Part I

Chapter 2—Fuel System

List of Contents

Description

1 Introduction

(*a*) Fuel is stored in a series of flexible bag-type tanks, in three groups, one group in the fuselage and one in each wing. The basic fuel system tankage can be increased by the carriage of two tanks in the bomb-bay.

(*b*) The tanks of each fuel tank group are pressurised by a group pressurisation system all three of which operate from a common air supply system tapped from the final stage of the compressor of all four engines.

(*c*) (i) The controls for fuel system usage are on a sliding panel AT between the two pilots and which slides forward under the

centre instrument panel when not in use. On the second pilot's console AF (Mk. 1) or side panel AAJ (Mk. 1A) are the fuel proportioner indicators.

(ii) Individual IN USE/NOT IN USE tank control switches are on panel FE on the port side of the fuselage and are not accessible in flight.

2 Tank capacities

(*a*) The following table shows the approximate usable fuel capacities, in pounds and calculated at 7·7 lb/gallon.

Tank and location	*No. off*	*Gallons usable fuel per tank*	*Pounds total usable fuel*	*Booster pumps per tank*
WING				
No. 1 Centre section	2	467	7,192	1
No. 2 Inner plane	2	295	4,542	1
No. 3 Inner plane	2	263·5	4,058	1
No. 4 Inner plane	2	323·5	4,981	1
No. 5 Inner plane	2	340·5	5,244	2
No. 6 Outer plane	2	475	7,315	2
FUSELAGE				
No. 7 Centre section	2	589	9,071	1
No. 8 Bomb-bay roof	1	342	2,634	1
No. 9 Bomb-bay roof	1	529	4,073	1
No. 10 Bomb-bay roof	1	773	5,952	1
No. 11 Bomb-bay roof	1	382	2,941	1
No. 12 Rear fuselage	2	524	8,069	1 (2 post-Mod. 820)
		Total, internal	66,072	
LONG RANGE				
Bomb-bay	2	988	15,216	2
		Total with long-range tanks	81,288	

(*b*) When Mod. 820 is embodied No. 7 P. & S. Tanks are interconnected, thus for operational purposes the two tanks become one. This ensures a continued supply of fuel from both tanks should either tank booster pump fail.

(*c*) Mod. 820 also makes provision for additional booster pumps in No. 12P and 12S tanks thereby ensuring a continued supply should a single pump failure occur. The pumps are controlled by two circuit breakers on Sliding Panel AT, the switching being arranged so that one circuit breaker controls the No. 1 pumps in each tank whilst the other circuit breaker controls the No. 2 pumps in each tank. The control switches on panel AT are identified by the annotations 12P AND S NO. 1 PUMPS and 12P AND S NO. 2 PUMPS.

3 Fuel proportioners

(*a*) Three mechanical vane type fuel proportioners are provided, one for each wing and fuselage group. Fuel from the bomb-bay tanks is not proportioned.

(*b*) The proportioners provide the desired ratio of fuel flow from individual tanks.

(*c*) Each proportioner consists of a number of cells each connected to a particular tank. Each cell contains a set of rotors, a bypass valve and a fuel outlet valve. Both valves of the wing groups proportioners are electrically controlled; only the bypass valve of the fuselage group proportioner is controllable.

4 Fuel recuperators

Four fuel recuperators are provided and are piped in pairs, each pair feeding two engines. Each recuperator is of $2\frac{1}{2}$ gallon capacity and ensures that the engines are supplied with fuel under negative G conditions. The recuperators are re-charged from the main fuel feed system when negative G conditions no longer exist.

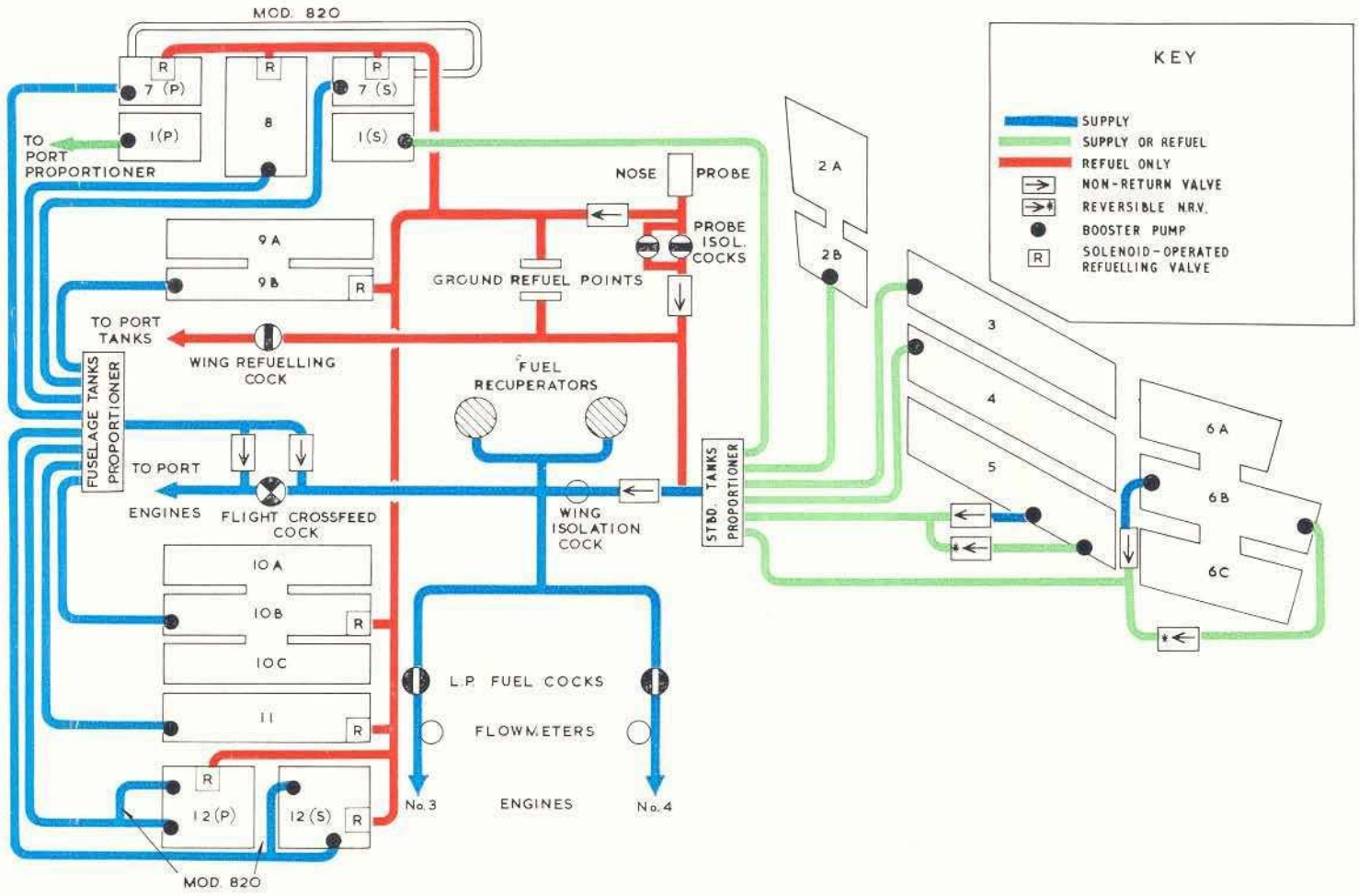

Fig. 1 Fuel system diagram

5 Fuel feed to the engines

(*a*) *Fuselage group*

From the fuselage proportioner fuel is fed to the engine gallery line, either side of the crossfeed cock and then to each of engines via the LP cocks.

(*b*) *Wing groups*

From each wing group proportioner fuel is fed to the wing gallery line and then through wing isolation cocks to the engine gallery line on the associated side. The forward bomb-bay tank feeds into the port wing gallery line via long range isolation cock and the aft bomb-bay tank into the starboard gallery line. Cross-feeding can be actioned by the use of the flight cross-feed cock, or, in emergency, by the wing refuelling cock.

6 Tank pressurisation system

The internal fuel tank pressurisation system automatically maintains a 2·75 PSI differential pressure between the fuel tanks and atmosphere for all conditions of flight. The system is divided into three groups with a common air supply tapped from all four engines. One or more engines can pressurise all three groups. A vent valve gives both inward and outward venting should the normal control system malfunction, outward venting occurring at 4 PSI and inward venting at 0·14 PSI.

7 Ground refuelling system

(*a*) Two pressure refuelling connections are on the starboard side of the fuselage, one for refuelling both wing groups and bomb-bay tanks and the other for refuelling the fuselage tanks.

(*b*) The wing groups are fuelled via the normal gallery lines and proportioners, but the fuselage group is provided with separate refuelling lines.

(*c*) All tanks are fitted with high level float switches which control either the proportioner cells (wing groups) or the refuelling valves (fuselage group) to cut off the supply to the affected tank.

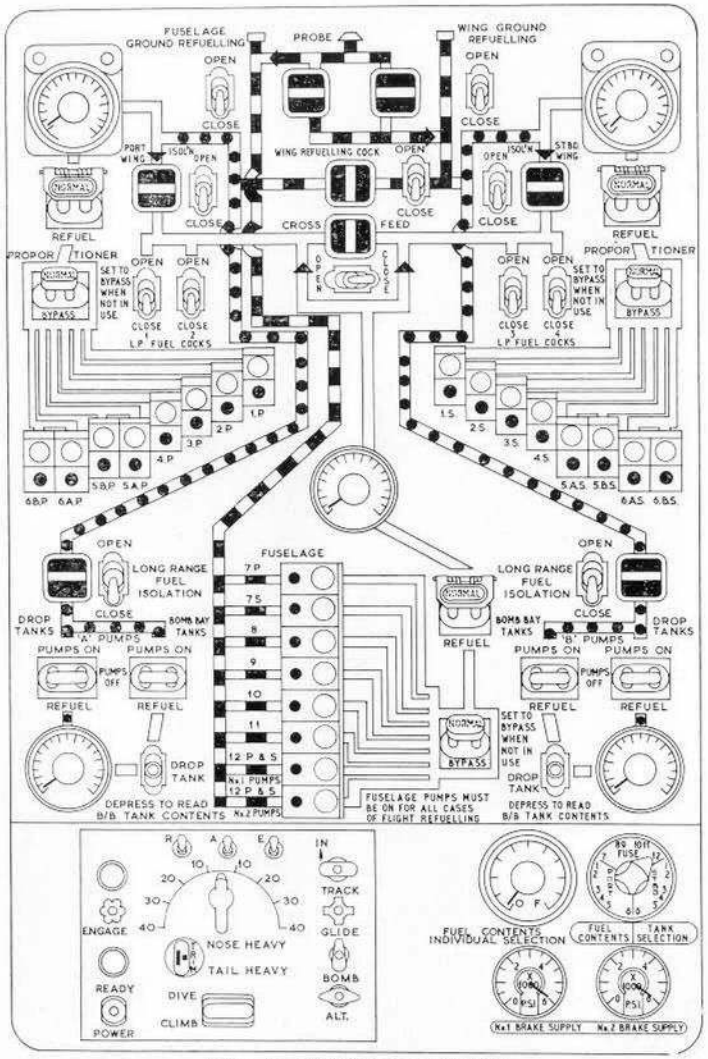

Fig. 2 Sliding panel AT

Controls and Indicators

8 Sliding panel AT

(*a*) This is the main fuel control panel and slides in runners below the centre instrument panel. The panel is in the form of a mimic diagram of the fuel system and is transilluminated.

(*b*) On the panel are the following controls:

Three proportioner controls
Two wing isolation switches and indicators
One wing refuel switch and indicator
Four LP cock control switches
One cross-feed cock switch and indicator
Twenty-four booster pump circuit breakers
Two long range isolation cock switches and indicators
Two drop tank booster pump controls
Two controls, one for fwd. and one for aft bomb bay tank booster pumps
Five fuel contents gauges
Two bomb-bay tank fuel gauge selector switches
Tank contents selector
Two probe isolation cocks switches

9 Internal tanks booster pumps controls

(*a*) Twenty-four circuit breaker switches control the aircraft booster pumps. Eight are provided for each wing group and eight for the fuselage group.

(*b*) Post Mod. 820 each No. 12 tank circuit breaker controls one pump in each tank, so that failure of one pump, or its electrical supply does not affect full delivery rate.

(*c*) When Mod. 2842 is embodied twelve nylon studs are fitted adjacent to and for ease of identification of those circuit breakers which control fuel pumps supplied from the port bus-bar.

10 Bomb-bay tanks booster pumps controls

The FWD BOMB-BAY and AFT BOMB-BAY TANK controls switches, PUMPS, ON/OFF/REFUEL, are on the port and starboard side of the fuselage tank booster pump switches. Since each controls one pump in each tank, both switches must be on if only one tank is fitted in order that both pumps in that tank are operative.

11 Drop tanks booster pumps controls (not in use)

(*a*) Outboard of the two bomb-bay tank switches are two similar DROP TANK, PUMPS ON/OFF/REFUEL switches which operate in an identical fashion to the bomb-bay tank switches.

(*b*) Forward of each DROP TANK SWITCH is a DROP TANK FUEL ISOLATION, OPEN/CLOSE switch which must be set to OPEN before fuel will flow to the wing gallery lines. A magnetic indicator adjacent to each switch gives "flow line" indication of the position of the cock, or striped indication if electrical supply is lacking.

12 LP warning lights

(*a*) Four red warning lights, one for each engine are mounted on the lower edge of the pilots centre engine instrument panel A. The light is controlled by a pressure switch mounted on the corresponding engine and connected to the fuel supply line between the low pressure filter and the engine driven pump; the switch contacts close if the pressure in the line falls below $2\frac{1}{2}$ PSI.

(*b*) When Sapphire Mod. 1099 is embodied an additional 9 PSI absolute pressure switch is fitted. This gives a positive indication of low fuel pressure at altitude.

13 Fuel proportioner controls

(*a*) Three PROPORTIONER, NORMAL / BYPASS control switches are situated, one at each forward corner of the panel and one at the aft end of the panel.

(*b*) The settings of the switch are

NORMAL . Proportioned fuel from all tanks containing fuel in the respective group is fed to the engines, provided that the individual tank control switches are selected to " in-use." This setting is also used for refuelling

BYPASS . All cells of the proportioner set to bypass

(*c*) Above each proportioner switch is a NORMAL/REFUEL switch. When the switch for the fuselage group is set to REFUEL the refuelling valves solenoids are energised ; when the wing groups switches are set to REFUEL, the wing proportioner cells are activated to the refuel condition and the reversible NRV's in tanks 5 and 6 are operated.

(*d*) Individual cell bypass selection switches, IN USE/NOT IN USE are on panel FE on the port side of the fuselage and are set to NOT IN USE for any tank not required to be refuelled. Selection of NOT IN USE places that cell in BYPASS regardless of the setting of the proportioner switch on panel AT; the appropriate magnetic indicator will show striped.

(*e*) Proportioner magnetic indicators are on the 2nd pilot's side panel AAJ (Mk. 1 a/c panel AF), they give the following indications:

NORMAL . . .	Black
BYPASS . . .	Striped
REFUEL . . .	White (if tank is not full) Striped (tank full)

14 Fuel contents gauges

(*a*) Five fuel contents gauges are provided which give total contents indications of the three internal and the two long range groups. A further total contents gauge is situated on the navigator's panel; this gauge does not include the bomb-bay and drop tank fuel.

(*b*) A further contents gauge and a selector switch are situated on the aft sloping portion of the sliding panel. By appropriate switch selection this indicator may be used to ascertain the contents of individual tanks or the aggregate contents of two or more adjacent tanks.

(*c*) Adjacent to each drop tank/bomb-bay tank contents gauge is a DEPRESS TO READ B/B TANK CONTENTS button, since these gauges normally read drop tank contents. When Mod. 3583 is embodied the switch function is reversed and the bomb-bay tank contents can be read direct.

(*d*) *Fuselage tanks low level warning*

(i) A magnetic indicator (400 GALS. FUS RESERVE WARNING) on the aft sloping portion of the centre sliding panel AT shows white when the contents of the fuselage tanks group have fallen to 3,080 lb. The indicator is operated by float switches in the Nos. 11 and 12 tanks, therefore the stated amount of fuel is available only when correct fuel proportioning has been maintained.

(ii) When Mod. 820 is embodied the indicater is deleted.

15 Wing isolation cocks switches and magnetic indicators

Each wing group has an isolation cock controlled by an OPEN/CLOSE switch on panel AT. Adjacent to each switch is a flowline magnetic indicator. The cocks isolate the wing tanks from the engines.

16 Wing refuelling cock and indicator

(*a*) An electrically-actuated crossfeed cock is provided to isolate the port and starboard wing groups, and is controlled by an OPEN/CLOSE switch on panel AT. Normally the cock is only opened during refuelling and defuelling but can be used in the air in conjunction with the flight crossfeed cock to use trapped fuel in the event of a wing isolation cock failing in the closed position.

(*b*) A flowline magnetic indicator is adjacent to the switch.

17 Crossfeed cock and indicator

(*a*) The flight crossfeed cock in the engine fuel gallery line is controlled by a CROSSFEED, OPEN/CLOSE switch. Normally the switch is left in the CLOSE position. A flowline magnetic indicator is above the switch.

(*b*) When Mod 3606 is embodied, the electrical supply to the cross-feed cock is derived from No. 1 LV bus-bar (feeder 3P7) instead of No. 2. Since the electrical supply for the wing refuelling cock is derived from No. 2 LV bus-bar, in the event of a single LV bus-bar failure, cross-feeding of fuel can be carried out by use of the appropriate cock.

18 LP cock controls

LP FUEL COCKS, OPEN/CLOSE control switches enable the LP fuel cocks of Nos. 1, 2, 3 and 4 engines to be actuated as desired.

19 Fuel flowmeter

A fuel flow indicator controlled by a five-way switch on the co-pilot's side panel AD gives the fuel flow reading for any particular engine. A " Fuel Gone " meter is situated on the navigator's centre panel.

20 Fuel tanks pressurisation controls

(*a*) The controls are mounted on 1st pilot's panel AAF and comprise of three FUEL VENT PRESSURE ISOLATION, NORMAL/ISOLATE switches, three pressure gauges and a temperature gauge.

(*b*) With the switches set to NORMAL all tank groups are pressurised when the engines are running. Setting any switch to ISOLATE causes that group to be depressurised.

(*c*) The pressure gauges read 0 to 10 PSI and are marked in red at 5 PSI which pressure must not be exceeded.

(*d*) The temperature gauge reads the temperature in the fuselage system gallery line and this must not be allowed to exceed 100°C.

(*e*) A red warning light is on the pilots coaming panel and comes on if the pressure differential in any group falls below 0·14 PSI.

21 Fuel filter de-icing system controls (Mk. 1A only)

(*a*) The fuel filter in each engine supply line is de-iced by hot air tapped from that engine compressor and passed to a heat exchanger through which the fuel flows. The hot air from each engine enters the associated system through a solenoid-operated gate valve which may be manually or automatically controlled by four MAN/OFF/AUTO switches, one for each engine, on 2nd pilot's panel AF. A warning light for each gate valve indicates that the gate value is open.

(*b*) When MAN is selected the gate valves are opened and the associated warning lights come on. When AUTO is selected, the solenoids are actuated when both the fuel temperature drops to 10°C and the pressure differential across the filter rises to $2\frac{1}{2}$ PSI. The solenoid remains activated and the warning lights remain on until either fuel temperature rises above 25°C or the pressure differential falls.

(*c*) The electrical supply to the systems is from the 28-volt bus-bars.

Normal Management of the System

22 General

The main aims of fuel system management are to ensure an adequate and reliable supply of fuel to the engine under all operating conditions, and at the same time, to control the proportion of fuel in each tank so that the aircraft CG position remains reasonably constant within the laid down limits. With all fuel booster pumps in operation and all the proportioners selected to NORMAL, these requirements should be achieved automatically. However, in practice, one of the wing groups may feed more slowly than the other. It is also desirable to reduce the stresses on the airframe and therefore selective use of the wing and fuselage fuel tank groups must be made to achieve even loading and to control the ratio of wing/fuselage loads.

23 Selection between fuel tank groups

(*a*) If a group proportioner is selected to NORMAL and all the booster pumps in that group are not operating, fuel supply from that group may be inadequate to supply engine requirements. In order to avoid engine malfunction due to fuel starvation, proportioners and booster pump circuit breakers must be selected in the correct sequence as follows :

(*b*) *Changing to wing groups from fuselage group*

Wing tank booster pump circuit breakers . .	Closed (on)
Wing proportioner switches	NORMAL
Fuselage proportioner switch	BYPASS
Fuselage tank booster pump circuit breakers .	Tripped (off)

(*c*) *Changing to fuselage group from wing groups*

Fuselage tank booster pump circuit breakers .	Closed (on)
Fuselage proportioner switch	NORMAL
Wing proportioner switches	BYPASS
Wing tank booster pump circuit breakers . .	Tripped (off)

(*d*) *Selecting forward bomb-bay tank*

Flight crossfeed	OPEN
Port LONG RANGE FUEL ISOLATION switch	OPEN
A & B bomb-bay tank switches	Both ON

Use the reverse order to switch off the bomb-bay tank.

24 Fuel system control

(*a*) Before flight ensure that all IN USE/NOT IN USE switches at Panel FE are selected IN USE for all serviceable fuel tanks. It is not considered safe to take-off with an unserviceable and empty tank unless its fuel line to the proportioner is physically blanked off in addition to selecting its proportioner cell to NOT IN USE at panel FE.

(*b*) Before starting the engines carry out the checks of fuel control indications in accordance with the aircraft check list. Open the LP cocks, select the fuselage proportioner to NORMAL, switch on all fuselage booster pumps and check that all LP warning lights are out.

(*c*) Before taxying switch on all wing group booster pumps and select both wing proportioners to NORMAL. Switch off the fuselage booster pumps but leave the fuselage proportioner selected to NORMAL.

(*d*) Take-off with all booster pumps on (except bomb-bay tanks) and all proportioners selected to NORMAL.

(*e*) After take-off select the wing proportioners to BYPASS and the wing booster pumps OFF.

(*f*) When the fuselage group contents indicate 10,000 lb. select the wing groups on and the fuselage group off. The wing cross-feed cock may be opened as required to maintain balance of fuel contents but when either wing group indicates 5,000 lb. the cross-feed cock should be closed and should remain closed for the rest of the flight.

(*g*) When either wing group contents indicate 5,000 lb. select the wing proportioners to BYPASS, leaving the booster pumps on. Select the fuselage proportioner to NORMAL and the fuselage booster pumps on. Switch off all the booster pumps in one wing group to prove that the fuselage proportioner is working properly; then switch the pumps on again. With these selections fuel should continue to be supplied from the wings rather than from the fuselage. Monitor the individual wing tank contents and, as each tank indicates empty the booster pump must be switched off within 30 minutes. When the fuselage group gauge indicates that the fuselage tanks have started to feed, select the fuselage proportioner to BYPASS.

(*h*) The minimum fuel state recommended for final landing is 8,000 lb. Regardless of fuel state it is recommended that during the final approach to land, roll or overshoot, the booster pumps of all wing and fuselage tanks containing fuel are switched on. The proportioners may be selected to NORMAL or BYPASS according to the fuel state but, in the event of any fuel low pressure light illuminating, all proportioners should be selected to BYPASS. On completion of an overshoot the fuel controls may be re-selected as required.

25 Fuel control with bomb-bay tank operable

(*a*) When a bomb-bay fuel tank is fitted and operable the wing and fuselage groups should be controlled as in para. 24. In addition, at 20,000 feet, select the CROSS-FEED cock OPEN, switch *both* BOMB-BAY TANK switches to PUMPS ON, and the port LONG RANGE FUEL ISOLATION cock OPEN. When the bomb-bay tank contents fall to 700 lb. CLOSE the LONG RANGE FUEL ISOLATION cock, select the BOMB-BAY TANKS switches to PUMPS OFF and CLOSE the CROSS-FEED cock.

(*b*) 700 lb. of fuel must be held in reserve in the bomb-bay tank to prevent the possibility of the booster pumps dry-running for an excessive period, with an attendant fire hazard (the pumps must not be dry-run for more than 30 mins.). The possibility of pumps continuing to run after being switched off exists if a fuse in the LV supply to the booster pump blows when the pumps are running.

(*c*) If a bomb-bay tank is fitted and its booster pumps operable, 700 lb. fuel must be loaded in the tank regardless of the fact that the tank may not be used.

26 Contents checks

Systematic checks should be made of all tank contents every thirty minutes when cruising at 40,000 ft. or above, and more frequently when operating at lower levels. Check the individual tank contents for a given group and ensure that their total equals the amount indicated on the group contents scale. The individual tank contents of a group not in use should be checked in case a booster pump has failed to switch off. The various fuel tank readings should also be checked against the fuel calculator chart to ensure that the fuel is proportioning correctly. If the fuel is not proportioning correctly and an attempt is made to balance the fuel in a group of tanks by manipulation of the booster pumps, the associated proportioner should be switched to BYPASS as a precautionary measure and returned to NORMAL as soon as balancing is completed.

27 Booster pump control

(*a*) To avoid the possibility of low pressure warning lights flickering or engines flaming out, the minimum number of usable booster pumps to be switched on is given below.

Group	*State*	*Attitude*	*No. of pumps to avoid*	
			L.p. lights	*Flame-out*
Fuselage	Normal	Climb	6	5
	Normal	Dive	2	2
	Bypass	Climb	5	4
	Bypass	Dive	2	2
Each wing	Normal	Climb	4	4
	Normal	Dive	2	2
	Bypass	Climb	3	3
	Bypass	Dive	2	2

NOTE 1: The above figures are for flight at sea level at 100% RPM with no fuel tank pressurisation.

NOTE 2: Should delivery pressure from the system drop suddenly due to uncovering of pumps, a full recuperator will delay the onset of flame-out for periods between 10 and 60 seconds depending on altitude and RPM.

(*b*) (i) If bus-bar failure occurs and paralleling action is not taken, the proportioners must be set to BYPASS since only four pumps will be available in any one tank group. Post-Mod. 2842 the circuit breakers controlling pumps supplied by the port bus-bar are identified with illuminated studs.

(ii) If an MV bus-bar failure occurs, an immediate check of all fuel gauge readings must be carried out and logged. Reference to the table below will establish the amount of unusable fuel trapped within a group at the time of failure. This quantity remains constant for the remainder of the flight and must be subtracted from all subsequent group readings to establish the approximate amount of available fuel.

Group contents at time of bus-bar failure	*Port MV failed*		*Stbd MV failed*	
	Constant Unusable fuel		*Constant Unusable fuel*	
	Per Wing	*Fuselage*	*Per Wing*	*Fuselage*
2,000	1,000	600	1,000	300
4,000	2,000	1,200	2,000	700
6,000	2,900	1,800	3,100	1,000
8,000	3,800	2,400	4,200	1,300
10,000	4,800	3,000	5,200	1,700
12,000	5,700	3,600	6,300	2,000
14,000	6,600	4,200	7,400	2,300
16,000	7,600	4,800	8,400	2,700
18,000	—	5,400	—	3,000
20,000	—	6,000	—	3,300
25,000	—	7,500	—	4,200
30,000	—	9,000	—	5,000
Unusable tanks	2, 3, 6	9, 10	1, 4, 5	8, 11

(iii) Each special feeder supplies LV control power to half the cells in each proportioner. Should a special feeder fail, operation of the proportioner control will affect only three cells in each wing proportioner and four cells on the fuselage proportioner. The other cells will remain in the position selected at the time of the failure.

(*c*) *Low fuel states*

Because tanks 8 and 9 tend to empty very quickly with the fuselage proportioner in BYPASS, if the flight is to be continued below a total fuselage fuel state of 8,000 lb. the pumps in tanks 8 and 9 must be switched off until the total fuel contents fall to 7,000 lb. If possible under these conditions maximum RPM should be avoided by using only as much power as is necessary. Extreme attitudes and large accelerations should also be avoided.

(*d*) (i) When flight is to be continued below a total fuel state of 8,000 lb. and a bomb-bay fuel tank is fitted and operable, the normally unusable fuel remaining in the wing groups can be transferred to the bomb-bay tank and then delivered to the engines.

(ii) When the fuselage group begins to overfeed the wing groups, indicating that no more fuel can be obtained from the wing groups, check that the fuselage group is feeding correctly and select the fuselage proportioner to BYPASS (para. 24(g)).

(iii) Transfer the fuel remaining in the wing groups to the bomb-bay tank by making the following selections :

Wing isolation cocks . .	CLOSED
Refuelling cross-feed cock .	OPEN
Long range isolation cock .	OPEN
Bomb-bay pumps switches .	REFUEL
Wing booster pumps . .	ON

(iv) When the fuel has been transferred, it is delivered to the engines by making the following selections :

Wing booster pumps . .	OFF
Refuelling cross-feed cock .	CLOSED
Bomb-bay tank pumps .	ON
Port wing isolation cock .	OPEN

(v) When the contents of the bomb-bay tank fall to 100 lb. select :

Bomb-bay pumps . .	OFF
Long range isolation cock .	CLOSED
Wing isolation cocks . .	CLOSED
Refuelling cross-feed cock .	CLOSED

(v) Throughout these procedures the flight cross-feed cock must remain CLOSED and frequent checks should be made to ensure that the low pressure warning lights remain out.

28 Management of the fuel tanks pressurisation system

Before starting the engines, and in accordance with the aircraft check list, check that the three tank pressure gauges indicate zero and that the temperature gauge reading is normal. Select the FUEL VENT PRESSURE ISOLATION switches to NORMAL. Under certain conditions the red FUEL TANK LOW PRESSURE warning lamp on the pilot's coaming panel may be illuminated when the engines are stationary. After starting the engines check that this light is out, and that the tank pressures and temperatures are normal. In flight the three tank pressure gauges and the temperature gauge must be checked periodically. If the reading of any pressure gauge exceeds 5 PSI, the appropriate isolation switch should be switched to ISOLATE, until the pressure reduces to below this figure. If the fuselage vent temperature exceeds 100°C its isolation switch must be set to ISOLATE until the temperature reduces below this figure.

29 Management of the fuel filter de-icing system (Mk. 1A aircraft)

(*a*) Normally all four switches should be selected to AUTO. However if flying with only six booster pumps in operation and the fuel low pressure warning lights come on and remain on after the proportioner has been set to BYPASS, thus indicating possible icing conditions, select the de-icing switches to MAN for a period not exceeding three minutes and return the switches to AUTO. This time limit is necessary since the systems are not protected by the temperature switches when selected to MAN.

(*b*) The selection of MAN in the conditions above is advantageous since the systems are brought into operation earlier than under AUTO control and any possible filter icing is cleared and fuel pressure increased before possible flame-out occurs.

(*c*) If, with the switches at AUTO, less than four warning lights come on, the systems associated with the lights which are not illuminated should be selected to MAN. This is because it is unlikely that icing conditions can occur at one filter and not at another; failure of a light to come on in these circumstances indicates possible failure within the automatic side of that system.

(*d*) MAN must never be selected for a period exceeding three minutes for the reason stated in (*a*) above.

(*e*) It has been found that at low fuel flow conditions e.g. during descent, the pressure differential may be insufficient to operate the automatic switch of the fuel filter de-icing system. If the system has operated during a sortie, it is to be selected to MAN for periods of up to 3 minutes during the descent.

30 Management of the ground refuelling system

(*a*) *Refuelling—internal tanks*

(i) Before refuelling internal tanks, all booster pumps circuit breakers must be tripped, the proportioner control switches set to NORMAL, the LP cocks closed and the flight cross-feed cock closed. Ensure that the WING REFUELLING CROSSFEED COCK switch is set to OPEN. Set the WING ISOLATION COCKS to CLOSED.

(ii) During refuelling of tanks 5 and 6, port and starboard, the four NRV indicators on panel AAJ (AF, Mk. 1) should show white.

(iii) Delivery to each tank automatically ceases when the tank is full. However, if the tanks are to be partially filled, they should first be filled and then defuelled until the correct amount remains.

(*b*) *Refuelling—bomb-bay tanks*

(i) The bomb-bay tanks, though refuelled through the wing tanks couplings, are independent of the wing tanks. Either bomb-bay tank may be isolated by leaving the appropriate tank switch at PUMPS OFF, and closing the long range isolation cock.

(ii) Before refuelling the bomb-bay tanks, ensure that all booster pumps circuit breakers are tripped, all LP cocks closed, TANKER MASTER switch NORMAL (Mk. 1 only) and the WING REFUELLING COCK magnetic indicator shows " in line ". Set the WING REFUELLING COCK to OPEN.

(iii) The port and starboard wing LONG RANGE FUEL ISOLATION switches should be set to OPEN and their indicators should then show " in line ".

(iv) The FWD or AFT BOMB-BAY TANKS pump switch should then be set to REFUEL, as appropriate. The associated electrically-operated refuelling cocks should then be open, indicated by the appropriate magnetic indicators on panel AAJ (AF, Mk 1) showing white. Fuel delivery may then commence.

(*c*) When refuelling has been completed as indicated by the contents gauges and magnetic indicators reset the switches as follows:

NORMAL/REFUEL switches	NORMAL
WING REFUELLING COCK magnetic indicator	Cross-line. Switch to CLOSE
PROPORTIONER switches	NORMAL

Malfunctioning of the System

31 Asymmetric wing contents

(*a*) Although it is possible to fly with one wing group full and the other one empty, the maximum permissible difference for landing is 8,000 lb and this should be considered the maximum practical asymmetry. If this difference is reached it will be necessary to balance fuel as follows:

(i) Select CROSS-FEED cock OPEN.

(ii) Select the proportioner switch for the lighter wing group to BYPASS.

(iii) Switch off the booster pumps in the lighter wing group. Check that the fuel LP WARNING lights remain out.

(iv) Monitor the contents gauges and when fuel balancing is achieved switch on the booster pumps, select the proportioner switch to NORMAL and CLOSE the CROSS-FEED cock.

(*b*) Except in cases of extreme asymmetry, do not cross-feed if either wing group contents indicate less than 5,000 lb.

32 Booster pump failure

(*a*) Tanks 5P, 5S, 6P and 6S in the wing groups and the bomb-bay fuel tank each contain two fuel pumps. Post-Mod. 820 tanks 12P and 12S in the fuselage group also contain two fuel pumps and in addition, tanks 7P and 7S are interconnected. Thus single booster pump failures in any of these tanks will not affect fuel proportioning.

(*b*) If a booster pump fails in any tank containing only one booster pump, the fuel proportioner will not ensure correct fuel delivery from that tank regardless of whether fuel tank pressurisation is on or off. Depending on the particular tank affected, varying reduced rates of delivery can be expected as follows: —

Tank group	*Tank pump failed*	*Percentage reduction in delivery rate*
WING	1	100%
	2	63%
	3	23%
	4	26%
FUSELAGE	7 (Pre-Mod. 820)	61%
	9	58%
	10	48%
	12 (Pre-Mod. 820)	100%

Practically, these figures may be regarded as a measure of non-available fuel ; expressed as a percentage of the fuel remaining in the tank when the pump fails. In extreme cases, e.g. failure of a pump in a No. 1, 7 or 12 tank at an early stage in the flight, it may subsequently be necessary to resort to fuel balancing to maintain the CG within limits. If fuel balancing becomes necessary it can be best done by leaving unused an appropriate amount of fuel, as shown by the CG calculator, in the No. 12 or No. 1 tanks. Similarly it may be necessary to leave fuel in a wing tank in order to maintain symmetry. This will obviously increase the amount of non-available fuel, which must not be included in the reserve for landing. The provisions of paragraph 27 must also be borne in mind.

(*c*) If it is necessary to fly with an unserviceable booster pump in any tank containing only one booster pump, the tank must be filled to at least 50% of its capacity and its proportioner cell selected to NOT IN USE at panel FE. Amend the fuel drill to maintain the CG within limits. One unserviceable booster pump in a tank containing two pumps will not affect the fuel drill.

33 Proportioner failure

(*a*) The complete failure of a proportioner will be indicated by the failure of the affected tank group to feed when its proportioner switch is at NORMAL and its booster pumps are on. However, fuel may still be supplied to the engines through the action of the engine-driven HP pumps drawing fuel from the other groups, provided their switches are at BYPASS. Some loss in engine speed may be experienced however until a serviceable tank group is selected to feed the affected engines.

(*b*) If a fuselage proportioner fails while it is in use, select the wing groups on and proportioners NORMAL. Decide by the fuel and CG calculators how the fuel should be extracted from individual fuselage tanks to maintain the correct CG. Then select the fuselage proportioners to BYPASS, ensure all fuselage booster pumps are on and select off the wing groups. Control the fuel flow from individual fuselage tanks as calculated, by selective use of the fuselage booster pumps.

(*c*) If a wing proportioner fails while it is in use, select the fuselage group on and proportioner NORMAL. Decide by the fuel and CG calculators how the fuel should be extracted from the affected wing group individual tanks to maintain correct CG. Then select the failed proportioner's switch to BYPASS, ensure all the booster pumps for that group are on, and select off the fuselage groups. Control the fuel flow from the individual tanks of the affected group as calculated, by selective use of that group's booster pumps.

34 Engine failure

If an engine fails, open the flight cross-feed cock, and allow the three remaining engines to feed from both sides.

35 Fuel tank pressure failure

In flight the three tank pressure gauges and the vent temperature gauge should be checked periodically. If the reading of any pressure gauge exceeds 5 PSI the appropriate isolation switch should be switched OFF or altitude must be reduced to return the pressure below this figure. If the fuselage vent temperature exceeds 100°C, its isolation switch must be set to OFF.

36 Other failures

Stores hang-up may necessitate departure from the normal management in which case CG position should be maintained by selective use of the fuel tanks in accordance with the fuel and CG calculators.