Part I

Chapter 4—Hydraulic System and Aircraft Controls

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Description

1 General

(*a*) Hydraulic power, supplied by two electrically-driven pumps operates the following services:

Undercarriage
Nose-wheel steering
Wheelbrakes
Flaps
Blue Steel doors
Airbrakes
Bomb doors (see Chap. 16)
RAT scoops (close only).
Brake parachute doors unlocking

(*b*) The hydraulic fluid is drawn from a tank, divided into two halves, each half of which feeds one pump. The pressure output from each pump (4000 PSI) is fed to two electrically-operated selectors, the normal master and the emergency master. With a serviceable system the normal master selector is open and supplies the individual circuits each having its own selector.

(*c*) The emergency master selector is normally closed but is opened under emergency conditions and feeds pressure through pipelines independent of the normal system, to selectors for the emergency operation of

Undercarriage . . .	DOWN
Flaps	DOWN
Airbrakes	CLOSED
Bomb doors .	OPEN and CLOSE

(*d*) The electrical arrangement of the master selectors is such that when an emergency selection is originated the normal master selector closes and the emergency master opens. If the emergency condition is due to an individual circuit fault the master selectors revert to their normal settings after the affected circuit has been operated, but if the emergency is due to loss of hydraulic fluid, all systems have to be operated on emergency.

2 Hydraulic reservoir

(*a*) The hydraulic tank is at the rear of the nosewheel bay together with the hydraulic pumps. The total capacity of the system is 20½ gallons of which 5 gallons are contained in the accumulators, when fully charged. The emergency level of the tank is 9½ gallons.

(*b*) Fluid returning to the hydraulic tank from the pumps and services is divided betwen the two compartments.

(*c*) A float switch in each half of the tank operates when the fluid level in the respective compartment has fallen to 4¾ gallons and switches off the associated pump. Additionally warning lights in the cockpit come on to indicate that the float switches have operated.

3 Accumulators

Accumulators are fitted in the main power circuit (one per pump), the wheelbrakes system, the nosewheel steering system and the brake parachute system. Charging details are as follows:

Accumulator	*No. off*	*Location*	*Air charge* PSI
Power	2	Nosewheel bay	3,000
Wheelbrakes	4	Nosewheel bay	1,800
Nosewheel steering	1	Nosewheel bay	350
Brake parachute	1	Rudder stbd fuselage fairing	1,800

Controls and Indicators

4 Hydraulic pump controls

(*a*) A switch for each pump is on the AEO's panel BB. Each switch has three positions, NORMAL—OFF—EMERGENCY. Two green pump contactor lights are above the switches and two pump ammeters are mounted on panel BC. Two red lights on pilots panel AW illuminate when the associated emergency float switches operate and an amber light on panel AZ illuminates if the system reverts to the emergency condition, or if an emergency selection is made.

(*b*) When a switch is at NORMAL the green contactor light illuminates to indicate that electrical power is being supplied to the motor and the associated pump runs continuously. An automatic cut-out valve allows the pump to run off-load until pressure falls to 3,600 PSI ± 100 when the valve closes until pressure increases to 4,000 PSI ± 50. If the emergency level float switch operates the power supply to the associated pump motor is interrupted. When the switch is at EMERGENCY the float switch is bypassed.

5 Protection units

(*a*) Protection units are fitted in the normal supply lines to the selectors of the following services:

Undercarriage
Bomb doors
Flaps
Airbrakes.

The purpose of a unit is to isolate the normal supply to the circuit and provide an alternative path for the return fluid.

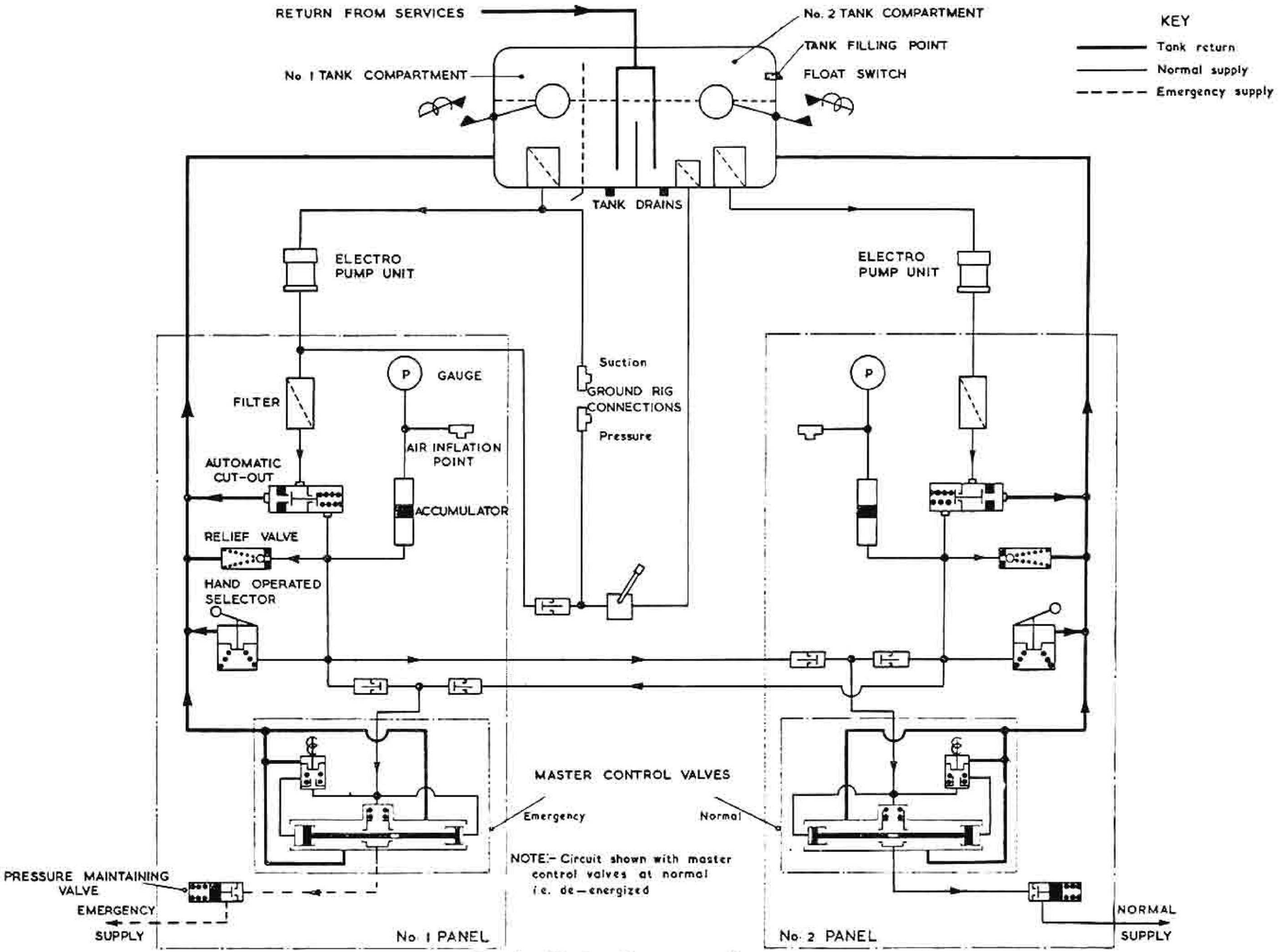

Fig. 1 Hydraulic system diagram

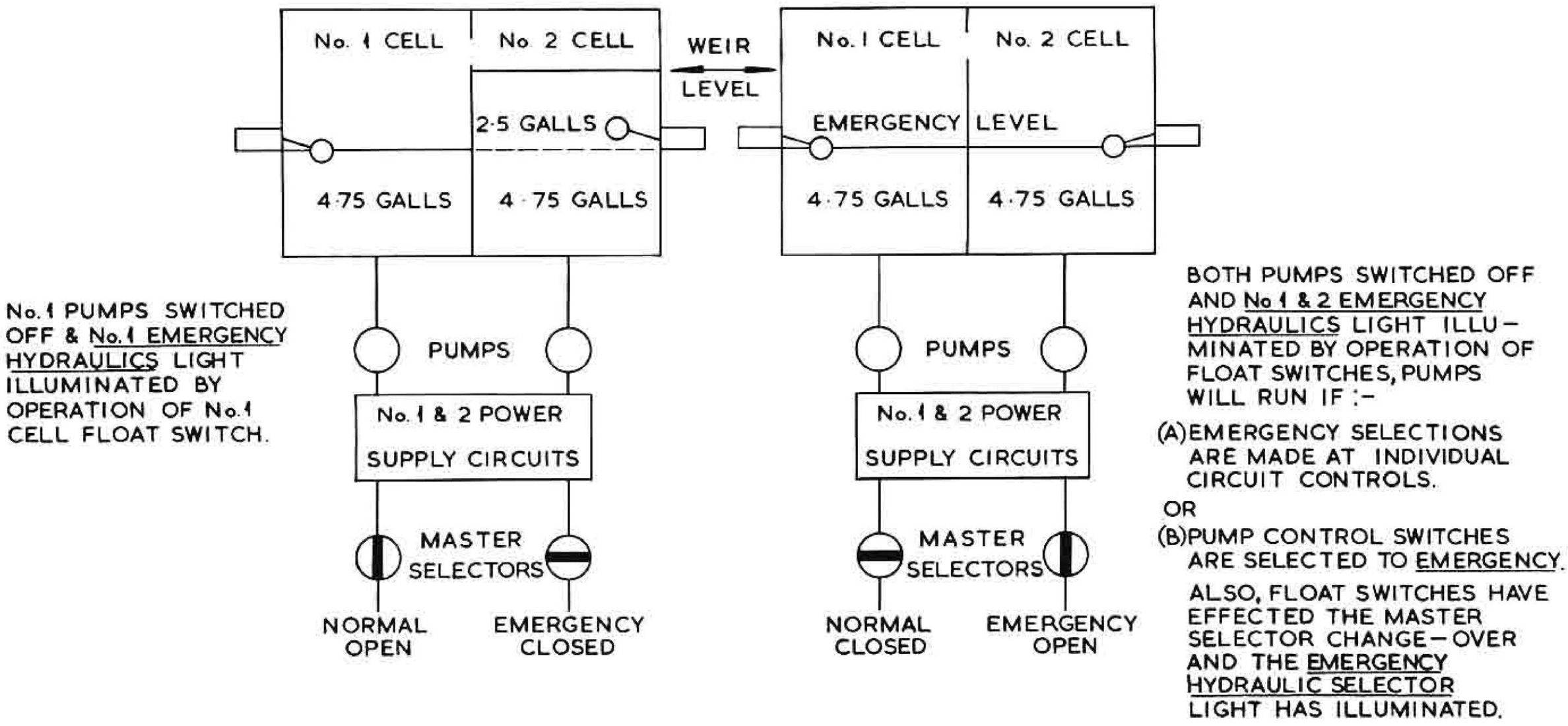

Fig. 2 Hydraulic fluid levels under fault conditions

(*b*) Normally pressure fluid has an unrestricted path through the protection unit to the selector, but when an emergency selection is made emergency circuit pressure is connected to the piston of the associated protection unit to close the normal supply line. Once a protection unit has been operated, normal selection of its associated service cannot be made again in flight since the units must be manually reset and are inaccessible in flight.

6 Undercarriage control

(*a*) The undercarriage is hydraulically operated and electrically selected by one of three pushbuttons, UP, DOWN and EMERGENCY-DOWN, in the centre of panel A. The buttons are mechanically interlocked, so that when any one button is pressed in, the button left in by a previous selection is released.

(*b*) When the aircraft is on the ground the undercarriage cannot be retracted since micro-switches on the bogie mechanism prevent the completion of the UP circuit until the weight of the aircraft is off the wheels. Additionally the UP button is electro-mechanically locked and cannot be depressed until a pitot switch operates at 105 knots to release the lock. Post-Mod. BC070 an undercarriage test switch is fitted at the rear of panel AE. A TEST selection overrides the 105 knot pressure switch.

NOTE: The electro-mechanical lock can be overridden, for servicing purposes, by twisting the UP button fully clockwise.

(*c*) The brakes are automatically applied when an undercarriage UP selection is made and before the retraction cycle commences. To achieve this there is a 3 second delay before fluid is allowed to pass to the undercarriage circuit; during this three seconds the maxaret spill line is pressurised from the undercarriage UP line and the units are cocked, thus applying the brakes.

(*d*) When a DOWN selection is made, the UP line pressure is relieved and the brake units are depressurised and released.

(*e*) A standard position indicator is on panel AZ.

(*f*) The 2nd pilot's ASI incorporates an undercarriage warning device. This consists of a window in the face of the instrument in which a flag marked U/C oscillates if any undercarriage unit is not locked down at speeds below 160 knots and if the Blue Steel fin remains down when the undercarriage is lowered.

(*g*) Mod. 3733 introduces circuit-breakers on distribution board AJ (in lieu of sealed fuses) for the normal and emergency undercarriage operating circuits and for the undercarriage position indicator.

7 Undercarriage emergency control

(*a*) When an EMERGENCY DOWN selection is made, the pressure supply from the pumps is changed from the normal to the emergency circuit, the protection unit is closed and the emergency selector valve opens to feed fluid to the lowering jacks.

(*b*) When the undercarriage is locked down the pressure supply reverts to normal provided that the float switches have not operated, but further undercarriage selection will not be possible and nosewheel steering will not be available.

(*c*) *Independent emergency lowering nitrogen system*

(i) An independent system is fitted for emergency lowering of the main and nosewheel undercarriage. The system operates from an independent nitrogen supply and caters for the case of complete hydraulic failure.

(ii) At the rear of the first pilot's seat, facing inboard, is a control unit which incorporates a pressure gauge and a charging point. When the flap at the top of the unit is lifted a lever is revealed. When the lever is pushed fully down a valve is opened which permits nitrogen, stored in a single bottle in the starboard wing root, to pass to the undercarriage emergency lowering lines. Once the undercarriage is lowered in this way it cannot be raised again until the system has been ground-serviced.

(iii) The following table lists the nitrogen bottle charging pressures, which are also given on a plate on the control unit:

Temp. °C	−40	−20	0	20	40	70
PSI . .	2,380	2,590	2,800	3,000	3,200	3,510

Tolerances in pressure are ± 25 PSI

8 Wheelbrakes control

(*a*) A maxaret braking system controlled by the rudder pedals is fitted. Four hydraulic accumulators are included in the system to provide a reserve of pressure in an emergency.

(*b*) Two separate pressure supplies feed the inboard and outboard brakes respectively of the port and starboard wheel units. Depression of either pilot's rudder pedals feeds pressure to both the inboard and outboard brakes associated with the rudder pedal which is depressed.

(*c*) Two pressure gauges on panel AT, one for the inboard brakes and one for outboard brakes, indicate the supply pressure of 4,000 PSI to the wheelbrakes reducing valves.

(*d*) A hand-operated parking brake is fitted at the forward end of panel AE. A warning light alongside the undercarriage selector switch on panel A comes on whenever the parking brake is applied.

(*e*) *Emergency operation*

With the hydraulic circuit in EMERGENCY, only accumulator pressure will be available for braking. The brake parachute must always be streamed and maxaretting and unnecessary brake application avoided. When the aircraft has come to rest, no further taxying should be attempted ; have the aircraft towed to dispersal.

9 Nosewheel steering

(*a*) The GROUND STEERING MASTER switch and the steering control wheel are on panel AA. Hydraulic pressure to the circuit is only available after the undercarriage has been selected down on the normal system.

(*b*) Nosewheel steering is effected by two opposed steering jacks to which hydraulic pressure is electrically controlled following movement of the handwheel. The handwheel may be operated clockwise or anti-clockwise to give a steering range of approximately 45° in either direction. When the handwheel is stopped and held in any position the nosewheel is held at a similar position giving a constant turning radius.

(*c*) When the handwheel is released the nosewheel is free to caster.

(*d*) No emergency system is incorporated, i.e. no steering power is available if the undercarriage has been lowered on emergency or if both hydraulic tank float switches have operated.

(*e*) The handwheel may be pulled out from its normal position by up to 3 inches for greater ease of operation.

(*f*) A ground test switch is on console AE.

10 Airbrakes control

(*a*) The airbrakes, which are fitted in the tail cone, are operated by a single hydraulic jack which is electrically controlled by interconnected levers one on each pilot's throttle quadrant, inboard. Control is of the "follow-up" type and airbrake selection is infinitely variable between the OPEN and CLOSE positions. The 1st pilot's lever only has a third (gated) position—EMERGENCY CLOSE.

(*b*) Movement of either lever causes the hydraulic jack to operate. When the selected position is reached electrical supply is terminated and the brakes are then hydraulically locked.

(*c*) A two-position magnetic indicator on panel AZ shows IN, or striped according to the position of the airbrakes.

11 Airbrakes emergency control

(*a*) The emergency system is for use only to close the airbrakes.

(*b*) When the 1st pilot's selector is set into the EMERGENCY IN gate, the hydraulic system operates in the emergency condition until the airbrake is fully closed. The airbrakes are then inoperative and no further selection can be made.

12 Braking parachute control

(*a*) The SAFE-STREAM switch is on the 1st pilot's panel AE. When Mod. 3926 is embodied the switch is moved to panel AA.

(*b*) (i) The doors are unlocked by hydraulic pressure and opened by spring pressure. The system is controlled by two SAFE/STREAM selector switches, one for the normal and one for the emergency system, ganged together so that they operate simultaneously. When they are set to STREAM the parachute is ejected. When they are returned to SAFE the parachute is jettisoned.

(ii) If there is no pressure available from the aircraft's normal hydraulic system, emergency accumulator pressure will unlock the doors.

(iii) Unless there is prior knowledge of normal hydraulic system failure, there is no indication that the emergency accumulator pressure has been used to stream the parachute.

(iv) Should the parachute inadvertently stream, provided the switches are set at SAFE, it is automatically jettisoned.

13 Flaps control

(*a*) The three position UP, TAKE-OFF, DOWN control switch is on panel A together with a gated NORMAL-EMERGENCY selector switch. A position indicator which indicates the positions of both flaps, in divisions, is on panel AZ.

(*b*) When any position is selected, an electrically-operated selector valve allows fluid to flow to a hydraulic motor which mechanically drives the flaps through shafting. When the selected position is reached the selector valve is closed and the flaps are hydraulically locked in position.

14 Flaps emergency control

When the EM DOWN selector is operated after first raising the locking guard, the hydraulic system is switched to emergency and the flaps are lowered fully down ; they cannot be raised thereafter. (See para. 23(*d*)(ii)).

15 Ram air turbine scoops

(*a*) The appropriate scoop is held closed by normal hydraulic pressure, if the RPM of either or both engines on the side is above 50%. If the engine speed of both engines on one side is below 50% RPM the appropriate scoop is opened by spring pressure.

(*b*) Control of the scoops is dealt with in Chap. 1, para. 12.

Normal Management of the System

16 Functional and pre-flight checks

Prior to starting the engines, and when an MV supply is available, check the function of both hydraulic pumps and all hydraulic services in accordance with the check list. Check that both BRAKE SUPPLY gauges read 4,000 PSI, and that the pressure does not fall when both pumps are switched OFF. It is recommended that the switches are not moved from NORMAL to EMERGENCY or *vice versa* without pausing at the OFF position. Before taxying select one pump to NORMAL and the other pump to EMERGENCY.

17 Normal in-flight management

Take-off with one pump at NORMAL and the other at EMERGENCY. On completion of the after take-off checks, and when all hydraulically-operated controls are retracted or closed, switch OFF the second pump and leave the other pump selected to NORMAL. It is recommended that the switching on and off of pump motors at altitude should be avoided except in cases of system failure or malfunction. All flying except during take-off and landing should be carried out with one hydraulic pump selected to NORMAL (and running continuously) and the other pump selected to OFF. The time for operation of some services will be slightly longer than when two pumps are running, but this should not affect the safe operation of the aircraft. Periodic checks must be made of the pump ammeter indications. During the checks before landing, switch the second pump to NORMAL. Both pumps should remain selected to NORMAL for final landings only and until the aircraft is dispersal with wheel chocks in position.

18 Approximate times of operation for hydraulic services

Service	*Time of Operation (seconds)*			
Undercarriage .	Up to down	12–16	Down to up	12–16
Flaps . . .	Up to take-off	14–16	Take-off to up	14–15
	Take-off to down	4½–5	Down to take-off	3½–4
	Up to down	18–20	Down to up	17–18
Air brakes . .	Close to open	4–5	Open to close	2–3
Bomb-doors . .	Close to open	3–4	Open to close	6–8

NOTE 1: The above times are valid when both hydraulic pumps are in operation. When only one hydraulic pump is in operation the times may be increased by up to 100%.

NOTE 2: The undercarriage lowers and retracts in flight in approximately seven seconds but the times stated above include the period of time for the doors to close and the jacks to lock.

Malfunctioning of the System

19 Pump failure

If the pump which is selected to NORMAL fails, the sortie should be abandoned except in operational conditions. See Flight Reference Cards.

20 Overloading of pump motors

If the on-load indication on a pump motor ammeter exceeds 45 amps the pump should be switched OFF except in extreme emergency.

21 Excessive cut-in rate

If, during flight, the cut-in rate of the pump which is selected to NORMAL (as observed on its ammeter) increases to more than once per 30 seconds. See Flight Reference Cards.

22 Overheating of pump motors

If a pump ammeter reading exceeds 16 amps when the pump is idling overheating should be suspected. Switch OFF the pump as soon as possible. See Failed Pump procedure in Flight Reference Cards.

23 Loss of hydraulic fluid (tank float-switch operation)

(*a*) If a hydraulic leak occurs causing loss of fluid in one system, the float switch in the appropriate hydraulic tank compartment will operate when the fluid level in that compartment reaches 4·75 gallons. This will illuminate the appropriate HYDRAULIC WARNING light on the pilot's coaming panel, and will automatically switch off the associated pump motor if it is selected to NORMAL. If the pump motor is selected to EMERGENCY it

will continue to run and must be switched OFF manually. Approximately 2·5 gallons of fluid will be available in the other tank compartment to allow normal operation of services. However, during operation of services return fluid will be divided between the tank compartments allowing further loss of fluid, and when the second tank compartment contents fall to 4·75 gallons the second float switch will operate. The second pump motor will be automatically switched off (if it is selected to NORMAL) and the second HYDRAULIC WARNING light will illuminate. At the same time the EMERGENCY HYDRAULIC SELECTOR warning light will illuminate indicating that the Normal Master Selector has closed and the Emergency Master Selector has opened.

(*b*) If both pumps are running and a hydraulic fluid leak occurs downstream of the Normal Master Selector both tank float switches will operate and both HYDRAULIC WARNING lights and the EMERGENCY HYDRAULIC SELECTOR warning light will illuminate simultaneously.

(*c*) If all three hydraulic warning lights are illuminated the pump motors will run only when a service Emergency selection is made with the pump motors selected to NORMAL, or if the pump motors are selected to EMERGENCY. (NOTE.—It is not necessary to select the pump motors to EMERGENCY in order to obtain Emergency operation of a service). The following Emergency selections only may be made:

Undercarriage . . .	EMERGENCY DOWN
Flaps	EMERGENCY DOWN
Airbrakes	EMERGENCY CLOSE
Bomb Doors . . .	OPEN or JETTISON, EMERGENCY CLOSE (open and close once only to avoid excessive loss of fluid)

(*d*) (i) The order of service selection will be at the captain's discretion but normally the undercarriage should be lowered first if possible.

(ii) Whilst the flaps emergency selector has only NORMAL and EMERGENCY DOWN selection positions, intermediate flap positions may be obtained by selecting EMERGENCY DOWN and then cancelling the selection by selecting NORMAL when the flap position indicators show that the required position has been reached.

(iii) If bomb door operation is necessary it is essential to check that the normal bomb door selector is at CLOSE before selecting EMERGENCY CLOSE. Failure to do so will cause automatic re-cycling of the bomb doors with possible loss of hydraulic fluid.

(iv) When an Emergency selection of any service, except undercarriage EMERGENCY DOWN, is completed, the pump motors will be switched off automatically provided that they are selected to NORMAL. However, following completion of an undercarriage EMERGENCY DOWN selection, the pump motors will continue to run until they are selected OFF, or a normal DOWN selection is made. As the undercarriage will normally be the first service to be operated under these emergency conditions, the pump motors must be switched OFF on completion of each Emergency selection to avoid unnecessary loss of fluid.

(*e*) Nosewheel steering will not be available and only accumulator pressure will be available for operation of the wheelbrakes. This should provide adequate pressure for one full stop landing, but unnecessary harsh braking causing operation of the maxaret units must be avoided. When the brake pressure gauges indicate 2,000 PSI further brake application will cause the gauge reading to fall to zero.

24 Hydraulic service failure

(*a*) If a hydraulic service fails to operate following a normal selection, and the failure is not apparently caused by a main system failure (e.g. float switch operation), those services which incorporate Emergency selections may be operated as described in the preceding paragraph. Make the appropriate Emergency selection of the service required. During the Emergency operation the EMERGENCY HYDRAULIC SELECTOR warning light will illuminate indicating that the hydraulic system is in the Emergency condition. On completion of the operation the main hydraulic system will revert to its normal condition and the EMERGENCY HYDRAULIC SELECTOR light will go out. No further operation of the failed service can then be made, but the remaining services may be operated normally.

(*b*) If the undercarriage has been lowered by selecting EMERGENCY DOWN, reselect NORMAL down so that the pump(s) switch OFF automatically if a subsequent loss of fluid causes the float switch(es) to operate.