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NAVY DEPARTMENT

BUREAU OF AERONAUTICS

WASHINGTON, D. C.

AERONAUTICAL ENGINE LABORATORY
REPORT ON

MODEL TEST OF PRATT & WHITNEY
AIRCRAFT XR-4360-4 ENGINE

ISSUED BY

NAVAL AIR MATERIAL CENTER PHILADELPHIA
NAVAL AIR EXPERIMENTAL STATION
NAVY YARD, PHILADELPHIA (12), PA.

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MODEL TEST OF PRATT & WHITNEY AIRCRAFT XR-4360-4 ENGINE

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PROJECT NO. - 4321.

DATES OF TEST - FROM: 26 May 1944 TO: 18 August 1944.

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OBJECT

1. The purpose of this test, authorized by reference (a), was to determine the endurance, dive, and crankshaft torsional vibration characteristics of the Pratt and Whitney Aircraft Model XR-4360-4 engine, in accordance with Specifications AN-9502b and AN-9504.

CONCLUSIONS

2. The XR-4360-4 engine is not considered suitable for service use in its present stage of development because:

(a) The mod 1 test was not satisfactorily completed.

(b) Certain operational characteristics are unsatisfactory.

3. As a result of type and dive test operation, the following unsatisfactory engine conditions were indicated which are considered serious:

(a) Failure of the variable speed supercharger drive couplings.

(b) Failure of the rear master rod bearing.

(c) Failure of the rear intermediate main bearing.

(d) Unsatisfactory appearance of other main and master rod bearings (see paragraph 31(a)(6)).

(e) Failure of B-2 and B-3 pistons and cylinder assemblies by scuffing.

(f) Ring failures on B-2, B-3, and A-7 pistons.

(g) Cracked cam bearings on A-B, and C-D rows.

(h) Cracked cam retainers on A-B and C-D rows.

(i) Push rod failures.

(j) Pitting on inner race of propeller thrust bearing.

(k) Failure of exhaust port inserts.

(l) Burning of the intake and exhaust valve faces, erosion of metal on the heads of several exhaust valves, and excessive formation of carbon deposit on valve stems.

(m) Failure of intake manifold pipes.

(n) Intake pipe drain valve failures.

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PLATES - 44.

(o) Failure of ignition harness conduit.

(p) Failure of magneto housings.

(q) Failure of magneto pressure pump and altitude valves.

(r) Feathered cam drive gears on A-B bank.

4. In addition to the conditions noted in paragraph 3, the following unsatisfactory conditions considered of a minor or isolated character were also observed as a result of the endurance test:

(a) Loose push rod ball sockets in A-7 and D-7 rocker arms.

(b) Loose (improperly staked) oil hole plug in one of the knuckle pins on the A row.

(c) Cracked oil drain line to rear rocker box sump.

(d) Evidence of high operating temperatures on several exhaust rocker arms.

(e) Cylinder cooling baffle failures.

(f) Cracked cylinder fins.

(g) Engine stud failures.

(h) Cracked crankcase scavenge pump.

(i) Scored cam follower, pin, and tappet.

(j) Galled fuel pump intermediate drive pinions.

(k) Scored impeller oil seal sleeve.

5. Operation of the engine with regard to idling, acceleration, deceleration, smoothness (excepting surging within specific ranges), and scavenging (40 p.s.i. oil out pressure - crankcase breathing) is considered satisfactory. Poor starting (evidenced by lower manifold and cylinder fuel loading - not by failure to start), excessive external oil leakage, and speed-power surge tendencies near rated and take-off, are decidedly unsatisfactory.

6. The performance of the Bendix Stromberg injection carburetors, model PR100A-3, is considered unsatisfactory. The barrel type mixture control valve incorporated in this model carburetor is susceptible to sticking and malfunctioning.

7. The present design of the supercharger drive system incorporating two variable speed slip type couplings with the attendant troubles arising from unequal division of load, borderline oil temperature rise at maximum slip, and sensitive method of slip control, is not considered satisfactory for service use.

8. Operation with AN-F-28R fuel and the full spark advance position of 35 degrees BTC (manual control) at 60 per cent rated power and 84 per cent rated speed at best economy fuel flow conditions was not considered satisfactory due to detonation.

9. Use of the reduction gear type torquemeter as presently developed for the subject engine for determination of brake horsepower output is not considered satisfactory due to inaccurate results obtained.

10. The use of reinforcing brackets to support the rear section is considered unacceptable. A strengthened rear section has been designed by the manufacturer to overcome this condition but parts were not available at the time the subject engine was built or before the test was started.

11. Mixture distribution during the various periods of operation at the type test conditions was generally satisfactory.

12. The crankshaft torsional vibration characteristics of the XR-4360-4 engine, employing a 14'-0" diameter Hamilton Standard Hydromatic propeller, Model 24E60, with blade design 6517A-14, are considered satisfactory according to the manufacturer's specification of permissible maximum amplitudes (reference (d)). Specification AN-9504 was adhered to although it is not specifically applicable to four-throw crankshafts.

13. Operation of the Champion C-34-S spark plugs throughout the test was generally satisfactory.

RECOMMENDATIONS

14. The XR-4360-4 engine is not recommended for service use in its present stage of development.

15. It is recommended that redesign and development work be expedited to effect improvement in the operation and/or endurance qualities of the following conditions or assemblies (specific conditions noted in paragraph 3) and that an engine incorporating the necessary modifications, including a strengthened rear case, be subjected to an endurance test as soon as practicable.

(a) Supercharger drive system.

(b) General lubrication including master rod and main bearings, pistons, and cam drive gears.

(c) Cam bearings and retainers.

(d) Exhaust valve and rocker box operating temperatures.

(e) Intake manifolds and related drain valves.

(f) Ignition system including harness leads, magnetos, pressurizing pump, and altitude valves.

(g) Engine torque measuring system.

16. Redesign of the PR100A3 carburetor barrel type mixture control valve and/or employment of more suitable material necessary to minimize malfunctioning is recommended. It is also recommended that a carburetor setting based on engine requirements be installed and the consistency of metering improved.

17. Operation in the full spark advance position of 35 degrees BTC at 60 per cent power, is not recommended for use until engine characteristics at the 35 degree condition have been fully investigated by engine calibration. This work is currently being performed at the Aeronautical Engine Laboratory under Project TED No. NAM-04394.

18. Requirements for the torsional vibration characteristics of a four-throw crankshaft should be considered for inclusion in Specification AN-9504.

19. It is recommended that the poor operating characteristics - starting, external oil leakage, and surging - be corrected before further model or calibration tests are authorized.

DESCRIPTION OF SUBJECT

20. The XR-4360-4 engine is an air-cooled engine having 28 cylinders arranged in four radial rows of seven cylinders each (Plates 6 to 10, inclusive). The rows are located about the crankcase in such a way as to form a right hand helix consisting of seven banks of four cylinders. The front row (propeller end) is designated as the "D" row and the rear row (anti-propeller end) is designated the "A" row. The banks are numbered from 1 to 7, inclusive, counting clockwise from the rear of the engine. Cylinder number A-1 is the top rear cylinder. Master rod locations are A-1, B-4, C-4, and D-1. Each bank of four cylinders is fired by an individual magneto firing both left and right plugs. Each magneto is mounted on the nose section directly in front of the bank that it fires. The propeller shaft and reduction gearing are of the single rotation, single speed type, having an integral torquemeter for determining propeller shaft torque. The supercharger is a single stage, variable speed type driven through hydraulic couplings which provide sufficient boost to maintain take-off power from sea level to 1500 feet altitude in maximum slip. The impeller, shown on Plate 13, has an inducer on the entrance side of the main impeller wheel for the purpose of pre-boosting and improving entrance flow characteristics. The variable speed hydraulic drive is of the dual drive split coupling type. Engine oil is supplied to the couplings through a valve which meters the oil flow and reduces the pressure. The oil is then metered out centrifugally through holes in the periphery of the coupling housing until the outflow is equal to the input of oil. The amount of relative slip between the "driver" and "runner" halves of the coupling is dependent upon the oil level maintained in the coupling during rotation, which is, in turn, dependent upon the flow of oil regulated by the metering valve. The engine as received for model testing incorporated two high ratio variable speed clutches, the low ratio clutches having been omitted from this model. Upon failure of these clutches, a fixed ratio supercharger drive system was installed to complete the endurance test.

21. The following is a tabulation of the general engine characteristics. For a more complete description see reference (e).

(a) Manufacturer:

Name	-	Pratt and Whitney Aircraft Division of United Aircraft Corporation,
Location	-	East Hartford, Connecticut.

(b) Model and Ratings:

Model	-	XR-4360-4.
Type	-	Air-cooled, four-row, radial, 28 cylinder, single stage, variable speed supercharger.
Ratings (Manufacturer's Guarantee):		
Take-off	-	3000 BHP at 2700 RPM.
Normal		
Maximum Slip	-	2500 BHP at 2550 RPM at 5000 feet.
Minimum Slip	-	2200 BHP at 2550 RPM at 14,500 feet.
Military		
Maximum Slip	-	3000 BHP at 2700 RPM at 1500 feet.
Minimum Slip	-	2400 BHP at 2700 RPM at 13,500 feet.
Maximum Dive Speed	-	3060 RPM.
Engine No.	-	P-17.

(c) General Data:

Bore and Stroke	-	5.75 x 6.00 inches.
Cylinder Arrangement	-	Four-row, radial.
Total Displacement	-	4360 cu. in.
Compression Volume Ratio	-	7.00:1.
Impeller Gear Ratios (Variable)	-	
Maximum Slip (20%)	-	6.08:1.
Minimum Slip (3%)	-	7.29:1.
Impeller Diameter	-	14 inches.
Reduction Gear Ratio	-	0.425.
Propeller Shaft	-	S.A.E. No. 60.
Crankshaft Dampers	-	2- 3-1/2 order (front and rear).
Dimensions (Overall)		
Length	-	96.75 inches.
Diameter	-	52.5 inches.
Dry Weight of Engine Including Carburetor and Spark Plugs	-	3325 lbs.
Maximum Specific Outputs	-	0.69 BHP per cu. in., .90 BHP per lb.
Grade Oil Required	-	Navy Symbol 1100.
Grade Fuel Required	-	Specification AN-F-28R.

(d) Carburetor:

Make and Model	- Bendix Stromberg PR100A3.
Type	- Injection.
Serial No.	- 334532A.
Setting No.	- None.
Fuel Pressure Required	- 16-18 lbs. per sq. in.

(e) Ignition:

Magnetos	- Seven Scintilla DF4RN-1.
Serial Nos.	- No.1 - 41973, No. 2 - 45666, No.3 - 41707, No. 4 - 41709, No.5 - 45669, No. 6 - 41713, No.7 - 44459.
Timing - BTC Right and Left Plugs -	
Starting	- 5 degrees.
Normal	- 20 degrees.
Cruising	- 35 degrees - manual control.
Spark Plugs	- Champion C-34-S.
Firing Order	- A1 - B5 - C2 - D6 - A3 - B7 - C4 - D1- A5 - B2 - C6 - D3 - A7 - B4 - C1 - D5- A2 - B6 - C3 - D7 - A4 - B1 - C5 - D2- A6 - B3 - C7 - D4

(f) Accessory Drives:

Accessory Drive	Ratio To Crankshaft	Cont. Torque	Static Torque	Direct. Rotation	Type & Number
Starter	3.000:1	-	-	C	1 - Type III
Generator	3.000:1	600	3600	C	3 - Type IA
Vacuum Pumps	1.304:1	*	2250	**	3 - Type II
Fuel Pump	0.800:1	275	1200	C.C.	1
Tachometer	0.500:1	12	200	Left - C. Right - C.C.	1 - Type I 1 - Type II
Magnetos	0.500:1	200	1400	C.C.	7
Governor (Single Prop.)	0.956:1	300	1300	C.C.	1

* If all three drives are used, the continuous torque is 150 inch pounds at each side drive and 300 inch pounds at the center drive. 600 inch pounds are available if only the center drive is used.

** Main or center pad - C.
Side pads - C.C.

METHOD OF TEST

22. Prior to the actual conduct of the type test, data, such as spark and valve timing, compression volume ratio, weights, etc., were checked. Navy contract 1100 grade oil and current contract Specification AN-F-28R fuel were used during all engine operation. The subject engine was equipped with Champion C-34-S type spark plugs and the appropriate accessories, including a propeller governor, starter, two generators, and three vacuum pumps. Auxiliary cooling of the closed cowl rear suction type was used to maintain the cylinder temperatures at the manufacturer's specified limits. Due to the method used in cowling the engine, no accurate cooling airflow requirements were determined. The reduction gear (0.425) was of the torquemeter type. This was not used, however, for measuring brake horsepower due to inconsistency and variation of the torquemeter constant over the entire power range. Brake horsepower calculations were made from calibration data obtained on a similar engine at the Aeronautical Engine Laboratory.

23. Throughout the 150-hour endurance test the power was absorbed by a four-blade, 14'-0" diameter Hamilton Standard Hydromatic propeller, Model 24E60 with blade design 6517A-14 (Plates 11 and 12). Propeller pitch control was accomplished by means of a Hamilton Standard Governor Model 4U18M3C, Serial No. 285-828, regulating both inboard and outboard oil pressures. Prior to the endurance running, a torsional vibration survey of the propeller-engine combination was conducted together with a propeller stress survey. Results of the torsional vibration survey are presented on Plate 5. The torsional vibration amplitudes were measured with Sperry-MIT equipment, the torsiograph being connected to the rear of the crankshaft by a special shaft. Harmonic components were determined with a General Radio wave analyzer. Since Specification AN-9504 does not cover maximum acceptable amplitudes for four-throw crankshafts, those specified in the manufacturer's specification, reference (d), were used to govern these tests in addition to interpolation of the allowable limits of Specification AN-9504 for two and six-throw crankshafts.

24. For all operation, the engine was mounted on a cable supported drum type stand (Plates 11 and 12). A dynamic suspension (airplane type) mount was used to support the engine on the stand. Engine exhaust, oil, and crankcase breathing were vented to atmospheric pressure. Sea level operation was conducted with zero scoop pressure and 80 - 90°F carburetor air temperature except when engine surging required the use of colder carburetor air and altitude pressure to obviate the condition. Oil-in temperature of 167°F and oil-out pressure of 40 pounds per square inch (or percentage thereof depending on RPM) were maintained except during the take-offs and military runs. During these periods, the oil-in temperature was maintained at 185°F in accordance with Specification AN-9502b.

25. The fuel consumptions used were those specified in reference (b), and were obtained by operating the carburetor manually, because of incorrect mixture values obtained in the automatic positions. Runs at 60 per cent and 42 per cent normal rated power were made at best economy conditions. Because of detonation (visual indication) with 35 degrees spark advance at

60 per cent rated power, this period of operation was conducted at the normal spark advance position of 20 degrees BTC. The 15 hour best economy period at 42 per cent normal rated power was run with 35 degree spark advance.

26. The subject engine completed 77 hours of the scheduled 150-hour type test with the variable speed (hydraulic coupling) supercharger drives. At this point, total failure of the drives occurred. The remainder of the test was then conducted with a set of fixed ratio (6.08:1) supercharger drive gears. At 89-1/4 hours, the carburetor, Serial No. 334532A, was replaced by another PR100A3 carburetor, Serial No. 334543, in an effort to overcome the tendency to flood. The flooding characteristic, however, could not be overcome by the change of carburetors. The endurance test was terminated as a result of engine failure during preliminary dive trials following completion of the 150-hour endurance test.

RESULTS AND DISCUSSION

27. The outline of test summarized from Specification AN-9502b is presented as Plate 1. Running data on the test are shown in the form of a graphic log (Plates 2 and 3), and a table of averages (Plate 4). The measured amplitudes of torsional vibration are plotted on Plate 5. Plates 6 to 44 are photographs of the engine, test set-up, and various failures that occurred during the test.

28. Results of the torsional vibration survey indicate a maximum measured amplitude of 0.74 degree. Specification AN-9504 does not provide limits for four-throw crankshafts. However, interpolating between ± 0.5 degree for two-throw crankshafts and ± 1.5 degrees for six-throw crankshafts, maximum allowable amplitude of ± 1.0 degree would be indicated for four-throw crankshafts. Since no significant amplitudes were present for harmonics higher than the second order and the maximum amplitude measured was 0.74 degree, the torsional vibration is not considered excessive. This value is well below the limits noted in the manufacturer's specification (reference (d)) which permits a maximum amplitude of ± 1.5 degrees.

29. The following undesirable operating characteristics were noted during conduct of the endurance test:

(a) Surging:

(1) At rated power and speed, an erratic power surge with an amplitude of 4 to 5 inches manifold pressure occurred. This condition was initially attributed to the operation of the hydraulic couplings installed in the engine and was associated with the throttle and slip control position. The slip control linkage length was changed to move the surge range between normal and take-off conditions. The surge condition was then also present at 3500 feet altitude at normal

rated power. The linkage was then estimated to give a slip of 19 per cent at take-off. The control as received from the manufacturer was set to give an approximate slip of 15 per cent although it was supposed to be carefully calibrated and set to 20 per cent.

(2) At 90 per cent rated power and minimum slip, a pronounced steady surge condition of 1 to 1-1/2 inches manifold occurred.

(3) Take-off operation conducted later at part throttle and relatively hot CAT resulted in an erratic surge condition, Operation at approximately 1000 feet altitude was required to avoid the surging condition.

(4) Take-off operation with fixed ratio supercharger drive gears resulted in a similar surging condition. Take-off periods were therefore run at full throttle, critical altitude, and with approximately 45 degrees F carburetor air temperature to eliminate the surging.

Surging was also obtained with the No. P-1 calibration engine at similar power conditions and it is understood that Pratt and Whitney Aircraft have also experienced the same difficulty. It is the opinion of the Naval Air Experimental Station that the surging condition results primarily from an improper supercharger-engine combination (probably over-capacity supercharger). The degree of surge is believed to be appreciably accentuated by the hunting tendency of the hydraulic drives as influenced by speed, load, oil pressure, temperature, and metering changes.

(b) Starting - During the early portion of the test, difficulty was experienced in starting the engine. A spray of fuel is discharged from the exhaust stacks of the lower cylinders in the "D" row as soon as the engine picks up speed after the mixture control is moved out of idle cut-off. No reason for the flooding tendencies could be determined. In order to eliminate the possibility of hydraulic lock in the lower cylinders, a starting procedure giving relatively dry starts was developed and adhered to throughout the test. This procedure consisted of starting the engine and continuing to run on the prime until an engine speed of approximately 600 RPM was obtained. Fuel pressure was then applied to the carburetor. With the hydraulic supercharger drive gear system it is believed that the transition from prime to carburetor running is difficult in view of little or no drive of the impeller (impeller fuel injection) at cracked throttle openings. Installation of fixed ratio supercharger drive gears did not correct this condition. A second PR100A3 carburetor was tried with similar results.

(c) Oil Pressure - A decrease in main engine and other related oil pressures was observed to occur with application of increased oil-out back pressure. At normal rated power and speed, a rise in back pressure from 12 to 40 pounds per square inch resulted in a drop of approximately 5 pounds in the main engine oil pressure which similarly affected the other engine oil pressures. A drop in oil flow of approximately 11 pounds per minute also was noted. During operation of the variable speed couplings, the main engine oil pressure dropped approximately 6 pounds per square inch when changing from maximum to minimum slip conditions. It is believed that these variables may prove troublesome during engine operation in service if the airplane oil system is not up to par and/or the main engine pressure is not set high enough at sea level.

(d) The sensitivity of the supercharger control linkage setting is quite high - approximately 2-1/2 thread turns on control adjustment for 5 per cent slip. This condition is considered critical since any small increase in slip above 20 per cent at high RPM will result in excessive coupling temperature and failure. In view of the sensitivity of coupling slip to engine oil pressure and oil-in temperature, some positive method of determining slip would be highly desirable. It is understood that equal distribution of oil to each coupling is also quite a problem, both as to the distribution (by piping) to the couplings and as to metering of oil from the couplings. The supercharger control was directly connected to the throttle linkage so that at take-off throttle setting, a value of approximately 19 per cent slip (low ratio) would be obtained. At throttle openings greater than take-off, the supercharger control decreased the clutch slip until a minimum value of approximately 3 per cent slip (high ratio) was obtained at full throttle.

30. Throughout the endurance test, failures of various types occurred, reflecting on the reliability of the engine. It is the opinion of the Naval Air Experimental Station that the following conditions are serious and warrant early attention and correction:

(a) Hydraulic supercharger drive couplings - After 77 hours of endurance, failure of the hydraulic coupling pinions occurred during a take-off period of operation (Plates 18 to 23, inclusive). Fixed ratio supercharger drive gears were installed in place of the variable speed hydraulic couplings for the remainder of the endurance test. Similar failures have been experienced during development tests at the manufacturer's plant. The 4360-4 engine, Serial No. P-1, presently undergoing calibration tests at the Naval Air Experimental Station, has experienced two failures of a similar nature, one failure occurring after a total of 48.6 hours operation and the other after 125.7 hours.

(b) Piston Scuffing - Failure of B-3 cylinder after 98-3/4 hours endurance required installation of a new cylinder, piston, and set of rings (Plate 17). Upon examination of the damaged cylinder, (discovered by excessive flange temperatures) the top ring on the piston was found broken and collapsed in the groove. The cylinder walls and piston faces were severely scuffed. After 61.2 hours of operation on the No. P-1 calibration engine, both B-2 and B-3 cylinders were replaced because of scuffing of the cylinder and piston. These failures were probably aggravated by a detonation condition noticed in the two cylinders as a result of oil leakage at the impeller shaft. Another replacement of B-3 cylinder was necessary on the No. P-1 engine at 88.8 hours. The failures were very similar to those experienced on the No. P-17 engine, although no ring failures occurred. During the last five hours of endurance at rated power and 110 per cent rated speed, a progressively greater amount of cooling air was required to cool the "B" row of cylinders. The B-2 cylinder flange temperature was critical, eventually climbing to an excessive temperature prohibiting operation at this condition during the last 1/4 hour of the endurance test. An examination of the B-2 cylinder upon disassembly of the engine disclosed Nos. 1, 2, and 4 piston rings broken (Plate 39). A portion of the top edge of the top land of the piston was feathered by pieces of the broken ring spreading the groove open and distorting the top land. In view of the localized failure of cylinders on the "B" row, it is believed that a marginal lubrication condition exists on this bank. Relative leanness of the Nos. 2 and 3 banks of cylinders tends to aggravate this condition. See reference (f) for a discussion of failures of a similar nature.

(c) Push Rods - At 49-1/2 hours of endurance, erratic firing of the C-5 cylinder was investigated and found to result from a broken intake push rod (Plate 15). Upon examination, the rod was found broken in two, approximately 1 inch from the rocker arm end at the sweated shoulder of the reinforcing sleeve. The push rod was so badly mutilated at the point of failure that it was impossible to obtain any information as to the type or cause of failure from the fracture. A micro examination close to the point of failure revealed decarburization .004" to .006" deep with cracks extending radially from the decarburized area. The hardness of the rod as determined on a Rockwell tester was B 97-98 which closely agrees with the manufacturer's specification for heat treatment of the part. After 81.7 hours operation, a similar failure on the D-7 exhaust of the No. P-1 calibration engine occurred. It is believed that the intake push rod on the D-7 cylinder which was found badly bent resulted from the failed exhaust push rod. It is believed that failure of the push rod on the No. P-17 engine resulted from fatigue cracks initiated in the decarburized area where the physical properties were considerably lowered. The failure on the No. P-1 calibration engine probably resulted from similar causes.

(d) Intake Pipes - Several intake pipe failures occurred during the tests. The B-1 intake pipe was found cracked at 96 hours and repaired by brazing. The B-2 intake pipe failed after 98-3/4 hours (Plate 24). At 116 hours endurance, further failures on the B-1 intake pipe occurred (Plate 25). At 121-1/2 hours endurance, the B-7 intake pipe failed by cracking. At 145 hours endurance, a broken intake pipe hose connection between the C-5 and D-5 cylinders was replaced (Plate 42). Cracking of the intake pipes appears to have resulted from relative vibration of adjacent cylinders which was probably accentuated by some engine backfiring. Intake pipe failure of the C-4 and D-1 intake pipes on the No. P-1 engine after 81.7 and 40.3 hours, respectively, further substantiates the weakness of the present design. Since one manifold supplies combustible mixture to one bank, a broken intake pipe adversely affects the firing of four cylinders. See reference (f) for further discussion of this type failure and remedy effected for the test of reference (g).

(e) Exhaust Port Adapter Elbows - Failure of exhaust port adapter elbows occurred several times throughout the test (Plate 14). The exhaust system consisted of individual flanged stacks approximately 10 inches long. At 81-3/4 hours endurance, the exhaust system was modified to permit the use of short stacks approximately 5 inches long. This appeared to materially reduce the number of adapter elbow failures. Failure of the adapters is believed to have resulted from excessive weight of the exhaust stack combined with a relatively poor adapter design. During preliminary runs on the P-1 engine a similar failure was experienced while employing the same type of stacks (10 inch). However, since the installation of an exhaust collector no further trouble has been experienced. It is believed that airplane installations employing individual or siamese stacks will encounter similar exhaust port adapter elbow failures.

(f) Exhaust Valve Sticking - At 121-1/2 hours, mis-firing of the B-5 cylinder was investigated and found to result from a sticking exhaust valve. The upper end of the valve stem had a thin coating of hard carbon baked on the surface, which caused the valve to stick in the open position. This was corrected by removing the carbon and polishing the valve stem. This condition again occurred on the B-5 cylinder at 139-1/2 hours and was corrected in the same manner. No other instances of sticking valves occurred on the No. P-1 or P-17 engine. It is possible that insufficient valve guide clearance combined with high rocker box temperatures are responsible for this condition.

(g) Carburetor Mixture Control Valve (Barrel Type) - Considerable trouble and damage to the mixture control mechanism occurred during the test as a result of the barrel type mixture control valve employed in the subject engine. A sticky gum substance (probably from the fuel) forms between the barrel valve and the housing causing the valve to seize and become inoperative. Pressure applied by the hydraulic control mechanism, used at this laboratory for engine controls, is sufficiently great to shear the taper pin in the "click" positioning arrangement and prevent further functioning of the valve. This sticking condition was corrected by removing the barrel valve and housing and polishing the mating surfaces. Similar troubles were experienced with a second PR100A3 carburetor supplied by the manufacturer. The type of fuel used during the subject tests conformed to Specification AN-F-28R. It is to be noted that this condition occurred during shut-down periods of the engine.

(h) Ignition Harness - During the 150-hour endurance test, it was necessary to replace all of the seven ignition harnesses because of shielding conduit failures (Plate 44). The flexible conduit failures occur near the soldered end connections of the spark plug conduit and the middle of the short length of magneto conduit. Failure of the spark plug elbow tube body also occurs near the coupling nut. The failures appear to result from vibration. With the present design, the ignition harness is not supported to the engine at any place along the entire length of the manifold. The only means of holding it in place is by the spark plug elbows and the attachment at the magneto distributor cover. The design of the solid "U" tubing used for spark plug elbows on the"D"row is conducive to failure. As this harness does not employ detachable or rewirable leads, failure of one lead necessitates replacement of a complete harness assembly. Similar harness failures have occurred on the No. P-1 engine which employs the same installation.

(i) Magneto - At 145 hours of endurance, failure of the No. 1 bank to fire satisfactorily on the left magneto was investigated. Inspection showed that the magneto housing was cracked three-quarters around at a point approximately 2 inches from the flange (Plate 42). Upon disassembly of the engine after 150 hours of endurance, a fine crack was noticed in a similar location on No. 2 magneto (Plate 43). It appears that Type I magneto and harness system used during the endurance tests is not able to withstand the vibration accompanying normal engine operation. Modified versions of the magneto and harness system have since been manufactured and are presently undergoing tests at Pratt and Whitney Aircraft.

(j) Magneto Pressure Pump and Altitude Vent Valves - At 31-1/2 hours of endurance, failure of the magneto pressure pump occurred. Inspection indicated that several of the altitude vent valves were found closed and the fibre key locking the pump rotor to the shaft was found sheared (Plate 40). The sheared key resulted from an overload condition imposed on the pump by reason of the failure of the altitude vent valves. A second set of altitude valves installed after repair of the pump also failed after a short period of operation. Further details on the magneto pressure pump and altitude valve will be reported under Project TED No. NAM-04170 which covers testing of these items.

(k) Carburetor Fuel Transfer Pipe - At 99-3/4 hours of endurance, fuel leakage at the banjo fitting of the carburetor transfer fuel pipe occurred as the result of a slight crack. This failure was repaired by brazing the crack. A supporting bracket was installed to restrict vibration of the transfer tube. See reference (g) for a similar type failure.

(l) Engine Studs - During the test, two studs on the generator drive pad (side drive) and one stud on the rear case were replaced due to breakage. It is believed that these stud failures may have been induced by the addition of the rear case supporting brackets which were installed beneath the stud and the nut. These brackets will be eliminated in subsequent models which will employ strengthened rear cases.

(m) Intake Pipe Drain Valves - After 77 hours endurance, the intake pipe drain valves on Nos. 3, 4, and 5 banks were all replaced because of mechanical failure of two of the valves (Plate 16). Pratt and Whitney Aircraft are familiar with the unsatisfactory operational life of these valves (reference (f)), and at present are developing a unit designed to give more satisfactory operation.

31. A summary of the unacceptable conditions of the engine, based on complete visual and magnetic inspections upon disassembly after the final failure is as follows:

(a) In the opinion of the Naval Air Experimental Station, the most serious conditions which require prompt attention and correction are:

(1) Rear Intermediate Main Bearing Failure - This bearing was severely scored and burned. The main bearing support was also damaged by the pounding action of the crankshaft (Plates 29 and 31). It is believed that this failure caused the rear intermediate crankcase to crack at the cam bearing support (Plate 38). An inspection of the rear intermediate journal showed scoring and grooves on the side adjacent to the counterweight. Failure of this bearing is believed to result from inadequate lubrication aggravated by unequal load distribution over the bearing width (as caused by crankshaft deflection). For a discussion by Pratt and Whitney Aircraft relative to this type failure see reference (g).

(2) Rear Row "A" Master Rod Bearing Failure - The condition of the master rod bearing on the "A" row was similar to that of the rear intermediate main bearing, the bearing material being badly scored and burned (Plate 28). The yoke section of the master rod and the lower half of the rod were distorted as a result of the intense heat and pounding to which it was subjected between the time of engine failure and stopping of the engine. The "A" row crankpin was severely scored on the bottom side indicating the failure to have probably occurred during dive (inertia load) operation (Plate 27). It is believed that this failure can also be attributed to inadequate lubrication rather than local chipping of the silver as discussed in references (f) and (g).

(3) Cam Bearings - The rear intermediate cam bearing (A-B row) was cracked in two places while the front intermediate cam bearing (C-D row) was cracked in one place (Plate 37). These cracks did not appear to affect the cam operation in any way. Failure of the rear cam bearing might have been caused by the cracked cam bearing support but no similar reason can be given for the crack in the front bearing. For a discussion of other failures see references (f) and (g).

(4) Cam Retainer - Both the rear and front intermediate cam retainers were cracked through at similar positions. The cracks occurred at a slot cut several inches from the end of the retainer which is used to locate the main bearing support (Plate 36). Failure of these retainers did not affect engine operation or the condition of other parts.

(5) Ring Failures - While the general condition of the rings was satisfactory upon completion of the tests, the top two compression rings and the two oil control rings on the B-2 cylinder were found to be broken upon disassembly of the engine (Plate 39). The compression rings were broken into numerous pieces, two of the pieces becoming wedged one above the other in the top groove, spreading the groove apart and raising the top land on the piston. In addition the oil scraper ring on the A-3 piston was found to be broken about 3/4 inch from the end. The XR-4360-4 engine employs the same ring arrangement as the R-2800-B series engines.

(6) Bearings - In general, the condition of the main and master rod bearings was unsatisfactory (Plates 26 to 32, inclusive). The top half of the "B" master rod bearing had a crack about 1/2 inch long starting at the cut-out in the side of the bearing half used to position the bearing in the master rod. This crack probably resulted from the sharp corner left in the cut-out. The front main bearing had several deep grooves cut into it while the rear main bearing had a series of fine grooves. This scoring condition is probably the result of foreign material in the lubrication system. The front intermediate main bearing had approximately 50 per cent of the lead washed out. The lead facing on other bearings was also appreciably washed in varying amounts. In general, inspection indicated many local high pressure areas which probably resulted from a combination of crankshaft deflection, improper bearing (clearance) relief, and inadequate lubrication. For a discussion of failures attributed to local chipping of the silver see references (f) and (g).

(7) Propeller Thrust Bearing - The rear inner race on this bearing had a deep pit, probably the result of a defective raceway (Plate 35). The surface on one of the balls had a satin finish instead of a bright, highly polished surface. It is believed that this

one ball was not completely finished at the time of installation in the bearing. Neither of these conditions affected any other parts on the engine although it is believed that the pitted inner race would eventually gall the balls and result in total failure of the bearing. A more advanced failure is discussed in reference (g). It appears that a condition approaching overloading may be present here which in combination with possible variable and mediocre manufacture and inspection of the bearing and additional short time loading applied when operating in maneuverable airplanes may cause considerable trouble in the future. It is believed that installation of a dual (ball-roller type) bearing should be considered.

(8) <u>Cam Drive Gears</u> - The teeth on the two cam drive gears on A-B row were badly feathered and the cam gear pinion shafts were blue as a result of operation at high temperature. Similar gears and shafts on the other rows were in a satisfactory condition.

(9) <u>Push Rods</u> - Seven exhaust push rods had slight bulges at one end near the section at which the ball end tip is brazed. During the test, failure of an intake push rod occurred at this section. Eight exhaust rods and one intake push rod had slight indications of being bent. The bent push rods and rods with bulged ends cannot be definitely established as having resulted from engine operation. However, in view of similar failures experienced in both Nos. P-1 and P-17 engines, it is recommended that push rods be more closely inspected upon manufacture to preclude the possibility of installing defective rods in engines during assembly.

(10) <u>Valves</u> - One intake valve had a burned area of approximately one inch on the seat while a second intake valve had a fine circumferential groove, 1/16 inch wide pounded into the center of the valve seat (Plate 33). Three exhaust valves had slight guttered notches and burned areas on the top edge of the seat (Plate 34). Slight indications of erosion were also noted on the heads near the edges of several exhaust valves.

(11) <u>Exhaust Valve Stems</u> - All of the exhaust valve stems had a thin layer of carbon baked on the stem about one inch from the keeper end. It was necessary to remove this carbon before the valves could be removed from the cylinders. This condition indicates

high rocker box temperatures which is conducive to sticking valves. During the test, No. B-5 exhaust valve was stuck in the open position at 121-1/2 and 139-1/2 hours of endurance as a result of carbon deposit.

(12) Intake Pipes - Two intake pipes were cracked near the flange while a third had started to crack near a primer fitting. Failure of intake pipes on this model engine appears quite common. See also references (f) and (g). In view of the serious consequences which result from intake pipe failures, it is imperative that a satisfactory solution for this condition be expedited. Several intake pipe failures occurred during the endurance test as mentioned previously.

(b) Other conditions of a minor or isolated character are as follows:

(1) The push rod ball socket in Nos. A-7 and D-7 rocker arms was loose. This condition probably results from either an undersize socket or oversize bore.

(2) The oil hole plug in one of the knuckle pins on the "A" row of cylinders was found loose. This plug is held in position by staking. Due to improper workmanship, the plug worked loose during the test and was found partially backed out. Should the plug have come out entirely during engine operation, it would have resulted in a crankshaft lubrication failure with its attendant results.

(3) One of the oil drain lines to the rear rocker box sump was found cracked. This engine has numerous external oil lines subject to failure or loosening by vibration unless adequately braced.

(4) Several of the exhaust rocker arms showed evidence of operation at high temperatures. The area near the adjusting screw was blue. This condition was most serious on the No. 3 bank and part of the No. 2 bank. Removal of the adjusting screws from the rocker arms on both the intake and exhaust valves was quite difficult due to oil carbonization in the threads. It is believed that the above conditions result from operation at high rocker box temperatures.

(5) A moderate amount of baffle failures occurred as a result of the type test. The most serious failures occurred on five of the seven baffle mounting strips which attach to the crankcase by angle clips. These angle clips were cracked and separated from the

baffle strips. Nine of the cylinder baffle strips which attach the cylinder baffles to the rocker boxes were broken. However, none of the baffles were split or cracked. Modifications to the above attaching parts will probably be necessary to insure satisfactory endurance operation.

(6) The impeller oil seal sleeve in the impeller case had deep grooves on the bottom half which were caused by the impeller oil seal ring carrier lands. The position of the grooves in the sleeve seems to indicate misalignment of the impeller shaft bearings and seal sleeves. However, the scoring may have resulted from the supercharger drive failure at 77 hours endurance and/or unequal load distribution of the high ratio supercharger drives.

(7) The outer gear on the crankcase scavenge pump of "A" bank (geroter pump) was cracked. This condition may have occurred as a result of chips from the failed bearings entering the pump.

(8) One cam follower, pin, and tappet was slightly scored. In general, the condition of the rest of these parts was satisfactory.

(9) Both fuel pump intermediate drive pinions were lightly galled. The location of the galling indicates poor tooth contact resulting from misalignment of the pinion and the driven gear. Neither of these accessory pads was loaded during the engine tests as an auxiliary external fuel pump was used. Similar trouble was experienced during a test run at Pratt and Whitney Aircraft - reference (g).

32. Crankshaft - A general examination of the crankshaft journals and bearings indicates that there is considerable deflection of the shaft present at least under inertia loads and that the two bearings which failed were overloaded due to inertia forces (Plates 26, 30, 31, and 32). Each crankpin journal of the shaft showed high pressure loading and scratching on the inside (inertia load area) and each main bearing journal showed similar conditions on the side of the journals adjacent to the loaded crankpin area indicating bending due to inertia loading. The front intermediate main bearing which had most of the lead washed off showed a very high pressure area nearest the "B" bank crankpin. It is believed that this bearing would have failed in a short time.

33. It is understood that the manufacturer is presently modifying the following parts in an effort to correct some of the conditions experienced on the No. P-17 engine:

(a) Crankshaft - The modified crankshaft will have two oil holes in the main journal instead of one, and the main bearings have been tapered or relieved toward the edges to allow for shaft deflection.

(b) Lubrication - The location of the oil jet in the "B" bank is being changed in an attempt to improve lubrication of the cylinders.

(c) Intake Pipe - Additional clearance between sections of intake pipe and softer rubber connections are being tried to correct the cracking condition of these pipes.

(d) Intake Pipe Drain Valves - These valves are being completely redesigned for better endurance.

(e) A new harness and magneto system has been designed for this engine which is presently undergoing laboratory tests.

(f) A Bendix PR100B-3 and C-3 carburetor are being developed to overcome difficulties encountered with the A-3 model.

(g) The supercharger design is undergoing modification to correct the surging condition.

(h) Modifications to the torquemeter design are being made to give accurate torque results.

(i) The supercharger drive system is being revised to incorporate two low gear constant speed hydraulic couplings and two variable speed high gear clutches. Experimental development on overriding clutches is also being continued. It is understood that the subsequent type of low gear couplings is permitted to run full of oil, permitting a wide variation in oil flow to the low gear coupling while maintaining a constant slip. When the flow of oil to the high gear coupling permits the high gear clutch to override the low gear clutch, the oil supply to the low gear coupling is cut off. Wide faced drive gears have been installed to preclude possibility of failures.

(j) A modification to the spark advance mechanism design has been made for production engines.

(k) The crankcase scavenge system is being modified to permit better scavenging.

(l) A strengthened rear section, conical nose housing and strengthened crankcases are planned for production engines.

(m) Slight modifications to the cylinders are being made to facilitate cowl installations.

REFERENCES

(a) Project Authorization - Bureau of Aeronautics Restricted Letter Aer-E-41-RWS 2855 of 6 January 1944.

(b) Model Test Conditions - Bureau of Aeronautics Restricted Letter Aer-E-41-RWS 51719 of 18 March 1944.

(c) Model Test Specification - Specification AN-9502b dated 11 August 1942.

(d) Model Test Specification (Restricted) - Pratt and Whitney Aircraft, Specification N-7039 dated 1 December 1943, for Model R-4360-4 Engine, Paragraph E-22.

(e) Preliminary Overhaul Manual (Restricted) - Pratt and Whitney Aircraft - Preliminary Instructions, Wasp Major (R-4360) TSB1G (Semi-Production) dated 27 March 1944.

(f) Reliability Test of Wasp Major Engine No. X-117 - Pratt and Whitney Aircraft Report No. 512 of 23 August 1944.

(g) 150 Hour Type Test Endurance on Wasp Major Engine X-117 - Pratt and Whitney Aircraft Report No. 516 of 15 September 1944.

[illegible]
[illegible]
[illegible]

Run	Total Time	Run No.	Supercharger Gear	[illegible]	Duration	Altitude	RPM : MAP	[illegible]	[illegible]	[illegible]	[illegible]	Max. Temp.	Max. Temp.	Supercharger	[illegible]	Duration	Altitude	RPM : MAP	Fuel	Air	Max. Temp.	Max. Temp.	Remarks
Par. P-3a(1) (a)	0 - 5	1	Low	5	5	5,000'	2550:2500	2040:.700	-	-	178	450	350	-									
(b)	5 - 10	2	High	5	5	14,500'	2550:2500	2050:.700	-	-	150.5	450	350	-									
(c)	10 - 15	3	High	5	5	14,500'	[illegible]	[illegible]	-	-	169	450	350	-									
(d)	15 - [illegible]	4	[illegible]	5	5 min.	S.L.	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	1	1 min.	S.L.	[illegible]					Note 1
Par. P-3a(2)	35 - 40	5	Low	5	5 min.	S.L.	2700:3000	[illegible]:.750			202	450	350	Low	10	10 min.	S.L.	Idle - as low as practicable					
Par. P-3a(3)	40 to	6	Low	15 Periods	15 min.	1,500'	2700:3000	2190:.950	-	-	202	450	350	Low	15 Periods	15 min.	1,500'	1600					Note 2
	55	7	High	7 Periods	15 min.	13,900'	2700:2400	1890:.770	-	-	161.7	450	350	High	7 Periods	30 min.	S.L.	1600					Note 2
Par. P-3a(4)	55 - 80	8	Low	12-1/2	2-1/2	S.L.	2550:2500	1800:.720			178	450	350	Low	12-1/2	2-1/2	S.L.	2370:2000	1230 : .615		153:450	350	
Par. P-3a(5)	80 - 105	9	Low	12-1/2	2-1/2	S.L.	2550:2500	1800:.720			178	450	350	Low	12-1/2	2-1/2	S.L.	2270:1750	900 : .560		140:400	355	
Par. P-3a(6)	105 - 130	10	Low	12-1/2	2-1/2	S.L.	2550:2500	1800:.720			178	450	350	Low	12-1/2	2-1/2	S.L.	2145:1500	- : O.K.		127:400	355	Note 3
Par. P-3a(7)	130 - 145	11	Low	15	15	S.L.	1430:1050	- : O.K.			135	400	355										Note 3
Par. P-3a(8)	145 - 150	12	Low	5	5	S.L.	[illegible]:2500	1800:.720			148	450	350										Note 4

ENGINE RATINGS:

Take-off . . . . . . 3000 BHP at 2700 RPM

Normal
- Low Gear . . . . . 2500 BHP at 2550 RPM to 5,000'
- High Gear . . . . . 2200 BHP at 2550 RPM to 14,500'

Military
- Low Gear . . . . . 3000 BHP at 2700 RPM to 1,500'
- High Gear . . . . . 2600 BHP at 2700 RPM to 13,900'

NOTE 1 - The conditions of operation for the second alternate period of 5 minutes shall be that obtained by shifting to the lower gear ratio. A constant speed propeller shall be used.

NOTE 2 - BHP during second alternate period to be obtained without change of propeller pitch.

NOTE 3 - The second alternate period of Run No. 10 and Run No. 11 will be made with best economy mixture strength and with the spark control in the advance position.

NOTE 4 - During the last 1/2 hour of the running specified by Par. P-3a(8) the engine shall be operated for 2 ten-minute periods spaced 10 minutes apart in the higher gear ratio at not less than 40% BHP nor less than 70% RPM.

- Standard altitude carburetor air temperature shall be used on runs 1, 2, 3, 6, and 7.
- 85 - 90°F CAT shall be used on all sea level runs.
- Maintain [illegible] pounds oil out pressure on all runs at 40% power and above except take-off.
- Maximum cylinder and/or flange temperatures shall be maintained during all runs.

Obs. BHP = tabulated BHP x [illegible]

PLATE I

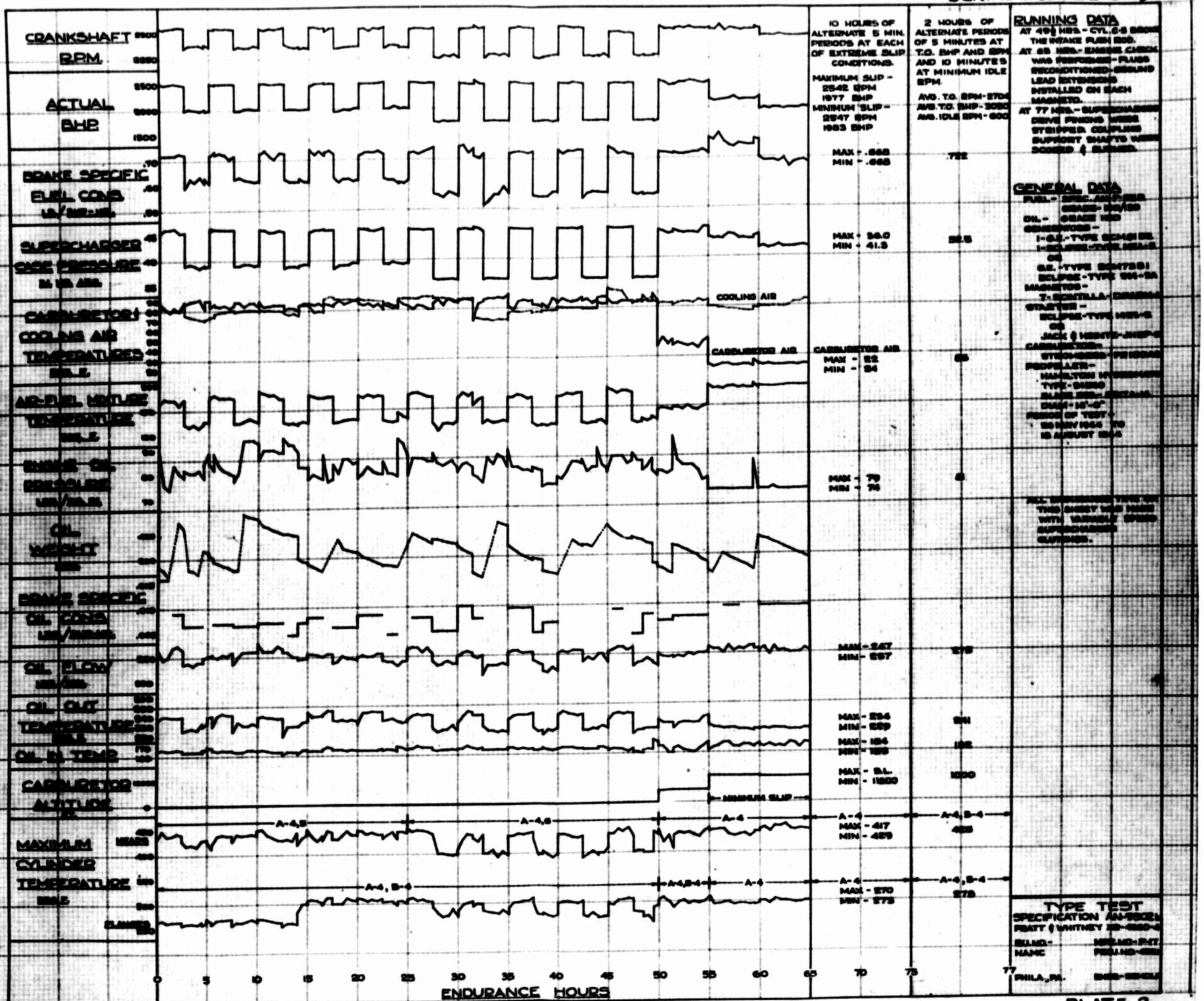

CRANKSHAFT R.P.M.
ACTUAL BHP
BRAKE SPECIFIC FUEL CONS.
SUPERCHARGER CASE PRESSURE
CARBURETOR & COOLING AIR TEMPERATURES
AIR-FUEL MIXTURE TEMPERATURE
OIL WEIGHT
BRAKE SPECIFIC OIL CONS.
OIL FLOW
OIL OUT TEMPERATURE
OIL IN TEMP.
CARBURETOR ALTITUDE
MAXIMUM CYLINDER TEMPERATURE
COOLING AIR
CARBURETOR AIR
MINIMUM SLIP
A-4,5
A-4,6
A-4
A-4, B-4
A-4,B-4
10 HOURS OF ALTERNATE 5 MIN. PERIODS AT EACH OF EXTREME SLIP CONDITIONS.
MAXIMUM SLIP - 2542 RPM 1977 BHP
MINIMUM SLIP - 2547 RPM 1983 BHP
MAX - 34.0
MIN - 41.3
CARBURETOR AIR
MAX - 22
MIN - 24
MAX - 79
MIN - 76
MAX - 247
MIN - 257
MAX - 234
MIN - 229
MAX - 184
MIN - 188
MAX - S.L.
MIN - 11800
MAX - 417
MIN - 459
MAX - 270
MIN - 275
2 HOURS OF ALTERNATE PERIODS OF 5 MINUTES AT T.O. BHP AND RPM AND 10 MINUTES AT MINIMUM IDLE RPM.
AVG. T.O. RPM - 2700
AVG. T.O. BHP - 3000
AVG. IDLE RPM - 600
.722
36.5
1090
RUNNING DATA
GENERAL DATA
TYPE TEST
SPECIFICATION AN-9502
PRATT & WHITNEY
PHILA., PA.
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
77
ENDURANCE HOURS

PLATE 2

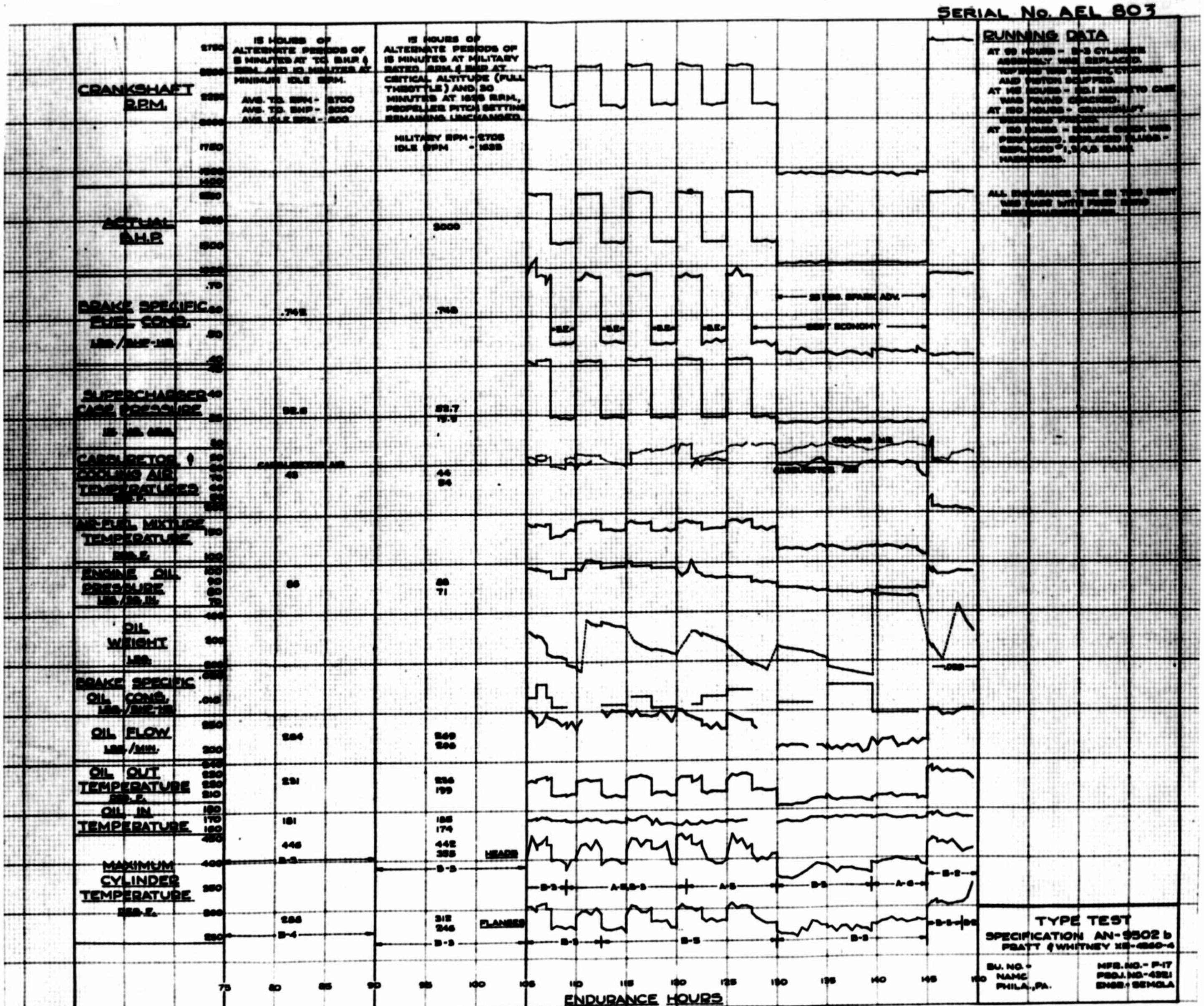

SERIAL No. AEL 803
CRANKSHAFT R.P.M.
ACTUAL B.H.P.
BRAKE SPECIFIC FUEL CONS. LBS./BHP-HR.
SUPERCHARGER CASE PRESSURE
CARBURETOR & COOLING AIR TEMPERATURES
AIR-FUEL MIXTURE TEMPERATURE
ENGINE OIL PRESSURE
OIL WEIGHT
BRAKE SPECIFIC OIL CONS.
OIL FLOW
OIL OUT TEMPERATURE
OIL IN TEMPERATURE
MAXIMUM CYLINDER TEMPERATURE
HEADS
FLANGES
RUNNING DATA
COOLING AIR
CARBURETOR AIR
BEST ECONOMY
ENDURANCE HOURS
TYPE TEST
SPECIFICATION AN-9502 b
PRATT & WHITNEY
PHILA., PA.

PLATE 3

Test of PRATT & WHITNEY XR-4360-4 ENGINE NO. P-17

Serial No. AEL 803
Sheet No. of

Date

Test Equip. TABLE OF AVERAGES - AN-9502 b TYPE TEST

Test Engineer

Observer

% N.R.P.	100	80	100	70	100	*100	*90	SHIFTS *90	*90	TAKE-	TAKE-	IDLE	LOW GEAR MIL.	IDLE	100	60	42	100
% N.R.S.	100	93	100	89	100	100	100	100	100	OFF	OFF				100	84	56	110
SUPER. SLIP CONTROL	MAX.	MAX.	MAX.	MAX.	MAX.	MIN.	MIN.	MIN.	MAX.	MAX.	FIXED RATIO (6.08:1) SUPERCHARGER DRIVE GEARS							
TOTAL HOURS	12½	12½	12½	12½	5	5	5	5	5	EIGHT 15 MIN. PERIODS	5	10	5	10	12½	12½	15	5
RPM	2346	2367	2280	2270	2250	2345	2472	2547	2542	2704	2700	600	2708	1635	2546	2147	1440	2809
BHP	2300	2000	2300	1782	2314	2175	1990	1985	1977	3050	3000		3000	–	2500	1500	1056	2497
B.S.F.C.	.725	.616	.728	.557	.720	.764	.685	.668	.660	.722	.742		.748	–	.723	.451	.408	.729
B.S.O.C.	.008	.007	.009	.005	.007	.010	.009	–	–	–	–		–	–	.011	.007	.007	–
ENG. OIL PRESS.	82	87	82	82	81	72	72	74	79	81	86		88	71	98	94	77	95
OIL FLOW	257	250	257	233	246	259	254	257	247	275	264		269	206	263	247	196	270
OIL IN TEMP.	166	165	166	165	164	167	167	165	164	182	181		185	174	165	163	165	166
OIL OUT TEMP.	241	232	241	225	231	224	224	229	234	241	231		236	199	222	207	200	227
SUPER. RIM PRESS.	46.0	39.1	46.0	36.0	45.2	43.9	41.9	41.3	36.0	52.5	52.6		52.7	19.9	46.1	34.5	33.2	47.0
CARB. AIR TEMP.	85	86	85	87	43	21	21	24	22	85	+45		+44	+54	82	84	79	85
COOL. AIR TEMP.	83	82	83	81	85	77	82	–	–	83	94		94	89	92	90	96	87
MAX. HEAD TEMP.	438	425	436	394	434	439	446	429	417	425	446		442	355	436	408	361	430
CYL. NOS.	A-4,5 B-3	A-4,6 B-2,5	A-2,4,5 B-3,5	A-2,4,5 B-3,5	A-4 B-3	A-4	A-4	A-4 B-3,5	A-4 B-3,5	A-2,3,4 B-2,3,4	B-3		B-3	A-5 B-5	A-4,5 B-3	A-5,6 B-3,4,5	B-3 D-6	B-2
MAX. FLANGE TEMP.	285	284	303	276	300	298	301	273	270	278	288		312	246	300	265	261	306
CYL. NOS.	A-4 B-4	A-4 B-4	A-4 B-4	A-4 B-4	A-4 B-4	A-4 B-4	A-4 B-4	A-4 B-4	A-4	A-4 B-4	A-4 B-4		B-3	B-4 C-4	A-3,4 B-2,3,4	A-4 B-4	B-3	B-2,3,4
ALTITUDE	S.L.	S.L.	S.L.	S.L.	5000	10600	10680	11800	S.L.	+1000	+2800		+2700	+2700	S.L.	S.L.	S.L.	S.L.
TYPE TEST HOURS	0-25		25-50		50-55	55-60	60-65	65-75		75-77	78-90		90-105		105-130		130-145	145-150
RUN NO.	8	8	9	9	1	2	3	4	4	5	5	5	6	7	10	10	11	12
PERIOD	1st	2nd	1st	2nd	1st	1st	1st	1st	2nd	1st	1st	2nd	1st	2nd	1st	2nd	1st	1st

VARIABLE SPEED SUPERCHARGER DRIVES REMOVED AND FIXED RATIO (6.08:1) DRIVE GEARS INSTALLED.

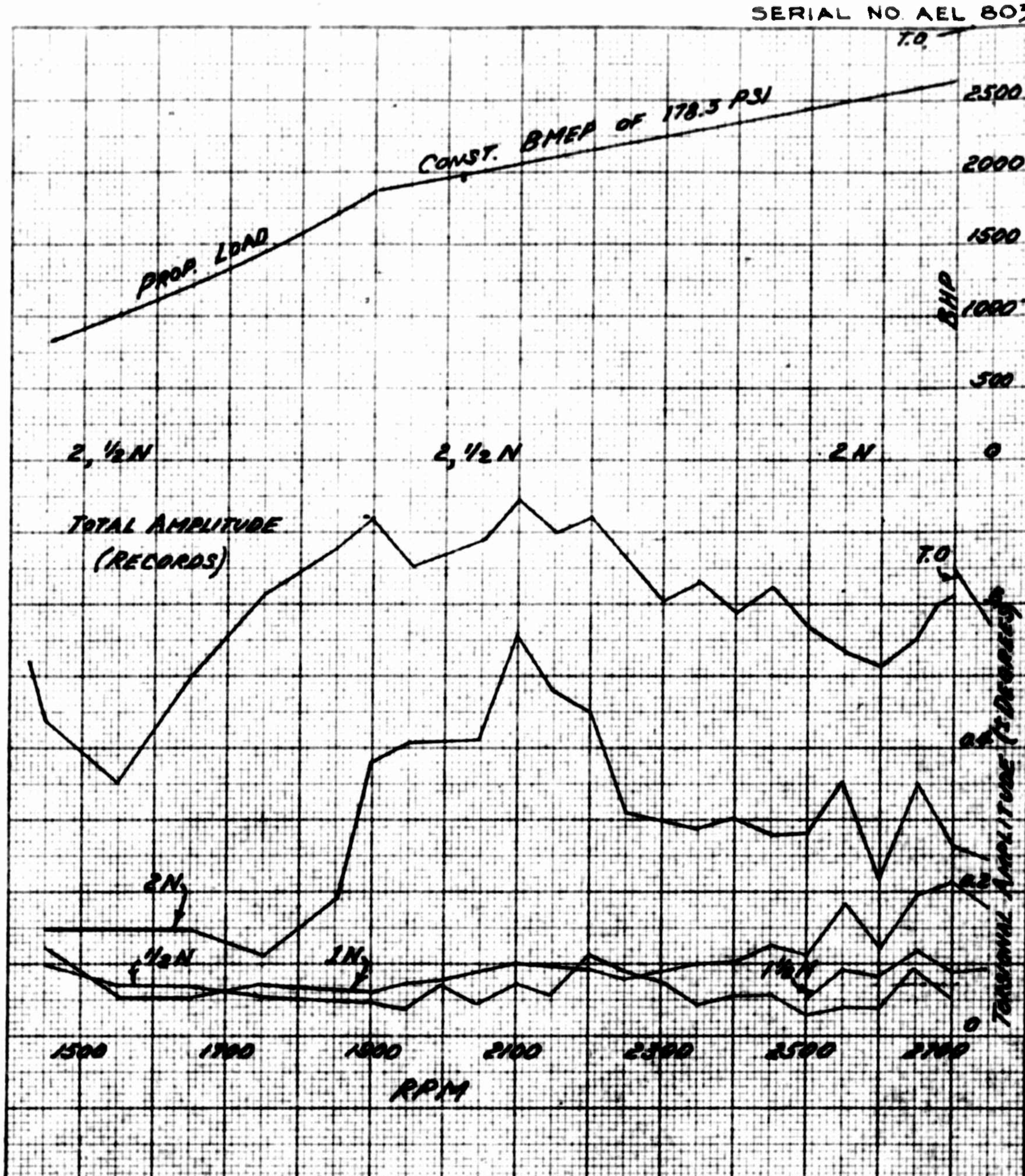
* PERCENTAGES BASED ON MINIMUM SLIP NORMAL RATED.

\+ ALTITUDE PRESSURES AND TEMPERATURES USED TO PREVENT SURGING.

Pub. No. T4-11100-A1-6-HAF 1422-1,000

PLATE 4

SERIAL NO. AEL 803



ENGINE RATING: T.O. - 3000 BHP @ 2700 RPM
NORMAL RATED - 2500 BHP @ 2550 RPM

DAMPERS: 3 1/2 ORDER FRONT AND REAR

REDUCTION GEAR: 0.425

PROPELLER: 14'0" - 4 WAY HAM. STD.
BLADE DES. 6517 A - 14
HUB DES. 24 E60

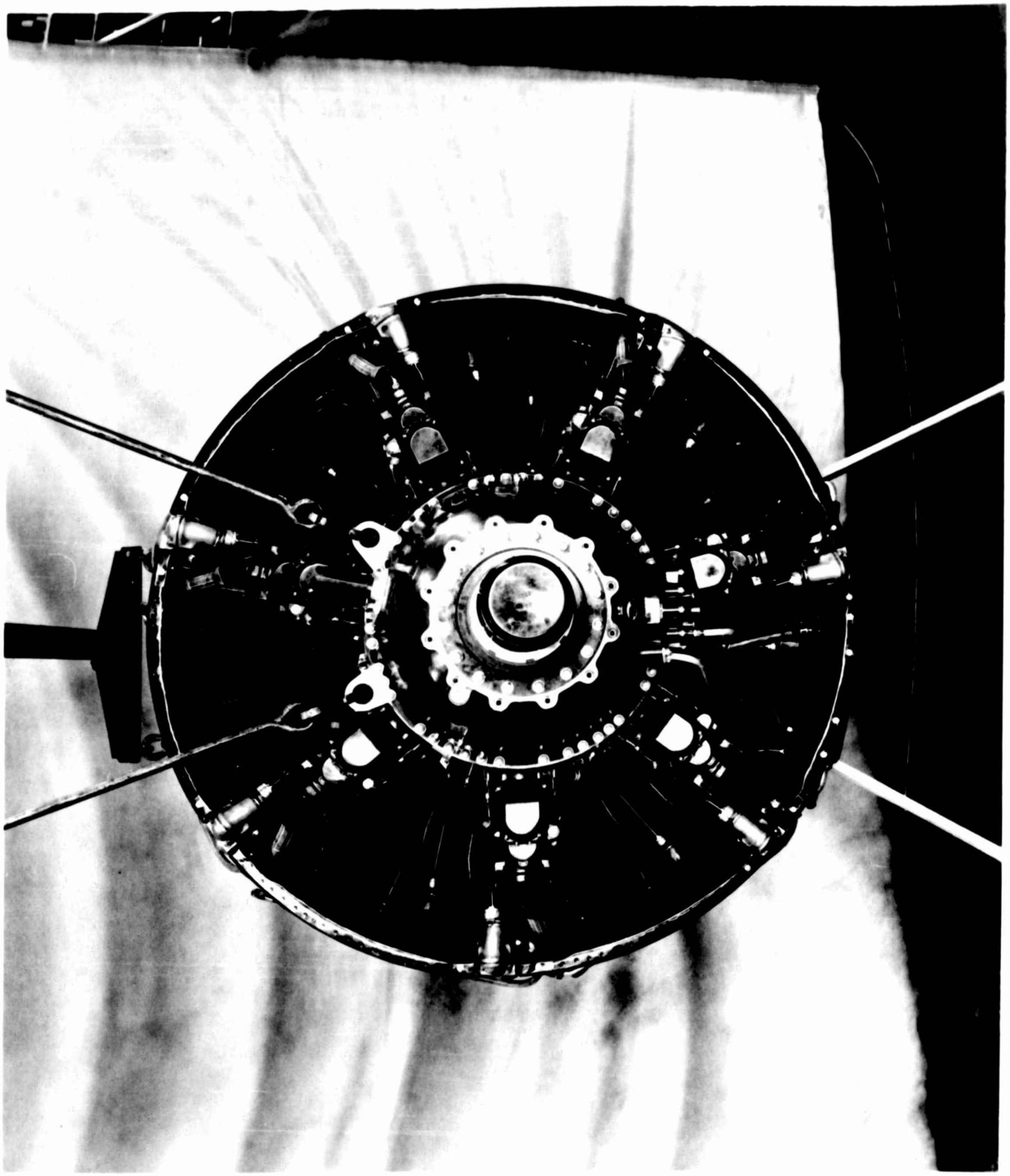
TORSIOMETER MOUNTED ON CRANKSHAFT EXTENSION

TORSIONAL VIBRATION SURVEY OF XR-4360-4 ENGINE WITH A HAM. STD. 4-WAY FLIGHT PROPELLER

AERONAUTICAL ENGINE LABORATORY
NAVAL AIR EXPERIMENTAL STATION, PHILA., PA.
ENGR. KRESSIN

ENGINEERS PUBLISHING CO.
183

PLATE 5



FRONT VIEW
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 6

AEL-803

Naval Air [illegible]
Navy Yard, Philadelphia

OFFICIAL PHOTOGRAPH
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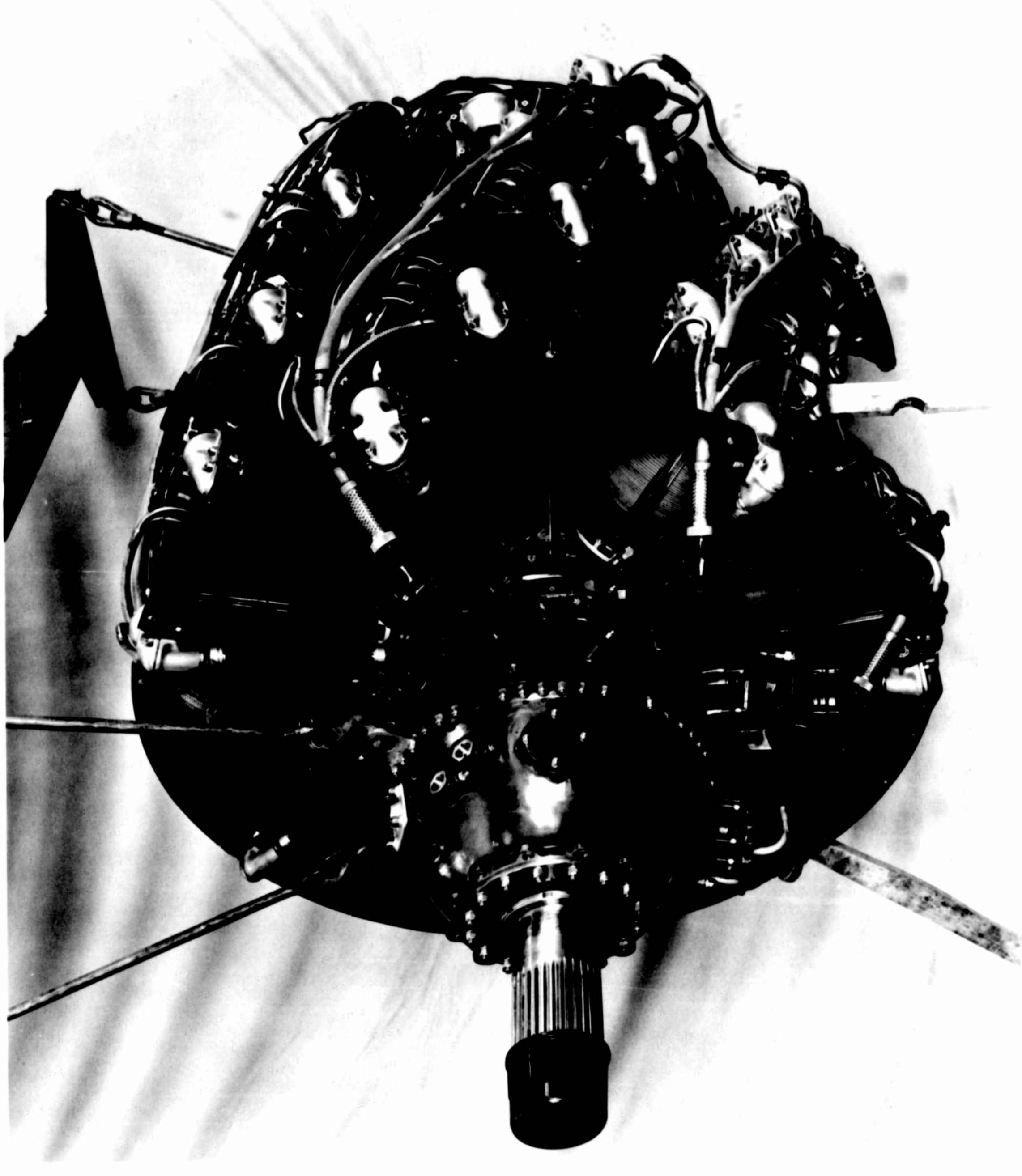
Negative Number 232713



3/4 FRONT VIEW
PRATT & WHITNEY XR-[illegible]

PLATE 7

AEL-803

PHOTOGRAPH NOT FOR PUBLICATION

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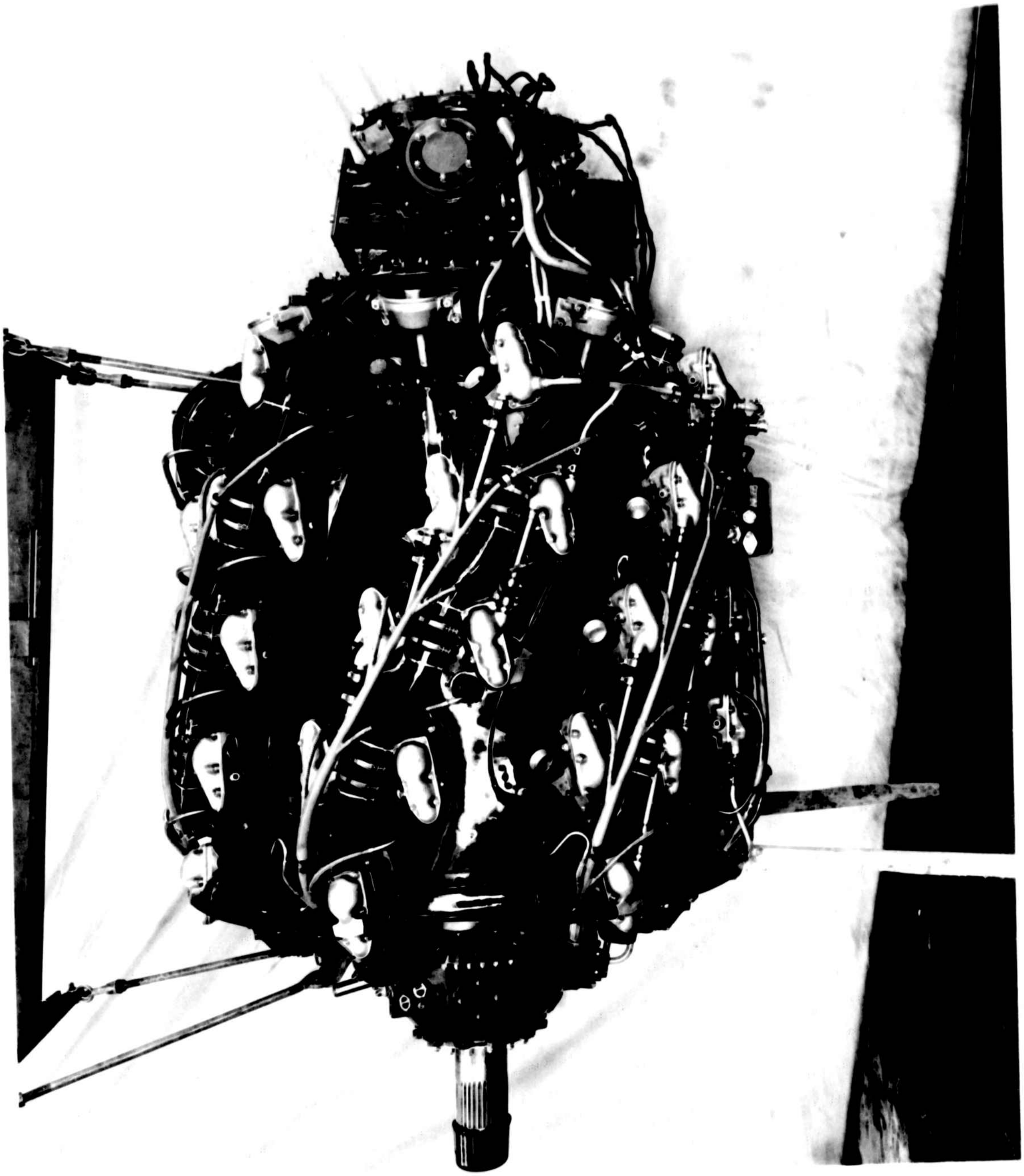

SIDE VIEW
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 8

3/4 REAR VIEW
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 9

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Naval Air ... Navy Yard Philadelphia

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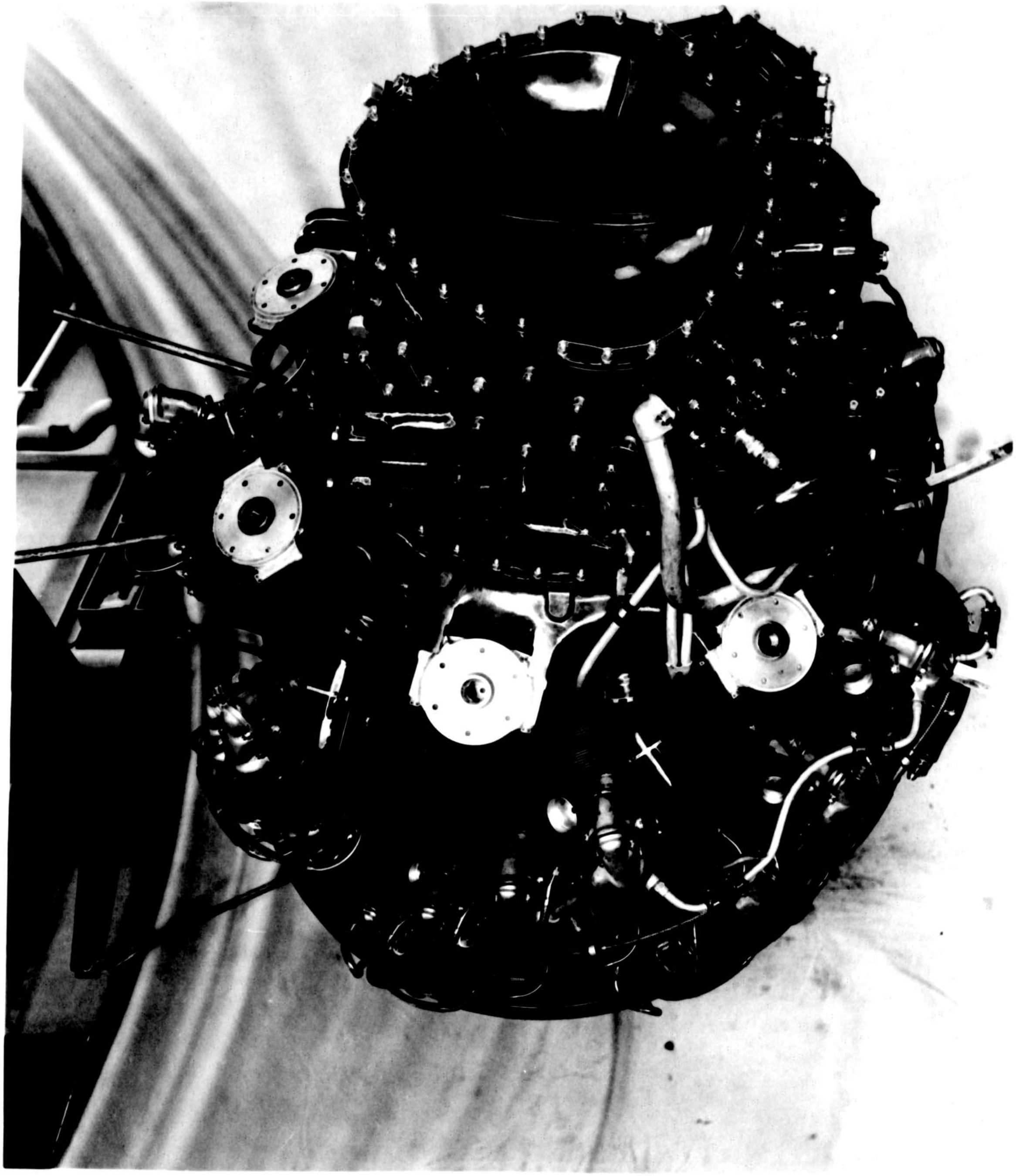
Negative Number 232711

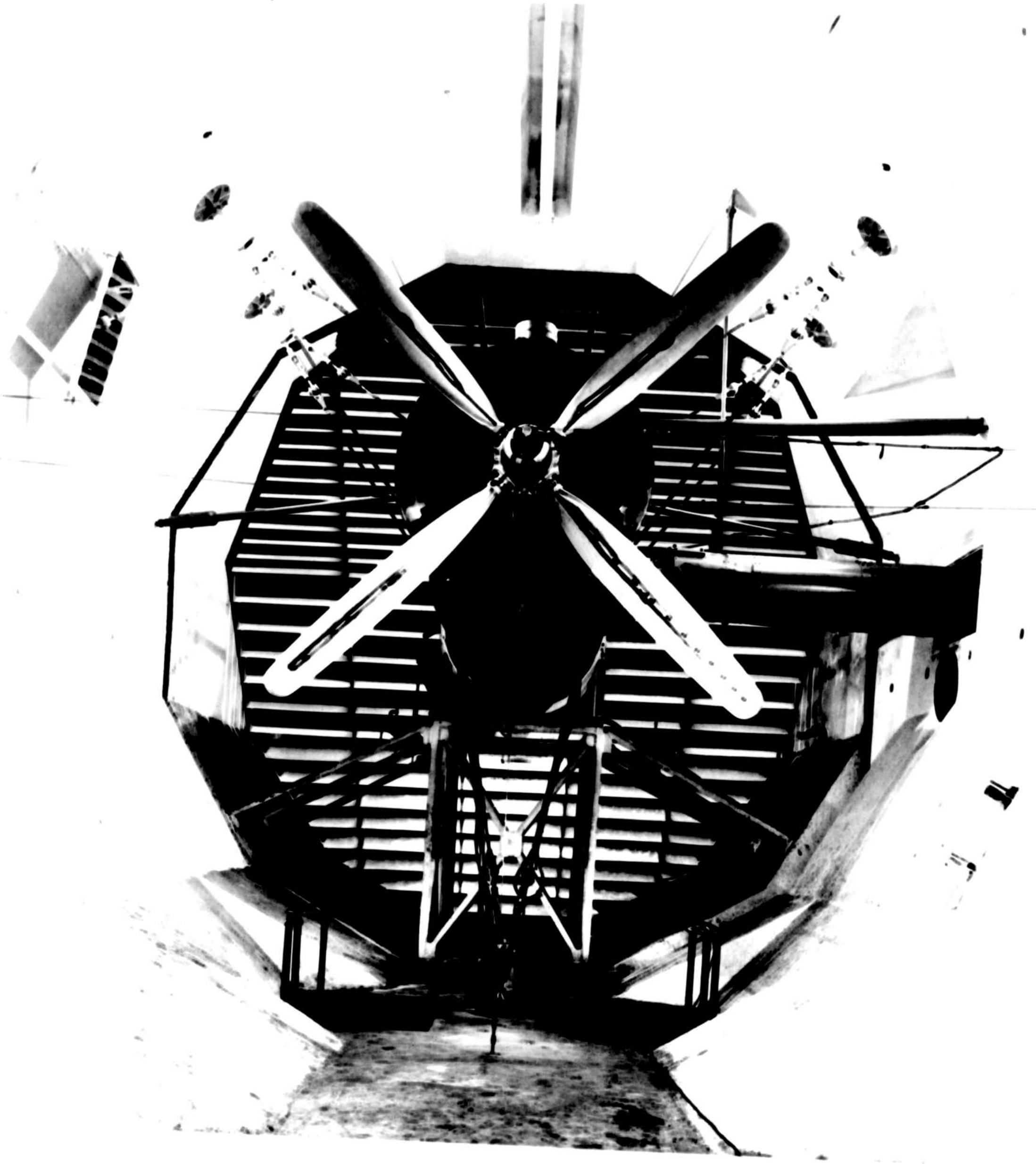


3/4 REAR VIEW
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 10

TEST CELL INSTALLATION
PRATT & WHITNEY XR-4360-4 ENGINE

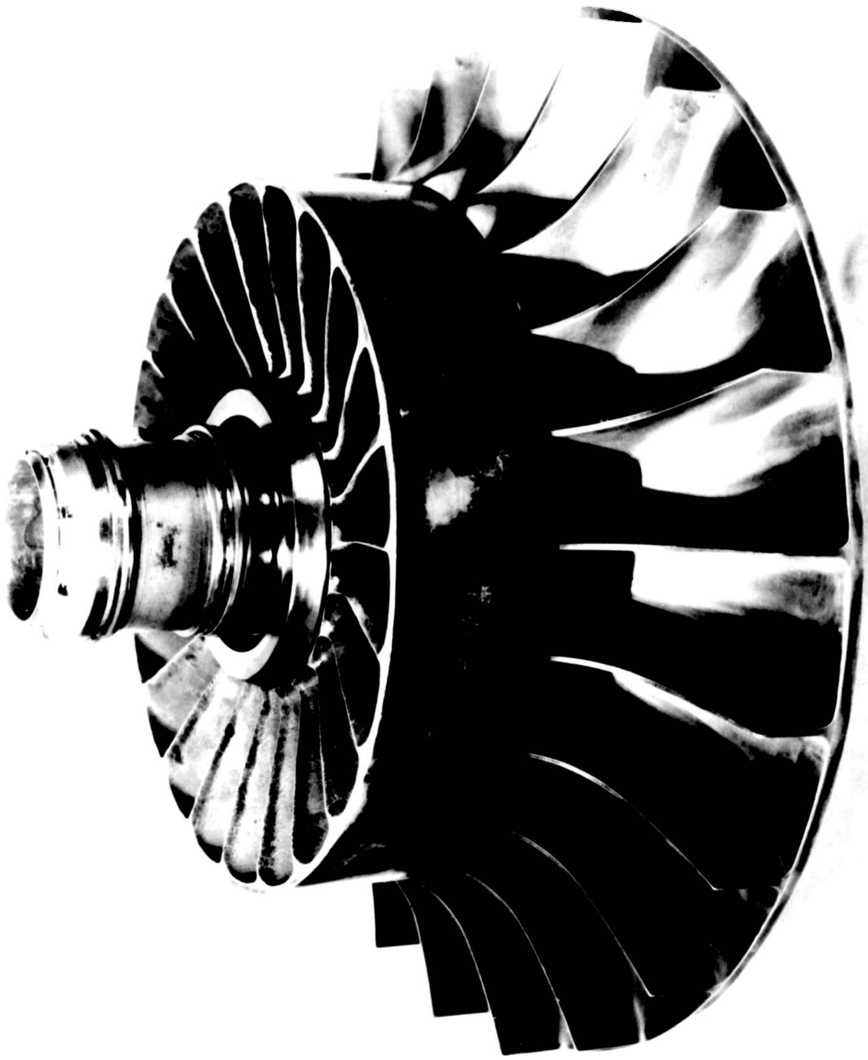
PLATE 11



TEST CELL INSTALLATION
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 12

AEL-803



IMPELLER AFTER SUPERCHARGER DRIVE FAILURE AT 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 13

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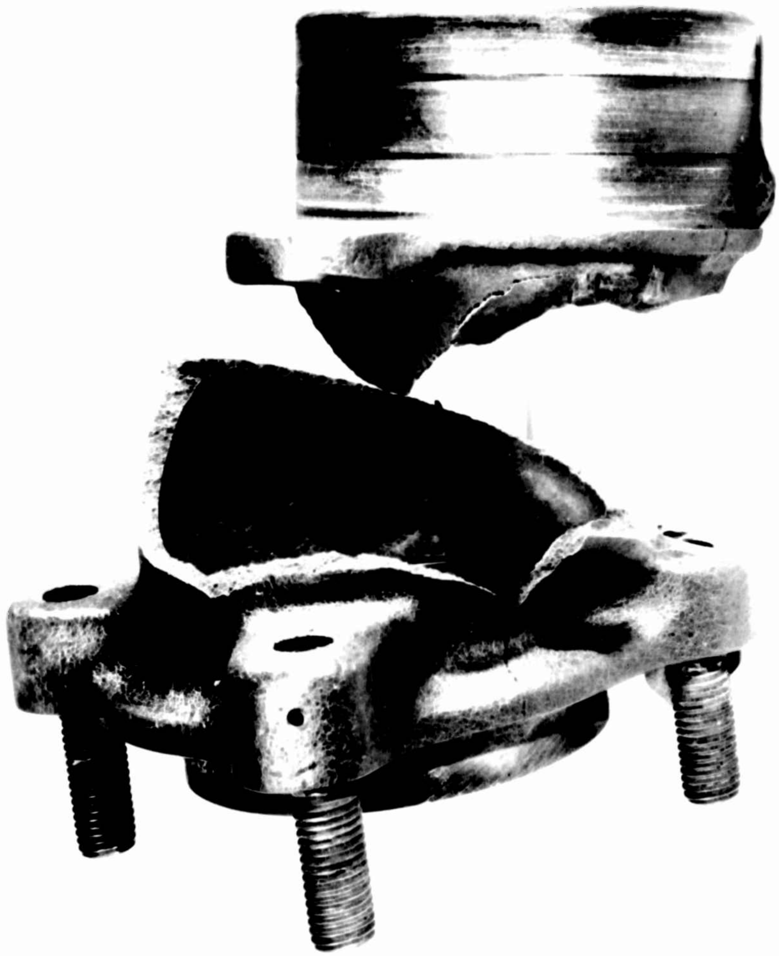
Negative Number 234372

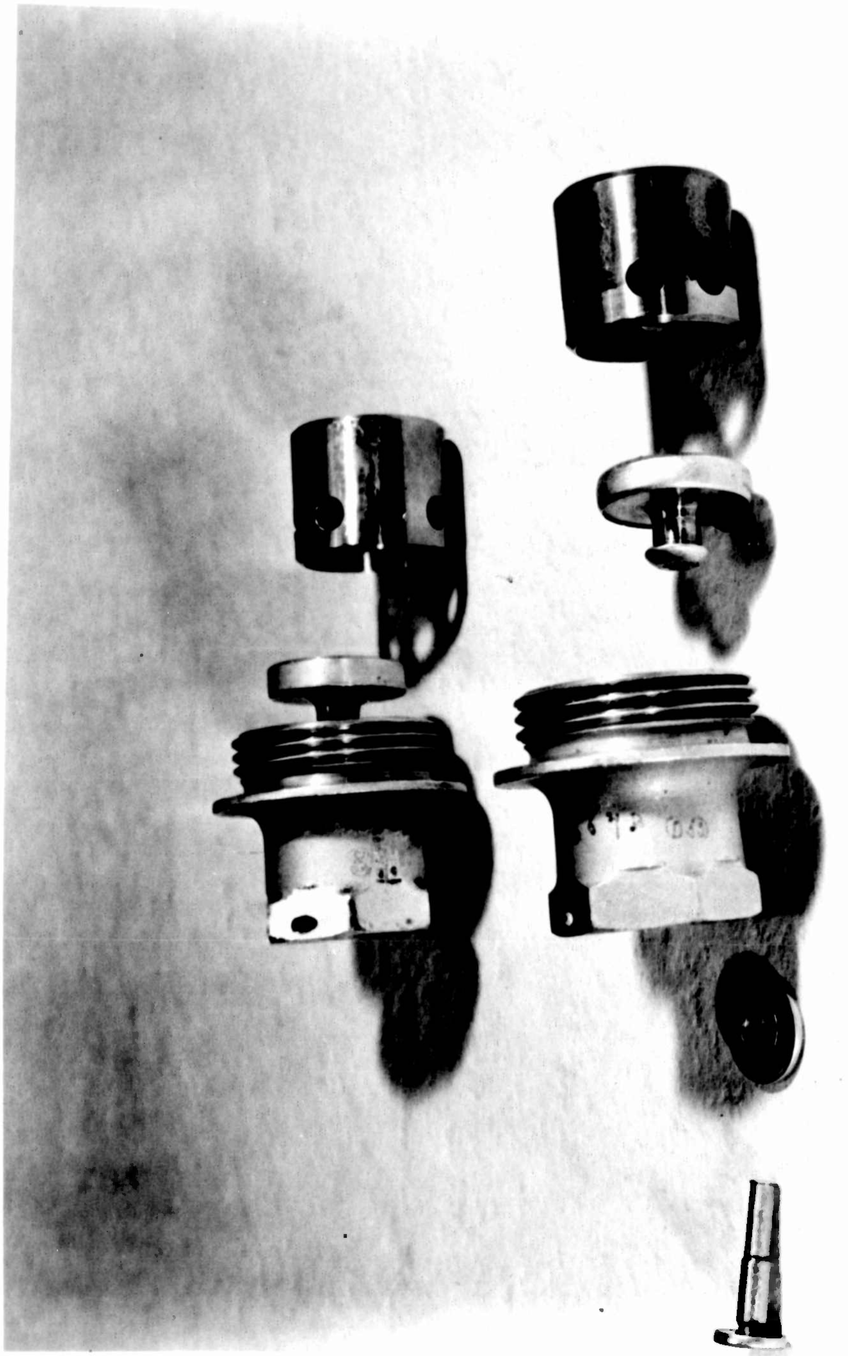


"A"-3 EXHAUST PORT INSERT
AFTER 2-1/2 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

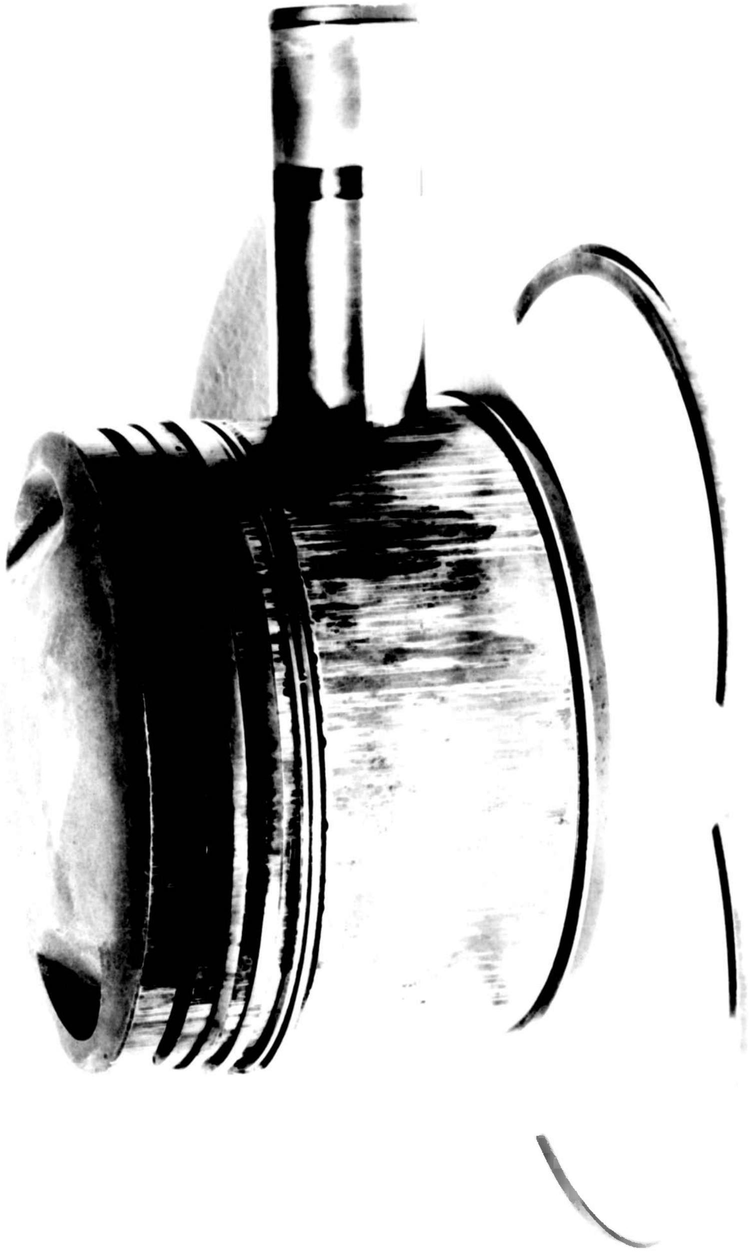
PLATE 14

"C"-2 INTAKE PUSH ROD
AFTER 49-1/2 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 15



INTAKE PIPE FUEL DRAIN VALVES
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE



"B"-3 PISTON
AFTER 93-3/4 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 17

Naval Air Experimental Station,
Navy Yard, Philadelphia

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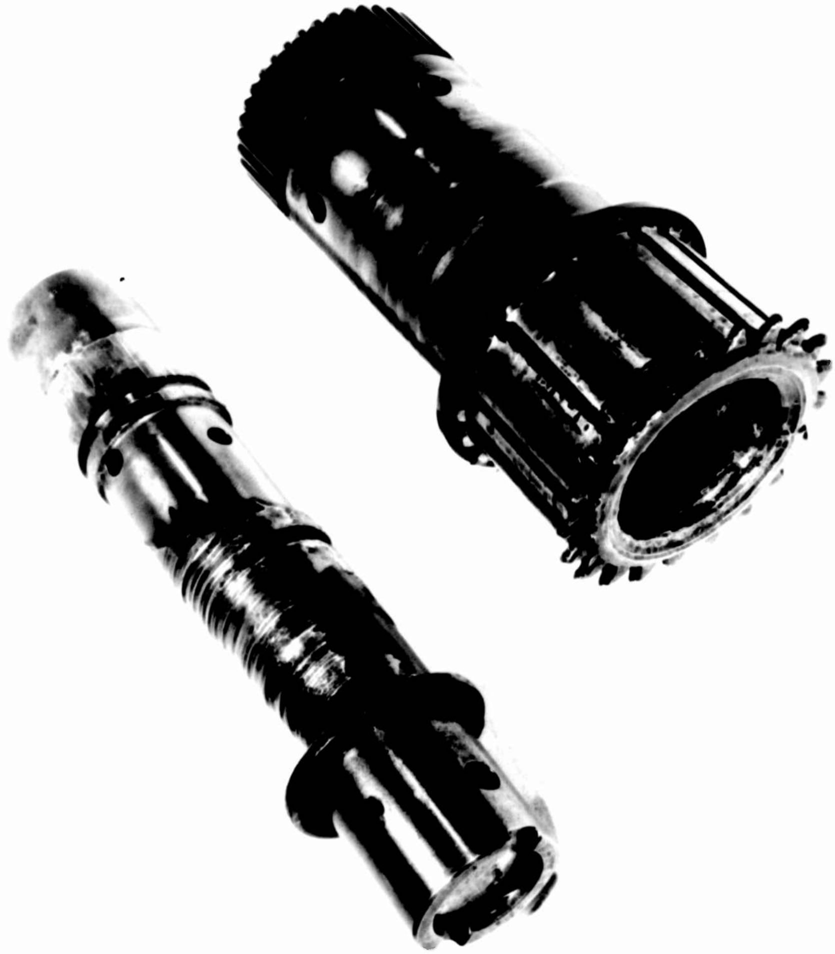
Negative Number **234667**



PRIMARY STEP-UP PINION, RIGHT SHAFT
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

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Naval Air Experimental Station
Navy Yard, Philadelphia

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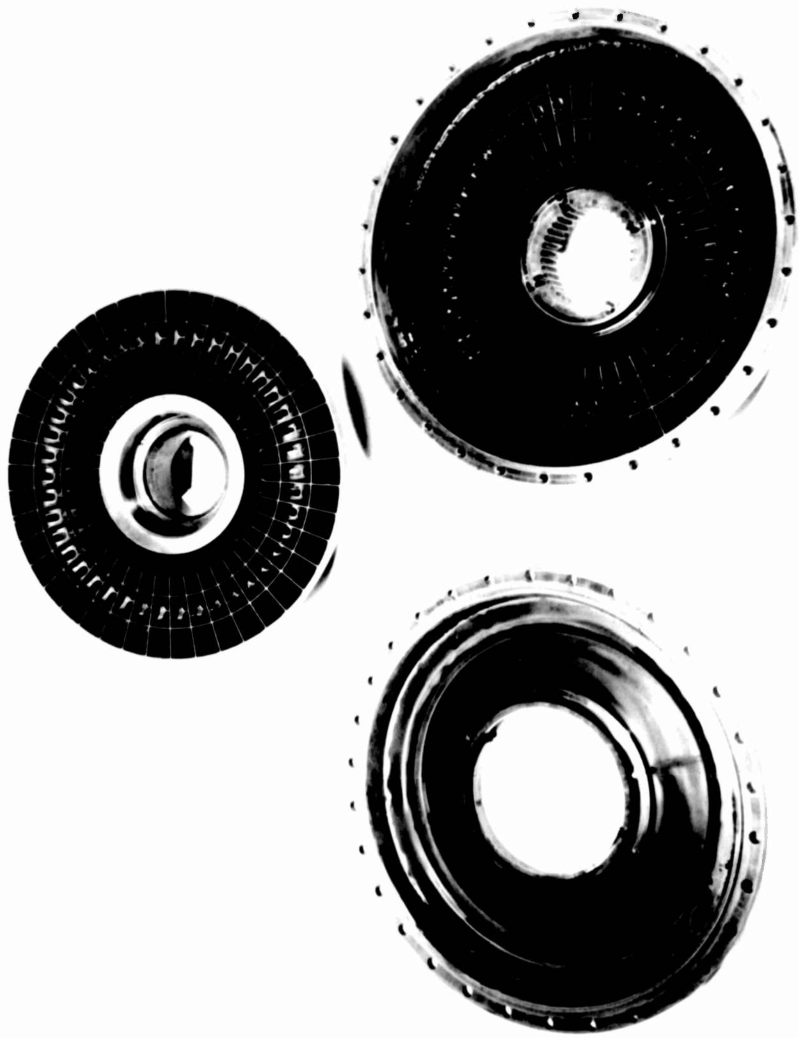

RIGHT COUPLING - VARIABLE SPEED DRIVE
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 19

AEL-803

OFFICIAL PHOTOGRAPH
NOT FOR PUBLICATION

Negative Number 234664

RIGHT COUPLING - VARIABLE SPEED DRIVE
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 20

AEL-503

Naval Air Experimental Station
Navy Yard, Philadelphia

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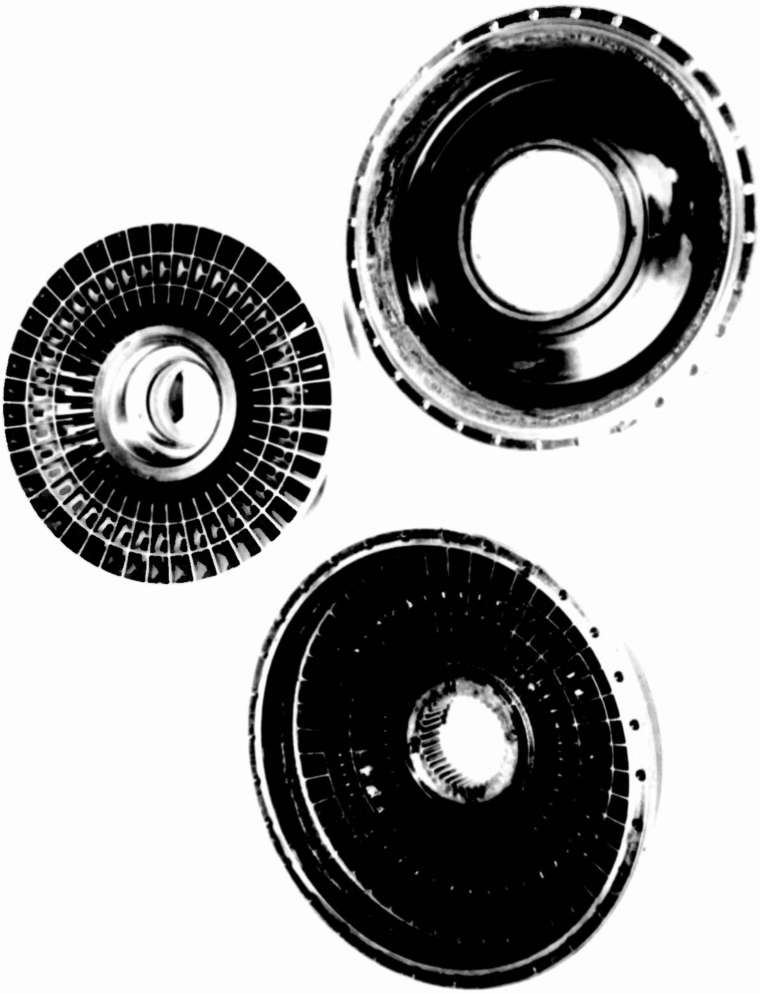
Negative Number 234669

PRIMARY STEP-UP PINION, LEFT SHAFT
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 21

LEFT COUPLING - VARIABLE SPEED DRIVE
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE



LEFT COUPLING - VARIABLE SPEED DRIVE
AFTER 77 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

Naval Air Experimental Station,
Navy Yard, Philadelphia

OFFICIAL PHOTOGRAPH
NOT FOR PUBLICATION

Negative Number **235366**

"B"-2 INTAKE PIPE
AFTER 98-3/4 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 24

Naval Air Experimental Station,
Navy Yard, Philadelphia

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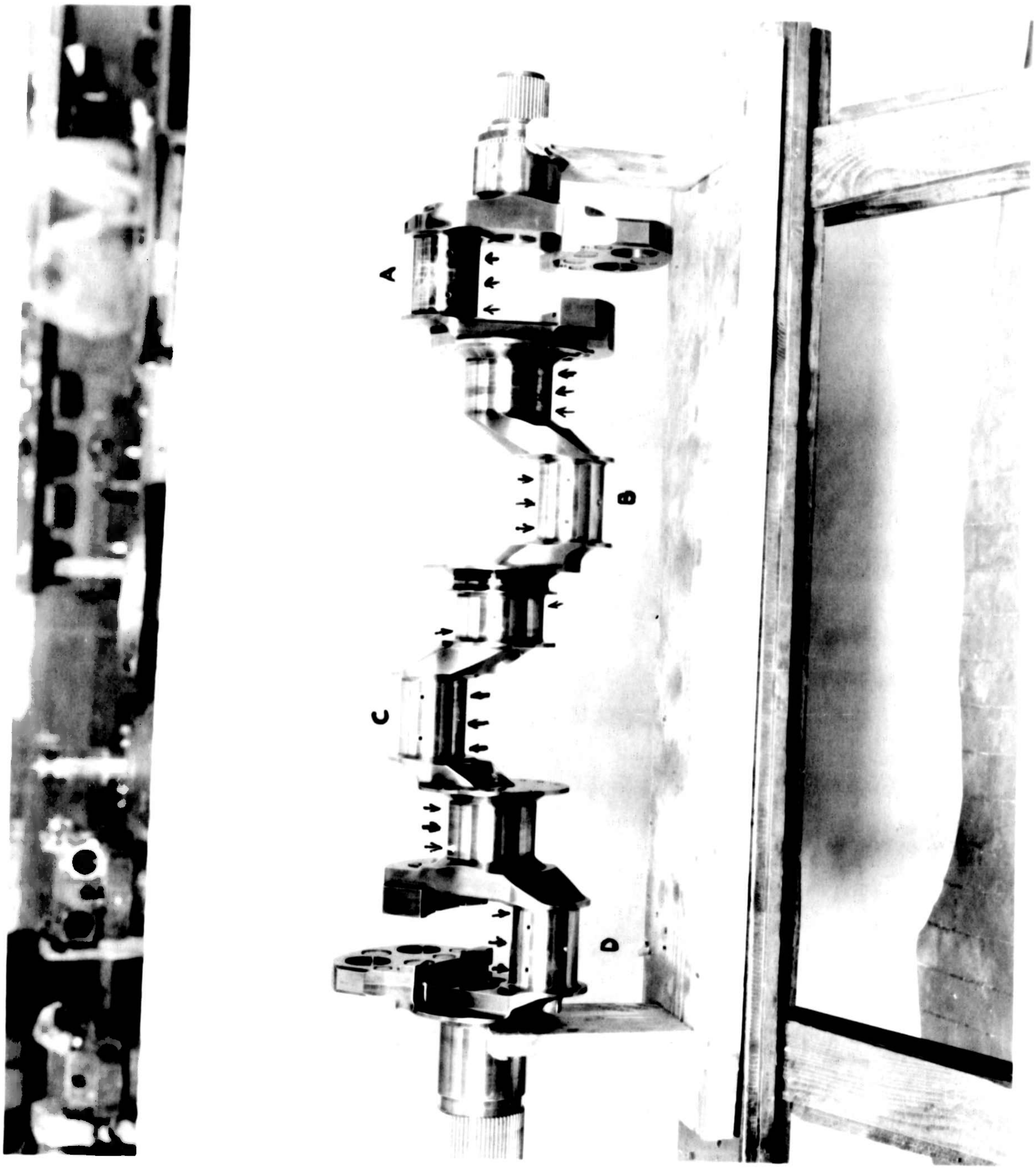
Negative Number 235367

"B"-1 INTAKE PIPE
AFTER 116 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 25



CRANKSHAFT
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

Naval Air Experimental Station,
Navy Yard, Philadelphia

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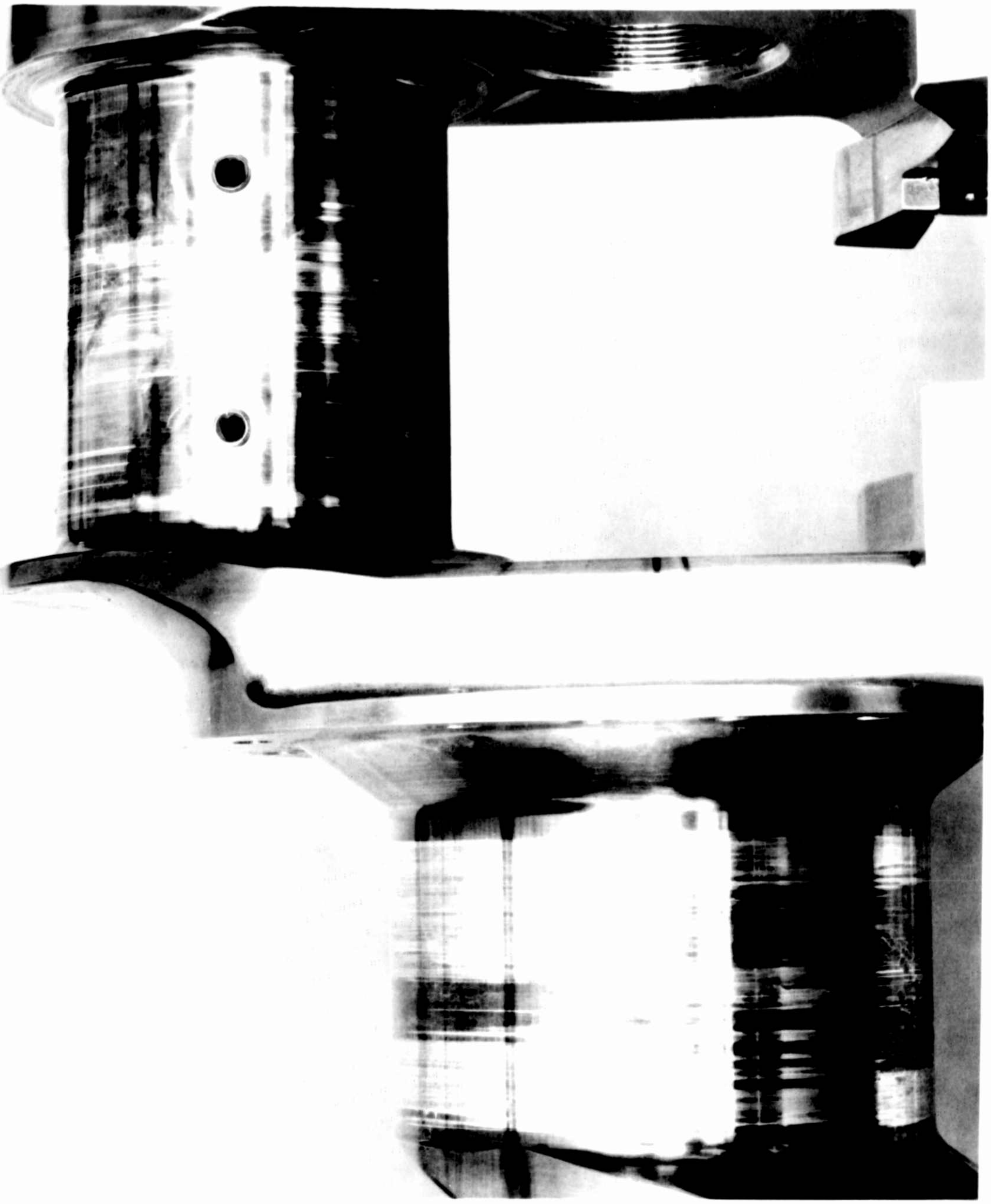
Negative Number 235606



REAR INTERMEDIATE MAIN BEARING & "A" ROW CRANKPIN
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 27

AE[illegible]-03

Naval Air Experimental Station,
Navy Yard, Philadelphia

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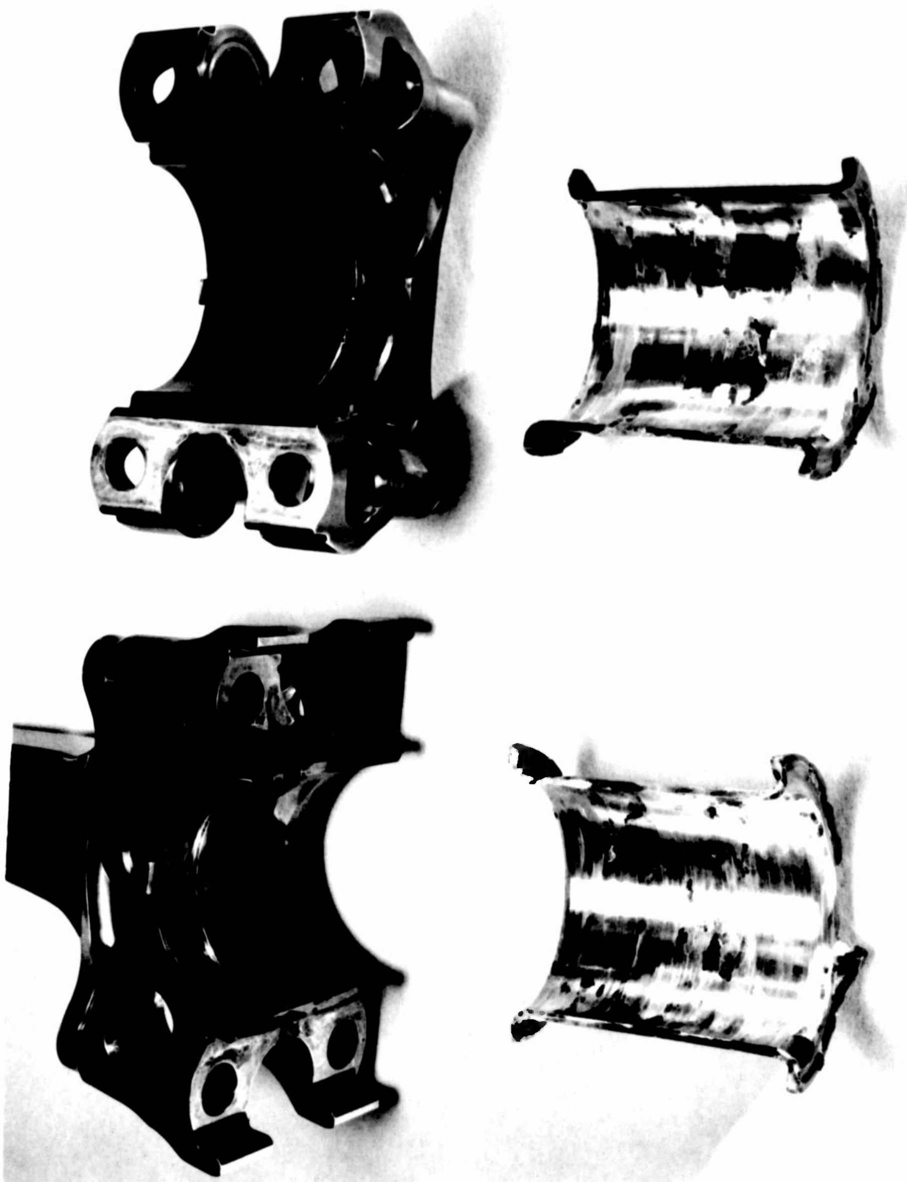
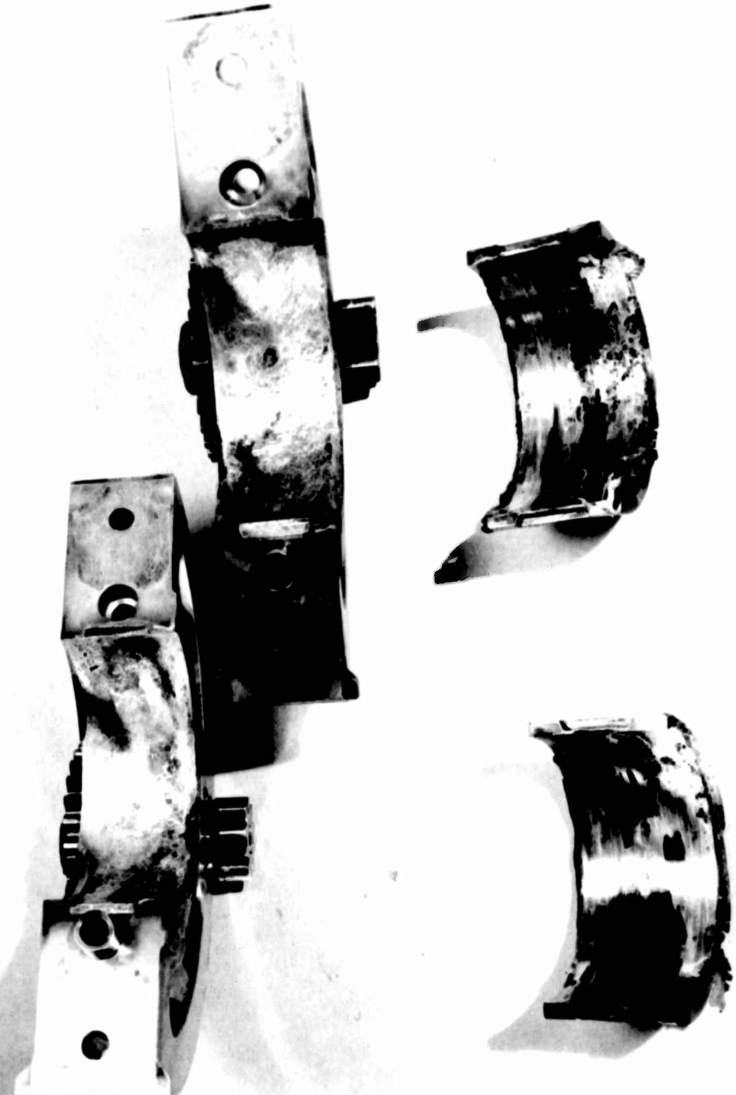
Negative Number 235588



"A" ROW MASTER ROD & BEARING
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 28

AEL-?03



REAR INTERMEDIATE MAIN BEARING
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 29

AEL-803

Naval Air Experimental Station, Navy Yard, Philadelphia

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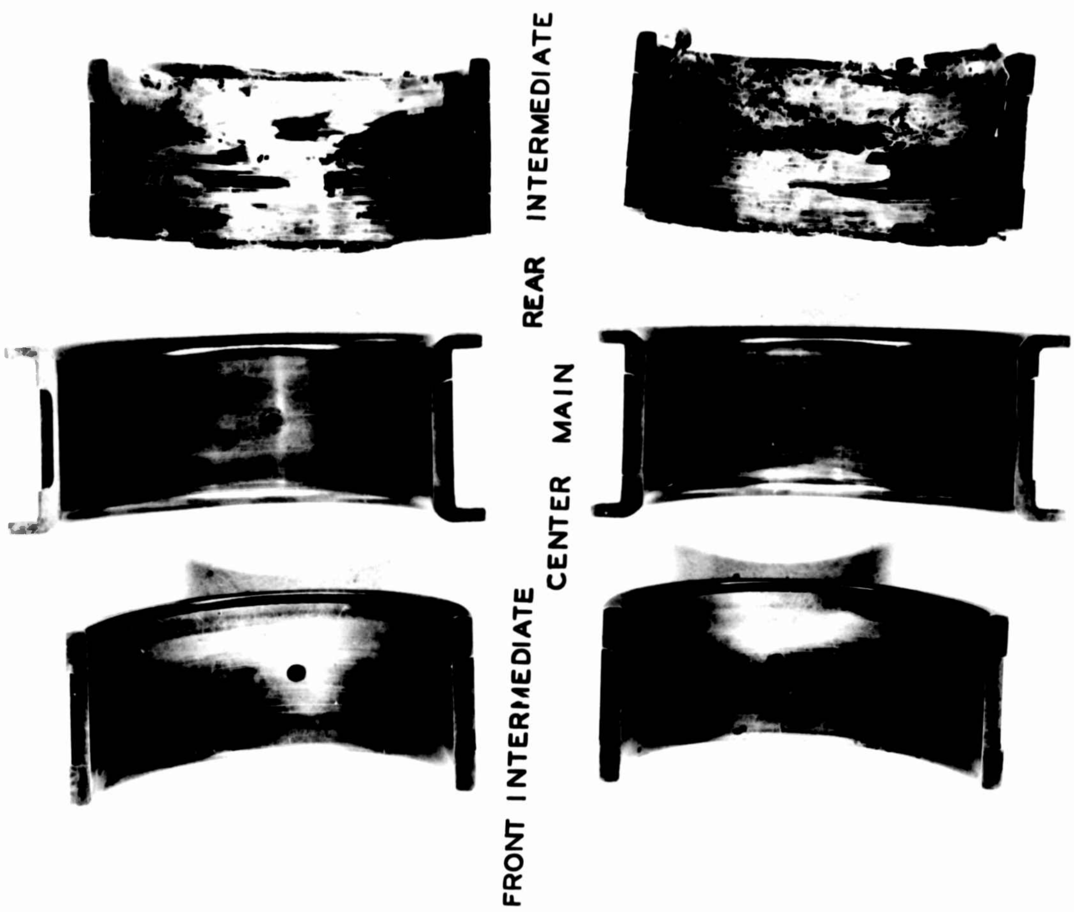
Negative Number 235647

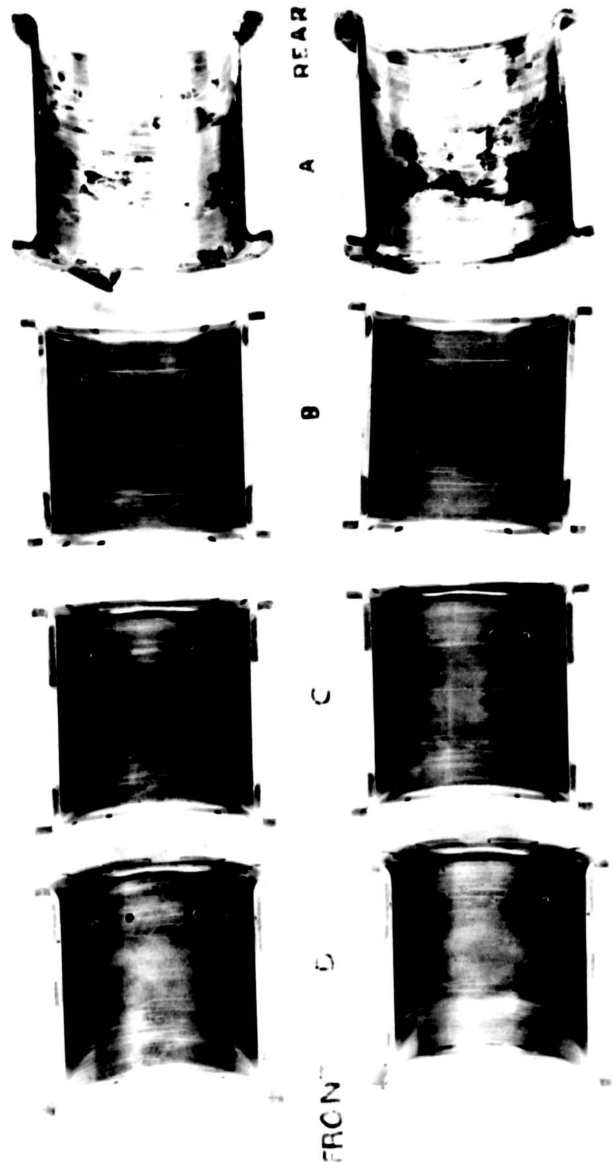
FRONT INTERMEDIATE MAIN BEARING
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 30



CRANKSHAFT BEARINGS
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 31

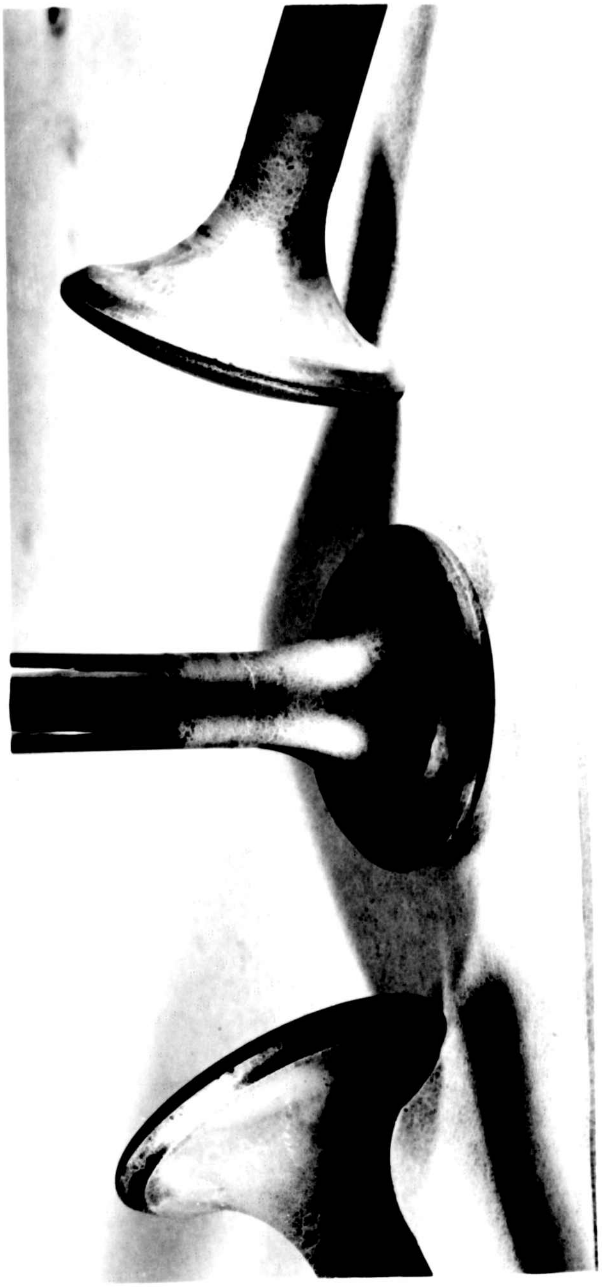


MASTER ROD BEARINGS
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY R-4360-4 ENGINE

NOT FOR PUBLICATION

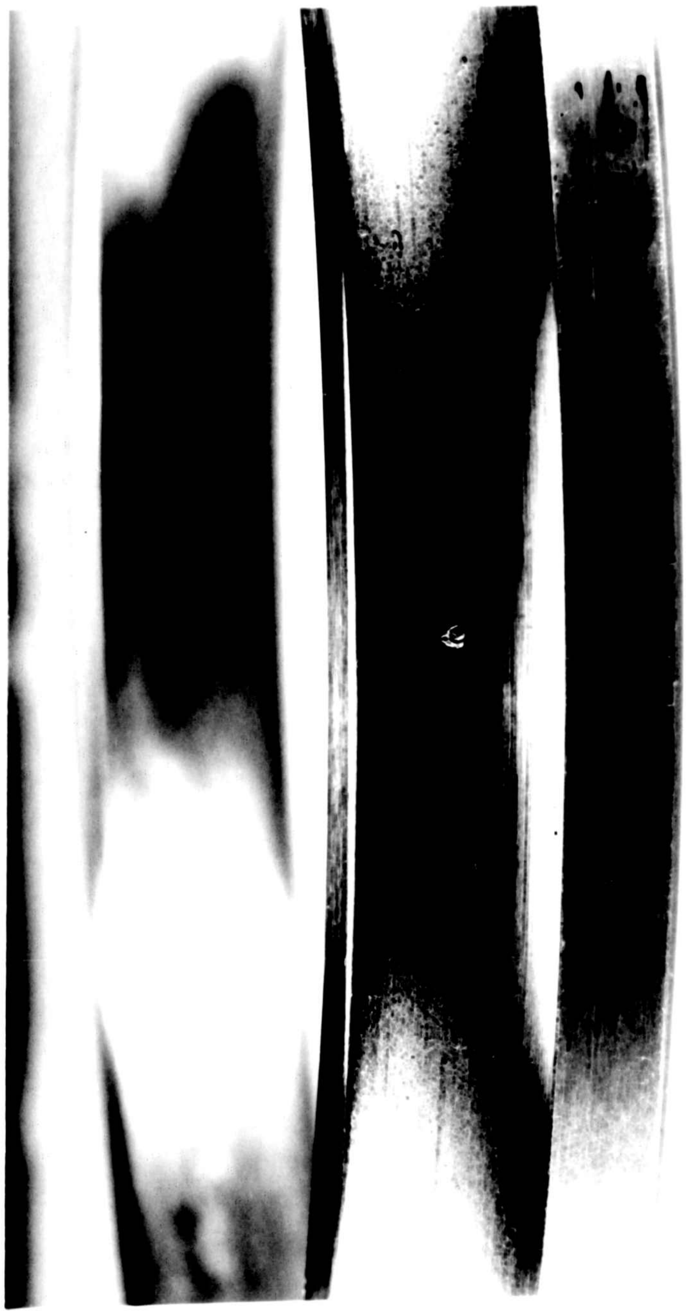
INTAKE VALVES
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 33

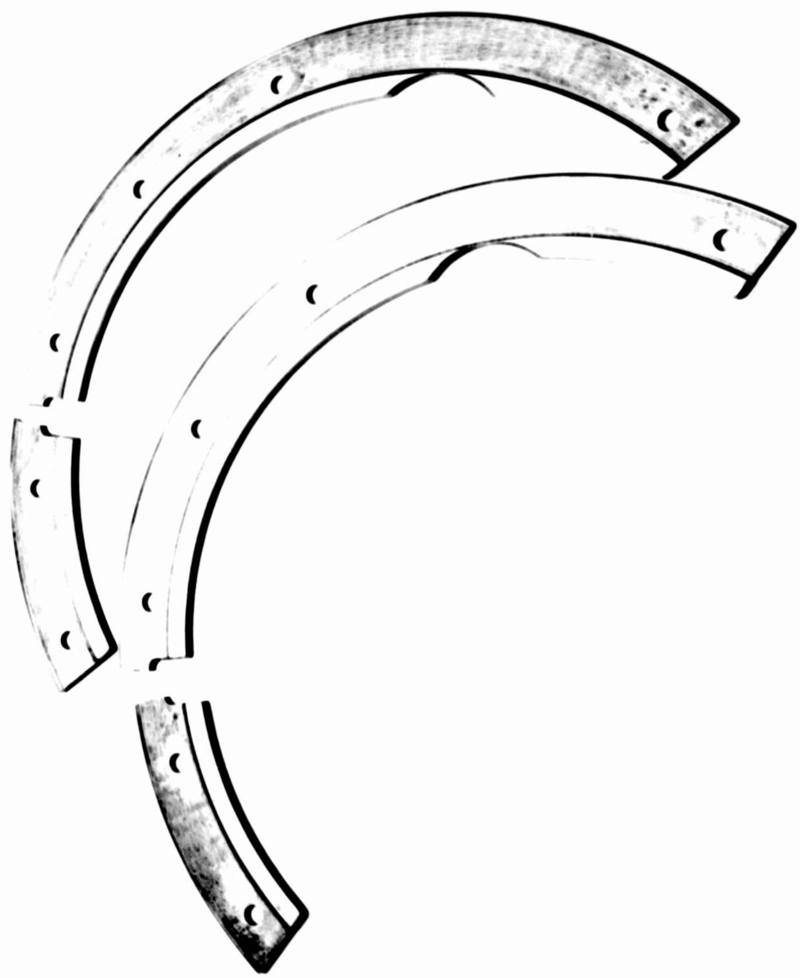


EXHAUST VALVES
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 34



PROPELLER THRUST BEARING REAR INNER RACE
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY AR-4360-4 ENGINE



"A" - "B" ROW & "C" - "D" ROW CAM RETAINERS
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

LAT.

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Navy Yard, Philadelphia

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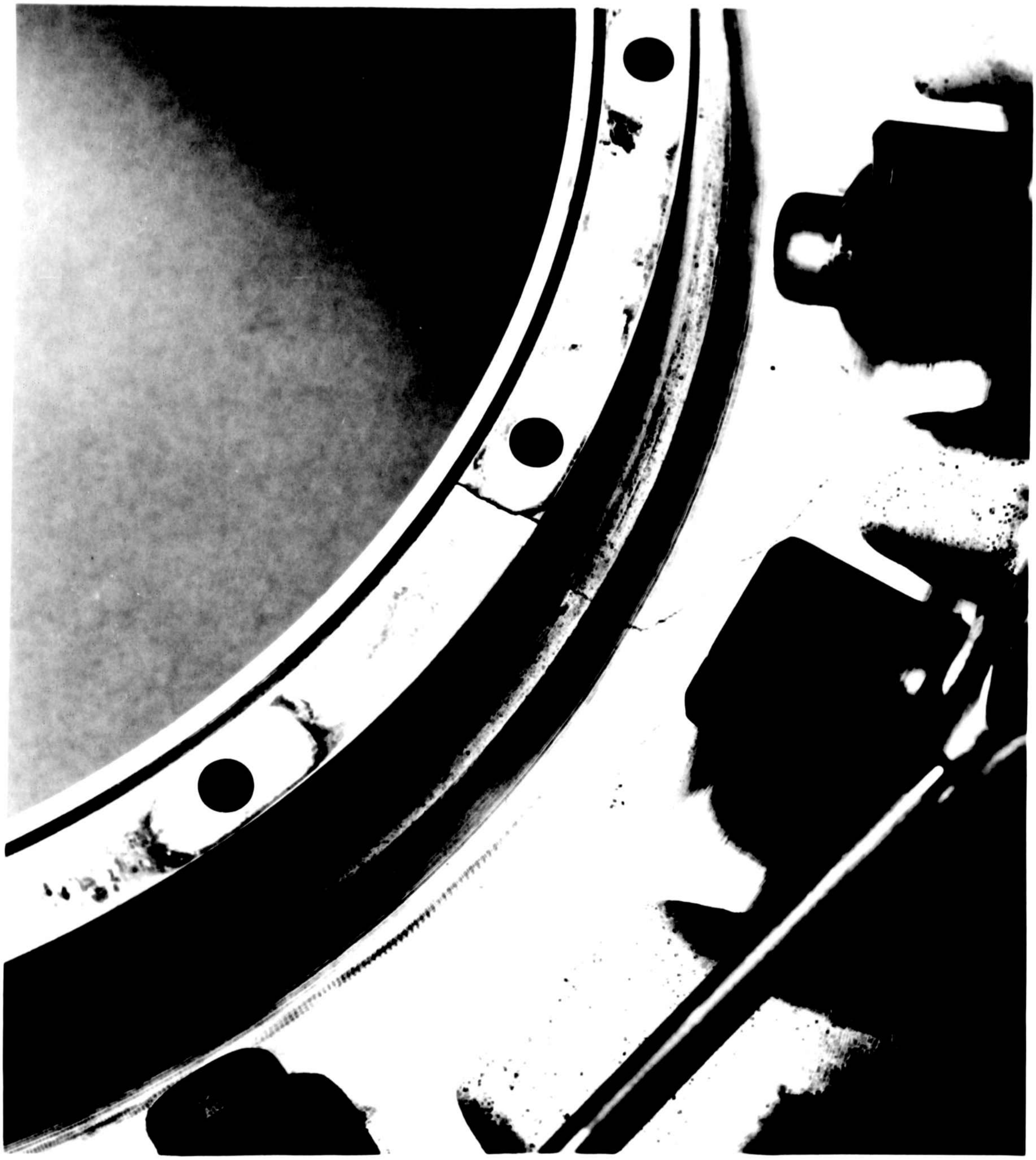
Negative Number 235586

REAR INTERMEDIATE C.S. BEARING
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 37



REAR INTERMEDIATE CRANKCASE
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 3[illegible]

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Naval Air Experimental Station,
Navy Yard, Philadelphia

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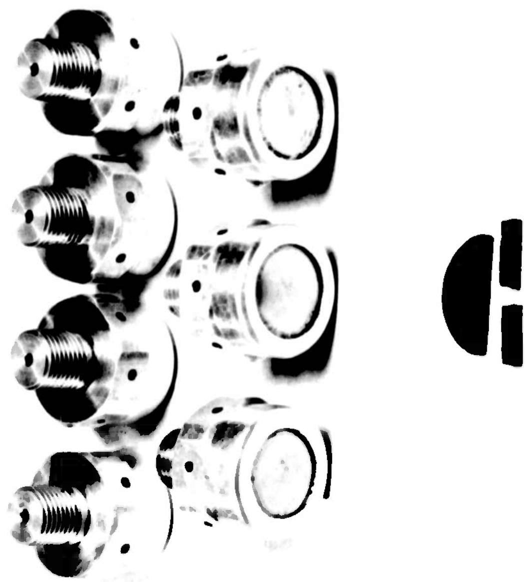
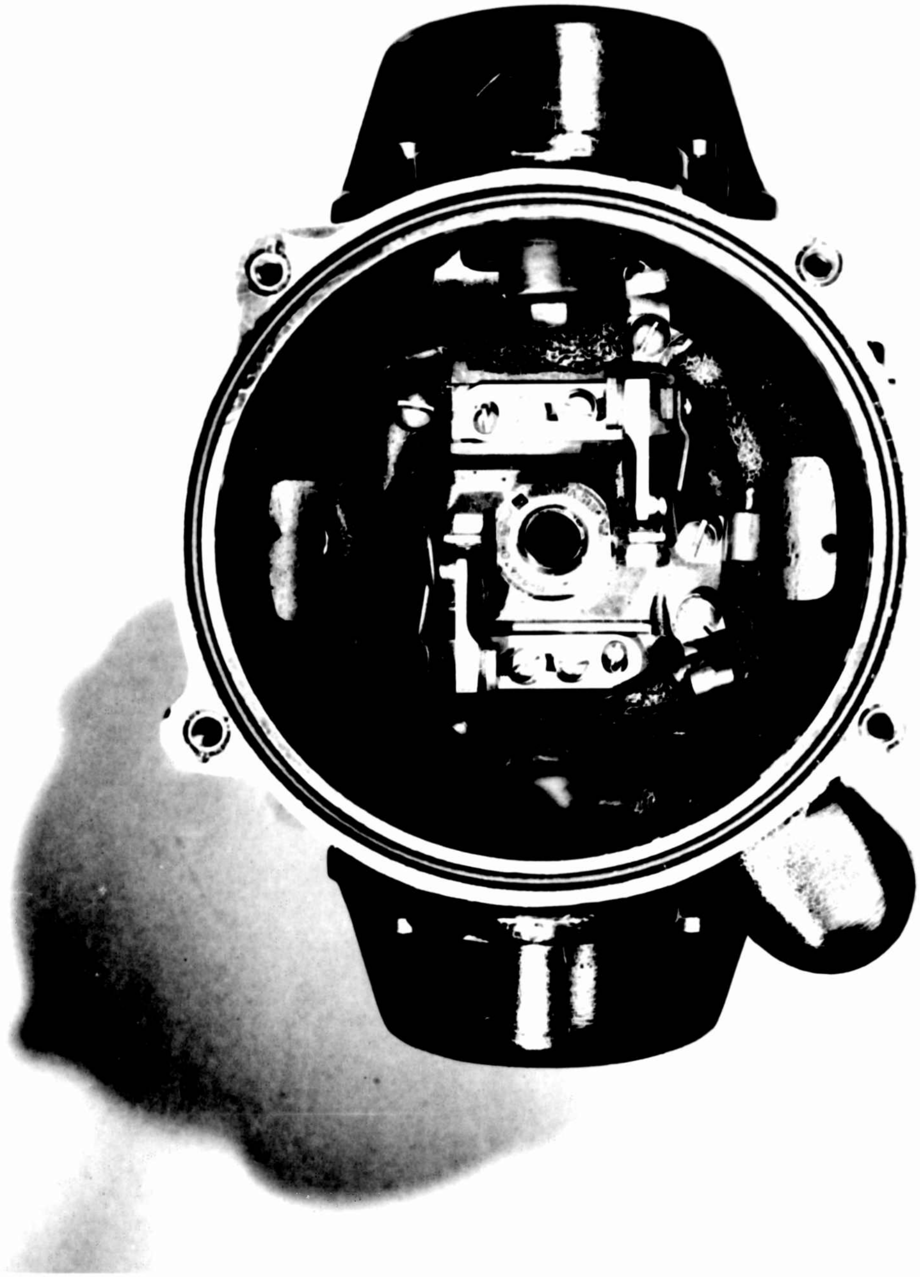
Negative Number 235576

"B"-2 PISTON
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 39

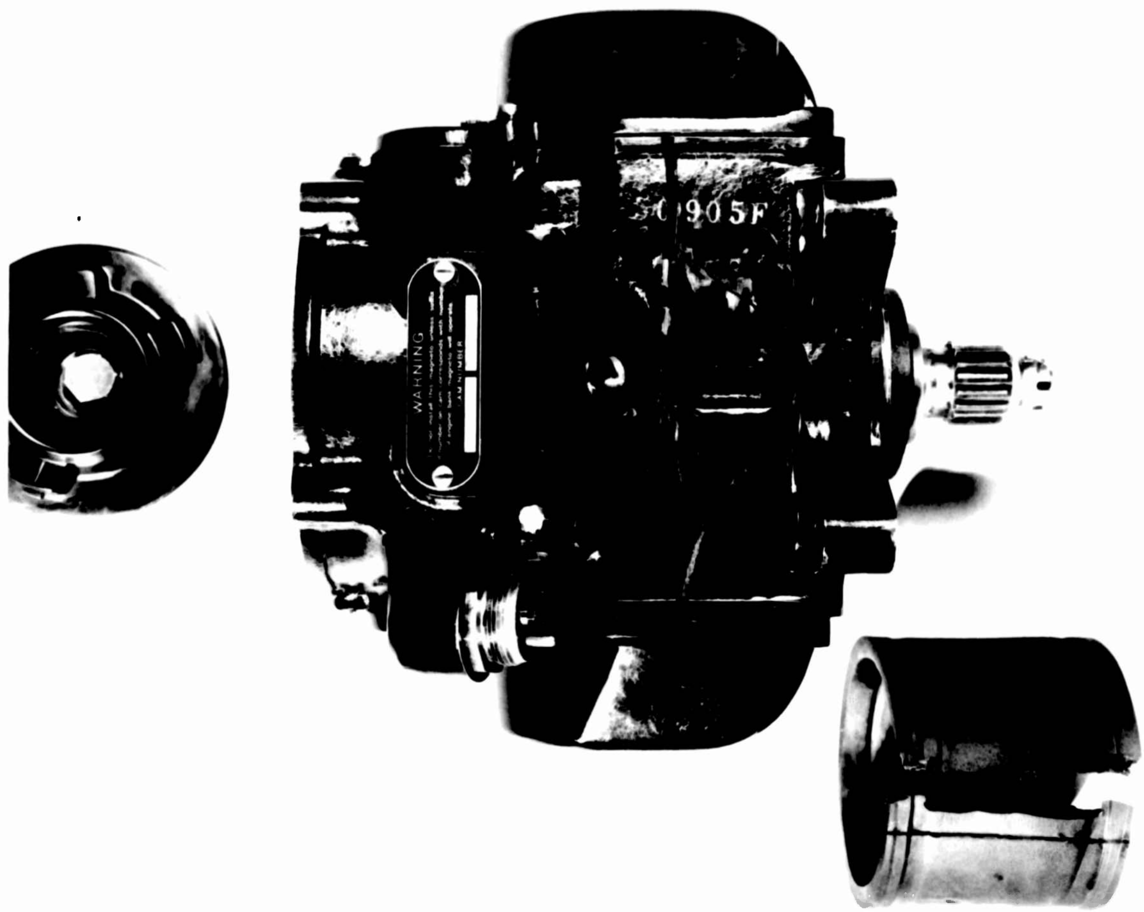


ALTITUDE VENT VALVES AND MAGNETO
SUPERCHARGER PUMP WOODRUFF FIBRE KEY
AFTER 24 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

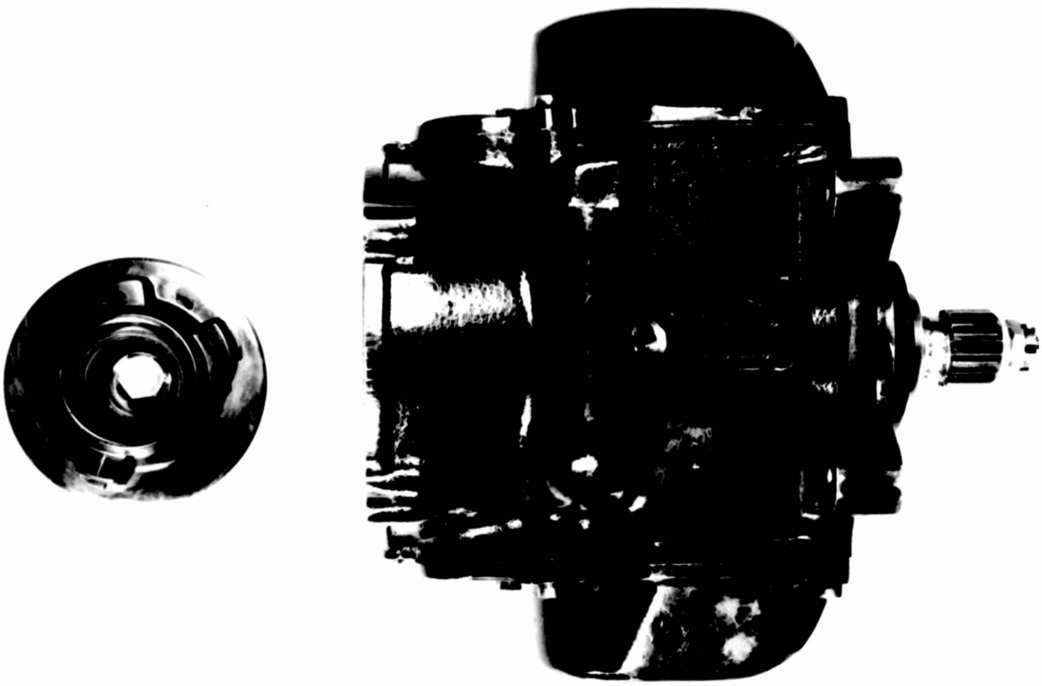


TOP VIEW - NO. 1 MAGNETO
AFTER 145 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 41



NO. 1 BANK MAGNETO & INTAKE MANIFOLD COUPLING
AFTER 145 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE



NO. 2 BANK MAGNETO
AFTER 150 HOURS ENDURANCE
PRATT & WHITNEY XR-4360-4 ENGINE

PLATE 43

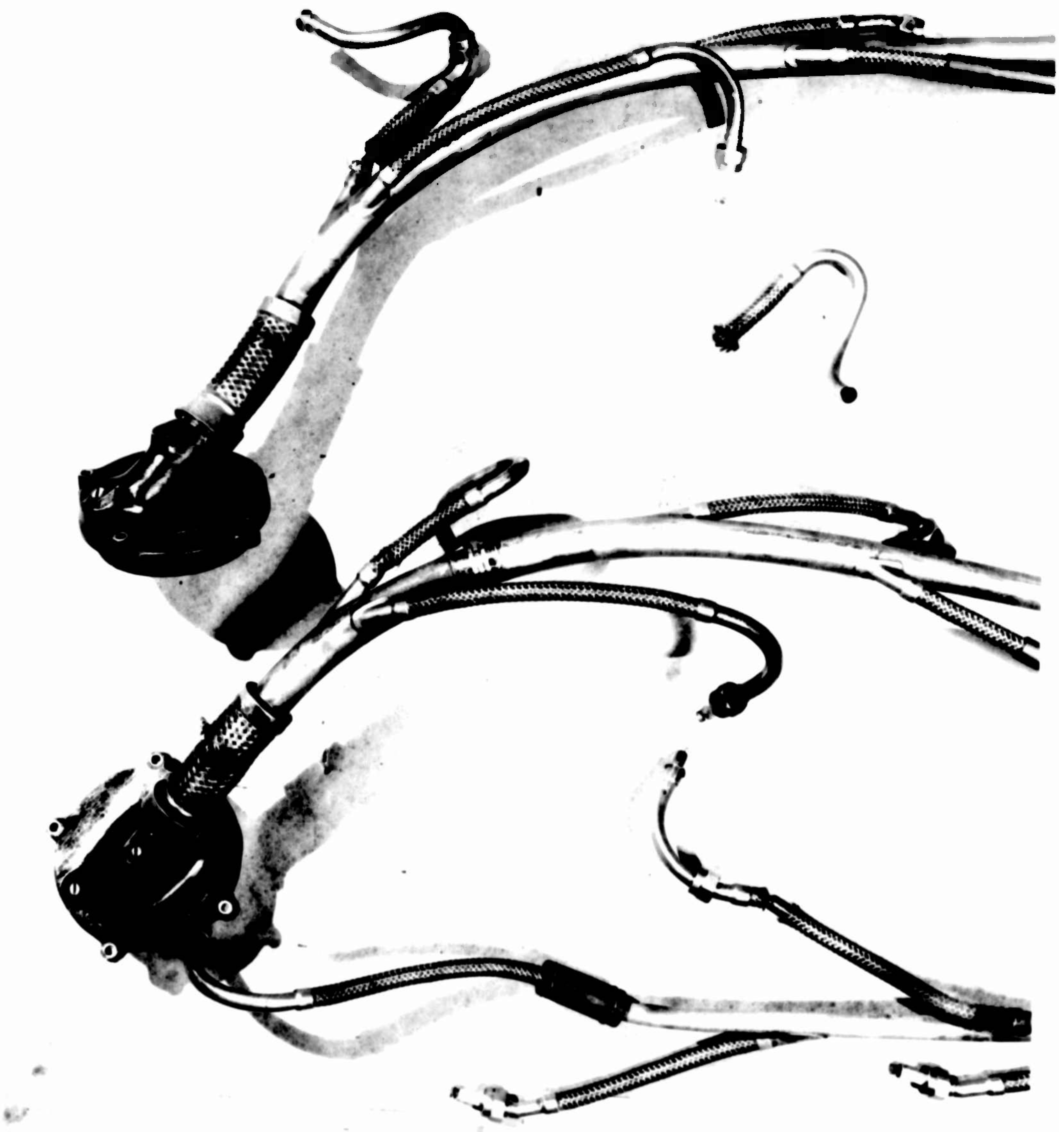


PLATE 44

RFEL - C
1659
A.T.I.
38274

A 21/7 245 1560 RESTRICTED

TITLE: Model Test of Pratt & Whitney Aircraft XR-4360-4 Engine

AIRCRAFT ENGINES

AUTHOR(S): Semola, A. J.

ORIGINATING AGENCY: Naval Air Material Center, Aeronautical Engine Lab., Phila, Pa.

PUBLISHED BY: Bureau of Aeronautics, Washington, D. C. MODEL TESTS

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ABSTRACT:

In accordance with spec. AN-9502B and AN-9504, a P & W XR-4360-4 reciprocating aircraft engine was tested to determine its endurance, dive, and crankshaft torsional vibration characteristics. The P & W XR-4360-4 engine is an air-cooled, four-row, radial, 28-cylinder power plant with variable-speed supercharger. The engine was scheduled for a 150-hr type test endurance run, but due to the various failures which occurred, the endurance tests were terminated at the half-way mark. On account of the test results, it was decided that, in its present stage of development, the XR-4360-4 engine is not suitable for service use. It is recommended that the engine be redesigned and development work be expedited to correct and improve the endurance qualities of all defective parts.

EO 10501 dd 5 NOV 1953

OVER

DISTRIBUTION: Copies of this report obtainable from Air Documents Division; Attn: MCIDXD

DIVISION: Power Plants, Reciprocating (6) 27

SECTION: Performance (13)

SUBJECT HEADINGS: Engines - AN specifications (32860.5); Engines, Reciprocating - Performance evaluation (34078.15); Engines, Reciprocating - Vibration analysis (34079.8); -4360 (76750)

AD-A800 377

Air Documents Division, Intelligence Department, Air Materiel Command

AIR TECHNICAL INDEX

Wright-Patterson Air Force Base, Dayton, Ohio

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NTIS, auth: USNAPTC ltr, 29 Dec 73

POWER PLANTS, RECIPROCATING