - 30 x 8.8 TYPE VII

a. Conventional Tires

(1) Fabrication

Twelve 30 x 8.8 22 PR tires were fabricated by conventional methods to provide controls for the filament-wound tires. The same cord, 3360/2 nylon, was used in the fabrication of the eight-ply bias-angle control tires selected for use in the subscale tire program.

(2) Static Testing

Table XIV lists the static testing date for the conventional control tires. All requirements of MIL-T-5041, the conventional tire specification, are met. The static deflection (31.5%) shown is an average of the three tires. This is the percent deflection to be used to describe the deflection of this control tire at the rated conditions. Load-deflection curves taken during dynamic tests may show different characteristics because of changes in the method and equipment used to obtain the data.

Load-deflection curves for six pressures are shown for Tires A-10 and A-13 in Figures 19 and 20. Tire A-13 is more representative of a conventional cord tire. The major differences between the two tires are the effects of outside diameter differential and of the rapid collapse of the A-10 tire upon bottoming.

(3) Dynamic Testing

Five conventional control tires were subjected to endurance tests; five others were employed in take-off tests. All tires satisfactorily completed the requirements of the static tests and the 25 cycles of the 40 mph outboard 10°-camber test of the basic test method. In the constant-roll test, which was performed after the 25 cycles of the camber test, it was necessary to reduce the speed to 3.2 mph to maintain an average temperature below 200°F. After data analysis, a final speed-time curve of 3.5 ± 0.3 mph was established.

TABLE XIV

STATIC TEST DATA ON 30 X 8.8 22PR T-VI
(Conventional Bias Nylon; Tire Serial Number 15955.014/A)

Item	MIL-T-5041	A-10	A-11	A-13
Tire weight, lb	71 (max)	53.40	53.20	52.80
Bead seat pressure, psi	50 - 200		45*	190
Burst pressure, psi	1035 (min)		1070	1060
1. Type of rupture	-		(Bead break)	(Bead break)
Air Retention				
1. Loss, %	5% (max)			.47
2. Initial conditions				
a. Inflation, psi	295		295	295
b. Room temperature, °F	-		(12 psi drop in 5.5 days)	75
3. 24 hour conditions				
a. Inflation, psi	-			292
b. Room temperature, °F	-			73
Inflated dimensions				
1. Initial				
a. Inflation, psi	295	295	295	295
b. Tire outside diameter, in.		29.66	29.66	29.66
c. Section width, in.		8.42	8.48	8.50
2. After 12 hours minimum				
a. Tire OD, in.	29.50 to 30.40	29.78	29.75	29.83
b. Section width, in.	8.35 to 8.90	8.52	8.54	8.58
c. Shoulder diameter, in.	27.40	-	25.11	25.29
d. Width of shoulder diameter, in.	7.90 (max)	-	6.75	6.85
Loaded data				
1. Inflation, psi	295	295	295	295
2. Load, lb	21,000	21,000	21,000	21,000
3. Static deflection				
a. Inch deflection, in.		1,958	1,985	1,975
b. % deflection, %	28 - 35	31.3	31.7	31.4
c. Static loaded radius, in.	12.61-14.36	12.932	12.89	12.95

*Indicator malfunction-visual estimate: 170 psi minimum.

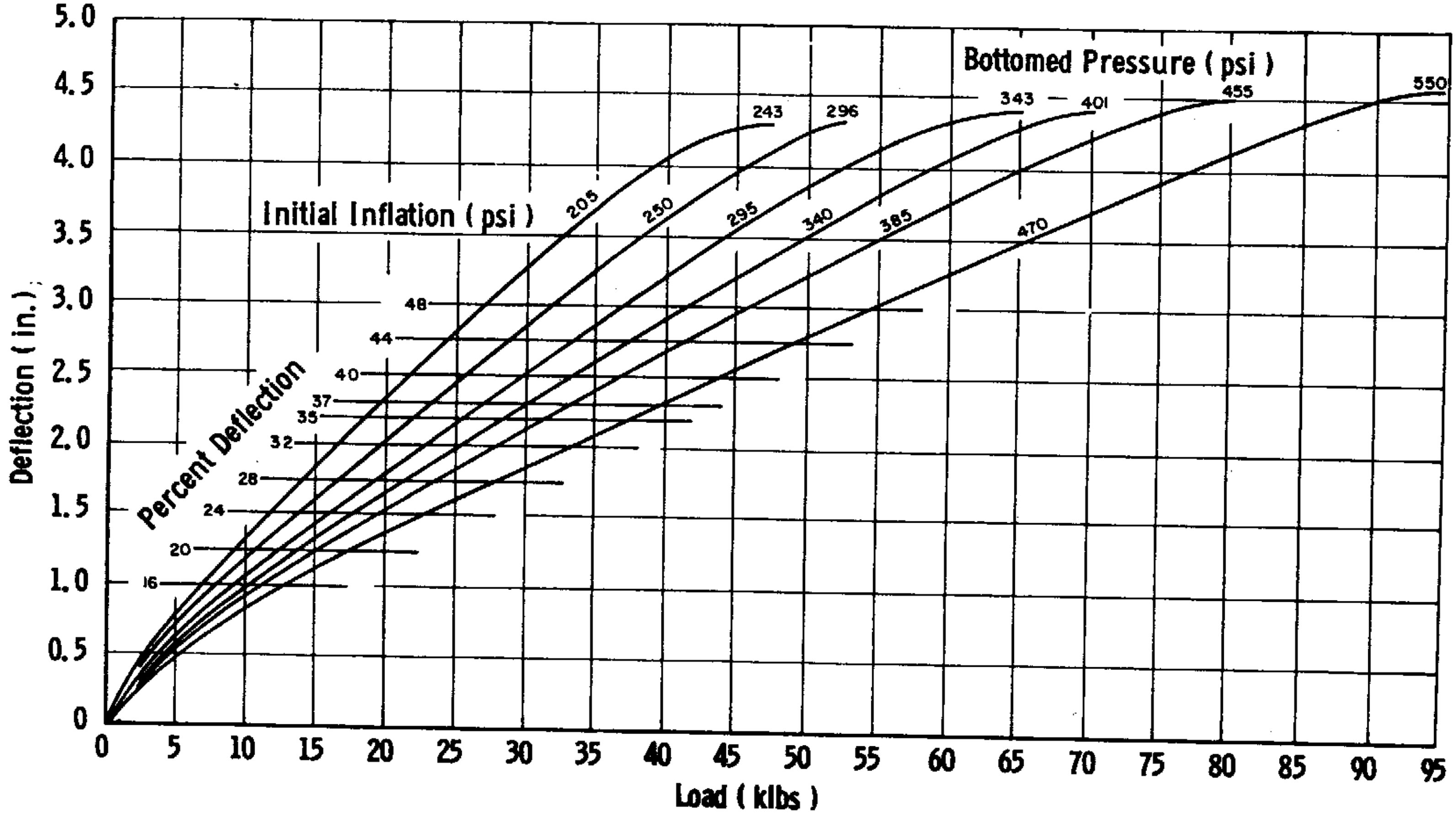


Figure 19. Load-Deflection of Conventional Tire A-10 at Various Inflation Pressures

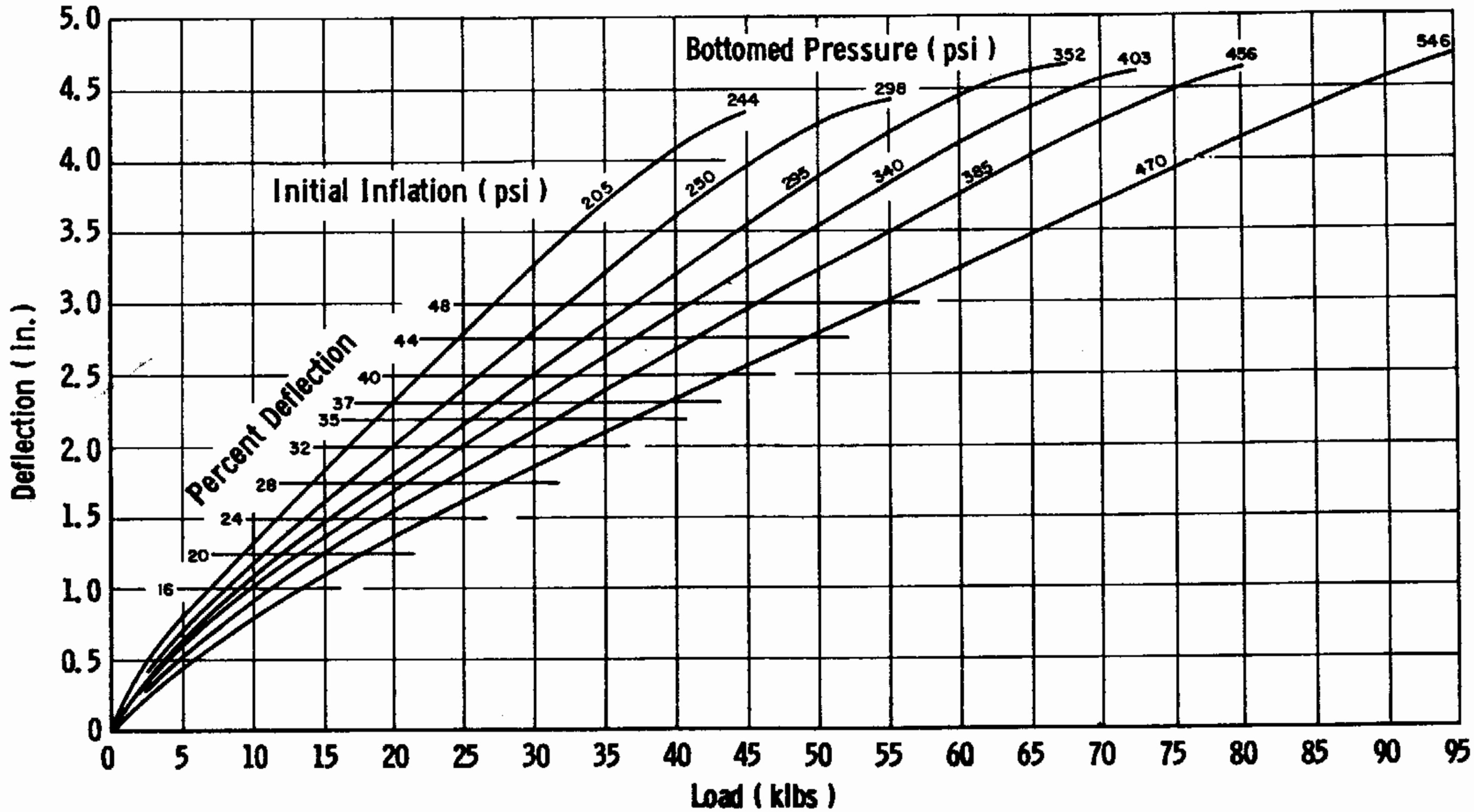


Figure 20. Load-Deflection of Conventional Tire A-13 at Various Inflation Pressures

b. Filament-Wound Tires

(1) Fabrication

Five constructions of filament-wound tires were fabricated in the process development phase of the program to evaluate different reinforcing materials and to obtain useful processing data preparatory to fabrication of prototype tires. Table XV gives the basic construction features of these five types of 30 x 8.8 tires. Included for comparison are the construction features of the control, or conventional 30 x 8.8 22 PR tire.

TABLE XV

CONSTRUCTION FEATURES OF 30 x 8.8 22 PR TIRES

Design Type	Estimated Wt. (lb)	Carcass Cord Type	No. of Plies	Cured EPI*	Cured Angle(°)	Belt Type Cord	Belt No.of Plies	Belt Cured EPI	Belt Cured Angle(°)
Conventional Bias	53	3360/2 nylon	8	16	33.5				
F/W Bias	49.2	3360/2 nylon	8	16	33.5				
F/W Geodesic	49.8	3360/2 nylon	4	6.2	62.8	5/3 glass	6	16	30
F/W Radial Nylon	49.8	3360/2 nylon	4	10	90.0	5/3 glass	6	16	15
F/W Radial Glass	49.3	5/3 glass	3	12.4	90.0	5/3 glass	6	16	15
F/W Radial Wire	54.6	7X3 wire	2	12	90.0	7X3 wire	4	18	20

* EPI = ends per inch

Detailed instructions were prepared for the fabrication of each construction shown above. They are presented in Appendix VI as Engineering Manufacturing Instructions.

It was planned to fabricate ten 30 x 8.8 tires of each of the five types of construction described above in the process development phase. Because of technical difficulties and a decision to concentrate effort on the fabrication of 49 x 17 prototype tires only, twenty-two filament-wound subscale tires were produced. Of this number, four were of the bias nylon type, four were of the geodesic nylon type, five were of the radial nylon type, four were of the radial glass type, and five were of the radial wire configuration. Following are the identifying symbols for each of these types:

BN - Bias nylon
GN - Geodesic nylon
RN - Radial nylon
RG - Radial glass
RW - Radial wire

The winding data for these tires is summarized in Table XVI.

(a) End-Count Control

The data show that end-count variation is greatest in the bias-wound tires and least in the radial-wound tires. The higher variation shown by the bias-wound tires is caused by winding on a slip pattern and minor, but significant, slippage of the carcass on the driving belt. The slippage or rolling of the cords on the sidewall results in variation in cord placement. The gradual change from a rubber-covered mandrel to a cord-covered mandrel in contact with the driving belt produces variable frictional resistance and slippage. Adjustments in the ratio control are made to compensate for these conditions. The response is not rapid enough, however, to maintain accurate end-count control.

The high degree of uniformity in end count for the radial tires is due to the nonslip (90°) winding path and to better traction on the belt. Winding of the cord perpendicular to the mandrel does not introduce any slippage or rolling of the cord. The direction of the cord with relation to the driving belt on radial-wound tires also contributes to a more uniform wrap by providing a cog-type surface. This is demonstrated in Figure 21 showing the winding of a radial wire 30 x 8.8 carcass.

It is believed that the use of rubber-cement-coated cord, as developed in the 49 x 17 prototype tire phase of the program, would improve the end-count control on the 30 x 8.8 subscale tires. Results have shown that less slippage and rolling of the cords result when cement-coated cord is used.

TABLE XVI

WINDING DATA FOR 30 x 8.8 22 PR F/W TIRES

Tire Ident.	Spec. Ends per Ply	Actual Ends per Ply 1	2	3	4	5	6	7	8	Average Ply Ends	% Strength Level(Ref. Min. Ends)
BN-1	755	608	648	655	694	691	670	520	546	629	81.9
BN-2	755	607	597	660	603	546	705	733	646	638	84.4
BN-3	720	460	476	688	674	716	756	728	714	652	90.0
BN-4	720	692	690	712	660	660	711	716	662	688	94.6
GN-1	555	572	632	477	640					580	94.5
GN-2	555	698	566	590	464					578	92.8
GN-3	555	621	596	590	568					594	102.5
GN-4	555	598	628	614	624					616	104.5
RN-1	883	890	892	894	896					893	101.1
RN-2	883	898	882	884	900					891	100.9
RN-3	883	910	890	900	900					900	101.9
RN-4	883	884	886	885	890					886	100.3
RN-5	883	893	890	896	896					894	101.5
RG-1	1091	1092	1098	1092						1094	100.3
RG-2	1091	1066	1084	1094						1081	99.1
RG-3	1091	1070	1082	1092						1081	99.1
RG-4	1091	1076	1080	1090						1082	99.2
RW-1	1055	1051	1076							1063	100.7
RW-2	1055	1060	1068							1064	100.8
RW-3	1055	1070	1076							1073	101.7
RW-4	1055	1056	1060							1058	100.1
RW-5	1055	1066	1074							1074	101.4

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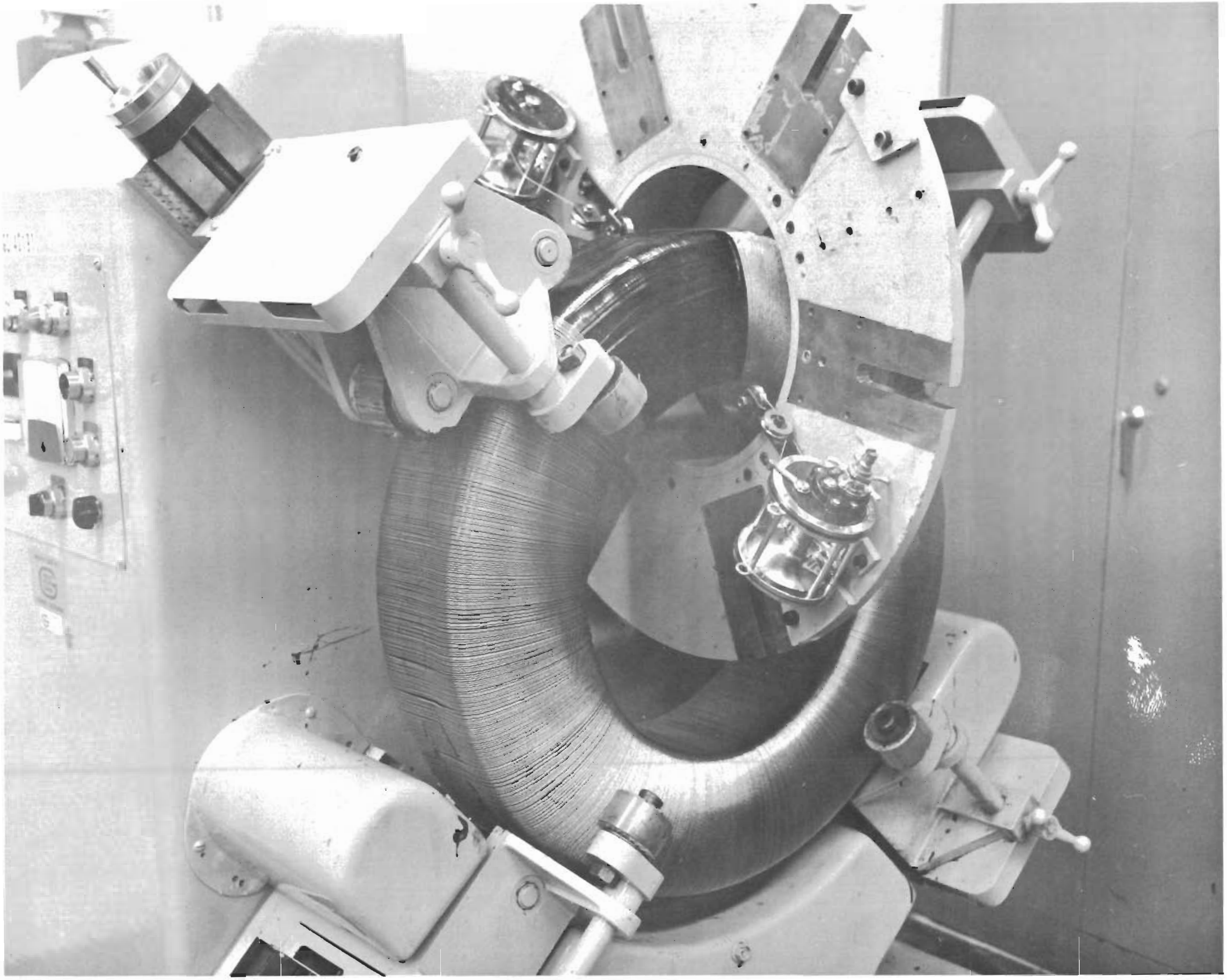

Figure 21. Winding of Radial Wire Carcass

(b) Cured Cord Angles

Dynamic tests have shown that good performance is obtained when the cord angle is within a certain range. This range has been established for various stations around the tire for bias and geodesic cord paths, and the winding cams were designed to produce cord angles within the specified range. The following stations were selected as points where cord angles were checked after cure of the tires.

Station No.	Location
1	At the crown centerline
2	1.5 in. from the crown centerline
3	3.0 in. from the crown centerline
4	4.5 in. from the crown centerline
5	6.0 in. from the crown centerline
6	At the ID centerline

The cord angles were checked on BN-1 (bias nylon) and GN-1 (geodesic nylon) to determine how close they were to the target values. The results were:

Cured Cord Angles Along the Neutral Axis (°)

Tire Ident.	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
	T[a]	A[a]	T	A	T	A	T	A	T	A	T	A
BN-1	33.8	40.5	34.6	41.5	39.3	43.5	47.5	48.0	54.1	50.0	63.1	49.0
GN-1	65.7	65.5	65.4	65.5	64.3	64.0	60.3	62.0	55.4	62.0	46.4	58.5

[a] T = target angle, A = actual angle

The cord angles (±) obtained on tire BN-1 versus the desired cured cord angle were:

Crown	+6°
Upper sidewall	0°
At maximum section	-5°
At flange	-10°
Along ID	-14°

The cured cord angles on tire BN-1 were obviously too far from the target values to provide good dynamic performance. It was decided that a new mandrel profile and winding path were required to correct the cord angles. This necessitated a new mold for the mandrel and a new cam for the winding machine.

The cured cord-angles on tire GN-1 were very close to the target values except for Station 6 at the ID centerline. This angle, however, is not critical inasmuch as the cords in this area are not flexed. The mandrel and cord path for the geodesic tires were considered acceptable. Figure 22 shows a geodesic filament-wound carcass.

The following cured cord angles were obtained on two of the bias nylon tires after the change to a new mandrel profile and winding path was made:

Tire	Cured Cord Angles Along the Neutral Axis (°)											
	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
Ident.	T[a]	A[a]	T	A	T	A	T	A	T	A	T	A
BN-3	33.5	36.5	34.3	---	38.8	---	46.2	---	53.5	---	62.0	---
BN-4	33.5	37.0	34.3	37.4	38.8	41.7	46.2	49.7	53.5	52.6	62.0	53.0

[a] T = target angle, A = actual angle

The cured angles obtained with the modified bias configuration were definitely improved over the values obtained on the first tire although not as much as desired. It was decided to continue fabrication of these tires and determine the effect of the cord angles on dynamic performance.

(c) Tire Weights

Table XVII gives the total tire weights for the 30 x 8.8 subscale tires. Included also are the control tire weight and the carcass weights for each.

Examination of the tire weight values shows that the geodesic nylon and the radial nylon tires offer the greatest potential for weight reduction of filament-wound tires. Tire GN-2 showed 16.1% reduction and RN-5 showed 18.8% reduction when compared with a conventional 30 x 8.8 tire. The radial wire tires showed an increase in weight over the conventional tires even though they were only two-ply tires. The bias-wound tires were approximately 9 to 10% lower in weight than the conventional bias construction.

(d) Winding time of Radial vs Bias Cord Paths

The time required to wind a radial cord path is much less than the time required to wind bias or geodesic cord paths. The shorter radial winding time is due to the fact that the radial winding cord is applied on a non-slip path, not involving spool movement on the winding head. The radial winding can, therefore be accomplished near to the machine's full speed. The approximate winding-time ratio for radial wrap vs bias wrap is one-to-eight.

768-065

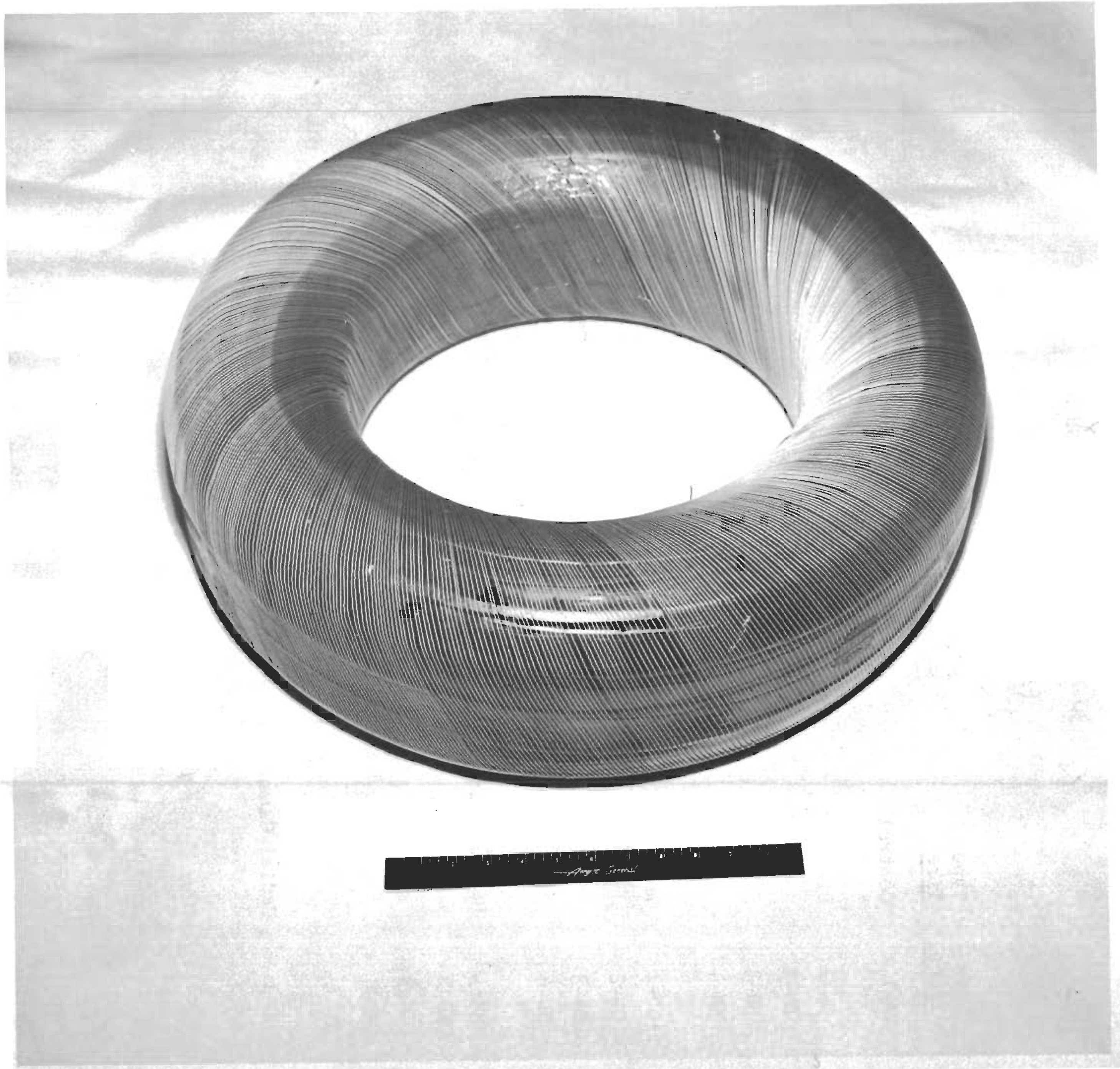

Figure 22. Filament-Wound Geodesic-Nylon Carcass

TABLE XVII

30 X 8.8 22 PR TIRE WEIGHTS

(100% MANDREL REMOVAL)

Tire Ident.	Type Tire	Estimated Weight(lb)	Carcass Weight(lb)	Total Actual Weight(lb)	% of Control
A-1	Control	53.0			
BN-1	Bias	49.2	39	49.3	92.7
BN-2			37	48.0	90.5
BN-3			37	47.3	89.3
BN-4			40	49.5	93.3
GN-1	Geodesic	49.8	28	44.5	83.9
GN-2			28	44.8	84.5
GN-3			29	44.5	83.9
GN-4			28	46.0	86.8
RN-1	Radial Nylon	49.8	30	48.2	91.0
RN-2			28	47.3	89.4
RN-3			27	45.2	85.3
RN-4			26	44.3	83.5
RN-5			25	43.0	81.2
RG-1	Radial Glass	49.3	29	48.3	91.0
RG-2			30	49.1	91.8
RG-3			30	48.0	90.7
RG-4			30	44.5	84.0
RW-1	Radial Wire	54.6	34	56.5	106.7
RW-2			33	55.5	104.8
RW-3			32	54.5	103.0
RW-4			30	51.7	97.4
RW-5			31	54.2	102.2

(2) Test Results

(a) Air Retention

An air-retention test was made on tire BN-1 to determine how well it compared with the air retention of conventional tires.

This test was made according to MIL-T-5041D. The specification requires that the tire remain inflated for 24 hours, during which time normal growth in dimension occurs. The pressure is then adjusted to the operating level and held for another 24 hours. The air loss is based on the drop in pressure after adjustment. Following are the results obtained on tire GN-1:

Time	Pressure (psi)	Temperature (°F)
Initial	295	78
After one day	284	76
After adjustment	295	76
One day after adjustment	292	74
Air loss - 0.6%		

The air loss permitted by the specification is 5.0%. The 0.6% value, therefore, indicates that the filament-wound tire, after a successful cure, has excellent air-retention characteristics.

(b) Burst Strength

The burst strength requirement of the 30 x 8.8 22 PR tire is 1035 psi. The burst pressure attained by tire BN-2 was 1090 psi, which is 5% over the minimum requirements. Tire BN-4 burst at 930 psi which is 90% of the minimum requirement. Both of the bias nylon tires burst in the crown area.

Tire GN-1 attained a burst strength of 710 psi. The break was in the carcass at the heel. The cord structure in this tire was tight. Tire GN-2 burst at 550 psi due to a break in the RLA. Tight cord segments were also noted in this tire. Tire GN-4 burst at 675 psi at a sidewall blister.

Tire RG-3 had a burst strength of 545 psi. The carcass cords ruptured on the ID at an air port. Inspection showed a broken RLA in this area.

Tire RW-2 failed in the hydrostatic burst test at 700 psi. Tire RW-5 would not hold water pressure above 620 psi. This tire started leaking at a depression where cords are separated for the air port. The cord structure in this tire was loose.

The relatively low burst strength values of the filament-wound 30 x 8.8 subscale tires were due to a variety of causes. In some cases, the cord structure was tight and in the others loose. In either case, the load-carrying capacity of the tire was not uniform and some cords carried more of the load produced by the inflation pressure than others. The cure for this condition is completely uniform cord tension. Magnetic brake tension devices were installed on the winding machine late in the subscale tire program. Additional studies will be required to determine their value in tension control.

The failure of some of the subscale tires on burst was due to a break in the RLA. This situation was recognized and a stronger RLA was incorporated in the tire construction. No more failures of the RLA occurred after this change was made.

(c) Performance of Subscale Tires

Table XVIII shows a summary of the results obtained on the subscale tires.

Analysis of the general summary of results on the 30 x 8.8 tires shows that, in addition to mechanical failure, there was a high number of cure failures due to causes such as tightness and looseness of cords, RLA breaks, and variable cord lengths. Inasmuch as the filament-wound carcass must support the air-containing member (the inner liner) during cure, the need for accurate cord wrapping tension and placement is obvious. If the cords are too loose, insufficient support is provided. If they are too tight and not backed up by tread and sidewall rubber, the inner liner will be extruded between cords. The large-diameter cords (0.042 in.) and the spacing between cords inherent in a filament-wound construction do not provide the best support for the inner liner. Although the most obvious failure is that which occurs during cure, the low burst strength values and low air retention could be attributed to a weakened inner liner. Smaller cords (0.029 in. in diameter), as used in the 30 x 7.7 tire program, would provide more liner support and should be considered in future studies. A full molded inner liner should also be considered.

The strength requirements of radial tires would, however, not permit the use of smaller-diameter cords. The losses during cure of this type of tire were particularly high during the current program. This occurred in spite of the fact that the end count control of these tires,as shown in Table XVI, was very accurate. The causes of these cure failures can be attributed to heat shrinkage of the nylon during cure and lack of cord length control of the glass and wire reinforcements during winding. Correction of the shrinkage problems requires changing to a larger green carcass profile. Glass and wire cord, being essentially nonextensible, require very accurate control of the length of each wrap. The results of a wrap that is too loose or too tight are shown in the summary in Table XVIII, which shows that cure failures were encountered in radial wire tires under each condition. In fact, the tolerance limits in wire cord length

TABLE XVIII

GENERAL SUMMARY OF RESULTS ON SUBSCALE 30 X 8.8 TIRES

Bias Nylon (8 plies)

BN-1 - Cured OK. Tight cords. Cord angle out of specification.
BN-2 - Cured OK. Crown burst 1090 psi.
BN-3 - Cured OK. New cord path. Failed on air retention test.
BN-4 - Cured OK. Crown burst 930 psi. Failed on air retention.

Geodesic Nylon (4 plies) (6 breakers)

GN-1 - Cured OK. Tight cords. Bead heel burst 710 psi. RLA break.
GN-2 - Cured OK. Tight cords. Burst at 550 psi. RLA break.
GN-3 - Lost during cure due to crimped fill line.
GN-4 - Cured OK. Burst at 675 psi. Failed on air retention test.

Radial Nylon (4 plies) (6 breakers)

RN-1 - Lost during washout due to defective drain valve.
RN-2 - Lost during cure. High cord shrinkage during cure.
RN-3 - Lost during cure. High cord shrinkage during cure.
RN-4 - Lost during cure. High cord shrinkage during cure.

Radial Glass (3 plies) (6 breakers)

RG-1 - Lost during cure. Tight wrap. Short cord length.
RG-2 - Lost during cure. Tight wrap. Short cord length.
RG-3 - Cured OK. Loose wrap. Burst at 545 psi at air port.
RG-4 - Lost during cure due to sidewall rupture.
RG-5 - Cured OK. Loose wrap. Burst at 620 psi at bead ledge.

Radial Wire (2 plies) (4 breakers)

RW-1 - Blistered during cure. Loose wrap.
RW-2 - Cured OK except for one blister. Loose wrap. Burst at 700 psi in blister.
RW-3 - Lost during cure. Tight wrap. Cavity in shoulder area.
RW-4 - Lost during cure. Cavity in shoulder area.
RW-5 - Cured OK. Loose wrap. Burst at 450 psi at port area.

based on the analysis of the loose- and tight-cord tires must be within a 0 to 0.45% range in the overall tire assembly. It is doubtful if such close dimension control can be realized in commercial practice. These results, however, emphasize the need for "total assembly control" which can only be achieved by an intensive study program.

(3) Nondestructive Test Methods

(a) Visual Inspection

The inspection of conventional tires is a relatively uncomplicated process because it is possible to use visual inspection with reasonable expectation of detecting flaws. This is because the open structure of a conventional tire permits viewing both the inside and outside of the tire. Other more sophisticated techniques such as fluoroscopy, radiography, ultrasonic, infrared, and microwave may be used on conventional tires if desired (Ref. 1). Visual inspection, however, is still the most popular NDT method. The inspection techniques that can be used in filament-wound tires are, however, somewhat limited because of the closed structure inherent in this type of tire.

(b) Ultrasonics

An ultrasonic technique was considered but was eliminated because of the need for a transmitting transducer on one side of the section being examined and a receiving transducer on the other side. This scanning procedure is not feasible for F/W tires. The usefulness of this technique for inspection of filament-wound tires would be definitely limited.

(c) Infrared

The infrared NDT technique has been used to detect tire delaminations and temperature buildup during dynamic operation (Ref. 2). A test method that can be used under static conditions, however, is needed for filament-wound tires.

(d) Microwave

Microwave inspection techniques have been proposed as NDT methods for tires (Ref. 3). A short study of microwave inspection was conducted at Aerojet's Sacramento facility on two tires (30 x 7.7) from a previous program. Visual inspection showed no defects. The tires were given a cursory examination to determine the optimum inspection band. The Ka band (26 to 40 GHz) and K band (18 to 26 GHz) were used. The Ka band equipment provided adequate penetration but the initial investigation revealed no defects. A complete evaluation of this technique would require an extensive study of tires with built-in defects.

(e) Holography

Holography has been used experimentally to study defects in conventional tires (Ref. 4). The results of a study performed for General Tire and Rubber Company by GC Optronics, Inc. showed that such structural features as tread, liner, fabric, and calendar splices were clearly revealed. Correlation between radial-force variations and fringe concentricity (particularly in the turnup region) was observed. Holographic nondestructive testing is based on two holographic recordings of the same object in a single photographic emulsion with the object having been slightly displaced between recordings. When such a hologram, containing these two wavefronts, is reconstructed, the two wavefronts are simultaneously recreated. Variations occur in the geometry of a fringe, which relates to the deformation of the surface. The deformation of the object depends on the significant structural strength of material properties as well as the defects. Information about these properties and characteristics can be directly obtained from the holographic interference patterns. This technique could be considered for application to the inspection of filament-wound tires.

(f) Radiographic Inspection

A radiographic NDT technique has been reported as giving better than 0.7% sensitivity through the sidewalls of a filament-wound tire (Ref. 1). The authors of this study concluded, "The application of this technique as a method of quality control during production of this tire may be expensive but will be useful during production and during periodic maintenance inspection of the aircraft."

(g) Fluoroscopic Inspection

The fluoroscopic NDT method was adopted for use in the current program because the technique of using this method has been in use at General Tire and Rubber Company for several years and has proven quite successful for detection of flaws in a tire carcass. The fluoroscopic unit used is a Picker Fluoroscope, a 100 kva unit with 500-watt peak power. It is adapted to Polaroid photographic capability. With this instrument, it is possible to determine the angle of the cord path, foreign objects, blister or bubbles, inner liner separations, and sand clinging on the inside of the carcass. The density and mass of the RLA and carcass along the ID do not permit detection of defects in this area and, therefore, limit the usefulness of fluoroscopic examination. A study of advanced techniques for NDT of filament-wound tires may provide the information needed for complete inspection of the finished product.

(4) Quality Assurance Plan

Quality assurance was considered of major importance in this manufacturing methods program. The primary objectives of quality assurance were to record and document variables associated with tire quality, and to use the results of these findings to improve methods and processes to assure that the manufacturing processes produces a tire of the quality level designated by drawings and specifications. The approved quality assurance plan covered the following areas.

(a) Procured Material Control

Quality Engineering reviewed purchase requisitions and prepared inspection procedures for purchased raw materials, assemblies, and services. The purpose of this review was to assure that specific quality requirements, such as compliance with applicable specifications, certifications, technical data, and identification of materials, were a part of the purchase order. Inspection instructions listed the sequence of characteristics to be inspected, inspection techniques, and tools or gages to be used, and provided space for "acceptance stampoff" of characteristics by the inspector.

Because of the proprietary nature of this program, the greater portion of the productive raw materials were provided by General Tire and Rubber Company (GT&R), Akron, Ohio. Materials were accepted on the basis of an acceptable certificate of conformance. In accordance with accepted industry practice, the rubber compounds were certified by the compounder and the textiles were certified by the textile engineer. In addition to these certifications, laboratory evaluation work was performed (adhesive testing, for example) to insure conformance with the prescribed properties. All other material (glass roving, glass fabric, valve parts, etc.) was purchased from Aerojet suppliers who have consistently met standards of quality and reliability established by the company and verified by survey and/or performance. These materials were accepted at Receiving Inspection on an acceptable certification of conformance, unless otherwise specified. Non-conforming materials detected during inspection were documented, identified, and segregated for nonconforming material action.

(b) Procured Sercies (GT&R)

The final fabrication and testing of filament-wound tires were performed by General Tire and Rubber Company in accordance with Aerojet's purchase order. This included the application of the tread, sidewall, filler, and chafer material, and final curing. Internal quality control methods presently being used in producing aircraft tires were employed in this program.

The areas of control were in-process testing of raw materials, surveillance inspection throughout the fabrication process, final visual inspection, and fluoroscopic inspection.

(c) Engineering Documents

Quality Engineering reviewed engineering documents pertinent to the program to identify special controls, processes, test equipment, fixtures, and tooling to assure product quality.

(d) Integrated Inspection Planning

The in-process inspection planning was integrated with the Engineering Manufacturing Instruction (EMI) for each tire size and construction. These EMI's were used during the process development phase of the subscale and prototype tire fabrication. Quality Engineering reviewed these documents and set up fabrication inspection points to assure satisfactory product quality.

(e) In-Process Control

Quality Engineering performed in-process surveillance throughout the process development phase of the program to assure that variables associated with the tire quality were accurately measured, recorded and documented in the EMI. After fabrication of the tires was complete, Quality Engineering checked these for final workmanship and dimensional requirements.

(f) Final Inspection

Final product acceptance at Aerojet consisted of verification of complete documentation, visual inspection for good workmanship and dimensional checks as required to assure acceptability to GT&R tooling. Each tire shipped to GT&R was accompanied by an inspection acceptance sheet. Final acceptance at GT&R was in accordance with established standards presently being employed on military aircraft tires. These standards included visual inspection for workmanship and sample fluoroscopic inspection for carcass defects, tread blows, tears, blisters, etc. Qualification and final static and dynamic testing were in accordance with Specification MIL-T-5041D and USAF Drawing No. 60D2561-J.

SECTION VI

PROCESS AND EQUIPMENT DEMONSTRATION (TASK D)

The purpose of this task was to evaluate the design, processes and equipment by the fabrication and testing of prototype 49 x 17 26 PR tires. During the performance of this task, tire design and fabrication procedures, tool design, and processing methods were critically analyzed and, where necessary, were modified to improve the quality of the finished product. Static tests were conducted according to MIL-T-5041D and dynamic tests were conducted according to USAF Drawing 60D2561-J.

1. EQUIPMENT AND PROCESS CHECKOUT

a. Filament-Winding Machine

The tire-winding machine was checked out previous to acceptance in accordance with "Checkout Process Specification, 49 x 17 Tire Winding Machine" Appendix IV). One of the improved features of this machine is the ply insulation applicator which provides for the application of the insulation to the carcass while the carcass is in the machine. The ply insulation applicator performed satisfactorily on the sides of the carcass. The flat crown of the 49 x 17 prototype tire, however, does not permit the use of the applicator in this area because of the distance between the pressure roller and the crown of the tire. A modification of the platform on which the applicator is mounted and of the control cam would be required to permit the use of the mechanical ply stock applicator on this size of tire. During the current program, the insulation layer at the crown was applied as a 12-in.-wide sheet. This procedure was quite satisfactory. The ply insulation mechanical applicator provided a substantial time saving over the hand technique as used on the subscale tire. A detailed procedure for tire-winding machine operation is presented in Appendix V, "Instruction Manual for Toroidal-Winding Machine."

b. Process Checkout

The following preliminary manufacturing procedure was prepared for the filament-wound 49 x 17 26 PR tire.

(1) Materials and Components

- Rim-locking assembly (RLA): glass fabric and glass roving reinforced plastic composite
- Winding mandrel: SR-6 sand composition
- Textile cord: Type 6-6 nylon 3360/2

Elastomers as follows:

Inner liner: 0.025-in. gage of Compound XK-985B (Neop/NR/SBR)
XGP-192: 13-in. width of Compound XK-985B
XGP-191: 2-in. width of Compound XK-985B

Ply stock: 0.025-in. gage of Compound XK-984A (NR/BR)
XGP-193: 13-in. width of Compound XK-984A
XGP-194: 2-in. width of Compound XK-984A

(2) Terminology

For definitions of the terms that are used in this section of the report, refer to the list "Definition of Terms" that appears following the Table of Contents.

(3) Fabrication Procedures

(a) Mandrel

- Fill the bottom of the mold with SR-6 sand material.
- Lower the insert into the mold, locate, and force in place.
- Tamp sand around the mandrel and compact it well.
- Smooth off top edge and remove insert and center plug.
- Lower the bond-locating device into the inner wall until it seats in lower plate and forms lifting channels.
- Cure 2-1/2 hr at 250°F in an air-circulating oven.
- Invert the mandrel and cure 1-1/2 hr at 250°F.
- Attach the sling to the turnover plate and invert again.
- Complete above steps for other mandrel half.
- Pick up the second mandrel half with bonding device.
- Apply paste of SR-6 and Steinex C to edge of mandrel.

- Mate the two halves and position with adjustable screws.
- Cure the bonded mandrel one hour at 250°F.

(b) Rim Locking Assembly (RLA)

- Line the mandrel with Style 341 glass fabric prepreg.
- Apply second layer of Style 341 glass fabric prepreg.
- Wind S-901 prepreg roving over fabric prepreg.
- Build up layers of fabric and roving to specified thickness.
- Wind one edge of the RLA with S-901 prepreg roving, under 10 lb of tension, to the specified contour.
- Position the valve reinforcements according to Aerojet Drawing No. 1269203 (See Figure 28, page 30).
- Wind S-901 prepreg roving over reinforcements to opposite edge.
- Wrap the wound shell with nylon shrink tape and cure 2 hr at 200°F, plus 2 hr at 250°F, plus 4 hr at 325°F.
- Remove the tape and buff off resin flash.
- Bore holes 180° apart, face off the flange pad and cut chamfer.
- Sandblast the RLA shell and apply Chemlok 205 primer and Chemlok 220 cover coat. Dry 15 minutes between coats.
- Clean the bushing and nut with Hughson B727-6 paste.
- Apply Chemlok 205 primer and Chemlok 220 cover coat to both.
- Assemble the bushing and nut in RLA shell and tighten.

- Drill holes and insert dowel pins.
- Wrap the RLA shell with one layer of XGP-192 liner rubber.
- Vacuum bag the assembly and cure 60 minutes at 285°F.

(c) Mandrel-RLA Assembly

- Insert the rubber-covered RLA into the mandrel.
- Apply one layer of XGP-191 liner-rubber radially around the mandrel and RLA.
- Apply two layers of XGP-191 circumferentially from bead to bead.
- Apply one layer of XGP-192 along the RLA ID and stitch to the XGP-191.
- Vacuum bag cure the assembly 120 min. at 285°F.
- Cool the assembly slowly.
- Blend the RLA edge into the mandrel contour with XGP-194, ply insulation.
- Wash the cured inner liner with toluene and buff lightly.
- Brush a layer of XK-985B liner dispersion over inner liner.

  NOTE: Dispersion to consist of 22% XK-985B in toluene by weight.

(d) Cord Treatment

- Make up a 25% by weight dispersion of XK-984A ply stock in white gas. Mix thoroughly.
- Place dispersion in dip tank and thread two cords through tank and Teflon wiper.
- Run dispersion-coated cords past two 7-ft-long Chromalox radiant heaters and over spools for two passes.

- Wind on two spools. Total travel - 80 ft.

- Control speed and heat to produce tacky but dry surface on cord.

(e) Winding of Carcass

- Install the mandrel-RLA assembly in the filament-winding machine and assemble winding head.

- Apply the starter layer by building up one ply of XGP-194 from bead to bead and one layer of XGP-193 along the ID.

- Attach one cord to the starter layer and wind several revolutions. Adjust the ratio control to obtain the correct cord spacing (approximately 0.080 in.).

- Remove the cord wrap and attach six cords.

- Wind one ply of cord to produce:
  Crown angle - 40°
  Total ends per ply - 1230 ± 30
  Ends per inch - 14.14 ± 0.14

- Apply one layer of XGP-194 from bead to bead.

- Apply one layer of XGP-193 along the ID.

- Wind second ply of cord and continue applying insulation and cord until eight cord plies have been applied. NOTE: The winding direction is to be alternated from ply to ply.

- Apply layer of XGP-193 and XGP-194 over last ply of cord and remove carcass from machine.

- Wrap the carcass in polyethylene film and place in shipping crate.

(f) Component Assembly

- Cleanse outer carcass surface with white gas.

- Apply two 0.030-in. layers of XK-985B on carcass ID.

- Attach rectangular filler strips on each side of heel.
- Apply 3.25-in.-wide chafer around filler strip and along sidewall.
- Apply 5.25-in.-wide chafer over first chafer.
- Apply lower sidewall from chafer to 33.0-in.-diameter.
- Apply 14-in.-wide breaker over crown so cords are at 51° angle.
- Mount carcass on Orbitread machine.
- Insert program control card in machine and apply tread.
- Remove carcass from Orbitread machine and set up in washout equipment.
- Introduce 140°F water into cavity and soak for 90 minutes.
- Invert carcass and soak for 60 minutes.
- Remove sand and water by vacuum extraction.
- Insert segmented curing ring and inflate to 5 psi.
- Lubricate chafer area and exterior of tire.
- Awl at top of bead heel filler to 0.010-in. depth at 2-in. intervals.

(g) Curing

- Connect high-pressure lines, thermocouple monitor, and pressure gage to press. Check cure cycle.
- Lower carcass into mold and install curing line.
- Close mold and start cure cycle.
- Open mold and remove water in tire by vacuum.

- Trim flash and vents.
- Awl to depth of 0.25 in. every 4 in. between bead corrugations.
- Visually inspect exterior of tire.
- Inspect for blisters, separations, and cord path angle with fluoroscope.

2. FABRICATION OF 49 X 17 PROTOTYPE TIRES

a. Technical Review

During the preliminary phases of the fabrication effort, several problem areas were reviewed by technical representatives of AFML, GT&R, and Aerojet. A summary of the discussion is presented here.

(1) Cord Placement

Emphasis was placed on the importance of accurate cord placement in obtaining cured tires for testing. If the cords are not accurately placed and do not have the proper spacing, the inner liner may blow out during the cure. The ultimate and most desirable condition is the parallelism of cords evenly spaced and completely surrounded by rubber as obtained in calendered cord fabric. This condition cannot be completely achieved in filament winding because of the large cord diameter (0.042 in.) and the simultaneous movement of the mandrel and the winding head. It is also impossible to stitch the ply insulation between the cords when they are close together. It is necessary, however, to approach this condition as closely as possible.

The cord angle is also very critical and it is desirable that it be within the specified range to provide the calculated burst strength and good dynamic performance. The optimum cured crown angle was described as 35°. The crown angle as wound should be 39.4° to produce the above cured angle. The wound angle, however, is dependent on the cam design and is not subject to operator manipulation. The cured crown angle of 35° was selected to ensure tread retention during high-speed operation. Tests on conventional tires, however, showed that tread retention is maintained with a cured crown angle of 36.5° ± 1°. This angle was selected as the target for the 49 x 17 prototype tires.

(2) Cord End-Count

The control of end count is also considered very important. The target in the initial fabrication program was 1200 ends per ply for the neutral axis. For a tire with a cured crown angle of 35°, this end count would produce a tire with a burst factor (burst pressure/operating pressure) of 4.0. The burst factor, however, is dependent on the cured angle as well as the end count of the reinforcement. It was determined that a somewhat higher end count was required for the crown angle obtained during cure. The minimum burst factor required by the specification was 3.50. It was desired to maintain a safety margin over this minimum. A target of 1230 ± 30 ends per ply was selected for the 49 x 17 tire to provide a burst factor of approximately 3.70.

(3) Stitching Rollers

It was suggested that a pressure roller be mounted on the frame for use in stitching down the cords in the shoulder area. It was assumed that stitching would hold the cords in place and prevent the rolling of cords that had occurred in the filament-winding of the 30 x 8.8 subscale tires. If a roller were attached to the frame of the machine, it would have to apply pressure immediately after the cord was laid down. This would require a set of two rollers on each side of the mandrel to function when the cord angle was reversed after each ply. It was decided to postpone the installation of stitching rollers until the efficiency of the cement-coated cord in maintaining cord placement was determined.

(4) Inner-Liner Integrity

A method of checking the integrity of the inner liner before and after wrapping was suggested as a processing safeguard. The current practice of building up three layers of calendered stock for the liner should normally ensure a leak-tight liner. Various techniques had previously been tried for checking the integrity of the liner, and some had not proven successful. Pressurization with air or a halogen gas had been found unsatisfactory because, when this is done, the liner lifted off the mandrel and bagging occurred which could not be tolerated. The application of vacuum inside the mandrel and retention for a period of time was adopted and successfully used in the prototype tire program.

(5) Bleeder Cloth

To save time, it was suggested that a fabric bag be used as a bleeder cloth, instead of fabric tape, during the vacuum-bag curing of the inner liner. Although wrapping with tape is a rather time-consuming process, it provides a method for holding the inner liner tightly against the mandrel, an important requirement. Tape also is adaptable to the irregular shape of the part and is not easily distorted during the cure. To avoid wrinkles and folds in the inner liner, very accurate tailoring of a fabric bag would be required.

b. Processing Improvements

During the fabrication effort, a number of processing problems were encountered. The following is a brief discussion of the processing improvements that were adopted to alleviate these problems.

(1) Inner-Liner Fabrication

The planned fabrication procedure for the inner liner was circumferential winding of two-inch-wide tape from bead to bead. Three layers of inner liner were selected for the buildup to avoid leaks. During the early fabrication of prototype tires, considerable bagginess in the liner occurred at the edge of the RLA. This resulted in an undesirable buildup in this area. The problem was solved by applying the initial wrap radially. The second and third layers were applied as circumferential wraps.

(2) Bonding of Liner to Mandrel

A problem encountered in the filament-winding of the first tire was the formation of a bubble between the mandrel and the inner liner at the contact point between the rubber-covered mandrel and the carrier belt in the winding machine. This bubble caused cord stretching and distortion in the crown area. Bubble formation was attributed to liner separation from the mandrel because of repeated rotation of this assembly during machine setup. Normally, the inner liner is slightly adhered to the mandrel. The problem of the bubble formation was solved by application of a layer of inner-liner dispersion on the sand mandrel before cure of the inner liner at the crown extending outward two inches from the bonding line. This dispersion preserved the bond of the inner liner to the sand mandrel long enough to prevent bubble formation.

(3) Retention of Cords on Side of Carcass

Two cord payoff heads were employed in the first winding trials. It was found, however, that the tack of the cord was not adequate to hold it in place on the sides of the carcass. More rolling and sliding of cords appeared to take place on the 49 x 17 tire than was observed on the 30 x 8.8 tire because of the larger radius of the side wall. Variations in tension and winding speed were tried without success. To alleviate this condition, the cord was coated with a cement made from the ply stock and dried by festooning it between rollers and conveying it past Chromalox heaters. Figure 23 is a schematic layout of this operation. The cement-coated cord had excellent tack and showed very little sliding or rolling on the carcass. Six payoff heads were used successfully on all of the

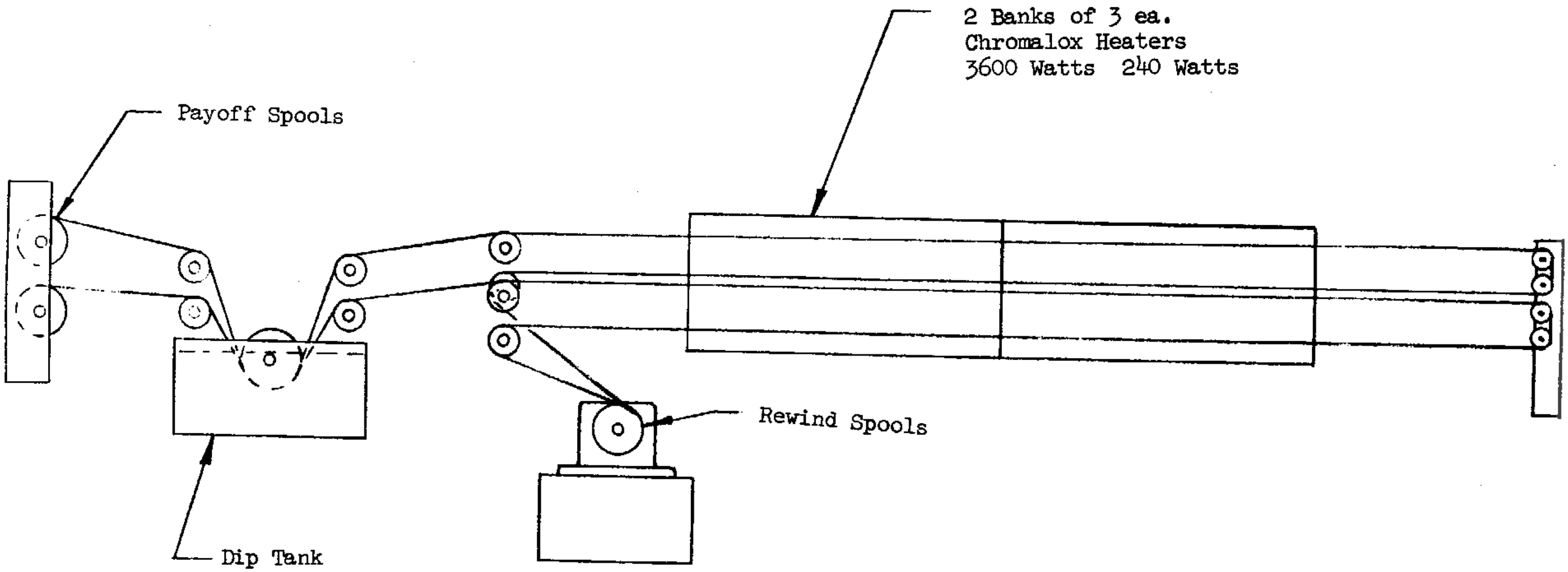

Figure 23. Schematic Layout of Cord Treating Equipment

49 x 17 tires. Cord crossovers were not entirely eliminated, however, and were more prevalent on the side of the carcass where the cord is carried under the RLA and up the side of the carcass. Complete elimination of cord crossovers in the winding pattern selected for this tire does not appear to be technically feasible. This winding pattern is based on the path produced by calendered parallel cord fabric laid on a flat drum and inflated from the inside preparatory to curing. This produces a reverse S curve in the cord path on one side, and the filament-winding process must duplicate it. In the winding of this path, the cord from the payoff head must cross over (in space) the cord already in place and then clear this cord before it is affixed to the carcass. The cord being laid down does not always clear the cord in place and a crossover occurs. A modification of the winding path or a lower end count, which would provide more space between cords, would reduce or eliminate crossovers.

(4) Cord Bridging

The cams for the T-120850 toroidal winding machine are designed to produce a rather abrupt change in direction of the cord when it passes from the side of the toroid to the inside of the toroid in order to produce the desired bias path on each side. In winding the 49 x 17 tire, it would be desirable for the cord to be perpendicular to the inside center line of the carcass. This is impossible because of the simultaneous movement of the mandrel and winding head. As a result of this movement and the large width of the 49 x 17 tire, bridging of the cords takes place on the inside between the two contact points on the edge of the RLA. This produces an air gap of 1/4 to 3/4 in. between the inside surface of the RLA and the layer of cords. It was necessary to hand stitch the cords to the ply insulation on the preceding layer to reduce this air gap. The remaining air, which could not be entirely eliminated by hand stitching, was forced out of the carcass by the segmented curing rings. This procedure was satisfactory in eliminating any deleterious effect caused by cord-bridging across the rim-locking assembly's inner side.

(5) Orbitread Equipment

The AMF Series 200 Orbitread Machine operated satisfactorily in the application of the tread on the 49 x 17 tire. It was not entirely satisfactory in the application of the sidewalls of this tire because of gouging by the stitcher in the area of receding curvature on the carcass. This occurred when the extruded strip was started at a tire diameter of 26 inches. When the start was made at 28-inches diameter or higher, no gouging took place. Because of this condition, the lower part of the sidewall was applied by hand using calendered stock.

(6) Adhesion of Inner Liner Compound to Rim-Locking Assembly

The purpose of covering the RLA with inner liner compound was to protect the composite's outside surface from the curing medium. Although excellent adhesion between these members was obtained in laboratory studies (see Table X on page 36), there occurred several instances of poor adhesion on the inside tire cavity after the final cure. While the blisters appeared between the rubber and the RLA presented an undesirable appearance, they did not interfere with RLA functioning. Longer solvent drying time and more hand stitching were tried but with only moderate success. Further investigation of this problem using higher curing pressures, special tie cements, or a lower final curing temperature is indicated.

(7) Open Splices in Inner Liner

Open liner splices were observed in a sectioned part of the last tire cured. The appearance was similar to that of an undercured condition or of an entrapped solvent. The liner had been subjected to two curing steps and had been checked for air retention after the first cure. An undercure was therefore, not indicated. A major design change in this specific tire required the attachment by adhesive bonding of a cured liner flap to the inner liner's main body. Considerable solvent evaporation time was provided; however, it is possible that residual solvent still remained. Provision for more complete solvent removal is indicated.

(8) Adhesion Between Plies

Separation between the inner liner and the plies and between individual plies was observed for the tires that failed to cure and the tires that failed uring dynamic testing. The tires that failed to cure properly contained inner liner openings. These openings permitted the curing medium to enter the cavity between liner and plies before bonding was accomplished. Separations were also caused during dynamic testing by sudden surges of inflation-air through the perforated liner.

Prevention of separation during curing can be achieved by avoiding inner-liner openings during fabrication. A technique to prevent inner-liner openings was tried. Three-ply inner-liner buildup and leak testing after the initial cure were followed in the fabrication effort to insure an integral liner. Liner surface buffing and the use of a Neoprene tie cement improved bonding of the cured liner to the uncured ply compound. Full molding of the inner liner was also considered. This technique, however, did not eliminate the difficult bonding of a cured Neoprene elastomer compound to an uncured compound of different elastomeric composition.

A proposed solution to the separations produced during dynamic testing was the removal of inner liner from the area of cord abrasion. This was done because cord abrasion produced performation to the outside of the RLA in the last tire tested. The validity of this proposed solution was not determined because of tire curing failure. Further investigation of this approach is recommended.

c. Fabrication Operations

A detailed procedure for all fabrication operations for the 49 x 17 tire is presented in Appendix VI, entitled "Engineering Manufacturing Instructions" (EMI). Figure 24 shows a process flow chart for tire-carcass buildup. The following is a discussion of process modifications and the man-hour requirements for these operations.

(1) Mandrel

The operations followed in the fabrication of mandrels are those shown in Paragraph (a) of Section IV, 1 - Equipment and Process Checkout. The tooling performed satisfactorily and no modifications were required.

It was found after fabrication of the first 49 x 17 prototype tire that the section width of the cured tires was larger than desired, so a decision was made to reduce the mandrel width starting with tire LBN-3[10]. This was accomplished by scraping out 1/4 in. of the mandrel material on each side of the center plug before curing the mandrel.

A study of the effect of compacting pressure and cure time on the sand mandrel washout time was made to establish optimum processing conditions. Two-inch diameter by four-inch long plugs were molded from SR- 6 sand compound and subjected to varying cure times and compacting pressures. The plugs were then immersed in 125°F water and the time for complete disintegration was determined. The standard cure of 2-1/2 hr at 250°F in the mold and 3-1/2 hr at 250°F out of the mold was used for the compacting test. The standard cure of 2-1/2 hr at 250°F in the mold plus varying cure times out of the mold on specimens compacted under 8 psi pressure was used in the investigation of cure time. The results of these studies were:

Effect of Compacting Pressure		Effect of Cure Time	
Pressure (psi)	Washout Time (min.)	Total Cure (hr)	Washout Time (min.)
4	2	6	2
8	3	8.5	2
16	4	14.5	4

The test results indicate that higher compacting pressures and long curing times do increase the washout time. The increased washout time is moderate and would not produce any major difficulties in processing. The results indicate that long cure times should be avoided to prevent low solubility and long washout time.

The fabrication of the sand mandrel is a two-man operation, requiring ten hours for completion.

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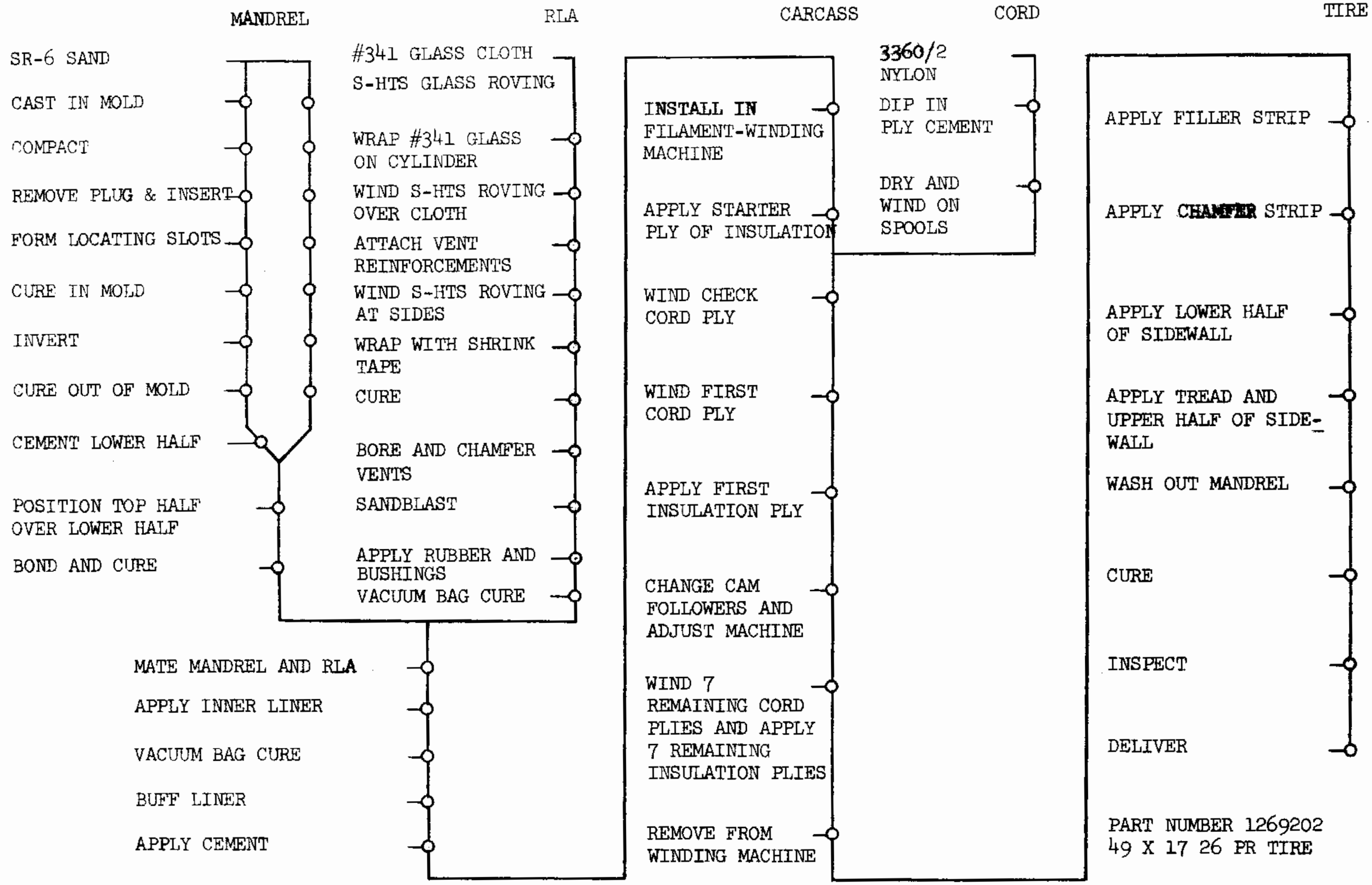
[10] LBN - large bias nylon



PROCESS FLOW CHART

49 X 17 26 PR FILAMENT-WOUND TIRE

Figure 24

(2) Rim Locking Assembly (RLA)

The RLA was fabricated according to the procedures described in Paragraph (b) of Section IV, 1 - Equipment and Process Checkout. The only modification required for the tooling was the addition of inserts in each of the vent openings to improve the locating of the holes for the drilling operation.

Figures 25 and 26 show the RLA shell before and after being covered with rubber. The rubber covering was reduced from two thicknesses to one on tire LBN-7 and all succeeding tires to provide less buildup on the inside of the carcass and easier insertion of the curing mold rings. A 1.6-lb weight saving resulted from this reduction.

The fabrication of the RLA is partially a two-man operation and partially a one-man operation. A total of 32 man-hours are required for this operation.

(3) Mandrel-RLA Assembly

The fabrication procedure for the mandrel-RLA assembly, which includes the inner liner fabrication, is described in Paragraph (c) of Section IV, 1 - Equipment and Process Checkout. Figure 27 shows a wrapped mandrel ready for vacuum cure. The inner liner was checked for leaks after cure by subjecting it to a vacuum of 15-in. of Hg for five minutes. Retention of vacuum was considered evidence of a leak-proof liner. The mandrel-RLA assembly fabrication is a one-man operation requiring ten man-hours.

(4) Cord Treatment

The procedure used for coating the cord with cement is described in Paragraph (d) of Section IV, 1 - Equipment and Process Checkout. This is a one-man operation, requiring twenty man-hours per tire.

The coating of the 3360/2 nylon cord with rubber cement to improve uncured adhesion during fabrication subjects the cord to a moderate amount of heat and tension. A study of the effect of this treatment on tensile and elongation was made to determine if any change in properties took place. Fourteen-inch lengths of the uncoated and coated cord were wrapped around a capstan and pulled to produce tensile failure on the Instron test machine. The elongation was measured on a 10-in. measured length of the cord. The results

169-039

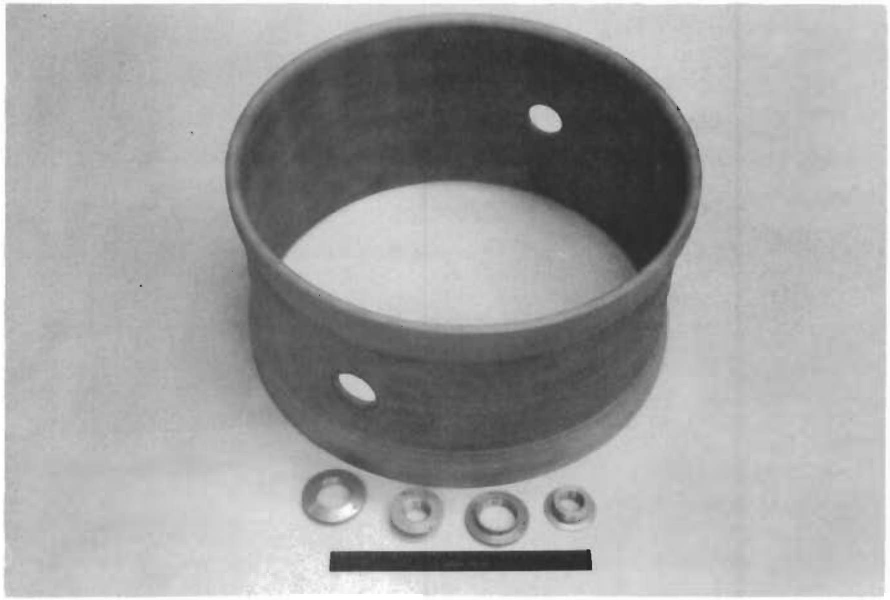


Figure 25. 49 x 17 Rim-Lock Shell with Bushings and Nuts

169-038

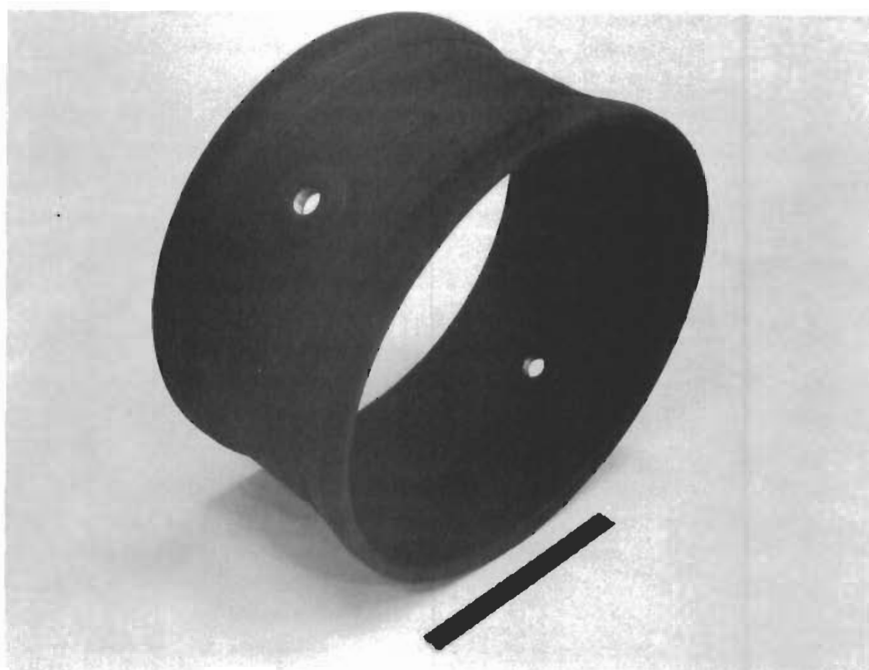


Figure 26. Rubber-Covered 49 x 17 Rim-Locking Assembly

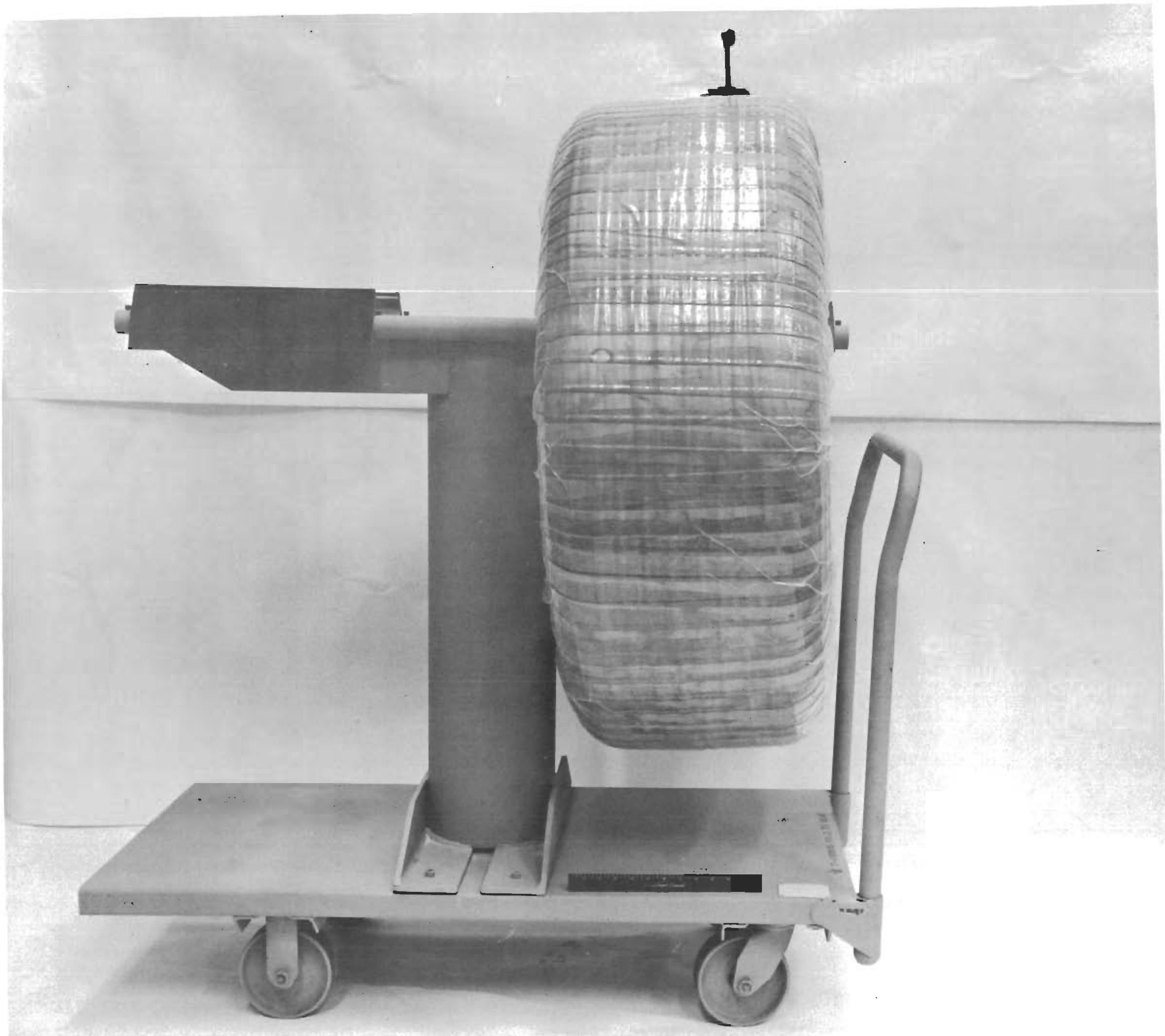


Figure 27. Wrapped Mandrel Body for Cure

are tabulated below:

Specimen Number	Treatment of Cord		Ultimate Load (lb)	Elongation in 10-in. (%)
1	Uncoated		118	15
2	Uncoated		116	16
3	Uncoated		117	16.5
4	Uncoated		119	18
		Average	117.5	16.5
5	Coated		114	16
6	Coated		112	16
7	Coated		115.5	16.5
		Average	113.8	16.2

The results indicate that coating of the cords does not produce any major change in the properties of the cord. The nominal tensile strength of the 3360/2 nylon cord has been listed as 120 lb[9]. The slightly lower tensile strength shown in the above data can be attributed to the treatment given this cord in the application of the bonding material by the producer of the cord and is not considered a significant reduction in strength. The fabric laboratory of General Tire concurred in these findings.

(5) Winding of Carcass

The procedure used in winding of the tire carcass is described in Paragraph (e) of Section IV, 1 - Equipment and Process Checkout. Figure 28 shows the filament winding of a 49 x 17 tire. This is basically a one-man operation. Total time requirements can be reduced, however, by an additional helper for preparation and assistance in insulation application. The total fabrication time for eight windup plies is twenty man-hours. An additional two man-hours are required to install the mandrel and RLA in the machine, and three man-hours to remove, measure and prepare the mandrel for shipment.

Table XIX lists the values for cord ends per ply of each tire.

The progressive improvement in operation and control of the filament-winding machine is shown by the trend of the average cord ends per ply toward the target value of 1230. Both manual control and automatic feedback control were used in the winding of tires. Although the automatic device provides good control of total end count, the cord

[9]General Tire and Rubber Co.

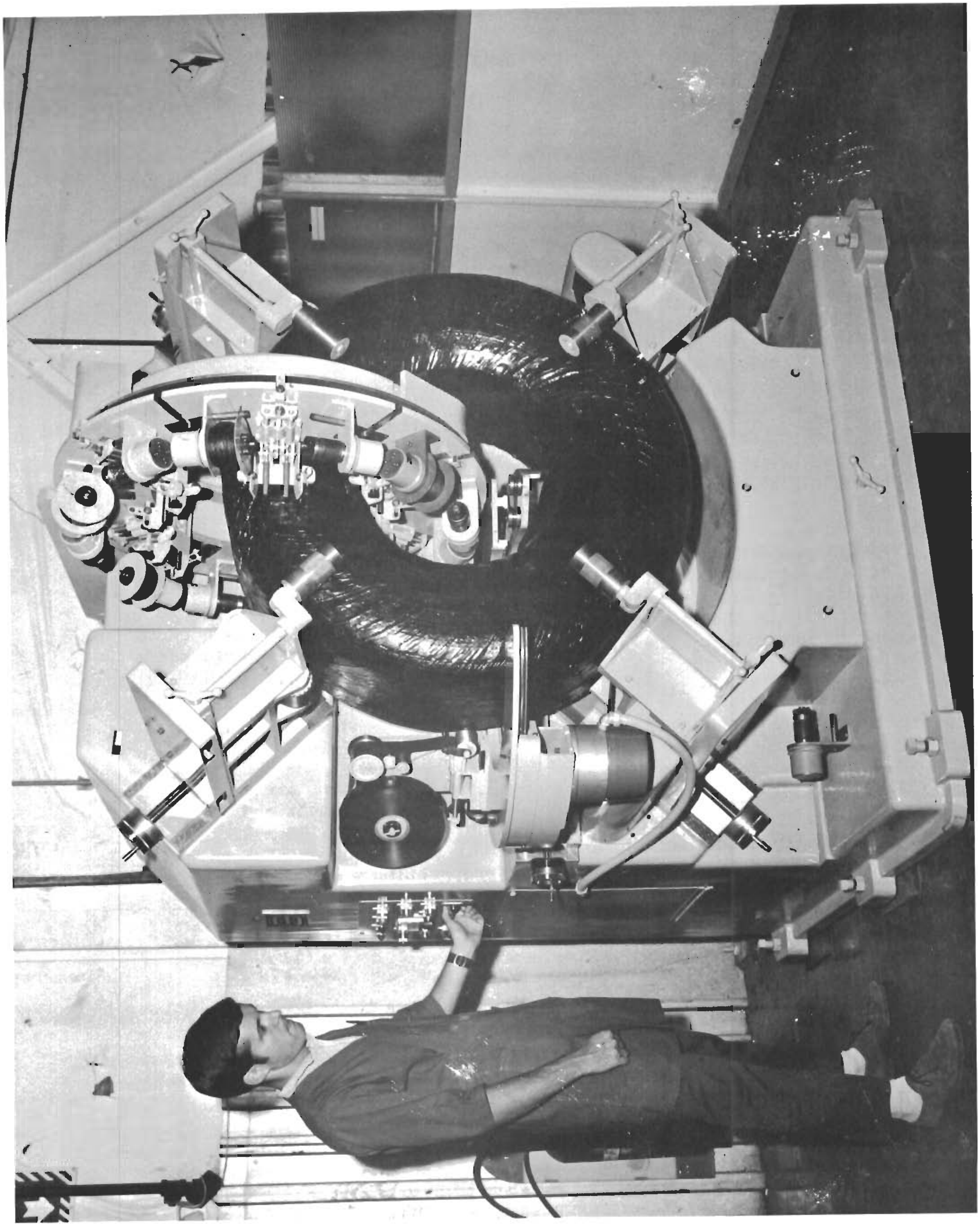


Figure 28. Filament Winding of 49 x 17 Tire

968-873

TABLE XIX

CORD ENDS PER PLY - 49 X 17 26 PR TIRES

Ply No.	LBN-1*	LBN-2*	LBN-3*	LBN-4*	LBN-5*	LBN-6*	LBN-7*	LBN-8*	LBN-9*	LBN-10*	LBN-11*	LBN-12*	LBN-13*	LBN-14*	LBN-15*
1	1101	1371	1243	1260	1278	1260	1260	1260	1230	1254	1254	1236	1236	1236	1296
2	1250	1300	1242	1260	1284	1260	1236	1212	1212	1212	1242	1236	1230	1242	1200
3	1176	1287	1242	1242	1260	1248	1230	1236	1248	1206	1230	1242	1224	1230	1248
4	1176	1302	1278	1272	1260	1258	1248	1230	1230	1212	1242	1218	1218	1230	1236
5	1208	1344	1224	1206	1224	1284	1254	1224	1218	1248	1236	1230	1248	1236	1260
6	1236	1337	1230	1260	1230	1230	1212	1236	1206	1248	1230	1230	1230	1224	1243
7	1266	1230	1260	1242	1282	1230	1254	1230	1218	1260	1230	1242	1222	1224	1236
8	1200	1191	1236	1206	1260	1230	1242	1212	1212	1230	1212	1230	1206	1218	1248
Total	9613	10362	9955	9948	10078	9990	9936	9840	9774	9870	9876	9864	9814	9840	9967
Average	1202	1295	1244	1244	1259	1246	1240	1230	1222	1237	1234	1233	1227	1230	1246

*Tire designation

spacing is not as uniform as desired because of a tendency to over-compensate. In manual operation, the operator can make changes rapidly and can avoid over-compensation. Automatic control, however, is desirable and would be a necessity in a production operation.

(6) Orbitreading and Mandrel Removal

The procedures used in preparation of the tire for application of the tread and for mandrel removal are described in Paragraph (f) of Section IV, 1 - Equipment and Process Checkout. The application of the filler strip and chafer strips is performed by one operator. Orbitreading is a one-man operation as is the mandrel removal. The time requirement for these operations is eight man-hours. The vacuum process for mandrel removal was used after the fabrication of tire LBN-1. The efficiency of this operation is shown by the following values, Table XX.

TABLE XX

MANDREL REMOVAL DATA - 49 X 17 F/W TIRES

Tire No.	Mandrel Wt. (lb)	Mandrel Weight Removed (lb)	% Removal
LBN-1	353	148	42
LBN-2	355	351	98.9
LBN-3	307	306.8	99.9
LBN-4	309	308.2	99.7
LBN-5	312	N/R	N/R
LBN-6	333	316.8	95.1
LBN-7	314	311.9	99.7
LBN-8	319	319	100
LBN-9	325	325	100
LBN-10	324	324	100
LBN-11	332	332	100
LBN-12	328	318	97.0
LBN-13	330	328.9	99.7
LBN-14	310	N/R	N/R
LBN-15	308	305.5	99.4

(7) Curing

The procedure used in curing of the tire is described in Paragraph (g) of Section IV, 1 - Equipment and Process Checkout. A small-diameter quick-disconnect fill line in the curing equipment was replaced by a large-diameter straight-through line after the curing of tire LBN-1 which was lost in the cure because of sediment in the line. A pressure gage was also installed on the drain line to ensure full curing pressure. A thermocouple was placed in the internal fill line at the flexible line connection after the cure of tire LBN-3 which was lost in the cure when it was inadvertently filled with 250 psi air instead of hot water. This thermocouple provided continuous monitoring of the inside temperature during cure. The mold external temperature was also monitored.

d. Estimated Production Fabrication Time

Preparation, loading, unloading, and curing are one-man operations requiring five man-hours.

The man-hour requirements for a full scale production operation were estimated on the basis of the following assumptions: (1) adequate production equipment would be provided; (2) the winding machine would be automated to the maximum degree possible; (3) the mandrel and rim-locking assembly would be fabricated by standard short-cycle procedures; and (4) the cord and rubber would be supplied ready for immediate installation in the winding machine. Table XXI is a comparison of these high-volume production man-hour requirements for a filament-wound 49 x 17 tire compared with the actual man-hour requirements of a small scale operation.

Table XXI Man-Hour Requirements

Operation	Low Volume Production (Actual)	High Volume Production (Estimated)
Mandrel Fabrication	10	1.00
RLA Fabrication	32	2.20
RLA-Mandrel Mating	10	2.50
Cord Cementing	20	0
Mandrel Installation in Machine	2	1.25
Winding of 8 plies	20	9.00
Carcass Removal from Machine	3	1.25
Filler, Chafer Strip Application	2	1.50
Orbitreading	2	1.50
Mandrel Washout	4	2.50
Loading, Curing, Unloading, Finishing	5	3.00
Total	110	25.70

It will be noted that the estimated man-hour requirements for a full scale production operation for the 49 x 17 26 PR filament-wound tire are substantially lower than those required for low volume production. These estimates are based on maximum utilization of men and equipment. A meaningful comparison with the man-hour requirements of conventional 49 x 17 26 PR aircraft-tire production is not available because of variations in manufacturing procedures between producers.

e. Weight Reduction

Potential weight saving is one of the advantages of filament-wound tires; so, a continuing study was made of areas where weight reductions could be made. The specified maximum weight of the 49 x 17 tire when manufactured to USAF Drawing 60D2561-J is 215 lb. In the "K" revision of this drawing, the nonskid depth was increased from 0.30 to 0.40 in. A maximum weight for this tire has not yet been established, although it would probably be approximately 218 lb. A conventional tire fabricated to this latest revision by General Tire was reported as weighing 189 lb. The estimated weight of the original design of the filament-wound 49 x 17 tire was 182 lb. This represents a weight saving of 16.5% when compared with the estimated specified maximum weight of 218 lb. The weight saving of the filament-wound tire, when compared with the reported actual weight of a conventional tire, was 3.5%.

A weight of 196 lb for tire LBN-2 exceeded the target weight of 182 lb. The following areas of weight reduction in tire LBN-3 and all succeeding tires are:

Mandrel width and end count reduction	3.00 lb
ID elastomer gage reductions	2.41 lb
Tread shoulder reduction	3.34 lb
Sidewall gage reduction	4.50 lb
Total estimated weight reduction	13.25 lb

The weight of tire LBN-4 was reported by GT&R as being 182 lb, so the changes produced the desired reduction in total weight. An additional reduction in weight of 6.0 lb was produced by a reduction in the ply insulation thickness from 0.025 to 0.020 in.

Table XXII shows the component and total tire weights.

TABLE XXII

MATERIAL WEIGHTS (LB) - 49 X 17 F/W TIRES

Tire No.	RLA Shell	F/W Carcass	Tread and Assembly	Total Tire
LBN-1	23.0	126	69.0	---
LBN-2	23.5	124	72.0	196
LBN-3	22.5	124	66.0	182
LBN-4	22.0	123	65.1	182
LBN-5	21.5	123	N/R	184
LBN-6	22.6	123	53.0	176
LBN-7	22.0	120	58.0	178
LBN-8	21.8	123	65.2	180
LBN-9	22.0	123	61.3	180
LBN-10	20.8	126	63.4	180
LBN-11	22.2	124	53.0	184
LBN-12	20.0	115	60.1	173
LBN-13	22.0	111	64.0	174
LBN-14	20.0	111	N/R	N/R
LBN-15	127.5	233	62.0	296

The data in Table XXII show that the reductions in weight of the RLA and in ply insulation thickness contributed very little to a reduction in total weight. The major contribution was made by a reduction in the tread and component assembly. Tires LBN-12, LBN-13 and LBN-15 contained modified RLA configurations. The lowest total tire weight of the remainder was shown by tire LBN-6 which also had the lowest tread and assembly weight. Potential future reductions in this area could be the use of exact weight treads and sidewalls.

e. Testing and Analysis

The purpose of this phase of the work was to demonstrate the performance characteristics of a filament-wound 49 x 17 26 PR Type VII Aircraft Tire. As a basis of evaluation, the test criteria of MIL-T-5041D, "Tires, Pneumatic, Aircraft," and USAF Drawing No. 60D2561-J were used.

(1) Mounting

The mounting of conventional tires relies on inflation to seat the beads. With filament-wound tires, it is necessary to force flanges inward to the tire bead heel. This mounting is accomplished by applying the load with a load machine.

A specially designed 49 x 17 26 PR aircraft wheel was used for static testing. A cast-aluminum test-wheel with a rim contour in accordance with the profile specified in Military Standard MS 24368(USAF) was used for dynamic testing.

(2) Static Testing

The static test data obtained on tires LBN-2 and LBN-4 are summarized in Table XXIII. The static testing of tires LBN-2 and LBN-4 was confined to measurements and hydrostatic burst testing. More extensive static testing was delayed pending the completion of dynamic testing. It was believed that the anticipated design changes for improvement of dynamic life would invalidate the static test results obtained on preliminary construction designs.

Tire LBN-2 showed a hydrostatic burst-test pressure of 670 psi which compared favorably with that predicted. This produced a burst factor (burst pressure/operating pressure) of 3.94. Tire LBN-2 had a range of 1191 to 1371 wraps per ply which indicated 104.3% of the required strength level. This indicated that more reinforcement was incorporated in this tire than was required by the specified minimum burst factor of 3.50, as shown in USAF Drawing 60D2561-J. The rupture location in this tire was in the crown area which is normally considered a desirable failure point.

Tire LBN-4 showed a hydrostatic burst test pressure of 625 psi which was below the 655 psi predicted value. This produced a burst factor of 3.67. Tire LBN-4 had a range of 1206 to 1272 wraps per ply which should have produced 100.56% of the required strength level. This indicates that the full strength of the cord was not attained because of nonuniformity of end count and spacing of cords. The value of 3.67 for the burst factor, however, is safely above the 3.50 specification minimum and indicates that the selected range of 1230 ± 30 end count provides a satisfactory margin of safety. Tire LBN-4 exhibited adequate air retention capability in that the loss of air was less than half that permitted by the specification. The OD of tire LBN-4 was close to the maximum allowable, although within the specification. The section width was 0.51 in. over the maximum, even though the winding mandrel for this tire had been reduced by 0.405 in. The high section width was attributed to the low crown winding angle and excessive cord length in the outer plies. To increase the crown winding angle would have required the fabrication of new winding cams for the filament-winding machine. This did not appear to be justified until the results of the dynamometer tests showed the effect of a low crown winding angle on dynamic performance.

(3) Dynamic Testing

Dynamic testing was conducted in accordance with USAF Drawing No. 60D2561, Revision J. Each test was preceded by a two-mile, 30-mph taxi roll at 170 psi and 39,600-lb load. Five 49 x 17 F/W tires were subjected to this test. Three of these tires were of the original

TABLE XXIII

STATIC TEST DATA - 49 X 17 F/W TIRES

Item	Specified	LBN-2	LBN-4
Air Retention	5% Maximum Loss 12 Hr Minimum	N/R[a]	2.35%
Inflated Dimensions			
Inflation (psi)	170	170	170
Outside Diameter (in.)	47.70-48.75	N/R	48.72
Section Width (in.)	16.40-17.25	N/R	17.76
Shoulder Diameter (in.)	43.00	N/R	42.93
Shoulder Width (in.)	14.50 Maximum	N/R	14.44
Hydrostatic Burst Pressure			
Burst Pressure (psi)			
Predicted		680	680
Actual	595 Minimum	670	625
Burst Factor (Actual)	3.5 Minimum	3.94	3.67
Rupture Location		Carcass Crown	Carcass Crown

[a] N/R - Not recorded because of safety procedures exercised.

design and construction. Table XXIV shows the data obtained on the three tires. Data obtained on the two tires of revised design will be reported in a later section. Figure 29 shows a 49 x 17 F/W tire mounted for testing on the dynamometer.

(a) Air Retention and Inflated Dimensions

The standard 36-hr air retention test was conducted on only one tire, LBN-5. Due to the need for expediting the dynamic testing, the remaining tires were held inflated for only 18 hours. A 15 psi pressure drop to allow for growth was established for these tires. All met this requirement. The inflated OD of the tires was near the maximum and the section widths exceeded the allowed maximum. These results were the same as obtained in static testing.

(b) Deflection

The deflection of these tires under load met the specification requirements. After the early failure of Tire LBN-5, a safety measure was instituted that prevented deflector measurements after the break-in cycle.

(c) Dynamic Test Results

Examination of Table XXIII shows that these tires failed during the following time periods:

Tire	Failure Period
LBN-5	Between speeds of 70 to 100 mph in the acceleration segment of the first taxi takeoff cycle.
LBN-7	Midway of the taxi segment of the first take-off cycle.
LBN-8	During break-in.

All tires failed in the bead area because of chafing at the 0.5-in. rim lock edge radius. The sequence of events leading to failure was (1) chafing through the inner liner under the RLA, (2) loss of internal pressure and increase in deflection, (3) abrading of cords to separation through four or five inner plies, and (4) total structural failure of carcass requiring unlanding. The total mileage span of the failures ranged from 1.877 to 5.06 miles. Total flex cycles or tire revolutions ranged from 920 to 2480. The chafing is the result of relative movement between the carcass and the rim lock. The magnitude of this movement increases rapidly as the chafing progresses.

TABLE XXIV

DYNAMIC TEST DATA - 49 X 17 F/W TIRES

Item	Specification	LBN-5	LBN-7	LBN-8
Air Retention	5% max loss 12 hr min	1.8%	5.88%[a]	7.64%[a]
Inflated Dimensions				
Inflation (psi)	170	170	170	170
Outside diameter (in.)	47.70-48.75	48.77	48.31	48.75
Section width (in.)	16.40-17.25	17.68	17.54	17.79
Shoulder diameter (in.)	43.00	42.78	N/R	N/R
Shoulder width (in.)	14.50 max	14.34	N/R	N/R
Deflection Checks (39,600-lb load)				
Before Break-in				
Flat plate @ 170 psi	28% min 35% max	31.5%	30.5%	31.8%
10-ft dia curved surface @ 197 psi	---	31.3%	31.1%	31.6%
After Break-in				
Flat plate @ 170 psi	---	31.0%	N/R[b]	N/R[b]
10-ft dia curved surface @ 197 psi	---	31.0%	N/R[b]	N/R[b]
Break-in Cycle (39,600-lb load, 170 psi, 30 mph, 2 miles)				
Roll distance (ft)	10,560	10,560	10,560	9,896
Results	---	Completed	Completed	Blowout
Contained air temp (°F)				
Start	---	78	81	67
Final	---	128	142	123
Max inflation (psi)	---	N/R	187	187
Taxi-take-off per USAF Drawing 60D2561-J				
Failure cycle	---	1	1	0
Failure point	---	@ 75 mph	5550 ft of taxi	(Break-in failure)
Contained air temp (°F)				
Start	---	90	80	---
Final	---	149	109	---
Max inflation (psi)	---	N/R	204	---

[a] Percent pressure loss due to diffusion plus initial tire growth during initial 18 hours of inflation. Diffusion alone projects less than 5%.

[b] Not recorded because of safety procedures.

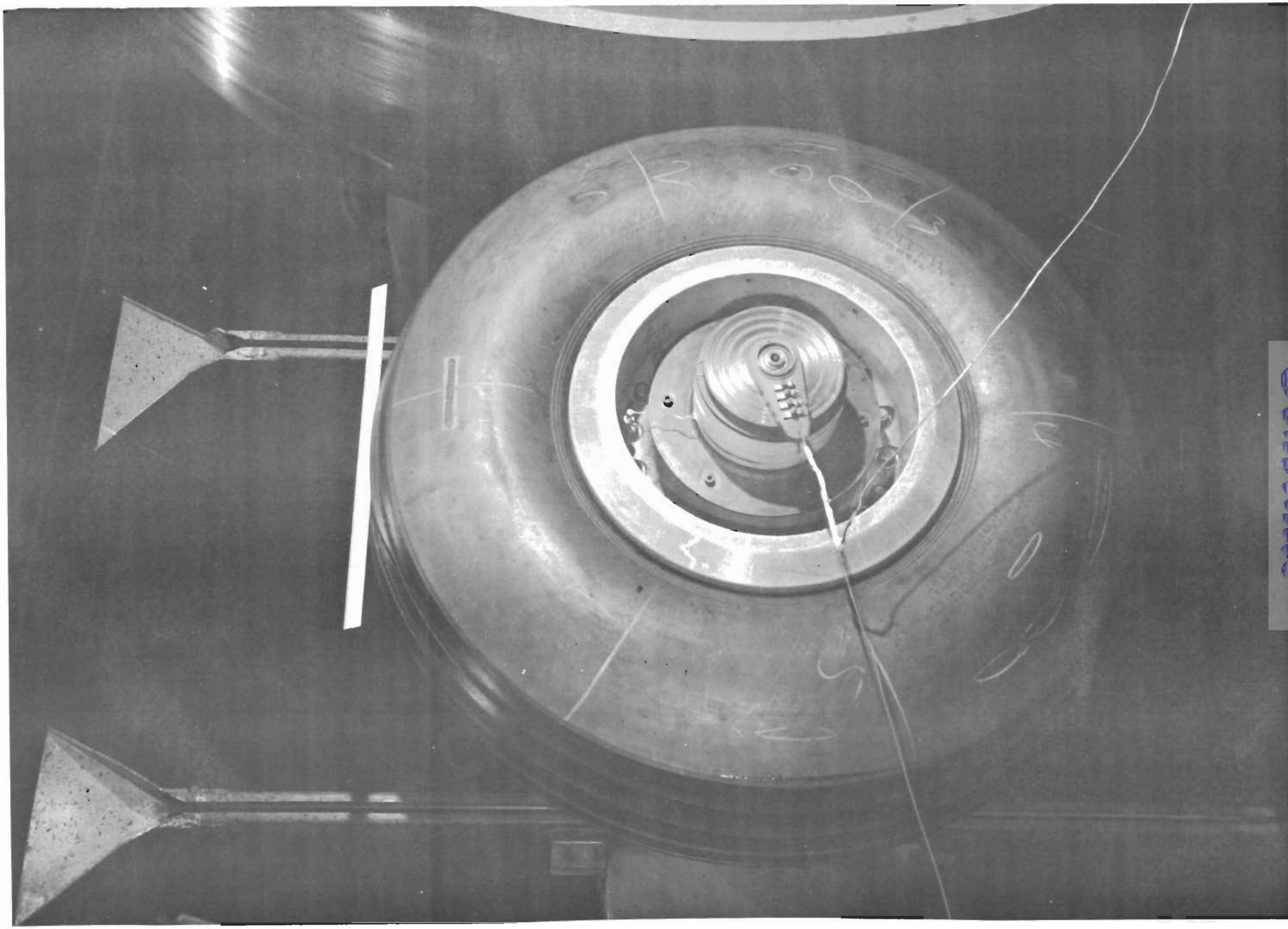


Figure 29. 49 x 17 Filament-Wire Tire Mounted for Testing on Dynamometer

3. DESIGN AND PROCESS EVALUATION

a. Analysis of Dynamometer Test Results

The early failures of three prototype tires on the dynamic test indicated a major design deficiency and the need for corrective measures. Inspection of the failed tires and analysis of the results resulted in selection of the following factors as being important in the solution of the problem:

- Abrasion of the cords at the 0.50-in. radius of the RLA
- Extension during flexing of cords and rubber at the edge of the RLA
- Lack of clamping pressure at the heel of the tire in the bead area
- Lack of adhesion between the rubber-covered RLA and the inner liner.

A decision was made to fabricate three tires of a modified design and fabrication procedure that included the following:

- Recutting the 5^{o} taper on the inside of the RLA to a point 3-1/2 in. from the centerline to increase clamping pressure.
- Increasing the radius at the edge of the RLA to reduce stress concentration on the cords in this area.
- Incorporating a barrier membrane between the edge of the RLA and the inner liner to prevent contamination in this area.
- Incorporating rubber-coated fabric separators between cord plies to raise the modulus of the composite and reduce cord chafing.

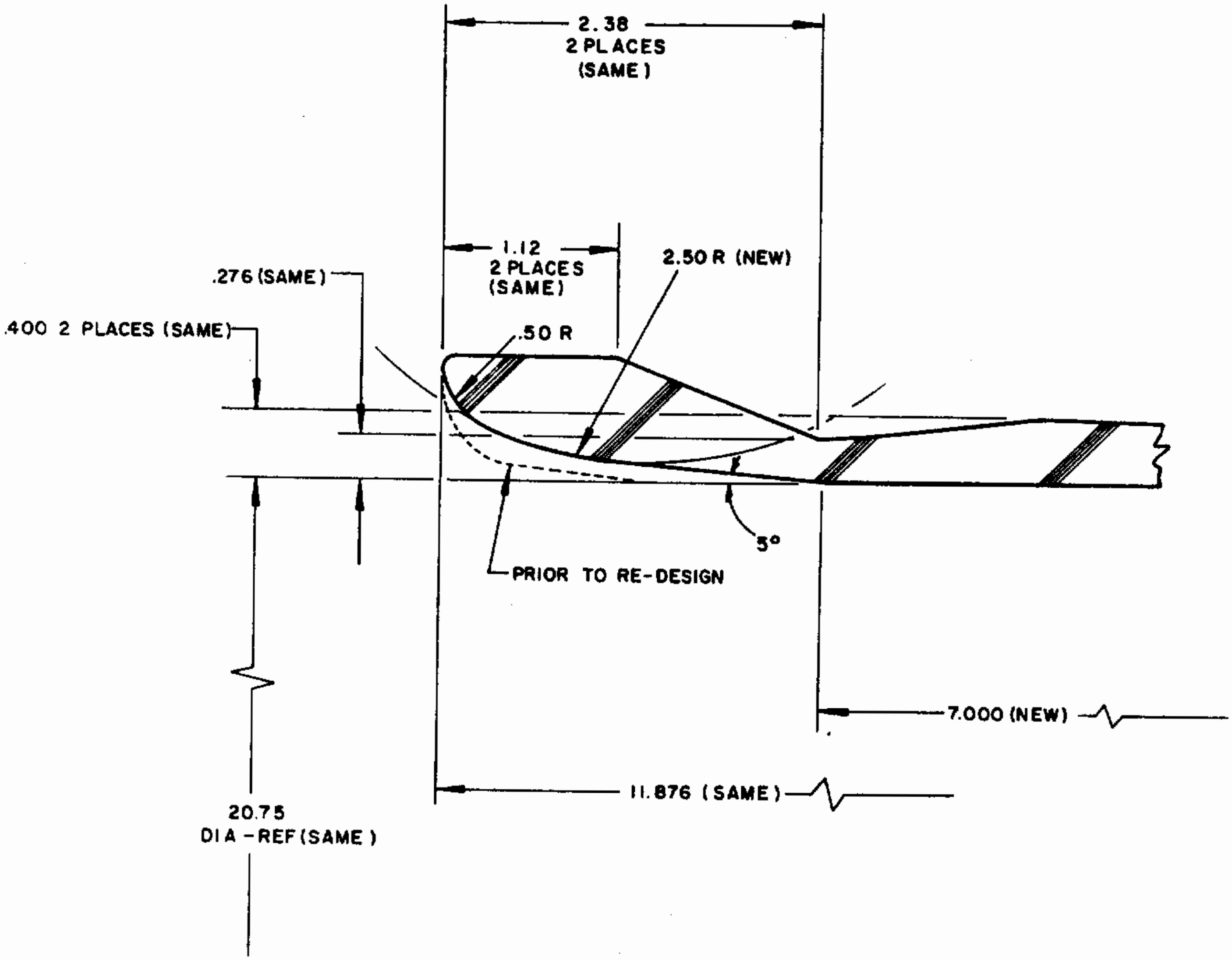
b. Fabrication and Testing of First Design Modification

(1) Fabrication

The modified design of the RLA profile is shown in Figure 30. This design was stress analyzed with the conclusion that the modified RLA would withstand dynamic testing if the imposed loads were no greater than those associated with the rated tire pressure of 170 psi.

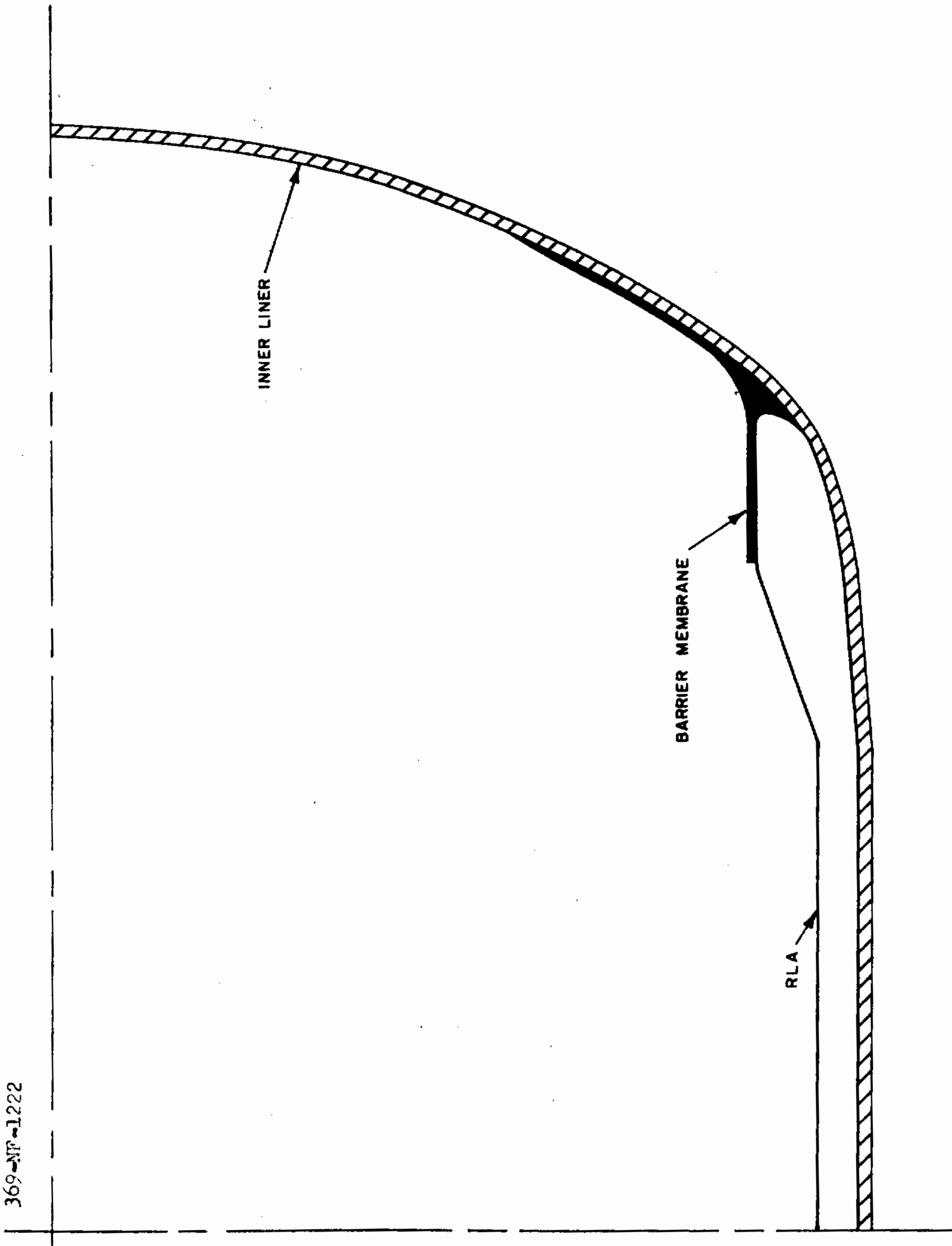
Rim locking assembly shells on hand were recut to the modified design for tires LBN-12, LBN-13, and LBN-14.

A membrane of the inner liner compound was attached to the outside of the RLA and the inner liner to prevent contamination of the cavity between the edge of the RLA and the inner liner. This modification is shown in Figure 31.



MODIFICATION OF RLA PROFILE

Figure 30



DESIGN OF BARRIER MEMBRANE

Figure 31

Sever. reinforcing inserts of 0.029-in.-thick rubber-covered 840/2 nylon cord were placed between the cord plies around the edge of the RLA to reduce cord chafing and increase the modulus of the rubber/cord composite. These are shown in Figure 32.

A rubber filler strip was vulcanized to the flange area of both sides of the tires to increase the cured rim width dimension.

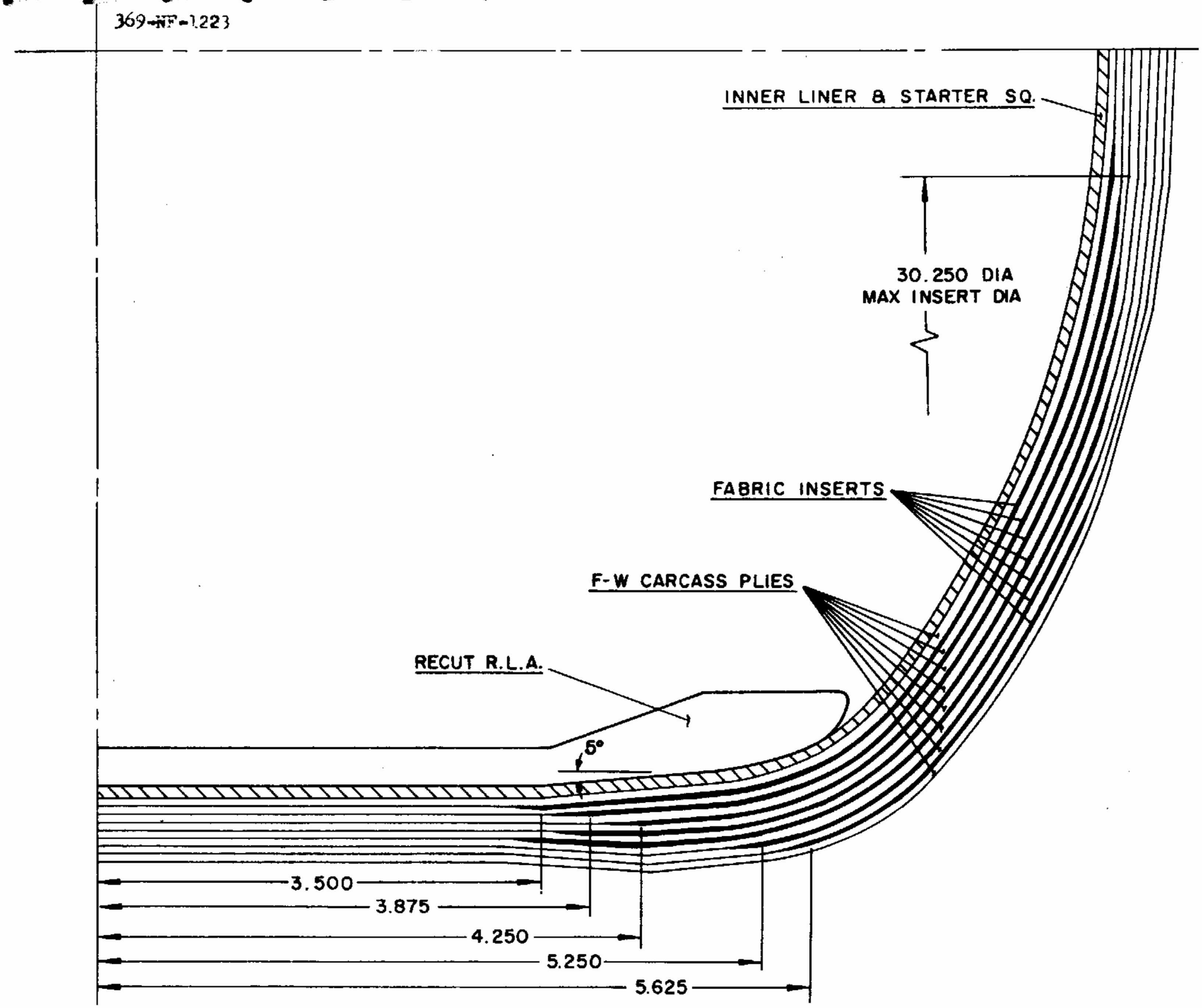
(2) Testing and Analysis of Results

Tires LBN-12 and LBN-13 were subjected to the dynamic test requirements specified on USAF Drawing 60D2561J. The outside diameters of these tires were within the specified limits. The section width of tire LBN-12 was 0.18 in. over, and that of tire LBN-13 was 0.28 in. over the specified maximum. The deflections of these tires under a 39,600-lb load were well within the specification limits. The dynamic test data for tires LBN-12 and LBN-13 are shown in Table XXV.

Both tires completed the break-in cycle, but failed during the acceleration segment of the first taxi-takeoff cycle. It was reported that blisters appeared on the sidewall during the acceleration of the tires. Examination showed that the inner liner was sheared off at the underside of the RLA, although it was well-bonded inboard from the separation. The breaks in the inner liner permitted the inflation air to enter the carcass and produce blisters under the sidewall. The cords were broken in the same area as in earlier tires and extended to the fourth and fifth plies. There was also some delamination in the RLA, either due to rotation of the edge of the RLA or to the absence of a glass fabric envelope around the 341 glass laminate.

The failure of tires LBN-12 and LBN-13 during dynamic testing at approximately the same speed and time period as tires LBN-5, LBN-7, and LBN-8 showed that the design modifications did not produce any improvement in dynamic performance. The chafing of the cords at the edge of the RLA continued in spite of an increase in radius of 2.00 in. in this area. The incorporation of fabric inserts between the plies did not reduce this chafing, and the increase in modulus produced by this construction obviously did not contribute to an increase in dynamic life. Although the clamping pressure was increased by extension of the taper on the underside of the RLA and by the filler strips vulcanized to the flange areas, there still was considerable distortion of the carcass in this area. The failure of the inner liner during the early stages of the dynamic test was quite obvious and indicated a need for redesign of the liner. A cross section of tire LBN-12 is shown in Figure 33. The failure area is shown in Figure 34.

The processing and cure of tire LBN-14, which was of the same design as tires LBN-12 and LBN-13, was delayed to permit curing of this tire in the recut mold. Curing was accomplished in the recut mold. The tire had an average cured rim width dimension of 13.253 in., which compares with the design width of 13.250 in. After tire LBN-14 was cured, a blown area between plies 7 and 8 in the crown and a small sidewall blow within ply 8 was observed. These were caused by the failure of the inner liner to contain the internal curing medium. The location of the opening in the inner liner that permitted the leakage could not be determined.



DESIGN OF REINFORCING INSERTS

Figure 32

TABLE XXV

DYNAMIC TEST DATA ON 49 x 17 F/W TIRES OF MODIFIED DESIGN

ITEM	SPECIFICATION	LBN-12	LBN-13
Air Retention	5% max. loss	7.64% [a]	6.47% [a]
Inflated Dimensions	12 hr min.		
Inflation (psi)	170	170	170
Outside diamteter (in.)	47.70-48.75	48.69	48.66
Section width (in.)	16.40-17.25	17.43 [b]	17.53
Shoulder diameter (in.)	43.00	N/R	N/R
Shoulder width (in.)	14.50 max.	N/R	N/R
Deflection Checks (39,600 lb load)			
Before break-in			
Flat plate @170 psi	28% min. 35% max.	31.0%	30.2%
10-ft dia curved surface @197 psi	---	31.3%	29.8%
After break-in			
Flat place @170 psi	---	N/R [c]	N/R [c]
10-ft. dia curved surface @197 psi	---	N/R [c]	N/R [c]
Break-In Cycle (39,600 lb load, 170 psi 30 mph, 2 miles)			
Roll distance (ft)	10,560	10,560	10,560
Results	Completed	Completed	Completed
Contained air temp (°F)			
Start	---	68	64
Final	---	80 [d]	147
Max. inflation (psi)	---	182	191
Taxi-Takeoff per USAF Dwg 60D2561 Rev. J			
Failure cycle	---	1	1
Failure point	---	@ 95 mph	@ 90 mph
Contained air temp (°F)			
Start	---	75	89
Final	---	147	156
Max. inflation (psi)	---	221	220

(a) Percent pressure loss due to diffusion plus initial tire growth during initial 18 hours of inflation. Diffusion alone projects less than 5%

(b) Not recorded; (c) Not recorded because of safety procedures exercised; (d) Thermocouple malfunction. Repaired following indicated cycle

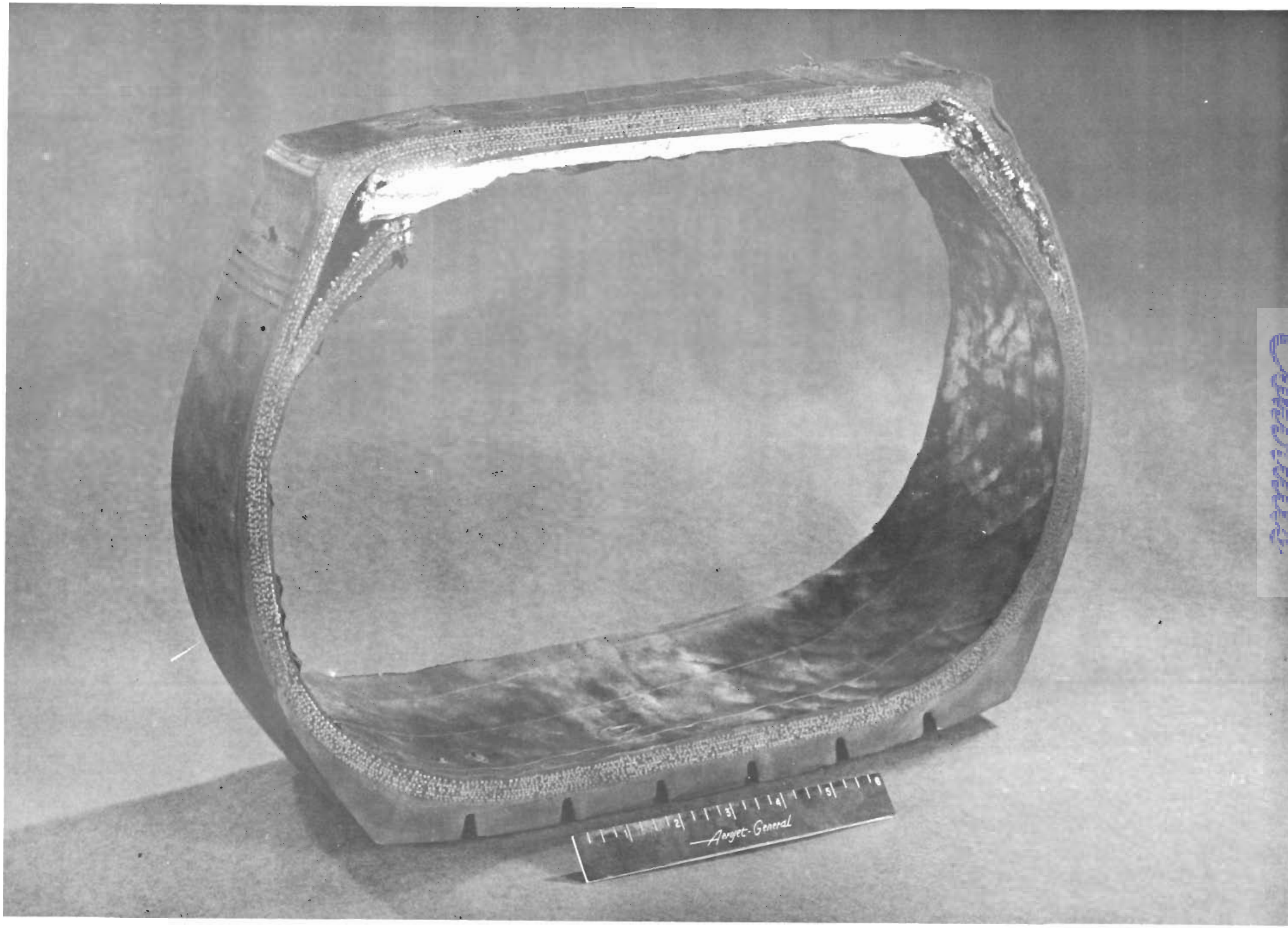


Figure 33. Cross Section of Tire LBN-12 After Dynamic Test

CN769-010

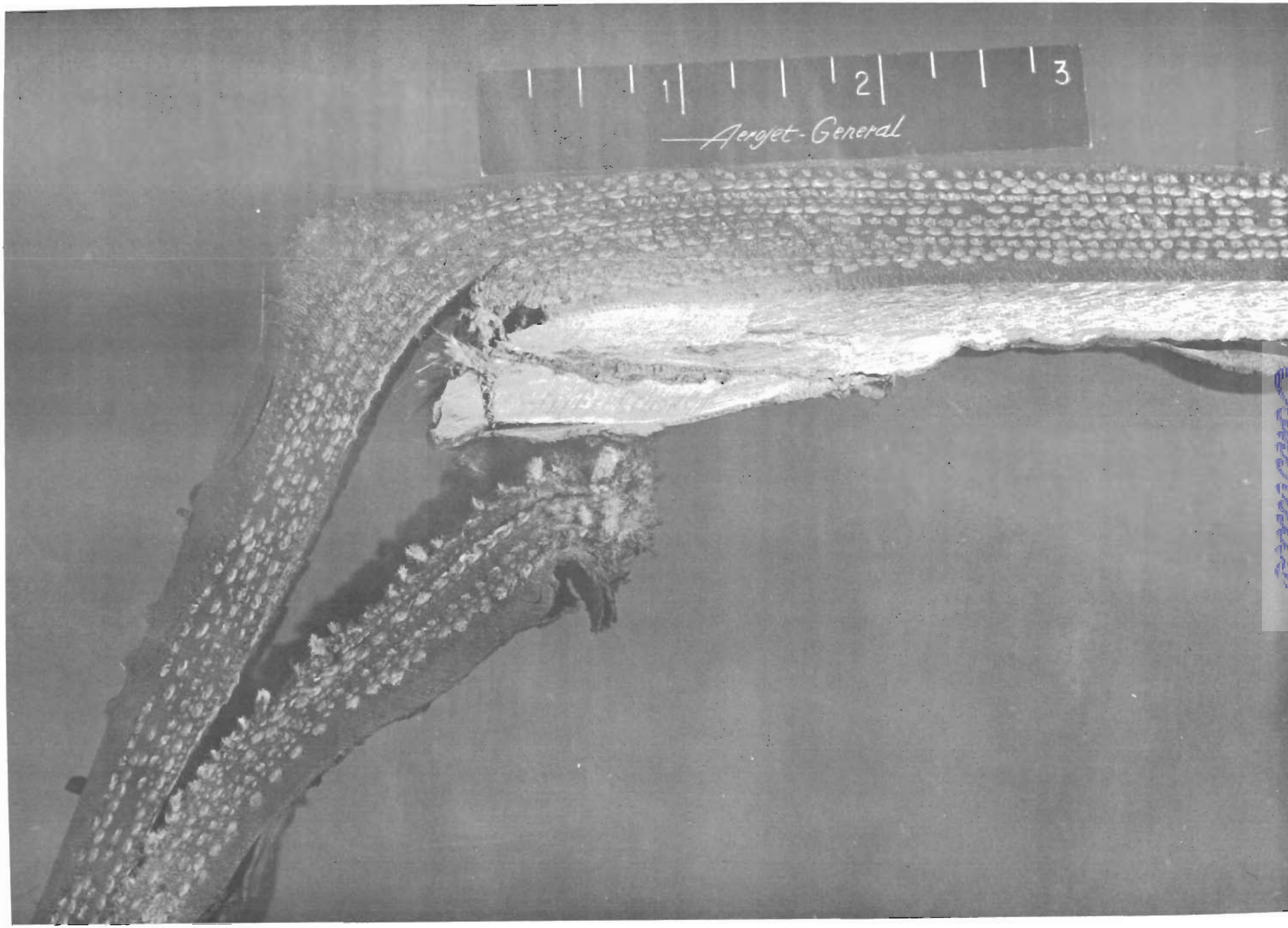


Figure 34. Failure Area of Tire LBN-12

The results of the tests on tires of modified design and construction were analyzed at a technical conference attended by representatives of USAF, Aerojet, and GT & R. It was concluded that the major cause of the failure of filament-wound tires during dynamic testing was the outboard deflection of the RIA which permitted lifting of the tire from the rim and excessive movement of the cords in this area. It was decided to fabricate an additional tire to determine the effect of increased RIA stiffness and the following recommended design modifications on dynamic performance:

- Rigidize the RIA by fabricating from steel and use brass plating for adhesion
- Incorporate a high-modulus rubber filler on the inside of the RIA to reduce cord chafing
- Relocate the inner liner to the outside diameter of the RIA to preserve tire inflation during dynamic operation
- Adhesively bond the inner liner to the carcass by a suitable cement to promote improved tire integrity
- Recut the mold to a larger rim width and the bead ring to a smaller diameter to increase clamping pressure on the test wheel

c. Fabrication of Second Design Modification

(1) Modification of RIA

Type 4130 steel was selected for the RIA of the second modified design because of its high modulus and machineability. A stress analysis was made of four configurations using this steel; the design shown in Figure 35 was selected. This steel RIA weighed 127.50 lb which is approximately 105 lb more than the resin/glass-fabric composite RIA. Following is a comparison of the hoop strain of the steel RIA with those of the composite RIA's used on the various sizes of bias path filament wound tires.

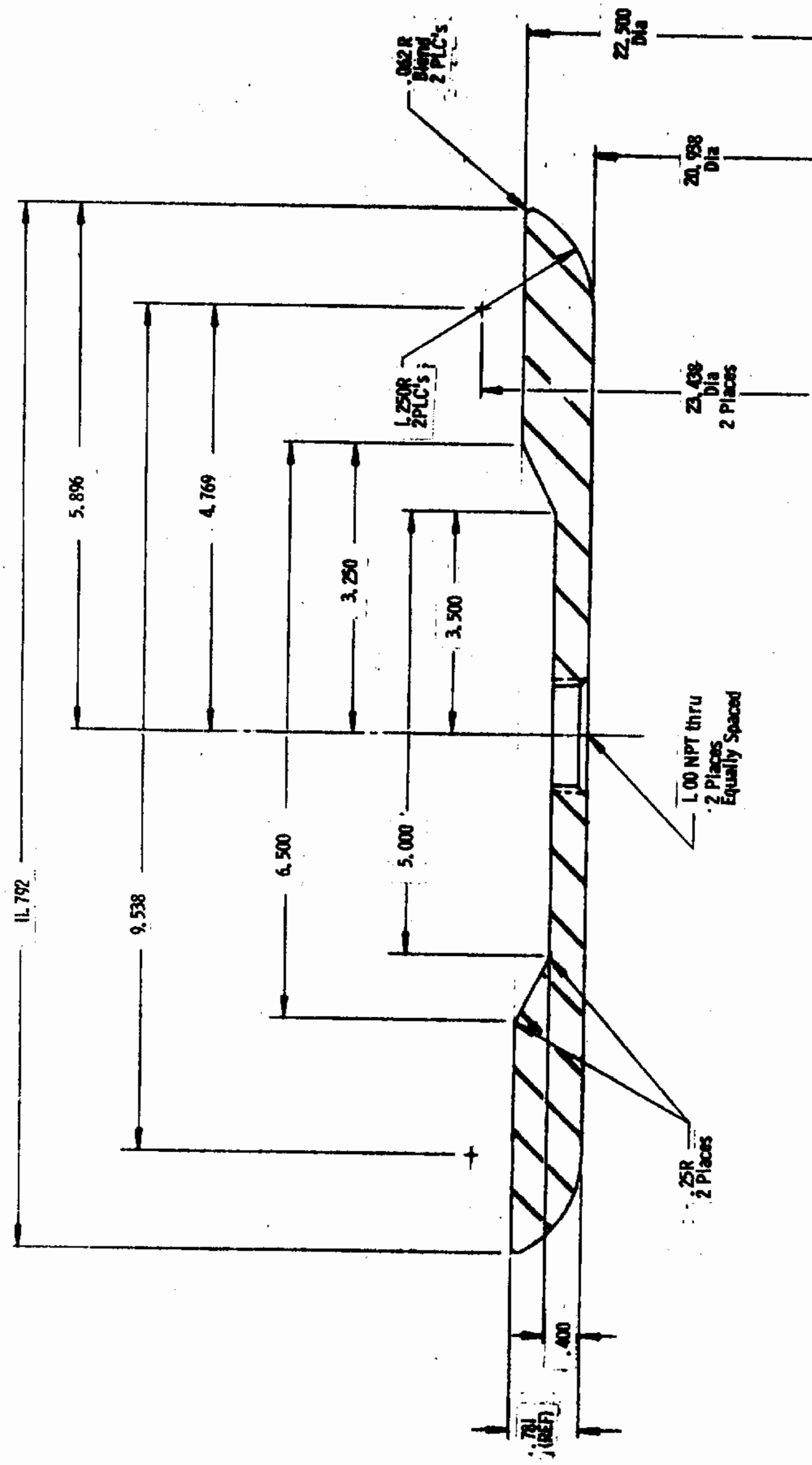


Fig. 35 SHELL, STEEL RIM LOCKING ASSY
49 x 17 TIRE

Tire Size	Type RLA	Inflation Pressure (psi)	Hoop Strain (in./in.) Maximum Allowable	Calculated
30 x 7.7	Composite	165 (rated)	0.008	0.0032
		660 (burst)	0.015	0.0126
30 x 8.8	Composite	295 (rated)	0.0065	
		1035 (burst)	0.0120	0.0021
49 x 17	Composite	170 (rated)	0.0090	
		595 (burst)	0.0170	0.007
49 x 17	Composite	595 (burst)	0.0170	0.011*
49 x 17	4130 Steel	595 (burst)	0.0170	0.0025

* Based on modified RLA used in tires LBN-12, LBN-13, and LBN-14.

This comparison shows that the calculated hoop strain of the steel RLA is approximately one-third that of the standard design in a resin/glass-fabric composite and one-fourth that of the modified RLA used in tires LBN-12, LBN-13, and LBN-14.

It was planned to use brass plate on the steel RLA to obtain maximum adhesion. The bonding of rubber to brass, however, requires relatively high molding pressures. A vacuum-bag curing pressure of 14.5 psi is used in the curing of rubber on the mandrel and RLA in the F/W tire process. The adhesion of rubber to brass plate under these low pressure conditions was questioned,,so a bonding study was conducted. The results of this study showed that a resin adhesive system, Chemlok 205 - Chemlok 220, produced seven times higher peel adhesion than brass plate under the same curing conditions. On the basis of this study, the resin adhesive system was selected for bonding the high-modulus rubber and the inner-liner rubber to the steel RIA. Degreasing and buffing were used to prepare the surface of the RLA for bonding.

(2) High-Modulus Rubber on RIA

In the standard construction of the F/W 49 x 17 tire, a low-modulus rubber compound was bonded to the RIA. Although a bonding system had been developed that produced failure in the rubber itself, shear failure occurred between the glass composite and the inner liner during dynamic testing. This indicates that extremely high shearing forces are exerted at the interface. It was decided that a stepdown in modulus from the RIA to the cord/rubber composite was desirable to accommodate these high shearing forces. Accordingly, Compound XB1097, a high modulus compound of 300 was selected for bonding directly to the steel RIA. Compound K-70, an intermediate modulus compound based on NR, was selected for the middle layer. Compound XK984A, the cord insulation compound, has a low modulus. The buildup of these compounds is shown in Figure 36.

(3) Reinforcing Inserts between Cord Plies

On tires LBN-12, LBN-13 and LBN-14, cord-reinforced inserts were used between plies. Although no improvement in dynamic performance was shown by these tires, the cause of early failure was attributed to other factors than the inserts. The value of the cord in the inserts was questioned in that most of the rubber insulation had been forced out from between the cords. It was decided to use unreinforced rubber inserts in tire LBN-15 to provide separation between plies. The location of these inserts is shown in Figure 36.

(4) Relocation of Inner Liner

The relocation of the inner liner from the underside of the RIA to the outside of the RIA was made by first bonding a flap across the outside diameter of this member, then splicing this cured flap to the remainder of the inner liner. A Chemlok 205-220 resin adhesive system was used for bonding the inner liner compound XK985B, to the steel RIA. Anchorweld SO-132D adhesive was used for bonding the buffed cured flap of XK985B to the uncured toroidal wrap of this compound.

(5) Bonding of Inner Liner to Ply Insulation

The adhesion of the inner liner to the ply insulation has been marginal on some of the filament-wound tires because of (a) bonding a cured compound to an uncured compound, (b) bonding of two dissimilar polymers, and (c) bonding late in the processing cycle. Buffing of the cured inner liner was tried but unbonded areas were still observed. A combination of buffing and application of Anchorweld SO-132D produced good peel adhesion and was used on tire LBN-15.

(6) Recutting of Tire Mold

The rim width deminsions of the tire mold were increased from 13.250 to 13.406 in. It was estimated that this change would produce approximately 0.056-in. interference with the rim when mounted. The bead rings were recut from a diameter of 19.938 to 19.906 in. This increased the ledge interference from 4/64 to 6/64 in. or by 50%.

(7) Filament-Winding of Carcass

Eight plies of 3360/2 nylon cord were filament-wound over the rubber-covered mandrel in the usual manner. The nontacky surface of the K-70 inserts at the radius in the heel area produced considerable rolling of the cords on the side of the carcass so a layer of ply stock dispersion was applied

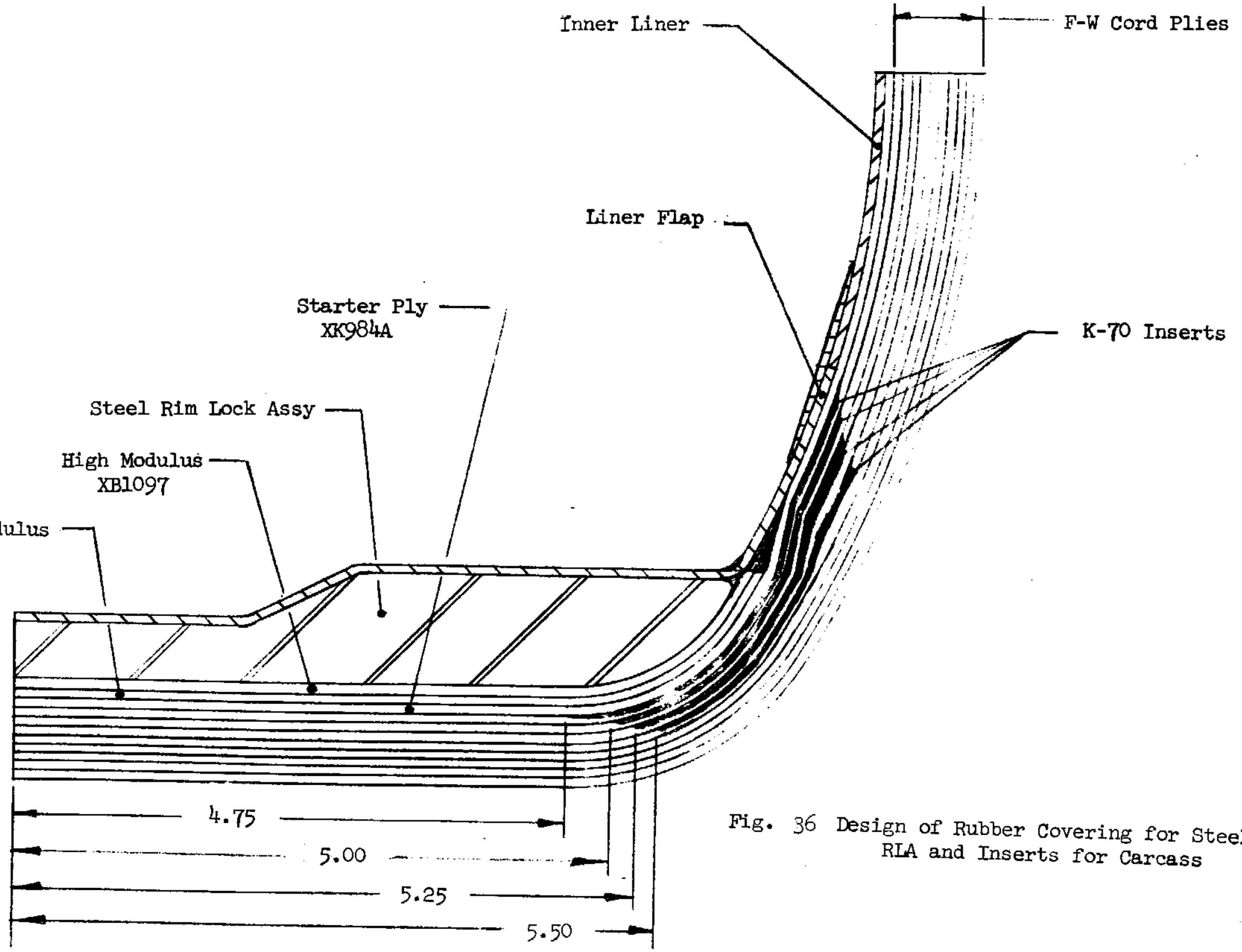


Fig. 36 Design of Rubber Covering for Steel RLA and Inserts for Carcass

to hold the cords in place. The weight of the carcass, which was 105 lb heavier than a normal carcass, produced more wobbling and lateral movement on the belt than is usually experienced. Cord spacing was somewhat difficult to control because of this condition. The heavy carcass weight also caused peeling of the nonskid panels from the driving belt. This was corrected by dusting the surface of the panel with zinc stearate.

The following, Table XXVI, is a tabulation of the winding data on tire LBN-15:

TABLE XXVI

WINDING DATA FOR TIRE LBN-15

Winding Data

Ply No.	Cord Ends Per Ply	Crown Cord Angle (°)	Cord Ends per Inch Min	Cord Ends per Inch Max
1	1296	40	10	14
2	1200	40	9	12
3	1248	40	9	14
4	1236	40	8	11
5	1260	40	9	14
6	1243	40	7	13
7	1236	40	7	14
8	1248	40	8	12
Average	1246		8	13

(8) Application of Components and Tread

The breaker, filler, chafer strips, and ID liner were applied to the carcass before Orbitreading. After the tread was applied, the remaining sections of the sidewalls were applied by hand. Following are the weights of the components of tire LBN-15:

Steel RLA shell	127.5 lb
Cord and elastomer	105.5 lb
Breaker, sidewalls, filler, etc.	15.0 lb
Orbitread	48.0 lb
Total weight of tire	296.0 lb

(9) Curing

The green tire was externally lubricated and the bead ledges were lightly lubricated with a silicone solution. It was awled at the top of the bead heel filler to a depth of 0.10 in. (through the two 0.50 chafers). During the first insertion of the segmented curing-ring, some interference was noted. The ring was removed and the plies were thoroughly stiched down. The segmented curing-ring was then inserted without difficulty. No problems were encountered in the closing of the mold.

Upon mold opening, it was noted that the tread was depressed in one area, indicating the presence of a separated segment. A small (1-in. diameter) blister with a 2-in.-long feeder along the cord path was noted directly above the upper bead corrugation. Water exuded rapidly from this blister when it was awled 90 hr after cure.

d. Analysis of Results on Tire LBN-15

A complete failure analysis was performed on tire LBN-15 to determine the cause of the large blister that occurred during cure. Fluoroscopic inspection confirmed the presence of the blister. A scentalator test using 10 psi of Freon, a pressurization test of 50 psi nitrogen, and inflation to 170 psi operating pressure, however, failed to show any openings in the tire.

A white waxy deposit found on the cords in the blown area was identified as depolymerized nylon which is produced by a combination of heat and moisture. The heat was supplied by the curing medium and the moisture must have been forced through the inner liner during the high pressure cure. The presence of water in the carcass was confirmed by the small blister under the sidewall.

The opening in the liner through which water entered the carcass was either an open splice observed in the liner or a perforation found in the inner liner along the sidewall below the blister. This perforation must have occurred between vacuum testing of the liner and curing of the tire as it would not have held any vacuum. A possible cause suggested for the cut was the falling of a broken section of the sand mandrel during the turnover operation used in the washout. A second scuffed area found near the perforation tended to confirm this explanation. The open splice in the liner appeared to be caused by solvent trapped from the bonding cement.

Removal of the tread section over the blister showed the breaker, the 8th ply, and the 7th ply bonded to the tread. The condition of the remainder of the plies was fair, but the carcass could have no more than 50% of its design strength. The inner four plies would be operating under twice the design stress if a dynamic test were performed. The defect was not repairable so the tire was not considered suitable for testing.

e. Performance of Prototype 49 x 17 Tires

Table XXVII is a summary of the results obtained on the 15 prototype 49 x 17 tires produced in the program.

Analysis of the general summary of results on the 49 x 17 tires shows the cure performance was good in that the only cure failures of the standard design tires were due to malfunctioning of equipment. The two cure failures in the modified design tires were due to openings in the liner, the cause of which was not definitely determined. The burst strength of the 49 x 17 tires was satisfactory as well as the air retention and the deflection characteristics. The section widths of all 49 x 17 tires exceeded the prescribed limit of 17.25 in. by 0.54, 0.51, 0.29, 0.28, and 0.21 in. This condition was attributed to low cord angles and variable end counts.

The dissappointing dynamic performance of the 49 x 17 tires was not explainable on the basis of any specific design feature or material weakness. The modified tires incorporating suggested improvements did not perform enough better than the standard design tires to justify any conclusions, and there was insufficient time remaining in the program to permit identification of the major contributing factors to poor dynamic performance. More time and a methodical approach would be required to identify specific design details for corrective treatment. The design features requiring additional investigation are: (1) stiffness of the rim-locking assembly; (2) modulus of the rubber and cord at the edge of the rim-locking assembly; and (3) improved inner-liner integrity effected by its transfer of the inner liner from the underside to the outside of the rim-locking assembly.

TABLE XXVII

GENERAL SUMMARY OF RESULTS ON 49 X 17 26 PR TIRES

Tire Ident.	Design	Results
LBN-1	Std	Thermocouple tire - Lost during cure due to sediment in pressure fill line.
LBN-2	Std	Cured OK - Crown burst at 670 psi.
LBN-3	Std	Lost in cure due to inadvertent pressurization with air.
LBN-4	Std	Cured OK - Crown burst at 625 psi. Inflated dimensions OK except section width.
LBN-5	Std	Cured OK - Air retention OK, inflated dimensions OK except section width, deflection OK, completed break-in cycle, failed on first taxi-takeoff cycle at 75 mph.
LBN-6	Std	Cured OK - Satisfactory for static testing.
LBN-7	Std	Cured OK - Air retention OK, inflated dimensions OK except section width, deflection OK, completed break-in cycle, failed at 5550 ft of taxi-takeoff.
LBN-8	Std	Cured OK - Air retention OK, inflated dimensions OK except section width, deflection OK, failed during break-in cycle.
LBN-9	Std	Cured OK - Satisfactory for static testing.
LBN-10	Std	Cured OK - Satisfactoryfor static testing.
LBN-11	Std	Cured OK in recut mold. Satisfactory for testing.
LBN-12	Modified	Cured OK - Air retention OK, inflated dimensions OK except section width, deflection OK, completed break-in cycle, failed in taxi-takeoff at 95 mph.
LBN-13	Modified	Cured OK - Air retention OK, inflated dimensions OK except section width, deflection OK, completed break-in cycle, failed on taxi-takeoff at 90 mph.
LBN-14	Modified	Cured in recut mold - Blistered in crown during cure.
LBN-15	Modified	Cured in recut mold - Blistered in plies during cure.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

1. The feasibility of fabricating filament-wound aircraft tires using nylon, glass and wire cord reinforcements in bias, geodesic and radial cord paths was successfully demonstrated in a study program on 30 x 8.8 subscale tires. The curing difficulties encountered in this program with radial wound tires indicate a possible requirement for a segmented type curing mold in place of the conventional clamshell type. Improved integrity of these tires during cure may also be provided by premolding the liner as an inner tube and splicing it on the sand mandrel. Additional studies of the geodesic cord path tire are recommended because of the weight-saving potential shown by this construction.

2. Mechanization of the tire filament-winding process and the insulation-application process was demonstrated by the successful operation of the prototype tire winding machine and by production of large tires. Additional refinements contributing to tire fabrication mechanization include applying the tread and sidewalls to the filament-wound carcass while it is still in the winding-machine. The use of a calendered or extrusion-coated tire cord in the winding-machine should also be considered for providing more accurate cord spacing.

3. Optimum operating procedures were established for prototype tire filament-winding equipment. The abrupt direction changes in the cord-laydown required by the bias design introduced cord crossovers are considered undesirable for good dynamic performance. Investigation of improved cord tackifying techniques is recommended to correct this condition. Incorporation of additional sensing points on the filament-winding machine is required to improve automatic feedback control of cord-end count.

4. Satisfactory strength, air retention and deflection characteristics were shown by all the 49 x 17 26 PR prototype tires tested to these requirements.

5. Satisfactory dynamic performance was not achieved by the 49 x 17 prototype tire because of severe cord chafing at the underside of the rim-locking assembly. The chafing caused perforation of the inner liner, loss of pressure, breaking of the cord reinforcement, and unlanding of the tire before completion of one taxi take-off cycle. Design modifications, which include stress-concentration reduction, an increased bead area modulus, and cord reinforcement, produced no improvement in dynamic life. The dynamic performance of the 49 x 17 tire was poor when compared to the performance of the 30 x 7.7 F/W tire. In a previous Air Force program the 30 x 7.7 F/W tire survived 50 high-speed landing cycles. This dynamic performance disparity demonstrates the extremely difficult scaling up problems encountered in the current program. Redesign of the 49 x 17 tire and also the wheel may be required to produce a major performance improvement. The performance requirement is described in the military testing specification designated in USAF Drawing 60D2561J.

6. The manner and location of failure of all filament-wound tires during dynamic testing for this and preceding programs are essentially the same. The results indicate the need for a higher modulus and a lower deflection for the RLA and cord/rubber composite. In addition, a better understanding of the forces imposed on the tire during dynamic testing is needed. Determination and analysis of these forces and deflections are pre-requisites to the modification of tire design and materials.

7. The versatility of the filament-winding concept in producing complicated cord paths for tires has been demonstrated on Air Force programs. It is possible that some of these unique design configurations, which may not always be available in conventional fabrication methods, could produce tires of superior service performance. It is recommended that this versatility be utilized in a study of experimental tire designs. The designs of current interest include the belted bias, the modified bias or geodesic, and a combination of radial and geodesic. An evaluation of these designs would most profitably be conducted on the small winding machine, which has recently been improved by incorporating most of the features of the large winding machine. After determination of the optimum winding path for superior dynamic performance on small tires, the results could then be applied to fabrication of a larger tire.

I. INTRODUCTION

In order to continuously wind filaments at specified angles on a toroidal mandrel, three motions are required from a winding machine:

A. Rotation of the mandrel about its own axis.

B. Rotation of the filament payoff head about the mandrel.

C. Displacement of the payoff head perpendicular to its plane of rotation.

A cam is required to provide the proper relationship between the rotation and displacement of the payoff head for a specified angular position of the mandrel. The purpose of this computer program is to perform calculations for the design of these cams to be used in a filament-winding machine for the manufacture of filament-wound tires. Calculations are based on equations presented in Appendix VII and VIII.

II. COMPUTER REQUIREMENTS

This program was written in FORTRAN IV for the IBM 360/65 digital computer and was compiled under the 'G' level compilers. Required tape specifications are:

Input, Logical 5 (DDNAME = FT05F001)

Output

Printed, Logical 6 (DDNAME = FT06F001)
Punched, Logical 1 (DDNAME = FT01F001)
Plotted, PLOT TAPE (DDNAME)

Data set PLOT TAPE is subsequently processed by a utility program, which directs the plot information to a Calcomp plotter. A card listing of the FORTRAN IV source decks for the computer program is given in Appendix IX.

III. WRAP PROGRAM OPERATIONAL PROCEDURES

A. PROGRAM DESCRIPTION

The program is composed of a main program and seven function subprograms, which appear as external statements in the main program. A discussion of each of these components follows.

1. Main Program

This deck contains the iteration scheme necessary to establish geometric continuity between the rotating mandrel and the revolving payoff head. The library integrating subroutine ROMBRG is called by this deck, as required.

a. Winding Path Table

The program begins by establishing a table of wrap angles vs. radii from data contained in the common BLOCK DATA subprogram.

b. Hyperbolic/Circular Section Intersection

Coordinates of the intersection of the hyperbola and adjacent circular section (R3P, AP) are established by means of slope equality based on an initial guess for the angle of advance across the hyperbola (DELTA). If convergence is not obtained after KV iterations, calculations will proceed using the last calculated values for R3P and AP.

c. Total Angle of Advance and Arc Length

Angles of advance across the remaining geometric sections are established by calling the library Romberg integration subprogram. Each specific function to be integrated is established in the corresponding external FUNCTION subroutine, and the function together with calculated limits are then incorporated into the ROMBRG call statement. The total angle of advance (T) is the summation of the angles of advance across each geometric section (including the hyperbolic section).

Total arc length is calculated by the same techniques using the required FUNCTION subroutines.

d. Rotational Balance

The number of revolutions of the winding head (AN) is calculated and tested for an integer number. The purpose, here, is to obtain a practical gear ratio between the mandrel rotation and payoff head rotation. If AN is not an integer, the initial guess for DELTA is incremented by DT/2.0 and steps b. through d. are repeated, until an integer value for AN is obtained.

If convergence is not obtained in JMAX iterations, the initial input value for the number of rotations of the mandrel (AM) is incremented by 1.0 and steps b. through d. are repeated.

e. Geometry Table

A table of points, spaced in equal angular increments (DELPHI), is generated for presentation as printed output and for use in the CAM program as punched card output.

2. Subprogram FUNCTION FT2X (PHI)

The purpose of this subroutine is to define a function of PHI for determination of the angle of advance (TH2X) across each circular section (2X) by Romberg integration techniques. The function has the form:

$$f(\phi) = \frac{b \tan \alpha}{r_1 + b \cos \phi}$$

3. Subprogram FUNCTION FS2X (PHI)

The purpose of this subroutine is to define a function of PHI for determination of the arc length (S2X) across each circular section (2X) by Romberg integration techniques. The function has the form:

$$f(\phi) = \frac{b}{\cos \alpha}$$

One subroutine of this form is required for each of the three circular sections.

4. Subprogram FUNCTION TABL (R)

This subroutine is used to interpolate for wrap angles {AL(I)} at radial points [R (I)] which lie in between the input values of radii [RAD (I)].

B. INPUT INFORMATION

Data are entered into the main program through labeled COMMON by using a BLOCK DATA subprogram. A series of eleven DATA cards in the BLOCK DATA subprogram define all variables required to execute the program. See Appendix X for a sample problem.

1. Wrap Pattern for Circular Sections

Three cards are required to describe wrap angles at up to 30 designated radial stations.

a. DATA DEGR/⟵ Enter the "degree" value of the wrap angle for each station in columns 17-71, as needed ⟶ /

b. DATA AMIN/⟵ Enter the "minute" value of the wrap angle for each station in columns 17-71, as needed ⟶ /

c. DATA RAD/⟵ Enter the station diameter in columns 16-71, as needed ⟶/

2. Wrap Pattern for Outer Cylinder

If the wrap angle varies across the outer cylindrical section of the mandrel, this wrap angle variation with increasing polar distance (YC) is designated by three additional cards. The value of the wrap angle recorded for the last station in this series of cards must agree with the value of the wrap angle recorded for the first station in the preceding series of cards. The maximum number of variations in angle across the outer cylinder is fixed at 10.

Card 4. DATA DGR/⟵ Enter the "degree" value of the wrap angle for each station in columns 16-71, as needed ⟶ /

Card 5. DATA AMM/⟵ Enter the "minute" value of the wrap angle for each station in columns 16-71, as needed ⟶ /

Card 6. DATA YC/ ⟵ Enter the station polar distance in columns 15-71, as needed ⟶ /

If the wrap angle does not vary across the outer cylindrical section, enter 10*0.0 between the slash marks on each card and set N4=1 on Card 11.

3. <u>Circular Section Geometry</u>

A series of three cards is used to describe the parameters required to generate the three circular sections of the mandrel. Refer to Figure 1 for a pictorial representation of these values.

Card 7. DATA D2, D3/⟵ Enter values ⟶/

Card 8. DATA R1, R2, R3/⟵ Enter values ⟶ /

Card 9. DATA L1, L2, L3/⟵ Enter values ⟶/

4. <u>Control Data</u>

The next two cards complete the series of data required to run a single case. All parameters are defined in the nomenclature (Section V).

Card 10. DATA ST1, ST3, RRHO1, DELPHI, ALMIN, ALMAX/ ⟵ Enter Values ⟶ /

Card 11. DATA N0, N4, AM, DELTA, DLO/⟵ Enter data ⟶/

It should be noted that N4=1, if the cylinder wrap angle variation option is not used.

C. OUTPUT INFORMATION

1. Punched Card Output

The primary output of the wrap program is a series of punched manila cards, the number of which (NPTS) is calculated from the equation:

$$NPTS = \frac{180^{\circ}}{DELPHI} + (N4-1) + 1.5$$

Each card contains values for PHI, R, Y, THETA, AL, and ARC at DELPHI increments along the mandrel surface. Two additional cards containing geometric data (L1, L3, R2, R3, SR1, YB, R3P, AP, DELTA) complete the series of punched output. This series of cards is used as input to the CAM program.

2. Printed Output

Since the previously discussed punched output is not interpreted, the same data is represented as printed output for inspection. In addition, many of the calculated parameters in the program are printed (see the source listing, Appendix IX so that the nonconvergence of iteration schemes and non-practical solutions can be remedied by adjustment of data on input cards 10 and 11. Appendix X contains output for a sample problem.

D. ADDITIONAL COMMENTS

A few special situations were encountered during program "check out" which may lead to undesirable cam designs. These cases are discussed, and methods for controlling the situations are presented in the following paragraphs.

1. Nonconvergence of R3P/AP

Convergence of the iteration scheme for determination of the coordinates of the hyperbola/circle itersection is represented by an equality between AP and APP. Inspection of the printed output will sometimes reflect an inequality in these values, although the program proceeded to completion. In most cases, equality can be obtained by changing the iteration increment (DLO) by a power of ten. The printed output will dictate whether an increase or decrease in DLO is required to force convergence.

2. Impractical Gear Ratio (AN/AM)

Since the required gear ratio for controlling rotational motion is highly sensitive to the input value of DELTA, cases may arise which converge on undesirable gear ratios, as a result of an improper estimate of DELTA. Values for DELTA will normally range from 5° to 40°, depending on the amount of bridging (depth of hyperbola) required to establish a wrap pattern. For most mandrel geometries, a value of 15° or 7° for DELTA will produce gear ratios of 3:1 or 4:1, respectively.

In some instances, the relaxation of the limits (ALMAX/ALMIN) of the wrap angle at the last contour point will produce the additional range in parameters required to converge on a desirable gear ratio.

3. Depth of Hyperbola

In theory, a large number of hyperbolas will satisfy the requirements for a specific wrap pattern and mandrel geometry. A practical consideration is the interference of the bridged filament with the revolving payoff head, a situation caused by a calculated hyperbola, which is too deep for the specified radius of travel of the payoff head. Since the depth of the hyperbola is directly proportional to the value of DELTA, a decrease in DELTA will produce a more shallow hyperbola.

4. Control of Surface being Wrapped

For thin-walled toroids, the surface (mandrel, outside or neutral axis) used to establish the required wrap pattern does not influence the cam design. As more layers are added, the thickness of the wall increases, and it may be necessary to establish different cam designs for control of the wrap pattern on the outer surfaces. Control of the surface being wrapped is established by fixing ST1 at a value for the liner thickness and allowing ST3 to vary from zero to the maximum value of the thickness. Differences in cam designs should be noted, in order to establish whether the required degree of wrap pattern accuracy is obtained at the outer surfaces.

IV. CAM DESIGN PROGRAM OPERATIONAL PROCEDURES

A. PROGRAM DESCRIPTION

The program consists of a main program and one subprogram, GETST, both of which were written to be used in conjunction with the previously-described WRAP program. A discussion of the primary functions of the program is presented below.

1. Main Program

a. Basic Input

The program begins by reading a title card, control parameter cards and the data cards generated by the WRAP program. A sample input sheet is contained in Appendix X.

b. Initialize Plot Routine

If graphical representation of output data is desired, the main program calls the library subroutine PLOTS to initialize the plotting routines.

c. OM0 "Do" Loop

The angular displacement of the filament at zero time (OM0) is initialized and the subprogram GETST is called. The subprogram calculates a cam design for the given OM0 and returns. OM0 is then incremented by DOM0, and the process repeated until NLOOP cam designs are produced.

2. Subprogram GETST

This deck controls the solution of all equations used to obtain a cam design and calls the CALCOMP plot routines, as required.

a. Geometry Table

The program begins by completing the data table for the other two quadrants of the mandrel cross section from mirror image data generated by the WRAP program.

b. Calculation of EP

The angular position of the payoff heat, at time equals zero (EP), is calculated from the quadratic equation as outlined in Appendix VII.

c. Iteration for Time Variable

The payoff head is assumed to have unit velocity (OM2=1.0), and the velocity of the mandrel is computed as:

$$OM1 = \frac{THETA(P)}{\pi}$$

Following the procedure outlined in Appendix VII the time variable $\{T(I)\}$ is computed by iteration techniques. If a solution is not found after JMAX iterations, T(I) is set at T(I-1) and the program continues.

A special option in the program (ILOC=1) allows the payoff head to follow the contour of the mandrel, instead of rotating about a fixed coordinate system. This option provides a separate set of equations for use in the iteration scheme for T(I) and in the later calculation of S(I). If the option is used, a message: "PAYOFF HEAD IS ON SURFACE OF MANDREL," is printed.

d. Displacement of Payoff Head

At this point in the program, the values of all variables are known, and the displacement of the payoff head |S(I)| is computed directly as a function of its angular position:

$$ZZ(I) = OM2 \left| \quad T(I) \right| + EP$$

These two variables, evaluated at equal angular increments around the contour, are the data required for a specific cam design.

e. Interference between Payoff Head and Mandrel

A special test, outlined in Appendix VIII, determines whether the payoff head has penetrated the space occupied by the toroid. If this situation has occurred, a message: "*** CASE TERMINATED *** PAYOFF HEAD PENETRATED MANDREL," is printed.

f. CALCOMP Plot Routines

If NPLOT is input as 0, an additional table of S(I) versus ZZ(I) data is prepared for plot output. The CALCOMP support routines required to prepare the plot are then called. These routines, which are available from the 360 library, are:

Routine Name	Function
PLOT	Moves pen from one point to another.
AXIS	Draws coordinate axis (X or Y).
LINE	Draws a curve through a set of points.
NUMBER	Draws a floating point number.
SYMBOL	Draws BCD information.
PAGE	Provides restart points on plot tape.

B. INPUT INFORMATION

The following sequence of punched cards numerically defines the case to be analyzed.

1. Card 1

Columns 1 to 20 may contain any title information and will head the printed and plotted output.

2. Card 2

This card contains option control parameters. A value must be entered for each parameter.

Columns 1 - 12	No. of Data Cards - M
13 - 24	Contour Follower Option - ILOC
25 - 36	Debug Option - PRINT
37 - 48	Plot Option - NPLOT

The Debug and Contour Follower options are obtained by placing the integer, 1, in the appropriate column; if the options are not required, the character, 0, is used. If NPLOT is equal to the character, 0, selected printed data will also be plotted on graph paper, The integer, 1, is used if no plot is required.

3. Card 3

This card contains additional control parameter information.

Columns	1 - 12	Radial Distance to Center of Rotation of Payoff Head - H
	13 - 24	Radius of Rotation of Payoff Head - K
	25 - 36	Angular Displacement of Filament from Plane of Payoff Head at Zero Time - OM0
	37 - 48	OM0 Increment - DOM0
	49 - 60	No. of Increments required - NLOOP

The maximum number of increments, which may be applied to OM0, is ten (i.e., NLOOP = 10).

4. Cards 4 and 5

These two cards are punched output from the WRAP program. Data contained on Card 4 are:

Columns	1 - 12	Polar Distance to Generator of Circular Section III - L1
	13 - 24	Polar Distance to Generator of Circular Section IV - L3
	25 - 36	Radius of Circular Section III - R2
	37 - 48	Radius of Circular Section IV - R3
	49 - 60	Radial Distance to Generator of Section III - SR1
	61 - 72	Polar Distance to Intersection of Sections III and IV - YB

Data contained on Card 5 are:

Columns	1 - 12	Radial Coordinate of Hyperbola Intersection - R3P
	13 - 24	Polar Cordinate of Hyperbola Intersection - AP
	25 - 36	Angle of Advance across Hypberbola - DELTA

5. Cards 6 through M

This series of punched cards is obtained as output from the WRAP program and completes the necessary input to run a given case.

C. OUTPUT INFORMATION

1. Printed Output

Output for each cam design begins with the title and a brief listing of control parameters.

a. Radial Distance to Center of Rotation of Payoff Head - H

b. Radius of Rotation of Payoff Head - K

c. Angular Displacement of Filament at Zero Time - OM0

d. Angular Velocity of Mandrel - OM1

e. Angular Velocity of Payoff Head - OM2

Following this data, a table of values for PHI, R, THETA, ALPHA, Y, TIME, S, ZZ, and Z is printed out for 360° of the mandrel contour. It should be noted that the angular position of the payoff head as a function of time is:

$$Z = \text{THETA(I)} - \text{OM0} - \text{OM1}\left[\text{T(I)}\right]$$

2. Plotted Output

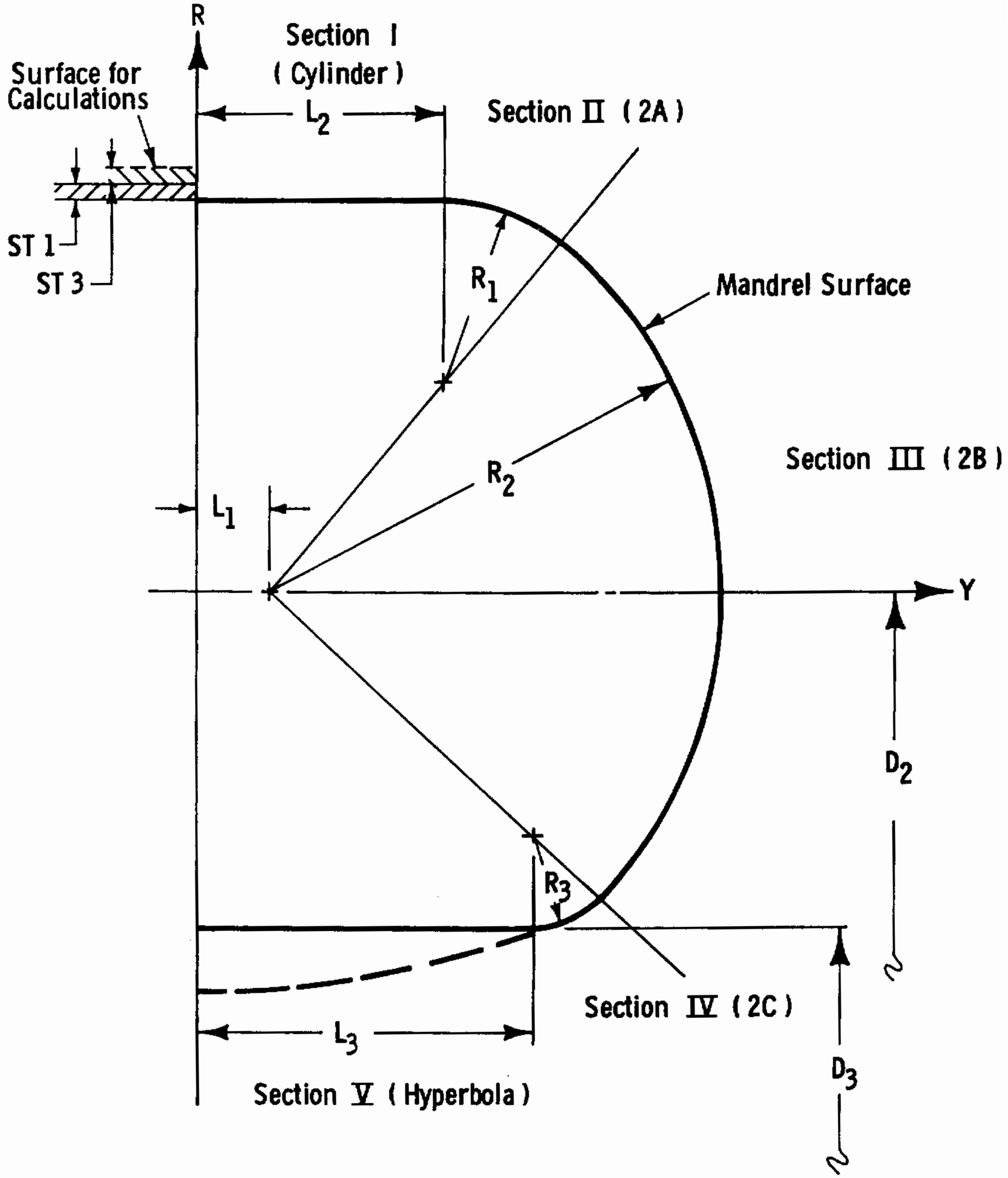
Stroke limitations of the payoff head make it desirable to have a pictorial representation of all cam designs for inspection. The plot option satisfies this requirement by graphically representing NLOOP cam designs [S(I) versus ZZ(I)] as a function of OM0. It should be noted that both cam shape and total stroke are quite sensitive to OM0.

V. NOMENCLATURE

Fortran Symbol	Engineering Symbol	Description	Units
ALMAX	-	Maximum value of ALPHA (N0)	degrees
ALMIN	-	Minimum value of ALPHA (N0)	degrees
ALPHA, AL	α	Winding angle at point i	degrees
ALPN	α_p	Winding angle at point p	degrees
ALQ	α_q	Winding angle at point q	degrees
AM	X	Number of rotations of mandrel	-
AN	N	Number of revolutions of payoff head	-
AP, APP	y_p	Polar coordinate of hyperbola intersection	in.
ARC	S	Arc length to point i	in.
DELPHI	-	Increment of phi along filament path	degrees
DELTA	Δ	Angle of advance across hyperbola	degrees
DLO	-	Increment for AP iteration scheme	in.
DOM0	-	Increment of OM0	degrees
DT	Δ_Δ	Increment of DELTA	degrees
D2	-	Cross section center-to-center diameter	in.
D3	-	Minimum mandrel diameter	in.
EP	ϵ	Angular position of payoff head at $t = 0$	radius
H	h	Radial distance to center of rotation of payoff head	in.
ILOC	-	Parameter controlling contour follower option	-

Fortran Symbol	Engineering Symbol	Description	Units
K	k	Radius of Rotation of Payoff Head	in.
L1	c	Polar Distance to Generator of Circular Section III	in.
L2	a	Polar Distance to Generator of Circular Section II	in.
L3	f	Polar Distance to Generator of Circular Section IV	in.
M	-	Number of Geometry Data Cards for CAM Program	-
NPLOT	-	Parameter Controlling Plot Option	-
N0	-	Number of Points in Input Table for Circular Sections	-
N4	-	Number of Points in Input Table for Cylindrical Section	-
OM0	ω_o	Angular Displacement of Filament at t = 0	degrees
OM1	ω_1	Angular Velocity of Mandrel	rad/sec
OM2	ω_2	Angular Velocity of Payoff Head	rad/sec
PHI	Φ	Angle Between Normal and Plane Parallel and through Axis of Rotation at point i	degrees
PRINT	-	Parameter Controlling Debug Option	-
R, RAD	r	Radial Distance from Mandrel Axis of Rotation to Point i	in.
RB	r_b	Radius at Intersection of Sections III and IV	in.
RRHO1	-	Number of Cords per inch	1/in.
R1 + ST	b	Radius of Circular Section II	in.
R2 + ST	d	Radius of Circular Section III	in.

Fortran Symbol	Engineering Symbol	Description	Units
R3 + ST	g	Radius of Circular Section IV	in.
R3P	r_p	Radius Coordinate of Hyperbola Intersection	in.
SDEL	S_V	Filament Arc Length across Hyperbola	in.
S	S (δ)	Displacement of Payoff Head	in.
SI	S_I	Filament Arc Length across Section I	in.
SR1	r_1	Radial Distance to Generator of Section III	in.
SR2	r_2	Radial Distance to Generator of Section IV	in.
ST	-	Normal Distance from Mandrel Surface to Surface used for Calculations	in.
ST1	-	Thickness of Liner	in.
ST3	-	Thickness of Wrap	in.
S2A	S_{II}	Filament Arc Length across Section II	in.
S2B	S_{III}	Filament Arc Length across Section III	in.
S2C	S_{IV}	Filament Arc length across Section IV	in.
T	t	Total Angle of Advance	degrees
THETA	θ	Angle of Advance to Point i	degrees
THI	θ_I	Angle of Advance across Section I	degrees
TIME, T(I)	t	Time to Arrive at Point i	sec.
TH2A	θ_{II}	Angle of Advance across Section II	degrees
TH2B	θ_{III}	Angle of Advance across Section III	degrees
TH2C	θ_{IV}	Angle of Advance across Section IV	degrees
Y, YC	y	Polar Distance to Point i	in.
Z	ψ	Angular Displacement of Filament	radius
ZZ	δ	Angular Position of Payoff Head	degrees



MANDREL GEOMETRY REQUIRED FOR WRAP PROGRAM INPUT

Figure 1

APPENDIX I

STRESS ANALYSIS RIM-LOCKING ASSEMBLY

49 x 17 TIRE

I. OBJECTIVE

The purpose of this appendix is to provide a stress analysis of the 49 x 17 Rim-Locking assembly (RLA) to establish the design validity and to determine the expected safety margins.

II. SUMMARY

This stress analysis was conducted for the design shown in Aerojet Drawing 1269207. The basic design criteria considered were

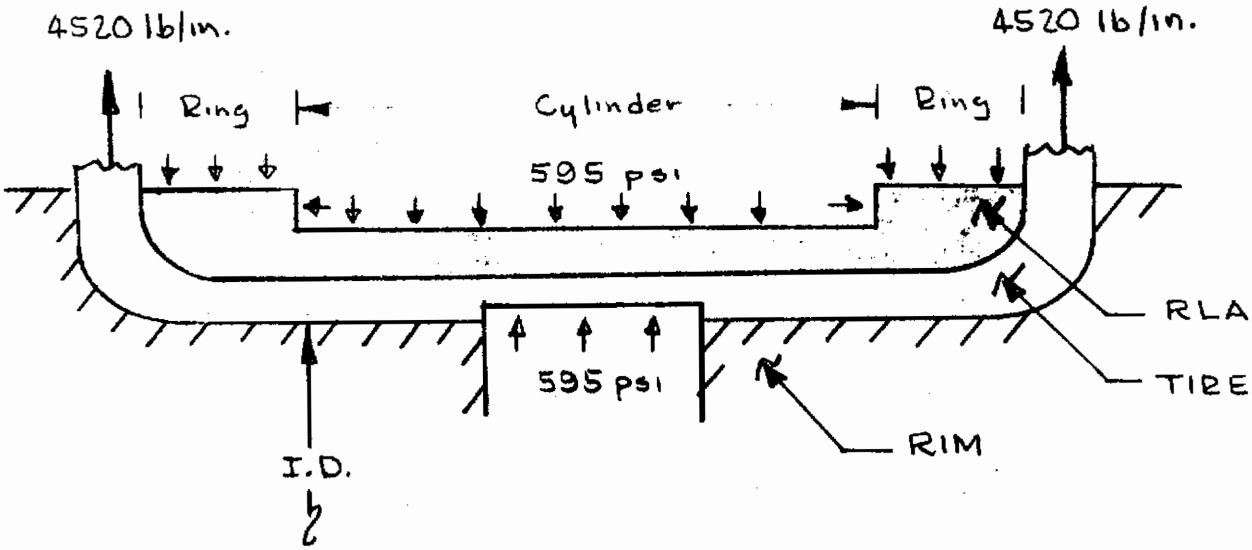
- Design burst pressure, 595 psi
- Casing load at rim, 4520 lb/in.
- Allowable hoop strain, 0.017 in/in.
- Allowable lateral deflection, 0.094 in.

The calculated safety margins were based on minimum allowable ultimate strengths of composite materials. They indicate that the RLA is adequate for the specified load conditions.

III. DISCUSSION

A. DESCRIPTION

The schematic below shows the relationship between the RLA, tire carcass, and rim in addition to the location of imposed loads.



The cylindrical portion of the RLA is constructed from interspersed layers of laterally-oriented 341-Glass cloth and hoop-directed S-901 Glass filaments encased in an epoxy matrix. The end rings are sections built up from additional hoop-directed glass roving/epoxy. Two additional layers of 181-Glass Cloth, biased at 45 degrees, cover the entire inside diameter and the edges of the rings.

The rim is assumed to offer rigid support for the RLA, both laterally in tension and circumferentially in compression. Because of this rigid support along the inside diameter and the opposing external pressure along the outside diameter of the RLA, structural instability is not expected.

B. MATERIAL PROPERTIES

The following material properties were taken from MIL-HNDBK-17 (Reference I-1):

1. 341-Glass Fabric/Epoxy

a. Compression

$E_L = 5.12 \times 10^6$ psi, $F_{CU} = 60{,}000$ psi

$E_H = 2.08 \times 10^6$ psi, $F_{CU} = 26{,}300$ psi

b. Tension

$E_L = 4.58 \times 10^6$ psi, $F_{TU} = 85{,}000$ psi

$E_H = 1.82 \times 10^6$ psi, $F_{TU} = 10{,}200$ psi

c. Flexure

$E_L = 5.00 \times 10^6$ psi, $F_B = 110{,}000$ psi

$E_H = 1.93 \times 10^6$ psi, $F_B = 21{,}700$ psi

2. 181-Glass Fabric/Epoxy

$E_H = E_L = 2.2 \times 10^6$ psi

$F_{TU} = F_{CU} = 26{,}600$ psi

The allowable ultimate tensile strength of the S-901 Glass/epoxy hoop composite was determined from the Aerojet Structural Materials Handbook (Reference I-2) as follows:

$$F_{TU} = K_1 \, P_{VG} \, \sigma_{F,\,MIN}$$

where

$\sigma_{F,\,MIN} = 415{,}000$ psi ultimate filament strength

$P_{VG} = 0.673$ percent glass by volume

$K_1 = 0.85$ correction for diameter

$F_{TU} = 0.85\ (.673)\ (415{,}000) = 235{,}000$ psi

The directional moduli of the hoop composite are

$$E_H = 0.673\ (12.4 \times 10^6) = 8.35 \times 10^6 \text{ psi}$$

$$E_L = 0.5 \times 10^6 \text{ psi (matrix only)}$$

Additional allowable strengths of the total interspersed cylindrical section of the RLA were determined by testing actual specimens. The results were

$$F_{CU,\ MIN} = 34{,}900 \text{ psi}$$

$$F_{B,\ MIN} = 68{,}400 \text{ psi}$$

It is assumed that Poisson's Ratio is negligible for all composite materials used in the analysis.

IV. ANALYSIS

A. COMPOSITE CYLINDRICAL SECTION

At a distance from the ring section, the RLA may be treated as a right circular cylinder subjected only to an end load. The resulting compressive stress is

$$\sigma_C = \frac{P_0}{TC_1}$$

where

$$P_0 = 4520 \text{ lb/in.}$$

$$t_{C_1} = 0.25 \text{ in.}$$

$$\sigma_C = \frac{4520}{0.25} = 18{,}100 \text{ psi}$$

The margin of safety is

$$M.S. = \frac{F_{CU}}{\sigma_C} - 1$$

$$M.S. = \frac{34{,}900}{18{,}100} - 1 = \underline{\underline{+0.93}}$$

B. DISCONTINUITY ANALYSIS

At the discontinuity, the RLA is separated into two circular free bodies (ring and cylinder) subjected to the loads and bending moments shown in Figure I-1. Section properties are calculated, rotations and deflections of each free body are equated, and the discontinuity stresses at the juncture are established.

1. Cylinder - Composite Beam Properties

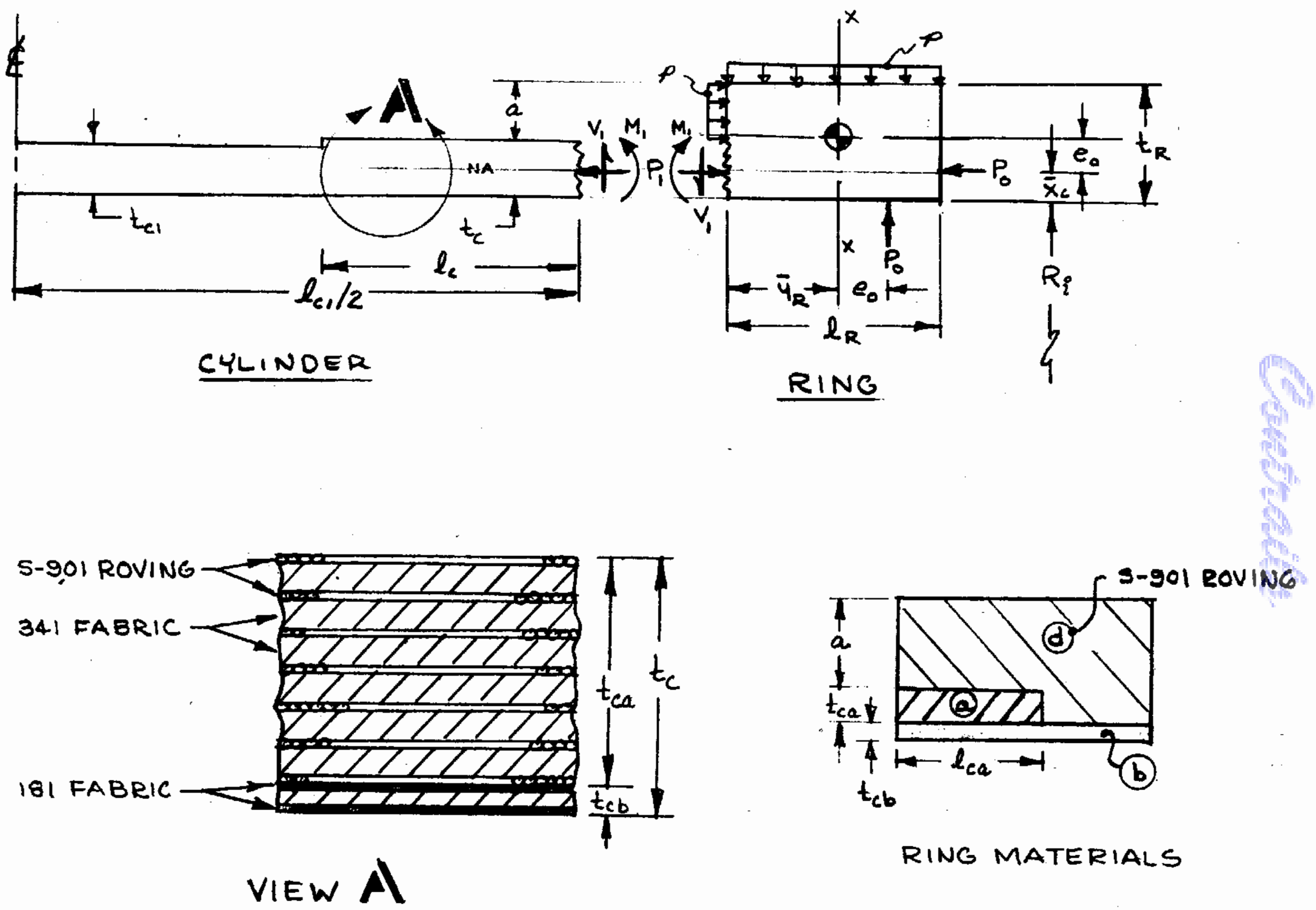
The thickness of each composite layer is 0.010 in., and from View A of Figure I-1 the total material thicknesses are

$$t_{341} = 0.260 \text{ in.}$$

$$t_{181} = 0.020 \text{ in.}$$

$$t_{901} = 0.070 \text{ in.}$$

$$t_C = 0.350 \text{ in.}$$


CYLINDER
RING
VIEW A
RING MATERIALS
S-901 ROVING
341 FABRIC
181 FABRIC
NA

a. Modulus

The composite modulus in the longitudinal direction is

$$E_{LC} = \frac{\sum^{n} E_{LC2°}\, t_{2°}}{t_C}$$

$$E_{LC} = \frac{[0.5(.07) + 5.0(.260) + 2.2(.02)] x\ 10^6}{0.350}$$

$$E_{LC} = 3.94 \times 10^6 \text{ psi}$$

The composite modulus in the hoop direction is

$$E_{HC} = \frac{\sum^{n} E_{HC2°}\, t_{2°}}{t_C}$$

$$E_{HC} = \frac{[8.35(.07) + 1.93(.260) + 2.2(.02)] \times 10^6}{0.350}$$

$$E_{HC} = 3.23 \times 10^6 \text{ psi}$$

b. Neutral Axis

The neutral axis of the cylinder section is

$$\bar{X}_C = \frac{\sum^{n} E_{LC2°}\, t_{2°}\, \bar{X}_{2°}}{E_{LC}\, t_C}$$

For ease of calculation, the cylinder can be divided into two symmetrical sections 'a' and 'b' as shown in Figure I-1. Then,

$$\bar{X}_C = \frac{E_{LCA}\, t_{CA}\, \bar{X}_A + E_{LCB}\, t_{CB} \bar{X}_B}{E_{LC}\, t_C}$$

$$\bar{X}_C = \frac{[.5(.07) + 5.0(.240)]\ .195 + [2.2(.02) + 5.0(.02)].020}{3.94\ (0.350)}$$

$$\bar{X}_C = \frac{1.235(.195) + 0.144(0.020)}{1.379}$$

$$\bar{X}_C = 0.177 \text{ in.}$$

c. Flexural Rigidity

The flexural rigidity per inch of circumference is calculated from

$$D_C = E_{LC} I_C = 1/12 \left[(E_{LCA}\, t_{CA}) t_{CA}^2 + (E_{LCB}\, t_{CB}) t_{CB}^2 \right]$$

$$+ (E_{LCA}\, T_{CA})\, (\bar{X}_A - \bar{X}_C)^2 + (E_{LCB}\, T_{CB})\, (\bar{X}_C - \bar{X}_B)^2$$

$$D_C = 10^6 \quad \frac{1.235(.31)^2 + 0.144(.04)^2}{12} + 1.235(.018)^2 + 0.144(.157)^2$$

$$D_C = 13{,}860 \text{ lb-in.}$$

d. Stiffness

The modulus of the beam foundation (stiffness) is

$$k_C = \frac{E_{HC}\ t_C}{R_C^2}$$

with

$$R_C = R_{2^\circ} + \bar{X}_C = 10.375 + 0.177 = 10.552 \text{ in.}$$

$$k_C = \frac{3.23 \times 10^6\ (.350)}{(10.552)^2}$$

$$k_C = 10{,}150 \text{ lb/in.}^3$$

e. Beam Characteristic (λ)

The beam characteristic is defined to be

$$\lambda_C{}^4 = \frac{kC}{4D_C}$$

$$\lambda_C{}^4 = \frac{10{,}150}{4(13{,}860)} = 0.183 \text{ in.}^{-4}$$

and it follows that

$$\lambda_C^3 = 0.208 \text{ in.}^{-3},\ \lambda_C^2 = 0.428 \text{ in.}^{-2},\ \lambda_C = 0.654 \text{ in.}^{-1}$$

2. Ring - Composite Properties

The required ring dimensions are:

$$A = 0.4 \text{ in.},\ t_{CA} = 0.31 \text{ in.},\ t_{CB} = 0.04 \text{ in.},\ \ell_{CA} = 0.626 \text{ in.}$$

$$\ell_R = 1.126 \text{ in.},\ t_R = 0.75 \text{ in.}$$

a. Centroid

The lateral distance to the centroid of the ring is

$$_R = \frac{\sum^n E_{H2°} A_{2°} \overline{Y}_{2°}}{\sum E_{H2°} A_{2°}}$$

Again using the 'a' and 'b' sections for the extension of the cylinder into the ring:

$$Y_R = \left\{(E_{HCA}\, t_{CA})\ell_{CA}\overline{Y}_A + (E_{NCB} t_{CB})\ell_R\ \overline{Y}_B + E_{HCD}\left[a\ell_R^2/2 + t_{CA}\,(\ell_R^2 - \ell_{CA}^2)/2\right]\right\} \Big/ \left\{(E_{HCA}\, t_{CA})\ell_{CA} + (E_{HCB}\, t_{DB})\ell_R + E_{HCD}[a\ell_R + t_{CA}\,(\ell_R - \ell_{CA})]\right\}$$

$$Y_R = \left\{[8.35(.07) + 1.93(.24)]\,(.626)(.313) + [2.2(.02) + 1.93(.02)]\,(1.126)(.563) + 8.35\,[.4\,(1.126)^2/2 + .31\,(1.126^2 - 0.626^2)/2]\right\} \Big/ \left\{[8.35(.07) + 1.93(.24)]\,(.626) + [2.2(.02) + 1.93(.02)]\,(1.126) + 8.35\,[.4\,(1.126) + .31\,(1.126 - 0.626)]\right\}$$

$$Y_R = \frac{3.5090}{5.8046} = 0.605 \text{ in.}$$

The radial distance to the centroid of the ring is

$$\bar{X}_R = \frac{\sum^{n} E_{H2^\circ} A_{2^\circ} \bar{X}_{2^\circ}}{\sum^{n} E_{H2^\circ} A_{2^\circ}}$$

$$\bar{X}_R = \frac{1}{5.8046} \Big\{ 1.048(.626)(.195) + 0.083(1.126)(.02) + 8.35[.4(1.126)(.55) + .31(.5)(.195)] \Big\}$$

$$\bar{X}_R = \frac{2.4506}{5.8046} = 0.422 \text{ in.}$$

b. Flexural Rigidity

The flexural rigidity of the ring is calculated from

$$D_R = (EI)_R = \sum^{n} E_{HC2^\circ} I_{2^\circ}$$

$$D_R = \sum^{n} (E_{HC} T_C)_{2^\circ} \ell^3_{2^\circ} / 12 + (E_{HC} T_C)_{2^\circ} \ell_{2^\circ} (\bar{X}_R - \bar{X}_{2^\circ})^2$$

$$D_R = 10^6 \Big\{ \frac{1.048(.626)^3 + 0.083(1.126)^3 + 8.35[.4(1.126)^3 + .31(.5)^3]}{12} + 1.048(.626)(.292)^2 + 0.083(1.126)(.042)^2 + 8.35[.4(1.126)(.042)^2 + .31(.5)(.271)^2] \Big\}$$

$$D_R = 6.134 \times 10^6 \text{ lb-in.}^2$$

3. Ring Distortion

The ring is assumed to be subjected to a uniformly distributed twisting couple of M_t in-lb per linear inch, which causes the ring to rotate about its centroid through an angle,

$$\theta_R = \frac{M_T R_R^2}{D_R}$$ (Reference I-3, page 225)

The bending moment is

$$M_T R_R = P_0 e_0 R_{2^\circ} + V_1 Y_R R_C - (P_0 - P_1) e_0 R_C$$

$$- \rho a \ (R_A - R_R) R_A + \rho \ell_R (Y_R - \ell_R/2) R_0$$

$$- M_1 R_C$$

The load (P_1) is calculated from a force balance on the ring in the lateral direction:

$$\Sigma F = (P_0 - P_1) 2\pi R_C - \rho a (2\pi R_A) = 0$$

Solution of the equation yields

$$P_1 = P_0 - \frac{\rho a \ R_A}{R_C}$$

with

$$R_A = R_{2^\circ} + t_C + a/2$$

$$R_A = 10.375 + 0.350 + 0.200 = 10.925 \text{ in.}$$

$$P_1 = 4520 - 595(.4)(10.925)/10.552$$

$$P_1 = 4520 - 246 = 4274 \text{ lb/in.}$$

and with

$$e_0 = \bar{X}_R - \bar{X}_C = 0.422 - 0.177 = 0.245 \text{ in.}$$

$$R_R = R_{2^\circ} + \bar{X}_R = 10.375 + 0.422 = 10.797 \text{ in.}$$

$$R_0 = R_{2^\circ} + t_R = 10.375 + 0.750 = 11.125 \text{ in.}$$

the bending moment is

$$M_T R_R = 4520(.245)(10.375) + V_1(.605)(10.552)$$

$$- 246(.245)(10.552) - 595(.4)(.128)(10.925)$$

$$+ 595(1.126)(.042)(11.125) - M_1(10.552)$$

$$M_T R_R = 10{,}833 + 6.384\ V_1 - 10.552\ M_1$$

The rotation becomes

$$\theta_R = \frac{10.797}{6.134 \times 10^6} \left\{10833 + 6.384\ V_1 - 10.552 M_1\right\}$$

$$\theta_R = \left[190.7 + 0.1124\ V_1 - 0.1857 M_1\right] \times 10^{-3}$$

The radial deflection of the ring at the discontinuity is given by

$$\delta_R = \frac{R_R \sum^n P_X R_X}{\sum^n E_{H2^\circ}\ A_{2^\circ}} - Y_R \theta_R$$

$$\delta_R = 10.797[4520(10.375) - 595(1.126)(11.125) - 10.552\ V_1] / 5.8046 \times 10^6$$

$$- 0.605[190.7 + 0.1124\ V_1 - 0.1857\ M_1] \times 10^{-3}$$

$$\delta_R = \left\{0.1122\ M_1 - 0.0876\ V_1 - 42.0\right\} \times 10^{-3}$$

4. Cylinder Distortion

The cylinder is subjected to uniformly distributed discontinuity forces (V_1) and bending moments (M_1). The rotation (Reference I-3), Cases 14 and 15, p. 302) of the neutral axis is

$$\theta_C = \frac{V_1}{2D_C \lambda_c^2} + \frac{M_1}{D_C \lambda_C}$$

$$\theta_C = \frac{V_1}{2(13860)(.428)} + \frac{M_1}{13860(.654)}$$

$$\theta_C = \left\{0.0843 V_1 + 0.1103 M_1\right\} \times 10^{-3}$$

The radial deflection of the cylinder (Reference I-3, Cases 14 and 15, p. 302) is

$$\delta_C = \frac{V_1}{2D_C\lambda_C{}^3} + \frac{M_1}{2D_C\lambda_C{}^2}$$

$$\delta_C = \frac{V_1}{2(13860)(.280)} + \frac{M_1}{2(13860)(.428)}$$

$$\delta_C = 0.1288\ V_1 + 0.0843\ M_1 \quad x\ 10^{-3}$$

5. Discontinuity Forces & Moments

Equating the rotation (Equation 2) and the deflection (Equation 3) of the cylinder to the rotation (Equation 4) and the deflection (Equation 5) of the ring, respectively, yields the following relations:

$$M_1 = 1505 + 7.756\ V_1$$

$$V_1 = -6835 + 10.609\ M_1$$

Simultaneous solution of Equations 6 & 7 yields

M_1 = 634 in.-lb/in.

V_1 = 109 lb/in.

C. HOOP STRAIN

The maximum tensile strain in the hoop direction occurs at the extreme end of the ring section of the RLA and is given by the equation

$$\epsilon_{\theta max} = \frac{\delta_R + (\ell_R - \bar{Y}_R)\theta_R}{R_{2^\circ}}$$

where, from Equation 3, the deflection is

$$\delta_R = \left\{0.1122(634) + 0.0876(109) - 42.0\right\}\ x\ 10^{-3}$$

δ_R = 0.039 in.

and the rotation, from Equation 2, is

$$\theta_R = \left\{190.7-0.1124(109)-0.1857(634)\right\} \times 10^{-3}$$

$$\theta_R = 0.061 \text{ radian}$$

The maximum tensile strain is

$$\epsilon_{\theta max} = \frac{0.039 + 0.521(.061)}{10.375} = 0.007 \text{ in./m.}$$

and the margin of safety is

$$\text{M.S.} = \frac{0.017}{0.007} - 1 = \underline{\underline{+1.43}}$$

D. LATERAL DEFLECTION

Assuming no lateral deflection occurs across the ring and the cylinder is of minimum thickness (t_{C1}), then the lateral deflection is

$$\Delta L_C = \frac{P_1 \ell_{C1}}{E_{LC1} t_{C1}}$$

where

$$\ell_{C1} = 9.624 \text{ in.}$$

$$E_{LC1}\, t_{C1} = [0.5(.05) + 5.0(.180) + 2.2(.02)] \times 10^6$$

$$= 0.97 \times 10^6$$

Thus,

$$\Delta L_C = \frac{4274(9.624)}{0.97 \times 10^6} = 0.042 \text{ in.}$$

and the margin of safety is

$$\text{M.S.} = \frac{0.094}{0.042} - 1 = \underline{\underline{+ 1.24}}$$

E. MAXIMUM STRESSES

1. Lateral Stress in Cylindrical Section

a. Tensile Stress

The maximum tensile stress occurs in the inside fibers of the 181-Glass Fabric. The combined, membrane and bending, stress is

$$\sigma_{T_{181}} = \frac{M_1 E_{L_{181}} \bar{X}_C}{D_C} - \frac{P_1 E_{L_{181}}}{E_{LC} t_C}$$

$$\sigma_{T_{181}} = \frac{634(2.2 \times 10^6)(.177)}{13860} - \frac{4274(2.2 \times 10^6)}{3.94 \times 10^6(.35)}$$

$$\sigma_{T_{181}} = 17,800 - 6800 = 11,000 \text{ psi}$$

The margin of safety is

$$M.S. = \frac{26,600}{11,000} - 1 = \underline{\underline{+1.42}}$$

b. Compressive Stress

The maximum compressive stress due to the lateral load and bending moment occurs in the outside fibers of the 341-Glass Fabric:

$$\sigma_{C_{341}} = \frac{M_1 E_{L_{341}} (X_{max} - \bar{X}_C)}{D_C} + \frac{P_1 E_{L_{341}}}{E_{LC} t_C}$$

$$\sigma_{C_{341}} = \frac{634(5.0 \times 10^6)(.163)}{13860} + \frac{4274(5.0 \times 10^6)}{3.94 \times 10^6(.35)}$$

$$\sigma_{C_{341}} = 37,300 + 15,500 = 52,800 \text{ psi}$$

The margin of safety is

$$M.S. = \frac{60,000}{52,800} - 1 = \underline{\underline{+ 0.14}}$$

2. Hoop Stress in Cylindrical Section

The maximum hoop stress in the cylinder due to the shear load and bending moment is given by

$$\sigma_T = \frac{2M_1\lambda_C^2 R_C}{T_C} + \frac{2V_1\lambda_C R_C}{t_C}$$

$$\sigma_T = \frac{2(634)(.428)(10.552)}{0.35} - \frac{2(109)(.654)(10.552)}{0.35}$$

$$\sigma_T = 16,400 - 4300 = 12,100 \text{ psi}$$

Assuming that the S-901 Glass/Epoxy composite carries the entire hoop load, the composite stress is

$$\sigma_{T_{970}} = \sigma_T \frac{t_C}{t_{970}}$$

$$\sigma_{T_{970}} = \frac{12,100(.35)}{0.07} = 60,500 \text{ psi}$$

The margin of safety is

$$M.S. = \frac{235,000}{60,500} - 1 = \underline{\underline{+\,2.88}}$$

3. Hoop Stress in Ring

The maximum hoop stress in the ring, due to bending, occurs in the hoop composite at the outer edge and is given by

$$\sigma_T = \frac{M_T\, R_R\, E_{H_{970}}\, (\ell_R - \overline{Y}_R)}{D_R}$$

From Equation 1, the bending moment is

$$M_T R_R = 10,833 - 6.384(109) - 10.552(634)$$

$$M_T R_R = 3450 \text{ in.-lb}$$

and the hoop stress is

$$\sigma_T = \frac{3450(8.35 \times 10^6)(.521)}{0.6134 \times 10^6} - 24{,}500 \text{ psi}$$

The margin of safety is

$$M.S. = \frac{235{,}000}{24{,}500} - 1 = \underline{\underline{+ \text{ HIGH}}}$$

REFERENCES

I-1. Military Handbook 17, Plastics for Flight Vehicles, Part I, November 1959.

I-2. Structural Materials Handbook, Aerojet-General Corporation, Structural Materials Division, February 1964.

I-3. R. J. Roark, Formulas for Stress and Strain, 4th Edition, McGraw-Hill, New York, 1965.

APPENDIX II

TAPE WINDING OF 6-PLY TOROIDAL TIRE

APPENDIX II

TAPE WINDING OF 6-PLY TOROIDAL TIRE

1. REFERENCES

Technical Report, Filament-Wound Toroidal Tire, AFML-TR-67-154, June 1967, by Frank S. Salcedo (Table I, used in 3 below).

Dwg. No. BK-3300 by the General Tire and Rubber Co.--Mandrel; Rim-Locking Ring Details, 30 x 7.7 toroidal tire, T-VII 12 PR.

2. GENERAL DESCRIPTION

This design analysis will determine the wall thickness and configuration of a torus-shaped carcass made from six plies wrapped with nylon calendered tapes.

A water-soluble mandrel and inserted rim-locking ring are wrapped with neoprene-rubber tape, then vacuum-bagged and cured at 250°F, constituting a solid, rigid structure--the mandrel assembly.

The mandrel is located in a winding machine which provides three basic motions to produce desired winding path of each ply:

a. Rotation of the mandrel at constant angular velocity about the axis of the toroid.

b. Rotation of the filament-payoff head at constant angular velocity around a portion of the toroid.

c. Incremental movement of the filament-payoff head to accomplish an accurate filament path during rotation of the winding head.

The wrapped tape edges are adjacent to each other on the crown of each ply, and begin to overlap on both sides of the carcass. This overlap increases toward the inside of the torus where it is uniformly distributed because of the cylindrical shape.

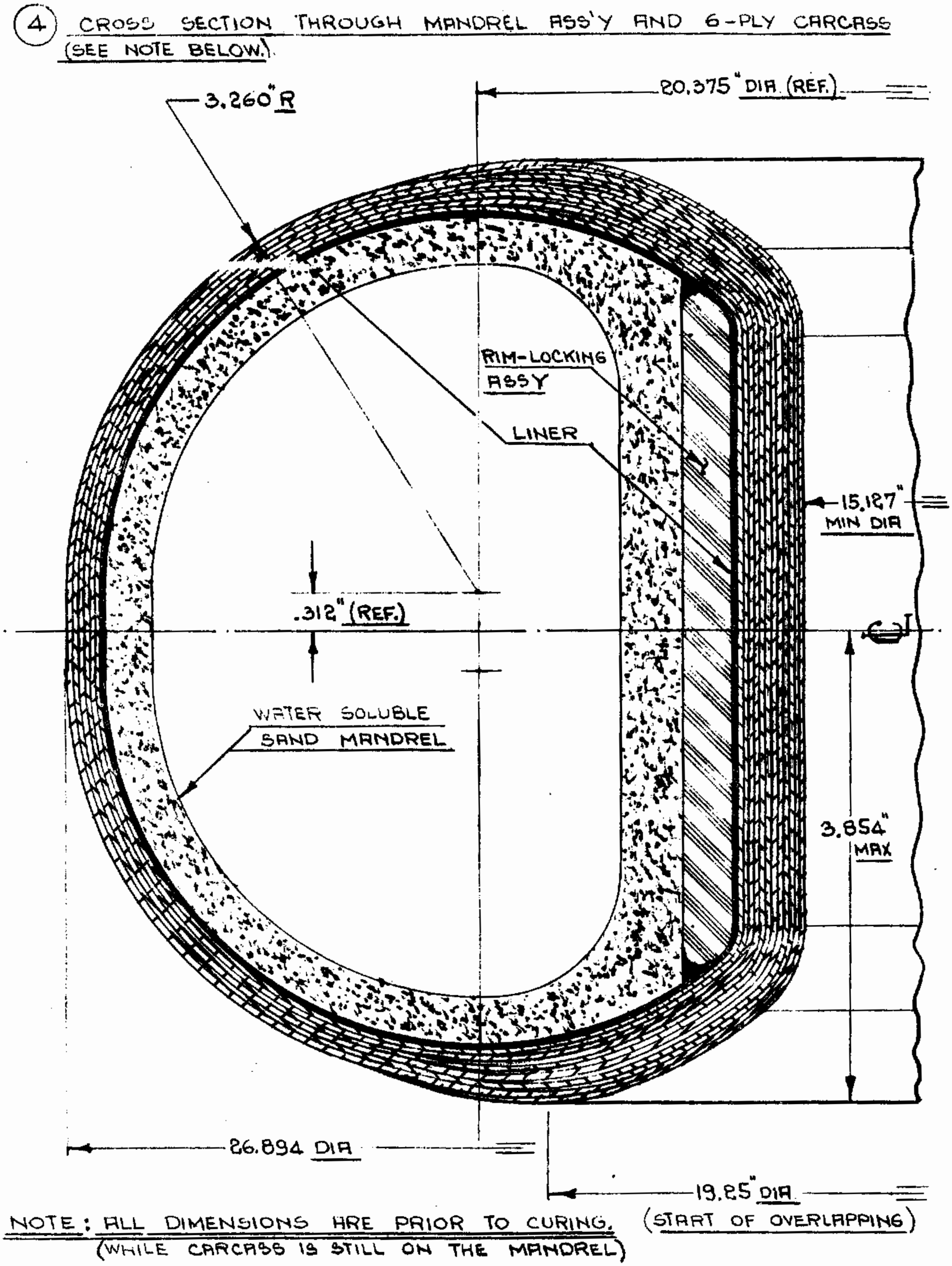
The tape is 0.047-in. thick and 0.25-in. wide.

3. WINDING PATH AT NEUTRAL CARCASS AXIS

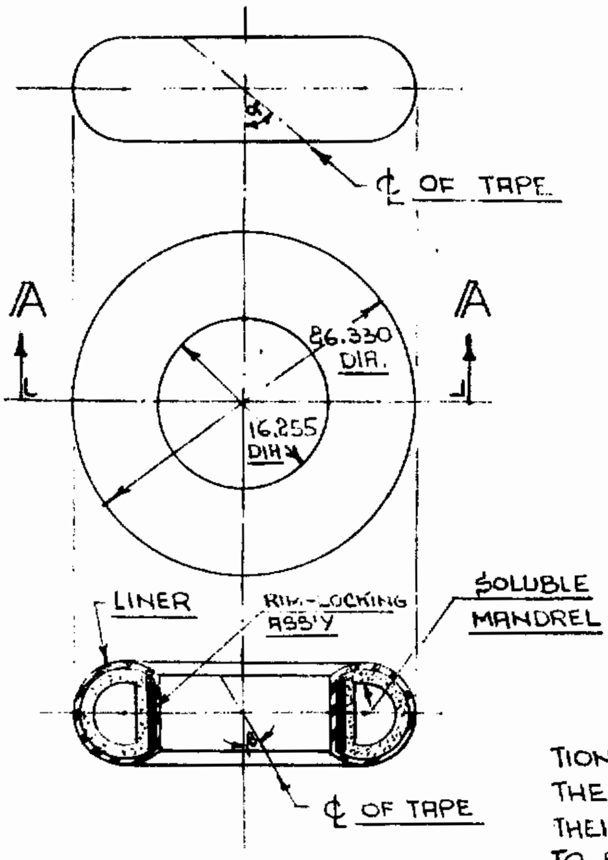
The neutral axis is the surface between plies 3 and 4 in the carcass structural reinforcement.

NEUTRAL STATION	NEUTRAL-STATION DIAMETER (IN.)	NEUTRAL WINDING PATH	
		DEGREES	MINUTES
1 (crown OD)	26.65	53	51
2	26.62	53	46
3	26.40	53	8
4	26.08	52	2
5	25.48	50	32
6	24.82	49	3
7	24.08	46	51
8	23.22	44	43
9	22.28	42	28
10	21.28	40	3
11	20.30	37	58
12	19.32	35	50
13	18.32	33	43
14	17.38	31	47
15	16.58	30	3

NOTE: The angles listed above are applied to each ply.


4 CROSS SECTION THROUGH MANDREL ASS'Y AND 6-PLY CARCASS
(SEE NOTE BELOW)
3.260" R
20.375" DIA (REF.)
RIM-LOCKING ASSY
LINER
15.187" MIN DIA
.312" (REF.)
WATER SOLUBLE SAND MANDREL
3.854" MAX
26.894 DIA
19.25" DIA
(START OF OVERLAPPING)
NOTE: ALL DIMENSIONS ARE PRIOR TO CURING.
(WHILE CARCASS IS STILL ON THE MANDREL)

(5) MANDREL CONFIGURATION FOR 1ST PLY



SECTION "A - A"

α — WINDING ANGLE ON CROWN O.D.
β — WINDING ANGLE ON I.D. OF TORUS.

MANDREL PLUS LINER:

MANDREL O.D. —— 26.250 IN.
LINER (.04 IN.× 2) —— .080 IN.
26.330 IN.

O.D. = 26.330 IN.

RIM-LOCKING ASS'Y. I.D. — 16.335 IN.
LINER (.04 IN.× 2) — .080 IN.
16.255 IN.

I.D. = 16.255 IN.

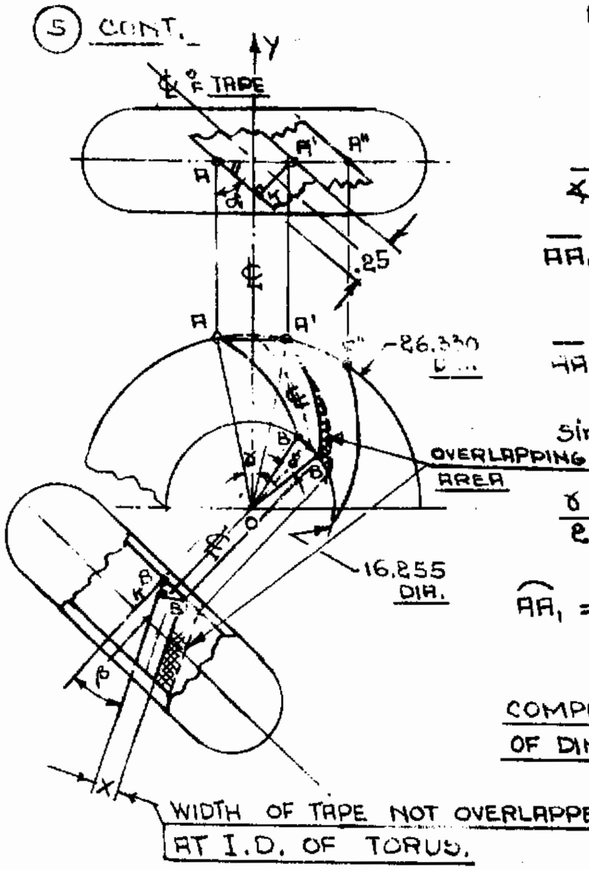
THE DIAMETERS OF NEUTRAL STATIONS 1, 2 & 3 ARE GREATER THAN THE COMPUTED O.D. (ABOVE); THEREFORE THEIR AVERAGE WINDING ANGLE SUPPOSED TO BE TRANSPOSED TO THE ORIGINAL, STARTING SURFACE AT THE CROWN OF THE MANDREL IS:

FROM (3):

STATION	STATION DIA.	WINDING PATH DEGREES	MINUTES
1	26.65	53	51
2	26.62	53	46
3	26.40	53	8
AVE.		53°	35' ON THE CROWN

NOTE: AS WILL BE NOTED IN THE FOLLOWING COMPUTATIONS, THE DIFFERENCES IN ARC AND CHORD LENGTHS ARE INSIGNIFICANT (1ST PLY ON CROWN ARC = .4211741 INCH ; CHORD = .4211235 INCH). THEREFORE, THE CHORD LENGTHS WERE USED TO REPRESENT A SURFACE.

(5) CONT.



$\overline{AA'} = \overline{A'A''} = .25$ INCH

$\alpha = 53° \; 35'$

$$\begin{array}{r} 90° \\ -\;53° \; 35' \\ \hline \measuredangle A = 36° \; 25' \end{array}$$

$$\overline{AA_1} = \frac{A'K}{\sin 36° \, 25'} = \frac{.25}{.59365} = .4211235$$

$$\overline{AA_1} = 2R \sin\frac{\gamma}{2}$$

$$\sin\frac{\gamma}{2} = \frac{\overline{AA_1}}{2R} = \frac{.4211235}{26.330} = .015994$$

$$\frac{\gamma}{2} = 0° \; 55' \qquad [\gamma = 1° \, 50' = 1.833°]$$

$$\widehat{AA_1} = \frac{\pi R \gamma}{180°} = \frac{\pi \times 13.165 \times 1.833°}{180°} = .4211741$$

COMPARISON OF DIMENSIONS: $\overline{AA_1} = .4211235$; $\widehat{AA_1} = .4211741$

O.D. CIRCUM. $= 2\pi R = 26.330 \times \pi = 82.6762$ INCHES

$$\frac{\text{O.D. CIRCUM.}}{\widehat{AA'}} = \frac{82.6762}{.4211741} = 196.299, \text{ SAY } 196.3 \text{ TAPES (NUMBER OF ARCS } AA')$$

I.D. CIRCUM. $= 2\pi r = 16.255 \times \pi = 51.0407$ INCHES

$$\frac{\text{I.D. CIRCUM}}{\text{N}^{\underline{o}} \text{ OF TAPES}} = \frac{51.0407}{196.3} = .2600137, \text{ SAY } .260$$

$\widehat{BB_1} = .260$ INCH

$\beta = 30° \; 9'$ $\qquad \widehat{BB_1} = \dfrac{\pi r \delta}{180}$ $\qquad \delta = \dfrac{BB_1 \times 180}{\pi r} = \dfrac{.260 \times 180}{\pi \times 8.1275} = 1.834°$

$$\begin{array}{r} 90° \\ -\;30° - 9' \\ \hline \measuredangle B = 59° - 51' \end{array}$$

$$\delta = 1.834° \qquad \left[\frac{\delta}{2} = 0° \, 55'\right]$$

$$\overline{BB_1} = 2r \sin\frac{\delta}{2} = 2r \sin 0° \, 55' = 16.255 \times .016 = .2601$$

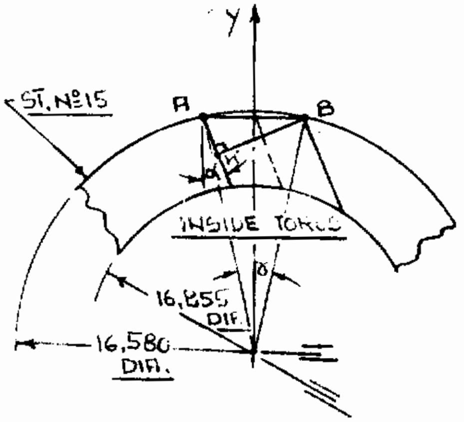
$B'K = X = .2601 \times \sin 59° \, 51' = .2601 \times .86471 = .2249$

[NOTE: $\measuredangle \gamma$ MUST BE EQUAL $\measuredangle \delta = 0° \, 55'$]

	.2500 INCH (TAPE WIDTH)
−	.2249 INCH
	.0251 INCH OVERLAP 1ST PLY

(5) CONT.

(a) OVERLAPPING DIMENSIONAL MAGNITUDE ON STATION № 15



$\alpha = 30° \ 9'$

$\measuredangle A = 59° \ 51'$

CIRCUM. OF DIA. ST № 15 $= 2\pi R = 16.58 \times \pi = 52.0612$

$\frac{\text{CIRCUM ST. № 15}}{\text{№ OF TAPES}} = \frac{52.0612}{196.3} = .265 \qquad \overset{\frown}{AB} = .265$

$\overset{\frown}{AB} = \frac{\pi R \gamma}{180}$

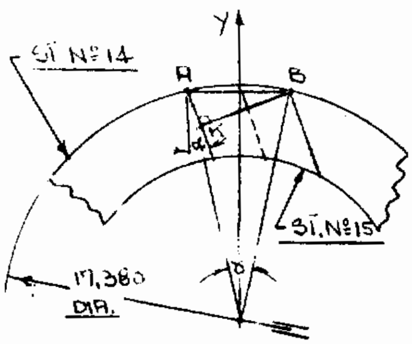
$\gamma = \frac{\overset{\frown}{AB} \times 180}{\pi R} = \frac{.265 \times 180}{\pi \times 8.29} = 1.83° \qquad \left[\frac{\gamma}{2} = 0° \ 55'\right]$

$\overline{AB} = 2R \sin\frac{\gamma}{2} = 16.58 \times \sin 0° \ 55' = 16.58 \times .016 = .26528$

$\overline{BK} = \overline{AB} \sin 59° \ 51' = .26528 \times .86471 = .22939$

.2500" — TAPE WIDTH
− .2294" — $\overline{BK}$
.0206" — OVERLAPPING AT POINT "B"

(b) OVERLAPPING DIMENSIONAL MAGNITUDE ON STATION № 14



$\alpha = 31° \ 47'$

$\measuredangle A = 58° - 13'$

CIRCUM. OF DIA. ST. № 14 $= 2\pi R = 17.38 \times \pi = 54.5732$

$\frac{\text{CIRCUM ST. № 14.}}{\text{№ OF TAPES}} = \frac{54.5732}{196.3} = .27801 \qquad \overset{\frown}{AB} = .278$

$\overset{\frown}{AB} = \frac{\pi R \gamma}{180} \qquad \gamma = \frac{\overset{\frown}{AB} \times 180}{\pi R} = \frac{.278 \times 180}{\pi \times 8.69} = 1.833°$

$\left[\frac{\gamma}{2} = 0° \ 55'\right]$

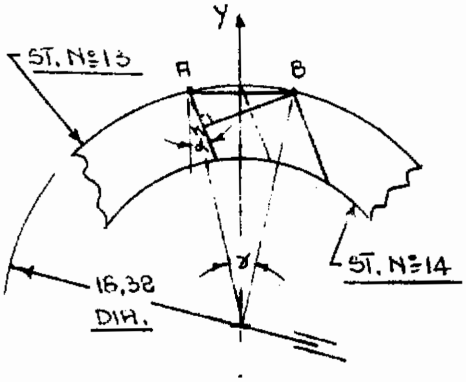
$\overline{AB} = 2R \sin\frac{\gamma}{2} = 17.38 \times \sin 0° \ 55' = 17.38 \times .016 = .27808$

$\overline{BK} = .AB \times \sin 58° \ 13' = .27808 \times .85004 = .23638$

.2500" — TAPE WIDTH
− .2364" — $\overline{BK}$
.0136" — OVERLAPPING AT POINT "B"

(5) CONT.

(c) OVERLAPPING DIMENSIONAL MAGNITUDE ON STATION Nº 13



$\alpha = 33° 43'$
$\measuredangle A = 56° 17'$

CIRCUM. OF DIA. ST. Nº13 = $2\pi R = 18.32 \times \pi = 57.5248$

$$\frac{\text{CIRCUM ST. Nº13}}{\text{Nº OF TAPES}} = \frac{57.5248}{196.3} = .29304 \qquad \widehat{AB} = .293$$

$$\widehat{AB} = \frac{\pi R \gamma}{180} \qquad \gamma = \frac{\widehat{AB} \times 180}{\pi R} = \frac{.293 \times 180}{\pi \times 9.16} = 1.83°$$

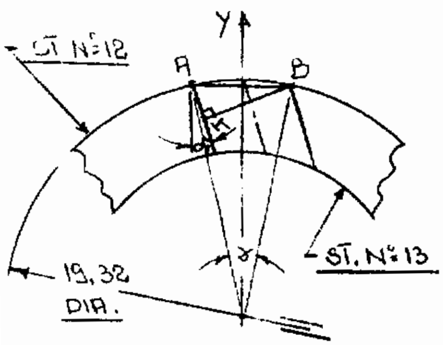
$$\left[\frac{\gamma}{2} = 0° 55'\right]$$

$\overline{AB} = 2R \sin\frac{\gamma}{2} = 18.32 \times \sin 0° 55' = 18.32 \times .016 = .29312$

$\overline{BK} = \overline{AB} \sin 56° 17' = .29312 \times .83179 = .2438$

.2500"	— TAPE WIDTH
− .2438"	— BK
.0062	— OVERLAPPING AT POINT "B"

(d) OVERLAPPING DIMENSIONAL MAGNITUDE ON STATION Nº12



$\alpha = 35° 50'$
$\measuredangle A = 54° 10'$

CIRCUM. OF DIA. ST. Nº 12 = $2\pi R = 19.32 \times \pi = 60.6648$

$$\frac{\text{CIRCUM. ST. Nº12}}{\text{Nº OF TAPES}} = \frac{60.6648}{196.3} = .30904$$

$$\widehat{AB} = \frac{\pi R \gamma}{180} \qquad \gamma = \frac{AB \times 180}{\pi R} = \frac{.309 \times 180}{\pi \times 9.66} = 1.83°$$

$$\left[\frac{\gamma}{2} = 0° 55'\right]$$

$\overline{AB} = 2R \sin\frac{\gamma}{2} = 19.32 \times \sin 0° 55' = 19.32 \times .016 = .30912$

$\overline{BK} = AB \sin 54° 10' = .30912 \times .81072 = .2506$

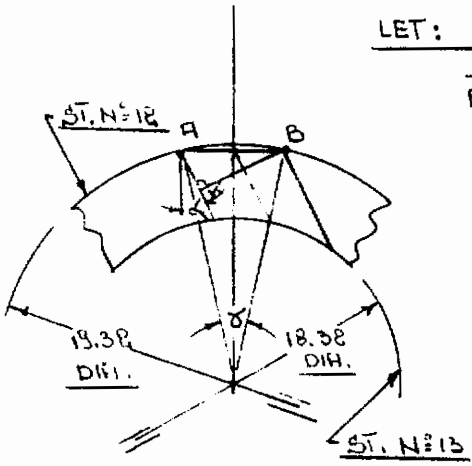
.2500"	— TAPE WIDTH
− .2506"	— BK
−.0006"	— NO OVERLAPPING (GAP)

NOTE: GAP DOES NOT EXIST; THEREFORE, OVERLAPPING MUST START BETWEEN STATION Nº 12 AND STATION Nº 13.

(5) CONT.

(c) DIAMETER ON WHICH OVERLAPPING BEGINS

ON STATION № 12 AND STATION № 13, ANGLE $\gamma = 1.83°$; THEREFORE, ON ANY DIAMETER BETWEEN THESE STATIONS, $\measuredangle\gamma$ IS CONSTANT.



LET: $\overline{BK} = .2500$

$\alpha = 35°50'$

$\measuredangle A = 54°10'$

$$\overline{BK} = \overline{AB} \sin A$$

$$\overline{AB} = \frac{\overline{BK}}{\sin A} = \frac{.25}{.81078} = .308$$

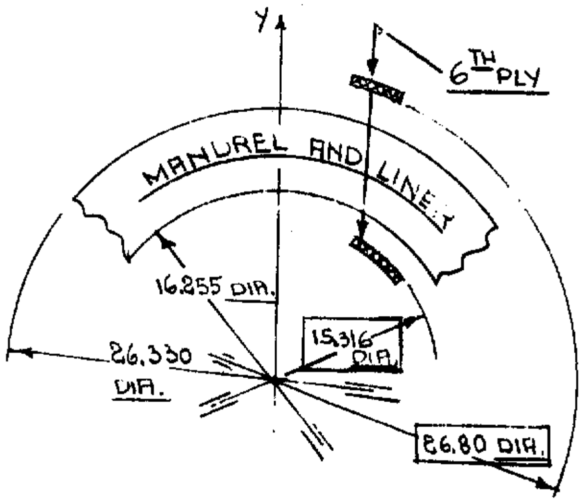
$$\gamma = 1.83° \qquad \frac{\gamma}{2} = 0°55'$$

$$\overline{AB} = 2R \sin\frac{\gamma}{2}$$

$$2R = \frac{\overline{AB}}{\sin\frac{\gamma}{2}} = \frac{.308}{.016} = 19.25$$

1ST PLY OVERLAPPING BEGINS ON DIA. 19.25 INCHES.

(6) CARCASS DIAMETERS AT SURFACE OF EACH PLY



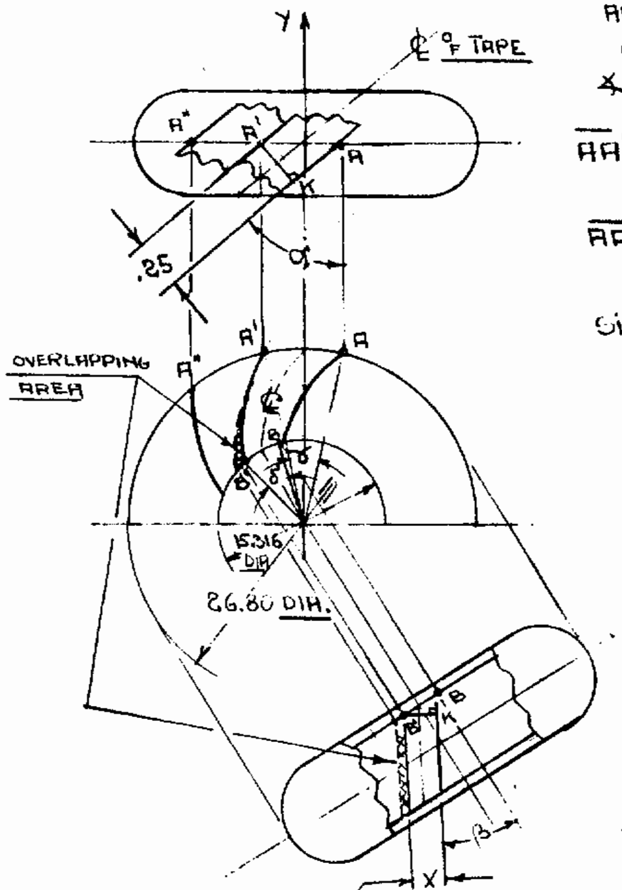
O.D.	I.D.
MANDREL SURFACE FOR 1ST PLY	
26.250	16.335
+ .08	− .08
26.330	**16.255**
1ST PLY SURFACE	
26.330	16.255
+ .094	− .094
26.424	16.161
	− .094
	16.067
2ND PLY SURFACE	
26.424	16.067
+ .094	− .188 (2×.094)
26.518	**15.879**
3RD PLY SURFACE	
26.518	15.879
+ .094	− .188
26.618	**15.691**
4TH PLY SURFACE	
26.618	15.691
+ .094	− .181
26.706	**15.503**
5TH PLY SURFACE	
26.706	15.503
+ .094	− .181
26.800	**15.316**

6TH PLY IS WRAPPED ON DIAMETERS:

O.D. = 26.80 INCHES

I.D. = 15.316 INCHES

⑦ CARCASS CONFIGURATION FOR 6^{TH} PLY



$\overline{AA'} = \overline{A'A''} = .25$ INCH

$\alpha = 53° \ 51'$

$\measuredangle A' = 36° \ 9'$

$$\overline{AA'} = \frac{A'K}{\sin 36°9'} = \frac{.25}{.5899} = .4238$$

$$\overline{AA'} = 2R \sin \frac{\gamma}{2}$$

$$\sin \frac{\gamma}{2} = \frac{\overline{AA'}}{2R} = \frac{.4238}{26.80} = .0158 \qquad \frac{\gamma}{2} = 0° \ 55'$$

$$[\gamma = 1.833°]$$

$$\widehat{AA'} = \frac{\pi R \gamma}{180} = \frac{\pi \times 13.4 \times 1.833}{180} = .4285$$

COMPARISON OF DIMENSIONS: $\overline{AA_1} = .4238$, $\widehat{AA_1} = .4285$

O.D. CIRCUM. $= 2\pi R = 26.80 \times \pi = 84.152$ INCHES

$$\frac{\text{O.D. CIRCUM.}}{\widehat{AA_1}} = \frac{84.152}{.4285} = 196.387 \ (\text{NUMBER OF ARCS } AA')$$

SAY 196.4 TAPES.

I.D. CIRCUM. $= 2\pi r = 15.316 \times \pi = 48.092$

$$\frac{\text{I.D. CIRCUM.}}{\text{N}^{o} \text{ OF TAPES}} = \frac{48.092}{196.4} = .2448 \qquad \widehat{BB'} = .2448 \text{ INCH}$$

$\beta = 30° \ 9'$

$\measuredangle B = 59° \ 51'$

$$\widehat{BB_1} = \frac{\pi r \delta}{180}$$

$$\delta = \frac{\widehat{BB_1} \times 180}{\pi r} = \frac{.2448 \times 180}{\pi \times 7.658} = 1.83° \quad \left[\frac{\delta}{2} = 0° \ 55'\right]$$

$$\overline{BB'} = 2r \sin \frac{\delta}{2} = 15.316 \times \sin(0° 55') = 15.316 \times .016 = .245056$$

$$\overline{B'K} = \overline{BB'} \sin(59° \ 51') = .245056 \times .86471 = .2119$$

.2500	— TAPE WIDTH
− .2119	— $\overline{B'K}$
.0381	INCH OVERLAPPING AT POINT "B'."

NOTE: OVERLAPPING BEGINS ON DIA. 19.25 INCHES (AS ON 1^{ST} PLY) BECAUSE ALL DIMENSIONS OF EACH STATION ARE THE SAME.

(8) CONCLUSIONS

THE WRAPPING TECHNIQUE FOR EACH CONSECUTIVE PLY IS THE SAME IN SPITE OF THE CHANGING LEFT AND RIGHT HAND WINDING DIRECTIONS.

IN EACH PLY THE BEGINNING OF OVERLAPPING IS ESTABLISHED AT THE DIAMETER 19.25 INCHES. THIS WAY, EACH PLY CONSISTS OF SINGLE AND DOUBLE THICKNESSES RELATIVE TO THE ABOVE-MENTIONED DIAMETER.

TAKING ALL 6 PLIES IN CONSIDERATION, WE BUILD UP 12 PLIES WALL AT THE INSIDE TORUS, MAKING I.D. = 15.187 INCHES, MINIMUM.

WIDTH OF THE CARCASS TORUS WILL CORRESPOND TO 7.708 INCHES, AND THE CROWN DIA. TO 26.894 INCHES.

NOTE: THESE DIMENSIONS ARE PRIOR TO CURING (WHILE CARCASS IS STILL ON THE MANDREL).

APPENDIX III

Engineering Drawings

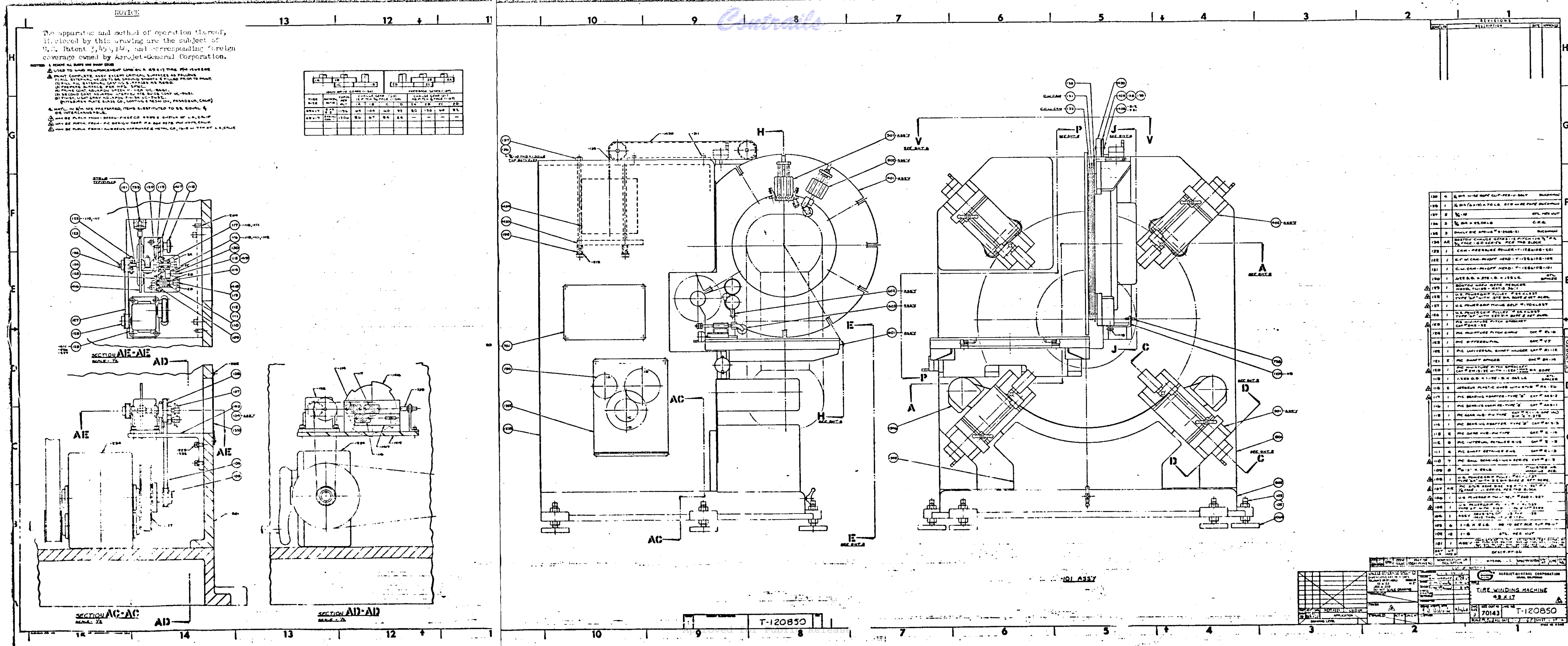
Appendix III

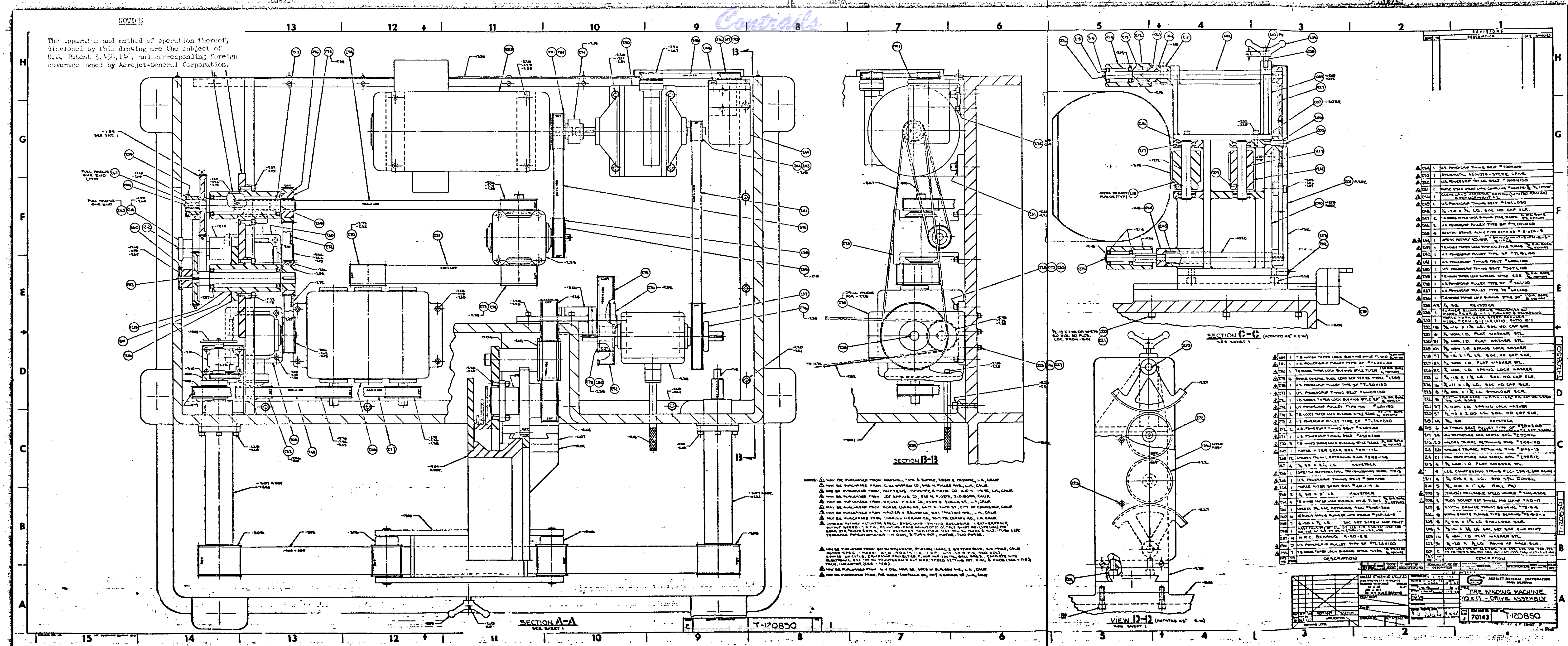
Engineering Drawings

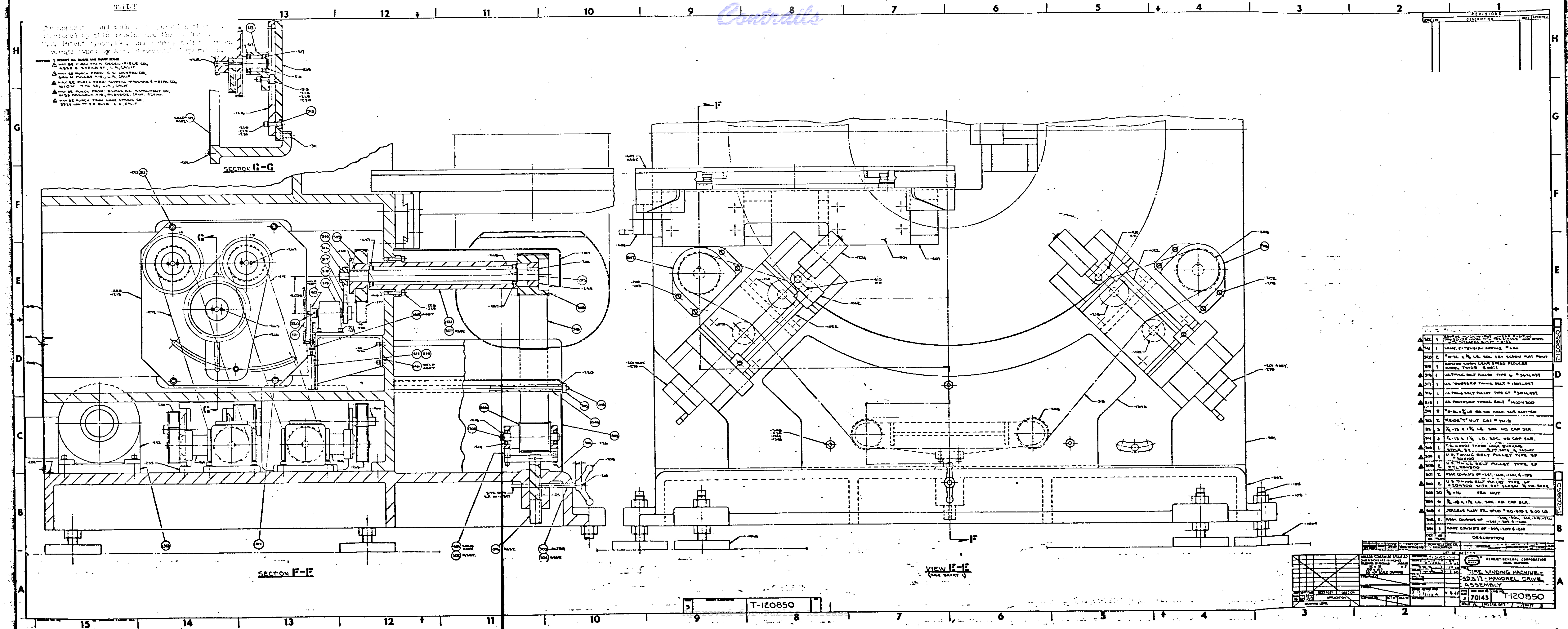
30 x 8.8 22 PR Subscale Tire and 49 x 17 26 PR Prototype Tire

Reproduced on succeeding pages are the following drawings of tooling for the 30 x 8.8 and 49 x 17 tires

Drawing No.	Title
T-120850, Sheets 1-14	Tire Winding Machine 49 x 17
T-120853-1	Cam-Payoff Head 30 x 8.8 Bias Tire
T-120853-2	Cam-Pressure Roller 30 x 8.8 Bias Tire
T-120853-3	Cam-Payoff Head 30 x 8.8 Geodesic Tire
T-120853-4	Cam-Payoff Head 30 x 8.8 Bias Tire
T-1286108-1	Cam-Payoff Head 49 x 17 Bias Tire
T-1286108-2	Cam-Pressure Roller 49 x 17 Bias Tire
T-1286125	Mandrel-Rim Lock Assy - 49 x 17 Tire
DK 4784	Segmented Curing Ring - 30 x 8.8 F/W Tire
DK 5619-2	Cavity Profile and Tread - 49 x 17 Tire
DK 5620-1	Tire Mold Details - 49 x 17 Tire
DK 5621-1	Bead Rings - 49 x 17 Tire Mold
DK 5622	Segmented Curing Ring - 49 x 17 Tire
DK 5623	Items Detail Segmented Curing Ring - 49 x 17 Tire
DK 5649	Curing Ring Assembly Detail - 49 x 17 Tire Mold


NOTICE
The apparatus and method of operation thereof, disclosed by this drawing are the subject of U.S. Patent 3,45?,1??, and corresponding foreign coverage owned by Aerojet-General Corporation.
SECTION AE-AE
SECTION AC-AC
SECTION AD-AD
101 ASSY
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE
49 X 17
70143
T-120850
DESCRIPTION
APPLICATION
DRAWING LEVEL
DO NOT SCALE DRAWING

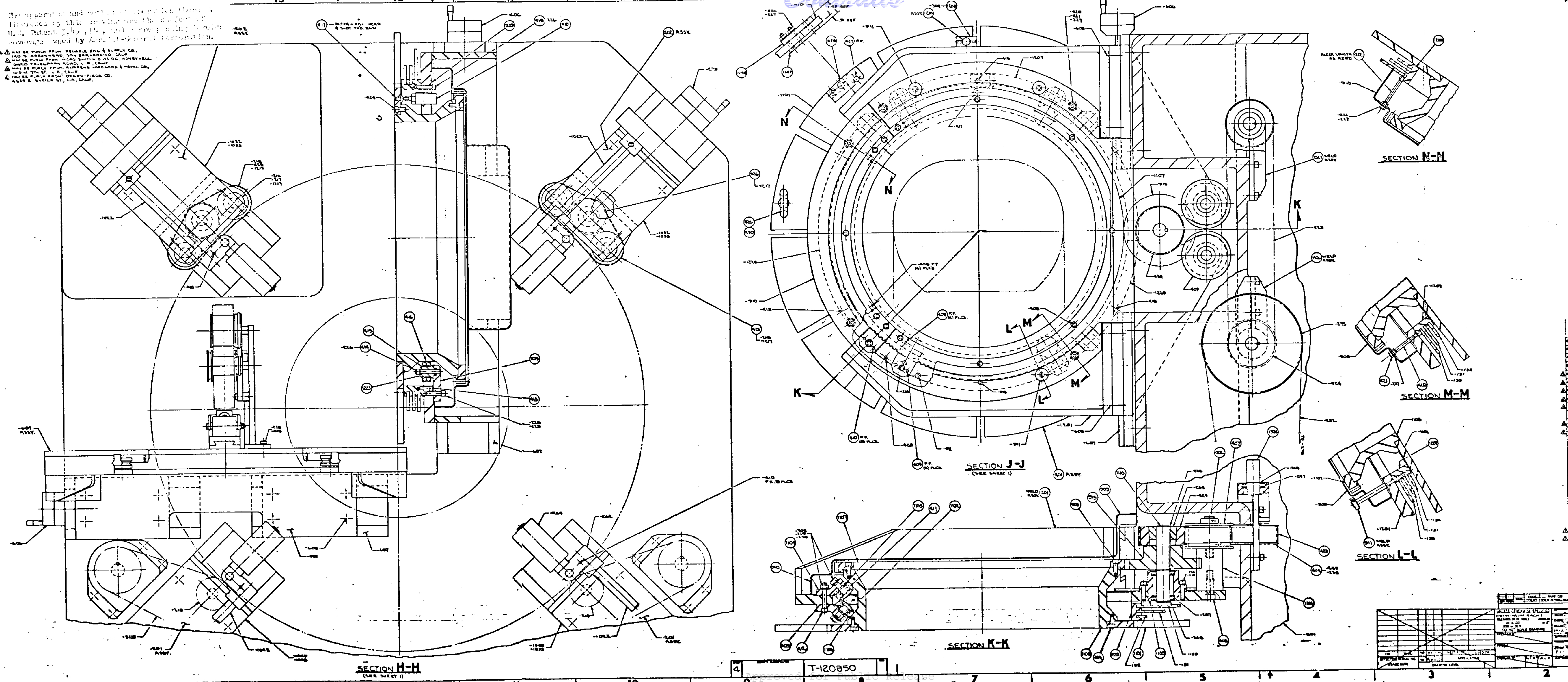

NOTICE
The apparatus and method of operation thereof, disclosed by this drawing are the subject of U.S. Patent 3,458,146, and corresponding foreign coverage owned by Aerojet-General Corporation.
Contrails
SECTION A-A
SECTION B-B
SECTION C-C
VIEW D-D
DESCRIPTION
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED
DO NOT SCALE DRAWING
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE
99 X 17 - DRIVE ASSEMBLY
J
70143
T-120850


NOTICE
NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES
MAY BE PURCH FROM DEGEN-FIELD CO, 4550 E. SHEILA ST., L.A., CALIF
MAY BE PURCH FROM: C.W. WARREN CO, L.A., CALIF
MAY BE PURCH FROM: L.A., CALIF
MAY BE PURCH FROM: BOURNS, INC., INSTRUMENT DIV, RIVERSIDE, CALIF.
MAY BE PURCH FROM LANE SPRING CO. 3919 WHITTIER BLVD. L.A., CALIF
SECTION G-G
SECTION F-F
VIEW E-E
DESCRIPTION
LIST OF MATERIALS
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE - 42 X 17 - MANDREL DRIVE ASSEMBLY
70143
T-120850
T-120850

NOTICE

The apparatus and method of operation thereof illustrated by this drawing are the subject of U.S. Patent 3,[illegible] and corresponding foreign coverage owned by Aerojet-General Corporation.

NOTES: △1 MAY BE PURCH FROM RELIABLE BRG. & SUPPLY CO., 140 S. ARROWHEAD, SAN BERNARDINO CALIF.
△2 MAY BE PURCH FROM MICRO SWITCH DIVISION, HONEYWELL, [illegible] TELEGRAPH ROAD, L.A., CALIF.
△3 MAY BE PURCH FROM AUFFENS HARDWARE & METAL CO., 1410 W. 7TH ST., L.A., CALIF.
△4 MAY BE PURCH FROM DEGEN-FIEGE CO. 4553 E. SHEILA ST., L.A., CALIF.



ITEM NO	QTY REQ'D	DESCRIPTION
430	1	5/8-10 HEX NUT
429	1	5/8 DIA. SHOULDERED EYE BOLT [illegible] (OR EQUIV)
428	2	5/8-11 x 2" LG. FLAT HD. SOC. CAP SCREW
427	1	1/2 DIA. x 1 1/2 LG. C.R.S.
△426	2	U.S. TIMING BELT PULLEY TYPE GF [illegible] 1" DIA. BORE WITH SET SCR. NO KEYWAY
△425	2	U.S. POWERGRIP TIMING BELT #[illegible]300
△424	3	U.S. TIMING BELT PULLEY TYPE SF #[illegible]150
△423	1	U.S. POWERGRIP TIMING BELT #750H150
△422	2	JERGENS ALLOY STL. STUD-PART #50-512 (4" LG)
421	12	5/16-18 HEX NUT
△420	4	JERGENS ALLOY STL. STUD-PART #50-512 (3" LG)
△419	1	MICRO SWITCH - DOUBLE POLE - DOUBLE THROW CAT #[illegible] (ROLLER TYPE)
418	6	5/16-18 x 1 1/2 LG. SOC. HD. CAP SCREW
417	1	1/4-16 x 1/2 LG. TRUSS HD. MACH SCR. PHILLIPS
416	4	NEW DEPARTURE BEARING #Z99520[illegible]
415	4	WALDES TRUARC RETAINING RING #5108-100
414	4	1/2-13 x 2" LG. SOC. HD CAP SCREW
413	4	5/16-18 x 1" LG. SOC. HD CAP SCREW
412	4	3/8-16 x 2 1/2 LG. SOC. HD. CAP SCREW
411	8	M.R.C. BEARING #9201-SBKZZ
410	16	1/4 DIA. x 2" LG. STD. STL. DOWEL
409	8	1/4 DIA. x 1 1/2 LG. STD. STL. DOWEL
408	3	5/16 DIA x 1" LG. STD. STL. DOWEL
△407	2	UNIVERSAL NEEDLE BRG. FLANGED PULLEY IDLER PART #PIF
△406	2	UNIVERSAL IDLER SHAFT PART #50-8
405	14	3/8-16 x 1" LG. SOC. HD. CAP SCREW
404	12	1/4-16 x 3/4 LG. SOC. HD CAP SCREW
403	2	3/8 DIA x 1 1/2 LG SHOULDER SCREW
402	2	[illegible]
401	1	[illegible]

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCE ON DECIMALS .XX ± .03 .XXX ± .010 DO NOT SCALE DRAWING

AEROJET-GENERAL CORPORATION

TITLE: TIRE WINDING MACHINE 45 x 17 - CARRIAGE ASSY.

CODE IDENT NO. 70143 | SIZE J | DWG NO. T-120850 | SHEET 2

T-120850

NOTICE

The apparatus and method of operation thereof, disclosed by this drawing are the subject of U.S. Patent [illegible], and corresponding foreign patents, owned by Aerojet-General Corporation.

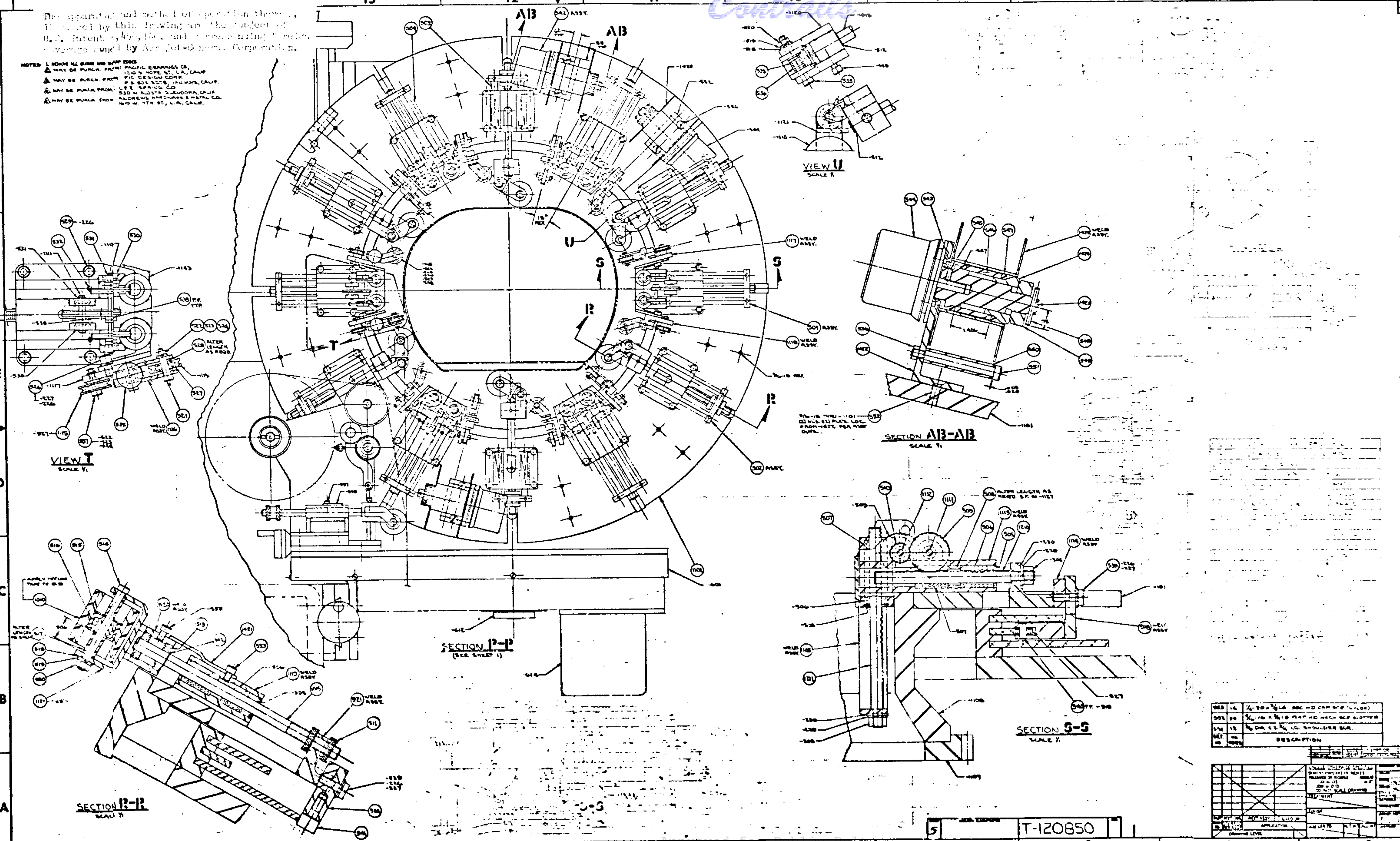
NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES

△ MAY BE PURCH. FROM: PACIFIC BEARINGS CO, 1210 S. HOPE ST., L.A., CALIF.

△ MAY BE PURCH. FROM: PIC DESIGN CORP. P.O. BOX 5278, VAN NUYS, CALIF.

△ MAY BE PURCH. FROM: LEE SPRING CO. 530 W. ALOSTA GLENDORA, CALIF.

△ MAY BE PURCH. FROM: ANDREWS HARDWARE & METAL CO. 1610 W. 7TH ST., L.A., CALIF.



DET. NO.	NO. REQ'D	DESCRIPTION
550	12	3/16 O.D. x .035 WALL x 2 5/8 LG. SEAMLESS MECH. STL. TUBING
△ 549	13	JERGENS KNURLED NUT PART NO. KN-785
548	14	3/16 DIA. x 1 1/2 LG. DOWEL
547	24	PARKER "O" RING # 2-325
546	12	1 3/8 O.D. x 1/8 WALL x 1 3/8 LG. SEAMLESS MECH. STL. TUBING
545	12	#10-32 x 1/2 LG. SOC. SET SCR (NYLOK) CUP POINT
544	12	G.E. HYSTERESIS BRAKE #CR9560-AA801AA
543	48	#10-32 x 1/2 LG. FLAT HD. MACH. SCR. SLOTTED
542	12	ASSY. CONSISTS OF -543 THRU -551 -536 -477 -473 & -1424
541	6	MCGILL SEALED CAM FOLLOWER "SCF" SERIES BEARING # CF-3/4-S
540	6	1/4 DIA. x 3/16 LG. DRILL ROD
539	12	5/16-18 x 1" LG. PAN HD. MACH. SCR. SLOTTED
538	24	.093 DIA. (#50) x 1/2 LG. DRILL ROD
537	12	1/4 DIA. x 1/2 LG. SHOULDER SCREW
536	12	5/16-18 HEX NUT
△ 535	6	LEE TORSION SPRING # LT-054K-4-L (OR EQUIV)
△ 534	6	LEE TORSION SPRING # LT-054K-4-R (OR EQUIV)
533	6	3/8 DIA. x 1 1/2 LG. SHOULDER SCREW
532	52	#10-32 x 1" LG. SOC. HD. CAP SCREW
531	24	TRUARC RETAINING RING # 5100-28
530	24	NEW DEPARTURE NCA SERIES BALL BEARING # Z99R6
529	48	3/8-16 x 1" LG. SOC. HD. CAP SCREW
528	24	1/2 O.D. x .120 WALL x 5/8 LG. STL. TUBING
527	30	NEW DEPARTURE NCA SERIES BALL BEARING # Z99R4A
526	12	5/16-18 x 1/2 LG. SOC. HD. CAP SCREW
△ 525	12	JERGENS PLASTIC KNOB WITH STUD PART # PK1A
524	24	#10-32 HEX NUT
523	24	3/16 NOM. I.D. SPRING LOCK WASHER
522	24	3/16 NOM. I.D. FLAT WASHER
521	12	1/4 DIA. x 3/4 LG. SHOULDER SCREW
520	12	1/4-20 HEX NUT
519	12	1/4 NOM. I.D. SPRING LOCK WASHER
518	12	1/4 NOM. I.D. FLAT WASHER
517	12	1/2 O.D. x .035 WALL x 1.0 LG. STL. TUBING
516	6	M-R-C KAYDON BALL BEARING "CSP" SERIES BEARING # CSP-5
515	12	TRUARC RETAINING RING # 5008-25
514	6	3/8 DIA. x 3 LG. SHOULDER SCREW
513	36	NEW DEPARTURE NCA SERIES BALL BEARING # Z99R5
512	24	TRUARC RETAINING RING # 5108-50
△ 511	16	JERGENS KNURLED NUT PART # KN-500
△ 510	6	PIC SPUR GEAR CAT. NO. G61-[illegible]
△ 509	18	PIC SPUR GEAR CAT. NO. G61-36
508	6	1/2 O.D. x 1/8 WALL x 5/8 LG. STL. TUBING
△ 507	18	THOMPSON BALL BUSHING - SPEC TYPE - BUSHING # OPN-81420
△ 506	32	THOMPSON BALL BUSHING "A" TYPE BUSHING # A-81420
505	32	TRUARC RETAINING RING # 5107-97
△ 504	12	LEE EXTENSION SPRING # LE-05-[illegible]
△ 503	14	LEE EXTENSION SPRING # [illegible]
502	6	ASSY CONSISTS OF [illegible]
501	6	ASSY CONSISTS OF [illegible]

DET. NO.	NO. REQ'D	DESCRIPTION
553	14	1/4-20 x 3/4 LG. SOC. HD. CAP SCR. (NYLOK)
552	24	5/16-18 x 3/4 LG. FLAT HD. MACH. SCR. SLOTTED
551	12	3/8 DIA. x 2 3/4 LG. SHOULDER SCR.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS .XX ± .03 .XXX ± .010 ANGLES ± 0°
DO NOT SCALE DRAWING

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

TITLE: TIRE WINDING MACHINE
49 X 17 - PAY OFF HEAD ASSY

DWG SIZE: J | CODE IDENT NO.: 70143 | DWG NO.: T-120850

SHEET 3

T-120850

NOTICE

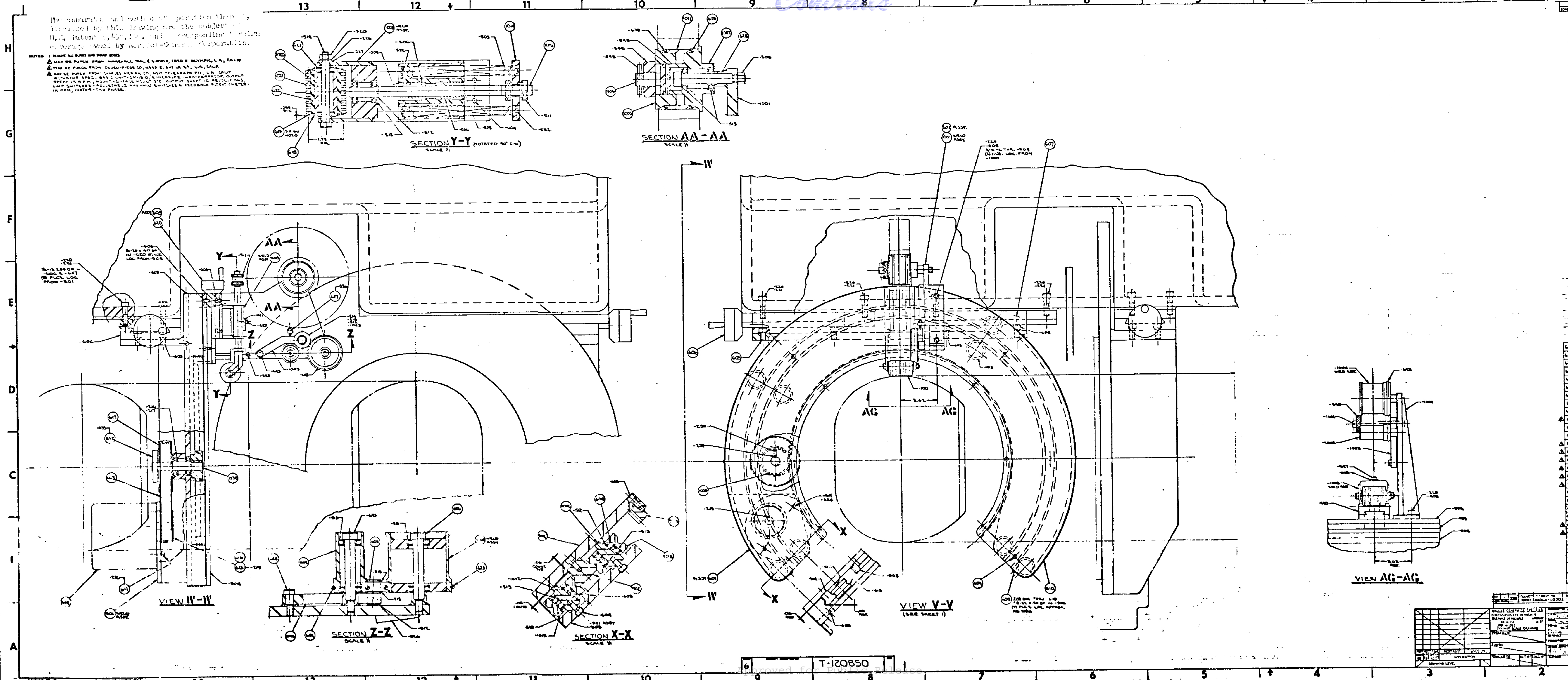
The apparatus and method of operation there[illegible] disclosed by this drawing are the subject of U.S. Patent [illegible] and corresponding foreign coverage owned by Aerojet-General Corporation.

NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES

2. MAY BE PURCH. FROM MARSHALL TOOL & SUPPLY, 1950 E. OLYMPIC, L.A., CALIF.

3. MAY BE PURCH. FROM CRESCO-PIECE CO., 4553 E. SHEILA ST., L.A., CALIF.

4. MAY BE PURCH. FROM CHARLES MERAM CO., 5017 TELEGRAPH RD., L.A., CALIF. ACTUATOR SPEC.: BASIC UNIT-SM-15[illegible], ENCLOSURE-WEATHERPROOF, OUTPUT SPEED-5 R.P.M., MOUNTING-FACE MOUNT (STD), OUTPUT SHAFT 10 REVOLUTIONS, LIMIT SWITCHES-ADJUSTABLE MAX-MIN SWITCHES & FEEDBACK POTENTIOMETER-1K OHM, MOTOR-TWO PHASE.



DET NO.	NO. REQD	DESCRIPTION
629	2	PARKER "O" RING # 2-334
628	1	1/2 DIA. X 2 1/2 LG. SHOULDER SCR.
627	1	AMERICAN # ADB-500Z5 (OR EQUIV) SPRING PLUNGER
626	2	1/2 DIA. X 3" LG. SHOULDER SCR.
625	1	3/8 DIA. X 1/2 LG. SHOULDER SCR.
624	1	PARKER "O" RING # 2-325
623	1	PARKER "O" RING # 2-338
622	1	RUBBERCRAFT # 355 PURE GUM RUBBER 50-60 S.O.R. [illegible]
621	2	NEW DEPARTURE BEARING # Z99R6
△ 620	1	BIDDLE DOVETAIL SLIDE LEAD SCR SERIES MODEL [illegible]
619	2	.0508 (16GA) X 1 3/8 SQ. C.R.S. SHEET
618	2	TRUARC RETAINING RING # 5108-112
△ 617	1	U.S. TIMING BELT PULLEY TYPE SF # 30H100
△ 616	1	U.S. TIMING BELT PULLEY TYPE SF # TL16H-00
△ 615	1	T.B. WOODS TAPER LOCK BUSHING TYPE TL [illegible] 3/8 DIA. BORE [illegible] KEYWAY
△ 614	1	JORDAN ROTARY ACTUATOR # SM-1510-[illegible]
△ 613	1	U.S. POWERGRIP TIMING BELT # [illegible]
△ 612	1	T.B. WOODS TAPER LOCK BUSHING [illegible] 1 DIA. BORE 1/4 KEYWAY
611	16	5/16-18 X 3/4 LG. SOC. HD CAP SCR.
610	1	.059 (16GA) X 1 7/8 X [illegible] LG. C.R.S. SHEET
609	7	#8-32 X 3/8 LG. ROUND HD MACHINE SCREW
608	16	TRUARC RETAINING RING # 5[illegible]-112
△ 607	2	BIDDLE DOVETAIL SLIDE [illegible] SERIES MODEL [illegible]
△ 606	2	BIDDLE DOVETAIL SLIDE LEAD SCR. SERIES [illegible]
605	16	1/4-[illegible] X [illegible] SOC. HD CAP SCREW
604	35	1/4-20 X 1/2 [illegible] CAP SCREW
603	1	ASSY CONSISTS OF [illegible]
602	1	ASSY. CONSISTS OF [illegible] -440, -519, -1001 THRU -1007 [illegible]
601	1	ASSY. CONSISTS OF [illegible]

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DECIMALS ANGULAR ± [illegible]
.XX ± .03
.XXX ± .010
DO NOT SCALE DRAWING

DRN C. COOK

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

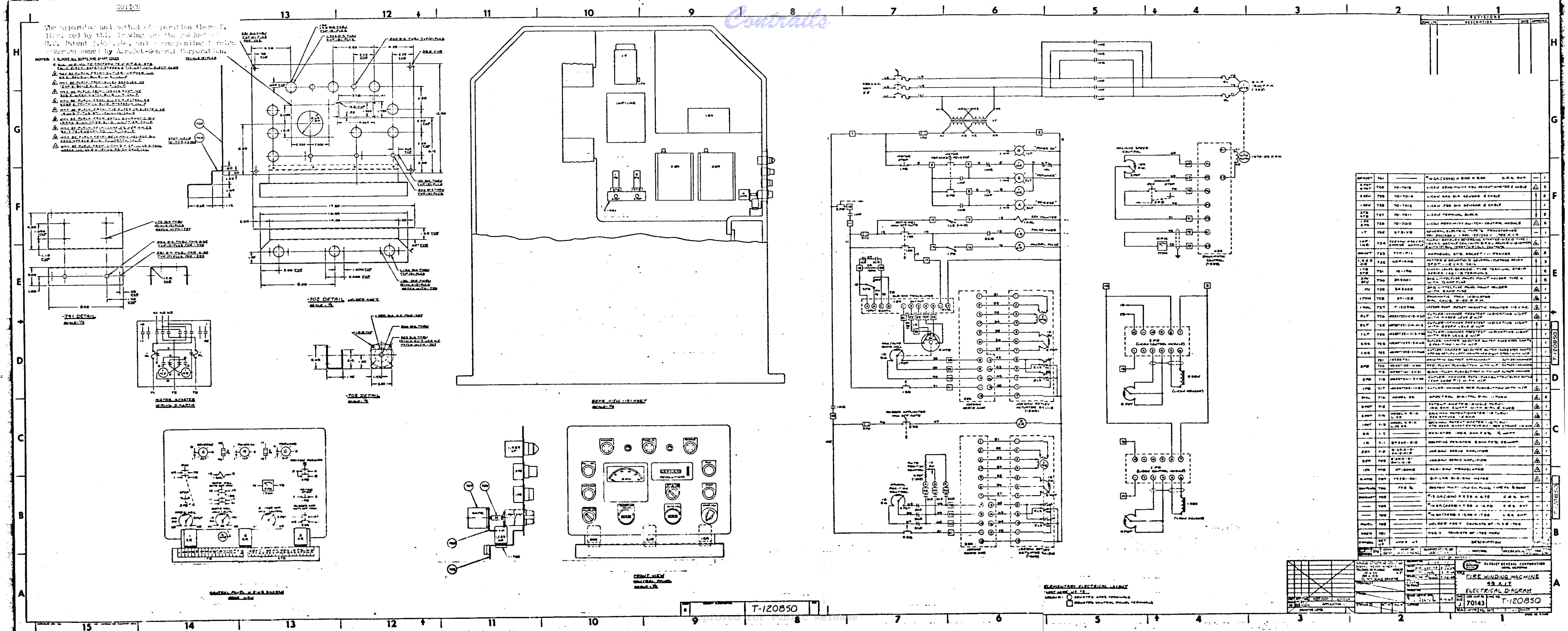
TITLE TIRE WINDING MACHINE
42 X 17 - RUBBER APPLICATOR
ASSEMBLY

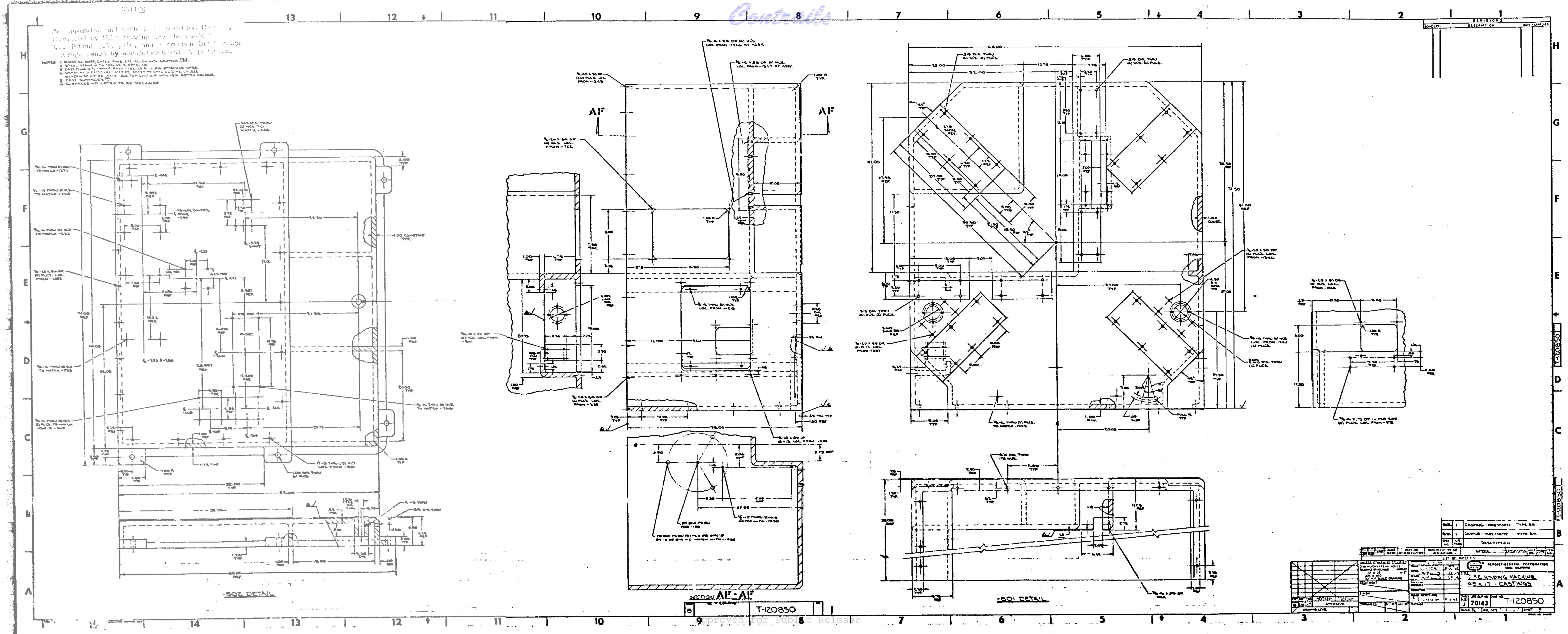
DWG SIZE J | CODE IDENT NO. 70143 | DWG NO. T-120850

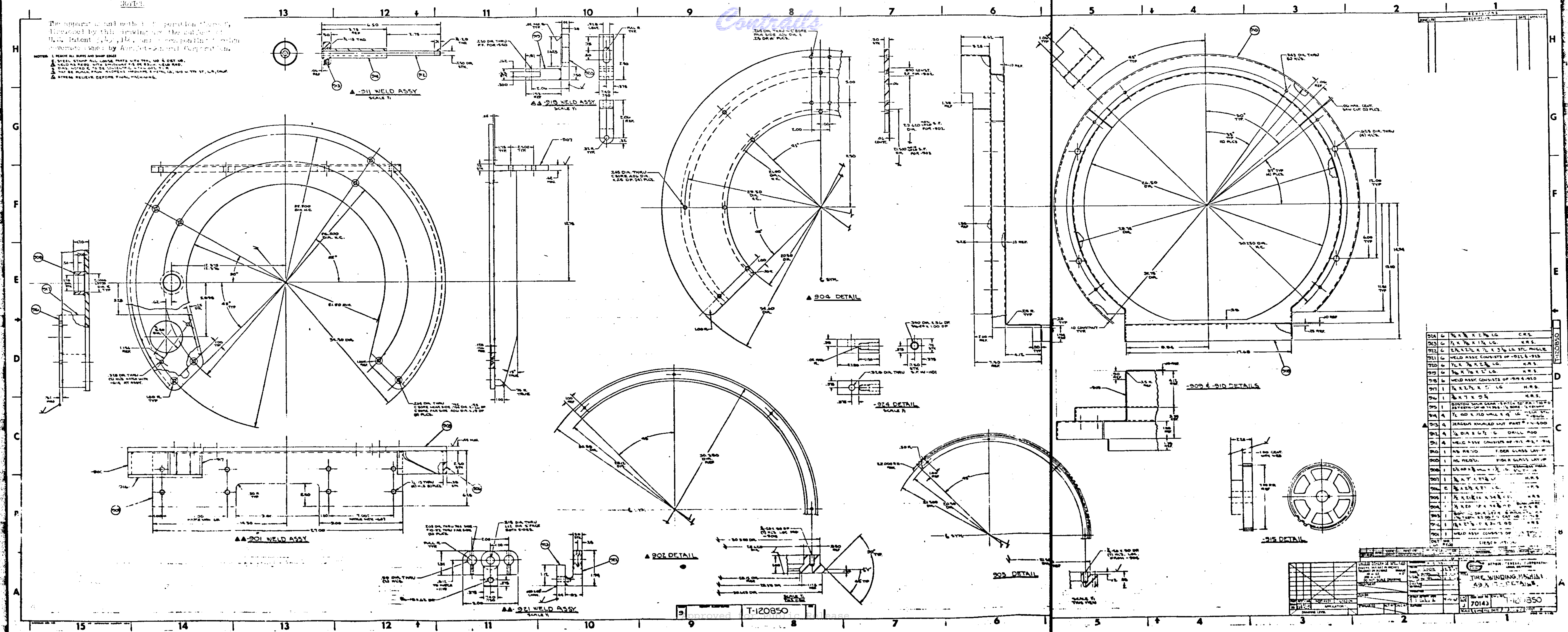
SCALE [illegible] | REL DATE 2-[illegible]-67 | SHEET

T-120850

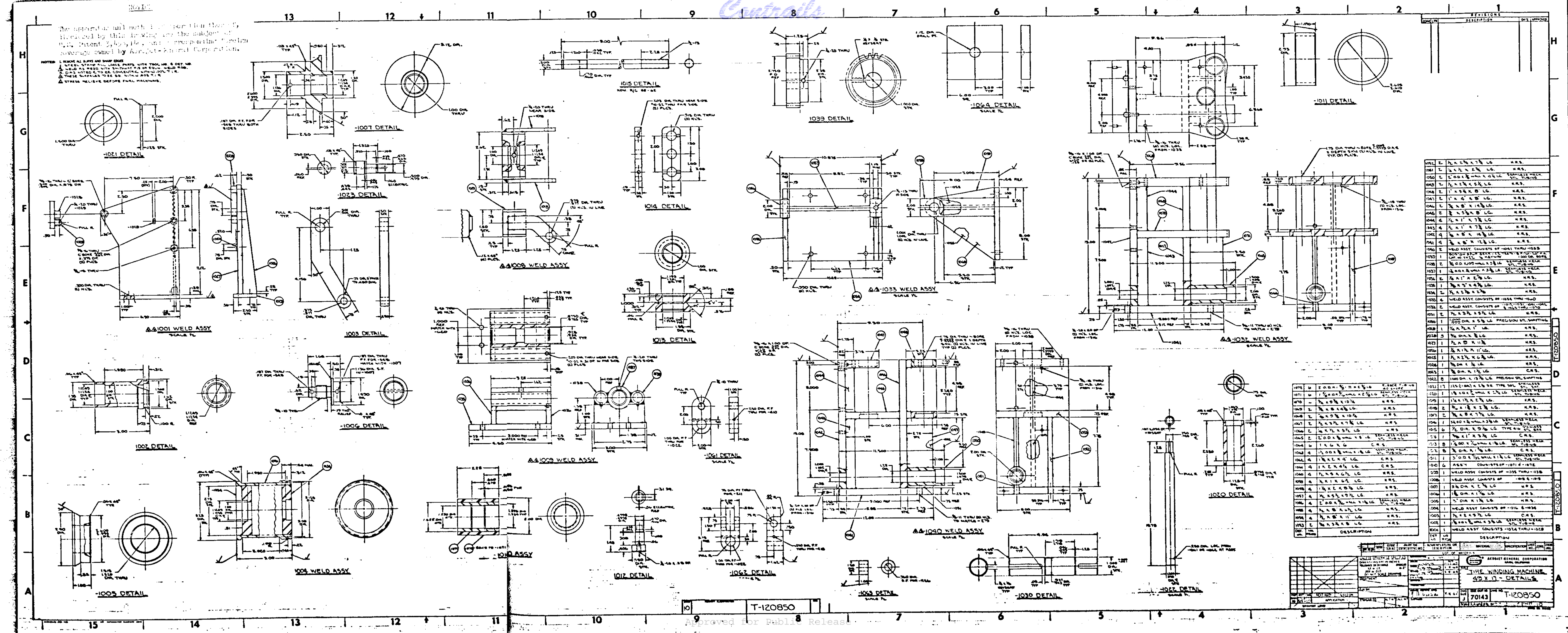
6 | T-120850

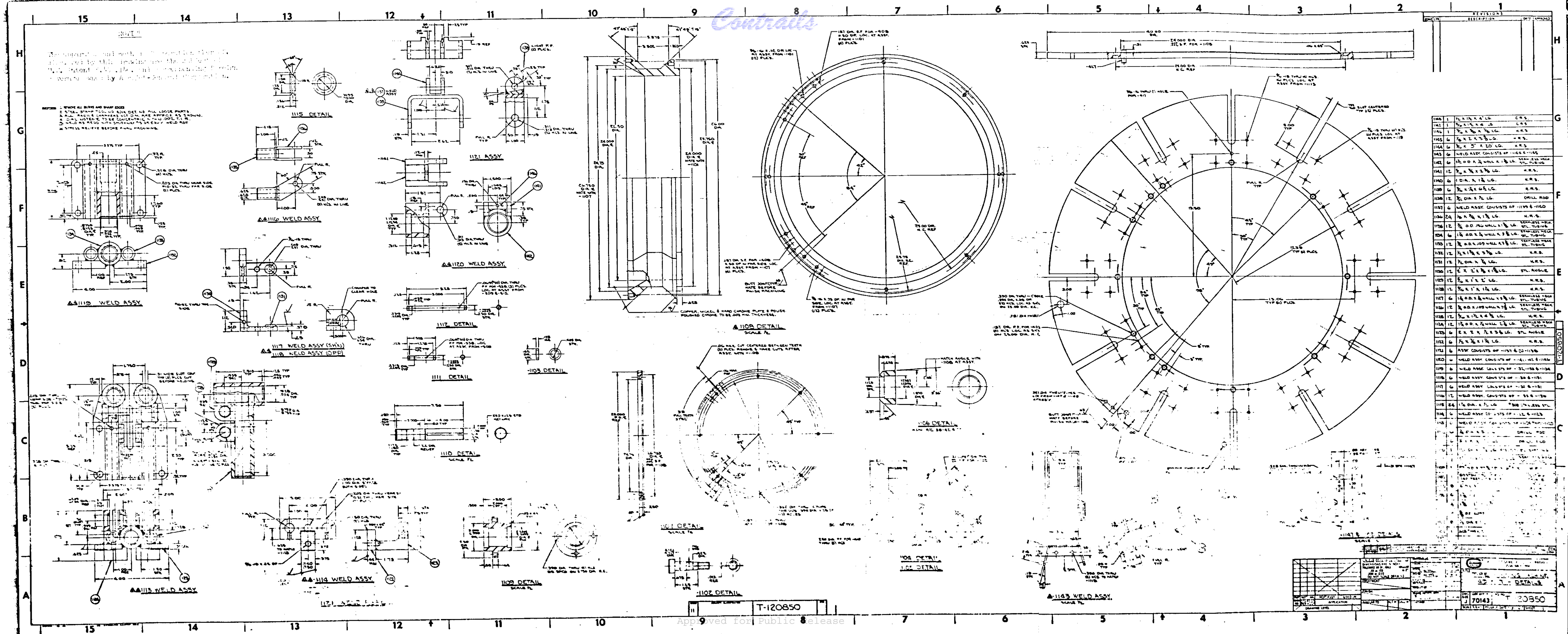

NOTICE
The apparatus and method of operation thereof, disclosed by this drawing are the subject of U.S. Patent [illegible], and corresponding foreign patents owned by Aerojet-General Corporation.
NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES
-791 DETAIL
-702 DETAIL
-705 DETAIL
MOTOR STARTER WIRING DIAGRAM
REAR VIEW -101 ASS'Y
FRONT VIEW
ELEMENTARY ELECTRICAL LAYOUT
DESCRIPTION
LIST OF MATERIAL
AEROJET GENERAL CORPORATION
TIRE WINDING MACHINE
99 X 17
ELECTRICAL DIAGRAM
70143
T-120850
T-120850

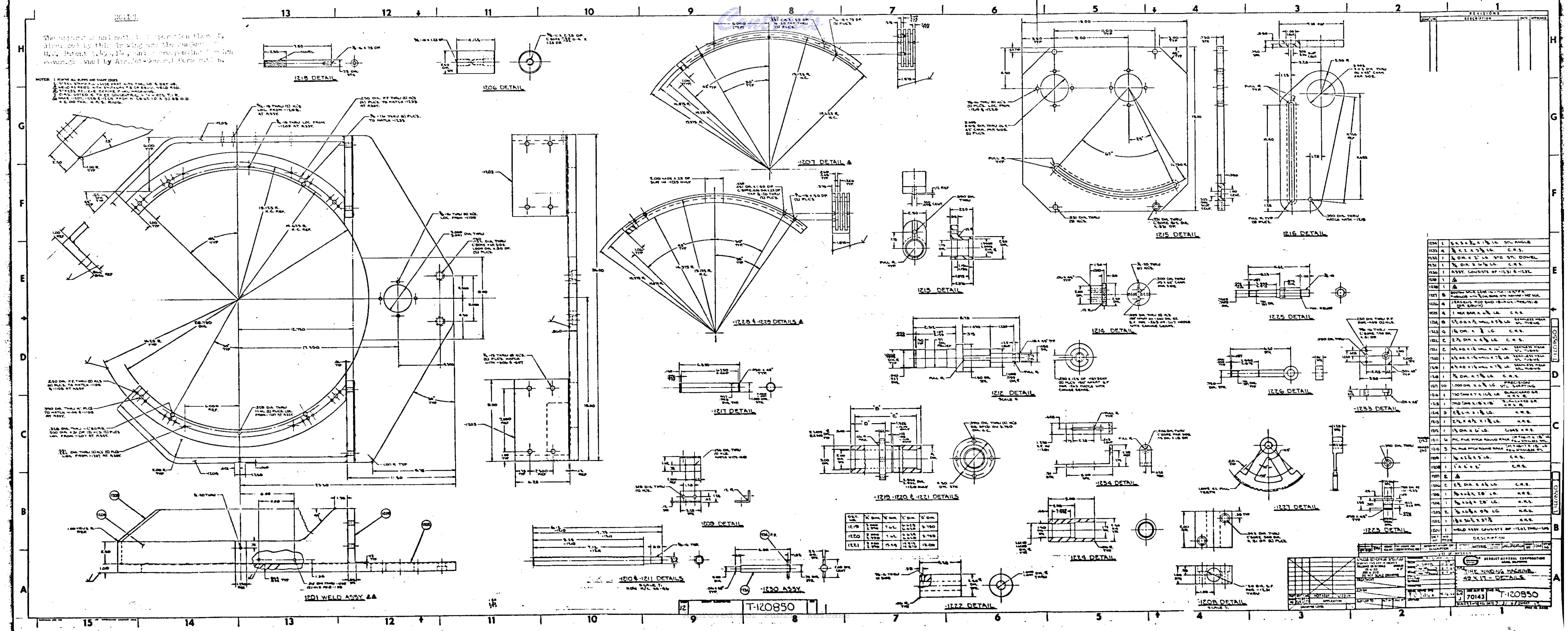

NOTICE
Aerojet-General Corporation.
NOTES:
SURFACES INDICATED TO BE MACHINED
AF
SECTION AF-AF
-802 DETAIL
-801 DETAIL
T-120850
CASTING - MEEHANITE TYPE GA
DESCRIPTION
LIST OF MATERIALS
AEROJET-GENERAL CORPORATION
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TREATMENT
APPLICATION
DRAWING LEVEL
MATERIAL
SPECIFICATION
TITLE
WINDING MACHINE
- CASTINGS
70143
T-120850
REVISIONS
DESCRIPTION



▲-911 WELD ASSY
SCALE 1/1
▲-918 WELD ASSY
SCALE 1/1
▲-904 DETAIL
-909 & -910 DETAILS
-924 DETAIL
▲-901 WELD ASSY
▲-902 DETAIL
-903 DETAIL
-915 DETAIL
▲-921 WELD ASSY
924 6 5/16 x 3/4 x 2 3/8 LG. C.R.S.
923 6 1/2 x 7/8 x 1 1/4 LG. H.R.S.
922 6 2 1/2 x 2 1/2 x 1/2 x 3 1/8 LG. STL. ANGLE
921 6 WELD ASSY. CONSISTS OF -922 & -923
920 6 1/2 x 7/8 x 2 3/8 LG. H.R.S.
919 6 5/16 x 7/8 x 2" LG. H.R.S.
918 6 WELD ASSY. CONSISTS OF -919 & -920
917 1 1/4 x 2 1/2 x 5" LG H.R.S.
916 1 3/8 x 7 x 9 1/4 H.R.S.
913 4 JERGENS KNURLED NUT PART # KN-500
912 4 1/4 DIA x 6 1/2 LG. DRILL ROD
910 1 AS REQ'D. FIBER GLASS LAY-UP
909 1 AS REQ'D. FIBER GLASS LAY-UP
907 1 3/8 x 7 x 27 3/8 LG H.R.S.
901 1 WELD ASSY. CONSISTS OF
DET NO. NO. REQ'D. DESCRIPTION
UNLESS OTHERWISE SPECIFIED
DO NOT SCALE DRAWING
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE
70143
T-120850

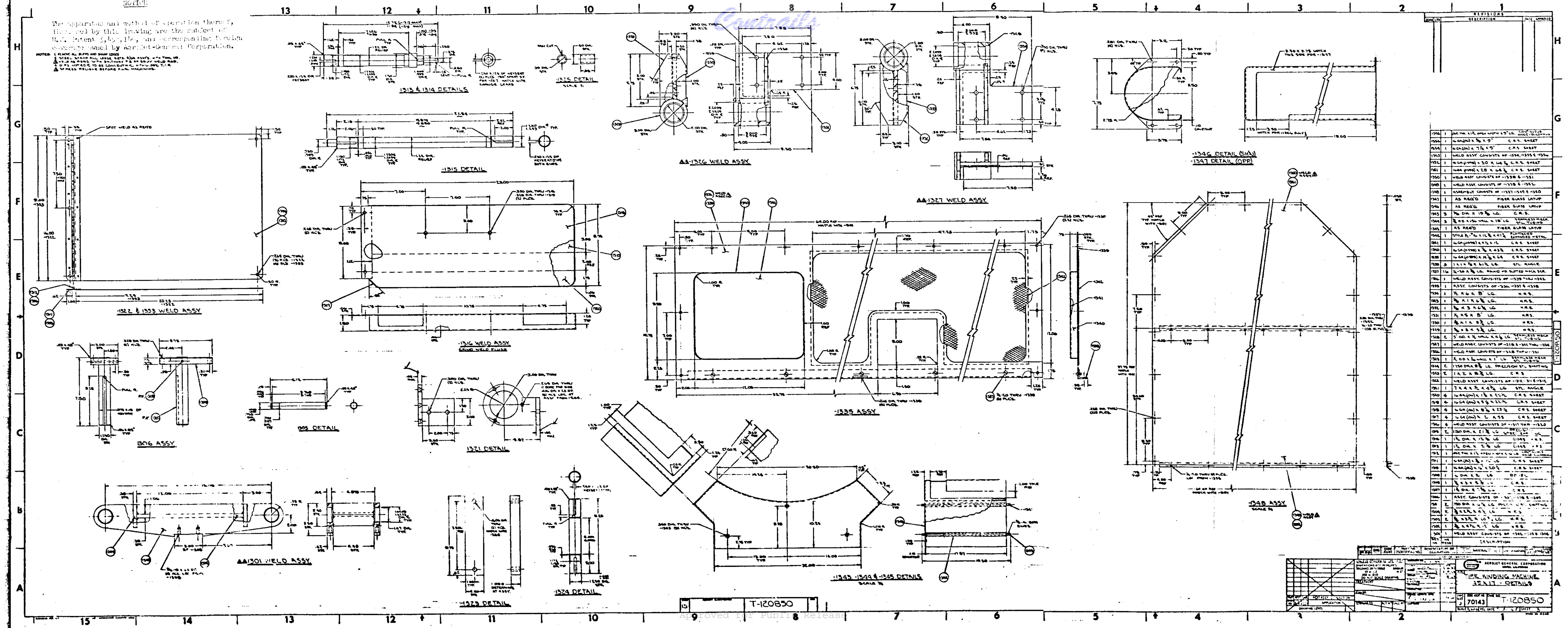

NOTICE
The apparatus and method [illegible] or portion thereof, disclosed by this drawing are the subject of U.S. Patent 3,[illegible] and corresponding foreign coverage owned by Aerojet-General Corporation.
NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES
2. STEEL STAMP ALL LOOSE PARTS WITH TOOL NO. & DET. NO.
3. WELD AS REQD. WITH SMITHWAY #15 OR EQUIV. WELD ROD.
4. DIA'S NOTED TO BE CONCENTRIC WITHIN .005 T.I.R.
5. THESE SURFACES TO BE SQ. WITHIN .005 T.I.R.
6. STRESS RELIEVE BEFORE FINAL MACHINING.
-1021 DETAIL
-1007 DETAIL
1015 DETAIL
1039 DETAIL
-1064 DETAIL
-1011 DETAIL
-1023 DETAIL
1016 DETAIL
-1001 WELD ASSY
1003 DETAIL
-1008 WELD ASSY
-1033 WELD ASSY
-1037 WELD ASSY
1013 DETAIL
1002 DETAIL
-1006 DETAIL
-1009 WELD ASSY
-1061 DETAIL
-1020 DETAIL
-1040 WELD ASSY
-1005 DETAIL
1004 WELD ASSY
-1010 ASSY
1012 DETAIL
-1062 DETAIL
-1063 DETAIL
-1030 DETAIL
-1022 DETAIL
DESCRIPTION
LIST OF MATERIALS
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE
49 X 17 - DETAILS
70143
T-120850


1115 DETAIL
1121 ASSY
1116 WELD ASSY
1120 WELD ASSY
1119 WELD ASSY
1117 WELD ASSY (SHN)
1118 WELD ASSY (OPP)
1112 DETAIL
1111 DETAIL
1103 DETAIL
1108 DETAIL
1106 DETAIL
1110 DETAIL
1101 DETAIL
1102 DETAIL
1113 WELD ASSY
1114 WELD ASSY
1109 DETAIL
1143 WELD ASSY
T-120850
70143

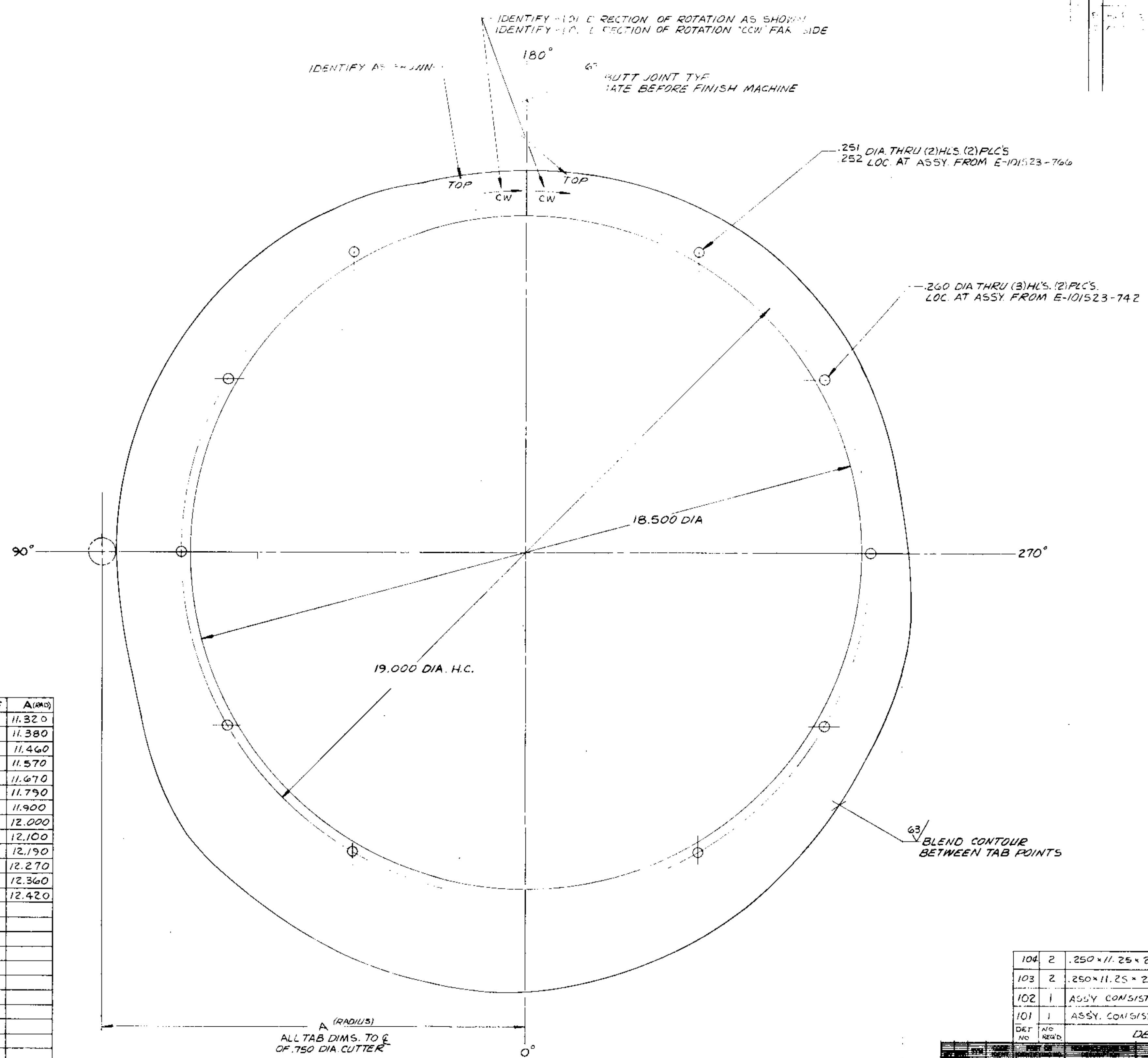

NOTICE
NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES
2. STEEL STAMP ALL LOOSE PART WITH TOOL NO. & DET NO.
3. WELD AS REQD. WITH SMITHWAY F.S OR EQUIV. WELD ROD.
4. STRESS RELIEVE BEFORE FINAL MACHINING.
5. DIAS. NOTED TO BE CONCENTRIC WITHIN .002 T.I.R.
6. MAKE -1201, -1228 & -1229 FROM A 28.62 I.D. X 30.88 O.D. X 2.00 THK. H.R.S. RING.
1218 DETAIL
1206 DETAIL
-1207 DETAIL
-1228 & -1229 DETAILS
1215 DETAIL
1216 DETAIL
1213 DETAIL
1214 DETAIL
1225 DETAIL
1212 DETAIL
-1217 DETAIL
1226 DETAIL
-1233 DETAIL
1209 DETAIL
-1219, -1220, & -1221 DETAILS
-1234 DETAIL
-1227 DETAIL
-1223 DETAIL
-1210 & -1211 DETAILS
-1230 ASSY.
-1224 DETAIL
-1222 DETAIL
-1208 DETAIL
1201 WELD ASSY
1201 1 WELD ASSY CONSISTS OF -1202 THRU -1205
DESCRIPTION
LIST OF MATERIALS
AEROJET-GENERAL CORPORATION
TIRE WINDING MACHINE
49 X 17 - DETAILS
70143
T-120850
T-120850

NOTICE

The apparatus and method of operation thereof, illustrated by this drawing are the subject of U.S. Patent 3,[illegible], and corresponding foreign coverage owned by Aerojet-General Corporation.



NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. USE WITH E-101523
3. STL. STAMP W/T-NO. & DASH NO.



DEGREE	A(RAD)	DEGREE	A(RAD)	DEGREE	A(RAD)
0	12.420	150	11.180	300	11.320
5	12.440	155	11.100	305	11.380
10	12.450	160	10.970	310	11.460
15	12.460	165	10.850	315	11.570
20	12.450	170	10.830	320	11.670
25	12.450	175	10.820	325	11.790
30	12.440	180	10.820	330	11.900
35	12.460	185	10.840	335	12.000
40	12.480	190	10.870	340	12.100
45	12.500	195	10.900	345	12.190
50	12.490	200	10.920	350	12.270
55	12.370	205	10.950	355	12.360
60	12.160	210	10.970	360	12.420
65	11.940	215	10.980		
70	11.740	220	11.000		
75	11.670	225	10.990		
80	11.650	230	10.970		
85	11.650	235	10.970		
90	11.650	240	10.920		
95	11.670	245	10.910		
100	11.670	250	10.860		
105	11.640	255	10.820		
110	11.620	260	10.780		
115	11.580	265	10.840		
120	11.550	270	10.940		
125	11.500	275	11.040		
130	11.460	280	11.160		
135	11.420	285	11.240		
140	11.350	290	11.280		
145	11.270	295	11.300		

DET NO	NO REQ'D	DESCRIPTION
104	2	.250 × 11.25 × 22.75 6061-T6 ALUM.
103	2	.250 × 11.25 × 22.75 6061-T6 ALUM.
102	1	ASS'Y CONSISTS OF -103 & -104
101	1	ASSY. CONSISTS OF -103 & -104

LIST OF MATERIALS

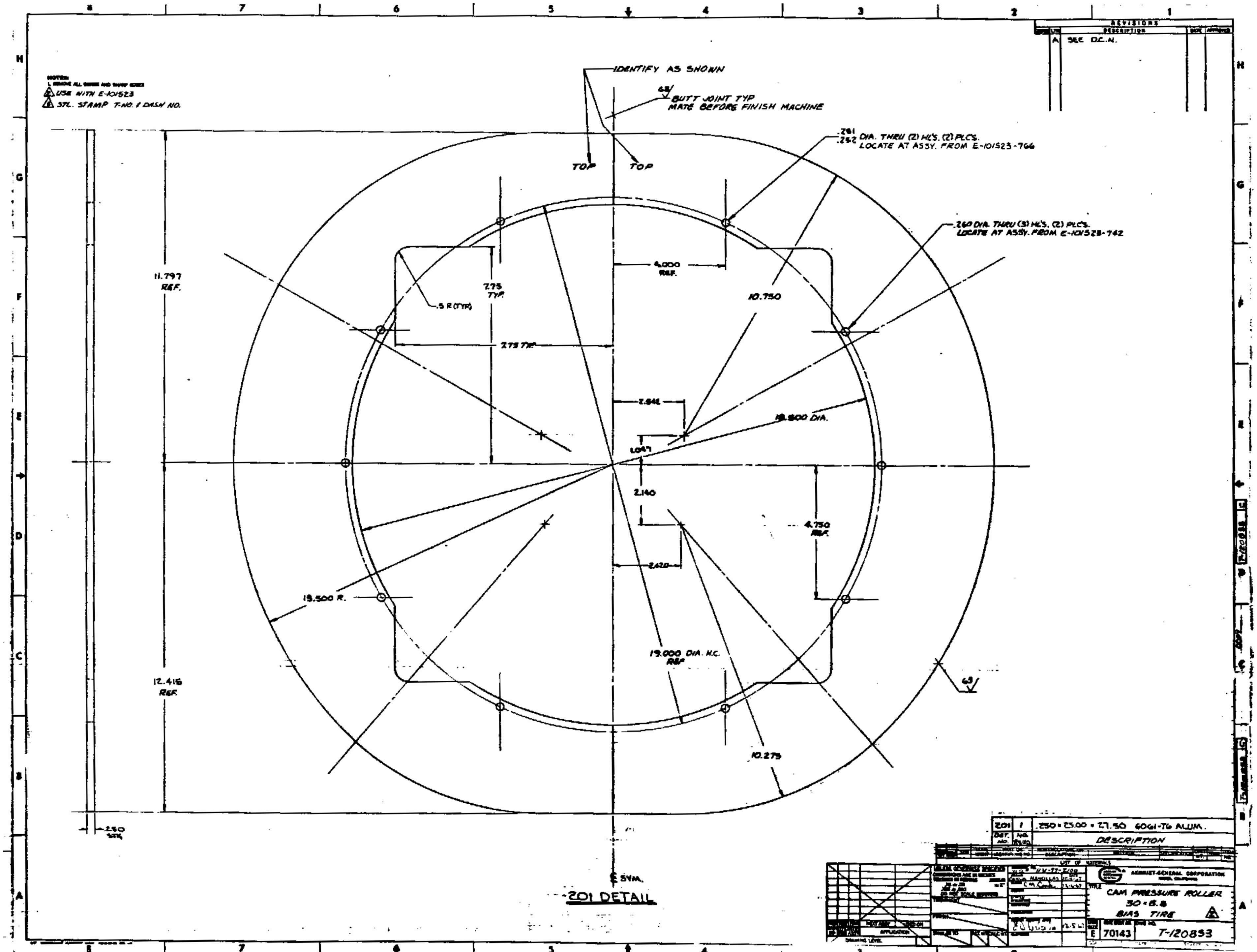
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

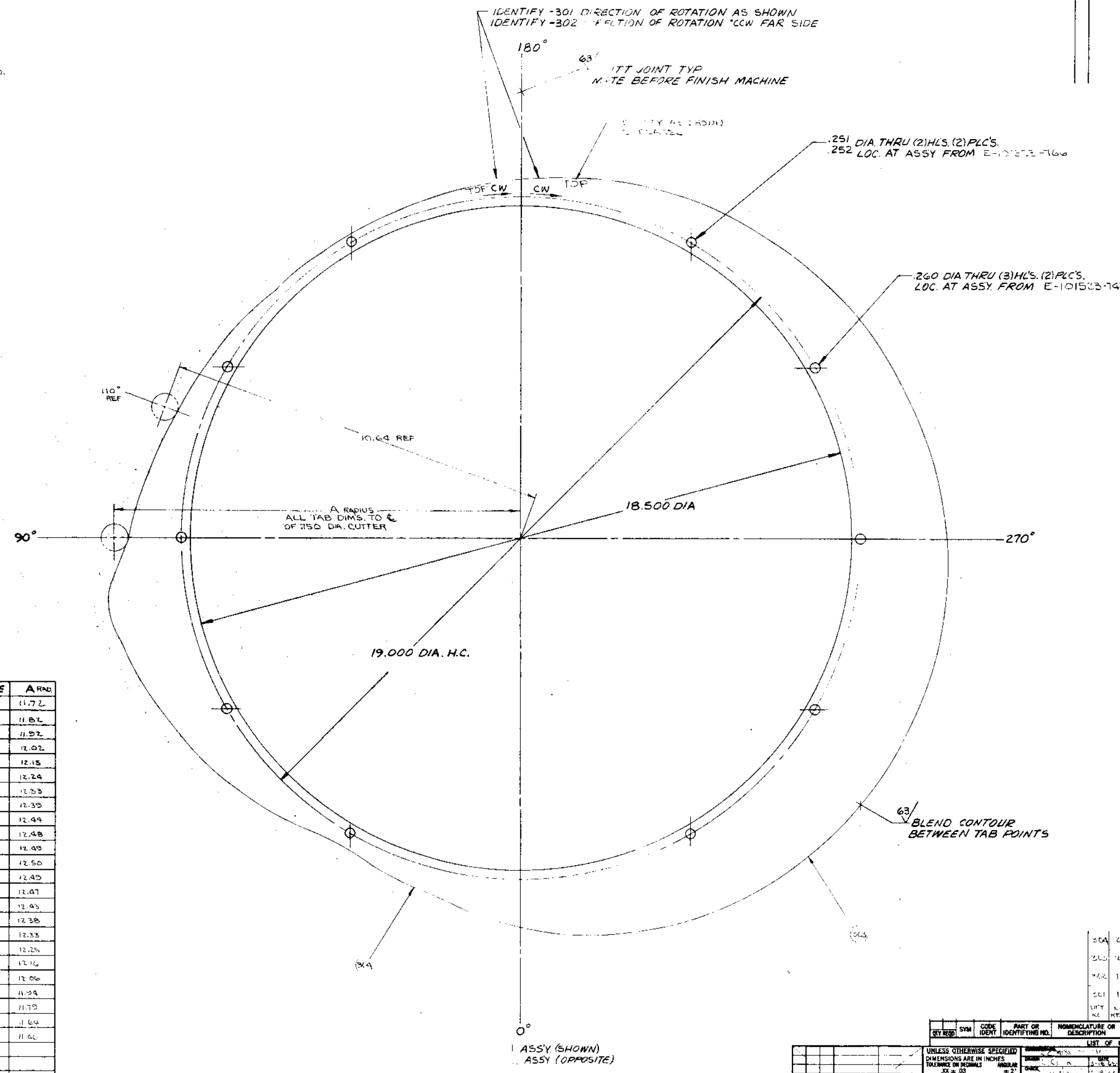
TITLE: CAM PAYOFF HEAD 30 × 8.8 BIAS TIRE

DWG SIZE: E — CODE IDENT NO. 70143 — DWG NO. T-120853

SHEET 1 OF 1


REVISIONS
A SEE D.C.N.
NOTES:
USE WITH E-101523
STL. STAMP T-NO. & DASH NO.
IDENTIFY AS SHOWN
BUTT JOINT TYP
MATE BEFORE FINISH MACHINE
TOP
TOP
.261
.262 DIA. THRU (2) HL'S. (2) PLCS.
LOCATE AT ASSY. FROM E-101523-766
.260 DIA. THRU (3) HL'S. (2) PLCS.
LOCATE AT ASSY. FROM E-101528-742
11.797 REF.
12.416 REF.
.250 STK.
.5 R (TYP)
7.75 TYP.
7.75 TYP.
4.000 REF.
10.750
18.800 DIA.
2.846
1.047
2.140
4.750 REF.
2.420
19.500 R.
19.000 DIA. H.C. REF
10.275
℄ SYM.
-201 DETAIL
201 | 1 | .250 × 25.00 × 27.50 6061-T6 ALUM.
DASH NO. | REQD. | DESCRIPTION
LIST OF MATERIALS
AEROJET-GENERAL CORPORATION
CAM PRESSURE ROLLER
30 × 8.8
BIAS TIRE
E 70143 T-120853

NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. USE WITH E-101523.
3. STEEL STAMP WITH TOOL NO. & DET. NO.



DEGREE	A RAD.	DEGREE	A RAD.	DEGREE	A RAD.
0	11.27	120	10.41	240	11.72
[illegible]	11.04	125	10.34	245	11.82
10	10.81	130	10.24	250	11.92
15	10.62	135	10.14	255	12.02
20	10.51	140	10.15	260	12.15
25	10.42	145	10.12	265	12.24
30	10.33	150	10.13	270	12.33
35	10.44	155	10.14	275	12.39
40	10.65	160	10.16	280	12.44
45	10.85	165	10.20	285	12.48
50	11.05	170	10.26	290	12.49
55	11.25	175	10.32	295	12.50
60	11.41	180	10.41	300	12.49
65	11.60	185	10.48	305	12.47
70	11.78	190	10.59	310	12.43
75	11.94	195	10.68	315	12.38
80	12.10	200	10.81	320	12.33
85	11.86	205	10.92	325	12.25
90	11.41	210	11.04	330	12.16
95	11.19	215	11.15	335	12.06
100	10.98	220	11.23	340	11.94
105	10.62	225	11.36	345	11.79
110	10.64	230	11.50	350	11.64
115	10.53	235	11.64	355	11.46

DET NO.	NO. REQ'D	DESCRIPTION
304	2	.250 X 12.00 X 21.25 6061-T6 ALUM.
303	2	.250 X 12.50 X 21.50 6061-T6 ALUM.
302	1	ASSY CONSISTS OF -303 & -304
301	1	ASSY. CONSISTS OF -303 & -304

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

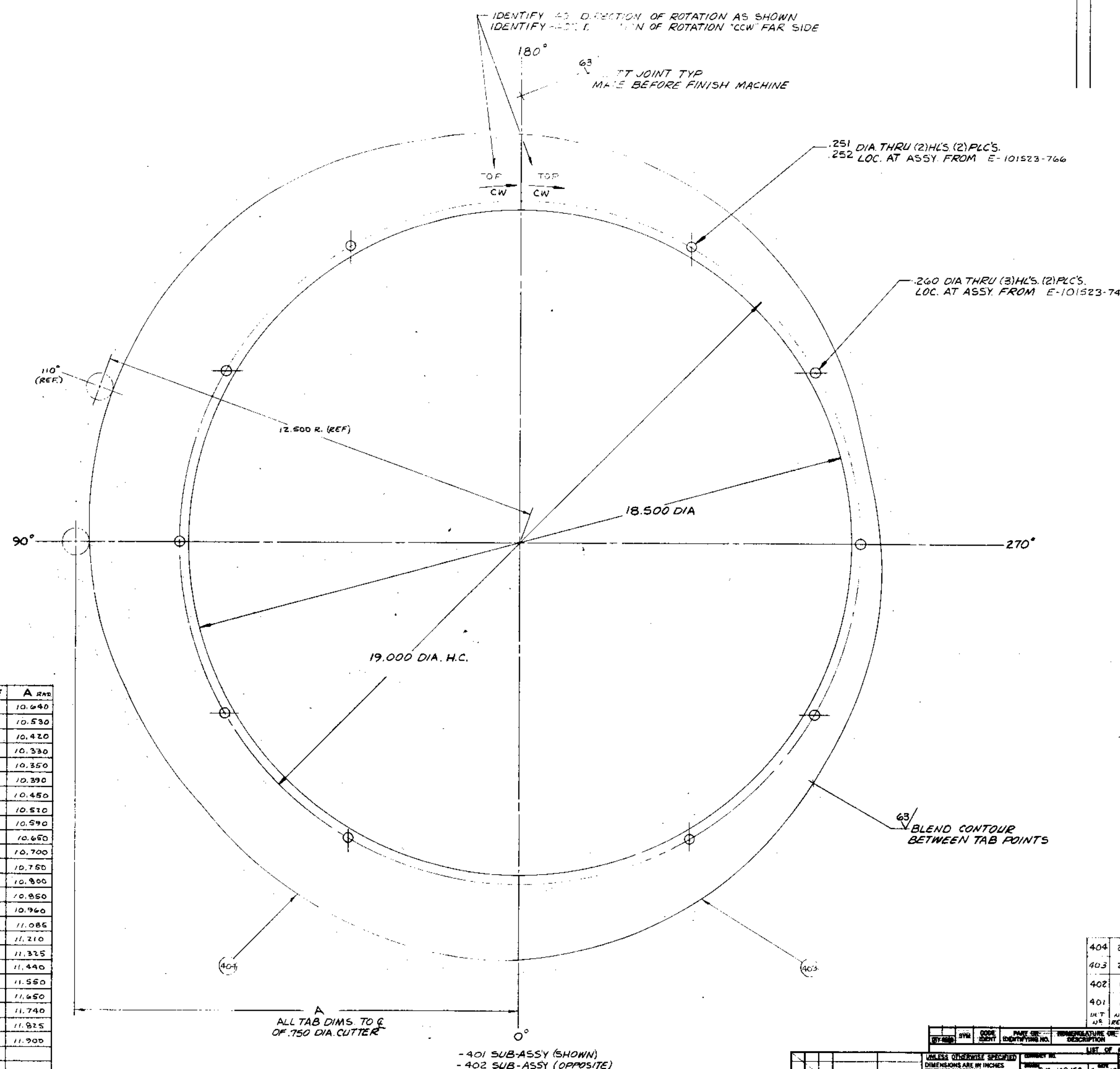
AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

TITLE: CAM RAYOFF HEAD 30 X 9.5 GEODESIC TIRE

DWG SIZE: E | CODE IDENT NO. 70143 | DWG NO. T-120853

SHEET 3

NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. USED WITH E-101523
3. STEEL STAMP WITH TOOL Nº & DET. Nº



DEGREE	A RAD	DEGREE	A RAD	DEGREE	A RAD
0	11.975	120	12.492	240	10.640
5	11.995	125	12.480	245	10.530
10	12.005	130	12.440	250	10.420
15	11.995	135	12.425	255	10.330
20	11.980	140	12.380	260	10.350
25	11.965	145	12.320	265	10.390
30	11.945	160	12.245	270	10.450
35	11.925	155	12.150	275	10.520
40	11.905	160	12.030	280	10.590
45	11.888	165	11.930	285	10.650
50	11.876	170	11.860	290	10.700
55	11.932	175	11.800	295	10.750
60	11.988	180	11.740	300	10.800
65	12.044	185	11.680	305	10.850
70	12.100	190	11.610	310	10.960
75	12.200	195	11.640	315	11.085
80	12.300	200	11.460	320	11.210
85	12.350	205	11.380	325	11.325
90	12.390	210	11.290	330	11.440
95	12.435	215	11.190	335	11.550
100	12.470	220	11.080	340	11.650
106	12.492	225	10.970	345	11.740
110	12.500	230	10.860	350	11.825
115	12.500	235	10.750	355	11.900

REVISIONS

DET Nº	NR REQ'D	DESCRIPTION	MATERIAL
404	2	.250 x 12.50 x 24.00	6061-T6 ALUM.
403	2	.250 x 12.50 x 24.00	6061-T6 ALUM.
402	1	ASS'Y CONSISTS OF -403 & -404	
401	1	ASS'Y CONSISTS OF -403 & -404	

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCE ON DECIMALS .XX = .03 .XXX = .010 ANGULAR ± 2°. DO NOT SCALE DRAWING

DRAWN D. M. WARNER 6-17-68

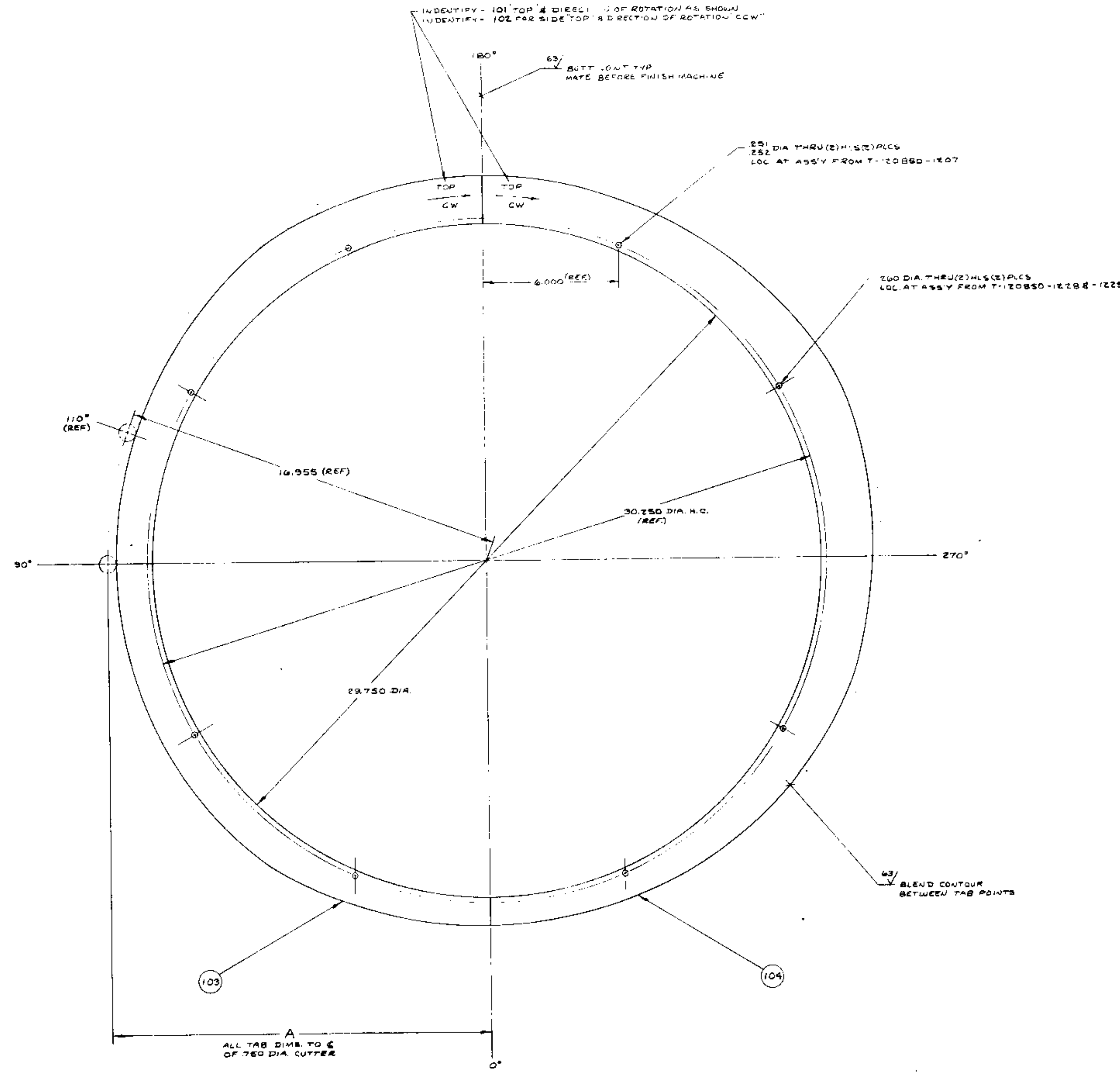
AEROJET-GENERAL CORPORATION AZUSA, CALIFORNIA

CAM PAYOFF HEAD 30 x 8.8 BIAS TIRE

SIZE E CODE IDENT NO. 70143 DWG NO. T-120853

T-120853

NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. (△) THIS TOOL USED WITH T-120850 TO FAB P/N 1269202
3. (△) STEEL STAMP WITH TOOL Nº & DET Nº



- 101 SUB-ASS'Y (SHOWN) △
- 102 SUB-ASS'Y (OPPOSITE) △

DEGREES	A RAD.	DEGREES	A RAD.	DEGREES	A RAD.
0	16.875	120	17.050	240	17.940
5	16.535	125	17.115	245	17.950
10	16.576	130	17.195	250	17.885
15	16.625	135	17.275	255	17.785
20	16.685	140	17.365	260	17.685
25	16.770	145	17.465	265	17.600
30	16.885	150	17.455	270	17.535
35	16.995	155	17.445	275	17.495
40	17.000	160	17.430	280	17.475
45	16.995	165	17.415	285	17.475
50	16.980	170	17.400	290	17.415
55	16.960	175	17.390	295	17.325
60	16.940	180	17.380	300	17.235
65	16.905	185	17.375	305	17.145
70	16.870	190	17.370	310	17.066
75	16.865	195	17.385	315	16.965
80	16.845	200	17.400	320	16.880
85	16.835	205	17.425	325	16.800
90	16.856	210	17.475	330	16.725
95	16.875	215	17.530	335	16.665
100	16.900	220	17.600	340	16.685
105	16.925	225	17.675	345	16.535
110	16.956	230	17.760	350	16.510
115	17.000	235	17.850	355	16.500

DET Nº	Nº REQ'D	DESCRIPTION	
104	2	.250 X 17.75 X 34.00	6061-T6 ALUM
103	2	.250 X 17.00 X 34.00	6061-T6 ALUM
102	1	ASS'Y	CONSISTS OF -103 & -104
101	1	ASS'Y	CONSISTS OF -103 & -104

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

DRAWN D.M. WARNER 5-18-68
CHECKED 7-30-67
D. M. WARNER 5-18-68
DESIGN ACTIVITY APPD M.J. Sanger 5-29-68

AEROJET-GENERAL CORPORATION

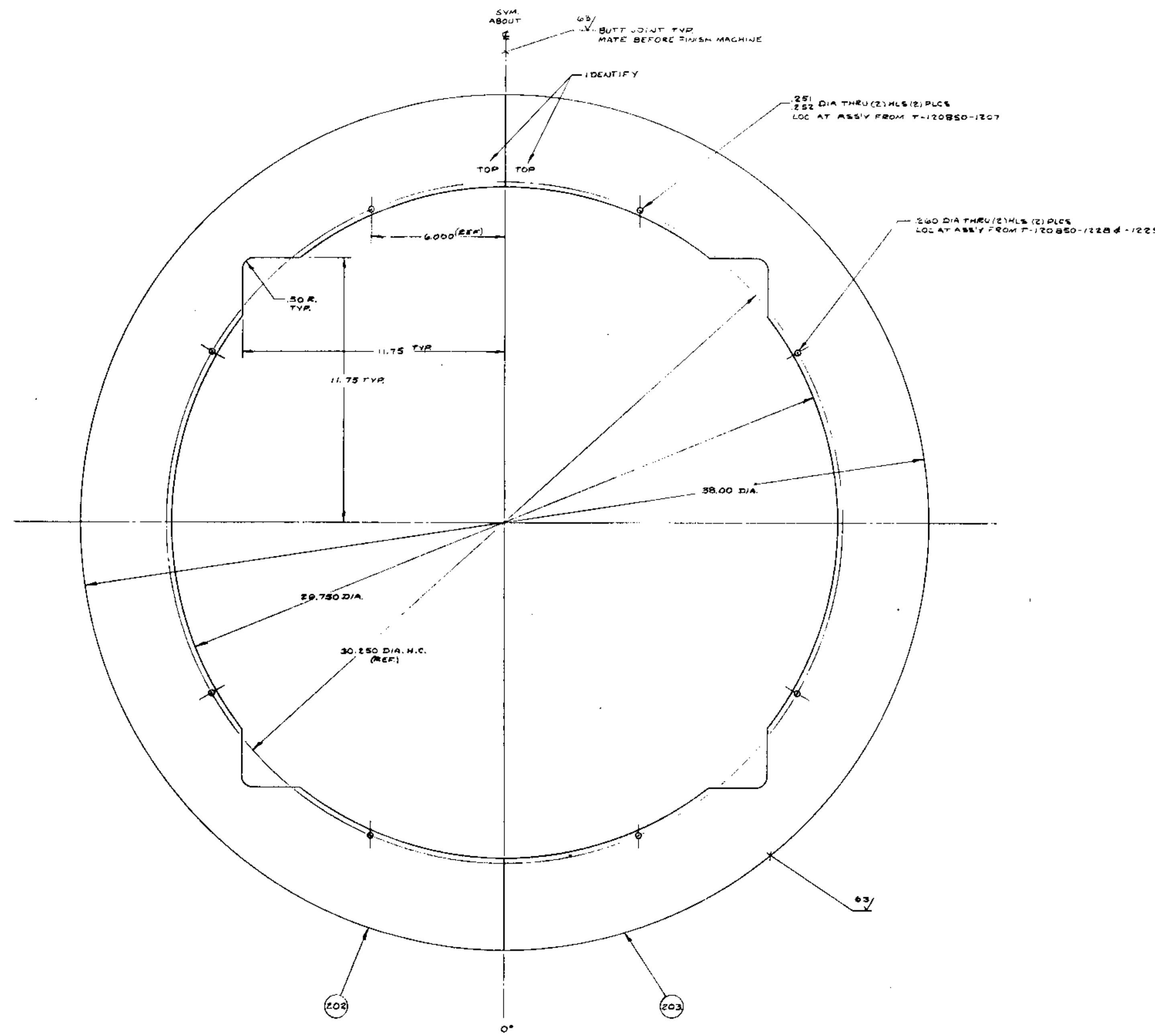
TITLE: CAM - PAYOFF HEAD 49 X 17 TIRE - BIAS

SIZE E | CODE IDENT NO. 70143 | DWG. NO. 1286108

SCALE ½ | REL. DATE 7-31-67 | SHEET 1 OF 2

NEXT ASSY | USED ON | APPLICATION | DRAWING LEVEL T

NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
△1 THIS TOOL USED WITH T-120850 TO FAB P/N 1269202
△2 STEEL STAMP WITH TOOL Nº & DET Nº



-201 SUB-ASS'Y △2

DET Nº	Nº REQ'D	DESCRIPTION	
203	1	.250 × 19.25 × 38.25	6061-T6 ALUM.
202	1	.250 × 19.25 × 38.25	6061-T6 ALUM.
201	1	ASS'Y	CONSISTS OF -202 & -203

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCE ON DECIMALS .XX ± .03 .XXX ± .010 ANGULAR ± 2°
DO NOT SCALE DRAWING

TREATMENT
FINISH

DRAWN D. M. WARNER 5-28-68
CHECK M. J. Senger 7-30-68
DESIGN D. M. WARNER 5-28-68
DESIGN ACTIVITY APPD M. J. Senger 5-28-68

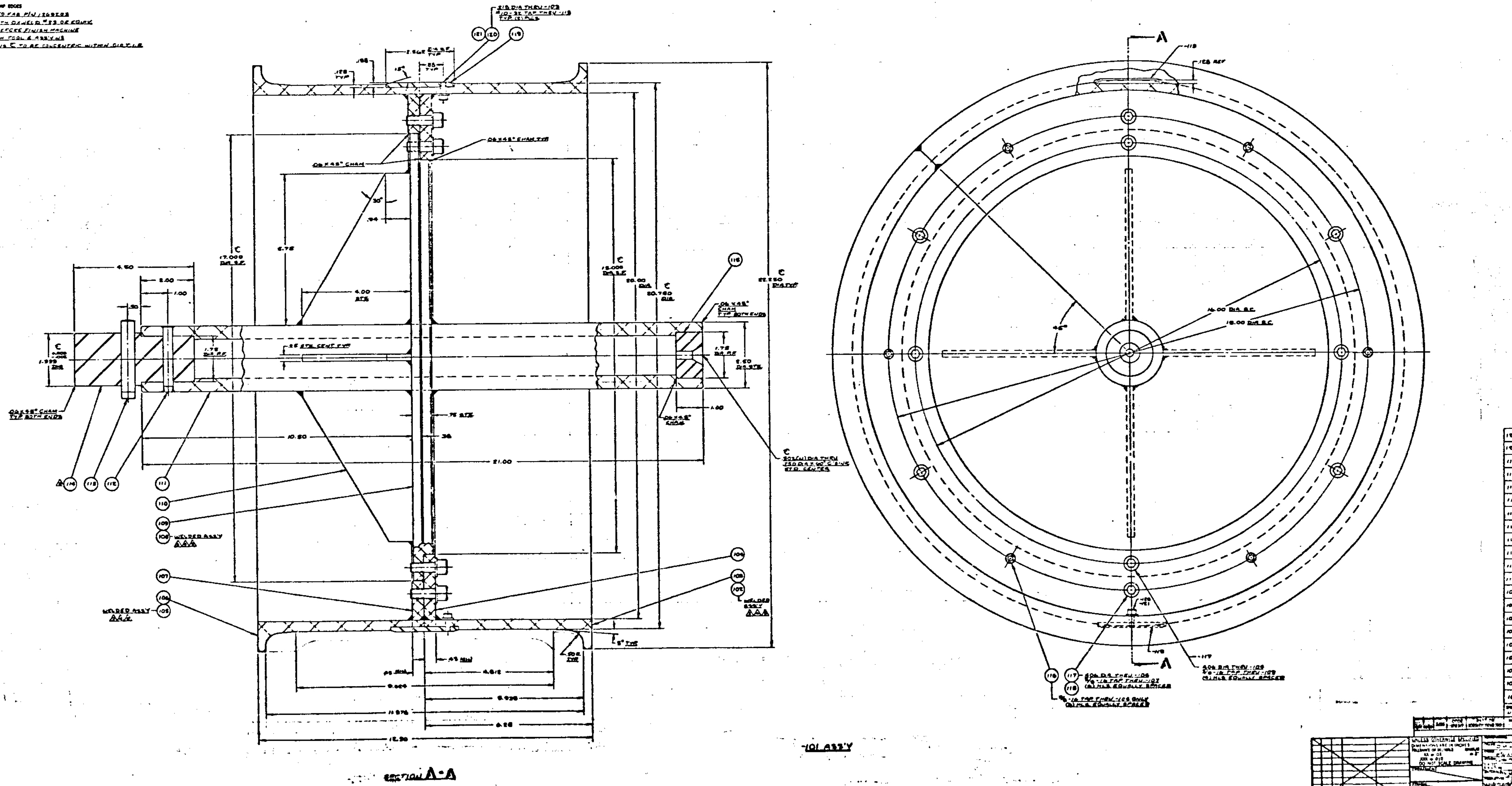
AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

TITLE
CAM - PRESSURE ROLLER
49 X 17 TIRE - BIAS △1

DWG SIZE E | CODE IDENT NO. 70143 | DWG NO. 1286108
SCALE 1/2 | REL DATE 7-31-68 | SHEET

Approved for Public Release

NOTES: 1. REMOVE ALL BURRS AND SHARP EDGES
2. THIS TOOL USED TO FAB P/N [illegible]
3. WELD AS REQ'D WITH [illegible] OR EQUIV.
4. STRESS RELIEVE BEFORE FINISH MACHINE
5. STEEL STAMP WITH TOOL & ASS'Y NO.
6. DIAS MARKED THUS C TO BE CONCENTRIC WITHIN .010 T.I.R.



121	2	3/16 NOM DIA	PLAIN STL WASHER
120	2	#10-32 X .50 LG	SOC. HD. CAP SCR.
119	2	2.75 DIA X .50 LG	H.R.S.
118	10	3/8 NOM DIA	PLAIN STL WASHER
117	10	3/8-16 X 1.00	SOC. HD CAP SCR.
116	6	3/8-16 X .50	FLAT POINT SOC. SET SCR.
115	1	1 3/4 DIA. X 1.12	C.R.S.
114	1	2 DIA. X 4.62	C.R.S.
113	1	1/2 DIA X 3.00	DOWEL
112	1	3/8 DIA X 2.50	DOWEL
111	1	2 1/2 O.D. X .50 WALL X 21.25	6061-T6 ALUM TUBING
110	4	1/2 X 4.00 X 6.75	6061-T6 ALUM
109	1	3/4 X 17.25 DIA	6061-T6 ALUM
108	1	WELDED ASS'Y CONSISTS OF -109, -110 & -111	
107	1	1/2 X 20.25 DIA	6061-T6 ALUM
106	1	1 3/4 X 6.50 X 70.00	6061-T6 ALUM
105	1	WELDED ASS'Y CONSISTS OF -106 & -107	
104	1	1/2 X 20.25 DIA	6061-T6 ALUM
103	1	1 3/4 X 6.50 X 70.00	6061-T6 ALUM
102	1	WELDED ASS'Y CONSISTS OF -103 & -104	
101	1	ASS'Y	CONSISTS OF -102 THRU -121
PART NO	NO REQD	DESCRIPTION	

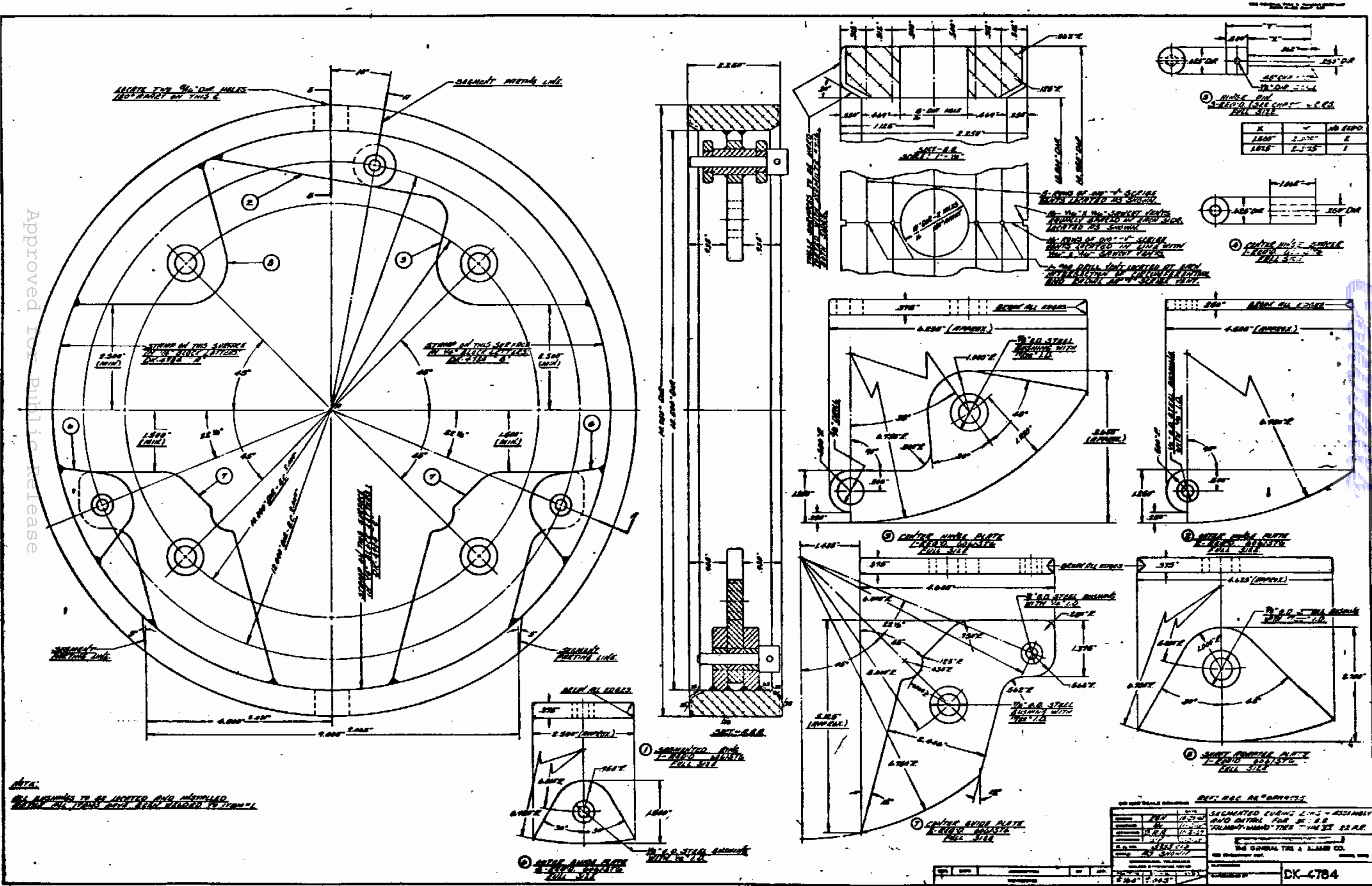
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES OF DECIMALS .XX ± .03 .XXX ± .010
DO NOT SCALE DRAWING

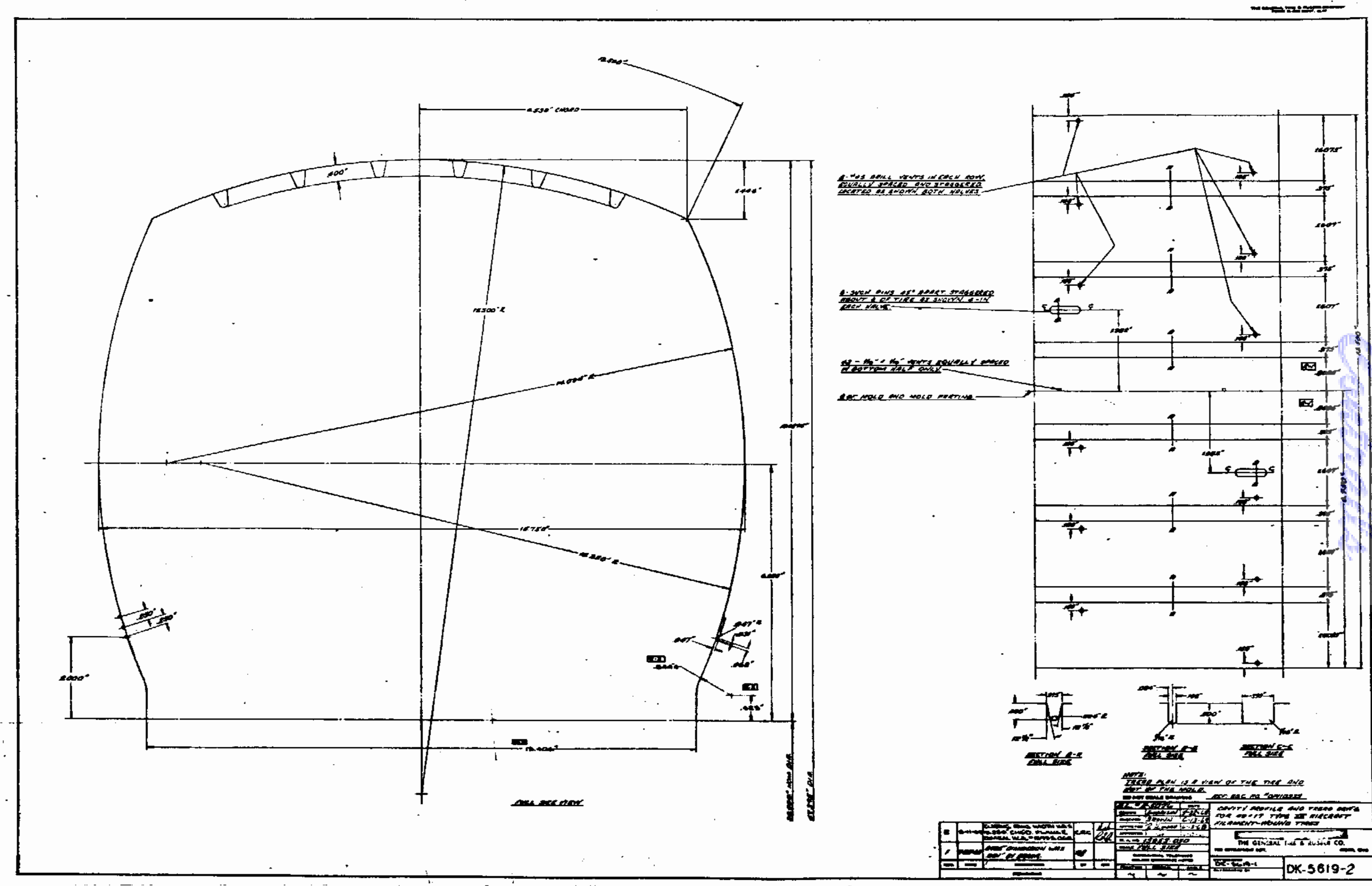
AEROJET-GENERAL CORPORATION

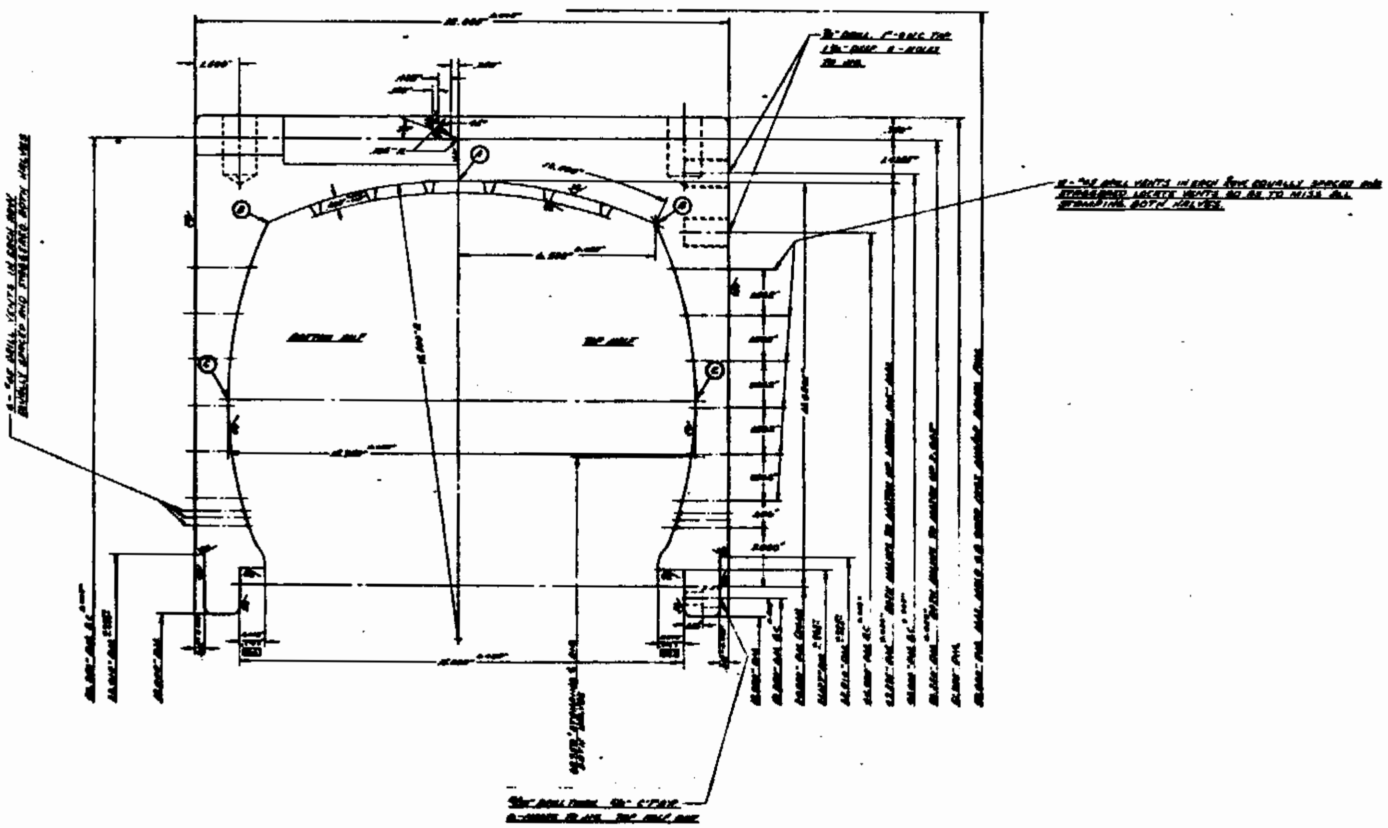
TITLE: MANDREL - RIM LOCK ASSY 49 X 17 TIRE

70143 | DWG NO. 1286125

1		1286125	A


SEGMENTED CURING RING ASSEMBLY
THE GENERAL TIRE & RUBBER CO.
DK-4784
SEGMENT PARTING LINE
SECT-B-B
SECT-A-A
FULL SIZE
NOTE:
ALL BUSHINGS TO BE LOCATED AND INSTALLED AFTER ALL ITEMS HAVE BEEN WELDED TO ITEM #1
ROUND ALL EDGES
CENTER HINGE PLATE
CENTER GUIDE PLATE
HINGE PIN
AS SHOWN


4.530" CHORD
.400"
15.500" R
FULL SIZE VIEW
8-#45 DRILL VENTS IN EACH ROW, EQUALLY SPACED AND STAGGERED LOCATED AS SHOWN BOTH HALVES
42 - VENTS EQUALLY SPACED IN BOTTOM HALF ONLY
℄ OF MOLD AND MOLD PARTING
SECTION A-A FULL SIZE
SECTION B-B FULL SIZE
SECTION C-C FULL SIZE
NOTE: TREAD PLAN IS A VIEW OF THE TIRE AND NOT OF THE MOLD.
CAVITY PROFILE AND TREAD VENTS FOR 49-17 TYPE III AIRCRAFT FILAMENT-WOUND TIRES
FULL SIZE
THE GENERAL TIRE & RUBBER CO.
DK-5619-2



BILL OF MATERIAL		SIZE: 40x17 / MOLD DRWG.: DK-5620-1 / DESIGN: AIRCRAFT TYPE III
ITEM NO.	DESCRIPTION	REFERENCE
1	MATERIAL	CAST STEEL
2	MOLD PLAN VIEW	DK-[illegible]-3
3	DOWEL PINS	AK-[illegible]-1 TYPE II
4	CAVITY PROFILE	DK-[illegible]
5	TIRE TREAD	DK-[illegible]
6	TREAD VENTING	DK-[illegible]
7	SIDEWALL VENTING	DK-5620-1

NOTES:

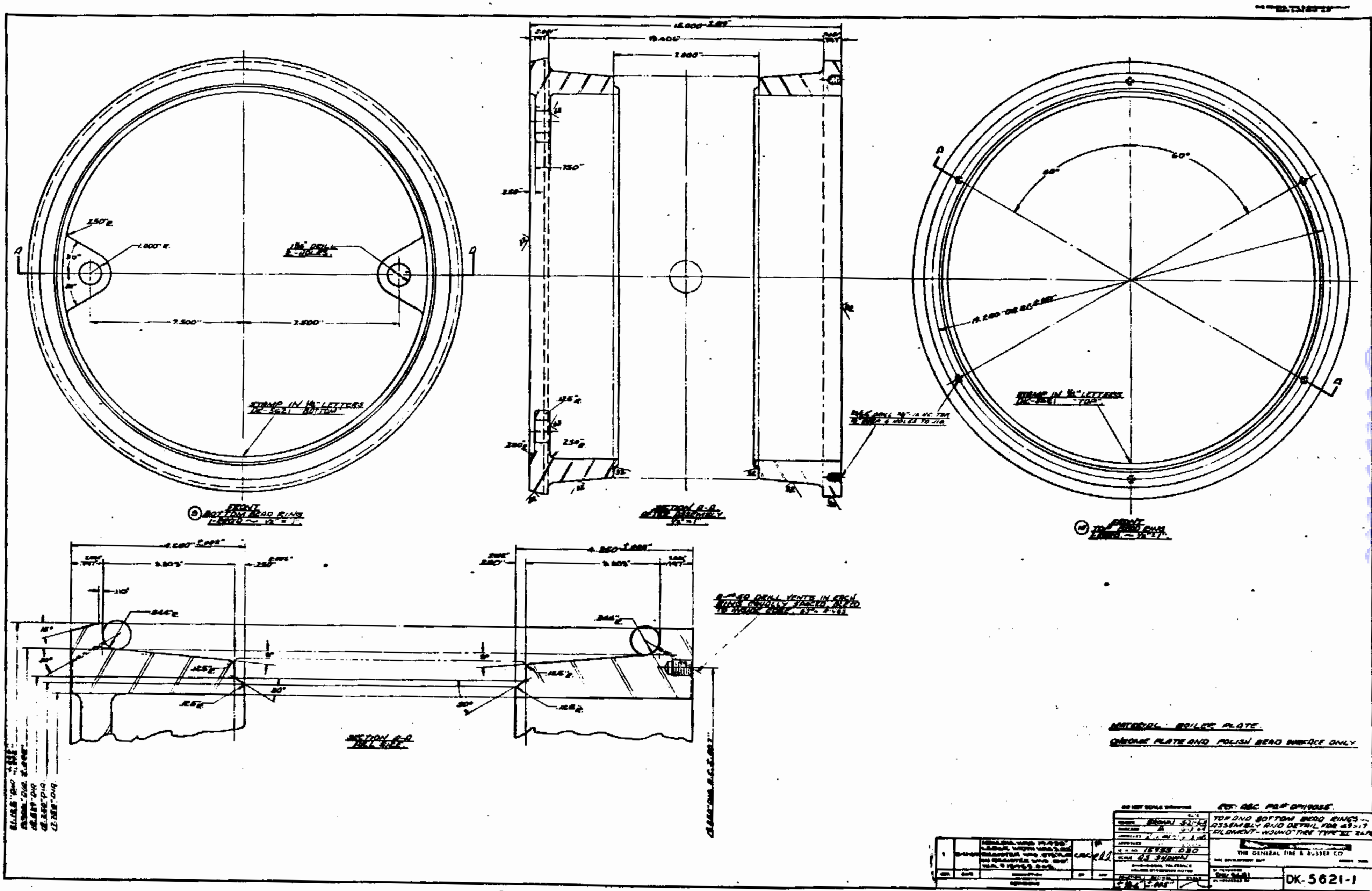
Entire mold cavity to be sandblasted with the [illegible] [illegible] method: [illegible] [illegible] [illegible] [illegible] [illegible] at [illegible] [illegible]

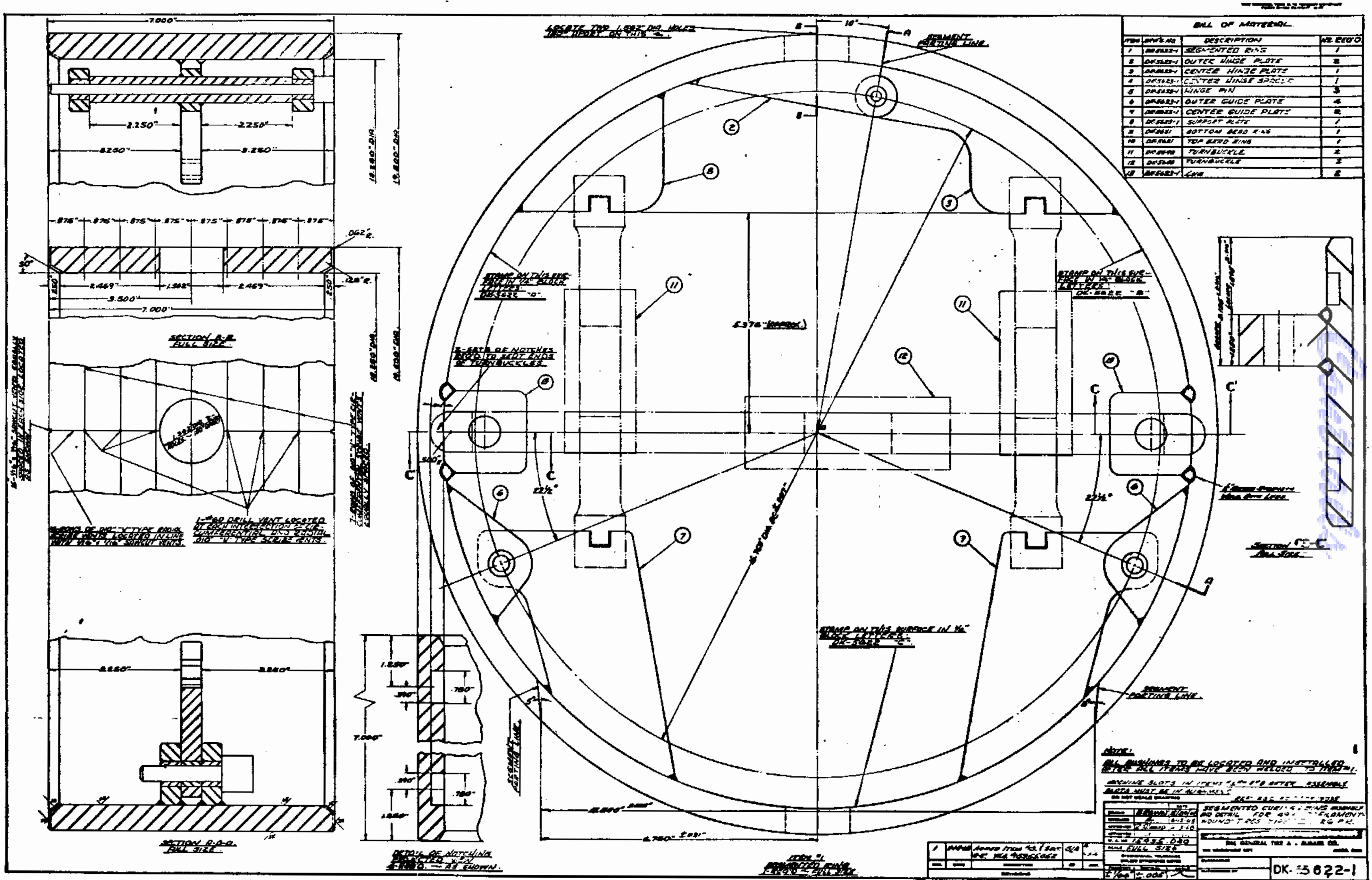
[illegible] T.I.R. at points A, B & C [illegible]

TIRE MOLD DETAILS FOR 40x17 TYPE III AIRCRAFT [illegible] TIRE

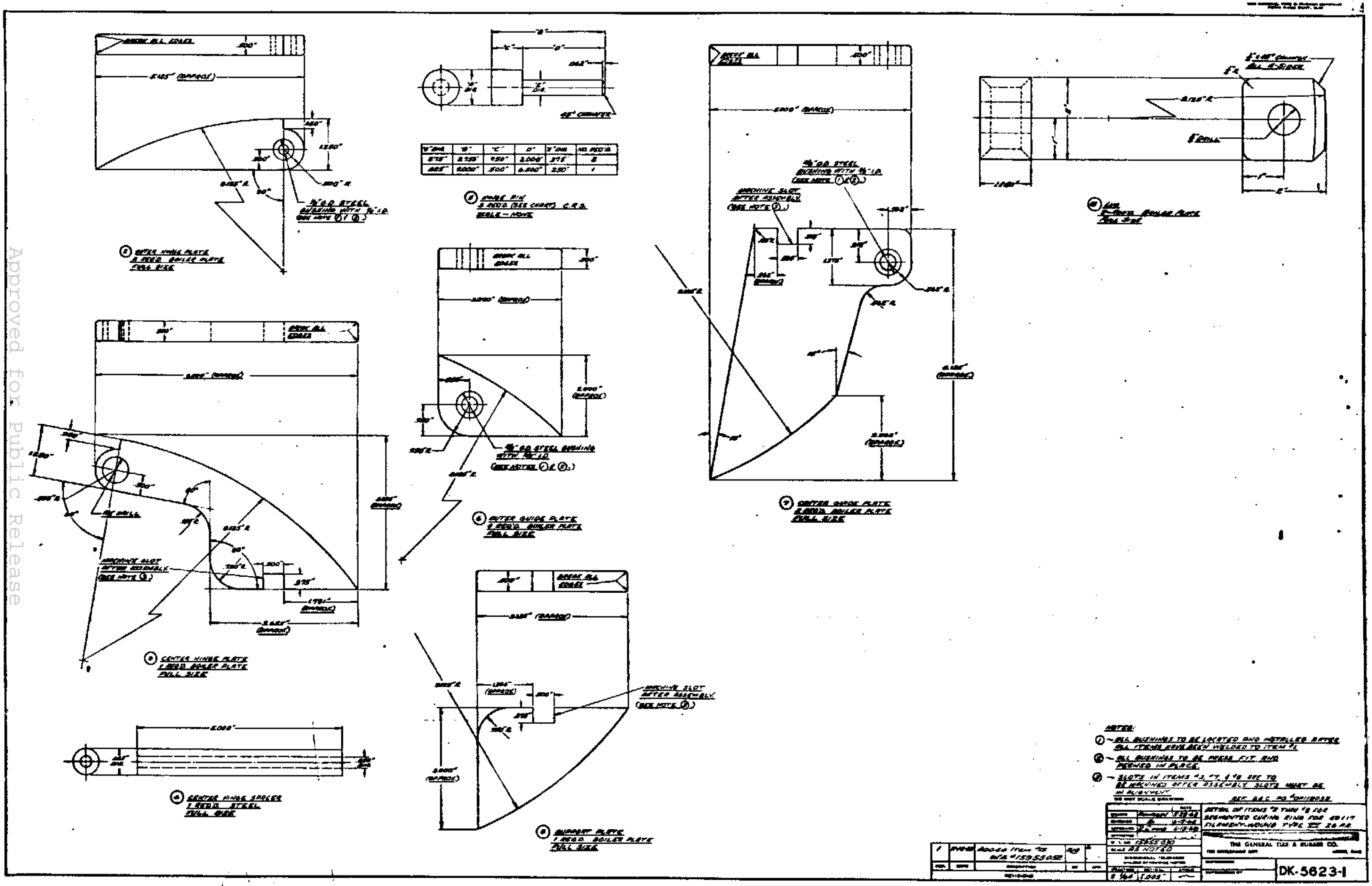
THE GENERAL TIRE & RUBBER CO.

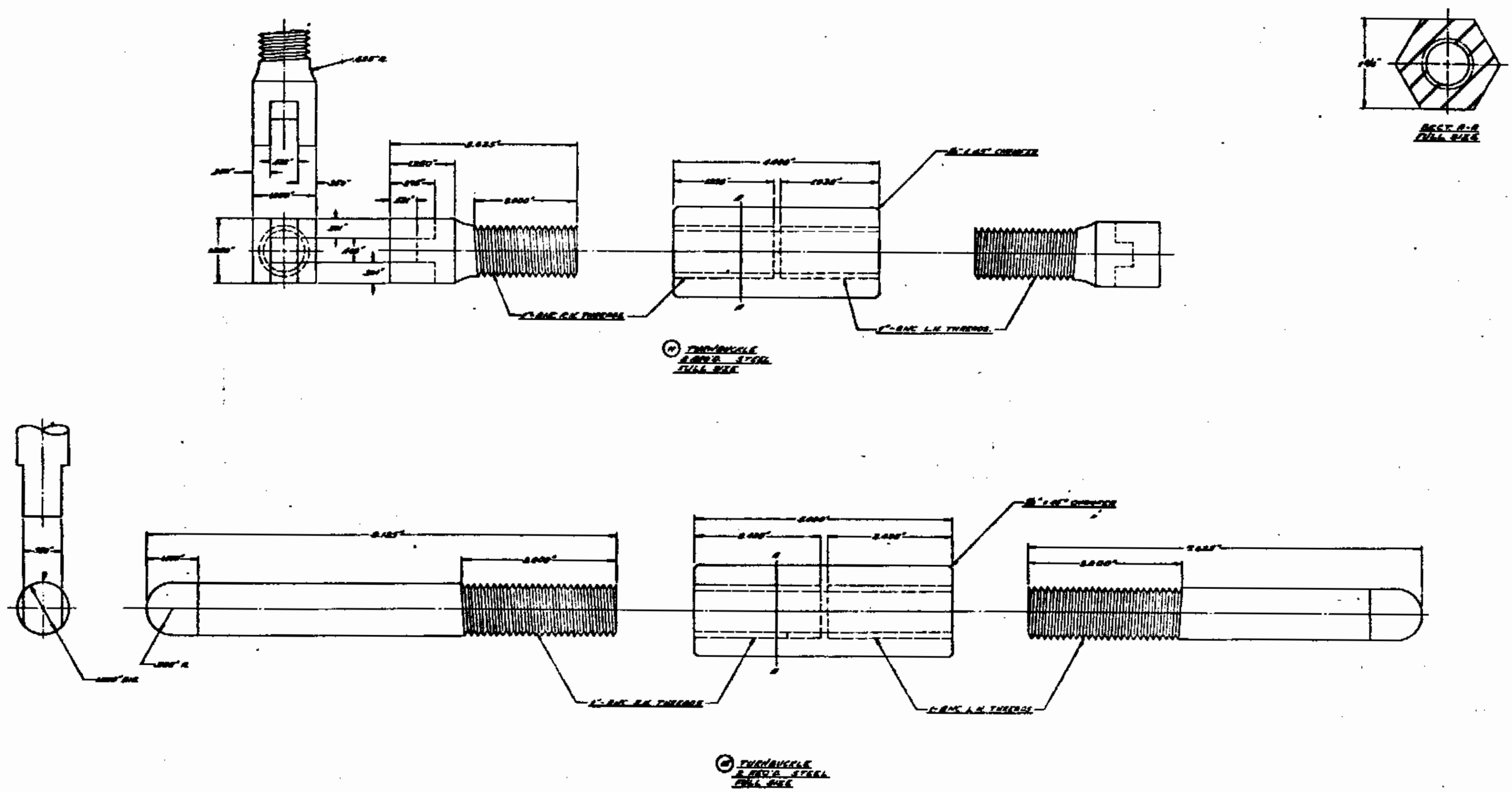
DK-5620-1


FRONT BOTTOM BEAD RING
STAMP IN 1/4" LETTERS DK-5621 BOTTOM
SECTION B-B
FRONT TOP BEAD RING
STAMP IN 1/4" LETTERS DK-5621 "TOP"
SECTION A-A FULL SIZE
MATERIAL: BOILER PLATE
CHROME PLATE AND POLISH BEAD SURFACE ONLY
REF. DGC. PO# GP19055
TOP AND BOTTOM BEAD RINGS — ASSEMBLY AND DETAIL FOR 49×17 "FILAMENT-WOUND" TIRE TYPE III
THE GENERAL TIRE & RUBBER CO
DK-5621-1



ITEM	DWG. NO.	DESCRIPTION	NO. REQ'D
1	[illegible]	SEGMENTED RING	1
2	DF5623-1	OUTER HINGE PLATE	2
3	[illegible]	CENTER HINGE PLATE	1
4	DF5623-1	CENTER HINGE SPACER	1
5	[illegible]	HINGE PIN	3
6	[illegible]	OUTER GUIDE PLATE	4
7	[illegible]	CENTER GUIDE PLATE	2
8	[illegible]	SUPPORT PLATE	1
9	[illegible]	BOTTOM BEAD RING	1
10	[illegible]	TOP BEAD RING	1
11	[illegible]	TURNBUCKLE	2
12	[illegible]	TURNBUCKLE	1
13	[illegible]	LUG	2


NOTES:
① ~ ALL BUSHINGS TO BE LOCATED AND INSTALLED AFTER ALL ITEMS HAVE BEEN WELDED TO ITEM #1
② ~ ALL BUSHINGS TO BE PRESS FIT AND PEENED IN PLACE.
③ ~ SLOTS IN ITEMS #3, #7, & #8 ARE TO BE MACHINED AFTER ASSEMBLY. SLOTS MUST BE IN ALIGNMENT
REF. A&C NO. #0P110032
DETAIL OF ITEMS #2 THRU #8 FOR SEGMENTED CURING RING FOR 48117 FILAMENT-WOUND TYPE IV 26 R.R.
AS NOTED
THE GENERAL TIRE & RUBBER CO.
DK-5823-1



DETAIL OF ITEMS FOR TYPE III FILAMENT-WOUND SEGMENTED CURING RING ASSEMBLY

AS NOTED

THE GENERAL TIRE & RUBBER CO.

DK-5649

APPENDIX IV

CHECKOUT PROCESS SPECIFICATION

49 x 17 TIRE-WINDING MACHINE

APPENDIX IV

CHECKOUT PROCESS SPECIFICATION, 49 x 17 TIRE-WINDING MACHINE

1. SCOPE

a. This document establishes the procedure to be followed in checking the winding machine that will be used to fabricate the filament-wound carcass for 49 x 17 tires.

b. Carcass fabrication consists of applying alternate layers of reinforcement-cord and rubber-squeegee plies. The cord will be applied to the mandrel in alternate right- and left-hand patterns using a prescribed tension. The insulation-squeegee plies will be positioned over each layer of cord.

c. The manufacturing techniques and equipment developed for the program will be verified with the fabrication and testing of 49 x 17, 26-ply rated, Type VII, aircraft tires.

2. MACHINE CAPABILITIES

a. Capacity - 38-in. OD minimum to 50-in. OD maximum, with maximum cross section of 18 in. (diameter)

b. Winding patterns - radial and helical

c. Payoff system - six payoff assemblies and six pressure-roller assemblies (cam-controlled)

d. Tension system - 12 adjustable hysteresis tension devices, range 0 to 6 in.-oz

e. Winding-head speed range - 2 to 40 rpm

f. Rubber applicator - cam-controlled.

3. MECHANICAL SYSTEMS CHECK PRIOR TO OPERATION

a. Check the oil level in the variable-speed transmission and all speed reducers.

b. Check all transmissions for freedom of movement.

c. Check the alignment of all shaft couplings.

d. Check the alignment of all jack shafts and bearings.

e. Check all timing belts, chains, and sprockets for alignment and proper tension.

f. Check the backlash, alignment, and lubrication of all gears.

g. Check all slides for alignment and freedom of movement.

h. Check all payoff assemblies and pressure-roller assemblies for alignment and freedom of movement.

i. Check the tension range of all tension devices.

4. ELECTRICAL SYSTEMS CHECK

a. Visually inspect all wiring and terminal connections.

b. With power on, check the operation of the mandrel and carriage drive motor as follows:

(1) Check the direction of rotation.

(2) Check the forward and reverse operation of the motor.

(3) Depress the machine-run button, and check the speed range with the speed control.

c. With the power on, check the operation of the ratio-adjust actuator as follows:

(1) Set the ratio-adjust selector switch in the manual position and check the range of the actuator with the ratio-adjust control.

(2) Set the motor-selector switch in the forward position and start the motor.

(3) Set the ratio-adjust control to the approximate ratio required.

(4) Depress the run button and adjust the machine speed.

(5) Check the actuation of the automatic control by observing the ratio indicator. The mandrel and carriage are synchronized when readings on the indicator stabilize.

d. With the power on, check the operation of the rubber applicator as follows:

(1) Set the motor-selector switch in the reverse position and start the motor; set the rubber-applicator selector switch in the manual position and check the limits of rotation of the rubber-applicator head by adjusting the manual position control

(2) Set the rubber-applicator selector switch in the "auto" position and check the automatic control as follows:

(a) Set the motor-selector switch in the reverse position and start the motor.

(b) Depress the run button and adjust the machine speed.

(c) Visually check the rubber-applicator rotation as the mandrel rotates. (Rotational feed is controlled by a cam coupled to the mandrel drive.)

5. OPERATIONAL CHECK

a. Winding-Operation Check

(1) Install the test mandrel in the machine.

(2) Install the change gears and cams required for bias winding.

(3) Install spools of cord on the tension devices.

(4) Select the direction of the winding head (carriage).

(5) Thread the cord through the payoff system, anchor it to the mandrel, and set the tension.

(6) Engage the pressure roller with the mandrel.

(7) Set the motor-selector switch in the forward position and start the motor.

(8) Set the ratio-adjust selector switch in the "auto" position and set the ratio-adjust control to the approximate ratio required.

(9) Depress the run button and adjust the machine speed.

(10) Wind the test pattern.

(11) Stop the machine, and check the cord angles.

b. Rubber-Application Check

(1) Disengage the winding head and pressure rollers, and cut the cords.

(2) Set the motor-selector switch in the reverse position and start the motor.

(3) Set the rubber-applicator selector switch in the "auto" position.

(4) Depress the run button and adjust the machine speed.

(5) Run the machine until the rubber strip reaches the starting position.

(6) Stop the machine, thread the rubber through the system, and anchor the strip to the mandrel.

(7) Engage the rubber-stitching roller with the mandrel.

(8) Start the machine to apply rubber and check the lead.

(9) Stop the machine.

6. REFERENCES

T. R. Henderson, J. A. Holloway, M/Sgt. H. P. McMakin, "Radiographic Techniques for Examining the Filament-Wound Tire," AFML TR-68-275, November 1968.

Heinrich, R. H. "Simulated Service Testing," Rubber World, May 1968

Hothschild, R., "Principals and Applications of Microwave in Material Testing," Bulletin 1000 of Microwave Instruments Co., Corona del Mar, California.

Study of Tire Uniformity Structural Features, and Defects by Halographic Nondestructive Testing (HNDT), GC Optronics, Inc., Ann Arbor, Michigan Jan. 29, 1969

APPENDIX V

INSTRUCTION MANUAL FOR A TOROIDAL WINDING MACHINE

I. INTRODUCTION

The winding machine described in this manual is designed to produce filament-wound toroidal shapes on a toroidal mandrel. The machine possess a high degree of versatility in that reinforcing filaments or tapes can be laid on the mandrel in bias, geodesic, radial, or other cord path combinations. This manual presents specific procedures for operating this machine according to AGC Drawing No. T-120850.

II. CAPABILITIES

The toroidal winding machine will wind predetermined helical patterns on toroidal mandrels ranging in size from 38 inches to 50 inches (outside diameter) with a cross section diameter ranging from 10 inches to 18 inches. The number of helical circuits (winding-head revolutions per one mandrel revolution) ranging from 2:1 through 2000:1 are determined by four change-gears located in the machine's right side. The number of turns (winding head revolutions) are indicated by an electrical counter located on the control panel. The gear changes required to produce the desired number of cords-per-inch can be determined using the formuli given in Section VB. Change-gears to produce the cord-per-inch shown in Section 5b are provided to fulfill any additional pattern requirements. Change-gears ranging from 40 to 120 teeth are required. These gears may be purchased as "off-the-shelf" items from transmission product distributors throughout the United States and Canada.

III. DESCRIPTION

A. DRIVES

The mandrel and winding-head are driven by one prime mover. To compensate for the changing drive ratio between the prime mover and mandrel, a variable-speed gear box is employed between the prime mover and winding-head. An electro-mechanical pickup, located between the mandrel and winding-head coordinates the mandrel and winding-head rotation ratio. Driven through change-gears the electro-mechanical pickup instantaneously senses and corrects winding-head speed variations, initiating speed corrections through the variable-speed gear box. The change-gears select the required winding pattern. Winding speed is controlled by the variable-speed prime mover. To wind right- or left-hand helical patterns, the winding-head is rotated clockwise or counterclockwise. The direction of winding-head rotation is selected through a reversing gear box.

B. MANDREL SUPPORT

The winding-machine utilizes the rotating-mandrel, friction-drive concept. The mandrel is supported by three "endless" timing-belt assemblies and four-roller assemblies mounted on four cross slides. Adjustment for diameter change is accomplished by adjusting the cross slides. The cross slides are similar in appearance to a four-jaw lathe chuck. A change in cross section adjustment is accomplished by adjusting the four roller-assemblies, each assembly consisting of two self-centering rollers. The mandrel is driven by the lower timing belt. This belt contacts 25% of the mandrel's O.D., minimizing drive slippage and reducing local pressure due to mandrel weight.

C. WINDING-HEAD

1. The winding-head rotating about the tire's cross section carries spools of cord, hysteresis brakes, payoff-head assemblies, and pressure-roller assemblies. The cord is dispensed from a spool, tensioned by a hysteresis brake. It is passed over intermediate guide-rollers and is applied to the mandrel surface by a cam-controlled payoff-roller. To minimize the machine setup time required for changing from right- to left-hand helical patterns, right- and left-hand tension brakes, payoff rollers, and pressure rollers are provided.

2. The winding-head consists of a gear-driven ring-assembly supported by four bearing-assemblies. A quadrant of the ring assembly is removable to provide an opening for mandrel installation and removal. The quadrant is positioned for removal by rotating the winding-head manually until the winding-head lock-pin can be inserted in the index hole provided in the ring assembly. As a safety feature the lock pin can not be inserted until the cam adsembly is removed. The cam assemblies mounted on the winding-head support-bracket consist of two sections. When changing winding-pattern the cams are removed and replaced by removing four thumb-screws.

3. The payoff roller, supported by the winding-head, is adjustable in directions parallel and perpendicular to the winding head's axis of rotation and radially about the perpendicular adjustment. The parallel and radial adjustments are used to align the payoff-roller with the predetermined winding path. The payoff roller's circular path about the tire cross-section is set with the perpendicular adjustment.

4. In operation the payoff head, supported by the winding head, rotates in a circular path about the tire's cross section. While traveling in a circular path, the payoff head is also capable of reciprocating parallel to the winding head's rotation axis. This reciprocating motion is controlled by a cam mounted on the winding-head support. The cam provides a means of modifying the basic path of the payoff head generated by the change-gears. Two cams are provided to minimize machine setup time when changing from right- to left-hand helical patterns. The right- or left-hand cam is selected by loosening a lock screw, positioning the cam-follower over the required cam and tightening the lock screw.

D. PRESSURE ROLLER

A pressure roller is provided for use for winding-patterns which are on a slip path. This roller assembly, supported by the winding-head, is spring-loaded against the mandrel surface, rolling on the cord as the cord is applied. The pressure roller's radial position in relation to the tire's cross section is controlled by a non-rotating cam mounted on the winding-head support. A radial adjustment is provided for setting the winding-head's initial pressure.

E. RUBBER APPLICATOR

The rubber-applicator assembly, mounted on the machine's left side, consists of a gear-driven ring-assembly supported by four bearing-assemblies. The ring-assembly, rotating through a 270 degree arc about the tire's cross section, carries a rubber-applicator head. The rubber-applicator head supports a spool of rubber stock. It guides the rubber strip to the mandrel and stitches the rubber to the mandrel surface. The rubber-applicator ring-assembly is centered about the tire's cross section by adjusting the cross slide. Change in cross section adjustment is accomplished by adjusting the stitching-roller assembly which is slide-mounted on the ring assembly. The stitching-roller assembly is spring-loaded against the mandrel surface. When the stitching roller is not in use, it is manually retracted and locked in retracted position with a lock which is provided. The rubber-applicator head rotates in a circular path about the tire's cross section as the tire rotates about its center. The rubber-applicator head's rotation rate is controlled by a cam which is driven by the mandrel drive.

IV. MACHINE INSTALLATION

The machine weighs approximately 8000 lbs. The weight is distributed over four leveling-pads. The machine occupies an approximate six-foot-by-six-foot area and is approximately seven feet in height (after leveling). The machine may be put into operation after the following tasks are performed: The machine is placed on the steel leveling pads provided, and leveled by adjusting the four leveling screws in the machine base. A circuit breaker is then installed into the 440 volt, 60 cycle, 3-phase line and connected to the machine as shown on the wiring diagram (E-101523, Sheet 6).

V. MACHINE SETUP

A. MACHINE PREPARATION

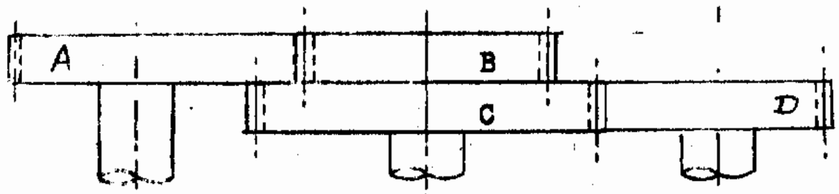
The machine should be kept clean. It is especially important that no rubber cement is allowed to accumulate which would interfere with any of the machine's motions. Before attempting winding operations, a check for obstructions should be made by rotating the winding-head by hand.

B. CHANGE-GEAR SELECTION

1. The number of helical circuits (winding-head revolutions per one mandrel revolution) and cords-per-inch (winding head advance in one mandrel revolution) are selected by placing four predetermined change-gears on their corresponding shafts in the change-gear box. The change-gear box is located in the right side of the machine.

2. The gears may be changed by pulling off the retaining knobs, unlocking the "pork chop" and the cluster-gear shaft-housing. The predetermined gears are then placed on the corresponding shafts. The cluster-gear shaft-housing is adjusted until minimum backlash is obtained between "A" and "B" gears and lock. The "pork chop" is rotated about "A" gear until minimum backlash is obtained between "C" and "D" gears and lock. Gears should not be preloaded; i.e., a slight backlash is preferable to preloading.

3. The change gears for the ratios listed in the following tab block are supplied with the machine. Additional ratios that may be required for future patterns can be determined by the formula given in "4" below:



Winding Pattern	Mandrel Rev	Carriage Rev	Cords per Inch	Change Gear (GD) 12 Pitch 3/4 Face			
				A	B	C	D

4. Change-gear formula

A = Input-gear teeth
B&C = Cluster-gear teeth
D = Output-gear teeth
P = Carriage revolutions
M = Mandrel revolutions

$$\frac{A}{B} \cdot \frac{C}{D} = \frac{2P - 4M}{P}$$

C. CONTROL OF CAM-PAYOFF HEAD

To program a cord path about the toroid, a revolution ratio for the mandrel and the winding-head is selected. Based on this ratio, payoff head positions are programmed in relation to the angular rotation of the winding-head about the toroid's cross section. Equations for digital computer solutions, required when programming the machine's motions, may be obtained from the following: Computer Program for the Design of Cams to Filament-Wind Tires, Contract F33615-67-C-1726, Project 360-7.

VI. MACHINE OPERATION

A. MANDREL INSTALLATION DIRECTIONS

1. Place the winding-head gear-shift lever in neutral position.

2. Remove the cam assembly's front section by removing upper and lower thumb-screws.

3. Rotate the winding-head manually until the winding-head lock-pin can be inserted in the index hole.

4. Remove the four bolts which attach the removable quadrant to the winding-head ring-assembly.

5. Remove the winding-head quadrant by swinging it out on the upper hinge; hoist.

6. Adjust the four mandrel-support cross-slides to clear the mandrel which is to be installed.

7. Adjust four cross-section guide-roller assemblies to clear the mandrel.

8. Open the four front cross-section guide-rollers by hinging them outwardly to clear the mandrel outside diameter.

9. Attach the slings to the mandrel and hoist in the machine. As the mandrel is lowered into the machine, release the lower belt-tensioner.

10. Adjust the lower two mandrel-support slides and the two lower cross-section guide-rollers in order to raise and center the mandrel.

11. Adjust the upper two mandrel-support slides within one inch of the mandrel, and adjust the upper two cross-section rollers to center the mandrel.

12. Remove the slings from the mandrel.

13. Lock the lower belt-tensioner.

14. Install the quadrant in the winding-head ring-assembly by hanging it onto the upper hinge. Lower it slowly until it engages with the main ring-assembly. There must be no mismatch of the outer bearing surface at either joint. Install four bolts into the quadrant and tighten.

15. Disengage the winding-head lock-pin.

16. Install the cam assembly and attach it with upper and lower thumb screws.

B. RUBBER-APPLICATOR OPERATION

1. Set the "FOR.-REV." selector to "REV."

2. Set the speed adjustment control to "ZERO."

3. Set the rubber-applicator selector to "AUTO."

4. Remove the Number 12 tension device from the winding-head. Rotate the head so that the head's open space is at the lower in-board side. This is done to permit full travel of the rubber-applicator head in the bead area.

5. Depress "FOR.-REV." button to start motor.

6. Depress "RUN" button.

7. Center the rubber-applicator head about the mandrel by adjusting the slides.

8. Check the rubber-applicator head's position. The head may be positioned at the start position by allowing the machine to run; or it can be positioned by resetting the cam. The cam is located in the change-gear compartment located below the control panel.

9. Start the rubber strip by threading it over the guide roller and tacking it to the mandrel.

10. Engage the stitching-roller with the mandrel by releasing the lock.

11. Start rotating the mandrel by increasing the speed-adjustment control.

12. After rubber application the applicator head may be positioned in the rear by selecting "MANUAL" and adjusting the manual-control pot.

13. For normal or emergency stop, depress the "STOP" button (letting the motor run).

14. To shut down the machine, depress the "MOTOR STOP" button and set the rubber-applicator selector to the "OFF" position.

C. HELICAL- (BIAS-) WINDING OPERATION - MANUAL CONTROL

1. Install the change-gears selected for winding operation.

2. Install the cord spools on spindles of tension devices and tighten collet by turning the knurled knob clockwise.

3. Set tension by rotating the tension-device housing.

4. Select for a clockwise or counterclockwise cam by loosening the lock screw, positioning the cam follower over the selected cam, and tightening the lock screw.

5. Select the winding-head's direction of rotation by shifting the winding-head gear-shift level to a clockwise or a counterclockwise position.

6. Adjust the upper two mandrel-support slides to apply light pressure on mandrel. (After winding each layer, all four slides are retracted equally to compensate for the diameter increase.)

7. Adjust the four cross-section guide-roller assemblies, allowing 0.03 to 0.06 in. clearance to the mandrel, and lock with hand cranks (after winding each layer-reset clearance).

8. Adjust the lower belt-tensioner by loosening the hand crank momentarily, and tightening after each layer.

9. Set "FOR.-REV." selector to "FOR."

10. Set the speed-adjustment control to "ZERO."

11. Depress the "FOR.-REV." button to start the motor.

12. Attach one cord to the mandrel's surface.

13. Set the ratio-adjust control to approximate the ratio required.

14. Depress the "RUN" button.

15. Start the mandrel rotation by increasing the speed-adjustment control.

16. Hold the ratio-adjust selector in the manual position (approximately 30 seconds) and release.

17. Wind test pattern and reset ratio-adjust control; hold ratio-adjust selector in manual position after each setting until required cord spacing is obtained.

18. Stop mandrel rotation by setting the speed-adjustment control on "Zero."

19. Remove the cord test-pattern.

20. Set the revolution counter to "ZERO."

21. Thread each of the six cords through the guide rollers and attach to the mandrel surface. While threading each cord, the winding head can be rotated and stopped for access by using the speed-adjustment control.

22. After threading, increase the speed with the speed-adjustment control and reset the ratio-adjustment control. Hold the ratio-adjust selector in the manual position after each setting, as required to maintain proper cord spacing.

23. After the wind is completed, set the speed-adjust control on "ZERO."

24. For normal or emergency stop, depress the "STOP" button (letting the motor run).

25. To shut down the machine, depress the "MOTOR STOP" button.

26. Place the winding-head gear-shift level in the neutral position.

D. HELICAL- (BIAS-) WINDING OPERATION - AUTOMATIC CONTROL

The use of this control requires a minimum of eight three-quarter inch diameter metallic discs or plugs which are equally spaced on the toroid inside diameter.

1. Follow the manual control steps "1" through "11."

2. Loosen the hand knob and set the mandrel-position sensor three-eighths of an inch from the metallic disc, or plug on the mandrel's inner diameter (using the plastic feeler-gage).

3. Depress the "RUN" button.

4. Thread each of the six cords through the guide rollers and attach the cords to the mandrel surface. While threading each cord, the winding-head can be rotated and stopped using the speed-adjust control.

5. Set the ratio-adjust control to approximate the ratio required.

6. Set the ratio-adjust selector to "AUTO."

7. Set the revolution-counter to "ZERO."

8. Start mandrel rotation and increase speed with the speed-adjust control.

9. After the wind is completed, set the speed-adjust control to "ZERO."

10. For a normal or emergency stop, depress the "STOP" button (letting the motor run).

11. To shut down the machine, depress the "MOTOR STOP" button.

12. Place the winding-head gear-shift lever in neutral position.

13. Loosen the hand knob and retract the mandrel position-sensor before removing the mandrel from the machine.

E. RADIAL-WINDING OPERATION

1. Steps "1" through "3" and "5" through "11" are the same as manual control. For Step "4" remove all the cam followers.

2. Set the ratio-adjust control on "500."

3. Depress the "RUN" button.

4. Thread each of the six cords through the guide-rollers and attach to the mandrel surface. While threading each cord, the winding-head can be rotated and stopped by using the speed-adjust control.

5. Set the revolution-counter to "ZERO."

6. Start the mandrel with the speed-adjust control.

7. Hold the ratio-adjust selector in the manual position (for approximately 30 seconds); then return to the "OFF" position.

8. The machine stop is the same as for the manual control Steps "24," "25" and "26."

APPENDIX VI

E.M.I. (ENGINEERING MANUFACTURING INSTRUCTIONS)

Appendix VI

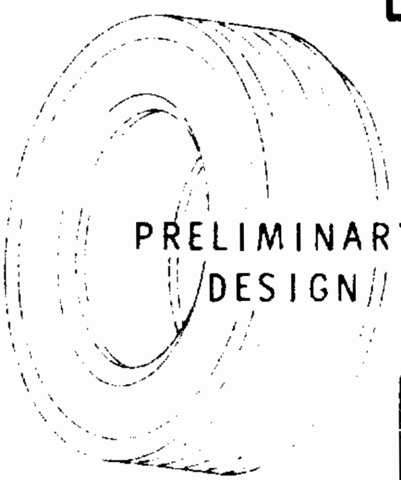
E.M.I. Engineering Manufacturing Instructions

Reproduced on succeeding pages are the following E.M.I. Engineering Manufacturing Instructions for the 30 x 8.8 22 PR and 49 x 17 26 PR Filament-Wound Tires.

EMI - 30 x 8.8 Bias Nylon Tire
EMI - 30 x 8.8 Geodesic Nylon Tire
EMI - 30 x 8.8 Radial Nylon Tire
EMI - 30 x 8.8 Radial Glass Tire
EMI - 30 x 8.8 Radial Wire Tire
EMI - 49 x 17 Bias Nylon Tire

ENGINEERING MANUFACTURING INSTRUCTION

FILAMENT WOUND TIRE



- PART NAME Carcass FW 30x8.8 22 PR Bias Nylon
- PART NUMBER 1269159
- NEXT ASSEMBLY A-5068A-1
- EFFECTIVE TIRE SERIAL NUMBER 15955, 022/A-1

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION

TABLE OF CONTENTS

PART NUMBER 1269159

PART NAME Carcass, FW 30 X 8.8 22 PR Bias Nylon

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269159	Carcass FW 30x8.8 22 PR Bias Nylon	TOOLING

DESCRIPTION	QTY	TOOL NUMBER
Mold, Sand Mandrel	1	T-120852
Vibrator, Syntron ST-3	1	AGC Inv. #
Drill, Hand w/drill #31	1	
Mandrel, RLA Bias	1	T-120848
Winding Machine, Toroidal	1	AGC Inv. #40191
Winding Machine, Horizontal	1	AGC Inv. #101517
Turntable, Horizontal	1	AGC Inv. #40191-2
Winding Machine, 6"	1	AGC Inv. #401518
Vertical Layup Fixture	1	NSN

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	[signature]	1/8/68		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269159	Carcass FW 30x8.8 22 PR Bias Nylon	PRODUCTIVE MATERIALS

MATERIAL REQUIREMENTS

DESCRIPTION	QTY	SOURCE
Sand, Weldron 70/30 & Stynex-C (SR-6)	54 lb	AGC, Sacto Facility Foundry
Stynex-C		Carver Foundry Co.
Glass Cloth, 181		J. P. Stevens
Rubber XGP-120A		General Tire & Rubber Co.
Adhesive		Hughson Chemical
Primer		Hughson Chemical
Rubber XEF-221		General Tire & Rubber Co.
Rubber, XGP-120A		General Tire & Rubber Co.
Rubber, XGP-122A		General Tire & Rubber Co.
Rubber, XGP-121A		General Tire & Rubber Co.
Nylon-V-2222		General Tire & Rubber Co.
ROVMAT, 2 oz.		Fiber Glass Industries
GLASSMAT, 2 oz.		Fiber Glass Industries
Resin, 1031		Shell Chemical Co.
Resin, 815		Shell Chemical Co.
MNA		E. V. Roberts
BDMA		E. V. Roberts

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
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APPR. PROJ. ENGR.		1/8/8		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269159	Carcass FW 30x8.8 22 PR Bias Nylon	NON-PRODUCTIVE MATERIAL

MATERIAL REQUIREMENTS

DESCRIPTION	QTY	SOURCE
Kanaba Wax	A/R	Commercial
PVA, Thalco 500G	A/R	Commercial
DC-20 or R621	A/R	Dow Chemical Co.
Vacuum Bag, 50" x 70	2	Commercial
White Gas	A/R	Commercial
Shrink Tape, cotton	100 yd	H. M. Royal, Inc.
Acetone	A/R	Commercial

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
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CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	[signature]	1/8/8		

ENGINEERING MANUFACTURING INSTRUCTION

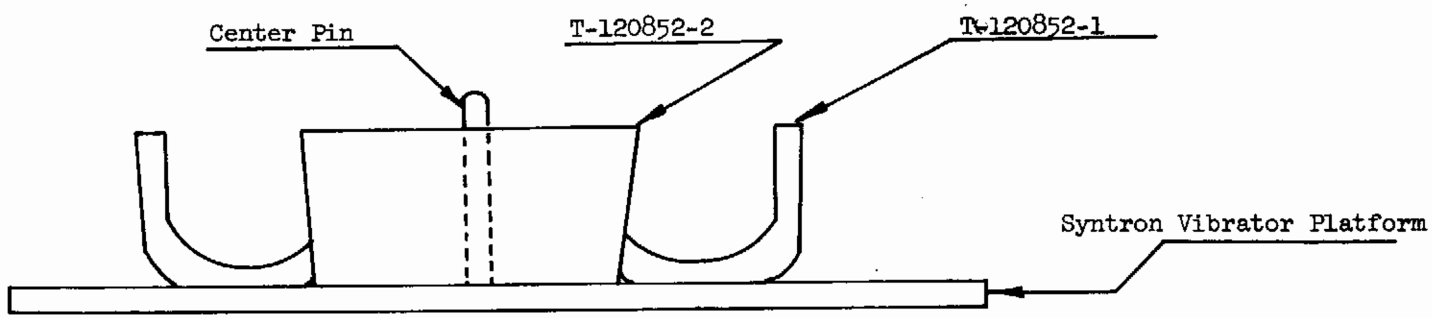
INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba wax.
2. Position cavity section (T-120852-1) onto platform of Syntron vibrator.
3. Install center core (T-120852-2), small end down, over 3/4 dia. center pin and into mating surface of cavity shell.

SKETCH #1



3a. Weigh out 28 lbs. of SR-6 sand.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 01	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

4. Add 20 lbs. of sand formulation SR-6 into cavity. Distribute sand as uniformly as possible.

5. Sweep and tamp with shop aid as required to compact sand against walls on the I.D. and O.D.

6. Position spider located male core (T-120851-103) over center-pin.

7. Turn on vibrator at minimum amplitude and vibrate for 3-4 minutes or until ring has settled to stops on spider. Turn off vibrator.

8. Add more sand around inner and outer annulus. Manually tamp with shop aid ram until sand is compacted and flush with inner and outer surfaces of mold.

9. Lightly tap ends of spider to loosen core. Lift core from mold using lift and eyes on spider. Strike off loose particles and edges, as required.

10. Rotate slightly center aluminum core (T-120852 and carefully lift from center pin. Cut four (4) shallow notches in inner lip of sand core.

11. Place cavity section (T-120852-1) with sand core into preheated (250°F) and cure for one (1) hour.

12. Remove from oven. Invert part onto flat plate and remove mold, and return to oven for (1) hour at 250°F. Remove from oven, cover mandrel with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

13. Wash all mold details in warm water and rewax per Opn. #1.

14. Repeat operations 2 through 12 to make other half of mandrel.

15. After both halves have cooled, blow out all loose sand and residue. Coat mating surfaces with Stynex "C" and join halves. Maintain concentricity of O.D.

16. Place mandrel in preheated (250°F) oven for one (1) hour.

17. Remove assembly from oven. Cool with asbestos blanket.

18. When cool, scuff bond resin flush with adjacent sand surfaces.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22PR Bias Nylon

~~19. Brush or spray PVA solution onto all mandrel surfaces. Apply thin coat as required.~~ JWalsh 1/8/?

20. Inspection:

a. Weight ________ lbs.

b. O.D. - 25.094 : Actual _______ in.

c. I.D. at outer corners - 17.060 ± .030 : Actual _______ in.

d. Section width - 7.500 : Actual ______ in.

e. Mark weight on mandrel with brush pen (felt tip).

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

RIM-LOCKING ASSEMBLY FABRICATION

1. Prepare mandrel (T-120848) for use as follows:

   a. Disassemble clean and coat all details with DC-20 or R-671. Bake on for four (4) hours at 300°F.

   b. Reassemble using -109 detail only (.12 thick center spacer). Refer to Sketch #2.

   c. Coat all surfaces in contact with resin with Kanaba wax.

2. Install mandrel in winding machine (AGC 101518).

3. Mix batch of Shell 58-68 epoxy resin 2300 grams. Use 815 instead of 828.

4. Preimpregnate cloth and ROVMAT with resin - 40%/50% by weight.

5. Precut (2) strips 181 glass bias cut cloth 12" wide x 42" long. Preimpregnate with resin 58-68R (modified).

6. Cut: (1) 6.5" wide x 102" lengths of 2 oz. glass ROVMAT. Nip edges 3/4" to 1" every 3" to 4" on both edges.
   (2) 4.3" wide x 106" lengths of 2 oz. glass ROVMAT.

7. Wrap 181 glass cloth strip on mandrel. Tension as required to conform to contour. Tie in place as required using 20 end dry roving.

8. Layup (1) 6.5" wide strip of ROVMAT and (1) ply of 181 cloth. Secure in place using closely spaced layer of 20-end S-901 dry glass roving at 10 lb. tension. Start at center line and continue wrap as far to edge as radii will permit, then continue to other side and return to center line for tie off.

9. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered in groove. Secure in place using closely spaced layer of 20-end dry roving as in Item 8 above.

10. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered. Roll out air as required. Apply layer of dry 20-end S-901 roving using 10 lb. tension to compact above bulk. Roving should be closely spaced and continued as far out toward edges as 4.3" wide matt will permit. Start at center line and proceed as in Item 8 above.

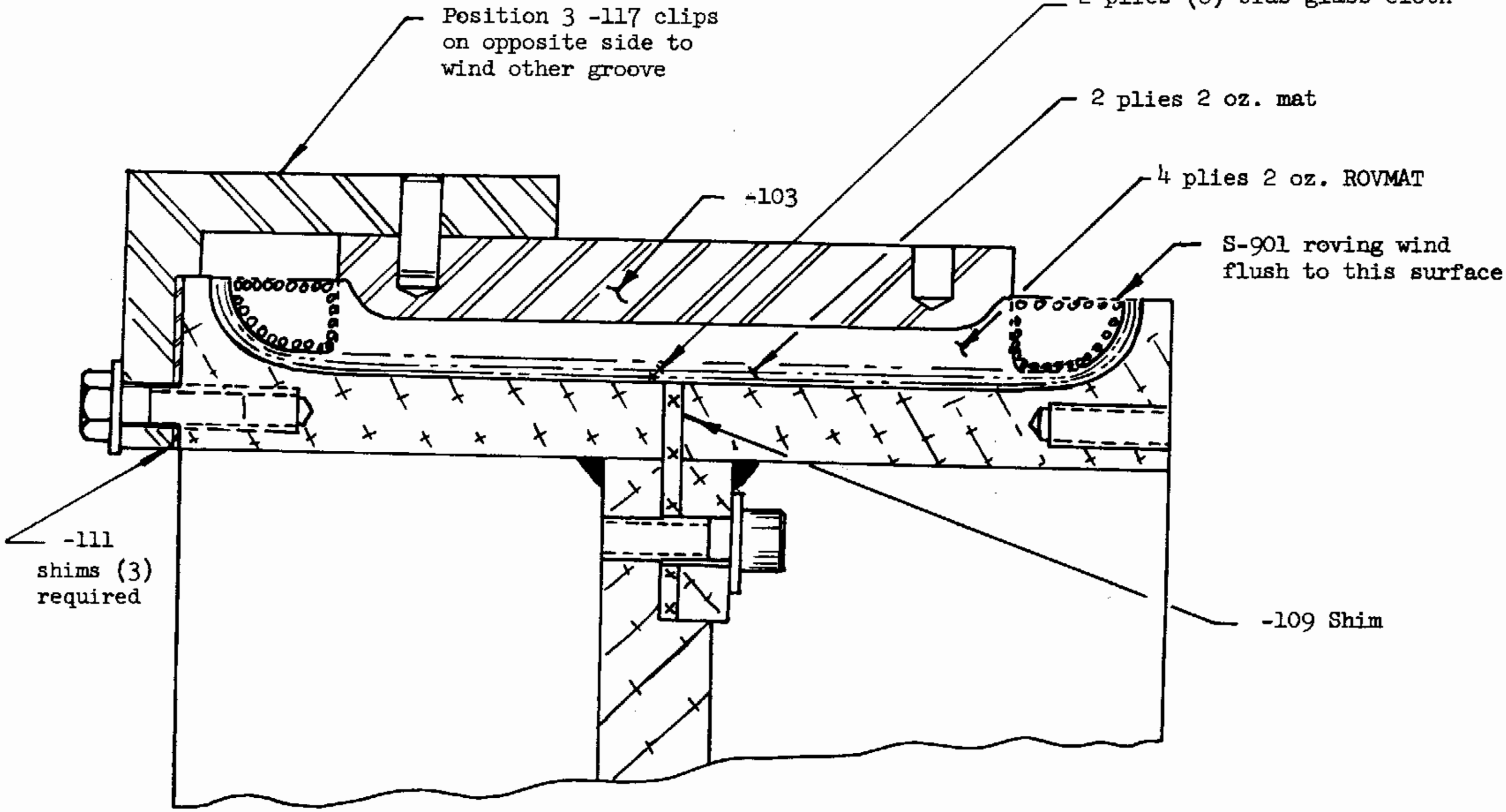
PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO.	PART NAME	

SKETCH #2



BIAS NYLON RLA

T-120848-1 Assy.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 02	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

11. Apply -103 band assembly using (3) -117 clips and 3 -111 shims on one side to locate band in center of mandrel. (see Sketch #2). Secure band with (4) bolts.

12. Set up and wind 20-end roving S-901 wetted with 58-68R in annulus between band and mat supported by mandrel. Use 8 lb. tension. Wind flush with outer surface of mandrel.

13. Transfer -117 clips and -111 shims to opposite side and wind 2nd annulus.

14. Trim excess material flush with mandrel outer surface. Wipe excess resin from mandrel. Wrap with bleeder material.

15. Place mandrel assembly in oven and cure as follows:

    200°F - 2 hours } or continuous rate of rise 50°F per hour.
    250°F - 4 hours }
    300°F - 4 hours

16. Cool in oven at cooling rate of approximately 50°F per hour.

16. Remove band -103 and -117 clips. Measure O.D.; if larger than 17.000 dia send to machine shop for trim to size (16.930 - 16.930).

17. Remove part from mandrel. Remove flash as required. Generate .05 R on outer edge as required by hand sanding.

18. Drill and chamfer (2) holes 180° apart per drawing.

19. Inspect:

    I.D. - 15.750 : Actual ______ in.
    Width - 5.812 : Actual ______ in.

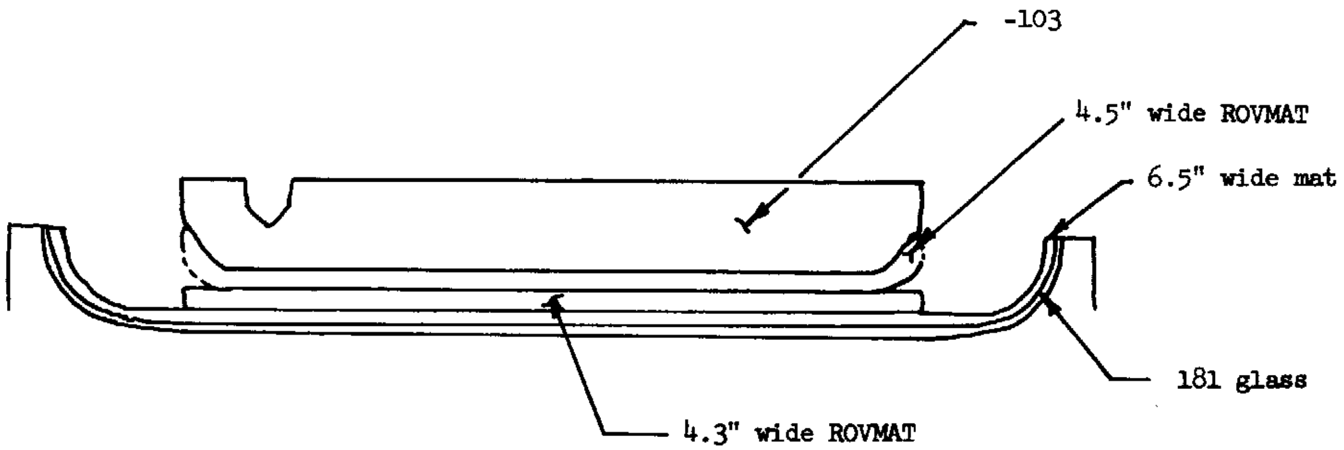
PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR	Bias Nylon

SKETCH #3



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

RIM-LOCKING ASSEMBLY LINER APPLICATION

1. Scuff sand RLA P/N 1269151 as required. Wash surfaces with acetone.

2. Coat all surfaces with Chemloc 203 primer. Dry 10 minutes @ 150°F. Recoat with Chemloc 220 adhesive and dry 10 minutes @ 150°F.

3. Cut (4) 3" dia O.D. - 0.5" dia I.D. donuts from XGP-120A rubber. Preply into (2) each (2) layer donut rings.

4. Position 3" dia rings over holes in rim-locking assembly O.D. Keep 0.5" center hole centered with holes in RLA.

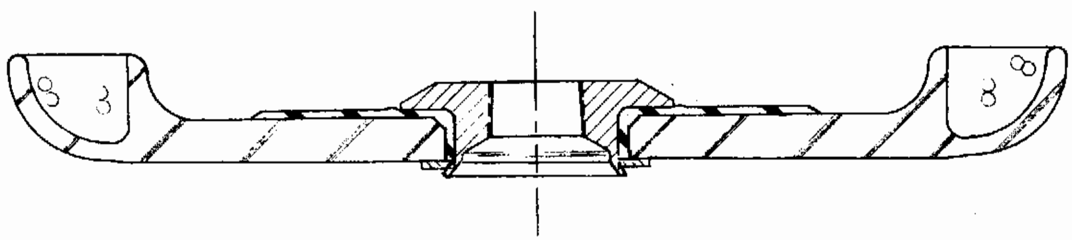
5. Wash in acetone bushing P/N 1269153 and washer P/N 1269152. Air dry. Coat external surfaces as in Operation #2 above.

6. Press bushings through rubber rings on RLA with flange on O.D. of RLA. There should be rubber captured between bushing and RLA hole to act as seal.

7. Install washer, chamfered inner edge outward, over protruding end of bushing. See Sketch #4.

7a. Swage lip of bushing onto washer using 74°/90° cone in arbor press.

SKETCH #4



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 03	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

8. Drill through existing holes in head of bushing using #31 drill (.120" dia) to a depth of .28 from face of bushing (4) places.

9. Press .125 dia x .25 long dowels into holes, flush or below face of bushing.

10. Slit XGP-120A to 2" wide strips.

11. Circumferential wrap two layers of XGP-120A over RLA using near butt-joint. Stagger seams of first and second layer. Stitch first layer to RLA before applying second layer. Remove all air pockets between layers and around flanges of bushings.

12. Wrap with prereleased cotton shrink cloth. Vacuum bag.

13. Cure per separate instructions.

14. Remove bag and bleeder. Clean up as required. Trim rubber from bushing holes.

15. Inspect for cure hardness, blisters, delamination.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 04	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR	Bias Nylon

INNER LINER FABRICATION:

1. Dry fit RLA (P/N 1269154-1) into mandrel. Trim mandrel as required. ~~Recoat with PVA as required.~~ Air dry.

2. Mate RLA with mandrel. Install assembly in vertical support fixture. Coat I.D. of RLA with rubber dispersion. Center RLA. Allow dispersion to air dry 20 minutes. Apply XEF-221 rubber filler to outer edges of RLA. Blend profile with mandrel and RLA as required.

3. Roll up 2" wide strips of XGP-120A rubber.

4. Starting at I.D. of tire radially wrap strips until torus is covered with one layer of rubber. Use 1/8" overlap.

5. Transfer assembly to horizontal turn table (AGC 40191-2).

6. Starting at bead heel circumferentially wrap 2" wide strips of XGP-120A rubber. Continue to bead heel on opposite side. Stitch thoroughly to remove air between 1st and 2nd ply.

7. Repeat step #6 continuing rubber approximately 1/2 in over edge of RLA. Stitch to remove air between 2nd and 3rd ply.

8. Cut openings at two bushings. Wrap entire torus with prereleased cotton shrink tape. Apply vacuum bag. Check for leaks.

9. Install part in oven and cure per separate instructions.

10. After cool down, remove bag and bleeder cloth.

11. Trim rubber at bushings as required and insert 2 plugs (shop aids).

12. Inspect for cure, blisters and lack of bond at seams.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

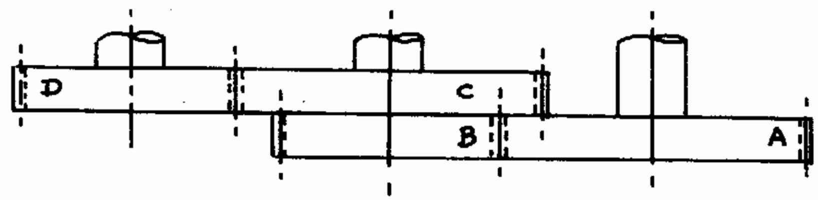
OPER NO 05	PART NO 1269159	PART NAME Carcass FW 30x8.8 22 PR	Bias Nylon

CARCASS WINDING:

1. Coat entire surface of inner liner with a 12% solids dispersion of XGP-121 and white gasoline. Allow to air dry 20 minutes.

2. Wrap one (1) ply of XGP-122A on I.D. Wrap one (1) layer XGP-121A circumferentially from bead to bead. Join at bead with XGP-122A piece. Hold overlap to 1/8-in. maximum. Stitch and awl as required to remove air.

3. Set up winding machine AGC 40191 with cams T-120853. Use gear ratio as follows:



D = 85
C = 80
B = 69
A = 55

4. Fill winding reels with V-2222 cord (Nylon 3360/2).

5. Remove winding ring segment from machine. Back off roller supports and remove outer rollers as required.

6. Place carcass assembly in winding machine. Replace ring segment and rollers. Adjust belt tension by turning belt spring tension handle counterclockwise. Allow belt to settle then tighten handle. Adjust slides on roller support belts to make contact with the carcass.

7. Turn machine on and rotate mandrel slowly. Adjust side support rollers to center tire on drive belt.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 05	PART NO 1269159	PART NAME Carcass FW 30x8.8 22 PR	Bias Nylon

8. While tire is turning, wipe entire surface of tire with white gas. Maintain tire rotating to air dry.

9. While tire is rotating engage winding ring by moving gear level to the left. This will cause ring to turn counterclockwise (left helix).

10. Stop machine. Ensure that payoff cam followers are on the left side cam. Install winding reels on winding ring. Thread cord through rollers and press on rubber. Lower pressure rollers to mandrel surface.

11. Start mandrel rotation. Quickly increase speed to 15 RPM. Adjust cord spacing by turning variable gear setting as required. Increasing numbers increases the cord end-count (reduces spacing between cords). Stop mandrel rotation when proper cord spacing is attained, i.e., 15 ends per inch.

12. Cut off cord from tire carcass. Set machine counter to zero.

13. Begin tire mandrel rotation and wind a complete layer of cord. Make adjustments as necessary to variable gear ratio setting to maintain uniform end count. When cord closes with first revolution, turn off machine. Disengage winding ring by moving lever to center position.

14. Record number of cords. (Counter No. X2) ______________. Angle at crown __________.

15. Rotate mandrel and paint with dispersion of XGP-121. Continue rotation for 10 minutes to dry.

16. Repeat Step #5 and remove tire. Place on horizontal turn table.

17. Repeat Steps #2, 4, 6, 7, 8.

18. Place cam follower rollers on right cam. Engage winding ring for right helix (move handle to right).

19. Repeat Steps #10 through #15.

20. Repeat Steps #2 through #19 until a total of 8 cord plies and 9 rubber layers. Cord path directions will alternate left and right helix. Each layer of rubber will be stitched and awled as required to remove all air.

21. With a silver pen write identification number on sidewall (I.D. number shown on cover page of these instructions.) Also show mandrel weight. Draw line at center line of crown.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 06	PART NO 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

INSPECTION:

1. Measure and record:

   O.D. ____________

   I.D. ____________

   Section Width ____________

   Carcass Weight ____________

2. Verify I.D. number and prepare inspection acceptance tag.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 07	PART NO. 1269159	PART NAME Carcass FW 30x8.8 22 PR Bias Nylon

PACKAGING:

1. Wrap tire carcass with polyethylene strips.

2. Place in special container P/N ______________.

3. Send to Building 118 for shipment to:

   The General Tire & Rubber Co.
   Development Experimental Workshop
   Attn: Mr. H. E. Hazelton
   1708 Englewood Avenue
   Akron, Ohio 44305

4. Forward this document to Document Control Center, Building 159.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

FILAMENT WOUND TIRE

PRELIMINARY DESIGN

- PART NAME Carcass, F.W. Tire 30 x 8.8 22 PR. Geodesic Nylon
- PART NUMBER 1269158
- NEXT ASSEMBLY A-5068A-2
- EFFECTIVE TIRE SERIAL NUMBER 159556 022/ B-1

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION

TABLE OF CONTENTS

PART NUMBER 1269158

PART NAME Carcass, FW 30 x 8.8 22 PR Geodesic nylon

OPER NO.	OPERATION TITLE	OPER NO.	OPERATION TITLE
01	Mandrel Fabrication		
02	RLA Fabrication		
03	RLA Liner Application		
04	Inner Liner Fabrication		
05	Carcass Winding		
06	Inspection		
07	Packaging		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME
		1269158	Carcass FW 30 x 8.8 22 PR Geodesic Nylon

DESCRIPTION	QTY	TOOL NUMBER
Mold, Sand Mandrel	1	T-120855
Vibrator, Syntron ST-3	1	AGC Inv. #
Drill, Hand w/drill #31	1	
Mandrel, RLA Radial	1	T-120849
Winding Machine, Toroidal	1	AGC Inv. #40191
Winding Machine, Horizontal	1	AGC Inv. #101517
Turntable, Horizontal	1	AGC Inv. #40191-2
Winding Machine, 6"	1	AGC Inv. #401518
Vertical Layup Fixture	1	NSN

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	J D alcide	1/4/68		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269158	Carcass FW 30x8.8 22 PR Geodesic Nylon	PRODUCTIVE MATERIALS

DESCRIPTION	QTY	SOURCE
Sand, Weldron 70/30 & Stynex-C (SR-6)	56 lb.	AGC, Sacto Facility Foundry
Stynex-C		Carver Foundry Co.
Glass Cloth, 181		J. P. Stevens
Adhesive		Hughson Chemical
Primer		Hughson Chemical
Rubber, XGP-120A		General Tire & Rubber Co.
Rubber, XGP-122A		General Tire & Rubber Co.
Rubber, XGP-123A		General Tire & Rubber Co.
Nylon-V-2222		General Tire & Rubber Co.
ROVMAT, 2 oz.		Fiber Glass Industries
GLASSMAT, 2 oz.		Fiber Glass Industries
Resin, 1031		Shell Chemical Co.
Resin, 815		Shell Chemical Co.
MNA		E. V. Roberts
BDMA		E. V. Roberts

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR TOOL ENGR.				
APPR. COGN. ENGR				
APPR. PROJ ENGR.	[signature]	1/8/8		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269158	Carcass FW 30x8.8 22 PR Geodesic Nylon	NON-PRODUCTIVE MATERIALS

DESCRIPTION	QTY	SOURCE
Kamaba Wax	A/R	Commercial
PVA, Thalco 500G	A/R	Commercial
DC-20	A/R	Dow Chemical Co.
Vacuum Bag, 50" x 70	2	Commercial
White Gas	A/R	Commercial
Shrink Tape, cotton	100 yd	H. M. Royal
Acetone	A/R	Commercial

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR TOOL ENGR.				
APPR COGN ENGR.				
APPR. PROJ ENGR.	[signature]	1/3/3		

ENGINEERING MANUFACTURING INSTRUCTION

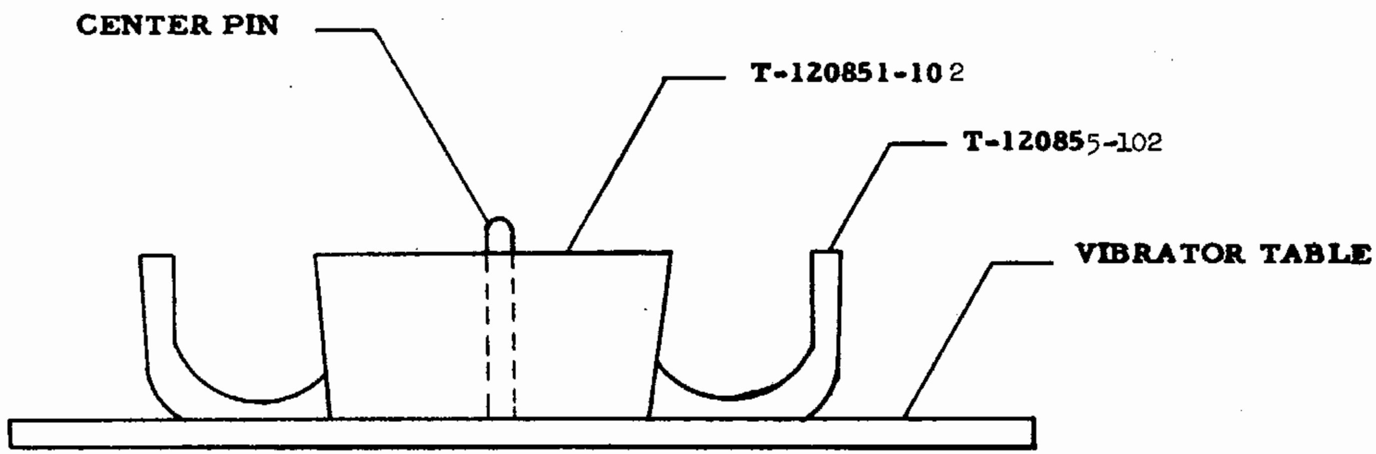
INSTRUCTION SHEET

OPER NO 01	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba wax.
2. Position cavity section (T-120855-102) onto platform of Syntron vibrator.
3. Install center core (T-120853-102), small end down, over 3/4 dia. center pin and into mating surface of cavity shell.
   3a. Weigh out in 4 containers 28# of SR-6 sand.

SKETCH



PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 01	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

4. Add 20 lbs. of sand formulation SR-6 into cavity. Distribute sand as uniformly as possible.

5. Sweep and tamp with shop aid, as required, to compact sand against walls on the I.D. and O.D.

6. Position spider located male core (T-120851-103) over center pin. Install (3) .75 thk. spacers

7. Turn on vibrator at minimum amplitude and vibrate for 3-4 minutes, or until ring has settled to stops on spider. Turn off vibrator.

8. Add more sand around inner and outer annulus. Manually tamp with shop aid ram until sand is compacted and flush with inner and outer surfaces of mold.

9. Lightly tap ends of spider to loosen core. Lift core from mold using lift and eyes on spider. Strike off loose particles and edges, as required.

10. Rotate slightly center aluminum core (T-120851-102) and carefully lift from center pin. Cut 4 shallow notches in inner lip of sand core.

11. Place cavity section (T-120855-104) with sand core into preheated (250°F) and cure for one (1) and 1/2 hours.

12. Remove from oven. Invert part onto flat plate and remove mold. Return mandrel to oven and cure for One (1) more hour. Remove from oven and cover mandrel with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

13. Wash all mold details in warm water and rewax per Op. #1.

14. Repeat Operations 2 through 12 to make other half of mandrel.

15. After both halves have cooled, blow out all loose sand and residue. Coat mating surfaces with Stynex "C" and join halves. Maintain concentricity of O.D.

16. Place mandrel in preheated (250°F) oven for One (1) hour.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 01	PART NO 1269158	PART NAME Carcass FW 30x8.8 22 PR Geodesic Nylon	

17. Remove assembly from oven. Cool with asbestos blanket.

18. When cool, scuff bond resin flush with adjacent sand surfaces.

19. **Inspection:**

    a. Weight ________ lbs.

    b. O.D. - 26.000: Actual __________ in.

    c. I.D. at outer corners - 16.644 $\pm$ .030: Actual _______ in.

    d. Section width 7.125 : Actual __________ in.

    e. With brush pen, mark weight on sidewall, and add serial number.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 02	PART NO. 1269158	PART NAME Carcass FW 30x8.8 22 PR Geodesic Nylon

RIM-LOCKING ASSEMBLY FABRICATION

1. Prepare mandrel (T-120849) for use as follows:

   a. Disassemble clean and coat all details with DC-20 or R-671. Bake on for four (4) hours at 300°F.

   b. Reassemble — Refer to Sketch #2.

   c. Coat all surfaces in contact with resin with Kanaba wax.

2. Install mandrel in winding machine (AGC 101518).

3. Mix batch of Shell 58-68 epoxy resin 2300 grams. Use 815 instead of 828.

4. Preimpregnate cloth and ROVMAT with resin - 40%/50% by weight.

5. Precut (2) strips 181 glass bias cut cloth 12" wide x 42" long. Preimpregnate with resin 58-68R (modified).

6. Cut: (1) 6.5" wide x 102" lengths of 2 oz. glass ROVMAT. Nip edges 3/4" to 1" every 3" to 4" on both edges.
   (2) 4.3" wide x 106" lengths of 2 oz. glass ROVMAT.

7. Wrap 181 glass cloth strip on mandrel. Tension as required to conform to contour. Tie in place as required using 20 end dry roving.

8. Layup (1) 6.5" wide strip of ROVMAT and (1) ply of 181 cloth. Secure in place using closely spaced layer of 20-end S-901 dry glass roving at 10 lb. tension. Start at center line and continue wrap as far to edge as radii will permit, then continue to other side tie off.

9. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered in groove. Secure in place using closely spaced layer of 20-end dry roving as in Item 8 above.

10. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered. Roll out air as required. Apply layer of dry 20-end S-901 roving using 10 lb. tension to compact above bulk. Roving should be closely spaced and continued as far out toward edges as 4.3" wide matt will permit. Start at center line and proceed as in Item 8 above.

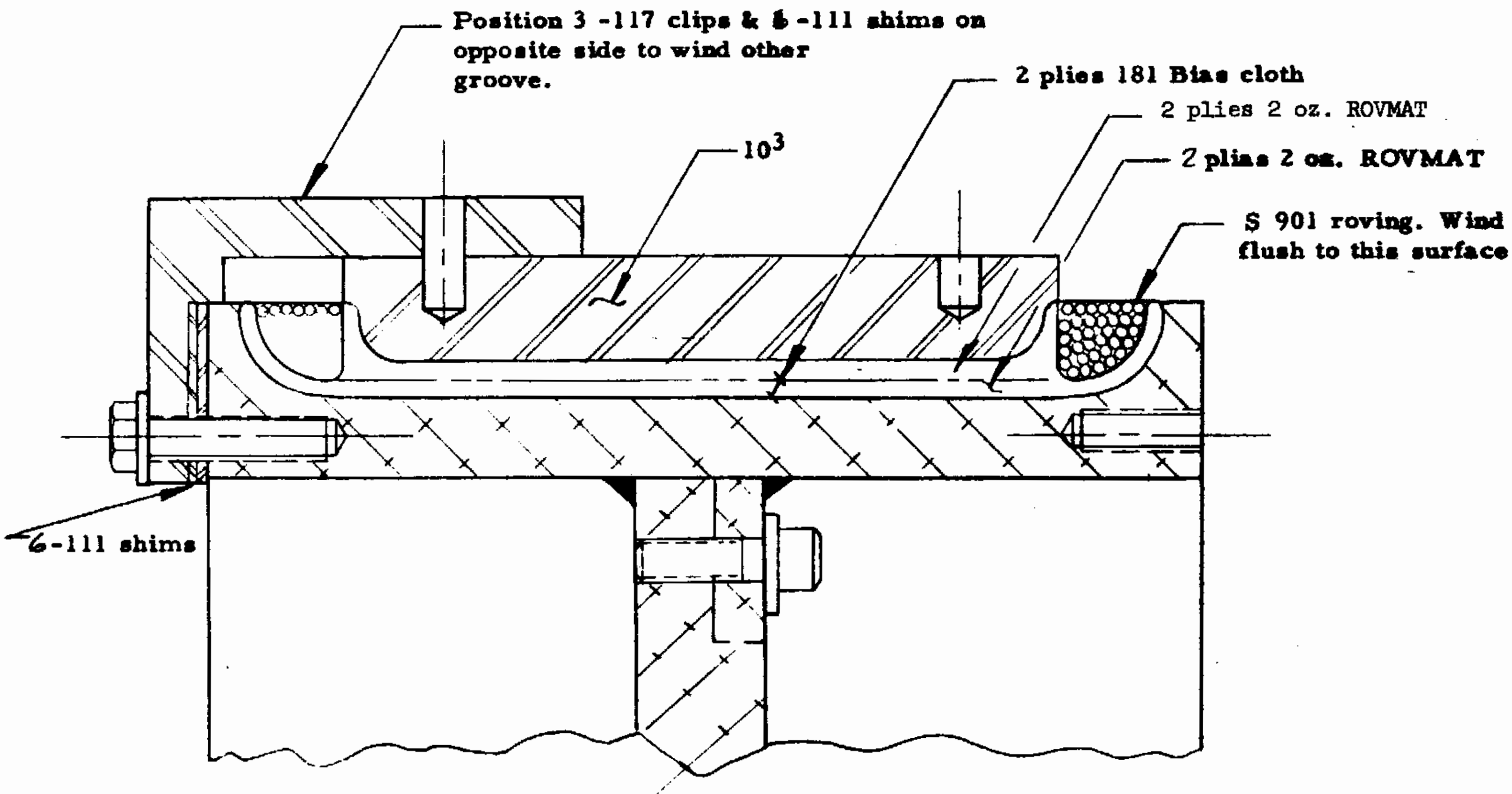
PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

SKETCH #2



Geodesic Nylon RLA

T-120849-1

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 02	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

11. Apply -103 band assembly using (3) -117 clips and (6) -111 shims on one side to locate band in center of mandrel. (See Sketch #2). Secure band with (4) bolts.

12. Set up and wind 20-end roving S-901 wetted with 58-68R in annulus between band and mat supported by mandrel. Use 8 lb. tension. Wind flush with outer surface of mandrel.

13. Transfer -117 clips and -111 shims to opposite side and wind 2nd annulus.

14. Trim excess material flush with mandrel outer surface. Wipe excess resin from mandrel. Wrap with bleeder material.

15. Place mandrel assembly in oven and cure as follows:

    200°F - 2 hours)
    250°F - 4 hours) or continuous rate of rise, 50°F per hour.
    300°F - 4 hours)

    Cool in oven at cooling rate of approximately 50°F per hour.

16. Remove band -103, -111 shims and -117 clips. Measure O.D.; if larger than 16.575 dia., send to machine shop for trim to size (16.575 - 16.544). Record final dia. ______________.

17. Remove part from mandrel. Remove flash as required. Generate .05 R on outer edge, as required, by hand sanding.

18. Drill and chamfer (2) holes 180° apart per drawing.

19. Inspect:

    I.D. - 15.344 : Actual __________ in.

    Width - 6.062 : Actual __________ in.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

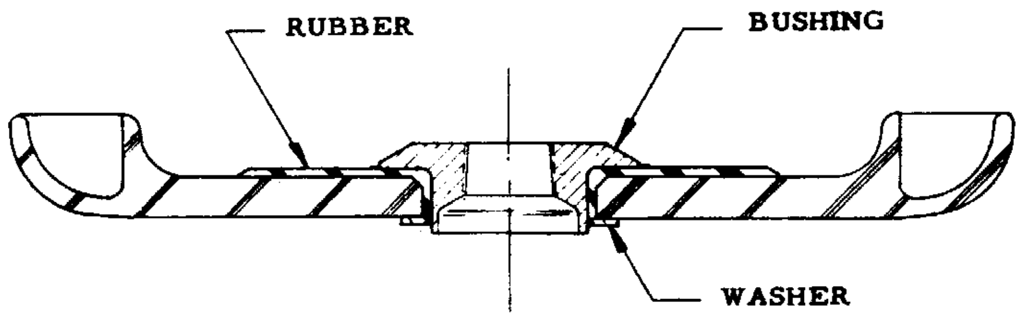
OPER NO 03	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

RIM-LOCKING ASSEMBLY LINER APPLICATION

1. Scuff sand RLA P/N 1269151-3 as required. Wash surfaces with acetone.
2. Coat all surfaces with Chemlock 203 adhesive. Dry 15 minutes @ 150°F. Repeat with Chemlock 220.
3. Cut (4) 3" dia. O.D. - 0.5" dia. I.D. donuts from XGP-120A rubber. Preply into (2) each (2)-layer donut rings.
4. Position 3" dia. rings over holes in rim-locking assembly O.D. Keep 0.5" center hole centered with holes in RLA.
5. Wash in acetone, bushing, P/N 1269153, and washer, P/N 1269152. Air dry. Coat external surfaces with Chemlock 203 and 220. Dry as in Step #2.
6. Press bushings through rubber rings on RLA with flange on O.D. of RLA. There should be rubber captured between bushing and RLA hole to act as seal.
7. Install washer (chamfered inner edge outward) over protruding end of bushing. See Sketch #4.

   7a. Flange lip of bushing onto washer using 74°/90° cone.

SKETCH # 4



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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

8. Drill through existing holes in head of bushing using #31 drill (.120" dia.) to a depth of .28 from face of bushing (4) places.
9. Press .125 dia. x .25 long dowels into holes, flush or below face of bushing.
10. Slit XGP-120A to 2" wide strips.
11. Circumferential wrap two layers of XGP-120A over RLA using near butt-joint. Stagger seams of first and second layer. Stitch first layer to RLA before applying second layer. Remove all air pockets between layers and around flanges of bushings.
12. Wrap with prereleased cotton shrink cloth. Vacuum bag.
13. Cure per separate instructions.
14. Remove bag and bleeder. Clean up as required. Trim rubber from bushing holes.
15. Inspect for cure hardness, blisters, delamination.
16. Mark with S/N B-X

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 04	PART NO 1269158	PART NAME Carcass FW 30 x 8.8 22 PR Geodesic Nylon	

INNER LINER FABRICATION:

1. Dry fit RLA (P/N 1269154-3) into mandrel. Trim mandrel as required.
2. Mate RLA with mandrel. Install assembly in vertical support fixture. Coat I.D. of RLA with rubber dispersion. Center RLA. Allow dispersion to air dry 20 minutes.
3. Roll up 2" wide strips of XGP-120A rubber.
4. Starting at I.D. of tire, radially wrap strips until torus is covered with one layer of rubber. Use 1/8" overlap.
5. Transfer assembly to horizontal turn table (AGC 40191-2).
6. Starting at bead heel, circumferentially wrap 2" wide strips of XGP-120A rubber. Continue to bead heel on opposite side. Stitch thoroughly to remove air between 1st and 2nd ply.
7. Repeat Step #6 continuing rubber approximately 1/2 in. over edge of RLA. Stitch to remove air between 2nd and 3rd ply.
8. Cut openings at two bushings. Wrap entire torus with prereleased cotton shrink tape. Apply vacuum bag. Check for leaks.
9. Install part in oven and cure per separate instructions.
10. After cool down, remove bag and bleeder cloth.
11. Trim rubber at bushings, as required, and insert 2 plugs (shop aids).
12. Inspect for cure, blisters and lack of bond at seams.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

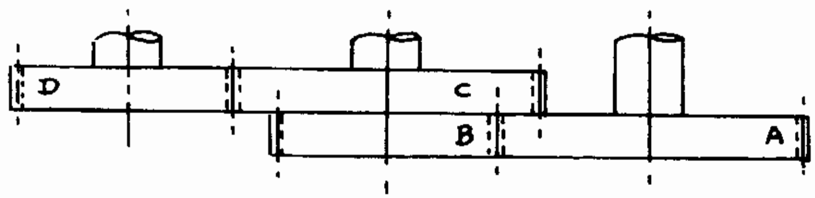
OPER NO 05	PART NO 1269158	PART NAME Carcass FW 30x8.8 22 PR	Geodesic Nylon

CARCASS WINDING:

1. Coat entire surface of inner liner with a 12% solids dispersion of XGP-121 and white gasoline. Allow to air dry 20 minutes.

2. Wrap one (1) ply of XGP-122A on I.D. Wrap one (1) layer XGP-123A circumferentially from bead to bead. Join at bead with XGP-122A piece. Hold overlap to 1/8-in. maximum. Stitch and awl as required to remove air.

3. Set up winding machine AGC 40191 with cams T-120853-301. Use gear ratio as follows:



D = 48
C = 68
B = 85
A = 75

4. Fill winding reels with V-2222 cord (Nylon 3360/2).

5. Remove winding ring segment from machine. Back off roller supports and remove outer rollers as required.

6. Place carcass assembly in winding machine. Replace ring segment and rollers. Adjust belt tension by turning belt spring tension handle counterclockwise. Allow belt to settle then tighten handle. Adjust slides on roller support belts to make contact with the carcass.

7. Turn machine on and rotate mandrel slowly. Adjust side support rollers to center tire on drive belt.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 05	PART NO 1269158	PART NAME Carcass FW 30x8.8 22 PR	Geodesic Nylon

8. While tire is turning, wipe entire surface of tire with white gas. Maintain tire rotating to air dry.

9. While tire is rotating engage winding ring by moving gear level to the left. This will cause ring to turn counterclockwise (left helix).

10. Stop machine. Ensure that payoff cam followers are on the left side cam. Install winding reels on winding ring. Thread cord through rollers and press on rubber. Lower pressure rollers to mandrel surface.

11. Start mandrel rotation. Quickly increase speed to 15 RPM. Adjust cord spacing by turning variable gear setting as required. Increasing numbers increases the cord end-count (reduces spacing between cords). Stop mandrel rotation when proper cord spacing is attained, i.e., 7.32 ends per inch.

12. Cut off cord from tire carcass. Set machine counter to zero.

13. Begin tire mandrel rotation and wind a complete layer of cord. Make adjustments as necessary to variable gear ratio setting to maintain uniform end count. When cord closes with first revolution, turn off machine. Disengage winding ring by moving lever to center position.

14. Record number of cords. Page 06-1. Total cords 555. Angle of crown 24°.

15. Rotate mandrel and paint with dispersion of XGP-121. Continue rotation for 10 minutes to dry.

16. Repeat Step #5 and remove tire. Place on horizontal turn table.

17. Repeat Steps #2, 4, 6, 7, 8.

18. Place cam follower rollers on right cam. Engage winding ring for right helix (move handle to right).

19. Repeat Steps #10 through #15.

20. Repeat Steps #2 through #19 until a total of 4 cord plies and 5 rubber layers. Cord path directions will alternate left and right helix. Each layer of rubber will be stitched and awled as required to remove all air.

21. With a silver pen write identification number on sidewall (I.D. number shown on cover page of these instructions.) Also show mandrel weight. Draw line at center line of crown.

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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 06	PART NO 1269158	PART NAME Carcass FW 30x8.8 22 PR	Geodesic Nylon

INSPECTION:

PLY	Cords Counter X2	Crown L
1		
2		
3		
4		

1. **Measure and record:**

   O.D. __________

   I.D. __________

   Section Width __________

   Carcass Weight __________

2. **Verify I.D. number and prepare inspection acceptance tag.**

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 07	PART NO 1269158	PART NAME Carcass FW 30x8.8 22 PR	Geodesic Nylon

PACKAGING:

1. Wrap tire carcass with polyethylene strips.
2. Place in special container P/N ______________.
3. Send to Building 118 for shipment to:

   The General Tire & Rubber Co.
   Development Experimental Workshop
   Attn: Mr. H. E. Hazelton
   1708 Englewood Avenue
   Akron, Ohio 44305

4. Forward this document to Document Control Center, Building 159.

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ENGINEERING MANUFACTURING INSTRUCTION

FILAMENT WOUND TIRE

PRELIMINARY DESIGN

- PART NAME Carcass, F.W. Tire 30 x 8.8 22PR. Radial Nylon
- PART NUMBER 1269155
- NEXT ASSEMBLY A-5068A-3
- EFFECTIVE TIRE SERIAL NUMBER 15955, 022/C-1

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION

TABLE OF CONTENTS

PART NUMBER 1269155

PART NAME Carcass, FW 30 x 8.8 22 PR Radial Nylon

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	NON-PRODUCTIVE MATERIALS
		1269155	Carcass FW 30x8.8 22 PR Radial Nylon	

DESCRIPTION	QTY	SOURCE
Kanaba Wax	A/R	Commercial Clean Surface Products Co., Palatine, Illinois
PVA, Thalco 500G	A/R	Commercial
DC-20	A/R	Dow Chemical Co.
Vacuum Bag, 50" x 70	2	Commercial R. & F. Paper Converting Co.
White Gas	A/R	Commercial
Shrink Tape, cotton	100 yd	H. M. Royal
Acetone	A/R	Commercial

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	[signature]	1/3/8		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	PRODUCTIVE MATERIALS
		1269155	Carcass FW 30x8.8 22 PR Radial Nylon	

DESCRIPTION	QTY	SOURCE
Sand, Weldron 70/30 & Stynex-C (SR-6)	56 lb.	AGC, Sacto Facility Foundry
Stynex-C		Carver Foundry Co.
Glass Cloth, 181		J. P. Stevens
Rubber, XGP-120A		General Tire & Rubber Co.
Adhesive		Hughson Chemical
Primer		Hughson Chemical
Hughson B-727-6 Cleaner		[illegible]
Rubber, XGP-120A		General Tire & Rubber Co.
Rubber, XGP-122A		General Tire & Rubber Co.
Rubber, XGP-123A		General Tire & Rubber Co.
Nylon-V-2222		General Tire & Rubber Co.
ROVMAT, 2 oz.		Fiber Glass Industries
GLASSMAT, 2 oz.		Fiber Glass Industries
Resin, 1031		Shell Chemical Co.
Resin, 815		Shell Chemical Co.
MNA		E. V. Roberts
BDMA		E. V. Roberts

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
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ENGINEERING MANUFACTURING INSTRUCTION
INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME
		1269155	Carcass FW 30 x 8.8 22 PR Radial Nylon

DESCRIPTION	QTY	TOOL NUMBER
Mold, Sand Mandrel	1	T-120851
Vibrator, Syntron ST-3	1	AGC Inv. #
Drill, Hand w/drill #31	1	
Mandrel, RLA Radial	1	T-120849
Winding Machine, Toroidal	1	AGC Inv. #40191
Winding Machine, Horizontal	1	AGC Inv. #101517
Turntable, Horizontal	1	AGC Inv. #40191-2
Winding Machine, 6"	1	AGC Inv. #401518
Vertical Layup Fixture	1	NSN

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	J Dalcide	1/4/68		

ENGINEERING MANUFACTURING INSTRUCTION

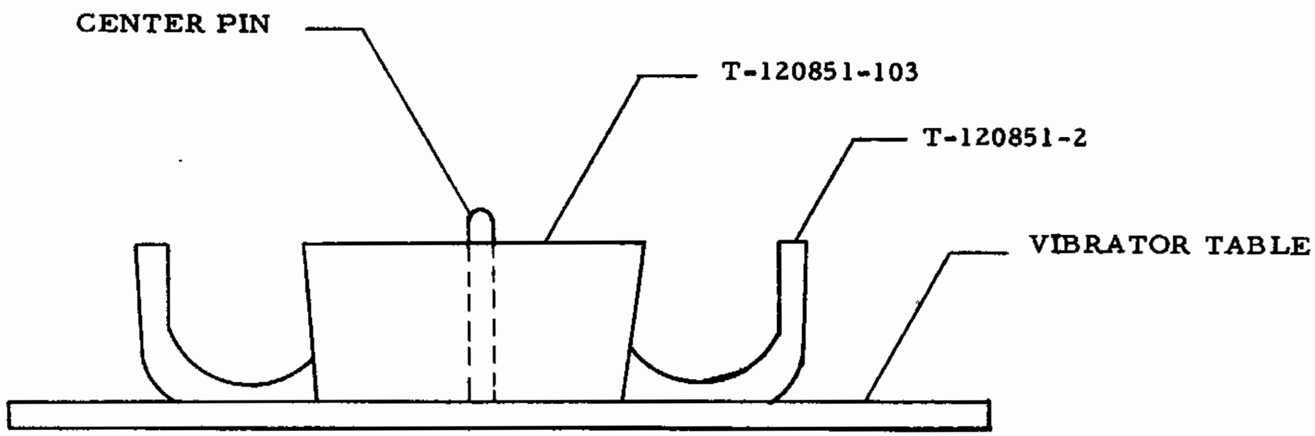
INSTRUCTION SHEET

OPER NO 01	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba wax.
2. Position cavity section (T-120851-2) onto platform of Syntron vibrator.
3. Install center core (T-120851-103) small end down, over 3/4 dia. center pin and into mating surface of cavity shell.
   3a. Weigh out in 4 containers 28# of SR-6 sand.

SKETCH



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269155	PART NAME Carcass FW 30x8.8 22 PR Radial Nylon	

17. Remove assembly from oven. Cool with asbestos blanket.

18. When cool, scuff bond resin flush with adjacent sand surfaces.

19. Brush or spray PVA solution onto all mandrel surfaces. Apply thin coat as required.

20. <u>Inspection</u>:

    a. Weight _______ lbs.

    b. O.D. - 26.375: Actual _________ in.

    c. I.D. at outer corners - 16.644 $\pm$ .030: Actual ______ in.

    d. Section width - 6.625: Actual _________ in.

    e. With brush pen, mark weight on sidewall, and add serial number.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 01	PART NO 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

4. Add 20 lbs. of sand formulation SR-6 into cavity. Distribute sand as uniformly as possible.

5. Sweep and tamp with shop aid, as required, to compact sand against walls on the I.D. and O.D.

6. Position spider located male core (T-120851-103) over center pin.

7. Turn on vibrator at minimum amplitude and vibrate for 3-4 minutes, or until ring has settled to stops on spider. Turn off vibrator.

8. Add more sand around inner and outer annulus. Manually tamp with shop aid ram until sand is compacted and flush with inner and outer surfaces of mold.

9. Lightly tap ends of spider to loosen core. Lift core from mold using lift and eyes on spider. Strike off loose particles and edges, as required.

10. Rotate slightly center aluminum core (T-120851-103) and carefully lift from center pin. Cut 4 shallow notches in inner lip of sand core.

11. Place cavity section (T-120852-1) with sand core into preheated (250°F) and cure for one (1) hour.

12. Remove from oven. Invert part onto flat plate and remove mold. Return mandrel to oven and cure for One (1) more hour. Remove from oven and cover mandrel with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

13. Wash all mold details in warm water and rewax per Opn. #1.

14. Repeat Operations 2 through 12 to make other half of mandrel.

15. After both halves have cooled, blow out all loose sand and residue. Coat mating surfaces with Stynex "C" and join halves. Maintain concentricity of O.D.

16. Place mandrel in preheated (250°F) oven for One (1) hour.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269155	PART NAME Carcass FW 30 x8.8 22 PR Radial Nylon	

RIM-LOCKING ASSEMBLY FABRICATION

1. Prepare mandrel (T-120849) for use as follows:
   a. Disassemble, clean and coat all details with DC-20. Bake on for four (4) hours at 300°F.
   b. Reassemble. Refer to Sketch #2.
   c. Coat all surfaces in contact with resin with Kanaba wax.
2. Install mandrel in winding machine (AGC 101518).
3. Mix batch of Shell 58-68 epoxy resin 2300 grams. Use Epon 815, instead of 828.
4. Precut (1) strip 181 glass cloth 7" wide x 50" long. Impregnate with resin 58-68R.
5. Cut: (3) 6.5" wide x 49" lengths of 2 oz. glass mat
   (2) 4.3" wide x 98" lengths of 2 oz. glass ROVMAT.
   (1) 4.5" wide x 99" lengths of 2 oz. glass ROVMAT.
6. Preimpregnate cloth and ROVMAT with resin - 40-50% by weight.
7. Wrap 181 glass cloth strip on mandrel, Tension, as required, to conform to contour. Tape in place, as required, outside of part boundaries.
8. Layup (3) 6.5" wide strips of mat. Roll out air as required. Secure in place using closely-spaced layer of 20-end S-901 dry glass roving at 10 lb. tension. Start at centerline and work to each end.
9. Layup (2) 4.3" wide strips of ROVMAT using manual tension to compact. These layers must be centered in groove. Roll out air as required.
10. Layup (1) 4.5" wide strips of ROVMAT using manual tension to compact. These layers must be centered. Roll out air as required. Apply layer of dry 20-end S-901 roving, using 10 lb. tension to compact above bulk. Roving should be closely spaced and continued as far toward edges as 4.3" wide as mat will permit. Winding should start at center and go to each end as in Step #8.

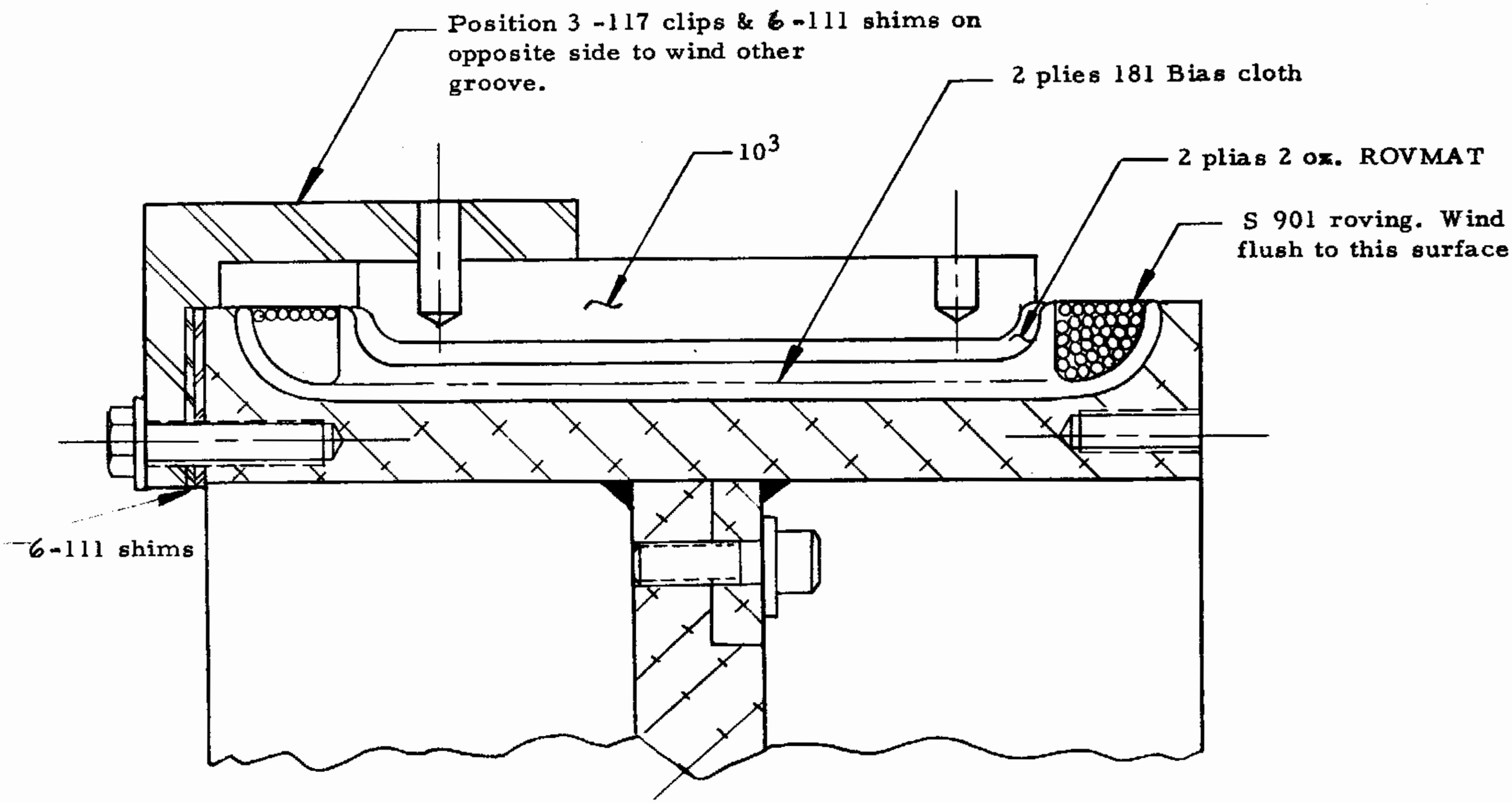
PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

SKETCH #2



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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

11. Apply -103 band assembly using (3) -117 clips and -111 shims on one side to locate band in center of mandrel. (See Sketch #2). Secure band with (4) bolts.

12. Push 4.5" wide ROVMAT inward against -103 band.

13. Set up and wind 20-end roving S-901 wetted with 58-68R in annulus between band and mat supported by mandrel. Use 8 lb. tension. Wind flush with outer surface of mandrel.

14. Transfer -117 clips and -111 shims to opposite side and wind 2nd annulus.

15. Trim excess material flush with mandrel outer surface. Wipe excess resin from mandrel. Wrap with bleeder material.

16. Place mandrel assembly in oven and cure as follows:

    200^{o}F - 2 hours)
    250^{o}F - 4 hours) or continuous rate of rise, 50^{o}F per hour.
    300^{o}F - 4 hours)

    Cool in oven at cooling rate of approximately 50^{o}F per hour.

17. Remove band -103, -111 shims and -117 clips. Measure O.D.; if larger than 16.575 dia., send to machine shop for trim to size (16.575 - 16.544). Record final dia. ____________.

18. Remove part from mandrel. Remove flash as required. Generate .05 R on outer edge, as required, by hand sanding.

19. Drill and chamfer (2) holes 180^{o} apart per drawing.

20. Inspect:

    I.D. - 15.344 : Actual ________ in.

    Width - 6.062 : Actual ________ in.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

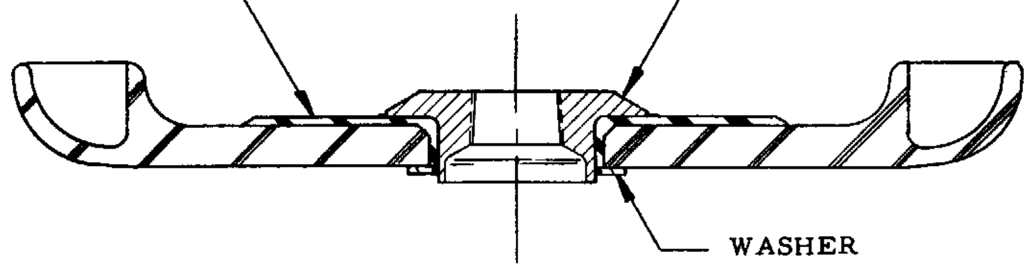
OPER NO 03	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

RIM-LOCKING ASSEMBLY LINER APPLICATION

1. Scuff sand RLA P/N 1269154 as required. Wash surfaces with acetone.
2. Coat all surfaces with Chemlock 203 adhesive. Dry 15 minutes @ 150°F. Repeat with Chemlock 220.
3. Cut (4) 3" dia. O.D. - 0.5" dia. I.D. donuts from XGP-120A rubber. Preply into (2) each (2)-layer donut rings.
4. Position 3" dia. rings over holes in rim-locking assembly O.D. Keep 0.5" center hole centered with holes in RLA.
5. Wash in acetone, bushing, P/N 1269153, and washer, P/N 1269152. Air dry. Coat external surfaces with Chemlock 203 and 220. Dry as in Step #2.
6. Press bushings through rubber rings on RLA with flange on O.D. of RLA. There should be rubber captured between bushing and RLA hole to act as seal.
7. Install washer (chamfered inner edge outward) over protruding end of bushing. See Sketch #4.

   7a. Flange lip of bushing onto washer using 74°/90° cone.

SKETCH # 4



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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

8. Drill through existing holes in head of bushing using #31 drill (.120" dia.) to a depth of .28 from face of bushing (4) places.
9. Press .125 dia. x .25 long dowels into holes, flush or below face of bushing.
10. Slit XGP-120A to 2" wide strips.
11. Circumferential wrap two layers of XGP-120A over RLA using near butt-joint. Stagger seams of first and second layer. Stitch first layer to RLA before applying second layer. Remove all air pockets between layers and around flanges of bushings.
12. Wrap with prereleased cotton shrink cloth. Vacuum bag.
13. Cure per separate instructions.
14. Remove bag and bleeder. Clean up as required. Trim rubber from bushing holes.
15. Inspect for cure hardness, blisters, delamination.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
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ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 04	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

INNER LINER FABRICATION:

1. Dry fit RLA (P/N 1269154-3) into mandrel. Trim mandrel as required. Recoat with PVA as required. Air dry.
2. Mate RLA with mandrel. Install assembly in vertical support fixture. Coat I.D. of RLA with rubber dispersion. Center RLA. Allow dispersion to air dry 20 minutes.
3. Roll up 2" wide strips of XGP-120A rubber.
4. Starting at I.D. of tire, radially wrap strips until torus is covered with one layer of rubber. Use 1/8" overlap.
5. Transfer assembly to horizontal turn table (AGC 40191-2).
6. Starting at bead heel, circumferentially wrap 2" wide strips of XGP-120A rubber. Continue to bead heel on opposite side. Stitch thoroughly to remove air between 1st and 2nd ply.
7. Repeat Step #6 continuing rubber approximately 1/2 in. over edge of RLA. Stitch to remove air between 2nd and 3rd ply.
8. Cut openings at two bushings. Wrap entire torus with prereleased cotton shrink tape. Apply vacuum bag. Check for leaks.
9. Install part in oven and cure per separate instructions.
10. After cool down, remove bag and bleeder cloth.
11. Trim rubber at bushings, as required, and insert 2 plugs (shop aids).
12. Inspect for cure, blisters and lack of bond at seams.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

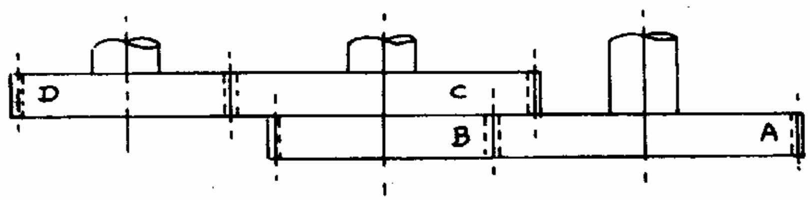
CARCASS WINDING:

1. Coat entire surface of inner liner with a 12% solids dispersion of XGP-121A and white gasoline. Allow to air dry 20 minutes.

2. Wrap one (1) ply of XGP-122A on I.D. Wrap one (1) layer XGP-121A circumferentially from bead to bead. Join at bead with XGP-122A piece. Hold overlap to 1/8-in. maximum. Stitch and awl, as required, to remove air.

3. Set up winding machine, AGC 40191. No cams are required. Use gear ratio as follows: Connect auxiliary ~~300~~ 150:1 gear box at rear of machine.

A–
B–
C–
D–



4. Fill winding reels with V-2222 cord (Nylon 3360/2).

5. Remove winding ring segment from machine. Back off roller supports and remove outer rollers as required.

6. Place carcass assembly in winding machine. Replace ring segment and rollers. Adjust belt tension by turning belt spring tension handle counterclockwise. Allow belt to settle, then tighten handle. Adjust slides on roller support belts to make contact with the carcass.

7. Turn machine on and rotate mandrel slowly. Adjust side support rollers to center tire on drive belt.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

8. While tire is turning, wipe entire surface of tire with white gas. Maintain tire rotating to air dry.
9. While tire is rotating, engage winding ring by moving gear level to the left. This will cause ring to turn counterclockwise (left helix).
10. Stop machine. Ensure that payoff is parallel with the winding ring. Install winding reels on winding ring. Thread cord through rollers and press on rubber.
11. Start mandrel rotation. Quickly increase speed to 15 RPM. Adjust cord spacing by turning variable gear setting as required. Increasing numbers increases the cord end-count (reduces spacing between cords). Stop mandrel rotation when proper cord spacing is attained; i.e., 10 ends per inch.
12. Cut off cord from tire carcass. Set machine counter to zero.
13. Begin tire mandrel rotation and wind a complete layer of cord. Make adjustments, as necessary, to variable gear ratio setting to maintain uniform end count. When cord closes with first revolution, turn off machine. Disengage winding ring by moving lever to center position.
14. Record number of cords. (Counter No. X2) ____________. (883 reference.)
15. Rotate mandrel and paint with dispersion of XGP-123A. Continue rotation for 10 minutes to dry.
16. Repeat Step #5 and remove tire. Place on horizontal turn table.
17. Repeat Steps #2, 4, 6, 7, 8.
18. Engage winding ring for right helix (move handle to right).
19. Repeat Steps #10 through #15.
20. Repeat Steps #2 through #19, until a total of 4 cord plies and 5 rubber layers. Cord path directions will alternate left and right helix. Each layer of rubber will be stitched and awled, as required, to remove all air.
21. With a silver pen, write identification number on sidewall (I.D. number shown on cover page of these instructions.) Also, show mandrel weight. Draw line at centerline of crown.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 06	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

INSPECTION:

1. Measure and record:

   O.D. ____________

   I.D. ____________

   Section Width ______________

   Carcass Weight ______________

PLY	CORDS
1	
2	
3	
4	

2. Verify I.D. number and prepare inspection acceptance tag.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 07	PART NO. 1269155	PART NAME Carcass FW 30 x 8.8 22 PR Radial Nylon	

PACKAGING:

1. Wrap tire carcass with polyethylene strips.
2. Place in special container, P/N ______________.
3. Prepare shipper and send to Building 118 for shipment to:

   The General Tire & Rubber Co.
   Development Experimental Workshop
   Attn. Mr. H. E. Hazelton
   1708 Englewood Avenue
   Akron, Ohio 44305

4. Forward this document to Document Control Center, Bldg. 159.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

FILAMENT WOUND TIRE

- PART NAME Carcass FW 30x8.8 22 PR Radial Glass
- PART NUMBER 1269156
- NEXT ASSEMBLY A-5068A4
- EFFECTIVE TIRE SERIAL NUMBER 15955, XXX/D-1

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION

TABLE OF CONTENTS

PART NUMBER 1269156

PART NAME Carcass, FW 30x8.8 22 PR Radial Glass

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269156	Carcass FW 30x8.8 22 PR Radial Glass	TOOLING

DESCRIPTION	QTY	TOOL NUMBER
Mold, Sand Mandrel	1	T-120851-3
Vibrator, Syntron ST-3	1	AGC Inv. #
Drill, Hand w/drill #31	1	
Mandrel, RLA Bias	1	T-120849
Winding Machine, Toroidal	1	AGC Inv. #40191
Winding Machine, Horizontal	1	AGC Inv. #101517
Turntable, Horizontal	1	AGC Inv. #40191-2
Winding Machine, 6"	1	AGC Inv. #401518
Vertical Layup Fixture	1	NSN

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY	H. Waldo	1-28-68		
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	F. Salado	1-30-68		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269156	Carcass FW 30x8.8 22 PR Radial Glass	NON-PRODUCTIVE MATERIAL

DESCRIPTION	QTY	SOURCE
Kanaba Wax	A/R	Commercial
PVA, Thalco 500G	A/R	Commercial
DC-20	A/R	Dow Chemical Co.
Vacuum Bag, 50" x 70	2	Commercial
White Gas	A/R	Commercial
Shrink Tape, Cotton	100 yd	
Acetone	A/R	Commercial

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	PRODUCTIVE MATERIALS
		1269156	Carcass FW 30x8.8 22 PR Radial Glass	

DESCRIPTION	QTY	SOURCE
Sand, Weldron 70/30 & Stynex-C (SR-6)	54 lb.	AGC, Sacto Facility Foundry
Stynex-C		Carver Foundry Co.
Glass Cloth, 181		
Adhesive		Hughson Chemical
Primer		Hughson Chemical
Rubber, XGP-120A		General Tire & Rubber Co.
Rubber, XGP-124A		General Tire & Rubber Co.
Rubber, XGP-121B		General Tire & Rubber Co.
Glass V-2240		General Tire & Rubber Co.
ROVMAT, 2 oz.		Fiber Glass Industries
GLASSMAT, 2 oz.		Fiber Glass Industries
Resin, 1031		Shell Chemical Co.
Resin, 815		Shell Chemical Co.
MNA		E. V. Roberts
BDMA		E. V. Roberts

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

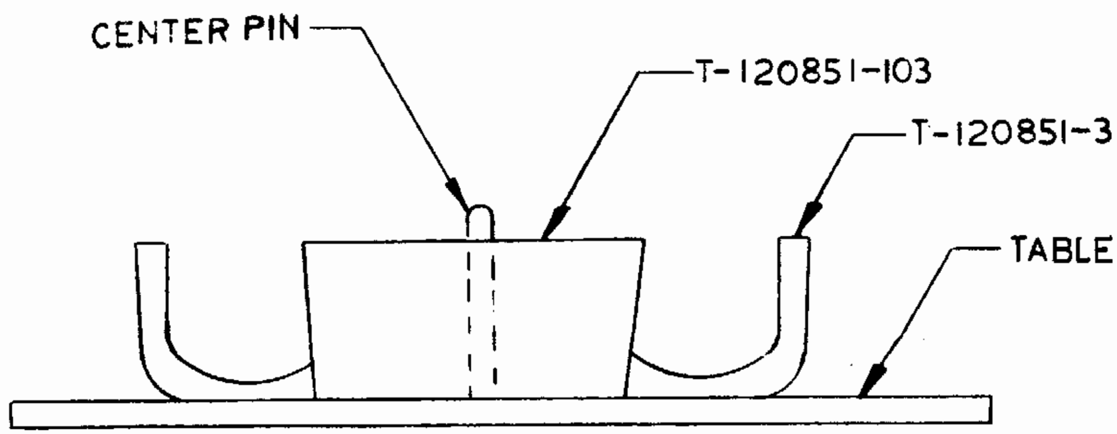
INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba wax.
2. Position cavity section (T-120851-3) onto platform of Syntron vibrator.
3. Install center core (T-120851-103), small end down, over 3/4 dia. center pin and into mating surface of cavity shell.

SKETCH #1



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass

4. Weigh out 30 lbs. SR-6 sand into 4 containers.

5. Add 20 lbs. of sand formulation SR-6 into cavity. Distribute sand as uniformly as possible.

6. Sweep and tamp with shop aid as required to compact sand against walls on the I.D. and O.D.

7. Position spider located male core (T-120851-103) over center pin.

8. Turn on vibrator at minimum amplitude and vibrate for 3-4 minutes or until ring has settled to stops on spider. Turn off vibrator.

9. Add more sand around inner and outer annulus. Manually tamp with shop aid ram until sand is compacted and flush with inner and outer surfaces of mold.

10. Lightly tap ends of spider to loosen core. Lift core from mold using lift and eyes on spider. Strike off loose particles and edges as required.

11. Rotate slightly center aluminum core (T-120851-103) and carefully lift from center pin. Cut four (4) shallow notches in inner lip of sand core.

12. Place cavity section (T-120851-3) with sand core into preheated (250°F) and cure for one (1) hour.

13. Remove from oven. Invert part onto flat plate, remove mold and return to oven for one (1) hour at 250°F. Remove from oven. Cover mandrel with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

14. Wash all mold details in warm water and rewax per Opn. #1.

15. Repeat Operations 2 through 12 to make other half of mandrel.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

16. After both halves have cooled, blow out all loose sand and residue. Coat mating surfaces with Stynex "C" and join halves. Maintain concentricity of O. D.

17. Place mandrel in preheated (250°F) oven for one (1) hour.

18. Remove assembly from oven. Cool with asbestos blanket.

19. When cool, scuff bond resin flush with adjacent sand surfaces.

20.

21. Inspection:

    a. Weight ________ lbs.

    b. O. D. - 26.375: Actual ________ in.

    c. I. D. at outer corners - 16.644 $\pm$ .030: Actual ________ in.

    d. Section width - 6.812: Actual ________ in.

    e. With brush pen mark weight of S/N (D-1 through D-10) on side wall.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

RIM-LOCKING ASSEMBLY FABRICATION

1. Prepare mandrel (T-120849) for use as follows:
   a. Disassemble clean and coat all details with DC-20 or R-671. Bake on for four (4) hours at 300°F.
   b. Reassemble using (1) -109 Detail only. (.12 thk. center spacer). Refer to Sketch #2.
   c. Coat all surfaces in contact with resin with Kanaba wax.

2. Install mandrel in winding machine (AGC-101518).

3. Mix batch of Shell 58-68 epoxy resin 2300 grams. Use 815, instead of 828.

4. Preimpregnate cloth and ROVMAT with resin - 40/50% by weight.

5. Precut (2) strips 181 glass bias-cut cloth 12" wide x 42" long. Preimpregnate with resin 58-68R (modified).

6. Cut: (1) 6.8" wide x 102" lengths of 2 oz. glass ROVMAT. Nip edges 3/4" to 1" every 3" to 4" on both edges.
   (2) 4.3" wide x 103" lengths of 2 oz. glass ROVMAT.

7. Wrap 181 glass cloth strip on mandrel. Tension as required to conform to contour. Tie in place as required using 20-end dry roving.

8. Layup (1) 6.5" wide strip of ROVMAT and (1) ply of 181 cloth. Secure in place using closely-spaced layer of 20-end, S-901 dry glass roving at 10 lb. tension. Start at center line and continue wrap as far to edge as radii will permit. Then, continue to other side and return to center line for tie off.

9. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered in groove. Secure in place using closely-spaced layer of 20-end dry roving, as in Item #8 above.

10. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered. Roll out air as required. Apply layer of dry 20-end, S-901 roving using 10 lb. tension to compact above bulk. Roving should be closely-spaced and continued as far out toward edges as 4.3" wide mat will permit. Start at center line and proceed as in Item #8 above.

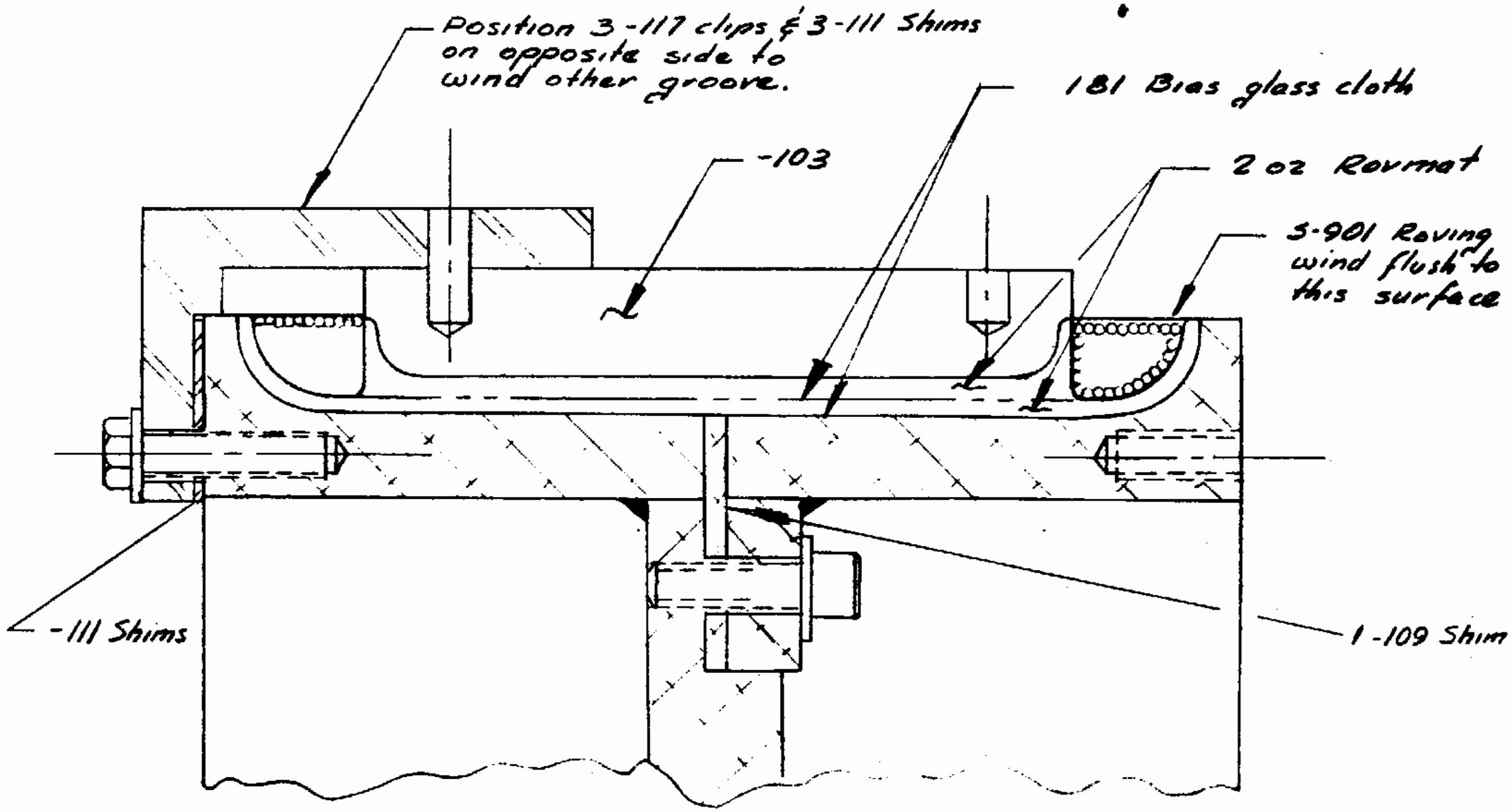
PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

SKETCH #2



RADIAL GLASS RLA

T-120849-2 Assy.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

11. Apply -103 band assembly using (3) -117 clips and (3) -111 shims on one side to locate band in center of mandrel. (See Sketch #2.) Secure band with (4) bolts.

12. Set up and wind 20-end roving S-901 wetted with 58-68R annulus between band and mat supported by mandrel. Use 8 lb. tension. Wind flush with outer surface of mandrel.

13. Transfer -117 clips and -111 shims to opposite side and wind 2nd annulus.

14. Trim excess material flush with mandrel outer surface. Wipe excess resin from mandrel. Wrap with bleeder material.

15. Place mandrel assembly in oven and cure as follows:

    200^{o}F - 2 hours)
    250^{o}F - 4 hours) or continuous rate of rize 50^{o}F per hour.
    300^{o}F - 4 hours)

    Cool in oven at cooling rate of approximately 50^{o}F per hour.

16. Remove band-103 and -117 clips. Measure O.D.; if larger than 16.575 dia. send to machine shop for trim to size (16.575 - 16.544).

17. Remove part from mandrel. Remove flash as required. Generate .05 R on outer edge as required by hand sanding.

18. Drill and chamfer (2) holes 180^{o} apart per drawing.

19. Inspect:

    I.D. - 15.344: Actual ________ in.

    Width - 6.188 Actual ________ in.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

RIM-LOCKING ASSEMBLY LINER APPLICATION

1. Scuff sand RLA P/N 1269151 as required. Wash surfaces with acetone.

2. Coat all surfaces with Chemloc 203 primer. Dry 10 minutes @ 150°F. Recoat with Chemloc 220 adhesive and dry for 10 minutes @ 150°F.

3. Cut (4) 3" dia. O.D. - 0.5" dia. I.D. donuts from XGP-120A rubber. Preply into (2) each (2)-layer donut rings.

4. Position 3" dia. rings over holes in rim-locking assembly O.D. Keep 0.5" center hole centered with holes in RLA.

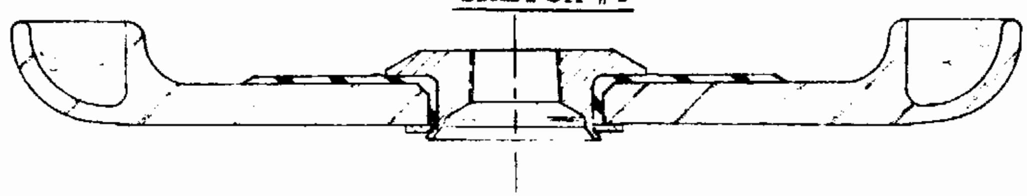
5. Wash in acetone bushing P/N 1269153 and washer P/N 1269152. Air dry. Coat external surfaces as in Item 2 above.

6. Press bushings through rubber rings on RLA with flange on O.D. of RLA. There should be rubber captured between bushing and RLA hole to act as seal.

7. Install washer over protruding end of bushing, chamfered inner edge outward. See Sketch #4.

8. Swage lip of bushing onto washer using 74°/90° cone in arbor press.

SKETCH #4



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

9. Drill through existing holes in head of bushing using #31 drill (.120" dia.) to a depth of .28 from face of bushing (4) places.

10. Press .125 dia. x .25 long dowels into holes, flush or below face of bushing.

11. Slip XGP-120A to 2" wide strips.

12. Circumferential wrap two layers of XGP-120A over RLA using near butt-joint. Stagger seams of first and second layer. Stitch first layer to RLA before applying second layer. Remove all air pockets between layers and around flanges of bushings.

13. Wrap with prereleased cotton shrink cloth. Vacuum bag.

14. Cure per separate instructions.

15. Remove bag and bleeder. Clean up as required. Trim rubber from bushing holes.

16. Inspect for cure hardness, blisters, delaminations.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 04	PART NO 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

INNER LINER FABRICATION:

1. Dry fit RLA (P/N 1269154-4) into mandrel. Trim mandrel as required. Recoat with PVA as required. Air dry.
2. Mate RLA with mandrel. Install assembly in vertical support fixture. Coat I.D. of RLA with rubber dispersion. Allow dispersion to air dry 20 minutes. Blend profile with mandrel and RLA as required.
3. Roll up 2" wide strips of XGP-120A rubber.
4. Starting at I.D. of tire, radially wrap strips until torus is covered with one layer of rubber. Use 1/8" overlap.
5. Transfer assembly to horizontal turn table (AGC-4019 1-2).
6. Starting at bead heel, circumferentially wrap 2" wide strips of XGP-120A rubber. Continue to bead heel on opposite side. Stitch thoroughly to remove air between 1st and 2nd ply.
7. Repeat Step #6 continuing rubber approximately 1/2 in. over edge of RLA. Stitch to remove air between 2nd and 3rd ply.
8. Cut openings at two bushings. Wrap entire torus with prereleased cotton shrink tape. Apply vacuum bag. Check for leaks.
9. Install part in oven and cure per separate instructions.
10. After cool down, remove bag and bleeder cloth.
11. Trim rubber at bushings as required and insert 2 plugs (shop aids).
12. Inspect for cure, blisters and lack of bond at seams.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 05	PART NO 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

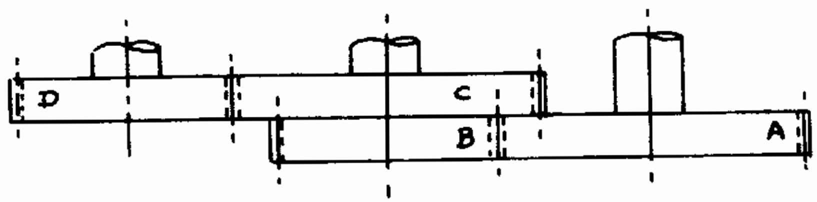
CARCASS WINDING:

1. Coat entire surface of inner liner with a 12% solids dispersion of XGP-124A and white gasoline. Allow to air dry 20 minutes.

2. Wrap one (1) ply of XGP-121B on I.D. Wrap one (1) layer XGP-124A circumferentially from bead to bead. Join at bead with XGP-121B piece. Hold overlap to 1/8 in. maximum. Stitch and awl as required to remove air.

3. (a) Set up winding machine AGC-40191 with cams T-120853.
   (b) Use gear ratio as follows:

   A=
   B=
   C=
   D=



   (c) Connect auxilliary ~~300~~ 150:1 gear box at rear of machine.

4. Fill winding reels with V-2240 cord (glass ECC 75 5/3).

5. Remove winding ring segment from machine. Back off roller supports and remove outer rollers as required.

6. Place carcass assembly in winding machine. Replace ring segment and rollers. Adjust belt tension by turning belt spring tension handle counterclockwise. Allow belt to settle, then tighten handle. Adjust slides on roller support belts to make contact with the carcass.

7. Turn machine on and rotate mandrel slowly. Adjust side support rollers to center tire on drive belt.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 05	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

8. While tire is turning, wipe entire surface of tire with white gas. Maintain tire rotating to air dry.

9. While tire is rotating, engage winding ring by moving gear level to the left. This will cause ring to turn counterclockwise (left helix).

10. Stop machine. Install winding reels on winding ring. Thread cord through rollers and press on rubber. Lower pressure rollers to mandrel surface.

11. Start mandrel rotation. Quickly increase speed to 15 RPM. Adjust cord spacing by turning variable gear setting as required. Increasing numbers increases the end-count (reduces spacing between cords). Stop mandrel rotation when proper cord spacing is attained, i.e., 13 ends per inch.

12. Cut off cord from tire carcass. Set machine counter to zero.

13. Begin tire mandrel rotation and wind a complete layer of cord. Make adjustments as necessary to variable gear ratio setting to maintain uniform end count. When cord closes with first revolution, turn off machine. Disengage winding ring by moving lever to center position.

14. Record number of cords (1090 ref.) (Counter No. X2) __________. Angle at crown __________.

15. Rotate mandrel and paint with dispersion of XGP-124A. Continue rotation for 10 minutes to dry.

16. Repeat Step #5 and remove tire. Place on horizontal turn table.

17. Repeat Steps #2, 4, 6, 7, 8.

18. Engage winding ring for right helix (move handle to right).

19. Repeat Steps #10 through #15.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

20. Repeat Steps #2 through #19 until a total of 3 cord plies and 4 rubber layers. Cord path directions will alternate left and right helix. Each layer of rubber will be stitched and awled as required to remove all air.

21. With a silver pen, write identification number on sidewall (I. D. number shown on cover page of these instructions). Show mandrel weight. Also draw line at center line of crown.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 06	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

INSPECTION:

1. Measure and record:

   O. D. __________

   I. D. __________

   Section Width __________

   Carcass Weight __________

PLY	CORDS
1–	
2–	
3–	

2. Verify I. D. number and prepare shipping tag.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 07	PART NO. 1269156	PART NAME Carcass FW 30x8.8 22 PR Radial Glass	

PACKAGING:

1. Wrap tire carcass with polyethylene strips.

2. Place in special container P/N ______________.

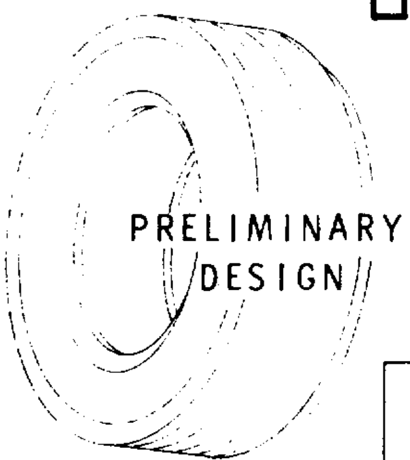
3. Send to Building 118 for shipment to:

   The General Tire & Rubber Co.
   Development Experimental Workshop
   Attn. Mr. H. E. Hazelton
   1708 Englewood Avenue
   Akron, Ohio 44305

PREPARED BY	H. Waldo	1-28-68	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	F. Salcedo	1-30-68	COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

FILAMENT WOUND TIRE



- PART NAME: Carcass FW 30x8.8 22 PR Radial Wire
- PART NUMBER: 1269157
- NEXT ASSEMBLY: A-5068A-5
- EFFECTIVE TIRE SERIAL NUMBER: 15955, 022/E-1

AEROJET GENERAL

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION

TABLE OF CONTENTS

PART NUMBER 1269157

PART NAME Carcass, FW 30 x 8.8 22 PR Radial Wire

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire

DESCRIPTION	QTY	TOOL NUMBER
Mold, Sand Mandrel	1	T-120851
Vibrator, Syntron ST-3	1	AGC Inv. #
Drill, Hand w/drill #31	1	
Mandrel, RLA Bias	1	T-120849
Winding Machine, Toroidal	1	AGC Inv. #40191
Winding Machine, Horizontal	1	AGC Inv. #101517
Turntable, Horizontal	1	AGC Inv. #40191-2
Winding Machine, 6"	1	AGC Inv. #401518
Vertical Layup Fixture	1	NSN

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION
INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269157	Carcass FW 30x8.8 22 PR Radial Wire	PRODUCTIVE MATERIALS

DESCRIPTION	QTY	SOURCE
Sand, Weldron 70/30 & Stynex-C (SR-6)	64 lb.	AGC, Sacto Facility Foundry
Stynex-C		Carver Foundry Co.
Glass Cloth, 181		J. P. Stevens
Adhesive		Hughson Chemical
Primer		Hughson Chemical
Rubber, XGP-120A		General Tire & Rubber Co.
Rubber, XGP-125A		General Tire & Rubber Co.
Rubber, XGP-125B		General Tire & Rubber Co.
Brass Plated Steel Wire, S-033		General Tire & Rubber Co.
ROVMAT, 2 oz.		Fiber Glass Industries
GLASSMAT, 2 oz.		Fiber Glass Industries
Resin, 1031		Shell Chemical Co.
Resin, 815		Shell Chemical Co.
MNA		E. V. Roberts
BDMA		E. V. Roberts

	DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY			
CHECKED BY			
APPR. TOOL. ENGR.			
APPR. COGN. ENGR.			
APPR. PROJ. ENGR.			

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269157	Carcass FW 30x8.8 22 PR Radial Wire	NON-PRODUCTIVE MATERIAL

DESCRIPTION	QTY	SOURCE
Kanaba Wax	A/R	Commercial
PVA, Thalco 500G	A/R	Commercial
DC-20	A/R	Dow Chemical Co.
Vacuum Bag, 50" x 70	2	Commercial
White Gas	A/R	Commercial
Shrink Tape, cotton	100 yd	H. M. Royal, Inc.
Acetone	A/R	Commercial

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY				
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

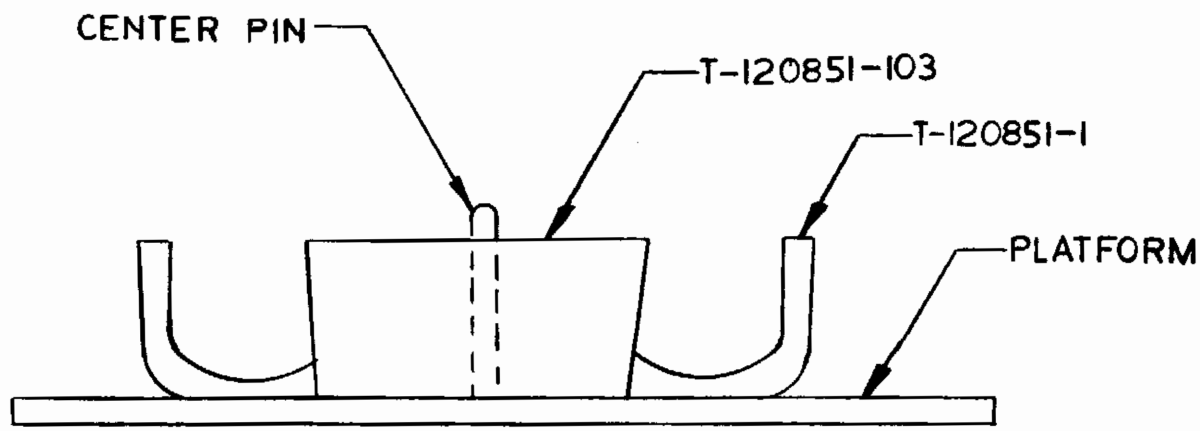
MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba wax.

2. Position cavity section (T-120851-1) onto platform of Syntron vibrator.

3. Install center core (T-120851-103), small end down, over 3/4 dia., center pin and into mating surface of cavity shell.

SKETCH #1



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 01	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

4. Add 20 lbs. of sand formulation SR-6 into cavity. Distribute sand as uniformly as possible.

   4a. Weigh out 32 lbs. of SR-6 sand into 4 containers.

5. Sweep and tamp with shop aid, as required to compact sand against walls on the I.D. and O.D.

6. Position spider located male core (T-120851-103) over center-pin.

7. Turn on vibrator at minimum amplitude and vibrate for 3-4 minutes, or until ring has settled to stops on spider. Turn off vibrator.

8. Add more sand around inner and outer annulus. Manually tamp with shop aid ram until sand is compacted and flush with inner and outer surfaces of mold.

9. Lightly tap ends of spider to loosen core. Lift core from mold using lift and eyes on spider. Strike off loose particles and edges as required.

10. Rotate slightly center aluminum core (T-120851-103) and carefully lift from center pin. Cut four (4) shallow notches in inner lip of sand core.

11. Place cavity section (T-120851-1) with sand core into preheated (250°F) and cure for one (1) hour.

12. Remove from oven. Invert part onto flat plate, remove mold and return core to oven for one (1) hour at 250°F. Remove from oven. Cover mandrel with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

13. Wash all mold details in warm water and rewax per Opn. #1

14. Repeat Operations 2 through 12 to make other half of mandrel.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 01	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

15. After both halves have cooled, blow out all loose sand and residue. Coat mating surfaces with Stynex "C" and join halves. Maintain concentricity of O. D.

16. Place mandrel in preheated (250^{o}F) oven for one (1) hour.

17. Remove assembly from oven. Cool with asbestos blanket.

18. When cool, scuff bond resin flush with adjacent sand surfaces.

19. Brush or spray PVA solution onto all mandrel surfaces. Apply thin coat as required.

20. Inspection:

    a. Weight ________ lbs.

    b. O.D. - 26.375: Actual ________ in.

    c. I.D. at outer corners - 16.644 $\pm$ .030: Actual __________ in.

    d. Section width - 7.188: Actual __________ in.

    e. Mark weight and S/N (E-1 through E-10) on mandrel with brush pen (felt tip).

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

RIM-LOCKING ASSEMBLY FABRICATION

1. Prepare mandrel (T-120849) for use as follows:
   a. Disassemble, clean and coat all details with DC-20 or R-671. Bake on for four (4) hours at 300°F.
   b. Reassemble. Refer to Sketch #2.
   c. Coat all surfaces in contact with resin with Kanaba wax.
2. Install mandrel in winding machine (AGC-101518).
3. Mix batch of Shell 58-68 epoxy resin 2300 grams. Use 815, instead of 828.
4. Preimpregnate cloth and ROVMAT with resin - 40/50% by weight.
5. Precut (2) strips 181 glass bias-cut cloth 12" wide x 42" long. Preimpregnate with resin 58-68R (modified).
6. Cut: (1) 6.8" wide x 102" lengths of 2 oz. glass ROVMAT. Nip edges 3/4" to 1" every 3 to 4" both sides.
   (2) 4.3" wide x 103" lengths of 2 oz. glass ROVMAT.
7. Wrap 181 glass cloth strip on mandrel. Tension as required to conform to contour. Tie in place as required using 20 end dry roving.
8. Layup (1) 6.5" wide strip of ROVMAT and (1) ply of 181 cloth. Secure in place using closely-spaced layer of 20-end S-901 dry glass roving at 10 lb. tension. Start at centerline and continue wrap as far to edge as radii will permit. Then, continue to other side and return to centerline for tie-off.
9. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered. in groove. Secure in place using closely-spaced layer of 20-end dry roving, as in Item 8. above.
10. Layup (1) 4.3" wide strip of ROVMAT using manual tension to compact. These layers must be centered. Roll out air as required. Apply layer of dry 20-end S-901 roving, using 10 lb. tension to compact above bulk. Roving should be closely spaced and continued as far out toward edges as 4.3" wide matt will permit. Start at centerline and proceed as in Item 8. above.

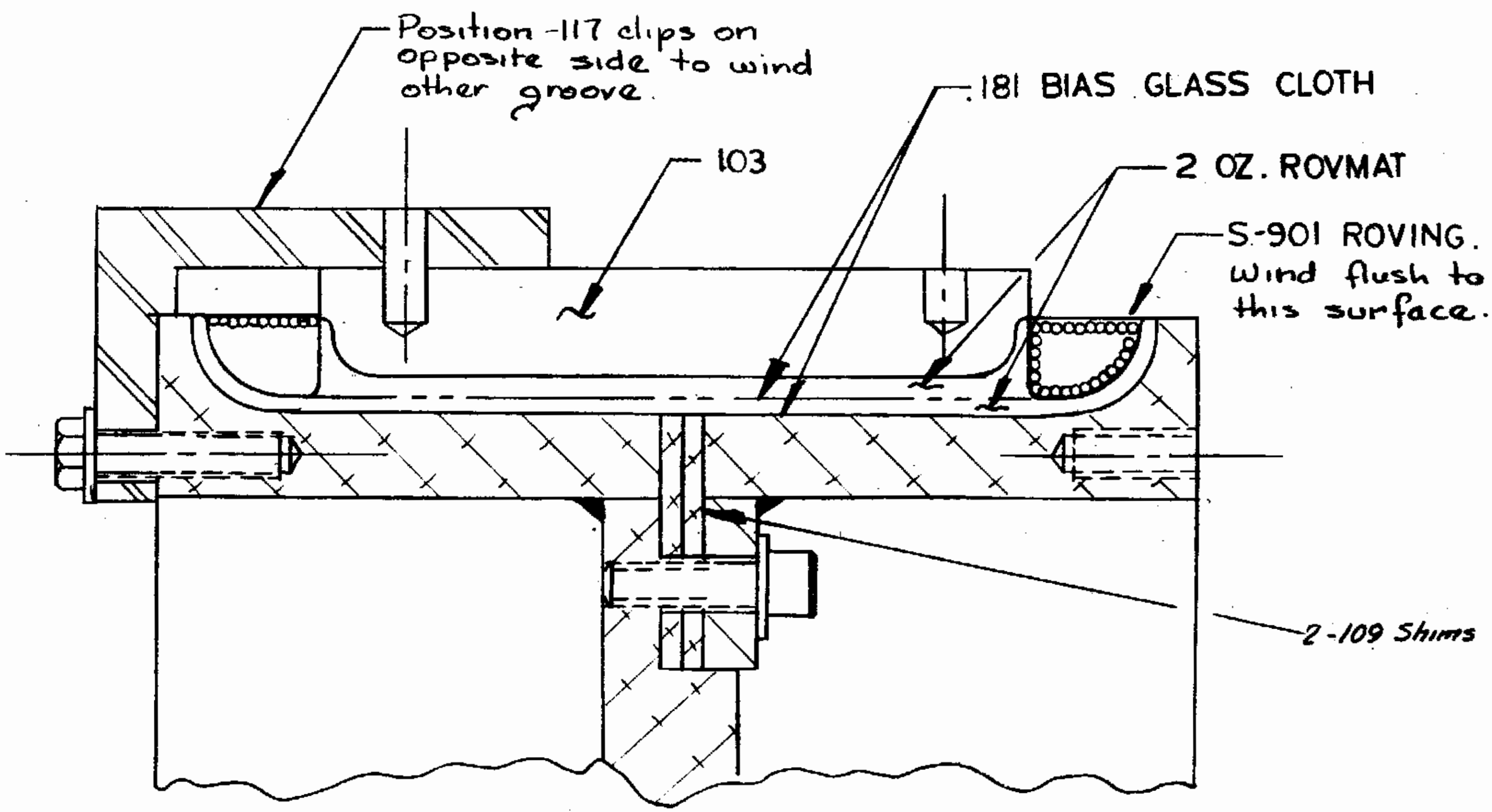
PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

SKETCH #2



RADIAL WIRE RLA

T-120849-3 Assy.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 02	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

11. Apply -103 band assembly using (3) -117 clips on one side to locate band in center of mandrel. (See Sketch #2.) Secure band with (4) bolts.

12. Set up and wind 20-end roving S-901 wetted with 58-68R in annulus between band and mat supported by mandrel. Use 8 lb. tension. Wind flush with outer surface of mandrel.

13. Transfer -117 clips and -111 shims to opposite side and wind 2nd annulus.

14. Trim excess material flush with mandrel outer surface. Wipe excess resin from mandrel. Wrap with bleeder material.

15. Place mandrel assembly in oven and cure as follows:

    200°F - 2 hours)
    250°F - 4 hours) or continuous rate of rize 50°F per hour.
    300°F - 4 hours)

    Cool in oven at cooling rate of approximately 50°F per hour.

16. Remove band -103 and -117 clips. Measure O.D.; if larger than 16.575 dia., send to machine shop for trim to size (16.575 - 16.544).

17. Remove part from mandrel. Remove flash as required. Generate .05R on outer edge as required by hand sanding.

18. Drill and chamfer (2) holes 180° apart per drawing.

19. Inspect:

    I.D. - 15.344: Actual ________ in.
    Width - 6.312: Actual ________ in.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

RIM-LOCKING ASSEMBLY LINER APPLICATION

1. Scuff sand RLA P/N 1269151-5 as required. Wash surfaces with acetone.

2. Coat all surfaces with Chemlock 230 primer adhesive. Dry 40 minutes @ 150°F. Recoat with Chemlock 220 adhesive and dry 10 minutes @ 150°F.

3. Cut (4) 3" dia. O.D. - 0.5" dia. I.D. donuts from XGP-120A rubber. Preply into (2) each (2)-layer donut rings.

4. Position 3" dia. rings over holes in rim-locking assembly O.D. Keep 0.5" center hole centered with holes in RLA.

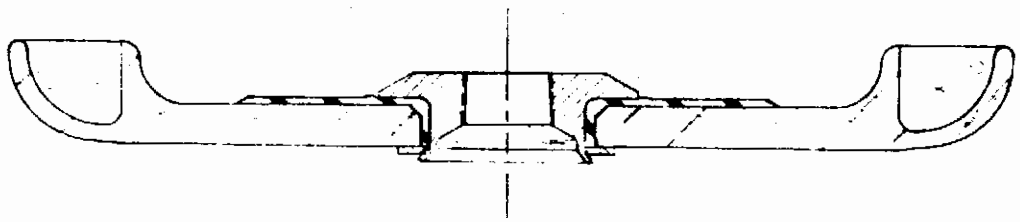
5. Wash in acetone bushing P/N 1269153 and washer P/N 1269152. Air dry. Coat external surfaces as in Opn. #2 above. Air dry 30 minutes.

6. Press bushings through rubber rings on RLA with flange on O.D. of RLA. There should be rubber captured between bushing and RLA hole to act as seal.

7. Install washer, chamfered inner edge outward, over protruding end of bushing. See Sketch #4.

8. Swage lip of bushing onto washer using 74° to 90° cone in arbor press.

SKETCH #4



PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 03	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

8. Drill through existing holes in head of bushing using #31 drill (.120" dia.) to a depth of .28 from face of bushing (4) places.

9. Press .125 dia. x .25 long dowels into holes, flush or below face of bushing.

10. Slit XGP-120A to 2" wide strips.

11. Circumferential wrap two layers of XGP-120A over RLA using near butt-joint. Stagger seams of first and second layer. Stitch first layer to RLA before applying second layer. Remove all air pockets between layers andaround flanges of bushings.

12. Wrap withprereleased cotton shrink cloth. Vacuum bag.

13. Cure per separate instructions.

14. Remove bag and bleeder. Cleanup as required. Trim rubber from bushing holes.

15. Inspect for cure hardness, blisters, delamination.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 04	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire

INNER LINER FABRICATION:

1. Dry fit RLA (P/N 1269154-5) into mandrel. Trim mandrel as required. Recoat with PVA as required. Air dry.

2. Mate RLA with mandrel. Install assembly in vertical support fixture. Coat I.D. of RLA with rubber dispersion. Center RLA. Allow dispersion to air dry 20 minutes.

3. Roll up 2" wide strips of XGP-120A rubber.

4. Starting at I.D. of tire, radially wrap strips until torus is covered within one layer of rubber. Use 1/8" overlap.

5. Transfer assembly to horizontal turn table (AGC-40191-2).

6. Starting at bead heel, circumferentially wrap 2" wide strips of XGP-120A rubber. Continue to bead heel on opposite side. Stitch thoroughly to remove air between 1st and 2nd ply.

7. Repeat Step #6 continuing rubber approximately 1/2 in. over edge of RLA. Stitch to remove air between 2nd and 3rd ply.

8. Cut openings at two bushings. Wrap entire torus with prereleased cotton shrink tape. Apply vacuum bag. Check for leaks.

9. Install part in oven and cure per separate instructions.

10. After cool down, remove bag and bleeder cloth.

11. Trim rubber at bushings, as required, and insert 2 plugs (shop aids).

12. Inspect for cure, blisters and lack of bond at seams.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

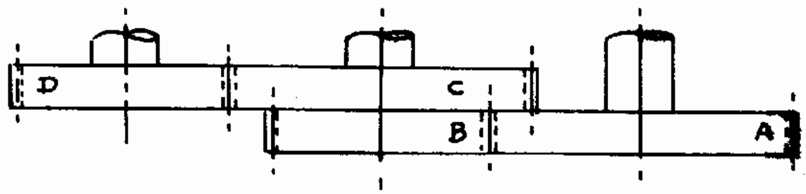
CARCASS WINDING:

1. Coat entire surface of inner liner with a 12% solids dispersion of XGP-125A and white gasoline. Allow to air dry 20 minutes.

2. Wrap one (1) ply of XGP-125B on I.D. Wrap one (1) layer XGP-125A circumferentially from bead to bead. Join at bead with XGP-125B piece. Hold overlap to 1/8 in. maximum. Stitch and awl, as required, to remove air.

3. a. Set up winding machine AGC-40191 with cams T-120853.
   b. Use gear ratio as follows:

A-
B-
C-
D-



   c. Connect auxiliary ~~300~~ 150:1 gear box at rear of machine.

4. Fill winding reels with S-033 wire (wire 5x7).

5. Remove winding ring segment from machine. Back off roller supports and remove outer rollers as required.

6. Place carcass assembly in winding machine. Replace ring segment and rollers. Adjust belt tension by turning belt spring tension handle counterclockwise. Allow belt to settle, then tighten handle. Adjust slides on roller support belts to make contact with the carcass.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire

7. Turn machine on and rotate mandrel slowly. Adjust side support rollers to center tire on drive belt.

8. While tire is turning, wipe entire surface of tire with white gas. Maintain tire rotating to air dry.

9. While tire is rotating, engage winding ring by moving gear level to the left. This will cause ring to turn counterclockwise (left helix).

10. Stop machine. Install winding reels on winding ring. Thread cord through rollers and press on rubber. Lower pressure rollers to mandrel surface.

11. Start mandrel rotation. Quickly increase speed to 15 RPM. Adjust cord spacing by turning variable gear setting as required. Increasing numbers increases the cord end-count (reduces spacing between cords). Stop mandrel rotation when proper cord spacing is attained, i.e. 12.6 ends per inch.

12. Cut off cord from tire carcass. Set machine counter to zero.

13. Begin tire mandrel rotation and wind a complete layer of cord. **Make adjustments as necessary to variable gear ratio setting to maintain uniform end count. When cord closes with first revolution, turn off machine.** Disengage winding ring by moving lever to center position.

14. Record number of cords. (1055 Ref.) (Counter No. X2) __________. Angle at crown __________.

15. Rotate mandrel and paint with dispersion of XGP-125A. Continue rotation for 10 minutes to dry.

16. Repeat Step #5 and remove tire. Place on horizontal turn table.

17. Repeat Steps # 2, 4, 6, 7, 8.

18. Engage winding ring for right helix (move handle to right).

19. Repeat Steps #10 through #15.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 05	PART NO. 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

20. Repeat Steps #2 through #19 until a total of 2 cord plies and 3 rubber layers. Cord path directions will alternate left and right helix. Each layer of rubber will be stitched and awled, as required, to remove all air.

21. With a silver pen, write identification number on sidewall (I. D. number shown on cover page of these instructions). Also show mandrel weight. Draw line at centerline of crown.

PREPARED BY			TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO 06	PART NO 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

INSPECTION:

1. Measure and record:

   O.D. __________

   I.D. __________

   Section Width __________

   Carcass Weight __________

PLY	CORDS
1	
2	

2. Verify I.D. number and prepare inspection acceptance tag.

PREPARED BY			TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO. 07	PART NO 1269157	PART NAME Carcass FW 30x8.8 22 PR Radial Wire	

PACKAGING:

1. Wrap tire carcass with polyethylene strips.

2. Place in special container, P/N ______________.

3. Send to Building 118 for shipment to:

   The General Tire & Rubber Co.
   Development Experimental Workshop
   Attn. Mr. H. E. Hazelton
   1708 Englewood Avenue
   Akron, Ohio 44305

4. Forward this document to Document Control Center, Building 159.

PREPARED BY	H Waldo	1-16-68	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY			COGN. ENGR.			F Salado	1-16-68

ENGINEERING MANUFACTURING INSTRUCTIONS

FILAMENT WOUND TIRE

PART NAME: CARCASS FW 49 X 17 26 PR TYPE VII
AIRCRAFT TIRE, BIAS NYLON

PART NUMBER: 1269202

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

ENGINEERING MANUFACTURING INSTRUCTION
INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269202	Carcass F/W 49 x 17 Bias Nylon	NON-PRODUCTIVE MATERIALS

DESCRIPTION	QTY	SOURCE
Kanaba Wax		Clean Surface Products Co., Palatine, Illinois
DC-20		Dow Corning Corp., Midland, Michigan
Vacuum Bag, 50" x 70" PVA		Blake, Moffitt, & Towne, City of Commerce, Calif.
White Gas		Union Oil Co., Covina, Calif.
Shrink Tape, Cotton, 3" wide, 2" wide		H.M. Royal Co., 1911 Woodruff Ave., Downey, Calif.
Shrink Tape, Nylon		Ram Chem. Co., 210 E. Alondra, Gardena, Calif.
Glass Bleeder Cloth		Thalco Uniglass Industries, 643 Flotilla St., L.A., Calif.
Hughson B-727G Paste Cleaner		Hughson Chem. Co., Erie, Pa.
Acetone		Commercial
Toluene		Commercial
Nylon Vacuum Bag Film Capran 90		General Chemical Div., Pottsville, Pa.

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY	M. SANGER	4-25-69		
CHECKED BY				
APPR. TOOL. ENGR.				
APPR. COGN. ENGR.				
APPR. PROJ. ENGR.	M J Sanger	5-13-69		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER. NO.	REV NO.	PART NO.	PART NAME	
		1269202	Carcass F/W 49 x 17 Bias Nylon	PRODUCTIVE MATERIALS

DESCRIPTION	QTY	SOURCE
SR-6 Sand Mandrel Materials		AGC, Sacto Facility Foundry
70-30 Wedron Sand - 81.0% by wt		Wedron Silica Sand Co., Wedron, Ill.
Silica Flour - 6.0% by wt		Any local foundry supply company
Steinex "C" Resin - 13.0% by wt		Carver Foundry Co., Muscatine, Iowa
#341 Glass Cloth Prepreg W/E-787 Resin		U.S. Polymeric, Inc., 700 East Dyer Rd., Santa Ana, Cal.
20-end S-HTS/E-787 Roving USP Nominal		U.S. Polymeric, Inc., 700 East Dyer Rd., Santa Ana, Cal.
Chemlok 205 Primer		Hughson Chemical Co., Erie, Pa.
Chemlok 220 Adhesive		Hughson Chemical Co., Erie, Pa.
XK-985 Compound		General Tire & Rubber Co., Akron, Ohio
XGP-191		General Tire & Rubber Co., Akron, Ohio
XGP-192		General Tire & Rubber Co., Akron, Ohio
Anchorweld S0132D		Roberts Consolidated Industries, 600 E. Evergreen Ave. Monrovia, Calif.
XGP-193		General Tire & Rubber Co., Akron, Ohio
XGP-194		General Tire & Rubber Co., Akron, Ohio
V-2222 3360/2 Nylon Cord		General Tire & Rubber Co., Akron, Ohio
XGP-122		General Tire & Rubber Co., Akron, Ohio
WP1014 Chafer Fabric		General Tire & Rubber Co., Akron, Ohio
XCP-2493 Breaker		General Tire & Rubber Co., Akron, Ohio
XT-4822A Tread Stock		General Tire & Rubber Co., Akron, Ohio

		DATE	CHANGE AND EFFECTIVITY	DATE OF CHG.
PREPARED BY	M. SANGER	4-25-69		
CHECKED BY				
APPR. TOOL. ENGR				
APPR. COGN. ENGR				
APPR. PROJ. ENGR.	M. Sanger	5-13-69		

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO	PART NO. 1269202	PART NAME Sand Mandrel 49 x 17 Bias Nylon	AF FW Bias Nylon 49 x 17 carcass SK 131168

MANDREL PREPARATION:

1. Wax all mold surfaces with Kanaba Wax.

2. Position cavity section (T-1286126-102) on to platform of Syntron vibrator.

3. Position center core (T-1286126-107) small end down, over 3/4 in. dia center pin and into mating surface of cavity section.

4. Weigh out approx 80# of SR-6 sand formulation into cavity. Distribute sand as uniformly as possible.

5. Sweep and tamp sand with shop aid template, as required, to compact sand against walls on the ID and OD.

6. Position spider located male core (T-1286126-116 and -119) over center pin.

7. Turn on vibrator at near maximum amplitude and vibrate for 3-4 minutes, or until ring has settled to stops on spider. Turn off vibrator.

8. Add more sand around inner and outer annulus. Manually tamp with shop-aid ram until sand is compacted and flush with inner and outer surfaces of mold.

9. Lightly tap ends of spider to loosen core. Lift core from mold using lift, sling and eyes on spider. Strike off loose particles and edges, as required.

10. Rotate slightly center aluminum core (T-1286126-107) and lift from center pin.

11. Lift handling tongs (T-1286127-101) and with the three pins extended, lower fixture into center of mandrel, removing sand as required to seat fixture center locating shoulder in hole in plate, T-1286126- and seat fixture pins in sand. Remove fixture.

12. Secure three eye bolts to outer flange of cavity section and using three-legged sling, lift and position cavity section on cart.

13. Place cavity section with sand core into preheated oven (250°F) and cure for (2) two and 1/2 hours.

PREPARED BY	H. WALDO	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. J. SANGER	5-13-69	COGN. ENGR.			M J Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Sand Mandrel 49 x 17 Bias Nylon	AF FW Bias Nylon 49 x 17 Carcass SK 131168

14. Remove from oven. Position and bolt in place on top of cavity section, (T-1286128) inverting fixture. Lift cavity and mandrel and invert assembly. Position inverting fixture plate on cart. Remove bolts retaining cavity to plate. Insert three eye bolts into holes provided in inner edge of cavity and lift cavity smoothly and carefully from sand mandrel.

15. Replace mandrel into oven and continue cure for (1) one and 1/2 hours. Remove from oven and cover with asbestos blanket to control cooling rate and prevent cracking from thermal shock.

16. Wash all mold details in warm water and rewax per Operation #1.

17. Repeat Operation 1 through 16 to make other mandrel half.

18. After both mandrel halves have cooled, bolt handling harness (T-1286129-101) over sand mandrel to inverting fixture plate. Pick up and invert mandrel assembly, setting mandrel down on steel cart with handling harness (T-1286129) between cart and mandrel. Remove inverting fixture and plate.

19. Using inverting fixture, lift first mandrel half and position handling tongs (T-1286127-101) centrally in mandrel ID. Extend three pins and lower mandrel into preformed notches. Remove inverting fixture.

20. Coat mating surfaces with slurry of Stienex "C". Install (4) four T-1286127-118 locating blocks on pads of handling harness (T-286129).

21. Using handling tongs (T-1286127),pick up upper mandrel half and position on to lower mandrel half.

22. Using jack screws in base of handling tongs, adjust height of mandrel using template (T-1286127-117) from face of pads on handling harness. Add bonding slurry as required to insure minimum porosity of bond.

23. Place mandrel in preheated oven (250°F) for one (1) hour.

24. Cool down in oven or remove from oven and cool under asbestos blanket.

25. When cool, scuff bond resin flush with adjacent surfaces using mushroom sander.

PREPARED BY	H. WALDO	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO	PART NO 1269202	PART NAME Sand Mandrel 49 x 17 Bias Nylon	AF FW Bias Nylon 49 x 17 Carcass SK 131168

26. Inspection.

   a. Weight ___________ lbs.

   b. OD 42.00: Actual ___________ in.

   c. ID at outer corners - 22.375 ± .030: Actual ___________ in.

   d. Section width 15.875: Actual ___________ in.

   e. With brush pen, mark weight on sidewall and add serial number.

PREPARED BY	M. WALDO	5-13-69	TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269207	PART NAME Shell Rim Lock 49 x 17 FW AF Tire	

RIM LOCK FABRICATION:

1. Prepare mandrel (T-1286125) as follows:

   a. Disassemble, clean and coat all details with DC-20 or R-671. Bake on for four (4) hours at 300°F.

   b. Reassemble, precoating all details in contact with resin, using Kanaba Wax.

2. Install mandrel in winding machine (AGC No. 26725).

3. Precut (2) strips prepreg 341 glass cloth, 16 in. wide x 60 in. long. Cut V notches every 3 in. on side.

4. Cut (1) 13.5 in. wide x 131 in. length, prepreg 341 glass cloth. Nip edges 1 in. to 1.5 in. every 3 in. to 4 in. on both edges.
   Cut (8) 9.7 in. wide x 132 in. lengths, prepreg 341 glass cloth.
   Cut (8) 1.6 in. wide x 135 in. lengths, prepreg 341 glass cloth.

5. Cut (4) 4 in. dia discs of prepreg 341 glass cloth. Apply 2 small prepreged discs over each boss insert.

6. Wrap 16 in. wide prepreg 341 glass cloth on mandrel. Tension as required to conform to mandrel. Tie in place as required, using 20-end S-HTS prepreg roving.

7. Wrap 13.5 in. wide strip 341 cloth. Secure in place using closely spaced layer of 20-end S-HTS glass roving at 10 lbs per strand tension. Start at center line and continue to wrap as far as edge radius will permit. Rapidly traverse to centerline and continue to wrap to opposite radius and tie off.

8. Wrap (2) lengths 9.7 wide prepreg 341 cloth, using manual tension. These plies must be centered in groove. Secure in place using 20-end S-HTS roving applied as in Operation 7 above.

9. Repeat Operation No. 8 three more times, filling outer annuluses flush to cloth surfaces.

10. Cut 4 each circles of the following sizes from prepreg 341 glass cloth: 7.0 in., 6.6 in., 5.8 in., 5.4 in., 5.0 in., 4.6 in., 4.2 in., 3.8 in. dia.

11. Lay up plies, 2 each of each size, centered over pins in plug in mandrel. Start with 6.6 in. diameters and finishing with 7.0 in. diameters. Repeat on second boss. Continue hoop wrap across center section from that applied in Operation No. 9.

PREPARED BY	H. Warner	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO	PART NO. 1269207	PART NAME Shell Rim Lock 49 x 17 FW AF Tire	

12. Wrap (2) lengths 1.6 in. wide strips 341 cloth using manual tension. Position outboard edge of strips approximately over edge of laminate applied in Operation No. 8 and 9 above. Inboard edge of strip should be approximately 2.8 in. from outer edge of mandrel. Secure wrap in place using 20-end roving with 10# tension per strand.

13. Repeat Operation No. 12 for second buildup of 1.6 in. wide strips.

14. Wrap hoop windings as required to approx profile required. Use shop aid template of contour. Apply (1) ply of roving to center section.

15. Repeat Operations 12, 13 and 14 for opposite side buildup. Trim both outer edges as required.

16. Over wrap rim lock with bias cut dacron cloth. Then overwrap rim lock with (2) layers of shrink tape, using care to maintain contour of part.

17. Position mandrel assembly in oven and cure as follows:

200°F - 2 hours)
250°F - 4 hours) or continuous rate of rise, 50°F per hour. A chart record of cure temp and time is required.
325°F - 4 hours)

18. Cool in oven at rate of approximately 50°F per hour.

19. Remove shrink tape and bleeder cloth. Measure OD. If larger than 22.280 dia, send to machine shop for trimming to size (22.250 ± .030 dia).

20. Remove part from mandrel. Remove flash as required. Generate .05R on outer edges as required by hand sanding or filing.

21. Deliver rim lock to machine shop for boring, facing and chamfering.

22. Using small drill, drill through rim lock using conical depressions on ID for location. These holes must be accurately drilled as they will be used to locate centers of pockets on ID.

23. Set up on rotary table using suitable shop aid clamping.

24. Using holes drilled above, locate centers of premolded pockets and bore 2.062 dia (2) places per drawing.

PREPARED BY	H WALDO	5-13-69	TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO	PART NO. 1269207	PART NAME Shell Rim Lock 49 x 17 FW AF Tire	

25. Face off bosses (2) places .400 thick measured at hole centerline per drawing.

26. Chamfer 2.18 dia x 45° (2) places per drawing and deburr as required.

27. Inspect: *

    a. ID 20.750.

    b. Width.

    c. OD at outer edges.

    d. ID (2) holes 2.062.

    e. Thickness of bosses .400 (2) places.

28. Sand blast lightly all over to remove glaze.

29. Deliver to tire winding area, Building 163.

* NOTE: Record data as required on data sheet for each RLA and tire.

PREPARED BY	H. WA_DD	5-13-69	TOOL ENGR			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269203	PART NAME Rim Lock Assembly 49 x 17 FW AF Tire	

RIM LOCK ASSEMBLY:

1. Wash shell-rim lock (P/N 1269207) in acetone.

2. Coat all surfaces with Chemlock 205 Primer. Dry 15 minutes @ 150°F. Repeat with Chemlock 220 Adhesive.

3. Cut (4) 6 in. dia OD x 1.5 dia ID donuts from XK-985 rubber. Preply into (2) each two-layer donut rings.

4. Position 6 in. dia rings over holes in shell OD. 1.5 dia must be concentric with holes in shell. Precoat area with Gasoline/XK-985 Dispersion.

5. Clean with Hughson B727-6 Cleaner, Bushing P/N 1269208, and Nut P/N 1269209. Air dry. Coat external surfaces with Chemlock 205 and 220. Dry as in Step #2.

6. Insert bushing, P/N 1269208, into holes in shell, P/N 1269207, from outside, extruding rubber ring thru hole. Trim excess rubber from ID of shell. Bushing should be positioned so that the two pin holes are perpendicular to the lateral axis of the shell.

7. Clamp bushing in place, using "C" clamp or temporarily inserting nut. Drill (2) holes .125 dia thru holes in bushing to total depth of .40 ± .03. Press (AN122691) (2) .125 dia x .375 long steel dowels in these holes. Pins should be flush or below surface of bushing.

8. Lubricate MS28775-130 O-ring with XK-985/gasoline dispersion and install O-ring on Nut, P/N 1269209, and assemble nut to bushing quickly before dispersion dries out. Cinch nut down, using shop aid spanner. There should be some bulging of the rubber around edge of the bushing.

9. Precoat all surfaces of rim lock assembly with XK-985/dispersion. Air dry.

10. Cut (4) strips 13 in. wide x 22 in. long of XGP-192 (XK-985 compound).

11. Apply 13 in. wide x 22 in. long elastomer to ID of rim lock. Overlap ends 1/8 in. Center each ply and carry sides around outer radius to outer edge. Stagger joints of second ply. Stitch rubber AR to remove air.

12. Cover outside of rim lock with 2 in. wide strips XGP-191 (XK-985 compound). Use 1/8 in. wide side and end lap joints. (2) plies should be applied, staggering joints as required. Stitch rubber AR to remove air.

PREPARED BY	H WALDO	5-12-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M.J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269203	PART NAME Rim Lock Assembly 49 x 17 FW AF Tire	

13. Wrap with prereleased cotton shrink cloth. Vacuum bag.
14. Cure 60 minutes at 285°F.
15. Remove bag and bleeder. Clean up as required.
16. Inspect for cure hardness, blisters or delamination.
17. Mark with S/N.

						PROJECT ENGR.	DATE
PREPARED BY	H. WALDO	5-13-69	TOOL ENGR.				
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Green Carcass 49 x 17 FW AF Tire	

INNER LINER FABRICATION

1. Dry fit RLA, P/N 1269203, into sand mandrel. Trim mandrel and/or RLA rubber liner as required. Buff ID of RLA and coat with dispersion.

2. Mate RLA with mandrel. Pick up and support mandrel using T-1286129 handling harness. Place on handling cart, T-120854.

3. Coat area around circumference of mandrel approximately 2 in. each side of bond line with 12% dispersion of XK-985B compound and toluene. DO NOT ATTEMPT TO GET HEAVY COAT OR SATURATE SURFACE.

4. Radially wrap mandrel using 2 in. wide XGP-191 liner stock using 1/8 in. overlap at crown.

5. Circumferentially wrap two plys using 2 in. wide XGP-191 from bead to bead. Wrap one ply of 13 in. wide XGP-192 along ID, stretching as necessary to make joint outside RLA OD. NOTE: Last ply of 2 in. wide stock should stop approximately 2 in. outside bead area. Stitch all plys thoroughly.

6. Cut openings at two bushings. Wrap entire torus with pre-released cotton shrink tape. Apply vacuum bag. Check for leaks. Vacuum tap should be over one of the bushings.

7. Install part in oven and cure 90 minutes at 285°F. Cure chart required.

8. Cool slowly. Remove vacuum bag and bleeder cloth.

9. Plug the two valve openings and pull vacuum on liner through suitable fitting. Carcass liner must be leak-free for not less than 5 min.

10. Wipe carcass liner with Toluol or Benzine to remove all contaminates. Buff surface of inner liner. Apply by brush Anchorweld S0132D over complete liner surface. Air dry.

11. Using handling harness, lift and position mandrel/carcass in winding machine, T-120850. Release belt tension as mandrel is lowered into position. Retract sensor before installing. Rough position lateral guide rollers. Position lower support slides to index marks, and zero graduated collars. Tension belt. Position upper stabilizing belts. Verify tangent surface on interior of RLA is 5.175 from lower edge of winding ring. Replace winding ring segment. Insure all mating surfaces are clean and free of burrs, etc. Tap ring details as necessary with rawhide mallet to insure proper seating of ring components.

						PROJECT ENGR.	DATE
PREPARED BY	H WALDO	5-13-69	TOOL ENGR.			M.J. Sanger	5-13-69
CHECKED BY	M SANGER	5-13-69	COGN. ENGR.				

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Green Carcass 49 x 17 FW AF Tire	

APPLICATION OF STARTER LAYER

1. Disengage winding ring drive gear selector.

2. Turn on machine, slowly, adjust clearance of side guide rollers to approximately .08 on each side.

3. Apply one strip of 13 in. wide XGP-193 to crown area. Suggest cutting strip 133 in. long. Remove 2 in. wide strip of separator from each side after stock is applied. Stitch insulation thoroughly to remove air. Pierce all air blisters.

4. Set the motor selector switch in the reverse position and start the motor. Set applicator switch in "auto" position.

5. Apply 2 in. wide XGP-194 strip to side wall using elastomer application head. Start application at shoulder as far as possible and continue to bead area as far as machine will permit. NOTE: One payoff reel tensioner will have to be removed and winding ring be positioned for adequate clearance of elastomer head at bead area.

6. Repeat Oper 5 on opposite side. Patch open areas at edge of crown.

7. Position (2) square head plugs in bushings. Face of plugs must be 0.90 in. from face of RLA and of equal height. Square face must be parallel to center line of tire. Verify uniform height by rotating mandrel so that bushing face coincides with the lower edge of elastomer application support flange, approx 3/8 (.375) space. Adjust bushings until they are equal using suitable shims. Adjust sensor head to be 1/4 in. (.25) from face of plugs.

8. Apply insulation along the ID by stretching 12 in. long strips of 8 in. wide XGP-193 from heel to heel. Stitch down.

PREPARED BY	H WALDO	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5/13/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Green Carcass 49 x 17 FW AF Tire	

WINDING OF CARCASS

1. Adjust upper stabilizing heads. Assure winding head cam followers are on cam nearest winding head (left cam). Install fresh full reels of coated 3360/2 nylon cord (V-2222) on six tensioners. Assure all tensioners set at same setting. Assure all discharge rollers are set at same angle, height and location from face (use shop aid template).

2. Set the motor-selector switch in the forward position and start the motor.

3. Preset winding head ratio trimmer to 45.0 (approx). Engage winding head gear selector. Right side of slot. Position manual/automatic feed switch to automatic.

4. Depress run button and attach one cord. Set the ratio-adjust control switch in manual position. Adjust to produce desired cord spacing.

5. Remove test cord.

6. Using drive speed control, start mandrel rotation at 2 rpm. Momentarily switch feed control from auto to manual and back to auto to index feedback cam. Reset counter to 0000. Start each cord in succession, then advance speed control to give approx 6 rpm.

7. Continue wrap until 1230 ± 30 cords have been applied. Cord spacing should be uniform with space between cords not to esceed .080. Cord end count normal to cord path should be 13.71 to 14.61 per inch. Cord angle should be 49°/49'/51°26', target angle is 50°46'. If any of these parameters are exceeded, contact project engineer. There should be a minimum of crossed over cords. No cords on crown shall be abraded by belt. Record on data sheet total cords, crown angle and ends per inch.

8. Using elastomer application head, apply 2 in. wide XGP-194 from shoulder to bead on both sides. Apply 13 in. wide x 133 in. long strip XGP-193 on crown. Bring cord cut ends out at shoulder. Apply 8 in. wide by 12 in. long strips of XGP-122A rubber along ID. Stretch XGP-122A and join on side wall at outer RLA diameter. Separate cords at plugs as required and stitch down. Add wedge-shaped fill in the cord void using one layer of XGP-194 trimmed as required. Stitch insulation as required.

9. Back out lower slides 0.057. Rotate mandrel until plugs coincide with flange on elastomer application support and check as Oper 7 above. Adjust slides equally to get same gap as in Oper 7 above.

PREPARED BY	H. WALDO	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-13-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Green Carcass 49 x 17 FW AF Tire	

10. Change gear selector to give right hand wrap. Change winding head cam followers to right hand cam. Install fresh rolls of coated V-2222 cord. Reset guide rollers .080 gap.

11. Repeat Oper 3 through 8.

12. Repeat 1 through 11 three more times for eight plies total. Mark centerline at crown.

13. Remove carcass from machine, reversing installation procedure.

14. Measure OD, width, ID, weight. Record as required on data sheet.

15. Wrap carcass with poly strips and install in shipping carton.

PREPARED BY	H. WALDO	5-13-69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	M. SANGER	5-12-69	COGN. ENGR.			M. J. Sanger	5-13-69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Carcass Receiving And Inspection	49x17 F-W Bias Nylon

1. Visually inspect the unopened crate for any external crate damage, which would indicate any damage due to shipping and subsequent damage to the tire carcass.
2. Cut and discard crate lid metal retaining bands and lift crate lid vertically until tire is cleared.
3. Inspect exposed tire for any damage or broken mandrel in the exposed areas.
4. Use two 3.5x60 inch nylon cinch slings, inserted at the crate hub cut-outs 180° apart, for removing the carcass from the shipping crate. Slowly raise and remove cracass from the crate with a differential hoist using a metal single tree for connecting to the two nylon cinch slings.
5. Place, without impacting, the carcass in an upright position, remove the protective polyethelene wrapping, and screw the valve plugs in so they do not extend inward beyond the depressed carcass.
6. Weigh, inspect for damage, measure for dimensional conformity, and lay flat on the power turn table.

PREPARED BY	[signature]	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	[initials]	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Component Assembly	49x17 F-W Bias Nylon

All tire materials except Orbitread (1)

1. Cleanse outer carcass surface with white gas sparingly as required and allow to dry.
2. Apply two .030" layers of XK-985B (.060" total), each 9 inches wide, centered on the carcass I.D.
3. Apply 3/4x3/4 S-43 rectangular filler to the heel. Set inside edge of the filler 5.875 inches from the I.D. centerline.
4. Apply .050 inch gauge by 3.25 inches wide #1 chafer. Set lower edge 5.875 inches form I.D. centerline just covering the heel filler. Turn-up and stitch up the sidewall.
5. Apply .050 inch gauge by 5.25 inches wide #2 chafer. Set lower edge 3.75" from I.D. centerline. Turn-up and stitch along bead ledge and sidewall.
6. Apply lower sidewall rubber XT-4822A of .070 inch gauge and 6 inches wide. Set lower edge at 21.50 inch diameter. Turn-up and stitch up the sidewall to a diameter of 33.00 inches.
7. Use nylon cinch slings (2), turn tire over on the opposite side and repeat above steps 3,4,5, and 6.
8. Apply one breaker ply at angle right of XCP-2493 (.056" gauge) prepared to 14 inches wide and a bias angle of 51 degrees. Weigh the assembly.
9. Apply 14x136 inch wrap of 6 mil smooth polyhelene protective wrap to the carcass O.D.
10. Mount the carcass by the I.D. on cantilevered arm cart and transport to the Orbitread machine area.

[1] Orbitread - Trade name of American Machine and Foundry Company

PREPARED BY	E. W. Almond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	WS	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Orbitread	49x17 F-W Bias Nylon

1. Set Orbitread model 200C as follows:

   a.) 20" hub (Disconnect tire pressure line).
   b.) Low sprocket ratio on the tire rotational drive.
   c.) Insert double strainer in extruder.
   d.) Set extruder die opening for 1.5 inch ribbon.
   e.) Place rubber tire centering adaptor cylinder around the O.D. of the 20" hub.

2. Position 18 inch wide by 16 feet long belt sling around the tire O.D. Connect sling ends to electrical overhead hoist and transfer the tire to the Orbitread machine hub - still holding the weight of the tire by the hoise. (CAUTION: DO NOT IMPACT THE ORBITREAD MACHINE WITH THE TIRE WEIGHT.) With the tire axle line near coincident with the hub axle line, expand the 20" hub, with the adapter cylinder, until it just makes contact with the tire I.D. (Minor raising or lowering of the tire may be required for total contact). Position the tire for true conicity on the rubber tire centering adaptor cylinder then expand the 20" hub to full travel. Lower the sling for a slow transfer of the tire weight to the hub. Remove sling and hoist. Drive the tire rotation slowly to allow full positive expansion of all hub segments. Lightly swab the tread area with white gas and allow to completely dry.

3. Place #1 pass machine control card in machine and set pot dials as specified on the card. Feed XT-4822A tread stock ribbon having cross section dimensions of .375 x 2.5 inches into the machine extruder. Set the specified winding radius shown on the control card and index the tire to the starting position. (This is controlled by the machine control card). Apply tread stock of #1 pass. after application, measure the applied station gauges.

4. Repeat step 3 above except use #2 pass machine control card.

5. The finished applied tread is gauged. All light or starved areas will be increased to the desired gauge by manual machine operation.

6. Return the tire to the building area and weigh the entire assembly.

PREPARED BY	R. L. Almond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	WB	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Mandrel Removal	49x17 F-W Bias Nylon

Set-Up: NOTE: Use nylon thread sealent tape, or equivalent, on all pipe thread connections.

1. Remove both valve hole plugs and insert 4.5" long 1" brass pipes threaded on both ends with 1" Anpt threads. During plug removal and pipe insertion, spread the carcass cords with plier spreaders to prevent cord damage by the plug and pipe threads.

2. Remove the utility truck lid (D-17714-1). Using two nylon cinch straps and the aid of the overhead crane, position the tire in the utility truck so that the pipes are 90° away from tub axis of rotation. Replace utility truck lid and secure with all eight bolts.

3. Index the utility truck tub to a horizontal position. Connect the fill and drain lines from the sediment tank (D-17716) to the two pipes in the tire.

4. Inspect all connections to insure all are leak-free.

Mandrel Removal

1. Introduce hot tap water (approximately 140°F) into the tire cavity and fill the tire. When the tire is half full drainage will start through the drain line. When drainage begins adjust the fill valve for a nominal drain condition to maintain a circulating system. Maintain this condition for 90 minutes at which time the mandrel will be starting to break-up on the lower half of the tire.

2. Rotate the utility truck tub 180° so that the previously top half of the tire is then on the bottom. The hot water flow is to be continued for 60 minutes. Inspect the tire to insure the mandrel has dissolved and no large chunks remain. If chunks exist, continue the hot water flow until the mandrel is in a granular state. Rotate the tire to an upright position with the drain pipe on the bottom and drain the tire with the supply valve in the off position and the fill line vent valve to the atmosphere in the open position to prevent pulling a vacuum in the tire cavity during drain.

3. When drain is complete, remove the drain line from the 1" pipe in the tire. Leave the tire in an upright position with the connected fill line at the top position and the other open pipe at the bottom position. This is the set-up for the grandular sand extraction.

4. A trap of at least 40 gallon capacity is to be placed in a vacuum line between the vacuum pump and tire. The trap is to be adjacent to the tire so that a minimum line length from the trap to the tire is required.

PREPARED BY	R. L. Almond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	[illegible]	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Mandrel Removal	49x17 F-W Bias Nylon

Continued

The line trap is to be fitted with a vacuum gauge and gate valves in the line on both ends of the trap. A vacuum pump with a capacity of 22 inches of mercury is to be used for raising the sand water mixture a height of 3 feet during removal.

5. Remove the sand from the tire by using the following sequence:

a.) Close vacuum line valve on the tire side of the trap.
b.) Open vacuum line valve on the pump side of the trap and allow maximum vacuum build-up in the trap.
c.) Place vacuum line, of 3/4" transparent hose with a 16 inch adaptor for insertion into the tire through the 1" pipe, into the tire cavity. Insert adaptor to the granular sand in the tire.
d.) Open the fill line valve and slowly feed cold water into the tire cavity.
e.) With the vacuum line inserted in the tire, open the vacuum line valve on the tire side of the trap to initiate extraction. Maintain cold water feed into the tire so that water is constantly being extracted along with the sand or line clogging will result.
f.) The process efficiency is to be monitored visually by observing the flow condition through the 3/4" transparent vacuum line.
g.) Minor rocking of the tire may be utilized near extraction end to agitate the sand to a position directly beneath the pipe for extraction. Empty vacuum line trap as required. (Usually four times for the total extraction process). This phase of extraction and trap emptying will require approximately 60 minutes.
h.) Fill the tire 40 to 50% with cold water, close the tire system and agitate by turning the utility truck tub on its axis of rotation through $\pm$ 180° to wash the clinging sand from the inner liner. Slow rocking is to be conducted for 5 minutes.
j.) Extract all remaining water and sand from the tire possible with the vacuum line for total drain.
k.) Disconnect all lines to the tire.

6. Remove the tire from the utility truck and weigh. The reduction in weight due to the removal must equal or exceed 98% of the original mandrel weight. If this reduction in weight is met the removal is sufficient. If not, return the tire to the utility truck for additional agitation and sand extraction until the 98% weight reduction is attained.

PREPARED BY	[signature]	4/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	[initials]	6/23	COGN. ENGR.			M.J. [signature]	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Tire Preparation For Cure	49x17 F-W Bias Nylon

1. Insert segmented curing ring (DK-5622-1) centered on tire I.D. and holes in alignment with the pipes. Expand with turnbuckles (DK-5649).
2. Inflate the tire to 5 psi, to maintain tire shape and prevent distortion, and cap the 1" pipes.
3. Place tin serial strip midway up the sidewall and cover with gum strip to hold in position.
4. Lubricate the chafer in the bead ledge area with silicone bead lubricant.
5. Spray the total exterior of the tire with external tire lubricant.
6. Awl at the top of the bead heel filler to a depth of .010" at 2 inch intervals - both sides.

PREPARED BY	R. L. Ellmond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	uB	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Curing	49x17 F-W Bias Nylon

Curing Equipment Set-up

1. Mount 49x17 mold (DK-5620-1) with attached bead rings (DK-5621-1) in a 55 inch McNeil press. Check for adequate mold parting line squeeze.

2. By pass the shear strip action on the curing press.

3. Connect 3/8 inch flexible high pressure lines with quick disconnect fittings to the press fill and drain lines at center pot base.

4. Install thermocouple monitor in fill line at juncture of flexible line connection.

5. Mount pressure gauge down stream from the tire in a spur from the drain line.

6. Install spur line to atmosphere from drain line. This spur line is to contain the pressure gauge and hand valve for continuous monitoring of the internal pressure in the tire and manual draining of the internal tire pressure.

7. Set cure cycle on the press automatic timer control. Connect flexible lines with shop aid adaptor. Close the press and cycle the cure to check all cure cycle functions and insure all lines open.

8. Open press and insure clean mold cavity and all mold vents open. Remove flexible line shop aid adaptor.

Tire Loading Into Mold Cavity

1. By using an overhead crane, lift the tire by eye belts screwed in brackets welded to the segmented curing ring. Center and level the tire on the lower bead ring. Remove eye bolts.

2. Manually, slowly close the press in increments to within 1.5 inches of fully closed mold to press the tire on the bead rings. This operation is done with the 5 psi in the tire placed there just after the segmented curing ring was inserted. The mold is then opened for inspection and curing line connections. (Due to its weight, the tire remains on the bottom bead ring.).

3. Inspect the bead ledges of the tire to insure proper bead ring/tire interference fit and insure the bead rings are not "plowing" tire materials ahead of the bead ring toe which would be pinched between the bead ring and segmented curing ring.

PREPARED BY	K. L. Almond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	WB	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Curing	49x17 F-W Bias Nylon

4. Mount male quick disconnect fitting to the 1" pipe in the front area of the press. The male quick disconnect fitting with siphon and siphon mounting adaptor are to be mounted to the 1" pipe in the rear mold area. Mount this item by inserting the siphon into the tire cavity and screwing the adaptor on the 1" pipe.

5. Attach the flexible fill and drain lines to the front and rear pipes respectively with the quick disconnectors.

6. Manually close the mold and start the cure cycle. A qualified individual will constantly monitor all time-temperature-pressure segments during the cure.

7. At cure end, place the press in manual operation and open manual valve installed parallel to the drain line. This is for safety to insure no high pressure in the tire at mold opening.

8. Open the mold, remove curing lines at quick disconnectors, insert eye bolts in the segmented curing ring, and use overhead crane to remove the tire from the mold.

9. Inspect for and crayon mark any surface imperfections such as voids, blisters, etc. while the tire is hot.

10. Remove any remaining water in the tire by inserting a vacuum line into the tire cavity.

11. Remove 1" pipes and strip the segmented curing ring from the tire.

PREPARED BY	L. L. Allmond	6/20/69	TOOL ENGR.			PROJECT ENGR.	DATE
CHECKED BY	[illegible]	6/23	COGN. ENGR.			M. J. Barger	6/30/69

ENGINEERING MANUFACTURING INSTRUCTION

INSTRUCTION SHEET

OPER NO.	PART NO. 1269202	PART NAME Final Finish And Inspection	49x17 F-W Bias Nylon

1. Trim all flash and vents from the tire.
2. Remove the tin serial strip from the sidewall.
3. Awl each 4 inches to a depth of .250" between the outer two bead corrugations - both sides.
4. Visually inspect the exterior, weigh the tire, and measure hardness of various external surfaces.
5. Measure the moment of out-of-balance.
6. Inspect with available fluoroscopic unit.
7. Ship tire to destination as directed by the project engineer.

						PROJECT ENGR.	DATE
PREPARED BY	R. L. Almond	6/20/69	TOOL ENGR.				
CHECKED BY	WB	6/23	COGN. ENGR.			M. J. Sanger	6/30/69

APPENDIX VII

ANALYSIS OF A WINDING MACHINE DESIGN FOR A FILAMENT-WOUND TIRE

APPENDIX VII

ANALYSIS OF A WINDING MACHINE DESIGN FOR A FILAMENT-WOUND TIRE

by M. Claire Zethraeus, Computing Sciences Division

Equations are derived in a form suitable for digital computer solution to solve the following design problem: A filament payoff head is rotating at constant velocity around a portion of a toroidal mandrel. The mandrel is also rotating at constant velocity about the axis of the toroid. It is desired to so design a cam to provide a third motion to the payoff head (perpendicular to a plane which contains the toroid axis and the plane of rotation of the payoff head) that filaments will be deposited on a specified path on the mandrel.

The winding machine has been designed to wind a tire of a specified shape. The shape considered has an outer cylindrical section, three circular toroidal sections, and an inner cylindrical section (see Figure VII-1). The filament is fed from a payoff head rotating at a constant angular velocity on a cylindrical surface with axis of rotation in the plane of symmetry and tangent to a circle of given radius (see Figure VII-2).The filament will be continuously wound while the mandrel also rotates at a different constant velocity. The winding angles are specified in a t.ble as a function of radial distance from the mandrel axis of rotation (Table VII-1). The payoff head is displaced parallel to the axis of the cylinder in addition to the uniform angular motion in order to lay the filament at the specified angle.

The total angle of advance, Θ_T, of the winding mandrel required for one revolution of the payoff head will be determined first (see Figure VII-3). Θ_T is used to determine the relative angular velocities of the mandrel and the payoff head.

Next a series of points, J_i, along the filament path spaced in equal increments of ϕ are selected. ϕ_i is the orientation of an outward normal to the surface of the mandrel.

The displacement, $S(\delta)$, of the payoff head is then determined for each of these points. $S(\delta)_i$ is the value of the z-coordinate of the position, H_i, of the payoff head while filament is laid on the point J_i. H_i is the point of

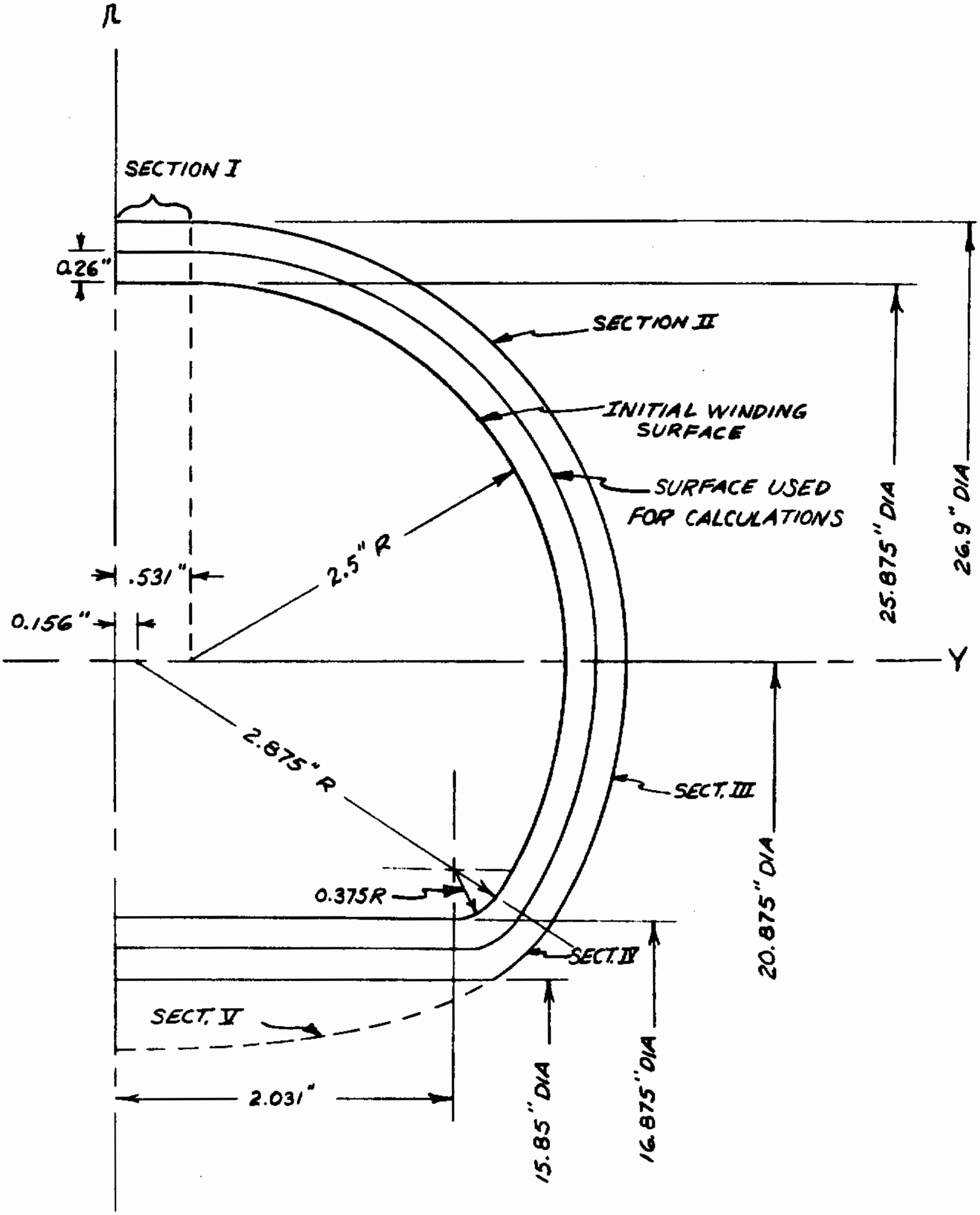


Figure VII-1. Geometry of Filament-Wound Tire Winding Mandrel

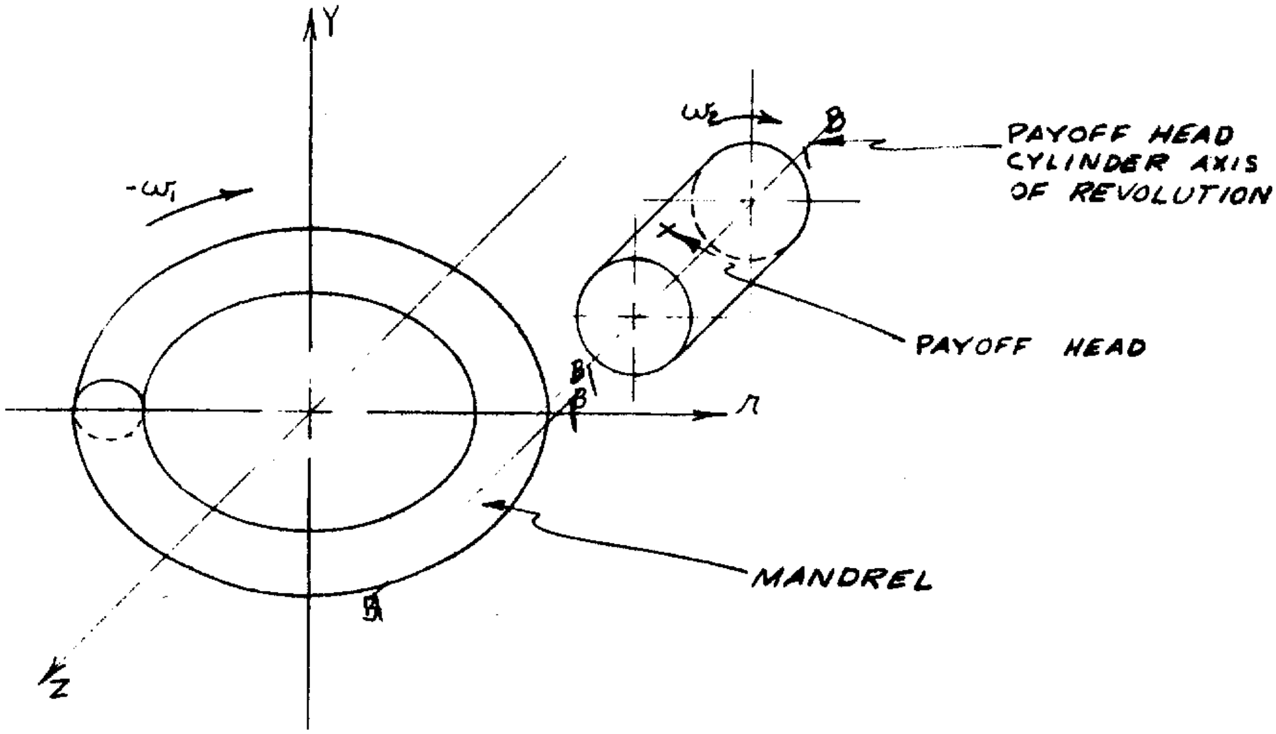


Figure VII-2 . Tire Mandrel and Filament Head

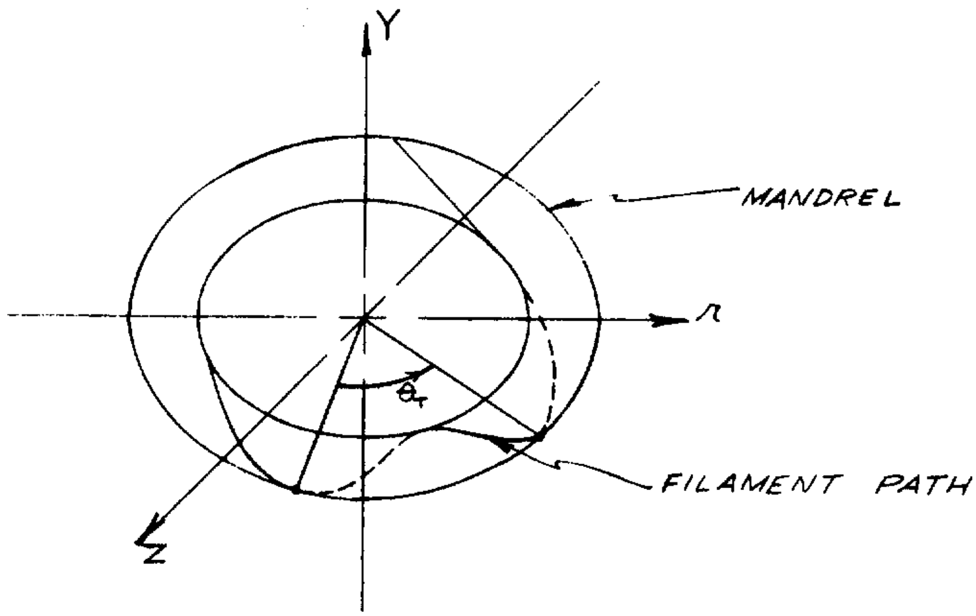


Figure VII-3. Mandrel and Filament Path

TABLE VII-I

CORD WINDING PATH FOR 30 x 7.7 12PR FILAMENT-WOUND TIRE

Reference: Mandrel Profile - DK-2277-1

(The winding angle is that angle made between the cord and a plane through the axis of tire rotation measured in the plane tangent to the mandrel.)

The winding angle shown is that at a given station on the periphery of the mandrel. The angle at a given station shall be maintained in successive plies on a plane passing through the normal to the mandrel surface station.

Mandrel Station	Station Radius	Winding Path	
		Degrees	Minutes
1 (OD)	12.9375	51	38
2	12.930	51	35
3	12.840	51	5
4	12.650	50	3
5	12.375	48	35
6	12.015	46	44
7	11.60	44	40
8	11.13	42	25
9	10.635	40	7
10	10.14	37	55
11	9.65	35	47
12	9.175	33	47
13	8.75	32	1
14 (ID)	8.4375	30	45 ($\pm 5^\circ$ ID only)

intersection with the payoff head cylinder of a line tangent to the filament at J_1 (see Figures VII-4 and VII-5).

The Total Angle of Advance, θ_T:

Since the mandrel is divided into five geometric sections, it is necessary to determine separately the angle of advance across each. Because of the toroidal shape, filament bridging occurs across the inner sections of the mandrel. The equations of the surface are as follows:

Section I, Outer Cylindrical Portion

$$r = r_1 + b$$

where

r_1 = the radial distance from the mandrel axis of rotation to the center of the circle of Section II.

b = the thickness of previous layers plus the radius of the circle in Section II.

Section II, Circular Toroidal Portion

$$(r - r_1)^2 + (y - a)^2 = b^2, \text{ for } y > a \text{ and } r_1 < r \leq r_1 + b$$

Section III, Circular Toroidal Portion

$(r - r_1)^2 + (y - c)^2 = d^2$, for $y > a$ and $r_b \leq r < r_1$, where r_b is the radius at the intersection of Sections III and IV.

Section IV, Circular Toroidal Portion

$(r - r_2)^2 + (y - f)^2 = g^2$, for $y > f$ and $r_p < r < r_b$, where r_p is the radius at the intersection P of the bridged portion and Section IV. (1)

Section V, Bridged Portion

Using Figures VII-6 and VII-7, the minimum point of filament bridging occurs at

$$r = r_p \cos \Delta$$

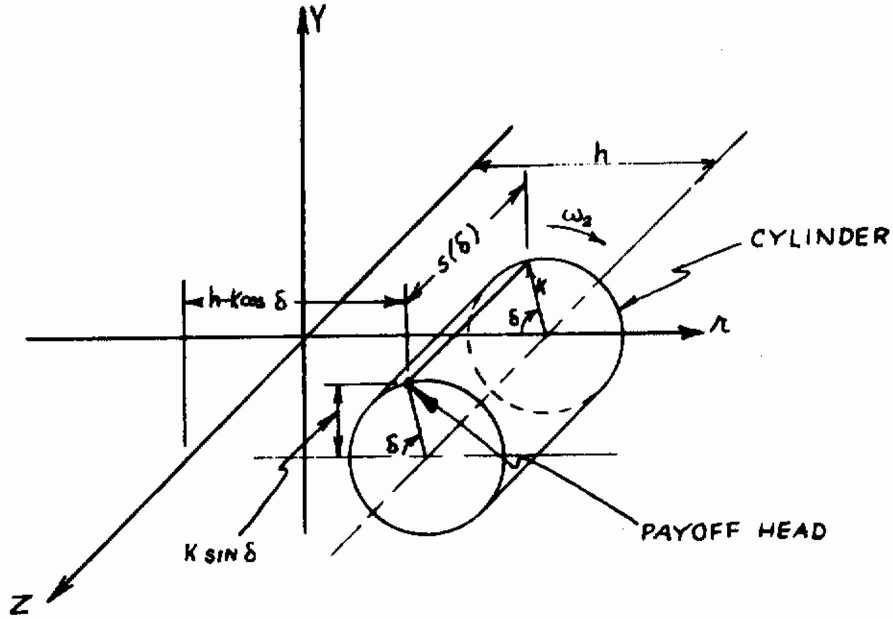


Figure VII-4. Displacement, S(δ), of Payoff Head

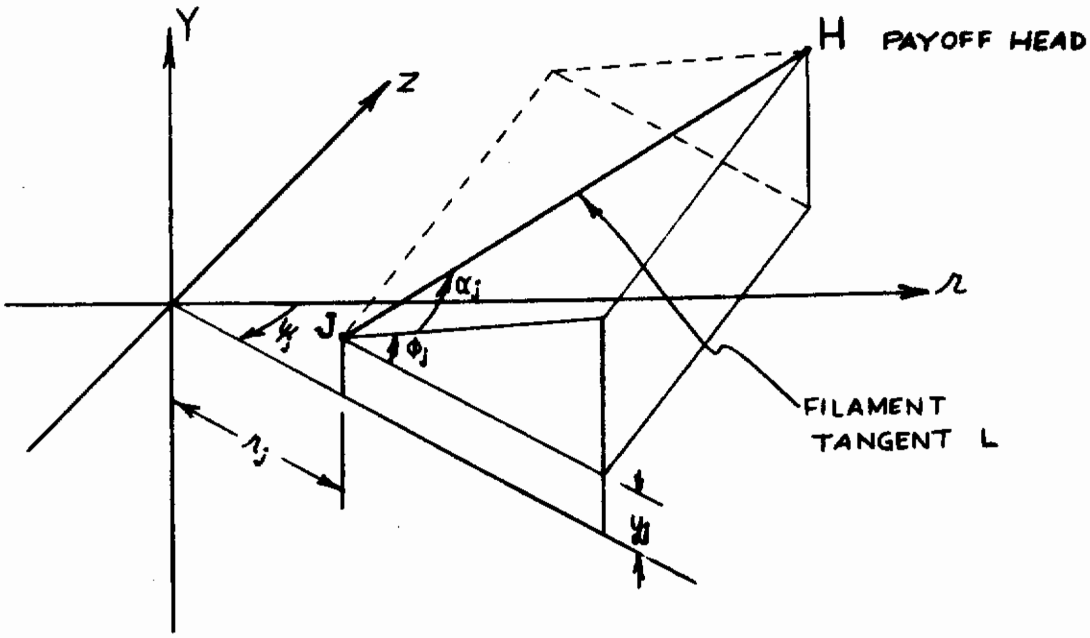


Figure VII-5. Geometric Relationships, Displacement of Head

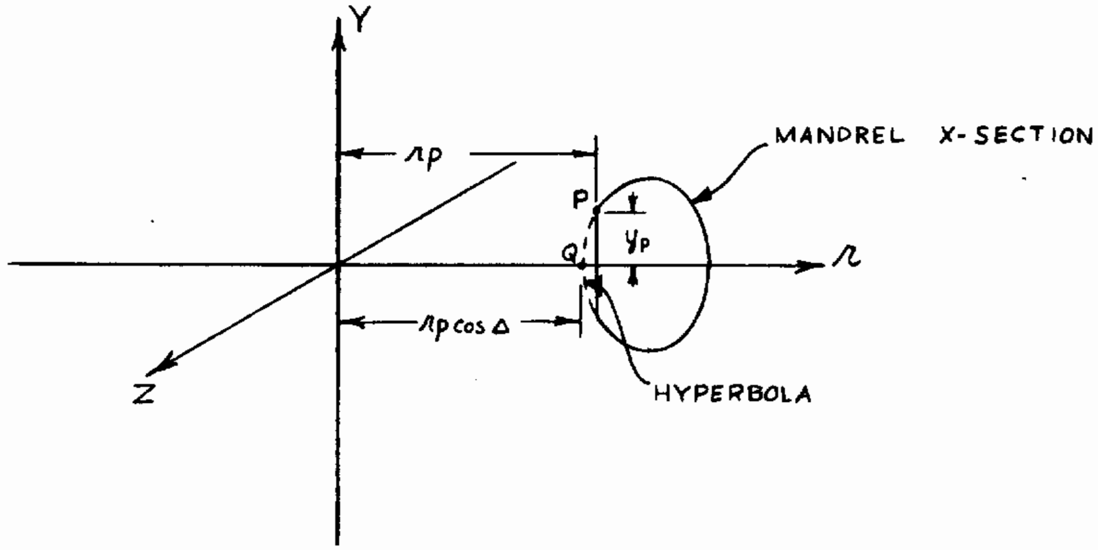


Figure VII-6. Minimum Point Q of Filament on Hyperbola

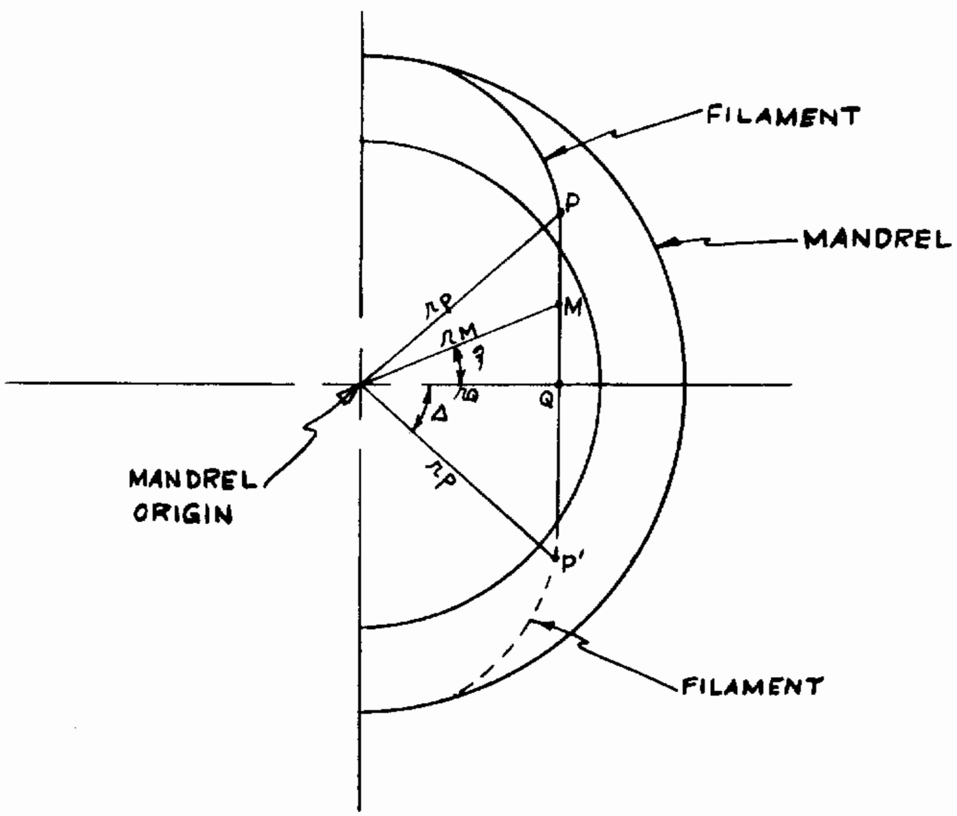


Figure VII-7. Point M on Filament

where

Δ is the angle of advance across Section V.

For a point M on the bridged filament

$$r_m \cos \xi = r_p \cos \Delta$$

where ξ is the angle between chords from the origin to M and to Q, the minimum point of the hyperbola.

Then, using Figure VII-8

$$\frac{r_m \sin \xi}{r_p \sin \Delta} = \frac{y_m}{y_p}$$

and

$$r_m^2 = r_p^2 \cos^2 \Delta + \left(\frac{y_m}{y_p}\right)^2 r_p^2 \sin^2 \Delta$$

or

$$\left(\frac{r_m}{r_p}\right)^2 - \left(\frac{y_m}{y_p/\sin \Delta}\right)^2 = \cos^2 \Delta$$

and in general

$$\left(\frac{r}{r_p}\right)^2 - \left(\frac{y}{y_p/\sin \Delta}\right)^2 = \cos^2 \Delta \qquad (2)$$

Equation (2) describes a hyperbola. It is necessary to develop equations for only 1/2 of the mandrel surface, since the mandrel is symmetric about the horizontal plane y = 0.

Equation (1) at the point P becomes

$$y_p = f + \sqrt{g^2 - (r_p - r_2)^2} \qquad (3)$$

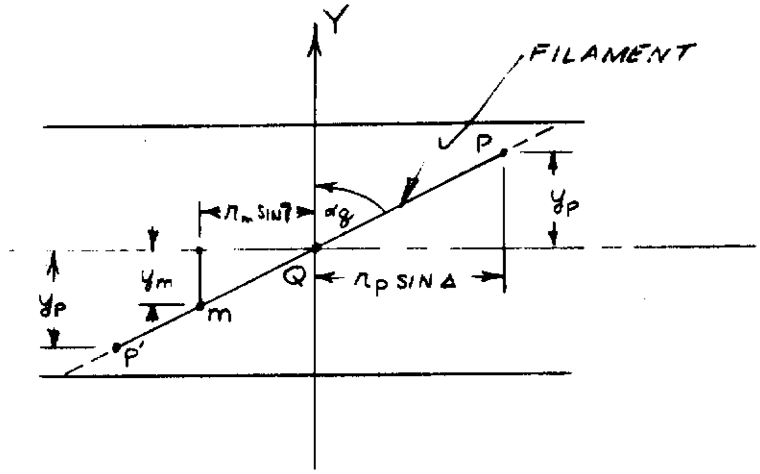


Figure VII-8. Winding Angle at Q

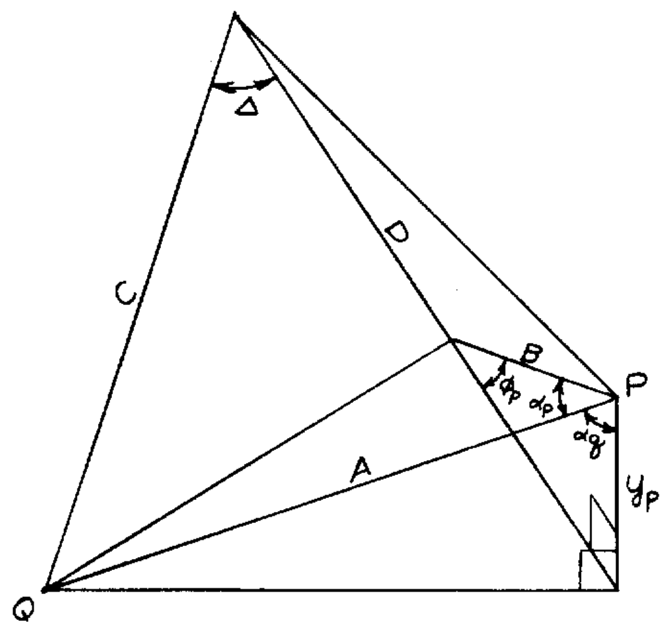


Figure VII-9. Geometric Relationships, Winding Angle

The slope of the hyperbola [Equation (2)] and the slope of Section IV [Equation (1)] are equal at the point P.

The slope of Section IV at any point is

$$SL_{IV} = \frac{r_2 - r}{y - f}$$

and at P is

$$SL_{IV_p} = \frac{r_2 - r_p}{y_p - f}$$

The slope of the hyperbolic section at any point is

$$SL_V = \frac{r y_p^{\,2}}{y r_p \sin^2 \Delta}$$

and at P is

$$SL_{V_p} = \frac{y_p}{r_p \sin^2 \Delta}$$

Since $SL_{IV_p} = SL_{V_p}$

$$\frac{y_p}{r_p \sin^2 \Delta} = \frac{r_2 - r_p}{y_p - f}$$

and it follows that

$$y_p = \frac{f + \sqrt{f^2 + 4 r_p \sin^2 \Delta \, (r_2 - r_p)}}{2} \qquad (4)$$

The angle between the positive y-axis and an outward normal to the surface at P is

$$\phi_p = \tan^{-1}\left(\frac{r_2 - r_p}{y_p - f}\right) \tag{5}$$

The winding angle at Q, the minimum point of the hyperbola, is (see Figure VII-8)

$$\alpha_q = \tan^{-1}\left(\frac{r_p \sin \Delta}{y_p}\right) \tag{6}$$

Using Figure VII-9, the winding angle α_p at the point P on the hyperbola is

$$\alpha_p = \cos^{-1}\left\{\frac{-(C^2 + D^2 - 2CD \cos \Delta) + A^2 + B^2}{2AB}\right\} \tag{7}$$

where

$$A = \frac{y_p}{\cos \alpha_q}$$

$$B = \frac{y_p}{\sin \phi_p}$$

$$C = r_q$$

$$D = r_p - \frac{y_p}{\tan \phi_p}$$

The arc length across the hyperbolic portion is

$$S_V = \frac{r_p \sin \Delta}{\sin \alpha_q}$$

The arc length of the filament across Section I is

$$S_I = \frac{a}{\cos \alpha_I}$$

where α_I is the winding angle across the outer cylinder obtained from Table VII-I

Then the angle of advance across Section I is

$$\theta_I = \frac{S_I \sin \alpha_I}{r_1 + b} \qquad (8)$$

Using Figure VII-10, on the circular sections

$$dS \cos \alpha = \sqrt{dr^2 + dy^2}$$

$$dS \sin \alpha = r d\theta$$

where θ is the angle of advance, S is the arc length, and α is the winding angle obtained from Table VII-I.

It follows that

$$r d\theta = \tan \alpha \sqrt{dr^2 + dy^2}$$

Using the polar angle ϕ

$$\sqrt{dr^2 + dy^2} = r_c d\phi$$

where r_c is the radius of the circular portion

and

$$r = r_o + r_c \cos \phi$$

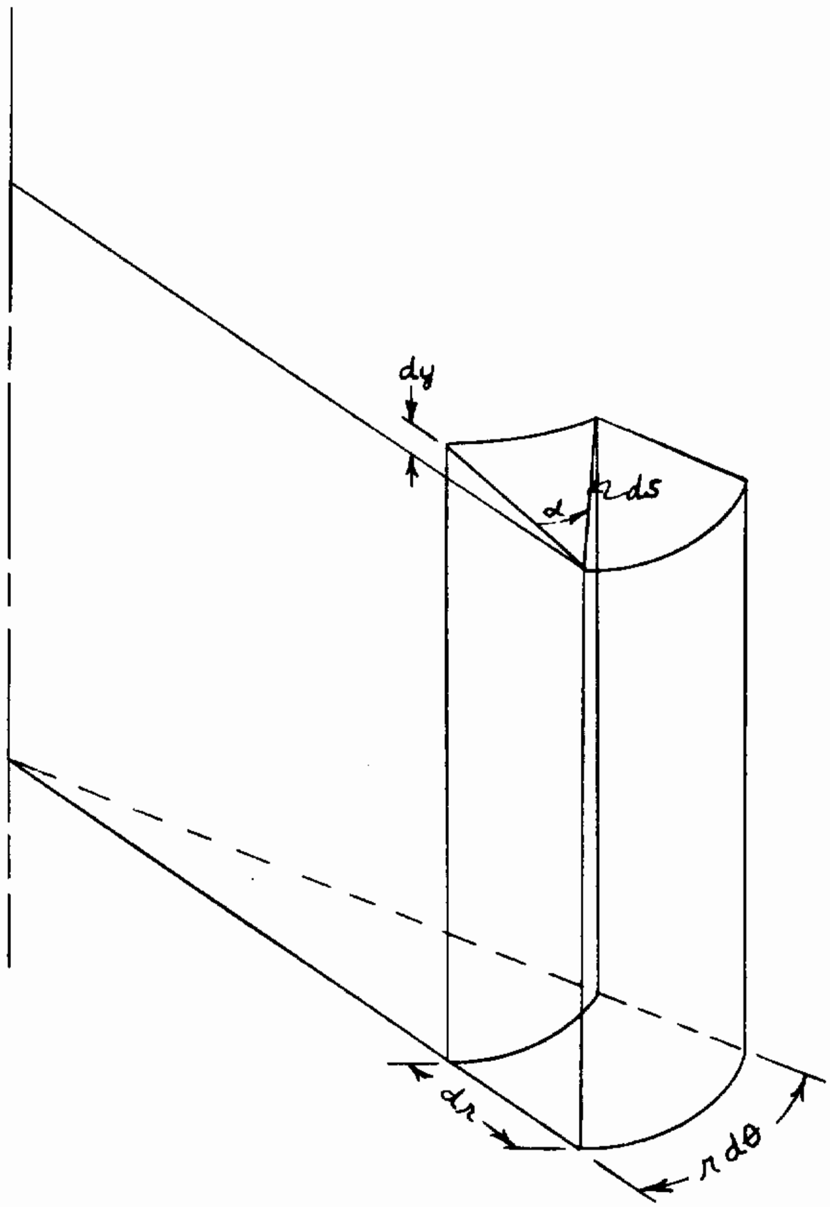


Figure VII-10 . Angle of Advance, θ, and Arc Length, S, Across Circular Sections where r_o is the r-coordinate of the center of the circle.

Then

$$r d\theta = r_c \tan \alpha \, d\phi = (r_o + r_c \cos \phi) \, d\theta$$

and

$$d\theta = \frac{r_c \tan \alpha \, d\phi}{r_o + r_c \cos \phi}$$

Since

$$dS = \frac{\sqrt{dr^2 + dy^2}}{\cos \alpha}$$

$$dS = \frac{r_c d\phi}{\cos \alpha}$$

Then integrate

$$\theta_{II} = \int_{\Phi_I}^{\Phi_{II}} \frac{b \tan \alpha d\phi}{r_1 + b \cos \phi} , \qquad S_{II} = \int_{\Phi_I}^{\Phi_{II}} \frac{b d\phi}{\cos \alpha} \tag{9}$$

where

$$\Phi_I = 0 , \qquad \Phi_{II} = \pi/2$$

$$\theta_{III} = \int_{\Phi_{II}}^{\Phi_{III}} \frac{d \tan \alpha d\phi}{r_1 + d \cos \phi} , \qquad S_{III} = \int_{\Phi_{II}}^{\Phi_{III}} \frac{d d\phi}{\cos \alpha} \tag{10}$$

where

$$\Phi_{III} = \tan^{-1}\left(\frac{y_b - y_1}{r_1 - r_b}\right)$$

$$\theta_{IV} = \int_{\Phi_{III}}^{\Phi_{IV}} \frac{g \tan \alpha d\phi}{r_2 + g \cos \phi}, \qquad S_{IV} = \int_{\Phi_{III}}^{\Phi_{IV}} \frac{g d\phi}{\cos \alpha} \tag{11}$$

where

$$\Phi_{IV} = \tan^{-1}\left(\frac{y_p - f}{r_2 - r_p}\right)$$

Then the total angle of advance for one revolution of the payoff head is

$$\theta_T = 2(\theta_I + \theta_{II} + \theta_{III} + \theta_{IV} + \Delta) \tag{12}$$

After N revolutions of the payoff head and X rotations of the mandrel, the filament must be laid on the mandrel at a fractional angular displacement ρ from the filament initially wound on the mandrel.

For specified X and ρ

$$N\,\theta_T = 2\pi X + \rho \tag{13}$$

Method of Computer Solution for θ_T, the Total Angle of Advance:

Initially the desired value for X is chosen and a first guess for Δ is made. For design parameters of the configuration, see Table VII-II.

(i) θ_I is computed using Equation (8)

(ii) θ_{II} is computed using Equation (9)

TABLE VII-II

FILAMENT-WOUND TIRE DESIGN VALUES USED

	Value, in.
a	0.531
b	2.760
c	0.156
d	3.135
f	2.031
g	0.635
r_1	10.4375
r_2	8.625
h	10.594
k	3.75
ρ	$\tan^{-1}\left\{\frac{1/21 \text{ in.}}{(r_1 + b)}\right\}$
X	1

(iii) θ_{III} is computed using Equation (10)

(iv) r_p and y_p are computed using Δ and Equations (3) and (4)

(v) ϕ_p is computed using Equation (5)

(vi) $\dot{\alpha}_q$ is computed using Equation (6)

(vii) α_p is computed using Equation (7)

(viii) α'_p is computed by interpolating in the winding path table using r_p. α'_p is used only to indicate whether α_p is within the required range.

(ix) θ_{IV} is computed using Equation (11)

(x) θ_T is computed using Equation (12)

(xi) N is computed using Equation (13)

(xii) If N is an integer then θ_T is the total angle of advance required, otherwise an increment of Δ is computed using the following formula

$$\Delta_\Delta = \frac{1}{2}\left(\frac{2\pi X + \rho}{N_{truncated}} - \theta_T\right)$$

(xiii) The new Δ is computed by adding Δ_Δ to the previous Δ and the process is repeated from step (iv) until N is in integer.

The Displacement of the Payoff Head, $S(\delta)$:

During the wrapping process, the payoff head rotates at an angular velocity ω_2 and the mandrel at an angular velocity ω_1. The time required for one revolution of the payoff head is

$$T = 2\pi/\omega_2$$

and for the mandrel to advance through the angle θ_T

$$T = \theta_T/\omega_1$$

Then

$$2\pi\omega_1 = \theta_T\omega_2$$

The cylinder on which the payoff head rotates is

$$(r - h)^2 + y^2 = k^2$$

The position of the payoff head on the cylinder is (see Figure VII-4)

$$r = h - k \cos \delta$$

$$y = k \sin \delta$$

$$z = S(\delta)$$

where

$$\delta = \omega_2 t + \epsilon$$

$$t = \text{time}$$

ϵ = angular position of the payoff head at time $t = 0$.

Let L be a straight line drawn tangent to the filament at the point J and intersecting the payoff head cylinder. Construct the coordinate system 0 such that the origin is at J and the coordinate axis r_o coincides with L (Figure VII-5).

The equations of L are

$$y_o = 0$$

$$z_o = 0$$

Rotate the y_o axis through the winding angle, $-\alpha$, to form system 1 for which

$$y_1 = y_o$$

$$z_1 = z_o \cos \alpha + r_o \sin \alpha$$

$$r_1 = r_o \cos \alpha - z_o \sin \alpha$$

Rotate the z_1 axis through the angle ϕ to form system 2 for which

$$y_2 = y_1 \cos \phi - r_1 \sin \phi$$

$$z_2 = z_1$$

$$r_2 = r_1 \cos \phi + y_1 \sin \phi$$

Rotate the y_2 axis through $-\psi$, the angular displacement of the filament on the mandrel at time t, to form system 3.

$$\psi = \theta - \omega_o - \omega_1 t$$

where ω_o is the angular displacement of the filament at $t = 0$ and θ is the angle of advance.

Then

$$y_3 = y_2$$

$$z_3 = z_2 \cos \psi + r_2 \sin \psi$$

$$r_3 = r_2 \cos \psi - z_2 \sin \psi$$

Translate the origin of system 3 to the mandrel origin

$$y = y_3 + y_j$$

$$z = z_3 + r_j \sin \psi$$

$$r = r_3 + r_j \cos \psi$$

where r_j is the distance of J from the mandrel axis of rotation and y_j is the distance in the polar direction.

After the rotations and the translation, the equations of L may be represented as follows:

$$y = -r_o \cos \alpha \sin \phi + y_j$$

$$z = r_o \sin \alpha \cos \psi + r_o \cos \alpha \sin \psi \cos \phi + r_j \sin \psi$$

$$r = r_o \cos \alpha \cos \phi \cos \psi - r_o \sin \alpha \sin \psi + r_j \cos \psi$$

Eliminate r_o and substitute in (14) for r, y, and z.

Then

$$\frac{k \sin \delta - y_j}{-\cos \alpha \sin \phi} = \frac{h - k \cos \delta - r_j \cos \psi}{\cos \alpha \cos \phi \cos \psi - \sin \alpha \sin \psi} \tag{15}$$

$$\frac{k \sin \delta - y_j}{-\cos \alpha \sin \phi} = \frac{S(\delta) - r_j \sin \psi}{\sin \alpha \cos \psi + \cos \alpha \sin \psi \cos \phi} \tag{16}$$

$$\frac{h - k \cos \delta - r_j \cos \psi}{\cos \alpha \cos \phi \cos \psi - \sin \alpha \sin \psi} = \frac{S(\delta) - r_j \sin \psi}{\sin \alpha \cos \psi + \cos \alpha \cos \phi \sin \psi} \tag{17}$$

At time $t = 0$, $\theta = 0$, $\alpha = \alpha_q$, $y_j = 0$, $r_j = r_q$ since winding is assumed to begin at the point Q, the minimum point of the hyperbola.

At $t = 0$, Equation (15) becomes

$$\frac{h - k \cos \epsilon - r_q \cos \omega_o}{\sin \alpha_q \sin \omega_o} = \frac{k \sin \epsilon}{\cos \alpha_q} \tag{18}$$

Solve (18) for ϵ

$$h - r_q \cos \omega_o - k \cos \epsilon = k \tan \alpha_q \sin \omega_o \sqrt{1 - \cos^2 \epsilon}$$

$$(h - r_q \cos \omega_o)^2 - k^2 \cos^2 \epsilon - 2k (h - r_q \cos \omega_o) \cos \epsilon$$

$$= k^2 \tan^2 \alpha_q \sin^2 \omega_o (1 - \cos^2 \epsilon)$$

The quadratic equation for cos ϵ is

$$k^2 (1 + \tan^2 \alpha_q \sin^2 \omega_o) \cos^2 \epsilon - 2k (h - r_q \cos \omega_o) \cos \epsilon$$

$$+ (h - r_q \cos \omega_o)^2 - k^2 \tan^2 \alpha_q \sin^2 \omega_o = 0 \qquad (19)$$

Cos ϵ is the larger in magnitude of the roots of Equation (19).

Method of Computer Solution for $S(\delta)$, the Displacement of the Payoff Head:

First a table of points spaced in equal increments of ϕ along the filament path on the mandrel is constructed. For each point on the mandrel, the table contains values for ϕ, θ, α, r, and y

where

- ϕ_i is the angle an outward normal to the point i makes with a plane parallel and through the mandrel axis of rotation.
- θ_i is the angle of advance at the point i.
- α_i is the winding angle at i.
- r_i is the radial distance of i from the mandrel axis of rotation.
- y_i is the distance of i in the polar direction.

Then ϵ is computed using Equation (19).

The payoff head is assumed to have unit velocity and the velocity of the mandrel is computed as

$$\omega_1 = \Theta_T / 2\pi$$

Then for each point i, using an iterative solution, t_i is computed using Equation (15).

For each point i, $S(\delta)$ is computed directly using Equation (16) or (17).

Values of $S(\delta_i)$, the displacement of the payoff head, are tabulated for each δ_i, where δ_i is the angular position of the payoff head at time t_i. The results of one of the calculations are shown in Figure VII-11.

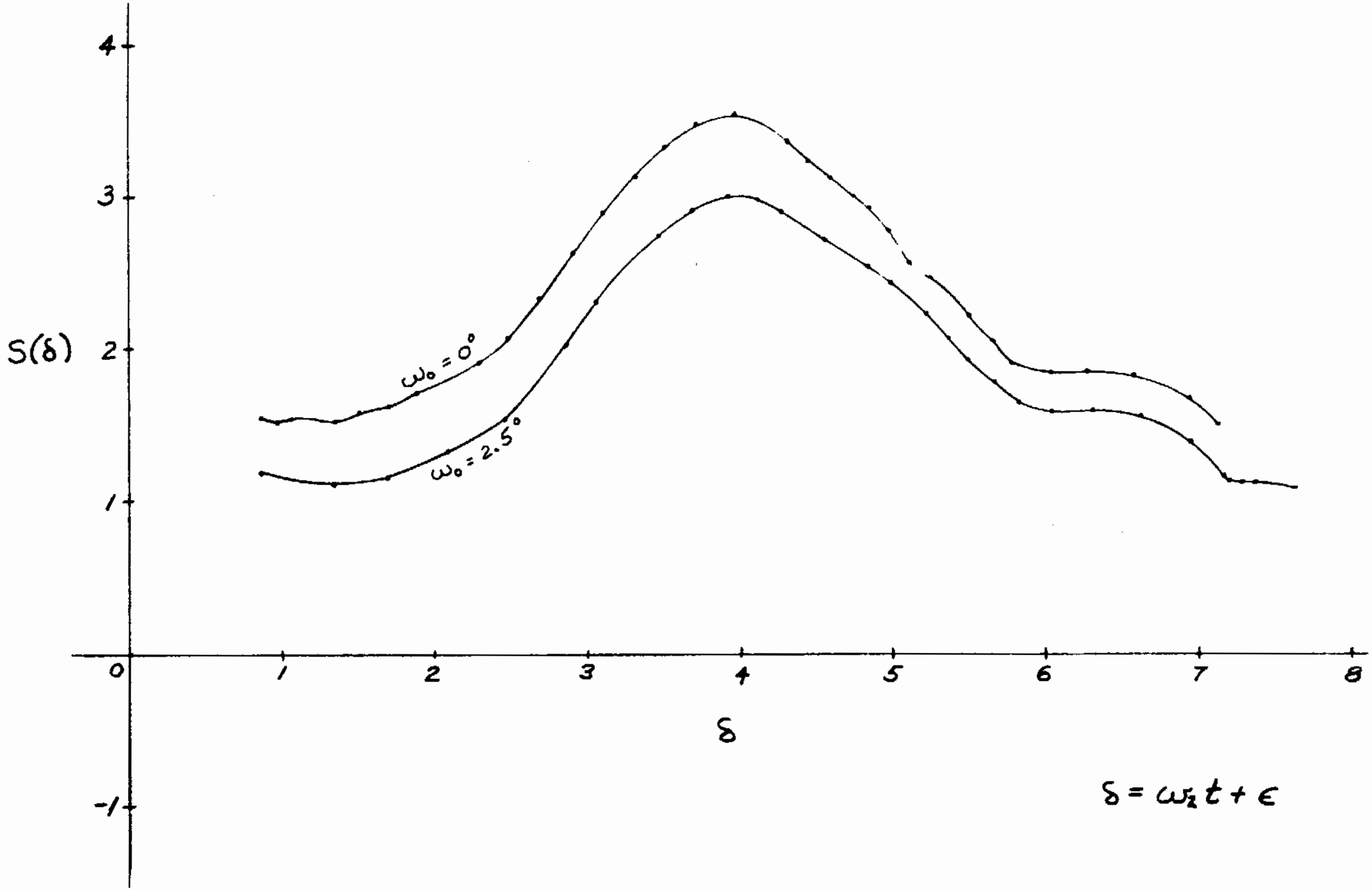


Figure VII-11 . Results of Calculation for S(δ) vs δ

APPENDIX VIII

SUPPLEMENT TO THE WINDING-MACHINE DESIGN ANALYSIS

APPENDIX VIII

SUPPLEMENT TO THE WINDING-MACHINE DESIGN ANALYSIS

To generate equations for checking interference between payoff head and mandrel, assume first that r_p and y_p in the program are the values of r and y at the intersection of the hyperbola to the circle on the "surface for calculations." If they are not on this surface, then they must be corrected for it before the formulae below are used.

Next, check if $r_i < D_2/2$. If not, no intersection is possible (and formulae below are not valid).

If $r_i < D_2/2$, then calculate:

$$r_c = \sqrt{S^2 + (h - k \cos\delta)^2}$$

$$y_c = k \sin\delta$$

These are polar coordinates of the payoff head at a particular value of S = cam stroke

h = cylinder center radial distance

k = cylinder radius

δ = angular displacement of payoff head

We now must find which range y_c is in.

According to the range, different tests apply. If the answer to the test is YES, there is no interference. If the answer is NO, there is interference between payoff head and mandrel.

1. $0 \leq |y_c| \leq y_p$

is $r_c < r_p \left[\cos^2\Delta + (|y_c| \sin\Delta / y_p)^2\right]^{1/2}$

Calculate limit for range of second test.

$$y_b = \frac{fg - cd}{g - d}$$

This is the value of 'y' at the intersection of circular regions III and IV.

2. $y_p < |y_c| \leq y_b$

is $r_c < D_2/2 - \left[(d-g)^2 - (f-c)^2\right]^{1/2} - \left[g^2 - (|y_c| - f)^2\right]^{1/2}$

3. $y_b < |y_c| \leq (d+c)$

is $r_c < D_2/2 - \left[d^2 - (|y_c| - c)^2\right]^{1/2}$

4. $|y_c| > (d+c)$

All symbols conform to those used in the analysis contained in Appendix VII, except as defined above.

APPENDIX IX

FORTRAN IV COMPUTER LISTING

APPENDIX IX

FORTRAN IV COMPUTER LISTING

This section contains the program listing for both the WRAP program and the CAM program. The BLOCK DATA subprogram is listed in Appendix X as input for the sample problem.

```
              C703A           WRAP PROGRAM *** FOR THE DESIGN OF CAMS TO
              C                              FILAMENT WIND TOROIDS
              C
0001                EXTERNAL FT2A,FS2A,FT2B,FS2B,FT2C,FS2C
0002                COMMON /AA/ ALPH(30),RAD(30),DEGR(30),AMIN(30),NO
0003                COMMON /BB/ D2,D3
0004                COMMON /CC/ R1,R2,R3
0005                COMMON /DD/ L1,L2,L3
0006                COMMON /EE/ ST1,ST3,RRHO1
0007                COMMON /FF/ R(100),Y(100),THETA(100),PHI(100),AL(100)
0008                COMMON /GG/ YC(10),DGR(10),AMN(10),N4
0009                COMMON /HH/ DELPHI,ALMIN,ALMAX,AM,DELTA,DLO
0010                COMMON/II/A,B,C,D,F,G,SR0,SR1,SR2
0011                DIMENSION ALC(10)
0012                DIMENSION ARC(100)
0013                REAL L1,L2,L3
0014                REAL L,M
0015                DATA  PI/3.141593/
0016                DATA RADIAN/57.29578/
0017                ASIN(ARG) = ATAN2(ARG,SQRT(1.0-ARG**2))
0018                ACOS(ARG)=ATAN2(SQRT(1.0-ARG**2),ARG)
0019                TAN(ARG) = SIN(ARG)/COS(ARG)
              C
              C     MESSAGE TO PRINTER OPERATOR
              C
0020                WRITE (1,1000)
0021           1000 FORMAT (1HS,10X,67HPLACE 5081 MANILA CARDS INTO PUNCH STACKER,BCD
                   1PUNCH OUTPUT FOLLOWS)
0022                JMAX = 2C
0023                IMAX = 10
0024                DELPHI = DELPHI / RADIAN
              C
              C     SET UP RHO VALUES
              C
0025                RRHC1 =1./RRHO1
0026                RRHO = RRHO1
              C
              C     AM IS NUMBER OF TURNS ON MANDREL REQUIRED
              C
0027                IPASS = 0
              C
```

```
0028              DELTA = DELTA/RADIAN
0029              DELTC = CELTA
0030              DTO = 9999.0
            C
            C     CONVERT DEGREES AND MINUTES OF WINDING PATH TO RADIANS
            C
0031              DO  100 I=1,NO
0032              ALPH(I) = DEGR(I)/RADIAN + AMIN(I)/RADIAN/60.0
0033          100 RAD(I) = RAD(I)/2.0
            C
            C     ALMIN IS MINIMUM VALUE FOR ALPH (NO)
            C
0034              ALMIN = ALMIN / RADIAN
            C
            C     ALMAX IS MAXIMUM
            C
0035              ALMAX = ALMAX / RADIAN
0036              N1 = NO -1
0037              N2 = NO -2
            C     INITIALIZE ALPH (N1)
0038              ALPHC = ALPH(N1)
            C
0039              SR1 = D2/2.C
0040              D5 = SQRT(ABS((R2-R1)**2-(L2-L1)**2))
0041              SRO = SR1 + D5
0042              A = L2
0043              C = L1
0044              F = L3
0045              SR2 = D3/2.+ R3
0046              IF((R2-R1).LE.0.C) GO TO 20
0047              RB1 = R2*D5/(R2-R1)
0048              YB1 = R2*(L2-L1)/(R2-R1)
0049              GO TO 21
0050           20 RB1 = 0.C
0051           21 RA = D2/2. + RB1
0052              ST = 0.0
0053              KPASS = C
0054           13 D = R2 + ST
0055              G = R3+ST
0056              B= R1+ST
0057              ASTAR = G**2 -D**2
```

```
0058            BSTAR = -2.0* (G**2*SR1 -D**2*SR2)
0059            CSTAR = G**2*SR1**2 -D**2*SR2**2
          C
          C     RB, YB IS POINT OF INTERSECTION OF CIRCULAR SECTIONS II B AND II C
          C
0060            RMIN = D3 / 2.C - ST
0061            RB =(-BSTAR+ SQRT(ABS(BSTAR**2 -4.0*ASTAR*CSTAR)))/(2.0*ASTAR)
0062            YB = C +SQRT(ABS(D**2-(RB-SR1)**2))
0063            IF (KPASS.EQ.1) GO TO 14
0064            KPASS = 1
0065            ST = ST1 + ST3
0066            WRITE (6,12)
0067         12 FORMAT (1H1,20X,18HWINDING PATH TABLE //1H0,10X, 7HSTATION,10X,12H
               XWINDING PATH,15X,6HRADIUS   )
0068            DO 36 I = 1,NO
0069            IF (RAD(I).LT.RB) GO TO 33
0070            IF (RAD(I).LT.RA)  GO TO 32
0071            IF (I.GT.1) GO TO 31
0072            RAD(I) = RAD(I) + ST
0073            GO TO 35
0074         31 YII = A + SQRT(B**2 - (SRO - RAD(I)) **2)
0075            GAMMA = ATAN2(YII-A,SRO-RAD(I))
0076            GO TO 34
0077         32 YII = C + SQRT(D**2 - (SR1 - RAD(I)) **2)
0078            GAMMA = ATAN2(YII-C,SR1-RAD(I))
0079            GO TO 34
0080         33 YII = F + SQRT(G**2 - (SR2 - RAD(I)) **2)
0081            IF(I.EQ.NO) GO TO 37
0082            GAMMA = ATAN2(YII-F,SR2-RAD(I))
0083            GO TO 34
0084         37 GAMMA = C.0
0085         34 RAD(I) = RAD(I) - ST * COS(GAMMA)
0086         35 ALOU = ALPH(I) * RADIAN
0087         36 WRITE (6,11) I,ALOU,RAD(I)
0088         11 FORMAT (1H0,10X,I5,12X,F10.3,17X,F8.3)
0089            GO TO 13
          C
          C     SET UP LIMITS OF INTERGRATION
          C
0090         14 PHIC = C.C
0091            IF (ABS(D5).LT.1.0E-2) GO TO 15
```

```
0092              PFIA = ATAN2((L2-L1),D5)
0093              GO TO 16
0094           15 PHIA = PI/2.C
0095           16 CONTINUE
            C
            C     COMPUTE ANGLE OF ADVANCE ACROSS SECTION II A
            C
0096              CALL ROMBRG(FT2A,10,PHIO,PHIA,TH2A)
            C
            C     COMPUTE ARC LENGTH ACROSS SECTICN II A
            C
0097              CALL ROMBRG(FS2A,10,PHIO,PHIA,S2A)
0098              IF(N4.LE.1) GO TO 161
            C
            C     CCNVERT DEGREES AND MINUTES OF CYLINDER WINDING PATH TC RADIANS
            C
0099              DO  160 I=1,N4
0100          160 ALC(I) = DGR(I)/RADIAN + AMN(I)/RADIAN/60.0
            C
            C     SI IS ARC LENGTH ACRCSS CUTER CYLINDER
            C
0101              THI = 0.C
0102              SI = C.0
0103              NPS = N4-1
0104              DO 170 I =1,NPS
0105              J = N4-I
0106              DY = YC(J+1) - YC(J)
0107              ARM = DY/COS(ALC(J))
0108              SI = SI + ARM
0109          170 THI = THI + ARM*SIN(ALC(J))/(SRC+B)
0110              GO TO 175
            C
            C     THI IS ANGLE OF ADVANCE ACROSS CUTER CYLINDER
            C
0111          161 SI = A/CCS(ALPH(1))
0112              THI = SI*SIN(ALPH(1))/ (SRC+B)
0113          175 CONTINUE
0114              THI     = RADIAN *    THI
0115              WRITE (6,1) A,B,C,D,F,G,SRO,SR1,SR2,RB,YB
0116            1 FORMAT (2H01,1P10E12.4)
0117              WRITE (6,2) SI,THI
```

```
0118          2 FORMAT ( 2H02 ,1P10E12.4)
0119            THI = THI / RADIAN
          C
0120            J=1
0121        150 IK = 0
          C     GUESS INITIAL R3P
          C
0122            SIND = SIN(DELTA)
0123            ICV=0
0124            KV=C
0125            IPSS=1
0126            RMAX = RAD(N2)
0127            DLR = DLO
0128            R3P=RMIN
0129        333 IF (R3P.GT.RB) GO TO 337
0130            AP=F+SQRT(ABS(G**2-(R3P-SR2)**2))
0131            APP=(F+SQRT(ABS(F**2+4.0*(SR2-R3P)*(R3P*SIND**2))))/2.0
0132            PH = ATAN((SR2-R3P) / (AP-F))
0133            GC TO 338
0134        337 AP = C + SQRT(ABS(D**2 -(R3P-SR1)**2))
0135            APP =(C + SQRT(ABS(C**2 +4.*(SR1-R3P)*(R3P*SIND**2))))/2.0
0136            PH = ATAN((SR1-R3P) / (AP-C))
0137        338 CONTINUE
0138            SINP = SIN(PH)
0139            COSP = COS(PH)
0140            WRITE (6,9) R3P,AP,PH,APP,DLR
0141          9 FORMAT ( 2H09, 1P10E12.4)
0142            IF(ABS(APP-AP).LT.1.0E-3)GO TO 366
0143            SIGN2=1.C
0144            IF(APP-AP.LT.0.C)SIGN2=-1.C
0145            GO TO (344,355),IPSS
0146        344 R3P=R3P+DLR
0147            IF(R3P.GT.RMAX) GO TO 377
0148            IF(R3P.LT.RMIN) GO TO 388
0149            KV=KV+1
0150            IF(KV.GT.30) GO TO 366
0151            IPSS=2
0152            SIGN1=SIGN2
0153            GC TO 333
0154        355 IF(SIGN2.EQ.SIGN1) GO TO 344
0155            DLR=-DLR/2.0
```

```
0156            KV=C
0157            IDV=IDV+1
0158            IF(IDV.GT.5) GO TO 366
0159            GO TO 344
0160        377 R3P=RMAX
0161            AP = C + SQRT(ABS(D**2 -(R3P-SR1)**2))
0162            PH = ATAN((SR1-R3P) / (AP-C))
0163            GO TO 366
0164        388 R3P=RMIN
0165            AP=F+SQRT(ABS(G**2-(R3P-SR2)**2))
0166            PH = ATAN((SR2-R3P) / (AP-F))
0167        366 CONTINUE
          C
          C     R3P IS R COORDINATE OF HYPERBOLA-CIRCLE INTERSECTION
          C
          C
          C     AP IS APRIME-Y COORDINATE OF INTERSECTION OF HYPERBOLIC SECTION
          C     AND SECTION II C
          C
          C
          C     SINE(DELTA) - DELTA IS ANGLE OF ADVANCE ACROSS HYPERBOLIC SECTION
          C
          C
          C     ALQ IS WINDING PATH AT MINIMUM POINT OF HYPERBOLA
          C
0168            ALQ = ATAN2(R3P*SIND,AP)
0169            COSQ = COS(ALQ)
0170            SINQ = SIN(ALQ)
          C
          C     ALPRP IS WINDING PATH COMPUTED USING EQUATION FOR WINDING PATH
          C     ACROSS HYPERBOLA
          C
0171            SINT = SIND
0172            ARG = 1.0 / 2.0 * (SINP/COSQ + COSQ/SINP - COSQ * COSP**2/SINP
               X*((TAN(ALQ) * TAN(PH))**2 -2.0*SINT*TAN(ALQ)*TAN(PH) +1.0))
0173            ALPN  = ACOS(ARG)
0174            IF (ALPN .GT.PI/2.0) ALPN  = PI - ALPN
          C
          C     INTERPOLATE FOR NEW ALPH (NO)
          C
0175            IF(R3P.LT.RAD(N1)) GO TO 449
```

```
0176            ALPH(N1) = ALPH(N2) +(ALPN -ALPH(N2))*(RAD(N1)-RAD(N2))/(R3P -
               X RAD(N2))
0177            GO TO 450
0178        449 ALPH(N1) = ALPHO
0179        450 ALPH(NO) = ALPH(N1) +(ALPN -ALPH(N1))*(RAD(NO)-RAD(N1))/(R3P -
               X RAD(N1))
0180            IF (ALPH(NO).GT.ALMAX) ALPH(NO) = ALMAX
0181            IF (ALPH(NO).LT.ALMIN) ALPH(NO) = ALMIN
0182            ALPRU    = RADIAN *    ALPN
0183            ALU      = RADIAN *    ALQ
0184            DELL = ASIN(SIND) * RADIAN
0185            WRITE (6,3) R3P,AP,ALPRU,DELL,ALU,ALPH(N1),ALPH(NO)
0186          3 FORMAT ( 2H03 ,1P10E12.4)
          C
          C     TEST FOR CONVERGENCE ON ALPHA
          C
          C     SAVE PREVIOUS R3P
          C
          C
          C     COMPUTE NEW R3P
          C
          C
          C     IF NO CHANGE IN R3P SINCE LAST PASS-ACCEPT VALUE
          C
0187        300 DELTA = ASIN(SIND)
          C
          C     SDEL IS ARC LENGTH ACROSS HYPERBOLIC SECTION
          C
0188            SDEL = R3P * SIND /SIN(ALQ)
          C
          C
0189            PHIB = PI - ATAN2(YB-C,SR1-RB)
0190            PHIC = 0.0
0191            TH2C = 0.0
0192            S2C = 0.0
0193            IF (R3P.GT.RB) GO TO 303
0194            PHIC = PI - ATAN2(AP-F,SR2-R3P)
0195            CALL ROMBRG(FT2C,10,PHIB,PHIC,   TH2C)
          C
          C     COMPUTE ARC LENGTH ACROSS SECTION II C
          C
```

```
0196              CALL ROMBRG(FS2C,10,PHIB,PHIC,    S2C)
0197              GC TO 3C7
0198          303 CCNTINUE
0199              PHIB = PI - ATAN2(AP-C,SR1-R3P)
0200          307 CCNTINUE
            C
            C     COMPUTE ANGLE OF ADVANCE ACROSS SECTION II B
            C
0201              CALL ROMBRG(FT2B,1C,PHIA,PHIB,TH2B)
            C
            C     COMPUTE ARC LENGTH ACROSS SECTICN II B
            C
0202              CALL ROMBRG(FS2B,10,PHIA,PHIB,    S2B)
0203              WRITE (6,5) DELTA,SDEL,PHIO,PHIA,PHIB,PHIC
0204            5 FORMAT ( 2H05, 1P1CE12.4)
0205              TH2C = TH2C * RADIAN
0206              TH2B = TH2B * RADIAN
0207              TH2A = TH2A * RADIAN
0208              WRITE (6,6) TH2A,S2A,TH2B,S2B,TH2C,S2C
0209            6 FORMAT ( 2H06, 1P10E12.4)
0210              TH2A = TH2A / RADIAN
0211              TH2C = TH2C / RADIAN
0212              TH2B = TH2B / RADIAN
0213              RHO = RRHO /(SRO+B)
            C
            C     T IS TOTAL ANGLE OF ADVANCE UN MANDREL FOR 1 REVCLUTION OF PAYOFF
            C     HEAD
            C
0214              T =(THI + DELTA + TH2A+TH2B +TH2C)*2.0
            C
            C     AN IS NUMBER OF REVOLUTICNS OF PAYOFF HEAD REQUIRED
            C
0215              AN =(2.0* PI*AM +RHO) /T
0216              NT =AN +0.5
            C
            C     T COMPUTE DELTA T REQUIRED
            C
0217              DT =(2.0*PI*AM + RHO)/FLOAT(NT) -T
            C
            C     TEST FOR CHANGE IN T
            C
```

```
0218            IF (ABS(DT).LT.1.0E-6) GO TO 400
          C
          C     TEST FOR CHANGE IN DT FROM PREVIOUS PASS
          C
0219            IF (ABS(DT-DTO).LT.1.0E-5) GO TO 310
0220            DTO = DT
          C
          C     COMPUTE NEW DELTA
          C
0221            DELN = DELTA +DT /2.0
0222            DELTA = DELN
          C
          C     COMPUTE NEW ALPHA (WINDING PATH)
          C
0223            SINDN = SIN(DELN)
0224            SIND = SINDN
0225            DELN = DELN * RADIAN
0226            DT = DT * RADIAN
0227            T    = T    * RADIAN
0228            WRITE (6,7) RHO,ALPH(NO),T,AN,DT,DELN,ALPN,SINDN,AM
0229          7 FORMAT ( 2HO7, 1P10E12.4)
0230            DELN = DELN / RADIAN
0231            DT = DT / RADIAN
0232            T    = T    / RADIAN
0233            J=J+1
0234            IF (J.LT.JMAX) GO TO 150
          C
          C     INCREASE M BY 1
          C
0235        310 AM =AM+1.0
0236            IF (AM.GT.5.0)    GO TO 400
          C
          C     RESET ALPH N1
0237            ALPH(N1) = ALPHO
          C
0238            DELTA = DELTO
          C
          C     RESET COUNTER
          C
0239            J=1
0240            GO TO  150
```

```
0241        400 CONTINUE
0242            WRITE (6,7) RHO,ALPH(NO),T,AN,DT,DELN,ALPN,SINDN,AM
0243            WRITE(1,88) C,F,D,G,SR1,YB,R3P,AP,DELTA
0244         88 FORMAT ('P',6E12.5)
           C
           C    COMPUTE PHI AT POINTS OF INTERSECTION OF SECTIONS
           C
0245            PHI1 = PI/2.0
0246            IF (ABS(D5).LT.1.0E-2) GO TO 17
0247            PHIAB = ATAN2(RB1,YB1)
0248            GO TO 18
0249         17 PHIAB =0.0
0250         18 CONTINUE
0251            IF(R3P.LT.RB) GO TO 410
0252            PHIC3= +ATAN2((AP-C),(SR1-R3P)) - PI/2.0
0253            PHIBC = PHIC3
0254            GO TO 42C
0255        410 PHIC3= +ATAN2((AP-F),(SR2-R3P)) - PI/2.0
0256            PHIBC=+ATAN2((YB-C),(SR1-RB)) - PI/2.0
0257        420 PHIW = PHI1  * RADIAN
0258            PHIX = PHIAB * RADIAN
0259            PHIY = PHIBC * RADIAN
0260            PHIZ = PHIC3 * RADIAN
0261            WRITE (6,8) PHIW,PHIX,PHIY,PHIZ
0262          8 FORMAT ( 2H08, 1P10E12.4)
0263            PHI(1) = -PI/2.0
           C
           C    GENERATE TABLE OF RADIUS (R), Y-COORDINATE (Y), ANGLE OF ADVANCE
           C    (THETA), WINDING PATH (AL), ANGLE NORMAL TO MANDREL
           C    MAKES WITH Y-AXIS (PHI)
           C
0264            Y(1) =0.C
0265            R(1) = R3P*COS(DELTA)
0266            THETA(1) = 0.0
0267            AL(1) = ALO
0268            ARC(1) = 0.0
           C
           C    NPTS IS NUMBER OF POINTS IN TABLE
           C
0269            NP   = PI/DELPHI+1.5
0270            NPS = N4 - 1
```

```
      NPTS = NP + NPS
      NPT = NPTS + 1
      DO  601  I=1,NPTS
      IF (I.EQ.1) GO TO 60C
      PHI(I) = DELPHI*FLOAT(I-1) + PHI(1)
      IF(I.GT.NP) PHI(I) = PHI(NP)
      IF (PHI(I).GE.PI/2.0-DELPHI/10.C) GO TO 550
      IF(PHI(I).EQ.0.0) GO TO 531
      TANP= TAN(PI/2.C+PHI(I))
      IF (PHI(I).GT.PHIAB) GO TO 540
      IF (PHI(I).GT.PHIBC) GO TO 530
      IF (PHI(I).GT.PHIC3) GO TO 520
C
C     FOR PHI LESS THAN PHIC3
C
  510 L = R3P**2 *SIND**2/AP**2/TAN(PI/2.0+PHI(I))
      Y(I) =  COS(DELTA) /SQRT((L/R3P)**2 -(SIND/AP)**2)
      R(I) = Y(I) *L
      ARC(I) = Y(I) * SDEL / AP
      RCE = R3P * COS(DELTA)
      ARG = RCE / R(I)
      THETA(I) = ACOS(ARG)
      GO TO 575
C
C     FOR PHI LESS THAN PHIBC
C     AND GREATER THAN PHIC3
C
  52C L= SR2 + F/ TANP
      M =  -1.0/TANP
      ASTAR = M**2 +1.0
      BSTAR =2.C*M*(L-SR2) -2.0*F
      CSTAR=(L-SR2)**2 +F**2 -G**2
      ARGU = BSTAR**2 - 4.0 * ASTAR * CSTAR
      Y(I) = (-BSTAR + SQRT(ABS(ARGU)))/(2.0*ASTAR)
      R(I) = L +M*Y(I)
      IF (PHI(I-1).GE.PHIC3) GO TO 525
      PHIL = PI/2.C -PHI(I)
      PHIU = PI/2.C -PHIC3
      CALL ROMBRG(FT2C,10,PHIL,PHIU,THETA(I))
      CALL ROMBRG(FS2C,10,PHIL,PHIU,ARC(I))
      THETA(I) = THETA(I) + DELTA
```

```
      ARC(I) = ARC(I) +SDEL
      GO TO 575
  525 PHIL= PI/2.-PHI(I)
      PHIU= PI/2.-PHI(I-1)
      CALL ROMBRG(FT2C,10,PHIL,PHIU,THETA(I))
      CALL ROMBRG(FS2C,10,PHIL,PHIU,ARC(I))
      THETA(I)= THETA(I)+THETA(I-1)
      ARC(I) = ARC(I) + ARC(I-1)
      GO TO 575
C
C     FOR PHI LESS THAN PHIAB
C     AND GREATER THAN PHIBC
C
  530 L = SR1 + C/TANP
      M = -1.0 / TANP
      ASTAR = M**2 +1.0
      BSTAR = 2.0*M*(L-SR1) -2.0*C
      CSTAR = (L-SR1)**2 +C**2 - D**2
      ARGU = BSTAR**2 - 4.0 * ASTAR * CSTAR
      Y(I) = (-BSTAR + SQRT(ABS(ARGU)))/(2.0*ASTAR)
      R(I) = L +M*Y(I)
      GO TO 532
  531 Y(I) = D+C
      R(I) = SR1
  532 IF (PHI(I-1).GE.PHIBC)GO TO 535
      IF(R3P.GT.RB) GO TO 430
      PHIL =-PHIBC +PI/2.0
      PHIU = PI/2.0 -PHI(I-1)
      CALL ROMBRG(FT2C,10,PHIL,PHIU,THA)
      CALL ROMBRG(FS2C,10,PHIL,PHIU,ARL)
  430 PHIL= PI/2.0 - PHI(I)
      PHIU= PI/2.0 -  PHIBC
      CALL ROMBRG(FT2B,10,PHIL,PHIU,THB)
      CALL ROMBRG(FS2B,10,PHIL,PHIU,ARM)
      IF(R3P.GT.RB) GO TO 440
      THETA(I) = THETA(I-1) + THA+THB
      ARC(I) =ARC(I-1)+ARL + ARM
      GO TO 575
  440 THETA(I) = THB + DELTA
      ARC(I) = ARM + SDEL
      GO TO 575
```

```
0342        535 PHIL = PI/2.0 - PHI(I)
0343            PHIU = PI/2.C - PHI(I-1)
0344            CALL ROMBRG(FT2B,10,PHIL,PHIU,THA)
0345            CALL ROMBRG(FS2B,10,PHIL,PHIU,ARL)
0346            THETA(I) =THETA(I-1) +THA
0347            ARC(I) =ARC(I-1) + ARL
0348            GC TO 575
           C
           C    PHI IS LESS THAN PI / 2
           C    AND GREATER THAN PHIAB
           C
0349        54C L = SRO + A/TANP
0350            M = -1.0 / TANP
0351            ASTAR = M**2 +1.0
0352            BSTAR = 2.0*M*(L-SRO) -2.0*A
0353            CSTAR = (L-SRO)**2 +A**2 - B**2
0354            ARGU = BSTAR**2 - 4.0 * ASTAR * CSTAR
0355            Y(I) = (-BSTAR + SQRT(ABS(ARGU)))/(2.0*ASTAR)
0356            R(I) = L +M*Y(I)
0357            IF (PHI(I-1).GE.PHIAB) GO TO 545
0358            PHIL = PI/2.0 - PHIAB
0359            PHIU = PI/2.C - PHI(I-1)
0360            CALL ROMBRG(FT2B,10,PHIL,PHIU,THA)
0361            CALL ROMBRG(FS2B,10,PHIL,PHIU,ARL)
0362            PHIU = PHIL
0363            PHIL = PI/2.C- PHI(I)
0364            CALL ROMBRG(FT2A,10,PHIL,PHIU,THB)
0365            CALL ROMBRG(FS2A,10,PHIL,PHIU,ARM)
0366            THETA(I) = THETA(I-1) +THA+THB
0367            ARC(I)= ARC(I-1) + ARL+ARM
0368            GC TO 575
0369        545 PHIU = PI/2.C - PHI(I-1)
0370            PHIL = PI/2.C- PHI(I)
0371            CALL ROMBRG(FT2A,10,PHIL,PHIU,THB)
0372            CALL ROMBRG(FS2A,10,PHIL,PHIU,ARM)
0373            THETA(I) = THETA(I-1)      +THB
0374            ARC(I) = ARC(I-1) + ARM
0375            GO TO 575
           C
           C    FOR PHI EQUAL TO PI/2
           C
```

```
  550 IF(I.EQ.NP) GO TO 551
      THA = 0.0
      ARL = 0.0
      GO TO 552
  551 PHIL =PI/2.0 -PHI(I)
      PHIU =PI/2.0 -PHI(I-1)
      CALL ROMBRG(FT2A,10,PHIL,PHIU,THA)
      CALL ROMBRG(FS2A,10,PHIL,PHIU,ARL)
      IF(N4.LE.1) GO TO 553
  552 Y(I) = YC(NPT - I)
      AL(I) = ALC(NPT - I)
      ALP = AL(I)
      IF(I.EQ.NP) GO TO 555
      DY = YC(NPT-I+1) - YC(NPT-I)
      ARM = DY/COS(ALP)
      GO TO 554
  555 ARM = 0.0
      GO TO 554
  553 Y(I)=0.0
      ARM =  A/COS(ALPH(1))
      ALP = ALPH(1)
  554 R(I) = SRO + B
      THETA(I)=ARM*SIN(ALP)/R(I)     + THETA(I-1)+ THA
      ARC(I) = ARC(I-1)+ARL+ARM
      IF(N4.LE.1) GO TO 575
      GO TO 600
  575 IF(R(I).LT.R3P) GO TO 590
C
C     COMPUTE ALPHA WINDING PATH USING TABLE
C
      AL(I) = TABL(R(I))
      GO TO 600
  590 SINZ = SQRT (1.0- ACOS(R3P*COS(DELTA)/R(I))**2)
C
C     COMPUTE WINDING PATH USING HYPERBOLA EQUATION
C
      COSQ = COS(ALQ)
      SINQ = SIN(ALQ)
      PH = - PHI(I)
      SINP = SIN(PH)
      COSP = COS(PH)
```

```
0411              SINT = SIN(THETA(I))
0412              ARG = 1.C / 2.0 * (SINP/COSQ + COSQ/SINP - COSQ * COSP**2/SINP
                 X*((TAN(ALQ) * TAN(PH))**2 -2.0*SINT*TAN(ALQ)*TAN(PH) +1.0))
0413              ALPRP = ACOS(ARG)
0414              IF (ALPRP.GT.PI/2.0) ALPRP = PI - ALPRP
0415              AL(I) = ALPRP
0416          600 WRITE(6,10)I,PHI(I),R(I),Y(I),THETA(I),AL(I),ARC(I)
0417              WRITE(1,99)  PHI(I),R(I),Y(I),THETA(I),AL(I),ARC(I)  ,I
0418         99   FORMAT ('P',6E12.5,I8)
0419          601 CONTINUE
0420           10 FORMAT (3H010, I12,1P6E14.6)
0421              RETURN
0422              END
```

```
0001          FUNCTION FS2A(PHI)
        C
        C     COMPUTE VALUE (ARC LENGTH) FOR DS AS FUNCTION OF DO
        C     CIRCULAR SECTION II A
        C
0002          COMMON/II/A,B,C,D,F,G,SRO,SR1,SR2
0003          REAL L,M
0004          IF(ABS(PHI-1.570796).LT.1.0E-05) GO TO 7
0005          TANP= SIN(       -PHI)/COS(       -PHI)
0006          IF(ABS(TANP).LT.1.0E-02) GO TO 5
0007          L = SRO + A / TANP
0008          M= -1.0/TANP
0009          AS =M**2+1.0
0010          BS = 2.0*M*(L-SRO) -2.0*A
0011          CS = (L-SRO)**2 + A**2 -B**2
0012          Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
0013          R = L+M*Y
0014          GO TO 6
0015        5 Y = A
0016          R = SRO + B
0017          GO TO 6
0018        7 Y = A+B
0019          R = SRO
0020        6 ALP = TABL(R)
0021          FS2A = B/COS(ALP)
0022          RETURN
0023          END
```

```
0001             FUNCTION FT2A(PHI)
            C
            C    COMPUTE VALUE FOR (ANGLE OF ADVANCE) AS FUNCTION OF DO (PHI)
            C    FOR ROMBERG INTEGRATION
            C    CIRCULAR SECTION II A
            C
0002             COMMON/II/A,B,C,D,F,G,SRC,SR1,SR2
0003             REAL L,M
0004             IF(ABS(PHI-1.570796).LT.1.0E-05) GO TO 7
0005             TANP= SIN(       -PHI)/COS(       -PHI)
0006             IF(ABS(TANP).LT.1.0E-02) GO TO 5
0007             L = SRO + A / TANP
0008             M= -1.0/TANP
0009             AS =M**2+1.0
0010             BS = 2.0*M*(L-SRO) -2.0*A
0011             CS = (L-SRO)**2 + A**2 -B**2
0012             Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
0013             R = L+M*Y
0014             GO TO 6
0015           5 Y = A
0016             R = SRO + B
0017             GO TO 6
0018           7 Y = A+B
0019             R = SRO
0020           6 ALP = TABL(R)
0021             FT2A = SIN(ALP)/COS(ALP)*B/(SRO+B*COS(PHI))
0022             RETURN
0023             END
```

```
      FUNCTION FS2B(PHI)
C
C     COMPUTE VALUE (ARC LENGTH) FOR DS AS FUNCTION OF DO
C     CIRCULAR SECTION II B
C
      COMMON/II/A,B,C,D,F,G,SR0,SR1,SR2
      REAL L,M
      IF(ABS(PHI-1.570796).LT.1.0E-05) GO TO 5
      TANP= SIN(        -PHI)/COS(        -PHI)
      L = SR1 + C / TANP
      M= -1.0/TANP
      AS =M**2+1.0
      BS = 2.0*M*(L-SR1) -2.0*C
      CS = (L-SR1)**2 + C**2 -D**2
      Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
      R = L+M*Y
      GO TO 6
    5 Y = D+C
      R = SR1
    6 ALP = TABL(R)
      FS2B= D/ COS(ALP)
      RETURN
      END
```

```
0001                FUNCTION FT2B(PHI)
              C
              C     COMPUTE VALUE FOR (ANGLE OF ADVANCE) AS FUNCTION OF DO (PHI)
              C     FOR ROMBERG INTEGRATION
              C     CIRCULAR SECTION II B
              C
0002                COMMON/II/A,B,C,D,F,G,SR0,SR1,SR2
0003                REAL L,M
0004                IF(ABS(PHI-1.570796).LT.1.0E-05) GO TO 5
0005                TANP= SIN(       -PHI)/COS(       -PHI)
0006                L = SR1 + C / TANP
0007                M= -1.0/TANP
0008                AS =M**2+1.0
0009                BS = 2.0*M*(L-SR1) -2.0*C
0010                CS = (L-SR1)**2 + C**2 -D**2
0011                Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
0012                R = L+M*Y
0013                GO TO 6
0014              5 Y = D+C
0015                R = SR1
0016              6 ALP = TABL(R)
0017                FT2B= SIN(ALP)/COS(ALP)*D/(SR1+D*COS(PHI))
0018                RETURN
0019                END
```

```
FORTRAN IV G LEVEL 0, MOD 0            FS2C            DATE = 67353        10/28/23          PAGE 0001

 0001                FUNCTION FS2C(PHI)
              C
              C      COMPUTE VALUE (ARC LENGTH) FOR DS AS FUNCTION OF DO
              C      CIRCULAR SECTION II C
              C
 0002                COMMON/II/A,B,C,D,F,G,SR0,SR1,SR2
 0003                REAL L,M
 0004                TANP= SIN(        -PHI)/COS(       -PHI)
 0005                L = SR2 + F/TANP
 0006                M= -1.0/TANP
 0007                AS =M**2+1.0
 0008                BS = 2.0*M*(L-SR2) -2.0*F
 0009                CS = (L-SR2)**2 + F**2 -G**2
 0010                Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
 0011                R = L+M*Y
 0012                ALP = TABL(R)
 0013                FS2C = G / COS(ALP)
 0014                RETURN
 0015                END
```

```
FORTRAN IV G LEVEL 0, MOD 0              FT2C              DATE = 67353          10/28/23                PAGE 0001

 0001                  FUNCTION FT2C(PHI)
                 C
                 C     COMPUTE VALUE FOR (ANGLE OF ADVANCE) AS FUNCTION OF DO (PHI)
                 C     FOR ROMBERG INTEGRATION
                 C     CIRCULAR SECTION II C
                 C
 0002                  COMMON/II/A,B,C,D,F,G,SR0,SR1,SR2
 0003                  REAL L,M
 0004                  TANP= SIN(       -PHI)/COS(       -PHI)
 0005                  L = SR2 + F/TANP
 0006                  M= -1.0/TANP
 0007                  AS =M**2+1.0
 0008                  BS = 2.0*M*(L-SR2) -2.0*F
 0009                  CS = (L-SR2)**2 + F**2 -G**2
 0010                  Y = (-BS+SQRT(ABS(BS**2-4.0*AS*CS)))/(2.0*AS)
 0011                  R = L+M*Y
 0012                  ALP = TABL(R)
 0013                  FT2C = SIN(ALP)/COS(ALP)*G/(SR2 +G* COS(PHI))
 0014                  RETURN
 0015                  END
```

```
FORTRAN IV G LEVEL 0, MCD 0            TABL            CATE = 67353        10/28/23            PAGE 0001

 0001                FUNCTION TABL(R)
               C
               C     INTERPOLATE IN TABLE OF WINDING PATH (ALPH) VERSUS RADIUS ON
               C     MANCREL
               C
 0002                COMMON /AA/ ALPH(30),RAD(30),DEGR(30),AMIN(30),NO
 0003                DC 100  I= 1,NC
 0004                IF(R.LT.RAD(I)) GO TO 100
 0005                IF (I.EQ.1) GO TO 110
 0006                RXX = RAD(I) - RAD(I-1)
 0007                TABL = (ALPH(I)-ALPH(I-1))*(R-RAD(I))/(RXX        ) + ALPH(I)
 0008                GC TC 12C
 0009            100 CONTINUE
 0010                I=NC
 0011            110 TABL =ALPH(I)
 0012            120 RETURN
 0013                END
```

```
C703B           CAM PROGRAM *** FOR THE DESIGN OF CAMS TO
C                           FILAMENT WIND TOROIDS
C
          DIMENSION WORK(1000),XI(54),PHS(54),SI(54)
          DIMENSION THETA(52),R(52),PHI(52),ALPHA(52),Y(52),S(52),T(52)
          DIMENSION TITLE(5)
          COMMON/NEWC/ARC(52),L1,L3,R2,R3,SR1,YB,R3P,AP,DELTA
          COMMON/PTN/ILOC,PRINT,II,NLOOP,NPLOT,TITLE
          REAL K,L1,L3
          INTEGER   PRINT
          DATA RADIAN/57.29578/
          DATA NTAG/0/
      100 READ (5,330,END=1000) M,ILOC,PRINT,NPLOT
      330 FORMAT (6I12)
          READ (5,341) H,K,OMO,DOMO,NLOOP
      341 FORMAT (4E12.8,8X,I4)
          READ (5,101) TITLE
      101 FORMAT (5A4)
          READ (5,350) L1,L3,R2,R3,SR1,YB,R3P,AP,DELTA
      350 FORMAT (6E12.5)
          READ(5,340) (PHI(I),R(I),Y(I),THETA(I),ALPHA(I),ARC(I),I=1,M)
      340 FORMAT (6E12.5)
       54 OMO = OMO / RADIAN
          IF (NTAG.EQ.1) GO TO 53
          NTAG = 1
          CALL PLOTS(WORK,1000,DUMMY)
       53 CALL PAGE
          CALL PLOT(2.0,0.0,-3)
          DO 55 I=1,NLOOP
          II = I + 1
          CALL GETST(THETA,R,Y,ALPHA,PHI,M,H,K,OMO,T,S)
       55 OMO = OMO + DOMO / RADIAN
          GO TO 100
     1000 CALL PLOT(0.0,0.0,999)
          RETURN
          END
```

```
      SUBROUTINE GETST (THETA,R,Y,ALPHA,PHI,P,H,K,OMO,T,S)
      DIMENSION TITLE(5)
      COMMON/PTN/ILOC,PRINT,II,NLOOP,NPLOT,TITLE
      COMMON/NEWC/ARC(52),L1,L3,R2,R3,SR1,YB,R3P,AP,DELTA
      REAL K,L1,L3
      INTEGER P,COUNT
      INTEGER PRINT
      DIMENSION THETA(2), R(2), Y(2),  ALPHA(2), PHI(2), T(2), S(2)
      DIMENSION SI(54)
      DIMENSION OMEGA(10),XS(54,10),YS(54,10)
      DATA PI,RADIAN/3.14159,57.29578/
      DATA DIV/20.0/,NTAG/0/
      DATA SIMAX,SIMIN/+5.0,-5.0/
C
C     NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS
C        APPENDIX OF TM 153-63-003
C
C
C
C                                                  COMPLETE TABLES
      N=2*P
      L = P+1
      DO  300 I=L,N
      J = N-I
      PHI(I)= PI -PHI(J)
      R(I)= R(J)
      ARC(I) = 2.0 * ARC(P) - ARC(J)
      THETA(I)= 2.0*THETA(P)-THETA(J)
      ALPHA(I)= ALPHA(J)
  300 Y(I)=-Y(J)
C                                                  GET CONSTANTS H + K
      OM2=1.0
      OM1=THETA(P)/PI
C                                                  DETERMIN EPSILON PG 7
C
      A=  K**2*(1.0 +TAN(ALPHA(1))**2* SIN(OMO)**2)
      B=  -2.0*K*(H-R(1)*COS(OMO))
      C=  (H-R(1)*COS(OMO))**2 -K**2*  TAN(ALPHA(1))**2*SIN(OMO)**2
      DEN = 2.0 * A
      ROTT = SQRT(ABS(B**2 - 4.0*A*C))
      R1 = (-B + ROTT) / DEN
```

```
      R2 = (-B - ROTT) / DEN
      IF(ABS(R1) .LT. ABS(R2)) GO TO 320
      RCOT=R2
      IF (OMO.LT.1.0E-2) ROOT = R1
      GO TO 330
  320 ROOT=R1
      IF (OMO.LT.1.0E-2) ROOT = R2
  330 CONTINUE
      IF (OMO.EQ.0.)ROOT = (H-R(1)) / K
      EP = ATAN(SQRT(1.0 - ROOT**2) / ROOT)
C                                            PERFORM ITERATION FOR
C                                            T(I)
      NN=N-1
      DO 1500 I=1,NN
      IROOT = 1
      T(I) = 0.0
      IF(I .NE. 1) GO TO 1000
      TG = 0.0
      T(1)=0.0
      GO TO 1200
C                                            INITAL GUESS + CONSTANT
C                                            QUANITIES FOR DATA POIT
 1000 JMAX = 41
      ICUT = 0
      IL = 0
      ITY = 0
      DT = PI / 40.0
 3050 TG = DT
      IF (IROOT.EQ.1) TG = T(I-1)
      IF (ABS(SIN(PHI(I))).LT.1.0E-2) GO TO 4002
      X1= TAN(ALPHA(I))/SIN(PHI(I))
      X2= THETA(I)-OMO
      IF (1.0 - ABS(SIN(PHI(I)))).LT.1.0E-2) GO TO 4001
      X3 = TAN(PHI(I))
      GO TO 4002
 4001 X3 = 1.0E+20
 4002 TG1 = TG
      KT = 0.C
      IG = 1
 4000 IF (ILOC.GT.0) GO TO 8000
      IF (ABS(SIN(PHI(I))) .GT.1.0E-2) GO TO 1050
```

```
0069               CALP = - COS(ALPHA(I))
0070               Z=THETA(I)-OMO-OM1*TG
0071               A=COS(ALPHA(I))*COS(PHI(I))*COS(Z)-SIN(ALPHA(I))*SIN(Z)
0072               IF (ABS(A).LT.1.0E-2) GO TO 1044
0073               FT=A*(K*SIN(OM2*TG+EP)-Y(I))/(H- K*COS(OM2*TG+EP)-R(I)* COS(Z))
                  X / CALP
0074               GO TO 1C8C
0075          8000 FT = H - Y(I)*COS(OM2*TG) / SIN(OM2*TG) - R(I) *COS(THETA(I)
                  X - OMO - OM1 * TG)
0076               GO TO 1080
0077          1044 FT = H - K*COS(OM2*TG+EP) - R(I)*COS(Z)
0078               GO TO 1080
              C                                                   EVALUATE  A/B
0079          105C AB= X1*SIN(X2-OM1*TG)-COS(X2-OM1*TG)/X3
              C                                                   EVALUATE COMMON TERMS
0080               V1=COS(OM2*TG+EP)
0081               V2=COS(X2-OM1*TG)
0082               V3=K*SIN(OM2*TG+EP)-Y(I)
0083               V4= (V3+Y(I))*OM2
              C                                                   EVALUATE F(T)
0084               FT=H-K*V1-R(I)*V2-AB*V3
0085          1080 GO TO(5000,6000),IG
0086          5000 FT1 = FT
0087               SIGN1 = -1.0
0088               IF (FT1.GT.0.0) SIGN1 = 1.0
0089               IF (PRINT.EQ.0) GO TO 5050
0090               WRITE (6,144) TG,FT,DT,KT,I
0091          5050 IF (ABS(FT1).LT.1.0E-3) GO TO 1200
0092          3000 TG2 = TG1 + DT
0093               TG = TG2
0094               IG = 2
0095               GO TO 40C0
0096          6000 FT2 = FT
0097               IF (PRINT.EQ.0) GO TO 6050
0098               WRITE (6,144) TG,FT,DT,KT,I
0099           144 FORMAT (10X,3E16.8,2I12)
0100          6050 IF (ABS(FT2).LT.1.0E-3) GO TO 1200
0101               SIGN2 = -1.0
0102               IF (FT2.GT.0.0) SIGN2 = 1.0
0103               IF (SIGN2.NE.SIGN1) GO TO 3100
0104               TG1 = TG2
```

```
           KT = KT + 1
           IF (KT.GT.JMAX) GO TO 3200
           GO TO 3000
      3100 DT = - DT/2.0
           ICUT = ICUT + 1
           IF (ICUT.GT.8) GO TO 1200
           IL = 1
           KT = 0
           SIGN1 = SIGN2
           TG1 = TG2
           GO TC 3000
      3200 DT = DT/2.0
           IF (IL.NE.0) GO TO 1200
           JMAX = JMAX * 2
           ITY = ITY + 1
           IF (ITY.GT.3) GO TO 1201
           GO TO 3050
C                                            DETERMINE S(I)= F(T)
C
      1201 TG = T(I-1)
      1200 T(I) = TG
           IF (ILOC.GT.0) GO TO 8500
           IF (ABS(SIN(PHI(I))) .LT.1.0E-2) GO TO 1250
           X1= TAN(ALPHA(I))/SIN(PHI(I))
           X2= THETA(I)-OMO
           IF (1.0 - ABS(SIN(PHI(I))).LT.1.0E-2) GO TO 8501
           X3=TAN(PHI(I))
           GO TO 85C2
      8501 X3 = 1.0E+20
      8502 CB=-X1*COS(X2-OM1*T(I))-SIN(X2-OM1*T(I))/X3
           S(I) =  CB*(K*SIN(OM2*T(I)+EP)-Y(I))+R(I)*SIN(X2-OM1*T(I))
           GO TO 1499
      8500 S(I) = R(I) * SIN(THETA(I) - OMC - OM1 * T(I))
           IROOT = 1
           GO TO 1499
      1225 S(I) = R(I) * SIN(Z)
           GO TO 1499
      1250 Z=THETA(I)-OMO-OM1*T(I)
           C=COS(ALPHA(I))*COS(PHI(I))*SIN(Z) +SIN(ALPHA(I))*COS(Z)
           A=COS(ALPHA(I))*COS(PHI(I))*COS(Z)-SIN(ALPHA(I))*SIN(Z)
           IF (ABS(A).LT.1.0E-2) GO TO 1225
```

```
            S(I) = R(I)*SIN(Z) + C/A * (H-K*COS(OM2*T(I)+EP) - R(I)*COS(Z))
       1499 IROOT = IROOT + 1
            IF (PRINT.EQ.0) GO TO 9000
            WRITE (6,146) I,T(I),S(I)
        146 FORMAT (I12,2E16.8)
       9000 IF (IROOT.GT.1) GO TO 1500
            GO TO 1000
       1500 CONTINUE
            DO 1600 I=1,N
            THETA(I) = THETA(I) * RADIAN
            PHI(I) = PHI(I) * RADIAN
       1600 ALPHA(I) = ALPHA(I) * RADIAN
            O = OMO * RADIAN
            OMEGA(II-1) = O
            O1 = OM1 * RADIAN
            O2 = OM2 * RADIAN
      C
      C       PREPARE DATA FOR PLOT AND PLOT AXIS IF NEEDED
      C
            DO 2002 I=1,NN
            SI(I) = S(I)
            IF (S(I).LT.0.0) GO TO 1999
            IF (S(I).GT.SIMAX) SI(I) = SIMAX
            GO TO 2992
       1999 IF (ABS(S(I)).GT.SIMAX) SI(I) = SIMIN
       2992 XS(I,II-1) = (OM2 * T(I) + EP) * RADIAN
            YS(I,II-1) = SI(I)
       2002 CONTINUE
       1610 WRITE (6,1620)
       1620 FORMAT (1H1,25X,'***** NUMERICAL SOLUTION OF WINDING MACHINE EQUAT
           1IONS *****')
            WRITE (6,1622) TITLE
       1622 FORMAT (1H0,10X,5A4)
            J = II - 1
            IF (ILOC.GT.0) WRITE (6,1621)
       1621 FORMAT (1H0,30X,'PAYOFF HEAD IS ON SURFACE OF MANDREL')
            WRITE(6,1650) H,K,O  ,O1 ,O2 ,EP
       1650 FORMAT (///1H ,5X,'----- INPUT VALUES -----'/1H ,5X,'H',19X,F15.4/
           11H ,5X,'K',19X,F15.4/1H ,5X,'OMEGA (0)',11X,F15.4/1H ,5X,'OMEGA (1
           2)',11X,F15.4/1H ,5X,'OMEGA (2)',11X,F15.4/1H ,5X,'EPSILON',13X,F16
           3.5)
```

```
0178              WRITE(6,1660)
0179         1660 FORMAT (///15X,'PHI',9X,'R',9X,'THETA',7X,'ALPHA',9X,'Y',10X,'TIME
                 1',9X,'S',6X,'OM2*T+EP'///)
0180              NLINE = 20
0181              COSD = COS(DELTA)
0182              SIND = SIN(DELTA)
0183              YA = R2+L1
0184              DO 1680 I=1,NN
0185              IF(R(I).GT.SR1) GO TO 500
0186              ZZ = OM2*T(I)+EP
0187              RC = SQRT(S(I)**2 + (H-K*COS(ZZ))**2)
0188              YC = ABS(K*SIN(ZZ))
0189              IF(YC.GT.YA) GO TO 500
0190              IF(YC.LE.YB) GO TO 520
0191          510 TST = SR1 - SQRT(R2**2 - (YC-L1)**2)
0192              GO TO 555
0193          520 IF(YC.LE.AP) GO TO 530
0194              TST = SR1 - SQRT((R2-R3)**2 - (L3-L1)**2) - SQRT(R3**2 - (YC-L3)**
                 12)
0195              GO TO 555
0196          530 TST = R3P*SQRT(COSD**2 + (YC*SIND/AP)**2)
0197          555 IF(RC.LT.TST) GO TO 500
0198              WRITE(6,1700)
0199         1700 FORMAT (1H0,10X,'*** CASE TERMINATED *** PAYOFF HEAD PENETRATED MA
                 1NDREL')
0200              GO TO 1681
0201          500 ZZZ = THETA(I) / RADIAN - OMO - OM1 * T(I)
0202              WRITE (6,1670) PHI(I),R(I),THETA(I),ALPHA(I),Y(I),T(I),S(I),
                 1XS(I,II-1),ZZZ
0203         1670 FORMAT(6X,8F12.3,10X,F12.3)
0204              NLINE = NLINE + 1
0205              IF (NLINE.GT.46) NLINE = 0
0206              IF (NLINE.NE.0) GO TO 1680
0207              WRITE (6,1620)
0208              WRITE (6,1622) TITLE
0209              WRITE (6,1650) H,K,O,O1,C2,EP
0210              WRITE (6,1660)
0211              NLINE = 20
0212         1680 CONTINUE
0213         1681 DO 1690 I=1,N
0214              THETA(I) = THETA(I) / RADIAN
```

```
0215           PHI(I) = PHI(I) / RADIAN
0216      1690 ALPHA(I) = ALPHA(I) / RADIAN
          C
          C      PLOT WHEN (II - 1) EQUAL TO NLOOP OR NPLOT EQUAL TO 0
          C
0217           IF ((II-1).NE.NLOOP) GO TO 7050
0218           IF (NPLOT.EQ.1) GO TO 7050
0219           CALL PLOT(C.C,C.0,-3)
0220           XMAX = C.C
0221           DO 7010 I=1,NLOOP
0222           IF (XS(NN,I).GT.XMAX) XMAX = XS(NN,I)
0223      7010 CONTINUE
0224           YLL = -5.0
0225           DY = 1.0
0226           CALL AXIS(O.C,C.0,8HS-INCHES,8,10.0,90.0,YLL,DY,DIV)
0227           NXO = (XMAX / 20.0)
0228           NXO = NXO + 1
0229           XLL = NXC
0230           XLO = C.0
0231           DX = 20.0
0232           CALL AXIS(C.C,0.0,13HANGLE-DEGREES,-13,XLL,0.0,XLO,DX,DIV)
0233           YPT = 9.5
0234           DO 7005 KK=1,NLOOP
0235           KN = KK + 1
0236           XPT = 2.0
0237           IF (KK.GE.6) XPT = 5.0
0238           CALL SYMBOL(XPT,YPT,0.14,KN,0.0,-1)
0239           XPT = XPT + C.5
0240           CALL SYMBOL(XPT,YPT,0.14,8HOMEGA = ,0.0,8)
0241           XPT = XPT + 1.0
0242           CALL NUMBER(XPT,YPT,0.14,OMEGA(KK),0.0,3)
0243           XPT = 2.0
0244      7005 YPT = YPT - 0.25
0245           CALL PLOT(0.C,5.0,3)
0246           XAT = 0.5
0247           YAT = 5.0
0248      7030 CALL PLOT(XAT,YAT,2)
0249           YAT = 5.C5
0250           CALL PLOT(XAT,YAT,3)
0251           YAT = 4.95
0252           CALL PLOT(XAT,YAT,2)
```

```
0253                YAT = 5.0
0254                CALL PLOT(XAT,YAT,3)
0255                XAT = XAT + 0.5
0256                IF (XAT.LE.XLL) GO TO 7030
           C
           C          PRINT TITLE AND H,K
           C
0257                CALL PLOT(0.0,0.0,3)
0258                XPT = 1.0
0259                YPT = 1.5
0260                CALL SYMBOL(XPT,YPT,0.14,TITLE,0.0,20)
0261                XPT = 2.0
0262                YPT = 1.0
0263                CALL SYMBOL(XPT,YPT,0.14,4HH = ,0.0,4)
0264                XPT = 2.75
0265                CALL NUMBER(XPT,YPT,0.14,H,0.0,3)
0266                XPT = 2.0
0267                YPT = 0.5
0268                CALL SYMBOL(XPT,YPT,0.14,4HK = ,0.0,4)
0269                XPT = 2.75
0270                CALL NUMBER(XPT,YPT,0.14,K,0.0,3)
0271                CALL PLOT(0.C,5.0,-3)
0272                DO 7C22 I=1,NLOOP
0273                KN = I + 1
0274                YS(NN+1,I) = 0.0
0275                YS(NN+2,I) = 1.0
0276                XS(NN+1,I) = 0.0
0277                XS(NN+2,I) = 20.0
0278                CALL LINE(XS(1,I),YS(1,I),NN,1,1,KN)
0279          7022 CONTINUE
0280                XPT = 25.0
0281                YPT = -5.0
0282                CALL PLOT(XPT,YPT,-3)
0283                CALL PAGE
0284          7050 RETURN
0285                END
```

APPENDIX X

SAMPLE PROBLEM

APPENDIX X

SAMPLE PROBLEM

This appendix is included to demonstrate the use of the computer program to obtain a specific cam design. The sample problem is based on data listed in Appendix A and includes the following:

1. Wrap Program - 703A
   a. Input Block Data
   b. Output Data
2. Cam Program - 703B
   a. Input Sheet
   b. Output Data
   c. Plotted Cam Design

The approximate running time is 2.5 minutes and 1.0 minutes for the WRAP Program and CAM Program, respectively.

WRAP PROGRAM INPUT

```
FORTRAN IV G LEVEL 0, MOD 0          BLK DATA          DATE = 67353          10/26/23          PAGE 0001

0001            BLOCK DATA
          C
          C                  . SAMPLE PROBLEM
          C
0002            COMMON /AA/ ALPH(30),RAD(30),DEGR(30),AMIN(30),NO
0003            COMMON /BB/ D2,D3
0004            COMMON /CC/ R1,R2,R3
0005            COMMON /DD/ L1,L2,L3
0006            COMMON /EE/ ST1,ST3,RRHO1
0007            COMMON /FF/ R(100),Y(100),THETA(100),PHI(100),AL(100)
0008            COMMON /GG/ YC(10),DGR(10),AMN(10),N4
0009            COMMON /HH/ DELPHI,ALMIN,ALMAX,AM,DELTA,DLO
0010            REAL L1,L2,L3
          C     DEGR  WINDING PATH  DEGREES
0011            DATA DEGR/51.0,51.0,51.0,50.0,48.0,46.0,44.0,42.0,40.0,37.0,35.0,3
               13.0,32.0,30.0,16*0.0/
          C     AMIN  WINDING PATH  MINUTES
0012            DATA AMIN/38.0,35.0,5.0,3.0,35.0,44.0,40.0,25.0,7.0,55.0,47.0,47.0
               1,1.0,45.0,16*0.0/
          C     RAD   DIAMETER OF STATION (IS CONVERTED TO RADIUS BEFORE USING)
0013            DATA RAD/25.875,25.86,25.68,25.3,24.75,24.03,23.2,22.26,21.27,20.2
               18,19.3,18.35,17.5,16.875,16*0.0/
          C
          C     OUTER CYLINDER VARIABLE WRAP PATH VS 'Y' DISTANCE
          C     N4 IS NUMBER OF POINTS IN TABLE, LAST POINT ANGLE MUST AGREE
          C     WITH FIRST POINT ANGLE IN WINDING PATH TABLE
          C
0014            DATA DGR/10*0.0/
0015            DATA AMN/10*0.0/
0016            DATA YC/10*0.0/
          C
0017            DATA D2,D3/20.875,16.875/
0018            DATA R1,R2,R3/2.5,2.875,0.375/
0019            DATA  L1,L2,L3/0.156,0.531,2.031/
          C     RRHO1 IS DIVIDED INTO 1.0 LATER
0020            DATA ST1,ST3,RRHO1,DELPHI,ALMIN,ALMAX/0.2,0.06,29.0,10.0,25.75,35.
               175/
          C     ALMIN,ALMAX ARE CONVERTED TO RADIANS LATER.
0021            DATA NO,N4,AM,DELTA,DLO/14,1,1.0,5.0,0.0002/
0022            END
```

WRAP PROGRAM OUTPUT

WINDING PATH TABLE

STATION	WINDING PATH	RADIUS
1	51.633	13.197
2	51.583	13.189
3	51.083	13.090
4	50.050	12.880
5	48.583	12.576
6	46.733	12.179
7	44.667	11.721
8	42.417	11.202
9	40.117	10.656
10	37.917	10.113
11	35.783	9.579
12	33.783	9.061
13	32.017	8.597
14	30.750	8.177

```
1  5.3100E-01  2.7600E CC  1.5600E-01  3.1350E 00  2.031CE 00  6.3500E-01  1.0437E 01  1.0437E 01  8.8125E 00  8.3957E 00
1  2.5384E 00
2  8.5550E-C1  2.912CE CC
9  8.1775E 00  2.0316E CC  1.5699E 00  2.0502E 00  2.0000E-04
9  8.1777E 00  2.0469E 0C  1.5458E CC  2.0502E 00  2.0000E-04
9  8.1779E 00  2.0535E CC  1.5354E C0  2.0502E 0C  2.0000E-04
9  8.1778E 00  2.05C5E CC  1.54C1E CC  2.05C2E CC -1.000CE-04
3  8.1778E 00  2.0505E CC  1.9C92E C1  5.0000E 00  1.9168E 01  5.5880E-01  4.4942E-01
5  8.7266E-02  2.17C8E CC  C.C         1.5708E C0  2.2784E 00  3.1109E 00
6  2.1907E 01  6.3957E CC  9.4662E C0  2.7C97E CC  1.8633E 00  5.9301E-01
7  2.6128E-03  4.4942E-01  8.2297E C1  4.3762E 00  7.7401E 00  8.8701E 00  3.3322E-01  1.5419E-01  1.0000E 00
9  8.1775E 0C  2.0316E CC  1.5699E 00  2.0901E 00  2.0000E-04
```

9	8.1777E 00	2.0469E CC	1.5458E CC	2.0901E 00	2.0000E-04				
9	8.1779E 00	2.0535E OC	1.5354E CO	2.0900E 00	2.0000E-04				
9	8.1781E 00	2.0585E CC	1.5274E CC	2.0900E 00	2.0000E-C4				
9	8.1783E 00	2.0628E CC	1.5207E CO	2.0900E 00	2.0000E-04				
9	8.1785E 00	2.0666E OC	1.5148E CO	2.C900E 00	2.C000E-04				
9	8.1787E 00	2.0699E OC	1.5C94E CC	2.0900E 00	2.0000E-C4				
9	8.1789E 00	2.0731E CC	1.5045E CO	2.0900E 00	2.0000E-04				
9	8.1791E 00	2.0760E OC	1.4999E 00	2.C899E 00	2.0000E-04				
9	8.1793E 00	2.0787E CC	1.4956E CO	2.C899E OC	2.0000E-04				
9	8.1795E 00	2.0813E CC	1.4915E CC	2.C899E 00	2.0000E-04				
9	8.1797E 00	2.0837E CC	1.4877E CO	2.0899E 00	2.0000E-04				
9	8.1799E 00	2.0861E OC	1.484CE CC	2.C899E 00	2.0000E-C4				
9	8.1801E 00	2.0883E CC	1.4804E CO	2.0899E 00	2.0000E-04				
9	8.1803E 00	2.09C5E OC	1.4770E CO	2.0898E 00	2.0000E-04				
3	8.1803E 00	2.09C5E OC	3.0694E C1	8.8701E 00	3.1106E 01	5.5880E-01	5.3555E-01		
5	1.5481E-01	2.4415E CC	0.C	1.5708E 00	2.2784E 00	3.0478E 00			
6	2.1907E 01	6.3957E CC	9.5136E CO	2.7133E 00	2.0318E 00	5.6966E-01			
7	2.6128E-03	5.3555E-C1	9.0469E C1	3.9809E 00	-4.3178E-01	8.6542E 00	5.3571E-01	1.5047E-01	1.0000E 00
9	8.1775E 00	2.0316E 00	1.5699E OC	2.0873E 00	2.0000E-04				
9	8.1777E 00	2.0469E OC	1.5458E CO	2.0873E CO	2.0000E-04				
9	8.1779E 00	2.0535E OC	1.5354E CO	2.0873E 00	2.0000E-04				
9	8.1781E 00	2.0585E OC	1.5274E CO	2.0873E 00	2.0000E-04				
9	8.1783E 00	2.0628E OC	1.5207E CO	2.0873E CO	2.0000E-04				
9	8.1785E 00	2.0666E OC	1.5148E CO	2.0872E CO	2.0000E-04				
9	8.1787E 00	2.0699E OC	1.5094E 00	2.0872E 00	2.0000E-04				
9	8.1789E 00	2.0731E OC	1.5045E CO	2.0872E 00	2.0000E-04				
9	8.1791E 00	2.0760E 00	1.4999E CO	2.0872E CO	2.0000E-04				
9	8.1793E 00	2.0787E OC	1.4956E CO	2.0872E CO	2.0000E-C4				

9	8.1795E 00	2.0813E 00	1.4915E 00	2.0872E 00	2.0000E-04			
9	8.1797E 00	2.0837E 00	1.4877E 00	2.0871E 00	2.0000E-04			
9	8.1799E 00	2.0861E 00	1.4840E 00	2.0871E 00	2.0000E-04			
9	8.1801E 00	2.0883E 00	1.4804E 00	2.0871E 00	2.0000E-04			
9	8.1800E 00	2.0872E 00	1.4822E 00	2.0871E 00	-1.0000E-04			
3	8.1800E 00	2.0872E 00	3.0145E 01	8.6542E 00	3.0528E 01	5.5880E-01	5.2593E-01	
5	1.5104E-01	2.4231E 00	0.0	1.5708E 00	2.2784E 00	3.0530E 00		
6	2.1907E 01	6.3957E 00	9.5082E 00	2.7129E 00	2.0100E 00	5.7088E-01		
7	2.6128E-03	5.2593E-01	8.9983E 01	4.0024E 00	5.4478E-02	8.6814E 00	5.2612E-01	1.5094E-01	1.0000E 00
9	8.1775E 00	2.0316E 00	1.5699E 00	2.0877E 00	2.0000E-04			
9	8.1777E 00	2.0469E 00	1.5458E 00	2.0877E 00	2.0000E-04			
9	8.1779E 00	2.0535E 00	1.5354E 00	2.0876E 00	2.0000E-04			
9	8.1781E 00	2.0585E 00	1.5274E 00	2.0876E 00	2.0000E-04			
9	8.1783E 00	2.0628E 00	1.5207E 00	2.0876E 00	2.0000E-04			
9	8.1785E 00	2.0666E 00	1.5148E 00	2.0876E 00	2.0000E-04			
9	8.1787E 00	2.0699E 00	1.5094E 00	2.0876E 00	2.0000E-04			
9	8.1789E 00	2.0731E 00	1.5045E 00	2.0876E 00	2.0000E-04			
9	8.1791E 00	2.0760E 00	1.4999E 00	2.0875E 00	2.0000E-04			
9	8.1793E 00	2.0787E 00	1.4956E 00	2.0875E 00	2.0000E-04			
9	8.1795E 00	2.0813E 00	1.4915E 00	2.0875E 00	2.0000E-04			
9	8.1797E 00	2.0837E 00	1.4877E 00	2.0875E 00	2.0000E-04			
9	8.1799E 00	2.0861E 00	1.4840E 00	2.0875E 00	2.0000E-04			
9	8.1801E 00	2.0883E 00	1.4804E 00	2.0875E 00	2.0000E-04			
3	8.1801E 00	2.0883E 00	3.0206E 01	8.6814E 00	3.0594E 01	5.5880E-01	5.2700E-01	
5	1.5152E-01	2.4260E 00	0.0	1.5708E 00	2.2784E 00	3.0512E 00		
6	2.1907E 01	6.3957E 00	9.5088E 00	2.7129E 00	2.0094E 00	5.6987E-01		
7	2.6128E-03	5.2700E-01	1.5714E 00	4.0000E 00	0.0	1.5152E-01	5.2720E-01	1.5094E-01	1.0000E 00
8	9.0000E 01	0.0	-4.0542E 01	-8.4823E 01				

10	1	-1.570796E 00	8.086370E 00	0.0	0.0	5.339586E-01	0.0
10	2	-1.396263E 00	8.187107E 00	2.141272E 00	1.553231E-01	5.277312E-01	2.487846E 00
10	3	-1.221730E 00	8.215803E 00	2.248179E 00	1.632175E-01	5.299039E-01	2.616181E 00
10	4	-1.047197E 00	8.262598E 00	2.348486E 00	1.711276E-01	5.334470E-01	2.744733E 00
10	5	-8.726645E-01	8.326062E 00	2.439170E 00	1.790603E-01	5.382523E-01	2.873602E 00
10	6	-6.981316E-01	8.422361E 00	2.557547E 00	1.887260E-01	5.455437E-01	3.030540E 00
10	7	-5.235987E-01	8.870000E 00	2.870988E 00	2.285472E-01	5.769342E-01	3.676942E 00
10	8	-3.490658E-01	9.365267E 00	3.101934E 00	2.690282E-01	6.101479E-01	4.336908E 00
10	9	-1.745329E-01	9.893111E 00	3.243371E 00	3.102959E-01	6.464412E-01	5.013139E 00
10	10	0.0	1.043750E 01	3.290998E 00	3.525494E-01	6.847340E-01	5.708791E 00
10	11	1.745329E-01	1.091677E 01	3.249067E 00	3.906988E-01	7.193570E-01	6.339690E 00
10	12	3.490658E-01	1.138147E 01	3.124552E 00	4.298798E-01	7.538920E-01	6.990071E 00
10	13	5.235987E-01	1.181750E 01	2.921229E 00	4.701931E-01	7.871854E-01	7.661551E 00
10	14	6.981316E-01	1.221159E 01	2.645283E 00	5.117138E-01	8.182935E-01	8.355187E 00
10	15	8.726645E-01	1.255178E 01	2.305094E 00	5.544541E-01	8.459308E-01	9.070980E 00
10	16	1.047197E 00	1.282773E 01	1.911001E 00	5.983484E-01	8.691218E-01	9.807588E 00
10	17	1.221730E 00	1.303105E 01	1.474977E 00	6.432415E-01	8.865163E-01	1.056209E 01
10	18	1.396263E 00	1.315556E 01	1.010269E 00	6.888695E-01	8.973436E-01	1.132974E 01
10	19	1.570796E 00	1.319750E 01	0.0	7.857215E-01	9.011717E-01	1.295995E 01

CAM PROGRAM
BASIC INPUT

AGC JOB NO. 703 B

DATE ______

TITLE CARD

SAMPLE PROBLEM

M	ILØC	PRINT	NPLØT
19	0	0	0

H	K	ØMO	DØMO	NLØØP
10.594	3.75	2.5	2.5	5

The following sequence of cards are obtained from WRAP program (703A)

L1	L3	R2	R3	SR1	YB
0.15600E 00	0.203 10E 01	0.31350E 01	0.63500E 00	0.10437E 02	0.25384E 01

R3P	AP	DELTA
0.81801E 01	0.20883E 01	0.15152E 00

	PHI(I)	R(I)	Y(I)	THETA(I)	AL(I)	ARC(I)	I
*	Nineteen	cards from wrap	program output.				

* Note: 'M' Cards must be included

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	2.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.86167

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
-90.000	8.086	0.0	30.594	0.0	0.0	1.328	49.370	-0.044
-80.002	8.187	8.899	30.237	2.141	0.027	1.325	50.917	0.105
-69.998	8.216	9.352	30.361	2.248	0.091	1.324	54.573	0.097
-60.000	8.263	9.805	30.564	2.348	0.177	1.329	59.530	0.083
-50.000	8.326	10.259	30.839	2.439	0.300	1.332	66.561	0.060
-40.000	8.422	10.813	31.257	2.557	0.461	1.307	75.772	0.030
-30.000	8.870	13.095	33.056	2.871	0.644	1.382	86.249	0.024
-20.000	9.365	15.414	34.959	3.102	0.830	1.465	96.936	0.018
-10.000	9.893	17.779	37.038	3.243	1.019	1.565	107.746	0.012
0.0	10.437	20.200	39.232	3.291	1.209	1.686	118.644	0.007
10.000	10.917	22.385	41.216	3.249	1.402	1.792	129.718	-0.004
20.000	11.381	24.630	43.195	3.125	1.599	1.913	140.985	-0.014
30.000	11.817	26.940	45.103	2.921	1.798	2.053	152.375	-0.023
40.000	12.212	29.319	46.885	2.645	1.997	2.212	163.801	-0.031
50.000	12.552	31.768	48.468	2.305	2.198	2.389	175.296	-0.039
60.000	12.828	34.283	49.797	1.911	2.398	2.573	186.792	-0.045
69.998	13.031	36.855	50.794	1.475	2.600	2.750	198.323	-0.051
80.002	13.156	39.469	51.414	1.010	2.802	2.901	209.889	-0.055
90.000	13.197	45.018	51.633	0.0	3.057	3.024	224.514	-0.022
99.998	13.156	50.568	51.414	-1.010	3.249	2.984	235.552	0.026
110.002	13.031	53.182	50.794	-1.475	3.394	2.905	243.849	0.036
120.000	12.828	55.754	49.797	-1.911	3.535	2.795	251.899	0.045
130.000	12.552	58.269	48.468	-2.305	3.672	2.664	259.774	0.055
140.000	12.212	60.718	46.885	-2.645	3.806	2.524	267.455	0.064
150.000	11.817	63.097	45.103	-2.921	3.939	2.382	275.084	0.072
160.000	11.381	65.407	43.195	-3.125	4.073	2.246	282.712	0.079
170.000	10.917	67.651	41.216	-3.249	4.209	2.117	290.517	0.084

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	2.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.86167

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
180.000	10.437	69.837	39.232	-3.291	4.351	1.998	298.673	0.087
190.000	9.893	72.258	37.038	-3.243	4.497	1.869	307.057	0.093
200.000	9.365	74.623	34.959	-3.102	4.648	1.753	315.670	0.096
210.000	8.870	76.942	33.056	-2.871	4.802	1.651	324.529	0.098
220.000	8.422	79.223	31.257	-2.557	4.964	1.563	333.810	0.097
229.999	8.326	79.777	30.839	-2.439	5.183	1.577	346.325	0.053
240.000	8.263	80.232	30.564	-2.348	5.455	1.635	361.934	-0.008
249.998	8.216	80.685	30.361	-2.248	5.777	1.653	380.355	-0.080
260.002	8.187	81.138	30.237	-2.141	6.118	1.498	399.902	-0.158
270.000	8.086	90.037	30.594	-0.0	6.283	1.328	409.358	-0.044

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	5.0000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.67996

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
-90.000	8.086	0.0	30.594	0.0	0.0	0.998	50.418	-0.087
-80.002	8.187	8.899	30.237	2.141	0.028	0.990	52.000	0.061
-69.998	8.216	9.352	30.361	2.248	0.094	0.978	55.797	0.052
-60.000	8.263	9.805	30.564	2.348	0.182	0.968	60.859	0.038
-50.000	8.326	10.259	30.839	2.439	0.304	0.951	67.820	0.016
-40.000	8.422	10.813	31.257	2.557	0.461	0.899	76.820	-0.014
-30.000	8.870	13.095	33.056	2.871	0.640	0.943	87.086	-0.019
-20.000	9.365	15.414	34.959	3.102	0.822	0.996	97.509	-0.024
-10.000	9.893	17.779	37.038	3.243	1.006	1.066	108.038	-0.028
0.0	10.437	20.200	39.232	3.291	1.191	1.157	118.655	-0.033
10.000	10.917	22.385	41.216	3.249	1.379	1.239	129.412	-0.041
20.000	11.381	24.630	43.195	3.125	1.571	1.342	140.416	-0.050
30.000	11.817	26.940	45.103	2.921	1.765	1.467	151.542	-0.058
40.000	12.212	29.319	46.885	2.645	1.960	1.617	162.722	-0.066
50.000	12.552	31.768	48.468	2.305	2.157	1.790	174.006	-0.072
60.000	12.828	34.283	49.797	1.911	2.354	1.978	185.291	-0.078
69.998	13.031	36.855	50.794	1.475	2.553	2.167	196.681	-0.082
80.002	13.156	39.469	51.414	1.010	2.753	2.339	208.142	-0.087
90.000	13.197	45.018	51.633	0.0	3.007	2.501	222.696	-0.054
99.998	13.156	50.568	51.414	-1.010	3.199	2.500	233.700	-0.005
110.002	13.031	53.182	50.794	-1.475	3.345	2.452	242.066	0.004
120.000	12.828	55.754	49.797	-1.911	3.487	2.372	250.222	0.014
130.000	12.552	58.269	48.468	-2.305	3.627	2.270	258.255	0.022
140.000	12.212	60.718	46.885	-2.645	3.765	2.156	266.165	0.031
150.000	11.817	63.097	45.103	-2.921	3.903	2.036	274.057	0.038
160.000	11.381	65.407	43.195	-3.125	4.042	1.919	282.002	0.043
170.000	10.917	67.651	41.216	-3.249	4.184	1.810	290.140	0.047

***** NUMERICAL SOLUTICN UF WINDING MACHINE EQUATICNS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	5.COCC
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.87996

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
180.CCO	10.437	69.837	39.232	-3.291	4.332	1.706	298.647	0.048
190.000	9.893	72.258	37.038	-3.243	4.486	1.589	307.436	0.052
200.CCO	9.365	74.623	34.959	-3.102	4.643	1.484	316.418	0.054
210.000	8.870	76.942	33.056	-2.871	4.803	1.390	325.629	0.054
220.CCO	8.422	79.223	31.257	-2.557	4.971	1.308	335.226	0.052
229.999	8.326	79.777	30.839	-2.439	5.194	1.336	347.987	0.006
240.CCO	8.263	8C.232	30.564	-2.348	5.468	1.396	363.737	-0.055
249.998	8.216	8C.685	30.361	-2.248	5.788	1.391	382.018	-0.127
260.CO2	8.187	81.138	30.237	-2.141	6.123	1.192	401.212	-0.202
270.000	8.086	90.037	30.594	-0.0	6.283	0.997	410.423	-0.087

***** NUMERICAL SOLUTICN OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.594C
K	3.7500
OMEGA (0)	7.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.89307

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
-90.000	8.086	0.0	30.594	0.0	0.0	0.657	51.169	-0.131
-80.CC2	8.187	8.899	30.237	2.141	0.028	0.645	52.786	0.017
-69.998	8.216	9.352	30.361	2.248	0.096	0.623	56.653	0.008
-60.000	8.263	9.805	30.564	2.348	0.184	0.599	61.716	-0.006
-50.000	8.326	10.259	30.839	2.439	0.306	0.561	68.677	-0.028
-40.000	8.422	10.813	31.257	2.557	0.459	0.486	77.466	-0.057
-30.000	8.87C	13.095	33.056	2.871	0.636	0.501	87.591	-0.061
-20.000	9.365	15.414	34.959	3.102	0.815	0.524	97.874	-0.066
-10.000	9.893	17.779	37.038	3.243	0.996	0.566	108.227	-0.070
0.0	10.437	20.200	39.232	3.291	1.177	0.631	118.633	-0.073
10.000	1C.917	22.385	41.216	3.249	1.362	0.688	129.215	-0.081
20.000	11.381	24.630	43.195	3.125	1.551	0.771	140.025	-0.089
30.000	11.817	26.940	45.103	2.921	1.742	0.880	150.958	-0.096
40.000	12.212	29.319	46.885	2.645	1.934	1.018	161.961	-0.103
50.000	12.552	31.768	48.468	2.305	2.127	1.185	173.035	-0.108
60.000	12.828	34.283	49.797	1.911	2.321	1.374	184.144	-0.113
69.998	13.031	36.855	50.794	1.475	2.517	1.571	195.358	-0.117
80.CC2	13.156	39.469	51.414	1.010	2.714	1.760	206.678	-0.121
90.000	13.197	45.018	51.633	0.0	2.966	1.956	221.127	-0.087
99.998	13.156	50.567	51.414	-1.010	3.158	1.990	232.095	-0.038
110.CC2	13.031	53.182	50.794	-1.475	3.304	1.972	240.462	-0.029
120.000	12.828	55.754	49.797	-1.911	3.448	1.923	248.723	-0.020
130.000	12.552	58.269	48.468	-2.305	3.590	1.850	256.879	-0.012
140.000	12.212	60.718	46.885	-2.645	3.732	1.762	265.000	-0.005
150.000	11.817	63.097	45.103	-2.921	3.874	1.667	273.138	0.001
160.000	11.381	65.406	43.195	-3.125	4.018	1.572	281.364	0.006
170.000	1C.917	67.651	41.216	-3.249	4.165	1.482	289.819	0.008

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	7.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.89307

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
180.000	10.437	69.837	39.232	-3.291	4.320	1.399	298.678	0.008
190.000	9.893	72.258	37.038	-3.243	4.478	1.297	307.765	0.010
200.000	9.365	74.622	34.959	-3.102	4.641	1.204	317.064	0.011
210.000	8.870	76.942	33.056	-2.871	4.807	1.122	326.591	0.010
220.000	8.422	79.223	31.257	-2.557	4.978	1.045	336.364	0.007
229.999	8.326	79.777	30.839	-2.439	5.205	1.085	349.371	-0.040
240.000	8.263	80.232	30.564	-2.348	5.482	1.146	365.261	-0.102
249.998	8.216	80.685	30.361	-2.248	5.799	1.116	383.437	-0.173
260.002	8.187	81.138	30.237	-2.141	6.127	0.873	402.209	-0.247
270.000	8.086	90.037	30.594	-0.0	6.283	0.657	411.174	-0.131

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	10.0000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.90081

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
-90.000	8.086	0.0	30.594	0.0	0.0	0.307	51.612	-0.175
-80.002	8.187	8.899	30.237	2.141	0.028	0.291	53.230	-0.026
-69.998	8.216	9.352	30.361	2.248	0.096	0.259	57.132	-0.035
-60.000	8.263	9.805	30.564	2.348	0.184	0.223	62.159	-0.049
-50.000	8.326	10.259	30.839	2.439	0.304	0.167	69.050	-0.072
-40.000	8.422	10.813	31.257	2.557	0.456	0.069	77.733	-0.100
-30.000	8.870	13.095	33.056	2.871	0.631	0.057	87.788	-0.104
-20.000	9.365	15.414	34.959	3.102	0.810	0.052	98.001	-0.108
-10.000	9.893	17.779	37.038	3.243	0.989	0.066	108.302	-0.112
0.0	10.437	20.200	39.232	3.291	1.170	0.104	118.637	-0.115
10.000	10.917	22.385	41.216	3.249	1.353	0.137	129.131	-0.122
20.000	11.381	24.630	43.195	3.125	1.540	0.198	139.835	-0.130
30.000	11.817	26.940	45.103	2.921	1.729	0.289	150.663	-0.137
40.000	12.212	29.319	46.885	2.645	1.918	0.414	161.526	-0.143
50.000	12.552	31.768	48.468	2.305	2.109	0.573	172.424	-0.147
60.000	12.828	34.283	49.797	1.911	2.300	0.760	183.392	-0.151
69.998	13.031	36.855	50.794	1.475	2.493	0.963	194.431	-0.155
80.002	13.156	39.469	51.414	1.010	2.687	1.165	205.575	-0.158
90.000	13.197	45.018	51.633	0.0	2.937	1.391	219.918	-0.123
99.998	13.156	50.567	51.414	-1.010	3.127	1.456	230.781	-0.074
110.002	13.031	53.182	50.794	-1.475	3.273	1.466	239.148	-0.065
120.000	12.828	55.754	49.797	-1.911	3.418	1.446	247.445	-0.056
130.000	12.552	58.269	48.468	-2.305	3.563	1.401	255.741	-0.049
140.000	12.212	60.718	46.885	-2.645	3.707	1.342	264.002	-0.042
150.000	11.817	63.097	45.103	-2.921	3.852	1.274	272.334	-0.037
160.000	11.381	65.406	43.195	-3.125	4.000	1.204	280.806	-0.033
170.000	10.917	67.651	41.216	-3.249	4.152	1.138	289.525	-0.032

***** NUMERICAL SOLUTICN OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.594C
K	3.75C0
OMEGA (0)	10.C000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.90081

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
180.CC0	10.437	69.837	39.232	-3.291	4.312	1.076	298.665	-0.034
190.000	9.893	72.258	37.038	-3.243	4.476	0.991	308.051	-0.033
200.CC0	9.365	74.622	34.959	-3.102	4.642	0.912	317.595	-0.033
210.CC0	8.87C	76.942	33.056	-2.871	4.812	0.841	327.333	-0.035
220.CC0	8.422	79.223	31.257	-2.557	4.986	0.772	337.317	-0.039
229.999	8.326	79.777	30.839	-2.439	5.217	0.825	350.536	-0.087
240.C00	8.263	8C.232	30.564	-2.348	5.496	0.883	366.496	-0.149
249.998	8.216	80.685	30.361	-2.248	5.811	0.828	384.566	-0.220
260.001	8.187	81.138	30.237	-2.141	6.131	0.543	402.917	-0.292
270.0C0	8.086	90.037	30.594	-0.0	6.283	0.307	411.600	-0.174

***** NUMERICAL SOLUTION OF WINDING MACHINE EQUATIONS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	12.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.90290

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
-90.000	8.086	0.0	30.594	0.0	0.0	-0.051	51.733	-0.218
-80.002	8.187	8.899	30.237	2.141	0.028	-0.070	53.350	-0.070
-69.998	8.216	9.352	30.361	2.248	0.096	-0.111	57.217	-0.079
-60.000	8.263	9.805	30.564	2.348	0.183	-0.159	62.209	-0.093
-50.000	8.326	10.259	30.839	2.439	0.302	-0.231	69.029	-0.115
-40.000	8.422	10.813	31.257	2.557	0.452	-0.349	77.607	-0.142
-30.000	8.870	13.095	33.056	2.871	0.628	-0.389	87.697	-0.147
-20.000	9.365	15.414	34.959	3.102	0.806	-0.421	97.910	-0.151
-10.000	9.893	17.779	37.038	3.243	0.987	-0.437	108.264	-0.155
0.0	10.437	20.200	39.232	3.291	1.168	-0.427	118.669	-0.158
10.000	10.917	22.385	41.216	3.249	1.351	-0.418	129.163	-0.165
20.000	11.381	24.630	43.195	3.125	1.538	-0.381	139.868	-0.173
30.000	11.817	26.940	45.103	2.921	1.727	-0.309	150.660	-0.180
40.000	12.212	29.319	46.884	2.645	1.915	-0.198	161.452	-0.185
50.000	12.552	31.768	48.468	2.305	2.103	-0.048	172.245	-0.190
60.000	12.828	34.283	49.797	1.911	2.292	0.135	183.037	-0.193
69.998	13.031	36.855	50.794	1.475	2.481	0.341	193.900	-0.196
80.002	13.156	39.469	51.414	1.010	2.673	0.555	204.904	-0.198
90.000	13.197	45.018	51.633	0.0	2.920	0.806	219.036	-0.163
99.998	13.156	50.567	51.414	-1.010	3.108	0.899	229.828	-0.113
110.002	13.031	53.182	50.794	-1.475	3.254	0.935	238.160	-0.104
120.000	12.828	55.754	49.797	-1.911	3.399	0.942	246.492	-0.095
130.000	12.552	58.269	48.468	-2.305	3.545	0.927	254.823	-0.088
140.000	12.212	60.718	46.884	-2.645	3.691	0.895	263.225	-0.082
150.000	11.817	63.097	45.103	-2.921	3.840	0.854	271.733	-0.077
160.000	11.381	65.406	43.195	-3.125	3.990	0.812	280.363	-0.075
170.000	10.917	67.651	41.216	-3.249	4.147	0.768	289.310	-0.074

***** NUMERICAL SOLUTICN OF WINDING MACHINE ECUATICNS *****

SAMPLE PROBLEM

----- INPUT VALUES -----

H	10.5940
K	3.7500
OMEGA (0)	12.5000
OMEGA (1)	14.3298
OMEGA (2)	57.2958
EPSILON	0.90290

PHI	R	THETA	ALPHA	Y	TIME	S	OM2*T+EP	
180.000	10.437	65.837	39.232	-3.291	4.310	0.732	298.661	-0.077
190.000	9.893	72.258	37.038	-3.243	4.478	0.668	308.276	-0.077
200.000	9.365	74.622	34.959	-3.102	4.647	0.606	318.014	-0.078
210.000	8.870	76.942	33.056	-2.871	4.820	0.546	327.892	-0.081
220.000	8.422	79.223	31.257	-2.557	4.995	0.484	337.947	-0.085
229.999	8.326	79.777	30.839	-2.439	5.230	0.549	351.376	-0.134
240.000	8.263	80.232	30.564	-2.348	5.510	0.605	367.442	-0.196
249.998	8.216	80.685	30.361	-2.248	5.823	0.525	385.371	-0.266
260.001	8.187	81.138	30.237	-2.141	6.136	0.203	403.300	-0.337
270.000	8.086	90.037	30.594	-0.0	6.283	-0.051	411.737	-0.218

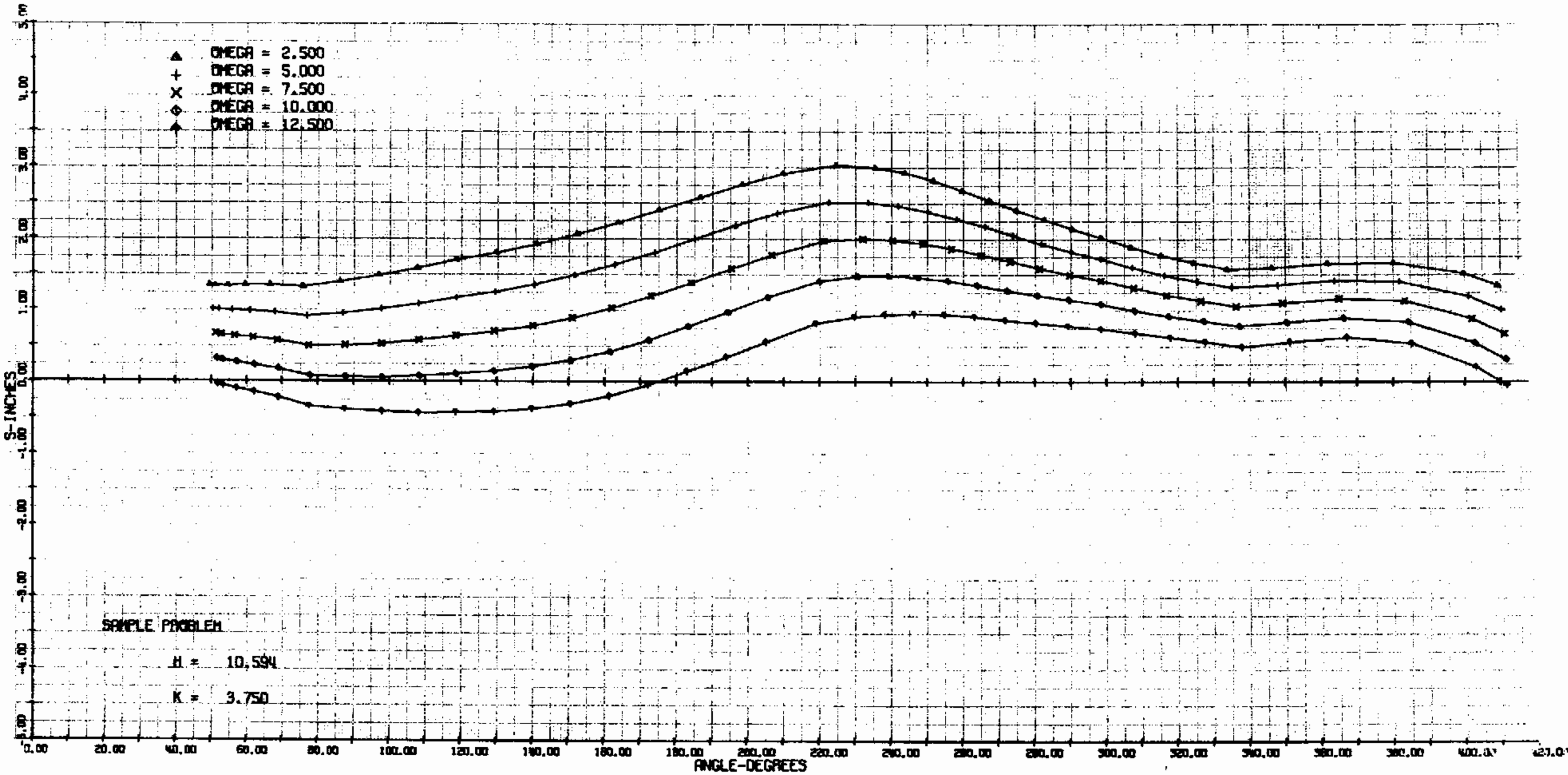


Figure X-1. Plotted Cam Design

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Structural Products Department, Azusa Facility Aerojet-General Corporation Azusa, California 91702	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Manufacturing Methods for Aircraft Tires by Filament-Winding Techniques

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Technical Report AFML-TR-69-226

5. AUTHOR(S) (Last name, first name, initial)
Sanger, Merle J. Waldo, Howard W.
Landes, Robert E.
Warner, Darrel M.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1969		4

8a. CONTRACT OR GRANT NO. F33615-67-C-1726 b. PROJECT NO. 360-7 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Aerojet-General Report No. 3720 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) Technical Report AFML-TR-69-226

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio 45433

13. ABSTRACT This work on the development of new and improved manufacturing methods, controls, equipment and processes was directed toward the fabrication of filament-wound, continuous-cross-section aircraft tires. Nylon, glass and wire reinforcements in bias, geodesic, and radial types of filament-wound configurations were investigated in the fabrication of subscale, 30 x 8.8, 22-ply-rated tires. Acceptable designs, materials and processes were developed for the fabrication of subscale tires. The findings of the work on subscale tires were applied to the fabrication of 49 x 17, 26-ply-rated, prototype tires, which were made with nylon reinforcement in a bias-type configuration. A carcass-winding machine was designed and fabricated for the fabrication of prototype tires. It was capable of utilizing glass and wire reinforcements in geodesic and radial configurations in addition to the nylon reinforcement and bias configuration selected for the prototype tires. Operating procedures and control techniques were developed for the production of 49 x 17 tires. Two tires were fabricated which exceeded the burst pressure requirements of USAF Drawing No. 60D2561J, the document which outlines the requirements for tires of this size. The dynamic test requirements of USAF Drawing No. 60D2561J were not achieved by the 49 x 17 prototype tires. The results of the dynamic tests indicated that major design modifications are required to produce satisfactory dynamic performance in the large 49 x 17 tires used on the C-5A and similar aircraft. Part I of this report and appendices I through VI report the design, process development, tooling, fabrication and testing of both subscale and full scale tire sizes, supported by detailed stress analysis for the rim-locking assembly, manufacturing instructions and equipment checkout. Part II presents the computer program for winding-machine cam design. Distribution of this Abstract is unlimited.

DD FORM 1 JAN 64 1473 0101-807-6800

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Aircraft tires						
Nylon cord, fiber-glass cord, wire cord						
Tire design: bias-cord tire, geodesic filament-wound tire, radial filament-wound tire						
Stress analysis: rim-locking assembly						
Static tests						
Checkout procedures						
Filament-winding machine						
Prototype tire						
Endurance tests						

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