CONTINENTAL AIRCRAFT ENGINE COMPANY
Detroit, Michigan

No. of pages: 21 May 25, 1934

Report

of

50-Hour Endurance Test

of

Continental Hyper Engine No. 2A

Contract W535 AC 6322

Reported by
C. F. Bachle
C. F. Bachle
Test Engineer

Approved by
N. N. Tilley
Chief Engineer

Continental Aircraft Engine Report #105

TABLE OF CONTENTS

INDEX OF ILLUSTRATIONS

OBJECT

To determine the endurance of the Hyper No. 2A cylinder when tested at 211 I.M.E.P., 215°F. carburetor air temperature and 3000 R.P.M.

SUMMARY

1. Fifty hour endurance run:

a) Average engine speed .... 2998 R.P.M.

b) Average I.M.E.P. .... 215.7 lbs./sq. in.

c) Average indicated fuel consumption .483 lbs./sa. in.

d) Average carburetor inlet air ..... 215 deg. F.

e) Average absolute carburetor press. 47.2 in. Hg.

f) Average prestone flow .... 15 gal./min.

The contract requirements were 3000 R.P.M.; 211 lbs. per sq. in. I.M.E.P.; 215 deg. F. carburetor air; .55 lbs. fuel per B.H.P. hr. which was later changed to .480 lbs. fuel per indicated H.P. hr.; and 15 gal. per min. prestone flow.

2. Inspection after the test revealed no defect with the exception of the compression rings which were worn. The power at the end of the run was slightly better than at the start indicating that the worn rings did not interfer with the operation of the engine.

3. Spark plugs continue to give trouble from lead fouling. Four sets were necessary to complete the endurance run.

CONCLUSIONS

The endurance of the Continental Hyper No. 2A cylinder is satisfactory when tested for 50 hours at 211 lbs./sq. in. I.M.E.P. and 3000 R.P.M.

RECOMMENDATIONS

That the first endurance run called for under the terms of contract W535 AC-6322 item 5, article 15 be considered completed.

INTRODUCTION

The Continental Hyper engine No. 2A was first run on 3-7-34, and the 50-hour endurance run was completed on 5-18-34. The test was run on dynamometer No. 5 with certain improvements in set-up described in "Method of Test".

DESCRIPTION

The engine was substantially the same as described in the report entitled "Continental Hyper Engine No. 2, August 3, 1933". However, the following changes were made:

1. Head casting heavier at exhaust port where a crack stopped the previous test.

2. The rocker hold-down stud-bosses were extended to the valve-seat bosses. This was done to prevent distortion of the cylinder head and appears to have satisfactorily overcome this trouble.

3. The cylinder material was changed from Aluminum Company of America alloy No. 254 to Y-alloy.

4. The cam contour was changed to give constant acceleration and loads at the opening and closing of the valves.

5. Needle bearing at the rocker roller pins. This was done to prevent a tendency to scuff the rollers and cam surface and has proved successful.

6. Piston with inner skirt shortened and changed ring set-up and clearances as shown in Fig. 1. Three compression rings instead of four were used in order to allow greater top land height and thus afford more heat protection for the top ring. To further protect the top ring a heat dam consisting of a narrow slot above the top ring was used.

7. No stellite on exhaust valve seat insert. This was done to

allow the valve to hammer in to a seat in case of distortion. Since the head casting changes appear to have improved the distortion trouble it is probably no longer necessary to continue this feature. The unstellited seat was satisfactory.

8. New exhaust valve with stellite welded head (drawing No. 4225). The former valve had a single piece head (drawing No. 3333). The valve is satisfactory.

METHOD OF TEST

Substantially the same test set-up was used in this test as described in previous reports dated February 6, 1933, and August 3, 1933. However, the following changes and improvements were made:

1. Change from dynamometer No. 2 to dynamometer No. 5 which was especially arranged to suit the Hyper requirements. No. 5 is a 150 H.P. General Electric T.L.C. 50 whereas No. 2 was a 75 H.P. machine. Considerable trouble was experienced with dynamometer No. 5 when the present testing was started and this accounts for some of the delay in the test program.

2. The carburetor air heating was done entirely by steam instead of by a combination of steam and electricity as formerly. The electric heaters had proved hard to maintain and also were much bulkier than the improved steam heater. Steam at 80 lbs. per sq. in. pressure surrounds the copper coils of an Elcelso No. 25 heater thru which the air passed. This heater has proved trouble free.

3. A packed NAR7 carburetor, loaned by the Air Corps, was used in place of the carburetor in the surge tank. This was done to prevent boiling of the fuel in the carburetor and was made necessary by the increase in carburetor air temperature from 170 deg. F. to 215 Deg. F.

4. A prestone out temperature regulator was added. This is a Powers No. 10 air operated regulator.

5. The prestone flow was measured with a sharp-edged orifice which had been calibrated under the test conditions. The flow was held at 15 gallons per minute by throttling the pump intake.

6. The volumetric fuel measuring system was changed to a balance weighing scale.

Fig. 10 shows a diagram of the test set-up.

The oil used in this test was Stanavo 120 which has a viscosity of 120 Saybolt seconds at 210 deg. F.

The fuel used was Stanavo aviation ethyl gasoline No. 87 for the first 31 hours and 25 min., and for the remainder of the test gasoline from the Standard Oil of Indiana complying with U. S. Army Air Corps Specification No. Y3557 and containing not less than 4 c.c. of tetra-ethyl lead per gallon. A sample was sent to Wright Field on 5-26-34.

The average prestone in temperature was 239 deg. F. and the average out 252 deg. F.

The average oil out temperature was 160 deg. F.

The dynamometer and the thermometers were calibrated before and after the endurance run.

The spark advance was 14 1/2 deg. for most of the test.

The boost measured at the carburetor inlet was between 17 and 18 inches of mercury.

The surge tank at the carburetor entrance had a volume equal to approximately 25 times the piston displacement.

RECORD OF TEST

The endurance log is shown in Fig. 9.

The following stops were required by the engine during the 50-hour endurance run:

1. 5 hours, 25 min. Ground in exhaust valve. It is thought that the valve seat was not down solidly against the head as this trouble was not encountered again.

2. 5 hours, 55 min. Changed H. T. 300 spark plugs after 6 hours on these plugs. During the first 6 hours an attempt was made to hold the brake specific fuel at .55 lbs. per B.H.P. hr. This resulted in heavy detonation and finally preignition.

3. 31 hours, 25 min. Changed H.T. 300 spark plugs after 25 1/2 hours on these plugs. Lead deposit or deterioration of the insulation caused missing.

4. 44 hours, 20 min. Changed H.T. 300 spark plugs after 13 hours on these plugs. The plugs of stop 3 were used with Stanavo aviation ethyl gasoline No. 87 which ordinarily has 2 c.c. of tetraethyl lead per gallon while the plugs of this stop were run with contract gasoline (Y3557-G) which had "not less than 4 c.c. of tetraethyl lead per gallon". The higher lead content of the later fuel undoubtedly caused the reduction in plug life.

The oil consumed during the last 44 hours and 5 min. was 21.75 gallons or .494 gal. per hour. It is thought that this relatively high oil consumption contributed to the tendency to detonate.

A temperature plug in the fuel charger hole showed about 450 deg. F. during the test.

Blowby as indicated by the crankcase pressure was constant throughout the run.

A gasometer could not be used because of the lack of seal at the crankshaft flywheel end. The crankcase pressure has been found to be a reliable indication of blowby.

RESULTS OF TEAR DOWN INSPECTION

Visual inspection after the test showed but one fault, the broken oil ring shown in Fig. 8. This failure is thought to have resulted from gas leakage by the compression rings putting pressures on the upper side of the oil ring and breaking it over the slots. The carbon formation on the head of the exhaust valve shows plainly where the stellite joins the steel. This is shown in Fig. 7. No unusual carbon deposits formed anywhere, nor were any parts scratched or unduly worn.

Rings:

The piston rings were made by the American Hammered Piston Co. with 45 deg. gaps set at .025 clearence. After the endurance run the gaps had increased to .075 on the top, .045 on the 2nd., and .060 on the third ring. The oil ring gap increased to .027. This corresponds to wear of .0125 on a side for the top, .005 on the 2nd. and .0075 on the third ring. No rings were stuck in the groove.

Piston:

Figure 1 shows the piston and ring clearances, and Fig. 6 shows the piston thrust side after the endurance run. The heat dam above the top compression ring was nearly filled with carbon, however, this need not impair its effectiveness as a heat dam.

Valves:

The intake valve was gasoline tight after the test and appeared normal in every way.

The exhaust valve allowed a slight seapage of gasoline after the test. However, the seat looked good and is shown in Fig. 7. The carbon was wire brushed off in one spot to show the surface.

The stellite on the adjusting screw end was cracked before the start of this run and does not appear to have changed during the test.

The exhaust valve seat was about 1/16" wide and did not change during the test as shown by the substantially unchanged valve clearance. The valve clearances before the test were set at .036 and afterwards were found to be .037 on the intake and .038 on the exhaust.

Cylinders:

The cylinder bore changed less than .001 in any direction and the average wear was about .0002.

The valve seats in the head were smooth and appear to be bearing evenly around the circumference. The valve guides were normal.

In removing the spark plugs during the endurance run while the cylinder was hot the inserts were forced into the combustion chamber so that about one-half of a thread was exposed.

Dimensional Checks:

No part or bearing was worn excessively as shown by the dimensional records, Figs. 2, 3, 4, and 5. The greatest wear shown is for the rocker arm bushing which was .0015 on the vertical diameter.

Other parts:

The connecting rod was found cracked at the upper end bolt boss. This probably originated from localized stresses in a thin section at the bolt head seat. The rocker housing bosses at the short cylinder studs were depressed and are to be refaced.

The coolant pump drive bevel gear had one tooth broken out.

DISCUSSION

Performance work was limited to that required to determine the optimum test conditions to meet the contract requirements. It was found that an I.M.E.P. of 211 lbs. per sq. in. at 3000 R.P.M. with 215 deg. F. carburetor air could be obtained at between 17 and 18 inches of mercury boost. The friction at 18 inches mercury boost was 47 lbs. per sq. in. leaving 164 B.M.E.P. to be shown by the engine. The mixture ratio was held at the minimum consistant with steady running and minimum detonation. This value was .483 lbs. per indicated horse power hour average for the 50 hours on .55 lbs. per brake horse power hour for an engine having 88 per cent mechanical efficiency. It will be noted that the average of the last 21 1/2 hours is .477 lbs. per indicated horse power hour.

No direct comparison in power between the cylinder of Hyper No. 2 and of No. 2A can be made. However, if a point at the 39 hour of the endurance run of the report of August 3, 1933 is taken the following values are read: carburetor pressure 43.6 in. Hg.; 165 deg. F. carburetor air temperature; and 211 lbs. per sq. in. I.M.E.P. If this is corrected to the conditions of this test as shown on the log at 41 1/2 hours the I.M.E.P. is identical.

$$\frac{47.4}{43.6} \times \sqrt{\frac{460 + 165}{460 + 218}} \times 211 = 220.2 \text{ I.M.E.P.}$$

In general, it is thought the performance is close to expectations and is comparable with the results of previous testing.

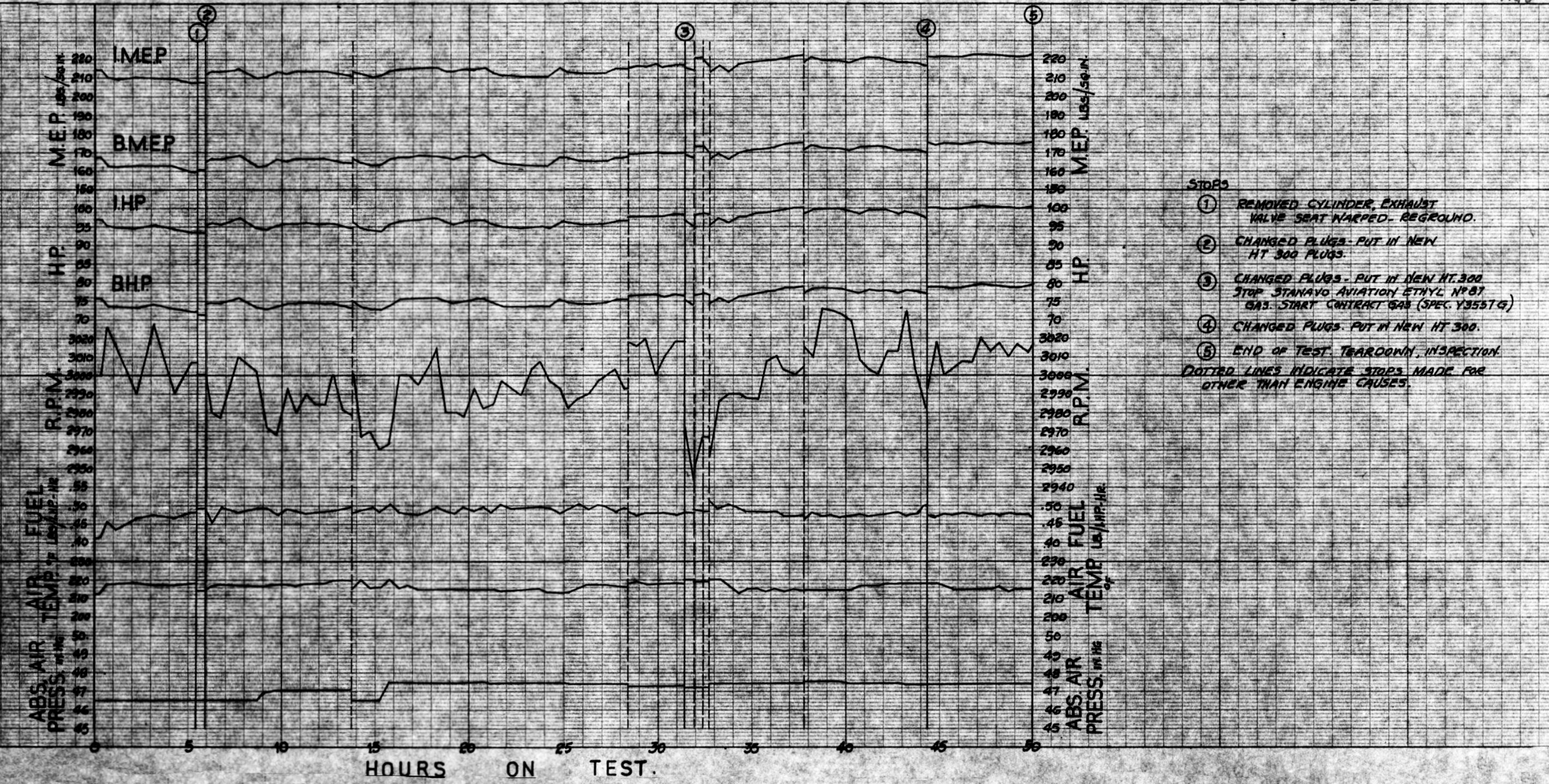
Considerable development was necessary before starting the endurance run. It was found that piston rings would wear badly or feather during the run in. On the theory that heat conditions were responsible, five pistons including the NAK cooled piston were tried and six types of rings including steel rings were used. Grinding the

Cylinder hot and honing instead of grinding were also tried. During the course of this development nine run-ins were required. The trouble was partially ascribed to the cylinder material which was S.A.E. 4130 steel heat treated to 350 brinell. A separate metallurgical report on cylinder barrel materials is being prepared. On disassembly of the cylinder from the head about three quarters of the threads were found stripped from the aluminum head. The piston ring trouble encountered is now thought to be largely the result of the poor thermal contact between the cylinder and head at these stripped threads.

A new head was assembled to a S.A.E. 1050 steel barrel and this cylinder was used in the 50-hour endurance run.

LOG OF ENDURANCE OF HYPER CYLINDER Nº 2A

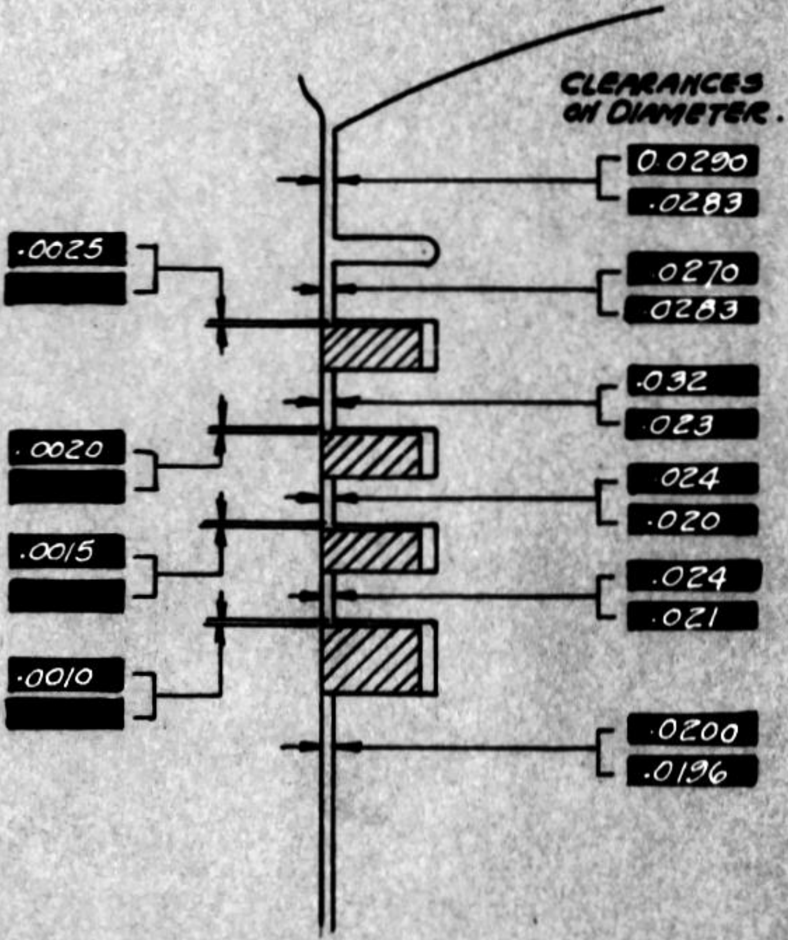
DATE 5-14-34 TO 5-18-34



HYPER CYLINDER No 2A

DATE: 5-18-34

FIG. 1



HYPER PISTON No 13

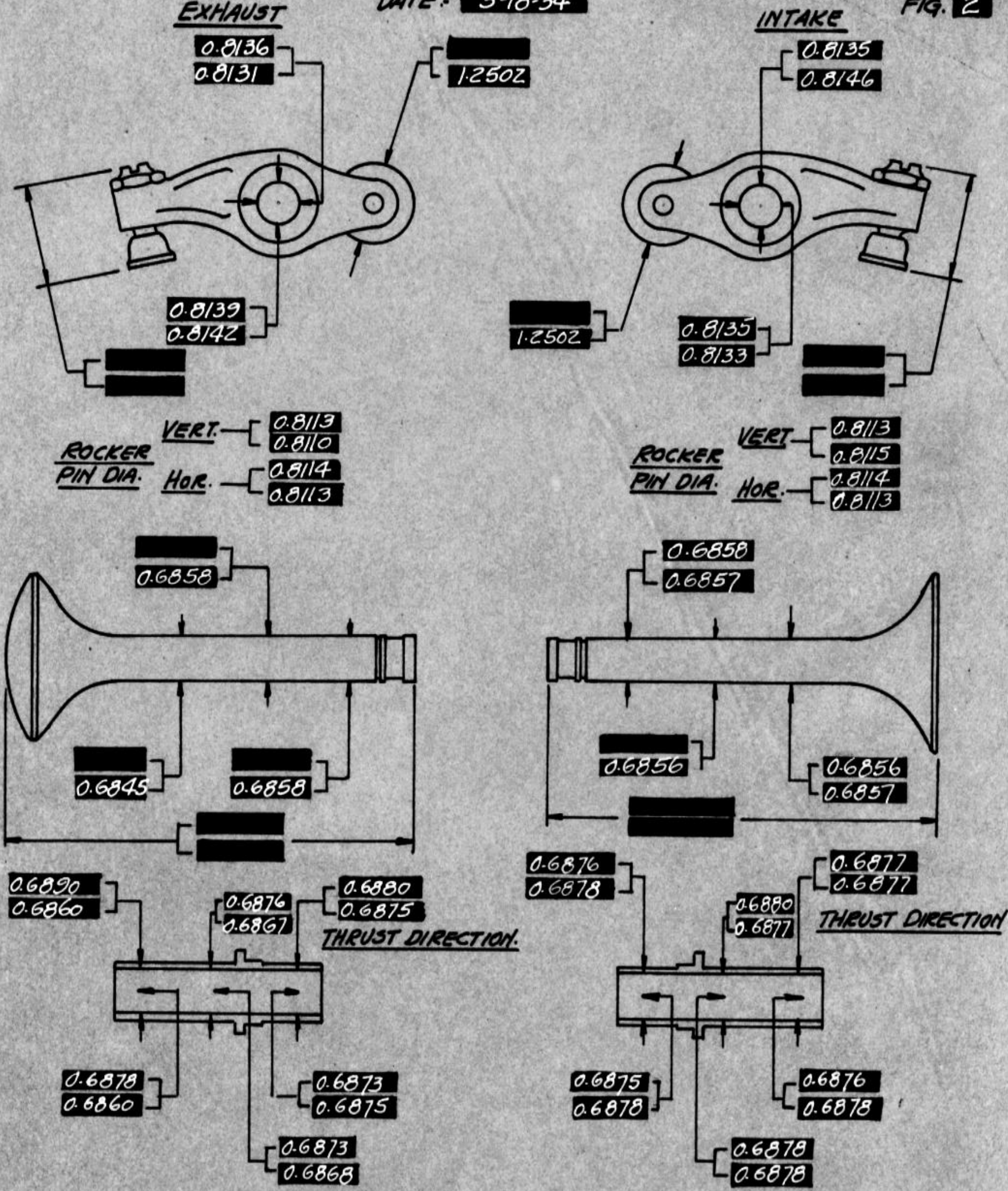
UPPER FIGURES IN BRACKETS SHOW DIMENSIONS TAKEN BEFORE TEST, LOWER FIGURES GIVE THOSE TAKEN AFTER THE TEST.

ENDURANCE TIME = 50 HOURS

HYPER CYLINDER No 2A

DATE:- 5-18-34

FIG. 2



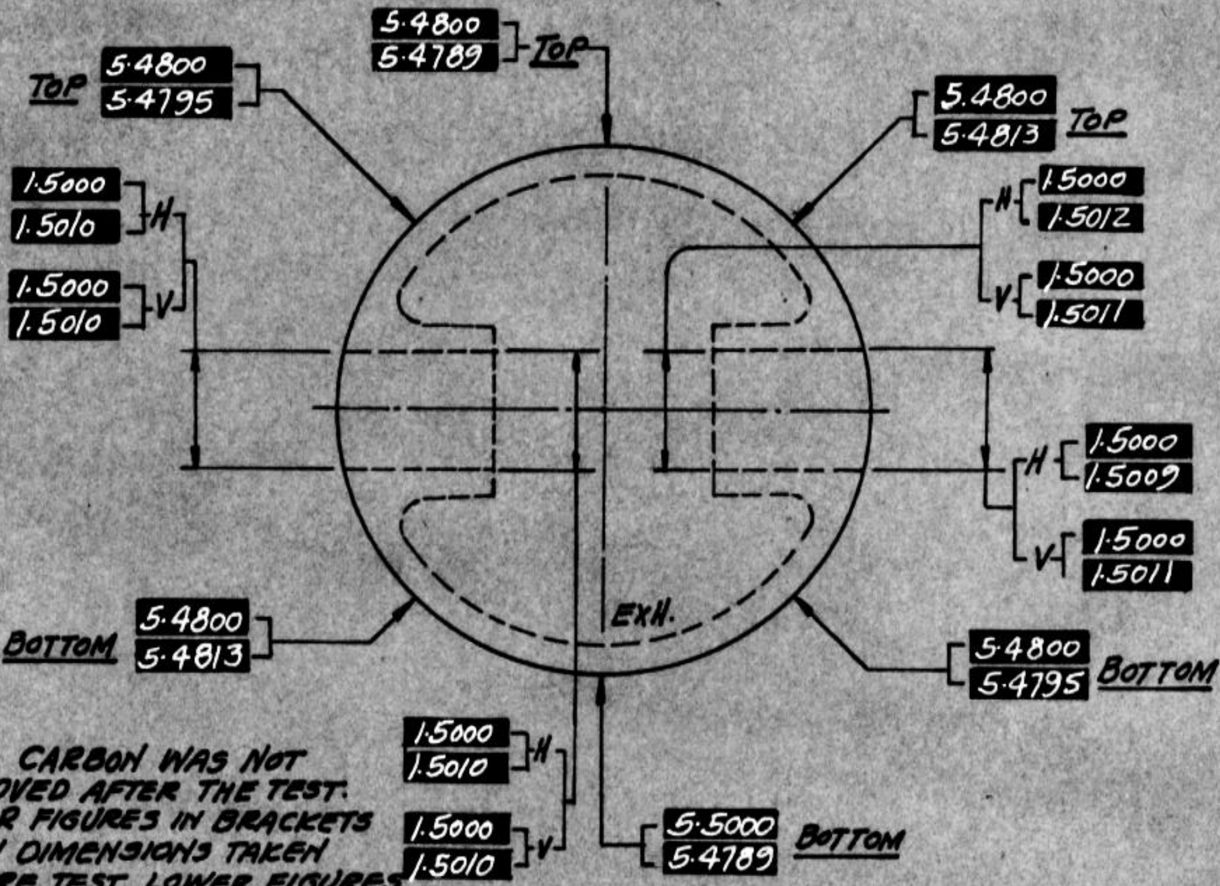
UPPER FIGURES IN BRACKETS SHOW DIMENSIONS TAKEN BEFORE TEST.
LOWER FIGURES SHOW THOSE TAKEN AFTER TEST.
ENDURANCE TIME = 50 HOURS

FIG. 3

HYPER CYLINDER Nº 2A

DATE: 5-18-34

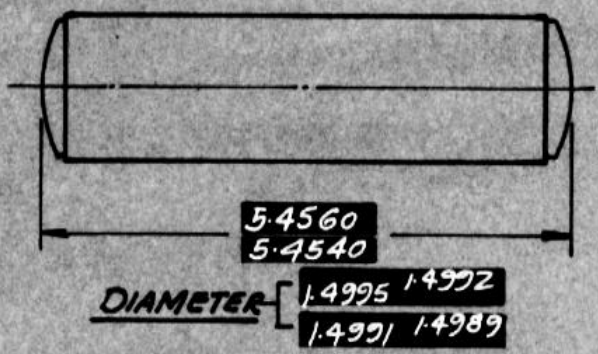
LAND DIA.		TOP	2	3	4
BEFORE		5·4710	5·4730	5·4680	5·4760
AFTER	MAX.	5·4732	5·4808	5·4821	5·4824
	MIN.	5·4711	5·4740	5·4771	5·4775



NOTE: CARBON WAS NOT REMOVED AFTER THE TEST. UPPER FIGURES IN BRACKETS SHOW DIMENSIONS TAKEN BEFORE TEST, LOWER FIGURES GIVE THOSE TAKEN AFTER TEST.
H = HORIZONTAL DIRECTION
V = VERTICAL "
ENDURANCE TIME = 50 HOURS

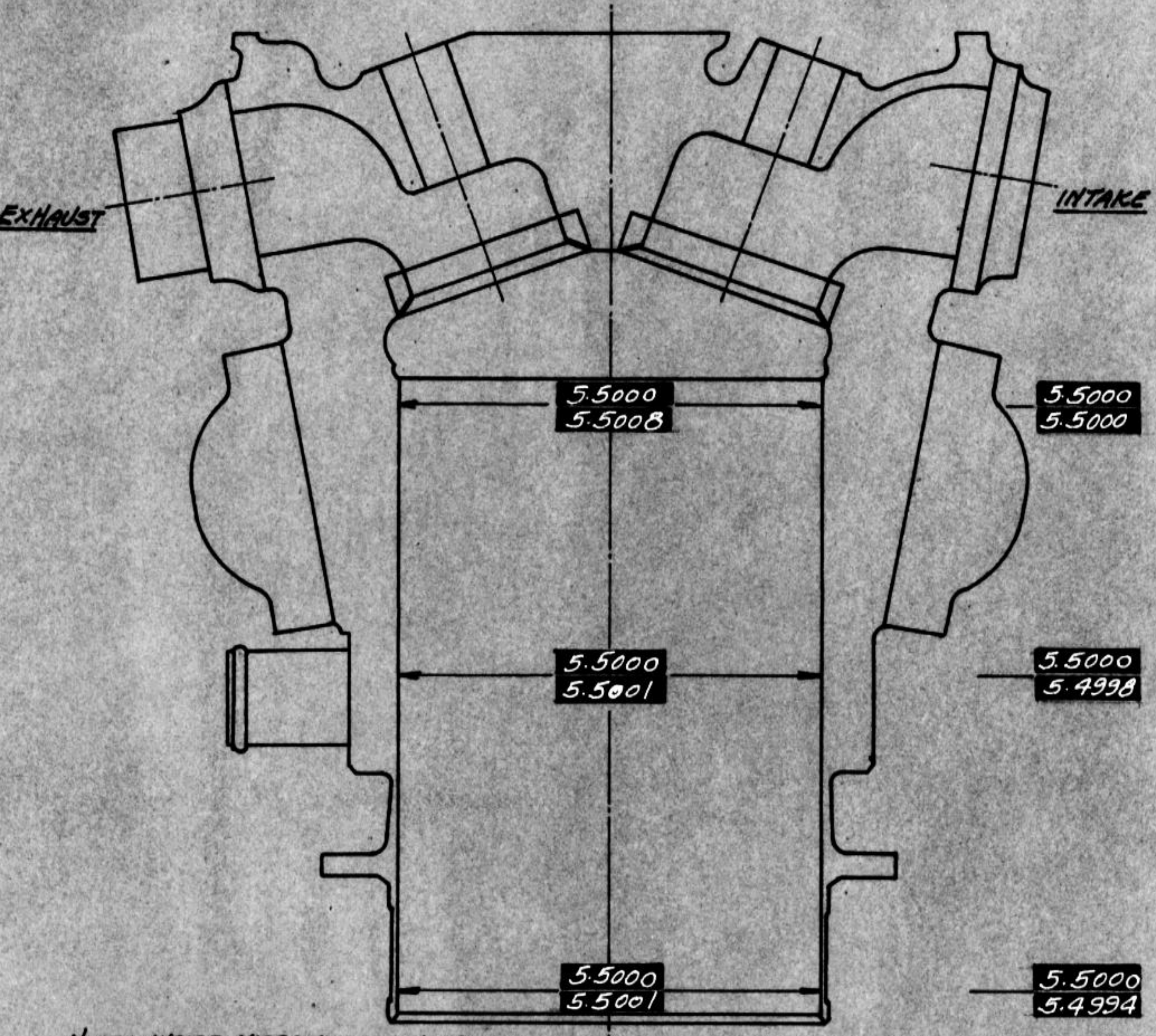
PISTON Nº 13

PISTON PIN



HYPER CYLINDER Nº 2A
DATE: 5-18-34

FIG. 4



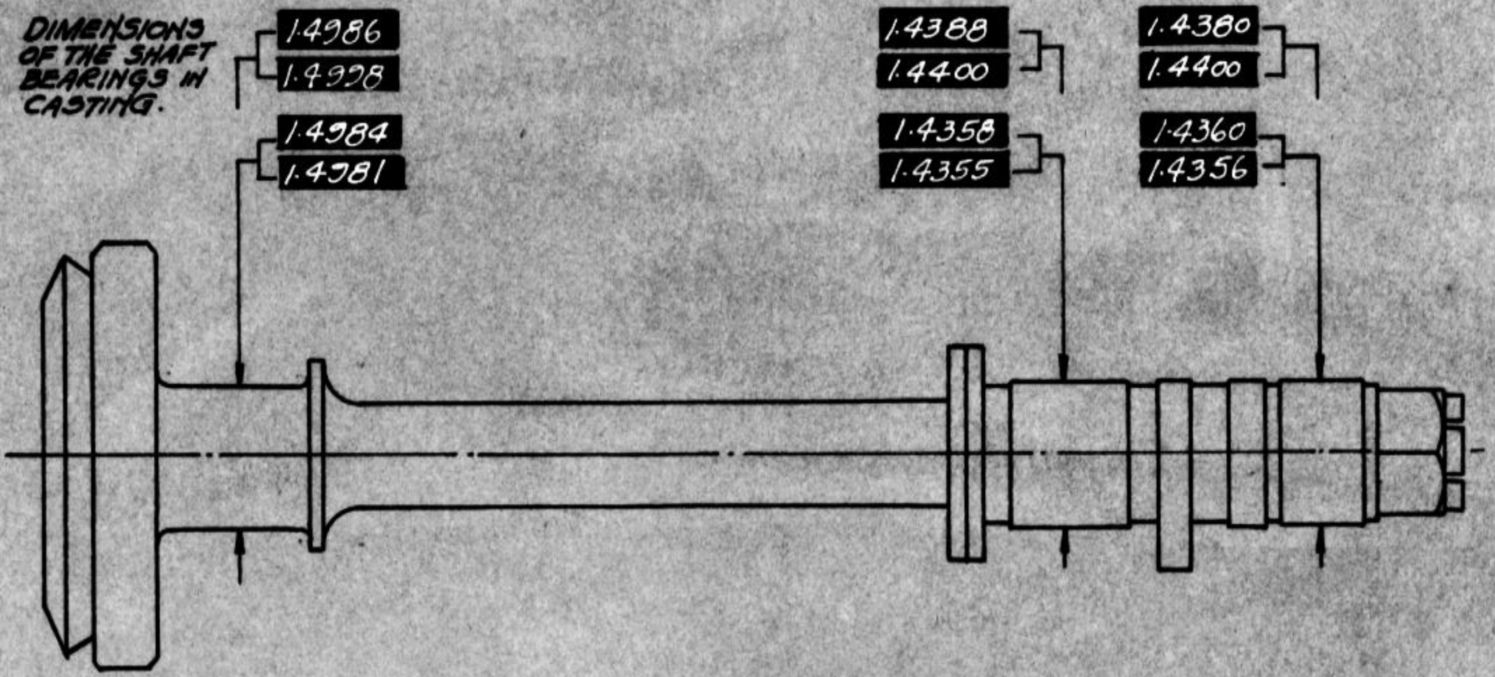
NOTE: INSIDE MICROMETERS USED FOR ALL READINGS. UPPER FIGURES SHOW DIMENSIONS TAKEN BEFORE START, LOWER FIGURES SHOW DIMENSIONS TAKEN AFTER TEST.
ENDURANCE TIME = 50 HOURS

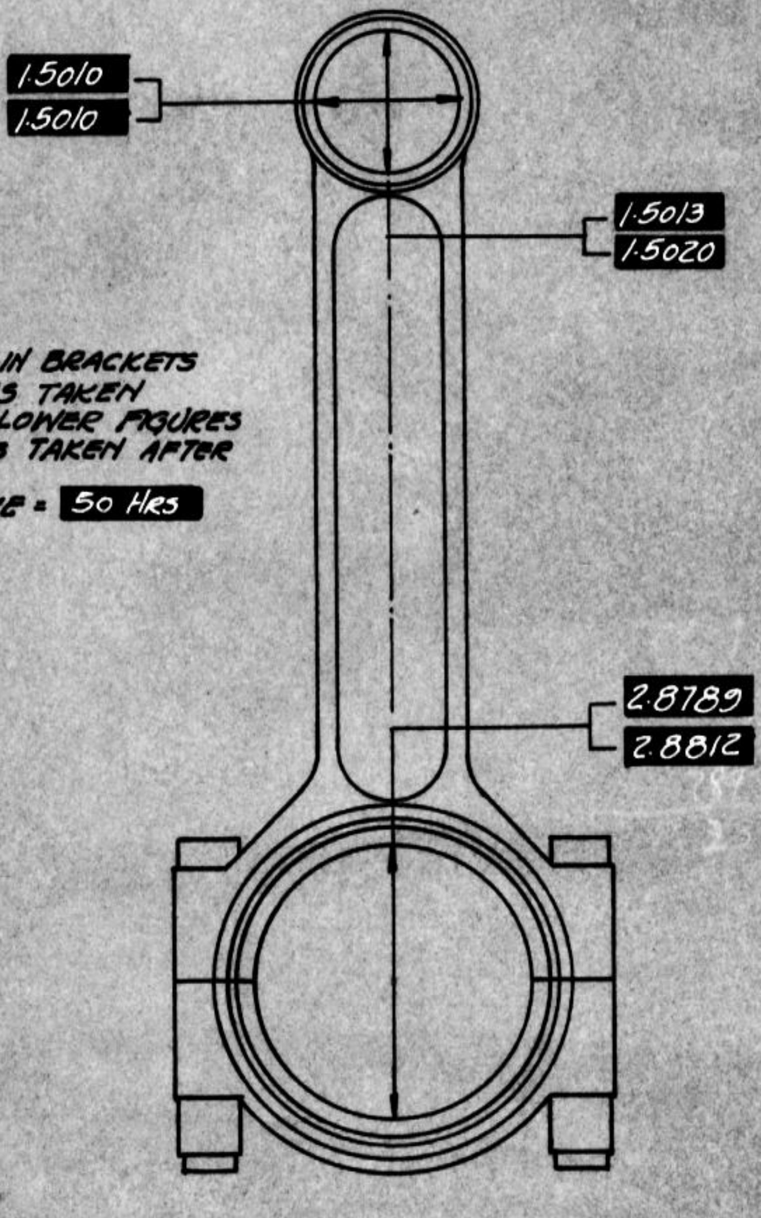
THESE DIMENSIONS TAKEN 90° FROM POSITION SHOWN.

HYPER CYLINDER Nº 2A

HYPER CYLINDER Nº 2A
DATE : 5-18-34

FIG. 5





UPPER FIGURES IN BRACKETS SHOW DIMENSIONS TAKEN BEFORE START, LOWER FIGURES SHOW DIMENSIONS TAKEN AFTER THE TEST.
ENDURANCE TIME = 50 HRS

FIG. 6

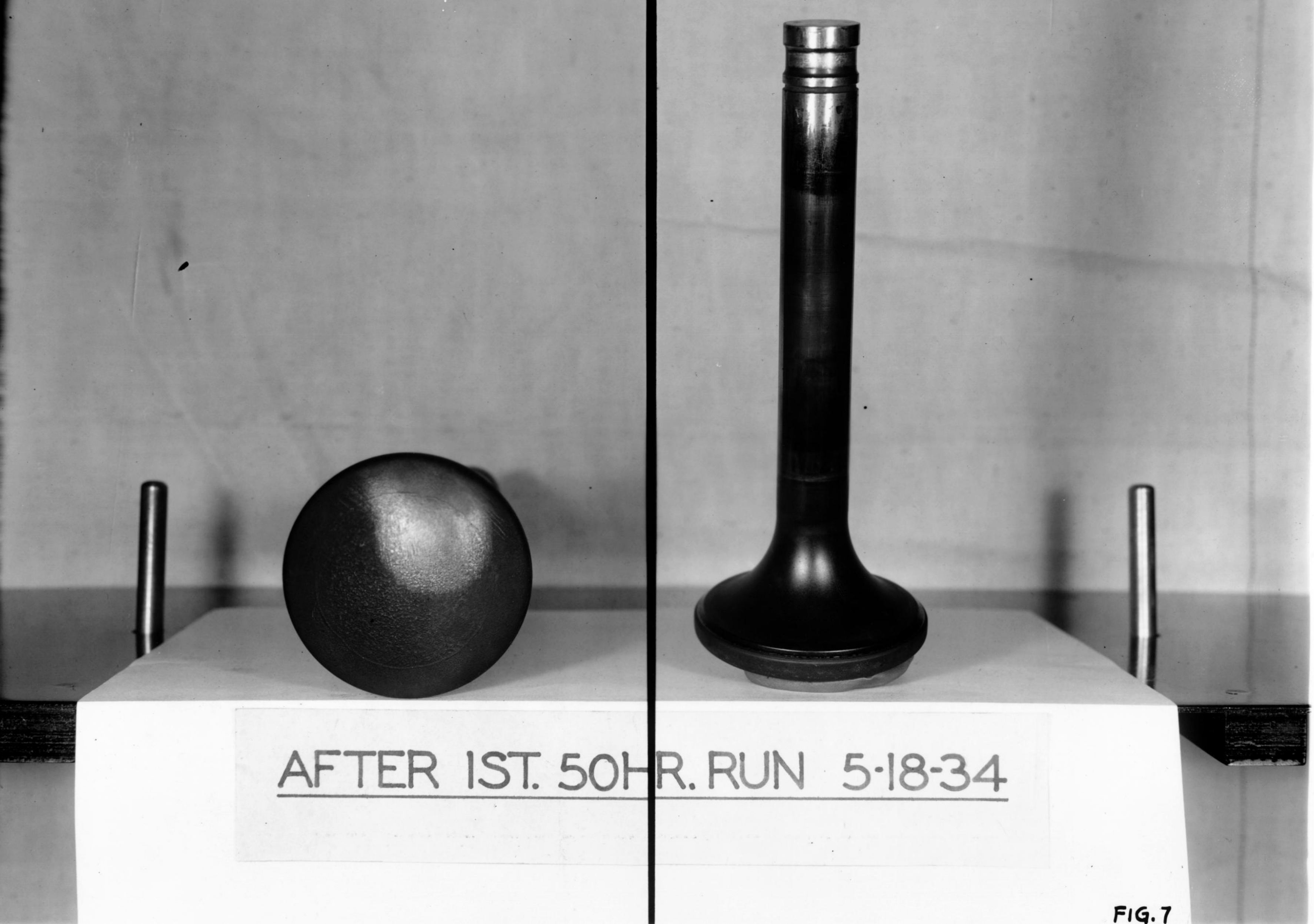


FIG. 7

FIG. 8

FIG. 8

FIG. 10

HYPER ENGINE SET-UP IN DYNAMOMETER ROOM No. 5.