AFFDL-TR-71-144

AD 745130

FILAMENT COMPOSITE WHEEL DEVELOPMENT FOR MILITARY AIRCRAFT

A. L. PRICE

WHITTAKER CORPORATION

RESEARCH AND DEVELOPMENT DIVISION

TECHNICAL REPORT AFFDL-TR-71-144

OCTOBER 1971

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AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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13. ABSTRACT

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Filament Winding						

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FILAMENT COMPOSITE WHEEL DEVELOPMENT FOR MILITARY AIRCRAFT

BY

A. L. PRICE

WHITTAKER CORPORATION
RESEARCH AND DEVELOPMENT DIVISION

FOREWORD

This record covers activities performed by Whittaker Corporation, Research and Development Division, San Diego, Calif., under Air Force contract No. AF33615-71-C-1089, "Filament Composite Wheel Development for Military Aircraft", in the period 22 October 1970 to 13 August 1971. The program was sponsored by the Air Force Flight Dynamics Laboratory (FEM), Wright-Patterson Air Force Base, Ohio, and conducted under Project 1369, Task 11. Lt. G. Shumaker was the program manager.

This technical report has been reviewed and is approved.

K. H. Digges

KENNERLY H. DIGGES
Chief, Mechanical Branch
Vehicle Equipment Division

ABSTRACT

A program was conducted wherein a fibrous graphite/epoxy aircraft wheel was designed, fabricated and delivered to the Air Force for testing. The composite wheel was fabricated using continuous fibers laid up on a male mold with multiple autoclave staging. The material was applied in broadgood patterns by hand and in continuous forms by filament winding. The completed layup was machined to proper configuration.

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INTRODUCTION

A program was conducted in which a composite wheel, the main landing gear wheel for the A-37B aircraft, was designed and fabricated utilizing epoxy and high modulus graphite fibers. Fiber reinforced plastic composite materials for aircraft wheel applications offer a number of potential advantages over metals. Composite materials have demonstrated their potential for weight reduction of numerous aircraft structural components. In the case of the composite wheel, an approximate 16% weight reduction over the same metal wheel was realized. In addition, composite materials offer the potential for increased corrosion resistance and greater fatigue life.

The objectives of this effort were to:

- Demonstrate the feasibility of constructing an aircraft wheel using graphite epoxy composite materials.

- Achieve lighter weight than is possible with present aluminum wheels.

Program tasks included:

- Select materials.
- Establish quality control procedures.
- Design wheel.
- Develop fabrication technology to build a prototype wheel.
- Fabricate prototype test wheel.

SECTION II

TECHNICAL DISCUSSION

1. PROCESS DEVELOPMENT

A process development effort was conducted to check out the fabrication process planned for the graphite/epoxy wheel and to establish prepreg material characteristics.

A wheel half was constructed on a steel mandrel using type E fiber glass and the 4617 resin system. E fiber glass was used in lieu of graphite to minimize costs, however, small samples of graphite were used to define the significant prepreg characteristics and these characteristics were translated to the fiber glass prepreg. Optimum characteristics of the graphite/epoxy prepreg were established as follows:

• Resin Content	37 ± 3%
• Volatile Content	5.5 ± 1.5% (nominal)
• Resin Solids/Volatile Ratio	0.19 ± 0.03
• Flow	17 ± 3%
• Drape	High
• Tack	Medium

The lamination sequence was established as follows:

- 6 compaction stages - 2 ± 1 hrs (depending on the degree of staging desired) @ 190°F ± 10°F and 50 ± 5 psig
- 1 final cure stage - 2 hrs @ 190°F ± 10°F and 50 ± 5 psig followed by 16 hrs @ 325°F ± 10°F and 50 ± 5 psig

Each layup consisted of (a) fibers oriented parallel to the wheel axis continuous through the wheel and radial in the face areas, (b) circumferential fibers perpendicular to the wheel axis, and (c) fibers ±45° to the wheel axis.

Both the ±45° and the parallel fibers were cut into approximately 1/2 inch width patterns from prepreg broadgoods sheets and applied to the layup by hand. Shorter patterns were placed in the extra thickness areas. The circumferential fibers were applied in the flange and cylindrical areas by winding single tow continuous filament prepreg directly onto the layup. The mandrel was placed in a lathe that had been modified for this operation. In the face areas of the wheel circumferential fiber annuli preforms were prepared by winding the single tow continuous fiber into aluminum forms, cooling to a low temperature to rigidize them, and manually transferring the preform to the layup. In the conical area of the wheel, circumferential fibers were wound on an aluminum form; frozen, and placed on the layup. Figure 1 indicates the areas of the wheel.

Once the fiberglass process development part had been completely laid up, it was machined, using a tracer lathe to the approximate configuration of the actual wheel half. This part was then cut up and analyzed for specific gravity, resin and void content. The results are presented in Figure 2.

Based on the results obtained from the physical and visual analyses of the process development wheel, changes were made in the layup procedure toward applying more effective pressure to the high resin content areas, toward eliminating fiber wrinkling in the circumferential fiber layers, and toward establishing better thickness control of the individual layers.

A photographic sequence of the layup of the fiber glass process development wheel is presented in Figures 3 through 20. Figures 6 and 7 show the boss areas in the graphite wheel mold and the preparation of epoxy/graphite prepreg to fit the bosses. The photo sequence is typical of the fabrication processes used for both the graphite and glass epoxy wheels.

2. QUALITY CONTROL PROVISIONS

The following quality control provisions were developed and established for the fabrication of the graphite/epoxy wheel:

a. Raw Materials

- Resin - Manufacturer's Certification
- Graphite - Manufacturer's Certification and Test Report

b. Processed Materials

- Resin - Thermal Gravimetric Analysis (TGA)
- Prepreg - Volatile weight loss after 15 minutes @ 325°F
  - Resin content - by digestion process
  - Flow - by SPI Procedure III (15 psi x 15 minutes @ 325°F)
  - Tack and drape - by visual inspection

c. Lamination (in-process inspection)

- Sign-off of Part Processing (Traveler)
- Dimensional Inspection after Each Cure
- Monitor Cure Temperature and Pressure with Continuous Recording Charts

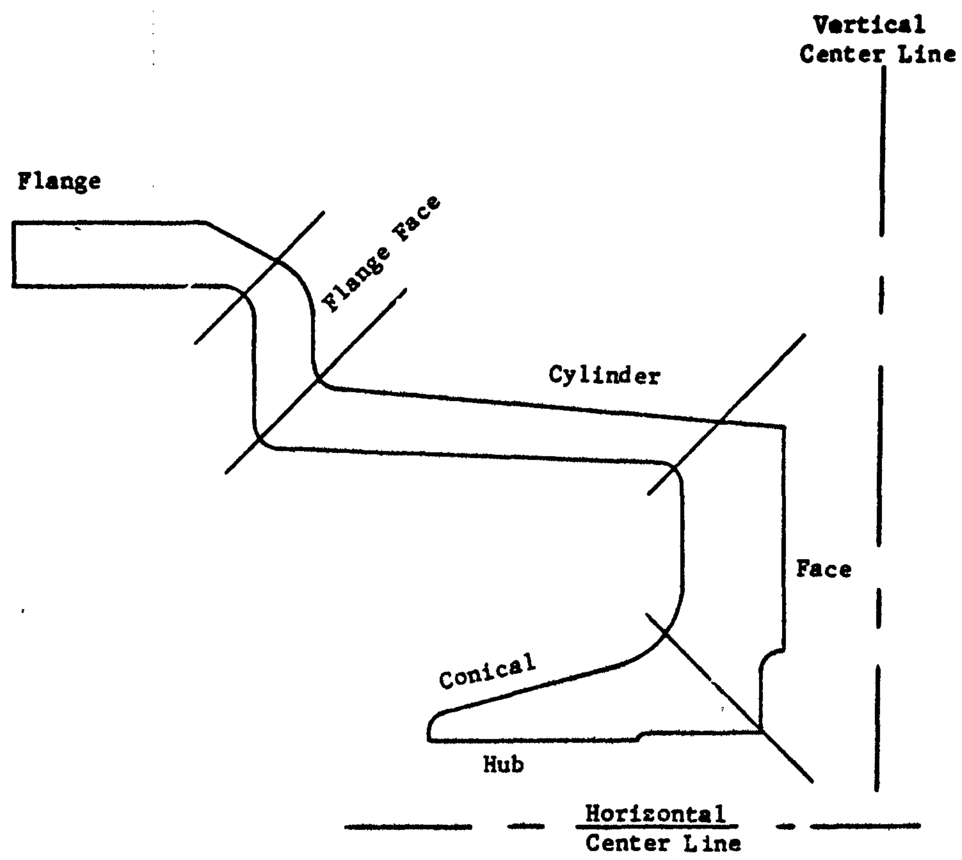
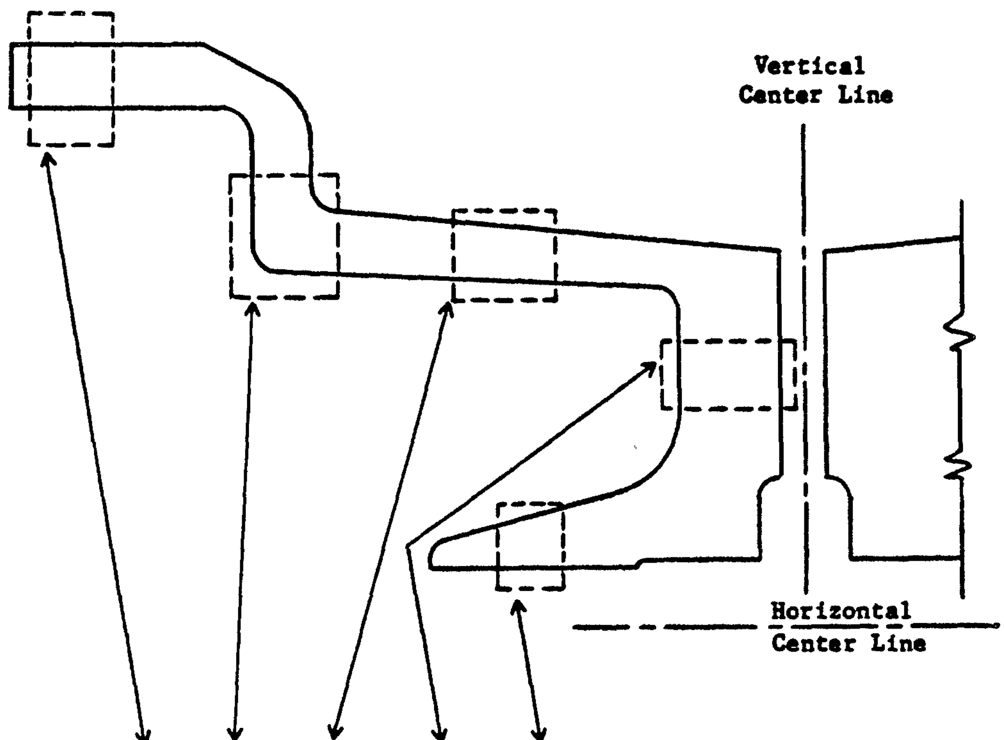


Figure 1. Notation used for Areas of the Wheel



RESIN CONTENT, % by wt.	19.10	21.80	17.30	16.50	17.60
SPECIFIC GRAVITY	2.13	2.08	2.16	2.17	2.15
VOID VOLUME	0	0	0	0	0

Figure 2. Results of the Physical Analysis of the Process Development Fiber Glass/Epoxy Wheel Half.

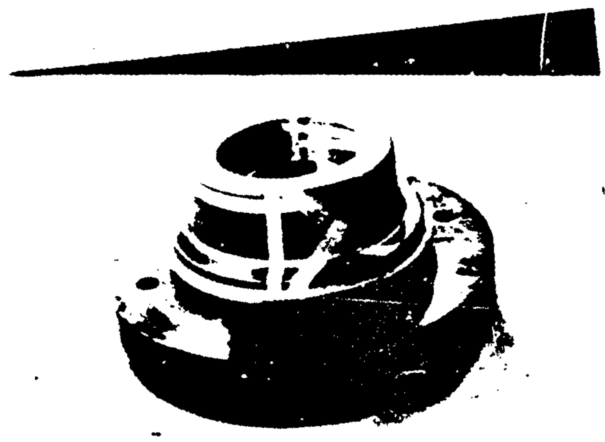
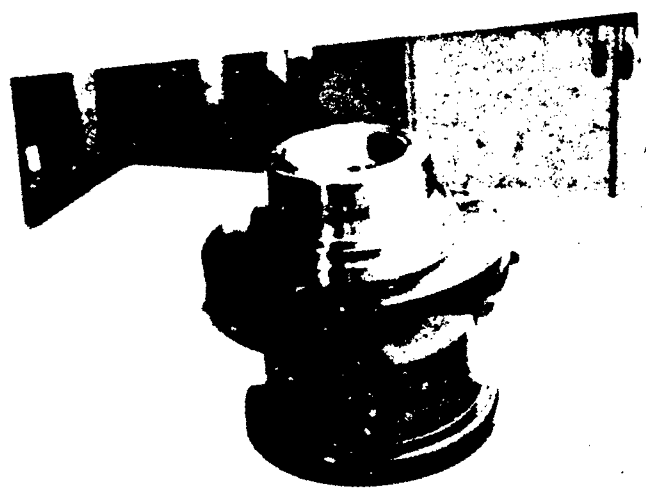


Figure 3.
Steel Mold with Fiber Lay-Up Patterns Demonstrated.

Mold is Show Prior to Modification for Graphite Epoxy Wheel Bolt Bosses.



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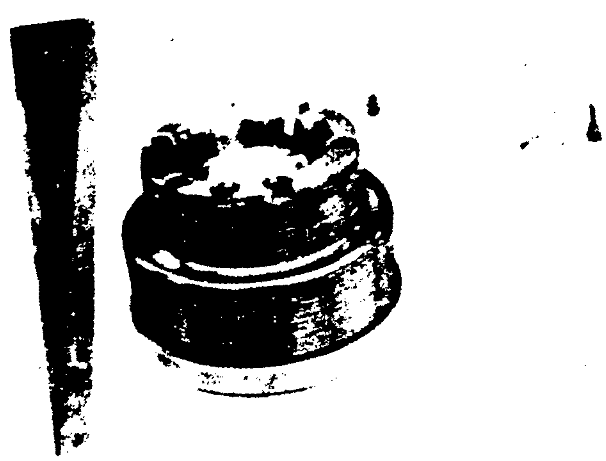

Figure 5.
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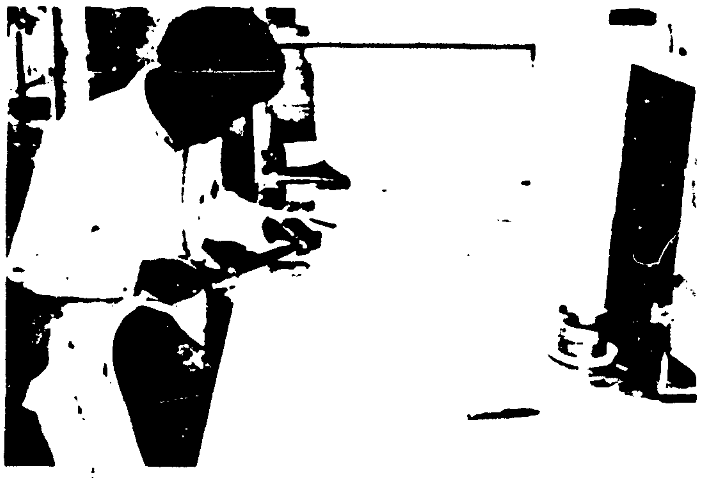
(Graphite Epoxy)

Figure 7
Bolt Boss Patterns
Applied to Mold
(Graphite Epoxy)



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Preparing Patterns
for Layup

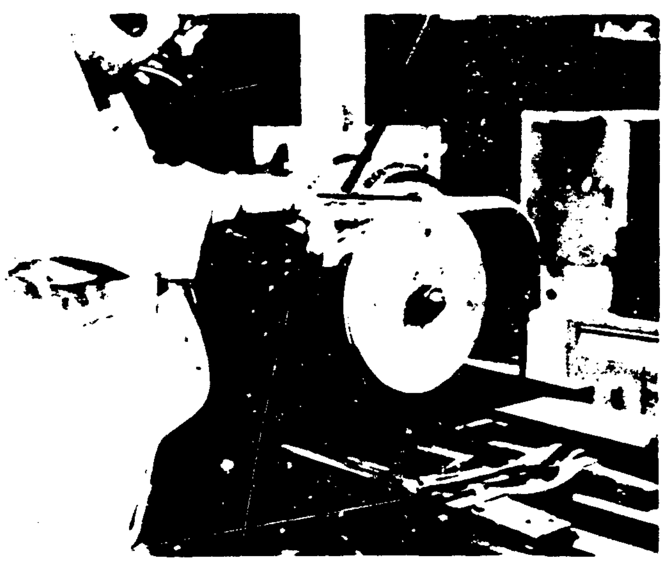

Figure 9.
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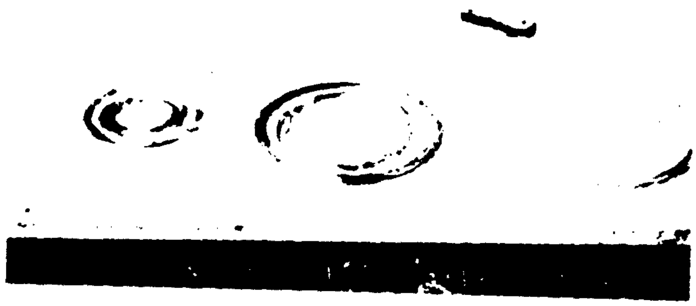

Figure 10.
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For Wheel Layup

Figure 11.
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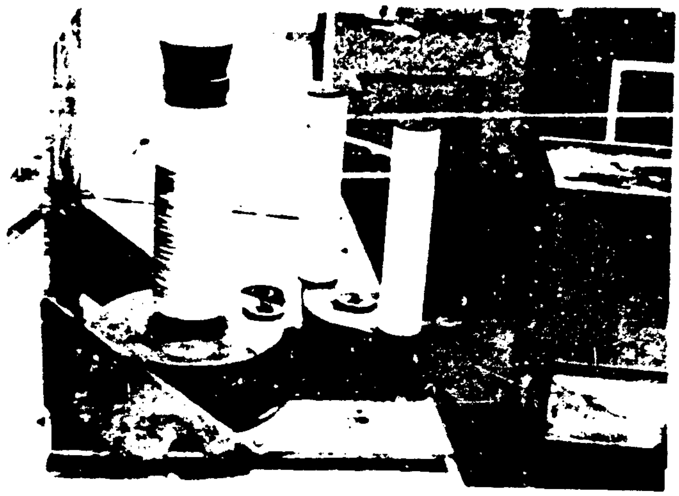

Figure 12.
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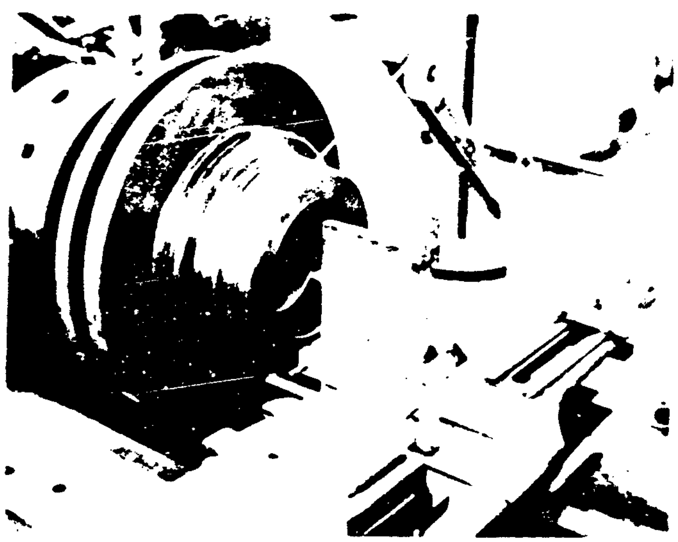
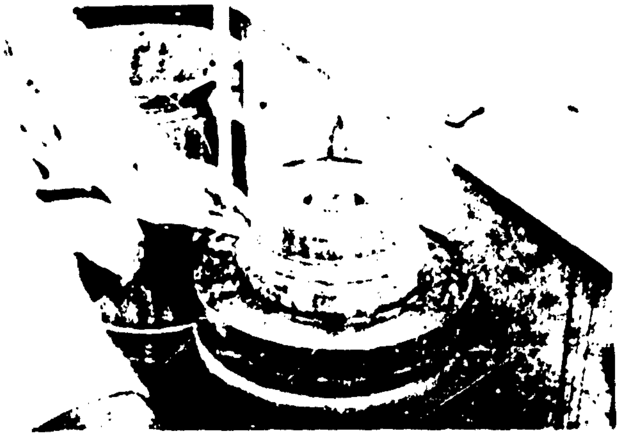


Figure 13.
Winding Circumferential
Fibers



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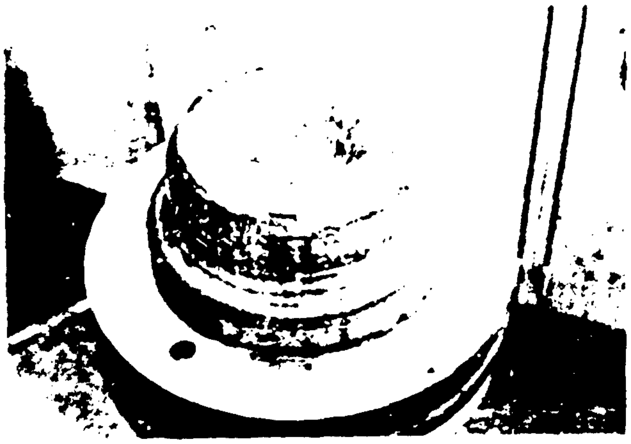

Figure 15.
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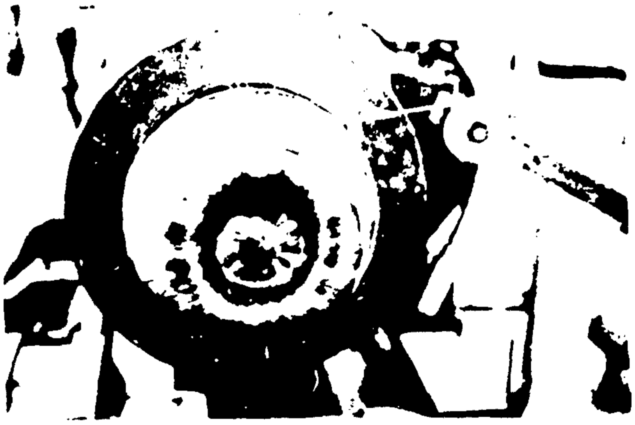

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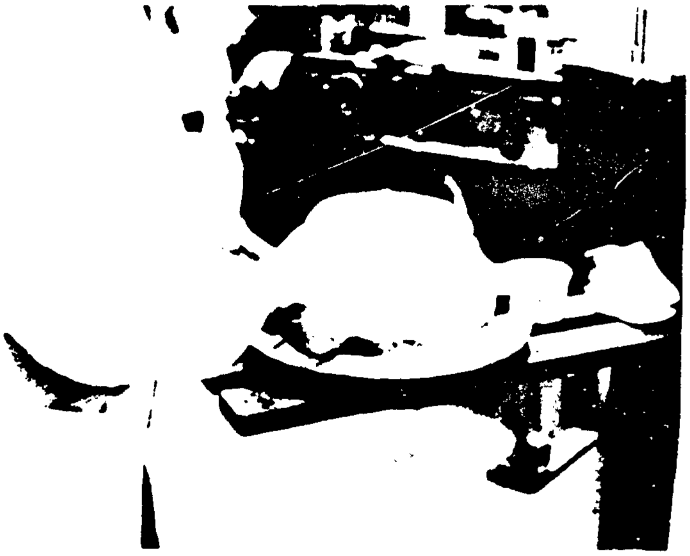

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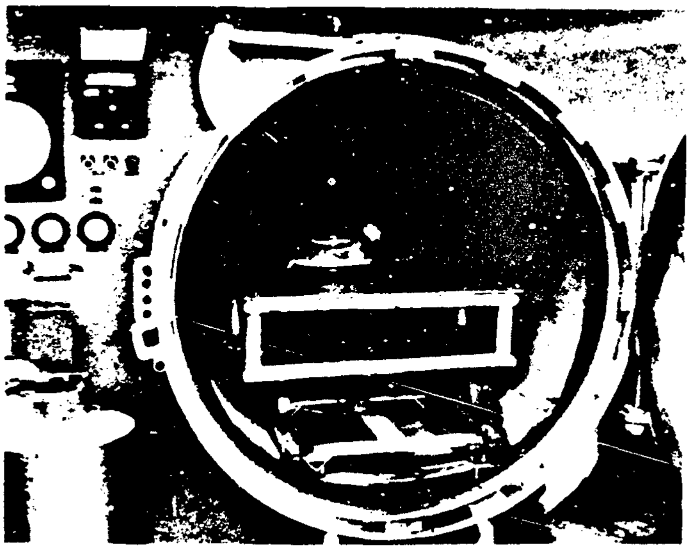


Figure 18.
Vacuum Bagged Part in Autoclave Ready for Curing

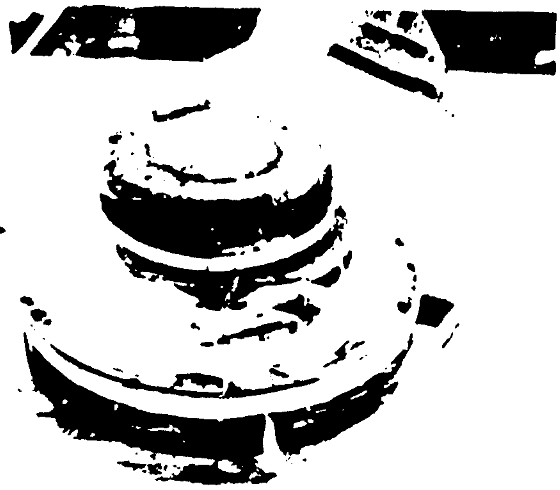


Figure 19.
Part After Autoclave Cure

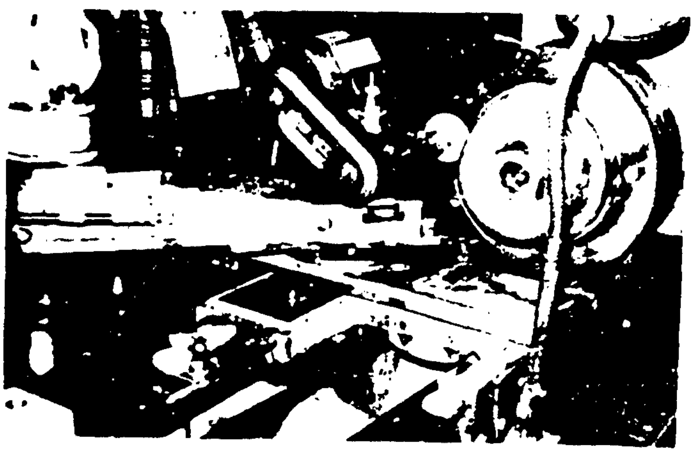


Figure 20.
Machining Laminated
Wheel Half Section

Visual Inspection, In-process, of Fiber Orientation and Laminate Quality

3. FABRICATION OF GRAPHITE/EPOXY WHEEL

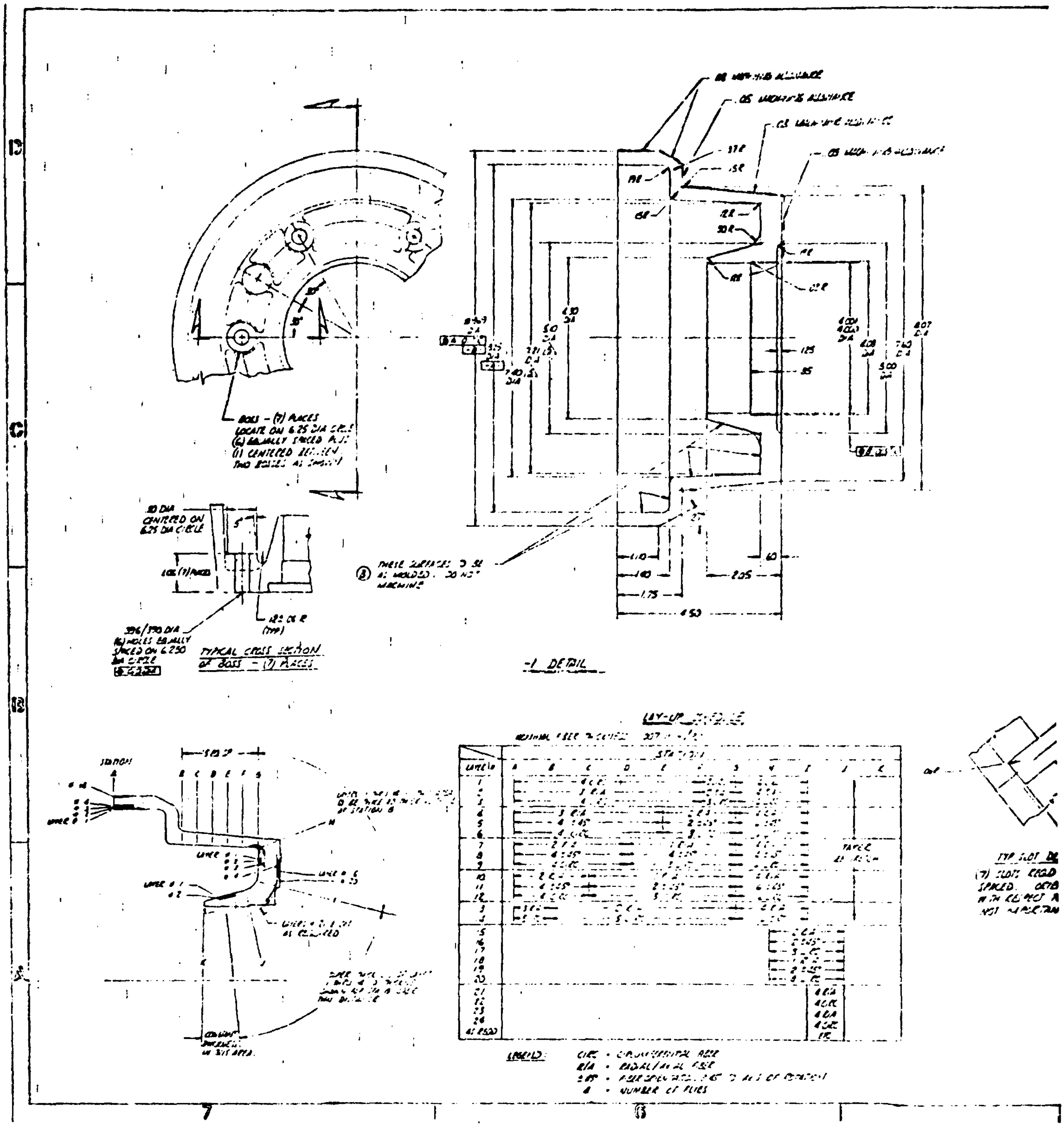
The wheel was laid up in accordance with the structural design and the fabrication process developed using glass fiber (Figure 21). No problems were encountered except that approximately 15% extra thickness buildup was experienced in the cylindrical section.

Upon final machining, which was accomplished on a tracer lathe using carbide cutter bits, it was noticed that insufficient material had been placed on the cylinder/mating face corner (see Figure 22) and it was necessary to add more plies on this area. Other difficulties were noted also in the final machining. The O-ring groove between the two half wheel specimens was a particular problem in that during the machining a rough surface was obtained which had to be repaired. It is suspected that the repair resin was not polished out completely, leaving some areas where the groove was not wide enough. Thus consequently, corner splitting occurred when the wheel halves were bolted together. A second problem involved drilling the bolt holes through the bosses. Some delamination occurred in the surface plies and a repair was necessary. A room temperature curing epoxy adhesive was used for the repair. Finally, in assembling the wheel with a tire in place, the side pressure exerted by the compressed O-ring created interlaminar shear stresses which failed the composite material (see Figure 23). This area was again repaired and modified by widening the O-ring groove from the low side of the tolerance to the high side of the tolerance. This resulted in less pressure being exerted by the O-ring and was a satisfactory solution to the problem. To eliminate this problem in the future the O-ring groove should be moved toward the center to a smaller diameter.

Offal rings from the wheel halves were analyzed for specific gravity and resin content, with the following results:

Wheel Half	Resin Content	Specific Gravity
#1	35.6%	1.53
#2	31.6%	1.52

With the aluminum hub, bearing cups and air valve installed, the wheel weighed 10.1 lbs, resulting in a weight-saving of 16% for the wheel



.08 MACHINING ALLOWANCE
.05 MACHINING ALLOWANCE
10 DIA
CENTERED ON
6.25 DIA CIRCLE
TYPICAL CROSS SECTION
OF BOSS - (7) PLACES
-1 DETAIL
LAY-UP
STATION
LAYER
LEGEND:
CIRC
R/A
4.50
1.75
2.05

A

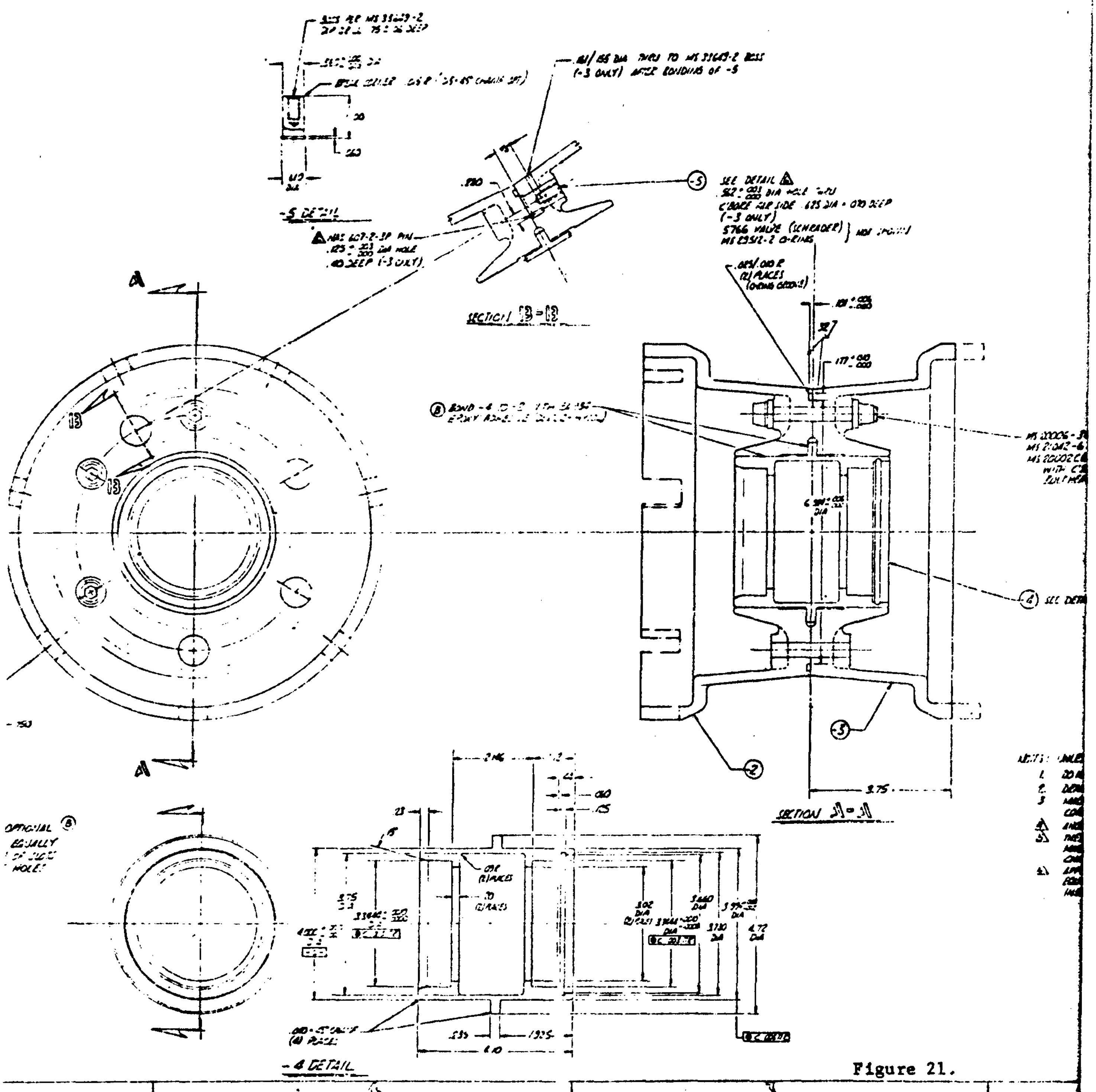
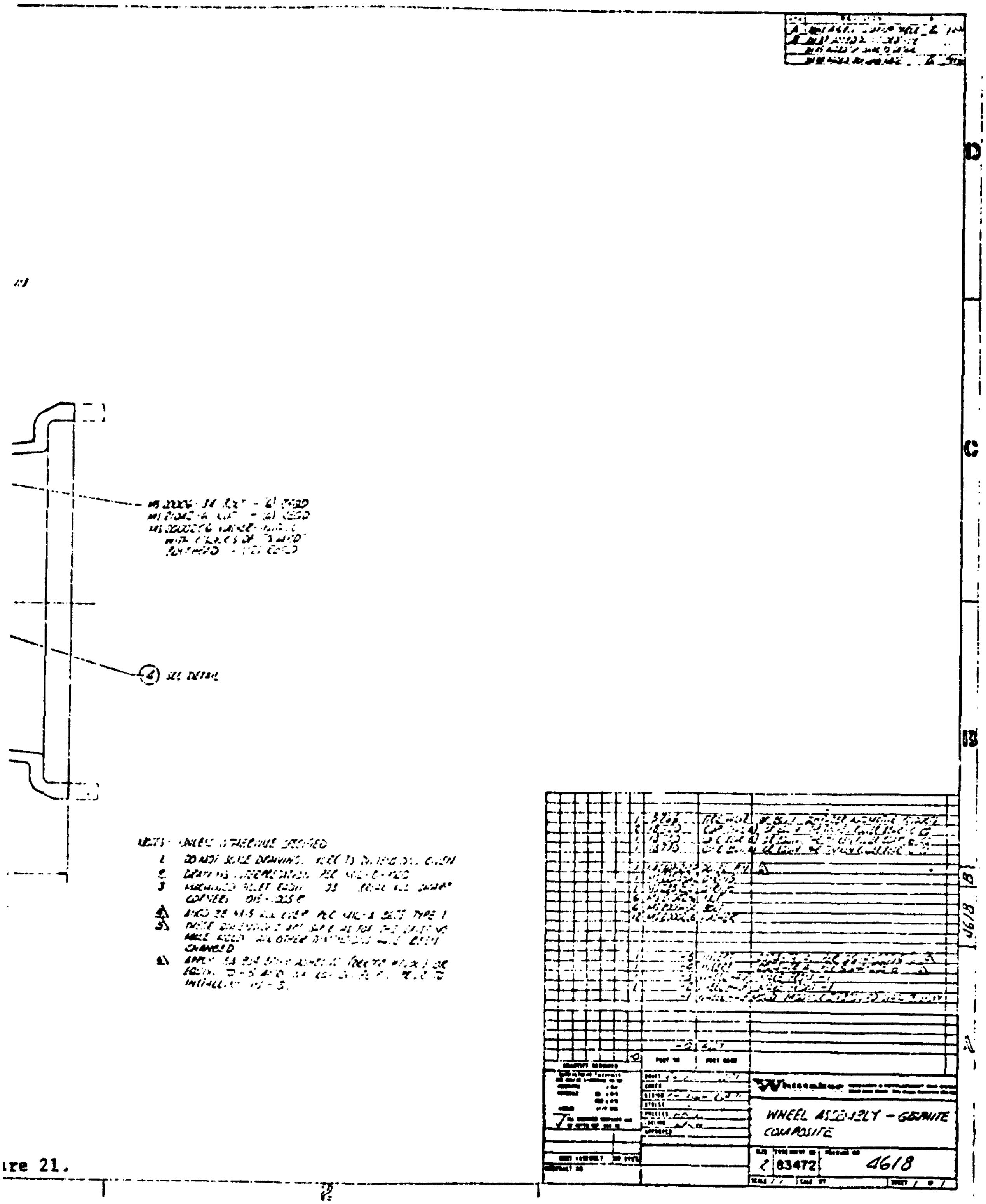


Figure 21.



ire 21.

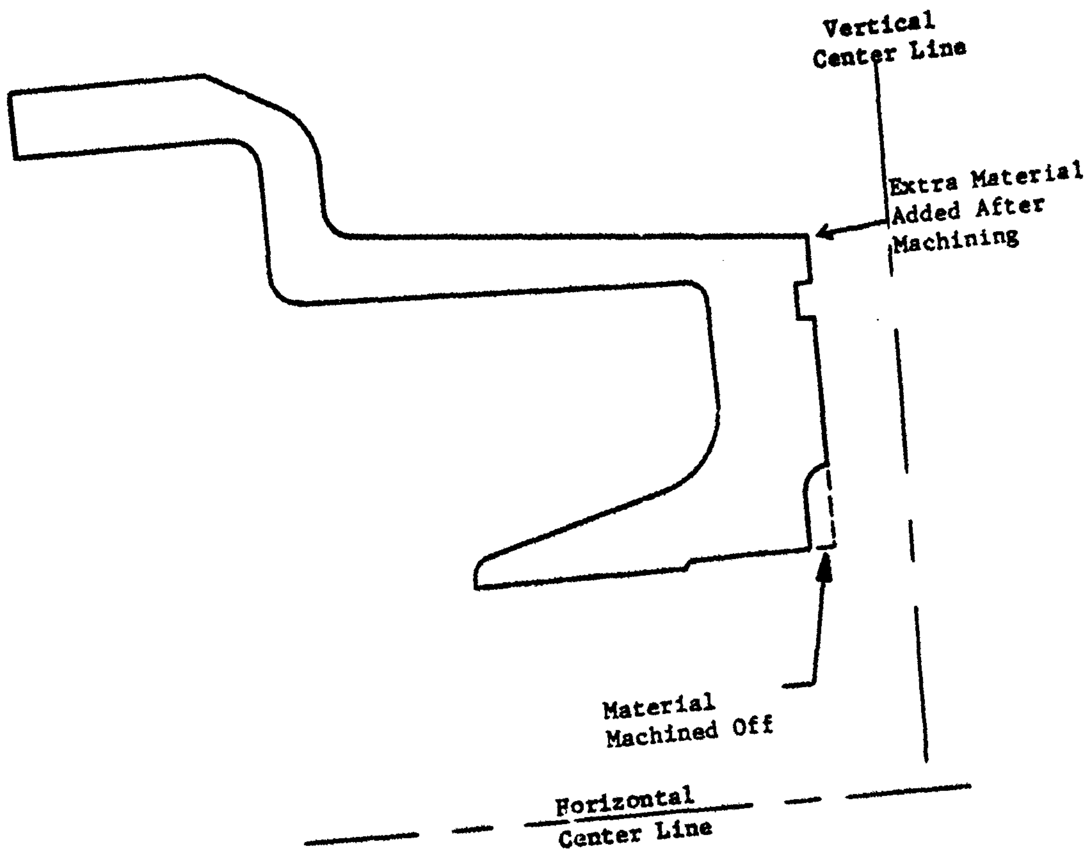


Figure 22. Area Requiring Additional Layup

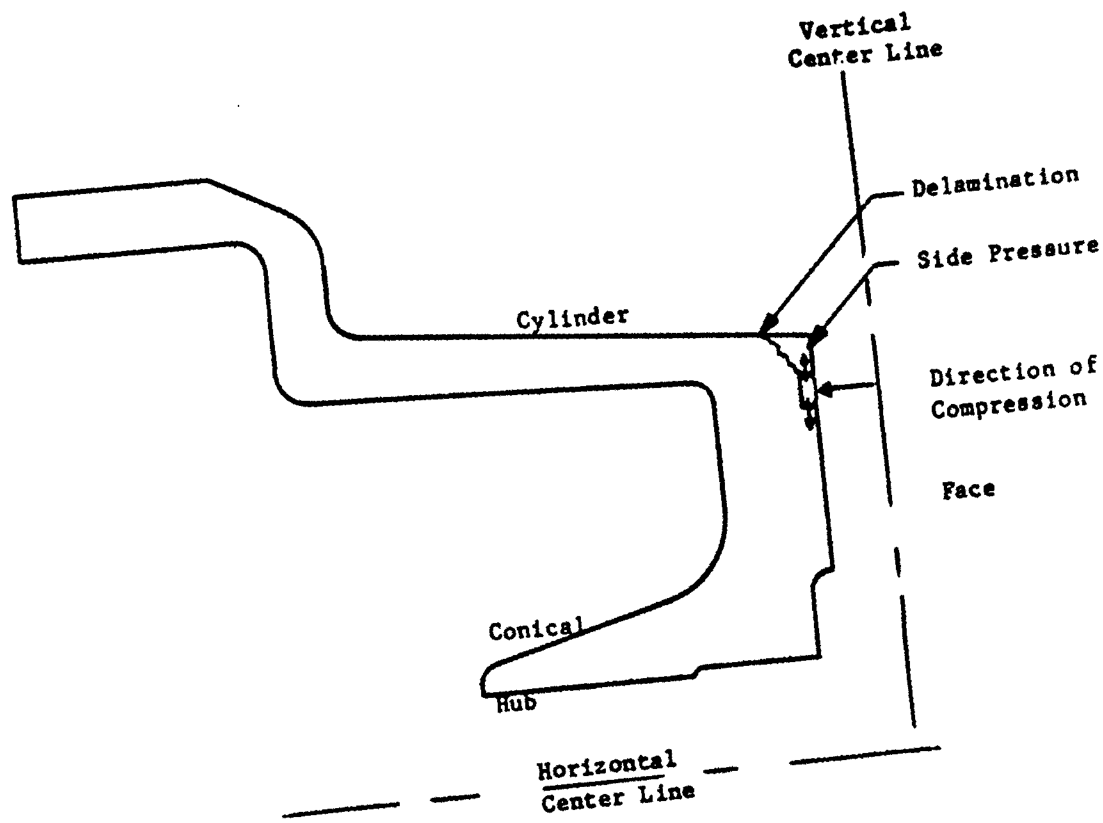


Figure 23. O-Ring Delamination

assembly. The completed wheel is depicted in Figure 24. The manufacturing process (job traveler) is included as Appendix A.

4. TOOLING

For the fabrication of the part, two (2) steel mandrels (one for each wheel half) defining the exposed wheel surface were utilized (Figure 3). One (1) of the molds was modified as required to accommodate the bosses for bolting the wheel together.

It was felt that the time savings realized in fabricating the two (2) wheel halves simultaneously more than offset the extra cost of the second mandrel.

5. DESIGN

The design philosophy in this effort was to replace the existing metal wheel with equivalent thickness of composite material. The wheel was not optimized for minimum weight. The wheel consisted of an aluminum hub fitted with the bearing cups which was bonded to the bore of one wheel half. Six (6) bolts were used to fasten the wheel halves together. The wheel was fitted with an air valve and an O-ring at the wheel mating faces to provide tubeless air retention. Braking requirements were not considered in the design, thus brake rotor slots were not included in the test article constructed. The prototype wheel was designed to the basic loads which appear in Appendix B.

6. STRESS ANALYSIS

The stress analysis associated with this effort will be published as AFFDL Technical Memorandum TM-72-02-FEM. Publication of this T.M. is forthcoming.

7. TEST RESULTS

Static and roll testing of this wheel has been conducted by the AFFDL (FEM) at WPAFB. The results of this test will be published as an AFFDL Technical Report (TR). Publication of this TR is forthcoming.

Figure 24. Completed Wheel

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

Graphite fiber composite material for aircraft wheel application offers potential for superiority over conventional metal wheels in the areas of weight and corrosion resistance.

A wheel is a complex structure subject to combined loading conditions which complicate the design and analysis problem. The use of a composite material having anisotropic properties further increases the difficulty of this problem. In order to obtain an optimized composite wheel, a series of test-failure analysis-redesign steps will be required.

This prototype wheel was designed to the approximate configuration and envelope of the metal wheel. In order to optimize the composite wheel, future efforts should study configurations which take better advantage of the properties and fabrication methods characteristic of composite materials. For example, eliminate sharp corners and rapid change of section thickness, etc. The hand layup fabrication process used for this prototype wheel results in a high per unit cost, therefore, more cost effective designs must be found. Designs which use some randomly oriented fiber and matched die molding techniques should be considered.

APPENDIX A

MANUFACTURING PROCESS

WHITTAKER CORPORATION APPENDIX A - MANUFACTURING PROCESS

Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

REQUESTED BY: A. PRICE | EXT. 274

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

2 REQ'D/ASS'Y

TOOL CONTROL

Contract No. F33615-71-C-1089 Property of Tool No. MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
		MATERIALS: (1) Union Carbide 4617
		(2) Meter-Length Modmor II
		(3) Mid-Length Modmor II
		REF: WRD Dwg. 4618 Rev A
	5	Impregnate midlength Modmor II with 37 ±3% 4617 Resin using dip
		process. Apply heat to remove volatiles. Take 2-g sample at
		0.75-lb intervals and submit to analytical lab for verification of
		resin content.
	6	Determine resin solids content on samples submitted.
	10	Lay up meter-length Modmor II in 1-lb quantities in 10 - 12 inch
		width sheets. Apply 37% ±3% resin solids. B-stage to 5.5 ±1%
		volatile. Achieve high drape and medium tack. Submit 3 samples
		from each lb for testing.
	11	Determine resin content and volatile content.
	15	Repeat operations 5 to 11 as required to furnish sufficient
		material to fabricate 1 wheel ass'y.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation F, M, or T, corresponding to the applicable Dept
	20	Prepare mandrels by washing with solvent, inspecting for burrs or
		surface irregularities and coating with DC 20. Bake coating at
		420°F - 500°F for 1 hr minimum.
	26	Inspect mold preparation.
	30	Set lathe at 5 TPI, set tensioner at 4 - 6 lbs. (Setting to be
		maintained for all subsequent circ operations.) Place mandrel
		in lathe. Wind 3 layers circumferential fibers (circs) Sta A to
		Sta G. Wind 1 additional circ Sta A to F.
	35	Place .028 spacer in flange annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	40	Cut discs to fit wheel bosses. Position 5 plies in bosses.
		Randomly orient fiber direction of discs.
	45	Cut approx. 1" width patterns of radial/axial (R/A) fibers for
		layup from Sta A to Sta K.
	50	Lay up 1 ply R/A cut in previous operation.
	55	Cut discs to fit wheel bosses. Position 30 plies in bosses.
		Randomly orient fiber direction of discs.
	60	Lay up 1 ply R/A cut in operation 45.
		23

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

REQUESTED BY | EXT.

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No. | Property of | Tool No. | MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	65	Cut discs to fit wheel bosses. Position 40 plies in bosses.
		Randomly orient fiber direction of discs.
	70	Cut patterns of R/A fibers Sta A to Sta F. Apply 1 ply to layup.
		Cut patterns of double thickness for Sta G to I. Apply to layup.
	75	Wind 3 circs Sta A to Sta G.
	80	Wind 1 circ Sta A to Sta F.
	85	Place .028 spacer in flange annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	90	Place .042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	91	Inspect layup for cleanliness, fiber alignment, and conformance
		to drawing.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation F, M, or T, corresponding to the applicable Dept
	95	Cover assembly with 1 ply 128-style unfinished peel/bleeder fiber glass. Bag in Capran vacuum bag. Place assembly in autoclave. Place 1 T/C on part, 1 T/C in air.
(1)	100	Precompact part at 50 ±5 psi x 190 ±10°F x 2^{+1}_{-0} hrs. Identify and store pressure and temperature recorder charts.
	105	When assembly is cool, strip bag and bleeder materials.
	106	Inspect precompaction cure records. Inspect part.
	110	Sand assembly. Prepare for next layup. Prime surface with 4617 resin.
	115	Cut discs for boss areas and place in any low areas remaining after cure. Maintain random orientation.
	120	Cut patterns and place double ply layer R/A on assembly Sta A to Sta K.
	125	Cut patterns and place 1 R/A on assembly Sta A to Sta E.
	130	Cut patterns and place double ply layer R/A on assembly Sta G to Sta K.
	135	Cut patterns for + and -45° fibers for layup Sta A to Sta K. Apply 1 layer + , 1 layer - .
		(25)

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER RD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√ or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

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SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No. Property of Tool No. MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	140	Cut patterns and apply 1 layer + , 1 layer - , Sta A to Sta E.
		Apply 2 layers + , 2 layers - , Sta G to Sta J.
	141	Inspect layup for cleanliness, fiber alignment, and conformance
		to drawing.
	145	Cover assembly with 1 ply 128-style unfinished peel/bleeder
		fiber glass. Bag in Capram vacuum bag. Place assembly in
		autoclave. Place 1 T/C on part, 1 T/C in air.
	150	Precompact part at 50 ±5 psi x 190 ±10°F x 2 $^{+1}_{-0}$ hrs. Identify
		and store pressure and temperature recorder charts.
	155	When assembly is cool, strip bag and bleeder materials.
	156	Inspect precompaction cure records. Inspect part.
	160	Sand assembly. Prepare for next layup. Prime surface with
		4617 resin.
	165	Wind 3 circs Sta A to Sta G.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation F, M, or T, corresponding to the applicable Dept
	170	Wind 1 circ Sta A to Sta E.
	175	Place 0.028 spacer in flange annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	180	Place 0.042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	185	Wind 6 circs on cone mandrel. Freeze to rigidize and place on
		assembly Sta I to Sta K. Trim as required to fit.
	190	Cut patterns and place 1 ply R/A Sta A to Sta K. Place 1 ply
		additional Sta A to Sta D. Place 2 additional plies Sta G to Sta I.
	195	Cut ±45° patterns. Place 2 + , 2 - layers Sta A to Sta K.
	196	Inspect layup for cleanliness, fiber alignment, and conformance
		to drawing.
	200	Cover assembly with 1 ply 128-style unfinished peel/bleeder
		fiber glass. Bag in Capram vacuum bag. Place assembly in
		autoclave. Place 1 T/C on part, 1 T/C in air.
	205	Precompact part at 50 ±5 psi x 190 ±10°F x 2 $^{+1}_{-0}$ hrs. Identify
		and store pressure and temperature recorder charts.
	210	When assembly is cool, strip bag and bleeder materials.

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. MJO 3025	Name of Item COMPOSITE WHEEL	
ROUTING INSTRUCTIONS: (Check One of Indicate Sequence by Numbers)		REQUESTED BY A. PRICE	EXT. 274

√ or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No.	Property of	Tool No.	MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	211	Inspect precompaction cure records. Inspect part.
	215	Sand assembly. Prepare for next layup. Prime surface with 4617 resin.
	220	Wind 3 circs Sta A to Sta G.
	225	Wind 1 circ Sta A to Sta D.
	230	Place .028 spacer in flange annular mold and wind mold full. Freeze to rigidize and remove ring from mold. Place ring on layup. Trim to fit as required.
	235	Place .042 spacer in web annular mold and wind mold full. Freeze to rigidize and remove ring from mold. Place ring on layup. Trim to fit as required.
	240	Wind 6 circs on cone mandrel. Freeze to rigidize and place on assembly Sta I to Sta K. Trim as required to fit.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation F, M, or T, corresponding to the applicable Dept.
	245	Cut patterns and lay up 1 ply R/A Sta A to Sta C.
		Add 1 ply Sta A to Sta C. Add 3 plies Sta H to Sta J.
	250	Cut ±45° patterns. Lay up 1 ply + , 1 ply -,Sta A to Sta K.
		Lay up 1 ply + , 1 ply - , Sta A to Sta C.
		Lay up 2 plies + , 2 plies - , Sta H to Sta J.
	251	Inspect layup for cleanliness, fiber alignment, and conformance
		to drawing.
	255	Cover assembly with 1 ply 128-style unfinished peel/bleeder
		fiber glass. Bag in Capram vacuum bag. Place assembly in
		autoclave. Place 1 T/C on part, 1 T/C in air.
	260	Precompact part at 50 ±5 psi x 190 ±10°F x 2 $^{+1}_{-0}$ hrs. Identify
		and store pressure and temperature recorder charts.
	265	When assembly is cool, strip bag and bleeder materials.
	266	Inspect precompaction cure records. Inspect part.
	270	Sand assembly. Prepare for next layup. Prime surface with
		4617 resin.
	275	Wind 3 circs Sta A to Sta G. Wind 1 circ Sta A to Sta C.
	280	Place 0.028 spacer in flange annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√ or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

REQUESTED BY A. PRICE — EXT. 274

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No. Property of Tool No. MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	285	Place 0.042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring
		on layup. Trim to fit as required.
	290	Wind 6 circs on cone mandrel. Freeze to rigidize and place on
		assembly Sta I to Sta K Trim as required to fit.
	295	Cut patterns and lay 2 R/A layers Sta A to Sta K. Place
		1 additional layer Sta A to Sta B. Place 2 additional
		layers Sta H to Sta J.
	296	Incpect layup for cleanliness, fiber alignment, and conformance
		to drawing.
	300	Cover assembly with 1 ply 128-style unfinished peel/bleeder
		fiber glass. Bag in Capram vacuum bag. Place assembly in
		autoclave. Place 1 T/C on part, 1 T/C in air.
	305	Precompact part at 50 ±5 psi x 190 ±10°F x 2^{+1}_{-0} hrs. Identify
		and store pressure and temperature recorder charts.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation P, M, or T, corresponding to the applicable Dept
	310	When assembly is cool, strip bag and bleeder materials.
	311	Inspect precompaction cure records. Inspect part.
	315	Sand assembly. Prepare for next layup. Prime surface with
		4617 resin.
	320	Wind 5 circs Sta A to Sta G.
	325	Place 0.028 spacer in flange annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring on
		layup. Trim to fit as required.
	330	Place 0.042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring
		on layup. Trim to fit as required.
	335	Wind 6 circs on cone mandrel. Freeze to rigidize and place on
		assembly Sta I to Sta K. Trim as required to fit.
	340	Cut patterns and place 2 layers R/A Sta H to Sta J.
	345	Cut patterns and place 1 +, 1 -45° layer Sta H to Sta J.
	350	Place 0.042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring
		on layup. Trim to fit as required.
	355	Cut patterns and place 2 layers R/A Sta H to Sta J.

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√ or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

REQUESTED BY	EXT.

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No.	Property of	Tool No.	MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	356	Inspect layup for cleanliness, fiber alignment, and conformance to drawing.
	360	Cover assembly with 1 ply 128-style unfinished peel/bleeder fiber glass. Bag in Capram vacuum bag. Place assembly in autoclave. Place 1 T/C on part, 1 T/C in air.
A	365	Precompact part at 50 ±5 psi x 190 ±10°F x 2 $^{+1}_{-0}$ hrs. Identify and store pressure and temperature recorder charts.
	370	When assembly is cool, strip bag and bleeder materials.
	371	Inspect precompaction cure records. Inspect part.
	375	Sand assembly. Prepare for next layup. Prime surface with 4617 resin.
	380	Cut patterns and place 1 layer R/A Sta H to Sta K.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS NOTE: Prefix the operation F, M, or T, corresponding to the applicable Dept
	385	Cut patterns and place 1 + , 1 -45° layer Sta H to Sta J.
	390	Place 0.042 spacer in web annular mold and wind mold full.
		Freeze to rigidize and remove ring from mold. Place ring
		on layup. Trim to fit as required.
	395	Continue layup, alternating 4 plies R/A Sta I to Sta K and
		annular ring layup described in operation 90 to achieve proper
		thickness in accordance with drawing.
	396	Inspect layup for cleanliness, fiber alignment, and conformance
		to drawing.
	400	Cover assembly with 1 ply 128-style unfinished peel/bleeder
		fiber glass. Bag in Capram vacuum bag. Place assembly in
		autoclave. Place 1 T/C on part, 1 T/C in air.
	405	Final-cure 2^{+1}_{-0} hrs x 190 ±10°F x 50 ±5 psig followed by
		16 ±2 hrs x 325 ±10°F x 50 ±5 psig. Temperature changes at
		1/2 °/min maximum.
	410	When assembly is cool, strip bag and bleeder materials.
	411	Inspect precompaction cure records. Inspect part.
	415	Machine wheel halves in accordance with drawing 4618.

WHITTAKER CORPORATION
Research & Development Division

MASTER JOB TRAVELER WRD-002	MJO/WO No. 3025-002	Name of Item COMPOSITE WHEEL

ROUTING INSTRUCTIONS:
(Check One of Indicate Sequence by Numbers)

√ or No.	ROUTE TO	DATE SUBMITTED	DATE REQUIRED	EST. HRS.	ACT. HRS.
	Fabrication				
	Machine Shop				
	Test Lab.				

REQUESTED BY A. PRICE — EXT. 274

SPECIAL REQUIREMENTS, MATERIALS, INSTRUCTIONS:

TOOL CONTROL

Contract No. Property of Tool No. MJO No.

COMPLETION INITIALS & DATE	OPERATION NO.	INSTRUCTIONS Note: Prefix the operation No. with F, M, T, or T.C. corresponding to the applicable department.
	416	Inspect wheel dimensionally, inspect for delamination, foreign
		material, etc. Assemble wheel, tighten bolts to 17 ft/lb,
		check for cracks, etc., around bolt bosses and in O-ring area.
	420	Install air valve insert. Bond using RTV silicone rubber
		adhesive. Drill hole in accordance with drawing.
	425	Install bearing cups, install aluminum hub in plastic wheel.
		Bond hub to inside wheel half, using EA 934 adhesive.
		Cure at R.T.
	426	Inspect metal components assembly.

USE REVERSE SIDE FOR ADDITIONAL INSTRUCTIONS

APPENDIX B

LOADS & DESIGN CRITERIA

INTRODUCTION

The composite military aircraft wheel will be designed to the loads and design criteria specified in this report. The loads are abstracted from Military Specification Mil-W-5013G, "Wheel and Brake Assemblies; Aircraft" and from U.S. Air Force Drawing No. 67J1951, "Wheel-Brake and Tire Assembly - Main Gear - Size 7.00-8/16 PR-Tubeless Type III". The numbers shown in parenthesis refer to paragraph numbers of Mil-W-5013G.

1.0 LOADS

1.1 STATIC LOADS

1.1.1 RADIAL LOAD (4.5.5)*

This load is less critical than combined loads and will not be used for design and analysis.

1.1.2 COMBINED LOADS (4.5.6)

LIMIT LOAD	~	SIDE LOAD	=	5,933 LBS.
		RADIAL LOAD	=	14,832 LBS.
YIELD LOAD	~	SIDE LOAD	=	6,823 LBS.
		RADIAL LOAD	=	17,057 LBS.
ULTIMATE LOAD	~	SIDE LOAD	=	8,899 LBS.
		RADIAL LOAD	=	22,248 LBS.

1.1.3 PRESSURE

p OPERATING = 125 psi (MAX.)

p BURST = 440 psi

*PARAGRAPH NUMBERS IN Mil-W-5013G

1.2 DYNAMIC LOADS

1.2.1 RADIAL LOAD ROLL TEST (4.5.8)

P_{RADIAL} = 6150 LBS
L = 1400 MILES
} WHEEL AT AMBIENT TEMPERATURE

1.2.2 COMBINED RADIAL - SIDE LOAD ROLL TEST

P_{RADIAL} = 6254 LBS

P_{SIDE} = 1564 LBS (ACTING INBOARD) WHEEL AT AMBIENT TEMP.

L = 400 MILES

2.0 DESIGN CRITERIA

2.1 STATIC LOADS

The composite wheel will be designed to support the static loads listed in paragraph 1.1 above. Composite material allowable stresses will be established.