MOTOR TORPEDO BOAT

Engineer's Handbook

NAVY DEPARTMENT
BUREAU OF SHIPS

NAVY DEPARTMENT

BUREAU OF SHIPS

Washington, 15 September 1943.

This handbook is presented as a handy guide to proper inspection, operation and maintenance of PT boat engineering equipment. Information for it has been carefully selected not only from manufacturer's manuals but also from the first-hand experience of operating personnel, in an effort to present the pointers most helpful in preventing the mistakes, misuse and neglect that necessitate major repairs.

PT boat operating personnel, base forces, as well as boat crews, should have access to this book. To encourage ready reference, it is published in a handy pocket size.

Additional copies of this handbook may be obtained from the Bureau of Ships.

E. L. COCHRANE
Vice Admiral, USN,
Chief, Bureau of Ships.

MOTOR TORPEDO BOAT

ENGINEER'S HANDBOOK

(Engine Room Force)

Including Operation of the
PACKARD 4M-2500
MARINE ENGINE

Prepared For Bureau of Ships
by
MOTOR TORPEDO BOAT REPAIR
TRAINING UNIT
NEWPORT (MELVILLE) R. I.

NavShips 250-222-7

RESTRICTED

TABLE OF CONTENTS

Engine Specifications Packard 4M–2500 Marine Engine Types W–8 and W–14

Specifications

Cylinder arrangement—Vee type	60°.
Number of cylinders	12.
Bore and stroke	6⅜″ x 6½″.
Total displacement (cu. in.)	2,490.
B. M. E. P. at rated speed and power (lb. per sq. in.):	
W–8	159.
W–14	179.
Compression ratio	6.4: 1.
Number of valves per cylinder	4.
Number of main bearings	8.
Firing order	1R–3L–4R–5L. 2R–1L–6R–4L. 3R–2L–5R–6L.
Rotation (viewed from reverse gear end)	R. H.
B. H. P. rating:	
W–8 (at 2,400 R. P. M.)	1,200 H. P.
(Emergency) at 2,500 R. P. M	1,350 H. P.
W–14 (at 2,400 R. P. M.)	1,350 H. P.
(Emergency) at 2,500 R. P. M	1,500 H. P.
Supercharger ratios:	
W–8	6.53: 1.
W–14	6.87: 1.
Weight (with reverse gear)	2,950 lb.

Standard Clearances and Adjustments

Piston in cylinders	.026″ to .032″.
Piston ring gap (all rings not chrome plated)	.025″ to .035″.
Piston ring gap (top chrome plated)	.050″ to .060″.
Piston pin in bushings	.001″ to .002″.
Piston pin in piston	.00075″L to .0005″ T.
Connecting rod bearing to crankpin (dia. clear.)	.0035″ to .005″.
Connecting rod bearing to blade rod (dia. clear.)	.0045″ to .0035″.
Connecting rod bearing end clearance	.008″ to .016″.
Crankshaft bearing: (dia. clear.):	
Bearing Nos. 1, 2, 3, 4, 5, 6, and 7	.0035″ to .005″.
Bearing No. 8	.0025″ to .0045″.
End clearance bearing No. 1	.007″ to .010″.
Valve rocker-roller clearance:	
Inlet	.007″ to .009″.
Exhaust	.010″ to .012″.
Valve stem clearance:	
Inlet	.0025″ to .0045″.
Exhaust	.006″ to .0085″.

Engine Timing

Valve timing—time on inlet	No. 6L, No. 1R.
Valve rocker-roller clearance for timing	.017″.
Inlet valve opens T. D. C. (with 0.017″ valve clearance)	
Ignition timed No. 1R cylinder (compression stroke) 36°, (+1° or −1°) B. T. D. C. (spark full adv.)	
Magneto points adjustable to synchronize breaker points	
Spark plug gap	.015″ to .018″.

General Boat Data

Elco and Higgins Boats

Lubricating oil:

Specification AN–VV–0–466a Grade 1100	SAE 50.
Pressure (lb. per sq. in.)	90 to 105.
Oil tank capacity (fill to ⅝)	30 gal.
Capacity (G. P. M.) at 2,400 R. P. M	20–24.

Fresh water cooling system:

Tank capacity:	
Elco	5 gal.
Higgins	5 gal.
Pump capacity (G. P. M.) at 2,400 R. P. M	200–300.

Sea Water Pump:

Capacity (G. P. M.) at 2,400 R. P. M	60.

Fuel system:

Fuel specification*	100 Oct.
Fuel pump capacity (G. P. M.) at 2,400 R. P. M	4.
Fuel pump pressure (P. S. I.)	6 to 7.

Fuel tank capacities:

Elco Center (fill to ⅝)	1,300 gal.
Elco Stbd. (fill to ⅝)	850 gal.
Elco Port (fill to ⅝)	850 gal.
Higgins (2) forward	800 gal.
Higgins (2) aft	700 gal.

Fuel Strainers.

All new boats and many of the old boats in the field are being equipped with the dual model GG–3112–20 Skinner Gasoline Filter for the removal of dirt and water from the

*See Operating Manual for use of lower octane fuels.

gasoline. The old type filter, which is being replaced, uses a filtering element made of closely spaced (clearance 0.0015) spiral wound wire. The Skinner filter is made of polymerized paper discs and an additional screen is provided at the fuel inlet of the carburetor.

Wobble Pump.

A "Thompson electric motor driven fuel pump" is provided on Elco installations, and some Higgins Boats. Other Higgins Boats have an AERO hand wobble pump to provide the initial 6 to 7 pounds fuel pressure needed for starting.

Electrical Equipment

Batteries: Lead acid type

Elco 77′ (Exide) 6XHM–13	100 A. H. cap.
Elco 80′ (Exide) 6XCK–21–35	150 A. H. cap.
Higgins 78′ Exide 6–DS–25–35	200 A. H. cap.

Generators: Main engines

Engine	W–8.
Gear ratio	2.183:1.
Delco Remy Model No. 1106703	28 v. 75 amp.
Engine	W–14.
Gear ratio	2.183:1.
Delco Remy Model No. 1106709	28 v. 40 amp.

Generators **(Auxiliary) varies with installations**

Capitol: Model–ICK	5.5 kw.
Generator—Eclipse, Type 914, Model 13	28.5 v., 200 amp., 5.5 kw.
Lawrence: Model 30–B	5 kw.
Generator—G. E. Model 2CM41A2	28.5 v., 175 amp., 5 kw.
U. S. Motors—Model BXB	28.5 v., 88 amp. 2.5 kw

Regulators: Main engine

Engines W–8:	
Delco Remy Model No. 1118466 (vibrating finger type)	28 v., 75 amp.
Engines W–14:	
(Built after 3/1/44) Delco Remy Model No. 1118405 (carbon pile type)	28 v., 40 amp.

Regulators: Auxiliary

Capitol:	
Eclipse, Type 1042, Model 20WG	28.5 v., 200 amp., 5.5 kw.
Lawrence:	
G. E. Spec. M416, Type GBD–1E7	28.5 v., 175 amp., 5 kw.
U. S. Motors:	
Manually controlled. Rheostat	

Starter

Cranking motor:	
Delco Remy Model No. 824	24 v.
Starter Armature to Engine ratio	24.75: 1.

Heat Exchangers (varies with installations)

The "Elco" type exchanger is a combination oil cooler and water heater exchanger and is being replaced by the "Harrison" type coolers.

The "Harrison" type are separate coolers for water and oil.

Oil Filters

An oil "IN" strainer is provided in the supply line between the tank and oil pump. An oil "OUT" strainer of the "Edge" type located between the oil pump and oil cooler (heat exchanger) insures that only clean oil (free from dirt, sediment, and foreign matter) reaches the engine.

All engines, after engine No. 7566, are equipped with a "Cuno" pressure oil strainer located in line between oil pump and bearings which subjects all engine oil to extremely fine filtering. Engines prior to No. 7566 are being converted, in the field, to incorporate the new Cuno strainer.

Propeller Shaft to Engine Ratios

Forward*	1: 1.
Reverse	1: 1.

All propellers are right hand.

MAINTENANCE INSTRUCTIONS

Periodic Inspection Schedule

A. Daily.

1. With fuel pressure up, check carburetor, fuel pump, valves, fuel lines and connections for leaks.

2. Check level of water in expansion tank. Inspect all water lines and hose connections for leaks. Check Prestone (in winter).

3. Check level of oil in supply tank; inspect all oil lines, filter and connections for leaks.

4. Check engine for any external oil or water leaks.

5. Clean the "Edge" type oil out strainer by revolving handle one full turn.

6. Check rotation of Cuno oil strainer by reversing sleeve nut.

7. Check the battery electrolyte hydrometer reading and level. Check electrical connections for tightness.

*On Elco boats equipped with Vee-drive, the port and starboard propeller shaft ratios to the engine are 29: 30. The center propeller shaft ratio 1 : 1.

8. (Higgins) Check the propeller shaft steady rest bearing for adequate lubricant and stuffing box (gland) for leaks.

9. Drain fuel filters at each refueling.

10. Check all throttle and spark control bolts and nuts and pins for tightness and proper safetying.

B. Every 25 Engine Hours.

1. Check magnetos, distributor block (cap) and rotor finger.

2. Clean magneto air vents and fuel pump air vents and carburetor air cleaner.

3. Inspect primer lines, distributor and magneto ventilating lines for leaks.

4. Oil tachometer magneto. (Light oil only.)

5. Drain the "Oil Out" and the "Cuno" pressure oil strainer through bottom plug. Check for possibility of salt water in oil, indicating leak in oil side of heat exchanger. Also check for metal particles indicating possible engine failure.

6. Check for security of generator, starter, magneto, distributors, reverse gear lever, reverse gear toggle pins and reverse gear and vee drive flange bolts.

7. Check exhaust manifold flange bolts for tightness. Check supercharger and carburetor flange bolts for tightness.

8. Check engine hold down bolts, reverse gear bolts and vee drive hold down bolts for tightness.

9. Check propeller shaft for freedom of rotation.

10. Check steering mechanism for binding or lost motion. Check steering control shaft for proper support.

11. Inspect all wiring for tight connections at all switches, junction boxes, magneto ground leads, overspeed cutout connections, generator and starter connections and ignition harness.

C. Every 50 Engine Hours.

1. Clean cartridge of "oil in" strainer and "Cuno" pressure oil strainer.

2. Clean magneto breaker housing and examine for broken or worn cam followers, damaged felts and excessive lubrication. Clean and synchronize breaker points and check timing.

3. Check valve clearances, valve springs and rocker arm rollers every 50, 150, 250 hours. Intake 0.007 to 0.009; Exhaust 0.010 to 0.012.

4. Clean starter and generator commutor with "00" sandpaper.

D. Every 100 Engine Hours.

(In addition to the items listed below check all the items covered in the 25 or 50 hour inspections.)

1. Remove and clean carburetor fuel inlet screen.

2. Remove drain plugs in carburetor main fuel chamber, diaphragm vent space, and accelerating pump chamber; install plugs securely and rewire.

3. Lubricate carburetor cam, roller, and metering pin. Check carburetor for flooding or leakage.

4. Remove fuel pump and lubricate drive splines and bearings.

5. On the "Edge" type oil strainer, remove element and clean.

6. Change engine oil.

7. Oil starter (commutator end) bushing.

8. Install new or reconditioned spark plugs.

9. Remove magneto and inspect rubber drive coupling.

10. Check clutch spring compression and record.

OPERATING INSTRUCTIONS

A. Preliminary Operations.

1. Before going down the ladder to engine room, check that emergency switch on bridge panel is in "ON" position.

2. Make sure that ventilator covers are removed. Then start ventilating fan to remove any gasoline fumes from engine room.

3. Check batteries—electrolyte gravity and level, tighten electrical connections.

4. Check fuel supply. If tanks are low, refer to "special refueling instructions" to refuel.

5. Check fresh water cooling supply. Supply tank should be ⅞ full.

6. Check oil level in oil supply tanks which should be ⅞ full.

NOTE.—On a new engine installation before starting for first time, pour a gallon of engine oil into reverse gear through one of the openings under the small cover plates.

7. Make sure that all muffler controls are in "Open" position.

8. Turn handle on the "Edge" type oil-out strainer two turns clockwise.

9. Remove the carburetor air cleaner covers.

10. Close all exhaust manifold drain valves.

11. Make sure that reverse gear lever is in *neutral.*

3. Instrument Panel Operation.

1. a. (Elco) Turn on the two key switches and the two toggle switches on main battery load switch panel. Turn on battery switches Nos. 1 and 2 on instrument panel. Turn on engine room load and main feed toggle switches.

b. (Higgins) Turn all "emergency switches" to "UP" position. Also turn on two battery switches.

2. Turn on the battery parallel switch and holding coil switch.

3. a. (Elco) Turn starting and ignition switch to "Starter" position to check engine for free turning.

CAUTION: Do not hold switch on for more than 30 seconds.

b. (Higgins) Push in on starter and safety buttons with the ignition switch in the "OFF" position, to check engine for free turning

CAUTION: Do not hold switch on for more than 30 seconds.

NOTE.—On a new engine installation before starting for first time, check for free turning by rotating with cranking bar. *All switches must be "OFF."* Reverse gear lever in forward drive position.

4. Completing checks, turn OFF battery parallel and holding coil switches until engine is to be started.

C. Fuel Supply Operations.

1. Check fuel level in gas tanks by operating level-ometer pumps or use check sticks.

2. Then select tank and turn both "High and Low" suction valves to the tank selected.

3. a. (Elco) Turn pointer of "Low" suction fuel line valve toward electric wobble pump and pointer of "High" suction valve away from electric wobble pump. Open the three gas manifold valves. Then turn on the electric wobble pump switch to build up the initial fuel pressure. This system applies to all Elco boats up to PT565.

b. (Higgins) Open wobble pump valve and fuel line valve from the tank selected (make sure wobble pump by pass valve is closed), open the three manifold valves. Operate hand wobble pump to build up initial pressure of 6 to 7 pounds. (To check for leaks, close fuel supply valves and observe fuel system for leaks.)

4. Set throttles to the proper position for starting:

a. Throttles closed for starting a cold engine.

b. Throttles slightly open for starting a warm engine.

NOTE: Never use primers unless engine is extremely cold.

D. Starting and Dock Warm-Up.

1. As soon as signal to start the engine is received, turn on the three holding coil and the three booster coil switches. Turn on the battery parallel switch.

2. Set all spark controls in retard position and set mixture control in full rich position. Open all sea water inlet scoops. Make sure all reverse gear levers gine are in neutral position.

3. a. (Elco) Turn the starting switch to the "starter and coil" position until engine starts. As soon as engine starts, turn switch to "Mags. I&E" position.

b. (Higgins) Turn ignition switch to "Start" position and push in on starter and starter safety button. Release buttons as soon as engine starts. Then turn ignition switch to the "Both" position.

4. Close the throttles to the idle position and immediately check oil pressure of all engines. If engine started does not show pressure within 5 seconds stop engine immediately. Locate cause of lack of oil pressure.

5. Turn fuel line valve to through tank suction line.

NOTE: On Higgins boats, open the wobble pump bypass valve.

6. Check for sea water circulation by feeling exhaust manifolds. Check fresh water temperature and regulate scoops accordingly.

7. Signal the "Bridge" when ready to get underway. The "OIL-IN" temperature should be at least 110° F.

E. Underway Operations.

1. Complete the warm-up underway whenever possible. This reduces the warm-up time and reduces possibility of fouling spark plugs.

2. As soon as boat captain gives the signal to shift gears, engage shifting lever with a smooth positive

motion. Open water-out scoops as soon as boat gets underway.

CAUTION: When shifting from ahead to reverse or vice versa, allow the engines to gain their normal idling speed of 800 to 850 R. P. M., then engage in forward or reverse as the case may be. *Do not slam* it in reverse or forward. *It may stall engine and that may mean the loss of the boat at some time.*

3. Keep careful watch on the gages at all times. As soon as "OIL-IN" temperature reaches 130° F., signal boat captain that boat is ready for full R. P. M.

4. *Instrument panel data.*

Oil pressure	90 to 105 lb.
Oil-out temp	140° to 200° F.
Oil-in temp	130° to 150° F.
Water-out temp	150° to 170° F.
Fuel pump pressure	6 to 7 lb.
Vee-drive oil press	10 to 20 lb.
Vee-drive oil temp	110° to 200° F.

Manifold pressure should be watched and checked with engine R. P. M. according to manifold pressure chart in operating manual.

5. As soon as engine speed has reached 1,200 R. P. M., advance spark on all three engines.

6. At this time if main engine (75-amp.) generators are going to be used, turn on main engine generator switches on main panel. 40-amp. generators may be cut in at 800 R. P. M.

7. Check each engine for water and oil leaks. Check all visible moving parts for vibration and overheating (that is, propeller shaft and steady rest bearing, etc.).

8. Check that nothing obstructs the suction end of self-bailers. Keep a steady watch of the instrument panel.

F. Stopping and Securing Engines.

1. When slowing down, retard spark control at 1,200 R. P. M. regulate, if necessary, the sea water scoops to maintain correct temperatures.

2. Handle controls smoothly and carefully when docking. *Do not let engine stall* by jerking controls into position.

3. After boat is docked and the captain signals to stop the engines, close the fuel supply line valves.

4. When engine stalls from lack of fuel or fuel pressure drops below 2 pounds, shut off ignition switch.

5. Close sea-water scoops, open all manifold drain valves (or plugs) and leave valves open.

6. Shut off all electrical switches not in actual use; secure all auxiliary equipment not in use.

7. Replace air cleaner cover on all engines. Wipe down engines while still warm.

TROUBLE SHOOTING

Capitol and Lawrence Auxiliary Generators

ENGINE TROUBLE SHOOTING

A. Failure to Start.

1. Ignition not turned on or batteries disconnected.
2. (Lawrence) Overspeed cut-out tripped.
3. Lack of fuel.

4. Flooding of carburetor.
5. Water or dirt in carburetor.
6. a. (Lawrence) Magneto breaker points dirty or with improper gap.
   b. (Capitol) Bad contact points in distributor or magneto.
7. Dead coil, shorted or open condenser.
8. Dirty spark plugs.
9. Defective ignition wiring.
10. Incorrect timing.
11. Valve sticking or improperly adjusted.
12. In cold weather—oil too heavy.

B. Low or No Oil Pressure.

1. Dirty or foreign matter under relief valve.
2. Low oil supply.
3. Lack of pump priming.
4. Leak in suction line.
5. Very cold oil.
6. Oil foaming in tank.
7. Dirt in oil screen.
8. High oil temperature.
9. Oil passage plug missing.
10. Excessive bearing clearance.

NOTE.—Oil pressure will vary from 5 to 15 pounds per square inch due to temperature changes. Any abnormal change in oil pressure should be immediately investigated.

C. High Oil Temperature and Consumption.

1. Insufficient oil supply.
2. Low grade or dirty oil.

661628—45——3

3. Worn piston rings (excessive blow-by in crankcase).

4. Improper performance of scavenging pump (Lawrence).

5. Overheated bearings or excessive bearing clearance.

6. Incorrect timing, causing overheating.

7. Improper venting of crankcase.

8. Clogged oil lines or strainer.

9. Piston rings installed improperly (causing blow-by).

10. Foam in oil.

NOTE.—If generator is secured for more than 24 hours, the shut off valve on the "oil in" line should be turned off to prevent crankcase from becoming filled with oil. (Lawrence.)

D. Uneven Running.

1. Spark plugs defective.

2. a. (Lawrence) Magneto points dirty or improperly adjusted.

   b. (Capitol) Distributor or magneto points bad or improperly set.

3. Defective ignition wiring, loose wires, or pulled out wires.

4. (Lawrence) Overspeed cut-out shorting out.

5. Valve trouble; burned, sticking valves or broken spring.

6. Governor surge or loose speed control screw.

7. Fuel mixture bad.

8. Leak in intake manifold, and flanges, or gaskets.

9. Engine overheating.

10. (Lawrence) Magnetos not synchronized.

11. Corroded or rusted linkage (of carburetor, governor, or thermostat).

12. (Capitol) Head gasket blown or leaking.

Auxiliary Generator

Electrical Trouble Shooting

A. Generator Operating Within Rated Speed But Voltmeter Indicates Low Generator Output.

1. Loose electrical connections or high resistance in field circuit.

2. a. Brushes excessively worn or loose in brush boxes.
   b. Brushes binding or not properly set.
   c. Weak brush spring tension.

3. Commutator dirty, worn or pitted.

CAUTION: Use only "00" sandpaper to clean commutator.

4. Armature grounded, open, or shorted.

5. Improper operation of carbon pile regulator.

B. Generator Operating Within Rated Speed But Voltmeter Registers Zero.

1. High resistance in field circuit. (Locate and correct.)

2. Open field circuit. (Locate and correct if possible. Replace generator field frame assembly.)

3. Generator field demagnetized. (Correct by polarizing according to instructions.)

C. Voltage Output Erratic.

1. Unstable operation of carbon pile regulator.

D. Generator Operating Within Rated Speed But No Output Registered on Ammeter.

1. Cut-out relay not closing.
2. Generator field demagnetized. (Polarize correctly.)

E. Ammeter Fluctuates Excessively When Under Heavy Load.

1. Generator system overloaded.
2. Improper operation of generator cut-out relay.

F. Ammeter Reads Off Scale in Wrong Direction.

1. Generator fields polarized in wrong direction. (Correct by polarizing correctly.)

G. Excessive Arcing at Brushes.

1. Brush spring tension weak.
2. Dirty, worn or rough commutator.
3. Brushes worn excessively.

H. Low Charging Rate and a Fully Charged Battery.

No load—normal operation.

I. Excessive Output to a Fully Charged Battery.

1. Voltage regulator unit out of adjustment or defective.

J. Low Battery and a Low Charging Rate.

1. Excessive resistance in circuit. (Charging.)
2. Batteries worn out. Loose connections.

K. Burned-Out Cut-out Relay Points.

1. Generator operating on reverse polarity generally causes this condition.

Main Engine Generators and Regulators

Trouble Shooting

NOTE.—All electrical work must be done by an efficient specialist. It is not the scope of this handbook to describe the methods of repairs, but rather a guide for the operator to locate the trouble and make emergency repairs.

A. Loss of Water in Electrolyte.

1. Frequent addition of water to the battery indicates excessive output to the battery and may be the result of the voltage regulator being set too high.

REMEDY: Reset voltage regulator. If in a tropical climate, adjust electrolyte to proper specific gravity and set voltage regulator accordingly.

B. Low Charging Rate and a Fully Charged Battery.

1. This indicates normal operation. To check this, apply a load to battery. If charging rate comes up, condition is normal.

C. Fully Charged Battery and a Hi-charging Rate.

1. This condition indicates that the voltage regulator is not functioning properly.

C. Voltage Output Erratic.

1. Unstable operation of carbon pile regulator.

D. Generator Operating Within Rated Speed But No Output Registered on Ammeter.

1. Cut-out relay not closing.
2. Generator field demagnetized. (Polarize correctly.)

E. Ammeter Fluctuates Excessively When Under Heavy Load.

1. Generator system overloaded.
2. Improper operation of generator cut-out relay.

F. Ammeter Reads Off Scale in Wrong Direction.

1. Generator fields polarized in wrong direction. (Correct by polarizing correctly.)

G. Excessive Arcing at Brushes.

1. Brush spring tension weak.
2. Dirty, worn or rough commutator.
3. Brushes worn excessively.

H. Low Charging Rate and a Fully Charged Battery.

No load—normal operation.

I. Excessive Output to a Fully Charged Battery.

1. Voltage regulator unit out of adjustment or defective.

J. Low Battery and a Low Charging Rate.

1. Excessive resistance in circuit. (Charging.)
2. Batteries worn out. Loose connections.

K. Burned-Out Cut-out Relay Points.

1. Generator operating on reverse polarity generally causes this condition.

Main Engine Generators and Regulators

Trouble Shooting

NOTE.—All electrical work must be done by an efficient specialist. It is not the scope of this handbook to describe the methods of repairs, but rather a guide for the operator to locate the trouble and make emergency repairs.

A. Loss of Water in Electrolyte.

1. Frequent addition of water to the battery indicates excessive output to the battery and may be the result of the voltage regulator being set too high.

REMEDY: Reset voltage regulator. If in a tropical climate, adjust electrolyte to proper specific gravity and set voltage regulator accordingly.

B. Low Charging Rate and a Fully Charged Battery.

1. This indicates normal operation. To check this, apply a load to battery. If charging rate comes up, condition is normal.

C. Fully Charged Battery and a Hi-charging Rate.

1. This condition indicates that the voltage regulator is not functioning properly.

4. Remove and clean fuel strainers.

5. Remove main fuel chamber drain plug and clean out recess in plug.

NOTE: This plug is a ¼-inch pipe plug and has a 5/16-inch hex. It is installed vertically in main fuel chamber.

6. Remove cam cover, check lever and metering pin for free movement. Check condition of springs. Check for any cotter pins or metering pins that may be missing. Place a few drops of SAE 30 oil on the metering pins, cam, and roller. Replace all cotter pins and safety wire.

Trouble Shooting

The purpose of these notes is to enable the mechanics to diagnose carburetor trouble without removing or dismantling the carburetor. It must be remembered that the carburetor is often blamed for trouble caused by faulty ignition, poor compression, and other causes. The carburetor should be diagnosed only after all other conditions are normal. The idle mixture adjustment is the only adjustment that boat personnel are authorized to make. All other carburetor adjustments must be made by base personnel.

A. Engine Will Not Start.

1. No fuel pressure.
2. No fuel in carburetor.
3. Failure of metering pin operating mechanism.

B. Engine Will Not Idle Properly.

1. Improper idle adjustment.

2. Air leaks between carburetor and engine.
3. Metering pin sticking.
4. Compensator needle valve leaking.

C. Engine Runs Too Rich in Cruising Range.

1. Metering pin sticking.
2. Metering pin or metering cam improperly adjusted.
3. Main air bleed clogged.
4. Compensator needle valve leaking.
5. Compensator spring weak or broken.
6. Main fuel chamber flooding.

D. Engine Runs Too Lean in Cruising Range.

1. Fuel pressure is low.
2. Air leaking into fuel passage.
3. Metering pin or metering cam improperly adjusted.

E. Engine Runs Satisfactorily in Cruising Range But Too Rich at Power Speeds.

1. Fuel pressure too high.
2. Main air bleed clogged.
3. Air leak into diaphragm vent space.
4. Main fuel chamber flooding.
5. Compensator spring weak or broken.

F. Engine Runs Satisfactorily in Cruising Range But Runs Lean at Power Speeds.

1. Fuel pressure too low.
2. Diaphragm vent or vent passages clogged.

3. Compensator spring tension too great.
4. Compensator venturi suction passage clogged.
5. Compensator venturi not seated.
6. Broken compensator diaphragm.

G. Engine Does Not Accelerate Properly.

1. Improper idle adjustment.
2. Accelerator pump check valve leaking or check valve spring broken.
3. Accelerating pump discharge nozzle leaking.
4. Pump diaphragm springs broken.

H. Fuel Level Too High.

The fuel level should be 4¼ to 4½ inches above the adapter plate on the test stand or 1⅝ to 1⅞ inches above the center line of diaphragms. If the fuel level is too high the most probable causes are:

1. Main fuel diaphragm levers bent outward.
2. Torsion spring too tight or stiff.
3. Main fuel diaphragms dry, shrunk, or too tight or stiff.

I. Fuel Level Too Low.

If the fuel level is too low, the most probable causes are:

1. Main fuel diaphragm levers bent inward.
2. Torsion spring too weak.

Engine Trouble Shooting and Corrective Measures

Packard 4–M–2500 Marine Engine

Since complaints on the performance of the Packard 4–M–2500 Marine Engine tends to vary with individual installations, it is difficult to locate the cause of the trouble without first studying the symptoms. In such cases it is best to consider what possible causes there are for the trouble at hand and then check them one by one, starting with the most likely cause. To help locate such troubles are the following suggestions:

A. Hard Starting or Failure to Start.

1. *Lack of Fuel.*—Check whether there is enough fuel in the tanks (using levelometer), and whether valves are turned on and lines correctly connected. Check if fuel pressure registers when using wobble pump. If all this fails to show cause of trouble, there may be an obstruction in the fuel lines or filter.

2. *Under Priming.*—The use of the primer is only necessary in very cold weather. If the primer is not used for a long time, the packing may dry out and the primer will not operate correctly. It should then be removed to check its condition and for obstructions in the lines. The primer should be primed with light oil before replacing.

3. *Over Priming.*—A more common cause for failure to start is that the supercharger and manifold are flooded due to improper throttle setting or excessive

use of primer. *To clear the engine of this condition, rotate engine with starter (cranking motor) through several revolutions, with the throttle open and the switch off. Then close throttle, turn on switch and start engine.

4. *Throttle Opening (Incorrect).*—It is important to have the throttle set so that the engine idles between 800 and 850 R. P. M. when not in gear. This position may vary with the individual installation and will have to be determined by experience. It is important to have the throttle closed when starting a cold engine. The throttle should be slightly open when starting a warm engine.

5. *Mixture Control (Improperly Set).*—The mixture control must be set in "full rich" when starting engine.

6. *Spark Plugs.*—Defective or wet plugs will cause hard starting. The plugs should be removed, cleaned, gap adjusted and be checked in a bomb at 200 pounds per square inch pressure. A new set of plugs may be installed for a quick check.

7. *Ignition Wiring (Defective).*—Examine wiring harness for chafing, corrosion and oil soaking. A common type of insulation failure is the burning of the carbon track on the insulating sleeve in the spark plug elbow.

8. *Switch or Ground Leads (Defective).*—A defective switch may ground the magneto even in the "ON" position. If the ground wires to the switch or overspeed cut-out are not properly insulated, this will

*A recommended method is to remove the drain plug in bottom of supercharger, draining out the fuel and replace plug.

ground out the magneto. Both complaints may be checked by disconnecting the ground leads at the magneto and starting the engine. *It must be remembered that when this is done, the engine will continue to run even after the ignition switch is shut off.*

9. *Overspeed Cut-out (Tripped).*—If the engine fails to run on the magneto, first check is to make sure the overspeed cut-out has been reset. Push the red button all the way down, then push it down the second time to make sure it stays down.

10. *Magneto Not Working.*—Weak breaker springs, worn, burned, or dirty contact points, defective coils or condensers, or a short circuit within the magneto are the most common causes. To check if the magneto is firing, disconnect one or more plug wires and hold them ⅜ inch from engine while it is being turned over with the starter (cranking motor). NOTE.—*Be careful that there is no gasoline or vapor near engine.*

11. *Distributors.*—In checking distributors, make sure that current is reaching distributors. Disconnect H. T. wire (running from magneto to distributor) at distributor cap and hold end near some part of engine and observe if it sparks while the engine is being turned over with starter. In checking distributor, look for cracked distributor cap or rotor (finger); also for carbon tracks on cap and rotor. Check for burned or corroded electrodes and carbon brushes.

12. *Booster coil.*—The booster coil furnishes the spark for starting by firing the intake plugs through the right distributor. If the engine will not start on booster coil and will on magneto (I&E), it is assumed that the

booster coil is not operating properly. Remove booster coil and service as per overhaul procedure.

13. *Incorrect Timing.*—Wear on the cam follower may retard the magneto timing. Otherwise, there is no chance for the magneto or distributor timing to change, except as a result of work performed on the engine. Recheck according to timing procedure.

14. *Starter Does Not Crank Engine.*—a. If the starter does not rotate with the button depressed, the cause may be a dead battery, loose connection, bad switch contacts, faulty cranking motor. If any of these conditions exist, check with voltmeter as per electrical trouble shooting.

b. If the starter rotates but does not crank the engine, it may be: Bendix pinion not engaging ring gear (check by depressing starter detent), Bendix clutch slipping. Remove starter and examine engine if it is free to rotate (check with cranking bar). Cold oil is often the cause of this.

B. Failure to Stop.

1. *Open Ground Connection.*—Loose ground terminals at magneto, overspeed cut-out, junction box, or at panel switch. Panel switch may not be grounded properly. Stop engine by shutting off fuel line valve or grounding overspeed cut-out and magneto primary circuit.

2. *An Overheated Engine.*—Will continue to run after the switch has been shut off. It can be stopped by shutting off fuel valve. Let engine cool down and locate trouble of overheating.

C. Loss of Engine R. P. M. Low Power—Uneven Running.

This complaint may be caused by any number of the causes enumerated under hard starting. In addition there are the following causes that may show up when the engine is running and the boat underway. If this trouble occurs on only one or two engines, the most probable causes are:

1. *Mixture Too Rich.*—If the engine rolls at idling speed and the exhaust is black and smoky, it may indicate the mixture is too rich. If no improvement results from adjusting idle adjustments, the carburetor should be checked by a competent specialist. Rich mixture is usually indicated by high manifold pressure at idling speeds.

2. *Mixture Too Lean.*—Fast idling and overheating are symptoms of this complaint. It may be caused by an obstruction in the fuel system such as a clogged fuel strainer. It may also be caused by an air leak into the intake manifold. It will usually be indicated by high manifold pressure.

3. *Poor Fuel.*—If the engine occasionally misses a few explosions or misfires, it may be due to dirt or water in the gas. If the strainers are dirty, the tanks should also be checked. The most common cause of water in the fuel is condensation in the tanks. It is therefore advisable to refill the tanks as soon as possible after each boat operation.

4. *Loss of Compression.*—If the engine is near its overhaul time, worn pistons, rings, and cylinders may cause a loss of compression and can logically be con-

sidered the possible cause of low power, loss of R. P. M. and uneven running. Valve grinding and replacements of pistons, rings and cylinders are a base operation.

5. *Ignition.*—After checking compression, check the ignition system as outlined in "Servicing the Ignition System."

6. *Other Causes.*—It must be remembered that roughness, loss of engine R. P. M., and low power can be caused by a number of things other than the engine. Most prominent among these are:

a. Overload.
b. Poor distribution of load.
c. Fouled boat bottom.
d. Fouled rudders and propellers that are corroded, nicked, bent, or wrong pitch.
e. Strut bearing too tight.
f. Engine out of line.
g. Low fuel pump pressure.
h. Throttle not operating properly.
i. High exhaust back pressure.

These conditions are indicated usually by high manifold pressure and loss of engine R. P. M.

Trouble Shooting (Cooling System and Oiling System)

A. High Water Out and Oil in Temperatures.

These are usually caused by a lack of sea water circulating through heat exchanger. It may be caused by an air pocket in the heat exchanger which can be bled to correct this condition. An obstructed sea water

scoop may also be the cause. It may sometimes be cleared by reversing the direction of boat, thus reversing direction of flow of water through heat exchangers. *Overheated exhaust manifolds* are also an indication of lack of sea water circulation.

B. Oil in Temperature Normal, Water Temperature High.

1. Fresh water pump not circulating properly. Remove plug at the reverse gear end of the side water manifolds. If a good strong stream flows from the open hole, the circulation is normal; but if there is little pressure, this would indicate that the fresh water pump was at fault and should be replaced.

2. Fresh water thermostat: To make sure that the thermostat is operating, open it wide by turning the adjusting nut clockwise as far as it will go. If the temperature drops, it may be assumed that the thermostat is at fault and should be replaced.

C. Expansion Tank Flooding and Sludge Forming in Fresh Water Cooling System.

This is usually caused by aeration in the fresh water system and a loose fresh water hose clamp is usually at fault. Observe for water leak in fresh water system when engine is not running. Obstruction in ½-inch supply line also will cause this condition.

D. High Oil-in Temperature.

1. Insufficient oil: If the oil level is low in supply tank, the small quantity of oil will flow through the

engine oftener in a much shorter time than normal and will cause the oil to heat up more.

2. Thermostat defective: If the by-pass valve sticks open the oil will not circulate through the cooler thus causing high oil temperature.

3. Oil cooler clogged: If the oil cooler becomes clogged with carbon and sludge, it will lose its cooling effect. This condition will seldom arise if the oil-out strainers are rotated daily and checked every 25 hours. If oil appears to be dirty, it is advisable to remove the cooler and clean it according to instructions.

E. High Oil-out Temperature.

1. Improper timing: Late magneto timing will cause engine to overheat. Check timing.

2. Lean mixture: This will cause overheating. Check for other symptoms of lean mixtures.

3. Piston rings worn: Excessive blow-by into the crankcase caused by worn rings will cause increased oil temperature. A sure symptom of this is heavy smoke fumes from the breather.

4. Excessive friction in bearings or cylinders: This will cause a sudden rise in oil-out temperatures. Any rise of oil-out temperatures beyond 200° F. usually indicates bearing failures and the engine should be stopped.

F. Low Oil Pressure.

1. Lack of oil: This obvious cause is very often overlooked.

2. Oil pressure relief valve: Carbon particles and

metal chips may hold the relief valve open, causing the pressure to escape to the inlet side of pumps. This valve is easily removed and should be cleaned if the pressure is suddenly found low. Loose lock nut causes valve to back itself off.

3. Leak in suction line: Any leak in the line from the tank to the pump will tend to suck air into the pump which will cause a lock and break the suction. An air leak into the suction line will cause oil pressure gauge to oscillate. This leak will have to be found and corrected. Before restarting the engine the oiling system may have to be primed in this manner: Disconnect oil gauge line located by No. 1 main bearing and rotate engine with starter until oil appears at line opening.

4. Improper oil: A heavy grade of oil used in extremely cold weather will cause it to congeal in the tank. Likewise, a grade of oil too light for high oil temperatures will cause a low oil pressure. It should be noted that normal oil pressure may drop to 60 pounds per square inch at idle with the hot oil, and may go as high as 150 pounds per square inch with cold oil.

5. Clogged oil filters: An excessively dirty "oil in" filter will tend to lower oil pressure especially at high speed.

A. Trouble Shooting and Adjustments of Reverse Gear.

1. Propeller flange creeps: The reverse gear brake band has to be centralized.

2. Brake band clearance: After centralizing the brake band, be sure there is positive clearance between band and drum.

3. Pull on lever required: If there is less than 90 pounds pull required on reverse gear lever (2 feet up on lever) to engage in reverse, adjust to get proper pull required (110 to 125 pounds).

4. Noise while engaging: If there is a clanging noise when engaging into forward drive, increase clutch spring compression by adding shims under toggle arm base. Such adjustments should be made only by base personnel.

5. Pressure plate travel: The toggle rod (old style) or pressure plate (new style) should travel three-sixteenths inch. If less than one-sixteenth inch, the friction ring would slip on the clutch cone. On new style, correct by adding shims under toggle base.

6. Sticking in forward drive: If the reverse gear is stuck in forward drive and will not disengage with shifting lever, pull shifting lever into neutral position with engine running and open throttle slightly to disengage forward drive.

7. Oil leaks: Check frequently for oil around propeller shaft flange. If leaking replace seal.

B. Trouble Shooting Universal Joints.

1. Leak of lubricant: The universal joint has a pressure relief valve to relieve the joint of excess grease. However, if grease is noticed on the universal joint, check the seals to see if the grease is coming from behind the seals. SAE 140 is recommended for lubrication.

2. Noisy universal joint: Check for noise in the universal joint. If noise is heard, needle bearings are probably worn and should be replaced.

C. Trouble Shooting V Drive.

1. Overheating: Overheating of the V drive is usually caused from excess oil in V drive housing.

2. Low oil pressure: If there is less than 12 pounds oil pressure on V drive, increase oil pressure to 20 pounds by adding shims behind pressure relief valve.

3. Abnormal oil pressure: If oil pressure is abnormal, oil pressure relief valve should be checked frequently for free movement.

4. Alignment: To align V drive with propeller shaft, use wooden shims under V drive housing.

5. Oil leaks: If there is an oil leak around V drive flange, the seal is worn and can be replaced without removing V drive from boat.

6. Check body hold-down bolts on the V drive housing frequently.

Where a new or reconditioned V drive is installed the result may cause loss of engine R. P. M. and high manifold pressure. The usual cause is that the gears are in the "wrong" position in the V drive. The upper gear has "29 teeth," the lower gear has "30 teeth." Reversing them will give the wrong ratio.

STEERING GEAR SYSTEM

IMPORTANT.—The Greatest Defensive Weapon of These Boats Is Their Maneuverability and as Such Should be Considered of the Greatest Importance.

Steering Gear System of the 80′ Elco M. T. B.

Operation.

It consists of steering wheel transmitting forces to sprockets and roller chains to a torque shaft running aft on the port side just under the main deck to the lazarette. The shaft there transmitting torque to steering gear assembly, the toggle arm, drag link and tiller arms operating the three rudders.

Maintenance and Lubrication.

Access to the sprockets and chain is made by removing the screws in the wooden panel under the steering wheel.

Proper tightness of the chain is made by an adjustable sprocket. The chain should be kept tight only to the extent that there be no noticeable backlash so that it would be impossible for the chain to jump the sprocket under any condition encountered. The chain should be well lubricated with medium grade oil or cup grease No. 2.

Cleaning, inspection and lubrication of the steering system should be done every 100 hours or at least once a month.

CAUTION: Prevent as much as possible entrance of dirt or foreign matter in the steering system as it will

damage the sprocket teeth and interfere with the operation of the chain.

Three small universal joints are provided in the torque shaft to prevent binding due to various loads such as; thrust, misalignment, or changes in hull shape. These universals are located at 8-foot intervals along the shaft and should be lubricated periodically through the fittings provided for the purpose.

Two sleeve joints are also provided in the shaft to simplify installation and removal. The shaft rests in steady rest bearing. There are three of these bearings known as Gimbel bearings and they should be lubricated periodically with an approved lubricant.

The Gemmer gear assembly in the lazarette should be kept filled with SAE 90 (or Navy symbol 600W).

The rudder posts are equipped with packing glands and should be kept just tight enough to prevent leakage.

These nuts are tightened with the special wrenches and locked in place with heavy safety wire. The packing used is regular flax packing.

Emergency Steering.

If it becomes necessary to steer the boat by hand, it is accomplished by removing the pins in the tiller arms, folding the drag links back out of the way and inserting the pipe tiller, stored in the lazarette, on the arm of the center rudder provided for this purpose. Signals are given to the operator from the bridge by personnel on deck.

Steering Gear System of the Higgins 78′ M. T. B.

Operation.

It consists of steering wheel transmitting forces to sprockets and roller chains to a torque shaft running aft from ammunition locker to a steering gear assembly in the lazarette which transmits forces through a toggle arm, drag links, tiller arms, and rudder posts to the two rudders.

All Higgins boats (except RPT 1–12) are equipped with a *special transmission* at the steering wheel to reduce the number of turns from hard over to hard over, so that a straight course may be maintained in a following sea, without the necessity of spinning the wheel.

This unit consists of a splined steering wheel shaft that may be pushed forward to engage directly with the sprocket, giving the number of turns in this position from hard over to hard over, approximately 17.

It may be pulled out to engage in spur gears and give a step up of 1: 4, in which position the number of turns from hard over to hard over is approximately 5. The lower reduction is preferred for maneuvering at low speed or in maintaining a steady course. The high ratio is for maneuverability at high speeds.

The housing should be kept filled to the level of the center pipe plug, with SAE 50 lubricating oil at all times;

Maintenance and Lubrication.

At approximately main deck level, in the chart house, is located a roller chain tension mechanism which is accessible for adjustments or lubrication by removing one of the small panels in the face of the control box. The chain should be well lubricated with medium grade (SAE 30) lubrication oil or cup grease No. 2.

The chain should be kept taut only to the extent that there be no noticeable backlash and so that it would be impossible for the chain to jump off the sprocket in a heavy sea.

NOTE.—It is important to prevent any small particles of debris from falling alongside steering chain as they may lodge between the sprocket and chain in lower housing, thus temporarily disabling the whole steering system.

Three small splined universal joints are provided in the torque shaft line to prevent binding due to thrust loads, misalignment or changes in hull shape. One universal joint is located just abaft the lower sprocket housing, the second in the store room, the third in the lazarette just forward of the main gear box. The splines should be lubricated periodically through the alemite fitting provided for this purpose.

The torque shaft located just above the main girder (port side lower) is equipped with steady rest bearings and fittings on the steady rest bearings for lubricaiton purposes. Cup grease is satisfactory for lubricating these bearings.

The main gear box, located in the lazarette, should be kept filled with No. SAE 90 or equivalent (Navy symbol SAE 90 is 600 W.).

The rudder posts are equipped with spanner type packing glands which should be kept only tight enough to prevent leakage and should be locked in position with lock nuts and wrenches provided. The best way of adjustment is to back off packing gland until water enters, then tighten until it stops.

The steering mechanism should be lubricated, inspected (and adjusted if necessary) every 100 hours of operation or at least every 30 days which ever occurs first.

Emergency Steering.

If it becomes necessary to steer by this method it is accomplished by removing the clevis pins in the tiller arms, folding the drag links back out of the way and attaching the aluminum pipe tiller (which is normally stowed in the lazarette) to the extension which extends through the deck on the port side (above the lazarette).

Any major repairs to the steering gear or control mechanism should be made at an overhaul base or tender where necessary equipment and material are available.

Propellers, Shafts, and Struts Elco 80′ M. T. B.

Description.

Elco boats have a shaft log and Syntron seal where the shaft comes through the hull in the engine room.

The Syntron seal is to prevent sea water from coming into the hull. If the bilges fill up often with sea water, check Syntron seal.

Maintenance.

There is no service maintenance on Syntron seals other than replacement (and only in extreme emergency can a Syntron seal be replaced while the boat is in the water). Syntron seals and shaft log should be replaced while the boat is in drydock.

Trouble Shooting.

There are numerous causes for damage to underwater gear on the hull (the shafts, propellers, and struts). Such causes are floating debris, running aground, etc.

Indications of a bent propeller shaft will be excessive vibration and leakage of sea water through the Syntron seal.

A bent strut will render excessive vibration.

After replacing a bent shaft, the engineer should check the hold-down bolts on the struts for tightness and alignment.

A bent or nicked propeller will also cause vibration usually at cruising speed or slightly less than cruising speed unless one blade of the prop has been completely sheared off in which case there will be excessive vibration at almost all speeds.

In all cases *except in extreme emergency*, the engine having a bent shaft should be secured. However, any major repairs such as replacement of shaft, props, strut, cutless bearing, Syntron seal, or shaft log, would be made at an overhaul base or tender, where necessary equipment and material are available.

Propellers, Shafts, and Struts and Steady Rest Bearings. Higgins 78′ M. T. B.

Description.

Each propeller shaft has one steady rest bearing inside the hull and struts with cutless bearings on the bottom of the hull, and a spanner type packing gland around each shaft.

The steady rest bearings are equipped with fittings for lubricating purposes. The steady rest bearings and packing glands for port and starboard shafts are located in the engine room The center shaft steady rest bearings and packing glands are located in the after tank room.

Maintenance.

The "Spanner type" gland around each shaft should be kept tight enough to prevent sea water from leaking into the bilges of the boat. If the bilges often fill up with sea water, the first places to check for leakage are the shaft packing glands.

Trouble Shooting.

There are many causes for damage to the underwater propulsion mechanism on the hull (i. e., the shafts, struts, and propellers). Such causes are, floating debris, running aground, etc.

Indications of a bent propeller shaft will be excessive vibration, leakage of sea water through the packing glands, and possibly the steady rest bearings in the

engine room (or aft tank compartment in the case of the center shaft) will wobble back and forth thwartships.

A bent strut will cause excessive vibration, and possibly a squeaking noise. This may be caused by the binding of the shaft and strut.

A bent or nicked propeller will also cause vibration, but only at cruising speed, or slightly less than cruising speed. However, if one blade of the propeller has been completely sheared off, there will be excessive vibration at all speeds.

CAUTION: After replacing a bent shaft the struts should be checked for alignment and for tightness of the securing bolts.

In all cases *except in extreme emergency*, the engine driving the bent shaft should be secured.

However, any major repairs such as replacement of the shaft, propellers, strut, cutless bearing, steady-rest bearing or packing gland should be done at an overhaul base or tender where necessary equipment and material are available.

Bilge Drainage

There are three methods of keeping the bilges dry on these boats, namely; manual pumping, mechanical pumping, and self-bailing. Both pumping systems operate off a manifold with take-outs in the low points of every watertight compartment, and should only be used when the boat is at the dock or in the event of an emergency in order to conserve the auxiliary generator motor which drives the mechanical pump. Underway, the self-bailers should be used. The me-

chanical bilge pump is fitted with connections so that it is possible to take sea water from overboard for use in washing down decks, flushing out bilges, etc.

The most important item in maintaining dry bilges is to keep them free from trash so that the limber holes through the frames will not become stopped up and to keep the packing glands (on Higgins) and Syntron seals (on Elco) from leaking.