Chapter 6 WATER-METHANOL SYSTEM

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DESCRIPTION

WARNING . . .

Methanol fires can be extinguished by carbon dioxide, carbon tetrachloride (C.T.C.) and methyl bromide. Use water for small fires only. When using these extinguishers, their poisonous effects must be remembered and adequate precautions taken. When working with water methanol, the following equipment must be used:—

(1) *Explosion proof lamps and torches.*
◀(2) *Sparkproof tools* ▶
(3) *Remote breathing apparatus.*
(4) *Protective clothing capable of protecting ALL of the body.*

Note . . .

Methanol can be absorbed through the skin as well as through the lungs. Do not take chances with methanol as absorbtion even in small quantities would eventually have serious effects.

1. The water/methanol system provides for Avon Mk. 20501 engine installations employing a 70/30 water/methanol mixture injection to augment the normal take-off thrust under sea-level I.C.A.N. conditions, or to restore the normal take-off thrust when operating in high ambient air temperatures or from high altitude airfields.

2. From a tank in the rear upper servicing bay, the mixture is gravity fed to four air turbine pumps, each capable of passing 2,600

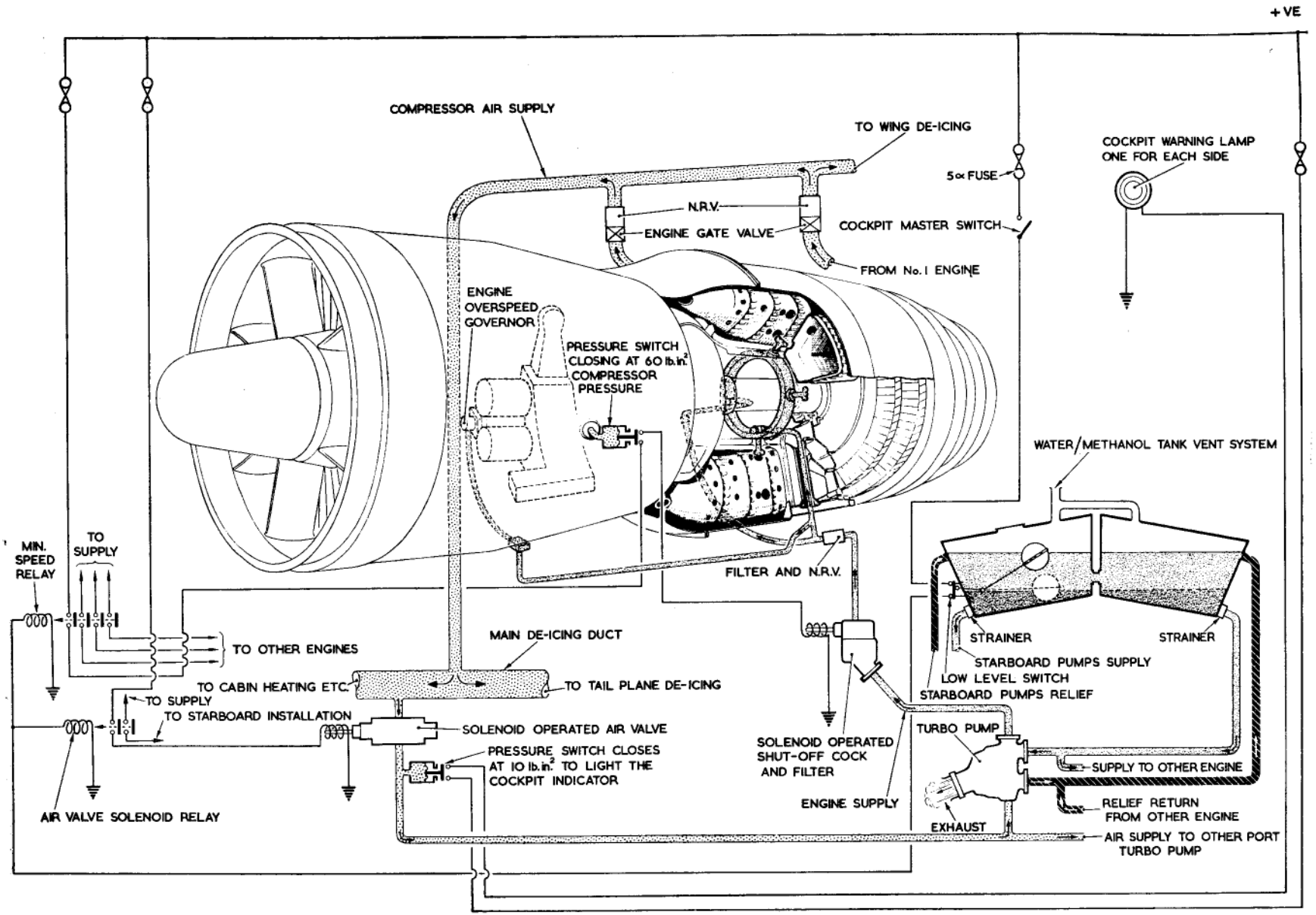

Fig. 1. System diagram

gall. per hour at a pressure of 450 lb/in², and thence to a connection on each engine port side via a shut-off cock embodying a filter, and a non-return valve. The pumps are driven by a compressor air supply tapped from the tail unit thermal de-icing duct, supply to the pumps being controlled by a solenoid-operated valve energized by a master switch in the cockpit. To prevent water/methanol mixture being injected into a dead engine, or in the early stages of slam acceleration, a shut-off cock in the supply line is solenoid-operated when the compressor pressure builds up to 60 lb/in² and closes a pressure switch to complete the circuit.

System operation

3. All engine installations are similar, a common water/methanol tank of two interconnected cells feeding directly to port and starboard, in each case under gravity through a common pipeline to the two pumps on that side. Each side has an independent air system tapped from the appropriate thermal de-icing duct (tail unit), a common air valve controlling the supply to two turbo pumps and a common pressure switch in the supply line operating a cockpit warning light to indicate the passage of hot air to the pumps. Direct control over electrical circuits in all engines is exercised by the cockpit master switch and the tank low-level switch through the minimum-speed relay to all four shut-off cocks, and the air valve relay to the two solenoid-operated air valves. The remaining circuit, giving shut-off cock opening, is in each case controlled by the pressure switch on each engine, operated by compressor pressure.

4. With the water/methanol mixture in the tank above the low-level mark (1 to 1½ gall.) the low-level switch will be closed, so that selecting the cockpit master switch to ON energizes the minimum speed and air valve solenoid relays. The air valve relay will close the circuit to energize the air valve solenoid and open the valve to permit passage of air under pressure from the aircraft de-icing duct to the pipelines serving the turbo pumps for the engines on that side. A pressure switch in the line between the air valve and the bifurcation to the pumps will close a warning lamp circuit when the pump supply pressure rises to 10 lb/in², thus giving visual warning that hot air under pressure is being supplied to the turbo pumps. At this time the shut-off cock is closed and water/methanol mixture cannot pass to the engine; pressure therefore built up in the pump and pipeline to the cock causes a relief valve (built in the pump) to open, and mixture is circulated back to the tank.

5. As cockpit master switch selection energizes the air relay valve, so also does it energize the minimum speed relay to close the shut-off cock circuit. The circuit is not completed by this action as it is also broken by the minimum speed override switch (a switch actuated by compressor pressure). When the compressor pressure rises to 60 lb/in² and the engine is ready to receive water/methanol injection, the minimum speed override switch completes the circuit to energize the shut-off cock solenoid and open the cock, permitting water/methanol mixture under pressure to pass to the engine via a non-return valve and filter. The flow is also directed to the engine fuel pump overspeed governor, ensuring that engine overspeeding will not occur before mixture is delivered to the engine in quantity and will afterwards be controlled at an overspeed of approx. 300 r.p.m., although this may be less in tropical conditions.

6. When the water/methanol mixture in the tank has fallen to the low-level position, the float-operated low-level switch will open and break the circuit to the relays, causing the air valves and shut-off cocks to close. Closing the air valves causes rapid pressure drop in the turbo-pump air supply lines, the pressure warning switch cuts the warning lamp circuit as the pressure drops below 10 lb/in² and extinguishes the lamp. Should one or both warning lamps stay "on" after injection is complete, it indicates a fault in the air valve solenoid or the valve, necessitating closure of the engine gate valves on the affected side to prevent turbo pump damage.

Tank (*fig* 3)

7. The 145 gall. tank is of irregular shape and has two interconnected light alloy cells, stiffened internally by lateral stiffeners and longitudinal diaphragms and externally by reduxed ripple plating. The diaphragms, three per cell and pierced by lightening holes, divide the cells into four interconnected compartments to prevent excessive surging. With tank replenishment carried out from the aircraft starboard side (*para.* 8), the mixture passes into the starboard cell to find its level through the interconnecting and balance pipes, and is cut off at a predetermined level by a float-operated replenishing valve. For turbo pump supply, the mixture passes through connections at the tank outboard extremities where strainers are embodied in the outlet connections. Adapters for the relief system piping are also at each outboard end and are positioned adjacent to the supply connections. On the starboard cell outboard wall is a float-operated low-level switch which opens when the mixture level falls to 1 to 1½ gall. and, in so doing, causes the closure of the valves controlling air supply to the turbo pumps and the shut-off cocks controlling mixture supply to the engines. The unused quantity of mixture is of particular importance since it ensures that the system is full and that resistance to pump rotation is available during the time taken for the air valve to close and air pressure at the pump to fade.

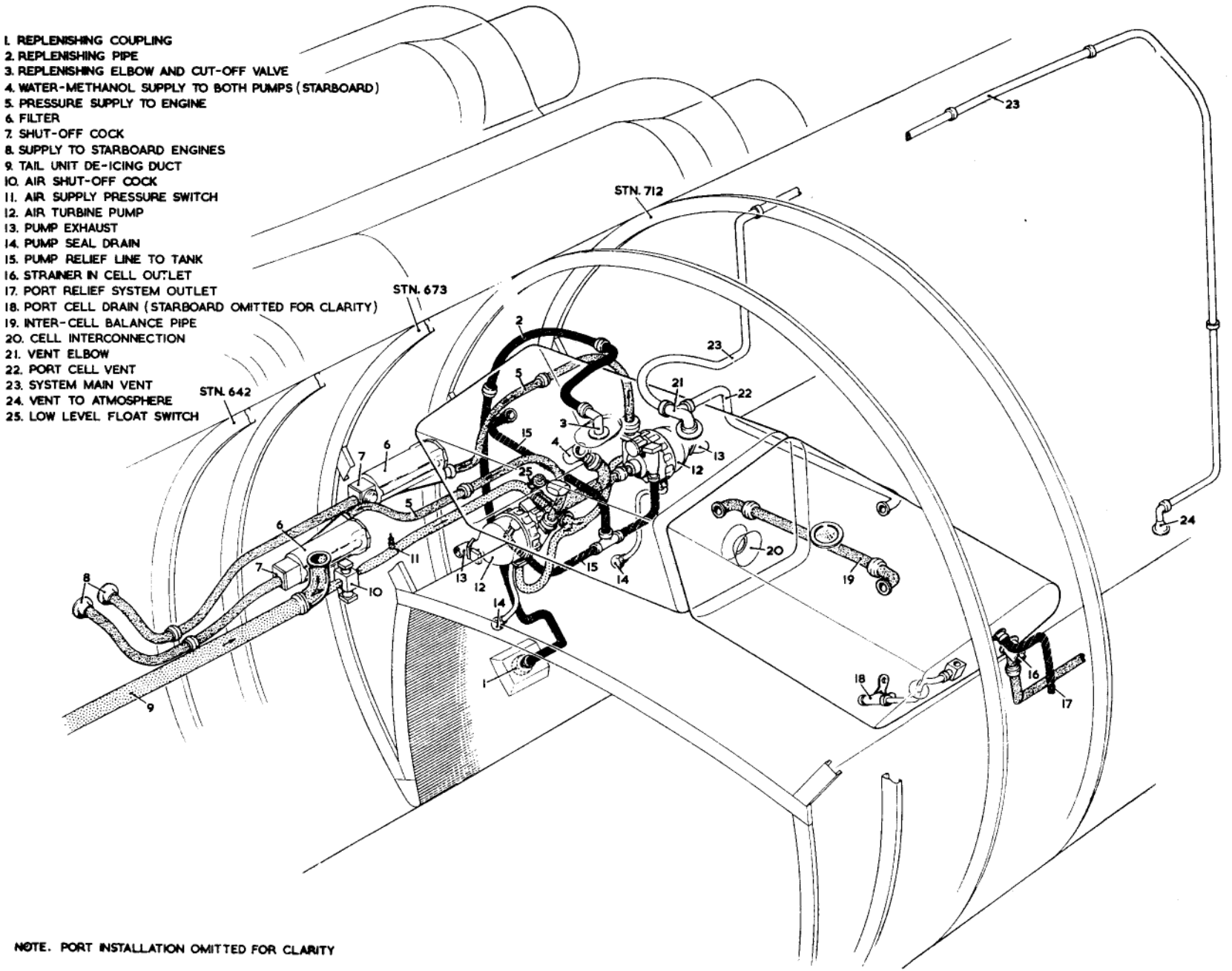

Fig. 2. Location diagram

Replenishing and draining (*fig.* 2)

8. Tank replenishment is effected from a ground connection on the fuselage starboard side at Stn. 700, the mixture passing through a pipe to the tank starboard cell at a rate of 50 gall. per minute under a pressure of 25 lb/in² until a predetermined level is reached and a float-operated valve seals the supply line. For draining, a cock is fitted in the base of each cell and is accessible in the bomb bay. Special drains are provided for the turbo pump seals, leakage being drained through small pipes and vented overboard. ◀Post-Mod. 3102, pumps Type RH3—3B are replaced by pumps RH6—3B with improved seals.▶

Venting (*fig.* 2)

9. A vent system is used to prevent tank damage when the water/methanol system is in use or being replenished. A vent pipe from the port cell is connected to the starboard cell vent elbow, the main vent being led from the elbow to fuselage Stn. 1030 and thence to atmosphere through a flame trap.

SERVICING

Checking the low-level float switch setting

10. To check the low-level float switch setting, to determine the quantity of unusable water/methanol mixture, proceed as follows: —

(1) Disconnect the electrical socket from the low-level float switch on the starboard tank cell outboard wall. Connect a test lamp and battery across contacts A and B.

(2) Replenish the tank with approx. 15 gall. of water/methanol mixture and ensure that the lamp circuit is complete (test lamp 'on').

(3) Commence draining the tank via the drain cock in the port cell base (accessible from the bomb bay) until either: —

(a) The test lamp goes 'out', or

(b) The port cell is completely drained.

If the port cell is completely drained and the lamp remains 'on', commence draining the starboard cell until the lamp goes 'out'. Close the drain cock.

(4) When the test lamp goes 'out', drain off and measure the quantity of mixture remaining in the tank, which should be from 1 to 1½ gall.

(5) Close and lock both drain cocks, remove the test lamp and battery and reassemble the switch socket.

Testing the system (four engines)

11. Having ensured that the water/methanol tank is full and that fuse E.21 is fitted, test the four engines as follows: —

(1) Start all four engines, check that maximum r.p.m. (8,000 r.p.m.) is obtained on each engine in turn, and return to slow running.

(2) Select 5,500 r.p.m. on No. 1 and 2 engines.

(3) Select No. 1 and 2 engine gate valve switches to normal (UP).

(4) Select the cockpit water/methanol master switch to ON and ensure that the air pressure warning lamp (port) comes 'on'.

Note . . .

If the pressure warning lamp does not come 'on', switch OFF *the water/methanol master switch and the gate valve switches, close down the engines and investigate* (*Book* 2, *Sect.* 5, *Chap.* 2).

(5) Switch OFF each gate valve switch in turn and ensure that the pressure warning lamp stays 'on'.

(6) Detail a man to check for water/methanol leaks between the tank and the turbine pumps and between the pumps and the shut-off cock.

Note . . .

Do not run the turbine pumps for periods longer than three minutes, and use intercommunication equipment.

(7) If no leaks are apparent, switch OFF the water/methanol master switch and ensure that the pressure warning lamp goes 'out'.

(8) If there are leaks, close down the engines and rectify before continuing the test.

(9) Open the throttle of No. 1 engine to the take-off position, switching the water/methanol master switch ON at 7,000 r.p.m.

(10) Ensure that the pressure warning lamp comes 'on', that No. 1 engine overspeeds by 300 ± 75 r.p.m., that No. 2 engine remains at 5,500 r.p.m. and that the jet pipe temperature does not exceed the permitted maximum (660 deg. C.).

Note . . .

In tropical conditions the overspeed may be slightly less.

(11) Maintain the take-off r.p.m. for approx. 15 sec., during which time a leak check must be made between the shut-off cock and the engine.

(12) Reduce r.p.m. to 5,500 and return the water/methanol switch to OFF.

(13) Repeat operations (9) to (12) on No. 2 engine.

(14) Shut down No. 1 and 2 engines and switch OFF the appropriate engine gate valves.

(15) Repeat operations (2) to (14) for No. 3 and 4 engines.

Testing the replenishing system (*fig.* 4)

12. The pipelines should be tested for leaks under pressure with either water or air, followed by a check to ensure correct replenishing rate and cut-out valve action. Proceed as follows: —

To test with water pressure

(1) Disconnect the replenishing pipe at the inlet elbow on the starboard tank cell and either blank off the pipe or secure to it an adapter fitted with a pressure gauge (0 to 50 lb/in²).

(2) Using the replenishing coupling, fill the supply line with water, venting all air from the line.

(3) Raise the water pressure in the line to 40 lb/in² and, holding at this pressure, check for leaks.

Note . . .

Where the pipe upper extremity is blanked, it will be necessary to fit a pressure gauge into the supply line.

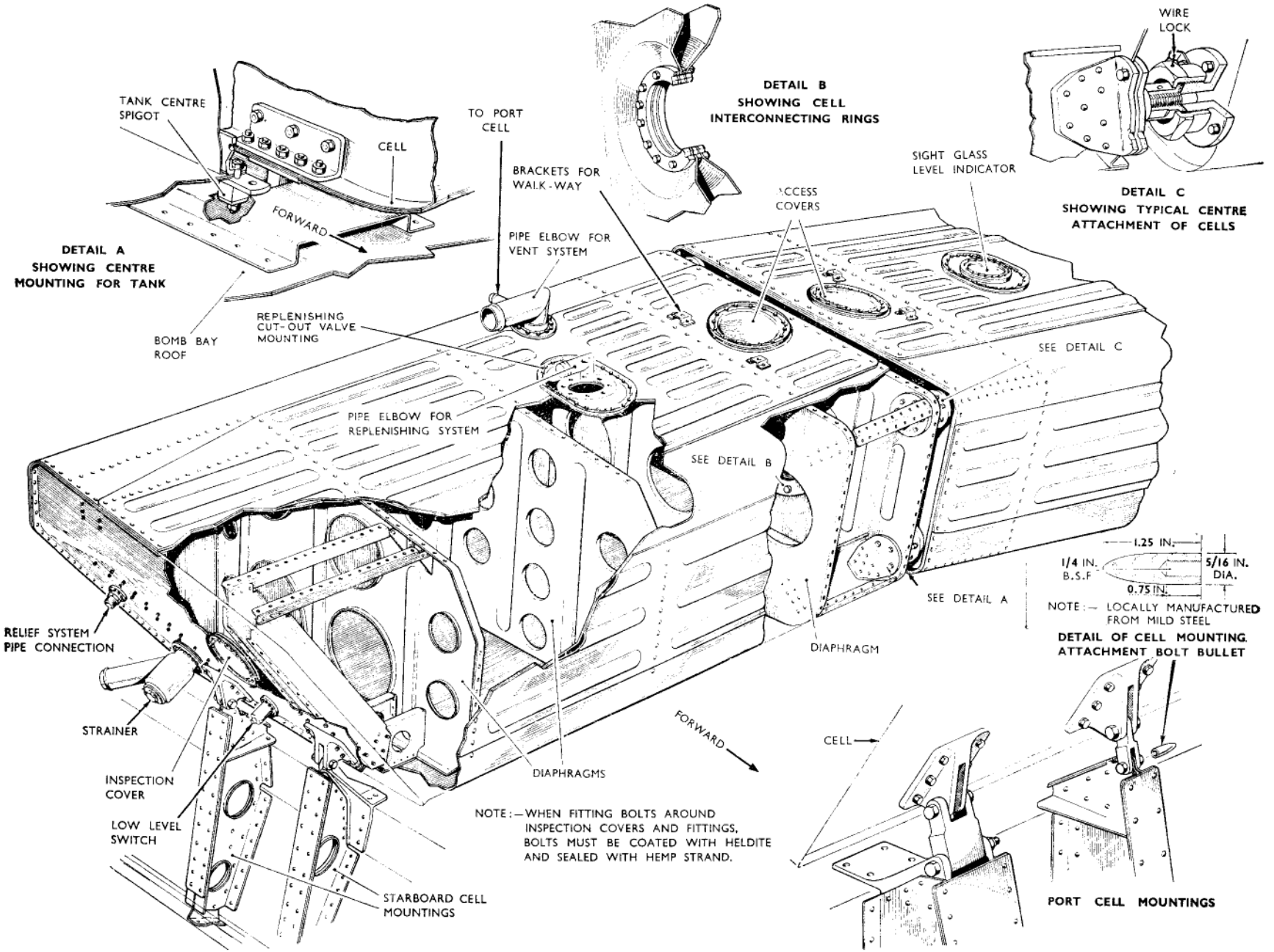

Fig. 3. Tank

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To test with air pressure

(1) Disconnect the replenishing pipe as in previous operation (1) and secure to the pipe an adapter fitted with a pressure gauge (0 to 50 lb/in²).

(2) From an external supply, raise the pressure to 40 lb/in² and cut off the supply.

(3) Check for leakage: the pressure must be maintained.

13. Reconnect the replenishing pipe at the tank elbow after releasing all air pressure or draining off all water as applicable, and check the replenishing action as follows:—

(1) Introduce water/methanol mixture via the replenishing coupling, using an external supply at 25 lb/in² pressure.

(2) Check that the flow is approximately 50 gall. per minute.

(3) Check that the replenishing cut-off valve closes correctly to cut the supply.

(4) Check the tank condition by means of the sight glass on the port cell upper surface.

Testing the vent system (*fig.* 4)

14. Proceed as follows:—

(1) Using a locally-made blank and rubber sealing washer as illustrated, blank off the vent outlet in the fuselage lower skin at Stn. 1030.

(2) Disconnect the pipe at the vent elbow on the starboard cell, and fit a locally-made adapter to enable the vent lines to be pressurized.

(3) Connect a controlled air supply having a suitable pressure gauge (0 to 5 lb/in²).

(4) Pressurize the line to 4 lb/in² and turn off the supply.

(5) Check for leaks. The pressure must be maintained without leakage.

Testing the tank, relief and pump feed pipes (*fig.* 4)

15. The tank, relief and feed pipes to the pumps are tested simultaneously as follows:—

(1) Disconnect the water/methanol supply pipe at the outlet side of each pump and insert the locally-made 18 s.w.g. blanking discs and rubber washers at the F.R.S.315K couplings to blank off the lines.

(2) Disconnect the replenishing pipe at the tank elbow and blank off the elbow.

(3) Disconnect the main vent pipe from the vent elbow on the starboard cell, and to the elbow fit a locally-made adapter to facilitate pressurizing the tank and pipelines.

Note . . .

The adapter, whilst accommodating the external air supply line should also embody a suitable pressure gauge (0 *to* 5 *lb/in²*); *alternatively, the gauge may be embodied in the supply line.*

(4) Turn on the external air supply and pressurize the tank and pipelines to 1½ lb/in². Turn off the air supply, note that the pressure is maintained and check for leaks.

Testing the piping—pumps to engines (*fig.* 4)

16. To test the piping between the pump outlet and the engine bulkhead, proceed as follows:—

(1) Disconnect the water/methanol supply pipe at the engine bulkhead, and to the pipe fit a blank and adapter, Ref. No. 28F/5726, 11258 and 11200.

(2) For No. 1, 2 and 4 engines, disconnect the supply pipe at the pump outlet and fit adapter, Ref. No. 26SR/95511 to the pipe.

(3) For No. 3 engine, disconnect the supply pipe at the pump outlet and remove the section of piping from the pump to the first connection; to this joint fit adapter, Ref. No. 26SR/95512.

(4) Open the water/methanol shut-off cock on the filter. This can be done by bridging the electrical circuit.

(5) Using a water container and pump, Ref. No. 4G/1439, with a pressure gauge, Ref. No. 4G/4182, fill the supply pipe with water and at the same time bleed off all air at the bulkhead blank.

(6) Close the bulkhead blank and raise the water pressure to 500 lb/in². Maintaining this pressure, check for leaks.

Note . . .

◀*Shut-off cocks and filters post-Mod.* 2998 *are Type FBS*2-2*A which have additional corrosion resistance and are each identified by a* ½ *in. dia. green spot. These items are superseded, post-Mod.* 3051, *by filters and shut-off cocks Type FBS*3-3*B having additional anti-corrosion treatment and an orifice of increased diameter in the attenuator plate.*▶

General precautions

17. Water/methanol mixture has a highly corrosive action; any spillage from leaks or through breaking joints during test must be carefully removed and such areas kept under

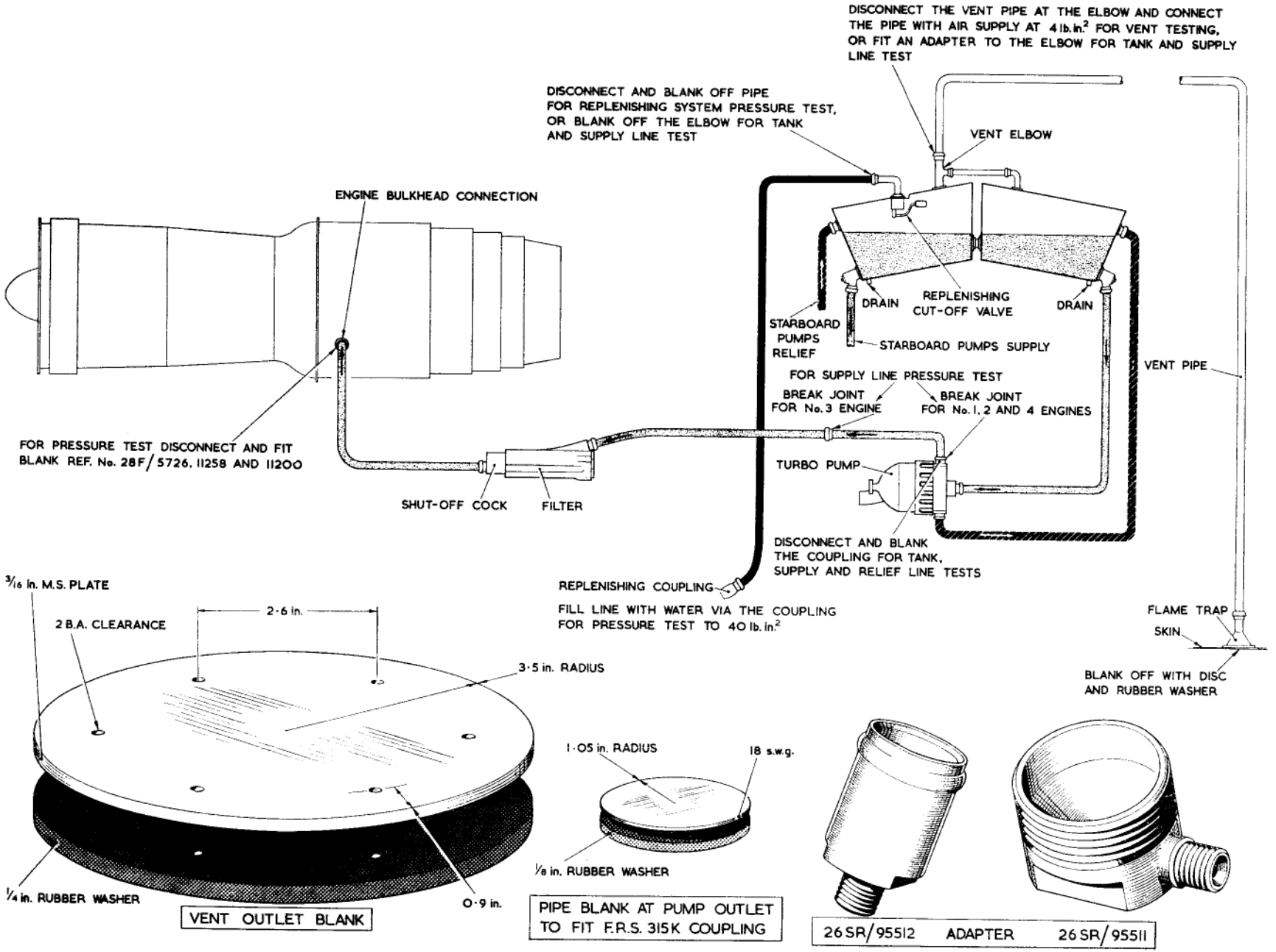

Fig. 4 Test diagram

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observation. The method of neutralizing areas and parts affected by the mixture is by washing in clean water, liberally applied, rubbing down vigorously and finally drying off thoroughly.

18. The turbine main and tail bearings are lubricated with grease XG-275. It is important to avoid over-lubricating; attention is therefore directed to the relevant instructions in A.P.4377A, Vol. 4.

19. On completion of all system tests, ensure that blanks are removed, and joints correctly made, locked and bonded where necessary.

REMOVAL AND ASSEMBLY

Tank removal (*fig.* 3)

20. To remove the water/methanol tank proceed as follows :—

(1) In the rear upper servicing bay, disconnect the P cock from the main fuel system vent ducting and remove the section of ducting between the manifold and the connection at the transfer tank rear end.

(2) Remove the thermal de-icing duct between the joints forward and aft of the transfer tank.

(3) Through the drain cock in the base of each cell (accessible from the bomb bay), drain all water/methanol mixture from the tank into a suitable receptacle.

(4) When draining appears to be complete, remove the strainer caps at each outlet, and drain any remaining fluid into a suitable receptacle.

(5) Disconnect from the tank, all accessible piping, the drain cocks, replenishing valve and pipe elbows, ensuring that any remaining fluid is collected in a suitable receptacle as each item is removed. Blank off all openings in the tank.

(6) Disconnect the electrical socket from the low-level switch on the starboard cell outer wall

(7) Remove the nuts from the outboard tank attachment bolts, fit a special assembly bullet (*fig.* 3) to each bolt to protect the threads, and tap out the bolts.

(8) Tilt the tank forward, release the securing bolts and remove the inter-cell balance pipe and elbows.

(9) Remove the cover on each cell upper surface to gain access to the nuts and bolts securing the cells at the interconnecting rings (*detail* B).

(10) Release the four tank inter-cell spigot connections (*detail* C).

(11) Lift the cells clear of the centre spigot connections (*detail* A).

(12) Handling each cell separately, turn it it onto its side, keep it as high as possible and pass it between the transfer tank cells.

Tank assembly (*fig.* 3)

21. Before attempting to fit the tank into the aircraft, each cell must be stripped of all components except the low-level switch and the centre spigots When assembling components and fittings to the cells, all securing bolts must be coated with Heldite and sealed with hemp strand. To assemble the tank into the aircraft proceed as follows :—

(1) Pass each cell in turn into the fuselage, turn it onto its side and, holding it as high as possible, pass it between the transfer tank cells.

(2) Fit the drain cock to the underside of each cell and place the cells approximately in position.

(3) Using the cell access holes, join the tank cells by the interconnecting rings and four tank joint fittings (*detail* B and C).

(4) Tilt the tank forward, taking care to avoid damaging the low-level switch, and fit the inter-cell balance pipe and elbows.

(5) Fit the replenishing valve and elbow.

(6) Fit the vent pipe elbows and inter-cell vent pipe.

(7) Engage the tank centre spigots (*detail* A).

(8) Using the special bullet, fit the special bolts to the outboard fittings.

(9) Fit all remaining components and pipes.

(10) Fit the fuel vent ducting and thermal de-icing duct.

(11) Test the assembly and installation in accordance with the tests described in this chapter.

Filter removal

22. To remove the filters, proceed as follows :—

(1) Drain each filter from the drain point.

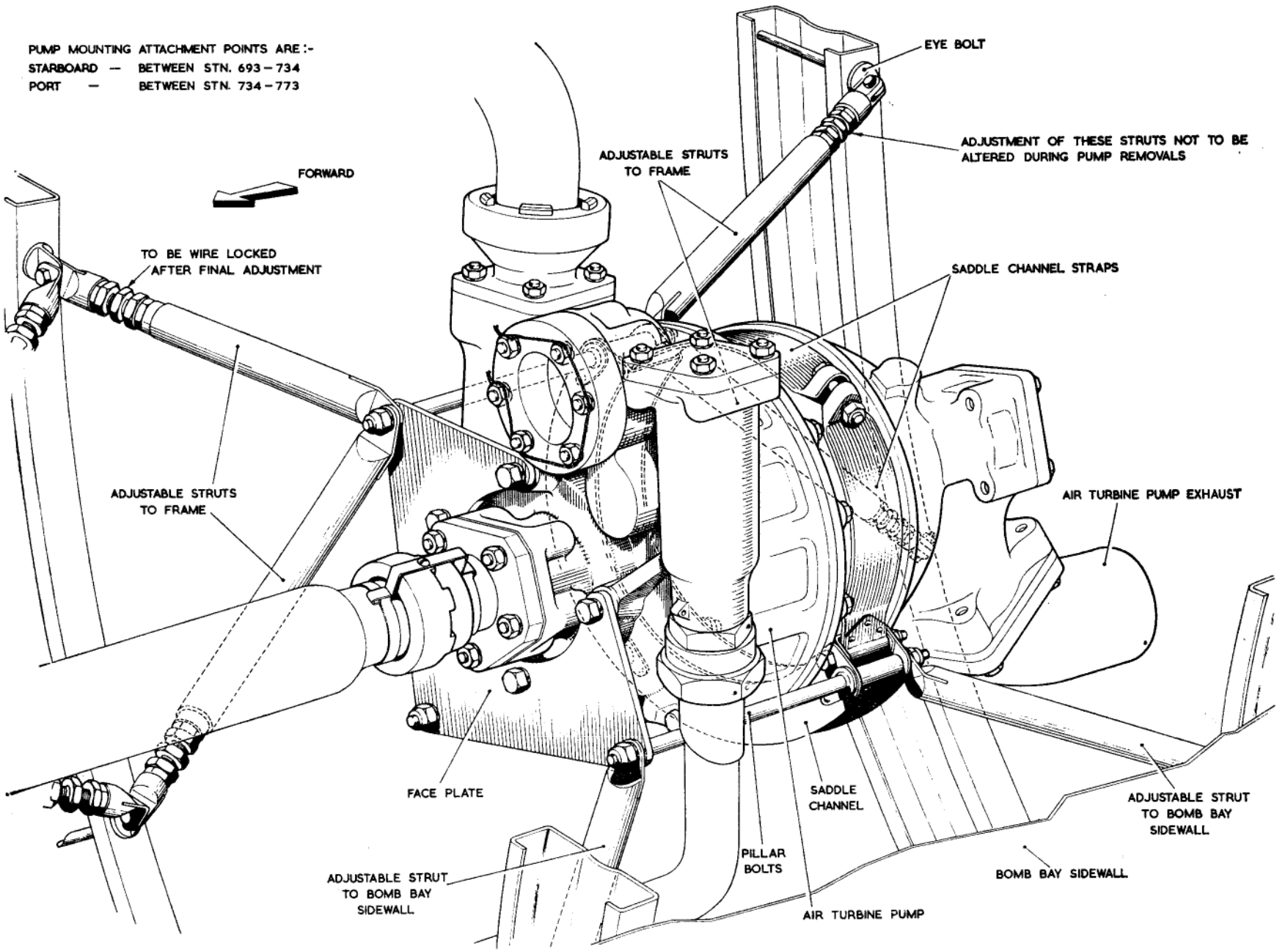

Fig. 5. Air turbine pump attachment

(2) Disconnect electrically at the shut-off cock.

(3) Disconnect all filter piping.

(4) Remove the four securing nuts and bolts and withdraw the filter, taking care to retain the distance pieces.

Filter assembly

23. The assembly sequence is the reverse of that given in para. 22 but, before assembly, it is essential to verify the drain position since this varies in the systems.

Port air turbine pump removal (*fig.* 5)

24. On the port system it is not possible to remove the rear pump until the forward pump has been removed; proceed as follows:—

(1) Drain the tank and system.

(2) Disconnect all pipe connections, taking care to collect into a suitable receptable any small remaining quantities of fluid that may drain from the broken connections.

(3) Remove the sections of relief and main supply system piping adjacent to the REAR pump.

(4) Slacken the nuts at the adjustable strut attachments to the pump mounting and disconnect the strut from the aircraft structure eyebolts. Do *not* alter the strut length.

(5) Remove the forward pump complete with struts.

(6) The rear pump can then be removed.

Note . . .

When removing pumps it should be noted that, despite careful system draining, a quantity of water/methanol mixture will remain in the pump casing below the inlet and outlet levels. Care must be taken to avoid spilling this during pump removal, and any inadvertent spillage must be adequately neutralized as described in para. 17.

Starboard air turbine pump removal

25. Proceed as follows:—

(1) Drain the tank and system.

(2) Disconnect all pipe connections, taking care to collect any fluid that may drip from them.

(3) Remove the section of air supply piping from beneath the foward pump.

(4) Slacken the nuts at the adjustable strut attachments to the pump mounting and disconnect the strut from the aircraft structure eyebolts. Do *not* alter the strut length.

(5) The rear pump can then be removed into the rear upper servicing bay and the forward pump through the servicing bay hatch into the bomb bay.

Air turbine pump assembly

26. Assembly into the aircraft is a reversal of the sequence given for removal in para. 24 and 25.

Table 1, Servicing and test equipment

Ref. No.	Part No.	Description	Remarks
26SR/95512	67479-7321	Water/methanol test adapter, bulkhead connection	For use when testing the system
26SR/95511	67479-7207	Water/methanol test adapter, at turbine pumps	
28F/5726	A.G.S.904J	Coupling sleeve, outer, $1\frac{1}{4}$ in. B.S.P.	
28F/11258	A.G.S.1140J	Nipple, blanking, $1\frac{1}{4}$ in. B.S.P.	
28F/11200	A.G.S.1103J	Body, union, $1\frac{1}{4}$ in. B.S.P.	
◀ 1B/	—	Pliers, sidecutting, sparkproof	For general use in servicing and testing
1C/6889	—	Spanner, D.E.O.J. sparkproof, $\frac{3}{16}$ in. × $\frac{1}{4}$ in. W	
1C/6890	—	Spanner, D.E.O.J. sparkproof, $\frac{5}{16}$ in. × $\frac{3}{8}$ in. W	
1C/6891	—	Spanner, D.E.O.J. sparkproof, 2 B.A. × 3 B.A.	
1C/6892	—	Spanner, D.E.O.J. sparkproof, 4 B.A. × 5 B.A.	
1C/6893	—	Spanner, D.E.O.J. sparkproof 6 B.A. × 8 B.A.	
1C/6897	—	Spanner, sparkproof, for A.G.S.605 clips	
1L/276	—	Spanner, sparkproof socket, 2 B.A.	
1L/277	—	Spanner, sparkproof socket, 4 B.A.	
1L/278	—	Bar extension, sparkproof, 4 in. × $\frac{9}{32}$ in., square drive	
1L/279	—	Handle, spinner, sparkproof, 6 in. × $\frac{9}{32}$ in., square drive	▶
4G/1439	—	Pump, pressure, Type B	For system pressure tests
4G/1442	—	Hose delivery, 8 ft., $\frac{3}{8}$ in. B.S.P.	
4G/4182	—	Gauge, pressure test, water/methanol systems