

Part I—Description and Management of Systems

Chapter I—Fuel System

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1 General

(a) Fuel is carried in fourteen pressurised tanks, five in each wing and four in the fuselage above and to the rear of the nosewheel bay. The tanks are of the flexible-bag type and each tank is enclosed by a metal casing which is part of the aircraft structure. The tanks are not self-sealing but are crash-proof.

(b) The tanks are divided into four groups, each group normally feeding its own engine. A crossfeed system enables the various groups to be inter-connected. Automatic fuel proportioning is normally used to control the fuel C of G position.

(c) The controls and indicators for the fuel system are grouped, in the form of a mimic diagram, on the fuel control panel which is on the retractable console. A handle (A/40) is provided to permit raising and lowering of the console.

(d) A pressure refuelling system for ground use and an in-flight refuelling system are incorporated (for in-flight refuelling, see Chapter 2 of this Part).

(e) Explosion protection is installed and is described in Chapter 5 of this Part.

2 Fuel tanks

(a) The tanks on each side of the aircraft are numbered from 1 to 7, Nos. 1 and 2 being the fuselage tanks and the remainder the wing tanks. The tank numbers correspond to the CG position of each tank, No. 1 having the furthest forward CG and No. 7 the furthest aft. Nos. 1, 4, 5 and 7 tanks comprise the outboard tank group in each wing (No. 1 group port, No. 4 group starboard).

Similarly Nos. 2, 3 and 6 tanks comprise the inner, Nos. 2 (port) and 3 (starboard), groups. Each group normally feeds its associated engine.

(b) *Tank capacity*

NOTE: Fuel states may vary $\pm 1\frac{1}{2}\%$.

The approximate tank capacities are:—

No. 1 and 4 (outboard) groups.

<i>Tank Nos.</i>	<i>Gall</i>	<i>Lb AVTUR (SpG 0·80)</i>	<i>Lb normal AVTAG (SpG 0·77)</i>
1	2× 630	2× 5,040	2× 4,851
4	2× 630	2× 5,040	2× 4,851
5	2× 513	2× 4,104	2× 3,950
7	2× 550	2× 4,400	2× 4,235
Total each group	<u>2× 2,323</u>	<u>2× 18,584</u>	<u>2× 17,887</u>

Total (both outboard groups):

4,646 37,168 35,774

No. 2 and 3 (inboard) groups

<i>Tank Nos.</i>	<i>Gall</i>	<i>Lb AVTUR (SpG 0·80)</i>	<i>Lb normal AVTAG (SpG 0·77)</i>
2	2× 950	2× 7,600	2× 7,315
3	2× 630	2× 5,040	2× 4,851
6	2× 737	2× 5,896	2× 5,675
Total each group	<u>2× 2,317</u>	<u>2× 18,536</u>	<u>2× 17,841</u>

Total (both inboard groups)

4,634 37,072 35,682

Total fuel 9,280 74,240 71,456

3 Fuel cocks

(a) *HP cocks*

The four HP cocks are opened by the initial movement of the throttle levers (B/29) from the fully closed position. The sleeves on the throttle levers must be held up to permit backward and forward movement over the IDLING gate, and also to permit movement from the HP COCK SHUT position to the IDLING gate.

(b) *LP cocks*

The four LP cocks are electrically controlled by four guarded ON—OFF switches on the underside of the coaming, centrally placed above the engine instrument panel.

Each LP cock is fitted with a by-pass through a non-return valve which forms a thermal relief valve for the fuel trapped between the engine and the LP cock when the cock is closed.

(c) *Cross-feed cocks and indicators*

(i) Three electrically-operated cross-feed fuel cocks, controlled by two-position switches (D/4) marked SHUT—OPEN on the fuel control panel, consist of a port cross-feed cock which interconnects the two tank groups on the port side, a starboard cross feed cock which interconnects the two tank groups on the starboard side, and a centre cross-feed cock which interconnects the No. 2 and No. 3 tank groups. It is possible to feed an engine from any tank group.

(ii) Three magnetic indicators (D/28) on the fuel control panel indicate the positions of the cross-feed cocks; if a cock is open its indicator will be black with a transverse white line, if it is closed the indicator will still be black but with a fore-and-aft white line. The transverse (open) indications are positive but the for-and-aft (shut) indications show only that SHUT has been selected and it does not follow that the cock has actually shut, e.g. with the switch at SHUT, if the actuator has failed and

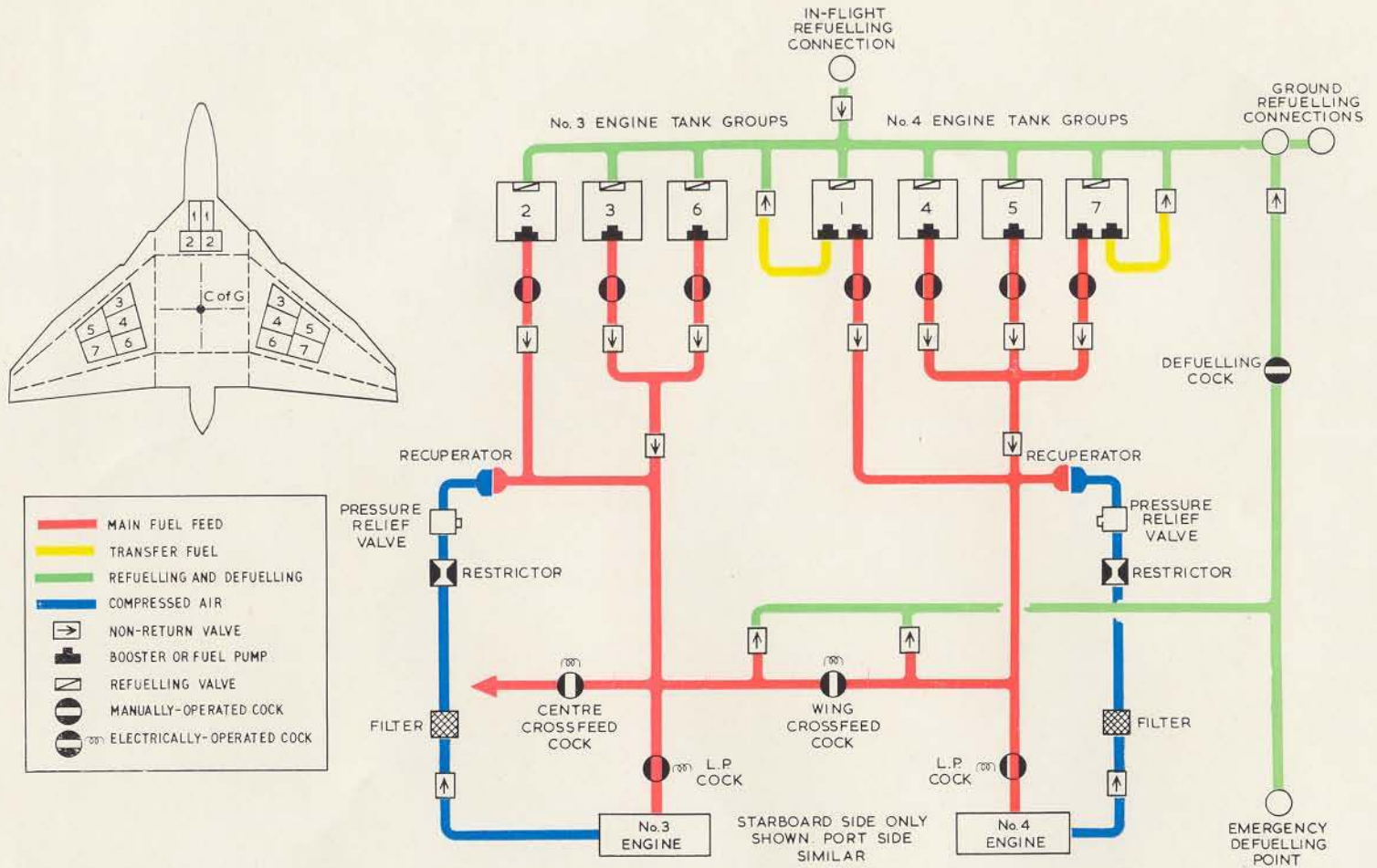


Fig 1 Simplified Fuel System Diagram

the cock does not shut, the indicator will still show a fore-and-aft white line.

4 Fuel booster-pumps and sequence timers

(a) *Booster-pumps*

An electrically-operated booster-pump is mounted in the base of a reservoir in each fuel tank to supply the engines at low pressure, each pump being controlled by an ON—OFF switch positioned in the appropriate place on the mimic diagram representation of the fuel tank in the fuel system layout on the fuel control panel. (Items D/6-11, 15, 18 and D/22-27). These switches should normally be left ON throughout flight.

(b) *Auxiliary booster-pumps*

Starvation of the booster-pumps in the fuel tanks, due to changes in aircraft attitude, is prevented by auxiliary pumps which are fitted at the inboard end of each wing tank and are electrically connected to the appropriate booster-pump. Whenever the booster-pump is set ON, the auxiliary pump will run and supply fuel to the reservoir in which the booster-pump is located, thus maintaining a constant level of fuel in the reservoir. Should the auxiliary pump fail, flap valves in the lower wall of the reservoir permit fuel to flow into the booster-pump. Normally the head of fuel in the reservoir holds the flap valves closed.

(c) An electrically-operated sequence timer, installed in each main wheel bay adjacent to the refuelling panel, maintains a balance of fuel about the C of G of the aircraft by causing each pump in a group to run at full speed in turn, whilst the remainder operate at reduced speed. The length of time each pump runs at full speed is proportional to the capacity of the tank, and therefore the fuel level in all tanks is kept reasonably constant. Any further trimming of the fuel C of G can be carried out by use of the fuel transfer pumps. (See para. 5 below.)

(d) Four AUTO-MANUAL switches (D/12 and D/21) one for each tank group, are on the fuel control panel. With all booster-

pumps ON and these switches at AUTO, sequence timing is in operation; to interrupt the sequence timing in any group, set the appropriate switch to MANUAL and, if it is desired to use fuel from any particular tank in the group, switch OFF all booster-pumps which are not required. The AUTO-MANUAL switches should be set to MANUAL after flight, in order to de-energise the relays.

5 Fuel transfer-pumps

(a) The fore-and-aft trim of the aircraft may be adjusted by transferring fuel forward or aft between tanks Nos. 1 and 7 on the port and starboard sides. Two three-position FWD-AFT C of G TRANSFER switches (D/20) for the port side and (D/13) for the starboard side, on the fuel control panel, each control two transfer pumps, one in the No. 1 and one in the No. 7 tank.

(b) With a switch set to FWD, the refuelling valve of No. 1 tank opens and No. 7 tank transfer pump starts and transfers fuel to No. 1 tank; setting a switch to AFT opens the refuelling valve of No. 7 tank and starts No. 1 tank transfer pump. The rate of fuel transfer is approximately 100 lb/min when transferring from No. 1 to No. 7 tank and approximately 50 lb/min when transferring from No. 7 to No. 1 tank; approximately 300 lb of fuel must be transferred to alter the C of G by 0.1 feet. After transfer, check that the desired amount of fuel has been transferred.

(c) If, when transferring fuel the receiving tank is full when the transfer pump is still running, a float switch closes the refuelling valve.

(d) Stowage for a C of G slide rule and fuel planning log is provided under the aft end of the starboard console.

(e) *Fuel C of G indicator*

(i) A fuel C of G position indicator (B/22), on the engine instruments panel indicates the C of G of the fuel system (not of the aircraft). The instrument registers automatically when

in-flight refuelling is in operation (see Chap 2 of this Part) but readings can be taken in other flight conditions by pressing the C of G CHECK button (B/21) adjacent to the instrument. This button can also be used, when flight refuelling is in progress, to regain the fuel contents gauge readings.

(ii) The face of the instrument has two arcs, one for each side of the fuel system ; each arc is divided into three segments, a central green section to indicate a safe range, and red outer sections marked NOSE HEAVY and TAIL HEAVY. The needles should be on or near the zero position if the fuel is correctly proportioned. Each green sector covers a range of 45,000 lb/ft which is divided into 15,000 lb/ft forward of zero and 30,000 lb/ft aft. If, for example both needles were on the forward limit of the green sector, the aircraft C of G would be 30,000 lb/ft forward of the position with equally proportioned fuel.

(iii) The instrument can be checked before flight by pushing the C of G CHECK button and observing any slight movement of the needles. If no movement is observed, it may be because of exact fuel proportioning. This can be checked by setting the flight refuelling MASTER SWITCH OFF (E/24), transferring fuel from No. 1 or 7 tanks and checking the indicator for movement whilst pressing the CHECK button.

6 Fuel pressure warning indicators

Four booster-pump fuel pressure warning indicators (B/15) (one for each engine tank group) on the centre panel show white if the booster-pump pressure in a particular engine feed line falls below 5 PSI.

7 Fuel contents gauges

(a) A capacitor-type system provides indication of fuel contents. The four gauges (B/23), one for each tank group, are on a panel forward of the throttle quadrant. Each gauge is calibrated with

two concentric scales, reading in pounds $\times 1,000$. Normally, each gauge reads the contents of its appropriate group, on the inner scale. An individual tank reading is obtained on the outer scale by pressing the pushbutton in the appropriate tank position on the mimic diagram.

(b) In no circumstances should two gauge pushbuttons in the same group be pressed simultaneously, as this will damage the instrument.

(c) Four group contents gauges are at the nav/plotter's station ; there is no means of reading individual tank contents on these gauges.

(d) Electrical supplies

The fuel contents gauges use 28-volt DC.

8 Fuel flowmeters

(a) A Mk 3 flowmeter system is installed. This system is designed to give the following approximate indications:—

- (i) Fuel consumption of individual engines (lb/min).
- (ii) Total fuel consumption of all four engines (lb/min).
- (iii) Total amount of fuel used (lb).

(b) An indicator (A/36) giving instantaneous flow for individual engines is on the co-pilot's instrument panel. Selection of an individual engine flow is obtained by pressing the pushbutton (D/5) which indicates the appropriate engine on the fuel system mimic diagram. The instrument will continue to indicate the flow to that engine until another engine is selected.

(c) A second indicator, giving total flow (lb) and total fuel consumed, is at the nav/plotter's station. The total flow is indicated by means of two pointers against a scale reading in 10 lb/min at each minor division and 100 lb/min at each major division. The total fuel consumed is indicated by means of a veeeder counter

recessed in the face of the instrument. A RESET—NORMAL switch, spring-loaded to NORMAL is adjacent to the instrument.

(d) Electrical supplies

The flowmeter system uses 115-volt AC from No. 3 inverter and 28-volt DC.

9 Fuel tank pressurisation and venting

(a) Each tank group can be pressurised with air from its associated engine. The system enables an air pressure of approximately 2PSI above ambient to be maintained in the tanks throughout the altitude range of the aircraft so as to prevent loss by boiling off fuel due to high altitude and high fuel temperature.

Pressurisation also prevents negative differential pressure in the tanks, thus preventing risk of tank collapse.

(b) A TANK PRESSURISATION switch (E/15) marked ON—OFF is on the flight refuelling panel.

(c) The wing tank vents have a common outlet on the underside of the wing; the fuselage tank vents also have a common outlet on each side of the fuselage.

9A Tank pressurisation indicators

Four TANK PRES IND. 1, 2, 3 & 4, one for each tank group, are on the in-flight refuelling panel. The indicators show black when the tanks are pressurised and white when they are depressurised

10 Recuperators

A recuperator of approximately 2½ gallons capacity is fitted to each tank group. One side of the recuperator is supplied with air at constant pressure from its associated engine, and the other side is supplied with fuel from that particular engine fuel feed pipeline at booster-pump pressure which is higher than the air pressure. Under conditions of negative G, if the booster-pumps are uncovered and there is a loss or reduction of pressure in the

fuel feed pipeline, the recuperator will discharge its full contents into the fuel feed pipeline, thus maintaining the supply to its associated engine for at least ten seconds even under the most adverse conditions. When normal conditions are resumed, the booster-pumps will again supply the engines and recharge the recuperators.

11 Refuelling and defuelling system

(a) Refuelling on the ground

(i) Two pressure-refuelling points, in the outboard side of each main undercarriage unit bay, are connected by separate pipelines to a common refuelling pipeline. This pipeline runs outboard to the individual refuelling valves in the base of each wing tank sump. Similarly each refuelling pipeline runs forward from the refuelling points along the front spar and into the fuselage to the refuelling valves in the fuselage tanks.

(ii) During refuelling each tank is filled to the same percentage of its capacity, to maintain a correct C of G position, by means of a selector potentiometer calibrated 0-100 per cent in the port main wheel-bay adjacent to the refuelling points. The selector operates through the electrical output of the contents gauge transmitter units.

(iii) A control panel at each refuelling point carries the switches for the system and indicator lights to show the progress of refuelling.

(iv) Only one tank in each group is filled at a time, automatic change-over to the next tank taking place when the first tank is filled to the selected percentage. The order of filling is 1, 4, 5 and 7 in the outboard groups and 2, 3 and 6 in the inboard groups.

(b) Defuelling

(i) Defuelling can be done in either of two ways. In each case it is important to check that the rear tanks have defuelled before defuelling the forward tanks.

1 Set the bowser to suck and open the defuelling cock. Close the tank servicing cocks on all forward tanks until the rear tanks have been defuelled, then open the tank servicing cocks on the forward tanks.

2 Set the bowser to suck and open the defuelling cock. Set the AUTO/MANUAL switches to MANUAL and set ON the rear tanks booster-pumps. The pressure from these pumps will keep the non-return valves closed in the lines from the forward tanks and the rear tanks are thus defuelled first.

(ii) In an emergency, when the refuelling connections are not accessible, the aircraft may be defuelled via EMERGENCY DEFUELLING connections on the upper surface of the main-planes, slightly to the rear of the front spar and close to the wing roots.

12 Normal use of the fuel system

NOTE: Use of AVTAG. Until further experience is gained, and pending the introduction of fuel tank pressure indication, a close check on fuel consumption, as indicated by the fuel contents gauges (not flowmeters), must be maintained, particularly when refuelling has taken place under warm temperate (or tropical) conditions.

(a) General

Before starting switch ON all LP cocks and set the AUTO/MANUAL switches to MANUAL. With the cross-feed cocks closed, check the operation of the booster-pumps by switching each one ON in turn and noting that the appropriate fuel pressure warning indicator shows black, and returns to white when the booster-pump is switched OFF. Post-STI/223, the outer group pumps should be checked first, otherwise false indications will be given by the fuel pressure warning indicators. Check the operation of the cross-feed cocks by switching ON one booster-pump and noting that the appropriate fuel pressure warning indicators show black when the cross-feed cocks are OPEN and return to white when the cross-feed cocks are SHUT. Before starting switch on one booster-pump in each group, check transfer-pump switches central and guarded, and all cross-feed cocks SHUT. After starting, switch

ON all booster-pumps and set the AUTO/MANUAL switches to AUTO. Check all these selections before take-off. Select tank pressurisation ON after take-off and OFF before landing. After landing, set all AUTO/MANUAL switches to MANUAL, switch OFF all booster-pumps except one for each engine in use. The engines must be shut down by closing the appropriate HP cock, the LP cocks must not be used for this purpose and are normally left ON. When all engines are shut down, switch OFF all booster-pumps.

(b) In flight

(i) Under normal conditions, with the AUTO/MANUAL switches at AUTO and all booster-pumps ON, fuel balancing will be maintained automatically, ensuring that the fuel c of G remains approximately constant.

(ii) Make systematic checks of all tanks contents at frequent intervals. It is recommended that, when checking contents, the buttons for corresponding tanks on opposite sides should be pressed simultaneously; both readings should be approximately the same. No two buttons in one group should be pressed at the same time, as damage to the mechanism will occur. It is recommended that fuel checks are made at least on the following occasions:—

Before take-off

At the top of the climb

At 30-minute intervals above 30,000 feet and more frequently below

Before let-down

Before joining the circuit pattern

(iii) Stores hang-up, booster-pump failure, etc. may necessitate a departure from automatic fuel balancing, in which case the c of G position can be maintained or altered by use of the transfer switches. A c of G slide rule is provided and is stowed below the starboard console. c of G checks should be made on the occasions listed above, except that once per hour should be sufficient at altitude. Checks should also be made before the release of any stores, and before and after in-flight refuelling.

(iv) When the contents of any tank in a group has fallen to 400 lb, the AUTO/MANUAL switch for that group should be set to MANUAL and the booster-pump for that tank switched off when the fuel level falls to 150 lb.

(v) Although all the fuel indicated on the fuel contents gauges is usable, owing to the wide distribution of fuel between tanks and the possibility of uncovering fuel pumps while manoeuvring the aircraft, the minimum recommended for final landing is 8,000 lb total. If it should become necessary to land with less fuel it is advisable, during the later stages of the flight, to retain as much fuel as possible in Nos. 3 and 4 tanks by selective use of the fuel pumps, rather than have small amounts of fuel in each of the 14 tanks.

(c) *Cross-feeding*

If an engine fails, or is shut down for a long period, or if the fuel feeds unevenly for any reason, cross-feeding will be necessary to maintain a lateral balance of the fuel. The appropriate cross-feed cock must be opened; the system can be left at AUTO but, due to pressure loss in the lines, the side on which the engine is not running will feed more slowly than the other. The booster-pumps should be switched off on the side containing less fuel, until lateral balance has been restored.

◀ **WARNING:** Do not cross-feed if the cause of imbalance is not known; if the cause is a leaking tank, more fuel will be lost. ▶

13 Booster-pump failure

(a) Failure of a booster-pump will be indicated by the contents readings of a tank remaining constant between fuel contents checks.

◀ If failure is suspected, switch the affected tank group to MANUAL and switch off all pumps except the suspect one; pump failure will be confirmed if the fuel pressure indicator shows white. If booster-pump failure is confirmed, the fuel remaining in that tank must normally be considered unusable and should not be included in the recommended minimum total fuel for landing. The group should be left at MANUAL and the c of G adjusted by selective use of the individual booster-pumps.

(b) Except in exceptional circumstances, fuel supply of an engine by suction feed only (no booster-pump running) must not be used in an attempt to use the contents of a tank with a failed booster-pump. Due to the fuel being supplied at a lower pressure, a rise in fuel temperature and turbulence at the engine-driven pump results, and cases have arisen where the flexible pipe lines from the engine-driven pump to the fuel control units have been damaged, thus causing leaks. If the engine speed is above 80% and the aircraft above 20,500 feet, the engine may flame out.

(c) If gravity feeding is essential a careful watch must be kept on the fuel contents gauges and RPM indicators. A pipe fracture may be indicated by inexplicable fuel asymmetry or by loss in engine RPM. Since such a failure might cause an engine-bay fire, the affected engine must be shut down, the LP and HP cocks shut and a careful watch kept for any signs of fire in the engine bay.

(d) If the c of G moves, it can be adjusted by use of the transfer pumps.

(e) Any gravity feeding carried out must be reported on landing, when the necessary action to inspect the flexible pipe-lines will be taken.

(f) If the booster-pump fails in a No. 1 or No. 7 tank, the fuel from the failed tank may be transferred to the serviceable tank with the sequence time switch set to MANUAL. The c of G ▶ should be adjusted as necessary and, as far as possible, a similar percentage of fuel kept in all tanks, by selective use of the booster-pumps.

13A Booster-pump running continuously at full speed

If, due to a relay failure, a booster-pump runs continuously at full speed when the group is selected to AUTO, the fuel level in that tank will fall more rapidly than in the corresponding tank on the other side of the aircraft. The group contents, however, will remain similar to the other groups. Select MANUAL for the affected group and maintain an even fuel distribution by selective use of the booster-pumps.

14 Sequence timer failure

Failure of a sequence timer will be indicated by the contents of one tank per group on one side falling while the remaining tank contents on that side remain constant. Select **MANUAL** for both groups on the failed side and maintain an even fuel distribution by selective use of the booster-pumps.

15 Leaking tanks

If a tank is leaking, its fuel level will fall continuously while the level in the other tanks falls more slowly. Attempt to confirm the leak by scanning the under-surface of the aircraft through the

periscope. To minimise fuel loss, a leaking tank should be used exclusively to feed up to three engines. Open the appropriate cross-feed cocks, select **MANUAL** for all tank groups and switch off all booster-pumps for the tank groups, except that in the leaking tank. Monitor the fuel contents and, when the tank is nearly empty, switch on all the other booster-pumps, select **AUTO** for all tank groups except for the leaking tank group which should be left in **MANUAL** and then switch off the booster-pump in the leaking tank. During this operation, make any necessary adjustments to the c of G by using the transfer pumps.



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