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Report No. 375

MECHANICAL DEPARTMENT

ADMIRALTY ENGINEERING LABORATORY

WEST DRAYTON, MIDDLESEX

AD 419503

FOSTER F.D.6. MARK VII ENGINE.

ADMIRALTY TYPE TEST PART I.

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A.E.L. REPORT NO. 375.

JULY, 1963.

ADMIRALTY ENGINEERING LABORATORY

WEST DRAYTON.

PODEN F.D.6. MARK VII ENGINE.

ADMIRALTY TYPE TEST PART I.

Approved

Deputy Superintendent.

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SUMMARY.

The Admiralty Type Test Part I of the Foden F.D.6 Mark VII engine is reported.

The engine was given an Admiralty Test Rating of 186 b.h.p. at 1,800 r.p.m.

The test was completed during the period April-May, 1963.

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CONTENTS.

A.E.L. REPORT NO. 375.

JULY, 1963.

ADMIRALTY ENGINEERING LABORATORY
WEST DRAYTON.

FODEN F.D.6. MARK VII ENGINE.
ADMIRALTY TYPE TEST PART I.

INTRODUCTION.

The engine tested was a turbocharged version of the Mark VI engine (No. 4944). See A.E.L. Reports Nos. 365 and 369. After conversion at the maker's works it completed 157 hours running before delivery to the laboratory.

All major wearing components had been renewed except the main bearing shells and camshaft bearings. The single helical gearing was replaced by straight spur; now part of the build of the Mark VI production engines.

In order to avoid the thermal failures experienced in the Mark IV test (A.E.L. Report No. 363) the fuel stop had been set by the manufacturers at an acceptable limit.

Because of the results of the endurance test of the Mark VI engine with OMD.112 lubricating oil (A.E.L. Report No. 369) it was agreed that Shell Rotella T.30 be used for these tests.

ENGINE DATA.

Vertical two-stroke, direct injection, compression ignition engine, exhaust turbo-charged and intercooled, with mechanical supercharger in series.

6 cylinders in line 3.62" (92 mm.) bore x 4.73"(120 mm.) stroke.

Maker's Rating (intermittent marine) 220 b.h.p. at 2,000 r.p.m.

Admiralty Test Rating (marine):- 186 b.h.p. at 1,800 r.p.m.

PRINCIPAL RESULTS.

Test	Average Fuel Consumption lb./b.h.p./hr.	Exhaust Shade	Average Lubricating Oil Consumption	
			lb./hr.	% Fuel
72 hours at 95% A.T.R.	0.371	C	0.28	0.43
12 " " 100% "	0.368	C	-	-
2 " " 110% "	0.370	SS	-	-

RANGE OF TESTS.

	r.p.m.	b.h.p.	b.m.e.p. p.s.i.
Loop Test	1,500	44.2 - 171.7	40 - 155
" "	1,600	47.2 - 182.9	40 - 155
" "	1,800	53.1 - 210.0	40 - 159.6
" "	2,000	59.0 - 221.5	40 - 150
" "	2,100	62.0 - 232.5	40 - 150

For results see Tables 1 - 8 and Figs. 1 - 6.

ENDURANCE.

72 hours at	95% A.T.R.	1,800 r.p.m.	176.7 b.h.p.	133 p.s.i. b.m.e.p.
12 " "	100% "	1,800 "	186.0 "	140 " "
2 " "	110% "	1,800 "	204.6 b.h.p.	154 " "

TEST PROCEDURE.

The engine was installed as received, solidly mounted on a test bed inclined at 15° to the horizontal and coupled through a cardan shaft to a Heenan & Froude DPX4D dynamometer. Distilled water was used in the coolant circuit. Raw water inlet temperature was variable between 58°F and 83°F.

TEST DATA.

Fuel: S.G. at 60°F - 0.8356
Cetane No. - 59
Sulphur - 0.91%

Lubricating Oil: Shell Rotella T.30.
(For analysis see Table 9).

DEFECTS ARISING DURING TEST.

A leakage of lubricating oil from the camshaft rear bearing into the tachometer generator caused failure of this unit. No other defects occurred.

GENERAL REMARKS.

Construction.

The construction and all main components of the Mark VII engine tested were identical to the Mark VI engine, the principal modification being the addition of the Holset Model 4 turbo-charger with a two-entry exhaust manifold and air-charge intercooler mounted over the heat exchanger at the R.H. side of the engine (see Frontispiece). A modified small-end bush which gives larger bearing area by the elimination of the internal oil way to supply piston cooling oil was fitted to the new connecting rods. The piston oil supply is now fed from the outside of the small-end bush. An increased capacity sea water pump was also fitted, driven off the front end of the camshaft.

The Holset turbo-charger (see Fig.17) consists of an integral turbine wheel and shaft to which is secured the compressor rotor. The rotating unit is carried in a centrally mounted core assembly with two engine oil pressure fed sleeve bearings which are fully floating. Piston-ring oil seals are fitted outboard of each bearing.

Accessibility.

Accessibility for routine maintenance is reasonable. The exhaust manifold is inaccessible without removing the charge cooler, heat exchanger and heat shield. An exhaust gas leak was experienced at the joint marrying the two-piece manifold which was not readily visible until the engine was stripped. A piston ring seal is to be fitted at this joint before commencing the Part III test.

Stripping the engine for major overhaul is comparable to the Mark IV engine. One mechanic and one labourer can strip the engine when it is mounted in an overhaul stand in 8 - 10 hours, rebuilding taking 14 - 16 hours.

Starting.

No difficulty was experienced when starting the engine at normal ambient temperatures.

It is intended to subject the engine to cold starting tests after the completion of the Part III test.

Slow Running.

The engine will idle satisfactorily when warm down to 320 r.p.m.

Vibration and Noise.

No undue vibration was experienced at any of the test speeds. The noise level appeared considerably less than the Mark VI engine and the exhaust noise level with the silencer supplied by the makers in series with the test cell arrangement was just audible.

Combustion.

The combustion characteristics of the engine are good, as shown by the condition of the exhaust ports and turbo-charger. Shading of the exhaust was not visible below 120 p.s.i. b.m.e.p. at any of the test speeds, and sensible shading was only noticeable at the maximum fuel stop position.

Lubricating Oil.

Samples of the Shell Rotella T.30 lubricating oil were analysed by A.O.L. and results given in Table 9. Shell International Petroleum Co. Ltd. also analysed a final sample with the following result:-

Viscosity Redwood I at 140°F (secs.)	233
Insolubles in n.Heptane (% wt.)	1.6
" in Benzene (% wt.)	1.0
T.B.N.E. mg.KOH/g.	3.2

They commented as follows:-

"The appreciable increase in viscosity and significant difference between the n.Heptane and Benzene insolubles point to appreciable oxidation of this oil charge. We would, however, be able to make more useful comments on oil deterioration in this engine when we have examined a series of samples from an endurance run".

Condition After Test.

The condition of the engine after test reflects the thermal limitation of the piston and small end assembly. Their appearance shows definite indications of overheating of the gudgeon pins and the eyes of the connecting rods. The lacquer glaze present on the liners and pistons is also thought to be due to their high temperature combined with lubricating oil oxidation. (See Table 9). Oxidation of the oil may be in part attributable to the turbo-charger, in which hot compressed air is bled into the bearing oil space

to prevent gas leakage. This could lead to foaming of the oil in the return pipe and oxidation.

It was observed that the pistons appeared to be hotter at the drive end of the engine remote from the oil feed. An increase in the main oil flow should improve this condition.

The condition of the cylinder heads was in general satisfactory, observing that the heads of the Mark VI engine showed some distress after the endurance test (see A.E.L. Report No. 369). The wear (0.0003" max.) experienced on the gudgeon pins was acceptable for the loading and hours run to date (309) and shows considerable improvement when compared with the Mark IV and Mark VI engines. No other major component showed appreciable wear, except the top of the valve stems indicating the non-rotation of the valves.

The condition of the Roots blower, partially stuck at the end of the test, was attributed to the effect of the high air temperature on the grease used in assembly.

The condition of the Holset turbo-charger was satisfactory and reflected the clear combustion condition of the engine exhaust. The injector needles showed evidence of blow-by which was considered to be due in part to the loss of setting pressure probably due to spring settling. It was established that the nozzles had not been re-set since they were initially fitted and had been in use for 309 hours.

FUTURE DEVELOPMENT.

Three non-ferrous prototype cylinder heads with insert valve seats and valve rotators are to be introduced for the Part III test. The lubricating oil flow rate is to be increased. A more efficient inter-cooler is to be tried in order to reduce the inlet air temperature.

CONCLUSIONS.

1. The turbo-charging of the Mark VI engine has considerably increased its power and improved the power/weight ratio. It can be recommended for Admiralty service for a 125 kW generator application.

2. This engine requires a high quality lubricating oil.

E.J. Watts, Sen.Sc.Asst.

K.E. Foster, Sc.Asst.

Submitted by W.H. Ray, P.S.O.

AEL/RO/PC.

SPECIFICATION AND COMPONENT REPORT.

Maker: Messrs. Fodens Ltd., Sandbach, Cheshire.

Type: Vertical two-stroke, direct injection, compression ignition engine, exhaust turbo-charged and intercooled with mechanical supercharger in series.

Type No.: F.D.6. Mark VII.

Purpose: Vehicle and Marine propulsion. Generator duties.

Maker's Continuous Rating: 200 b.h.p. at 2000 r.p.m. (B.S. 2953).

Admiralty Test Rating: 186 b.h.p. at 1800 r.p.m.

No. of Cylinders: Six.

Bore: 92 mm. 3.622" dia.

Stroke: 120 mm. 4.72"

Total Swept Volume: 4.8 litres. (293 cu.ins.).

Compression Ratio: 14 : 1 approx.

Piston Speed: 1575 ft./min. at 2000 r.p.m.

Firing Order: 1, 5, 3, 4, 2, 6.

Lubricating Oil Capacity: 5 gal.

Rotation Looking on Free End: Clockwise.

Timings:

Inlet Port opens 43° before B.D.C.
" " closes 43° after B.D.C.

Exhaust Valve opens 80° before B.D.C.
" " closes 42° after B.D.C.

Injection (static) begins 29° before T.D.C.

Tappet Clearance: 0.010" (cold).

Overall Dimensions:

Length 4' 3½"
Width 2' 7"
Height above crankshaft 2' 7½"
Depth below crankshaft 1' 6½"

Weight: 1680 lb. (dry) without gearbox.

Wt./b.h.p. at 200 b.h.p. rating 8.4 lb.
Wt./cu.in./Swept Volume 5.74 lb.
b.h.p./Litre 41.7 at 200 b.h.p. rating.

PARTICULARS OF ENGINE.

CONDITION AFTER TEST.

157 hours running at Messrs. Fodens Ltd.
152 " " " A.E.L.

CRANKSHAFT.

Material: Ni-Chr. Moly. Steel En.110.

No. of Bearings: 7.

Balance Weights: None.

Vibration Dampers: None.

Flywheel Location: Spigot mounting at drive end.

Drilling: Rifle drilled for large and small end lubrication and piston cooling.

Journals: Satisfactory appearance, some light surface scratching visible. No.1 shows scoring of considerable depth.

Crankpins: Satisfactory appearance, light surface scratching only. No.4 pin has score from oil hole.

MAIN BEARINGS.

Type: Steel backed, thin shell (replaceable).

Lining: Aluminium-tin.

See Fig.7.
Considerable scratching and scoring visible, particularly on cap halves, (mostly from previous running as Mark VI). Erosion patches as seen previously (no increase).

CRANKCASE AND CYLINDER BLOCK.

Type: Single alloy casting.

Material: Aluminium F.12.

Clean condition. Some evidence of slight lacquering overall. No undue deposits.

CYLINDER LINERS.

Type: Wet.

Material: Centrifugally cast C.I.

Bore Finish: 30-45 micro-ins. Honed.

Characteristic carbon-lacquer-ring at top of bores. Bores well polished with slight lacquer glaze overall.

PARTICULARS OF ENGINE.	CONDITION AFTER TEST.
CYLINDER HEADS.	
Material: Ni. Chr. Moly. Iron F.30.	Medium hard combustion deposit with some build up towards outer periphery.
Number: 6.	
Valve Seatings: Integral with heads.	Some light pitting visible on some seatings, otherwise satisfactory. No build-up in valve ports.
Valve Guides: Cast iron (replaceable).	
Position of Injectors: R.H. side, external to rocker covers.	
Gasket: "Armco" iron.	Satisfactory, but indications of imperfect sealing visible on most head joints.
PISTONS.	See Fig.8.
Material: Cast iron HG.301.	
Shape of Crown: Toroidal chamber.	Crowns: Combustion deposit, (particularly oil additive) on outer diameter of piston bowl and flat top. Undersides (particularly No.6) indicate considerable high temperature condition.
	Ring Lands: Light carbon and hard lacquer deposit.
	Ring Grooves: Light hard lacquer deposit (no carbon).
	Skirts: Light hard lacquer deposit overall. Some indications of light pick-up bottom of thrust sides and localised distortion patches.
	Gudgeon Pin Bosses (except No.1): Slight indications of fretting of gudgeon pins.

PARTICULARS OF ENGINE.	CONDITION AFTER TEST.
PISTONS. (Continued)	
No. of Compression Rings: One composite fire ring. Two wedge and taper faced rings.	Fire Rings: Generally satisfactory appearance. All free.
	Compression Rings: Ring faces bedded $\frac{1}{3}$ to $\frac{1}{2}$ across surface. All free.
No. of Oil Scraper Rings: One parallel taper faced ring.	Oil Scraper Ring: All free and of satisfactory appearance as compression rings.
GUDGEON PINS.	
Material: Oil hardened Nitralloy steel.	See Fig.8.
Type: Press fit into piston bosses.	All pins show indications (by discolouration) of over heated running conditions.
Location: By circlip.	Well defined polished appearance of loaded surfaces with slight wear (0.0003" max.).
	Some fretting visible where fitted in piston bosses.
CONNECTING RODS.	
Material: Forged 3½% nickel steel E.N.22.	Heat discolouration seen on top ends (non-thrust side) of all rods except No.1.
Centre Distance: 9.4995" - 9.5005"	
Drilling: For small end and piston cooling supply.	See Fig.9.
Type of Large End Bearing: Replaceable steel backed shell.	Rod halves show well defined loading indication with some scratching of surfaces due to dirt.
Lining: Aluminium-tin.	Large end bolt threads Nos. 2 and 5 rods show some deformation.
Material of Small End Bush: Solid steel - lead bronze lined.	All of satisfactory appearance, but some small patches of surface pitting or erosion seen in Nos. 1, 2 and 3 bushes.
VALVES.	
Exhaust.	See Figs. 10 and 11.
Material: Steel 21 4NS with Delpher stem end.	
No./Cylinder: 2.	
Seat Angle: 30°	Seats: Some very light pitting visible on most valves. No build-up under heads.

PARTICULARS OF ENGINE.

VALVES.

Exhaust. (Continued)

Throat Dia.: 1.170"

Lift: 0.295"

No. of Springs/Valve: 2

Operation: Overhead, by short push rods and rockers.

CAMSHAFT.

Material: Steel, Fox 540.

No. of Bearings: 7.

Type of Bearing: Plain split bearings (Alum.tin).

Type of Cam Follower: Roller.

TIMING GEARS.

Material: Steel B.S. EN.110.

Type: Straight spur.

Location: Spigot mounted and bolted to drive shafts at drive end of engine.

CONDITION AFTER TEST.

Stems: All free and oily in guides.
Valve stem ends show evidence of non-rotation of valves.

Valve Springs: Satisfactory.

Rockers: Satisfactory.

Tappet Adjusters: Show wear at contact area.

Journals: Satisfactory appearance.

Cams: Satisfactory, some light surface scratching visible on all cams.

Bearings: Satisfactory, surface scratching on all loaded halves.

Cam Followers: Some slight surface marking on all rollers.
Needle rollers and pins satisfactory.

All of satisfactory appearance showing even bedding of teeth.

PARTICULARS OF ENGINE.

TURBOCHARGER.

Type: Holset Model 4.

Location: At rear end of exhaust manifold (R.H. side).

Speed of Rotation: Up to 70,000 r.p.m.

ROOTS BLOWER.

Location: Bolted to L.H. side of air chest.

Speed of Rotation: 2.04 x crankshaft speed.

FUEL INJECTION PUMP.

Make: C.A.V.

Type: C.A.V. Ref. MML 6G80/185.

Plunger Dia.: 8 mm.

Location: Bolted to top of blower.

GOVERNOR.

Make: C.A.V.

Type: Hydraulic GLHVL2132.

Location: Integral with fuel pump.

CONDITION AFTER TEST.

See Figs. 13-16.

Turbine Wheel, Nozzle Ring and Casing: Very clean condition.

Compressor Rotor: Very light oily carbon deposit particularly at eye of rotor.

Compressor Housing and Extension: Light deposit of oily carbon overall.

Bearings and Shaft: Not stripped for examination, no excessive end or radial float.

Rotor lobes and casing coated with baked on grease (initially introduced when assembled) causing excessive turning torque.

Operation satisfactory - not examined.

Operation satisfactory - not examined.

PARTICULARS OF ENGINE.	CONDITION AFTER TEST.
INJECTORS.	
Make: C.A.V.	Spray on Test: Good.
Holder Type No.: BKBL/9785149.	Release Pressure: 185-210 atm.
Nozzle Type No.: BDLL28-5S76396.	Needle Valves: Nos. 3 and 6 slightly sticky in bores, remainder free. Some carbon build-up on tips. Wide dirty seats, heat stained tips with blow back indications to varying degree. (See Fig.12).
No. of Holes: One.	Springs and Rods: Satisfactory.
Dia. of Holes: 0.5 mm.	Nozzle Pressure Faces: Slightly pitted around edge of centre bore.
Spray Angle: 28° 30'	
Release Pressure: 225 atm. 3,300 p.s.i.	
FUEL FEED PUMP.	
Make: C.A.V.	Operation satisfactory. Not examined.
Type: Diaphragm. DFP38/44.	
Location: Integrally mounted with injection pump.	
FUEL FILTERS.	
Make: C.A.V.	
Type: Paper element.	Not examined.
No. Fitted: Twin elements in series.	

PARTICULARS OF ENGINE.	CONDITION AFTER TEST.
LUBRICATING SYSTEM.	
Type: Wet sump.	
Capacity: 5 gal.	
Type of Filter: Full flow felt element.	No undue sludge or deposits found.
No of Filters: One.	
Normal Oil Pressure: 50-60 p.s.i.	
Type of Pressure Pump: Gear wheel.	Not examined.
Type of Oil Cooler: Guided flow multi-tube (coolant cooled).	Oil Side: Clean.
COOLING SYSTEM.	
Type: Closed circuit. Heat exchange.	
Capacity: 4.5 gal.	
Type of F.W. Pump: Centrifugal.	Not examined.
Location: Bolted to auxiliary drive housing.	
Type of S.W. Pump: Positive displacement, 1½" Jabsco 4800-21.	Satisfactory.
Location: Driven by camshaft at front end of engine.	
Type of Heat Exchanger: Contra flow tube stack.	Not examined.
Temperature Control: 3-port thermostat 140°-150°-150°.	Operation satisfactory.
TURBO-CHARGER AIR COOLER.	
Maker: Universal Metallic Packing Co.	Air Side: Clean condition.
Type: Gilled tube.	

PARTICULARS OF ENGINE.	CONDITION AFTER TEST.
ELECTRICAL SYSTEM.	
Make of Starter: Simms 524SGR51/4.	Not examined.
Type of Starter: Solenoid operated.	
Location: Strapped R.H. side of engine at rear end of crankcase.	
Voltage: 24.	

TABLE 1.

1500 R.P.M. LOOP TEST.

b.m.e.p. p.s.i.	b.h.p.	Fuel Cons. lb/hp/hr.	Exhaust Smoke	Lubricating Oil			Coolant		Raw Water			Turbine		
				Main Press. p.s.i.	Temp. °F		Temp. °F		Temp. °F			In		
					In	Out	In	Out	In	Ins. Cir. Out	E.E. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F
40	44.2	.457	C	47	181	185	142	141	77	80	95	498	5.0	389
60	66.3	.414	C	46	189	197	142	143	81	85	102	558	6.4	483
80	88.5	.391	C	44	197	207	144	147	79	88	103	646	7.2	563
100	110.6	.388	C	43	200	213	142	150	79	82	106	718	8.5	645
120	132.8	.378	C/SS	41	212	225	147	158	80	88	111	805	10.1	675
140	155.0	.389	SS	39	224	237	154	167	80	85	115	895	11.7	765
155	171.7	.378	S	36	233	248	160	175	80	86	119	980	13.7	815

TABLE 1.

ft. BAROMETER:- 29.89 "Hg.

Raw Water			Turbo-Charger											Roots Blower			
			Turbine						Compressor					Boost Air			
Temp. °F			In		Out		r.p.m. x 10^3	Lub. Oil Press. p.s.i.	Air Inlet		Air Outlet Temp. °F	Press. Ratio P2/P1	Air Flow c.f.m.	In		Out	
In	Lub. Oil Out	H.E. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F	Press. "H_2O			Temp. °F	Depr. "H_2O (P1)				Temp. °F	Press. "Hg. (P2)	Temp. °F	Press. "Hg.
77	80	98	498	5.0	388	1.2	25.114	56	103	2.4	125	1.08	295	92	2.3	150	5.3
81	85	102	558	6.1	483	1.4	27.368	54	107	2.6	140	1.14	313	98	3.9	158	10.2
79	88	105	645	7.2	563	1.6	31.244	53	110	2.8	152	1.19	332	101	5.4	155	11.5
79	82	106	718	8.5	645	2.0	35.204	52	81	3.0	137	1.27	357	98	7.8	150	13.3
80	88	111	805	10.1	675	2.4	38.983	51	78	3.4	148	1.34	366	102	10.0	158	15.1
80	85	115	895	11.7	746	2.8	42.469	49	82	3.8	166	1.43	398	108	12.6	165	17.4
80	86	119	980	13.7	815	3.3	46.160	47	84	4.4	187	1.55	430	115	15.9	170	19.8

1600 R.P.M. LOOP TEST.

Brake H.P.	B.M.E.P. p.s.i.	Fuel Cons. lb/hp/hr.	Exhaust Smoke	Lubricating Oil			Coolant		Raw Water				
				Main Press. p.s.i.	Temp. °F		Temp. °F		Temp. °F			In	
					In	Out	In	Out	In	Out Min. Out	Out	Steam Temp. °F	Steam Pres. lbs
40	47.2	.464	C	48	177	185	141	139	75	76	99	485	6.1
60	70.8	.414	C	47	185	195	148	148	77	79	98	540	7.8
80	94.4	.390	C	46	195	207	144	147	80	86	107	667	8.8
100	118.0	.379	C	44	208	213	148	147	75	76	99	700	10.1
120	141.6	.376	C/C/HS	42	213	225	144	155	75	78	105	800	10.1
140	165.2	.376	C/C/HS	40	225	240	152	165	77	82	110	880	13.1
155	182.9	.378	C/C/HS	41	237	255	148	155	58	63	94	905	15.4

TABLE 2.

T. BAROMETER:- 29.82 "Hg.

Raw Water			Turbine				Turbo-Charger		Compressor				Boost Blower			
													Boost Air			
Temp. °F			In		Out		r.p.m.x 10^3	Lub. Oil Press. p.s.i.	Air Inlet		Air Outlet Temp. °F	Press. Ratio P2/P1	Air Flow c.f.m.	In		Out	
In	Lub. Oil. Out	Jck. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F	Press. "H$_2$O			Temp °F	Depr. "H$_2$O (P1)				Temp. °F	Press. "Hg. (P2)	Temp. °F	Press. "Hg.
75	76	99	485	6.1	365	1.5	26.850	57	64	2.6	90	1.11	328	81	3.0	142	11.2
77	79	98	540	7.3	408	1.8	29.170	56	68	2.9	107	1.17	341	88	4.9	150	12.6
83	86	107	647	8.8	535	2.0	32.750	55	73	3.1	123	1.25	349	97	6.6	155	13.8
75	76	99	700	10.1	595	2.5	36.560	54	76	3.6	138	1.30	382	95	8.6	150	15.6
75	78	105	888	12.1	678	3.1	41.880	53	79	4.1	160	1.40	415	104	11.5	155	18.2
77	82	110	880	13.7	735	3.5	43.960	51	85	4.6	180	1.48	437	112	13.9	170	19.9
58	63	94	905	15.4	763	3.8	47.880	52	74	5.2	179	1.57	465	102	16.4	155	22.8

2

1800 R.P.M. LOOP TEST.

b.m.e.p. p.s.i.	b.h.p.	Fuel Cons. lb/bhp/hr.	Exhaust Smoke	Lubricating Oil			Coolant		Raw Water			Tur	
				Main Press. p.s.i.	Temp. °F		Temp. °F		Temp. °F			In	
					In	Out	In	Out	In	Int. Cir. Out	E.E. Out	Mean Temp. °F	Mean Press. "Hg.
40	53.1	.485	C	49	183	190	142	160	66	67	83	443	7.9
60	79.6	.432	C	47	188	198	142	142	70	72	90	540	9.6
80	106.2	.396	C	46	198	208	143	145	73	75	96	620	11.2
100	132.7	.380	C	44	205	218	143	148	74	78	100	698	13.0
120	159.3	.369	C	42	220	233	148	159	79	84	109	785	15.6
140	185.9	.367	C	41	229	242	152	164	77	83	109	863	18.3
155	205.9	.374	[illegible]	39	239	254	158	172	77	84	112	920	21.2
159.6	210.0	.374	[illegible]	39	242	258	160	174	78	85	113	938	21.8

TABLE 3.

BAROMETER:-

Raw Water			Turbo-Charger											Roots Blower			
			Turbine						Compressor					Boost Air			
Temp. °F			In		Out		r.p.m. x 10^3	Lub. Oil Press. p.s.i.	Air Inlet		Air Outlet Temp. °F	Press. Ratio P2/P1	Air Flow c.f.m.	In		Out	
In	Inc. Clr. Out	H.E. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F	Press. "H_2O			Temp. °F	Depr. "H_2O (P1)				Temp. °F	Press. "Hg. (P2)	Temp. °F	Press. "Hg.
65	67	83	443	7.9	370	1.9	29.089	59	73	3.8	180	1.15	382	83	4.2	150	14.4
70	72	90	540	9.6	453	2.3	33.611	58	74	3.8	123	1.23	398	88	6.4	150	16.4
73	75	96	620	11.2	515	2.8	36.115	57	76	4.4	138	1.30	437	96	8.7	155	18.2
74	78	100	698	13.0	575	3.3	40.976	56	78	4.9	155	1.39	458	102	11.1	160	20.7
79	84	109	785	15.6	643	4.0	44.428	54	84	5.7	180	1.51	498	113	14.5	170	26.0
77	83	109	863	18.3	700	4.8	49.282	54	87	6.6	204	1.63	535	121	18.2	175	27.5
77	84	112	920	21.2	740	5.4	53.996	53	85	7.6	225	1.76	568	129	21.9	178	31.3
78	85	113	938	21.8	750	5.6	54.986	52	85	7.8	230	1.80	578	131	22.9	180	31.9

2000 R.P.M. LOOP TEST.

b.m.e.p. p.s.i.	b.h.p.	Fuel Cons. lb/bhp/hr.	Exhaust Smoke	Lubricating Oil			Coolant		Raw Water			Turbi	
				Main Press. p.s.i.	Temp. °F		Temp. °F		Temp. °F			In	
					In	Out	In	Out	In	Int. Cir. Out	H.E. Out	Mean Temp. °F	Mean Press. lbs.
40	59.0	.405	C	48	191	199	142	142	80	82	98	478	10.1
60	88.5	.403	C	47	200	209	145	146	80	85	104	578	11.9
80	118.0	.404	C	45	209	220	146	150	80	84	108	680	14.4
100	142.5	.391	C	44	217	230	150	159	80	85	112	788	16.8
120	173.1	.375	C	42	230	244	157	167	80	87	116	795	19.7
140	206.7	.376	C	41	236	247	160	172	75	83	115	878	23.3
150	221.5	.374	C	39	242	255	166	178	77	86	119	913	25.0

TABLE I

BAROMETER:- 29.82 "Hg.

Raw Water			Turbo-Charger											Roots Blower			
			Turbine						Compressor					Boost Air			
Temp. °F			In		Out		r.p.m. x 10^3	Lub. Oil Press. p.s.i.	Air Inlet		Air Outlet Temp. °F	Press. Ratio P2/P1	Air Flow c.f.m.	In		Out	
In	Int. Cir. Out	H.E. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F	Press. "H_2O			Temp. °F	Depr. "H_2O (P1)				Temp. °F	Press. "Hg. (P2)	Temp. °F	Press. "Hg.
80	82	98	478	10.1	393	2.5	31.980	60	73	4.4	120	1.18	444	95	5.0	170	18.1
80	83	104	578	11.9	463	2.8	36.180	59	75	4.9	137	1.26	465	100	7.3	170	20.3
80	84	108	680	14.4	535	3.7	41.430	58	77	5.7	156	1.36	504	107	10.3	175	23.5
80	85	112	788	16.8	593	4.2	46.350	57	78	6.5	177	1.47	535	115	13.3	180	26.5
80	87	116	795	19.7	640	4.9	49.740	56	79	7.5	197	1.59	573	123	16.7	190	30.3
75	85	115	878	23.3	698	5.6	53.830	55	81	8.7	223	1.73	612	131	20.8	195	34.8
77	86	119	913	25.0	783	6.2	56.290	55	85	9.3	240	1.80	632	137	22.7	200	36.6

2100 R.P.M. LOOP TEST.

b.m.e.p. p.s.i.	b.h.p.	Fuel Cons. lb/bhp/hr.	Exhaust Shade	Lubricating Oil			Coolant		Raw Water			In
				Main Press. p.s.i.	Temp. °F		Temp. °F		Temp. °F			
					In	Out	In	Out	In	Int. Cir. Out	H.E. Out	Hom Temp. °F
40	62.0	.498	C	49	195	202	143	143	75	78	102	480
60	93.0	.437	C	47	202	213	145	148	77	81	107	575
80	124.0	.403	C	46	212	223	149	156	77	85	112	668
100	155.0	.394	C	43	225	235	158	167	80	88	120	750
120	186.0	.382	C	41	237	250	167	177	80	89	124	825
140	217.0	.377	C/88	39	250	264	177	190	81	93	132	910
150	232.5	.382	C/88/88	37	256	270	182	195	82	94	135	950

TABLE 5.

BAROMETER :- 30.00 "Hg.

Ram Heater			Turbo-Charger										Roots Blower			
			Turbine						Compressor				Boost Air			
Temp. °F			In		Out		r.p.m. x 10^3	Lub. Oil Press. p.s.i.	Air Inlet		Air Outlet Temp. °F	Press. Ratio P2/P1	Air Flow c.f.m.	In		Out	
In	Int. Clr. Out	E.E. Out	Mean Temp. °F	Mean Press. "Hg.	Mean Temp. °F	Press. "H_2O			Temp. °F	Depr. "H_2O (P1)				Temp. °F	Press. "Hg. (P2)	Temp. °F	Press. "Hg.
75	78	102	480	11.7	405	2.8	34.120	61	69	5.1	124	1.20	472	94	5.7	175	20.5
77	81	107	575	13.8	475	3.2	38.580	60	71	5.7	142	1.29	498	101	8.0	178	25.0
77	85	112	668	16.6	560	3.9	44.080	58	74	6.6	164	1.40	535	110	11.3	190	26.7
80	88	120	750	19.2	600	4.7	48.270	57	78	7.4	189	1.51	563	121	14.4	195	30.0
80	89	124	825	22.5	660	5.6	52.550	56	80	8.6	215	1.64	608	131	18.1	201	34.4
81	93	132	910	26.6	715	6.7	56.460	54	84	10.3	248	1.82	651	146	23.2	215	39.9
82	94	135	950	28.7	740	7.3	59.798	52	85	11.1	262	1.91	680	152	25.7	220	42.8

2

TABLE 6.

72 HOURS ENDURANCE TEST. 95% A.T.R. 176.7 b.h.p. 133 p.s.i. b.m.e.p. 1800 r.p.m.

Average				1st 24 Hours	2nd 24 Hours	3rd 24 Hours	72 Hours
Fuel Consumption lb./b.h.p./hr.				.372	.371	.371	.371
Exhaust Shade				C	C	C	C
Lubricating Oil	Main Pressure p.s.i.			41	42	42	42
	Temp. °F	In		232	230	229	230
		Out		243	242	242	242
Coolant	Temp. °F	In		159	158	155	157
		Out		170	169	166	168
Raw Water	Temp. °F	In		78	78	74	77
		Out of Intercooler		85	85	82	84
		Out of Heat Exchanger		120	120	116	119
Turbo-Charger	Turbine Exhaust Gas	In	Mean Temp. °F	859	854	852	855
			Mean Press. "Hg.	17.0	16.7	16.7	16.8
		Out	Mean Temp. °F	699	697	696	697
			Press. "H$_2$O	4.6	4.6	4.6	4.6
	Speed r.p.m.			47,520	47,424	47,333	47,426
	Lubricating Oil Press. p.s.i.			55	55	55	55
	Compressor Air	In	Temp. °F.	79	78	77	78
			Depr. "H$_2$O (P1)	6.1	5.9	5.9	6.0
		Out	Temp. °F	189	186	186	187
		Press. Ratio P2/P1		1.55	1.54	1.54	1.54
		Air Flow c.f.m.		520	517	517	518
Roots Blower	Boost Air	In	Temp. °F	118	116	114	116
			Press. "Hg. (P2)	15.8	15.5	15.4	15.6
		Out	Temp. °F	174	173	173	173
			Press. "Hg.	25.7	25.3	25.2	25.4
Ambient Temperature °F				74	73	72	73
Barometer "Hg.				29.54-30.38			
Oil Consumption 18 pints. 19.9 lb. 0.28 lb./hr. 0.43% fuel.							

TABLE 7.

12 HOURS ENDURANCE TEST. 100% A.T.R. 186 b.h.p. 140 p.s.i. b.m.e.p. 1800 r.p.m.

Average				1st 4 Hours	2nd 4 Hours	3rd 4 Hours	12 Hours
Fuel Consumption lb./b.h.p./hr.				.369	.367	.367	.368
Exhaust Shade				C	C	C	C
Lubricating Oil	Main Pressure p.s.i.			42	41	42	42
	Temp. °F	In		230	236	231	232
		Out		244	249	244	246
Coolant	Temp. °F	In		156	160	154	157
		Out		165	171	166	167
Raw Water	Temp. °F	In		69	76	70	72
		Out of Intercooler		77	84	77	79
		Out of Heat Exchanger		113	120	114	116
Turbo-Charger	Turbine Exhaust Gas	In	Mean Temp. °F	876	890	879	882
			Mean Press. "Hg.	17.5	17.4	17.5	17.5
		Out	Mean Temp. °F	714	727	717	719
			Press. "H_2O	4.8	4.9	4.9	4.9
	Speed r.p.m.			48,383	48,513	47,735	48,214
	Lubricating Oil Press. p.s.i.			55	55	55	55
	Compressor Air	In	Temp. °F	80	87	82	83
			Depr. "H_2O (P1)	6.2	6.2	6.2	6.2
		Out	Temp. °F	195	203	192	197
		Press. Ratio P2/P1		1.57	1.57	1.57	1.57
		Air Flow c.f.m.		528	528	528	528
Roots Blower	Boost Air	In	Temp. °F	115	122	115	117
			Press. "Hg. (P2)	16.4	16.3	16.3	16.3
		Out	Temp. °F	174	178	174	175
			Press. "Hg.	26.3	26.0	26.2	26.2
Ambient Temperature °F				72	82	74	76
Barometer "Hg.				30.00-30.04			

TABLE 8.

2 HOURS OVERLOAD TEST. 110% A.T.R. 204.6 b.h.p. 154 p.s.i. b.m.e.p. 1800 r.p.m.

Average				1st Hour	2nd Hour	2 Hours
Fuel Consumption lb./b.h.p./hr.				.369	.371	.370
Exhaust Shade				88	88	88
Lubricating Oil	Main Pressure p.s.i.			41	41	41
	Temp. °F	In		242	242	242
		Out		256	255	256
Coolant	Temp. °F	In		162	162	162
		Out		175	175	175
Raw Water	Temp. °F	In		73	73	73
		Out of Intercooler		82	82	82
		Out of Heat Exchanger		120	120	120
Turbo-Charger	Turbine Exhaust Gas	In	Mean Temp. °F	943	948	946
			Mean Press. "Hg.	19.4	19.6	19.5
		Out	Mean Temp. °F	763	765	764
			Press. "H_2O	5.4	5.4	5.4
	Speed r.p.m.			51,360	51,570	51,465
	Lubricating Oil Press. p.s.i.			54	54	54
	Compressed Air	In	Temp. °F	86	87	87
			Depr. "H_2O (P1)	6.8	6.9	6.9
		Out	Temp. °F	218	220	219
		Press. Ratio P2/P1		1.24	1.25	1.25
		Air Flow c.f.m.		552	552	552
Roots Blower	Boost Air	In	Temp. °F	125	126	126
			Press. "Hg. (P2)	19.0	19.4	19.2
		Out	Temp. °F	180	180	180
			Press. "Hg.	28.6	29.0	28.8
Ambient Temperature °F				79	80	80
Barometer "Hg.					30.00	

TABLE 9.

SHELL ROTELLA T30 LUBRICATING OIL ANALYSIS.

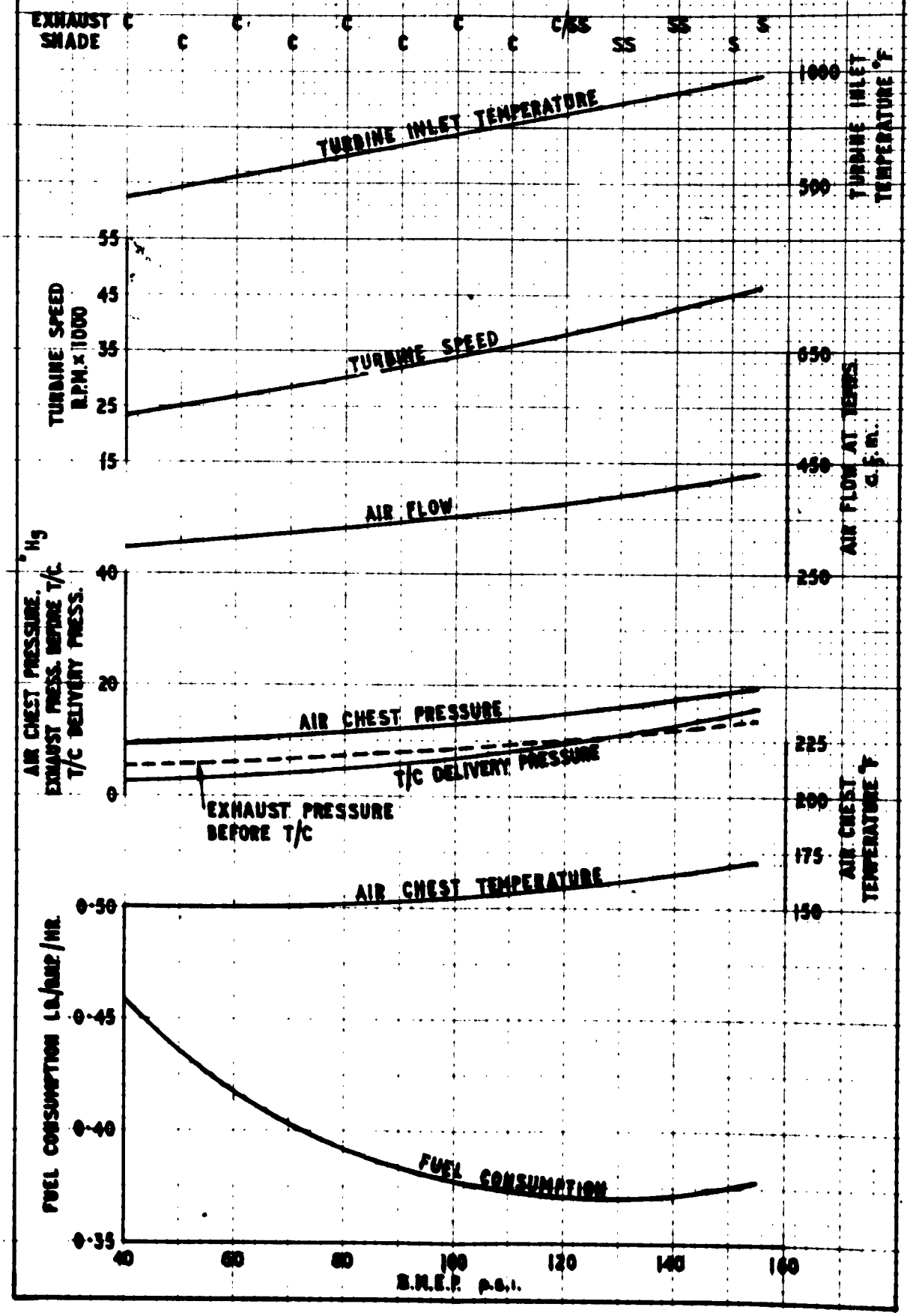
Hours Run by Sample	Unused	152
Flash Point °F.	445	435
Viscosity Kinematic at 100°F c.s.	111.6	172
Pentane Insolubles %	-	0.35
Benzene Insolubles %	-	0.24
ACIDITY (Electrometric Titration)		
Initial pH	8.2	5.5
Total Acid Number pH11 mg.KOH/g.	1.02	4.1
Total Base Number pH 4 " "	8.6	0.85
Carbon Residue (Ramsbottom) %	1.31	2.66
Sulphated Residue %	1.43	1.79
Water %	Nil	Less than 0.01
A.O.L. Reference No.	4075/62	660/63

A.E.I. REPORT No. 375

FIG. 1

FODEN F.D.G. MK. VII MARINE ENGINE. 1500 R.P.M.

PERFORMANCE CHARACTERISTICS WITH HOLSET MODEL 4 TURBO-CHARGER & 7½% ROOTS BLOWER.



A.E.L. REPORT No. 975
FIG. 2

FODEN FD6 MK VII MARINE ENGINE - 1600 R.P.M.

PERFORMANCE CHARACTERISTICS WITH HOLSET MODEL 4 TURBO-CHARGER & 70% ROOTS BOOST

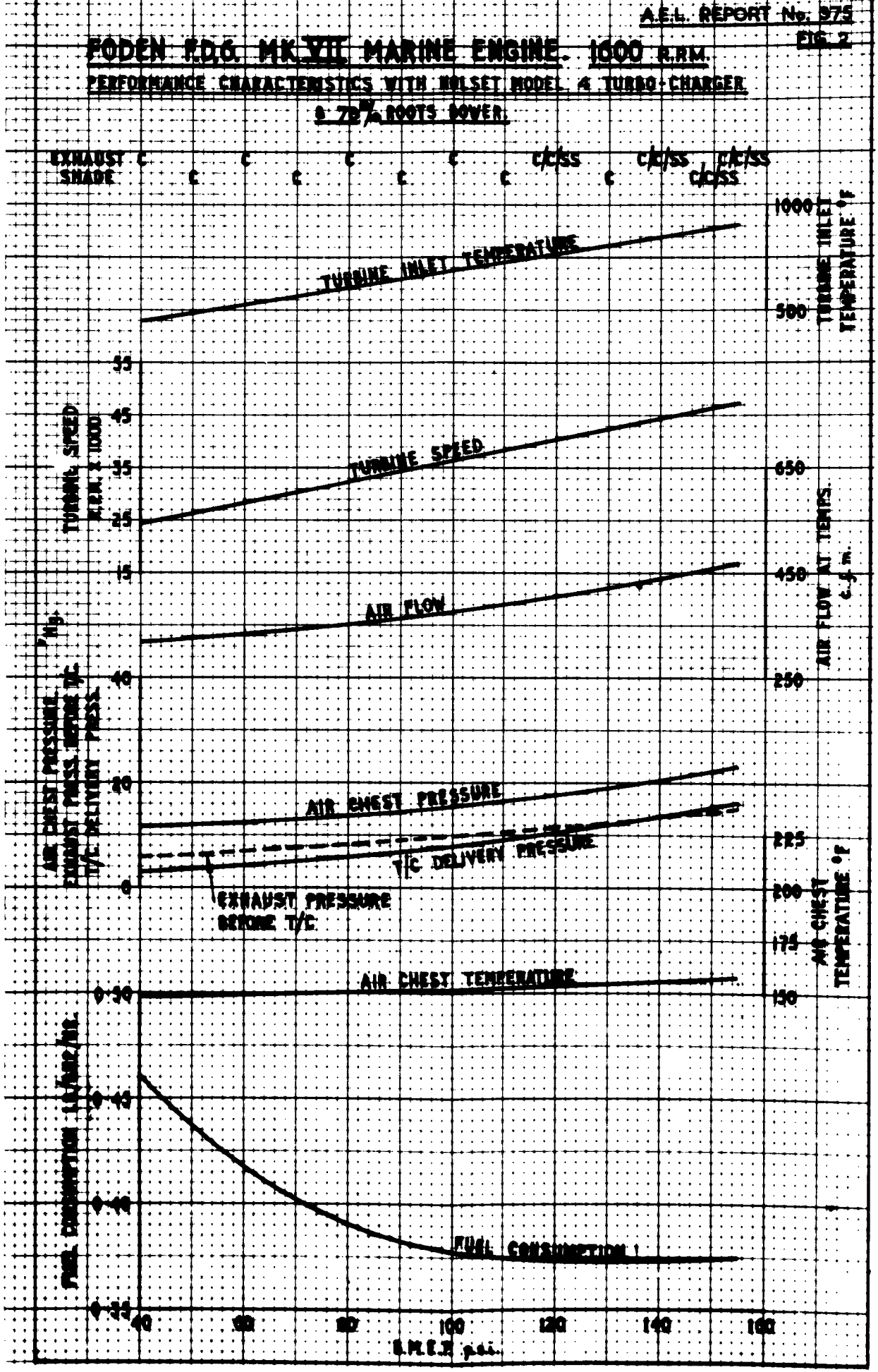
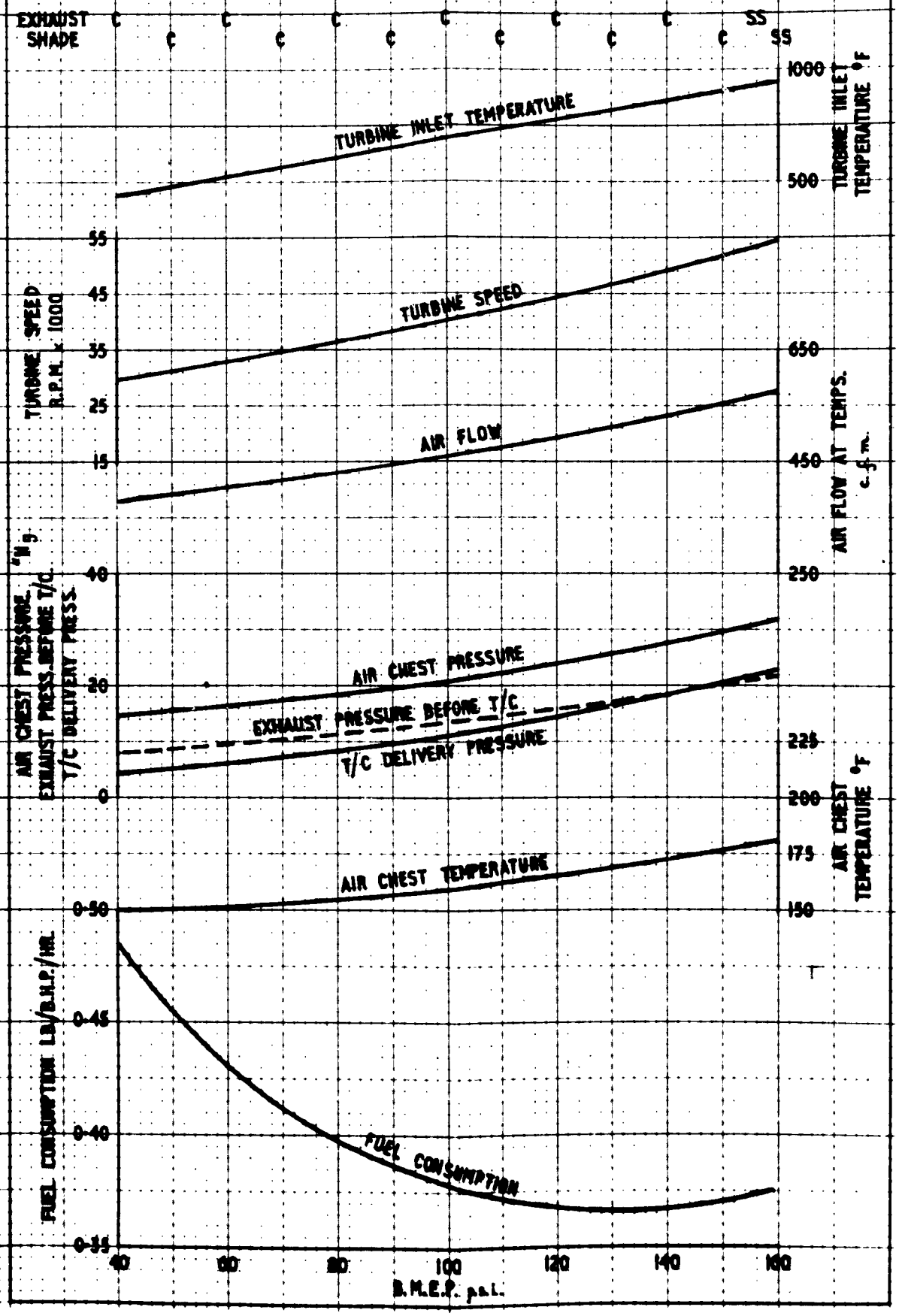


FIG. 14

FODEN F.D.6. MK. VII MARINE ENGINE. 1800 R.P.M.

PERFORMANCE CHARACTERISTICS WITH HOLSET MODEL 4 TURBO-CHARGER & 78% ROOTS BLOWER



A.E.L. REPORT No. 373

FIG. 4.

FODEN F.D.6. MK. VII MARINE ENGINE. 2000 R.P.M.

PERFORMANCE CHARACTERISTICS WITH HOLSET MODEL 4 TURBO-CHARGER & 78% ROOTS BLOWER.

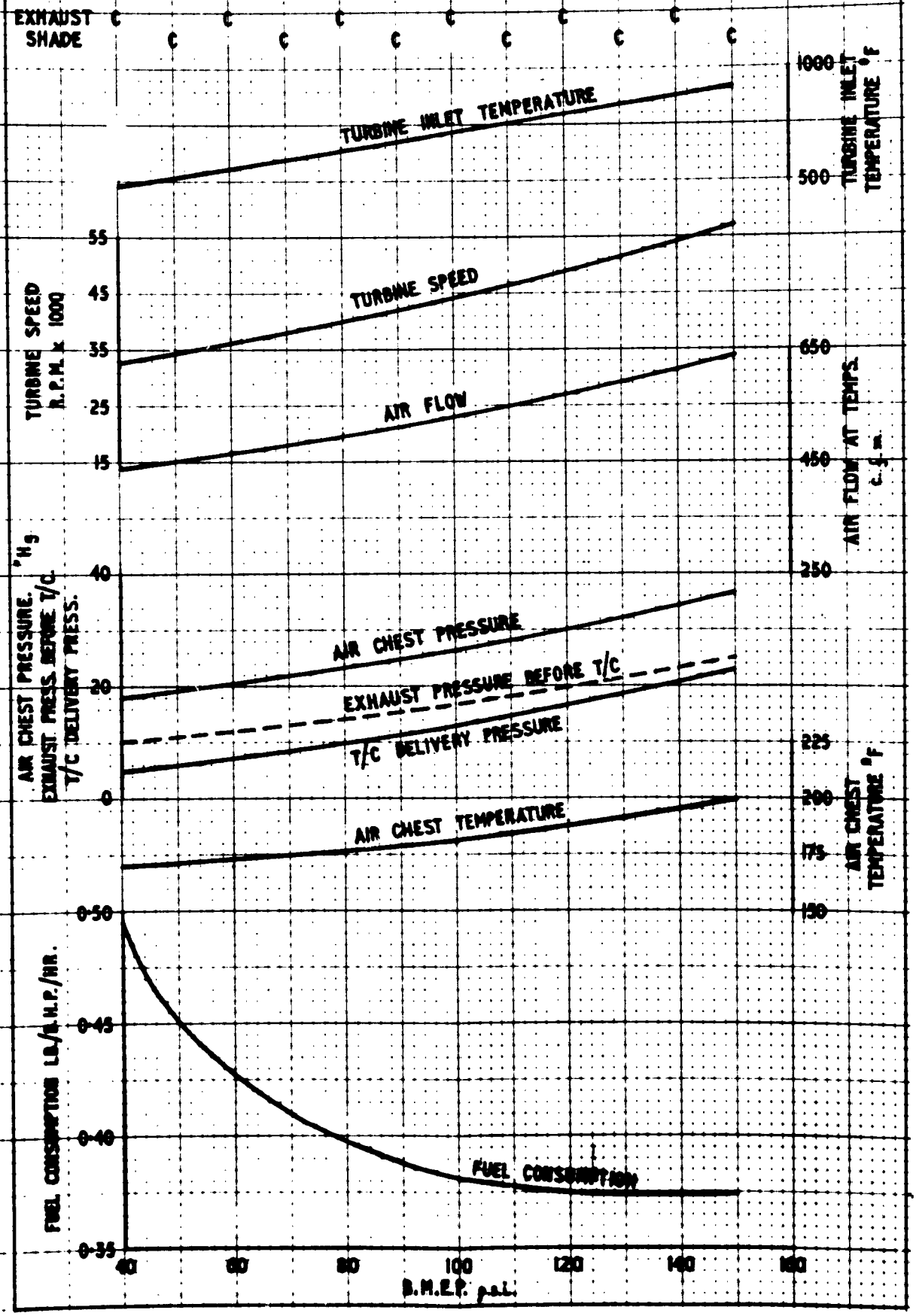
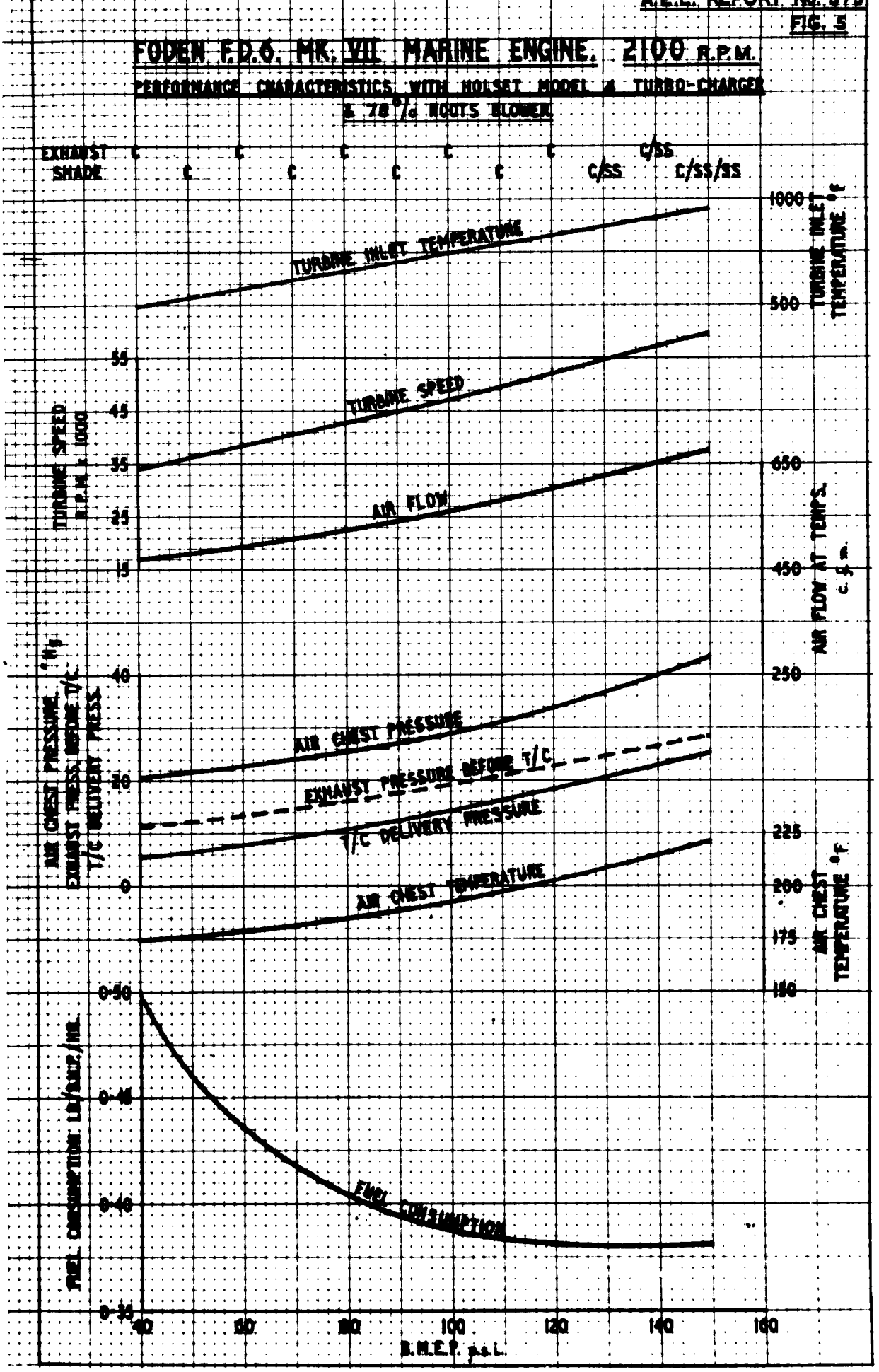
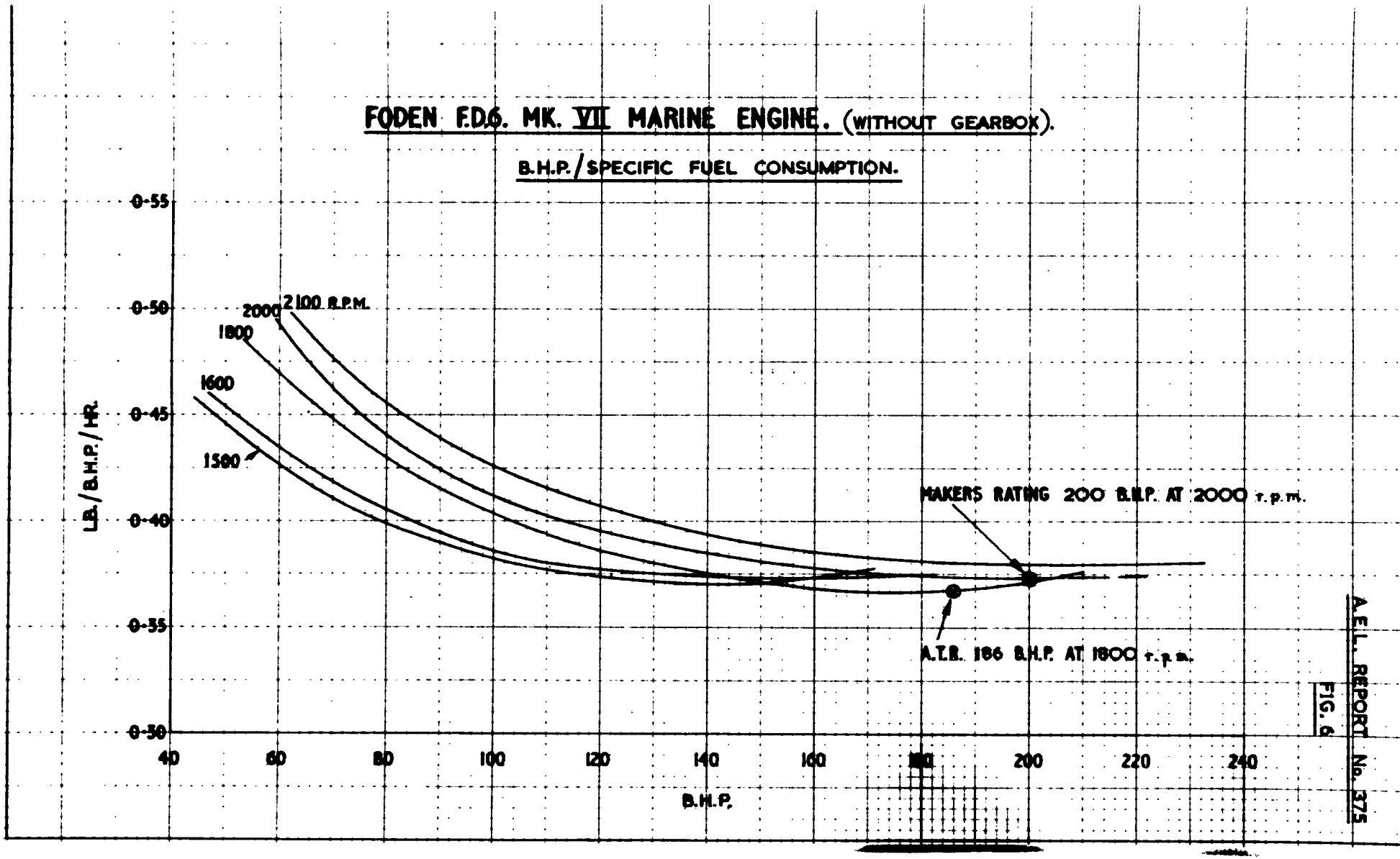


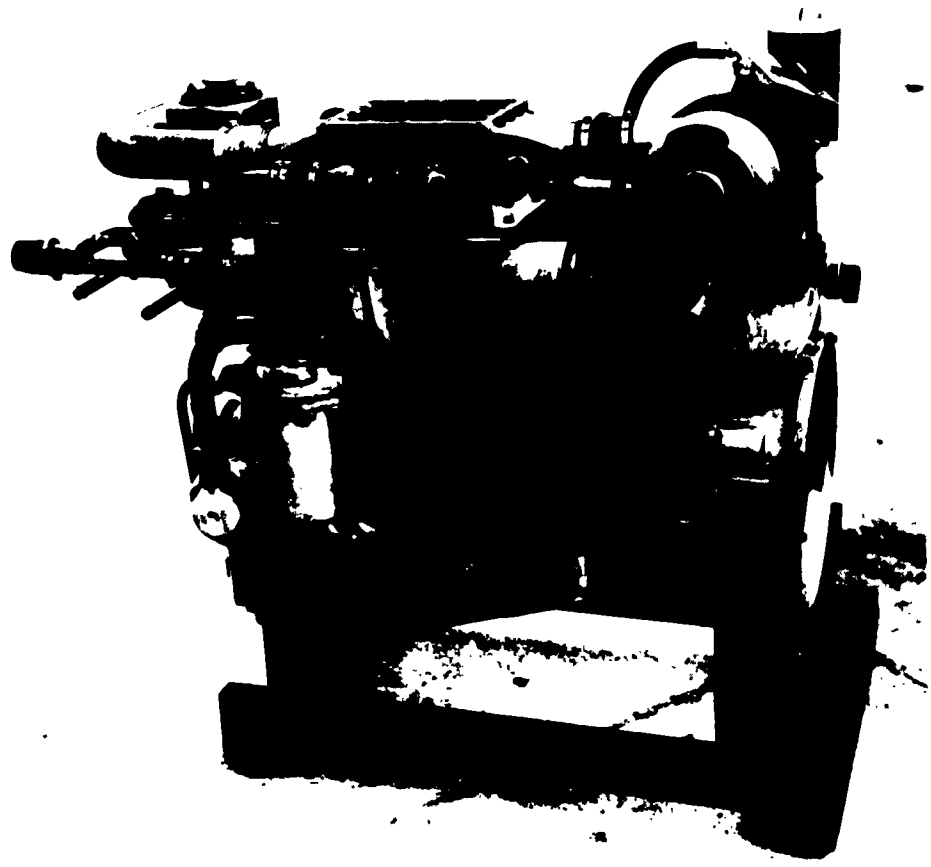
FIG. 5

FODEN F.D.6. MK. VII MARINE ENGINE. 2100 R.P.M.

PERFORMANCE CHARACTERISTICS WITH HOLSET MODEL 4 TURBO-CHARGER & 78 % ROOTS BLOWER




FODEN F.D.6. MK. VII MARINE ENGINE. (WITHOUT GEARBOX).
B.H.P./SPECIFIC FUEL CONSUMPTION.
LB./B.H.P./HR.
0·55
0·50
0·45
0·40
0·35
0·30
2100 R.P.M.
2000
1800
1600
1500
MAKERS RATING 200 B.H.P. AT 2000 r.p.m.
A.T.B. 186 B.H.P. AT 1800 r.p.m.
40
60
80
100
120
140
160
180
200
220
240
B.H.P.
A.E.I. REPORT No. 375
FIG. 6



FODEN F.D.6. ENGINE.

CRANKCASE HALVES

CAP HALVES

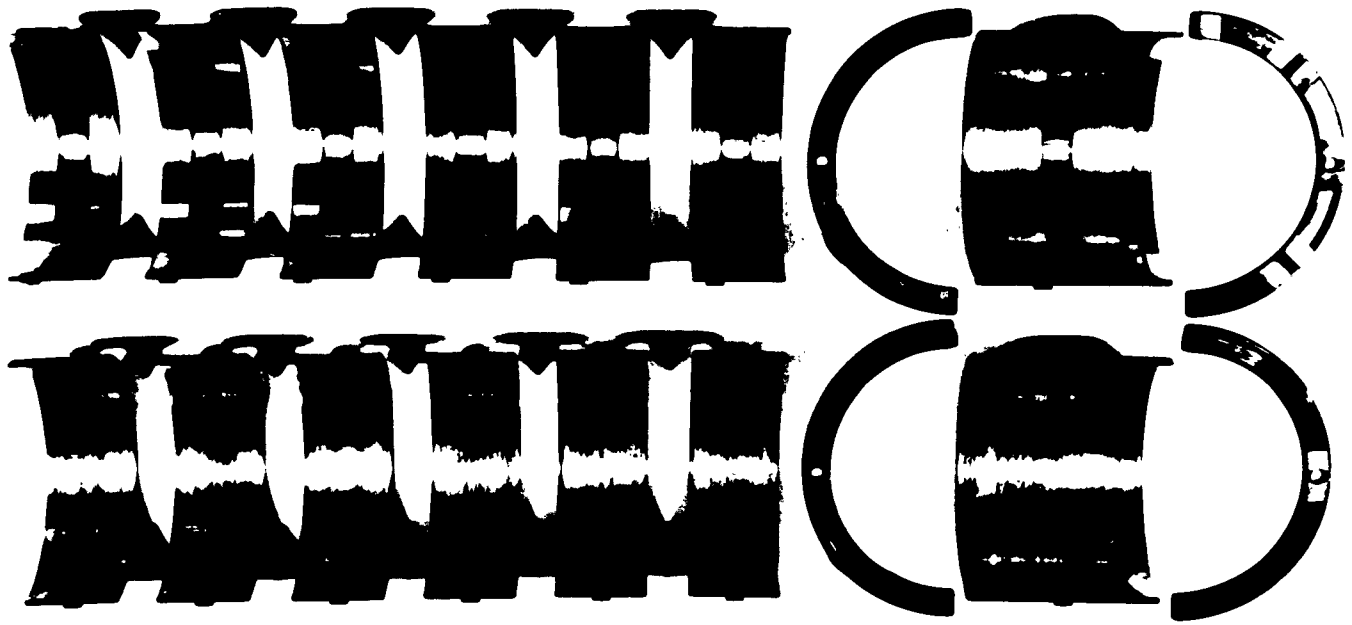


FIG.7. MAIN BEARING SHELLS AND THRUST WASHERS.

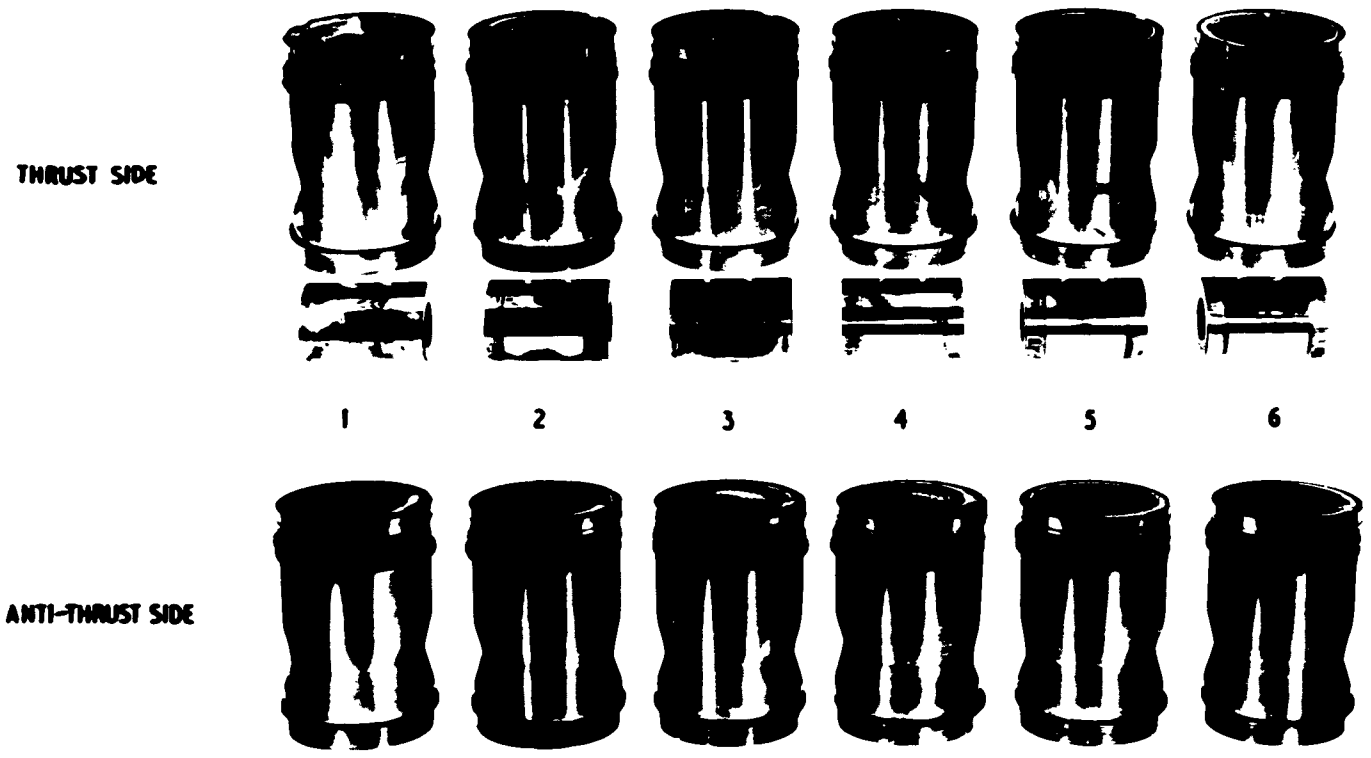


FIG.8. PISTONS AND GUDGEON PINS.

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FIG. 8.

ROD HALVES

CAP HALVES

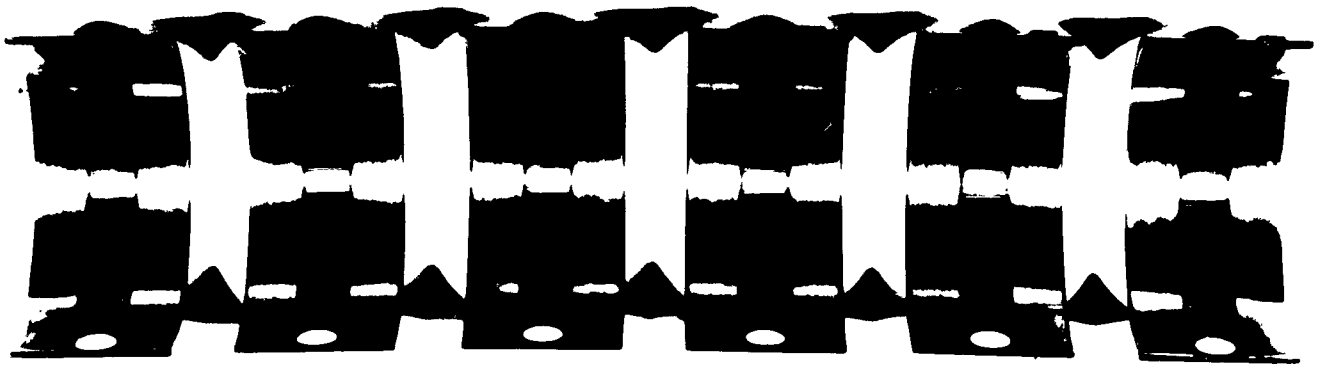


FIG.9. LARGE END BEARING SHELLS.

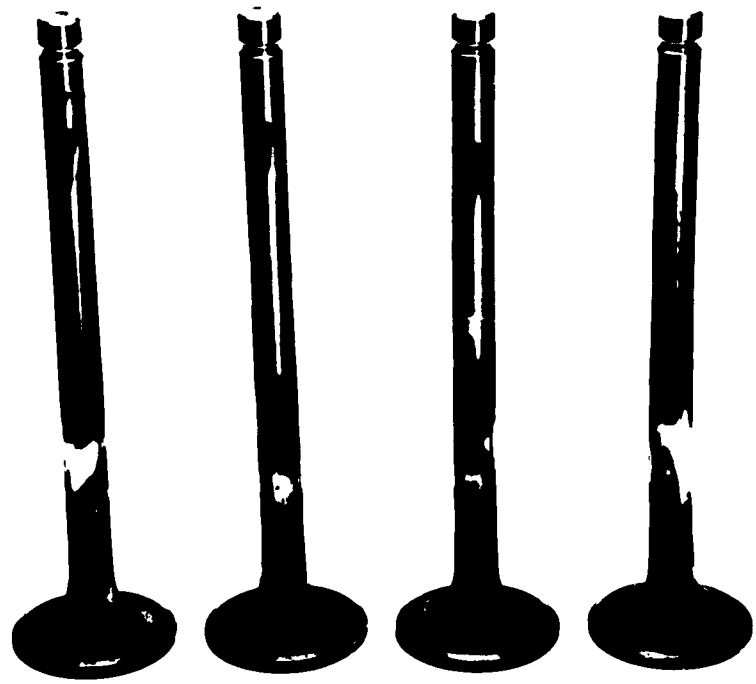


FIG. 10. REPRESENTATIVE EXHAUST VALVES.

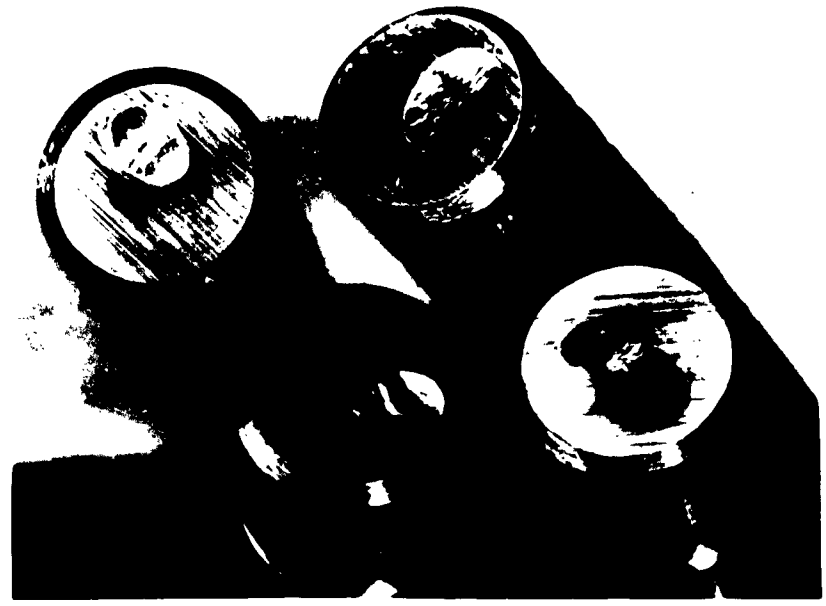
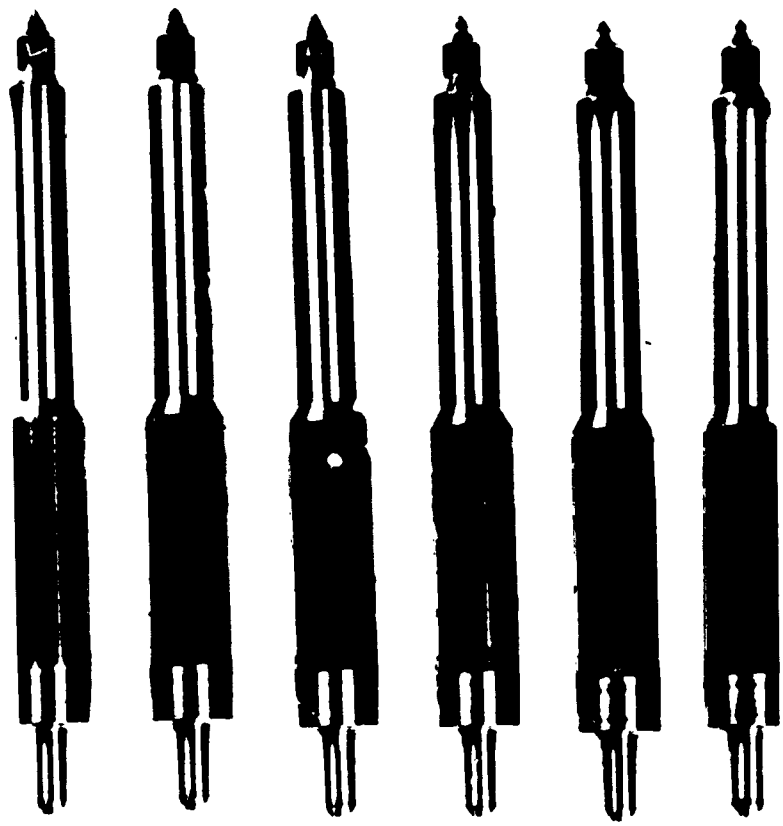


FIG. 11. VALVE STEM ENDS.



1 2 3 4 5 6

FIG.12. INJECTOR NEEDLES.

FIG.13. TURBINE CASING NOZZLE RING AND WHEEL.

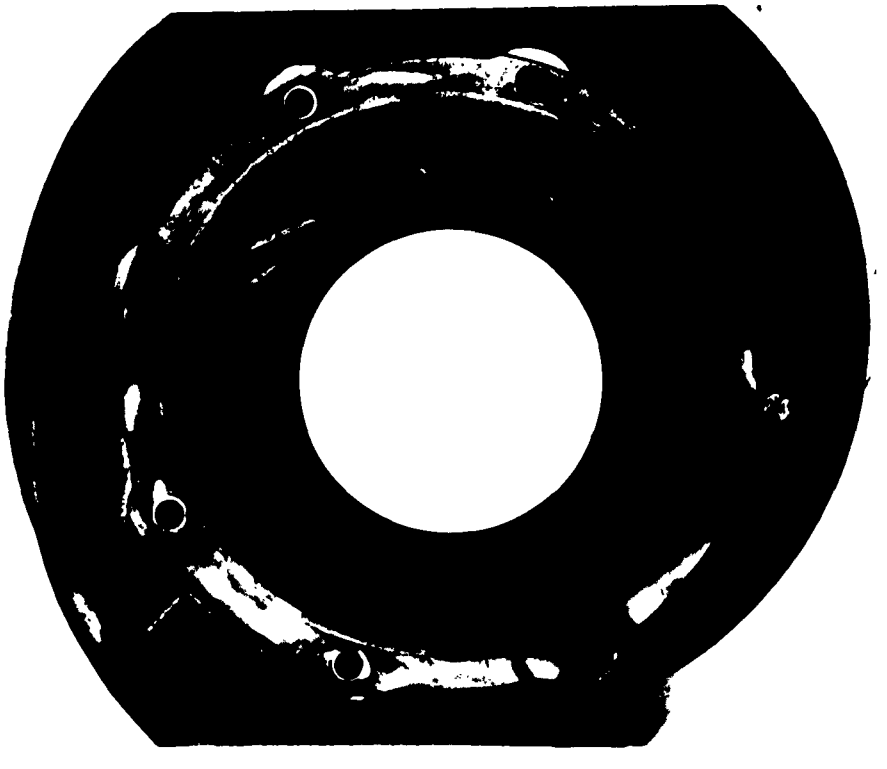


FIG.14 TURBINE HOUSING.

FIG. 15. COMPRESSOR ROTOR AND HOUSING.

FIG. 16. COMPRESSOR EXTENSION.

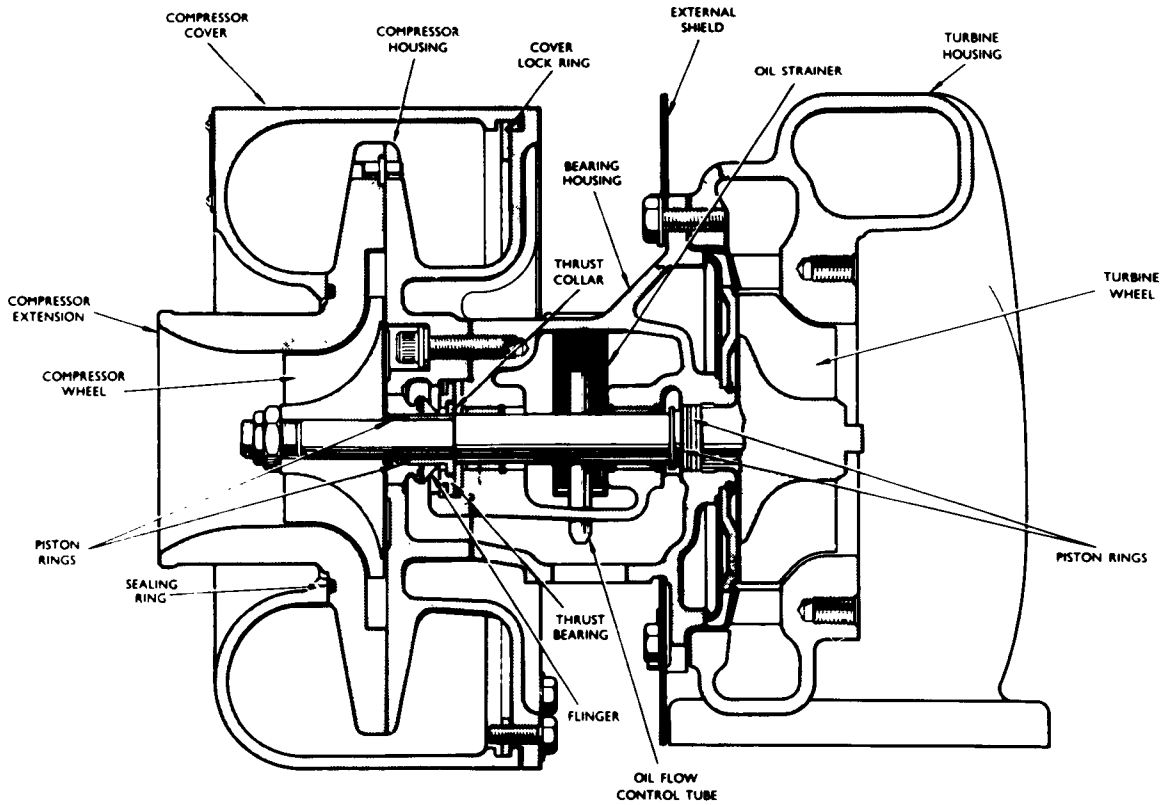


FIG.17. SECTIONAL VIEW 'HOLSET' MODEL 4 TURBOCHARGER.

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FIG.17.

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