SECRET

PROCESS PLANNING MANUFACTURING METHODS AND TOOL DESIGNING

FOR

PV 704 6-VIPER TEST RIG

DECEMBER 1957

AVRO AIRCRAFT LIMITED

PROCESS PLANNING,

MANUFACTURING METHODS AND TOOL DESIGNING

FOR

PV 704 6-VIPER TEST RIG

The following is a brief survey of the more interesting phases in the production of PV 704 and is intended to highlight some of the problems encountered in the production of a circular planform aircraft. No attempt has been made to fully explain each and every component in detail.

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PART 1

PLANNING AND TOOL DESIGN DEPARTMENT

Functions and Procedure

1. The procedure starts immediately a scheme is put into operation by the Design Office. The Planning Department offers suggestions and advice throughout this stage of design to ensure that the maximum possible economy for production is achieved according to the quantity required. A method of manufacture, assembly procedure, and the tooling requirements are established. Manufacturing estimates are prepared to compare alternative methods of manufacture and to forecast shop capacity and labour requirements. Design schemes are watched carefully for any items required which would be beyond the capacity of the company and preliminary drawings are requested for the issue of enquiries to sub-contractors.

2. The Design Office issues scheme drawings to the Planning Department incorporating the suggestions where possible offered by Planning. The method of manufacture and tooling requirements are then written by Supervision with reference to sketches where necessary. This information is prepared in the form of a guide to Planners and Tool Designers and serves to establish the discussions and conclusions arrived at in para. 1.

3. From this information and the scheme drawings, Tool Designers prepare schemes for jigs and tools, and Planners write their process on flimsy forms. During this period the Loft Department will be lofting the detail parts and will request from Planning, information on how the part is to be lofted to suit the manufacturing methods established. When this is done, the loft reproduction will, to some extent, dictate the method of manufacture to the shops and assist the Operator in interpreting the process card. It will also save the Planner from writing lengthy descriptions of what he wants, e.g. 'make drill and scribe template to drill all holes and scribe to loft', instead of explaining which holes are to be left undrilled, which holes and sizes are to be drilled for assembly purposes. This saves the Planner's time, helps the shops and eliminates the obvious chance of errors and costly correction of errors.

   Lofted glass cloths are checked by the Planning Department for production methods before being released for reproduction.

4. The Design Office issues assembly and sub-assembly drawings and detail drawings where a detail part has not been lofted. If a detail part

has been lofted, it will carry the additional information, not usually required on a loft, such as material specification, welding, heat treatment blocks and protective treatment; paper prints will be taken from the glass cloth and these will be called drawings. Metal reproductions for the shops will be taken in the usual manner.

The receipt of drawings covered by an Engineering Release Note, is treated as an official instruction to release the drawings for manufacture. The department receives two sets of drawings; one set is given to the Planners and one set to the Tool Designers allocated to the job.

5. The Planners now adjust their original processes written on the flimsy forms, to take care of the alterations and contingencies that have occurred in the Design Office during the preparation of firm drawings from schemes. These flimsy forms are now sent for typing on the correct process master form.

The process will include a full operation list and tooling call-up for each detail part, and a full operation list giving the sequence of assembly and tooling call-up, for each sub-assembly and main assembly.

For simplicity and to reduce paperwork to a minimum, the tooling requirements are specified on the process master opposite the operation on which it will be used. This eliminates a separate tool order. One copy of the process master is run for Manufacturing, one copy for each tool called up is run for Tool Manufacturing and one copy for each tool called up requiring tool design is run for the Tool Design Department. This system has the advantage of showing the Operator, who normally only gets an operation list, what his tooling should contain and showing the Tool Maker and Tool Designer the method of manufacture for which the tooling is required.

For further simplification a tool prefix is used in front of the part number to indicate a tool number, and the tool drawing number is the same as the tool number. Therefore, one number, is used instead of three, eliminating Tool Order Number Registers and Tool Design Number Registers. e.g.

Part Number	55 A 460	Bracket
Tool Number	BP 55 A 460	Blank & Pierce Tool to A-3-1 Standard
Tool Number	1FD 55 A 460	1st Form Die to Tool Drawing 1FD 55 A 460
Tool Number	2FD 55 A 460	2nd Form Die to Tool Drawing 2FD 55 A 460
Tool Number	ST 55 A 460	Special c/bore Cutter to Tool Drawing ST 55 A 460

Drawing changes are effected by noting the change on the bottom of the master or introducing a further sheet to the master if insufficient space is available. Separate work order changes are not used. Only in exceptional cases is a separate 'Rework Card' issued, if this is thought necessary by the complicated nature of the alteration. See Fig. 1 for sample process and tool order.

6. On receipt of official release of drawings, the Tool Designers proceed with the preparation of tool drawings, using the tool design schemes already in existence. They receive a copy of the process card from the Planning Department which serves as a tool design order, and a record of the tool design required. The Planners and Tool Designers work in close co-operation at this stage. All tool drawings are approved by Supervision before release to the shops.

7. This system was originated to achieve the following results:

   (a) to assist the Design Office in designing for the cheapest method of manufacture.

   (b) to be well ahead with preliminary planning, tool design schemes and sub-contract enquiries in the early stages of design to reduce lead time.

   (c) to reduce clerical work to a minimum particularly in the Planning Department thus breaking down the system so that technical staff only perform technical work and clerical work is done by clerical labour.

8. The system was put into operation in time for the 6-Viper Project, and proved to be completely successful. A complete package of Lofts, Drawings, Process Cards and Tool Drawings, all of which had been carefully co-ordinated, were issued to the shops in very short time following release of engineering information. A study of the records will substantiate this very short time cycle.

The records show a combined planning and tool design cost of 9.8 hours per assembly, sub-assembly or detail part. They include all discussions between the Design Office and Loft Department; they specify preliminary manufacturing methods and assembly procedures, process planning and tool designing; they cover all design alterations, drawing and loft "raise of issues", D.Q.F.'s, E.I.'s and E.C.N. forms.

PART 2

PROCESS PLANNING, MANUFACTURING METHODS AND TOOL DESIGNING

6-VIPER TEST RIG

The 6-Viper Test Rig consists of a PV 704 propulsion system mounted on a stand with all instrumentation, electrics and controls connected to an adjacent Test House.

The Planning and Tool Design Departments based their methods and designs on the requirement of one aircraft for the 6-Viper Test Rig, followed by two subsequent aircraft for test flying.

It became apparent during the early design stages, that an aircraft of this configuration could be built very economically by breaking down the airframe into common segments; the large duplication of detail parts would allow for easy tooling.

The following statistics which were taken on the aircraft components only, illustrate the advantages of this configuration.

1:21 was the ratio of different parts to total parts per aircraft

1.5:1 was the ratio of tools to different parts

14:1 was the ratio of total parts to each tool per aircraft

There is no doubt that the greatest advantage of a circular planform aircraft is the large multiplication of common parts that can be achieved by designing for radial components.

This is established in the early stages of design when the basic geometry is finalized and warrants careful consideration, as the major part of manufacturing economy is directly proportional to the number of radial components that can be permitted.

A circular aircraft with a large proportion of non-radial components would have a ratio of different parts to total parts no better than a conventional aircraft.

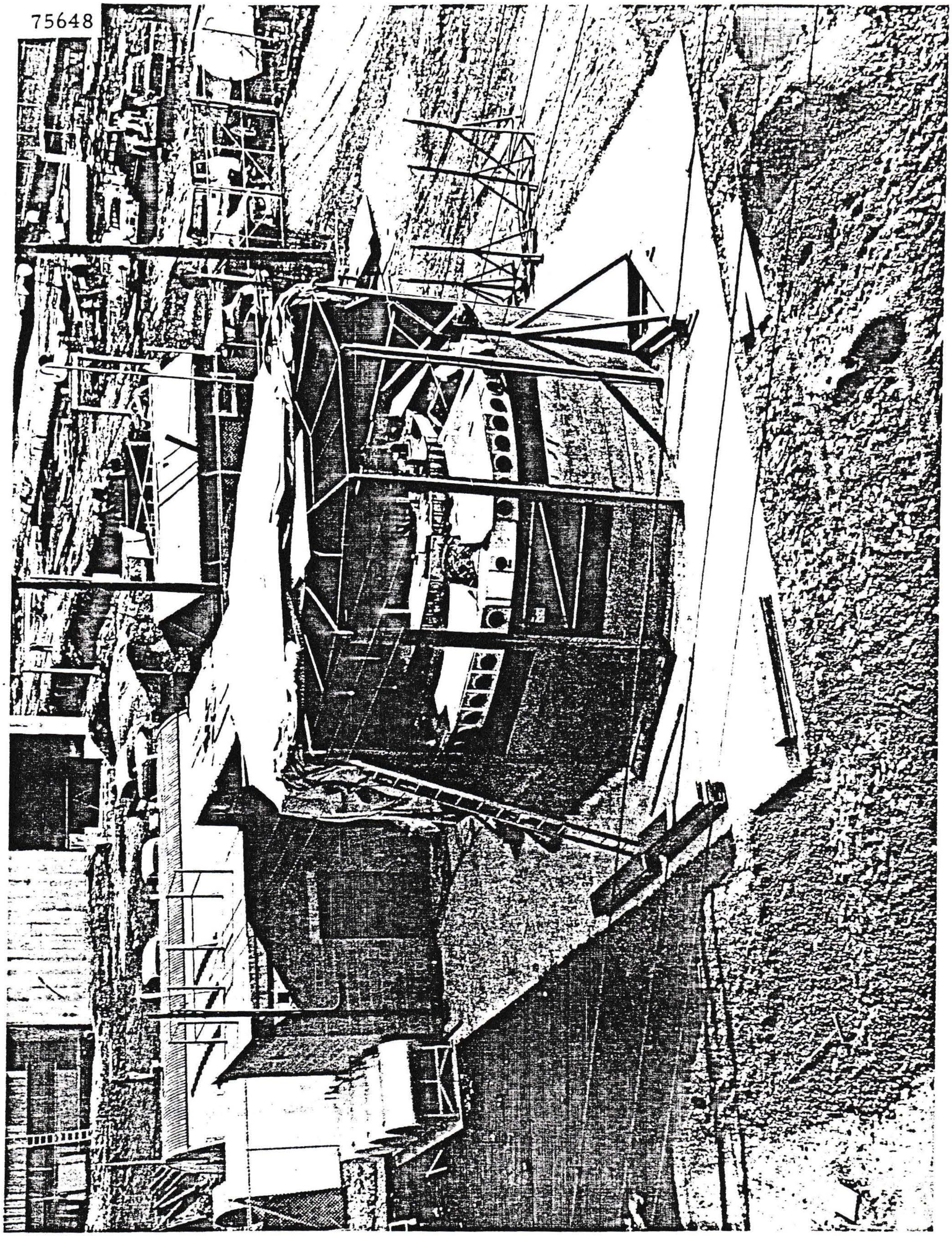

FIG. 2 6-VIPER TEST RIG DURING ERECTION AT TEST SITE

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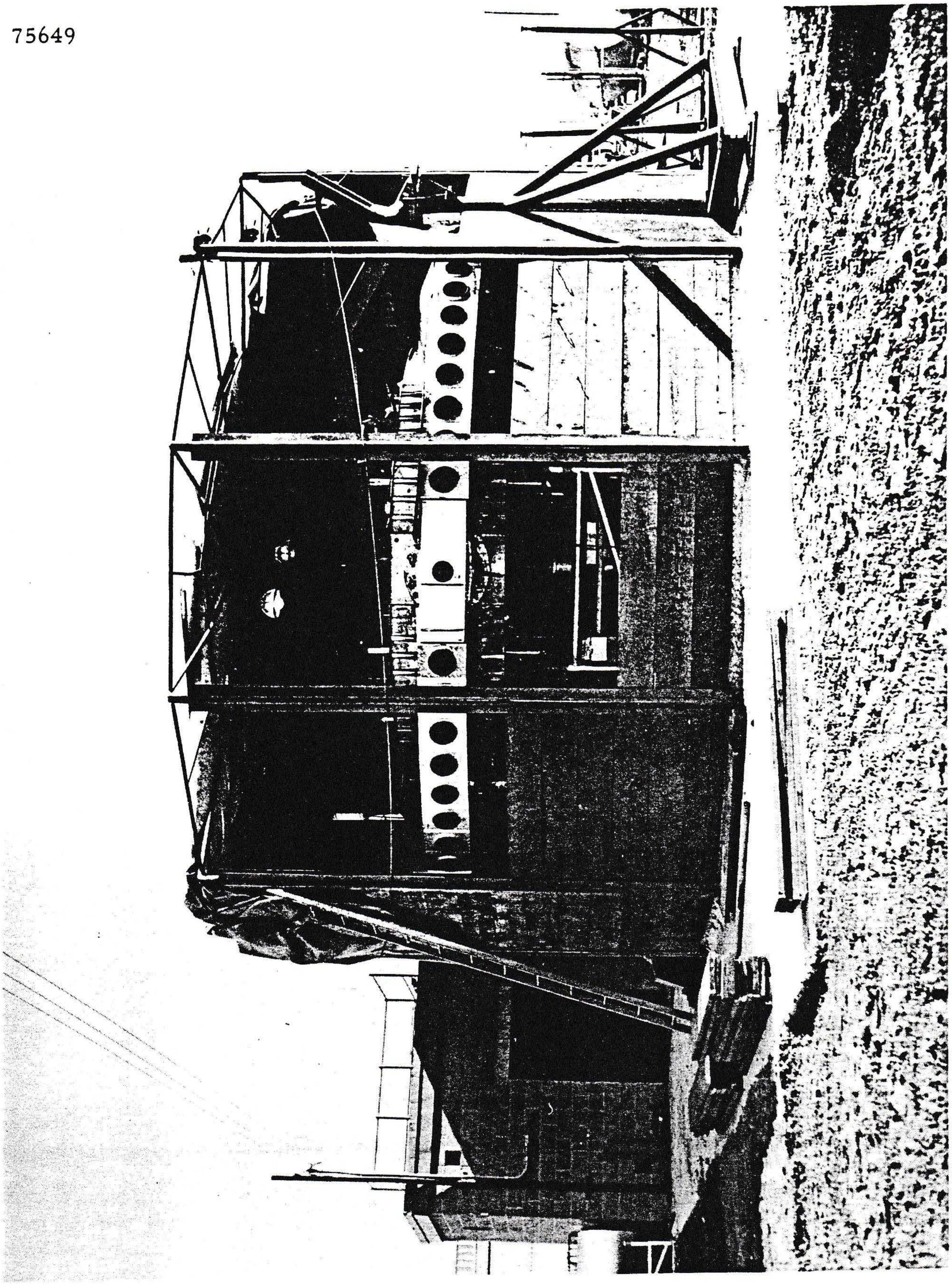

FIG. 3 6-VIPER TEST RIG DURING ERECTION AT TEST SITE

TURBINE AND COMPRESSOR

The main problems encountered on these components were the forming of 8 ft. diameter skins, the manufacturing of hollow blades and the nickel alloy brazing of blade segment assemblies.

In overcoming the skin forming problem, all known methods were studied and estimates compared to determine the most satisfactory. The stretch forming and drop hammer forming methods necessitated the subsequent welding together of the joints. This was an obvious disadvantage when compared to water die forming and spinning from both of which methods the component could be formed complete from a welded blank.

Water die forming was investigated thoroughly and had several obvious advantages. No special equipment was necessary. The die could easily be reworked for spring back, as there was no top tool and the die could be made from high tensile plaster. It was therefore possible by a sequence of tryouts and reworks to achieve an accurate pressing. This method provided the most satisfactory results with the smoothest finish, free from die and tool marks.

It was decided to manufacture a water die to produce a 1/10 scale replica of the most difficult skin to be formed in .010" and .015" 321 Stainless Steel sheet in order to develop this method on which so little information existed. The 1/10 scale was chosen for development because the die cost would be inexpensive and the forming problem was similar to the full size pressing of 8 ft. diameter .020" 321 Stainless Steel sheet. See Fig. 4.

A masonite female form block was turned to a master contour template with a centre plug to locate an aluminum draw ring. 1/8" Neoprene sheet was used for the 'top tool' retained by a masonite top plate sealed by bolts at close pitch around the periphery. A water inlet was provided in the top plate and pressure from the water main at approximately 70 p.s.i. introduced. A pressure gauge was connected to the inlet and indicator pins were introduced to the die so that the exact pressure required to fully form the part could be determined.

Various methods and procedures were tried until a consistently successful pressing was produced and all relevant data recorded.

Although the water die forming method was proved to be feasible, it was expected that further development would be necessary to achieve the successful manufacture of a full size pressing In order to maintan the tight schedule, it was decided to resort to spinning, a known and proved method, and then complete the water die development when the next requirement for such skins was forthcoming.

The spinnings were produced from welded blanks; maple was used for the chucks with steel reinforcing where necessary. Steel chucks could not be considered due to their cost and the small production quantity required. Greater tolerances and rougher finish therefore had to be accepted as a compromise against cost. The spinnings were produced to the specified standard by the Phoenix Company, Milwaukee, Wisc. and were delivered on schedule.

Due to the shop loading position at the time, it was decided to sub-contract the compressor and turbine blade assemblies to Turbo Products, Pacoima, California. However, before this work was sub-contracted, considerable work had been done in developing a method of blade forming and nickel alloy brazing because several other hollow blade assemblies were required in other components.

Two methods were finally established for forming, one for small to medium production runs and one for medium to high production runs.

Both methods used the same principle of forming the first stage open. The complete section was formed without the leading edge radius which was a developed straight line to the intersection points. The second stage only formed the leading edge radius which closed the blade.

The blade was then located in a welding fixture which held the form of the blade and was then either resistance seam welded with surplus material outside the weld and later sheared to the weld nugget, or heli-arc welded using an automatic feed and guide.

For the small production run, the blank was sheared and filed to a developed template; the 1st and 2nd stages were formed on the brake press to a contour template.

For the high production run which was developed but not used, the blade would be blanked, the 1st form on a press tool, and the 2nd form on a wrapping tool.

Several methods were tried for the nickel alloy brazing which assembles the blades to the top and bottom shrouds.

As the edges of the blades had a material thickness of only .010" butting against the shroud, no room was left for tacking and it was felt that fixtures should be avoided due to their cost. Fixtures were often very unsatisfactory when operating at such high furnace temperatures and they also reduced furnace capacity.

It was finally decided to use the 'Hit Kit' for tack welding. See Fig. 6. This was a resistance welding gun which operated from one side only and produced a pin point type of weld. To build up the thickness to be welded, 1/16" diameter wire of the same material as the parts to be welded was wrapped around the root ends of the blade to form a fillet, this being tacked to the blade and shroud by the 'Hit Kit'. Where possible tie bolts were passed through blades with nuts and washers over the shrouds to clamp the assembly together. This gave additional strength to the tack welds which were apt to break due to expansion in the furnace.

Where holes for tie bolts were not permissible, a system of clamping plates was used with the tie bolts outside the component.

The assembly was then prepared for the furnace by coating all joints with brazing paste and other areas with 'stop-off compound'.

Considerable attention was given to the dew point, time cycle, and temperature of the furnace which varies according to the nature of the work and material used. A controlled atmosphere hydrogen furnace was used for this operation.

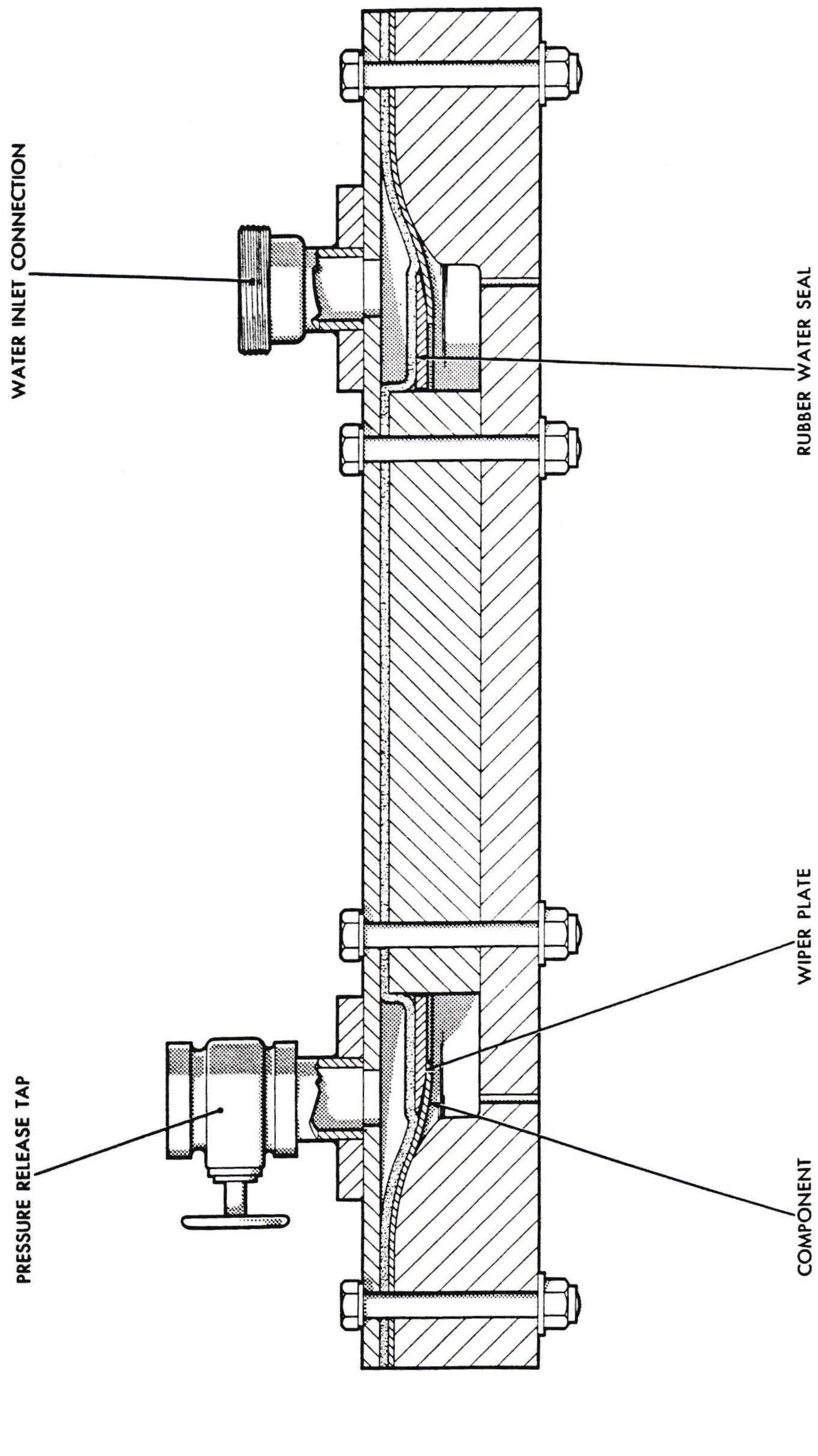

FIG. 4 SECTION THROUGH CIRCULAR WATER DIE

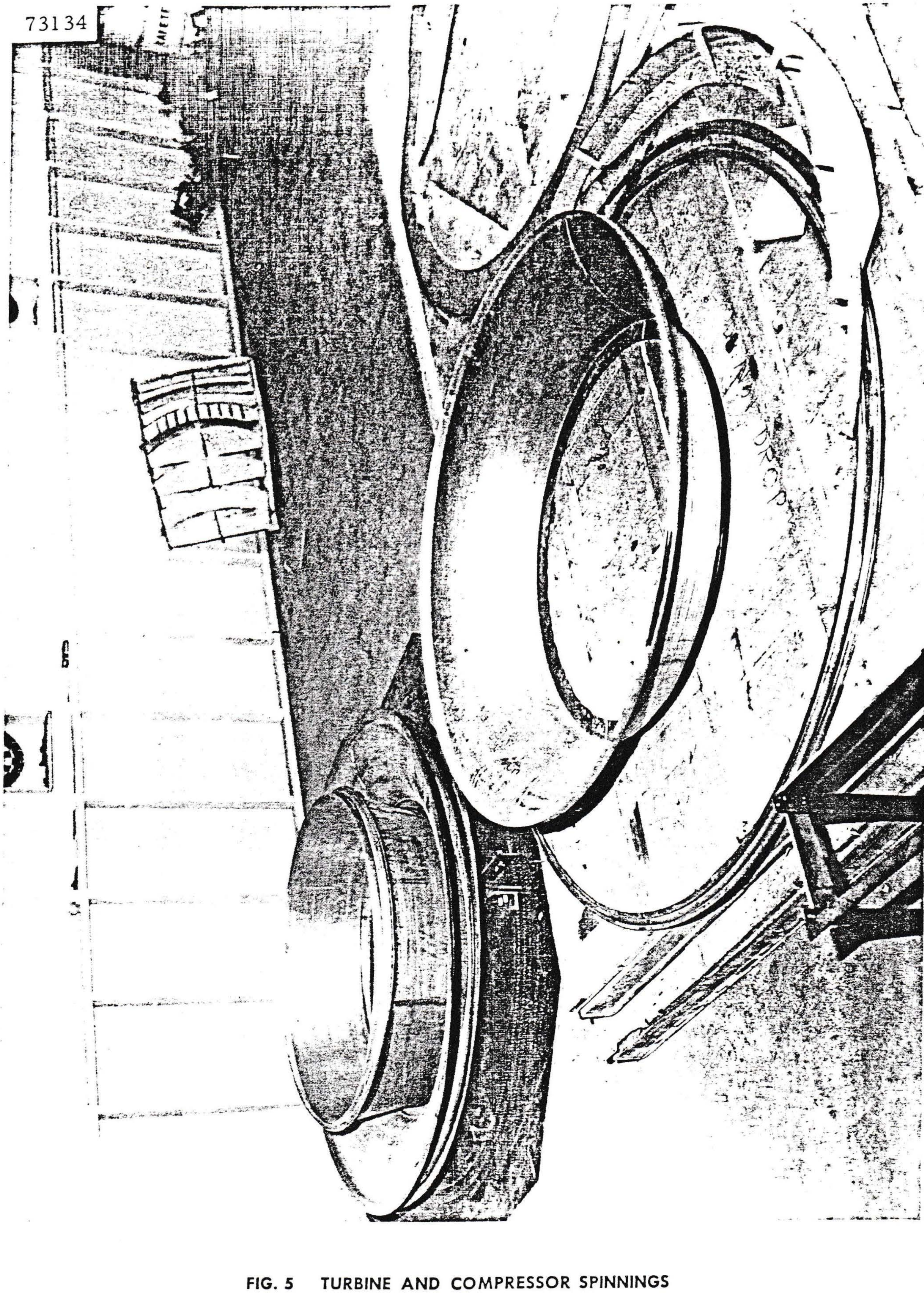

FIG. 5 TURBINE AND COMPRESSOR SPINNINGS

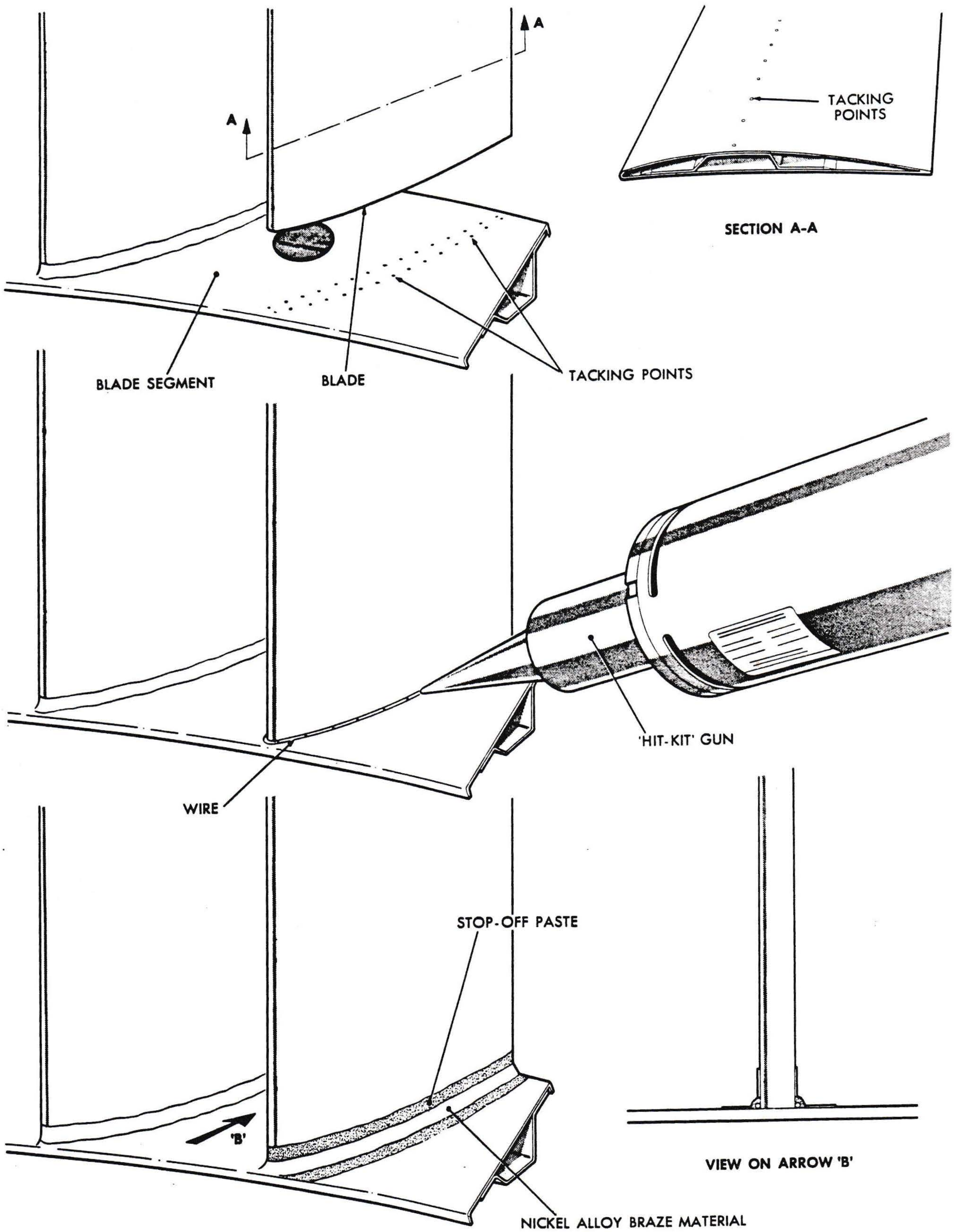

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FIG. 6 NICKEL ALLOY BRAZING PROCEDURE

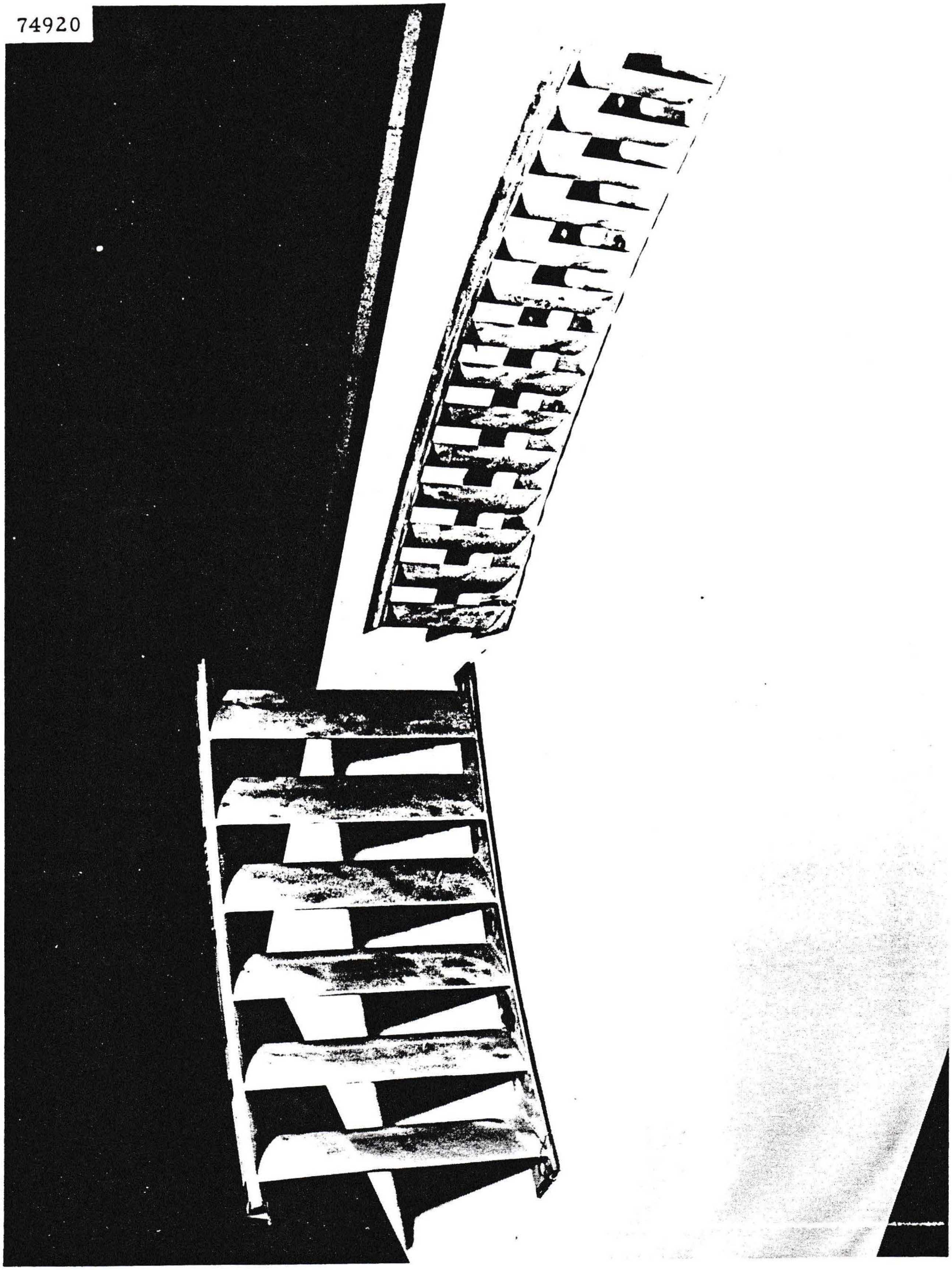

FIG. 7 COMPRESSOR AND TURBINE BLADE SEGMENT ASSEMBLIES AFTER NICKEL ALLOY BRAZING

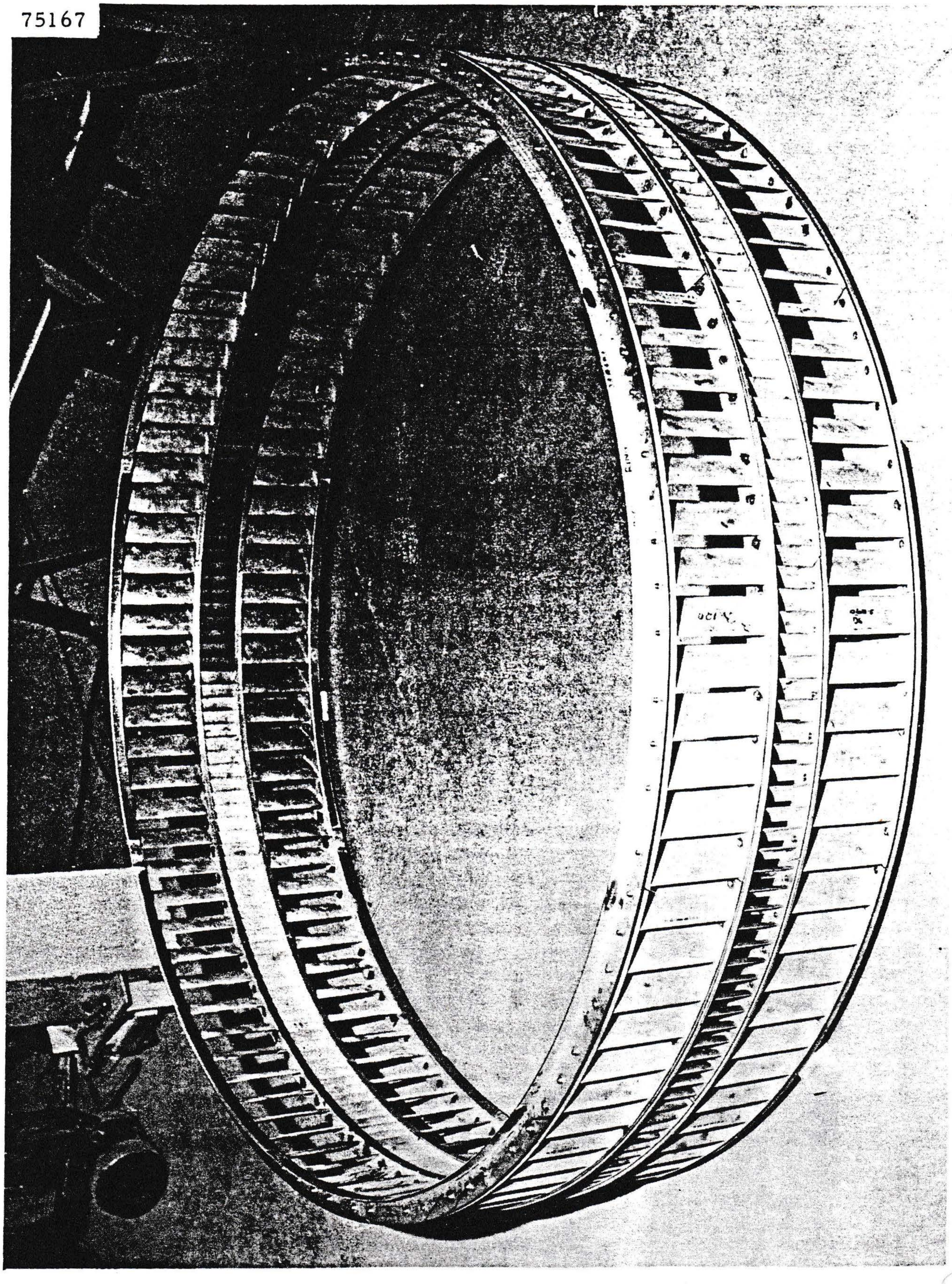

FIG. 8 TURBINE AND COMPRESSOR BLADE ASSEMBLY - ONE COMPLETE STAGE (APPROX. 100" DIA.)

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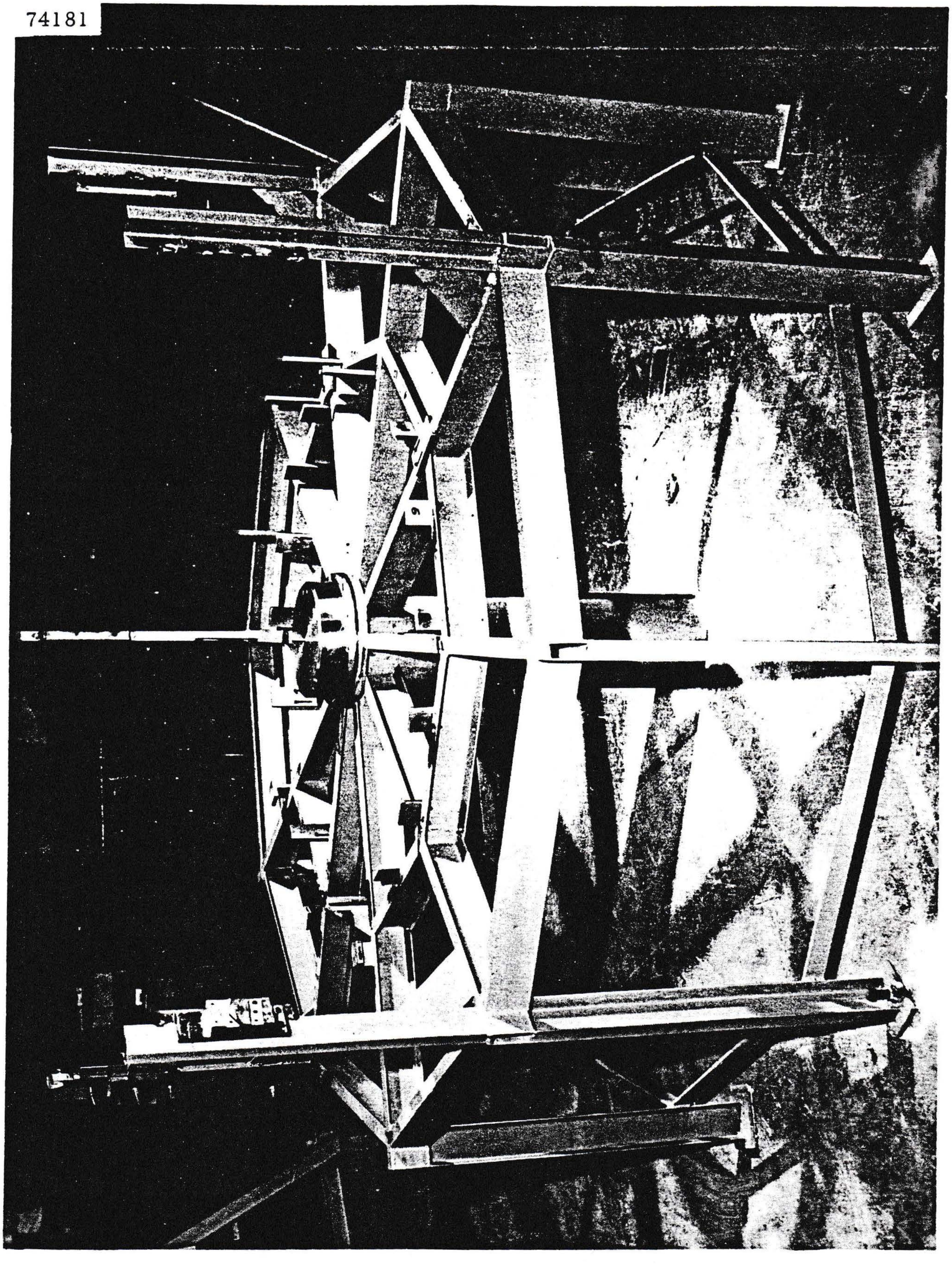

FIG. 9 ASSEMBLY JIG FOR UPPER AND LOWER ROTATING STRUCTURES

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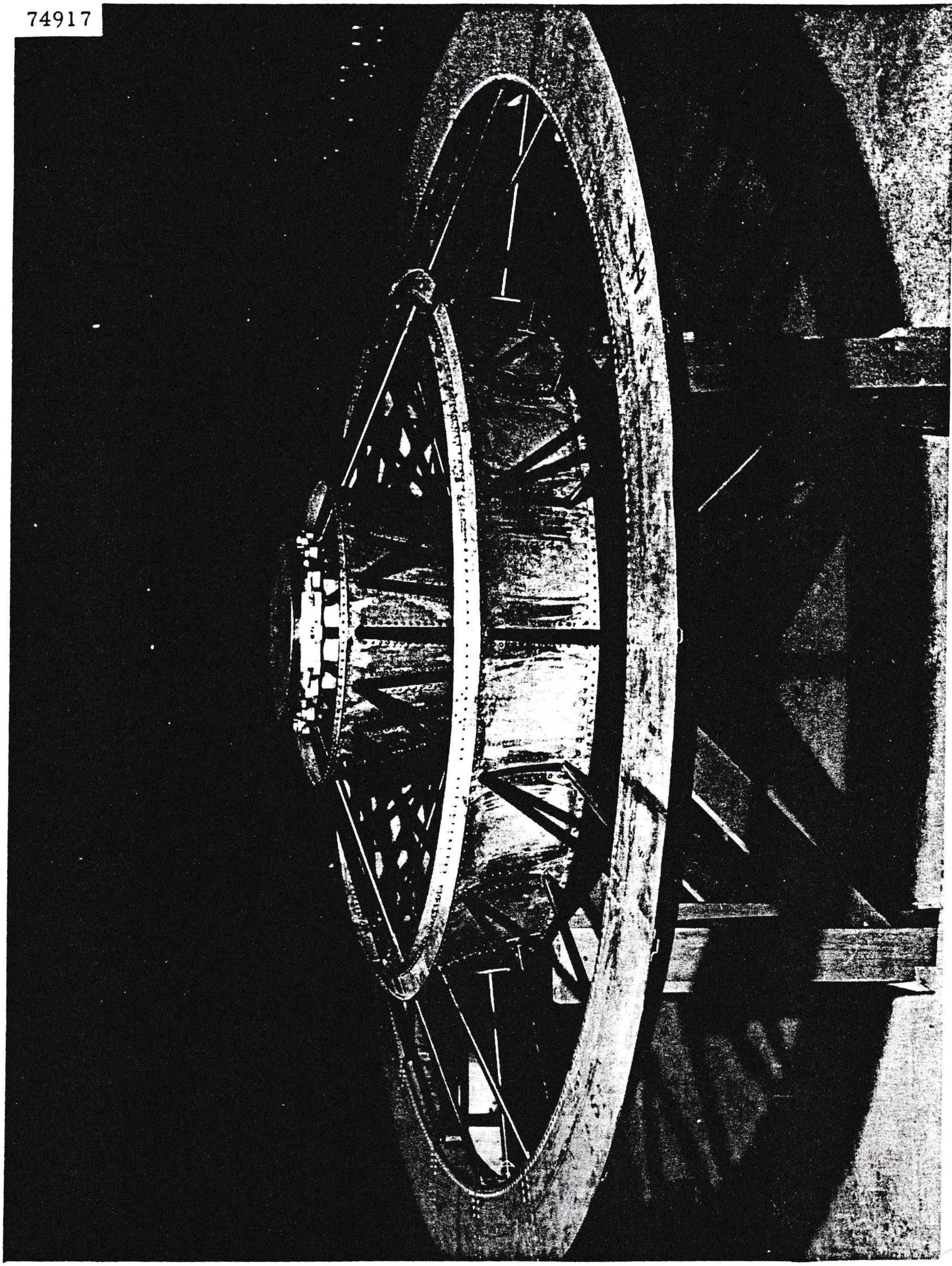

FIG. 10 TURBINE AND COMPRESSOR - ROTATING STRUCTURE

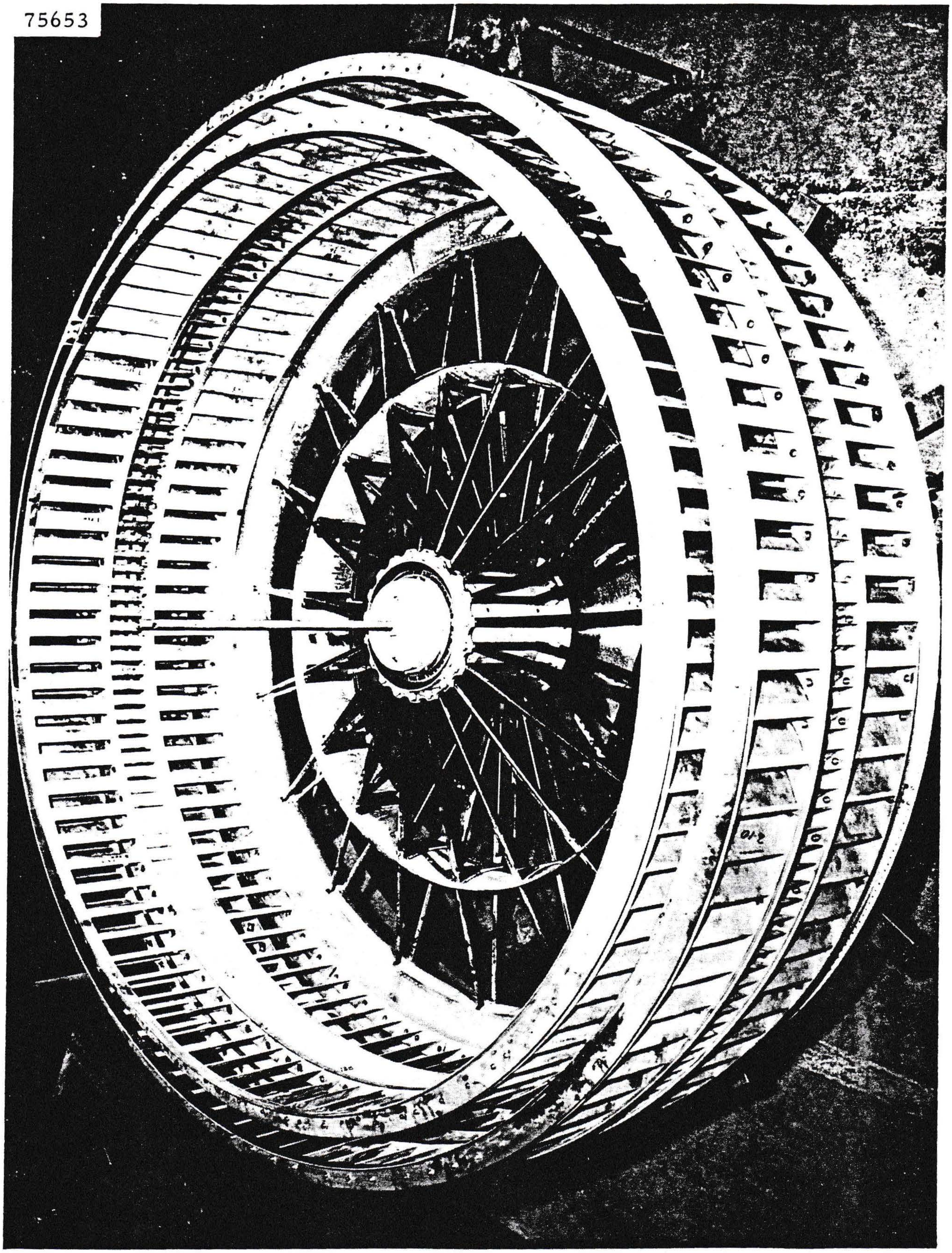

FIG. 11 TURBINE AND COMPRESSOR - ROTATING STRUCTURE WITH TWO STAGES

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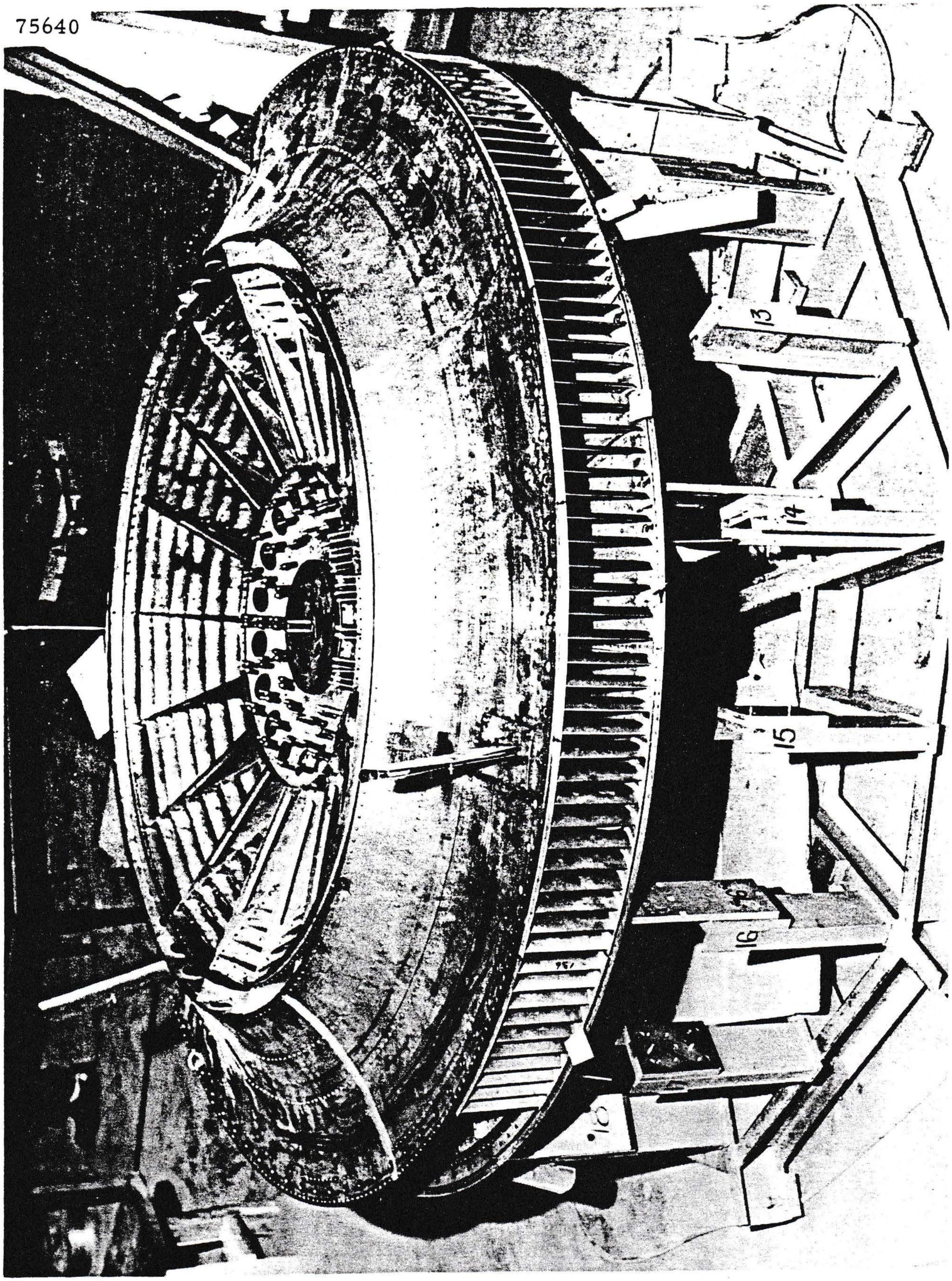

FIG. 12 FIXED CENTRE STRUCTURE - TURBINE AND COMPRESSOR IN ASSEMBLY JIG

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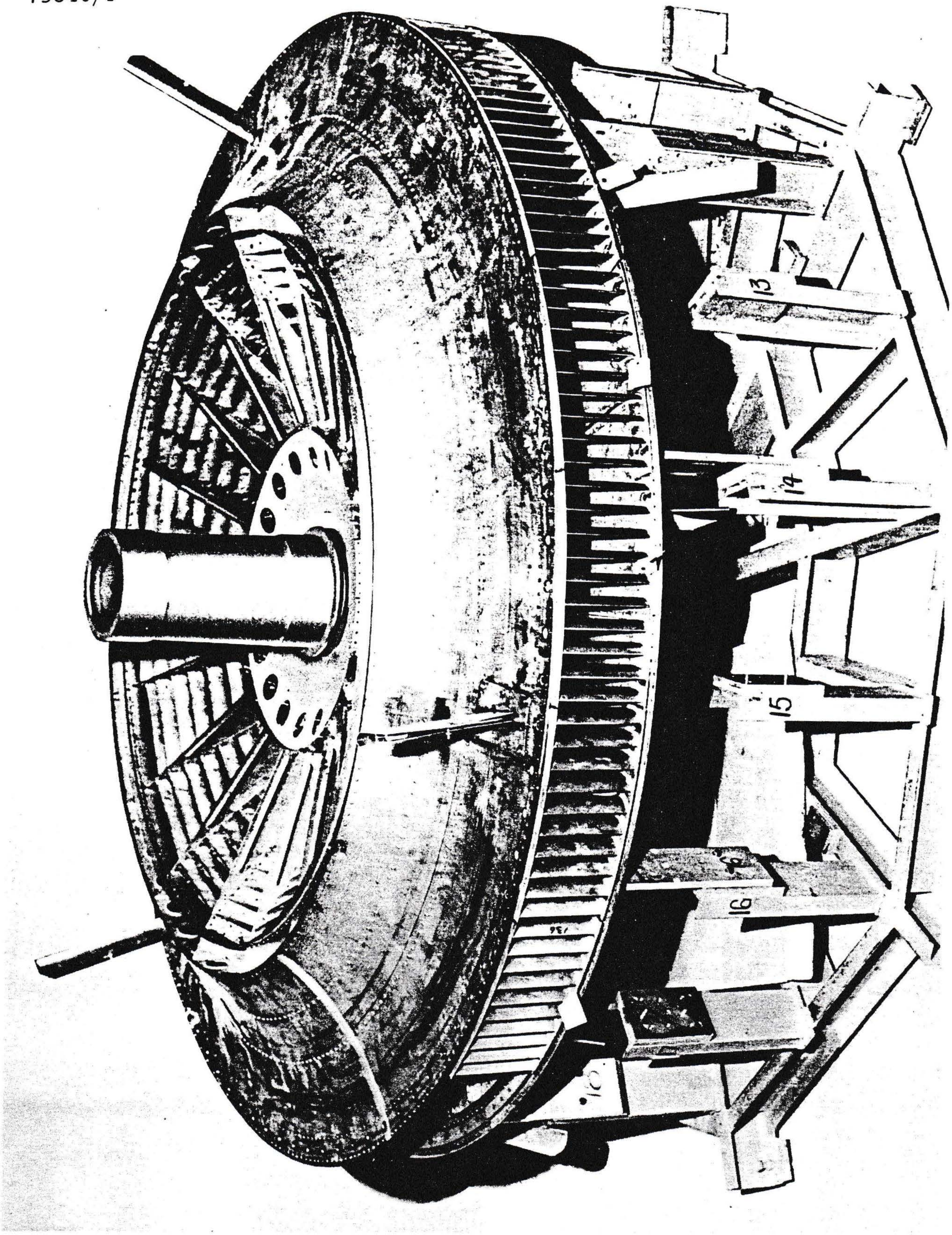

FIG. 13 FIXED CENTRE STRUCTURE AND SHAFT ASSEMBLED

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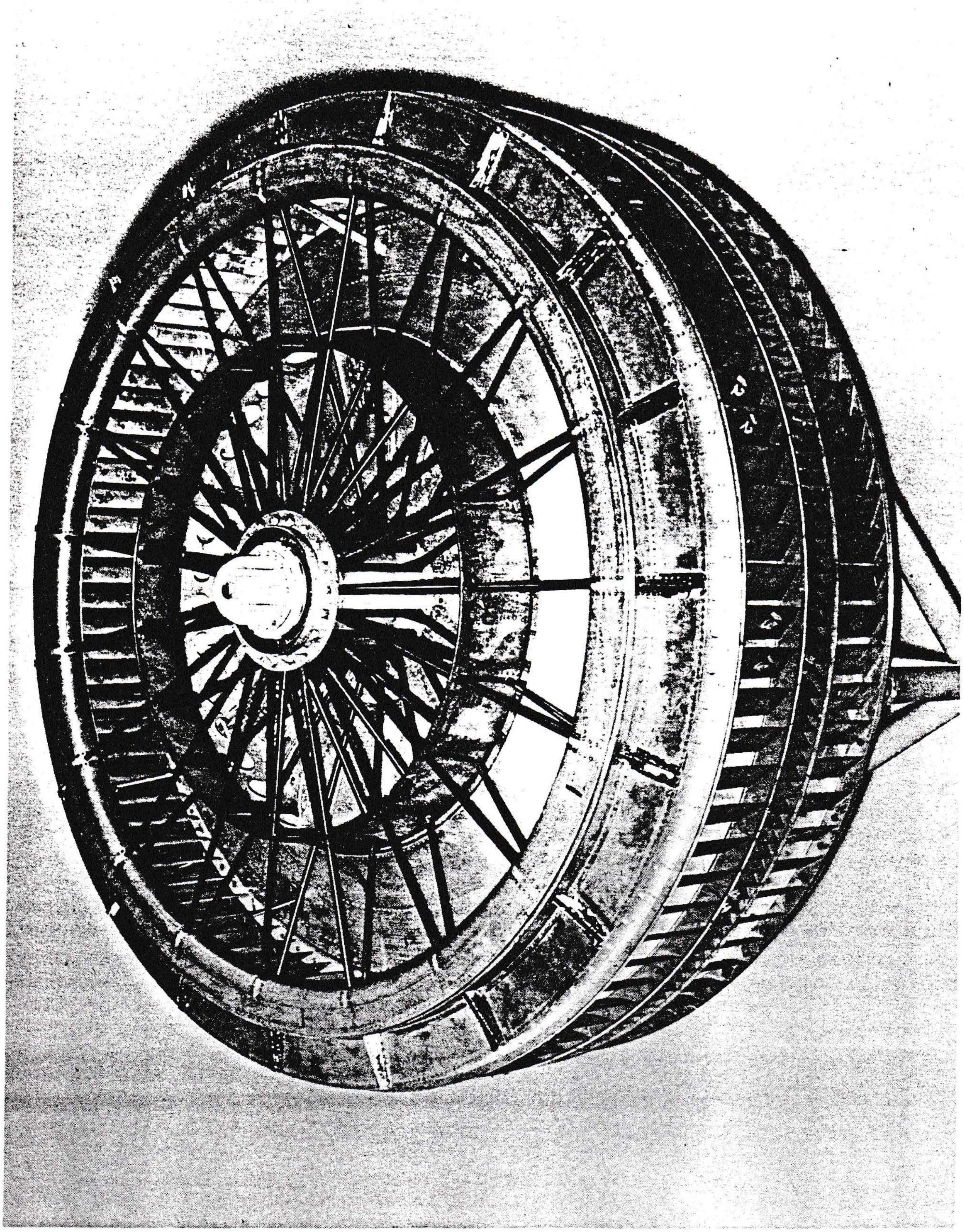

FIG. 14 TURBINE AND COMPRESSOR ASSEMBLY

FUEL TANKS

Due to the large number of common parts, advantage could be and was taken of medium production type detail tooling, i.e. the use of DRT and PF tools for ribs.

The main assembly jig was warranted by the fact that 12 components were required for each aircraft.

The jig located the tank wall and all aircraft bolt locations; sub-assembly jigs were used for the tank spars.

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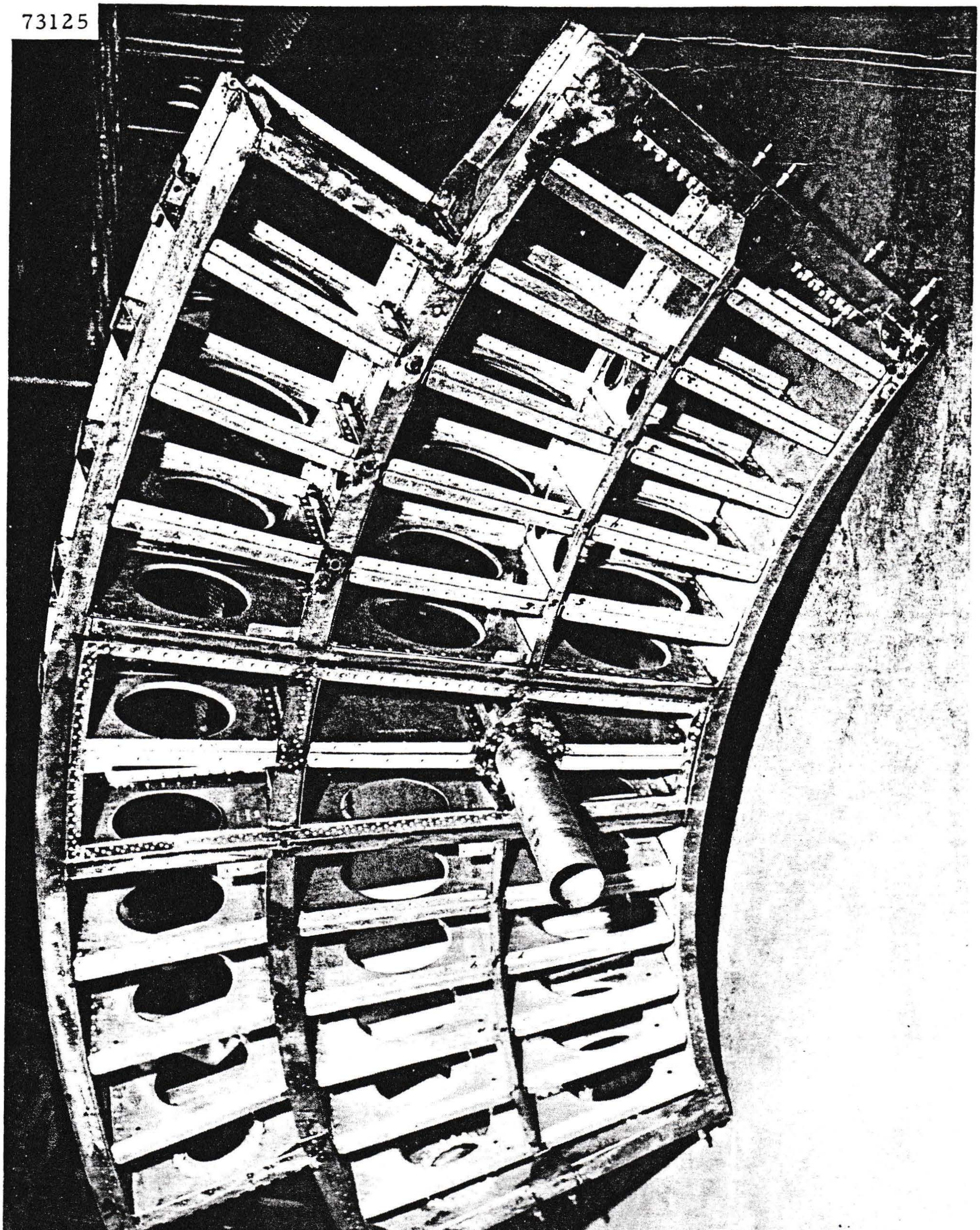

FIG. 18 FUEL TANK STRUCTURE

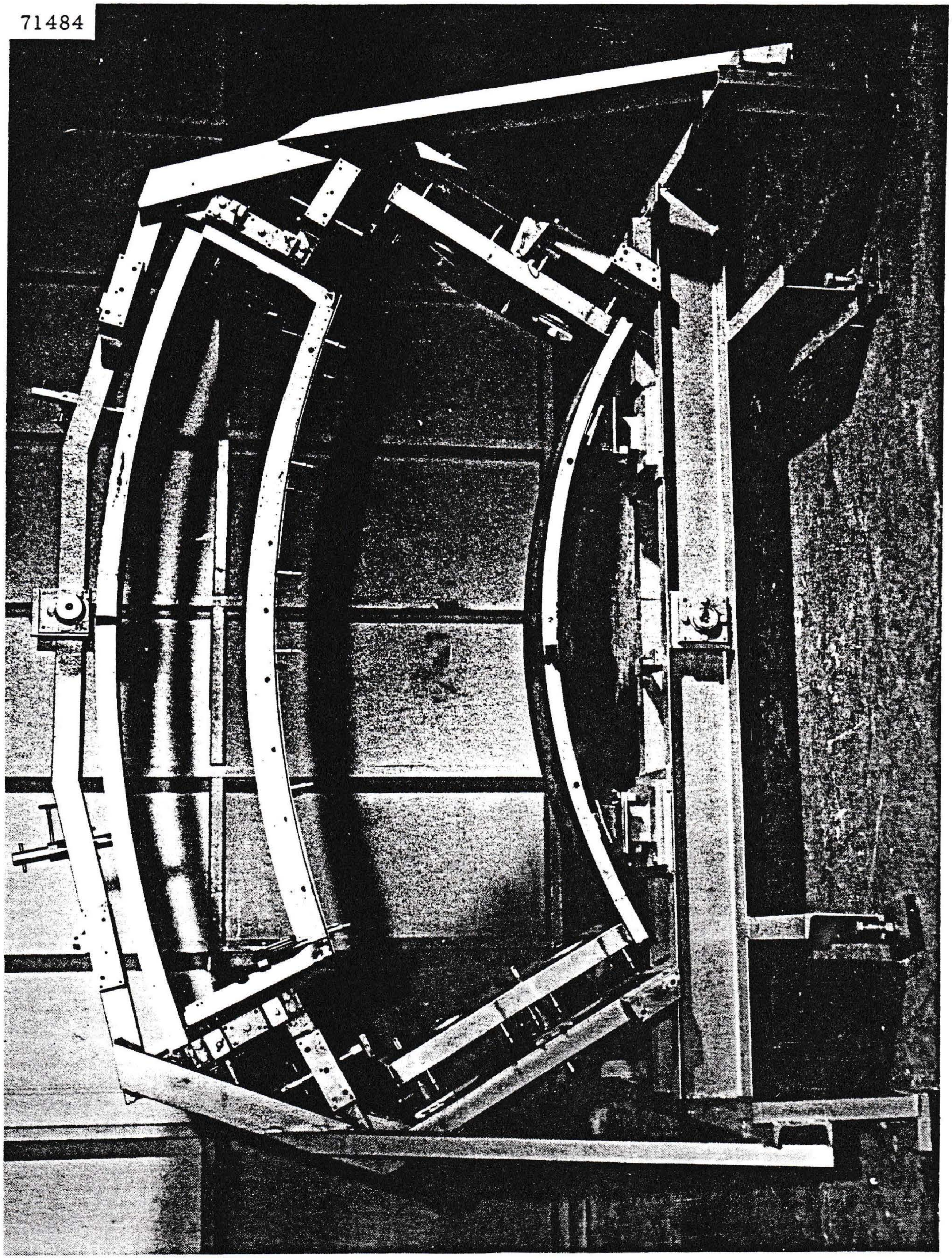

FIG. 19 FUEL TANK ASSEMBLY JIG

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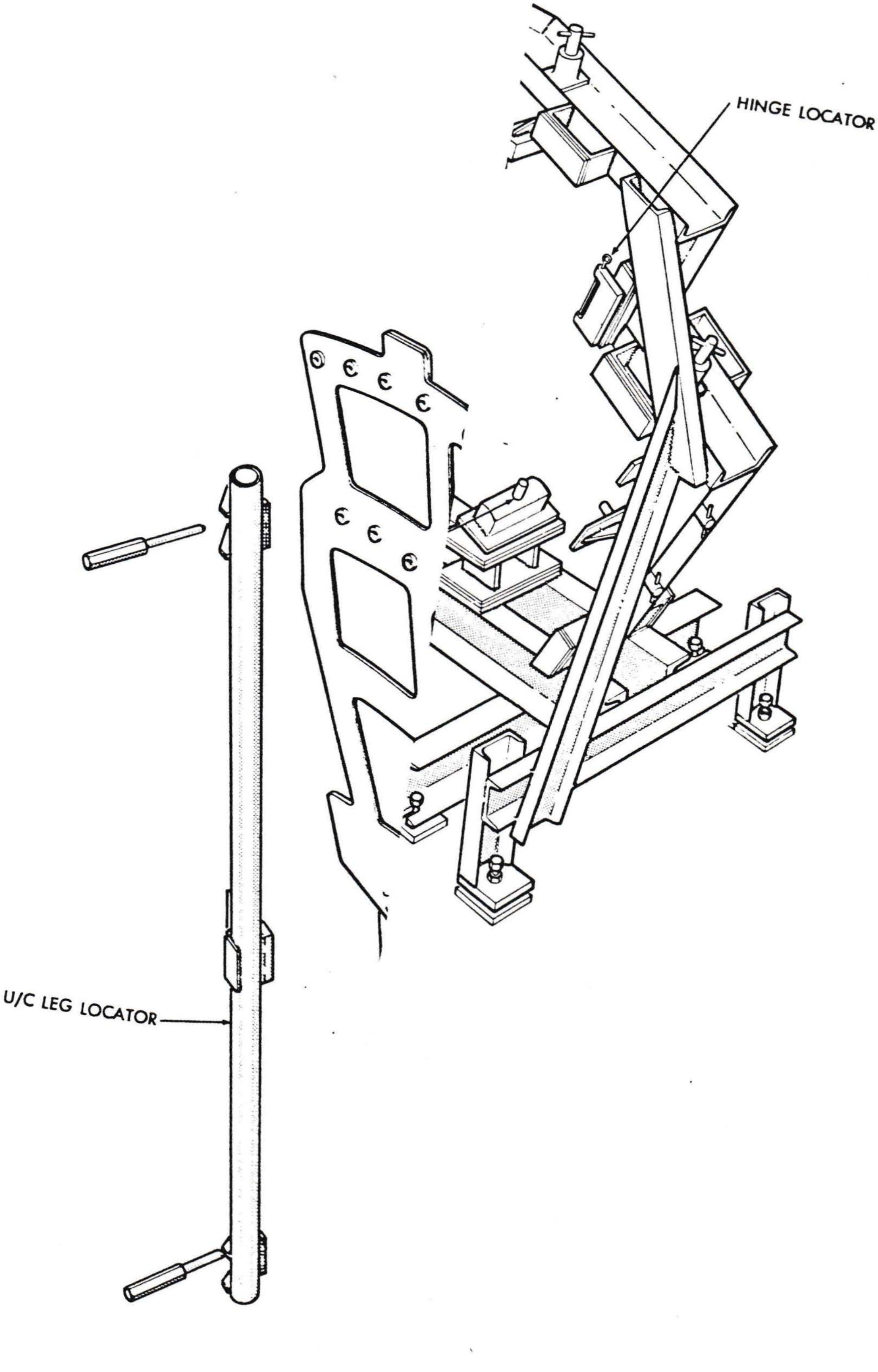

INNER WING ASSEMBLY

This assembly consisted of sheet metal ribs with rivetted extruded stiffeners and rivetted skin. Medium production detail tooling was made possible by treating all ribs as similar in the detail stage. In this way a larger quantity of common parts could be made which were modified as necessary at the rib assembly stage. Initially, manufacturing problems arose because the ribs were not radial; these problems were overcome by tooling as described.

The main segment assembly was controlled by a main assembly jig which located the wing ribs, main aircraft bolt positions, fuel tanks and segment extremities by means of engine mounting holes. Reasonably good tooling could be afforded for such an assembly due to the number of segments in each aircraft.

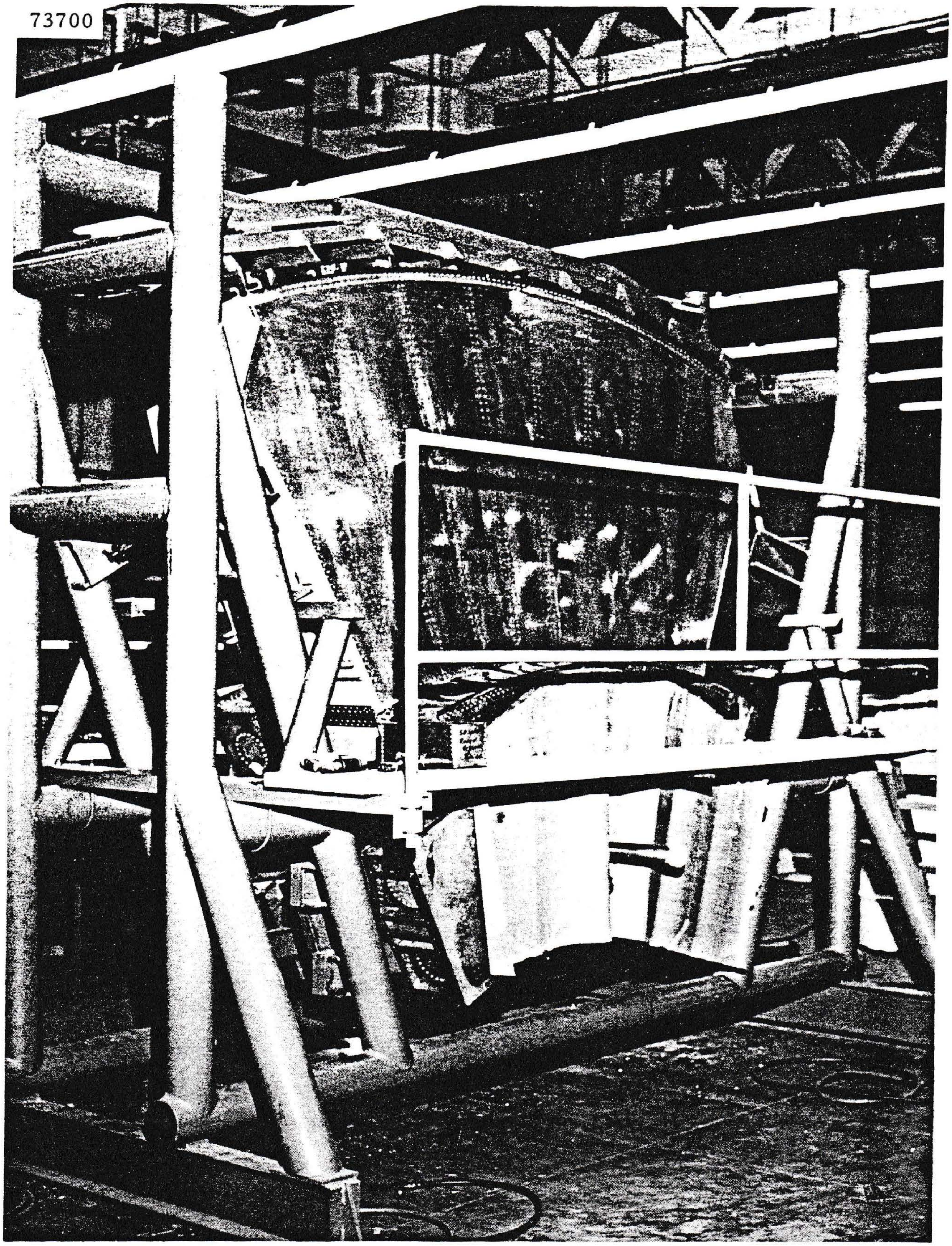

FIG. 21 INNER WING SEGMENT ASSEMBLY IN ASSEMBLY JIG

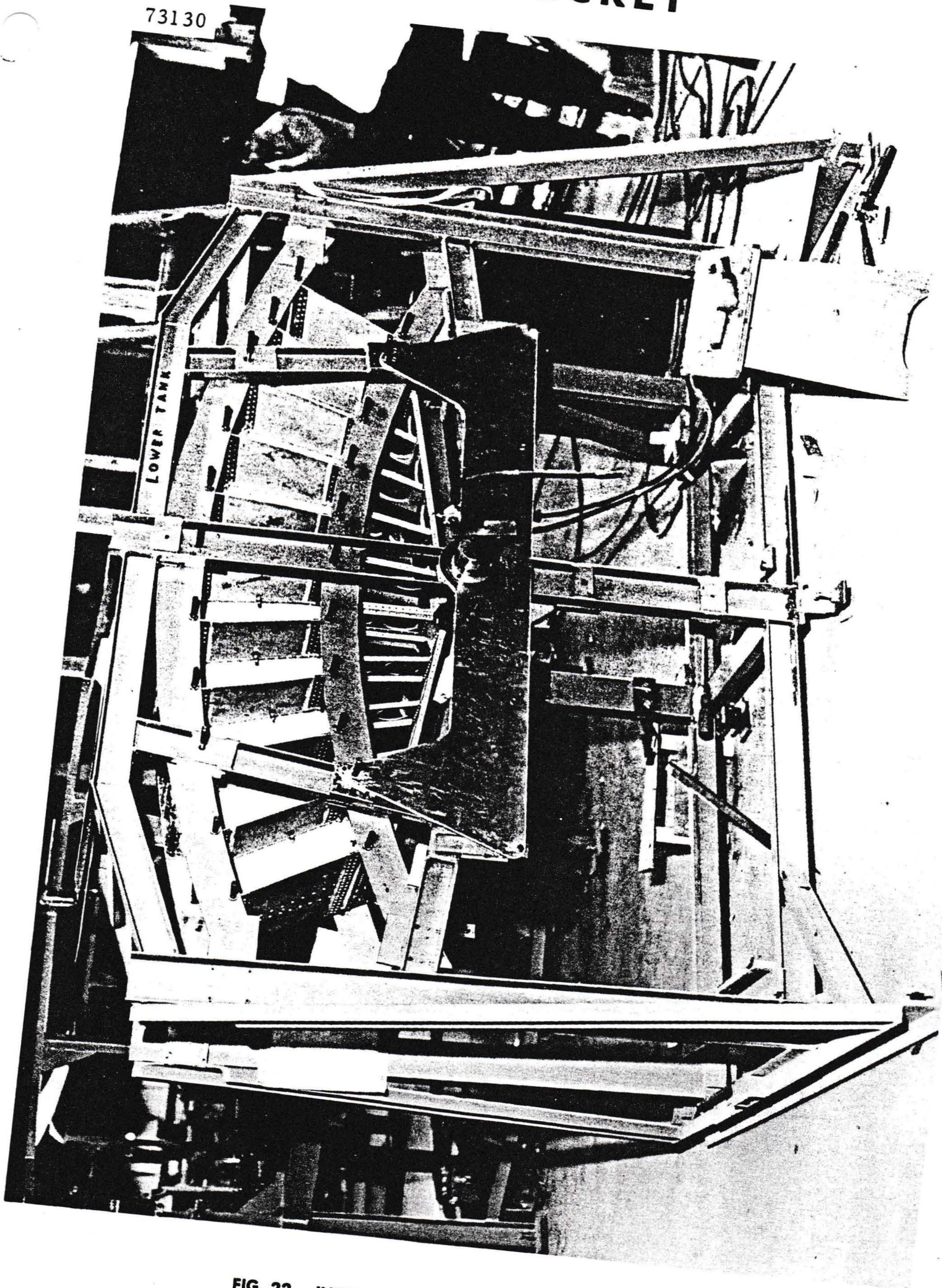

FIG. 22 INNER WING FAIRING IN ASSEMBLY JIG

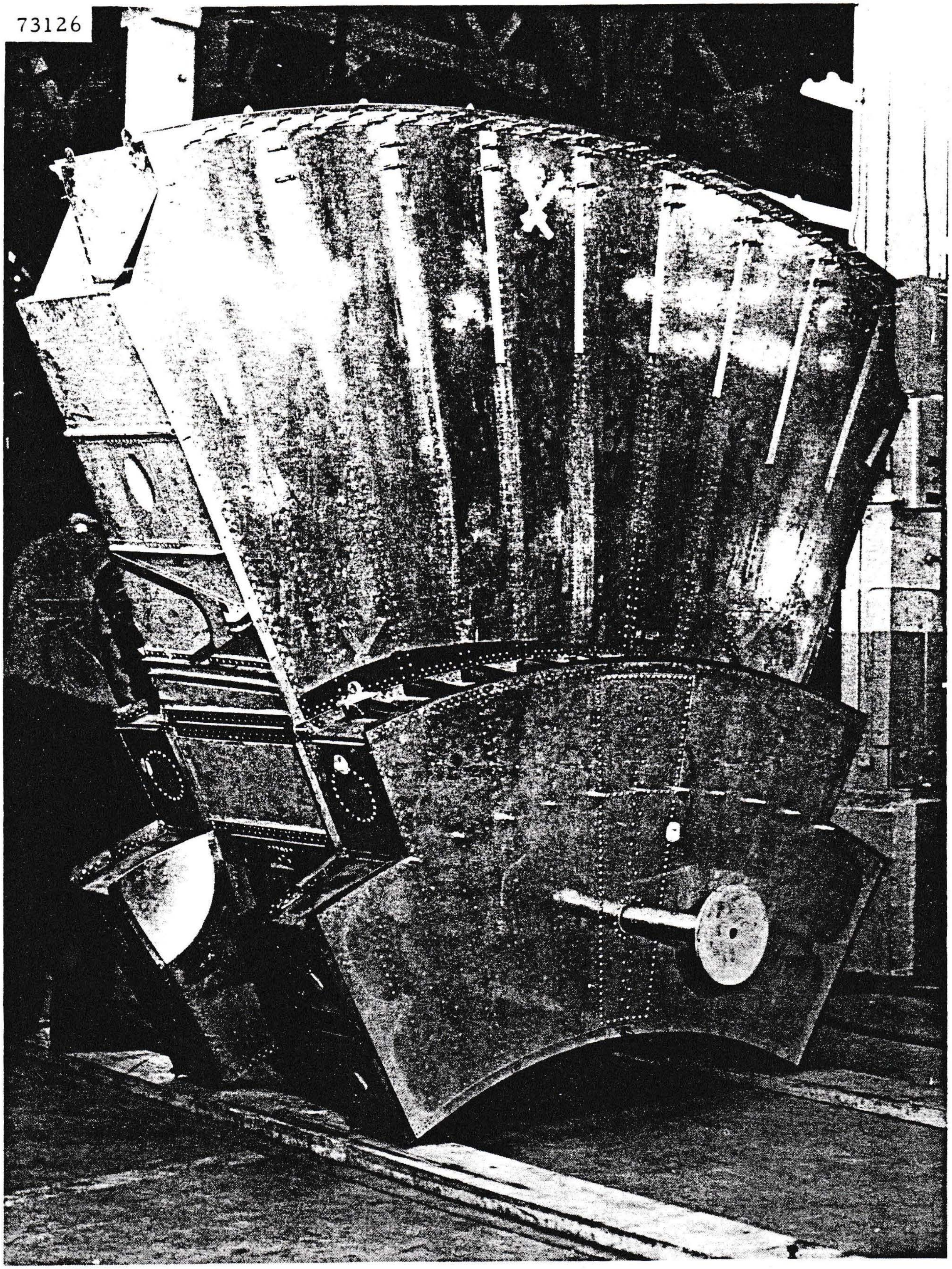

FIG. 23 INNER WING SEGMENT ASSEMBLY

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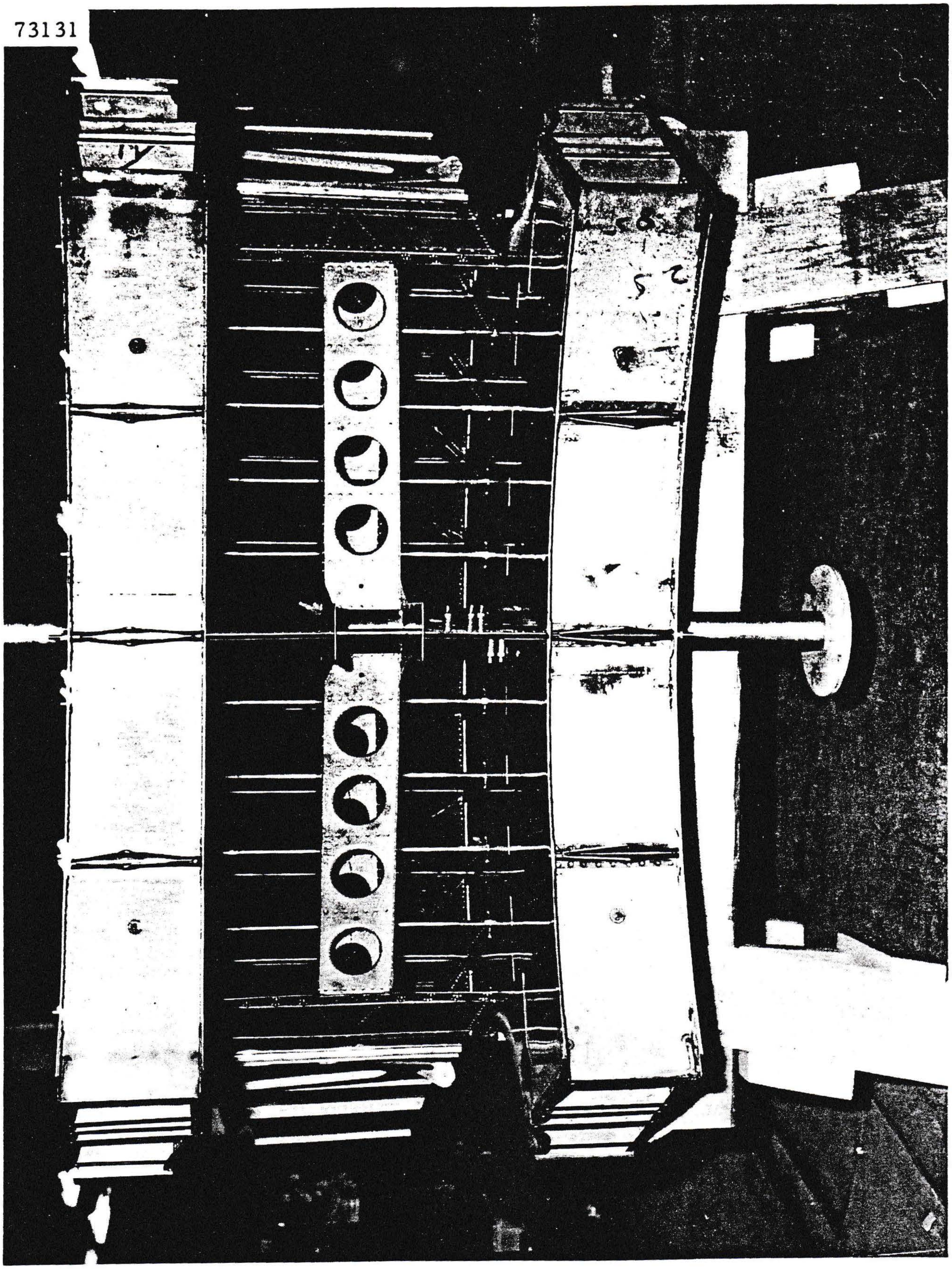

FIG. 24 INNER WING SEGMENT ASSEMBLY SHOWING FAIRING

AVRO PV 704 - TESTING-MAN HOURS & DOLLARS

SUMMARY

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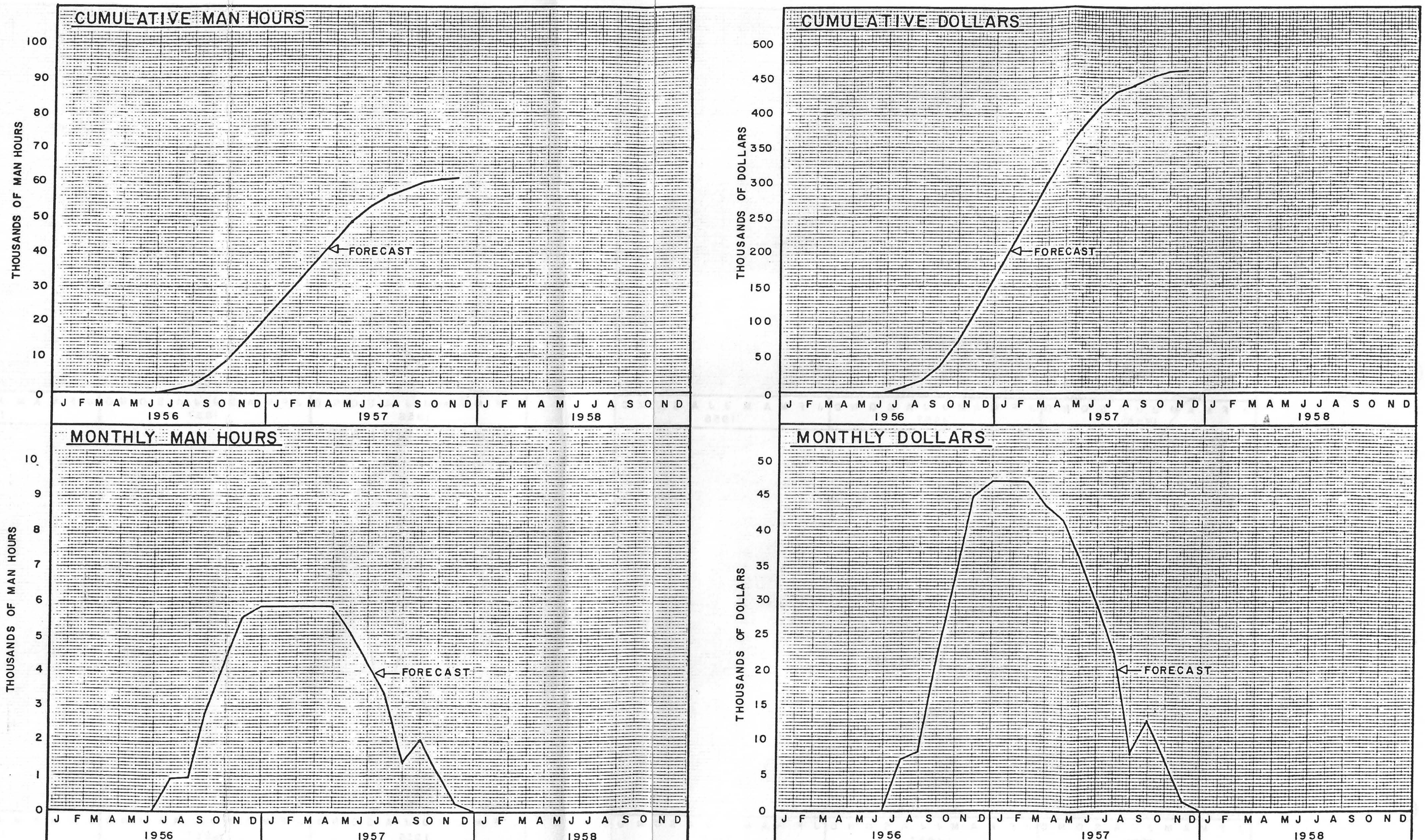

AVRO AIRCRAFT LIMITED

MALTON ONTARIO CANADA

AVRO PV 704 - PLANNING & TOOL DESIGN - MAN HOURS & DOLLARS

SUMMARY

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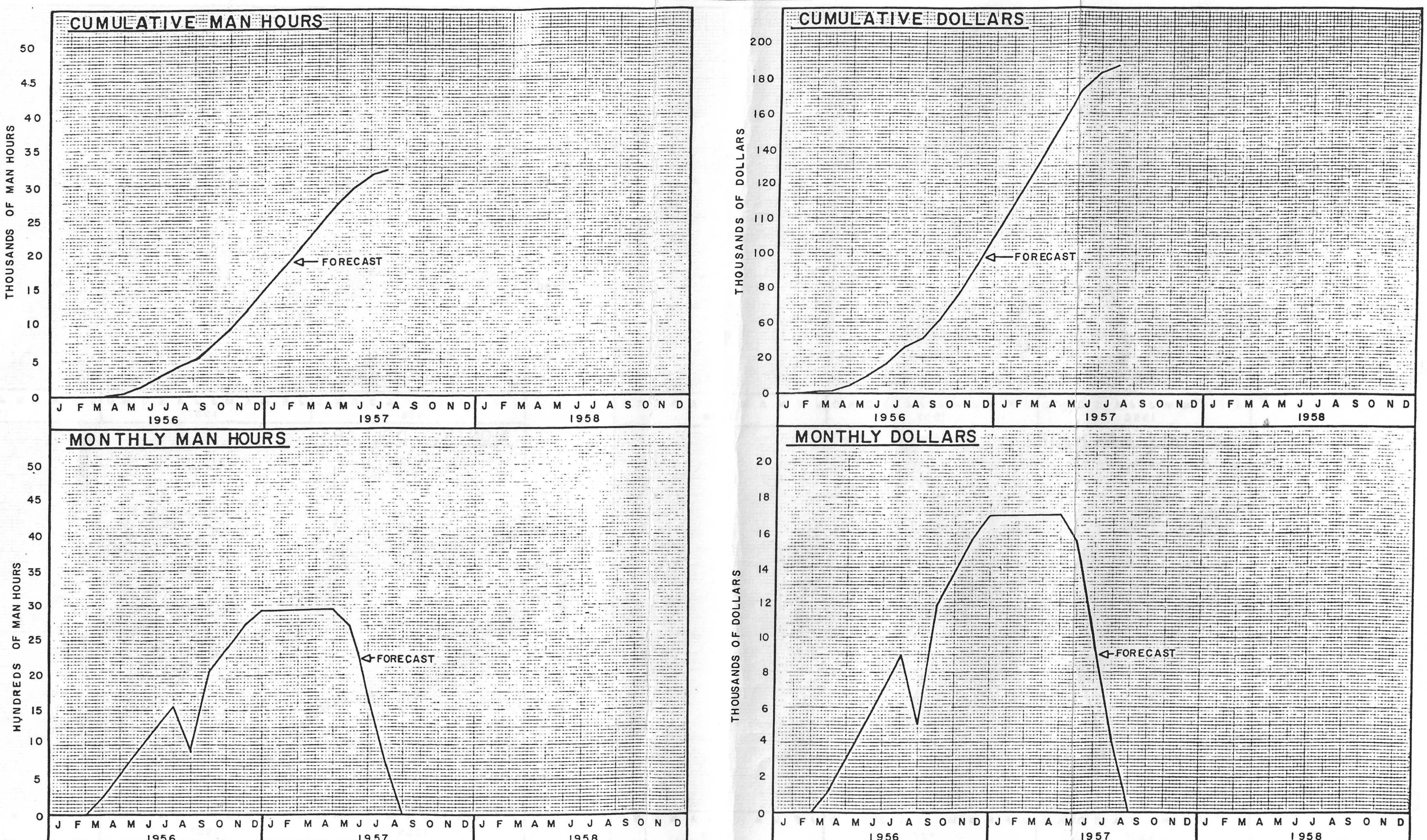


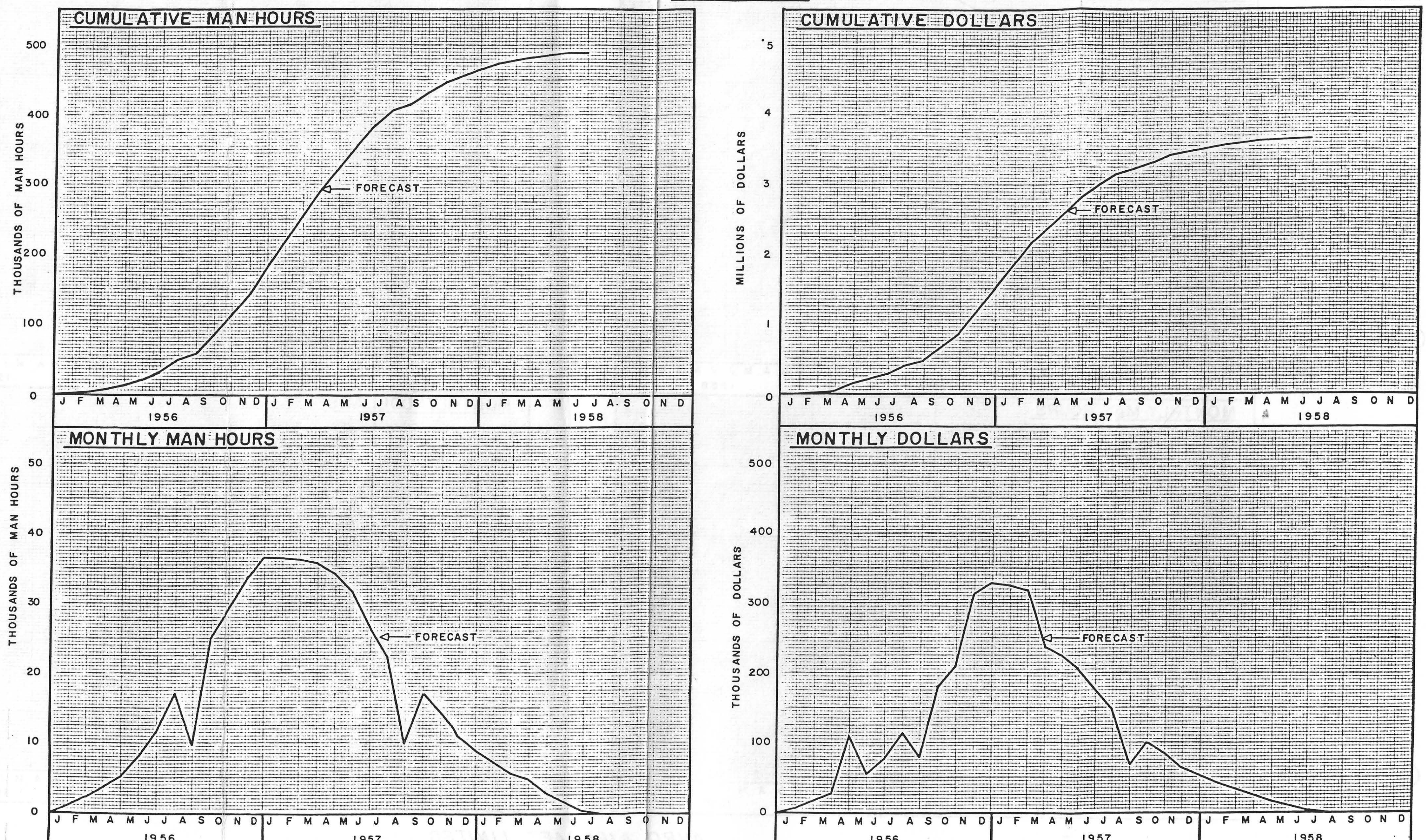
AVRO AIRCRAFT LIMITED

MALTON ONTARIO CANADA

SECRET

AVRO PV 704 - TOTAL PROGRAM - MAN HOURS & DOLLARS

SUMMARY



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MALTON ONTARIO CANADA

AVRO PV 704 - ENGINEERING - MAN HOURS & DOLLARS

SUMMARY

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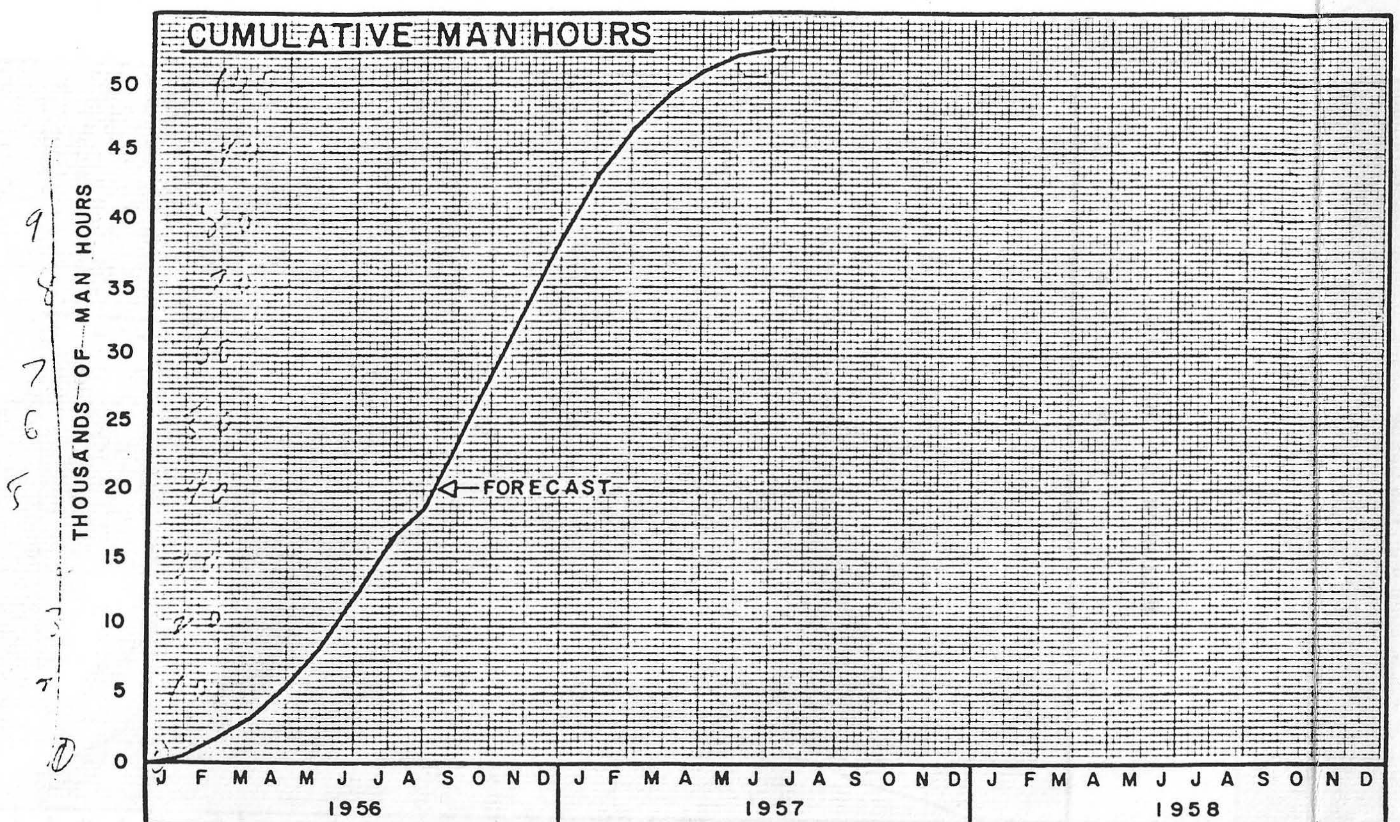

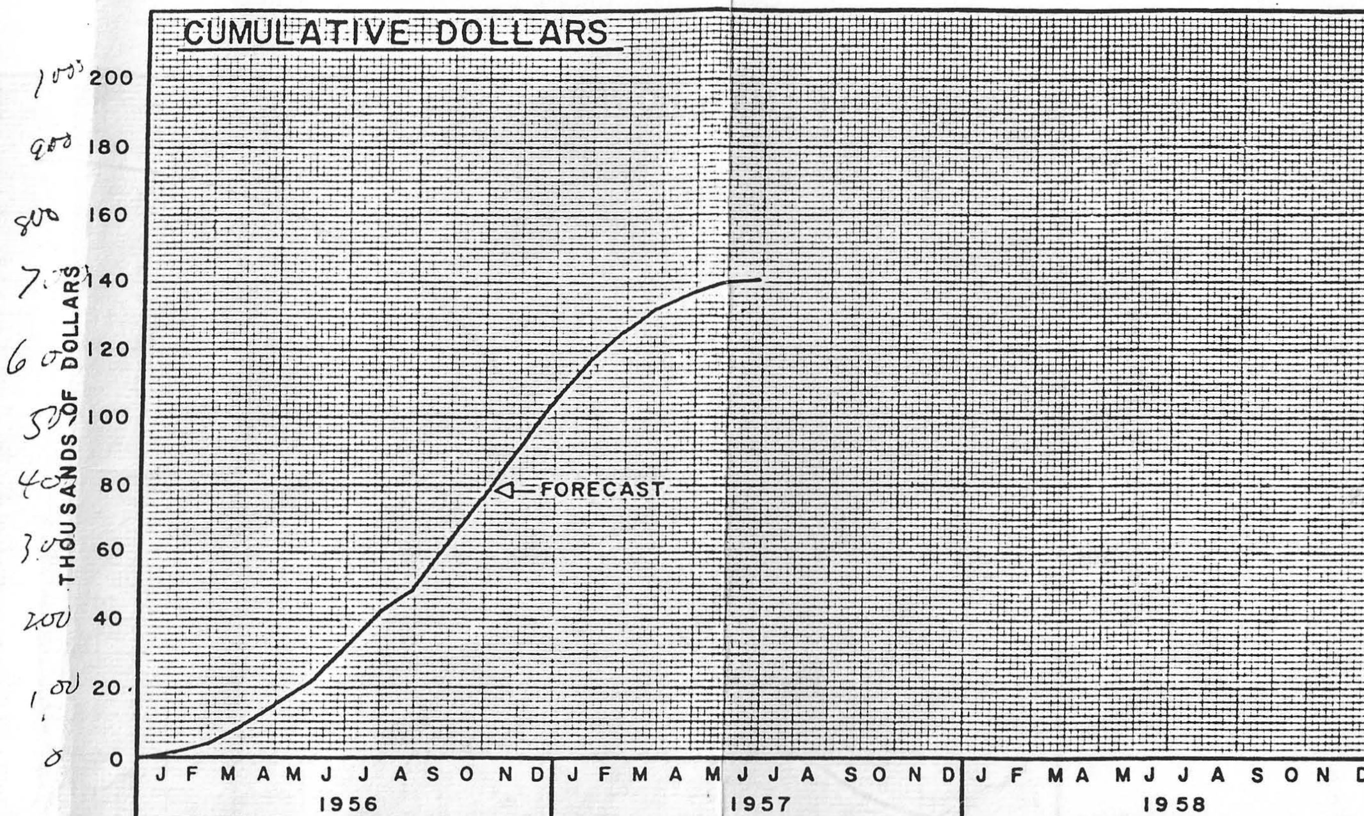

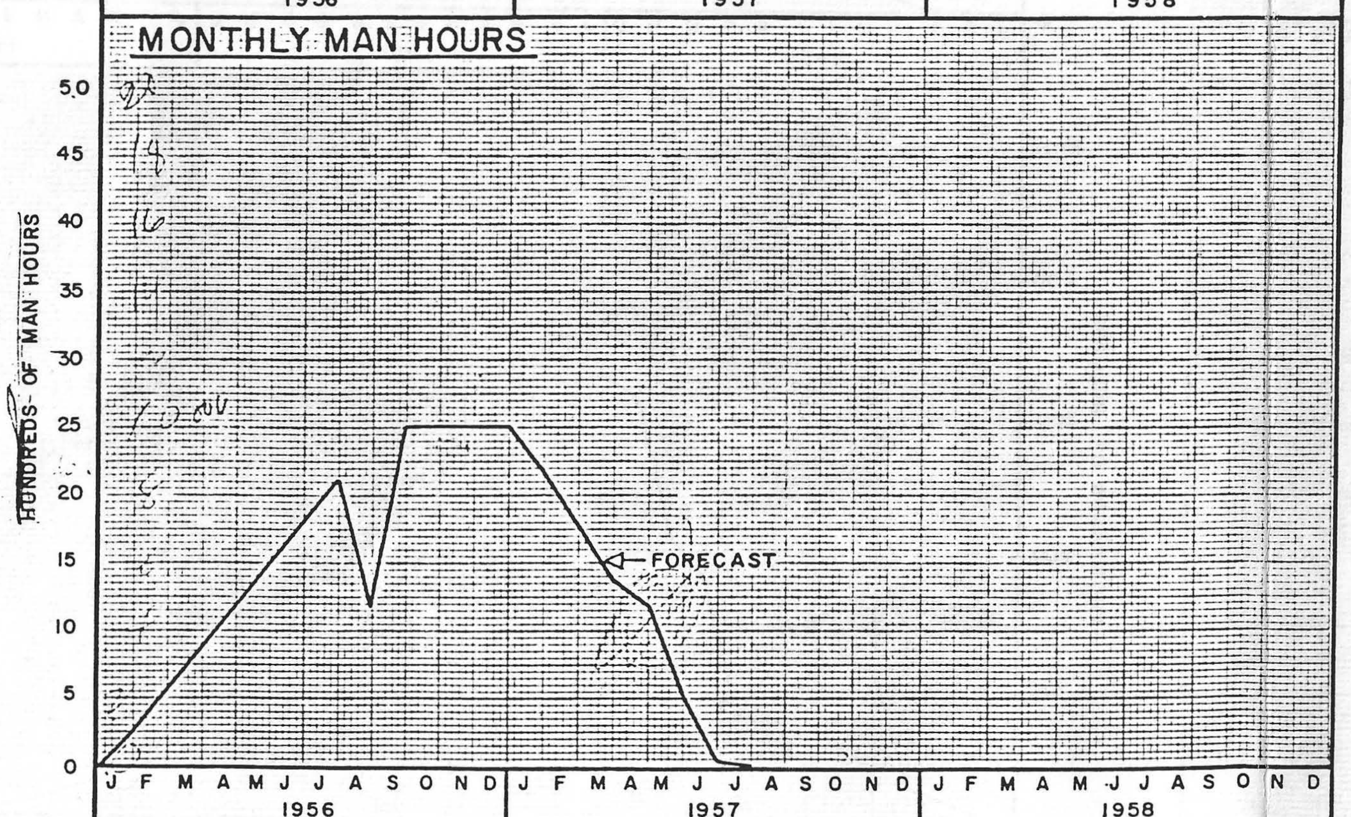

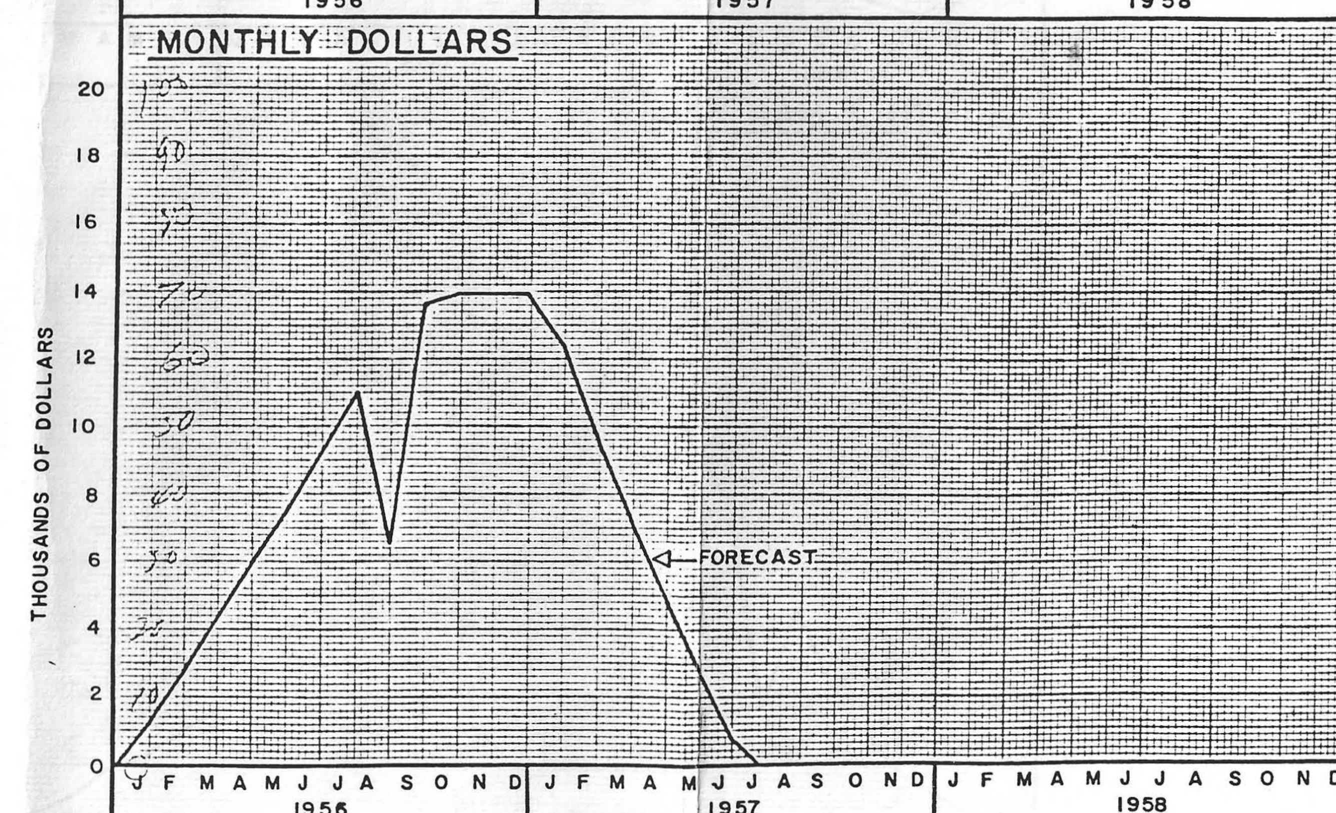

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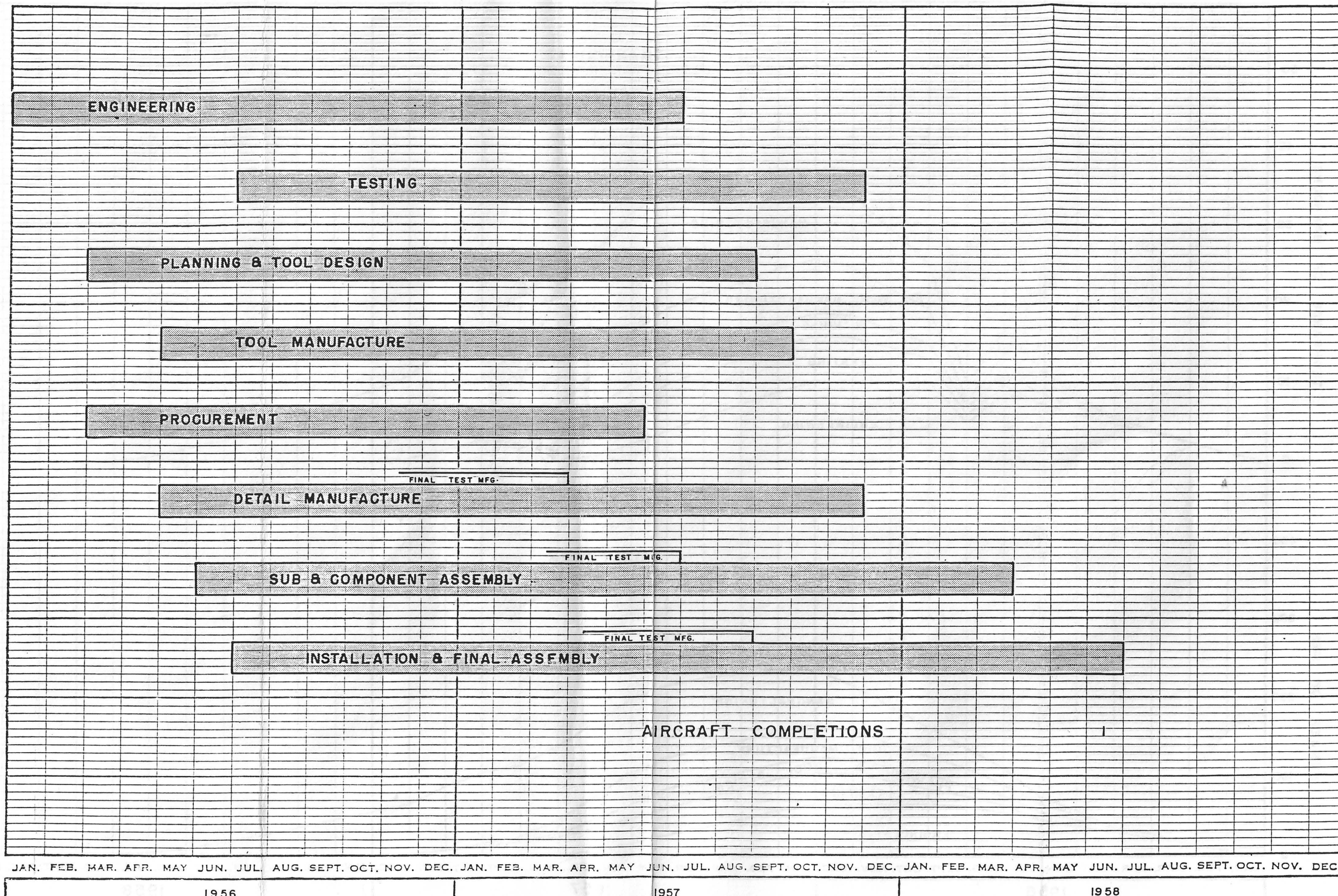
AVRO PV 704 PROGRAM – MASTER SCHEDULE



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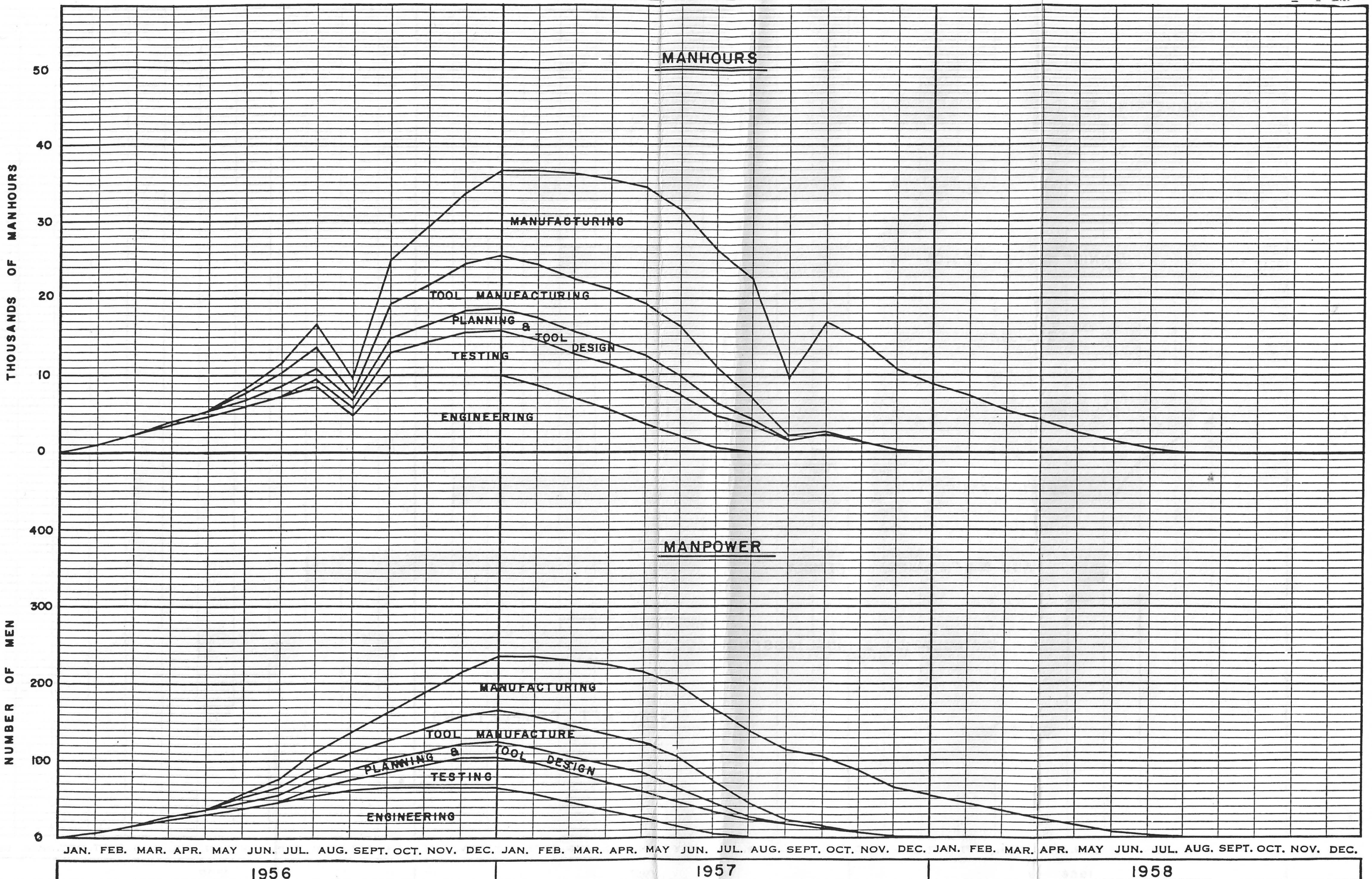
AVRO PV 704 PROGRAM

MONTHLY MANHOUR & MANPOWER

SECRET



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MALTON ONTARIO CANADA

AVRO PV 704 PROGRAM - TOTAL DOLLAR COST

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Date	Engineering	Testing	Planning & Tool Design	Tool Build	Manufacture	Total Monthly	Cumulative Costs
Jan/56	5,977					5,977	5,977
Feb.	13,946			1,620		15,566	21,543
Mar.	21,915		1,428	3,240	1,080	27,663	49,206
Apr.	29,885		3,332	4,860	69,120	107,197	156,403
May	37,853		5,236	9,090	3,276	55,455	211,858
Jun.	46,362		7,140	14,734	10,136	78,372	290,230
July	54,872	7,305	9,044	20,376	22,054	113,651	403,881
Aug.	32,585	8,385	5,236	14,734	18,660	79,600	483,481
Sept.	68,175	21,919	11,901	28,841	50,434	181,270	664,751
Oct.	69,255	33,459	13,805	34,482	60,718	211,719	876,470
Nov.	69,255	44,994	15,708	40,125	143,354	313,436	1,189,906
Dec.	69,255	47,062	17,067	42,714	152,980	329,078	1,518,984
Jan/57	60,187	47,062	17,067	41,094	160,334	325,744	1,844,728
Feb.	47,376	47,062	17,067	39,474	167,689	318,668	2,163,396
Mar.	35,645	43,822	17,067	39,474	101,401	237,409	2,400,805
Apr.	23,914	41,662	17,067	39,474	103,502	225,619	2,626,424
May	13,263	36,273	15,646	37,006	105,097	207,285	2,833,709
Jun.	3,160	29,446	9,957	27,138	105,097	174,798	3,008,507
July		22,618	4,319	17,269	101,857	146,063	3,154,570
Aug.		8,615		4,936	54,171	67,722	3,222,292
Sept.		12,917		2,973	83,759	99,649	3,321,941
Oct.		7,170			77,490	84,660	3,406,601
Nov.		1,419			62,503	63,922	3,470,523
Dec.					51,811	51,811	3,522,334
Jan/58					42,360	42,360	3,564,694
Feb.					32,908	32,908	3,597,602
Mar.					23,790	23,790	3,621,392
Apr.					15,779	15,779	3,637,171
May					8,766	8,766	3,645,937
Jun.					2,106	2,106	3,648,043
Total	702,880	461,190	188,087	463,654	1,832,262	3,648,073	
Consulting Services (Orenda Engines Ltd., Joseph Lucas Ltd.)						500,000	
Combustion & Fuel Systems Development						500,000	
GRAND TOTAL						4,648,073	

AVRO AIRCRAFT LIMITED

MALTON ONTARIO CANADA

AVRO P.V. 704 PROGRAM

DOLLAR COST

SECRET

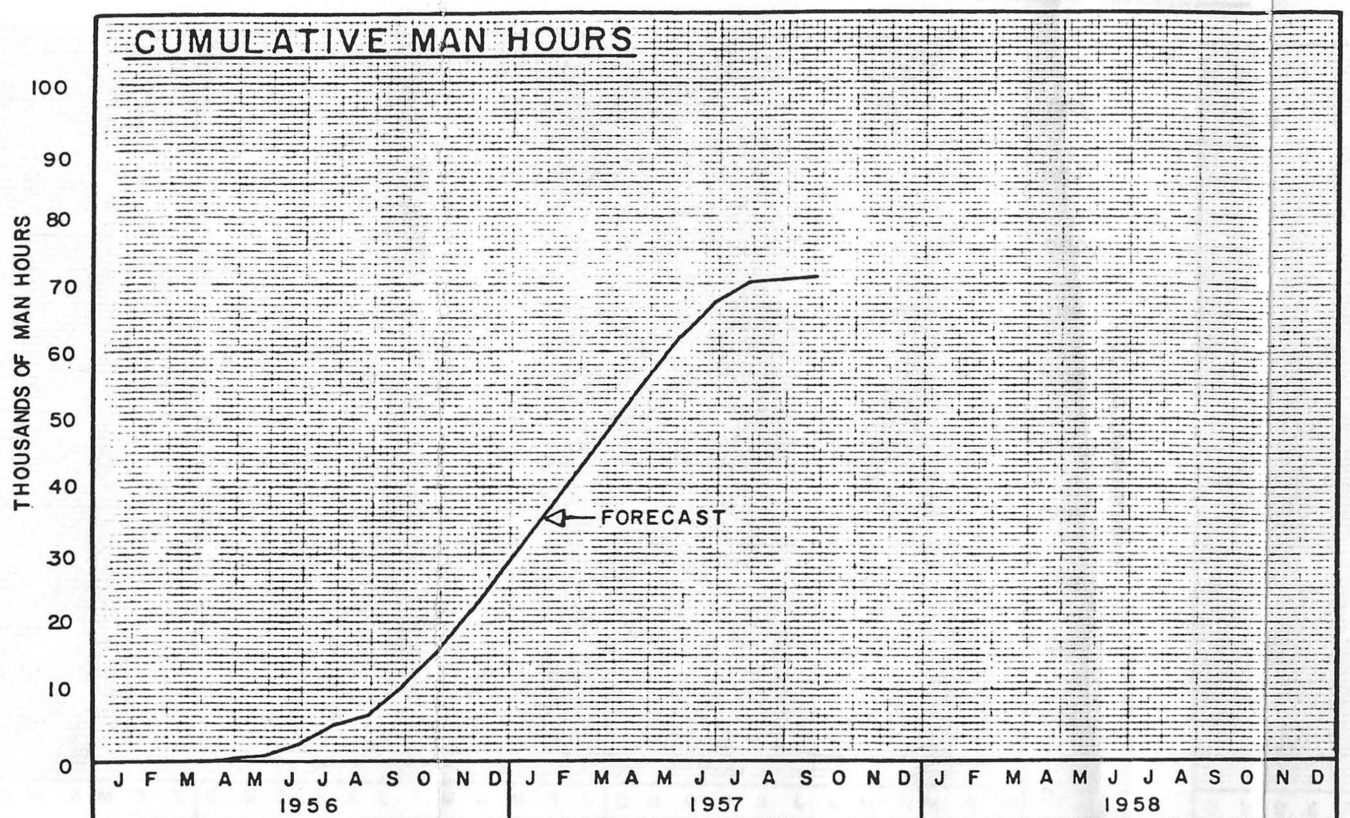
Description	Aug. 1/55 to July 30/56	Aug. 1/56 to July 30/57	Aug. 1/57 to July 30/58	Total
ENGINEERING				
Man Hours	32,760	72,240		105,000
Labour $2.75/hr.	$ 90,090	$ 198,661		$ 288,751
Plant O/Head 115%	103,604	228,461		332,065
Material & D/C	1,500	28,500		30,000
Admin. O/Head 8%	15,616	36,448		52,064
Total Cost	$ 210,810	$ 492,070		$ 702,880
TESTING				
Man Hours	975	55,708	4,717	61,400
Labour $2.75/hr.	$ 2,681	$ 153,198	$ 12,972	$ 168,851
Plant O/Head 115%	3,083	176,177	14,918	194,178
Material & D/C	1,000	63,000	-	64,000
Admin. O/Head 8%	541	31,389	2,231	34,161
Total Cost	$ 7,305	$ 423,764	$ 30,121	$ 461,190
PLANNING & TOOL DESIGN				
Man Hours	4,510	27,890		32,400
Labour $2.50/hr.	$ 11,275	$ 69,726		$ 81,001
Plant O/Head 115%	12,965	80,187		93,152
Material & D/C	-	-		-
Admin. O/Head 8%	1,940	11,994		13,934
Total Cost	$ 26,180	$ 161,907		$ 188,087
TOOL BUILD				
Man Hours	5,103	65,035	1,362	71,500
Labour $2.15/hr.	$ 10,971	$ 139,824	$ 2,929	$ 153,724
Plant O/Head 150%	16,456	209,738	4,394	230,588
Material & D/C	22,500	22,500	-	45,000
Admin. O/Head 8%	3,993	29,763	586	34,342
Total Cost	$ 53,920	$ 401,825	$ 7,909	$ 463,654
MANUFACTURE				
Man Hours	5,179	138,039	76,782	220,000
Labour $2.15/hr.	$ 11,135	$ 296,786	$ 165,082	$ 473,003
Plant O/Head 150%	16,703	445,210	247,624	709,537
Material & D/C	70,000	435,000	9,000	514,000
Admin. O/Head 8%	7,828	94,157	33,737	135,722
Total Cost	$ 105,666	$1,271,153	$ 455,443	$1,832,262
TOTAL P.V. 704				
Man Hours	48,527	358,912	82,861	490,300
Labour	$ 126,152	$ 858,195	$ 180,983	$1,165,330
Plant O/Head	152,811	1,139,773	266,936	1,559,520
Material & D/C	95,000	549,000	9,000	653,000
Admin. O/Head	29,918	203,751	36,554	270,223
Total Cost	$ 403,881	$2,750,719	$ 493,473	$3,648,073
Consulting Services Orenda Eng. Joseph Lucas		300,000	200,000	500,000
Combustion & Fuel Systems Development		300,000	200,000	500,000
GRAND TOTAL		$3,350,719	$ 713,473	$4,648,073

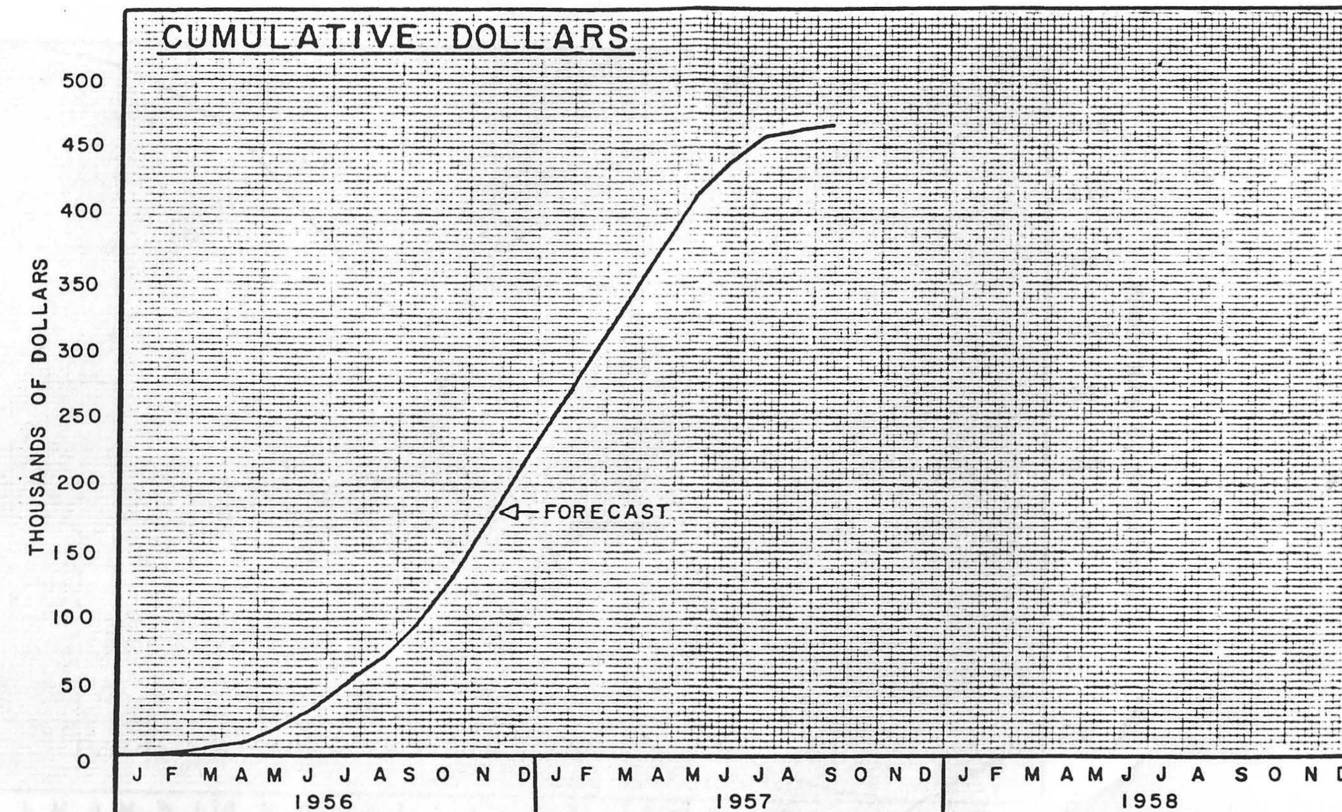
AVRO AIRCRAFT LIMITED

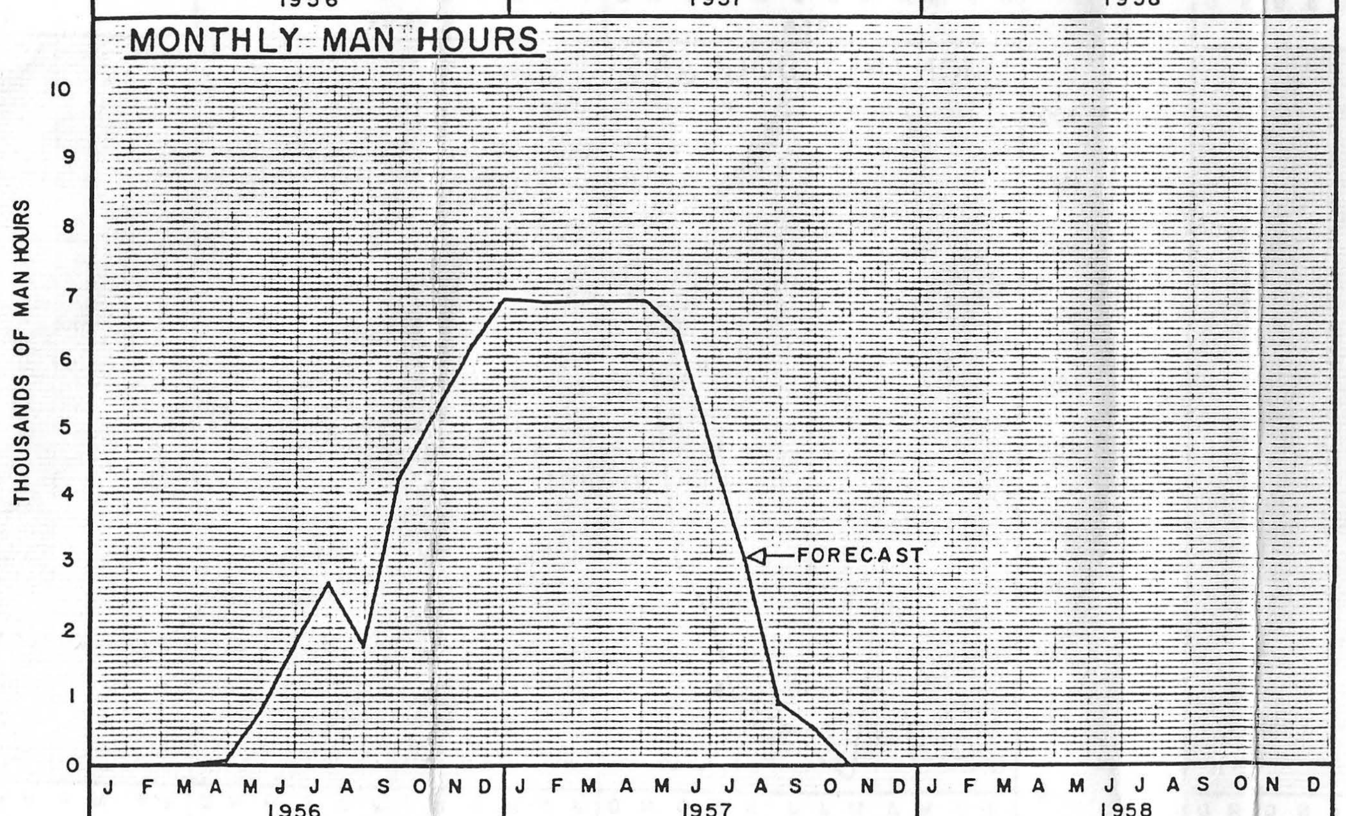
AVRO PV 704-TOOL BUILD - MAN HOURS & DOLLARS

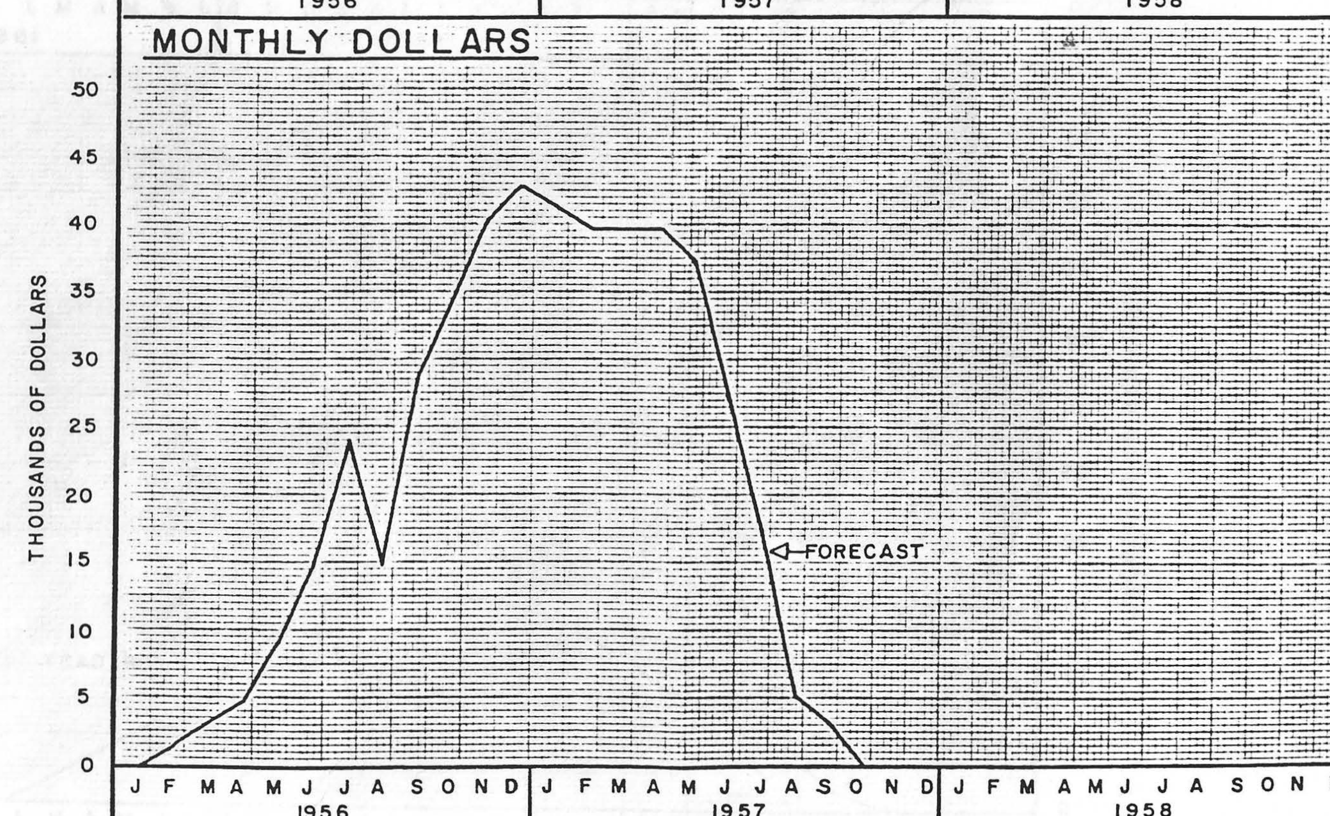
SUMMARY

SECRET









AVRO AIRCRAFT LIMITED

MALTON ONTARIO CANADA

AVRO PV 704 - MANUFACTURING - MAN HOURS & DOLLARS

SUMMARY

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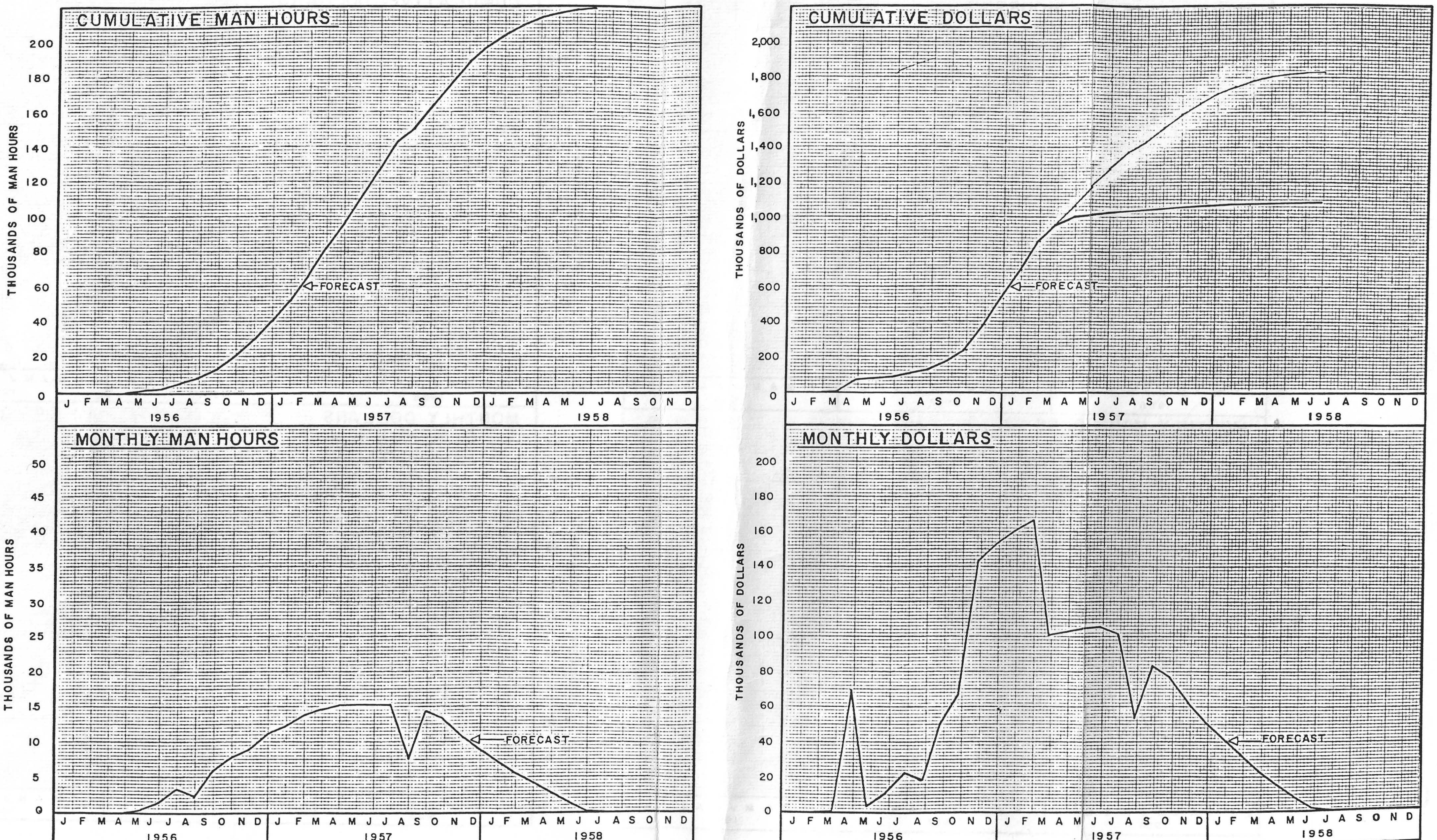

AVRO AIRCRAFT LIMITED

MALTON ONTARIO CANADA

MAIN AIRCRAFT INTAKES, COCKPIT STRUCTURE AND BOTTOM EXHAUST DUCT STRUCTURE

As the intakes were annular in shape, advantage was taken of the use of spinnings. The upper intake and cockpit structure skins were spun from a large flat blank. Maximum possible accuracy was maintained in the spinning and this was marked off for rib locations; all ribs and the internal structure were rivetted to the spinnings thereby obviating the necessity of an assembly jig.

74623

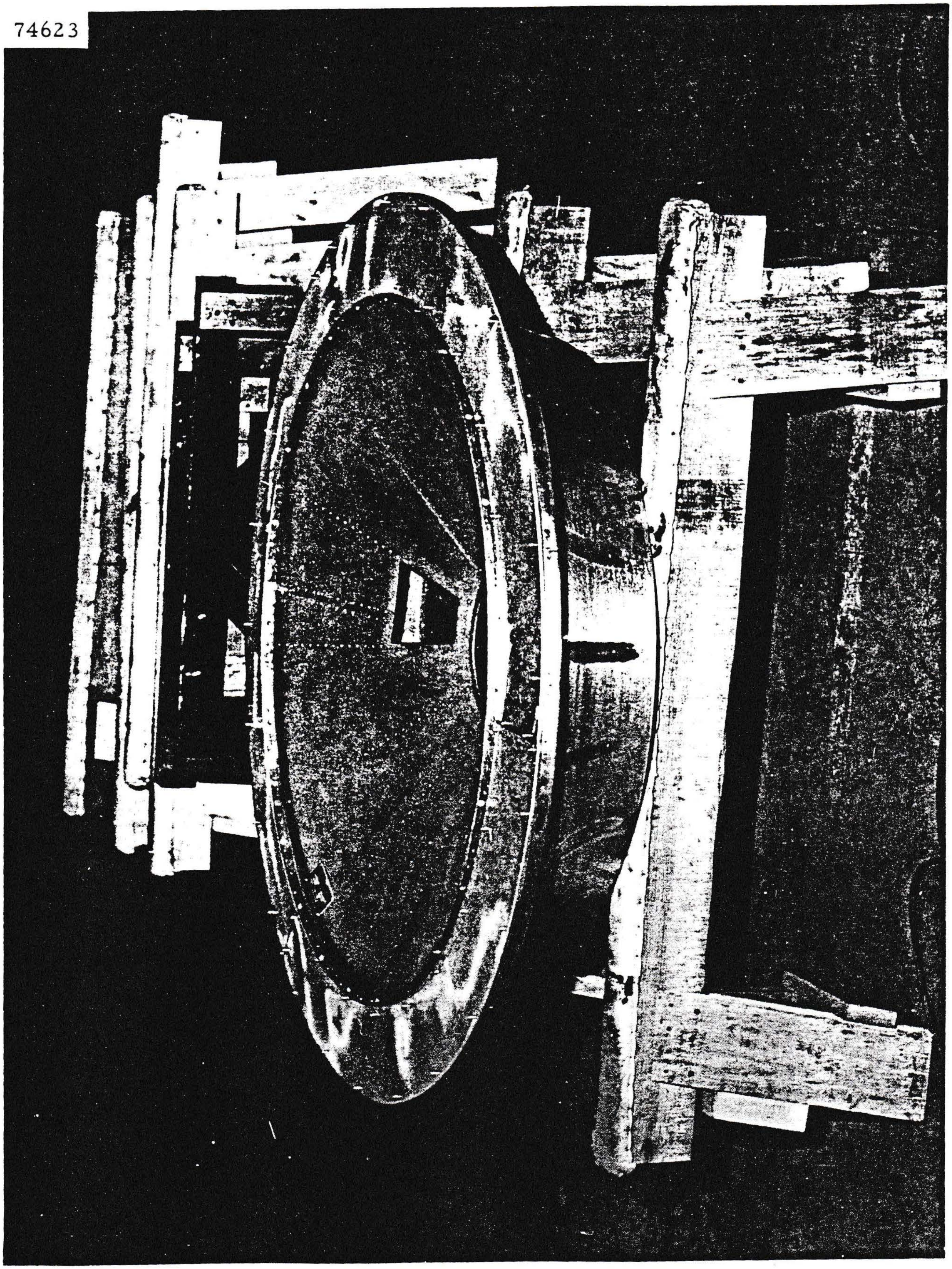

FIG. 33 COCKPIT STRUCTURE AND INTAKE DUCT

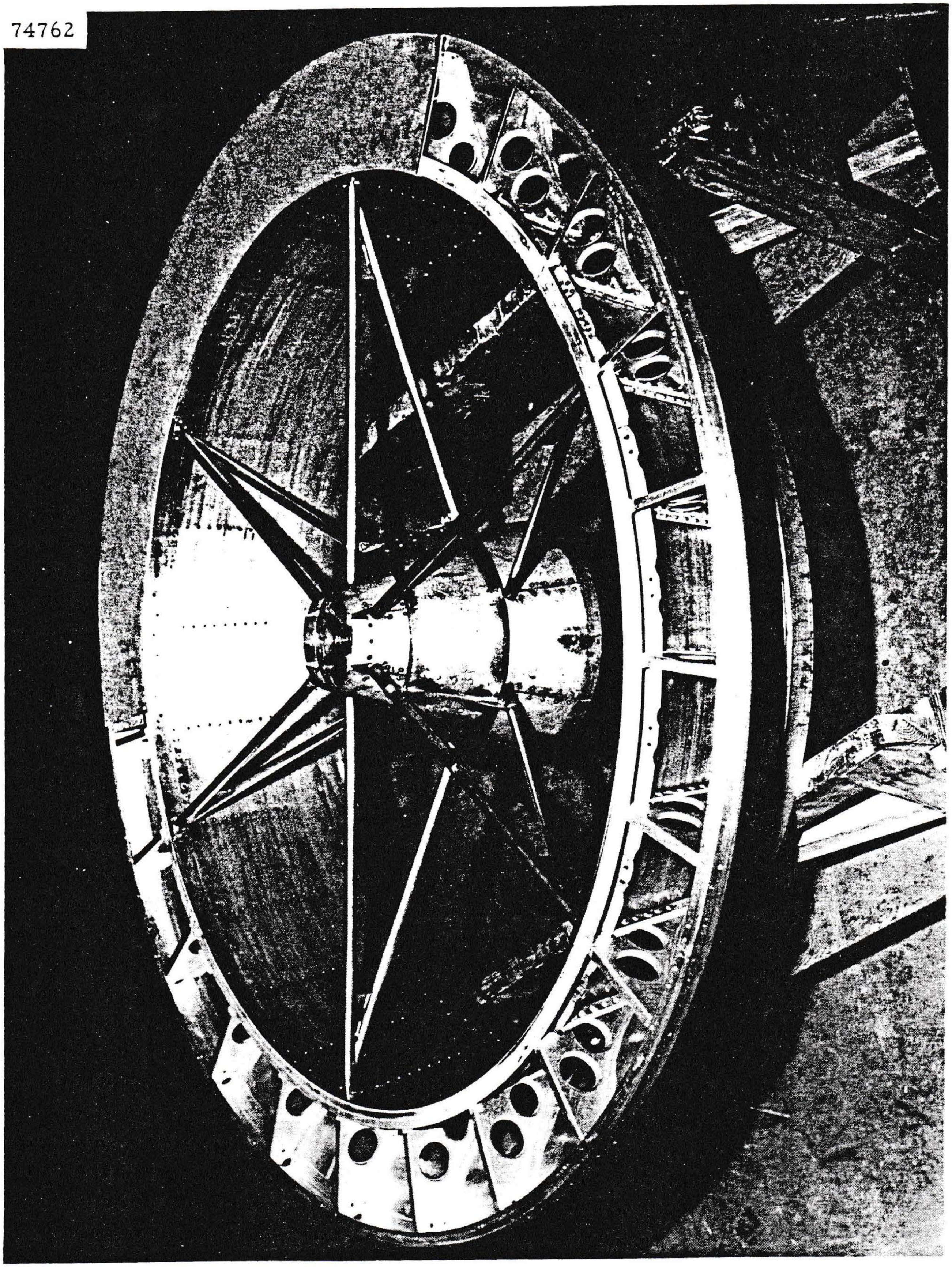

FIG. 34 BOTTOM EXHAUST DUCT STRUCTURE

ENGINE INTAKE

This was a conventional sheet metal assembly with the exception of the guide vane assemblies. The vanes were hollow formed from 321 stainless steel sheet and furnace copper brazed to shrouds of the same material. The method used in forming and assembling the vanes prior to furnace brazing was the same as that used in assembling the turbine and compressor segments. See page 9.

The main problem was to produce a guide vane assembly accurately enough to fit between the main skins without distorting the skins during rivetting. The skins were conical in shape with a shallow blister pressed into the cone. The guide vane assemblies ran across the cone and blister. They were not radial to the cone, and therefore presented a very awkward shape to fit. Once the vane assembly was brazed it was impossible to fit or adjust it to the aperture made by the top and bottom skins.

To overcome this problem, a top and bottom skin were formed on press form tools and located in the assembly jig. The vane shrouds were clecoed to the skins in their correct positions. The vanes, formed from a developed blank, were trimmed and fitted to the shroud which was located as explained above. The correct position of the vane in relation to the shroud was dictated by pick-up holes and pins.

The vanes could then be tacked and copper brazed with the assurance of a good fit on assembly to the intake box.

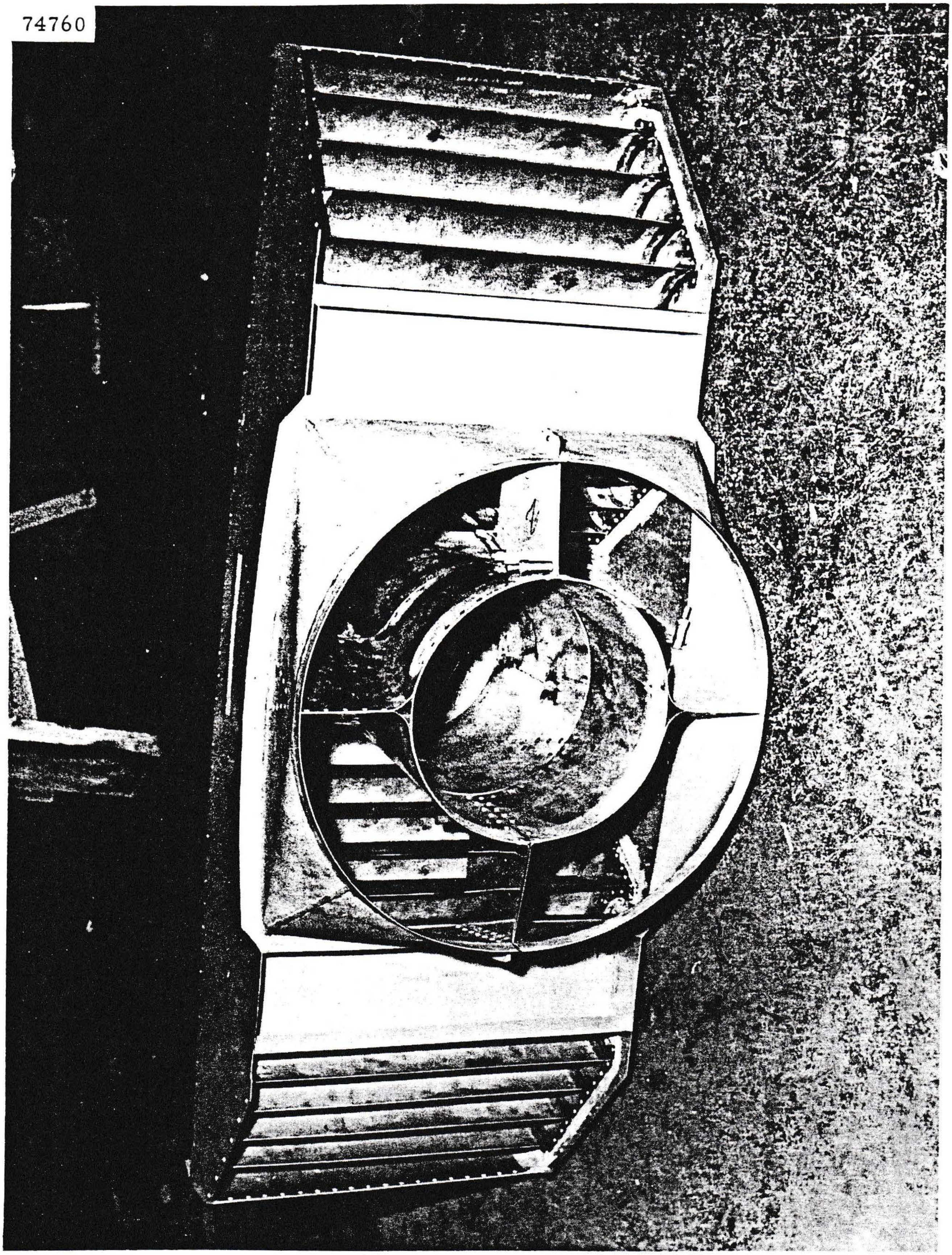

FIG. 35 SPECIAL AIR INTAKE FOR A. S. VIPER ENGINE

AIRFRAME ASSEMBLY

A main assembly jig was used for the airframe. The 6 wing components were located on their correct stations, indexed centrally by a spider locator carried in the jig beam, and on their outer stations by picking up an engine mounting position.

By locating the wing components accurately on their stations and centre lines, the engine bays were able to absorb any discrepancy in the size of these components.

The centre spider locator also served as a mock turbine-compressor and was used for setting all jet pipe seals.

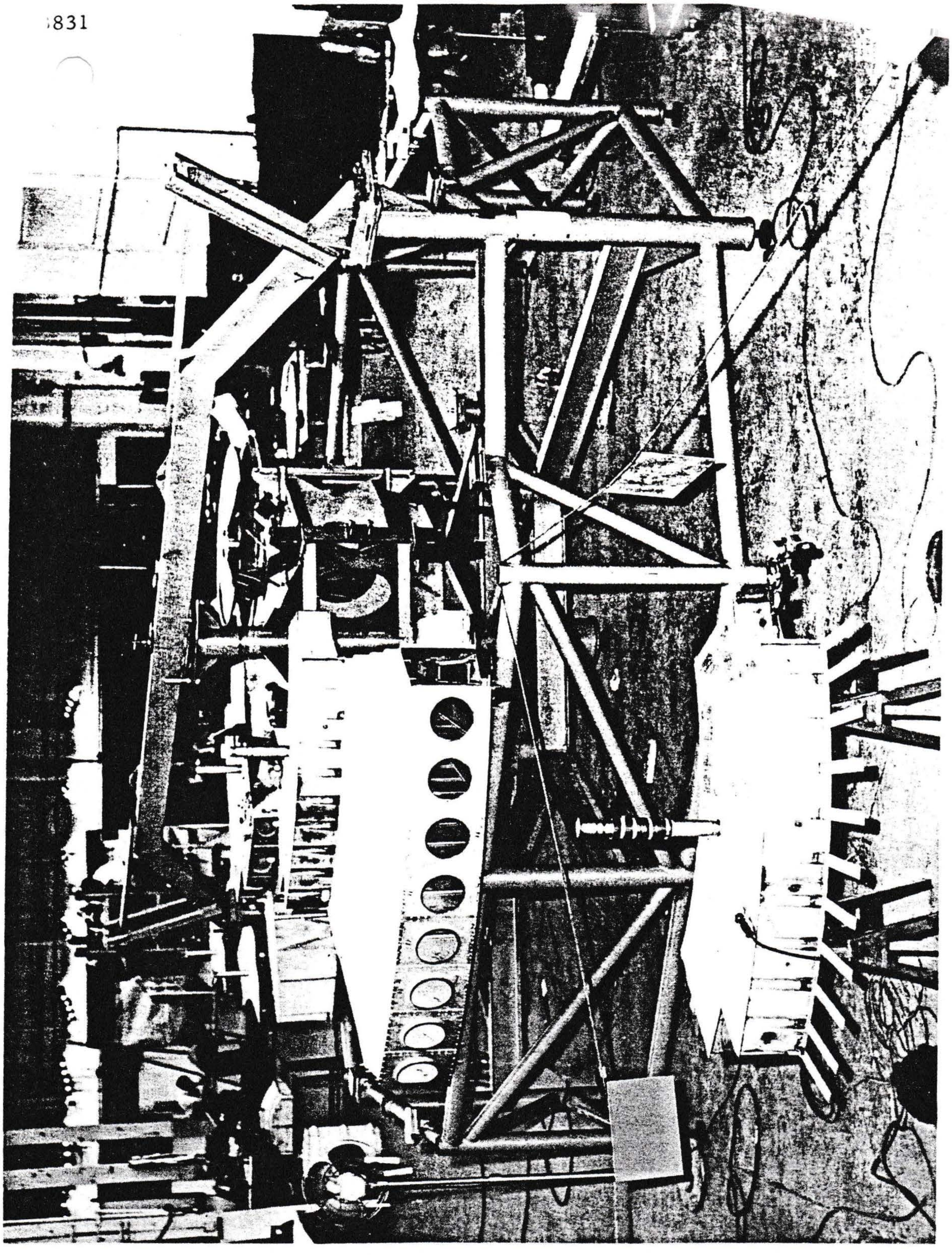

FIG. 36 INNER WING ASSEMBLY- 60° AIRFRAME SEGMENT LOADED IN FINAL AIRFRAME ASSEMBLY JIG

SECRET

73699

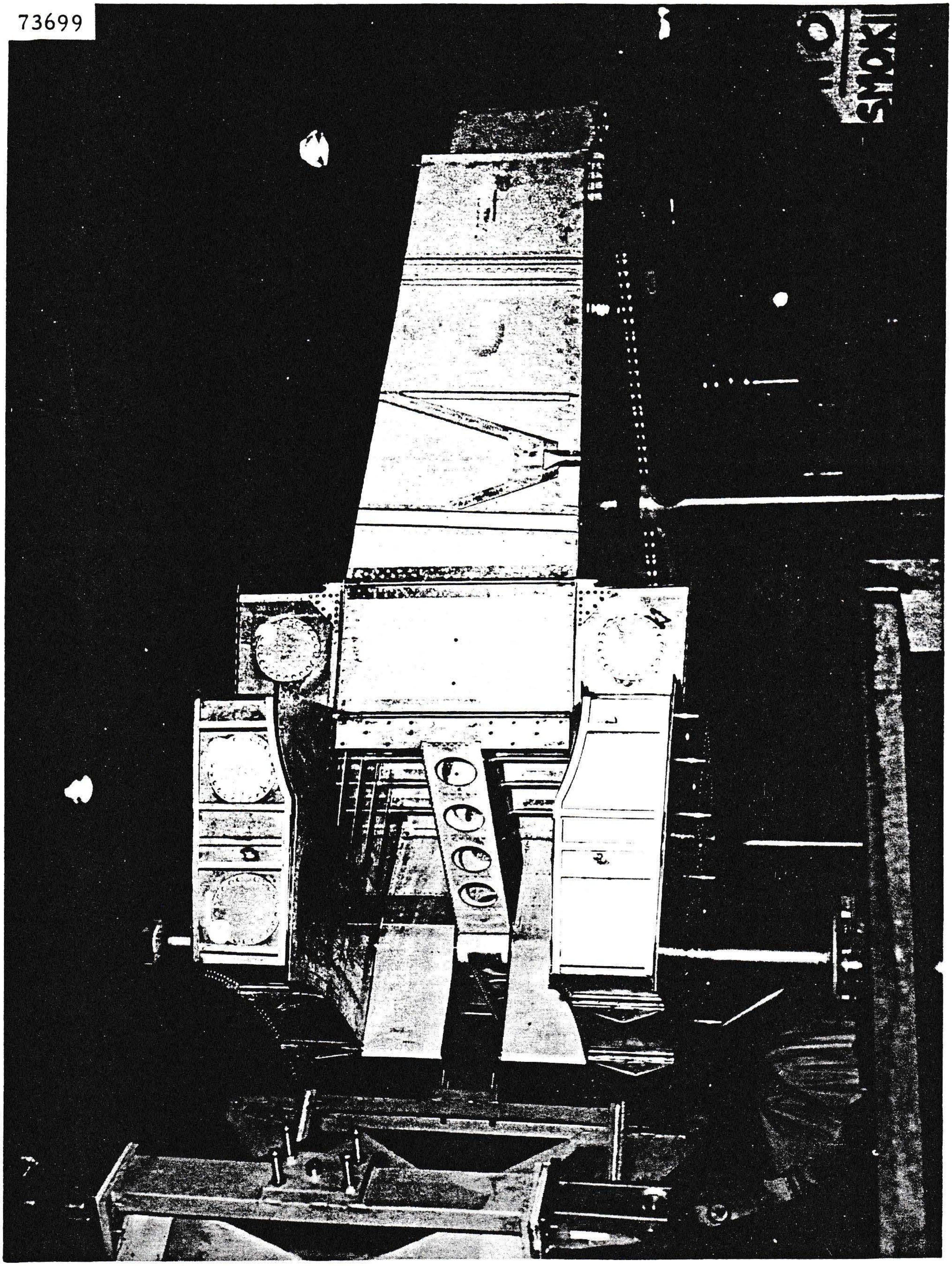

FIG. 37 INNER WING ASSEMBLY-60° AIRFRAME SEGMENT

74922

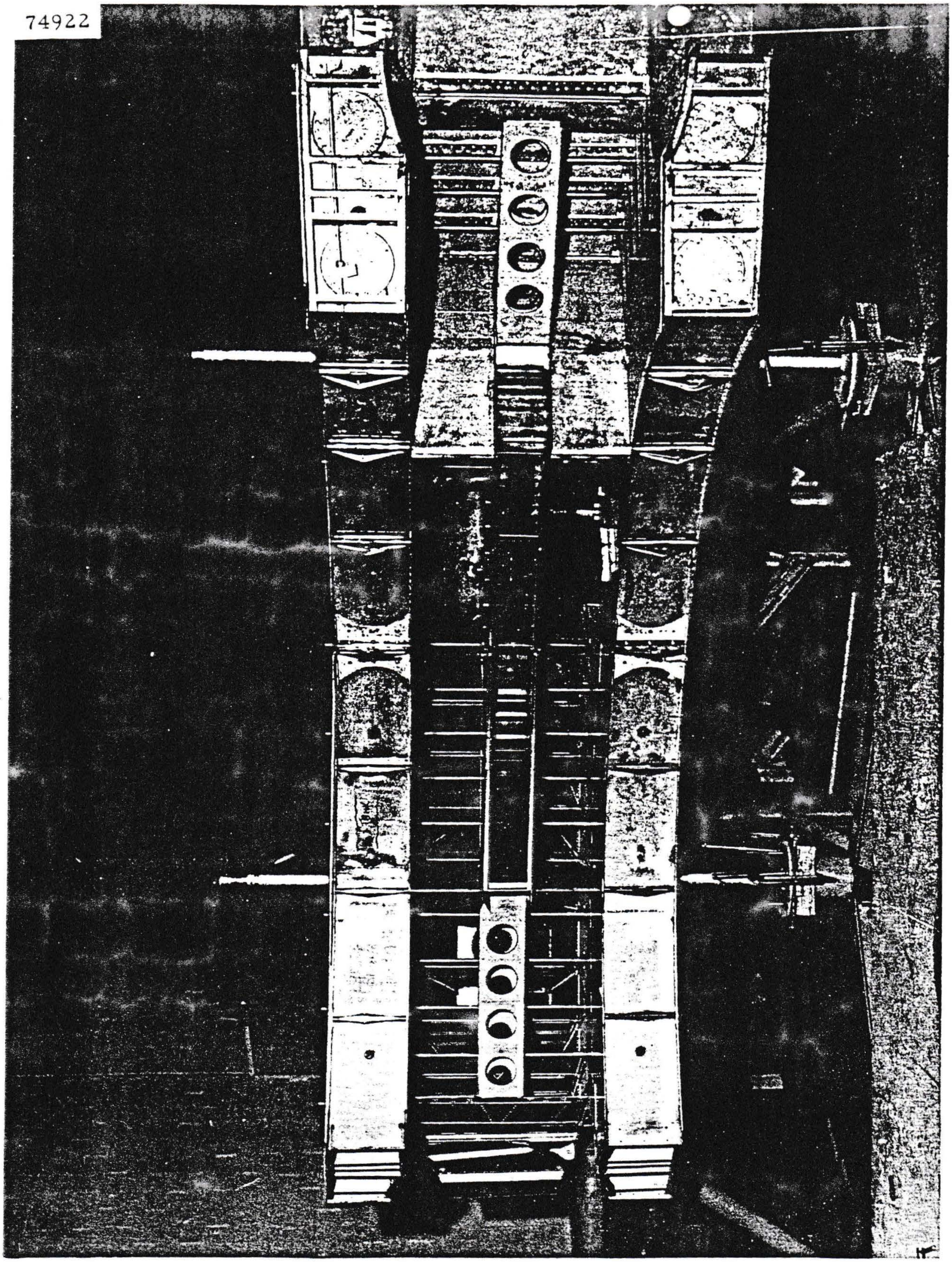

FIG. 38 TWO INNER WING SEGMENTS AND JET PIPE ASSEMBLED IN FINAL AIRFRAME ASSEMBLY JIG

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74624

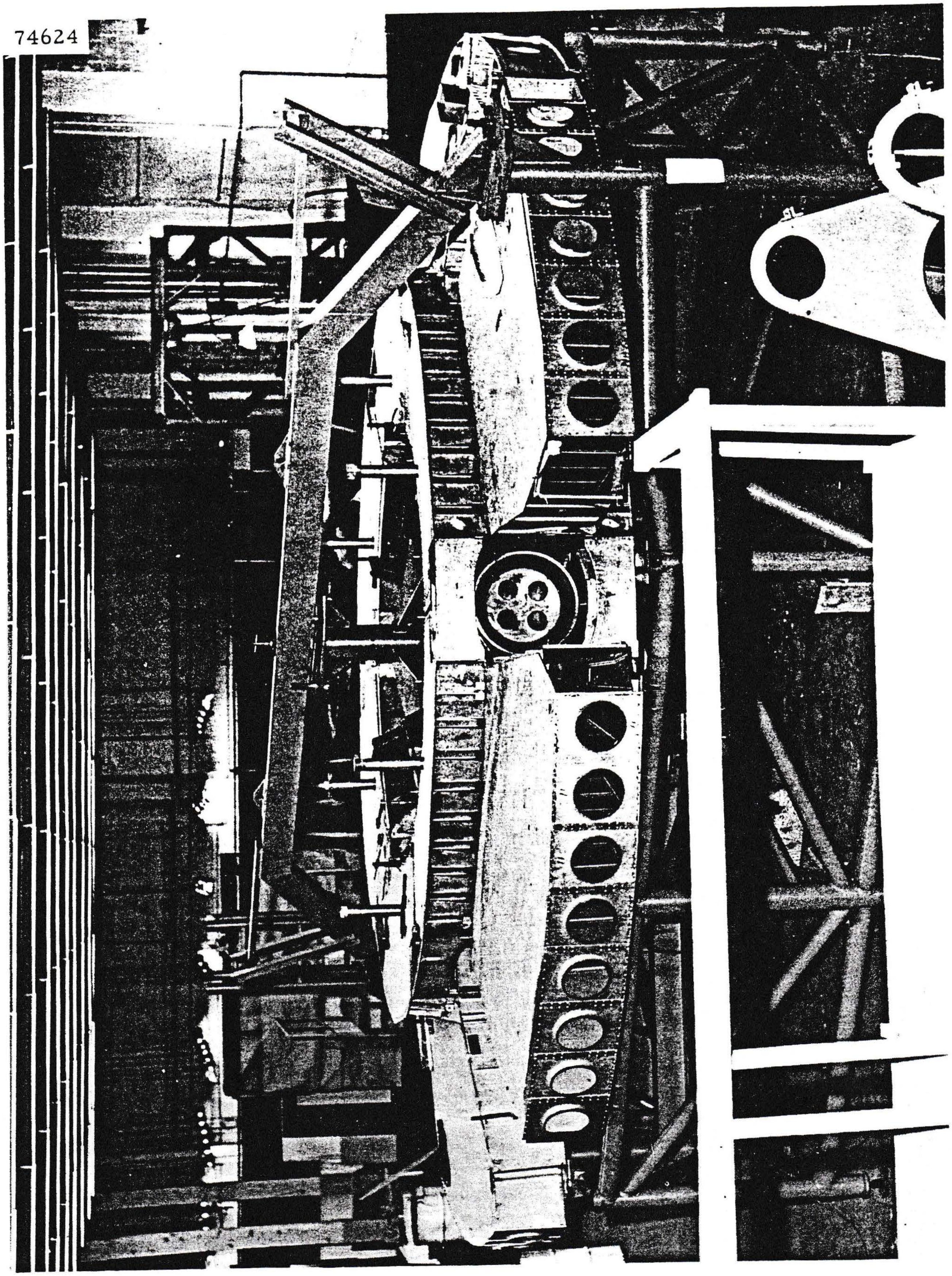

FIG. 39 ALL SEGMENTS OF AIRFRAME IN POSITION IN FINAL AIRFRAME ASSEMBLY JIG

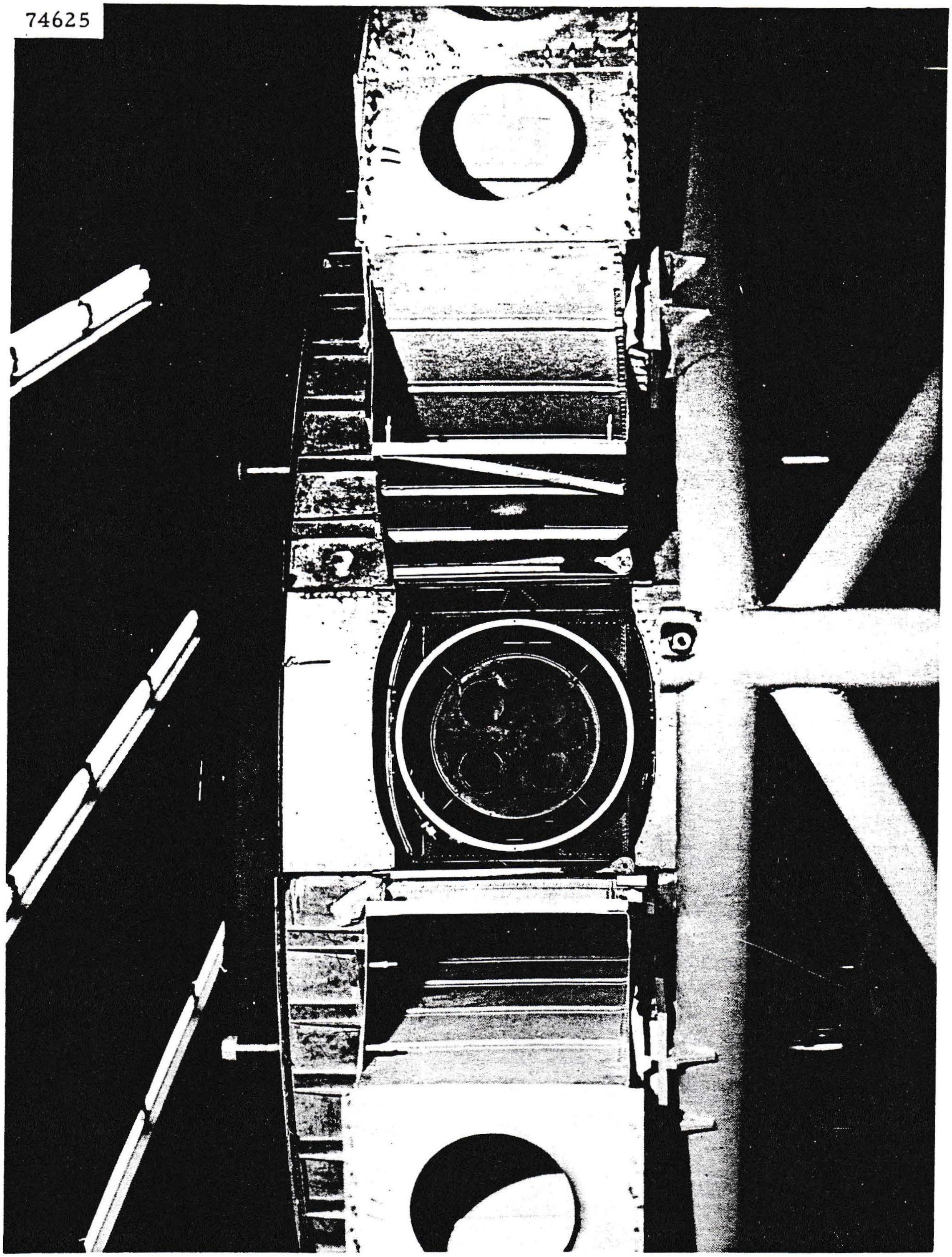

FIG. 40 ENGINE BAY-AIRFRAME ASSEMBLY

74763

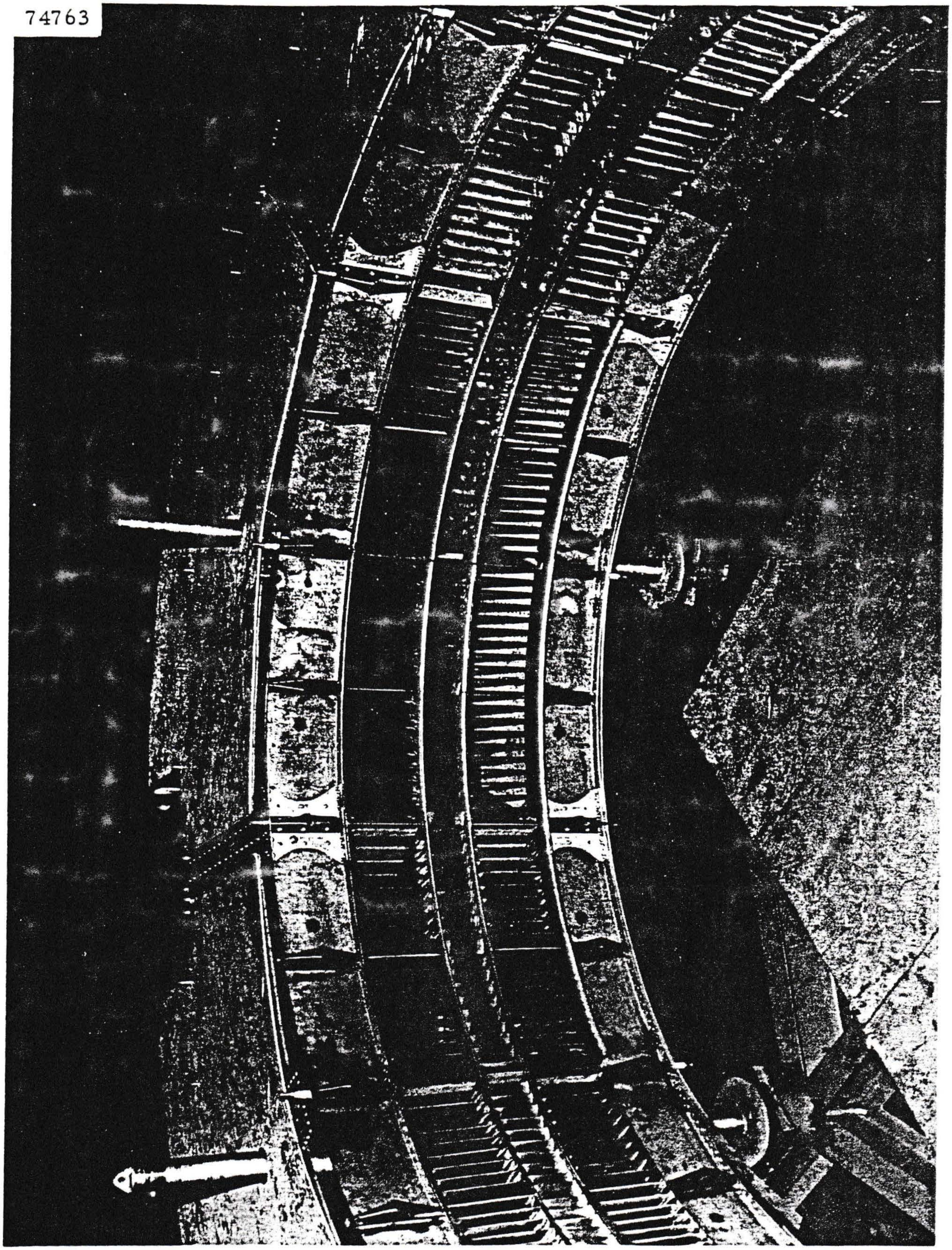

FIG. 41 CENTRE OF AIRFRAME SHOWING STATOR BLADES FOR TURBINE AND COMPRESSOR

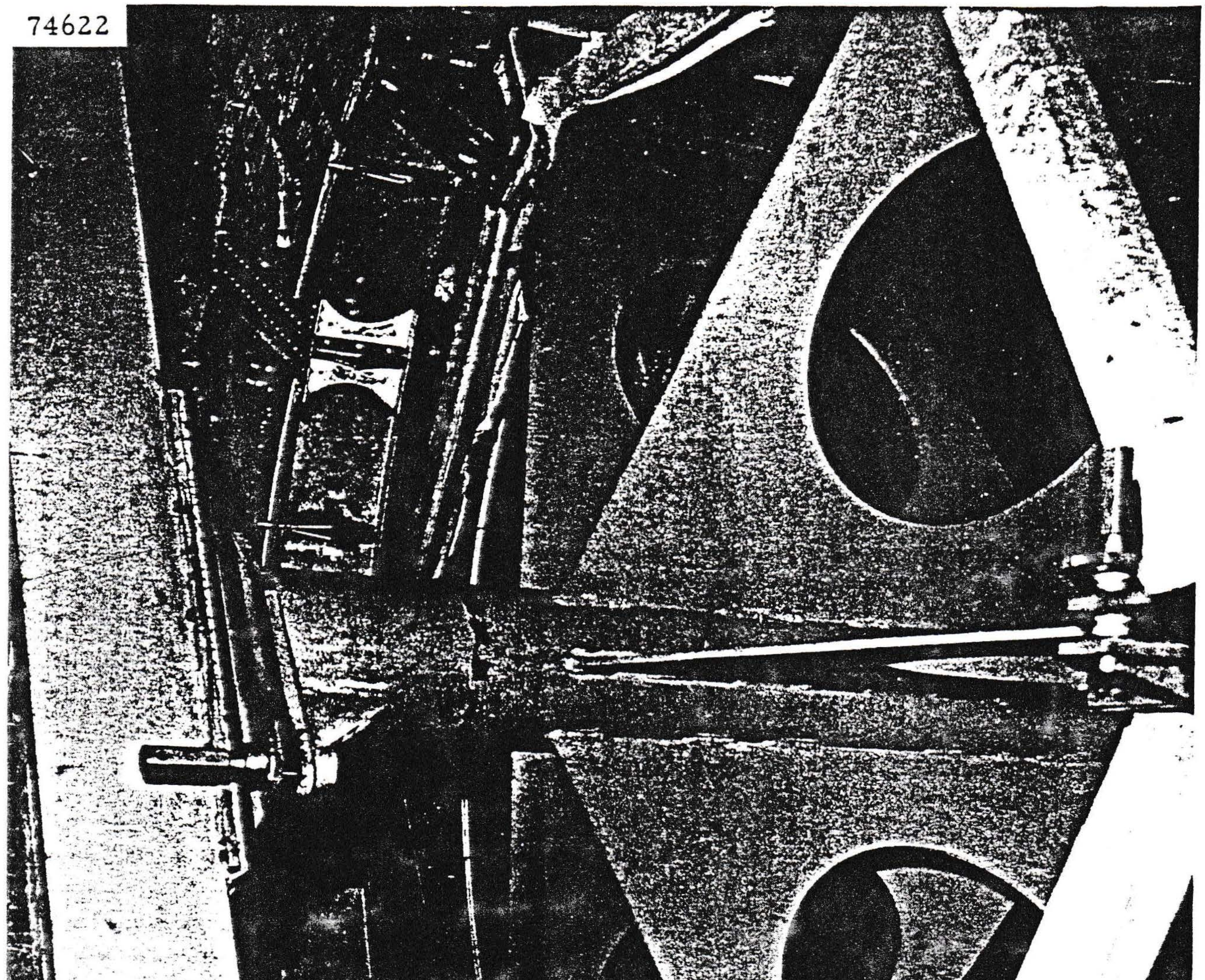

FIG. 42 JIG BEAM AND CENTRE LOCATOR - FINAL ASSEMBLY JIG

76417

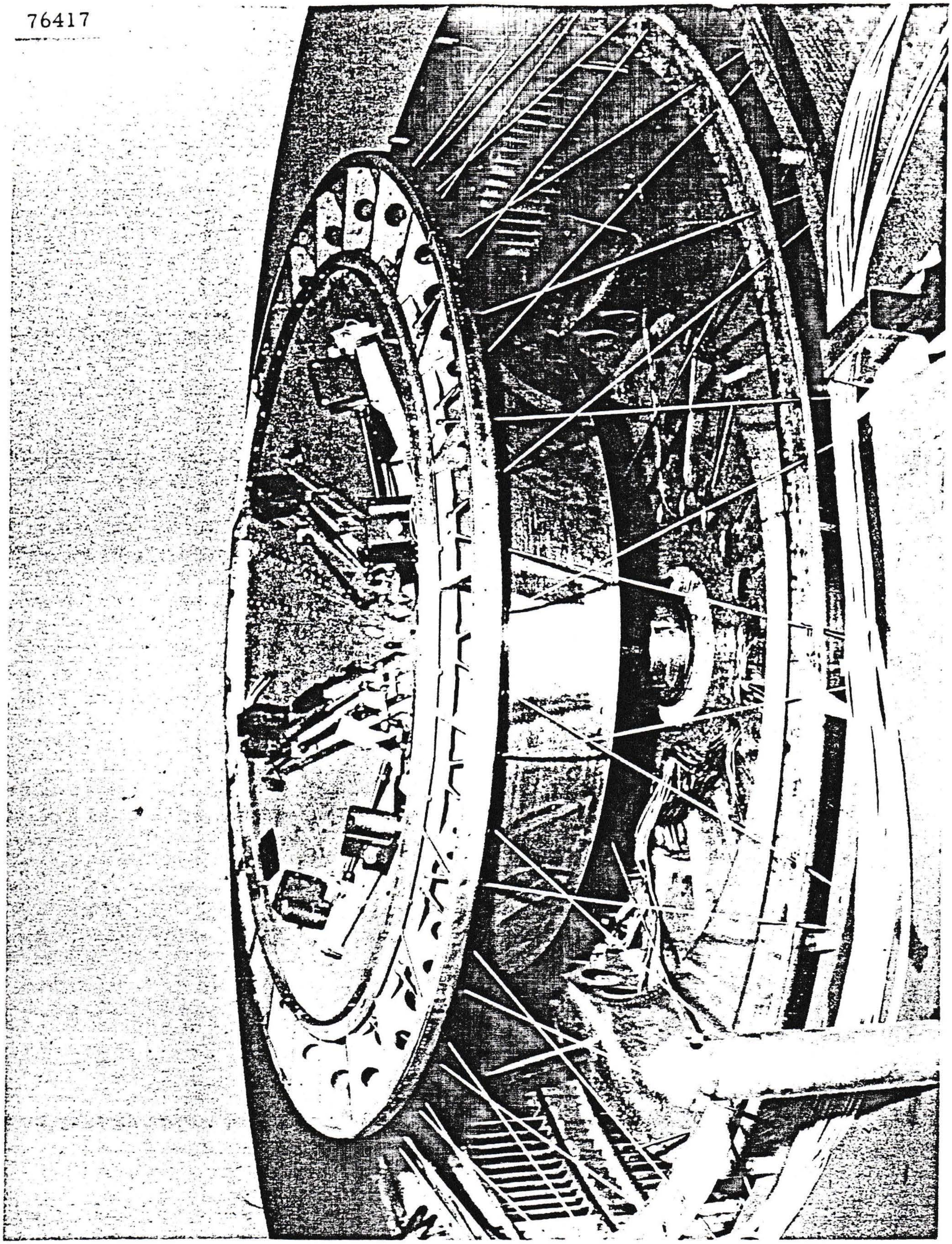

FIG. 43 COCKPIT STRUCTURE POSITIONED IN AIRFRAME